THE FIRST FOUR ASTEROIDS: A
HISTORY OF THEIR IMPACT ON ENGLISH
ASTRONOMY IN THE EARLY
NINETEENTH CENTURY

A dissertation submitted by

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ABSTRACT

This thesis examines how the first four asteroids (Ceres, Pallas, Juno and Vesta) were studied and written about in Great Britain in the early nineteenth century. It concentrates on the work of William Herschel, who pioneered the scientific study of the asteroids. Just as importantly, he introduced the word ‘asteroid’ to distinguish the new discoveries from planets and comets. Solving a mystery that has lasted for more than two hundred years, work for this thesis finally revealed the originator of the word ‘asteroid’.

A synoptic survey of the asteroid-related correspondence between astronomers within England and between England and the Continent is presented, with some 140 letters noted, most of which are given in full. The asteroids were also given extraordinary press coverage in the periodicals of the day. Each one of these entries, totalling more than 125 scattered across 34 magazines and journals, is listed with the full text given for many of them.

Based on every extant source, this thesis presents the first detailed examination of the scientific and popular impact the discovery of the asteroids had on English astronomy in the early nineteenth century.
ACKNOWLEDGEMENTS

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CHAPTER 1: INTRODUCTION

1.1 Exordium

All of the first four asteroids (often referred to in later years as ‘The Big Four’) were discovered in the first decade of the nineteenth century; the first, Ceres, by Giuseppe Piazzi in Palermo (1801); the second, Pallas, by Wilhelm Olbers in Bremen (1802); the third, Juno, by Karl Harding in Lilienthal (1804) and the fourth, Vesta, again by Olbers (1807).

Piazzi (1746–1826; Figure 1.1) was the Director of Palermo Observatory (Cunningham, 2007). Olbers (1758–1840; Figure 1.2) was a medical doctor who, as an astronomer, became first among ‘amateurs’ (Watson, 1910). Harding (1765–1834; Figure 1.3; Hockey, 2007), of English ancestry, was an assistant to a government official in Lilienthal, the amateur astronomer Johann Schröter (1745–1816) (Cunningham, 2007), who operated the largest telescopes in Germany.

Even though none of the asteroids were discovered in England, their discovery was well known and keenly followed by astronomers in England, especially William Herschel (1738–1822). This thesis will cover the period 1801-1840. After the first decade of the nineteenth century, no new physical observations of the asteroids were made, so the period from 1810-1840 is mostly given to a repetition of studies done in the century’s first decade. The next asteroid to be discovered after the ‘Big Four’ was Astraea in 1845 by Karl Ludwig Hencke (1793–1866), which began a new era in the history of asteroid studies.
Speculation that there may be a planet between Mars and Jupiter goes back to the writings of Johannes Kepler (1571–1630), and the topic was touched upon by several writers in the eighteenth century, including Baron Franz von Zach (1754–1832), the famous Hungarian-born astronomer (Brosche, 2001). Since 2004 I have been editing the *Collected Correspondence* of Zach, a series of books that has now reached eight volumes (see Cunningham, 2004a). These are: Volume 1: Letters with Jan Sniadecki; Volume 2: Letters to His Fatherland; Volume 3: Letters in British Archives; Volume 4: Letters with Giovanni Amici; Volume 5: Letters with Carl Gauss; Volume 6: Letters with German Dukes & Johann Wurm; Volume 7: Letters with Rudolf Abraham Schiferli; Volume 8: Letters with Johann Kaspar Horner.
While the idea of a ‘missing planet’ was quaintly regarded by most people as a chimera, it suddenly became of immense moment when Giuseppe Piazzi discovered Ceres. Nearly two centuries before the discovery, Thomas Wright (fl. early seventeenth century; 1604) wrote that “…the presence of any visible object, moveth much more vehemently the passion, than the imagination or conceit thereof in the absence.” Once the grand conceit of a missing planet became a “visible object”, the passions unleashed in the first few years of the nineteenth century reached levels rarely matched in the history of astronomy. Aside from the purely observational and mathematical aspects of their discoveries, this thesis will consider the ramifications of the deep personal animosities engendered by those discoveries.

Most books that cover the discovery and early study of the asteroids devote scant space to the topic, sometimes only a paragraph or two, rarely more than a couple of pages. Even biographies of Herschel give his work on the asteroids no more than a passing nod. For example, *The Story of the Herschels, A Family of Astronomers* (1878), devotes half a paragraph to the asteroids in a total of 117 pages. *Sir William Herschel* by Holden (1881: 108) does not even mention Ceres by name, although the asteroid nomenclature controversy is given two pages. *William Herschel and His Work* (Sime, 1900) also mentions the nomenclature controversy; additionally, he gives Herschel’s size and colour estimates for Ceres and Pallas, and updates asteroid discoveries up to Eros in 1899. *The Herschel Chronicle* (Lubbock, 1933) provides the most extensive coverage with a 5-page survey. While a few papers that have appeared in journals have addressed some specific issues, most of these have appeared in German or Italian, and primarily relate to the work done by German and Italian astronomers. Very little has appeared in English, especially as it relates directly to the work done in England. The important and valuable books about
William Herschel and his family by Michael Hoskin deal with many biographical and scientific matters, but scarcely mention asteroid studies.

Several important issues will be surveyed, including the origin of the asteroids; practical and philosophical questions raised by Herschel’s choice of the new word ‘asteroid’; the dearth of theoretical work in England compared to that on the Continent; the dichotomy between physical measurements made in England and Germany; and how the direction of research was influenced by the way information was managed and how it was perceived by the disparate personalities involved. This thesis is the first in-depth study of the impact of asteroid studies on English astronomy and how it relates to work done throughout Europe.

1.2 Research Methodology
I have been working on the history of asteroid research since 1989, and have published three large books on the subject. This substantial body of research forms the basis of the more focused topic of this thesis, a history of the impact on English astronomy of the discovery of the first four asteroids throughout the early nineteenth century. Over the course of the past two decades I have made several trips to obtain archival material in Europe.

Literature cited in this thesis covers not just that directly related to asteroid studies, but more wide-ranging sources in philosophy, medieval history, physics, semantics, etymology, meteorology, literature, mathematics, culture, botany and classical studies. All these seemingly disparate fields are the essential ingredients for a thorough understanding of the complex issues raised by the discovery and study of Ceres, Pallas, Juno and Vesta. That said, one can—in the words of Frank Ankersmit (2012), Emeritus Professor of Intellectual History at the University of Groningen—“... be a historian of genius without redrawing the disciplinary boundaries of historical writing by an inch.” This is both the goal and cautionary limitation I have followed in writing this thesis.

1.3 Outline of Thesis Topic and Chapter Structure
William Herschel performed the first truly scientific study of Ceres and Pallas, with later papers covering Juno and Vesta in a more cursory fashion. These five papers will be the subject of Chapter 2.

Studies of the physical properties of the asteroids will be examined in Chapter 3. Herschel’s conclusions regarding the size and (lack of) atmosphere associated with Ceres and Pallas also put him at odds with Johann Schröter, who studied these objects with the largest telescope in Germany. Reasons for this, and repercussions deriving from it, will also be examined in light of their existing rivalry going back many years. Heretofore unpublished letters in the Herschel Archives (Royal Astronomical Society, London) will form the basis of much of this work.

The methods used, and the mathematical basis employed, for the wildly-differing results in estimating the size of the asteroids (Herschel thinking them very small, while Schröter believing them to be quite large) will be studied closely, and related to modern studies of visual acuity and optics. A crucial document for this analysis is a paper Herschel (1805) published in the Philosophical Transactions of the Royal Society about the asteroid Juno.

Most controversially, Herschel named Ceres and Pallas ‘asteroids’. The creation of this word has always been attributed to him, but this thesis shows it was not his invention. This important discovery was made by me in 2013, proving that giving credit to Herschel for the word asteroid was wrong for 211 years. Further research
for this thesis has revealed that the Oxford English Dictionary (OED) is also incorrect in its entries for the words ‘asteroidal’ and ‘cometoid.’ The OED and a host of books and encyclopedias will have to be corrected as a result of the research developed for this thesis. The use of the word ‘asteroid’ generated a tremendous negative reaction on the Continent, where most astronomers rejected it tout court. It calls to mind the words of Sir Thomas Browne (1642): “Scholars are men of peace, they bear no arms, but their tongues are sharper than the razor of Actius; their pens carry farther, and give a louder report than thunder.” These sharp and caustic ripostes will be examined in Chapter 4, and possible explanations will be offered as to why they went far beyond dispassionate scientific discourse—papers in German, French, Italian and Latin are used for this analysis.

While William Herschel now has an unrivalled reputation amongst British astronomers of the period (e.g. see Hoskin, 2012), his reputation during his lifetime was quite different. Many of his fellow-British men of science thought him to be quite mad, and best confined to Bedlam, the hospital for the insane! The personal attacks launched against him in England for proposing the name ‘asteroid’ to describe Ceres and Pallas will be studied.

Chapter 5 will consider how the flow of information about the asteroids was managed, and how the varying personalities involved determined both the timing and nature of the studies being conducted. As the great composer Robert Schumann (1810–1856) noted, “In every age, there presides a secret league of kindred spirits.” (Schumann, 1853). This was nowhere more evident than in those few astronomers of the early nineteenth century who were variously fascinated by and obsessed with the first four asteroids. The work of this thesis will rely heavily on personal correspondence between British men of science and their Continental counterparts. Previous research I have done has uncovered correspondence long thought to be missing or lost, particularly letters from Carl Gauss (1777–1855) to Nevil Maskelyne (1732–1811), the Astronomer Royal (a paper about this discovery was published in 2004—see Cunningham, 2004.) It was through the mathematical efforts of Gauss that an ephemeris was developed that enabled Zach and Olbers to recover Ceres after it had been lost by Piazzi. A modified version of this orbital determination technique, along with Gauss’ correction procedures, is still employed by modern celestial mechanicians.

The role of Sir Joseph Banks (1743–1820), President of the Royal Society, will be evaluated. He was kept closely informed about developments on the Continent (especially about Ceres and Pallas) by Baron Franz von Zach in Gotha, Germany. The two men served in much the same role—as a clearing-house of scientific information—in their respective countries (and in the case of Zach for most of Europe). The crucial nature of this self-made but vital role will be examined in the broader context of the dissemination of scientific ideas in England and Europe in these early years of the nineteenth century.

In addition to the rivalry between Herschel and Schröter, there was a very intense rivalry between Zach and Maskelyne. How this impacted on the dissemination of knowledge about the asteroids from the Continent to England will be examined. Also, the speed with which information about the asteroids travelled back and forth will be noted.

Yet another crucial conduit of information about the first asteroid, Ceres, was that between Piazzi and his English colleagues Herschel and Maskelyne, whom he had personally met on a visit to England in 1788. The motives for his extraordinary
tardiness in informing anyone in England of his discovery will be looked at in the context of Piazzi’s character and his relationship with Continental astronomers.

In addition to Herschel, Maskelyne and Banks, several other British men of science were materially interested in the asteroids. Thomas Young (1773–1829), Foreign Secretary of the Royal Society, was in close contact by virtue of this position with many people in Europe. He kept his colleague Sir Henry Englefield (1752–1822) apprised of the latest asteroid research, and Englefield became one of the observers of these objects. He was followed later by Stephen Groombridge (1755–1832), who published several observational reports, and kept Herschel informed of his asteroid work over a 10-year period. The instruments and observatories of the various British astronomers of the day will be compared.

Observational and theoretical work will be examined in Chapter 6. Maskelyne’s extensive notes about the asteroids are preserved in the Cambridge University archives. These include mathematical calculations relating to the physical size of the asteroids, and various aspects of their orbital parameters. These notes have never before been published. As part of the work for this thesis, this material has been carefully transcribed and evaluated, and related wherever possible to information Maskelyne was receiving from Gauss, Zach and others on the Continent.

The flip side of observational work is theoretical. Several people, such as Barnaba Oriani in Milan (1752–1832), Carl Gauss in Göttingen and Friedrich Theodor Schubert in St. Petersburg (1758–1825) were involved in perturbation calculations relating to the asteroids. Not a single English astronomer or mathematician tackled the problems facing them. To explain this strange lacuna will require a look at the state of mathematical astronomy and education in England in the late eighteenth century.

The broader context of the study of asteroids in the early nineteenth century will be considered. What other pressing observational or theoretical issues were competing for the attention of astronomers, and was there any synergy between asteroid studies and these other studies? How did English studies of the asteroids compare with studies made by Continental astronomers? Were they better or worse, more detailed, or of a different nature? Did the quality and size of the telescopes and other measuring instruments used in England make the English measurements of the asteroids qualitatively better or worse than those made on the Continent? Did the English contribution to early asteroid studies have a measurable impact on how these four celestial objects were understood, or was this contribution just a coda to those made by astronomers in France, Germany, Sicily, Poland and elsewhere?

**TIMELINE 1801**

Jan. 1: Discovery of Ceres
Jan. 24: Piazzi sends letters to Bode and Oriani
Feb. 11: Piazzi makes his last observation of Ceres
Feb. 26: Lalande reads about the discovery in the Journal de Paris
Feb. 27: Lalande writes to Zach and Piazzi about the discovery
March 20: Bode receives Piazzi’s discovery letter
March 26: Bode reports the discovery to the Royal Academy in Berlin
April 2: Oriani receives Piazzi’s discovery letter
April 7: Zach is sent notice of Piazzi’s discovery in a letter from Oriani
April 14: Bode sends a “deceptive” letter to Zach with Piazzi’s positional data
May 6: Notice of discovery in the Jena newspaper
May 12: Notice of the discovery in the Berlin newspaper
May 13: Notice of the discovery in the Hamburg newspaper
May 31: Lalande receives Piazzi’s positional data from Piazzi
June: The first paper about the discovery is published in the MC
June 6: Bode writes Herschel about Piazzi’s discovery
Aug. 4: Piazzi notifies Seyffer of his discovery
Aug. 7: Notice of the discovery in a London newspaper
Sept. 1: Piazzi notifies Herschel of his discovery
Sept. to Oct: Gauss develops an ephemeris to aid the recovery of Ceres
Oct. 15: Piazzi’s printed account of his discovery reaches Zach
Oct. 22: Maskelyne receives a letter from Piazzi with details of his discovery
Oct. 25: Piazzi’s printed account of his discovery reaches Lalande
Dec. 7: Zach makes the first sighting of Ceres since February

TIMELINE 1802
Jan. 1: Olbers confirms the recovery of Ceres
Jan. 14: Zach sends data to Banks, enabling Ceres to be observed in England
Feb. 3: Maskelyne makes the first observation of Ceres from England
Feb. 7: Herschel makes his first observation of Ceres
Feb. 18: Herschel’s first paper about Ceres is read to the Royal Society
Feb: Englefield makes his first observation of Ceres
Mar. 15: Walker makes his first observation of Ceres
Mar. 28: Olbers discovers Pallas
Apr. 7: Gilpin sends Maskelyne positional data that enables him to find Pallas
Apr. 9: Gilpin makes his first observation of Ceres
Apr. 13: Lee makes the first observation of Pallas from England
Apr. 15: Maskelyne makes his first observation of Pallas
Apr. 21: Herschel makes his first observation of Pallas
Apr: Walker and Aubert observe Pallas from England
Apr. 25: Herschel asks William Watson for a term to describe Ceres and Pallas
May 3: Herschel asks Charles Burney Sr. for a term to describe Ceres and Pallas
May 5: Charles Burney Jr. coins the word asteroid
May 6: Herschel’s paper about Ceres and Pallas is read to the Royal Society
May 22: Herschel sends a letter to Continental astronomers about “asteroids”
June 10: Herschel rejects the nomenclature suggestions of Stephen Weston

TIMELINE 1804-1823
Sept. 1, 1804: Karl Harding discovers Juno
Sept. 12: Gauss observes Juno, and sends ephemeris data to England
Sept. 24: Herschel makes his first observation of Juno
Sept. 25: Maskelyne makes his first observation of Juno
Dec. 1, 1804: Herschel’s paper about Juno is read to the Royal Society
Mar. 29, 1807: Olbers discovers Vesta
Apr. 18: Young sends Herschel Olbers’ observations so that he may search for Vesta
Apr. 24: Herschel makes his first sighting of Vesta
Apr. 25: Groombridge makes his first observation of Vesta
Apr. 27: Maskelyne makes his first observation of Vesta
June 4: Herschel’s paper about Vesta is read to the Royal Society
Aug. 29, 1808: Groombridge sends his first letter of asteroid observations to Herschel. They will continue until 1818.
May 1, 1818: Lofft makes his first observation of Vesta
Apr. 5, 1823: Talbot makes his first observation of Vesta
CHAPTER 2: WILLIAM HERSCHEL’S SCIENTIFIC PAPERS ON THE ASTEROIDS

From 1802 to 1807, William Herschel (Figure 2.1) submitted five papers (in whole or in part) about the asteroids to the Royal Society. Together, they comprise the bedrock of the English response to the discovery of the newly-found celestial objects. His first report, read before The Royal Society on 18 February 1802, was not published until 1912, when his *Collected Scientific Papers* were edited by John Louis Emil Dreyer (1852–1926). His other papers were published in the *Philosophical Transactions of the Royal Society*. The second study, dealing with both Ceres and Pallas, was read on 6 May 1802. The third, from 1803, gave a description of Ceres and Pallas. The fourth paper, written in late 1804 and presented in early 1805, deals with the third asteroid, Juno. The final paper, from 1807, presents his observations of Vesta, the fourth asteroid. In the first two studies, he examined the colour and apparent sizes of the objects, looked for possible satellites following them or atmospheres surrounding them, and estimated their magnitudes. The final two studies were more restricted in nature, concentrating almost entirely on the apparent sizes of Juno and Vesta (see Appendix A for these papers). A detailed critique of Herschel’s papers is presented in various chapters of this thesis, dealing with individual areas of investigation such as size, colour, atmosphere and nomenclature.

It may fairly be observed that Herschel applied his long-held beliefs about observational astronomy to the study of these four new objects. In what might be termed his philosophy of astronomical study, Herschel wrote this about his study of supposed lunar volcanoes:

… the phenomena of Nature, especially those that fall under the inspection of the astronomer are to be viewed, not only with the usual attention to facts as they occur, but with the eye of reason and experience. In this we are, however, not allowed to depart from plain appearances; though their origin and signification should be indicated by the most characterising features. (Herschel, 1787: 229).

2.1 The Paper of February 1802 about Ceres

Herschel’s fine observational skills were well known, a fact that prompted Carl Gauss (Figure 2.2) to urge Herschel to study Ceres and Pallas (Forbes, 1971):

I am hoping to give you a large degree of precision with an already existing as well as a (yet to be made) observation and it will need to be decided whether the Ceres Ferdinandea had the same fate as Uranus Georgius, but was not recognised earlier on.

I am very curious whether your observations will enrich us this time with Ceres’ satellites or other physical characteristics [oddities] of this planet and I would be extremely honoured if in this case you would send word to me regarding this matter. (Gauss, 1802a).

Herschel needed no prodding, as his curiosity had already been piqued for months. How he learned about Ceres in 1801 will be examined in Section 5.3. Once he had a reliable ephemeris in hand, he began observing Ceres on 7 February.

He first saw it in a 10-foot reflector with a 9-inch mirror at a magnifying power of 600×: “I immediately perceived a star which appeared sufficiently different from another [star] at no great distance, to occasion a surmise that it was the planet.” (Herschel, 1802a: cix). Herschel did not say at this point why it appeared to be different from a nearby star.
He then changed magnification to 1200 but “… found a doubt still remaining that there might be a mistake.” (Herschel, 1802a: cix). Switching to the 20-foot telescope (Figure 2.3), which had a mirror of 18.7 inches, he again looked at what he supposed to be Ceres, using magnifications of 300× and 600×. While this still did not resolve his doubt, he was able to secure additional observations through partly cloudy skies over the next few days. This decided the matter: “… the star I had examined must be the new planet.” (Herschel, 1802a: cx).

On the matter of magnification, it must be noted that with his 20-foot reflector, a standard magnification was 157×, which gave a field of view of 15° 4′. It was with
Figure 2.2: Carl Gauss (courtesy: en.wikipedia.org).

Figure 2.3: Herschel's 20-foot telescope (courtesy: Michael Hoskin).
this telescope he discovered 2,500 deep-sky objects from 1783 to 1802. He used a 7-foot reflector, with a mirror of 6.3 inches and a magnification of 227×, to discover the planet Uranus in 1781.

For a modern telescope with a well-figured mirror, the maximum useable power is 60× per inch (Clark, 1990: 30). Therefore, Herschel’s 9-inch instrument had a theoretical maximum of 540×. Light, detail and field of view would have been seriously compromised at a magnification of 600×. The image must have been quite poor at 1200×, so it is not surprising using such an extreme magnification did nothing to allay his doubts. With the 18.7 inch reflector, a magnification of 900× is theoretically allowable, so the magnifications he used (300× and 600×) were within reasonable limits. On a more practical level, the quality of his optics, stability of his mounting (which was outdoors and subject to wind), and atmospheric stability (which was certainly not spectacular compared to a mountain-top site) certainly put a major constraint on his ability to see small planetary disks. A magnification of 600× can certainly be considered an upper useable limit.

The specific issue of observing Ceres at high magnification was addressed by Baron Franz von Zach (Figure 2.4) in a letter to Gauss:

The high magnifications impede a clear image of the planet. These high magnifications are the reason why Ceres appears so faint and dim, especially at the quadrant, overkill is possible! I saw the planet with my comet searcher and small telescope much better and more distinct than with any of my large and excellent instruments and unfortunately I only have high magnifications and smaller are not easily or quickly obtained. (Zach, 1802c).
On 13 February at 5am, Herschel (Herschel, 1802a: cx) finally saw Ceres with “... great distinctness.” He claims to have seen a “... disk, though very minute, being perfectly well defined all round.” (ibid.). He further estimated the disk of Ceres to be one second in size. Since the actual diameter that Ceres subtends at opposition is only 0.8 arcsecond, Herschel was clearly seeing more through the eyes of hope than reality. Determined to make a diameter estimate, he concluded, after comparing Ceres to Uranus which was also visible that morning, that Ceres “… is less than five-eighths of the diameter of our Moon.” (Herschel, 1802a: cx). Given that the Moon has a diameter of 2159 miles, this puts an upper limit on Ceres’ diameter of 1350 miles. For a first approximation, this is quite good, the real diameter being 578 miles.

Herschel’s friend Patrick Wilson (1743–1811; see Section 2.2) was quite anxious to know the status of the paper about Ceres: “Does your paper on the new Planet come in this week?” (Wilson, 1802a; his underlining). The paper on Ceres was read to the Royal Society the day following this letter, 18 February 1802.

2.2 The Paper of May 1802 about Ceres and Pallas
There was great advance interest in what Herschel was going to report about the newly-recovered Ceres, as we learn in this letter from Patrick Wilson, who was Regius Professor of Practical Astronomy at Glasgow University from 1784 to 1799. Here he is reporting a conversation he had with Sir Joseph Banks (Figure 2.5):
Last Sunday’s evening I was at Sir Joseph’s rooms, when he enquired kindly about you, and expressed some hopes of hearing farther from you as to the new planet by Thursday, in consequence of our having lately some intervals of a clear starry heavens.
P.S. I have received back Piazzi’s and Baron Zach’s schedules upon the new planet—pray shall I send them out to you in a parcel by coach? Mr. Tilloch has been greatly obliged by them.

(Wilson, 1802b).

The Mr. Tilloch referred to was Alexander Tilloch (1759–1825), a Scotsman who established the *Philosophical Magazine* in 1797. He published numerous articles about the asteroids, as detailed in Section 5.2.

In his second paper, which was read before the Royal Society on 6 May 1802, Herschel reported on observations he made of both Ceres and Pallas; the former from 25 February to 4 May; the latter from 21 April to 4 May.

This paper created a sensation across Europe, and became one of the most discussed and derided papers ever printed in a scientific journal. This was caused by two main factors, one observational, the other an attempt at a synthesis of knowledge, which is what we expect of a great scientific advance.

On the observational side Herschel arranged the presentation not in chronological order, but under various subject headings. First he was concerned with their magnitude, which in early nineteenth century terminology meant not their brightness, but their apparent size.

Next he gave a list of dates on which a search was made for possible satellites of Ceres and Pallas. This is followed by a single paragraph dealing with colour.

The next two sections deal with their appearance in terms of their disk, and whether or not they are surrounded by an atmosphere or coma.

His controversial conclusion is contained in a section “On the Nature of the new Stars.” Going beyond the observational work, Herschel became most famous (or notorious) for the introduction of the term ‘asteroid’, a matter that will be examined in detail in Chapter 4.

The paper concluded with a brief account of observations made on 4 May 1802, after the main paper had been written. This dealt entirely with the appearance of Ceres and Pallas—whether or not they showed a coma.

Herschel tried to continue his observations of Ceres and Pallas, but the weather did not cooperate, as we learn in a letter from Patrick Wilson:

> I’m sorry the weather has continued so long unfavourably for your seeing and examining further the new planet. The circumstances of the two lucid points seemed not much to be realized on by the company at the Royal Society on the 18th current—and amidst the conversation of the members, as passing out, that night, I overheard once or twice some wishes expressed for your soon having two or three hours more of serene atmosphere, in order to settle finally the matter of the lucid points. (Wilson, 1802c, his underlining).

**2.3 The Paper of June 1803 giving a Description of Ceres and Pallas**

Herschel’s third paper that treats the subject of the asteroids was read before the Royal Society on 9 June 1803. This lengthy paper actually concerns itself almost entirely with double stars, but he begins the paper by addressing the issue of nomenclature. Without mentioning Ceres and Pallas by name, he says they can just as easily be called planetoids as asteroids, but gives his reasons why they should not be lumped together with the large planets. His text is considered in Subsection 4.2.3.4, where the word planetoid is examined in detail.
2.4 The Paper of 1805 about Juno

Herschel enlisted the aid of his friend George Gilpin (1754–1810), clerk of the Royal Society, for early information about Juno, but Gilpin’s reply of 19 November came too late to be of much use:

I am extremely sorry that after waiting so long endeavouring to obtain for you what you want respecting the new planet Juno, that I am not as yet able to comply with your request. Mr. Harding certainly some time since sent the Elements of the Planet, and I was in hopes of obtaining a copy for you but I now despair of succeeding at least for the present. I send you a diary of its place [see Figure 2.6, below] which will enable you to find it for a few days longer. Also some observations made by Mr. Bode. I understand that its inclination is about 13º. This is all the information I can give you at present. (Gilpin, 1804).

Herschel’s fourth paper is dated 1 December 1804 and covers observations from 24 September through 11 October. Its opening paragraphs show Herschel trying to identify the newly-discovered object Juno in an unfamiliar star field. It is not until he receives a positional measurement from Nevil Maskelyne (Figure 2.7) on 27 September that he is conclusively able to identify Juno.

All his subsequent observations are designed to address a single subject—the diameter of Juno. Nowhere does he try to identify any satellites or assign any colour. In this, his observations are much more focused in their intent than his first two papers. See Subsection 4.2.6 on Juno’s diameter as measured by Johann Schröter’s method compared to the method used by Herschel.

His most important conclusion is in the sense of vindication. This is apparent at the beginning of the paper, where he states very matter-of-factly that he was “… not much surprised …” (Herschel, 1805: 57) to learn of Harding’s discovery. In his concluding remarks, Herschel says Juno “… resembles in every respect …” (Herschel, 1805: 62) both Ceres and Pallas.

He cites the smallness of its disk, and the considerable inclination and eccentricity of Juno, as putting it firmly in the camp of the asteroids. These characteristics, he specifically asserts, distinguish all three bodies from planets. He describes them as an “… ornament of our system …” (Herschel, 1805: 64), and thus more important than the discovery of another planet. This is the same argument he used in his letter to Piazzi, an argument Piazzi tossed aside with disdain.
2.5 The Paper of 1807 about Vesta
Herschel’s final asteroid paper was read on 4 June 1807. Its observations span one month: 24 April to 24 May. As was the case with Juno, he began by drawing a map of the stars in the region where Vesta was expected to be. His initial observations were hampered by a bright Moon, and then interrupted by bad weather from 25 April to 21 May. As with Juno, Herschel received a valuable positional measurement from Maskelyne, enabling him to firmly identify Vesta on 21 May. He had already seen Vesta in April, but could not distinguish it from field stars, so he knew at once when observations resumed in May that it had an asteroidal appearance.

It was actually in this paper that Herschel coined the word ‘asteroidal,’ a fact that is also a new discovery revealed in this thesis. According to the OED, the first use of the word ‘asteroidal’ was by the English astronomer Norman Lockyer (1836–1920) in 1868. But this is incorrect. Herschel (1807: 263) used it thus in describing his observations of the asteroid Vesta: “The spurious nature of the asteroidal disk …”

As with his Juno observations, he made no attempt to look for satellites, or assign a colour to Vesta. He was able to compare it with the planet Uranus, which was nearby in the sky, and this affirmed his belief that its disk was imperceptible. Its apparent disk of five or six tenths of a second was quickly shown to be spurious, and he assigns no specific upper limit to its actual size. For his work on the size of Vesta subsequent to this paper, see Subsection 3.1.1.
He notes in conclusion that “… we are now in possession of a formerly unknown species of celestial bodies.” (Herschel, 1807a: 66). In a nod to celestial mechanics, he also notes that due to their orbits, and small size, they will neither disturb the primary planets in their orbits, nor be disturbed by the primary planets. This is as close as he came to suggesting that the asteroids had been in their stable orbits since the early stages of the Solar System. Table 2.1, below, gives the dates of all the observations Herschel made of the asteroids, together with the telescopes and magnifications used each night, and the purpose or result of his observations.

Table 2.1: Herschel’s observations of asteroids.

<table>
<thead>
<tr>
<th>Date</th>
<th>Objects Seen</th>
<th>Instruments &amp; Magnification</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>07 February, 1802</td>
<td>Ceres</td>
<td>10 foot: 600 &amp; 1200</td>
<td>Low in sky</td>
</tr>
<tr>
<td>13 February</td>
<td>Ceres &amp; Uranus</td>
<td>10 foot: 600</td>
<td>Diameters compared and colour noted</td>
</tr>
<tr>
<td>25 February</td>
<td>Ceres</td>
<td>20 foot</td>
<td>Satellite search</td>
</tr>
<tr>
<td>28 February</td>
<td>Ceres</td>
<td>20 foot</td>
<td>Satellite search</td>
</tr>
<tr>
<td>04 March</td>
<td>Ceres</td>
<td>20 foot</td>
<td>Satellite search</td>
</tr>
<tr>
<td>05 March</td>
<td>Ceres</td>
<td>20 foot</td>
<td>Satellite search</td>
</tr>
<tr>
<td>06 March</td>
<td>Ceres</td>
<td>20 foot: 300</td>
<td>Satellite search</td>
</tr>
<tr>
<td>31 March</td>
<td>Ceres</td>
<td>20 foot</td>
<td>Satellite search</td>
</tr>
<tr>
<td>01 April</td>
<td>Ceres</td>
<td>7 foot: 370</td>
<td>Disk measured</td>
</tr>
<tr>
<td>21 April</td>
<td>Ceres &amp; Pallas</td>
<td>10 foot: 516</td>
<td>Disk measured; colour noted; coma seen around Ceres</td>
</tr>
<tr>
<td>22 April</td>
<td>Ceres, Pallas &amp; Jupiter</td>
<td>10 foot: 516 &amp; 881</td>
<td>Disks measured; colour noted; no coma around Ceres but Pallas appears cometary</td>
</tr>
<tr>
<td>28 April</td>
<td>Ceres &amp; Pallas</td>
<td>10 foot: 516 &amp; 550</td>
<td>Pallas less than Ceres; coma of Ceres and Pallas noted</td>
</tr>
<tr>
<td>30 April</td>
<td>Ceres</td>
<td>20 foot: 300, 477</td>
<td>Coma noted</td>
</tr>
<tr>
<td>01 May</td>
<td>Ceres &amp; Pallas</td>
<td>10 foot: 516</td>
<td>Uncommonly calm night for viewing</td>
</tr>
<tr>
<td>02 May</td>
<td>Ceres &amp; Pallas</td>
<td>10 foot: 516</td>
<td>Coma of asteroids compared to that of stars</td>
</tr>
<tr>
<td>24 September, 1804</td>
<td>Juno</td>
<td>10 foot</td>
<td>Chart of stars made; Juno noted but not identified</td>
</tr>
<tr>
<td>25 September</td>
<td>Juno</td>
<td>10 foot</td>
<td>Bright moon</td>
</tr>
<tr>
<td>26 September</td>
<td>Juno</td>
<td>10 foot</td>
<td>Hazy weather; Juno seen but not identified</td>
</tr>
<tr>
<td>27 September</td>
<td>Juno</td>
<td>10 foot: 496 &amp; 879</td>
<td>Juno identified</td>
</tr>
<tr>
<td>01 October</td>
<td>Juno</td>
<td>10 foot</td>
<td>No disk perceived</td>
</tr>
<tr>
<td>02 October</td>
<td>Juno</td>
<td>10 foot: 220, 288, 410, 496, 879</td>
<td>Low in sky, spurious disk noted</td>
</tr>
<tr>
<td>05 October, 1804</td>
<td>Juno</td>
<td>10 foot: 410, 496, 879</td>
<td>Air very pure; disk size estimated</td>
</tr>
<tr>
<td>07 October</td>
<td>Juno</td>
<td>10 foot</td>
<td>Retrograde motion</td>
</tr>
<tr>
<td>08 October</td>
<td>Juno</td>
<td>10 foot: 410, 496</td>
<td>Disk size estimated</td>
</tr>
<tr>
<td>11 October</td>
<td>Juno</td>
<td>10 foot</td>
<td>Disk size estimated</td>
</tr>
<tr>
<td>24 April, 1807</td>
<td>Vesta</td>
<td>10 foot: 460</td>
<td>Star chart drawn; Vesta seen but not identified</td>
</tr>
<tr>
<td>25 April</td>
<td>Vesta</td>
<td>10 foot</td>
<td>No noticeable change in stars seen</td>
</tr>
<tr>
<td>21 May</td>
<td>Vesta</td>
<td>10 foot: 75 &amp; 460</td>
<td>No disk seen</td>
</tr>
<tr>
<td>22 May</td>
<td>Vesta &amp; Uranus</td>
<td>10 foot: 460, 577, 636</td>
<td>No disk seen</td>
</tr>
<tr>
<td>23 May</td>
<td>Vesta</td>
<td>10 foot: 460</td>
<td>No disk seen</td>
</tr>
<tr>
<td>24 May</td>
<td>Vesta &amp; Uranus</td>
<td>10 foot: 577</td>
<td>No disk seen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20 foot: various</td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER 3: PHYSICAL PROPERTIES OF THE ASTEROIDS

3.1 Size

Even before he had announced his diameter results, Herschel was being shamelessly goaded on the subject by his friend the physician and naturalist Sir William Watson (1744–1824; see Section 5.13), who launched into an extraordinary digression about the possible size of the inhabitants of Ceres and Pallas:

I am much pleased that you propose to send me your further thoughts on these curious bodies. I am quite impatient to know how small you make them. One may be king of one of these planetels, and have no mighty kingdom either. I suppose they must be inhabited by Liliputians, and I please myself with the idea of their little cities, houses and ships, tho’ after all, as size is merely relative to other things, they will feel themselves as great as we do. The truth is that if the heavenly bodies are inhabited by such beings as we are, and have trees as we have, they cannot differ much from us and ours in size. For men and trees are so constructed that they could not subsist much larger or much smaller. Trees 40 times as big as ours it is well known could not sustain their branches, nor could the heart in a man of so much greater dimensions drive the blood to the extremeties. So a man too small would be subject to too great an irritability of the system. But enough of these surmises. (Watson, 1802b, his underlining).

3.1.1 Herschel’s Method for Determining Size

Herschel undertook a series of experiments of a curious nature purposely with a view to ascertaining the diameter of these objects. He found that their extreme smallness rendered the common methods inapplicable and therefore resorted to others of his own invention. Having heated some sealing wax and drawn it out into small threads he passed the ends of them through the flame of a candle. They consequently had at the end of each thread a small round globule of wax. It was now necessary to measure the diameter of these balls and this was accomplished by means of a solar microscope that projected their images on a sheet of paper and their size was thus ascertained with great accuracy. A row of these waxen balls thus arranged was placed on a card at the distance of 700 or 800 feet and viewed with a telescope. By knowing the distance at which they were placed, and their real diameters, it was easy to calculate the angles under which they would be seen (Babbage, 1815). Herschel examined the balls with different magnifying powers. With a telescope magnifying 150 times he could perceive a globule subtending only an angle of part of a second in diameter. (It results from this that Ceres is about 161 miles in diameter and Pallas 147 according to greatest extent, or 40 times smaller than the Moon.)

While the description by the British mathematician-astronomer, Charles Babbage (1791–1871; Figure 3.1) seems straightforward, Herschel’s contemporaries were somewhat perplexed. The French astronomer Pierre Méchain (1744–1804; Figure 3.2) was his usual diplomatic self:

The observations of the new star discovered by Dr. Olbers and of Piazzi’s star which you kindly gave me are endlessly curious and interesting. I admire your ingenious means of determining such small diameters and I would be delighted to be able to understand them, though I do not at all doubt their accuracy. (Méchain, 1802).

After his final paper on Vesta was published in the Transactions of the Royal Society (see Section 2.5), Herschel continued attempting to see if it had a noticeable disk. According his notes in the RAS Archives (see Appendix B) on 15 September 1808 he made several observations during the night, and believed he had succeeded in his quest:
Figure 3.1: Charles Babbage (courtesy: en.wikipedia.org).

Figure 3.2: Pierre Méchain (courtesy: en.wikipedia.org).
9h 40’ The Asteroid is now at a better altitude; I suspected that the feeble light of this little body would not bear the power 600 and used 350 which shows it better. Its diameter with this power is a little larger than that of the two stars above mentioned, and I believe it is its real diameter.

By the end of his observations that night Herschel was convinced Vesta showed a “… disk 1/4 of the diameter of Jupiter’s 4th satellite.” He continued looking at Vesta until 1814, but could not confirm his finding of 1808. In his final asteroid observation (made with the 10-foot reflector) dated 17 February 1814, he wrote: “I examined the Asteroid with several high powers but could not find any difference between its appearance and that of equal stars.”

Herschel had founded his career as an astronomer on his unwavering belief that he could see things through the telescope that no one else could, and he used a simile from his first love, music, to make the point. In response to those who found his use of the magnification 6450× unbelievable, he wrote to his friend Watson:

Seeing is in some respect an art which must be learnt. To make a person see with such a power is nearly the same as if I were asked to make him play one of Handel’s fugues upon the organ. Many a night have I been practising to see, and it would be strange if one did not acquire a certain dexterity by such constant practice. (Herschel, 1782a).

3.1.2 Reaction by Other Astronomers to Herschel’s Measurements

Never one to mince words, Baron von Zach was ruthless in his condemnation of Herschel’s diameter measurements, as evidenced in this letter he wrote to Barnaba Oriani (Figure 3.3), Director of Brera Observatory in Milan (the best appreciation of Oriani was published on the 100th anniversary of his death by Bianchi, in 1933):

What is your opinion of Herschel’s asteroids? Do you believe in the measurements of the diameters of Ceres = 0″.216 and of Pallas 0″.13. I do not believe it, with these pretensions one makes a fool of oneself. (Zach, 1802s, his underlining).
Gauss reinforced this viewpoint in a letter to Olbers (see also Section 5.14):
I wouldn’t have thought Pallas to be so small that Herschel would require 73,000 to produce one Mars. I don’t entirely comprehend on what Herschel could have based his statement, for he knew nothing whatever about the distance of Pallas. To want to distinguish between ‘planeta’ and ‘planetula’ seems to me to be almost pedantic. Mercury, Venus, Earth and Mars are also ‘planetulae’ compared with Jupiter, and perhaps our Sun compared with other fixed stars would just be a tiny ‘solarus.’ (Gauss, 1802d).

Olbers, however, had a more balanced approach:
The contrast between Schröter’s and Herschel’s measurements is most surprising. Just between us, I trust neither of them. I believe Schröter has included too much spurious light in his measurements, and he would have perhaps found a fixed star to be just as large. – And Herschel? – I mean, the eye could easily be misled in comparing such small dimensions. Even if he enlarged Pallas 500 times it would have appeared to him (according to his stated diameter) only as a 1’ 5″ – diameter disc appears to the naked eye. With such a diameter a disc actually still appears as a point, and whether one of two such small disks appears larger than the other depends only on the brightness of these small disks. The light from Pallas must certainly have become very feeble in the telescope after a 500-times magnification, and hence a probably brighter, though much smaller, disc could still appear as large as Pallas to the naked eye. – Nevertheless, I am convinced that Herschel is much nearer the truth than Schröter. (Olbers, 1802f, his underlining).

Maskelyne, in a private memorandum of May 1802, did not quite know what to make of Herschel’s diameter measurements (see Appendix E):
Dr. Herschel has made some curious observations of the apparent diameters both of Pallas and Ceres, from which he infers the real diameter of Pallas to be 95 miles and that of Ceres 162 miles. He considers them as if a different species from the known planets. In their motions and smallness they resemble comets, but in the clearness of their light the other planets.

In Paris, Joseph-Jérôme de Francais de Lalande (1732–1807; Figure 3.4) expressed his utter rejection of Herschel’s results, telling him bluntly that no one else could be persuaded of their soundness:
I have found with pleasure your letter about the planets of Piazzi and Olbers. I wish that we could interest others for acceptance of your ideas. But it is not possible to believe that the planet of Olbers has a diameter of only 70 miles. We could not see it [if it were that small]. (Lalande, 1802a).
On 5 August 1802 the German astronomer Johann Elert Bode (1747–1826; Figure 3.5) wrote to Herschel with some astonishment regarding the diameter Herschel had assigned to Ceres and Pallas:

Let me thank you for your kind letter of May 22 and your results of your studies regarding Ceres and Pallas. I read them not only with pleasure but also with a kind of astonishment because it remains inexplicable to me how you can obtain such small true diameters of these two celestial bodies since you agree with Dr. Gauss regarding their true distances, as I believe. I cannot imagine how extremely small you must find according to this the apparent diameters and how you are able to determine such small diameters. How can planetary bodies reflect their light if they themselves have only apparent diameters of parts of seconds. In March Ceres appeared as a 7th magnitude star and was visible to some of my friends with the naked eye. (Bode, 1802c).

### 3.1.3 Controversy with Johann Schröter

In addition to the magnification issue mentioned in 3.1.1, many astronomers were incredulous when Herschel informed them that Ceres and Pallas were very small. These results were in contrast to those obtained by Johann Schröter (Figure 3.6), who found them much larger (see Table 3.1; Schröter 1805 and 1816). The fact that these were the two most celebrated observational astronomers of their day is not in dispute. Herschel employed the largest telescopes in England, and Schröter, likewise, had the largest telescopes in Germany (e.g. see Cameron, 2012; Gargano, 2012). Their respective and contrasting observations were the subject of a treatise by a teacher at the Collegium Carolinum in Brunswick, August Christian Gelpke (1764–1842; 1801, 2nd edition 1806).

That Herschel and Schröter were well aware of each other’s methods is apparent in a letter Herschel wrote to him a decade before the asteroid size controversy erupted. The letter is an openly-sarcastic swipe by Herschel, contrasting his ‘old’ method with Schröter’s ‘new’ method. His use of underlining affirms this is a sarcastic tone, which he is to use more than once in his later public writing about Schröter’s Solar System observations. Clearly, Herschel was not impressed by Schröter’s claims, either then or a decade later when they used their respective instruments to measure the asteroidal diameters:

You mention your new Projection’s Micrometer; as I suppose that you have undoubtedly taken notice of my camera-eye-piece etc: whereby I project objects on a sheet of paper, upon a wall, upon a measuring scale, upon a set of disks, peripheries, lucid points, draw images of objects, let the points of a pair of compasses that they will exactly fit into any two holes that a person
makes upon a card fixed up at a distance etc. As I suppose you [are] acquainted with all these things I should be glad to know in which respects your new differs from my old Projection-micrometer. (Herschel, 1792, his underlining).

The year 1792 was an important one in the relationship between Herschel and Schröter, due to some extent to poor translation from German to English, as noted by the Greenwich astronomer William Thynne Lynn (1835–1911). In referring to recent observations of Venus, Lynn (1892: 346) wrote:

No one can read them without being struck by the fact to how great an extent they confirm the observations made by Schröter a century ago, the accuracy of which was so strenuously contested by Herschel in the ‘Philosophical Transactions’ for 1793, and reasserted by Schröter in 1795. My present purpose, however, in referring to this controversy is to point out the danger of trusting translations in matters of this kind and the importance of referring in disputed points to the originals. Amongst the observations of Schröter to which Herschel alluded, in a tone which he must have afterwards regretted, were what he calls “flat spherical forms conspicuous on Saturn.” What Schröter really wrote was “abgeplattete Kugelgestalt des Jupiter und Saturn,” meaning flattened spherical shape of the planets themselves, not of markings on them.

A point on which Herschel and Schröter were clearly at odds was the height of the mountains of Venus (James, 2003). Schröter believed them to be 5 or 6 times as high as those on Earth. Herschel correctly countered that no eye which is not considerably better than his, or assisted by much better instruments, will ever get a sight of them. So from this time it was made plain that Herschel believed his telescope was the worlds’ finest, and that Schröter was seeing things that could not in fact be seen. As in many propositions put forward by Schröter (such as the atmospheres of the asteroids considered in Section 3.2), he was unable to distinguish between an alethic possibility and an alethic necessity.

Despite this dispute, they maintained a correspondence. Herschel asked him for his views on the planetary nebula that he, Herschel, had discovered, and in 1797 Schröter sent him a short paper outlining his investigation. Herschel remained unimpressed by Schröter’s originality. In an undated personal note, he wrote:

Mr. Schröter says he cannot consider every Nebula a distant Milky Way. I have already proved the same in my paper on nebulous Stars and mention the Nebula in Orion among others as an instance. [RAS W.7/6]

With the relationship between them already strained in such a public forum as the Philosophical Transactions, and Herschel’s reaction to Schröter’s nebular conclusions, their subsequent disagreement about Ceres and Pallas is thus placed in a broader context. In his letter to an unknown correspondent in England (probably his friend George Best (1756–1823); see Section 5.14), Schröter makes his case quite forcefully, saying Ceres and Pallas are “… not asteroids.” and:

After having read Mr. Herschel’s paper on the two new planets (not asteroids) I discovered the reasons for his mistakes in measuring their diameters: Dr. Herschel measured the same way I did but

a) He positioned the projection disc at an immense distance from the eye, from 124 to 178 feet without realising that an illuminated body seen with the naked eye, except for a certain distance appears relatively the larger the farther it is removed from the eye. I made several tests with an identical illuminated disc of 1.2 inches by seeing it with one eye and with the other through a sextant’s tube without glass. By this it appeared at a distance of 170 feet 5 times smaller than with the other naked eye. The more I was approaching the larger it became proportionate to that one seen with the naked eye and finally both agreed at eight feet. I changed the eyes; but it was and remained the same. Consequently, Dr. Herschel obtained, since he did not use the greater but the true and much smaller diameter for his calculation, a five times smaller diameter as product.

b) He did not measure, as I did, the nebulosity as well but only the brighter disc. And he used magnifications of 400 to 800, much too great for such a pale and comet-like planet. Due to lack of light and acridity he thus did not distinguish the entire disc with nebulosity but only its brighter centre part which he, as he himself says, saw as a cometary nucleus. Thus he saw the
nebulosity’s diameter sometimes six to seven times greater than this nucleus, which was not the case with my magnifications. A calculation for his errors produced his diameter of Pallas equally great as I found it. As a test I will soon measure the Georgian planet (Uranus) in the same way and Mr. Harding, who is working incredibly eagerly, is writing a little work on it to which he will also attach a chart of the smallest stars of that celestial region which Pallas will pass next year to find it wherever possible. (Schröter, 1802b, his underlining).

Gauss also weighed in on the discrepancy between the Herschel and Schröter diameter results, as reported by Zach:

Gauss finds the diameter according to Dr. Herschel’s own measurement slightly greater. Dr. Herschel gives on April 22 according to a fairly good observation the diameter = 0″.17; and Dr. Gauss calculated the true diameter 26½ German miles (the distance from earth = 1.562). [A German mile is 25,000 feet, compared to 5,280 feet in an English mile.] In his latest letter he expressed his astonishment about Dr. Herschel’s and Dr. Schröter’s different results of the diameters because they were made according to one method. “I am very curious to learn what magnifications Dr. Herschel used. A magnification of 500 times would hardly turn an apparent diameter of 0″.17 into a disc, would it?” I, for my part, could not discern a trace of a disc at 300x magnification of neither Olbers’ nor Piazzi’s planet. (Zach, 1802t: 195).

As a matter of comparison, it is worthwhile looking at the diameter measurements made by both men of the planet Mars. At the opposition of 1783, Herschel made micrometer observations on three nights. He found an equatorial diameter of 9.13″ and a polar diameter of 8.57″. These figures were the first ever proving the oblateness of Mars, the ratio derived being 1:16.3 (Herschel, 1784b).

Also employing a micrometer, Schröter observed Mars on 1 and 3 September 1798 when Mars was near opposition. His figures were 9.84″ and 9.72″, giving an oblateness of 1:81 (quoted in See, 1901:97).

In his study of 22 diameter measurements of Mars, See (1901:104) gives a mean value of 9.67″. He notes that the filar micrometer is considered to be the best standard for such a measurement. So we see that Herschel underestimated the diameter of Mars; in fact, of the 22 measurements given by See, Herschel’s is by far the smallest, a figure of 9.47″ being the next closest (by Kaiser in 1862-1864). While Schröter’s measurement is higher than the mean, several others were larger still, with Lowell (1896) at 9.92″ being the largest.

Schröter was also closer to the correct figure of the oblateness, the modern figure being 1:500.

See (1900) also did a survey of diameter measurements of Venus. He lists one by Herschel, based on a single micrometer observation, of 18.790″ (Herschel, 1793: 217). Based on four days of study in 1792, Schröter derived a diameter of 16.7″ (Schröter, 1792:317). See (ibid.) gives a best value of 16.8″, nearly identical to Schröter’s result.

In 1807 Schröter wrote a book about the first three asteroids. Its contents were summarised in The Eclectic Review (1807: 182-183), which included this pithy sentence: “The observations themselves, Mr. Schröter defends against every possible objection, especially against the measurements of Dr. Herschel, which are in strong opposition to them.”

| Table 3.1 Asteroid diameters in km as determined by Herschel and Schröter. |
|-----------------------------|------------------|--------------|-------------|-------------|
|                            | Ceres            | Pallas       | Juno        | Vesta      |
| Schröter                   | 2,526            | 3,258        | 2,222       | 538        |
| Herschel                   | 259              | 236          | ----        | ----        |
| True size*                 | 932              | 523          | 271         | 528        |

*Only Ceres is spherical, so the other diameters are approximations of their irregular shapes.
The size of the asteroids (see Table 3.1) was commented on by Henry Moseley (1801–1872; 1839: 194), Professor of Natural Philosophy and Astronomy, in one of his lectures at King’s College, London:

So small are they, that they are indistinguishable to the naked eye, and their apparent diameters have never been measured with any tolerable accuracy, even with the aid of the most powerful telescopes. It is said, nevertheless, that the largest of them, Juno, cannot have a real diameter of more than 100 miles, or 1/80th that of the earth. If this be the case, her surface is only the 1/6400th that of the earth, and her bulk the 1/512,000th part.

3.2 Atmosphere
3.2.1 Why an Atmosphere Might Be Expected
The issues involved can be formalised as an application of probability theory to variative induction. In the following quote from the British philosopher John Stuart Mill (1806–1873), his words “animal or plant” have been replaced for the subject under discussion here by the word “planet”:

If we discover, for example, an unknown planet, resembling closely some known one in the greater number of the properties we observe in it, but differing in some few, we may reasonably expect to find in the unobserved remainder of its properties a general agreement with those of the former, but also a difference corresponding proportionately to the amount of the observed diversity. (Mill, 1843: 89).

A less rigorous formulation of this concept comes from Bernard de Fontenelle (1657–1757; 1686: 115):

You must own that when two things are similar in all that I know of them, I may reasonably think them similar if what I am unacquainted with in respect to them.

As Ait-Touati (2011: 87) has noted, this “… is the condition of a valid comparison, founded on bringing together similar objects, a formulation reminiscent of Descartes.”

3.2.2 Irradiation and Spurious Disks: Controversy with Johann Schröter
This expectation to find properties in the “unobserved remainder” led Schröter, Herschel and others to search for two properties in particular that are associated with the known planets—namely, satellites and an atmosphere. Thus, Olbers (1805, his underlining) wrote to Gauss:

Schröter has, as he informs me, changed much in his work concerning the new planets based on ideas I had pointed out; I thus hope that you will no longer consider the calculation of the masses, densities, and gravitation at the surface of these small heavenly bodies. The determination of these details rests upon a totally erroneous application of an unprovable statement of [Daniel] Melanderhjelm [1726–1810]. He had adopted the hypothesis that the planet’s atmospheric density at the surface varies as the square of the gravitational force at the surface. Schröter believed he could conclude the reverse, that the atmospheric density at the surface varied as the height of the visible portion of the atmosphere. For our Earth he adopted, along with La Hire [Philippe de La Hire, 1640–1718], a height of 38,000 Toisen. Since his telescopic observations gave him the heights of Pallas’ and Ceres’ atmospheres from 100 to 150 miles, he thus decided on a high atmospheric density at the surface of both planets, and this the same for the gravitational force and density. The result is, e.g., that the density of Ceres is 4½ to 5½ times that of gold, etc.— I pointed out to him (1) that Melanderhjelm’s so-called theory merely entails the somewhat strangely expressed theory that the ratio of the mass of the atmosphere of every planet to its total mass is always the same, and thus with every planet it would be about 1/800000 of its mass; (2) that this hypothesis, in itself very improbable, is refuted precisely by his observations of such large atmospheres surrounding such small heavenly bodies; and (3) that the heights of the visible atmospheres could by no means vary just like their density at the surface, etc. Just between us, I can’t at all believe that Ceres and Pallas have these large atmospheres. Rather, I assume them to be due to irradiation in the telescope.

In fact, Olbers had written to Gauss about the irradiation matter three years before:
What kind of small planets are Pallas and Ceres? Herschel found an apparent diameter of Ceres, as Zach writes, of only 1 ″, and of Pallas, as Bode informs me from LaLande’s letter, of only 1 1/2 ″. In this way, speaking confidentially, irradiation must have interfered with our friend Schröter’s observations. I admit, I have always suspected this; for my very nice 5-foot Dollond, at 240-times magnification, does not even show an appreciable disc for either planet, nor is there a definite difference from a fixed star. (Olbers, 1802b, his underlining).

As Olbers rightly pointed out, the theory upon which Schröter based his conclusions was faulty. He also rightly identified irradiation as the cause of these unsupportable atmospheres. The subject of spurious disks and irradiation was examined by Cooke (1896: 38):

Since the spurious disk is brightest at the centre, and really shades off into the dark ring, it is evident that its apparent linear extension will depend very intimately upon the brightness of the star in question, that the spurious disk formed when a bright star is viewed will appear larger than in the case of a dim one, although the maximum size can never amount to as much as the diameter of the first dark ring. To this must be added the effect of irradiation in the case of the brighter stars. As a matter of fact, it is notorious how much smaller the star-disks appear to be in the case of small (ie faint) stars than in the case of bright ones. In all objectives having their focal lengths equal to 15 times the aperture, then the linear diameter of the spurious disk may be said to average 0.0004 inches. With 6 inches aperture this corresponds to an angular diameter of 0.9 seconds, and in a 12-inch aperture to 0.45 seconds.

In his paper on Juno, Herschel repeatedly observes a disk of around 0.2 seconds of arc, using his 10-foot reflector with a 9-inch aperture (this instrument had a focal length 13.3 times the aperture, close to the 15 times figure used by Cooke). But he finds a similar disk is apparent when he looks at stars of comparable brightness. He therefore concludes that the disk of Juno is almost certainly spurious, and he assigns no size to the object, merely saying it is also very small.

Herschel then draws six corollaries relating to the identification of real or spurious disks, and he claims that a real disk as small as a quarter of an arc second can be seen and distinguished from a spurious disk by the application of high power in the range of 500 to 600. If the disk is real, it is seen as a larger disk at high power; if it is spurious, higher power does not reveal a larger disk.

3.2.3 Implications for the Origin of the Asteroids: Bode’s Law
The so-called Bode’s Law of planetary distances has a well-researched history (e.g. see Jaki, 1972). Based on a simple arithmetic relationship, it early on found expression in the popular press of the day. And its direct link with the asteroids was also made clear. For example, the Belfast Monthly Magazine, 1811, says that “Professor Bode, of Berlin, discovered the following analogy in the distances of the planets, and by means of it foretold the discovery of the new planets, Ceres, Pallas, Juno, and Vesta, whose distances (from the sun) are nearly the same.”

An article simply signed by J.T.B. of Deptford links the existence of the four asteroids with Bode’s Law of planetary distances. As this section shows, the supposed presence of atmospheres around the asteroids became linked to Bode’s speculations in the writings of English men of science in the 1830s:

It is singular that the existence of these bodies, or at least of a planet moving near the courses which they pursue, was indicated by a very curious law, discovered by Prof. Bode— that the excesses of the distances of the planets above Mercury form a geometrical series, of which the common ratio is 2: the mean distances at which the asteroids revolve are nearly equal, and complete the relation, which was before wanting. It is not easy to see the reason of this law, which is also lately found to prevail among the satellites of the system, relative to their mean distances from the centres of their respective primaries. Though hitherto unexplained, it is worthy of observation, that a similar law, relative to the periodic times and distances of the planets, remained veiled in obscurity until the connexion was discovered to be a necessary consequence of the laws of gravity. The explanation of this singular law may be reserved to some future period, when it will doubtless be found to be an important part of that grand
scheme, every particular of which indicates design and perfect harmony. (*London Literary Gazette*, 1829).

After reviewing numerical relationships found in plants, Charles Daubeny (1795–1867), Professor of Chemistry at Oxford (1822-1855), extends the discussion to planets, where he finds evidence of a Divine harmony:

Bode observed, that the magnitudes of the several orbits which the planets describe, bear a certain definite proportion one to the other, the distances of Mercury, Venus, the Earth, Mars, etc. from the sun, being that of the numbers 4, 7, 10, 16, 28; so that the differences are as 3, 3, 6, 12. The law was interrupted between Mars and Jupiter, so as to induce him to consider a planet as wanting in that interval; a deficiency long afterwards supplied by the discovery of four new planets in that very interval, all of whose orbits conform in dimension to the law in question, within such moderate limits of error, as may be due to causes independent of those on which the law ultimately rests.

There cannot be a sublime subject for contemplation, or one more calculated to elevate our ideas with respect to the Divine attributes, than the correspondence, which may thus be traced between the laws that pervade the whole of creation, from the ultimate particles of matter, which, by their extreme minuteness, baffle our very powers of conception, to those immense aggregates of them, which compose any one of the members of our own planetary system; and as, according to the grand conception of Boscovich [Roger Joseph Boscovich, 1711–1787], the attraction of gravitation, and that of cohesion, may perhaps turn out to be the same force exerted at different distances; so the various ways, in which, as we have seen, the tendency to definite proportions manifests itself throughout the whole of nature, will perhaps be eventually traced to the same law; of which, what is called the atomic theory is only one of the consequences.

It is this indeed which constitutes the most striking distinction between the effects of art and nature, the provisions of finite and of infinite intelligence; -- the former accomplishing its purposes by a multitude of particular contrivances and regulations, which being made to meet each circumstance as it arises, are inconsistent one with the other, and at the best are applicable to a limited number only, out of the infinite variety of possible cases; -- the other producing an immense series of effects by a few very simple laws, which not only at the time display an exact harmony, but afterwards, as we proceed in their investigation, are found to be the consequences of a still smaller number of first principles. (Daubeny, 1831: 423).

While the dispute over the existence of asteroidal atmospheres may at first seem to be an isolated one, it actually had a major influence over subsequent views of British writers as to both their origin and their relationship to comets. The widely-read author Charles Bucke (1781–1846), who resided in Pulteney Terrace in London, exemplifies how a completely false belief in asteroidal atmospheres was applied to (quite correctly) discredit both Bode’s Law and Olbers’ asteroid explosion hypothesis (see also Subsection 3.4.1; Cunningham and Orchiston, 2013; and Cunningham 2006b):

Planetary distance are coincidences; not principles. If the Asteroids formed, originally, one body, would not all and each of them present striking and permanent analogies? What, however, are the facts? The action of Juno not only differs from that of the rest, but from those of all the other known planets in the solar system. For when at her greatest distance from the sun, she is at double the distance she is when at the least; and the part of her orbit, which is bisected by her perihelion, is passed in half the time in which she traverses the one more distant. Then, as to the atmospheres of these planets: – that of Vesta is scarcely observable; that of Juno is more so; that of Pallas is still more extended; but Ceres! – her atmospheric substance rises to a height even superior to those of the other planets in the system all combined! Where then is the probability of these bodies ever having formed one? It is even possible, that Ceres and Juno may constitute connecting links between PLANETS and COMETS; – a supposition not to be lightly regarded; for it is rendered strikingly probable by the circumstance, that the aphelion of Encke’s comet lies at no greater distance from the sun, than the space between the orbit of Jupiter and those of the Asteroids themselves. They all breathe, as it were, in the same hemisphere on the universe. (Bucke, 1832: 253, his italics).

The matter is also taken up in the *Encyclopedia* of the distinguished Scottish scientist, David Brewster (1781–1868; Figure 3.7), who was almost certainly the
author. His theory was widely reported, and actually reprinted in the section about comets in *The London Encyclopedia* (1829: 249) edited by Thomas Curtis:

If the four new planets are the fragments of a larger body, endowed with an extensive atmosphere, each fragment would obviously carry off a portion of atmosphere proportioned to its magnitude; but two of the fragments, Juno and Vesta, have no atmosphere at all, consequently the atmospheres of Ceres and Pallas could not have been derived from the original planet, but must have been communicated to them at a period posterior to the divergency of the fragments.

Figure 3.7: David Brewster (courtesy: en.wikipedia.org).

Curtis cautions one to be wary of this idea: “We leave the reader to form his own judgment of this curious hypothesis; certainly the facts on which this writer reasons are themselves most extraordinary.” As indeed they were, since Ceres and Pallas have no atmospheres!

In an extensive refutation of Brewster’s description of the origin of the asteroids, an anonymous reviewer in an American publication had this to say about asteroidal atmospheres, invoking the memory of William Whiston (1667–1752), Lucasian Professor of Mathematics at Cambridge University:

Dr. Brewster recurs in another place to this hypothesis (Olbers’ explosion hypothesis) to explain a circumstance that two of the new planets have very extensive atmospheres, while the other two apparently have none. He admits, that this is a difficulty not easily accounted for upon the supposition that they were once united. He takes occasion, therefore, from a comet passing somewhere near the region of the paths of these bodies, about the year 1770, to furnish the extra quantities of this fluid. This reminds us of the romantick [sic] days of Whiston. (The North American Review, 1818).

3.3 Colour and Brightness

Basic to these studies of the asteroids was an interpretation of what their light (reflected from the Sun) revealed. It was while Ceres was being searched for in late 1801 that the dual nature of light itself was discovered.

A paper titled “On the theory of light and colours” was read before the Royal Society of London in November of 1801. It was written by the polymath Thomas
Young, who believed that Newton’s corpuscular theory of light was in error. Like William Herschel, Young was savaged in the pages of the January 1803 issue of the *Edinburgh Review* by none other than Henry Brougham (1778–1868, Figure 3.8; see Cunningham, 2006a), but in this passage about Young’s paper, Brougham threw Herschel a ‘bone’:

This paper contains nothing which deserves the name, either of experiment or discovery. It is in fact destitute of every species of merit. In the name of science let his papers not find admittance into that venerable repository which contains the works of Newton and Maskelyne and Herschel. (Burwick, 1986: 30).

It must be noted that Brougham’s attack was not merely literary ‘fluff’—it proved disastrous to Young. According to several contemporaries, his diatribe virtually stopped the spread of Young’s wave theory (e.g. see Goetschl, 1995: 1).

In his first paper on Ceres, Herschel (1802a: cx) noted its colour as “… faintly ruddy …”, but he qualified it by stating that “… perhaps it appeared rather the more so, on account of my viewing it after the Georgian planet which is of a mild bluish tint.” The well-known nineteenth century observer Thomas William Webb (1807–1885) complained that Herschel was rather too “… partial to red tints.” (Holmes, 2010: 87).

Herschel’s second paper contains three brief notes on colour: “February 13: The colour of Ceres is ruddy, but not very deep. April 21: Ceres is much more ruddy than Pallas. April 22: Pallas is of a dusky whitish colour.” (Herschel, 1802b: 220). As noted in Chapter 1, he assigned no remarks on colour to either Juno or Vesta in his published papers, but in his second-to-last observation of Vesta, he wrote “Its light is ruddy.” This appears in his unpublished notes on 16 February 1814 (see Appendix B). The amateur astronomers William Walker (Subsection 5.2.2.1) and Alexander Aubert (1730–1805) also saw Pallas as reddish (Section 5.3), and Maskelyne thought Ceres “… white with a reddish hue.” (Subsection 5.5.1.2).
The dictionary definition of ‘ruddy’ is ‘reddish’, or ‘rosy’, so Herschel was seeing the same colour many attribute to the planet Mars. Modern data give a U-V for Ceres of 1.15, with a flat spectrum in the visible region. The general consensus of modern telescopic observers is that Ceres appears white or bluish-white. It should be noted that Hubble Space Telescope images of Ceres appear to show a broad reddish area on its disk, but this is a false-colour image. Likewise Vesta appears white in a modern telescope with no ruddiness apparent.

Whether Herschel’s observation of Ceres, Vesta and other celestial objects as reddish “… was a purely subjective problem, a physiological one, or down to his speculum metal being a better reflector at the long-wavelength end of the spectrum, is still open to debate.” (Holmes, 2008: 87).

Despite the suggestion by Holmes, based on a modern understanding of the situation prevalent two centuries ago there is no definitive evidence that the speculum metal used by Herschel was responsible for him seeing reddish objects. This leaves the first two possibilities mentioned by Holmes as the culprits, and they almost certainly both had an effect.

According to Dr Roger Ceragioli of the Steward Observatory Mirror Laboratory, a mechanical cause is not to blame:

I doubt that the 18.7” mirror used in the 20-feet was more than just slightly yellow. His smaller mirrors looked “white”. Only the 48” may have looked positively yellow, and Herschel almost never used that telescope. I very much doubt that his mirrors were the cause of his bias toward seeing faint stars as reddish. It was something else.

There is no way to make a certain assessment of Herschel’s personal proclivity to assign reddish tints where they were unwarranted, but this personal bias was the likely factor. Both Schröter and Harding also (sometimes) found Ceres to be reddish, while at other times white or bluish (see Subsection 5.2.1), so atmospheric conditions, such as highly variable particulate matter, is also a possible component.

<table>
<thead>
<tr>
<th>Observer</th>
<th>Object</th>
<th>Colour</th>
<th>Date</th>
<th>Magnification</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walker</td>
<td>Pallas</td>
<td>Red</td>
<td>April</td>
<td>100</td>
<td>Brighter than Ceres</td>
</tr>
<tr>
<td>Herschel</td>
<td>Ceres</td>
<td>Ruddy</td>
<td>13 Feb</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dusky whitish</td>
<td>22 Apr</td>
<td>881</td>
<td></td>
</tr>
<tr>
<td>Maskelyne</td>
<td>Ceres</td>
<td>Nearly white, possible reddish cast</td>
<td>23 Feb</td>
<td>50 and 200</td>
<td>Moonlight strong</td>
</tr>
<tr>
<td>Aubert</td>
<td>Pallas</td>
<td>Reddish</td>
<td>April</td>
<td></td>
<td>Larger than Ceres</td>
</tr>
<tr>
<td>Lee</td>
<td>Pallas</td>
<td>Dull red</td>
<td>April</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.4 The Number and Origin of the Asteroids

3.4.1 The Asteroid Explosion Hypothesis: The Writings of Charles Bucke
The poet Thomas Campbell (1777–1844) paid a visit to Herschel in 1813. Here is an extract of a letter he wrote on 15 September 1813:
I asked him if he thought the system of Laplace to be quite certain, with regard to the total security of the planetary system from the effects of gravitation losing its present balance? He said, No; he thought by no means that the universe was secured from the chance of sudden losses of parts.

He was convinced there had existed a planet between Mars and Jupiter, in our own system, of which the little asteroids, or planetkins, lately discovered, are undubitably fragments; and ‘Remember’ said he ‘that though they have discovered only four of those parts, there will be thousands—perhaps 30,000 or more—yet discovered.’ This planet is believed to have been lost by explosion. (Beattie, 1850: 234).

Campbell’s conscientious biographer appears to have felt that the value of this charming account of Campbell’s interview with Herschel was in its report of astronomical facts and opinions, and he adds a footnote to explain that Herschel’s opinion never amounted to more than hypothesis having some degree of probability. Sir John Herschel (in Nov. 1847) remembers his father saying, ‘If that hypothesis were true, and if the planet destroyed were as large as the earth, there must have been at least 30,000 such fragments,’ but always as an hypothesis—he was never heard to declare and degree of conviction that it was so. (Holden, 1881: 110).

This Campbell extract is also notable for its use of yet another term to denote Ceres, Pallas, Juno and Vesta, namely ‘planetkins’. In 1818, Herschel repeated his assertion about 30,000 unseen asteroids to John Griscom (1774–1852), Professor of Chemistry and Natural Philosophy in the New York Institution (Griscom, 1823: 151).

Sir John Herschel (1792–1871; Figure 3.9) contributed his own remarks to the debate about the explosion hypothesis, and these were incorporated by the English writer Charles Bucke in his multi-volume work about the natural world (Bucke, 1837: 248):

It has been conjectured, that the ultra-Zodiacal planets are fragments of some greater planet, which formerly circulated in that interval; but has been blown to atoms by an explosion. This may serve as a specimen of the dreams, in which astronomers, like other speculators, may harmlessly indulge. (Herschel, 1833).
By the 1830s, the subject of the origin of the asteroids was fodder for the popular press in England. Bucke (see Subsection 3.2.3) got his views about the asteroids published in *The Literary Gazette*. He begins by postulating the existence of “… one large primary planet, or several small ones (like Ceres, Pallas, Juno, and Vesta) …” (Bucke, 1830: 450) between the orbits of Saturn and Uranus. In a postscript to his main article, Bucke suggests he will write more about the asteroids:

P.S. Should the above observations be favourably received, I shall take a future opportunity of making some remarks on the origin of Ceres, Pallas, Juno, and Vesta; the account of which, though sanctioned by many illustrious names, I cannot but esteem as being (to say the least) extremely unsatisfactory. Indeed, I think I shall be able to prove, that their cause of origin, as stated, involves an utter impossibility, according to the rules of gravity, and the simplest of the laws of projectiles.

By taking the new method of observance, perhaps many small planets may yet be discovered, even in regions which have been the most traversed. The highest of all possible magnifying powers, however, will be requisite. But astronomical observers should particularly bear in mind, what, no doubt, they constantly do, that Pallas does not subtend an angle sufficient to be measured, with any degree of precision, even by the best instruments; and that she ascends above the plane of the ecliptic even at an angle of 35º, which is nearly five times as much as any other planet—a very remarkable circumstance in itself, and almost sufficient to attest the existence of many other analogous bodies besides those already discovered. (Bucke, 1830:450).

The main body of the article just quoted is about the orbits of the planets and a proposed nomenclature for the satellites. In it, Bucke presciently says a future age will confirm the existence of a ring around Uranus. Meanwhile, his text about the explosion hypothesis prompted a riposte from J. Cullimore of Kennington:

I would further remark, in reference to your [Bucke’s] opinion of the received account of ‘the origin of Ceres, Pallas, Juno and Vesta, being (to say the least) extremely unsatisfactory,’ &- that the theory of their origin, from an exploded planet formerly between the orbits of Mars and Jupiter, which I take to be that you allude to, seems directly to result from Bode’s Law; because this law, and the harmony of the whole system, requires one original primary planet within that zone, and not four. Does it not therefore immediately follow, that the four asteroids must of necessity be fragments either of that original planet or of a dismembered secondary system like Jupiter’s? And this, independent of the arguments to be derived from the proximity and intersections of their orbits, which have conducted astronomers to the same conclusion. Indeed, with the above-mentioned law, and its proofs before us, any longer to suppose the asteroids original independent members of the solar system, would, I apprehend, be to suppose an anomaly in the all-perfect and harmonious works of creation. The existence of many, perhaps hundreds, of analogous fragments of the exploded planet or system, the majority of which are probably far too minute for the highest telescopic vision, may also doubtless be inferred. (Cullimore, 1830: 530).

The editor of the *Literary Gazette* felt compelled to comment upon the controversy between Bucke and Cullimore. This included the following paragraph specifically relating to the future discovery of small planetary bodies and their origin:

Respecting undiscovered planets, Mr. B. is, perhaps, nearer the mark than he is aware: several small planets are suspected; the splendid catalogues of stars by Bessel and [Friedrich Georg Wilhelm] Struve [1793–1864], and the list of the Astronomical Society, will tend very considerably to set this question at rest; when these catalogues come to be revised, by going over the stars again, some may be missed, others may be found, proving that some which have been classed as fixed stars are, in fact, planets. There is ground for the suspicion, which, if confirmed, will completely upset the “explosion system.” (page 530, his italics).

In his book of 1832, which has already been quoted in Subsection 3.2.3, Bucke elaborated on his disbelief in Olbers’ asteroid explosion hypothesis:

Dr. Olbers, and several other astronomers, have given to the idea, that a large planet once existed between the orbits of Mars and Jupiter; and that it separated into four parts, forming what are now called the Asteroids. Much learning has been called into action on this subject. It is argued, that Bode’s Law, and the law of Nature, are one; and that they both require the
existence of such a planet. If so, why does not this large body exist? If it were wanted in times past, it is wanted in times present.

If four planets will answer the purpose of the one, supposed to have burst, as, it appears, they very effectively do, what difficulty can there be in supposing, that they have existed from the creation and adjustment of the system; as well as Jupiter and Mars and all the other primary and secondary planets? Why, in fact, should we suppose Nature to have done an act, which is not only unnecessary, but which is in decided opposition to all the laws, by which she can be recognised? (Bucke, 1832: 251, his italics).

Bucke’s discourse about the origin of the asteroids is unique amongst writers in England, and is thus of great importance for our awareness how the asteroids were understood in England at this time. Bucke was not only unique, but correct in his assertions that the asteroids are primordial bodies, and that the hypothesis promulgated by Bode’s Law could not be equated with the laws of Nature. This is all the more remarkable since Bucke was not an astronomer, or even a man of science. He lived in poverty for most of his life, receiving assistance from the Literary Fund and a small pension from a patron. He is most remembered now for a dispute with the famous actor Edmund Kean, but during his lifetime Bucke was well-known. He was even mentioned as a “Scribleri” by Lord Byron (Lord George Gordon Byron, 1788–1824) (Prothero, 1898-1901(2): 202). Even though poor, Bucke was well-connected: his grandfather Sir Robert Walpole (1676–1745) was Prime Minister of England.

Another English writer of the period also firmly rejected the explosion hypothesis. A Mr. G. Rubie, who is described on the title page as a “… teacher of geography, the use of globes, astronomy, and navigation …” (Rubie, 1830) employed a unique argument in his assertion the asteroids are primordial:

But do we not see a beautiful variety in all the works of creation? And shall we then accuse the great Architect of the Universe, of introducing disorder in the arrangement of the planetary system or of having destroyed this imaginary Planet, with all its inhabitants (for they are all supposed to be inhabited), because he has introduced that variety? Nay, rather let us admit the hypothesis, that they are independent Planets, and that they were originally intended to occupy that part of the solar system, in which they now move. (Rubie, 1830:112).

The British public also read the French astronomer François Arago (1786–1853) cast doubt on the explosion hypothesis (Isis, 1832). Yet at the same time, Thomas Ewing was so sure the harmony of the Solar System must be preserved by the earlier existence of a large planet, that he termed the mere notion of primordial asteroids as subversive! Ewing (1839) describes himself on the title page of his book as a “teacher of Elocution, Grammar, and Composition, Geography, History, and Astronomy, No. 18, George Street, Edinburgh.” Ewing gives The Edinburgh Encyclopedia as a source for this discourse, which was originally printed anonymously in The Entertaining Magazine (1814):

The existence of four planets (Vesta, Juno, Ceres, Pallas), between the orbits of Mars and Jupiter, revolving round the sun at nearly the same distances, and differing from all the other planets in their diminutive size, and in the form and position of their orbits, is one of the most singular phenomena in the history of astronomy. The incompatibility of these phenomena with the regularity of the planetary distances, and with the general harmony of the system, naturally suggests the opinion that the irregularities in this part of the system were produced by some great convulsion, and that the four planets are the fragments of a large celestial body which once existed between Mars and Jupiter. If we suppose these bodies to be independent planets, as they must be if they did not originally form one, their diminutive size, the great eccentricity and inclination of their orbits, and their numerous intersections when projected on the plane of the ecliptic, are phenomena absolutely inexplicable on every principle of science, and completely subversive of that harmony and order which, before the discovery of these bodies, pervaded the planetary system. But if we admit the hypothesis, that these planets are the remains of a larger body, which circulated round the sun nearly in the orbit of the greatest fragment, the system resumes its order, and we discover a regular progression in the distances
of the planets and a general harmony in the form and position of their orbits. The elements of
the new planets furnish us with several direct arguments drawn from the eccentricity and
inclination of their orbits, and from the position of their perihelion and nodes, and all
concurring to show that the four new planets have diverged from one point of space, and have
therefore been originally combined in a larger body. (Ewing, 1839: 18).

3.4.2 The Nature of Hypothesis
It was sardonically noted by Alexander Maxwell (1820: 56) that “… the course of
nature, after all our conjectures, experiments, and calculations, may be very different
from any known hypothesis.”

Thomas Young (1773–1829; Figure 3.10) wrote cogently about the relationship
between hypothesis and theory. It will not be out of place to consider here the
contemporary view on what was meant by this term. The ancient Greek usage of the
term *hypothesi* meant the foundations of an intellectual structure:

Although the invention of plausible hypothesis, independent of any connexion with
experimental observations, can be of very little use in the promotion of natural knowledge; yet
the discovery of simple and uniform principles, by which a great number of apparently
heterogeneous phenomena are reduced to coherent and universal laws, must ever be allowed to
be of considerable importance towards the improvement of the human intellect. (Young,
1802a: 12).

Figure 3.10: Thomas Young (courtesy: en.wikipedia.org).

Young (1804; 1855: 204) has more to say on this subject:

There are two general methods of communicating knowledge; the analytical, where we proceed
from the examination of effects to the investigation of causes; the other synthetical, where we
first lay down the causes, and deduce from them the particular effects. In the synthetical
manner of explaining a new theory we necessarily begin by assuming principles, which ought,
in such a case, to bear the modest name of hypothesis; and when we have compared their
consequences with all the phenomena, and have shown that the agreement is perfect, we may
justly change the temporary term *hypothesis* into *theory*. This mode of reasoning is sufficient
to attach a value and importance to our theory, but it is not fully decisive with respect to its
exclusive truth, since it has not been proved that no other hypothesis will agree with the facts.
3.5 Orbital Properties

Only one English astronomer/mathematician in the early nineteenth century wrote about the orbital properties of the asteroids. Unfortunately we do not know who he was as the title page to his book *Essay on the System of the Earth* is missing. Only one copy seems to exist, and this is at Radcliffe Observatory in Oxford:

The difference of mean distance from the sun of the two asteroids Ceres and Pallas, is stated in Vince’s *Astronomy* to be as the difference between 276.74 and 276.759 or about .019, the distance of the earth being the standard at 100. Taking the real mean distance of the earth from the sun at about 95,000,000 miles... the distance between these asteroids must be about 18,000 miles. (Anon, 1811: 193-194).

In the past there have been a series of close approaches (at less than 10 million km or 6.2 million miles) between Ceres and Pallas, around year –13900, spaced by 4.6 y (just one orbital period). None will occur in the future before year 20000. (Aldo Vitagliano, private communication). Orbital analysis (Michalak, 2000) has shown the closest approach of Ceres and Pallas since their discovery (in 1825) was 17.5 million miles, so the conclusions drawn by the author of 1811 from his calculation of a mere 18,000 miles are necessarily faulty. The full text of this is in Appendix D.5. Vince’s *Principles of Astronomy*, mentioned near the beginning of this passage, was a standard work in astronomy. It was published in three volumes between 1797 and 1808 by Samuel Vince (1749–1821; Figure 3.11), Plumian Professor of Astronomy at The University of Cambridge.

In a footnote on page 194, the anonymous author of 1811 gives further support to the idea of the intercession of a comet in the history of Ceres, a supposition that was widely considered and even favoured by many other authors in this era:

I think I once saw in some publication (but wholly forgot where,) a statement that Ceres had been discovered to have a remarkably large atmosphere. If this be correct, it might be supposed to favour the presumption of an accession of a comet to this planet, and therefore to raise the possibility that the great angle of inclination of the orbit arises from the same cause.

Figure 3.11: Samuel Vince (courtesy: en.wikipedia.org).
CHAPTER 4: NOMENCLATURE

4.1 The Case of Uranus

The first observations of Uranus could perfectly well be described by a parabola; indeed, Mr. La Place found four different parabolas (Theorie du mouvement et de la figure elliptique des Planetes, p. 29); and it took almost five months of continued observations, till the greatest analyst of our times was able to exclude the parabolic orbit: Herschel discovered the planet in March 1781 and only in August was La Place able to derive the parabolic orbit. (Seyffer, 1801: 38).

Since the orbit of the new object was derived in France, the French came to the conclusion they had the right to name it. While the need for French astronomers to name the discoveries of others does strike one as rather pathetic, the psychology involved was not born with the discovery of Ceres. We read in a 1781 letter from Joseph Banks to William Herschel that the naming of his great discovery had better be done quickly: if Herschel failed to move with dispatch, Banks warned, “… our nimble neighbours, the French, will certainly save us the trouble of baptising it.” (Banks, 1781).

Herschel was unsure what to call his epochal discovery, but he was quite certain what it should not be called:

In the fabulous ages of ancient times the appellations of Mercury, Venus, Mars, Jupiter and Saturn were given to the Planets, as being the names of their principal heroes and divinities. In the present more philosophical era, it would hardly be allowable to have recourse to the same method, and call on Juno, Pallas, Apollo or Minerva, for a name to our new heavenly body. (Herschel, 1783a: 2).

It was the German astronomer Johann Bode who dubbed it Uranus, although Herschel’s belated choice of ‘Georgium Sidus’ was used in England for several decades (Herschel, 1783b: 4; Standage, 2000: 6). Herschel’s name for his discovery, Georgium Sidus (George’s Star), was meant to honour his patron King George III of Great Britain, and was inspired by Horace’s Julium Sidus to compliment Julius Caesar (Duncombe, 1757: 48). Thus we find Herschel’s friend William Watson specifically recommending Georgium Sidus “in the same manner as Horace” (Watson, 1782). It led the great politician and wit Horace Walpole (1717–1797) to remark cynically to the Earl of Buchan in 1785:

I am very ignorant in astronomy, and could wish to ask many questions; as, Whether our celestial globes must not be infinitely magnified? Must not that host of worlds be christened? Mr. Herschel himself has stood godfather for His Majesty to the new Sidus. His Majesty has a numerous issue; but they and all the princes in Europe cannot supply appellations enough for twenty millions of new-born stars. (Toynbee, 1905: 328).

4.2 Herschel’s Choice: ‘Asteroids’

4.2.1 The Search for a Name: Charles Burney Jr. creates ‘Asteroid’

Even though Herschel visited Paris (during a short interval of peace between Britain and France; Grainger, 2004) in August 1802, where he met Laplace and First Consul Bonaparte, he did not concern himself—as the French did—with the naming of the new celestial objects individually. His concern was their collective appellation, and for his choice ‘asteroids’ he was roundly criticised. Much of the censure came from his own country. Before considering the reaction, we must look into Herschel’s private letters to discover how he arrived at the terminology that is most widely used today.

The search for a new name began on 25 April 1802, when Herschel turned to his friend Sir William Watson for help (see Cunningham and Orchiston, 2011). At the time of writing the relevant portion of the letter reproduced below, he was likely aware that Newton (1726) had written an analysis of the motion of comets in the
third book of the *Principia*, in which he shows that comets “… are a sort of planet.”

Here is what Herschel (1802c; his underlining) wrote:

… I have now [to] request a favour of you which is to help me to a new name. In order to give you what will be necessary I must enter into a sort of history. You know already that we have two newly discovered celestial bodies. Now by what I shall tell you of them it appears to me much more poor in language to call them planets than if we were to call a rasor a knife, a cleaver a Hatchet, etc. They certainly move round the Sun. So do comets. It is true they move in ellipses; so we know do some comets also. But the difference is this they are extremely small, beyond all comparison less than planets; move in oblique orbits so that, if we continue to call that the ecliptic in which we find them, we may perhaps, should one or two more of them be discovered still more oblique, have no ecliptic left the whole heavens being converted into ecliptic which would be absurd. I surmise (again) that possibly numbers of such small bodies that have not enough matter in them to hurt one another by attraction, or to disturb the planets, may possibly be running through the great vacancies, left perhaps for them, between the other planets especially Mars and Jupiter. But should there be only two surely we can find a name for them. The diameter of the largest of them (at present entre nous) is not 400 miles, perhaps much less as I shall know in a few hours but have not time to wait. Now as we already have Planets, Comets, Satellites, pray help me to another dignified name as soon as possible. If it could any way express the condition of a nimble, small, interloper going obliquely through the majestic orbits of the great bodies of the Solar System it would be just what is required. But pray, if you can, help me soon. I am writing a paper in which if possible I would propose a name, but as it should go to London by next Thursday I am hardly willing to press you so much for haste. However you will give it a thought, and if two or three names could be proposed it would give me some choice. Greek derivation such as planet from πλαναω would probably be best.

The word written in Greek, ‘planao’, is the verb ‘to wander’.

Watson received Herschel’s letter the next day and responded after a day of thought:

I received much gratification at the perusal of your letters—the discovery of a new species of heavenly bodies is truly surprising, and I agree with you that a new name ought to be given such bodies. The best name I can think of is Planetel as a diminutive of Planet, just as Pickerel or Cockerel (used by Shakespeare) is of a Pike and a Cock. The sportsmen too call a young stag stagel. You may also use as the diminutive the word Planeret, as baronet is of the word Baron—so we say islet tartlet tablet cygnet, the respective diminutives of island, tart, table, Cygne the French for Swan. But as these are made by the mere addition of et, except tartlet, the word should be Planetet, and that does not sound well. Diminutives are also formed by adding –kin as manikin, lambkin, so you may say Planetkin—or better Erratikin—being the diminutive of Erratic. I should like Planetine (pronounced Planeteen) best of all, but I find no example of that way of diminishing in English. The diminutives formed by adding –ling such as duckling will not have place here—we cannot say Planetling. So upon the whole I think the word Planetel the least objectionable. Perhaps you may be more happy in your research after a new name.

P.S. Since I wrote the above I recollected that after the Romans we make diminutives by adding –ule such as spherule, a little sphere. So Planetule may be a little Planet. (Watson, 1802b).

One diminutive suggestion he did not make was to suggest the word ‘planetella’ (as in novella, a small novel). ‘Planetkin’ has entered the OED as a nonce word. It identifies the Scottish philosopher Thomas Carlyle (1795–1881) as the first person to use it in 1832 (Norton, 1887: 35). Even so, Herschel did, at least once, adopt Watson’s final suggestion. In his “Work to be done” (which relates to William’s discussion with his son John in 1816), he lists as the first task “To observe the 4 Planetules”. For an analysis of the word ‘planetule’ see Section 5.14. As Herschel stated in his 25 April letter, he intended to include the new name in his paper which was due “… by next Thursday.” This date was 6 May, which was in fact the date Herschel’s paper was read before the Royal Society.

Archival material at the Beinecke Rare Book Library of Yale University contains the ‘smoking gun’ letter that reveals who actually created the word ‘asteroid’.
In a letter of “Monday night May 10\textsuperscript{th} [1802]” from the English music historian Dr. Charles Burney Sr. (1726–1814; Figure 4.1) to his son Charles Jr. (1757–1817; Figure 4.2), Burney (1802a, his underlining) writes:

Herschel came hither today, to ask me if I c\textsuperscript{d}. furnish him a Latin or Greek name for the small stars that have been lately found, & called by some planets, & by others Comets; but he says they are neither one nor the other, but a new genus of erratic heavenly bodies within the ecliptic, that have orbits round the Sun: yet so small that they cannot be found by a Telescope. There are however 12 astronomers in Germany formed into a Society, who have divided the ecliptic into 12 parts, assigning one to each who is not to encroach on the other departments. The last new planet, as it is called, is not above 150 miles in diameter – Mercury or the Moon would make 1000 such – it has, however, a disk, and is in motion. – Now what can he call a star of this nondescript kind?

Does not Hadrian call his soul \textit{animula, vagula, blandula}? and is there not a diminutive of the Greek word \textit{Aστηρ} – \textit{Aστερικός} – & in Latin is not \textit{stellula} the diminutive of \textit{stella}? \textit{Aστηρ} implies any kind of heavenly body, be it planet, satellite, or fixt star – \textit{ Asteriscos, or Stellula wd. be a pretty name for one of these little wanderers, that are taking a peep at us.}

The first line of Pope’s imitations – “vital spark of heavenly flame” – suits this last little lady to a T – does it not? – if you say nay, send me a better for my friend, as soon as possible for it is to be given in to the secretary of the R.S. [Royal Society] tomorrow to be voted for reading on Thursday.

It must not be a \texttt{big} name for so \texttt{small} a star.
The first Greek word he uses is ‘aster’ ἄστηρ, and the second one ‘asteriskos’ ἄστερισκος. Burney has a ligature between sigma and tau, which was common in some types of Greek script. He was not using the ς form of sigma, which is only found at the ends of words, but a common ligature which somewhat resembles that form of sigma. The second vowel in the word is long, and so written with eta, not with epsilon. He was obviously having trouble with his Greek that night, as he had to insert the letter ρ in the second word with a caret, and the medial sigma in ἄστερισκος has the wrong shape (Figure 4.3).

The reference to Alexander Pope (1688–1744) is to the first line of his 1712 poem *The Dying Christian to his Soul*. The words are based on the death bed utterance attributed to Roman Emperor Hadrian: Animula, vagula, blandula, hospes comesque corporis. Pope had been inspired by these words from an early age, as he relates to Richard Steele what led him to pen his poem:

> I was the other day in company with five or six men of some learning; where chancing to mention the famous verses which the Emperor Adrian [sic.] spoke on his death-bed, they were all agreed that ‘twas a piece of gaiety unworthy of that prince in those circumstances. I could
not but differ from this opinion: methinks it was by no means gay, but a very serious soliloquy
to his soul at the point of his departure; in which sense I naturally took the verses at my first
reading them, when I was very young, and before I knew what interpretation the world
generally put upon them. (Pope, 1712).

From the cover of the letter from Burney Sr. in Chelsea to Burney Jr. in
Greenwich (a distance of only 11km) it can be read that Burney Jr. was sent this
letter by two-penny post at 9am on Tuesday morning. But was Burney Sr. correct in
dating this letter Monday 10 May? It would make sense if he dated it Monday 3
May, because it was to be that Thursday (6 May) when the paper was read. We see
here it was to be in the hands of the Secretary the very next day, which would be the
4th of May. My own reading of letters from this period has revealed incorrect
dates—sometimes the year is actually written incorrectly! It would certainly not be
impossible for a person working by candlelight late at night to get the day of the
week correct but the day of the month wrong by a week. It is also obvious by the
way the letter is written that it was done in haste—he twice had to use carets to insert
a phrase or a Greek letter in its proper place, and the last line quoted above was
written at the bottom of the letter after a paragraph of personal details—so it was
clearly an afterthought. He also wrote his son that the objects could not be found in a
telescope, another indication he was tired and writing in haste, since clearly they
were found using a telescope.

If we consider this letter as being in the hands of Charles Burney Jr. (in
Greenwich) on the morning of Tuesday, the 4th of May, we must conclude he
supplied an answer to Herschel that very day. Since there were four country mail
despatches and deliveries daily in that era, he could have devised an answer which
would have been in Herschel’s hands that evening. It is certainly clear from this
letter that Herschel had not chosen a word—he was also clearly in great haste to get
an appropriate word, since he visited Charles Sr. in person that day instead of writing
to him at leisure. Burney Sr. uses the phrase “… as soon as possible …”, thus
emphasizing how urgent it was.

The Latin Burney alludes to, with its use of the diminutive ‘–ula’, can be easily
traced. According to the Historia Augusta, the Emperor Hadrian composed shortly
before his death in 138 AD the following poem:

Animula, vagula, blandula
Hospes comesque corporis
Quae nunc abibis in loca
Pallidula, rigida, nudula,
Nec, ut soles, dabis iocos ...
P. Aelius Hadrianus Imp.

This translates as:
Roving amiable little soul,
Body’s companion and guest,
Now descending for parts
Colourless, unbending, and bare
Your usual distractions no more shall be there ...

Charles Burney Jr. likely supplied his answer to his father in writing, and Burney
Sr. then gave the response to Herschel. This may have been done verbally, as no
known letter exists. However, the ‘smoking gun’ letter was written later that year.
Dr Burney’s 2-page letter to Frances Crewe (postmarked 7 December 1802) is
definitive. In this he tells her that his son furnished Herschel with the word
‘asteroid’. He tells her about

… a new vol. of the Philosophical Trans. in wch are two curious astronomical papers by
Herschel. In one of wch he gives an acc of the 2 newly discovered celestial bodies, Ceres, &
Pallas. The first in magnitude is only 3/8 of the moon; its Diameter no more, if I understand
right, than 161 miles. The 2d, Pallas, still less, about 3/4 of Ceres– its Diameter about 147
miles– not an 8th p’ of Mercury– They are not allowed by Herschel to be either Planets or Comets, but asteroids, italick, a kind of star– a name with my son, the Grecian, furnished. (Burney, C., Sn., 1802b, his underlining).

Now, after more than two centuries, it has been established beyond doubt that Charles Burney Jr. invented the word asteroid! Thus, every book and reference that gives credit to Herschel for this appellation is incorrect. Charles Sr. deserves some of the credit for coining the word, as he chose the Greek word ‘aster’, and passed this idea along to his son, who added ‘–oid’.

Who was Mrs Crewe, the lady who became one of the very few people in the world who knew the truth about the word ‘asteroid’? Frances Anne Greville was born in 1748 to two published authors: Frances Macartney and Fulke Greville. The family had strong political connections, and strong ties to the great minds of the time. Frances’s father, Fulke, was a close friend of Dr Charles Burney Sr. In 1766, Frances married John Crewe (1742–1829), thus joining two powerful Whig families. John was created Lord Crewe in 1806. Frances, one of the most famous society hostesses of the age, died in 1818 (Rigg, 1888).

While there appears to have been no personal relationship between Herschel and Stephen Weston (see next page), the same cannot be said for Dr Burney Sr. An anecdote is related by his daughter Miss Burney in late 1786:

This morning my dear father carried me to Dr. Herschel. That great and very extraordinary man received us almost with open arms. He is very fond of my father, who is one of the council of the Royal Society this year, as well as himself. (Sime, 1900: 199).

Dr Burney has left vivid recollections of his visits to Herschel who, he wrote in 1798, “… is one of the most pleasing and well-bred natural characters of the present age, as well as the greatest astronomer.” (Sime, 1900: 201). They often met at meetings of the Royal Society, and Herschel frequently stayed at Burney’s house where he almost certainly met Charles Burney Jr.

Burney Jr. is referred to in the letter to Mrs Crewe as “… the Grecian …”. This was not just parental boast, as Burney Jr. was one of England’s pre-eminent Greek scholars in the late eighteenth and early nineteenth centuries. His major works were: Appendix ad lexicon Graeco-Latinum a Joan. Scapula constructum (1789), Remarks on the Greek Verses of Milton (1790), Richardi Bentleii et doctorum virorum epistolae (1807), Tentamen de metris ab Aeschylo in choricis cantibus adhibitis (1809) and Philemonos lexikon technologikon (1812).

In 1792, Charles obtained honorary doctorates in law from both King’s College, Aberdeen, and the University of Glasgow. In 1807, he became a deacon of the Church of England. The same year, through the influence of his close friend Samuel Parr, Charles was reinstated at his former Cambridge College. In 1808, he was both ordained a priest and granted the degree of MA from Cambridge by royal mandate. After his scandalous past at Cambridge was redeemed (he had stolen some books there in 1778), Charles continued to quickly advance in the church. He also continued to be lauded as a scholar; he was elected a Fellow of the Royal Society in 1802, made Professor of Ancient Literature at the Royal Academy in 1810, and elected to the Literary Club in that same year (The Burney Center, McGill University). Both father and son contributed to The Critical Review, which published important articles about the asteroids (see Subsection 4.2.2.6). Burney Sr. wrote about music, while Burney Jr. contributed articles on classical literature (Roper, 178: 21).

It certainly appears that Charles Burney Jr. had no interest in publicly claiming his invention of the word ‘asteroid’. Considering the great opprobrium heaped upon Herschel for choosing this word, that is perhaps not too surprising. Why is there no
letter in the Herschel archives of the Royal Astronomical Society about the important creation of the word asteroid? There seem to be two possibilities.

First, there was no letter from Charles Burney Sr. or Jr. to Herschel. It is probable that Burney Jr. informed Burney Sr. either by letter or in person, and that the word was given to Herschel by Burney Sr. in person.

Second, there was a letter from Burney Sr. to Herschel, but it was deliberately destroyed by Herschel. Again there seem to be two possible motives for this course of action. Either Herschel wanted to keep the credit for coining the word for himself, or, after he realised what great opposition the new word had created, he destroyed the letter to protect the Burney family from abuse.

Since Herschel hardly needed any more fame than he already possessed, it seems most likely that Burney Sr. told Herschel about it in person, in which case there was no letter to be found.

Even so, Herschel still felt uncomfortable with his choice. Clearly unimpressed by Watson’s ideas, Herschel turned to Sir Joseph Banks for help. Banks in turn turned the task over to Stephen Weston (1747–1830; Figure 4.4), a Fellow of the Royal Society since 1792 (Cotton, 1892:6), who subsequently reported back to Herschel (see Figure 4.5). This letter reads:

I applied to Mr. S. Weston as I always do in these occasions to stand God Father to your new species of moving stars and [he] has sent me a card which I enclose. I really think Aorate a good name and much better than any that has been hitherto suggested and the more so as it is not probable that any of this new kind of wanderers are visible to the naked eye. (Banks, 1802e).

In this letter to Herschel, Banks favoured ‘Aorate’ to describe Ceres and Pallas. The elements of the word are a- ‘not’, (h-/)ora- ‘see’, -t- passive participial suffix (i.e making ‘see’ into ’seen’), -e = -η fem. termination unusual in a compound containing a- ‘not’; ἄορατος is perfectly good Classical Greek for ‘invisible,’ the very attribute of Ceres and Pallas that Banks highlighted in his letter. The replacement of the termination -oς with the long vowel -η would automatically draw the accent on to the penultimate syllable. Weston may have finished his word with -η in imitation of several Greek names of goddesses that have the same ending. The most instructive is Persephone, thought to be a folk etymological modification of the original Persephatta, both forms being compounds with transparent etymologies and therefore not likely to form a fem. in -η.

Aorate and other words offered by Weston (on a card now apparently lost) were given by Banks to Herschel, who was clearly disappointed with the offerings:

The names you have done me the favour to send I have carefully examined, and beg leave to give you my remarks on them. The title of them, “Names for the new Planet,” shows immediately that none of them can possibly be used for the new species of bodies which we have to christen: for they are not planets.

If Mr. Weston were to have a definition of the thing we want a name for, he might possibly find a better than that of asteroids, which is not exactly the thing we want, tho’ still the most unexceptionable of any that have been offered by my learned friends. Will you do me the favour to consult him once more upon the subject, and mention to him that the bodies to be named are neither fixed stars, planets, nor comets, but have a great resemblance to all the three?

With this view before him he will probably succeed in an appropriate appellation. (Herschel 1802e).
In this extraordinarily frank letter, Herschel admits that the term ‘asteroids’ is not optimal—merely the best of an unremarkable suite of options. There is no evidence that Weston looked into the matter again. Perhaps Banks thought better of asking him a second time, or Weston simply did not offer any further ideas. Thus the word
asteroid, used in the 6 May paper, was the de facto choice to designate the newly discovered celestial bodies.

Holmes (2008: 509, footnote 134) erroneously claims that Rev Steven (sic) Weston was actually the person who suggested the word ‘asteroid’ to Herschel, even though Herschel specifically says in the 10 June 1802 letter that none of the names suggested by Weston could be adopted (Cunningham and Orchiston, 2011)!

To understand the actual meaning of the word Herschel chose, we must look at its Greek etymology:

Greek has two words for “star”: aster, which gives astero– in compound words, and astron, which gives astro– in compounds. The first means an individual star (usually a conspicuous one), whereas the second word is normally used in the plural to refer to “the stars” in general.

This distinction is generally observed in compound words, whether by luck or design: thus asterisk means “a little star”, and asteroids “like a star”, whereas astrology, astrometry, astronomy and astrophysics all refer to study of “the stars” in general. (Fitch, 1987).

In ancient Greek we find πλανήτης (planētēs), a variant of πλάνης (planēs, wanderer, planet). The planets were called by the Greeks ‘asteres planetai’ (wandering stars) or ‘planetai’ (wanderers). The Latin term used in place of the Greek was ‘stellae errantes’ (wandering stars); but Late Latin borrowed the Greek term in the plural form, ‘planetae’, while the singular was ‘planeta’. The English word ‘planet’ comes directly from the Latin ‘planeta’. In Greek, ‘aster’ is ἀστήρ. The word ‘astyrred’ is found in Old English as an adjective meaning starry (Borden, 1982).

In choosing ‘asteroid’ over ‘planet’, Herschel was also undoubtedly aware of the recent French trend to use the word ‘planete’ as a feminine noun, “… contrary to analogy and to etymology, considering them as immediately derived from the Greek …” in the words of English antiquarian Capel Lofft (1798: 406). Since the precedent had already been set to name the asteroids after female deities (and one that would be followed into the twentieth century), this left the planets firmly in the realm of male pagan deities, with the sole exception of Venus. This precedent was followed with the selection of the names Neptune and Pluto for future planetary discoveries.

According to the OED, the first use of the word ‘asteroidal’ is by the English astronomer Norman Lockyer in 1868. But I have established its first use by Herschel (1807a: 263) in describing his observations of the asteroid Vesta: “The spurious nature of the asteroidal disk …” Therefore research for this thesis has revealed an error in the OED, as mentioned in Section 2.5 (Cunningham, 2015a).

4.2.2 The Reaction in England
4.2.2.1 Henry Brougham

First to attack was an anonymous reviewer in the pages of the Edinburgh Review: “Dr. Herschel’s passion for coining words and idioms has often struck us as a weakness wholly unworthy of him. The invention of a name is but a poor achievement in him who has discovered whole worlds.” He added the insinuation that Herschel had devised the word ‘asteroid’ for the express purpose of keeping Piazzi’s and Olbers’ discoveries on a lower level than his own of Uranus. Apparently Herschel’s only response was to characterise it as “… the illiberal criticism of the Edinburgh Review.” (Clerke, 1901: 90).

How could such an attack have been launched, and by whom? The first issue of the Edinburgh Review was published 10 October 1802; the attack on Herschel appeared in the second issue in early 1803. The original staff were all very young, with Henry Peter Brougham (1778–1824) at the age of 23 the youngest of all.
All these were young men full of talent and ambition, to whom the *Edinburgh Review*, at its commencement, was a vent for feelings and theories that had been accumulating for years. Above all, it enabled them to give full utterance to those political principles that were so obnoxious to the rulers of the day, and so doubly proscribed in Scotland. Each individual no longer stood alone, but was part of a collected and well-disciplined phalanx; and instead of being obliged to express his opinions in bated breath, and amidst an overwhelming uproar of contradiction, he could now announce them in full and fearless confidence, through a journal which was sure of being heard and feared, at least, if not loved and respected (see Chambers, 1856).

The very publication of this new journal, the *Edinburgh Review*, was castigated by its intellectual opposite number, *The Anti-Jacobin Review and Magazine*: “As the object of the Edinburgh Review is the depreciation of whatever tends to elevate, or to support our country, a natural and obvious branch of their plan is to vilify every writer who supports constitutional loyalty, patriotism and order.” (J.B., 1803). Herschel, as the King’s Astronomer, is certainly covered under this broad umbrella, so the attack against him in the pages of the *Edinburgh Review* can as be seen not as an isolated one, but as part of a wider assault on British writers.

In the same vein, we read in Volume 14 of the *Cambridge History of English and American Literature* (Ward & Waller, 1907-1916: 37) that in the early issues of the *Review*, Brougham “… developed a policy of hostile criticism, of which English educational institutions were the object.”

Volume 12 of the *Cambridge History* (Ward and Waller, 1907-1921: 16) gives us further valuable insight into Brougham’s character:

Henry Brougham, the youngest of the three, was to become, in a few years and for a time, by dint of extraordinary energy and ability, one of the most powerful political leaders in England. His services to the *Review*, in its early days, had been quite invaluable. Hardly any public man of the nineteenth century approached more nearly to the possession of genius. But his great gifts were weighted with very serious faults of character and temper; and, as the years went on, he earned for himself universal distrust among his fellow-workers—editors of, and contributors to, *The Edinburgh*, or statesmen engaged in the wider field of British politics. It was long a tradition among *Edinburgh* reviewers that, on one occasion, a complete number of the *Review*, with its dozen or more of articles, was, from cover to cover, written by the pen of Brougham, and the story, whether true or not, is illustrative of the universality of capacity generally attributed to him.

Who was this precocious young man who dared castigate the great Herschel? Henry Brougham was born in 1778 into an intellectually-charged Edinburgh that had become known as the ‘modern Athens’ because of the many noted philosophers and scientists who lived there. By the tender age of 18, the Royal Society had already published his first scientific paper (Brougham, 1796) on the properties of light.

One of the founders of the *Edinburgh Review*, he was described at this stage of his life as an “… uncommon genius…” although by outward appearances tall, thin and quite ugly. This did not hinder his career, as he became Lord High Chancellor of England and one of the greatest statesmen of the nineteenth century. Lord Brougham lived to be 90 (for a general biography see Hawes, 1956; for his early life see New, 1961).

The fact that Brougham became the most brilliant legal mind of the age is a crucial factor in understanding his mindset as he approached the Herschel-asteroid matter. Many of the reasonings of lawyers, wrote the Scottish philosopher David Hume (1711–1776; Figure 4.6), are of an analogical nature. This was of the very nature of jurisprudence, which was
... in this respect, different from all the sciences ... [in that] in many of its nicer questions, there cannot properly be said to be truth or falsehood on either side. If one pleader bring the case under any former law or precedent, by a refined analogy or comparison; the opposite pleader is not at a loss to find an opposite analogy or comparison: and the preference given by the judge is often founded more on taste and imagination than on any solid argument. (Hume, 1748: 221).

In his *Edinburgh Review* article, Brougham was arguing—in part—from analogy, which Hume had specifically identified in his writings as inappropriate in the field of science. A quotation from the German philosopher Friedrich Schiller (1759–1805) seems apt: “The basis for your complaint seems to me to lie in the oppression of your imagination by your intellect.” (Schiller, 1788). One might say Brougham was ‘too clever by half’.

![Figure 4.6: David Hume (courtesy: en.wikipedia.org).](image)

Herschel first learned of the review article in a letter from his friend Watson:
The same day I received your letter I received one also from our excellent friend Sir Joseph Banks. Among other things he tells me that there has come out an Edinburgh review of which two numbers have appeared, which appears to him to be written with a very caustic spirit, decrying our literary men, in order to raise the merits of his own countrymen. He tells me you have not escaped his lash, and indeed, if depreciation of merit is his aim, you must be the first to aim at. You, I am persuaded, will regard his darts with due indifference, and trust as you have hitherto done, in a calm and dignified reliance that nothing can affect and overthrow truths and discoveries founded on experience and observation. (Watson, 1803).

Herschel’s friend David Brewster wrote a letter from Edinburgh, in which he scathingly told Herschel about the identity of his anonymous assailant:
I do not know if you have seen the review of some of your papers, in the first numbers of the Edinburgh Review. It may perhaps be interesting to you to be informed that the gentleman who reviewed them, and also Dr. Young’s papers, was Mr. Brougham, a member of your Society who seems to take pleasure in holding up to ridicule those characters only who are esteemed and revered. (Brewster, 1805).

### 4.2.2.2 Thomas Thomson

Brougham’s opinion had a major influence on his fellow Scotsman, Thomas Thomson (1773–1852; Figure 4.7). Thomson had been elected a Fellow of the RS in 1811, and the following year published his *History of the Royal Society*. In this tome he chose to launch a bitter personal attack on William Herschel, who had been elected a Fellow in 1781:

The distance between Mars and Jupiter is so great when compared with the other planetary spaces, and the distance from the sun, that astronomers had been looking for some primary planet in that position. Of late years these expectations have been more than accomplished by the discovery of no fewer than four planetary bodies almost all in the same place; but so small that Dr. Herschel refuses to honour them with the name of planets, and chooses [sic] to call them asteroids, though for what reason it is not easy to determine, unless it be to deprive the discoverers of these bodies of any pretence for rating themselves as high in the list of astronomical discoverers as himself. These four bodies have received the names of Ceres, Pallas, Juno, and Vesta. They were discovered by Mr. Piazzi, Dr. Olbers, and Mr. Harding. (Thomson, 1812: 358).

![Figure 4.7: Thomas Thomson (courtesy: en.wikipedia.org).](image)

Thomson’s attack was much more influential than Regnér’s swipe at Herschel for using “unjust influence” as his treatise was written in Latin and read by very few (Subsection 4.2.3.5). Sir Richard Phillips reinforced the scurrilous opinion of
Herschel’s motives offered by Thomson, stating in one of his later books that “Ceres ought to be taken in the measures of Schröter, for Herschel seemed disposed to underrate the new discoveries of other astronomers.” (Phillips 1836: 162).

The celebrated astronomer François Arago wrote:
I should require nothing further to annihilate such an imputation than to put it by the side of the following passage, extracted from a memoir by this celebrated astronomer (Herschel), published in the Philosophical Transactions for the year 1805: “The specific difference existing between planets and asteroids appears now, by the addition of a third individual of the latter species [Juno], to be more completely established, and that circumstance, in my opinion, has added more to the ornament of our system than the discovery of a new planet could have done.” (Arago, 1870: 217).

Without mentioning Thomson by name, Herschel’s noted biographer James Sime (1843–1895) poured vitriol on the attack:
Strange to say, the friend of Piazzi and Olbers, who discovered these small bodies, was charged with intending, by the suggestion of this diminutive [asteroid], to cast a slight on the achievement of his friends, in comparison with his own glory as the discoverer of the great planet, Uranus. A more stupid slander of a most generous heart could scarcely be imagined. That one scientific man should attack, or rather slander, another for giving to these small bodies a scientifically appropriate name, on the ground that he thereby intended to derogate from the credit of his own friends, whom he publicly extolled as “celebrated discoverers,” seems incredible. Yet it was done. (Sime, 1900: 191).

The attack was also dismissed by James Smith (1815: 555). “This insinuation appears too gratuitous to be considered either generous or just.”

Like Brougham, Thomson achieved great distinction. At the age of only 23 he became editor of the Encyclopedia Britannica. In 1798 he introduced the use of symbols into chemical science, and he became legendary in his post as Regius Professor of Chemistry in the University of Glasgow (Crum, 1855).

The antipathy towards William Herschel did not prevent either Thomson or Brougham from corresponding with his son John. The Royal Society archives contain letters from both of them. In any case, criticism of William Herschel was nothing new:

William was always a controversial figure, despite his personal charm. The controversies began in his first contacts with the Royal Society, where his claims as to the magnifications of his eyepieces were met with incredulity and Fellows said he was fit for Bedlam (that is, Bethlehem, the hospital for the insane). In the first decade of the 19th century, his ill-judged insistence on publishing papers on coloured rings also brought a lot of criticism. (Hoskin, 2003: 50).

Indeed, in 1802—the very year he employed the word ‘asteroid’ for the first time—Herschel was accused by the English author John Corry (1802: 81) of “…philosophical quackery.”

4.2.2.3 The German Connection
The motivation for Thomson’s personal attack is obscure, but it is interesting to note that both of the people who criticised Herschel were Scottish, born just five years apart. Even though we regard Herschel as an English astronomer, he was German-born, an ethnic element that may have played a factor in their disdain according to J. Arthur Thomson, Professor of Natural History, University of Aberdeen:

Britain is wont to be proud of William Herschel, who extended Newtonian methods to the study of the stars and recognised the occurrence of vast developmental changes in the heavens. But William Herschel was a Hanoverian. (Thomson, 1915: 143).

Even though Herschel, as a church organist, entirely conformed to the Church of England and thus fitted into the English scene without overt controversy, it is possible his Scottish detractors held this perfect melding into British society in light
regard. How foreign Protestants should be integrated into English society had been a topic of controversy just ten years before Herschel emigrated. For example, this is mentioned in two letters written by the Swiss mathematician Leonhard Euler (1707–1783; Figure 4.8) to Johann Wettstein (1693–1754). Wettstein was a foreigner (from Basel) who became closely associated with the British Royal Family as its Chaplain: “The newspapers are saying a great deal about Parliament’s plans to

naturalise the foreign Protestants.” (Euler, 1748a), and “I am amply aware that even after one has allowed foreigners to establish themselves in England, it will still be a long time before granting them subsidies (pensions).” (Euler, 1748b). Herschel became a naturalised British citizen in 1793 (by Act of Parliament, Private and Personal Acts c.38). As a result when the Hanoverian Guelphic Order of Knighthood was established and Herschel appointed, he was one of the British appointees announced in London, not one of the Hanoverian appointees announced in Hanover. In many ways Herschel was more English than the English.

Upon appointment as Astronomer to His Majesty, Herschel received a Royal pension of 200 pounds per year (agreed to in July 1782) from King George III (this compares to the salary received by Maskelyne, the Astronomer Royal, of 300 pounds). It was Sir Joseph Banks who induced the King to confer this appointment on Herschel (Ball, 1985: 246). The King invented the informal post near his residence at Windsor Castle so that he himself could further his own education in astronomy and also because he could think of no other way to fulfil his obligation to Herschel as his patron. An ancillary benefit was an opportunity to entertain his guests after dinner, by showing them Herschel’s telescopes.
George III (Figure 4.9) had another beneficent role in the saga of the asteroids: he granted Johann Schröter funds which were used in part to hire an assistant, Karl Harding, who discovered the third asteroid. Following along the pattern set by Herschel in commemorating the discovery of a planet with the name Georgium Sidus to honour King George III, the third asteroid was named Juno Georgia by Schröter to honour his patron—George III. (Eclectic Review, 1807: 183). The name Juno was actually proposed first by Olbers and accepted by Harding (1804a), but Schröter added Georgia to curry favour. This may have been a contributing factor in the appointment of Schröter, in July 1816, to the very same Hanoverian Guelphic Order of Knighthood that had been bestowed upon Herschel on 22 March of the same year. The Order was of recent mintage, having been founded just the year before as a result of Hanover’s elevation to the status of a kingdom by the Congress of Vienna (Vick, 2014).

Herschel was also elected to the Royal Society. Numerous Germans had been elected to the Royal Society during the eighteenth century, but many never visited England and “… therefore had little personal contact with English thought and culture.” (Davis, 1969: 51). It is possible that Herschel’s elevation, and physical presence at the very seat of power, caused some (such as Brougham and Thomson) to harbour some ill feelings towards him, even though by the time of their attack in 1802 Herschel has been thoroughly integrated into English society. Thus the assertion by J. Arthur Thomson that Herschel “was a Hanoverian” does not reflect the legal standing of Herschel as a British citizen, or his status as a paragon of British astronomy, but rather an underlying realisation that he was not born in England. While this was of no relevance to Herschel’s personal friends or multitude of admirers among the wider populace, it may have been one element that influenced his detractors.
The German connection here was quite strong (Beuermann, 2005). Herschel had been born in Hanover in 1738. It was none other than George III who was Elector of Hanover, and even though he never visited his Royal domain on the Continent he personally managed the diplomatic affairs of Hanover independently of England (Blanning, 1977). Was Herschel a part of the dual track method of ruling exercised by the King? According to Sime, he was. “In fact George III and his advisers dealt with Herschel, not as an Englishman but as a German.” (Sime, 1900: 94). How accurate this perception was is open to question, as Herschel did everything he could to distance himself from his Germanic roots. He dropped his Hanoverian name of “Friedrich Wilhelm” the moment he set foot in England, adopting the Anglicised “William.” He almost never spoke or wrote German again, and in his correspondence he wrote to Germans in English. Thus modern scholarship about Herschel (eg Hanham & Hoskin, 2013) casts doubt on Sime’s assertion.

Herschel’s relationship with Maskelyne is also of significance, as they often shared observational data on asteroids. As evidenced by the following letter that Herschel sent to his sister Caroline (1750–1848), he believed his instruments were superior to those used at the Royal Observatory:

> These two last nights I have been star gazing at Greenwich with Dr. Maskelyne and Mr. Aubert. We have compared our telescopes together, and mine was found very much superior to any of the Royal Observatory. (Herschel, 1782b).

Herschel was certainly correct here but the duties of Maskelyne at Greenwich were related to positional astronomy, and for this purpose Herschel’s telescopes were useless. Maskelyne was therefore not in possession of inferior instruments with regard to the work his post required.

That Herschel had superior optical telescopes was no idle boast (Bennett, 1976). Its reality was known far and wide: “I am still of the opinion that I have seen the two most wonderful things that have ever been seen in this Planet: the French Revolution and Dr Herschell’s telescope.” This was in a letter dated 7 October 1791 from the Scottish natural philosopher John Anderson (1726–1796) to Herschel’s friend James Lind MD (1736–1812). Herschel actually made much of his money from the sale of his telescopes, often made-to-order for wealthy clients (see Maurer, 1998). Maskelyne himself asked Herschel to make him a 7-foot telescope, which he did, although he never quite managed to replicate the perfection of the mirror used to discover Uranus in 1781.

Since Maskelyne had invited Herschel to “star gaze” at Greenwich, Herschel extended a reciprocal invitation to Maskelyne to observe with him at Windsor. The close and warm friendship between Herschel and Maskelyne is best illustrated by Maskelyne’s letter of 8 August 1782, two months after Herschel’s visit to Greenwich (quoted above) and the first after Herschel’s appointment as Astronomer to His Majesty.

> I hope you have had some good nights at Windsor for seeing your newly discovered double stars with your admirable telescope. I thank you for having shewn me many of them, which my own telescopes, tho’ reputed excellent, would not discover...Astronomy and Mechanics are equally indebted to you for what you have done; the first for your shewing to artists to what a degree of perfection telescopes may be wrought; & the latter for your discovering to Astronomers a number of hitherto hidden wonders in the heavens, which could not be explored before for want of telescopes equal to yours; and they are both likely to receive equal improvement from it in the construction of better telescopes, and in the application that may be made of them to the heavens for repeating and extending your observations. I hope you will do the astronomical world the favour to give a name yo your new planet, which is entirely your own, & which we are so much obliged to you for the discovery of. (Maskelyne, 1782).

Over the years the two men were in constant contact (as evidenced by 66 letters in the RAS archives), and Maskelyne was especially close to Caroline. He invited her
to visit him, took her to meet other astronomers and gave her astronomical presents. He even persuaded the Royal Society to have Caroline’s book published at the Society’s expense.

4.2.2.4 The Links Between Brougham and Thomson

There were certainly links between Dugald Stewart (1753–1828), Brougham, and Thomson, the attackers of William Herschel (Ency. Britannica, 1888: 306).

The noted historian and philosopher James Mill (1773–1836), while studying at Edinburgh, received his greatest intellectual impulse from Stewart, and Thomson was also a student of Stewart (Maas, 2003: 338-360)! When Mill began The Literary Journal in 1803, Thomson took charge of the science section. In 1808, Mill began writing for The Edinburgh Review, where Brougham wrote on mathematical subjects and Thomson was employed on antiquarian matters. The philosophical and social mindset that gave birth to The Edinburgh Review has been explored by Flynn (2002).

At the turn of the century, the young Scottish Whigs included Henry Brougham, Thomas Brown (1778–1820) and Francis Jeffrey (1773–1850)—another key figure in this mix. Jeffrey was another student of Stewart (1753–1828), but in the 1804 issue of The Edinburgh Review, he savaged Stewart’s philosophy so severely that subsequently “… all of Stewart’s writings were coloured by the fact that he believed moral philosophy was under siege.” (Tannoch-Bland, 1997: 308). It was yet another example of the attack-dog attitude shared by the trio—Herschel was just one of several prominent targets.

They were the product of the Scottish Enlightenment that made Edinburgh one of the chief centres of learning in eighteenth century Europe. When Sydney Smith (1771–1845) met them at the Academy of Physics in Edinburgh, the three polymaths were already deep into “… the investigation of nature, the laws by which her phenomena are regulated, and the history of opinions concerning these laws.” (Welsh, 1825: 77). Smith suggested they collaborate to publish a critical Review. Through the winter of 1801-1802, plans for The Edinburgh Review were developed at the very same time William Herschel was studying Ceres and Pallas. For Brougham, Ceres and Pallas were a ready-made subject for his exposition, giving full vent to his thoughts on the laws of nature and opinions concerning them.

Raised in this atmosphere of criticism—at both The Edinburgh Review with Brougham as an exemplar—and later within a London society noted for its personal attacks on prominent men, it is no wonder that Thomson had no compunction about firing a broadside against Herschel in 1812. Indeed, he was merely following the precedent set by Adam Smith (1723–1790; Professor of Moral Philosophy at Glasgow University), who wrote for the short-lived Edinburgh Review in 1755. Smith actually accused Dr Samuel Johnson (1709–1784), in his Dictionary, of being insufficiently grammatical (Buchan, 2003: 133)! To use a word Dr Johnson employed in his Dictionary, one might say Brougham exhibited ‘hebetude’—a bluntess that exhibited a particular insensitivity.

Temperamentally, Thomson was also well suited to this form of attack. He wrote a stinging piece of satire in 1799 (see Larder, 1970: 296), and his own personality was scathingly parodied by the well-respected scientist David Brewster (1806):

With a little judicious comprehension, the credendum of this philosopher (Thomas Thomson) might be easily imprisoned in the cavity of a nut shell. It is however of the gaseous kind, and would probably require a ground stopper to prevent evaporation.
Herschel received plaudits as well as barbs. In one of the most prestigious publications of the age, *The Monthly Magazine*, we read this account of him, in equal parts exalted pride in his accomplishments and snobbish sympathy for everyone else:

Astronomers, in different parts of the world, may be discouraged from continuing their observations, when it should seem, that their discoveries must be anticipated by our observer (Herschel); but, though he has so much the advantage, much is left to their labour and industry. (*The Monthly Magazine and British Register*, 1796: 45).

4.2.2.5 Sir Joseph Banks

While Herschel was scarcely acquainted with Brougham or Thomson, he was a close associate of Sir Joseph Banks, President of the Royal Society. One would have thought that Herschel would get a favourable hearing from Banks, but such was not the case. Banks wrote to Zach on 7 June 1802, and an extract was printed in the *Monatliche Correspondenz (Monthly Correspondence)* (1802b: 90) as follows:

Dr. Herschel still persists in his opinion in view of the small size of these two new planets, and continues to maintain that these must be strictly differentiated and classified especially from the planets and comets, except when these questionable comets are found in a quiescent state. I believe that he wishes to name them asteroids, because they are not visible to the naked eye.

We see no difficulty in the requirement that the light from such small bodies should reach us. That Zach took great delight in publishing this ‘barbed arrow’ in his journal can hardly be doubted. A review of papers in the *Monthly Correspondence* regarding Ceres and Pallas shows that this is in fact the only extract from a letter Zach received from Banks to be printed in the journal. What Herschel thought of this is unknown, but he may not have read it since he was not a subscriber to the journal.

Even though Zach rejected the term ‘asteroid’, he was ready to admit to Banks that the discoveries of Ceres and Pallas presented astronomers with a situation that demanded some sort of new categorisation:

The Pallas cannot be deemed a comet, if we understand by a comet a hairy blazing star, moving in a parabolical orbit. For she has not all the appearance of a nebula, or a dark gloomy star, not the least trace of a tail, bush, or pencil of spurious light. She looks rather clearer than Ceres; is about of the same size. She moves not in a parabolical curve. The Pallas cannot be deemed a planet, if we understand by planets, heavenly bodies revolving in little eccentric ellipses round the Sun, and pursuant to the law of distances, completed now by the discovery of Ceres, and extending to the Georgian planet, and perhaps beyond. The Pallas has no assigned place as a planet according to this law in our solar system. She moves in a too eccentric ellipsis, and has a too great inclination of the orbit, as that she might be ranked amongst our primary planets. This body gives us therefore the indication of a new species, that we might call planeto-comet, so we’ll have, fixed stars, primary planets, secondary planets, and planeto-comets. (Zach, 1802g).

While still avoiding use of the word asteroid, Banks finally wrote Herschel that “It gives me much pleasure ... that the Germans should so readily and properly have adopted the distinction which you have made between them and planets.” (Banks, 1807).

4.2.2.6 The Attack in *The Critical Review*

One of the most influential publications of the time was *The Critical Review, or, Annals of Literature*. The May issue (1803a, its italics) includes a detailed and damning critique by an anonymous reviewer of Herschel’s 1802 paper *Observations on the two lately discovered celestial Bodies*. After printing the substance of the paper where Herschel gives his seven criteria for distinguishing Ceres and Pallas from the other planets, the writer launches his first attack:

This reasoning is, however, too rigorous. By a similar argument, it might be contended that there should be no more than seven planets, seven colours, etc.: to which we may add, that the vacant space may be as aptly filled by two smaller bodies as by one larger. Had we found a
large planet, three times the united diameter of the two now under our eyes, we should not have contested its title; and we see not, as we shall presently show, that we ought, from any considerations, to combat the claim of either Ceres or Pallas. The other objection is still weaker. If we admit bodies, it is said, of such great geocentric latitudes, we may ask, What are they? We know only of three kinds of celestial bodies; planets revolving about the sun, deriving their light from it, with a determined annual parallax, and a diameter subtending a sensible angle; fixed stars shining with a light peculiarly their own, without any parallax, and subtending no sensible angle; and comets, deriving their light from the sun, which they seem to convey in a peculiar form, that of a coma, and a tail projected in a direction opposite to the sun, with a very considerable geocentric latitude—in other words, moving in a plane greatly inclined to that of the earth’s orbit. Ceres and Pallas are certainly observed with comae: are they not, therefore, comets? (page 17, his italics).

The reviewer then quotes Herschel’s five distinguishing characteristics of Ceres and Pallas, which give him a platform to launch his second attack:

In fact, the smallest coma of a comet exceeds that of Ceres or Pallas above a hundred times; and neither moves in orbs even approaching the eccentricity of a parabola, or is distinguished by a tail. It is also highly probable that the nuclei of comets are very small: they never disturb the planetary motions, though often disturbed by them. Why then are not these bodies planets? We see no reason for any distinction: they revolve round the sun, and are not comets. We must discover another system, before we are allowed to change the appellation. Mr. Herschel would call them asteroids; but he labours for a distinction, which, in the end, will fail him. (page 18, his italics).

He finally quotes Herschel’s definition of the term asteroid, and concludes his critique of the Philosophical Transaction paper:

We shall not extend our article by enlarging on our own original idea, that these bodies may have been comets constrained to revolve within less eccentric orbits; because, in reality, we know little of the nuclei of comets, and have no criterion by which we can measure their density, nor indeed, very correctly, their diameters. The suspicion may remain on record, to be tried by future observations, with little solicitude, in the author, respecting its truth or fallacy. (page 19, his italics).

The critique has one critical weakness. In the first passage quoted, he believes Ceres and Pallas have a comae, and are therefore comets. Unfortunately for his thesis, Ceres and Pallas do not exhibit comae, as they have no atmosphere at all. His belief that Ceres and Pallas are former comets is not true, although we now know that some asteroids were originally comets, so he glimpsed part of the real situation. If he had not held to the false belief that Ceres and Pallas exhibit comae, he may have been more reticent in criticising Herschel’s idea to discriminate between comets, planets and asteroids.

4.2.2.7 Neologism: The Philosophical and Social Context

The criticism levelled at Herschel must also be placed within the context of late eighteenth century/early nineteenth century British society. While we may view these remarks of Brougham and Thomson simply as misplaced criticism, they actually hold a place within the satirical framework that shaped so much of literary society at that time. Dr Johnson, in his famous Dictionary of the 1780s, defined lampoon as a “personal satire” that aimed “… not to reform but to vex.” According to the English satirist and scholar of Italian, Thomas James Mathias (1754–1835)

... all publick men, however distinguished, must in their turns submit to satire … [and] satire can never have effect, without a personal application … [since] it must come home to the bosoms, and often to the offences of particular men. (Mathias, 1801: 7).

Why did Brougham write anonymously? According to Mathias (ibid.):
It (satire) never has its full force, if the author of it is known or stands forth; for the unworthiness of any man lessens the strength of his objections.

As a leading light of the scientific establishment, it is thus not surprising to find Herschel one of its victims. Herschel was one of the astronomers targeted in a vicious satire. It was written by the famous John Wolcot (1738–1819), who wrote under the name Peter Pindar. It is quoted here from a collection of his works (Pindar, 1816: 455):

The fame of Herschel is a dying blast:
When on the moon he first began to peep,
The wond’ring world pronounc’d the gazer deep:
But wiser now th’ un-wondering world, alas!
Gives all poor Herschel’s glory to his glass;
Convinced his boasted astronomic strength,
Lies in his tube’s, not head’s prodigious length.

A footnote to this portion of the satiric verse is the real plunge of the knife into Herschel’s abilities:

We would not detract from Mr. Herschel’s real merit. —By a true German cart-horse labour, he made a little improvement on Dr. Mudge’s method of constructing mirrors: such are this gentleman’s pretensions to a niche in the temple of Fame—As for his mathematical abilities, they can scarcely be called the shadows of science.

This final ‘swipe’ goes to heart of the topic considered in Section 6.2 of this thesis—the fact that no astronomer in England performed any serious mathematical calculations on the orbits of the asteroids. It should be noted that Aubert, one of the few men in England who saw Ceres, was also savaged in the same satiric verse which featured Sir Joseph Banks as the man trying to defend the honour of Herschel and others. Wolcot actually began a long series of satires on scientists—and Banks in particular—in 1788 (Jones, 1966: 195)

Wolcot’s best-known poem is The Apple Dumplings and a King, which makes a mockery of King George III. He alleges that George, when visiting Herschel, was not interested in the majesty of the heavens, but only in the everyday objects that he imagined he saw through Herschel’s telescope while looking at the Moon (Robertson, 2009).

Another important context that must be kept in mind is that to the early modern mind, words were a system of exchange to which arbitrary value was attached, a value we agree to honour in the interests of establishing meaning (Maguire and Smith, 2012: 193). The phrase ‘coining a new word’, which we still use in the twenty-first century, is directly related to this concept as coins were (and are) a means of exchange, but their value was (and is) arbitrary. The word asteroid was ‘coined’ for Herschel to arbitrarily establish the value of Ceres and Pallas as a denomination separate from the planets.

One must also ask why it mattered so much to Brougham? Why did the identification of a new kind of object offend his sensibilities so much? The answer can be found in the very use of the word sensibility to frame the question. In the latter eighteenth century arose “… the doctrine of sensibility, which judged images, objects, texts, and experience in terms of their emotional effects.” (Bermingham, 2005: 12). It derived from the ‘science of sensibility’ which was founded on the optics of Isaac Newton and the psychology of John Locke (see Subsection 6.1.2). Brougham’s own use of the word ‘invidious’ (a word meaning ‘unfair’, and ‘likely to arouse resentment or anger in others’) immediately flags his tirade not as a dispassionate critique but as an emotional response. His sensibilities were offended by the new word ‘asteroid’ not entirely on the subjective grounds he chose to couch
the essay in, but through the very doctrine of sensibility that was so much a part of
the culture he was raised in.

Philosophically, the whole controversy can best be understood as an early
example of the nineteenth century attitude towards neologism. Words we now
regard as embedded within language, such as altruism, society, police and virtue,
were *avant-garde* at that time, and changed the way people thought. Resistance to
linguistic innovation in general was undoubtedly an element, not just to neologism
for its own sake, but to broader intellectual and social change. Viewed in this way,
the specific case of the new word ‘asteroid’ being introduced into the scientific
lexicon may be put in context. Brougham was not merely being satirical or
pedantic—he was voicing an underlying concern that new words may not just be
engines of change, but may actively remould the concepts to which they refer
(Dixon, 2008: 33). This was certainly the case with ‘asteroids’. If they could not be
called planets or comets, then people would be faced with a new metric to deal with,
one that seemed to most both unnecessary and dangerous. In the aftermath of the
political upheavals of the French revolution, any challenge to the *status quo* was
regarded as suspect—in the words of Brougham (1803: 428), “… perplexing our
ideas.” As perceptively stated by G.K. Chesterton (1874–1936), the importance of
the French Revolution in England can scarcely be overstated (see also Whatmore,
2008):

> It is not idle Hibernianism to say that towards the end of the 18th century the most important
event in English history happened in France. It would seem still more perverse, yet it would be
still more precise, to say that the most important event in English history was the event that
never happened at all—the English Revolution on the lines of the French Revolution.
(Chesterton, 1913: 17).

Stability is what people sought, and the clockwork regularity of the Solar System
was a bedrock in the minds of most people, one of the few things they could still rely
on in age rocked by revolution. Another planet they could accept, a new *kind* of
object was a step too far. Or so Brougham thought when he was writing in 1803, but
after a generation passed, and two more similar objects (Juno and Vesta) had been
found, the term ‘asteroid’ entered common parlance. Whatever professional
astronomers, and opinionated critics such as Brougham might have thought,
‘asteroid’ became imbued with a certain cachet that proved irresistible. Its very
existence remoulded concepts of the Solar System (no, Ceres was not the eighth
planet, it was an asteroid!) and raised questions about its very formation, just the sort
of intellectual revolution Brougham was trying to forestall.

According to Simon Schaffer, Professor of History and Philosophy of Science at
Cambridge University, Herschel called upon a conceptual framework to name these
new and novel objects, even as it repelled the cognoscenti:

> Brougham’s critique represented a Regency commonplace. Language’s stability represented a
commonsense, ordered world. Terms should refer to unproblematic objects. So Herschel’s
neologisms and ambiguities, his desperate coinage of a literary technology designed to stabilize
irreproducible and unreachable cosmological classes, scarcely carried conviction among the
polite society of the literati.

Calling these bodies “asteroids” fitted them into a large-scale investigative scheme centered
in Germany in which Herschel then took part, and fitted them, too, into the pattern of the solar
system. Herschel’s work demonstrated that naming novel objects required appeal to networks
of familiar concepts, and extended that network in one direction rather than another. Double
stars were fitted into the program of parallax measures; asteroids into the regime of celestial

This concept of a “… network of familiar concepts …” also finds expression in
the following passage about a system of established ideas:
What we come to call the truth or validity of some statement—historical report, scientific explanation, cosmological theory and so forth—is best seen not as its objective correspondence to an autonomously determinate external state of affairs but, rather, as our experience of its consonance with a system composed of already accepted ideas, already interpreted and classified observations, and, no less significantly, the embodied perceptual and behavioural dispositions that are thereby engendered and constrained. (Smith, 2010: no page number).

The use of the word ‘asteroids’ has attracted the attention of philosophers. In an analysis of William Van Orman Quine’s critique of modal logic, John P. Burgess, Professor of Philosophy at Princeton (2008: 207) uses Ceres, asteroid and planetoid as an example to examine “… a priori truth and linguistic truth.” He states:

Quine often complained that others were sloppy about distinguishing use and mention. If one is sloppy, quibbles and confusions can result if, as was commonly done, one uses “linguistic” interchangeably with “analytic” or “a priori” and “empirical” interchangeably with “synthetic” or “a posteriori” respectively. For consider:

(1) Planetoids are asteroids.
(2) Ceres is the largest asteroid
(1’) In modern English, “planetoids” and “asteroids” refer to the same things.
(2’) In modern English, “Ceres” and “the largest asteroid” refer to the same thing.

As to (1), discovery that planetoids are asteroids requires (for a fully competent speaker of modern English) mere reflection, not scientific investigation. As to (2), discovery that Ceres is the largest asteroid requires natural-scientific investigation of the kind engaged in by astronomers. Discovery that (1’) is the case requires social-scientific investigation of the kind engaged in by linguists. Discovery that (2’) is the case requires both kinds of scientific investigation. Since linguistics is an empirical science, using “Linguistic” and “empirical” for “analytic” and “aposteriori” can be confusing when dealing with meta-level formulations like (1’) and (2’) rather than object-level formulations like (1) and (2), but such usage was common.

In a broader philosophical context, the issues raised by Brougham relate to the very basic issues of how we perceive change, either as an evolutionary or a replacement process:

Whether we think of change as, at one end of the spectrum, replacement or, at the other, an unfolding of an essence or core forever present, our conception of change is intrinsically tied to our conception of entity or identity. Evolution-change may or may not assume an unfolding kernel or essence. Replacement-change permits newness and difference but tends to make its appearance, no matter how well prepared for, arbitrary and ultimately inexplicable. Unless there is some connection, or nexus, between what was and what comes after, we tend to think we have not a change but merely two things. (Bynum, 2001: 20).

In this framework of thought, Herschel’s letter to the leading astronomers (see Subsection 4.2.3.1) was his way of preparing the intellectual groundwork for replacement-change: the newness and difference of ‘asteroid’. But as Professor Caroline Bynum of Columbia University notes, this rarely prevents change from being regarded as arbitrary, which is precisely the way his choice was received by his contemporaries. Largely blind to the connection between asteroids and planets, they merely perceived two things, and decided to maintain the terminological status quo.

4.2.2.8 The Ancient Greek Precedent
Brougham’s fulminations were promulgated in the nineteenth century, and were rooted in the eighteenth century. But one thing Brougham could not do was appeal to ancient precedent, which clearly refuted his point of view:

While large areas of Greek science manifest a certain conceptual vagueness, there are important exceptions to this, cases where technical terms are coined and given clear working definitions. Anatomy, zoology, harmonics and astronomy all provide examples. Astronomy, especially, developed a wealth of technical terminology, clearly defined words for zenith, meridian, apogee, perigee, parallax, colure, station, retrogradation and many others, let alone geometrical terms such as homocentric, epicycle, eccentric. (Lloyd, 1987: 206).

The issue of distinguishing comets from planets was not born with the discovery of Pallas. Indeed, it has ancient roots. Aristotle mentions, but with evident contempt
for the notion, that the Pythagoreans taught that a comet is a planet, which appears after a long interval of time, and which, at the apex of the hyperbola which it describes, approaches as nearly to the Sun as Mercury. This notion was apparently one which the Pythagoreans obtained from the Chaldeans. (*The Classical Journal*, 1821: 282).

### 4.2.2.9 Capel Lofft

The noted writer Capel Lofft (1751–1824; Figure 4.10) had a great deal to say about the controversy. His first foray into the subject was published in October 1802, just months after the term ‘asteroid’ had been proposed by Herschel:

I wish to discuss with the respect due to a name to which *ASTRONOMY* is much indebted, the propriety of introducing a *new order of bodies* into the vocabulary of that science, under the appellation of *Asteroids*, and the principle on which the two *celestial Bodies* discovered by Professor Piazzi and Dr. Olbers are proposed to be thus characterised.

If the distinction be not plainly *necessary* and founded on facts, I apprehend it most clearly ought not to be admitted.

Now, to try whether it be necessary or not, we have to enquire whether these two bodies have no proper place assignable to them in astronomical description under the forms already in use.

A *Planet*, I think, is understood to be a body revolving round a Sun as its centre in an ellipsis not very greatly deviating from a circle; and accordingly capable of being seen, when its orbit has been once ascertained, either by the eye or with a telescope, and usually in the whole of it.

A *Comet*, I apprehend, is a body revolving in an ellipsis, very greatly deviating from a circle, and if returning (which both analogy and observation appear to indicate) so liable to perturbation, and so long for the most part in its period, and having generally so short a part of its orbit within reach of observation, and passing that part of it with such velocity, and so obliquely, for the most part, to the paths of the ordinary planets, that it may easily revolve without being observed at all.

The other circumstance of its being accompanied with a diffused light or *coma*, though it originally gave the name, is not universal of comets.

May it not be inferred therefore, that a body revolving round the Sun, if with great eccentricity and obliquity, so as to *cut* the orbits of the other planets or some of them, may be accounted a *comet*; and if revolving with moderate eccentricity and obliquity, so as not to cut the orbit of any planet, a *planet*—A difference derived from its lying out of the *limits* of the *Zodiac* seems not sufficient: the limits having been assigned by the early Astronomers, with mere reference to the observation of eclipses of the *Sun* and *Moon*; whence the *Zodiac* is also termed the *Ecliptic*.

A difference of *magnitude* can hardly exclude a celestial body from the order of *planets*: much less can it place it as an *Asteroid*, if on account of its smallness it is disputed whether to call it a planet. The difference of the magnitude of the planets is great and various: but the greatest of them is comparatively as nothing to a *fixed Star*. Indeed a large planet between *Mars* and *Jupiter* was greatly improbable, as it would much have disturbed *Mars*. Names of *similitude*, Linnaeus has observed, are too vague to be well suited to science. Even if in this instance a new name were required, this would be no slight objection to the choice of the name, and beside, how slight the similitude? It consists merely in resemblance to a *telescopic* star. But some *comets* have had the same resemblance: some of the *satellites* of Jupiter and Saturn have this resemblance: and the *Herschelian Planet* itself. The points of dissimilitude between a small body shining by reflected light and revolving round a sun, and a fixed star or sun, are incomparably greater than the single point of resemblance: faint and imperfect as it is in that solitary particular itself.

The *Piazzi* seems to have every claim to the title of a *planet*.

The small revolving body discovered by Dr. Olbers seems answer better to the idea of a comet.

1. By the very great eccentricity and obliquity of its orbit.
2. By its *intersecting* the orbit of the *Piazzi planet*.
3. By its very small distance, if an ordinary planet of the system, from the Piazzi: a circumstance incompatible with the beautiful harmony of distances, suggested by Bode, and with which the Piazzi so well agrees. The maxim that names in science are not lightly to be multiplied, Nomina non sunt temere multiplicanda, seems most forcibly to apply here.

We should see very clearly and determinate differences, before we admit other Bodies in Astronomy than FIXT STARS, primary and secondary planets, and comets.

I can hardly dwell on the observation, that the Piazzi would not fill its place between Mars and Jupiter with sufficient dignity as a planet.

Much better our immortal MILTON: -- that great Infers not excellence -- P. L. B. VIII. And otherwise ill-fares it with the Herschelian planet, only about the tenth of the magnitude of Jupiter. (Lofft, 1802a: 199, his italics).

Lofft evokes the name of Carl Linnaeus (1707–1778), the noted Swedish botanist who was a major influence on Joseph Banks (see Subsection 4.3.2).

The next issue of The Monthly Magazine included a correction by Lofft:

In my paper, which you have obligingly inserted, on Asteroids, as a term lately introduced into Astronomy without, I apprehend, sufficient reason, there is an inadvertence of mine at the end of it. The Herschelian planet is, I believe, about one third of the diameter of Jupiter; and so I should have expressed it. (Lofft, 1802b: 375).

His second article, quite brief, was published in The Monthly Magazine in January 1803. Here, in an article titled “On Asteroids, as a Class of Astronomical Bodies”, he clearly lays out what he believes to be an adequate definition to distinguish planets from comets:

In addition to what I said before, I would remark that the Piazzi Planet is much larger compared with Mercury than Mercury is to Jupiter; indeed more than three times that proportion: and consequently the Star discovered by Dr. Olbers, whether Planet or Comet, is not below the scale of relative difference already ascertained in the Planetary System.

If in any celestial body, shining by reflected light, and revolving round the Sun as a centre, the least axis is shorter, and the greatest longer, than that of a given planet, is not such body a Comet? And may not this be accepted as an astronomical definition? (Lofft, 1803a: 479, his italics).

Lofft’s third article, titled “Whether it would be preferable, according to their Phenomena, to call Ceres, Pallas, and Juno, simply Planets, or Asteroids, or
Cometoids”, was published in *Monthly magazine; or British Register* in July 1805 (Lofft, 1805; his italics):

On the planets Ceres, Pallas, and Juno, I formerly took the liberty to remark, that when the term *asteroids* was applied to the first of them by a great astronomer, it was liable to objection, as its analogies to the planets of our system, notwithstanding its smallness and eccentricity, were still such as to correspond far better with that denomination than with the denomination of *stars*. But the relative situation of them, now three have been discovered, to each other and to the sun, does make a difference. If the intersection, therefore, of the Ceres and Pallas, and the non-ascertainment of a *solid nucleus* to any of the three, and the thin *nebulose* [sic] light which has been observed to surround them, together with the circumstance of their being all of them small, and pretty nearly equidistant from the sun, should be thought sufficient to take them out of the denomination of *ordinary planets*; and if their eccentricity, so much less, I believe, than that of any known comet, though so large compared with the ordinary planets, together with their being visible during nearly the *whole* of their revolution, so far as can yet be judged, should be thought a reason against strictly classing them with comets, would not the term *cometoids* correspond best with the phenomena, as they resemble comets in many more particulars than they do any other celestial body, and differ from them in fewer and less material.

Lofft had no academic credentials to critique Herschel, and never made any serious astronomical observations. His reports to the English periodicals were primarily meteorological observations and poetry (Cunningham & Oestmann, 2013). Motivating his writing on the subject of Ceres and Pallas was his friendship and correspondence with Johann Schröter, who publicly contradicted both the observations of Ceres and Pallas by Herschel, and his choice of the word ‘asteroid’ to set them apart from comets and planets. There is no direct evidence Schröter encouraged Lofft to write articles in the English press to support his case at the expense of Herschel, but one may reasonably believe there was an animating influence at work here (see Section 5.9). See Subsection 4.2.3.4 for the origin of the word ‘cometoid’.

4.2.2.10 The Theological Response

Every age has its crackpots and that was certainly much in evidence in the early nineteenth century. The asteroids feature twice in a book by a Liverpool accountant Bartholomew Prescott (he died after 1849) that refutes the idea of the Copernican system, insisting that Earth is at rest in the centre of the Solar System (Prescott, 1803). In the first few pages of the book, written in Etruria, near Newcastle-under-Lyne, on 23 May 1803, the author feels constrained to offer a few remarks upon certain observations lately presented to the Royal Society, by a celebrated astronomer, concerning the planets Ceres and Pallas, lately discovered. I am of opinion, that the philosopher I allude to, does not by any means, consider the discovery as creditable to the solar system, but rather as making an inroad upon the boasted harmony of it: at any rate, he seems unwilling to allow them to be ranked amongst the Pythagorean world. To all appearance they have all things in common with the rest, and the only degrading circumstance is their diminutive size; but why should that doom them to be thrust out from the rank of planets, and also to be stigmatized by the epithet “Asteroid?” Since the astronomers admit that they perform their revolutions round the Sun, the smallness of their appearance can be no solid objection.

It is, notwithstanding, a serious charge against the pretended harmony of the solar system, that primary planets should be discovered belonging to it, whose magnitudes, if repeated five thousand times, would scarcely equal that of our moon, (according to the astronomers) or, if repeated three hundred thousand times, would barely equal the bulk of the earth. The moon, which the Newtonians term a secondary planet, or a mere satellite, five thousand times larger than one of these primaries! I should not at all be surprised if, (in order to prevent them from bearing witness to the inconsistency of the system, and at the same time to dispose of them to advantage, they were to assert), that such pigmy worlds are mere *make-weights* to balance the
disorders which are said to distract the machine of the universe, by the adventitious effects of planetary attraction.

The astronomer I have alluded to, gives the following definition of the new planets; it is so remarkable, that it cannot fail to strike the attention of the man of plain sense, as well as that of the philosopher. “Asteroids” says he “are celestial bodies which move in orbits, either of little or of considerable excentricity round the sun, the plane of which may be inclined to the ecliptic in any angle whatsoever. Their motion may be direct or retrograde; and they may, or may not, have considerable atmospheres, very small comas, disks or nuclei.” This spectator is determined to allow himself room enough to turn about in; he concludes his observations by remarking, that “many extensive views relating to the solar system might be hinted at;” yes, “views” not at all creditable to that system. He says “their motion may be direct or retrograde.” I would observe, that no other motion would at all be suitable to the solar system. By this observation, however, I would not have it inferred, that I consider the direct retrograde, or stationary appearances of planets, any proof of a motion of the earth, because I believe, have a direct reference or application to the motion of the sun, and I will give my reasons for this belief, confining myself to real appearances. (Prescot, 1803: vii, his italics).

The author was thus quite derisive of Herschel’s criteria, essentially saying they covered nearly every possible contingency and thus had little credibility. He also derides the fact that new worlds are thus disturbing the harmony of the Solar System that had held true for so long—reality can be annoying to those with closed minds!

In a footnote (dated 19 November 1802) later in the book, we find a truly astounding ‘swipe’ at the very existence of the newly-discovered celestial bodies:

Since the commencement of the present century, the discovery of two additional planets has been announced to the public; one of them is named Pallas and the other Ceres. These with the Georgium Sidus, are now incorporated with the solar system without disturbing in any wise the scales of gravity and attraction which had before been so nicely poised. It may indeed be said, that the two first mentioned are very insignificant worlds; one of them being (according to White’s Ephemeris) 140 miles in diameter; and the other about 200; so that upon a rough computation, from these dimensions, the smallest may be said to contain as much surface as Ireland, and the other about the same quantity as Great Britain. The whole quantity of matter contained in both, amounts to, probably, the five hundredth part of the bulk of the moon. Such petty worlds are a disgrace to the solar system! (Prescot, 1803: 80).

The best assessment of Prescott is by Albert Mott. After mentioning Mott’s 2-volume attack on the Newtonian system published in 1822, he writes:

He wrote with energy and was a man much respected by his friends; of considerable attainments, and, in some directions, of great ability. His book is one of the curiosities of our local literature. Works of this kind have a peculiar and certainly a melancholy interest. They remind us how easily a man may, in fact, become insane in his relation to any given subject when from any cause, whether ignorance, vanity, natural defect or wilful blindness, he comes to doubt everything rather than himself. (Mott, 1859: 117).

The year 1803 also saw the most curious periodical article ever published about the discovery of Ceres and Pallas. It appeared in The Evangelical Magazine (1803) and took the form of a theological discussion. It begins sensibly—and even presciently as it envisages many more asteroids—but after the first two paragraphs of the discussion the asteroids are never mentioned again. I have omitted these bizarre passages that run for several pages, and reprint here the first section of the article which is titled “The New Planet”:

Lately spending an evening with my esteemed friend Eusebius, a gentleman, whom I will call Euphemius, took occasion to remark on the recent discovery of a new planet, by Piazzzi, in Sicily, and called by him the Ceres Ferdinandea, about half the size of our moon, and performing its revolution round the sun in about four and a half of our years. He added, that he had just read, in a celebrated Philosophical Journal, of another planet, of still smaller dimensions, and equally slow in its celestial progress, which had been called the Pallas. Both these, he observed, had been called Asteroids; and, from their having so long escaped the acute eye of the astronomer, he supposed it very probable, that our system might contain more, perhaps, even many more such little planets, to reward, by their discovery, the research of future philosophers.
The company heard this intelligence with much attention: and Benevolus, who was present, endeavoured to give a moral improvement to the subject, which was worthy of his character.

Benevelos. How just is the observation of the venerable patriarch Job, “Lo! these are parts of his ways!” for, when we have pushed our enquiries to the utmost, how little do we know of the immense works of the Supreme Being! And how infinitely distant are we from penetrating into his presence who dwells in light inaccessible, and is concealed from us by the splendour of his glory!

Eusebius. True, Sir; but we cannot worship an unknown God. I wish this star might be like that which the Magi saw, and which led them to the place where Jesus was! I long to contemplate the works of Nature as well as grace through a Mediator, and to crown the head of my adorable Redeemer with rays of glory, drawn from all the discoveries of philosophy and science.

The Evangelical Magazine article is also notable for its early and unqualified use of the term ‘asteroid’. A generation later, Richard Banks of Birmingham published a book that attempted to relate The Deluge to a mechanical explanation of the Solar System. In this curious work he refers to Ceres, Pallas, Juno and Vesta as primary planets. In all of his calculations he includes the four objects with the large planets. This tortured calculation involved such things as ‘the quantity of rotation of all the planets’, ‘the total amount of equilibrium of the planets’, and ‘the total amount of hourly orbital motion of the planets’. When it came to the physical properties of the four new bodies, he was forced to rely on an estimate:

The diameters and diurnal rotations of the newly discovered Planets, Vesta, Juno, Pallas, and Ceres, are not known, but probably neither of them is less than 100 miles, nor greater than 400 miles in diameter. I have averaged the diameter at 300 miles and the diurnal rotation at 20 hours. (Banks, 1829: 18).

See Table 3.1 for the true sizes of the four asteroids, which, if averaged, results in a figure of 350 miles, close to the figure of 300 that he used.

All of these and many more calculations are set out to prove that “The Deluge and the Astronomical Miracles all come under the Law of Evolution; they not only prove its existence but they define it.” (Banks, 1829: 102; his italics). It was another instance of the insanity noted by Mott in his remarks on the books of Prescot. The one redeeming feature of the book is a rather dramatic map of the Solar System showing the four asteroids (see Figure 4.11).

Theological derision of the asteroids reached its peak in a work by William Grisenthwaite (1822: 255) of Wells, Norfolk:

If the Planets had moved in other curves; if they had been more or fewer in number; if their distances and revolutions had been different; if the Georgium Sidus, and the Asteroids had never been discovered, I cannot conceive how we should have felt the loss or change.

The diametrically opposite view of the value of the asteroids was taken by Sharon Turner (1768–1847; 1832: 53-54) in her study of sacred history. Even though her conclusions about Bode’s Law and the existence of a designing entity are wholly erroneous, Turner’s openness about the advance of science is refreshing:

The asteroids, or telescopic planets, that revolve between Mars and Jupiter need not be further noticed here than to mention their apparent confirmation of the new law which the scientific Bode had suggested; or, to speak more correctly, his recent perception of an ancient law; for what is novelty to us is antiquity to nature. His idea was, that the several planetary orbits have a progression in their magnitude. But this law seemed to be interrupted between Mars and Jupiter. Hence he inferred, that there was a planet wanting in that interval; a bold yet profound conjecture; but this predicted deficiency is now found to be supplied by the four new asteroids, which occur in the very space where the unexplained vacancy presented a strong objection to the theory. All their orbits conform in dimension to the law in question. Thus the deduction of Bode was ascertained to be one of those predictive anticipations of true science which, if just, are, like Newton’s inference of the combustibility of the diamond, sure to be verified by the
subsequent accessions of our philosophical knowledge. These asteroids move at half the distance of Jupiter and twice that of Mars, from Mercury. This establishment of such a law furnishes another impressive instance of the scientific plan and principles on which creation has been fabricated. Every new perception of the intelligent laws by which the heavenly bodies move and are regulated makes more palpable the impossibility that they can have occurred from any other origin than that of a designing, conceiving, selecting, and ordaining cause — a real, pre-existing, intellectual Creator. Such wonderful science, so exactly, so efficaciously, and so permanently operating, can never have arisen from mere confusion, from random motivity, or from irrational chance.

While her book was published in America, Turner (a Fellow of the Society of Antiquaries) was writing in Winchmore-Hill, Middlesex.

The most thoughtful exposition about the asteroids from a theological perspective comes from the pen of the famous English political philosopher William Godwin (1756–1836; Figure 4.12). In his book about man and his discoveries, Godwin (1831: 430-432) did what no other theological writer had attempted: he met the conjecture of Olbers about the fragmentation of a planet head-on. While his discourse contains kernels of reason, it is curiously deficient in one regard. He says that Herschel did not consider the four new objects in his study of the heavens. How such a glaring error could have been perpetrated by the well-read and intelligent Godwin beggars belief. In this discourse he quotes from the astronomer John Brinkley (1763–1835):
It is somewhat remarkable that, since the commencement of the present century, four new planets have been added to those formerly contained in the enumeration of the solar system. They lie between the planets Mars and Jupiter, and have been named Vesta, Juno, Ceres and Pallas. Brinkley speaks of them in this manner. “The very small magnitudes of the new planets Ceres and Pallas, and their nearly equal distances from the sun, induced Dr. Olbers, who discovered Pallas in 1802, nearly in the same place where he had observed Ceres a few months before, to conjecture that they were fragments of a larger planet, which had by some unknown cause been broken to pieces. It follows from the law of gravity, by which the planets are retained in their orbits, that each fragment would again, after every revolution about the sun, pass nearly through the place in which the planets was when the catastrophe happened, and besides the orbit of each fragment would intersect the continuation of the line joining this place and the sun. Thence it was easy to ascertain the two particular regions of the heavens through which all these fragments would pass. Also, by carefully noting the small stars thereabout, and examining them from time to time, it might be expected that more of the fragments would be discovered. M. Harding discovered the planet Juno in one of these regions; and Dr. Olbers himself also, by carefully examining them [the small stars] from time to time, discovered Vesta.”

These additions certainly afford us a new epoch in the annals of the solar system, and of astronomy itself. It is somewhat remarkable, that Herschel, who in the course of his observations traced certain nebulae, the light from which must have been two millions of years in reaching the earth, should never have remarked these planets, which, so to speak, lay at his feet. It reminds one of Esop’s astrologer, who, to the amusement of his ignorant countrymen, while he was wholly occupied in surveying the heavens, suddenly found himself plunged in a pit. These new planets also we are told are fragments of a larger planet: how came this larger planet never to have been discovered?

Till Herschel’s time we were content with six planets and the sun, making up the cabalistical number seven. He added another. But these four new ones entirely derange the scheme. The astronomers have not yet had the opportunity to digest them into their places, and form new worlds of them. This is all unpleasant. They are, it seems, “fragments of a larger planet, which had by some unknown cause been broken to pieces.” They therefore are
probably not inhabited. How does this correspond with the goodness of God, which will suffer no mass of matter in his creation to remain unoccupied? Herschel talks at his ease of whole systems, suns with all their attendant planets, being consigned to destruction. But here we have a catastrophe happening before our eyes, and cannot avoid being shocked by it. “God does nothing in vain.” For which of his lofty purposes has this planet been broken to pieces, and its fragments left to deform the system of which we are inhabitants; at least to humble the pride of man, and laugh to scorn his presumption? Still they perform their revolutions, and obey the projectile and gravitating forces, which have induced us to people ten thousand times ten thousand worlds. It is time, that we should learn modesty, to revere in silence the great cause to which the universe is indebted for its magnificence, its beauty and harmony, and to acknowledge that we do not possess the key that should unlock the mysteries of creation.

Godwin’s discourse is a remarkable combination of delusional fantasy and sober realisation of reality. On the one hand he expresses shock that these four newly-discovered bodies even exist, thus deranging a scheme that had held for a long time. How he could read the mind of God, thus knowing that all masses of matter in the Universe had to be inhabited by intelligent beings, is just one of the innumerable delusional fantasies that otherwise intelligent people created for centuries to explain what they could not understand. Godwin, however, is perceptive enough to realise that no one alive in his age had the key to unlock the mystery of creation, even in so small a matter as the origin of the asteroids. It took two centuries of scientific investigation—completely divorced from the brainwashing shackles of theology—for man to possess that understanding.

4.2.3 The Reaction on the Continent

4.2.3.1 Herschel’s Letter of 22 May 1802

In the modern equivalent of a multiple-address email, Herschel announced his choice of the term ‘asteroid’ to every Continental astronomer with a stake in the subject on 22 May 1802. On that date he wrote the following to Gauss, Méchain, Lalande, Laplace, Bode, Zach, Olbers, Karl Felix von Seyffer (1762–1822), Schröter and Piazzi. The full text of this is in Appendix D.3:

I explained (in my paper to the Royal Society) with the help of all my observations that these bodies cannot be called planets because of their small size and because they are beyond our zodiac. And, as I prove as well, they are not comets either and thus can only be regarded as a species between comets and planets which has been unknown to us and demands a name of its own. Since they resemble small stars and they are difficult to distinguish even with the best telescopes, I called them asteroids.

Here follows the definition of this word: “Asteroids are small celestial bodies that revolve around the sun on ellipses more or less eccentric and whose plane can be inclined towards the ecliptic at any angle. Their motion can be direct or retrograde. They may or may not have considerable atmospheres, very small comas, disks or nuclei.”

You see, sir, that this definition leaves us a great deal of space and with tolerating these three species of heavenly bodies, planets, asteroids and comets, we make it much easier to classify future discoveries. (Herschel, 1802d, his italics).

It was a fine example of optative etymology, but what was Herschel trying to do with this letter? By targeting all the leading astronomers, he was trying to build a consensus, but his reputation as something of a rebel, combined with his apparent proclamation of the term ‘asteroid’, foiled this approach. The concepts involved are neatly summarised by Smolin (2006: 295) in his discussion “What is Science?”:

Science requires both the rebel and the conservative. This seems at first paradoxical. How has an enterprise flourished for centuries that requires the conservative and the rebel to coexist? The trick seems to be to bring the rebel and conservative into lifelong and uncomfortable proximity, within the community and, to some extent, within each individual as well. Science is a democracy, in that every scientist has a voice, but it is nothing like a majority rule. Still, whereas individual judgment is prized, consensus plays a crucial role.
Herschel’s letter and his paper provoked an extraordinarily intense negative reaction amongst Continental astronomers. How much of this might have been due to a long-standing antipathy of Continental philosophers towards their English counterparts is unknown, as it was never explicitly stated, but the words of the Swiss mathematician Johann Bernoulli (1667–1748) need to be considered:

It is a characteristic of the English that they begrudge everything to other [nations] and attribute all things to themselves or their nation. (see Bardi, 2006: 210).

In The Netherlands, the mathematician and physicist Jean Henri van Swinden (1746–1823; Figure 4.13) gave his Dutch-language readers his negative opinion of the new word asteroid in a book he completed in December 1802:

Herschel nameth both the new Planets Asteroids, that is, who are looking like the shape of Stars, or Star-like, (just like Sphere, globe, Spheroid, globular). But this giveth no clearer notion of the matter. Let us learn from this large deviation of the recently discovered Planet Pallas, of a law, which was considered to be certain (i.e, that the Planets move, all, inside the Zodiac), that it is always perilous, and hardly sage, to draw up general laws from only few observations, if one is not brought there through basic Mathematical principles. (Swinden, 1803: 28).

While Swinden evoked “mathematical principles” in his attack on the word asteroid, other Continental astronomers deployed a range of “artillery” to bombard Herschel’s choice. Here is a survey of the responses in France, Germany, Italy and Sweden.

4.2.3.2 The Reaction in France

Herschel’s letter (specifically the one sent to Méchain) of 22 May 1802 was made public, and printed in French in the Gazette Nationale ou Moniteur Universel on 2 July 1802 (page 1164). The Moniteur was the official Government publication of the time. Pierre Laplace (1749–1827), in Paris, rejected the term ‘asteroid’ in a 17 June 1802 letter to Herschel:

As to the name you give to these stars [French: astres], I still see no reason not to continue calling them planets. Ceres differs only by its inclination, which is a bit large, but it follows only that it is necessary to spread the width of the zodiac, and even include Pallas, if as seems
likely its orbit is an ellipse, the eccentricity of which is only slightly greater than the orbit of Mercury. (Laplace, 1802).

An archival search has not revealed the reactions of other notable French astronomers at the time.

B. Voiron, writing a decade later, was so dismissive of the word ‘asteroid’ that he did not even mention Herschel’s name in connection with it:

Some scholars, who beheld them as appearing like a small star, proposed to include them in a particular class under the name of asteroids, but the general opinion of astronomers put them among the planets which are distinguished from other stars, not by volume but by the nearly circular orbits around the Sun they describe. (Voiron, 1810: 82).

4.2.3.3 The Reaction in Germany

Herschel’s term ‘asteroid’ was initially rejected by everyone on the Continent, with the single exception of Wilhelm Olbers:

I agree with you, honoured Sir, in your sagacious suggestion that Ceres and Pallas differ from the true planets in several respects, and the name asteroid seems to me to fit these bodies very well. Yet I would not lay too much stress on the difference in size, as the old planets differ from one another so much in this respect. Yet taking all the particulars together there seems to me to be a real difference between the asteroids and the true planets. (Olbers, 1802).

Johann Bode, Director of Berlin Observatory, wrote to Herschel with no small temerity. In a letter of August, 1802, he questioned not only Herschel’s diameter measurements but his choice of the term ‘asteroid’. In mid-1802, he was still very uncertain about the true nature of Pallas, especially since it conflicted with the mathematical progression of planetary distances now best known as Bode’s Law:

I believe or am still convinced that Ceres is the eighth main planet of our solar system and that Pallas is a neighbouring extraordinary planet (or rather comet) revolving around the sun. Thus there would be two planets between Mars and Jupiter where I have been expecting since 1772 only one and the known beautiful progressive order of the distances of the planets from the sun is only completely proven by this discovery since there was a gap at the distance 4+24=28. (Bode, 1802).

Baron von Zach adopted an extremely aggressive and fiery attitude when telling Oriani about Herschel’s choice:

Mr. Herschel just wrote me that he had observed Ceres and Pallas with his large telescopes, neither has any satellites at all, he found the diameters much smaller than Schröter. For Ceres 162, for Pallas 70 English miles. Furthermore he does not want these corpuscles to be called planets, he invents a class of its own and calls it asteroids. But this is nonsense. For in this case Mercury is an asteroid as well in comparison to Jupiter. So this nomenclature means nothing, it is arbitrary and offensive. (Zach, 1802).

His tone was slightly more dispassionate when relaying the news to Gauss:

Dr. Herschel wrote and tried to suggest his term asteroids to me. He wants to introduce three distinct species. Planets, asteroids and comets. He wrote: “I hope this classification will meet with your approbation and that you will do me the honour to adopt it.” But I have no inclination to do so because his definition of asteroids is not convincing. I rather stick to the name planet, together with you and Olbers. Only if there are several small planetulus between the older ones we can talk about a new classification, but today smallness, inclination and eccentricity do not decide on planetism or not planetism. Thus, Herschel’s definition of asteroids is arbitrary. (Zach, 1802).

Here Zach has independently arrived at the term ‘planetula’, the same appellation suggested by Watson to Herschel.

Gauss rarely allowed strong opinion to intrude into his letters, but when it came to Herschel and the asteroids he let the mask of scientific imperturbability slip:

Mr. Herschel also gave me information on his ‘Asteroids.’ What surprises me is (1) that he doesn’t announce it as being a modest proposal, but rather says simply “I call them”, and (2) that his reason in Ceres’ case consists in that it now “is out of the Zodiac.” That shows a very biased and, it seems to me, unphilosophical outlook. It is likewise strange that he withholds his measured apparent diameter. Should it be correct, then, as it seems to me, a smaller mass is
hardly important to be able to distinguish Pallas or Ceres from the remaining planets. (Gauss, 1802e).

The word scientist had not yet been coined in 1802, so Gauss is characterising Herschel’s outlook as unscientific when he uses the word ‘unphilosophical’. He is also strongly objecting to what he perceives as Herschel’s de facto pronouncement that the term asteroids must be adopted. Clearly, Herschel’s attempt at consensus-building, noted earlier, had failed miserably. Gauss expanded on his views in a letter (dated 16 October) to Zach, who published it in his journal, the Monthly Correspondence:

Dr. Herschel still is not willing, as Prof. Huth told me and who visited him in England, to tolerate the new planets, although as far as I know not a single astronomer has approved of his suggestion [of the term ‘asteroids’]. Basically, and I agree with you, it depends only on our agreement whether we call Ceres and Pallas planets or not. And people are not saying whether they are planets or not, but whether it is proper and becoming to call these celestial bodies planets that partly resemble the known planets and partly not at all. That the latter is irrelevant you have shown sufficiently in your July issue and that astronomers believed in a circle-like orbit and a dependent perennial character seems to be proven by the circumstance that all astronomers accepted their planetism without hesitation as soon as they learned of the orbit. It even appears to me that, if future finds prove our excellent Olbers’ hypothesis right—that Ceres and Pallas are only pieces of a destroyed planet, even then, we do not have to give up calling them planets. I believe it more important to study whether these celestial bodies are entitled to the name planet because of their fundamental characteristics than how they have become it. (Gauss, 1802g: 503).

As Gauss mentioned, Johann Huth (1763–1818) had personally received Herschel’s reaction to the general consensus that Ceres and Pallas should be thought of as planets. Huth did not meekly accept his refusal, but tried to reason the matter through with Herschel.

I think it unwise to introduce new names especially a general one, if we can avoid it. New categories entice us to see differences where there are none. The fact that Ceres and Pallas are smaller than the other planets cannot hinder us to expel them from the set of planets. The complete text of the letter is in section D.3. Herschel was unmoved by this entreaty. He never replied to Huth, but this did not stop Huth (1804: 266) from coining his own term of ‘coplanets’ to denote Ceres and Pallas.

4.2.3.4 The Reaction in Italy and the Origin of ‘Planetoid’ and ‘Cometoid’

Barnaba Oriani, writing to Piazzi on 1 September 1802, said that “Herschel’s ideas about the new planets are quite crazy. No astronomer can find them useful and Zach, in his journal, has rejected them.” (Oriani 1802b).

Piazzi, the discoverer of Ceres, also rejected the asteroid terminology—his overweening pride would not allow his discovery to be anything other than a primary planet. The tone he took in expressing his opinion to his friend Oriani was quite contemptuous. “Soon we will see dukes, counts and marchesi in the sky as well …” (Oriani, 1802a). In this letter to Zach, Oriani was quoting from a letter he had received from Piazzi. Oriani (ibid.) added his own thoughts: “You [Zach] have already successfully proven the planetism of Ceres and Pallas; consequently, it is useless to ponder Herschel’s new dynasty.”

With great glee, Zach repeated this information to all and sundry. On 15 September he told Gauss what Piazzi and Oriani thought, and two days later he told his friend Jan Baptist Sniadecki (1756–1830) in Cracow that “The Italians make fun of the asteroids.” (Zach, 1802v). The same day, Zach jovially responded to Oriani:

Piazzi’s remark about the celestial deities made me laugh, this bon mot is brilliant. You said I had successfully proven that the two stars were planets but you will be even more content to...
hear what I said about this matter in my September issue. Herschel’s dynasty is not popular in Germany either. (Zach, 1802).

Piazzi (1802c) wrote to Oriani, asking his opinion of Herschel’s proposed word ‘asteroid.’ Here he goes for the jugular, saying Uranus—Herschel’s great discovery—should be called an asteroid if his own discovery Ceres is an asteroid:

I hope you won’t be sorry if I transcribe a letter recently received from Herschel [this was dated 22 May]. What do you think? It looks to me (1). Whatever the name given to this new star doesn’t really matter. Are they moving stars? You can call them planetoids or cometoids, but not asteroids. (2) For me the only difference between comets and planets is their eccentricity and inclination. Consequently Ceres is a planet and Pallas a comet. (3) Ceres’ diameter is certainly not less than 5” at our distance from the Sun; therefore it has to be much larger than 162 miles. (4) If we call Ceres an asteroid so we must call Uranus an asteroid.

Piazzi’s candid opinion, given to his friend Oriani, was then transmitted to Zach, and finally spread like gossip to the rest of Europe. To his supposed friend Herschel, Piazzi was much more courteous as he sugar-coats a bitter pill:

I read with great pleasure the extract of your learned memoir on Ceres and Pallas which you were good enough to send me. New ideas and precious observations will always be yours to share, and I will always be one of your greatest admirers. But tell me, could we not establish as a distinctive mark between the planets and the comets the intersection of their orbits reduced to the ecliptic? And for the naming, could one not call the little planets planetoids? Because I confess the name asteroids seems to me more appropriate for the small stars. (Piazzi, 1802c, his underlining).

While most Continental astronomers were airily dismissive of Herschel’s choice, this letter shows Piazzi trying to reason with Herschel. In these important letters just quoted, Piazzi coins a word that has become widely used ever since to denote small planets such as asteroids, namely ‘planetoid’. The derivation of this word is also from Greek and Latin, and one wonders how Herschel would have responded to this suggestion from his friend Watson. Compared with the outrage that greeted the word ‘asteroid’, it seems highly likely that the word ‘planetoid’ would have raised far fewer objections. The suffix is used in mathematics (rhomboid, trapezoid), biology (arthropoid, humanoid), and chemistry (alkaloid), so its extension into astronomy would have raised few hackles. The ‘–oid’ suffix was used once again by the IAU, in its decision of 2008, when it named all spherical objects beyond the orbit of Neptune ‘plutoids’. (11 June meeting of the IAU Executive Committee, Oslo, Norway).

The suffix ‘–oid’ is derived from the Latin suffix –oides, which in turn came from the Greek. It possesses the meaning ‘having the likeness of’. In some words –oid has a slightly extended meaning—‘having characteristics of, but not the same as’, and it would be in this sense that Piazzi suggested the word because he uses the word ‘little’. Thus, he is signifying that the smallness of Ceres and Pallas is a distinguishing criterion for applying a different appellation to them. It might also be noted that the prefix ‘aster-’ is used in science as well. Just drop the letter ‘o’ from asteroid and we have the word asterid, which denotes such flowering plants as daisies, sunflowers and potatoes.

The other important issue raised in this short letter by Piazzi is the criterion by which comets should be distinguished from planets. He is saying that if an object is in a planetary orbit, such that it does not cross the orbits of any other planets, it should in fact be called a planet. Comets, conversely, intersect planetary orbits, and thus can be distinguished as a separate type of object. Even at the time of his writing, this criterion made little sense. By July of 1802 it had already been discovered that the orbit of Pallas crossed the orbit of Ceres. Thus, by his own definition, Ceres and Pallas could not be called planets (as other astronomers still insisted on) but they certainly could be called planetoids.
In 1803, Herschel actually used the designation ‘planetoid’ in a paper published by The Royal Society, but he did not attribute its creation to Piazzi by name:

As the solar system presents us with all the particulars that may be known, respecting the arrangement of the various subordinate celestial bodies that are under the influence of stars which I have called insulated, such as planets and satellites, asteroids and comets, I shall here say but little on that subject. It will, however, not be amiss to remark, that the late addition of two new celestial bodies [Ceres and Pallas], has undoubtedly enlarged our knowledge of the construction of the system of insulated stars. Whatever may be the nature of these new bodies, we know that they move in regular elliptical orbits round the sun. It is not in the least material whether we call them asteroids, as I have proposed; or planetoids, as an eminent astronomer, in a letter to me, suggested; or whether we admit them at once into the class of our old seven large planets. In the latter case, however, we must recollect, that if we would speak with precision they should be called very small, and exozodiacal; for, the great inclination of the orbit of one of them to the ecliptic, amounting to 35 degrees, is certainly remarkable. That of the other is also considerable; its latitude, the last time I saw it, being more then 15 degrees north. These circumstances, added to their smallness, show that there exists a greater variety of arrangement and size among the bodies which our sun holds in subordination, than we had formerly been acquainted with, and extend our knowledge of the construction of the solar, or insulated sidereal system. (Herschel, 1803: 339-340).

The first printed example of the words ‘planetoid’ and ‘cometoid’ comes from Brougham (1803: 430). He could not possibly have seen the private letter from Piazzi to Herschel, so it is he who must be given credit for the introduction of these words into the English language.

The OED regards ‘cometoid’ as an obsolete word, and gives its origin as W. Taylor 1805. In reality it was used by Capel Lofft (1805: 534) in the Monthly Magazine, but the OED (using the same publication and page number) erroneously gives the name Taylor as the originator. Thus, the OED entry is wrong both in citing its first use in 1805 instead of 1803, and attributing the 1805 use to Taylor instead of Lofft. This is a second error in the OED discovered during research for this thesis. Despite its obsolete status, there are many instances of the use of ‘cometoid’ in the modern literature as an object that exhibits the properties of both an asteroid and comet (e.g., Chaikin, 2003). After excoriating Herschel for bringing the word ‘asteroid’ into use, Brougham (1803) wrote:

To us, that name [asteroid] presents the idea of some body resembling fixed stars; whereas the two new planets have no one circumstance in common with those distant bodies. If a new name must be found, why not call them by some appellation which shall, in some degree, be descriptive of, or at least consistent with, their properties? Why not, for instance, call them Concentric Comets, or Planetary Comets, or Cometary Planets? Or, if a single term must be found, why may we not coin such a phrase as Planetoid or Cometoid?

4.2.3.5 The Reaction in Sweden

Herschel’s work was known throughout Europe, and reached the discerning mind of Lars Regnér (1746–1810), Professor of Astronomy at Uppsala University in Sweden. Like his Continental counterparts, Regnér not only rejected Herschel’s nomenclature, but made it clear in a little-read Latin dissertation of 1803 (Figure 4.14) that Herschel was wrong in using his great influence to “… draw both Ceres and Pallas from the rank of planets.” Regnér (1803: 9) dips his pen in the well of sarcasm when he adds “… let me not say unjust influence.”
It would be very tedious to bring all the inquiries of astronomers who have either located these bodies among the number of the planets, or who wanted to excluded them from it; indeed it would seem useless, since nearly all have long ago recognized the planet Ceres, and there are very few who are still in doubt about Pallas. The particular reasons why they do not want this planet are the eccentricities of its orbit, which are greater than the other planets, and its great inclination towards its ecliptic; but that is insufficient to fashion the orbit of a planet; and this does not constitute a known family obligation to a planet.

But Dr. Herschel, who has used the highest (let me not say unjust) influence to draw both Ceres and Pallas from the rank of the planets, besides these reasons, produces the notable meagerness of their volumes, and proposes the name Asteroids. These two bodies are admittedly very small. Through revised dimensions, Dr. Schröter has found that the diameter of Ceres, at the medium distance of the earth from the Sun = 3",44 or = 1/5 of the diameter of the earth, and truly it is somewhat lesser than the diameter of the Moon. Yet this greatly overcomes the magnitude of Pallas, whose diameter, measured by Dr. Herschel, is found only to = 0",265, at the medium distance of the earth from the Sun; and truly it is about 1/65 of the diameter of the earth, or 1/18 of the diameter of the Moon, or about = 18.5 milliaris Secuanis. Yet these micrometric observations are truly uncertain, and both of the most experienced astronomers of our time, Drs. Herschel and Schröter, differ too much from each other in this matter.

If the nature of the planets may be diverse, by reason of their diverse magnitude, and a truly new name would indicate new and particular characteristics, perhaps it would not be useless to adopt the denomination and division proposed by Dr. Herschel. But we plainly excuse this. And moreover it would then also be necessary to divide these five bodies that are already known by the name of planets for two thousand years into other classes: for Jupiter is far greater in size than Mercury, and Mercury than Pallas.
At last, since these bodies are whirled around the Sun, they should dwell continuously within the distances of the Planets from it, and they should remain visible under the entire course of the periodic times, with the times of the conjunctions with the Sun excepted; all of these things are characteristic to Planets: Certainly we see no reason why they should not be received among the ranks of the Planets. Perhaps it could happen that Pallas might lead itself beyond the sight of astronomers in the greatest distance from the earth and the Sun; but since this eclipse arises rather from its own scantiness than from the magnitude of its size, clearly it shows nothing against its qualifications as a planet. Concerning the other, it is more than plain that it might also appear in this position; for on the 21st of September of the preceding year, although there was no difference of the right ascension of it and the Sun except 30° 53',5 and for this reason its light was hardly weakened at all in the vicinity of the Sun, Dr. Messier [Charles Messier, 1730-1817] was still able to observe it. (Regnér, 1803: 9-10, his italics).

4.2.3.6 Zach’s Appeal to Ancient Authorities

The most extensive public analysis of the whole question about what to call Ceres and Pallas was written by Zach, and published in his journal, the *Monthly Correspondence*, in September 1802. In this passage he is much more circumspect about Herschel than he was in private correspondence, and he appealed to classical Greek and Roman authorities to set some ground rules:

A common question is: Are Ceres and Pallas really main planets of our solar system? Since there is no king in the free republic of science, who says tel est notre plaisir [such is our pleasure], the astronomers’ opinions vary, which is a sign of an unfinished definition of a planet. La Lande has already awarded those two heavenly bodies the planetary diploma – in his letters and even publicly in *Moniteur*. Dr. Herschel on the other hand suggests in his circular letter a new species of celestial bodies named asteroids. In our view both depend on arbitrariness, agreement, or consent of all astronomers. For the definition of planet is rather nominal than real. If we would like to engage in didactic disputes we have to go back to those times, where the knowledge about planets originates and their names were introduced. Democritus did not know the five main planets of our solar system yet, according to Seneca [see Burkert, 1972: 313]. Eudoxus brought this knowledge from Egypt to Greece 380 BC. The Greeks called those bodies “planets”, derived from the word πλανήτης, erraticus, irrend [roving/erratic] because these celestial bodies rove in space in contrast to fixed stars, which were called *Stellas inerrantes* and to comets, called *Stellas comatas*. Now the question is: Would the Greeks have classified Ceres and Pallas as wandering bodies or planets, if they were visible to their eyes? Certainly, for already Artemidorus answered this question by saying that there existed several still invisible planets: “There are not only these five stars running around, but these are the only ones that we have observed. There are countless others besides, moving secretly, unknown either because of the obscurity of their light, or because the position of their orbits is so great that they could only be seen when they came at last to their end.”

And also Seneca believed in a multitude of planets, by saying: “But you think that among the countless stars that distinguish the night with their varied splendour, and which suffer the air to be empty and inactive, there are only five to whom it is permitted to busy themselves, and that the others stand still, a fixed and motionless nation.” Just like Seneca then said about the planets “They compel us to be curious”: we are captivated by those two new roving bodies (for they wander like the other planets), which arrest our attention. Now is the time of which Seneca once said: “A time will come when the diligence of a distant age will draw those things that lie hidden into the light of day.” This day was the first of the 19th century and the diligence of the (world) wise men *Piazzi* and *Olbers*. (Zach, 1802u: 310-312; his italics).

It has been noted by scholars that the English reading public was especially receptive to thoughts and writings emanating from Germany in the late eighteenth and early nineteenth centuries. “… all things German were received with intense interest, if not with open arms, by English readers.” (Boening, 1982: 65).

This was certainly true in astronomy, where the great discoveries of Pallas, Juno and Vesta were accepted in the spirit of international amity. Even though many letters passed back and forth between astronomers in England and Germany, it appears that this did not extend to the periodical literature. Herschel specifically mentioned he did not read Zach’s journal, and it seems that whatever was being
written about the asteroids in *The Monthly Correspondence* reached England either through personal missives or an exchange between journal editors (see Subsection 5.2.1). On the Continent, *The Monthly Correspondence* was the only journal (and the first one) devoted to astronomy. Its contents, sent in by astronomers all over Europe, affirm that it was the vehicle for astronomical observations and contemplations to be published. All evidence confirms that Zach, as the editor of the journal and the director of a major observatory (Seeberg in Gotha), was highly regarded in all countries (Brosche, 2001) and had the same status on the Continent as Sir Joseph Banks did in England as a man of science to be seriously considered and consulted.

4.2.4 Herschel’s Vindication

We do not know with certainty what Herschel thought of the firestorm he had raised by his new terminology, but his likely reaction was resignation. He had become all too familiar with his views being either derided (lunar volcanoes), or misrepresented (a relationship between sunspots and the varying price of corn; Love, 2013). Herschel’s attitude to his critics is best summed up by David Brewster, writing about the reaction to Herschel’s discovery of infrared rays:

> An individual whose speculations [about] the discovery of Invisible Solar Heat had cast into the shade, attacked Dr. Herschel with an asperity far beyond the limits even of severe criticism; but though that venerable man often spoke, with suppressed feelings, at the attempt which was thus made to discredit and depreciate his labours; yet he never condescended to repel the charge. (Brewster, 1823: 220).

Whatever his views may have been about the criticism, Herschel never backed down. Indeed, he felt more vindicated than ever with the discovery of Juno in 1804:

> It will appear, that when I used the name asteroid to denote the condition of Ceres and Pallas, the definition I then gave of this term will equally express the nature of Juno, which, by its similar situation between Mars and Jupiter, as well as by the smallness of its disk, added to the considerable inclination and eccentricity of its orbit, departs from the general condition of planets. The propriety therefore of using the same appellation for the lately discovered celestial body cannot be doubted. The specific difference existing between planets and asteroids appears now, by the addition of a third individual of the latter species, to be more completely established, and that circumstance, in my opinion, has added more to the ornament of our system than the discovery of a new planet could have done. (Herschel, 1805a: 64).

This was reinforced even further with the discovery of Vesta in 1807:

> As cloudy weather has prevented an immediate continuation of my observations of Dr. Olbers’ new star, and its increasing distance from us will soon put it out of the reach of telescopes that are directed to it for no other purpose than an examination of its physical condition, I have sent you the inclosed paper, which indeed appears to me quite sufficient to determine that the new star is a fourth asteroid. (Herschel, 1807b).

The word ‘asteroid’ was in common use in England by 1830. One early adopter was William Phillips (1775–1828; 1817: 68), previously the author of two books on mineralogy. His 1817 book was intended as “… an introduction to the science for the use of young persons, and others not conversant with the mathematics.”

> “It is a remarkable fact,” he wrote, “that some irregularities observed in the motions of the old planets, induced some astronomers to suppose that a planet existed between Jupiter and Mars; a supposition that arose previous to the discovery of the four new planets, or Asteroids.” His suggestion that astronomers looked for a planet between Mars and Jupiter due to “irregularities” in their motions is curious, as the stated motivation by the Celestial Police and others such as Capel Lofft was the large gap between the planetary orbits.
The word ‘asteroid’ also was used in a popular magazine by a certain Thomas Cooke of Draycoth, near Derby (Cooke, 1830). The use was by no means universal, even in England. Miss Christian Cann (1828: 79) is quite clear that under the denomination of planets, are now comprised, Mercury, Venus, the Earth, Mars, Jupiter, Saturn, the Georgium Sidus, or Herschell, Ceres, Pallas, Juno, and Vesta; the four last named planets are recent discoveries.

Even so, there was still reluctance in the United States to regard the four objects as worthy of a special category. An anonymous member of the United States Naval Lyceum, in an essay on astronomy, included the four objects in a list of the primary planets (Anon, 1837: 119). But Herschel finally achieved professional vindication in that country when Benjamin Apthorp Gould (1824–1896; Figure 4.15), founder of the Astronomical Journal, gave his stamp of approval to the term, offering at the same time a straightforward definition:

By the common consent of astronomers, they have received the name of “asteroids,” a name proposed by the elder Herschel, in consequence of a theory of his own. The word asteroid, in its present signification, may be defined as “a small planetary body, which revolves around the sun between the orbits of Mars and of Jupiter.” (Gould, 1848: 28).

By the end of the century, the distinction between asteroids and planets was so accepted in English society that it could even be used to measure literary merit:

A group of dramatists and lyrical writers, among whom Beddoes is by far the greatest, link the generation of Keats and Shelley with that of Tennyson and the Brownings; but most of them are nebulous, and the most eminent mere asteroids in comparison with the planets which preceded and followed them. (Gosse, 1897: 332).
4.2.5 Analysis of the Criteria

The differing views just outlined allow us to examine more closely the criteria used, and the conclusions that were drawn from them. Quiddity was at the heart of the differing opinions about Ceres, Pallas, Juno and Vesta—what exactly was the essential nature of these heavenly bodies? Table 4.1 below lists the seven criteria Herschel gave in his papers, and how each applied to planets, comets, Ceres/Pallas, and finally the broader definition of asteroids.

Table 4.1: Herschel’s Criteria for Differentiating Asteroids from Planets or Comets.

<table>
<thead>
<tr>
<th>HERSCHEL’S CRITERIA</th>
<th>PLANETS</th>
<th>COMETS</th>
<th>CERES/ PALLAS</th>
<th>ASTEROID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Considerable size</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>(Notes 1, 3 and 5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small to moderate eccentricity (Notes 3, 4 and 7)</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>not necessarily</td>
</tr>
<tr>
<td>Low inclination (Notes 2, 3 and 7)</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>not necessarily</td>
</tr>
<tr>
<td>Motion is direct (Note 4)</td>
<td>yes</td>
<td>not necessarily</td>
<td>yes</td>
<td>not necessarily</td>
</tr>
<tr>
<td>They may possess satellites or rings (Note 8)</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>possibly</td>
</tr>
<tr>
<td>They have a considerable atmosphere (Note 6)</td>
<td>yes</td>
<td>Yes, in the form of tails, coma and haziness</td>
<td>Yes, in the form of haziness, but no discernable coma or tail</td>
<td>Possibly comas, disks, or nuclei</td>
</tr>
<tr>
<td>Their orbits are at a considerable distance from each other (Note 2)</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>

Note 1: This is the criterion Banks, Olbers and Regnér believe should be given little weight in distinguishing Ceres and Pallas from planets.

Note 2: These are the criteria that Huth says are of no importance in distinguishing Ceres and Pallas from the existing planets.

Note 3: These are the criteria that Zach and Regnér believe are of no value in distinguishing Ceres and Pallas from the existing planets.

Note 4: These are the criteria Huth says are important in defining a planet.

Note 5: This is the criterion Piazzi believes is important in distinguishing Ceres and Pallas from the other planets.

Note 6: Bode (1802b) believed that Pallas should be called a comet, even though it did not exhibit a tail or nebulosity. “Maybe the nebulosity around your comet is too thin to be discovered ...” he wrote to Olbers on 4 May 1802. “In order not to confuse the astronomical readership I call your moving star a comet because of its path.”

Note 7: These are the criteria Laplace believes are insufficient for distinguishing Ceres and Pallas from the planets.

Note 8. After 212 years, Herschel’s suggestion that asteroids may possess rings was verified when not one but two rings were found orbiting asteroid (10199) Chariklo. (Braga-Ribas, 2014).

While the criteria used by Herschel for distinguishing between the various types of objects is clear, the inherent assumption about the nature of comets is not. Our modern understanding of comets differs markedly from theories current at the time:

M. de Buffon [George-Louis-Leclerc, Comte de Buffon, 1707-1788] supposed that the planets were all struck off from the sun’s surface by the impact of a large comet. But Mr. Buffon did not recollect that these comets themselves are only planets with more eccentric orbits. (Darwin, 1791: 30).

Here we see the English natural philosopher Erasmus Darwin (1731–1802) stating shortly after the discovery of Uranus that the prime criteria for distinguishing planets from comets is their eccentricity. Darwin himself was inclined to the idea that objects could be ejected from the Sun by sun-quakes or solar volcanoes. Those that came from its equatorial zone became planets, while those ejected from the polar regions would have more eccentric orbits and thus became comets.

Zach muddied the waters further by his speculation that a planet can exhibit a tail. This actually proved prescient, as just such a phenomena was finally observed in 2013 when the Hubble Space Telescope imaged six tails emanating from a body in the inner asteroid belt designated P/2013 P5 (Jewitt et al, 2013), showing that the distinction between comets and asteroids is not rigid but rather covers a spectrum. Here is Zach (1801):
But why can a planet not have a tail as Saturn and Uranus have rings? Do the elements of the comet of 1770 not resemble those of Piazzi’s star? I answer this with Lexell’s words that Jupiter’s influence has totally changed the orbit of this comet. Why was it not seen any earlier and more often? Schröter and Herschel have proven that comets can be visible in a certain period and not in another.

In late 1801 the German astronomer Karl Felix von Seyffer (1762–1822) at the University of Göttingen wrote a treatise about the ‘New Star’ discovered by Giuseppe Piazzi. After translating Piazzi’s monograph for his German-language audience, Seyffer added his own analysis of the importance and meaning of this discovery. The nature of Ceres was central to his thoughts—was it a comet or a planet? It is particularly valuable to examine his views at this crucial time, before William Herschel coined the term ‘asteroid’. Like Herschel, he was struggling to identify criteria that should be used to distinguish comets from planets. Most intriguingly, he used Herschel’s own writings on the subject of how to classify celestial objects, published in 1795:

The question for the nature of this celestial body, whether it is a planet or a comet, cannot easily be answered. It seems to be remarkable that among those many voices which were gathered by Baron von Zach in his correspondence, since they belong to men whose name alone demands admiration, there was not one that expressed a difference of both kinds of moving stars. The term Planet, as it can be found in the most famous books on astronomy, does apparently no longer fit the expansion and unveiling of the building of the world as we know it now. After this tight terminology, although Herschel and La Place unlock new heavens due to their analysis and their telescopes, I dare prove that the zodiacal light is a planet, which revolves around the Sun. I consider it certain that this atmosphere which is reflected by the zodiacal light, is an atmosphere different from the solar atmosphere, cf. La Place’s *Mécanique céleste*, vol. 2, p. 170. Probably our Sun is a planet, probably all nebulae are, and all stars together that we can see in a bright winter’s night which, like our Sun does, revolve as planets around dark Suns; and their orbits will be calculated in several thousand years from now, just as we determine the elements of our seven planets! Through the field of Herschel’s telescope with a diameter of 15 minutes, at some place in the Milky Way, at 41 minutes time, a compressed cluster of stars moves which consists of not less than 258,981 stars; and Dr. Herschel says in his treatise *On the nature and Construction of the Sun and fixed Stars*, p. 26 with good reason: that these clusters of stars are huge lucid main planets: “They are in fact, only very capital, lucid, primary Planets, connected together in one great System of mutual Support.” I do not know any other certain way to distinguish a planet from a comet than by the great eccentricity of the latter. But if this feature is constant and determined I ask each astronomer with what reliability and accuracy can the eccentricity of this celestial body be determined from 24 observations? How reliable can elements be, calculated from such a small visible arc? The answer, that was actually given, that this body was already calculated in an ellipse and that the eccentricity and period of revolution (extremely accurately for a comet) were determined would be something similar to an ellipse, a circle – in conclusion. I do ask, with what degree of reliability can these elements be derived from such an extremely small visible arc?

The greatest or smallest inclination is nothing but an analogy of hitherto observations and cannot be a certain proof for planetism, for it is appropriate to call the moving stars of 1702, 1743, and 1759 comets and not planets. And it would be difficult, since the inclination of the orbit is most difficult to determine, to classify such stars whose inclination would come close to the assumed limit. And I do not consider any physical feature of moving stars like tail, nebulosity, lucidity or lack of these a distinctive characteristic for planets or comets. What physical character did the five comets, discovered by Mademoiselle Caroline Herschel (sister of William Herschel), have? Do we not owe this discovery a new opinion?!

The distinction between planet and comet should consequently be derived from something more consistent and more obvious, like the orbit of moving stars. Whether these orbits are returning or not returning is hard to determine as can be seen from the different results of the most diligent comet-calculators. Actually, we only know of the return of one single comet of 1531, 1607, 1632, 1759 of whose identity of the orbits is a fact. In order to constitute the character of moving stars one should pick something more certain and constant. The only
characteristic which is left and which is convenient regarding the small number of moving stars, to distinguish planets from comets:

The distances of several stars from the Sun be at perihelion \(p, p', p'', \ldots, p^{(n)}\)

The distances at aphelion \(a, a', a'', \ldots, a^{(n)}\)

I would call the star K (whose distances at perihelion and aphelion are \(p^{(k)}, a^{(k)}\)) a comet if there is another star I whose aphelion \(a^{(i)} < a^{(k)}\) and perihelion is \(p^{(i)} > p^{(k)}\). The star K would be a planet if no other star I described such an orbit, that at the same time \(a^{(i)} < a^{(k)}, p^{(i)} > p^{(k)}\). But whatever special or general terms are applied to Piazzi's star due to the uncertainty of the elements, its nature will always remain uncertain if we will not see it again. After all the above studies it appears to me that considering all observations nothing certain can be said about the nature of Ceres Ferdinandea. One or the other opinion seems to belong to those things of which [David] Hume said about [George] Berkeley [1685-1753]: that they do not allow falsification but neither create conviction. (Seyffer, 1801).

For more about the English philosopher Berkeley, see Subsection 6.1.1

In a seminar delivered to the Museum Society of Bremen on 25 October 1802, Olbers laid out his analysis of the criteria. In this anfractuous passage he criticises Herschel, but admits rather perversely that a distinction should be made between these newly-discovered objects and the planets:

According to the general opinion of all astronomers both celestial bodies are considered planets. If they are named once in a while differently, this only stems from the fact that previously the definition of a planet was too strict. That they are much smaller than the rest of the planets cannot exclude them from those: Pallas might be several 1000 times smaller in volume than Mercury but Mercury is also 27,000 times smaller than Jupiter. The extreme inclination of their orbits proves only that planets revolve on very inclined orbits around the Sun as well. But these differences of Ceres and Pallas from the older planets induced Mr. Herschel to create a new class of celestial bodies he wants to call asteroids. I do not like Mr. Herschel's reasons why he wants to make a distinction between Ceres and Pallas and the planets; But I do believe for very different reasons that the astronomers could really be persuaded to distinguish these two heavenly bodies, together with similar ones we might discover in the future, from the planetary gender as a species of its own. (Olbers, 1802d).

English writers were still debating the merits of Herschel's criteria into the 1830s.

The following example shows that the writer is selectively considering only one of Herschel's criteria—size—to criticise his distinction of the asteroids from planets and comets:

Herschel has made repeated attempts to measure the diameters of all, but their extreme smallness seems to render all observations of this sort very uncertain. The same observer considers them to form a class of bodies intermediate between planets and comets; and he has proposed to give them the name of asteroids. But there seems to be no reason why a certain size should be considered as an essential character of planets; it would seem more reasonable to make the difference to consist in the magnitude of the excentricity of the orbit. Of late the discovery of comets revolving within the solar system, has made it more difficult than ever to distinguish between planets and comets; unless we take for criterion, the degree of ellipticity. This will furnish us with a distinction, at once obvious and easy of application: in the case of the orbit of Juno (the most excentric of the planets) the ratio of the excentricity to the semi-major axis does not exceed 0.26, while for the comet of Encke it is 0.85, and for that of von Biela 0.75. (Library of Useful Knowledge. Natural Philosophy, 1834: 110-111).

4.2.6 Adoption of the Term 'Asteroid'

A careful examination of extant letters from the period shows that Wilhelm Olbers was the first to use the new word ‘asteroid’ in personal correspondence. The first instance is in a letter he wrote to J.-J. Lalande on 24 May 1802:

The star of 8th magnitude observed on
April 10, 1796 (Hist. Cel. p. 228)
Passage Zenith distance
12h 20′ 21″ 28.47.9

76
is missing in the skies. It was, I believe, another Asteroid: for, without doubt, we will certainly find others. (Olbers, 1802d).

A copy of part of the original letter, in French, is shown here in Figure 4.16.

Olbers later specifically made the case for use of the word ‘asteroid’ in a letter to Gauss:

It now appears to me appropriate to distinguish the small planetary bodies, which trace orbits of larger or smaller eccentricities and inclinations around the Sun between Mars and Jupiter, from the remaining major planets by using a separate classification under the name asteroids. This is all the more necessary since we’ll probably still find considerably more. (Olbers, 1804).

Olbers continued using the word asteroid in his correspondence, including a letter to Johann Schröter dated 31 March 1807 (see Erman, 1852: 89).

Karl Harding, the discoverer of Juno in 1804, was the next Continental astronomer to adopt the term. The first instance is in a letter he wrote to Gauss on 13 September 1804 about a diameter measurement of Juno:

Friend, why don’t you purchase a small telescope, even if the mirror was only 5 inches. You cannot imagine how clearly you would see tiny stars and the asteroids with it. Regarding the three interlocked orbits of our asteroids, I do not know what to think, furthermore, if Dr. Olbers’ hypothesis is correct and there are some more roaming around and we might even discover those. Schröter already tried to measure our stranger (Juno). Yesterday he found its diameter = 2″.3. This seems too much; a different method, namely the one Herschel used for Pallas, gave 1″.6. I believe that the latter result is more likely but it can be calculated that this method is wrong. But, please, dearest friend, not a single word about this matter, for he will announce it for himself soon. (Harding, 1804b).

As shown above in Figure 4.17, the last word of the fifth line in this extract of Harding’s 13 September letter is “asteroiden”. He is writing in an old version of German script.
However, Herschel’s own English colleague, Nevil Maskelyne, continued using the word ‘planet’ to describe Ceres, Pallas and Juno. Meanwhile, the term ‘asteroid’ was used by one of England’s literary giants, Samuel Taylor Coleridge (1772–1834; Figure 4.18).

In 1802 the English poet William Sotheby (1757–1833) published a five-act tragedy based on the Agamemnon story—it was called *Orestes*, after the son of Agamemnon. Sotheby sent a copy of the play to his friend Coleridge, who at the time was anxiously awaiting the arrival of the *Orestes* script at his home, Greta Hall, Keswick. Coleridge then wrote Sotheby:

> The newest subject, though brought from the planets (or asteroids) Ceres and Pallas, could not excite my curiosity more than “Orestes.” (Coleridge, 1895: 398).

Elsewhere, Coleridge made it clear he had no use for the concept of naming planetary bodies after royalty, making particular mention of Ferdinandea as the second part of the name given to Ceres by Piazzi:

> “Sostratos of Gnydos, son of Dexiteles, to the Gods, Protectors of Sailors”. – So it will be with the Georgium Sidus, the Ferdinandea, &c. &c. – Flattery’s Plaster of Paris will crumble away, and under it we shall read the names of Herschel, Piazzi, and their compeers. (Jackson and Jackson, 1995: 321).

While most of Europe turned its back on Herschel’s ‘asteroids’, the name caught on in America: “Ceres, Pallas, Juno, and Vesta are very small bodies, and called by Dr. Herschel *asteroids*”. This appeared in a book with the author name given as David Blair, but this was one of 11 pseudonyms used by Sir Richard Phillips (1767–1840; Figure 4.19), an English schoolteacher who founded *The Monthly Magazine* in 1796. “Phillips used a variety of publishing and marketing strategies, one of which was to use the names of living or deceased authors, most of whom were church ministers, to develop ‘trade’ books of elementary education.” (Issitt, 1998). One of these names was Rev. David Blair.
The Monthly Magazine printed many reports about the asteroids (see Chapter 5). The book (by “Blair”) included what appears to be the very first map in a book that depicts the asteroids (Blair, 1811: 85; Figure 4.20).

By the late 1820s the term had also become accepted by the British press: The London Literary Gazette (1829: 224-225) devotes more than a full page to “The Asteroids”. Some 27 years after Herschel had laid down the criteria for distinguishing asteroids from comets and planets, the article surveys the subject objectively (something his contemporaries singularly failed to do). The article was important enough to be reprinted in the United States, in the American Masonick Record and Albany Saturday Magazine (1829, 3: 162):
The form and position of the orbits of the asteroids, and the physical changes observed in them, suggests the idea of their being a sort of connecting link, uniting the planetary and cometary bodies. The orbits of the old planets vary but slightly from circles; those of the new planets are considerably eccentric, though not so much as those of comets. The orbits of the asteroids make greater angles with the ecliptic than the planets, and in this respect resemble comets, some of which have their paths considerably inclined, and ascend or descend at right angles to the earth’s path. More considerable and sudden changes are also observed in these small bodies than in the planets. Ceres and Pallas are sometimes pale, overclouded, or as if surrounded by a dense mist, and at other seasons, suddenly shine forth and display well-defined discs. Variations of a similar nature are also observed in the brilliancy of the other two.

Even though the ‘misty’ appearance of the asteroids was an artefact of poor optics and variations in Earth’s atmosphere, the criteria delineated in this article are nearly identical to those elucidated by Herschel.

Hughes and Marsden (2007) quote from several astronomy books of the 1820s that mention the word ‘asteroid’, but a measure of how it truly reached popular culture can be gleaned from a satirical ‘swipe’ at Ireland published in the review of a ‘silly book’ in the widely-read London Magazine. After noting that potatoes, a staple of the Irish diet, are ‘anti-intellectual’, the reviewer writes:

It seems hard to be “blown up sky-high” into an Asteroid, for a mistake in diet. And it is still far from certain that Ireland would fare better by becoming an Asteroid, for some of the little planets, the moon for example, are in want of bare necessaries. (Notes on the Various Sciences, 1825).

Clearly, the word had reached the popular lexicon by this date, but not all early writers were content with the term. John Vose (1767–1840), Principal of Pembroke Academy in New Hampshire, attacked it emotionally and on theological grounds:

These small planets, discovered in the present century, are called by Dr. Herschel asteroids. Some think the term not very properly applied, as they are really planets. The general name seems not perfectly proper. This however is an object of small moment. But every friend to Christianity must regret that proper names of heathen mythology are applied to the discoveries of Christian countries. (Vose, 1827: 60, his italics).

But as we have seen already, in the professional astronomical realm the term ‘asteroid’ only came into regular use later in the nineteenth century when Benjamin Apthorp Gould employed it in 1848 (see Subsection 4.2.4):

By the common consent of astronomers, they have received the name of “asteroids,” a name proposed by the elder Herschel, in consequence of a theory of his own. The word asteroid, in its present signification, may be defined as “a small planetary body, which revolves around the sun between the orbits of Mars and of Jupiter.” (Gould, 1848).

Indeed, it was Gould’s consistent use of ‘asteroid’ in the Astronomical Journal, which he founded in 1849, that strongly influenced the use of the word in the United States (though not in other countries). A British book of the same year uses the word ‘asteroid’ interchangeably with ‘meteor’ and ‘shooting star’ (Thomson, 1849). It is in this vein that we find another echo of Herschel’s assertion that it is better to be something other than a planet: “I would rather be a superb meteor, every atom of me in magnificent glow, than a sleepy and permanent planet.” (attributed to Jack London, 1876–1916). The reason ‘asteroid’ was eventually adopted can best be encapsulated in an observation made by the great British rhetoricians Charles Kay Ogden (1889–1957) and Ivor Armstrong Richards (1893–1979): “Language if it is to be used must be a ready instrument. The handiness and ease of a phrase is always more important in deciding whether it will be extensively used than its accuracy.” (Ogden and Richards, 1923: 12, their italics). ‘Asteroid’ certainly failed the accuracy test as Ceres and the other small objects were not ‘small stars’, but it embodied the ease of phrase necessary to establish its place in the popular lexicon.
A Dictionary of Science, Literature and Art, was quite pithy in its comment on the word ‘asteroid’. The Dictionary, popularly known as Brande’s Encyclopedia, was edited by William Thomas Brande (1768–1866), Professor of Chemistry in the Royal Institution of Great Britain. The 1842 edition (page 98) termed asteroids “… a fantastical name.” It may have derived this description from an earlier book, which carried some weight as it was written by Robert Woodhouse (1773–1827), Lucasian Professor Mathematics at Cambridge University: “The other four planets Vesta, Juno, Ceres, Pallas, (at first fantastically called Asteroids) have been discovered since 1801.” (Woodhouse, 1821: 21, his italics). It is this ‘fantastical’ name that is almost universally used today, except by the IAU which uses the term ‘minor planet’ (Cunningham et al., 2009). The later history of the terms used to describe these objects can be found in Hughes and Marsden (2007). The criteria to be used in distinguishing Ceres from other Solar System objects are still a matter of dispute, for in 2006 Ceres was officially reclassified as a ‘dwarf planet’ by the International Astronomical Union. This was technically defined by the IAU as follows:

A “dwarf planet” is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, (c) has not cleared the neighbourhood around its orbit, and (d) is not a satellite.

The naming of new planetary discoveries in the twenty-first century remains a highly-charged emotional issue that has engaged the attention of both professional astronomers and the public (Hadhazy, 2014: 64-70).

4.3 The Role of Classification in Science

4.3.1 Hierarchies and Orders

The urge to classify celestial objects has distant roots in English thought:

Divine differences have been gathered by learned men, to shew the several distinctions, and most honorable places, held to eternity amongst those heavenly Bodies: It is questionless, that the number of them are infinite (according to our apprehension) Nay, infinite their distinctions and places; yet, for our better understanding, and the strengthening of our sicke Capacities, they are drawne and contracted into these certain numbers of Hierarchies & Orders. (Markham, 1625: 3, his italics).

It was not until the Enlightenment provided the scientific framework that this necessity to place things in hierarchies and orders came to be applied with precision and with universal coverage to the natural world:

To master nature by fixed patterns is not the task of philosophy, and whenever philosophers have tried it, the result was a utopian scheme and a failure. The task of the sciences, however, is just this kind of mastership, and in order to become masters they have to limit their search for truth, have to resign themselves to a symbolically reduced pattern. This reduction will, as every ritual, be partly arbitrary and contingent. (Foss, 1949: 104).

It was just this arbitrariness that Herschel was vilified for, both in his choice of the term ‘asteroid’ and in his criteria for placing the planets, comets and asteroids into his symbolically reduced pattern. But in doing so he was far ahead of his time, as it is just this sort of methodology that has been used in science in modern times—the starkest example being the vast array of subatomic particles whose relationships to one another can only be understood through a symbolically-reduced pattern. In astronomy it is widely used in such things as classifying types of galaxies, stars and nebula. Each one of the schemes has its own degree of arbitrariness and contingent factors, but each is essential for humans to make sense of the Universe as revealed to us by our instruments and our senses (Dick, 2013).

In Herschel’s own time, classifying plants based on affinities was championed by the Portuguese naturalist Correai da Serra (1751–1823; Diogo et al, 2001). This concept in biology of using a resemblance in structure that suggests a common origin
was mirrored in astronomy by the asteroids, which most researchers believed had a common origin.

4.3.2 The Parallels with Botany
Whatever one may think about Herschel’s choice of the term ‘asteroid’, the fact is he felt the need to create a separate classification. In this, he was following in the footsteps of eighteenth century researchers such as Carl Nilsson Linnaeus (Figure 4.21) in botany:

The first step in wisdom is to know the things themselves. This notion consists in having a true idea of the objects; objects are distinguished and known by classifying them methodologically and giving them appropriate names. Therefore, classification and name-giving will be the foundation of our science. (Linnaeus, 1735).

![Figure 4.21: Carl Linnaeus (courtesy: en.wikipedia.org).](image)

It was actually Linnaeus (1767:563) who first used the word asteroid in a botanical sense, but this was in a book written in Latin. The place of Charles Burney Jr. is secure as a new creation of the word for introduction into the English language, derived from Greek, as he had no knowledge of the earlier Latin usage. It has been noted that “The discovery of a new planet or comet has a similar significance in astronomy as does in botany the description of new types of grasses.” (Savich, 1855:3). A century earlier the parallel between studying plants and celestial objects had been mentioned by the famous French scientist Jean-Jacques Rousseau (1712–1778): “Plants seem to have been sown profusely on earth, like the stars in the sky, to invite man to the study of nature by the attraction of pleasure and curiosity.” (Rousseau, 1782:62).

The multiple names attached to the recent Solar System discoveries (Uranus = The Georgian Planet = Herschel; Ceres = Hera = Piazzi) also found its parallel in botany, where the same species might have several designations (Phillips, 1841). The English love for botany as an intellectual aspect of their lives was well known in Germany:
... the sensibilities of the inhabitants [of England] have always shown a general tendency to appreciate ... the ownership and knowledge of the plant world as an essential part of their Bildung (self-cultivation). (Heinrich Gottlieb Reichenbach (1793–1879; 1822: ix, his italics).

Figure 4.2: Erasmus Darwin (courtesy: en.wikipedia.org).

For advice on a name suitable to describe Ceres and Pallas, Herschel sought the counsel of Sir Joseph Banks. One of the prime reasons for his choice of Banks was the fact that no one had a greater familiarity with the very problem Herschel was grappling with. In 1781 Erasmus Darwin (Figure 4.22) began a translation into English of Linnaeus’ Systema Vegetabilium. Darwin sent numerous letters to Banks for advice as he set out to create a new botanic language, “… creating vernacular compounds in English as Linnaeus had done in Latin.” (Uglow, 2002: 380). When System of Vegetables was published in 1783 it was dedicated to Banks (Gascoigne, 1994).

But why Banks? He established his reputation at age 23 by publishing the first Linnaean descriptions of the plants and animals of Newfoundland and Labrador, which he collected and classified on an expedition of 1766 (Lysaght, 1971). Nearly three decades later he called Linnaeus “… the God of my adoration.” (Banks, 1792). With a lifetime of experience classifying and naming newly-found objects in nature, he became the man both Darwin (in 1781) and Herschel (in 1802) turned to for sage advice. And as Banks knew better than anyone, “… the seemingly simple function of naming objects does not present a simple connection between a thing and a word.” (Goldstein, 1948: 196). Despite his vast experience, the seemingly simple task of creating the word needed to describe Ceres and Pallas eluded Banks.
CHAPTER 5: THE FLOW OF INFORMATION AND PERSONAL RELATIONS

5.1 The British Public: Where Did They Get Their News of Astronomical Discoveries?

In 1801 the population of the world is estimated to have been one billion (United States Census Bureau). Of this mass of humanity the number of people who had actually seen Ceres was likely no more than a dozen. An English population of eight million in 1800 had the remarkably high literacy rate of 62% (Schlossberg, 2011). How the public at large learned about Ceres and the other asteroids is the subject of this chapter. There were several conduits by which news of an astronomical nature made its way into general discourse. These may be broadly divided into magazines, newspapers and books. A contemporary account describes the value of the magazines in particular, and who was reading them:

There never were so many monthly and diurnal publications as at the present period; and to the perpetual novelty which issues from the press in this form, may be attributed the expansion of mind which is exhibited among all classes of the people. The monthly miscellanies are read by the middling orders of society, by the literati, and also by the highest of our nobility. The morning and evening journals fall into the hands of all classes: they display the features of the times; the opinions of the learned, the enlightened, and the patriotic ... Those [monthly magazines] in the most extensive circulation, and of general use to all enquirers ... are the Monthly Magazine, the Gentleman’s Magazine, the European Magazine, and the Universal Magazine. (The Picture of London, 1813: 331-343; their italics).

5.1.1 Magazines

A host of magazines or journals kept the British public fully informed about the discoveries of the four asteroids, and these are listed below. Most of the articles published are included in this Chapter in order to give a complete understanding of what was being related, how accurate the reports were and where the information was coming from. For the purposes of the accompanying Table 5.1, listing every article, each publication is given a number preceding its title.

1. The Monthly Magazine; or, British Register, founded by Richard Phillips, No. 6, New Bridge-Street, London. It began in 1796 and was a prime conduit of information to the reading public in England about the discovery of Ceres and Pallas.

2. A Journal of Natural Philosophy, Chemistry and the Arts (more popularly known by the name of its Editor, as Nicholson’s Journal) also ran extensive articles about Ceres. William Nicholson (1753–1815) began the Journal in 1797 and was the Editor until 1814.

3. The Philosophical Magazine, popularly known by the name of its Editor, Tilloch’s Journal. Alexander Tilloch founded the magazine in 1797 and remained its sole proprietor until 1822.

4. The Philosophical Magazine or Annals of Chemistry, Mathematics, Astronomy, Natural History and General Science. This publication, begun in the 1820s, was a “... new and united series of the Philosophical Magazine and Annals of Philosophy.” Printed by Richard Taylor, Red Lion Court, Fleet Street, London.

5. The Christian Observer was a periodical that appeared from 1802 to 1874. It was founded by William Hey (1736–1819), and published by the famed bookseller John Hatchard. Its Editor in 1804, when it published an article about the asteroids, was the Scotsman Zachary Macaulay (1768–1838).
6. *The New Monthly Magazine* contained one newsworthy article relating to Pallas (see Section 5.2.2). It was established in 1814 by Henry Colburn (1784–1855), and ran until 1884.

7. *The Edinburgh Philosophical Journal*, “… conducted by Dr Brewster and Professor Jameson …” was printed in Edinburgh for Archibald Constable and Company, and in London by Hurst, Robinson & Company.


20. *The Eclectic Review* ran from 1805 to 1868; edited until 1813 by Daniel Parken.

21. *The Edinburgh Journal of Science*, “… conducted by David Brewster.” It was printed by John Thomson in Edinburgh and T. Cadell in London. This journal, not to be confused with No. 7 on this list, began publication in 1822.


23. *The European Magazine, and London Review*. Published by the Philological Society of London. It was edited by Isaac Reed (1742–1807), and published by James Asperne (1757–1820).


27. The Evangelical Magazine. Printed for T. Williams, Stationer’s Court, Ludgate Street, London.
28. The Saturday Magazine ran from 1832 to 1844. It was published by the Committee of General Literature and Education, who were in turn sponsored by the Society for Promoting Christian Knowledge.
29. La Belle Assemblee or, Bells’ Court and Fashionable Magazine. It was a British women’s magazine and ran from 1806 to 1837. Printed for John Bell, Gallery of Fine Arts, Southampton-Street, Strand, London.
33. Belfast Monthly Magazine. Printed and Published by Joseph Smyth.
34. Isis, published by David France, Fleet Street, London.

<p>| Table 5.1: A Comprehensive List of Magazine Articles about the Asteroids: 1801-1839. |</p>
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<td>1804/May</td>
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<td>Brewster</td>
<td>C., P., Juno</td>
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<td>142-143</td>
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<td>66</td>
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<td>301</td>
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<td>67</td>
<td>207</td>
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<td>47</td>
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<tr>
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<td>182-183</td>
<td>C., P.</td>
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<td>70</td>
<td>751</td>
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<td>1808</td>
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<td>Herschel</td>
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<td>1808</td>
<td>19</td>
<td>259-264</td>
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<td>2</td>
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<td>19</td>
<td>264-265</td>
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<td>212</td>
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<td>164-165</td>
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<td>1817/Sept.</td>
<td>1</td>
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<td>C., P. and Juno</td>
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<td>11</td>
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<td>Pallas, Juno, Vesta</td>
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<td>4</td>
<td>431-433</td>
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<td>All four</td>
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<td>Vesta</td>
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<td>W. M. M.</td>
<td>Vesta</td>
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<td>586-587</td>
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<td>All four</td>
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<td>1824</td>
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<td>184</td>
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<td>224-225</td>
<td>J. T. B.</td>
<td>All four</td>
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<td>127</td>
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<td>18</td>
<td>1831</td>
<td>14</td>
<td>372</td>
<td></td>
<td>All four</td>
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<td>1831</td>
<td>13</td>
<td>316</td>
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<td>Journal</td>
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<tr>
<td>1832</td>
<td>All four</td>
<td>18</td>
<td>62</td>
<td>All four</td>
<td></td>
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<tr>
<td>1832</td>
<td>All four</td>
<td>1</td>
<td>365</td>
<td>All four</td>
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<td>1833</td>
<td>All four</td>
<td>18</td>
<td>370-371</td>
<td>All four</td>
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<td>All four</td>
<td>49</td>
<td>13</td>
<td>All four</td>
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<td>1838/July</td>
<td>All four</td>
<td>13</td>
<td>33</td>
<td>All four</td>
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<td>1839/Feb.</td>
<td>All four</td>
<td>14</td>
<td>75</td>
<td>All four</td>
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</table>

In this table, “author” means either an article specifically written by the person quoted, or an article about observations of the person quoted. The majority of these entries (which are sometimes just short letters from correspondents, or tables of data) were published in just a few of these 34 journals or magazines. Here are the publications with five or more articles:

*The Monthly Magazine*: 27
*Nicholson’s Journal*: 19
*Tilloch’s Journal*: 15
*The Scots’ Magazine*: 10
*Mechanics’ Magazine*: 8 (all after 1825)
*London Literary Gazette*: 5
*Edinburgh Magazine*: 5

### 5.1.2 Newspapers

There were many newspapers during this era, but *The Times* of London was the main conduit of current information that most sophisticated readers turned to for news. It reported on the discovery of Ceres, and continued publishing letters to the editor about the asteroids for decades to come. Some of these were in turn reprinted in *The Mechanics’ Magazine*. It even appears that Herschel was informed about the discovery of Juno by a friend who had read about it in an unnamed London newspaper (see Subsection 5.2.3).

### 5.1.3 Books, Dictionaries and Almanacs

The first books to mention Ceres and Pallas were published in 1803. One was by Samuel Miller (1769–1850), a Presbyterian minister in New York City. He devoted one page of his “additional notes” to the new objects, and makes particular mention that “Mr. Herschell [sic] proposes to designate these celestial bodies, for the present, by the term ‘Asteroids’.” (Miller, 1803: 465). This book—being published in New York—likely remained unknown in England, but shows how influential Herschel was in his choice of the new appellation.

Another book was by Charles Hutton, F.R.S. (1737–1823), translated and updated from an earlier work by Jacques Ozanam (1640–1718) and Jean Etienne Montucla (1725–1799; 1803). In volume 3 of this 4-volume work, Hutton devotes a page and a half to Ceres and Pallas, but he does not mention Herschel or the word ‘asteroid’. A decade later, Hutton (1815) wrote further details about the asteroids in a scientific Dictionary. A third book of 1803 was by William Jones (1763–1831), an optician with a shop at no. 30 Lower Holborn, London. He devoted three pages to the new discoveries, giving the colour of Ceres as reddish and that of Pallas as “pale and white.” He quotes positional measurements of Ceres by Maskelyne, and those of Pallas by Schröter. He notes the diameter measurements of Herschel and his reasons for thinking “that they both differ from the general character of planets,” but he forswears printing the word “asteroid.” Finally, Cavallo (1803: 175) offers a single paragraph on “two new planets, viz. the Ceres Ferdinandea, and Pallas, which, on account of their remarkably small size, Dr. Herschel proposes to discriminate by the appellation of asteroids.”
A schoolmistress, Margaret Bryan (before 1760–fl. 1851), devoted a footnote covering nearly a full page to Ceres and Pallas. Her book was in the form of “…familial lectures, in which the principles of that Science are clearly elucidated, so as to be intelligible to those who have not studied the Mathematics.” This book appears to be the first one published in England that was designed to reach a wide audience, and it may be that many members of the public who did not read the journals of the day first became acquainted with even the sketchiest details about Ceres and Pallas through this book. She gives the basic discovery information about them, followed by a few lines dealing with their orbits. She concludes with the diameter controversy, without mentioning Schröter by name:

Dr. Herschell’s [sic] observations make them to be much smaller; namely, the diameter of Piazzi about 162 miles, and that of Olbers only 95 miles. He also considers them of a different species from the other known planets, and calls them Asteroids; as, in the clearness of their light, they resemble the other planets and stars, while, in their size and motion, they resemble the comets. (Bryan, 1805: 110).

The six-volume *The British Encyclopedia* (1809) by William Nicholson devoted separate articles to each of the four asteroids. *A Portable Cyclopedia* by C. T. Watkins (1810) devotes just two small paragraphs to the asteroids in the Astronomy section, noting that “… these four planets Dr. Herschel calls asteroids.” It also includes them in a table of the Solar System, listing their apparent diameter as seen from Earth, diameter in English miles, time of revolving around the Sun, and inclination to the ecliptic.

Andrew Mackay (1760–1809), in a book about finding longitude, gives background information from the seventeenth century found in no other source:

The orbits of these four planets are contained between those of Mars and Jupiter; by comparing the great interval between the orbits of these two planets, with that between the orbits of any two adjacent planets formerly known, it was surmised by Mr. James Bernoulli, in his *Systema Cometarum*, Anno 1682, that there is a primary planet revolving about the Sun, between Mars and Jupiter, whose period is about 4 years and 157 days, and its mean distance 2.583. This planet, from its smallness, and great distance, he supposes not to be visible to an observer on the earth; and, also, that it has several satellites belonging to it. (Mackay, 1809: 28).

Samuel Vince first published *The Elements of Astronomy* in England. In its first American edition (1811) he added an appendix (page 229-236) to describe the four asteroids. This included elements of Vesta computed by Groombridge, and the controversy between Herschel and Schröter about the diameter measurements of Ceres. While not giving his own opinion as to which was correct, Vince clearly describes Schröter’s experiment and his conclusion that “… an illuminated projection-disc must not be removed about eight feet from the eye of the observer.”

John Wilkes (1750–1810) of Milland House, Sussex, published the *Encyclopedia Londinensis* (1812), in which he included separate entries for the asteroids. In the entry on Juno, for example, he quoted in full the discovery letter (10 November 1804) from Harding to Lalande. At the conclusion of the article, which has tables of positional data from 1804 and one of orbital elements by both Carl Burckhardt (1773–1825) and Gauss, Wilkes adds his own editorial aside:

It is impossible to behold the new planets without calling to mind the opinion of the ancients on this subject. Artemidorus, quoted by Seneca, book vii c.5, said, that the five planets were not the only ones, and that there existed a great number which were unknown to us. But the idea of Kepler is still more extraordinary: Inter Jovem et Martem (says that great astronomer) interposui novum planetam. The new planets furnish geometerians a vast field of investigation. The perturbations they experience must not only be considerable, but they will be very complicated, and very difficult to be calculated, on account of their great eccentricities and inclinations. (Wilkes, 1812: 529).

This extensive coverage of the asteroids is in stark contrast to *The General Gazetteer* by Richard Brooks (1812), which devotes only a footnote in the
Introduction to the first three asteroids. Even though it was published five years after the discovery of Vesta, the fourth asteroid is not mentioned. The following year, John Mason Good (1764–1827; 1813) published *Pantologia*, which gave just a few sentences to the discovery of the four asteroids in its Astronomy article.

John Playfair, Professor of Natural Philosophy at University of Edinburgh (1748–1819: Figure 5.1), gave a far more serious treatment of the asteroids, looking ahead to the age of computation in the late twentieth century when the perturbation of the asteroids could be properly calculated:

The inequalities of the small planets Juno, Vesta, Ceres and Pallas, have not yet been computed; the disturbances which they must suffer from Mars and Jupiter are no doubt considerable, and, on account of their vicinity, though their masses are small, they may somewhat disturb the motions of one another. Their action on the other bodies in the system is probably insensible.

As two of these planets have nearly the same periodic time, they must preserve nearly the same distance, and the same aspect with regard to one another. This offers a new case in the computation of disturbing forces, and may produce equations of longer periods than are yet known in our system. (Playfair, 1814: 276).

Figure 5.1: John Playfair (courtesy: en.wikipedia.org).

A highly-opinionated publication, both book and almanac, was published in London in 1815. Entitled *Evening Amusements; or, the Beauty of the Heavens Displayed* by William Frend (1757–1841), it devotes several pages to the asteroids but goes into an extended rant about the names given to them. A more sober publication was a *Dictionary* by Peter Barlow (1776–1862) of the Royal Military Academy, Woolwich, which contained entries on each of the four asteroids. It includes such details as a description of the atmosphere of Juno as perceived by Schröter, and orbital elements calculated by Burckhardt (Barlow, 1814: no numbers).

A multi-volume publication from Perth, Scotland in this era was the curiously named *Encyclopedia Perthensis*. Its main contributor and editor was Alexander
Aitchison, a Member of the Royal Physical Society. The second edition, of 1816, contains an out-of-date and strangely worded section on the New Planets. After mentioning that a new planet had been discovered by Piazzi, the article says:

Other two new planets were discovered by Dr Olbers, on the 28th March 1802, and proposed to be called CERES and PALLAS. They were seen by Mr. Harding, astronomer, assistant to Dr Schröter, on the 19th Feb. 1803. They appeared under 270 right ascension, and 78° N declination. (Encyclopedia Perthensis, 17: 614).

No mention here of Juno or Vesta, a rather useless inclusion of an observation by Harding, and a misleading sentence that reads as if Olbers discovered Ceres and Vesta. And of course the first two words are transposed!

The annual almanac *Time’s Telescope* was a popular publication read by a wide range of people. Its cover gave a taste of the contents: An Explanation of Saints’ Days and Holidays, Astronomical Occurrences in every month; comprising remarks on the phenomena of the celestial bodies; and a popular view of the Solar System; The Naturalists’s Diary; and meteorological remarks. The issue for 1814 is especially interesting as it devotes a major section of nine pages to the first four asteroids. This may have been written by David Brewster, as he was the most noted populariser of astronomy at the time. He may also have authored its 1832 article largely devoted to comets: “The orbits of the planets never intersect each other: the orbits of some comets intersect those of the Asteroids.” The next paragraph reprises the statement that the planetary orbits do not intersect, but “There is, however, an exception in the Asteroids, their paths do cross each other, but these small bodies may be considered a species of comets.” (Time’s Telescope, 1832). This is an interesting statement in light of Herschel’s attempt in his 1802 paper to make a distinction between comets and asteroids.

Also appearing in 1814 was a book by J. A. Stewart designed to appeal to young women. A survey of the solar system included one paragraph on the new “planets.” It does, however, include a remarkable assertion found nowhere else:

Four other planets have also been discovered by Dr. Herschel within the last twelve years, they are very small bodies, and very little is known of them, except that they belong to this system; their names are, CERES, PALLAS, JUNO, and VESTA. (Stewart, 1814: 212).

A neat way to eliminate the discovery work of Piazzi, Olbers and Harding! The revised edition of 1815 did not correct the error.

*A Popular Grammar of the Elements of Astronomy* by Thomas Squire makes mention of ‘asteroids’ only to dismiss them:

The primary Planets of the Solar System are those which revolve round the Sun as a common centre. The four small telescopic planets, which Dr. Herschel has called Asteroids, moving between the orbits of Mars and Jupiter, are properly primary Planets; their names are VESTA, JUNO, CERES, and PALLAS. (Squire, 1818: 47; his italics).

George Gregory (1754–1808), vicar of West-Ham in Essex and domestic chaplain to the Bishop of Landaff, published a three-volume Dictionary that included a brief mention about Ceres, Pallas and Juno, but not Vesta. “This planet (Juno) and the two former ones, Dr. Herschel proposes to call asteroides [sic], because they are so much smaller than any of the other planets.” (Gregory, 1819: no page numbers). The asteroids featured in several tables of data included in an earlier book he wrote (Gregory, 1808).

In later years information about the asteroids could be found in various reference books. For example, James Mitchell, (1787–1844; 1820 and 1823), included the discovery circumstances, physical data and orbital elements. Mitchell, who was elected a Fellow of the Geological Society in 1832, also gave a synopsis of Vesta observations by Groombridge in his 1823 book. William Shepherd (1822: 135) covered our knowledge of the asteroids in a single page. *The Perennial Calendar* by
the astronomer Thomas Forster (1789–1860; 1824: 280-281) reviewed the discovery of the asteroids in a single page. The *Universal Technological Dictionary* by George Crabb (1778–1851; 1823) devoted half a page to their orbital characteristics and colour, making no mention of the spurious atmospheres or the explosion hypothesis. Simeon Ackroyd Shaw (1785–1859; 1823: 93-94 and 126-129) devotes four pages to the asteroids, including a full page of details about the atmospheres of Ceres and Pallas. George G. Carey, described on the title page of his book as a “… lecturer on Natural Philosophy, Chemistry, Astronomy, &c.”, devoted three pages to a description of the asteroids. Much of this is devoted to a recounting of Olbers’ explosion hypothesis. Even though Carey (1825: 34) describes it as a “… very romantic idea …”, he lends it credence and offers additional support for the idea from the writings of Dr Brewster. The Rev. Robert Taylor (1784–1844; 1825: 65) included the asteroids in his survey of Nature. They merited a single paragraph and a table (giving least & greatest distance, and inclination). In the first chapter (Taylor, 1825: 3), he agreed with Herschel that the four new objects “…on account of their diminutiveness, are not deemed worthy of being classed among the planets. They are consequently distinguished by the term Asteroids.”

The *London Mechanics Register* (1826) devotes a paragraph to the four bodies, including a mention of the “convulsion of nature” that might have broken them into fragments. It is also a supporter of Herschel’s nomenclature choice. “These small bodies, which have been denominated Asteroids, present some curious anomalies to the contemplation of the Astronomer, for they revolve round the sun in orbits much more inclined to the ecliptic than any of the other planets, none of which deviate more than 8 deg. from the ecliptic.”

The *Pocket Encyclopedia* by Thomas Forster (1789–1860) contains separate entries for the four asteroids, repeating the false statement that Ceres and Pallas have dense atmospheres. His article on Vesta also relates Olbers’ asteroid explosion hypothesis (Forster, 1827).

The *London Encyclopedia* (1829, Volume 3: 104-105) gives brief entries to all four objects. It mentions the disparate diameter measurements of Herschel and Schröter, and says that Ceres, Pallas and Juno have considerable atmospheres. It also says “… they have been called Asteroids.” A *Dictionary of General Knowledge* (1831: 40) by George Crabb (1778–1851) briefly mentions the discovery of the four asteroids. John Narrien (1782–1860), a Fellow of the Royal Astronomical Society, devoted just a single paragraph to the asteroids in his historical overview of astronomy in 1833. The famous *Penny Cyclopaedia* (various editions including 1833) included entries for all the asteroids, including orbital elements taken from the *Nautical Almanac*. William Martin devotes three pages to the asteroids, mentioning at the outset they might be “fragments of a planetary body, shattered to pieces in consequence of a violent concussion with some comet.” (Martin, 1832: 59)

A book by John Mortimer Brinkley (1763–1835), the “… late Lord Bishop of Cloyne …”, repeats Olbers’ conjecture about the former existence of a large planet, and the consequent success in discovering Juno and Vesta (Brinkley, 1836).

A book by John Pringle Nichol (1804–1859), Professor of Practical Astronomy at the University of Glasgow, provides a concise one-page summary about the asteroids and their relevance to Solar System studies:

Our glance is next arrested by those curious bodies between Mars and Jupiter—the four new planets, VESTA, JUNO, CERES, and PALLAS—distinguished from all the other orbs by very marked characters. They are by very much the smallest group of bodies in our system. PALLAS, the largest of the four, being not greater than our Moon; and VESTA, the least, not exceeding in surface probably the kingdom of Spain! Accompanied by atmospheres, these
little bodies are in this respect similar to our Earth, but we have hitherto obtained no facts whereon to ground a hypothesis of farther analogy. One circumstance connected with them is very peculiar—they are about the same distances from the sun, and their orbits cut each other; while, as is well known, the other planets are separated from each other by vast intervals. The inference is not unwarranted that, probably they are one formation, answering in the history of its birth to the act, whatever it was, which produced one of the other planets, and merely differing from that act, in not consolidating the produced matter into one mass. We may be quite satisfied that in this variety there is still a perfect unity, and that these exceptions to the usual character of the planetary formations are no anomalies, nay, their use is to enable us to take a larger grasp of the fundamental character of our system, to free our views from specialty, and guide it to that central point from which all varieties will seem coordinate. What I have already written, shews that we are still far from that term; but the telescope is improving so rapidly that the time cannot be distant in which facts will be accumulated sufficient to encourage and sustain extensive generalizations. (Nichol, 1838: 156-157, his italics).

Nichol’s article is of notable importance. It provides false information (there are no atmospheres around the asteroids, and Pallas is not the largest) but completely (and correctly) discounts Olbers’ asteroid explosion hypothesis. His look into the future is quite prescient, as a study of asteroids in the twentieth century and today is crucial to our understanding of the “… fundamental character …” of the Solar System.

At the end of the time frame considered in this thesis, Reverend Thomas Lockerby (1777–1851) made mention of the four asteroids and provided some much-needed light-hearted commentary about them:

The immense distance of Uranus precludes all hope of coming at much knowledge of its physical state, and the minuteness of the four ultra zodiacal planets, Juno, Ceres, Vesta, and Pallas, is no less a bar to any inquiry into them. A man placed on one of them would spring, with ease, 60 feet high, and sustain no greater shock, in his descent, than he does on the earth from leaping a yard. (Lockerby, 1839: 323).

His book had the added benefit of a table of the planets (see Figure 5.2), which shows how they fit into the scheme of the Solar System as it was understood in 1839.

| PLANET | DIAMETERS IN ENGLISH MILES | DISTANCES FROM THE SUN IN ROUND NUMBERS | ANNUAL PERIODS AFTER THE SUN | DIURNAL ROTATIONS ROUND THEIR OWN AXES | DEGREES, ARCS, MIN.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>The Sun</td>
<td>882,000</td>
<td></td>
<td></td>
<td></td>
<td>25 9 0</td>
</tr>
<tr>
<td>Mercury</td>
<td>3,200</td>
<td>37,000,000</td>
<td>0 87 23</td>
<td></td>
<td>24 5 28</td>
</tr>
<tr>
<td>Venus</td>
<td>7,600</td>
<td>68,000,000</td>
<td>0 224 17</td>
<td></td>
<td>23 20 0</td>
</tr>
<tr>
<td>The Earth</td>
<td>7,960</td>
<td>95,000,000</td>
<td>1 365 6</td>
<td></td>
<td>1 0 0</td>
</tr>
<tr>
<td>Mars</td>
<td>4,200</td>
<td>144,000,000</td>
<td>1 323 0</td>
<td></td>
<td>1 0 40</td>
</tr>
<tr>
<td>Vesta</td>
<td>238</td>
<td>226,000,000</td>
<td>3 66 4</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Juno</td>
<td>1,425</td>
<td>252,000,000</td>
<td>5 183 0</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Ceres</td>
<td>1,824</td>
<td>263,000,000</td>
<td>4 920 0</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Pallas</td>
<td>5,000</td>
<td>265,000,000</td>
<td>6 242 0</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Jupiter</td>
<td>89,000</td>
<td>490,000,000</td>
<td>11 315 16</td>
<td>0 9 56</td>
<td></td>
</tr>
<tr>
<td>Saturn</td>
<td>79,000</td>
<td>900,000,000</td>
<td>29 161 19</td>
<td>0 10 16</td>
<td></td>
</tr>
<tr>
<td>Uranus</td>
<td>35,000</td>
<td>1,900,000,000</td>
<td>83 342 4</td>
<td>1 18 30</td>
<td></td>
</tr>
</tbody>
</table>

Figure 5.2: The Solar System table in Lockerby’s 1839 book.

But this hardly compares to another full page of tabular data about the solar system published in the same year. It appeared in the London publication The Ladies’ Diary (1839: 2), which one might think is a very unlikely source for such material, but a perusal of its pages shows many of its annual issues are replete with pages of mathematical calculations and proofs. This table (see Appendix D.5) represents the most complete understanding of the asteroids, and the major planets, during the period under analysis in this thesis. The two tables rely on differing sources, as their numbers are not coincident. The Ladies’ Diary table is as interesting for what it states as for what it omits. Inclination of the axis to the orbit is
completely unknown for the four asteroids, but most interesting is the “time of rotation on axis.” Only Juno gets a number here: “27 probably.” Where this figure came from is the source of most of the completely unsubstantiated figures relating to solar system objects: Johann Schröter. It was widely quoted in books and journals, including John Robison’s A System of Mechanical Philosophy (1822, 3: 69). Published in Edinburgh, this edition was published 17 years after Robison’s death and was updated by the inimitable David Brewster. For more on Robison (1739–1805), see Section 7.1

5.2 Reporting About the Individual Asteroids in the British Media

5.2.1 Ceres

In 1801, The Times of London, the leading newspaper of the day, calmly reported the discovery of Ceres in just two sentences:

An important discovery has been announced—that of a new planet. M. Piazzi, an Italian astronomer, claims the merit of this discovery. (The Times, 7 August 1801).

The first reports in the British magazines of the discovery of Ceres came seven months after its discovery. The reason for this tardiness was made bluntly apparent to the public in words that certainly were penned by Nevil Maskelyne:

An important circumstance in Astronomy has just occurred, no less than the Discovery of ANOTHER NEW PLANET!!! This celestial phenomenon moves between the orbits of Mars and Jupiter, and is an intermediate Planet between them. It was discovered by M. Piazzi, an Italian astronomer, on the 1st of January, 1801. He concealed the discovery, to preserve all the honour and observations to himself, till after six weeks close watching, he fell ill. It will not be in a situation, with regard to the Sun, to be observed again, till a month or two hence. It is but a small Planet, ranking only as a Star of the eighth magnitude, and therefore not visible to the naked eye. Its motion is nearly parallel to the ecliptic, at present about 4½º to the north of it, and nearly entering the sign of Leo. The distance from the Sun is about 2½ times that of the earth, and the periodical time nearly four years and two months. – Other particulars shall be given in our next. (The Monthly Magazine, 1801a).

Despite a promise to publish more information in the September issue, none was forthcoming, which sent Capel Lofft into a rage, as indicated by the following letter penned on 8 September 1801:

I confess myself one, perhaps of many, who have been mortified by your taking no notice of the New Planet in your last published number, although your preceding number announced a further account to be given of it in your next.* I have seen a private letter, by which it appears, that since the discovery of it by PIAZZI at PALERMO, it has been seen by Professor BODE at BERLIN; and I think there is no reason to doubt that it has been seen by the ASTRONOMERS at the NATIONAL OBSERVATORY at PARIS.

By the same letter it appears, that the discovery was communicated to the Royal Professor of Astronomy, Dr. MASKELYNE. In the dearth of astronomical intelligence, which we generally suffer in this country, it would be kind, as early as possible, to fulfil your intimation, and to lay before the public, as much as can be learnt respecting this interesting discovery at present.

* The account we promised exists in Von Zach’s Geographical Ephemerides, which, from some accident, has not yet come to hand from Germany. (Lofft, 1801).

This short paper and its editorial comment give rise to several interesting points. What is this “private letter” he refers to? Who wrote it? This cannot be answered for a certainty, but it contained a report that Bode and the French astronomers had seen Ceres, which was false.
The editorial comment gives us the very important clue that the sole source of information *The Monthly Magazine* was relying on was Zach’s first journal, here referred to as the *Geographical Ephemerides*. Its full name in German was *The Allgemeine Geographische Ephemeriden* (AGE). Unfortunately this cannot be correct, as the AGE was published for only two years: in 1798 and 1799!

![Monatliche Correspondenz](image)

*Figure 5.3: Title page of the Monatliche Correspondenz.*

In reality, Zach closed the AGE and opened a new chapter in his life and astronomy with the introduction in 1800 of his journal *The Monatliche Correspondence* (*Monthly Correspondence*; see Figure 5.3). It was the first journal devoted exclusively to the science of astronomy, and it was in this publication that all the reports about the discovery of the asteroids were printed. But how did *The Monthly Magazine* get a copy? Neither Herschel nor Maskelyne is known to have been subscribers. Perhaps it was an exchange between editors—Zach sent his
journal to the publication in London, and vice versa. Thus, it appears the readers of *The Monthly Magazine* would have been better informed than any of England’s leading astronomers. This makes a study of their publications about Ceres and Pallas all the more important, and indeed a critical factor in showing how these new objects were understood and subsequently studied in England.

*The Edinburgh Magazine; or Literary Miscellany* published an article about the recovery of Ceres by Brewster (1802a). It was (as he says) mostly written from “… facts taken from the Monthly Magazine for October last.” This was surely a mistake, as the October issue only contained the outraged letter by Lofft. The real report was published in the November issue.

The November paper in *The Monthly Magazine* concludes with a section taken from *The Monthly Correspondence* about what name should be given to the new object. Some suggest the name Vulcan, while others opt for Cupid. Brewster (1802a; his italics) here seamlessly inserts his own views without giving readers notice that the words are his, not an extract from *The Monthly Correspondence*:

> Notwithstanding the arguments, however, which have been brought forward to vindicate the propriety of each of these appellations, it is extremely probable that it will obtain the name PIAZZI; and it is surely much more proper, and congenial to the human mind, that the names of men of genius should be connected with their own discoveries, than that the titles of imaginary deities should be attached to the most stupendous works of the Creator. In the first case, some important advantages are obtained.— When we hear, for instance, of the planets *Herschel*, or *Georgium Sidus*, of *Piazzi*, or *Ferdinandea Sidus*, we are both acquainted with the astronomers by whose assiduity these planets were discovered, and with the name of the monarch in whose reign and territories this discovery was made. But, in the other case, no information is gained;— a name is merely given without any meaning whatsoever. If the planet distinguished by the name of *Jupiter* had been denominated *Galileo*, because this philosopher discovered its satellites; and if *Saturn* had been called *Cassini*, because the greatest number of its moons were discovered by this astronomer, how much more consistent would have been the appellation?

> Philosophers, indeed, have in all ages shewn an inclination for this method of nomenclature. The names of ingenious men have been used for distinguishing the spots upon the surface of the moon, even though they did not discover them. The *Boylean Vacuum*, the *Toricellian Vacuum*, *Galvanism*, and many other instances, shew that a nomenclature of this kind has not grown obsolete, even in later ages. Nay, if the planets and comets which may hereafter be discovered, should always be named from their discoverers, the most beneficial effects might be produced. The latent springs of unknown genius might be roused into action, and the indolence of philosophy might be stimulated to research, when the most illustrious of all honours was held forth as the reward of their labours.

P.S. Since the above remarks were written, I have seen a letter from a Member of the Royal Society of London, which mentions, that a paper, containing some particulars concerning the new planet was read at a meeting of the Society, on Thursday, December 10th, and that its magnitude is 1 ⅓ the magnitude of the earth being unity.

By suggesting that the first asteroid be called Piazzii, Brewster was of the same mind as Lalande in Paris and Joel Barlow (1809: 192-193) in the United States. But what neither of them thought of was what should be done if two planetary objects were discovered by the same person. This very event happened, as Olbers discovered both Pallas and Vesta. No more is heard of the idea of giving the name of the discoverer to his discovery after this.

Still, despite all these orbital calculations and false reports of observation, Ceres had not yet been recovered. A report in early 1802 gave some credence to the idea it was all a mistake:

> The Planet which was supposed to be discovered by M. Piazzi, at Palermo, about a year since, has hitherto eluded the researches of other astronomers. Similar in brilliancy and light to the stars of the eighth magnitude, it has none of those peculiar appearances which serve to distinguish comets of the same small size. In respect to colour, it resembles Jupiter; and, from the meridional observations taken by M. Piazzi, and his colleague, M. CACCIATORE
[Niccolò Cacciatore, 1780–1841], it appears, that this star, if a planet, possesses a revolutionary period that may be calculated at four and half or five years. About the beginning of May, 1801, the supposed planet crossed the Meridian at an early hour, when it disappeared. Since that time, M. Piazzi, assisted by M. M. Cacciatore and CARIOTTI, have been unable to discover it again either with a night telescope, or with an achromatic, having large apertures. It is not surprising, therefore, that during the last nine months other astronomers have failed in their researches, since to common difficulties is added an uncertainty of some degrees as to the precise point of the heavens in which it should be sought for. It has lately resumed the same situation in which it was at the time of its discovery; we expect, therefore, in a short time to be able to state the reports of the foreign astronomers, and to confirm or reject the existence of this supposed planet. *(The Monthly Magazine, 1802a).*

The next issue of *The Monthly Magazine* (see Figure 5.4) was able to report, at long last, the confirmation that Ceres was a real object. It featured two articles, one being a first-hand account of its observation from London. The first one, written on 25 March, began with an editorial note in square brackets:

[The following Communication came to hand too late to appear in its proper place, and we were unwilling to defer it on account of the interesting nature of its contents.] Finding amongst my astronomical friends as well as in the public in general a very high degree of solicitude respecting the appearance, situation, and other attendant circumstances of the newly-discovered planet, the Ceres Ferdinandea, I think it right to send to your useful Magazine the latest situation amongst the neighbouring stars, that the month will admit; that your readers may be enabled by a common night-glass, or a pocket telescope and a little
attention, to ascertain it. If an imaginary line is drawn from the star Theta Leonis, through Beta or the Lion’s Tail, and continued to the same distance to the left a little above that termination, a cluster of stars will be seen forming an equilateral triangle; the two western most stars being of the fourth magnitude, and the other point of the triangle formed by a star of very minute size. This last star forms also a smaller equilateral triangle with two stars of minute size, nearer to it than the larger ones (of the fourth magnitude). The Ceres, on the fifteenth instant (March) was to the east of the smaller point of the equilateral triangle; I saw it on that evening, and have regularly traced it on the sixteenth, twentieth, twenty-first, twenty-second, and this evening, the twenty-fifth, when it is arrived between the two western-most stars of the fourth magnitude. By continuing this line, it will be very easily perceived, for several evenings to come.

The Planet appears as large as most of the stars in its neighbourhood. It is calculated to be about half as large as the moon; and to be one third of the distance between Mars and Jupiter from the sun. It performs its period round the sun in four and a half of our years.

Discovered by M. Piazzi, of Palermo, in Sicily, on the first of January, 1801. It has been named Ceres Ferdinandea, in honour of the Goddess of Corn, the Protectress of Sicily, and the reigning Monarch of that island and Naples.

I have examined this Planet with magnifying powers from forty to one thousand times, but hesitate in asserting, that I can see it with a disc or decisive magnitude, as I can the Georgium Sides. (Walker, 1802a: 272-273).

This first report in the April issue of The Monthly Magazine about the reality of Ceres was signed W. Walker, Lecturer on the Eidouranion. This person can be identified as William Walker (1766–1816), son of the famous Adam Walker (1731–1821), a popular science lecturer who moved to the fashionable Hanover Square in London after many years as a travelling science lecturer (Dictionary of National Biography, 1885-1900). Adam and William wrote a popular work, An Epitome of Astronomy that went through fourteen editions by 1800, and was still being published in a 31st edition in 1824. In the 1780s, Adam invented a type of orrery he dubbed the Eidouranion. A huge machine some 20 feet in diameter, it is considered to be the ancestor of planetarium projectors. Adam and William were both involved in lecturing about the Eidouranion to audiences in London (King and Millburn, 1978: 310).

Walker’s article in The Monthly Magazine was accompanied by a table of positional data from 3 to 18 April, and a small chart showing the stars mentioned along with the path of Ceres (see Figure 5.5). Walker was also a regular contributor to The Gentleman’s Magazine. He submitted a nearly identical article, and the same diagram, to that publication (Walker, 1802b: 197). He dated the article the same day, 25 March, but towards the end inserted a claim that appears nowhere else: “It was discovered by M. Piazzi, at Palermo, on Jan. 1, 1801 and by the most honourable perseverance re-discovered by Dr. Maskelyne early in this year.” Since he then gives the positions of Ceres “… by Mr. Zach, at Gotha …”, he knew full well that Ceres had been rediscovered by Zach in December 1801, and later by Olbers. By giving credit to Maskelyne, he was obviously subject to craven motives of patronage.

While the search for Ceres had taken on epic dimensions, and the reading public was certainly under the impression that only the world’s finest instruments could locate it, the article by Walker (1802b) blithely states that a “… common night-glass …” is sufficient to see it! Many people must have wondered why it took a year to find something that could be spied by a common night-glass.

The second article in the April 1802 issue of The Monthly Magazine (1802a) followed the more traditional lines of reporting what had been done on the Continent. This article (printed here in Appendix E) was written by the Astronomer Royal, Nevil Maskelyne, but was signed with the pseudonym ‘Astrophilus’. It is of interest because it lists those astronomers in England who had seen Ceres: Aubert, Lee, Gilpin, Herschel and Maskelyne (see Section 5.3). The fact that Maskelyne is not
mentioned by name is another confirmation that the author was Maskelyne himself. As we also know from the previous article in this issue, William Walker had seen Ceres. How many more is unknown, but certainly the number is very small, an indication of the true size of the active observational community in England at this time. A survey of professional and private observatories in England is given in *The Monthly Magazine* (1813). At the time of this survey some 20 private observatories were listed, along with eight others such as Greenwich and Oxford. The article concludes with an estimate of the total number of observers worldwide—only about 100.

Now that the missing planet had been found, really serious information about Ceres could be printed. Herschel himself was kept personally informed about the coverage of this work through Tilloch’s publication:

I have this moment, just at post hour, received a note from Mr. Tilloch editor of the *Philosophical Magazine*, very respectfully extracting some *short account* of your paper, about the new Planet, to appear on the 1st March—and such an account as may appear to be communicated by one who attended the meeting—He says if he receives it on Monday it will be in time for insertion—so I have acquainted him that probably I may get something drawn up that would be correct in particulars; so as to do justice to your papers.—I wish much however that you yourself would draw up such an abstract and send it [to] me for tomorrow’s post, and which I could *transcribe* for Mr. Tilloch. (Wilson, 1802b, his underlining).

This was of great importance, for, as has been noted in Section 2, Herschel’s 18 February 1802 report to the Royal Society was not published until 1912, 110 years later! Tilloch pulled out all the stops, devoting pages 54-83 for a complete coverage of everything written about Ceres by Piazzi, Herschel and Capel Lofft, referring specifically to Lofft’s article in the *New London Review* of March 1800, in which he offered some conjectures about an intermediate planet between Mars and Jupiter (see Section 5.9). Thomas Firminger (Section 5.11) described Tilloch’s journal as “…one of the first channels of periodical scientific information.” (Firminger, 1811: 307).
The intelligentsia in England was also kept apprised of Continental reporting about Ceres. An article that appeared in the Paris-based *Moniteur* (1802) was translated into English for the *Journals of the Royal Institution* (1802). And *The Monthly Magazine* (1803d) published in summary an English translation of Lalande’s “History of Astronomy for the Year 1802”, which mentions Ceres perturbation calculations by Gauss and Oriani. The article led with the discovery of Pallas. It was also published in Lalande (1802c). *The Monthly Magazine* (1803e) also gave a full account of what Schröter and Harding were doing:

M. Schroeter, grand bailiff at Lilienthal, has several times observed the new planet Ceres Ferdinandea, and he has communicated certain results of his observations to the Royal Society of Sciences at Gottingen. On the 11th of January, 1802, M. Harding likewise observed this new planet in a magnified state of 136 and 288 times, with his reflector of 13 feet, and found its disc in a reddish light, nebulous, not terminated, and larger than a satellite of Jupiter. The infavourable weather and indisposition were the reason that M. Schroeter could not combine his observations with those of M. Harding, till the 25th of January. On that day, with the same magnifying, and by the same reflector, the disc of Ceres appeared to M. Schroeter under the perfectly round form of a planet, without scintillation, and for that time in a light not reddish, but perfectly white; it was exactly terminated, and every way similar to that of the planet Herschel; but it was inclosed in a nebulousness like that of a comet, very narrow, which completely environed it, and which made a strong contrast with the exact manner in which it was terminated. With respect to this singular termination, the new planet, in some measure, resembled the comet of 1799, described in the third volume of the Memoirs of M. Schroeter; only that its disc appeared clearer and more distinct, and its atmospheric nebulousness was extremely narrow. M. Schroeter, on the same night, by means of a microscope, with a magnifying power of 288 of his reflector, found the diameter of the disc exactly terminated, 1°815, and the entire diameter, including the nebulousness, 2°514, (M. Harding, 2°330); the right ascension was at 11h 36′ 18″ 19′ 50″, the north declination 11°54′ 43″. At the time of the following observations, the planet appeared always sometimes more, sometimes less, nebulous, and it no longer appeared exactly terminated as before; so that its aspect sometimes resembled a planetary nebula near Υ of Aquarius. Its white light varied on the 26th to a bluish; but on the 28th and 31st of January, with the same magnifying of the reflector, it approached to a reddish colour. On the 26th of January, the apparent diameter was 2°687; on the 28th 2°793; on the 31st 2°930. [The paper concludes with a table of positional measurements from January 10 to 31.]

The wholly spurious observations of a nebulousness, which became equated with a dense atmosphere, was repeated in books and journals for decades to come.

*The Repertory of Arts* (1802) seems an unlikely place to find mention of the asteroids, but as it published a summary of the proceedings of the Royal Society, we find the following, which is one of the first notices the reading public had about the new word ‘asteroid’. This comes from Herschel’s second paper read to The Royal Society (Section 2.2):

On the 6th of May, Dr. Herschell’s [sic] observations on the two lately discovered celestial bodies were read: he states the result of his attempts to measure the diameters of Ceres and Pallas, which are about 163 and 95 or 71 English miles. He proceeds to consider the nature of the new stars, and from various circumstances in which they differ from the general character of planets, he wishes to call them asteroids.

Nicholson’s publication, *A Journal of Natural Philosophy*, was a prime conduit of public information about Ceres. In its first volume (1802a) it reprinted a verbatim report about Ceres from the Royal Institution; an extract from Bode’s *Kurzer Entwurf der Astronomischen Wissenschaften* (1794) where he postulated the existence of a planet between Mars and Jupiter; and a letter from Englefield to Young (printed in Section 5.10).

The subject of the name Ceres Ferdinandea was also a source of continuing interest. In England, it was dryly noted in the *Annual Review of History and Literature* for 1804 (1805) that
... the King of Naples has added sixty pounds a year to Mr. Piazzi’s salary, for the discovery of the new planet, and honouring it with the royal name. So small a reward assuredly justifies astronomers in refusing to accede to the new title, and in immortalising the discoverer rather than the monarch.

The reading public was kept informed about Ceres for decades after its discovery. Here is a letter to *The Times* of London, reprinted in *The Mechanics’ Magazine* (1830a: 111):

The following information with respect to another of the new planets, is contained in the letter of a second correspondent of *The Times*:

“On Friday night last, (9th April) at 12 hours 48′, sidereal time, the planet followed the star Bode Librae, 3° 3/10, and was 6′ 46″ of a degree to the south of it. On Saturday night, at 14 hours 56′, she preceded the same star 13″ 75/100, and was 4′ 8″ 55/100 to the south of it. Clouds prevented me observing it on the meridian. Applying these quantities to the place of 82 Bode Librae, the data furnished by Encke’s, or the Berlin Ephemeris, are, I find, amply sufficient to enable the observer to direct his instrument to the spot which the planet occupies in the heavens. She has the brightness of a star of the seventh magnitude, has no peculiar colour, and can only be distinguished from the star 82 Bode Librae, by her motion. She is almost 4° south of β Librae, and precedes it about 6′ of time; hence the field of the finder being 4° in diameter, if β Librae be brought into the lower part of the circumference of the field, Ceres will be found in the upper.”

This letter, which was not signed, concludes with the ephemeris positions of Ceres from 18 April to 10 May.

### 5.2.2 Pallas

#### 5.2.2.1 Discovery and Subsequent Observations

*The Edinburgh Journal; or Literary Miscellany* published articles about Pallas, usually written by David Brewster:

The readers of the Edinburgh Magazine will be surprised to hear that another new planet has been discovered at Bremen by Dr Olbers, the same astronomer who rediscovered the planet Piazzi, after it had been lost sight of by the Italian philosopher. From the little information which we have been able to obtain concerning this interesting subject, it appears that the right ascension of this new planet upon the 28th of March, was 184° 56′ .49″, with 11° 33′ .30″ of north declination; and on March 29th, 184° 46′ .36[″], with 11° 53′ .0″ of declination. It is situated, therefore, within a few degrees of the planet Piazzi, and may be seen, in all probability, with an instrument whose magnifying power is sufficient for rendering Piazzi visible.

From a similarity between its variation in right ascension, and that of the planet Piazzi, in a given time, Dr Olbers conjectured that the distances of these bodies from the sun were nearly the same. This opinion, however, is evidently untenable, for several reasons, which will occur upon the slightest reflection.

Some eminent astronomers are firmly persuaded that this body is a planet, while others maintain, with perhaps equal plausibility, that it is a comet, on account of the similarity of distance between it and Piazzi[i]. We forbear, however, to indulge in conjecture, upon a question which depends solely on future observation, and which, from the small number which have already been made, it is impossible to decide.

(Brewster, 1802b: 287).

The concluding paragraph of this paper by Brewster, about the sorry state of astronomy in Great Britain, will be considered in Subsection 6.1.2.

Only three days after Brewster penned the article just quoted, William Walker in London wrote an article about the discovery for *The Gentleman’s Magazine*:

I do myself the pleasure of communicating to you the discovery of another new planet, by Dr. Olbers, at Bremen, on the 28th of March last. It is situated extremely near to the place which the Ceres is noted to have been in, on the little configuration of stars printed in your Magazine for that month. It is invisible to my naked eye, but evident through a night-glass; and, with a magnifying power of 100 times, on a good telescope, appears of a sensible magnitude, but of a feeble, pale, red light. I think it less bright than the Ceres, although the last admits no disc,
with any magnifying power I can use. It is at present about as far again from the Sun as we are. The Ceres is nearly three times as far from the Sun as ourselves, and Mars about one and a half. The Ceres is very near the star Beta, in the Lion’s Tail. (Walker, 1802c).

On the same day (26 April), Walker penned another short article which was sent to *The Scots Magazine*. It contained spurious details about Pallas that did not appear in his *Gentleman’s Magazine* piece:

The planet discovered by Mr. Olbers, at Bremen, on the 28th Mar. is now, in a very small degree, higher than the place of Ceres, on the 25th of March—and will be found near this place for some evenings to come. It is not visible to the naked eye, and through a telescope appears more faint than Ceres, and of a pale colour. It seems probable, that it is about as far again from the Sun as the earth—whilst Ceres is near three times as far off—but I acknowledge, that I have much hesitation in believing it a planet. The Ceres has advanced near to Beta Leonis, and each of these objects, by a night glass, may easily be discovered. (Walker, 1802d).

This same letter by Walker was published in the *Monthly Magazine* (Walker, 1802e).

Where did Walker get the notion Pallas was much closer to the Sun than Ceres?

In the May issue of *The Monthly Magazine*, a correspondent signed ‘Astrophilus’ contributed a one-paragraph article about the discovery. Based on archival research, this can be attributed to Maskelyne. For the text of his *Monthly Magazine* contributions in comparison with the full description he wrote in his logbook, see Appendix E.

A report in *The Edinburgh Magazine* (Brewster, 1802c; see Appendix D.5; see also Figure 5.6) shows not only the level of detail being imparted to the public, but the possible association of Pallas with comets that was being considered at the time. In this important article, David Brewster sets himself up as the prime opponent of Herschel in England. Brewster here uses the same criteria Herschel uses to distinguish planets from comets, but Brewster comes to the opposite conclusion—that Pallas is a comet. He appeals here to the wholly spurious concept of ‘uniformity’ to bolster his viewpoint, and he never uses the word ‘asteroid’, even though he read Herschel’s paper in which it was first introduced. The importance of his writing should not be underestimated. As a respected man of science, his numerous and very public expositions were seriously considered. As Herschel himself never wrote for the popular journals or newspapers, he never rebutted these disagreements, and many people must have been left with the impression that Herschel was wrong.

*The Monthly Magazine* kept its readers informed about the study of Pallas in great detail:

Baron de Zach, in a letter to Sir Joseph Banks, observes, “that Pallas is a planetary heavenly body, that moves between the orbits of Mars and Jupiter, with a very great eccentricity and inclination, and whose orbit comes very near to the orbit of the planet Ceres, perhaps touches it, perhaps even cuts it like two links in a chain, this way ∞, which can not yet be asserted with certainty, the observed area run over by this planet being too small.” Another very remarkable circumstance is, that the mean motions of Pallas and Ceres are very nearly, perhaps absolutely, the same: in this case, small as the masses of Ceres and Pallas may be, they will, nevertheless, exert a very sensible action upon the other, and thereby give occasion to very curious and interesting investigations in the mechanics of the heavens. (*The Monthly Magazine*, 1802g).

The following month, *The Monthly Magazine* (1802h) devoted nearly six pages to the new discovery. The article began with a mathematical equation, which indicated the level of sophistication expected from its readers. It then went on to describe the elements derived by Gauss based on observations at Gotha’s Seeberg Observatory. This section, like the following where Olbers’ hypothesis of a planetary explosion to
explain the origin of the asteroids is first broached, was in fact a virtual copy of Zach’s paper in the June issue of his journal, *The Monthly Correspondence* (Zach, 1802o: 591 and following). *The Monthly Magazine* nowhere states that it ‘lifted’ the article nearly verbatim from this source. *The Monthly Magazine* then switches to an account of Karl Seyffer’s investigations. He was the Director of the Göttingen Observatory, where Carl Gauss also was studying Ceres and Pallas. This account reads as if it may have been sent to the magazine—it certainly was not in *The Monthly Correspondence*. By calling Seyffer ‘intelligent’ and giving him credit for his role in the recovery of Ceres and Pallas, it appears the editor of *The Monthly Magazine* was embroidering the account as a thank-you to Seyffer for communicating the information. As it appears nowhere else, it is worth quoting here:

The intelligent Professor Seyffer, of Göttingen, who is one of the most zealous observers of the new planet, and may justly claim the merit of being one of the first rediscoverers of Ceres as well as of Pallas, proceeds to communicate his observations made on Pallas at the Royal Observatory of Göttingen, by which the ellipsis of Dr. Gauss is perfectly confirmed, and neither a parabola, nor a new larger ellipsis, to be admitted, as has of late been pretended to be found by French astronomers. Dr. Gauss, who has received part of his education at the celebrated University of Göttingen, and whom Professor Seyffer remembers, with the greatest satisfaction, as one of his friends and pupils, has made a third attempt of finding out the most
possibly accurate ellipsis for the orbit of Pallas, the result of which he has communicated in a letter to Professor Seyffer. On comparing his observations with these new elements of Dr. Gauss, M. Seyffer found them perfectly agreeing, except in some trifling differences, and they even correspond with the newest observations made on the 19th, 20th and 21st of June, so that there seems to be no occasion for making, for the present, any further corrections in them, as Professor Seyffer thinks they will be quite sufficient for re-discovering Pallas in the year 1803, provided the planet has light enough as to be seen, as it might be possible that Pallas, on account of its great distance from the earth, is not visible during the years 1803 and 1804, or, at least, is only to be seen by means of the most exquisite instruments, and that it is likely to appear again in the year 1805.

The Monthly Magazine article then continues with the substance of a letter written by Herschel to Seyffer of 22 May 1802, in which Herschel recounts his paper about Ceres and Pallas read before the Royal Society “… on the 7th and 13th of May.” It is here that readers of the magazine first see the word ‘asteroid’. The magazine states that Observations on the nature of the new planet from the masterly pen of the great Herschel, are entitled to the most distinguished attention of astronomers; and it is to this accurate and great observer, that we shall most probably be indebted for new and interesting discoveries relative to the nature of those stars.

The main body of the article then concludes with notice of the diameter differences of Herschel and Schröter. But far from being finished, the magazine then publishes four pages of orbital elements, an ephemeris from 24 May to 29 June, and observations by Olbers, Seyffer, Zach and Oriani. This article, the most extensive of any about Pallas in the publications of the day, ends with a poetical quote from The Seasons, a work from 1730 by James Thomson (1700–1748):

Thus far the observations of the new celestial body, Pallas, are published, but we shall not omit communicating, in future numbers of this Journal, many new observations and discoveries relative to the nature of so remarkable a body as this appears to be “among the radiant orbs, that more than deck, that animate the sky, the life-infusing suns of other worlds.” (The Monthly Magazine, 1802h, his italics).

The Journal of Natural Philosophy (Nicholson’s Journal) printed in full an English translation of Lalande’s 5 July address to the French National Institute on the discovery of Pallas (see Appendix D.5).

The Critical Review, while it did not publish any detailed information about Ceres and Pallas, did give notice about the publication of Johann Bode’s annual publication Astronomisches Jahrbuch. We read that the Yearbook contains 34 memoirs on astronomical subjects, many of which relate to the “… two new planets.” The Critical Review (1803b) considers this so important that it goes on to describe some of these, while completely ignoring the others aside from listing the names of some authors:

The first memoir, by the editor [Bode], is designed to show that the movable star (Ceres) is really a planet, long supposed to exist between Mars and Jupiter. The second relates to the re-appearance of Ceres, observed by Olbers; the third, the account of the discovery of another movable star (Pallas). Tilloch’s Journal made a point of publishing fresh material from France. In his annual report on astronomy, Lalande (1802b) began with the discovery of Pallas. The following year, Lalande (1803) offered additional information about it in Paris, which was duly translated for the English public:

The astronomers Delalande junior and Burckhardt observe with great assiduity the planet discovered by Dr. Olbers on the 28th of March 1802. Its longitude on the 1st of July at 11h 45’ was 9 signs 7° 14’ 25”, and its latitude 46° 23’ 18”. Burckhardt has thence deduced its revolution to be 1682 days, or four year seven months and twelve days; which is a day less than what was found some months ago, as may be seen in my Bibliographie Astronomique just published; but at present there is scarcely an uncertainty of a few hours. He is employed in calculating the derangements it must experience from the attraction of Jupiter, and which are
very complex; but he has presented to the Institute a learned memoir which leads to this research.

Continuing its report of asteroid observations from France, The Philosophical Magazine (1803d) informed readers of a unique occurrence, the appulse of an asteroid with a star. This account did not appear in any other English publication (see Appendix D.5 for the full text).

The Philosophical Magazine also kept readers apprised of information from Germany. It published a full report about Pallas by Zach and in a series of issues: The Philosophical Magazine (1803a; 1803b; 1803c) printed the positional data taken from Zach’s journal for Ceres and Pallas for the months of April, May and June.

A detailed description of Herschel’s seminal 1802 paper (Herschel 1802b) was widely covered in the English press: The British Critic (1804) devoted 3 pages to it; The Gentleman’s Magazine (1803) devoted just one paragraph to it; The Monthly Magazine (1803c) devoted nearly a page to a summary of the paper; but Nicholson’s Journal of Natural Philosophy (1803a and 1803b) trumped them all by publishing Herschel’s entire paper.

The English magazines even informed the public of communication between astronomers on the Continent:

Piazzi wrote to M. Seyffer on the 2d of February, that he had sought for the planet Ceres in vain during the month of December; through the greatest part of January, the weather had been unfavourable, and he had not found it again down to the instant of his writing; he was then proposing to seek for it with the elements of M. Gauss. M. Piazzi announces afterwards, that with those elements he found Ceres again, but it was only on the 23d of February, on account of the bad weather; and, he adds, that he is principally indebted for it to the ellipsis of M. Gauss. (The Monthly Magazine, 1803b).

In 1803 Seyffer published a monograph that reprinted Piazzi’s memoir on the discovery of Ceres together with his own reflections about Ceres. This publication was summarized in The Monthly Magazine (1804a; see Appendix D.5.)

The Edinburgh Philosophical Journal was another major publication that included data about the asteroids in later years. For example, it printed an ephemeris of Vesta (as calculated by Johann Franz Encke; 1791–1865) from 1 April through 27 August, and an ephemeris of Ceres monthly from 1 January through 1 December (both reprinted by the Berlin Astronomical Yearbook of 1822). It went beyond this mere recitation of numbers to also print the following important discovery:

Perturbations of the New Planets.— The celebrated M. Gauss of Goettingen has determined, in an exact manner, the masses of those planets which exert a sensible influence on the four new planets. He shews clearly, that the mass of Jupiter given by Laplace is wrong by more than a tenth part. The perturbations of Pallas produced by Jupiter amount to several degrees, and afford a very certain means of determining the mass of the latter. (The Edinburgh Philosophical Journal, 1822).

As for the Berlin Astronomical Yearbook, Encke (1828: 248-258) himself contributed an article in which he devotes two paragraphs to a discussion of the perturbations suffered by the asteroids.

The public was kept informed about Pallas long after it was discovered. This letter to The Times newspaper was reprinted in The Mechanics’ Magazine (1830a):

We extract the following interesting piece of astronomical information from a letter in The Times:—

“By reference to the Berlin or Encke’s Ephemeris, the planet Pallas was detected here last night. She has the appearance of a star of the 8½ magnitude, is of a bluish tint, and bears but a very feeble illumination. Her right ascension when on the meridian of my observatory (54° 21″ west of Berlin) was 15 hours 22’ 49″ and 52/100; and her northern declination was 17° 43’ and 45″. Hence her place, as given in the Berlin Ephemeris, affords data sufficient for finding her; but as that excellent work cannot, I believe, now be purchased in this country, the following extract will be useful to those who take interest in such matters.”

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The correspondent, F.R.S., who dated his letter 7 April 1830, then printed the ephemeris from 6 April to 24 May.

5.2.2.2 The Gold Medal

The tantalising prize of a gold medal was guaranteed to be of interest to many readers, even though very few could understand the quest itself. *The Universal Magazine* (1805) published the entire official text of the prize proposal, translated from the French publication *Connaissance des Temps* (1804). *The Scots Magazine* (Brewster, 1804) merely used an excerpt:

The national institute of France has offered a prize for the best theory of the perturbation of the planet Pallas, discovered by Dr Olbers. The formulae which astronomers have given for the perturbations of the other planets, and which, in the case of Ceres, have been developed to the fifth order, are not sufficient for the planet Pallas, whose eccentricity is greater than that of Mercury, and whose inclination is $34^\circ 37',$ nearly 5 times greater than that of any of the other planets. It is even difficult to conjecture what will be the powers and the dimensions of the products which it may be allowable to neglect, and the calculations may be of such length, and the formulae so complex, as to frighten the ablest astronomers from executing them.

This article, which included notices of other scientific matters, was signed ‘D.B.’ (for David Brewster) and dated Murrayfield, 17 August 1804. Several lines of this article were re-used in a subsequent article for Nicholson’s publication *A Journal of Natural Philosophy* (1806), but it was not Brewster who wrote either of them. The full text of the 1806 article is taken verbatim from the official announcement printed in the *Connaissance des Temps* of 1806, which in turn repeats a few lines from the initial prize offering of 1804. *The Monthly Magazine* (1806) also printed the 1806 prize question in full. The matter of the prize continued for another 12 years, when *The New Monthly Magazine* (1816; their italics) did its best to explain this complicated affair:

Five years since the Class of Sciences proposed as the subject of a double prize, the theory of the planets whose eccentricity and inclination are too considerable to allow of the exact calculation of their disturbances by methods already known. The Class did not require any numerical application, but only analytical formulas, yet disposed in such a manner, that an intelligent calculator might be able to apply them with certainty either to the planet Pallas, or to any other hitherto discovered, or which may hereafter be discovered. Two memoirs only having been received, in which the authors have not sufficiently conformed to the intentions expressed by the Class, it has prolonged the time for another year. The prize will therefore be adjudged in January 1817, and consist of a gold medal of the value of 6000 francs (250l.) Essays must be written in French or Latin, and none will be received after the 1st October next.

Thomson’s publication *Annals of Philosophy* (1816) published a similar article about the extension of the prize to 1817. That English mathematicians were fully aware of the prize offering is thus obvious, but none entered. The editors of these British publications never even suggested an Englishman might apply for this great prize, as there was no one even remotely capable of the task. The reasons for this dearth of mathematical brilliance will be considered in detail in Section 6.2. In the event, the Paris prize was never awarded.

France was not alone in offering a gold medal for asteroid work. In November 1824 the Royal Astronomical Society in London proposed the following prize question, but this medal was not awarded either. It was reported in *The Philosophical Magazine* (1824):

The gold medal for approved formulae, for determining the true place of either of the four newly discovered planets, Ceres, Juno, Vesta and Pallas; within such limits as the Council may think sufficiently correct for the present state of astronomy; such formulae in each case to be accompanied with comparisons of the observed places at various periods. All answers must be received before the 1st of February, 1827.
The sorry state of mathematics in England at the time, which is examined in Section 6.1, was certainly the prime reason this gold medal was never awarded.

5.2.3 Juno

The public may have been understandably confused about the discovery of new planets, as two more were announced in 1804. Herschel was informed of the first one by Patrick Wilson:

By a late paragraph, in the London papers, it is mentioned that Olbers has discovered a planet 3 times larger than Jupiter, at a period of 211 years; and with many satellites etc etc—all seems very apocryphal—I suppose there is no reality whatever in this account. (Wilson, 1804).

Here is how it was reported in The Times newspaper:

By a late paragraph, in the London papers, it is mentioned that Olbers has discovered a planet 3 times larger than Jupiter, at a period of 211 years; and with many satellites etc etc—all seems very apocryphal—I suppose there is no reality whatever in this account. (Wilson, 1804).

Here is how it was reported in The Times newspaper:

A letter from Germany states that Dr. Olbers has discovered a planet, which, from its immense size, he has called Hercules. It is three times the size of Jupiter, and goes round the Sun in the space of 211 years, because it is supposed to be 3,047,000,000 miles from the Sun; it looks to the naked eye like a star of the sixth magnitude, and is now in the sign Gemini. (The Times, 1804a).

The article offered further details of this new planetary discovery, making it appear beyond question that such an object had been found:

Dr. Olbers observed, on the 8th of December last, that it moved, and, on the 6th of February, that it was a planet, attended by seven satellites, one of which is twice the size of earth. It is inclined to the plane of the ecliptic, in an angle of 30 degrees. It is in 13 degrees North amplitude; and the Sun to an inhabitant of the Earth placed in it, with our powers of vision, would appear no larger than the smallest of the fixed stars. (ibid.).

The same report appeared in The Gentleman’s Magazine (1804). This remarkable report could scarcely be topped, but just three days later The Times managed to do just that. In an editorial comment one might expect that the discovery of such a planet would be welcomed as a major scientific advance. The Times was having none of it. In a statement that perhaps reflects the British attitude towards Napoleon and his wars of aggression, the newspaper issued this rebuke:

German news state the discovery of another, and an immensely large Planet. One would imagine, that when Europe is so troubled with “malignant stars,” men would have quite employment enough in discovering the modes of relieving themselves from earthly distress. (The Times, 1804b).

The discovery of Juno was related in several publications: The Scots Magazine, The Christian Observer, Nicholson’s Journal, and Tilloch’s Journal. This is valuable as it allows us to compare the extent, accuracy and level of detail given in these important publications in order to assess just what the public was learning. The full text of these communications is given in Appendix D.5 but here is how The Scots Magazine began.

The Scots Magazine (1804a) reported the discovery of another new planet and followed this up (1804b) with a brief notice that it not yet been seen in England. The Scots Magazine (1804d, their italics) had to preface its article about Juno with a disclaimer, since it had erred by publishing an account of the pseudo-planet earlier in the year:

Having in a former number laid before our readers an account of the discovery of a new planet, which has turned out to be false, they will probably be disposed to receive with hesitation any notice of a similar kind. We can assure them, however, that a New PLANET was discovered by Mr. Harding, of the observatory of Lilienthal, near Bremen, on the evening of Sept. 1st 1804. Mr. Harding was employed in constructing an atlas of all the stars down to the eighth magnitude, which lie within and near the orbits of the two new planets Ceres and Pallas; and while examining the stars in the constellation Pisces, he observed a small star, of the eighth magnitude, of which he could find no account in the Histoire Celeste of Lalande. Not knowing its true place, he put it down in his maps as accurately as he could estimate with his eye; but
two days after, when he looked for it again, he found that it was gone, but perceived another star, exactly like it, a little to the southwest of its place, which did not appear in that place before. Suspecting that this moveable star was a planet, he examined it again on the 5th of September, and perceiving that it had moved farther to the southwest, he found his conjecture verified. This new planet is perfectly similar to Ceres in its light and apparent magnitude. It is surrounded by no nebula, and moves retrograde towards the west with increasing southern declination. The daily motion of the new planet in right ascension is about 7' 56", or 31'.7 in time retrograde; and its daily motion in declination 12' 34" south.

The article also included the Right Ascension and Declination observed by Olbers and Harding from 1 through 10 September. It followed up this article with another one (The Scots Magazine, 1805) that gave its orbital elements. Tilloc’h’s Journal The Philosophical Magazine (1805) also reported this discovery: a report with nearly the identical words was published in The Gentleman’s Magazine (1805). A slightly re-written version of the article in Tilloc’h’s Journal was also published in The Universal Magazine (1805b), an interesting example of how information was shared.

The British Critic (1805) kept its readers informed in great detail about Juno. It devoted three pages to a description of Herschel’s 1805 Juno paper in the Philosophical Transactions.

Nicholson’s A Journal of Natural Philosophy kept its readers informed about the asteroids as the years went on. One of its contributors was Augustus Frederick Thoelden (died 1823) who lived at No. 10, St. Albans Street, Pall Mall. He was personally acquainted with Bode, who sent him letters which were then printed by Nicholson. A letter from Bode dated 18 September 1804 gives readers of this journal their first notice of the discovery of Juno:

On the first of September Mr. Harding discovered, at Lilienthal, a new moveable star; it appears to be of the eighth magnitude; its motion retrograde towards the South. Probably this may be another new planet in the orbit of Ceres and Pallas. (Bode, 1804).

This journal then prints the observational data from 1 through 10 September. Thoelden appends his own sentence to conclude the brief article: “The two last observations were made by Dr. Olbers, at Bremen. I received this intelligence yesterday, but at present this small planet (there are now three) is not discoverable, on account of the moon-shine.” (Thoelden, 1804: 143).

The same issue also gave notice of the discovery from Thomas Young (1804b: 112-113):

I have just received a letter from Dr. Gauss of Brunswick, F.R.S. dated September 11, in which he informs me that, a few days before, Mr. Harding at Lilienthal had discovered “a new moving star, most probably another new planet of our solar system.” Dr. Gauss is certainly a person on whose judgment much dependence may be placed: He has sent some further particulars of the discovery to the Astronomer Royal.

In a letter from Bode dated 23 October 1804, Bode sends Thoelden positional measurements from 21 September to 20 October, which Nicholson duly printed: “I herewith transmit to you,” says Bode, “some of my own observations of the newly discovered third planet, (which is to be called Juno) made at our Observatory.” (A Journal of Natural Philosophy, 1804b).

The Journal kept reporting asteroid data years later. The 1809 issue, for example, contained observations of Pallas, Juno and Vesta by Olbers and Gauss. Even the complete orbital elements were printed (A Journal of Natural Philosophy, 1809).

It is also instructive to compare what the American public was reading at the same time. In Philadelphia, The Evening Fire-side (1805) carried news about the discovery of Juno in its very first volume. The Monthly Anthology and Boston Review (1805) printed the same article:

Another new planet has been discovered by M. Harding, of Lilienthal, near Bremen, to which he has given the name of Juno. It is of the eighth magnitude, and attracted his attention, while
comparing with the heavens the 50,000 stars observed by Lalande. It appears to have a peculiar motion, and, after observing it for several days, he clearly ascertained that it was a planet. The same planet was observed by M. Burckhardt, who makes its annual revolution to be five years and a half. The following particulars have also been ascertained: Its inclination is 21 deg. Its eccentricity is a quarter of its radius. Its mean distance from the sun is three times that of the earth, or about an hundred millions of leagues; it is consequently farther than Ceres or Pallas, whose distance is ninety-six millions. Its diameter has not yet been ascertained; but its size appears nearly the same as that of Ceres, or the planet discovered by Piazzi. This is the twelfth planet discovered within a few years, Herschel having discovered Uranus and its six satellites, and two new satellites to Saturn; Piazzi discovered Ceres; Olbers discovered Pallas.

In the early nineteenth century, the reading public must have been somewhat confused by the terminology associated with the recent discoveries. Different publications had their own views on what constituted a planet. In the example just quoted we see satellites of primary planets, a primary planet, and the asteroids, all lumped into the general category of planets. The passage is also a good indication of the level of knowledge being imparted to the reading public about the discovery of Juno—an estimate of its size compared with Ceres, and the relevant figures of its orbital elements. On the six satellites of Uranus, see Cunningham (2015b).

*The Monthly Magazine* (1804b) also communicated news about Juno to its readers:

On the 21\textsuperscript{st} of September, about eleven o’clock at night, Mr. Bode, in the Observatory at Berlin, had a view of the new planet first discovered by Mr. Inspector Harding, at Berlin, on the 1\textsuperscript{st} of September. Its nearing was east-by-north, 14. of the Whale, according to Mr. Bode’s catalogue of the stars. It appeared as a planet of the seventh magnitude. He calculated its meridian altitude at 11h. 55\textdegree{} 21\textprimemin; its apparent right ascension at 359\textdegree{} 27\textprimemin{} 46\textsec; its south declination 3\textdegree{} 38\textprimemin{} 23\textsec. He considers it as a planet not known before Mr. Harding’s discovery, and belonging to the region of Ceres and Pallas.

The same publication kept its readers informed about the works of Gauss and Schroeter:

M. Gauss, already known as one of our greatest astronomers, has undertaken to calculate the attractions of Jupiter on the three new planets; but as there will be several hundred equations, he purposes to give only the methods by which our calculators may easily determine the quantities of those equations. A work, entitled *Lilienthalische Beobachtungen der neu entdeckten Ceres, Pallas, und Juno*; or Observations made at Lilienthal, on the recently discovered Planets Ceres, Pallas, and Juno, by Dr. J. H. Schroeter, 336 pages, 8vo. gives the observed diameters, but which appear too large according to the memoir of Herschel. He finds the first, or Piazzi, 3\textprimemin{} 5; if the distance be taken at one; diameter 587 leagues; the second, or Olbers, 4,\textprimemin{} 5; diameter 760 leagues; the third, or Harding, 3,\textprimemin{} 1; diameter 515 leagues. (*The Monthly Magazine*, 1806a; their italics).

One of the London journals designed to appeal to intelligent ladies makes an appearance here. *La Belle Assemblee* (1807: 89) published a lecture on astronomy by Margaret Bryan, which was part of her *Lectures on Natural Philosophy* (1806). Bryan ran a boarding school for girls in Blackheath, London, from 1795 to 1806, and the curriculum included mathematics and sciences—rarely offered to young women. She published her lecture notes on astronomy in 1797, and after their positive reception she decided to undertake another volume of lectures, which resulted in the book just mentioned. Half a page is devoted to Ceres, Pallas and Juno. She adopts the French style of naming. “The two first discovered are called Piazzi and Olbers, after the names of their discoverers.” She also gets the name of the discoverer of Juno wrong, calling him Hardinge, but does give credit to Herschel for naming the new objects asteroids.

Towards the end of the period covered by this thesis, an excellent synopsis of our understanding of Juno was printed in the London publication *A Dictionary of Mechanical Sciences, Arts and Manufactures* (1829: 534). It was, unfortunately, sadly misinformed by the fantasies of Schröter. It is quite astonishing how the
editor, Alexander Jamieson (1782–1850) of Sion Hill, Middlesex (who published his Celestial Atlas in 1822), could in the same breath say Juno has no nebulous appearance and yet claim it has a dense atmosphere.

The planet Juno is of a reddish colour, and is free from that nebulousness which surrounds Pallas. Its diameter, and its mean distance, are less than those of the other new planets. It is distinguished from all other planets by the great eccentricity of its orbit; and the effect of this is so extremely sensible, that it passes over that half of its orbit, which is bisected by its perihelion, in half the time that it employs in describing the other half, which is farther from the sun. From the same cause, its greatest distance from the sun is double the least distance, the difference between the two distances being about 127 millions of miles. Though there is no nebulous appearance around the planet Juno, yet it appears, from the observations of Schröter, that it must have an atmosphere more dense than that of any of the old planets of the system. A very remarkable variation in the brilliancy of this planet has been observed by this astronomer. He attributes it chiefly to changes that are going on in its atmosphere, though he thinks it not improbable that these changes may arise from a diurnal rotation performed in 27 hours.

The first three lines of this account of Juno had previously been printed in *The Worthies of the United Kingdom; or, Library for the People, Third Division* (1827: 14). The real diurnal rotation of Juno is 7.21 hours, not 27 hours.

### 5.2.4 Vesta

Notice of the discovery of Vesta was given to the British public by Thoelden, again from a personal letter he received from Bode. Thoelden dated this letter 18 May 1807, and the article was accompanied by a table of positional data from 29 March to 12 April by Olbers, and 13 April to 4 May by Bode:

Your astronomical readers will no doubt be highly gratified by being informed, that the indefatigable Dr. Olbers, at Bremen, has, on the 29th of March last, again discovered another new planet, to which he has given the name of Vesta. I have subjoined the observations hitherto made of this planet; first by Dr. Olbers himself, at Bremen; and those made afterwards by the astronomer royal, Professor Bode, at the Royal Observatory, at Berlin.

Mr. Bode tells me, that this planet was first discovered in the north wing of Virgo; that it belonged to that group of planets, which revolve round the Sun, between Mars and Jupiter; that its size appeared to be that of a star of the sixth magnitude, and might be seen with the naked eye; that its present place was between β, δ and ο Virgo; that its present motion was still retrograde; but that it soon would become stationary, and after that it would go on forward in its course, or orbit. (Thoelden, 1807: 439).

The June issue kept readers up to date on Olbers’ observations, and the study of Vesta in England:

Dr. Olbers has written to Dr. Young, foreign secretary to the Royal Society, announcing his discovery of another new planet, on the 29th and 30th of March last. This planet, which he calls Vesta, is apparently about the size of a star, of the 5th or 6th magnitude, and was first seen in Virgo. On the 28th of March, at 8h 21m, mean time 184° 8′: N. declination 11° 47′; on the 30th at 12h 33m mean time 1890 52′: N. declination, 11° 54′. It has since been seen by Mr. Groombridge, at his observatory on Blackheath, who says, it appears like a star of the sixth magnitude, of a dusky colour, similar in appearance to the Herschel (Uranus). (The Monthly Magazine, 1807a).

A small note in a subsequent issue related that Bode… took advantage of fine weather between the 23d of April and the 5th of May, to view the new planet Vesta, which he did nine times at Berlin, from the Royal Observatory, with the mural quadrant. (The Monthly Magazine, 1807b).

*The Scots Magazine* (1807) apprised its readers of the discovery:

A new planet, called Vesta, has been discovered by Dr Olbers, of Bremen, the same astronomer who discovered the planet Pallas. On the 29th March, at 8h 21m mean time, its right ascension in time was 184° 8′, and its declination 11° 47′ North. On the 30th of March, at 12h 33m, its right ascension was 189° 52′, and its declination 11° 54′ North. This planet has also been seen by Dr Maskelyne, Mr. Groombridge, Dr Herschell, and M. Schroeter. According to Mr Groombridge, its situation was … [positional data for April 25, 26 and 27 are
The planet Vesta appears like a star of the 7th magnitude. It shines with great brilliancy, and may be seen with the naked eye. Its diameter (according to a paper of Schroeter read lately in the Royal Society of London) is 0.″488; and according to the calculations of Dr. Gauss, it seems to be situated like the other three small planets, between the orbits of Mars and Jupiter. The following observations have been made upon Vesta by Professor Bode of Berlin. On the 15th May at 9h 2′ 56″, its right ascension was 178° 29′ 56″, and its declination 12° 35′ 49″ North.

The Scots Magazine (1808) also briefly noted the ongoing investigation of Vesta:

From various observations made on the newly-discovered planet Vesta, Mr Groombridge has ascertained part of the elements, which are as follow:

- Inclination of the orbit: 7° 8′ 20″
- Ascending node: 104° 38′
- Period: 3,182 years
- Mean radius: 2,163

From the increased angular motion in its orbit, the eccentricity appears to be considerable, but he has not yet sufficient data to determine the quantity.

That there were four ‘new planets’ in the Solar System was probably known to everyone in Great Britain who could read, and many who could not. That their existence was common knowledge can be seen by the fact they were the subject of poetry, and from their inclusion in a book of mathematical exercises for young persons and those who wanted to better educate themselves. This poetic tribute by A. Crocker (1808) encapsulated the discovery of—and mystery surrounding—the four new planets:

Beyond the orb of Mars behold we find
Four smaller bodies of the planet kind.—
The first, though last reveal’d to human sight,
Is Vesta call’d; of feeble, dusky light;
Whose bulk and distance are to us unknown,
Nor have her revolutions yet been shown.
Still farther off (with telescopic eye)
The late discovered Ceres we decry;
Of size minute, and various in her hue,
Sometimes a red, at others, white or blue.
See Pallas, gliding on in annual round,
The minimus of planet-stars, is found;
Of size so small, as well as feeble light,
No wonder she so long escap’d our sight.
In path elliptic, Juno wings her way,
And feebly sheds on us her silver ray;—
Her length of days (as yet to us unknown)
By future observations, will be shown.
Whate’er her bulk, her days how short or long,
Creative judgment has not made them wrong.
In ev’ry world, in ev’ry part, we find
Th’ unerring wisdom of th’ eternal mind. (Crocker, 1808).

Meanwhile, the mathematical book gives this money-based question:

If a barrel of oysters were purchased for the fourth part of a guinea, and sold for the third of a guinea, what would be gained by the sale of as many barrels as there are planets in the solar system, including Ceres, Pallas, Juno and Vesta. (Butler, 1811: 166).

Reports about Vesta were usually included in a larger survey of all four of the asteroids. This little snippet (reporting on a meeting of the Royal Academy of Berlin on 3 July 1817) from Blackwood’s Edinburgh Magazine (1817) is typical:

M. Bode read a memoir on the newly discovered planets, Ceres, Pallas, Juno and Vesta, and produced a brass model, shewing the true position of their orbits in the solar system.

Aside from amateur astronomer Stephen Groombridge and Herschel, reports of astronomers viewing Vesta in these early years of the nineteenth century are scarce. This report of 3 May 1818 by Capel Lofft appeared in the Monthly Magazine:
Mr. Crichmore, Mr. Bransby [James Hews Bransby, 1783–1847], and I, concur in thinking, that on Friday, the 1st of May, we saw the planet Vesta. Mr. Bransby saw it first, between 7 and 6 Virginis—in a line drawn from Spica toward Cor Caroli. The power used was a reflector, with rather above 100. It appeared like Saturn in his aphelion, when its apogee takes place at the same time, or when his light is diminished to our eye by that of the Moon; or a yellowish light, disc sensible; not absolutely defined; just discernible to the naked eye. This, for a small planet, so distant (about 180 millions of miles) from us, is more visible than could well have been expected. An opportunity was wanted of confirming the observation last night, the sky being clouded. Twenty-four hours would have been sufficient to have ascertained the change of place of a planet, whose motion in that time is well capable of being distinguished in its present position. The most convenient altitude to view Vesta, is about 9 P.M. or half after.

(The London Literary Gazette, 1818, his italics).

The London Literary Gazette (1818) reported some technical information of Vesta that was included in the French Journal des Savans for March, April and May:

Thus we find in this volume, tables of the planet Vesta, calculated by M. Daussy [Pierre Daussy, 1792–1861]. They contain not only the elliptical motion of that planet, but also the numerical value of the perturbations which it experiences from the other planets, so that they determine its position with an exactness comparable to that which we have a right to expect for the planets which have been the longest known.

The same publication gave readers notice of a favourable opposition of Vesta in 1820, with details on where it could be found between Gemini and Cancer: “By the assistance of a map of the constellation Gemini, this planet may be readily found with a good telescope, and her progress watched for upwards of two months.” (The London Literary Gazette, 1820).

Figure 5.7: William Henry Fox Talbot (courtesy: en.wikipedia.org).

Three years later there is this letter from the British inventor and photography pioneer William Henry Fox Talbot (1800–1877; Figure 5.7) in Cambridge to Charles Fielding (1791–1866):

The other day I thought I would try if I could see the new planet Vesta: having no instrument but your Telescope & Mayer’s catalogue of the Stars, there was some difficulty: at last I found the spot mentioned in the Ephemeris where the Planet was to have been, when lo! there was
nothing to be seen. A day or two after I found out there was a blunder of a whole degree in the Ephemeris (which was too bad) and having corrected this I looked again on the 5th and saw the Planet in its place. It was much smaller than I expected, being fainter than one of Jupiter’s Satellites. On the 7th I found it had changed its place considerably, which proved it to be the planet, & not an accidental star. I was highly delighted at having found it, as I believe very few Astronomers have seen it except those who have regular Observatories—I should like to shew it you when I am at Paris, but I am afraid it cannot be seen through a common telescope: it is very faint thro’ your large one, tho’ to be sure there are many stars about it much fainter still. (Talbot, 1823, his underlining).

At about this date the asteroids were included in another poem by a British author, a certain Thomas Edgar, who had his book printed in Scotland:

Next, four twin sisters, lately known,
In noble splendor do roll on—
Ceres, who agriculture taught—
Pallas, who arts and science brought
To ancient Greece, as poets tell,
In which she did the world excell—
Juno, the watchful, jealous wife,
Vesta, who virgin was for life. (Edgar, 1822).

The Edinburgh Philosophical Journal (1820) published positional data on Ceres, Pallas and Juno and all four asteroids in their 1821 issue. The Quarterly Journal of Science also kept its readers apprised about the asteroids in this time period, including data from Friedrich Bernhard Gottfried Nicolai (1793–1846). It printed an ephemeris for Vesta from 1 April to 29 August 1824 by “Prof. Encke, Bode’s Jahrb. 1824, p. 245”, and on the same page an ephemeris of Juno from 21 October 1822 to 7 April 1823 by “Prof. Nicolai, Bode’s Jahrb. 1824, p. 244) and an ephemeris of Ceres on the first day of each month of 1822, from “Bode’s Jahrb. 1822”. (The Quarterly Journal, 1822).

The Edinburgh Journal of Science (1827) had a feature on the elements of the four asteroids. The reader was informed that the data had “… been collected by Francis Baily, Esq. [1774–1844] the learned president of the Astronomical Society of London, who has given them in his Astronomical Tables and Formulae.”

The New Jerusalem Magazine (1827) devoted nearly three full pages to a survey of all four asteroids. It repeats the old canard that Ceres and Pallas are surrounded by dense atmospheres and that “… with a high degree of probability … [they are] the fragments of a large celestial body … [that] had been burst asunder by some immense irruptive force.” The almost wholly spurious account is at least partly redeemed at the end by a realistic account of the origin of meteorites, where “Dr. Brewster attributes the fall of meteoric stones to the smaller fragments of these bodies.”

In the 1830s, positional measurements of the asteroids were being made by Thomas Henderson (1798–1844), Professor of Practical Astronomy at the University of Edinburgh. For example, the opposition of Juno on 17 June 1838 is reported, along with a note that “… the opposition of Vesta on December 29, 1838, will be reported in (the) next Volume, as some of the observations were made in the beginning of 1839.” (Henderson, 1838).

A valuable insight into how people received information about the positions of the asteroids during this era comes from a letter to the editor of The Mechanics’ Magazine (1830b):

An esteemed correspondent reminds us that for general, and even nautical purposes, we need not have recourse to “Encke’s Ephemeris” to supply the deficiencies of the “Nautical Almanac” with regard to the new planets, Pallas and Ceres. He adds: “There is a regular ephemeris of them in “White’s Ephemeris” for every 6th day in the year, and, indeed, for every day near their respective oppositions. You will also find that even the renowned astrologer,
Francis Moore, gives the southing and declination of each of these four interesting bodies, for
five days near their respective oppositions, and specifies the fixed stars which they will then be
near. For example, he states, that on April 30th, Ceres in opposition will be ‘about 3° east of
the star μ, on the right foot of Virgo, and very near that marked 16 Librae.’ The correspondent
to The Times should have specified that the right ascensions and declinations of Ceres and
Pallas in ‘Encke’ are for the midnights, not the noons of the respective days.
The publication that still bore the name of the posthumous Francis Moore (1657–
1715) was Vox Stellaram or, A Loyal Almanack for the year of Human Redemption
1830. In stating that the sales of this almanac were in excess of 200,000 copies
annually, a writer of the time noted that “… this relic of ancient absurdity is probably
more read than any other work in the kingdom.” (The Quarterly Journal of
Education, 1832).

The four asteroids also featured briefly in a survey of the Solar System published
in The Imperial Magazine and written by William Coldwell in London on 25 May:
“Launched into ether, these minute orbs have survived the rush of the ages equally
with the larger spheres; yet do they seem to us sprung up yesterday, so completely
have they for ages been hidden from us.” (Coldwell, 1831: 316).

Finally, The Saturday Magazine (1838; see Figure 5.8) printed a survey of the
four asteroids as part of a review of “Popular Astronomy”. Consisting of a full page,
it unequivocally calls them ‘asteroids’. It briefly mentions the discovery
circumstances, the fact that too little is known of their diameters to even hazard an
estimate, and it mentions the possibility they are fragments of a former planet:
What mighty convulsion of Nature could have produced such a catastrophe, we can only
conjecture: nothing for certain on such a subject can be known to us, except that “He who
could make could also destroy.”

![Figure 5.8: Comparative Sizes of the Planets (after The Saturday Magazine, 1838).](image-url)
5.3 William Herschel: How He Learnt about the Discovery of Ceres

It is fortunate that Herschel could rely on a large network of friends to keep him acquainted with Continental discoveries, as official publications often came out weeks or months afterwards. In the case of Ceres, this was particularly acute because Piazzi wanted to keep the discovery to himself, in flagrant breach of astronomical protocol.

Piazzi waited an extraordinarily long time to inform his British colleagues of the discovery. Francisco Sastres (died 1822), the Neapolitan Consul in London, informed Herschel of the discovery in a letter dated 2 May. Herschel was closely associated with Naples, as it was the first Italian city to host a telescope made by him (Gargano, 2012), so he and Sastres were acquainted. Bode gave positional details in a letter on 6 June, but Herschel had to wait until a letter written on 1 September to get the news from Piazzi himself! Curiously, Piazzi sent his observations and calculated elements to Karl Seyffer in Germany a month earlier, on 4 August 1801. Why did he wait another month before informing Herschel? Perhaps his sense of shame finally overcame his reluctance to share the results with one of the greatest observational astronomers of the age. We also know Herschel communicated directly with Olbers. In a letter to Gauss of 10 October 1802 Olbers writes:

Herschel has had the kindness to send me a special copy of his treatise, Observations on the two lately discovered Celestial Bodies. His magnification was 516 times. Next he gives Pallas' diameter 110 ½ miles, and says it is 31,000 times smaller than Mercury. (Olbers, 1802f).

The Herschel correspondence is printed in Appendix D.3.

5.4 Sir Joseph Banks and Sir Charles Blagden: Their Role as a Conduit of Information between British and Continental Astronomers, Particularly Zach

Banks, in his role as President of the Royal Society, developed a web of correspondents in Europe. As the person primarily responsible for the botanical work on Cook’s first South Seas journey (1768–1771) he developed many close links with naturalists, notably Johann Friedrich Blumenbach (1752–1840) in Göttingen. Both men had a strong penchant to collect and Banks made a personal donation in the late 1770s of ethnographic items to the Academic Museum in Göttingen. This led Blumenbach in 1781 to formally request the transfer of a huge collection of rarities from the South Seas expedition. The appeal was made to the Privy Councillors of Great Britain’s Government in Hanover, and within a month King George III, in his role as Elector of Hanover, agreed to ship the entire collection to Göttingen, where it resides to this day (Krueger, 2006: 36-53). The King almost certainly elicited the opinion of Banks before agreeing to the transfer, but the episode shows how closely linked England and Germany were at this time. The links were not just in the realm of astronomy, but extended to other scientific spheres.

As President of the Royal Society, Banks was at the center of all aspects of British scientific life (Gascoigne, 1994), and he kept a study at his residence at No. 32 Soho Square where his correspondence throughout Great Britain and Europe was read and replied to (Widmalm, 1992; Figure 5.9). The most important element of the establishment—The Royal Society—viewed the relevance of the asteroids quite highly, as evidenced by the official account of its proceedings which gives the letters read to the Society and a synopsis of their contents (see Appendix D.5).

Banks received most of his information about the asteroids directly from Zach in Gotha, although Sir Charles Blagden was another important source. Blagden also transmitted information about the asteroids to France:
La Lande reports further that the secretary of the Royal Society of Sciences in London, Sir Charles Blagden, who has just arrived in Paris, brought news with him that Dr. Herschel had found Ceres’ diameter to be only one second at most. *(Monthly Correspondence, 1802a: 480).*

Charles Blagden (Figure 5.10) was born in April 1748 in Gloucestershire, in the small village of Wooten-under-Edge. He studied medicine at the University of Edinburgh, and upon the outbreak of war with the American Colonies was appointed surgeon to the British Army. He returned to England by early 1780 and settled in Plymouth. Not long after he began his scientific career as assistant to the famed chemist Henry Cavendish, a position he held until 1789.

Blagden was elected Secretary of the Royal Society on 5 May 1784, a post he retained until 30 November 1797. He enjoyed the confidence and friendship of Banks, and was a frequent visitor at his home in London. He forged close relations with most of the eminent men of science in his day, in England, France and Germany. In 1792 Blagden was rewarded with a knighthood by King George III (Getman, 1937: 72).

He spent much of his time in France, with annual visits often lasting six months. In 1819, he accepted an invitation from the scientist Claude Berthollet (1748–1822) to visit him in Arcueil, and it was here that he suddenly died on 26 March 1820. He is buried in Père la Chaise Cemetery in Paris. Blagden earned the admiration of Dr Johnson, who declared him to be “… a delightful fellow.” (Getman, 1937: 73).
The conduits of information about the asteroids, from the Continent to England are shown in Figure 5.11. Once the four recipients got information from their Continental colleagues, they shared it amongst themselves. Information from Zach, for example, was given by Banks to Maskelyne, and information Maskelyne received was given to Herschel. Information from Schröter reached both Herschel and Maskelyne through Best. In addition to what is represented on this chart, Piazzi sent...
information to Lofft, and Bode sent information to Thoelden. In each case these communications were printed in the London journals for all to read.

5.5 Nevil Maskelyne: His Observations of Ceres and Pallas

Nevil Maskelyne was born in London in 1732. He attended St. Catharine’s College, Cambridge, in 1749 and became a Fellow of Trinity College, Cambridge, in 1756, one year after being ordained as a minister. In 1758, at the age of only 26, he became a Fellow of the Royal Society (Burns, 2003: 181). Three years later the Society sent him to St. Helena to observe the rare transit of Venus (Wulf, 2012: 17). Poor weather foiled that plan, but on the journey he developed a method of determining longitude using the position of the Moon (Wulf, 2012: 33). This led directly to the establishment of the annual *Nautical Almanac*, which astronomers relied on for many years to come (Lockett, 2010: 161-162).

His scientific accomplishments catapulted him into the country’s top scientific position, Astronomer Royal, a post he held from 1765 to 1811. Together with Joseph Banks, the long-serving President of the Royal Society, Maskelyne represented one of the two pillars of the English scientific establishment for decades. Remarkably, he has been the subject of only one detailed biography (Howse, 1989).

The relationship between Maskelyne and Banks was a difficult one. It erupted into a full-scale war when Maskelyne openly opposed the selection of Banks for President of the Royal Society. For his opposition, Maskelyne was removed from the Council of the Society, but found himself in the uncomfortable position of being answerable to Banks as Chair of the Visitors of the Royal Observatory. Banks’ biographer described Maskelyne as “… a difficult and uncertain man.” (Carter, 1988: 319). Their animus lasted until Maskelyne died, but the cause of science forced them to cooperate for the public good.

Maskelyne had the good fortune to be Astronomer Royal during the discovery of Uranus and all four asteroids. As such he was a close associate of Herschel, even though his telescopes at Greenwich Observatory were inferior to those of Herschel. Maskelyne wrote and corresponded extensively about the asteroids, beginning with this letter or memorandum from the summer of 1801 (Maskelyne, 1801):

> There is great astronomical news: Mr. Piazzi, Astronomer to the King of the Two Sicilies, at Palermo, discovered a new planet the beginning of this year, and was so covetous as to keep this delicious morsel to himself for six weeks; when he was punished for his illiberality by a fit of sickness, by which means he lost track of it; and now a German Astronomer [Gauss], having got some of his observations, has calculated an orbit in our system as near as he could from such few observations, and had just informed us where he thinks it should be looked for in the course of the summer and autumn.

> It will not be so easy to recover, as the lost Cupid, when Venus said you might spy among 20 immediately by his air and complection. But this having been only a star of the 8th at first, & now for some months to come not bigger than the 10th or 12th will not be easily distinguished among 40,000 or 50,000 stars of similar appearance as it can be only known by its motion, which cannot be seen immediately but require observations of the relative position of several stars among which it is to be looked for. What a deal this imprudent Astronomer has to answer for! It is now publicly proposed, in a German publication, to all Astronomers in Europe to hunt for it.

Extensive observational measurements of the asteroids were made in England by only three people: Herschel, Maskelyne and Groombridge. Herschel’s observations are examined throughout this thesis, while those of Groombridge, from 1807 to 1823, are considered in Section 5.6. Here the observations of Maskelyne are looked at, and how they informed his contributions to public understanding through his articles in *The Monthly Magazine*, which he signed with the pseudonym ‘Astrophilus’.

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5.5.1 The Logbooks of Maskelyne
The records of Nevil Maskelyne, now housed in the RGO Archives at the Cambridge University Library, contain much information that has not been thoroughly examined. In 2003 I discovered the supposedly-missing correspondence between Maskelyne and Gauss (Cunningham, 2004b). Maskelyne’s logbooks contain not only mathematical calculations relating to the asteroids, but the original form of his articles about the asteroids that appeared in *The Monthly Magazine*.

5.5.1.1 Observations made by Maskelyne
Maskelyne (1811) kept a careful record of his observations (e.g. see Figure 5.12), and after some sets of recorded data he wrote a few lines to elaborate and explain his findings. These texts (in RGO 4/120) are transcribed below, and the 7 February observations are given as an example of how he recorded observations:

This was a very fine night. The planet appeared with a well defined disc; and so did the 34th of Virgo, a star of 6 magnitude. The planet also appeared smaller, than the as well as more distinct then the night before. The planet appeared much less than the wire which subtends an angle of 14,3 & the star appeared the least possible larger than the wires which covers 14,"8 in the heavens.

Figure 5.12: Maskelyne’s logbook entry for 7 February 1802 (courtesy: Cambridge University Archives).

On 7 February we can see he was comparing the position of Ceres (usually just denoted with the letter P for Planet) with the star 34 Virginis. One of the observations is rejected, as can be seen in the far left column. Another line of numbers is crossed out as “evidently wrong” followed by a line marked “repeated.” After these ‘raw’ figures were analysed, the resulting positional measurement for 4
February resulted in these figures, as published in the *Monthly Correspondence* (1802a: 467):

Mean Time: 17h 25′ 46″
Right Ascension: 188.42′ 56.″2
Declination: 12.44′ 45.″0 N.

After the 6 March 1802 observations, he wrote this:

At 9h 50′ Planet appeared excessive faint, with an aperture of 1/2 inch in diameter. I saw 34 Virgo very faint with [illegible] inch aperture, but not so faint as the planet before with 1/2 an inch aperture. Then looked at it with an aperture of .3 inch and it was scarcely distinguishable & much fainter than the planet appeared before. This was a fine night, and stars of 6 magnitude were visible. Perhaps with an aperture of 1/3 inch, the star 34 Virginis might have appeared equally faint as the planet with an aperture of half an inch. According to this the light of the planet is to that of the star as 9 to 25 or near three times less. The planet appeared of 8M.

After the 22 April 1802 observations, he wrote this:

From the time of Olbers’ planet passing the meridian till near 11 p.m. M. T., looked alternately at this planet & Ceres, & they seemed about equal in brightness. Which ever was observed last was thought to be the brightest. At the transit instrument tonight Olbers’ planet seemed equal in size & brightness to Ceres appeared when I observed it last at the meridian last night. Mr. Gilpin found that on April 22 and 23 the two new planets Ceres & Pallas appeared to him exactly of equal brightness. The French astronomers on 10th and 12th found the same.

Maskelyne then compiled a list of the magnitudes on a separate sheet, covering the period 3 February to 28 June 1802:

<table>
<thead>
<tr>
<th>Date</th>
<th>Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb. 3</td>
<td>7.8 M..9..8..8..8..8 Mean 8M fine night</td>
</tr>
<tr>
<td>March 4</td>
<td>Ceres 9M or less</td>
</tr>
<tr>
<td>April 22</td>
<td>Ceres &amp; Pallas appeared of equal brightness. On Apr. 22d &amp; 23d they appeared the same to Mr. Gilpin; on 10th &amp; 12th the French.</td>
</tr>
<tr>
<td>May 21</td>
<td>8M.8M..8M..8M T.F. [Thomas Firminger; see Section 5.11 of this thesis]</td>
</tr>
<tr>
<td>June 20</td>
<td>10M. a very fine night</td>
</tr>
<tr>
<td>July 3</td>
<td>10M.</td>
</tr>
<tr>
<td>Apr. 15</td>
<td>Pallas 7M by T.F. but he makes magnitudes too great, not being used to it</td>
</tr>
<tr>
<td>Apr. 21</td>
<td>9M.8..8</td>
</tr>
<tr>
<td>Apr. 22</td>
<td>9M.9</td>
</tr>
<tr>
<td>May 21</td>
<td>8M. T.F.</td>
</tr>
<tr>
<td>May 17</td>
<td>9M..9</td>
</tr>
<tr>
<td>June 11</td>
<td>9M</td>
</tr>
<tr>
<td>June 18</td>
<td>11 M T.F.</td>
</tr>
<tr>
<td>June 20</td>
<td>11M..11.12 A very fine night</td>
</tr>
<tr>
<td>June 28</td>
<td>10M A very fine night</td>
</tr>
<tr>
<td>From these observations Feb. 3 Ceres 8M</td>
<td></td>
</tr>
<tr>
<td>March 4</td>
<td>9M or less</td>
</tr>
<tr>
<td>Apr. 22</td>
<td>9 Apr. 21 Pallas 9M</td>
</tr>
<tr>
<td>May 17</td>
<td>9 May 17 9M</td>
</tr>
<tr>
<td>June 20</td>
<td>10M June 11 9M</td>
</tr>
<tr>
<td>July 3</td>
<td>10M June 20 11M to 12M</td>
</tr>
<tr>
<td></td>
<td>June 28 10M</td>
</tr>
</tbody>
</table>

We can see here how inaccurate magnitude estimates were before the days of photometers. In the case of Pallas, for example, its magnitude was said to range from 9th magnitude to as faint as 12th magnitude in the space of only nine days from 11 June to 20 June! Pallas reached opposition on 26 March 1802, just two days before it was discovered. Its magnitude then was about 8, so a fading to 9 throughout April, May and June was a reasonable estimate, but the sudden dip to 11
or 12, followed by a rise to 10 just eight days later, shows the unreliability of such visual measurements. This is even more remarkable when we consider Maskelyne’s notes about the two nights of 20 and 28 June. He regarded both as “very fine”, and yet saw very different magnitudes. This was from an extremely experienced observer. For the observation of 15 April he derided his assistant Firminger for making magnitudes too great due to lack of experience, but it appears from this that experience counted for little. While the observational skills of Herschel and Maskelyne were among the best of that era, they were not theoreticians and contributed nothing to our understanding of the orbital properties of the asteroids, a subject which is examined in Chapter 6.

5.5.1.2 The Memoranda
Interspersed with observational data and mathematical calculations, Maskelyne wrote several paragraphs about the asteroids that I term ‘memoranda’. They cover the period February 1802 to September 1804. Three of these were recast as magazine articles for the widely-read Monthly Magazine. Maskelyne’s first contribution about Ceres to The Monthly Magazine on 1 August 1801 pre-dated his logbook entries, and was given in Subsection 5.2.1. The first entry mentions when he initially received Piazzi’s account of the discovery of Ceres, and then summarises an account by Méchain of Paris that appeared in the Moniteur, the official gazette of France from 1789 to 1869. In many of the memoranda Maskelyne wrote a few words and then crossed them out—these instances are fully reproduced in the thesis, and the full text of the memoranda and associated Monthly Magazine articles can be found in Appendix E.

The memorandum of 23 February contains Maskelyne’s only mention of colour. He regards Ceres as primarily white with a reddish cast. This contrasts with the observations of Herschel, who found Ceres to be “ruddy”. In this case, Maskelyne was a better judge of colour as Ceres really does present a white appearance (see Section 3.3).

As was mentioned in Subsection 5.2.2.1, Maskelyne contributed articles to The Monthly Magazine, signing himself ‘Astrophilus’. One result of the re-write in The Monthly Magazine (1802f) is that the “they” referred to makes no sense. It can be seen from his logbook notes that Maskelyne was referring to Paris Observatory.

Another one of his logbook entries made it to the pages of The Monthly Magazine (1802g). In this case his name is given as ‘Astrophylus’ instead of ‘Astrophilus’. It is worth noting that while in his logbook Maskelyne refers to the two objects by the impersonal “it,” readers of the magazine saw them humanised as “him.” This is all the more curious as both were named after female goddesses. Whether it was Maskelyne or the magazine editor who made these changes cannot be known. The article gives a valuable insight into Maskelyne’s opinion of Herschel and his observations. He uses the word “curious” to describe Herschel’s diameter estimates. To modern eyes it may seem to imply a lack of confidence, but in Dr. Johnson’s Dictionary from this time period we find ‘curious’ to be defined as ‘accurate’, ‘exact’, and ‘careful not to mistake’. The Monthly Magazine (1802g) article is also notable for what it does not say. Maskelyne studiously avoids giving any publicity to the term ‘asteroid.’ He merely says Herschel believes them to be a “different species”. He was clearly uncomfortable with the new terminology. In his final memorandum, Maskelyne writes of the discovery of Juno by Harding, again using the word ‘planet’ to avoid the use of ‘asteroid’.

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Thomas Young: His Role as a Conduit of Information Between British and Continental Astronomers

Thomas Young was born in Milverton, Somerset in 1773. Even as a teenager, he had learned several languages. He obtained a Doctor of Physics degree in Göttingen, Germany, in 1796, and two years later established himself as a physician in London. In 1801 he was appointed Professor of Natural Philosophy at the Royal Institution, and in 1802 Foreign Secretary of the Royal Society. It is in this role that he communicated widely with astronomers and other scientists throughout Europe. In 1818 he became Secretary to the Board of Longitude and Superintendent of the Nautical Almanac Office, both of which brought him into close contact with Maskelyne. He died in London in 1829. Young’s most important accomplishment was to establish the wave theory of light (see Section 3.3). His career as a polymath was unrivalled, and is ably represented in a biography by Robinson (2007).

Through his astronomical lectures, Young kept the Royal Institution in London informed about Ceres. On 5 February 1802, he read an extract from the French-language publication Moniteur about the rediscovery of Ceres. Young illustrated the proportionate dimensions and distances of the planets on a large-scale diagram for the audience (Journals of the Royal Institution, 1802). Young also kept the English public informed about the asteroids by contributing to noted journals (see Section 5.2.3).

Just before the discovery of Vesta, Young wrote about the three objects discovered since 1801:

It appears doubtful, whether either of the three little planets newly discovered can be sufficiently solid, to give a firm footing to any material beings: we should probably weigh only a few pounds each if transported there. According to Dr. Herschel’s opinion, neither Ceres nor Pallas is much larger than a good Scotch estate, although they must, sometimes, appear to each other as planets of a most respectable size. The light reflected from Ceres is of a more ruddy hue than that of Pallas: both of these planets are attended by more or less of a nebulosity, proceeding, perhaps, from copious atmospheres; and in this respect, as well as in the great inclination of their orbits, they appear to have some affinity to comets. It is tolerably certain that neither of them is 200 miles in diameter; and Juno is also probably about the same size (Young, 1807: 534).

Stephen Groombridge

After Herschel completed his investigation of the asteroids, as presented in his papers on the subject, he turned his attention elsewhere and wrote nothing further about them aside from some personal notes (see Appendix B). The mantle was taken up by Stephen Groombridge (Figure 5.13) at his private observatory in Blackheath.

Groombridge was born in Goudhurst in 1755 and began his life as a linen-draper. He moved to Blackheath, a suburb of London, in 1802. There he continued as a linen-draper until retiring in 1815 (Clerke, 1885-1900: 270-271). Concurrent with the business was his interest in astronomy. In 1806 he obtained a transit circle of 4-foot diameter by Edward Troughton (1753–1835; the instrument is now in the collection of the Science Museum in London). This instrument was equipped with a 3½-inch telescope. It was situated next to his dining room, and with it he made 50,000 observations that were published as his star catalogue in 1832 (Clerke, ibid.), the year of his death. He also made many positional measurements of the asteroids, which he dutifully sent to William Herschel (see Appendix D.4). Through Stephen Lee, Herschel actually requested asteroid observations from Groombridge (Groombridge 1817a), a testament both to Herschel’s continuing interest in the
asteroids a decade after his last paper on the subject, and to his belief that the data from Groombridge was of a high calibre.

Groombridge became a Fellow of the Royal Society in 1812, and a founding member of the Royal Astronomical Society in 1820 (Clerke ibid.). He was described by Vince (1811: 235) as “… an ingenious and active astronomer, who has successfully devoted his leisure and his fortune to the advancement of astronomy.”

Planetary observations by Groombridge, chiefly of the asteroids, for 1807, 1808 and 1811, from 1812 to 1815, and from 1820 to 1823, were inserted in the Supplements to the *Berlin Ephemeris*. They were of great value for the theory of the asteroids, as at the time his observational instruments were equal to, if not more powerful than, those of any other observer in Europe (*Monthly Notices of the Royal Astronomical Society*, 1833).

As for Groombridge, he kept readers of the *Philosophical Magazine* up to date on the asteroids in the 1820s. For example, he gave the apparent places of the four asteroids (which he called Minor Planets) at the “… time of their ensuing opposition” in 1823 and 1824 (Groombridge, 1823b).

### 5.8 William Pearson

William Pearson (1767–1847), from his observatory at Parson’s Green in Greater London, published two papers about the asteroids in Nicholson’s *A Journal of Natural Philosophy* (Pearson, 1802a; 1802b). These papers are lengthy and are reproduced as Appendix C. Pearson served as a conduit of letters from Zach to the English reading public: Zach’s letters to Banks were given to Edward Troughton, who then passed them to Pearson, who in turn gave them to Nicholson for publication in his journal. Examples of this are *A Journal of Natural Philosophy* (1802e, 1802g).
According to Gurman and Harratt (1994: 281), Pearson’s prime interest in Ceres “… lay in including it in an orrery, rather than the astronomical problems associated with it.” Here is a portion of his profile from the Dictionary of National Biography:

Astronomer, was born at Whitbeck in Cumberland on 23 April 1767. Pearson was one of the original proprietors of the Royal Institution, and finished in 1803 a planetarium for illustrating Dr. Young’s lectures (Rees, Cyclopædia, art. ‘Planetarium’). To his initiative the foundation of the Astronomical Society of London was largely due. Pearson helped to draw up the rules, and acted as treasurer during the first ten years of the society’s existence. In 1819 he was elected F.R.S., and about the same time granted an honorary LL.D. He received, on 13 Feb. 1829, the gold medal of the Royal Astronomical Society. His death occurred at South Kilworth on 6 Sept. 1847. (Clerke, 1885-1900: 176).

Pearson’s orrery, now in London’s Science Museum, is shown in Figure 5.14. Dating from 1813, it shows 11 ‘planets’, including Ceres, Pallas, Juno and Vesta. There is an extensive description of Pearson’s orrery in The Cyclopædia edited by Abraham Rees (1743–1825) in the entry for ‘Planetarium’. The actual construction of this orrery is attributed to instrument-maker John Fidler of London. Here is an extract dealing with the inclusion of the asteroids, almost certainly written by Pearson:

To the arm of Mars and not far under it is made fast the wheel 166, which impels the wheel 53, and with it the 34 attached to it, round a stud on the arm of Pallas, while the intermediate pinion 15, opposed by the fixed wheel of 154, pulls the arms of both Pallas and Ceres round the same velocity in a period which was calculated to be a mean between the two, and as far as we yet know, is not much different from either. At the time when these periods were calculated (1806) those of Juno and Vesta had not been ascertained, nor had Vesta been discovered, but room was left during the progress of the work for their introduction, and arms were since inserted on the same tube that carries the other two arms, which may be adjusted by hand occasionally when their places are required for any particular purpose; but when the period of those little bodies are finally settled they may be also represented by appropriate mechanism. Below the four arms of the little planets, and fast to their common tube, revolved the wheel 182 in the common period of Pallas and Ceres, actuating the small wheel 40 and its attached pinion 17, carried by a stud on the arm of Jupiter. (The Cyclopædia, 1814: no page numbers).
Shown in Figure 5.15, and taken from the *Cyclopedia*, are the actual lengths of the arms of Pearson’s orrery for each of the planets and the asteroids.

![Figure 5.15: Some technical details of Pearson’s orrery (after *Cyclopedia*, 1814).](image)

<table>
<thead>
<tr>
<th>Planets</th>
<th>Radii Vector.</th>
<th>First Short Arms.</th>
<th>Second Short Arms.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>1.54 inches</td>
<td>0.62 inches</td>
<td>0.00 inches</td>
</tr>
<tr>
<td>Venus</td>
<td>2.9 inches</td>
<td>0.0 inches</td>
<td>0.00 inches</td>
</tr>
<tr>
<td>Earth</td>
<td>4.0 inches</td>
<td>0.0 inches</td>
<td>0.00 inches</td>
</tr>
<tr>
<td>Mars</td>
<td>6.1 inches</td>
<td>1.14 inches</td>
<td>0.00 inches</td>
</tr>
<tr>
<td>Vesta</td>
<td>9.4 inches</td>
<td>1.17 inches</td>
<td>0.39 inches</td>
</tr>
<tr>
<td>Juno</td>
<td>10.6 inches</td>
<td>4.04 inches</td>
<td>1.34 inches</td>
</tr>
<tr>
<td>Ceres</td>
<td>11.06 inches</td>
<td>1.31 inches</td>
<td>0.43 inches</td>
</tr>
<tr>
<td>Pallas</td>
<td>11.06 inches</td>
<td>4.15 inches</td>
<td>1.38 inches</td>
</tr>
<tr>
<td>Jupiter</td>
<td>20.8 inches</td>
<td>1.50 inches</td>
<td>0.50 inches</td>
</tr>
<tr>
<td>Saturn</td>
<td>( \frac{1}{2} = 18.65 )</td>
<td>2.48 inches</td>
<td>0.83 inches</td>
</tr>
<tr>
<td>Herschel</td>
<td>( \frac{1}{2} = 38.4 )</td>
<td>2.70 inches</td>
<td>0.90 inches</td>
</tr>
</tbody>
</table>

There was a serious interest during the eighteenth century and early nineteenth century in England to build orreries. This note in Brewster’s *Edinburgh Encyclopedia* (1832: 720) comes from an article titled ‘Planetary Machines’:

About the year 1801, one of the original proprietors of the Royal Institution suggested a plan for exhibiting the EQUATED motions of all the planets at that time discovered. This suggestion, being made soon after the two planets Ceres and Pallas had been discovered, was adopted; and Kenneth M’Culloch, an aged workman, brought up under James Ferguson, was employed in the construction of the machine in the workshops of the Institution.

While Pearson’s brass orrery appears to be the only one of its kind still in existence from the early nineteenth century, something similar though probably not as sophisticated existed in Germany. Bode, during a talk about the four asteroids at the Royal Academy in Berlin on 3 July 1817, “produced a brass model, shewing the true position of their orbits in the solar system.” (The New Monthly Magazine, 1817).

### 5.9 Capel Lofft

Capel Lofft was born in 1753, and was educated at Eton College and Peterhouse, Cambridge. He was called to the bar in 1775, and succeeded to the family estate near Bury St. Edmunds in 1781 (A Cambridge Alumni Database). Politically, Lofft was aligned with Charles James Fox (1749–1806) and Napoleon Bonaparte. Here is an extract of his obituary in *The Gentleman’s Magazine* (1824):

In 1797, upon the appearance of the Comet, Mr. Lofft played off of artillery of his philosophy upon the public with considerable glitter in the daily prints. He resided at Troston Hall, Suffolk, and was an active Magistrate for that county.

Among the earliest recollections of him, is his appearance at the County Meetings held at Stowmarket, during the last 25 years of the late King’s reign [George III]. His figure was
small, upright, and boyish; his dress—without fur, fashion, or neatness; his speaking small-voiced, long-sentenced, and involved; his manner—persevering, but without command. On these occasions Mr. Loftt invariably opposed the Tory measures which those meetings were intended to sanction; and he was assailed, as invariably, by the rude hootings and hissings of the gentry and the rabble. Undismayed however by rebuff, he would fearlessly continue to advocate the cause of freedom. Mr. Loftt’s conversational powers were of a high order; his richly-stored mind would throw out its treasures when surrounded by his friends, and few, if any, ever left him without improvement, or shared his converse without pleasure.

As we have already seen in Subsection 4.2.2.9, Loftt was in the forefront of English writers about the asteroids. Like the astronomers who belonged to the Lilienthal Society (Vereinigte astronomische Gessellschaft) in Germany, Loftt was pondering the existence of a planet between Mars and Jupiter before 1801.

In his remarks contained in *The New London Review* (March 1800) Loftt linked ancient Greek thought with modern ideas on the construction of the Solar System. No one else in the country is on record at this time as speculating about new planetary discoveries. His prediction in this article that the unseen planet would subtend a small angle is correct, although his estimate of 2.5 to 3 arcseconds was too large. This is not surprising as the very small size of Ceres perplexed most astronomers once it was studied in 1802.

Loftt also alludes here to the harmonic proportion between the planetary distances, which was famously noted by Olbers (see Subsection 3.2.3). Proportion comes up again in the last paragraph given here, where he links the mind of Pythagoras to the concept of proportion. That such notions are not mere alchemically philosophy was clearly elucidated by Mark Peterson, Professor of Physics and Mathematics at Mt. Holyoke College, who claims it was the mathematics of Renaissance arts—not Renaissance science—that became modern science:

> When Galileo [Galileo Galilei, 1564–1642] finally summarized in *Two New Sciences* the results of those experiments in music completed with his father so long ago, he did it in terms of proportionalities, although not the proportions of Pythagorean harmonies … The notion of proportion, central in all the arts, took on a new significance in Galileo’s work. The existence of unsuspected proportions in nature, waiting to be discovered, became a unifying theme in his thought. (Peterson, 2011: 289).

Thus Loftt, in England, and Bode, in Germany, were not just playing with numerology but working in the scientific tradition of Galileo. While modern science gives no credence to ‘Bode’s Law’, their search for unsuspected proportions in nature cannot be dismissed. Loftt’s article in *The New London Review* (Loftt, 1800: 226-228) is shown in full here in Figure 5.16, below.
The turn of the genius of Pythagoras, the circumstances, probably, of his times, his conferences with the Egyptian sages, and the objects which impress'd themselves during his travels in that country, all gave an allegorical form, partaking of the nature of hieroglyphic, to his mode of expression. Hence the precept not to stir fire with a sword,—not to turn back on a journey,—and many others.

This has been believ'd, and particularly by a very great philosopher*, to account for the Pythagorean language concerning the music or harmony of the spheres. A musical chord gives, says Maclaurin, the same notes with one double in length, when the tension or force with which the latter is stretched is quadruple; and the gravity of a planet is quadruple of the gravity of a planet at a double distance. From this similitude of proportions, he adds, the celebrated harmony of the spheres is suppos'd to be deriv'd.

Another way a certain harmonical proportion between the planetary distances may be consider'd.

If these distances, according to the latest observations, reduce'd to the lowest terms, be thus taken,

Mercury, Venus, Earth, Mars, Jupiter, Saturn, The Harlechian,

4 7 10 15 52 95 180

then double the distance of Venus from the Sun will be equal to the sum of the distances of the Earth and Mercury; double the distance of the Earth from the Sun will be very nearly equal to the sum of the distances of Mars and Venus; the difference being only 1-10 of the double distance of the Earth; double the distance of Jupiter from the Sun will be nearly equal to the sum of the distances of Saturn and Mars, the difference being less than 1-17 of the intermediate doubled; four times the distance of Mars from the Sun will be nearly equal to the distance of Jupiter and Saturn from the Sun added to each other; while the new planet will very nearly equal the distances of all the others added together; they exceeding it by 3 only; which is but 1-60 of the distance of the newly-discover'd Planet.

If, as many have suspected, an intermediate planet be suppos'd between Mars and Jupiter, whose distance to that of Mars should be as 39 to 15, the proportion of the distance of each intermediate planet added to itself, being equal to the sum of the two extremes added together, would very accurately obtain for five of the planets nearest the Sun; and in that supposition the sum of the distances of the four inferior planets would be nearly equal'd by the distance of the 5th, the sum of the distances of the 8th planet would exactly equal the sum of the distances of the three next to it, and the distance of the 7th planet, which would thus be Saturn, would almost exactly equal the distance of the three planets next below him.

If a planet were taken at 1/4 a greater distance than Mars from the Sun, the double distance of Mars would equal the sum of the distance of its two extremes on either side, consider'd as a mean term, the suppos'd planet and the earth. If it be objected that the attraction of Jupiter would be too considerable to allow of our sup-

* Maclaurin; in his View of the Discoveries of Sir Isaac Newton. P. 94.
posing a Planet thus situated, it would be small indeed to that of Jupiter and Saturn on the Herschelian Planet.

There seems, therefore, to be much reason to expect the discovery of such an intermediate * Planet.

For it seems very improbable, when even the Planets most distant from the Sun, and most liable therefore to disturbance from the attraction of neighbouring planets, (as their gravitation toward the Sun diminishes by their distance, and is as its square inversely,) never amount quite to double the distance of their nearest planet from the Sun, that Mars, so much nearer, should have the nearest planet beyond him above quadruple of his distance from the Sun.

If such a Planet be suppos'd to exist, and to be 1/9 less in diameter than Mars, about equal to the differences of the latest computed proportion between Jupiter and Saturn, (and it cannot well be imagin'd more than this,) its diameter in perigee, at five times the nearest distance of Mars from the Earth, would be about 5", which is less than half the diameter of Mercury; it would perhaps more probably be to Mars, as the diameter of Mars to that of the Earth; and then, being not much more than half the diameter of Mars, and at five times the perigeean distance, it could be seen from the Earth under an angle of only about 2¼ or 3 seconds. Now, the new discover'd Planet, which is scarcely at all discernible by the eye, and with some difficulty by a good telescope of considerable power, though its position and appearance have been for nineteen years back since its discovery nearly ascertain'd, is observ'd to have an apparent diameter of four seconds. A planet, therefore, of not more than three seconds might well be expected to elude the eye, and hitherto even the telescope; considering the total uncertainty near what part of the ecliptic we should be to look for it, and that its apparent motion, if at twice the distance of Mars, would be small. If its superior light above that of the Herschelian planet, from its comparative nearness, be objected, that light would depend on other circumstances also: if subject to such refraction as Mars appears to suffer, it would be very weak and obscure at such a distance, and, if seen under an angle of five or six seconds only, perhaps hardly discernible. Mars, when near to his apogee, and seen under an angle of two or three seconds, would disappear to us, if his place were not so well known. Now, even in perigee, or nearest distance to the earth, the apparent diameter of such a planet can hardly be suppos'd to exceed Mars in its apogee; and in apogee such a planet, even if its place were known, would hardly indeed be visible even to the best telescope.

But whether such a planet exist or not, some judgment may be form'd from what does appear of the principle and application of the Pythagorean harmony of the planetary spheres. The idea indeed of harmony in the full extent of the term, adaptation, accord, congruity, beautiful and sublime fitness of the means to the best and most perfect

* In Long's Astronomy, Art. 938, there seems considerable presumption that two stars set down were a Planet with ecliptic progress; and by the date it seems that the Herschelian would not then have been in that part of the ecliptic.
The following report appears to be the first description of Piazzi’s monograph that was published in the British media (while the monograph itself was published in *The Philosophical Magazine* (1802b)):

Piazzi has favoured me with his Tract published in Italian, viz.—Resultati delle Observazione della Nuova Stella; scoperta il Di Gennajo (1801) All’Osservatorio Reale di Palermo. If you have not seen it I would observe that it consists of 25 pp. sm. 8vo. and is written with elegant perspicuity and the modesty and simplicity of a man of science. He at first thought it a Planet: but afterward for a time suspected it to be a Comet, from its great diminution of light. Probably therefore it has, like Mars, a very dense and variable atmosphere. And if so this may account for the very great difference of its observ’d apparent Magnitude last year at Palermo and here in England last month. The highest diameter that at Palermo of 7″ makes it a third greater than the Earth, the lowest here of 2″ or even 1″ make it less than the moon, or at most about equal, as such small apparent magnitudes cannot be precisely ascertain’d. I think it is probable considering its position in the system, that it is somewhat less than Piazzi’s apparent magnitude would make it, but much greater then the other observations here would indicate. He gave up his suspicion of its being a comet when he found that its computation in a parabolic orbit would agree with the observations: and that consequently it must be presum’d to move like the regular Planets of our system in an ellipsis nearly approaching to a circle. And by calculating on an ellipsis of small Eccentricity it was re-discover’d. The Observations of this year seem to confirm its being a Planet.

Piazzi states that Bode in 1772 had calculated (from theory as it seems of a harmonic ratio of intervals between the Planets), that such a Planet would hereafter be discover’d at nearly the distance which this is found to be from the sun. (Lofft, 1802a).

Lofft claimed to be communicating with both Piazzi and a certain La Gamo in Palermo, but the identity of La Gamo is unknown:

Mr. Capel Lofft desires us to state, that he has been favoured by Signor La Gamo, Professor of Astronomy at Palermo, with further observations on the *Ceres Fernandez* [sic], or *Piazzi*, planet: from the results of which, as made by eminent astronomers, in various places, he thinks the diameter may be fairly taken as not less than 3½″. Its surrounding circle of nebulous light is a remarkable circumstance; but perhaps Mars would appear, he conceives, with like nebulosity if removed to an equal distance, and his light proportionably [sic] weakened. (Lofft, 1803; his italics).
5.10 Sir Henry Englefield

Henry Charles Englefield was born in 1752. He was elected Fellow of the Royal Society in 1778, and Fellow of the Society of Antiquaries in 1779. He was also a Fellow of the Linnaean Society. After serving for many years as Vice-President of the Society of Antiquaries, he became its President in 1811 (Wroth, 1885-1900: 374).

Englefield was much interested in the smaller bodies of the Solar System, having written the book *The Determination of the Orbits of Comets, According to the Methods of Father Boscovich, and M. De La Place, with New and Complete Tables* (1799). He also published *Tables of the Apparent Places of the Comet in 1661, Whose Return is Expected in 1789; with a New Method of Using the Reticule Rhomboid* (1788).

Englefield was knighted by King George III, and became a Baronet in 1780 on the death of his father, who also was named Sir Henry. Henry Charles Englefield died at his house in Tylney Street, Mayfair, on 21 March 1822 at the age of 70.

He was highly regarded and widely mourned by the scientific establishment, as attested by some of the following remarks in his obituary:

Sir Henry Englefield was an excellent chemist, a profound antiquary, an able mathematician, a finished classic, and in fact there was hardly any department of literature or science in which he did not excel. His critical taste was of the highest degree. It would be unjust to omit that the mental endowments which furnished such varied sources of refined pleasure to himself, were rendered equally advantageous and interesting to others, by the medium of a correct and easy style, the ornament of elegant manners, and above all, by innumerable instances of his amiable and benevolent disposition. (*The Gentleman's Magazine*, 1822).

Englefield was one of the few people in England to be kept apprised about the discovery of Ceres by Herschel himself (in a letter of October 1801). He observed it in February 1802, and wrote about it to Thomas Young:

I have seen the new planet twice, on Sunday night, and again last night. It is just visible to a common night-glass. With a power of 90 in my great telescope it was less bright than the 34 Virginis, near which it is. With a power of 200 no disc is visible, and with 300 I can scarcely say that it has a sensible diameter, more than what arises from irradiation, for small stars seen with such powers always appear dilated.

I looked at the Georgian [the planet Uranus] soon after the new planet, but clouds came on, and I did not try 300 on it last night. With 200 the Georgian is, I am sure, the brighter, and it was a very much more visible object in the night-glass.

Sunday

Last night I again saw the new planet, and observed it with a power of 400. With this great power it seemed to have an apparent magnitude, but was extremely small, faint, and ill defined. I then turned the telescope to the Georgian (which as you know is very near), and the superiority in size and brightness was very striking. The Georgian was not well defined, but I am sure it was full four times the diameter of the new planet, and much brighter in proportion to the different size. Indeed the brightness of the Georgian is very surprising, its vast distance from the sun being considered. I really think that the diameter of the new planet cannot exceed a second; and it is of a very faint light even for that diameter. I looked then at the double star gamma Virginis, and saw the two stars distant from each other full three times their apparent diameter, a proof of the good adjustment and high power of my telescope. (Englefield, 1802: 197).

5.11 Thomas Firminger

Thomas Firminger (1775–1861), who was an assistant to Nevil Maskelyne at the Royal Greenwich Observatory from 1799 to 1807, contributed some data about the asteroids to the magazines and journals of the day. To *The Philosophical Magazine*, for example, he published two tables of positions for Vesta. The first, from 27 April to 20 May 1807, “… were reduced from meridional observations.” (Firminger, 1807: 161). The second set, from 23 May to 22 June, “… do not claim so much merit in
point of accuracy, being deduced from comparisons with stars out of the meridian; they are, however, as accurate as such observations can be made.” (Firminger, ibid.).

Firminger’s single positional point for the date of 22 June 1807 was also published in the New Series of the Mathematical Repository (1809: 193).

Maskelyne indicates in his personal logbook notes that he cannot rely on Firminger entirely because of lack of experience. For an observation made on 15 April 1802, Maskelyne says Firminger estimated the magnitude of Pallas to be 7, “... but he makes magnitudes too great, not being used to it.”

XXV. On the Orbits of the newly discovered Planets. By Mr. Firminger, late Assistant at the Royal Observatory, Greenwich.

Since the discovery of the four small planets Ceres, Pallas, Vesta, and Juno, little seems to have been known in this country respecting their situations. The astronomers on the continent, however, have been more successful, and have not only kept up a constant series of observations on these small bodies, but have, with that indefatigable labour and address in the application of mathematics to every department of science, for which they are so peculiarly eminent, availed themselves of every opportunity to improve the elements of their orbits, and have given from time to time more correct ephemerides of their geocentric places. Unfortunately, the political affair pending between this country and France have precluded us the advantage of their investigations. It is therefore much to be regretted, that none of our own mathematicians and astronomers have imposed upon themselves the laudable and interesting task of furnishing the practical astronomer with such helps as might enable him to observe these planets at least in those positions of their orbits the most necessary to give the best determinations of their respective elements. Plate III, first given by Mr. Bode, but considerably enlarged, represents the relative situations of the orbits of these four planets, with respect to themselves, to Mars, and to the Earth. The dotted parts of the circles represent the southern half of their orbits, and the undotted parts the northern half. The positions of the planets on their respective orbits will be seen from the following tables of reference.

### Positions of Ceres.

<table>
<thead>
<tr>
<th>Position</th>
<th>Date</th>
</tr>
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<tbody>
<tr>
<td>a</td>
<td>January 1, 1808.</td>
</tr>
<tr>
<td>b</td>
<td>July 1, 1808.</td>
</tr>
<tr>
<td>c</td>
<td>January 1, 1809.</td>
</tr>
<tr>
<td>d</td>
<td>July 1, 1809.</td>
</tr>
<tr>
<td>e</td>
<td>January 1, 1810.</td>
</tr>
<tr>
<td>f</td>
<td>July 1, 1810.</td>
</tr>
<tr>
<td>g</td>
<td>January 1, 1811.</td>
</tr>
<tr>
<td>h</td>
<td>January 1, 1812.</td>
</tr>
<tr>
<td>i</td>
<td>July 1, 1812.</td>
</tr>
</tbody>
</table>

### Positions of Pallas.

<table>
<thead>
<tr>
<th>Position</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>January 1, 1808.</td>
</tr>
<tr>
<td>2</td>
<td>July 1, 1808.</td>
</tr>
<tr>
<td>3</td>
<td>January 1, 1809.</td>
</tr>
<tr>
<td>4</td>
<td>July 1, 1809.</td>
</tr>
<tr>
<td>5</td>
<td>January 1, 1810.</td>
</tr>
<tr>
<td>6</td>
<td>July 1, 1810.</td>
</tr>
<tr>
<td>7</td>
<td>January 1, 1811.</td>
</tr>
<tr>
<td>8</td>
<td>July 1, 1811.</td>
</tr>
<tr>
<td>9</td>
<td>January 1, 1812.</td>
</tr>
<tr>
<td>10</td>
<td>July 1, 1812.</td>
</tr>
</tbody>
</table>

### Positions of Vesta.

<table>
<thead>
<tr>
<th>Position</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>k</td>
<td>May 2, 1808.</td>
</tr>
<tr>
<td>l</td>
<td>November 2, 1808.</td>
</tr>
<tr>
<td>m</td>
<td>May 18, 1809.</td>
</tr>
<tr>
<td>n</td>
<td>May 29, 1807.</td>
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<tr>
<td>o</td>
<td>June 19, 1807.</td>
</tr>
</tbody>
</table>

### Positions of Juno.

<table>
<thead>
<tr>
<th>Position</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>January 1, 1808.</td>
</tr>
<tr>
<td>y</td>
<td>July 1, 1808.</td>
</tr>
<tr>
<td>z</td>
<td>January 1, 1809.</td>
</tr>
<tr>
<td>α</td>
<td>January 1, 1810.</td>
</tr>
<tr>
<td>β</td>
<td>July 1, 1810.</td>
</tr>
<tr>
<td>γ</td>
<td>January 1, 1811.</td>
</tr>
<tr>
<td>δ</td>
<td>July 1, 1811.</td>
</tr>
<tr>
<td>ε</td>
<td>January 1, 1812.</td>
</tr>
</tbody>
</table>

N.B.—Mr. Groombridge, whose indefatigable labours have been already so productive of improvements in practical astronomy, has observed Ceres at the last opposition, which happened on February 17th. The observed place, which he has done me the honour to communicate, agrees with surprising exactness to the computed one deduced from the last and most improved elements. Mr. Groombridge, I believe, is the only astronomer in this country who has observed this opposition.

Figure 5.16: Firminger’s 1811 paper in The Philosophical Magazine.
After he was dismissed by Maskelyne, Charles Francis Greville (1749–1809), a member of the King’s Privy Council, took an interest in Firminger. At his residence in Milford Haven he established an observatory, and appointed Firminger to superintend the observations. Unfortunately Greville died before this could happen, and Firminger became instead a teacher of mathematics in London (The Anti-Jacobin Review, 1810: 524). He died at age 86 at his residence, Warren-lodge, Edmonton. The paper by Firminger shown above in Figure 5.17 appeared in The Philosophical Magazine (1811: 131-133). Extracts from it were printed in the London journal Retrospect of Philosophical, Mechanical, Chemical and Agricultural Discoveries (1812: 22-23).

5.12 Sir David Brewster

Sir David Brewster has been mentioned many times in this thesis. His personal life was given a book-length treatment by his daughter, Margaret Gordon (1869). Brewster was born in 1781 and initially studied theology. In 1799 his fellow student Henry Brougham, who has also featured prominently in this thesis, persuaded him to study the diffraction of light. His discoveries in this field of study led to his election as Fellow of the Royal Society in 1815, and its Copley Medal. In 1818 he received its other prestigious honour, the Rumford Medal. He became famous with his invention of the kaleidoscope in 1815. Brewster’s editorial talents were equally stellar, first as Editor of the Edinburgh Magazine, and then Editor of the Edinburgh Encyclopedia (from 1808 to 1830). The first ten volumes of the Edinburgh Philosophical Journal were edited by Brewster and Robert Jameson. Brewster then became sole Editor of the Edinburgh Journal of Science in 1824, a position he held through sixteen volumes to the year 1832. In his many hundreds of journal and magazine articles Brewster became the face of science for the public in both Great Britain and America. Brewster achieved his highest honour with a knighthood in 1831, and became President of the British Association in 1849. In 1859 he became Principal of the University of Edinburgh, a post he held until shortly before his death in 1868.

According to Brewster (1814: 324), the discovery of the first four asteroids did not merely present astronomers with a few insulated facts, but rather were the agents by which the harmony of the Solar System was destroyed (a mighty task for four tiny objects!):

They exhibit to us new and unexpected phenomena, which destroy that harmony in the solar system which appeared in the magnitudes and distances of the planets, and in the form and position of the orbits. The six planets, which were formerly supposed to compose our system, were placed, excepting in the case of Mars and Jupiter, at somewhat regular distances from the Sun; they all moved from west to east, and at such intervals as to prevent any extraordinary derangements which might arise from their mutual action. Their magnitudes, too, with the exception of Saturn increased with their distance from the centre of the system; and the eccentricity, as well as the inclination, of their orbits, was comparatively small. In the system, as it is now understood and delineated by the most accurate observers, we find four very small planets between the orbits of Mars and Jupiter, placed at nearly the same distance from the Sun, and moving in very concentric orbits which intersect each other, and are greatly inclined to the plane of the ecliptic. The satellites of the Georgian planet, likewise, move almost at right angles to the plane of the orbit; and, what is still more surprising, the direction of their motion is opposite to that in which all the other planets and planetary bodies, whether primary or secondary, circulate round their respective centres.
5.13 Sir William Watson
Sir William Watson (1744–1824), was, like his father, a physician and naturalist. He was born in London in early September 1744 and educated at Charterhouse before entering Queens’ College, Cambridge, as pensioner on 17 February 1761, whence he migrated to Gonville and Caius College on 26 April 1762. Watson obtained his MB in 1766 and was elected Fellow of the Royal Society on 10 December 1767. A resident of Bedford Square in London, he graduated MD in 1771, then practised medicine in Bath. In December 1779 he joined the new Bath Philosophical Society, and was instrumental in introducing William Herschel, then a Bath musician, to the Society’s membership. Watson became Herschel’s close friend and correspondent. They discussed problems in natural history and astronomy and collaborated on measures of the heights of the hills round Bath, the results being published in 1810 in Joseph Wilson's *History of Mountains*.

Watson supplied Herschel with a valuable nebular catalogue in late 1781, successfully lobbied for Herschel’s royal pension in 1782, produced important drawings of Herschel’s 7-foot telescope in 1783, and in 1784 advised on the proper depiction of Uranus on Josiah Wedgwood’s portrait medallion of Herschel.

In 1785 he published *A Treatise on Time*, a philosophical essay dedicated to Herschel and heavily indebted to Joseph Priestley (1733–1804), another member of the Bath Society. Watson was linked by marriage with some members of the Lunar Society of Birmingham.

He was knighted on 6 March 1796, joined a revived Philosophical Society in Bath in 1799, and became the city’s Mayor in 1801. It was to Watson who Herschel turned for advice on a word to describe Ceres and Pallas, but his suggestions were rejected (Subsection 4.2.1). Watson died in Bath on 15 November 1824 (Schaffer, 2004).

5.14 Baron George Best
George August Best (1756–1823) was a Privy Councillor to the Royal Court of England, Knight Commander of the Royal Guelphic Order (KCH), and Chamber Secretary for the Electorate of Hanover. Best achieved his highest honour when he became a Baron (1816). When he was elected Fellow of the Royal Society (1791), his nomination paper was signed by Herschel, Blagden and Aubert (Figure 5.17), who became FRS in 1772. The nomination paper included the fact that Best was a Member of the free Oeconomical Society of Russia (Royal Society Archives, GB117). This Society was established in 1755 to promote agriculture in Russia.

Best (of German ancestry) studied law at Göttingen, as did his long-time friend Schröter—they served together in the Chamber in Hanover in the 1770s. Best arranged for the instruments of Lilienthal Observatory to be sold in 1799 to the University of Göttingen (Gerdes, 1991: 217). As revealed by letters held by the Royal Astronomical Society from Best to Herschel (W.1/13 B.61-64), Best served as an intermediary between him and Schröter for various purchases of astronomical equipment in the 1780s.

Of particular relevance here, Best was kept informed about Schröter’s observations of the asteroids. As we have already seen (Section 3.1.3), Schröter wrote two letters to Best in 1802 about the asteroids. The fact that they ended up in the Herschel Archives and the Royal Greenwich Observatory shows that Best was forwarding his correspondence from Schröter to Herschel and Maskelyne. Whether Schröter intended this or not cannot be known, although he probably expected it would be sent along to Sir Joseph Banks as well. This is confirmed in a letter from
Banks to Herschel on 23 April 1803 (Banks, 1803d; see Appendix D.1). Schröter’s letter about the discovery of Pallas (Schröter, 1802a; see Appendix D.3) was written directly to Best, who certainly shared it with anyone in London who was interested.

Best’s most interesting role in the saga of the asteroids as understood in England has to do with his report to Schröter about the Royal Society meeting of 6 May 1802. It involves an important historical point about the word ‘planetules’ (or, in the case to be discussed, ‘planetulas’) and the confusion that was caused in Germany about what word Herschel chose to describe Ceres and Pallas. Nowhere in Herschel’s seminal paper (Herschel, 1802b) are Ceres and Pallas termed ‘planetulas’, but as we can see in the correspondence between Carl Gauss and Wilhelm Olbers in 1802, they thought he had.

This is an extract from a letter Olbers sent to Gauss, in which he is quoting from a letter by Best sent to Schröter on 7 May 1802. Schröter then forwarded it to Olbers, who on 23 May relayed it to Gauss:

Herschel’s observations of Ceres and Pallas were read in the Society yesterday (6 May). They go to the 2nd or 4th of May... He denies they have any cometary and planetary characteristics and wants to name them planetulas, without thereby detracting from the discovery in the least. (Olbers, 1802b; underlining probably by Best).

Gauss (1802d) replied to Olbers, and correctly made the point that ‘planetula’ is the diminutive of ‘planeta’:

To want to distinguish between ‘planeta’ and ‘planetula’ seems to me to be almost pedantic. Mercury, Venus, Earth and Mars are also ‘planetulae’ compared with Jupiter, and perhaps our Sun compared with other fixed stars would just be a tiny ‘solculus.’

By 24 May, Olbers was aware that Herschel was using the term ‘asteroid’ to denote Ceres and Pallas as he was the first Continental astronomer to use the new word in private correspondence, as evidenced by his letter to the French astronomer Lalande (Olbers, 1802c). Based on what he read from Best via Schröter, Olbers may have believed Herschel used ‘planetulas’ in his Royal Society paper of 6 May, so it was Best’s account of the reading of Herschel’s paper that was the source of the confusion.

The other important point to note is that Best’s account of the Royal Society meeting of 6 May was the first one to be sent to any astronomer in the Continent. It was clearly sent the very next day, 7 May, so we can be fairly confident that Schröter was the first one to read about Herschel’s initial research results on Ceres and Pallas.
6.1 The Lack of Theoretical Work in England

6.1.1 Newton and Leibniz

Sir Isaac Newton’s (1643–1727; Figure 6.1) invention of calculus in England was one of the greatest mathematical achievements of all time, and certainly the foremost by any English mathematician. But the independent development of calculus on the Continent by Gottfried Wilhelm Leibniz (1646–1716), while beneficial for the long-term development of calculus, left English mathematicians behind because of its very different formulation. Even though the state of affairs in mathematics in England around 1800 is the prime concern here, a century earlier its health was scarcely any better (Newton alone excepted).

Figure 6.1: Sir Isaac Newton (courtesy: en.wikipedia.org).

Including a reference to Jacob (or James) Bernoulli (1654–1705), here is the view from 1802 of the French mathematician Edme Marie Joseph Lemoine d’Essoies (1751–1816), looking back to the previous century:

The methods which Newton discovered, and which enabled him to investigate all the great questions in mechanics and astronomy, were for some time a hidden treasure, of which he was the sole proprietor. And it is singular, that the English geometricians knew nothing of the new calculi, except what they collected in the Acta Eruditorum of Leipzig. James Bernoulli (a Swiss) was the first geometrician whose eyes were opened, and who began to second efforts of Leibniz. (Lemoine, 1802).

Were English astronomer/mathematicians too complacent to work on the orbital problems posed by the discoveries of Ceres and Pallas? To posit the question so boldly invites the insidious French trap, the question mal posée—that is, to distort the problem by oversimplifying it. The answer lies not just in mathematics, but in philosophy:
The brilliant achievements of British mathematicians, astronomers and physicists under the influence of Isaac Newton were followed by a long period of comparative inactivity. This was largely due to the fact that, during a considerable part of the eighteenth century, members of the British school were, more or less, out of touch with their continental contemporaries. A free exchange of views is essential to vigour and, the more varied the outlook and training of those concerned, the more fruitful is the intercourse. The effect of this isolation, moreover, was intensified by the manner in which English writers strove in their demonstrations to follow Newtonian forms. If Newton, in his *Principia*, confined himself to geometrical proofs, it was because their validity was unimpeachable; and, since his results were novel, he did not wish the discussion as to their truth to turn on the methods used to demonstrate them. But his followers, long after the principles of the calculus had been accepted, continued to employ geometrical proofs, whenever it was possible, even when these did not offer the simplest and most direct way of arriving at the result. In short, we may say that, in the course of English mathematical science, the last seventy years of the eighteenth century form a sort of isolated backwater.


To some extent, this malaise can be traced to the philosophical works of George Berkeley (1685–1753; Figure 6.2), who had a great influence on British thought during the Enlightenment. His views were also well known in Germany, as evidenced by the reference to Berkeley by Seyffer, quoted in Subsection 4.2.5 of this thesis. Berkeley pointedly asks towards the end of *The Analyst* (1736: 93):

> Whether mathematicians, who are so delicate in religious points, are strictly scrupulous in their own science? Whether they do not submit to authority, take things upon trust, and believe points inconceivable? Whether they have not their mysteries, and what is more, their repugnancies and contradictions?

One consequence of the controversy begun by Berkeley was a dramatic increase in the publication of English textbooks on calculus, especially between 1736 and 1758 (Guicciardini, 1989: 58). During this period twelve textbooks on fluxions were published, Berkeley’s attacks on Newtonian mathematics and the parallel developments on the Continent that advanced mathematics in ways that differed...
from the English (i.e. Newtonian) method worked in tandem to create the ‘isolated backwater’. Elizabeth Garber of the State University of New York has argued that the concept of such an ‘isolated backwater’ is unfounded, but she does draw a distinction between British and Continental mathematics:

Mathematicians [in England] were neither isolated nor cramped. However, during the eighteenth and early nineteenth centuries, mathematics served very different cultural purposes in Britain than those on the continent. As the foundation of a “liberal education” at Cambridge, mathematics served a social and cultural function unknown in continental Europe. The type and level of mathematics taught was directed towards developing standards of logical consistency rather than technical competence. (Garber, 1998: 188).

In France, the intellectual milieu of the mathematicians was dominated by René Descartes (1596–1650; Figure 6.3), for whom clarity and distinctness were warrants of truth (Graham and Kantor, 2009). Thus, when the discoveries of Ceres and Pallas demanded a novel mathematical approach, there was no one in England capable of rising to the challenge.

It is also important to understand the fluid nature of disciplines at the time. The case of Dugald Stewart (Figure 6.4) is a case in point. His father was a Professor of Mathematics at the University of Edinburgh, a post Dugald Stewart assumed on his father’s death. Then in 1785 he succeeded Adam Ferguson to the Chair of Moral Philosophy, where he studied the work of Locke within the framework of the Newtonian methodological heritage (Mortera, 2010). The links between Stewart, Brougham and Thomson have been noted earlier in this thesis (Subsection 4.2.2.4).

![Figure 6.3: René Descartes. (courtesy: en.wikipedia.org)](image1) ![Figure 6.4: Dugald Stewart (courtesy: en.wikipedia.org)](image2)

The Scottish contribution to the problems of British mathematics cannot be overestimated. Nearly all renowned British mathematicians of this time were both Scottish and ardent Newtonians. Scottish mathematicians are seen to have presided over the era in which British mathematics fell behind because of their collective adherence to geometry (Withers and Wood, 2002: 150). However, as Wickman (2009: 121) has perceptively pointed out, “Geometry in eighteenth-century Scotland was a cultural rather than simply a mathematical battleground, and the mistake in perceiving it as retrograde is a function of seeing it too narrowly.”

More generally, it is also crucial to recognise the inherent attributes of the Germans, the French, and the English. This triad, which was famously recognised by
the philosopher Georg Wilhelm Friedrich Hegel (1770–1831), was examined in great detail in The British Quarterly Review. The paper may have been written by the Review’s editor, Robert Vaughan (1795–1868). Casting the argument in an astronomical perspective, the author notes that England is the most

... comfortable [country in the world], so that if we wished to give some starveling inhabitant of Saturn or Georgium Sidus a fair idea of what is to be done in the way of making things ‘snug’ in the planet Terra, we should direct him to an English hotel. (The British Quarterly Review, 1851: 350).

In remarks that can surely be applied to William Herschel, who was born in Germany, the author notes that the English were colonised by peoples from Germany, and that “… German thought, through various channels, does exercise a decided influence on the opinions and principles of at least the three other leading nations of the world—France, England, and America.” (The British Quarterly Review, 1851: 356). In tracing the flow of this thought from Germany, he says “… the ideas which wound a slow and tortuous course through long sentences of German introversion, which were clipped and cut down and suited to the powers that be, in English, will come out clear, terse, and sparkling in French.” (The British Quarterly Review, 1851: 340). This concept may be kept in mind as we consider some of the philosophical underpinnings that influenced the development of mathematics in these countries.

6.1.2 Contemporary Views on the State of Mathematical Astronomy in Great Britain

Earlier in this thesis (Subsection 5.2.2.1) a paper by David Brewster (1802b) was quoted regarding the recent discovery of Pallas. In the final section of the paper dated 23 April 1802, Brewster laments the state of astronomy in England and Scotland:

We cannot conclude this paper without remarking the great progress of astronomical science, which has lately taken place. The discovery of three planets within the space of about twenty years, affords some reason for supposing that we are but little acquainted with the system to which we belong; and that some future period will disclose to our view, a plan more extensive and magnificent than the imagination of man has, as yet, conceived. But while we thus rejoice in the rapid progress of the noblest of sciences, we are concerned to state, that this progress is chiefly owing to the assiduity and genius of continental philosophers. It is a disgrace to our own country, that practical astronomy is so much neglected by men in a private capacity, and that so little has been done in Britain to forward this branch of physical science. We except, however, from this remark, the labours of Dr Herschel, as being the result of regal munificence, and not of public spirit. But to Scotland it is most particularly applicable. There is scarcely in this country an observatory of any importance, and some of those which are honoured with the name, are left in the most deplorable and ruinous condition. Who has not lamented, and lamented, too, with indignation, the ruinous state of the observatory in the metropolis of the kingdom?—fitted scarcely for the amusement of ladies and children, and far less for the improvement of Astronomical Science. Let it not be supposed, however, that this neglect of practical Astronomy arises from the indolence and inability of our countrymen. It is owing, without doubt, to the want of a Court to countenance and reward her deserving sons, and to that defect of literary talent and public spirit, which is so strikingly visible in the nobility of our land. (Brewster, 1802b: 287).

The state of mathematics in England may also be gauged by a contemporary assessment of a two-volume book published in 1815, which was directed at the British student. An Easy Introduction to Mathematics was written by Charles Butler (1750–1832; 1814) and critically reviewed in The Monthly Review, 1816. One passage is of particular relevance to the analysis in this section:

The chapter on Numbers seems to have been principally drawn from an old edition of Bonnycastle’s Arithmetic [John Bonnycastle, 1751–1821]: but all the more important numerical theorems which we owe to Fermat [Pierre de Fermat, 1607–1665], Euler, Waring
[Edward Waring, 1736–1798], Lagrange [Joseph-Louis Lagrange, 1736–1813], &c. are totally omitted; which certainly could never have happened if the author had been aware of the distinct treatises on this subject by Gauss and Legendre [Adrien-Marie Legendre, 1752–1833].

So the book, which was supposed to offer students a modern introduction to mathematics, was actually oblivious of the Continental advances.

More generally, this synopsis from 1807 of what a student should expect from an education at Cambridge is telling:

The purpose for which a young man is taught natural philosophy at the University of Cambridge, is at once to invigorate the intellect by an exercise specially adapted to strengthen and subtilize its operations, and to furnish that kind of information respecting the qualities and affections of objects of daily occurrence, as shall conduce to the pleasure, advantage, and respectability of his future life. (The Critical Review, 1807).

Thus an advanced education at England’s foremost university is described in terms that might be most appropriate for a ‘finishing school’ to prepare men for the pleasures of a refined life. The use of subtilize, which means ‘to elevate in character’, clearly has precious little to do with training in mathematical or astronomical research.

A writer in The Edinburgh Review in 1819 (possibly Brougham), elucidated the reasons for the sad state of English mathematics in the review of an astronomy book by Robert Woodhouse (1773–1827). In a digression from a strict review of the book, amounting to several pages, the reviewer attacked the Royal Society: “It is indeed much to be lamented that this Institution, intended for the advancement of science, should hold out so little encouragement to Mathematics.” He also fingered as a main culprit …the very extensive dissemination of general knowledge, which is so much the case over the whole of this kingdom. Literature and the Arts give abundant occupation to the mind of a man of liberal curiosity, and leave less inducement to attach himself to abstract studies … Nowadays, a man must be conversant in chemistry, mineralogy, entomology, modern languages, history, politics, and fifty hard-worded studies beside- so that, in fact, unless he choose to devote himself almost exclusively to Mathematics, he has little chance of aspiring to discovery, or even to eminence, in that pursuit.

In 1821, Dugald Stewart linked Leibniz with what he called “… the continental philosophy …”, suggesting that a habit of “… deference to the authority of Leibniz …”, combined with a short-sighted mistrust of honest John Locke (1632–1704: Figure 6.5), might be responsible for the “… striking contrast between the characteristic features of the continental philosophy … and those of contemporary systems which have succeeded each other in our own island.” (Rée, 2009: 25).

That men of science on the Continent might have looked askance at Locke, the most influential Enlightenment philosopher England produced, is an intriguing insight in the thinking of the time. Locke was often mentioned, by the English, in the same breath as Newton, as is well attested by some lines penned by David Garrick (1717–1779; 1755):

In the deep mines of science though Frenchmen may toil,
Can their strength be compar’d to Locke, Newton, and Boyle?

The concept that different regions would produce genii of different natures had been recognised in England for centuries (Barclay, 1633: 26):

That every age almost, hath a particular Genius different from the rest; that there is a proper Spirit to every Region, which doth in a manner shape the studies, and manners of the inhabitants, according to itself. That it is worth the labor, to find out those Spirits.
The “Region” inhabited by the English has for centuries been characterised as unintellectual. Here is the assessment of Sir Lewis Bernstein Namier (1888–1960), one of the most eminent British historians of the first half of the twentieth century, writing in a book about the late eighteenth century:

… the characteristically English attempt to appear unscientific springs from a desire to remain human. What is not valued in England is abstract knowledge as a profession. (Namier, 1961: 14-15).

Nothing could be considered more abstract than a knowledge of mathematics. The dearth of mathematical knowledge amongst British astronomers and instrument-makers was examined by James David Forbes (1809–1868; 1856: 848), Professor of Natural Philosophy at the University of Edinburgh:

Until very recent times, with few exceptions, our observers, however industrious, have merely used mechanically the apparatus put into their hands by intelligent and conscientious artists, who yet, never having occasion to apply their own handiwork to the purposes for which it was made, could not be expected to detect deficiencies of construction, nor to possess the mathematical knowledge required to remedy them.

More generally, Forbes (1856: 806) uses a quote from Jean-Baptiste D’Alembert (1717–1783), one of the greatest of all mathematicians, to place the state of affairs in England in proper context:

Some idea may be formed of the negation of mathematical talent in Britain during the later portion of the last century, when we find D’Alembert declaring, in 1769, that if an Englishman is to be elected one of the eight foreign associates of the Academy of Sciences, he will vote for [Philip] Earl Stanhope [1774–1786], as the best mathematician there, as he believes, not having read any of his works! If the choice was to be free, he should prefer M. de Lagrange!! A more cutting, though unintentional satire on the state of Mathematics in this country could not have been written.

Forbes (ibid.) agrees with the view put forward in Ward and Waller (1907-1916: 37-38) that the prime reason for this lack of knowledge was the use on the Continent of the

… Leibnitzian notation of differentials which was absolutely unfamiliar in England, [which] deterred almost every one even from perusing the writings of Clairaut [Alexis Clairaut, 1713–
and D'Alembert [Jean-Baptiste le Rond d'Alembert, 1717–1783], Lagrange and Laplace.

The notation of differentials, “… which could alone break down the barrier between British and foreign mathematicians, was first introduced at Cambridge by the efforts of John Herschel and Dean Peacock [George Peacock, 1791–1858] about 1816.” (Garber, 1998: 190). They, along with Edward Thomas Ffrench Bromhead (1781–1855), were the core of the Analytical Society which published its first and only book (written by Babbage and John Herschel) in 1813. The state of mathematics at that point may be gauged by the reaction to this book by Bromhead, who wrote that the Memoirs “… were too profound to do us any good and not one mathematician in 1000 can understand them.” (Cannell, 2001: 38). To remedy the situation, Babbage, Herschel and Peacock published an English translation of Sylvestre Lacroix’s (1765–1843) calculus book (Traité du Calcul Différentiel et du Calcul Intégral) in 1816, followed in 1820 by a book of worked examples in the new notation. Credit must also be given to Charles Hutton (1737–1823), Peter Barlow (1776–1862) and William Wallace (1768–1843; Professor of Mathematics at the University of Edinburgh), who introduced the French calculus to British mathematicians.

The sad state of English mathematics in the late 18th and early 19th centuries was well known, and commented upon by John Herschel in 1830:

In England, whole branches of Continental discovery are unstudied, and, indeed, almost unknown even by name. It is in vain to conceal the melancholy truth. We are fast dropping behind. In mathematics we have long since drawn the rein, and given over a hopeless race. (Quoted in Sime, 1900: 97).

This ignorance by the English of “branches of Continental discovery” did not go unnoticed by other authors:

Our Continental neighbours the Germans and the French, by no means neglecting to investigate the works of nature, and certainly gaining ground upon us in the processes of manufacture, have thought it also worth their while to study the philosophy of history, the philosophy of the fine arts, and the history of philosophy itself, of which three great branches of knowledge we scarcely possess even the idea. (The Quarterly Review, 1838: 501).

The anonymous reviewer in The Quarterly Review contrasts this absence of intellectual rigour to the English preference for the solution of more practical problems, an attitude he makes clear that does not motivate the greatest scientists, French, German or English:

Astronomy may occur to our readers. It is well known that an accurate knowledge of the motions of certain satellites is useful to the masters of vessels. But was this the object which animated Laplace in his profound mathematical studies, or was it this which pointed our Herschel’s telescope at the Georgium Sidus or the binary stars? (ibid.).

The state of English science, and its lack of theoretical versus practical achievements, was echoed a century later by the English astronomer Henry Crozier Plummer (1875–1946):

If the eighteenth century appears a dull and unenterprising period in English science, there are reasons for it. Newton established no school, and his country took no significant part in the triumphs of Euler, Lagrange and Laplace. The Royal Society passed into the hands mainly of dilettanti, and the English universities equally failed to see the opportunity for scientific studies. But the record is far from being one of unrelieved gloom. It is only necessary to remember that astronomy at least had two giants in James Bradley and William Herschel. (Plummer, 1943: 92).

Plummer goes on to give the names of such instrument-makers as James Short (1710–1768), John Bird (1709–1770), Ramsden and Dollond. So, “Admittedly England lagged behind in the field of mathematics, but compensated for this grievous error by the quality of the artists, such as those named.” (ibid.).
Specifically in the field of asteroid studies, a lot of work was done in the first few decades of the nineteenth century on the theories of the four asteroids. This was accomplished—first and most famously—by Gauss (1809) in Germany, and later extended by Giovanni Sante Gaspero Santini (1787–1877) and Francesco Carlini (1783–1862) in Italy, Ernst Schubert (1813–1873) and Friedrich Bernhard Gottfried Nicolai in Germany, and Pierre Daussy in France.

Again, England was notably absent (Airy, 1833: 156-159). In this survey of astronomy of the nineteenth century, George Biddell Airy (1801–1892; Figure 6.6), who would become Astronomer Royal just two years later, gave a very curious summary of asteroid studies to date, taking several back-hand swipes at the English involvement, or lack of it. While giving the discovery circumstances, he completely omits any mention of William Herschel and his physical study of the asteroids, concentrating almost entirely on orbital and perturbation calculations.

Speaking of Ceres, he notes that after its recovery in 1802 “… it has since been regularly observed at most observatories (at least the continental ones).” (Airy, 1833: 156). On the subject of mathematical work on the four asteroids, he further notes that “… the elements of all these orbits have been successively improved (entirely by the Germans).” (Airy, 1833: 157). Thus, in two parenthetical asides and one glaring omission, he totally dismisses all English involvement, studiously calling them planets so as not to introduce Herschel by way of explaining the introduction of the word ‘asteroid’.

Airy’s deliberate use of ‘planet’ instead of ‘asteroid’ can be characterised as an ‘abusive anachronism’, one of five types of anachronism identified by Thomas M. Greene (1926–2003), Professor of English and Comparative Literature at Yale University. In his typology, Greene (1986: 221) characterises such an anachronism
as one which single-mindedly adheres to a model that clashes contemptuously with contemporary usage. Few people by 1833 could really regard the four tiny objects between Mars and Jupiter as being in the same league as planets such as Jupiter, or even little Mercury. The word ‘asteroid’ was already in widespread use.

The editor of the Literary Gazette made it clear what he thought of the condition of state-sponsored intellectual assistance, on the occasion of the knighthood conferred upon the astronomer James South (1785–1867):

… his Majesty has placed 300 pounds a year at the disposal of Sir James to promote the cultivation of astronomy; a measure which we also hail as indicative of a desire in the highest quarter to rescue the British government from the imputation to which it is (as a government) too justly exposed, of great apathy towards every thing connected with literature, the arts, or science. (The London Literary Gazette, 1830).

The next generation, however, saw improvement, as noted by Samuel Warren FRS (1807–1877; 1854: 31):

Till within the last thirty years, it was considered that our English mathematicians were inferior to their continental brethren in the higher departments of mathematics; but I believe it is generally admitted that the former are now equal to any in the world.

To gain a full understanding of what was—or was not—done in England with respect to the early study of asteroids, we must also consider conditions on the Continent, both from a practical and philosophical perspective. This will serve to conclude the analysis presented in this thesis.

6.2 Theoretical Work in France and Germany
6.2.1 Contemporary Views on the State of Mathematics in Germany

At the turn of the nineteenth century there were only one or two mathematicians of note in Germany. A mathematician was “… essentially a pure drudge, whereas an astronomer was a scientific professional.” (Fauvel, 1993: 9). During the thirty years after the discovery of Ceres, mathematics in Germany experienced a renaissance, but it was not an attempt to copy the French style. “Rather, it was the growth of a new institutional style, a new way of doing mathematics. The kind of mathematics promoted tended towards what we would call ‘pure’ mathematics.” (Fauvel, 1993: 10).

This letter from Zach (1802f; his underlining) to the mathematician Carl Gauss in Brunswick, provides a cogent synopsis of the state of mathematical astronomy in Germany vis-a-vis that of France at the beginning of the nineteenth century:

I need not to say how pleased I was to read that your noble Duke [the Duke of Brunswick] had put you in such a position that allows you to devote yourself entirely and carefree to your sublime science.

The Duke has not only done you but also science a good turn. Mathematics are not strongly supported in Germany these days. And you see the result. The famous Göttingen University has no mathematician since Kästner’s death [Abraham Gotthelf Kästner, 1719–1800]. Let Klügel [Georg Simon Klügel, 1739–1812] die in Halle and Hindenburg [Carl Friedrich Hindenburg, 1741–1808] in Leipzig and there will be no mathematicians except in Brunswick. Stahl in Jena is doing fine but will die of starvation, all my efforts have not been successful to give him that what your excellent Duke gave you voluntarily. Our good Burckhardt had to leave his country to make his fortune otherwise he would have rotted in his little attic room. Töpfer wastes away in Grimma, this excellent head has to teach snotty little brats. In what is France today mathematicians are Senators and Councillors of state. In England they head the payrolls. Only in Germany they are starving. It has to be said publicly how much the Duke of Brunswick protects and supports the mathematic sciences. He gave us Klügel, is preserving Pfaff [Johann Friedrich Pfaff, 1765–1825] and he now gives us Gauss. If only he knew how grateful I am! He bestows his favour on these sciences because he is a great commander and understands how useful these sciences are for an engineer, artilleryman, sapper, and the general staff when you are at war. Friedrich the Great was not an expert on mathematics, but he anxiously made sure that his academy had enough mathematicians. He
had the best heads of Europe. He had Euler, Lagrange and Lambert [Johann Heinrich Lambert, 1728–1777]. In the writings of this great king he sometimes made fun of mathematics! But no, he did not mock mathematics but the mathematicians. And not even this he only mocked Euler because in truth he was angry at him because he left and went to Russia. Hence all the sarcasm that Euler had gone to observe the Great Bear of the North. How well did he not treat Maupertius [Pierre-Louis Moreau de Maupertius, 1698–1759] and Lagrange. You only have to read his letters to D’Alambert and how hard he tried to recruit Lagrange to know how much he wanted this great geometer for his academy. After this great king’s death his excellence the corporal Count Hertzberg, “who wanted to lead the academy like a regiment”, drove this excellent man to France, where Bonaparte, who protects the mathematic and astronomical science, too, made him Senator. Lagrange and La Place are now des grands seigneurs, have equipages in Paris, and earn almost 8,000 Reichsthaler. The German mathematicians deem themselves lucky if they only had a tenth of that! But enough of this jeremiad! Long live the Duke of Brunswick!

Several branches of mathematics, including geometry and algebra, were significantly advanced by German mathematicians in the eighteenth century. Statistics were first reduced to a scientific form in the eighteenth century, by the German Gottfried Achenwall of Göttingen (1719–1772), widely regarded as the father of statistics (P.W., 1801). The entirely practical role of mathematics was also codified for the military—officers in general, and engineers and artillerists in particular—in a 5-volume work by Georg Gottlieb Hahn (1756–1823; 1788), public teacher of the Military Science at the Military Academy of Stuttgart. A review of German progress noted that “Astronomy seems to have been improved more than any other branch of mathematics, in the eighteenth century, in Germany.” (The German Museum, 1802: 484).

6.2.2 Contemporary Views on the State of Mathematics in France

The state of mathematics in France was in marked contrast to that in Germany:

The ideology of the new French Republic from the 1790s onwards was one which promoted mathematics as tremendously significant. Mathematics was taken very seriously, both intrinsically and as a science in the service of the state. In all Europe, it was France where creative mathematics was primarily happening at the turn of the century. (Fauvel, 1993: 9).

While the mathematical vigour in France would seem to have given them the edge in tackling a new problem such as the orbit determination of Ceres, the exact opposite is what actually happened. The person who perhaps best put his finger on why this extraordinary situation occurred is Carl Gustav Jacob Jacobi (1804–1851). In his inaugural lecture as an ordinary Professor at Königsberg in 1832, Jacobi criticized the French mathematicians for putting too much stress on applied mathematics, and for mixing up the true and the incidental causes of progress in science:

We are unhappy that most French geometers who originate from the school of the famous Laplace have presently fallen into this error. While they seek to obtain the only salvation for mathematics in physical problems, they desert that true and natural path of the discipline, which has brought the analytical art to the importance which it now enjoys. In this way it is not so much pure mathematics, but its application to physical problems, that suffers. (cited in Schubring, 1993: 29).

In his Traité de Mécanique Céleste of 1799, Laplace had written that “Astronomy, considered in the most general manner, is a great problem of mechanics. The solution of this problem depends upon the accuracy of the observations and upon the perfection of the analysis.” (cited in Bowditch, 1829: xxiii).

Laplace’s attainment of great renown, both in France and internationally, did not protect him from philosophical attack by one of his own countrymen. Claude Henri de Rouvroy, better known by his title as the Comte de Saint-Simon (1760–1825), shows just how far a dislike of the English could be used to defend the intellectual
honour of France. In an early work, Saint-Simon (1808) declared that Laplace’s scientific achievements were flawed by an excessively derivative and hence unpatriotic adherence to the principles laid down by Newton. While praising the *Traité de Mécanique Céleste* (Figure 6.7) as a work that deserved a place in his ‘temple of glory’, Saint-Simon relegated Laplace to that of a ‘third-order’ talent (Fox, 2012: 40).

The reluctance of many eighteenth century Continental researchers in various fields to adopt the new world order as revealed by Newton is well known, but in the context of this thesis it is worth noting one in particular as it embodies both mathematics and its use in astronomical calculations. The spark was ignited by the publication of a book in which Newton (1728) applied his unique way of thinking to problems of history, theology and mythology. The Jesuit Etienne Souciet (1671–1744; 1727) wrote a lengthy rejoinder to Newton’s work (The manuscript was published in Paris in 1727 before its English language debut in 1728. Newton was still alive when Souciet was writing his reply, but he died in 1727 before reading it). In his rejoinder, Souciet tried to defend the practice of historical chronology, for—if Newton were correct—it could only be done by “… those who could deploy the tools of astronomy.” (Buchwald and Feingold, 2013: 354). Souciet tried to use astronomy
to counter Newton’s calculations, and seemed to imply that applying calculation to human affairs constituted an attack on human liberty, morality and even religion itself—a stark example of the differing approaches of the English and the French in a heady mix of societal values and mathematical-astronomical thought.

6.2.3 The Philosophical Difference Between French and German Mathematical Approaches

No failure to solve a ‘physical problem’ was more prominent than the failure of Laplace’s protégé Johann Carl Burckhardt (Figure 6.8) to determine the orbit of Ceres. Why did Burckhardt fail to compute the orbit of Ceres from the initial observations of Piazzi in 1801, while Carl Gauss succeeded? Even though the rediscovery of Ceres was a matter of great moment in the history of astronomy, it appears that no scholarly attention has been paid to this point.

Figure 6.8: Johann Carl Burckhardt (courtesy: en.wikipedia.org).

The answer involves the differing mix of mathematics, philosophy, and society in France and Germany, and “The mathematical language has more to commend it than being the only language which we can speak; it shows that it is, in a very real sense, the correct language.” (Wigner, 1960: 9). If mathematics provided the symbols for creating language, then the French and German astronomers used them to create quite different languages. For the French, the application of probability theory was the syntax that enabled lengthy symbolic equations to explain the orbital motions of planets and asteroids. The Germans, while impressed by the mathematical virtuosity of their French counterparts, opted for a more prosaic language, shorn of the flourishes so characteristic of much of French society. Quickly arriving at a workable result was their goal.

It has been noted by Grattan-Guinness (1983: 401) that

… around 1800 German astronomers such as Olbers, Encke, [Johann Georg von] Soldner [1776–1833], [Friedrich Wilhelm] Bessel [1784–1846] and Gauss began to develop compact and feasible methods for several areas of celestial and planetary mechanics. This approach contrasted sharply with the French love of long equations in celestial mechanics. Why did the French have this preference? It derives from Leonhard Euler’s
... wonderful idea about the series, and its implementation by Lagrange and Laplace. Philosophically, it may be boosted by the I-can-know-everything view of Laplace, that if you take enough terms in the series you will get an ‘exact’ answer. (Grattan-Guinness).

It was Euler (1744) who made the first real progress in understanding the orbit determination process from an analytical point of view. He introduced ‘infinite trigonometric series’ to simplify the calculation of perturbations (Golland and Golland, 1993: 54), but even so his method of orbit determination has been criticised as having “… calculations that are long and tiresome.” (Dubyago, 1961: 9).

Laplace’s support for lengthy series calculations also appears to stem from his belief that periodic forces produce periodic effects and therefore needed periodic functions in the mathematics (Ferraro, 2008). All of this was embodied in the Mécanique Céleste. Burckhardt translated the first two volumes of Laplace’s Mécanique Céleste into German (published in Berlin in 1801, the year Ceres was discovered). Burckhardt thus employed Laplace’s method of orbit determination, even though it was unsuited to the case of Ceres (Marsden, 1995). With the experience of Ceres, it is thus even more surprising that he used Laplace’s method on the newly-discovered Pallas in 1802. As explained by Zach (1802t) this led his calculations astray again.

German astronomers adopted an alternative strategy: since the phenomena are too complicated to handle exactly, they opted to settle for making an approximation. Two years before Mécanique Céleste appeared Wilhelm Olbers (1797) had given a nice means of approximating the paths of comets which contrasts strongly with Laplace’s lucubrations, and “Soon afterwards Gauss used a method of this kind to analyse the motion of the recently discovered minor planets.” (Grattan-Guinness, 2005: 256).

While the failure of Burckhardt can be partially explained in terms of mathematical arguments, there is a deeper philosophical background to the methods used by him and his rival Gauss. Founded by the French philosopher Petrus Ramus (1515–1572), the emphasis of Ramist logic on clarity, precision and testing encouraged the scientific spirit in Protestant countries—notably England and Germany. While it is true, as noted by Cajori (1897: 276), that “… his views respecting the basis of geometry controlled French textbooks down to the nineteenth century …” the full impact of Ramist philosophy was blunted in France as he was actually barred from teaching philosophy in France in 1544 and his philosophical works were repressed.

“Nature,” said Heraclitus (Patrick, 1889: 86), “loves to conceal herself.” Nature’s favourite hiding place, according to Parmenides (cited in Manley, 1980: 25), is in the differing beliefs, practices, and experiences of men—the very nature of Hegel’s geographic triad. It is to this we must look to understand the way Burckhardt and Gauss tried to shine the light of science (episteme) on that hiding place where Nature kept the secret of Ceres’ orbit.

“There usually may be found many ways to climb the same hill and various paths to the same city.” So wrote William Lewin in a prefatory letter to Gabriel Harvey’s (1545–1630) Ciceronianus (1577), the book that introduced the Ramist method to England. Harvey’s interest in astronomy fostered his regard for Ramus, who urged a return to observational astronomy of the Babylonians and Egyptians in an attempt to determine the non-hypothetical, directly observable regularity of the heavens (Johnson, 1937). Later, Johannes Kepler would claim to have met Ramus’ demands (Skalnik, 2002: 59).

Both Burckhardt and Gauss were trying to climb the same hill, but their approach differed greatly. Gauss applied the rigid rationalism of the Ramus short cut.
Burckhardt was stuck in the French tradition of Laplace’s method—the gradual establishment of a path through use and repetition, which had been successful before, but did not lead to the top of the hill.

The framework in which Gauss worked was one which places the source of order and regularity in universal, natural principles. It articulated its principles through discursive reason.

Burckhardt was bound by established social and scientific usages and customs. His framework articulated its principles though tradition. In the face of the challenge from physical reality posed by Ceres, it failed (Manley, 1980).

6.2.4 The German View of French and English Mathematics and Astronomy

For a contemporary German view of French mathematics, we need look no further than Gauss’ own teacher, Abraham Gotthelf Kästner (1719–1800; Figure 6.9). In 1756 he went to Göttingen University as Professor of Mathematics, a post he held until his death. On the vexed question of the calculus of Newton versus Leibniz, Kästner “… kept a middle position.” (Bullynck, 2014).

In a letter of 28 April 1797 to J.F. Pfaff, Kästner left no doubt about his opinion of the state of French mathematics (Pfaff, 1853: 222):

France is famed for the learned institution where Lagrange teaches; it is said that the students arrive there with such knowledge that they start where students at German universities leave off. Now that is a stiff breeze of French republicanism, more disturbing than their royalism. French teaching in the rudiments of mathematics is much poorer than at any German university, and certainly produces nobody who could listen to Lagrange with profit. It is particularly ridiculous to listen to someone whom one ought to read—and that is what those Germans who have learnt the rudiments do by themselves, if they have the time and inclination.

German researchers were very reluctant to apply highly-mathematical work in physics, which had been spearheaded by the French, because of its abstract nature.
Lagrange in particular was criticised in this regard as the ‘calculator’ who had eliminated images. “What good is a mechanics without figures, such as Lagrange’s?” asked Kästner of Pfaff in 1798. “I have not found any applications of Lagrange’s Mechanics yet.” (Pfaff, 1853: 216).

The views of Kästner were influential, and not confined to private letters. Through textbooks, articles and reviews, he was at the forefront of spreading mathematical thought in Germany, so his overtly-critical opinion of the mathematics devised by the Frenchmen Laplace and Lagrange surely had an impact. His “… role as a populariser and propagator of the mathematical sciences cannot be underestimated.” (Bullynck, 2006: 5).

The position of Germany in science was quite obvious to the medical theorist Johann Christian Reill (1759–1813). In a speech delivered in Halle in 1810, Reill claimed that the study of the natural sciences had undergone “… an almost complete revolution …” during just the few years of his teaching position, and the effort at explanation has made place for living intuition; the idea has entered the arena of the mechanical principle; and observation has achieved a standpoint from which to view things in their natural relations. Indeed, the machine of the heavenly bodies has been animated (Reill, 1817: 318).

He attributed this transformation entirely to German scholars, who “… have given birth to this renaissance of science.” (Reill, ibid.). His reference to the “machine of the heavenly bodies” undoubtedly refers to the contributions of Gauss to celestial mechanics, which were motivated by the discovery of Ceres.

There was also philosophical disagreement in Germany with Newton. Saint-Simon in France, as we have seen, appeared to be motivated by nationalism in his criticism of Newton. By contrast, Hegel kept his criticism on an intellectual plane. Even though his university teaching career began with a dissertation on Newtonian astronomy that was published in 1801, in his Lectures on the History of Philosophy, Hegel devoted only two pages to Newton (Hegel, 1805: 322-324), and “He certainly had no very high opinion of Newton’s ability to deal with thoughts … He was quite clearly of the opinion that Newton was not aware that when he was speaking about forces he was actually dealing with notions.” (Wahsner, 1993: 81). Johann Wolfgang von Goethe (1749–1832) also famously disagreed with Newton’s classic theory of white light and colour, but again this does not seem to have been motivated by base nationalism (Sepper, 1993). Hegel (1817) also openly criticised Newton’s theory of colour, and in a letter of July 1817 Goethe thanked Hegel for his remarks on the subject (Althaus, 2000: 139).

Zach’s fiery temper was never more evident than in the following letter he wrote to Carl Gauss (Zach, 1802h). At the root of the French attitude towards Ceres, Zach believed, was the very fact they did not discover it:

It is incredible how ridiculously these citizens behave: they consider it a disgrace that has been brought over the Grand Nation that they neither observed nor calculated the planet first. But still they make a great fuss, stretch their backs, speak in a high voice: “let us do it, we arrange all this.”

In this remarkable letter, Zach accuses the French of distorting the truth, of implying that observational data from Germany is their own, and of such jealousy that Ceres was found by a foreigner that French astronomers are like one “… who wants to cry his eyes out in front of Bonaparte like an old whore because he was not the first to rediscover the planet.” (Zach, ibid.).

In the battle over the name of the newly-discovered planet, Zach could hardly contain himself. He quoted a letter by Lalande in which he gloated that “… soon we [namely, the French] will have all satisfaction. And the name Juno is being used. The senator Laplace uses it exclusively.” (Zach, ibid.).
Zach was also dismissive of the French astronomer Pierre Méchain’s attitude: “Méchain plays the diplomat and is still maneuvering. He neither writes Juno nor Ceres, but only “the new planet”; it is ridiculous to see how anxiously and world-wisely he tries to avoid the nomen proprium [proper name].” (Zach, ibid.).

As we have seen in Section 4.1 Joseph Banks urged Herschel to name his planetary discovery before the French took it upon themselves to do it. French jealousy did not abate with the discovery of Pallas, as Zach (1802) urged Gauss to calculate its orbit: “Let us show the high-spirited French, who like it so much to push the Germans into second place.”

To further explore the difference between astronomy in France and Germany—a difference that led to such a divergent response to the discovery of Ceres—we must also look at the societal difference that characterised the scientific establishment of the two countries. Their genius loci was quite different. When one speaks of French mathematicians and astronomers, one invariably means those who worked in Paris. A detailed examination of how the centrality of Paris controlled the development of research throughout France has been made by Fox (2012). German scientists lived a much more fragmented existence, as clearly explained by Goethe in a conversation with Johann Eckermann (1792–1854) in May 1827. Lamenting that German talent is scattered hundreds of miles apart, he painfully acknowledges that Germans “… have been forced to buy our little wisdom dearly enough.” His praise of Paris is unbounded as a place “… where the highest talents of a great kingdom are all assembled on one spot, and, by daily intercourse, strife, and emulation, mutually instruct and advance each other.” He spotlights three great minds for particular praise: “… such men as Moliere, Voltaire, Diderot … have kept up such a current of intellect as cannot be found twice on a single spot in the whole world.” (Moorehead, 1998: 200).

It is notable that of all the great thinkers, Goethe mentioned Diderot in particular. Like Diderot, Goethe had a reputation of disparaging mathematics, famously declaring that mathematics has the completely false reputation of yielding infallible conclusions.

The development of French and German civilisation since the Renaissance, which was the web of incubation for the rise of science and mathematics in the eighteenth century, is a factor to be borne in mind when examining this rivalry:

Civilization, the French asserted, was a progressive human accomplishment, evolving over centuries. It was a supreme achievement of Reason, culminating in the Enlightenment. But for German intellectuals, civilization was a danger to Kultur. For them, culture was everything civilization was not. It developed out of spiritual values rather than reason; it was particular rather than universal; it was reflective rather than progressive. Culture, not civilization, was the touchstone of the Romantic Counterenlightenment. (Rothstein, 1999).

The German view of France was emphatically determined by the French Revolution, and the Napoleonic occupation of Germany: “By the time of Johann Gottlieb Fichte’s (1762–1814) Reden an die Deutsche Nation (Addresses to the German Nation) in 1806, Germany were presented as a unique and original nation that, unlike the French, had not lost touch with its original genius.” (Watson, 2010: 262).

Finally, it is useful to ask what German astronomers thought of how valuable the contribution of English astronomers had been in the decades covered in this thesis. Fortunately we have just such an account, from the pen of a Scotsman, James Finlay Weir Johnston (1796–1855), who attended the 1830 annual meeting of the GDNA, the Society of German Natural Researchers and Doctors. That year it was held in Hamburg. Johnston, a co-founder of The British Association for the Advancement
of Science, summarizes the presentation of the famous astronomer Friedrich Georg Wilhelm Struve (Figure 6.10) of Dorpat Observatory, and makes his own displeasure clear to the English readers of his account:

After the reading of the laws, and the list of members already arrived, the rostrum was occupied by Professor Struve from Dorpat, who delivered a long oration on the history, the importance, and the present state of astronomy. After magnifying astronomy above every other science that either was, is, or ever will be cultivated, he adverted to its history during the last hundred years. From this review he concluded, that during that time the main advancement of astronomy was due to Germany;—that at the present day Germany cultivated it most assiduously, and made the best astronomical instruments—a circumstance we are supposed to acknowledge, by engaging Repsold [Johann Georg Repsold, 1770–1830] of Hamburgh [sic], (whom they dignify with the name of immortal Repsold,) to furnish a transit instrument for the Edinburgh Observatory;—that after Germany Russia came next as a patron of astronomical science, by the building and equipping of observatories;—then follow England and Italy, France being lowest of all, having only two observatories at Paris and Marseilles. This discourse was neither judicious, nor, I believe, in general well received. No one science needs now-a-days to be exalted at the expence of others. Every man naturally ranks highest that particular branch of science to which he has dedicated himself: but he cannot expect to take other men along with him when he depreciates the departments to which they have with equal ardour addicted themselves. Nor is it necessary to drag in every name to exalt the scientific character of one country above that of other countries. Granted, as Sir James South has done in the Literary Gazette, that Germany deserves better of astronomy than England does,—yet why claim for that country the honour of names and labours which other countries will not concede?—“Why claim for Germany,” said a Polish professor to me, “men who were countrymen of mine.” And though the Herschels, we may add, be of German extraction, their labours at least are English. (Johnston, 1831: 219-220).

The account is particularly pertinent to this thesis as it makes clear that the work and discoveries of William Herschel and his son John were considered—even by a Scotsman, not an Englishman—to be entirely English. Even though their ancestry was German, their scientific work could not be appropriated by Germany. This account also shows that at least some German astronomers regarded England’s contribution to astronomy to be quite minimal, on a par with that of Italy.
CHAPTER 7: CONCLUDING REMARKS

When we meditate on the comparative diameters of Uranus, Saturn, Jupiter, and the Sun, we are astonished; but our curiosity is much more excited by the diminutive proportions of the Asteroids. They best suit the limited compass of our understanding. Man most admires the great; but he most loves the little.

This observation by Charles Bucke (1823: 231) encapsulates the quintessence of how the asteroids were viewed in England in the early nineteenth century. As this thesis has shown, their study by just a few astronomers in England was the subject of tremendous curiosity and widespread interest by the reading public. Virtually everything written about them in a professional context was quickly disseminated via magazines, newspapers, popular books, textbooks, almanacs and encyclopaedias so that everyone had access to what was known or merely conjectured. There is no question that the studies done in England in the early nineteenth century were an essential element in understanding the four new ‘planetary’ objects. At the forefront of these contributions were the first truly scientific studies of Ceres and Pallas by William Herschel in 1802, and his decision to distinguish them from the seven planets already known. Whichever side of the argument one was on regarding the wisdom of denoting them asteroids, it effected a paradigm shift in our understanding of the Solar System as the whole idea of what a planet or comet is came under detailed scrutiny for the first time. With his discovery of Uranus, Herschel enlarged the physical bounds of the Solar System, and with his decision to regard Ceres and Pallas as a new class of object, he set astronomers on a new path about the nature of the Solar System. For all the theoretical and observational work done by astronomers in Continental Europe, none had the leap of intellectual insight into the workings of the cosmos to effect this change. Only Herschel, with his reputation and determined purpose of mind, possessed the gravitas to make this happen.

7.1 Other Scientific Issues of the Era

The discovery of Uranus and the four asteroids in the late eighteenth and early nineteenth centuries were only one of many advances being made in science. The more fundamental aspects of the physical world were to a large extent poorly understood. It was a commonly-held opinion in the late eighteenth century that light, electricity, magnetism, heat and phlogiston were substances distinct from ordinary matter. (Jungnickel and McCormmach, 1999: 590). The study of light has been touched on several times in this thesis: David Brewster and the diffraction of light (Subsection 5.12), Thomas Young and the dual nature of light (Section 3.3); Henry Brougham's study of the nature of light (Subsection 4.2.2.1) and of course the spurious light that led Schröter and others to believe the asteroids possessed extraordinary atmospheres (Subsection 3.2.2). This false conclusion had far-reaching consequences that would lead many to believe in a cosmic catastrophe to explain the existence of the asteroids. While catastrophism has an honoured place in modern asteroid studies as the agent of mass extinctions (Cunningham, 1988: 113), in this period it was little more than a romantic idea that had no firm basis in physics.

On the subject of light Herschel wrote to the astronomer Samuel Vince about a paper in The Philosophical Transactions written by the English natural philosopher
John Michell (1724–1793) in which Michell first posited the existence of stellar black holes:

Mr. Michell’s excellent Paper [of 1783], if it should not be supported by facts (As I believe I can almost say from my own experiments it will not) must lead us to surmise pretty strongly that light is not subject to the common laws of motion. (Herschel, 1784a).

In this case Herschel was wrong and Michell’s paper is considered to be a landmark in stellar evolution (see Montgomery et al., 2009). At the beginning of the nineteenth century phenomena such as heat, light, electricity and magnetism could only be accounted for by the supposition of ‘imponderable fluids’:

The real crisis in the study of the imponderable fluids arose with the discovery of current electricity by Alessandro Volta (1745–1827) in 1800. The invention of the voltaic pile can be compared only to the discovery of X-rays or radio-activity in its effect upon the formation of theories of matter. The years 1800-1810 were so crowded with new discoveries and speculative theories to account for them, that the older theory of imponderables was hard-put to it to survive. (Williams, 1962: 4).

Volta was extending the work of Luigi Galvani (1737–1798), so the advances in this field were often called Galvanism. For a first-hand account of how important Volta’s discovery was, we need look no further than John Robison (Figure 7.1), Professor of Natural Philosophy at Edinburgh University from 1774 to 1805 (he was succeeded in this post by John Playfair; Subsection 5.1.3). In a letter to Brougham, he admitted to both confusion and frustration with other natural philosophers:

I confess that my notions of corpuscular action are altogether deranged by the phenomena of Galvanism. I can form no notion of Corpuscular force that does not necessarily connect it with position and distance … Yet our philosophers, many of them exceedingly sagacious and ingenious, talk on freely of currents, and influences and attractions and repulsions, as if they saw particles pushing one another about. (Robison, 1804).

Among the many landmarks of that first decade was the discovery of two new kinds of light: infrared radiation by William Herschel (Lequeux, 2009) and ultraviolet radiation (Frercksa et al., 2009) by Johann Wilhelm Ritter (1776–1810).

In the field of chemistry, it was Ritter who raised a basic question: how was it possible for the constituent elements of water (or any other decomposable substance) to pass undetected through a solution to the two electrically charged poles? “In the period 1800-10, this problem became the focus for a large-scale attack by the Germans and the English upon Lavoisier’s system of chemistry.” (Williams, 1962: 8).

Most sciences were still in their infancy in the early nineteenth century and our very understanding of how to view civilisation underwent a transformation at this time. In the year Pallas was discovered, Christian Kruse (1802) replaced maps of antiquity in his new atlas with sequential maps of Europe, and “By arranging a series of maps of the same geographic area at different moments in time, he was among the first to suggest a pattern of historical change in the growth of civilization.” (Schulten, 2013: 13).

Paradoxically, while much of the Earth was still unexplored and effectively unknown to Europeans in 1801-1802, the existence of two small objects between Mars and Jupiter was something certain that could be seen and measured. Continental drift was unknown and evolution had barely been glimpsed, but what was happening millions of miles away in space captured the imagination of the public and the natural philosopher alike—it was real, it was new and it was amazing.
7.2 The Continental Perspective on Asteroid Research

The discovery of the first four asteroids had an astonishing reach, going far beyond the astronomical community which in the early nineteenth century was confined to just a few professionals and a handful of motivated amateurs. It controversially entered the realm of German philosophy through the pen of Karl Joseph Windischmann (1775–1839) when he wrote about Ceres and Pallas (Windischmann, 1805) as part of his pantheistic mysticism. The importance attached to the discovery of the asteroids may be gauged in yet another work far removed from astronomy. It was written by a medical doctor, Johann Gaspar Spurzheim (1776–1832; Figure 7.2), an expert in phrenology. He was so stung by criticism in The Edinburgh Review (whose role in the asteroid naming controversy was extensively analysed in this thesis), that he felt compelled to publish a book (published a year after his death) to refute it. Spurzheim, who contemptuously refers to the Review as “the literary gospel of Edinburgh” (Spurzheim, 1833:6), invokes the discovery of asteroids in his defense. In listing the most prominent discoveries of science from his time into the past, he offers “Vesta, Juno, Pallas and Ceres” before all others (Spurzheim, 1833:41). Spurzheim is particularly apt for mention here in another sense, as he had one foot on the Continent and another in England: he was affiliated with the universities of Vienna and Paris, as well as being a licentiate of the Royal College of Physicians in London. The fact his book was published in America only serves to show the worldwide reach of these four tiny celestial objects.
The investigation of the asteroids considered in this thesis cover four categories: positional, theoretical, physical and descriptive. Positional work was typically done with transit instruments, which were widely used throughout Europe. Most astronomers connected with asteroid research were confined to this category, including Piazzi. The pages of Zach’s journal were filled with papers about the asteroids that reported positional data and magnitude estimates from every observatory, including Greenwich Observatory in England where Maskelyne made his observations. From 1807 onwards Bode’s journal in Berlin published the positional data of Groombridge. There was nothing to distinguish the accuracy of these observations from those made by Continental astronomers, but they were an important part of the raw material needed by the people who worked in the second category, theoretical. Mathematicians such as Gauss, Burckhardt and Oriani used this positional data from England and elsewhere to define the orbits and predict the future positions of the asteroids. Maskelyne did make some calculations based on his own observations, but these remained confined to his personal notes. Oriani and Gauss were the only professional theoreticians who also made their own positional measurements in these early years. The contribution from England was therefore nil in the theoretical category, for reasons thoroughly explored in this thesis. It is only in the third category of physical studies that a proper contrast can be made between the work in England and elsewhere, and it really is a study of the work of just two men—Herschel and Schröter. Herschel used a telescope with a mirror 18.7 inches in diameter, while Schröter used a much smaller one of 9.5 inches, which may explain to some extent their differing results. This was most apparent on the size of the asteroids which generated confusion for decades, as no one could competently decide which was correct, but Herschel’s reputation ensured that his results could not be ignored on the Continent. Thus the combination of English observations and the interpretation of those observations to describe the asteroids as physical entities assumed great importance for every astronomer, no matter what their nationality. The greatest source of controversy turned out to be one of nomenclature: the moliminous introduction of the word asteroid. The descriptive category involved a complete re-thinking of what the solar system was and how Ceres, Pallas, Juno and Vesta fit into it. Were they comets, planets, asteroids, or some hybrid object? What was at first merely a perplexing issue became an issue as hotly debated by astronomers as any
political issue of the day. Here of course the work of Herschel and his ‘dynasty of asteroids’ was the spark that set the issue aflame. In his efforts to establish a new hierarchy in the solar system, Herschel fell into the trap posited by Euripides in his famous tragedy Medea: “If you bring novel wisdom to fools, you will be regarded as useless, not wise.” (quoted in Hammond, 2014:63). Despite the extraordinary vehemence of the backlash against the introduction of this word, it eventually gained acceptance with both the public and with astronomers. This reason for this can be found in the work of the English rhetorician I. A. Richards, who wrote in 1923 “The handiness and ease of a phrase is always more important to deciding whether it will be extensively used than its accuracy.” (Berthoff, 1991:142). The early study of these four objects would have been vastly different in the absence of the English contribution, and Herschel’s novel wisdom in particular.

7.3 The Lasting Value of English Work on the Asteroids

One aspect of the asteroid studies examined in this paper, while an outgrowth of the scientific studies, is in a far different realm: the personal agendas, friendships and animosities that motivated the interaction between the asteroid researchers. While it cannot be reduced to a table of data or studied with statistics, it is nonetheless a crucial component we must take into consideration when evaluating what happened in those early years of the nineteenth century as these four new celestial objects transformed our knowledge of the Solar System.

As a prime nexus for the flow of scientific information, Nevil Maskelyne as Astronomer Royal assumed a pivotal role in garnering information about the asteroids from Continental researchers, especially Carl Gauss. Thus, his reputation cannot be overlooked. That he was held in great esteem by the French is clear from a letter written by Lalande to Maskelyne. In introducing to him John Baptiste Joseph Delambre, Lalande (1787) writes that Maskelyne was for Delambre “…the god of astronomy.” He was, however, not so highly regarded by the prime nexus of Continental astronomy, Baron Franz von Zach. In this letter to Gauss, Zach first expresses astonishment that Maskelyne said nothing about Pallas in a recent letter, second accuses Maskelyne of keeping observations to himself, and third says that Maskelyne is irritated by a difference between his positional measurements and those of Zach:

I do not intend to send you Maskelyne’s observations, because he informed me he wanted to do it himself. “I have sent several observations of the new planet C.F. to Dr. Gauss and will send him more. He promises to make the best use of them in his power.” In his last letter of April 15th he gave his last observation of Ceres on April 6th as follows: 10h 59′ 52″ RA Ceres 179° 28′ 19″ Decl. Ceres 18° 9′ 10″.2. I can read between the lines that he is not against a comparison with your elements and a publication in the M. C. So if you have a series please communicate it for this purpose. I have published two of your comparisons of Maskelyne’s observations. The astonishing thing is that Dr Maskelyne did not say a word about Pallas in his letter of April 15th. And on the same day I got a letter from Sir Joseph Banks of April 16th that Gilpin, clerk of the Royal Society of Sciences had found Ceres on April 9th and that a very ingenious young astronomer M Lee had observed Olbers’ heavenly body on April 13th at 11h 50′ 48″ m. t. RA Pallas 182° 24′ Decl. N 16° 27′. Apparently, the Astronomer Royal has not yet given up but keeps his observations to himself. It irritates him that my observations differ 10″ from his in declination. He believes my spider’s threads, which he dislikes, are to blame. But why do my stellar declinations correspond so well to Piazzi’s? (Zach, 1802I, his underlining).

The legacy that the astronomers who first studied the asteroids have left us is far richer than the heroic acts of observation that sought to discover the physical characteristics of tiny objects between Mars and Jupiter. That legacy shines a unique
light on the way astronomy actually worked during the early nineteenth century in a way that no other event of the era did. Like the transit of Venus expeditions of the eighteenth century, it lets us see and appreciate how astronomers in different countries acted and reacted to each other and celestial events. In the case of the transit expeditions, they were dealing with an event that could be predicted years in advance. While still imbued with rivalry, it also showed how nations could cooperate for the advancement of astronomy (Wulf, 2012). The case of the asteroids was far different. The surprise discovery set off a train of competing investigations. Instead of nationally-coordinated efforts, it was ‘every man for himself’ as astronomers scrambled to be the first to recover Ceres after it was lost by Piazzi in 1801. The recovery of Ceres by Zach and Olbers was followed closely by the discovery of Pallas in 1802 and the naming of the new objects as ‘asteroids’ by William Herschel, a word given to him by Charles Burney Jr. as research for this thesis discovered. The study of the asteroids became embroiled in a series of controversies and mutual recriminations. Abuse was heaped on Giuseppe Piazzi, discoverer of Ceres, for not letting others know of his discovery at once. Another extraordinary volley of abuse was heaped on Herschel for the introduction of ‘asteroid’ and his determination that Ceres and Pallas were not planets. German astronomers, rife with jealousies amongst themselves over the totemic prizes of new planets, were not only annoyed with the English but upset with the French for naming the new discoveries as they saw fit. With nearly every telescope or astronomical measuring instrument in the world focusing on Ceres and Pallas, the year 1802 in particular was a watershed. Even though the discovery of Uranus by Herschel in 1781 elicited a lot of observational and computational work, the directed and sustained effort granted to Ceres, Pallas, Juno and Vesta throughout the first decade of the nineteenth century had never been seen before. The discovery of the asteroids thus ranks as one of the greatest epochs in the history of astronomy, one that this thesis has examined from the particular point of view of astronomy in England, with major contributions by both the English and the Scots.

7.4 Possible Directions for Future Research
As its mandate, this thesis considered the impact of asteroid studies on English astronomy. With a vibrant free press comprising many magazines that published extraordinary levels of detail, the British public was certainly better informed about the four new celestial objects than the populace of any other country in the world. To study the entire interplay of scientific study, personal interactions and bizarre speculations about the asteroids in the early nineteenth century will require a pan-European perspective. The correspondence of every astronomer will have to be examined and translated into English and every scientific paper and book in a range of languages from Latin and Italian to German and French will have to be analysed. Particular attention will have to be paid to the emphasis on celestial mechanics that the French and Germans applied to the asteroids. This will include the various mathematical works of Laplace and Gauss, and a thorough study of the formulae and methods used in comparison to the state of celestial mechanics in the eighteenth century. This thesis has mined the rich resources that have languished for two centuries in the English archives. Other treasures await in the archives of Continental Europe.
REFERENCES
Abbreviations:
*Philosophical Transactions: Philosophical Transactions of the Royal Society, London*
RAS: Royal Astronomical Society
RGO: Royal Greenwich Observatory. (The archival letters are at Cambridge University)

*A Dictionary of Mechanical Sciences, Arts and Manufactures*, 1, 534 (1829).
A Journal of Natural Philosophy, 1, March, 193-197 (1802a).
A Journal of Natural Philosophy, 2, April, 284-295 (1802b).
A Journal of Natural Philosophy, 2, May, 20-22 (1802c).
A Journal of Natural Philosophy, 2, May, 48-55 (1802d).
A Journal of Natural Philosophy, 2, May, 56-60 (1802e).
A Journal of Natural Philosophy, 2, June, 141-142 (1802f).
A Journal of Natural Philosophy, 2, July, 213-215 (1802g).
A Journal of Natural Philosophy, 2, July, 221-222 (1802h).
A Journal of Natural Philosophy, 4, January, 120-128 (1803a).
A Journal of Natural Philosophy, 4, February, 142-147 (1803b).
A Journal of Natural Philosophy, 9, October, 112 (1804a).
A Journal of Natural Philosophy, 9, December, 301 (1804b).
A Journal of Natural Philosophy, 11, May, 57 (1805a).
A Journal of Natural Philosophy, 11, June, 99-102 (1805b).
A Journal of Natural Philosophy, 15, 260-262 (1806).
A Journal of Natural Philosophy, 19, 259-264 (1808a).
A Journal of Natural Philosophy, 19, 264-265 (1808b).
A Journal of Natural Philosophy, 23, 316-318 (1809).
*Annals of Philosophy, or Magazine of Chemistry, Mineralogy, Mechanics, Natural History, Agriculture and the Arts*, 7, 164-165 (1816).
Aubert, A., 1802. Letter to William Herschel, 12 March. RAS, A.35.
Aubert, A., 1802. Letter to William Herschel, 20 April. RAS, A.36.
Banks, J., 1802a. Letter to William Herschel. 16 February. RAS, B.38.
Banks, J., 1802b. Letter to William Herschel. 9 April. RAS, B.39.
Banks, J., 1802c. Letter to William Herschel. 16 April. RAS, B.40.
Banks, J., 1802d. Letter to William Herschel. 23 April. RAS, B.41.
Banks, J., 1802e. Letter to William Herschel. 7 June. RAS, B.42.
Banks, J., 1803a. Letter to William Herschel. 22 March. RAS, B.43.
Banks, J., 1807. Letter to William Herschel. 3 June. RAS, B.47.


*Belfast Monthly Magazine*, page 444 (1811).


*Blackwood's Edinburgh Magazine*, 1, September, 640 (1817).


Bode, J., 1801. Letter to Herschel, 6 June. RAS, B.117.


Bode, J., 1802b. Letter to Olbers, 4 May. Bremen University Archives.

Bode, J., 1802c. Letter to Herschel, 5 August. RAS, B.119.


Brewster, D., 1802c. Further notices respecting the two NEW PLANETS, with some remarks tending to shew that they cannot both belong to the Planetary System. *The Edinburgh Magazine*, 19, New Series, June, 445-448.

Brewster, D., 1803. Letter to William Herschel, 7 January. RAS, B.126 (2).


Brewster, D., 1806. *An Examination of the Letter addressed to Principal Hill*. Edinburgh. Published anonymously at the time. See also Larder (1970) page 303, footnote 35.


Clark, S., 2006. Rows over planetary status are as old as the asteroids. *New Scientist* issue 2567, 2 September issue.


Coldwell, W., 1831. Creation-V. *The Imperial Magazine*, 13, 314-316.


*Connaissance des Temps*, page 453 (1804).


Corry, J., 1802. *The Detector of Quackery; or, Analyser of Medical, Political, Dramatic, and Literary Imposture*. Hurst, London.


Crocker, A., 1808. *The Universe; A Philosophical Poem*. J. Poole, Taunton.


Firminger, T., 1807. Observations of the planet lately discovered by Dr. Olbers, which he has since named Vesta. The Philosophical Magazine, 28(110), 161.


Firminger, T., 1812. On the orbits of the newly discovered planets. Retrospect of Philosophical, Mechanical, Chemical and Agricultural Discoveries, 7, 22-23.


Freud, W., 1815. Evening Amusements; or, the Beauty of the Heavens Displayed. J. Mawman, London.


Gauss, C., 1802b. Letter to Maskelyne, 3 April. RGO 119/2.


Groombridge, S., 1818. Letter to William Herschel, 7 September. RAS, G.32
Groombridge, S., 1817b. Letter to William Herschel, 4 June. RAS, G.26
Groombridge, S., 1817a. Letter to William Herschel, 12 April. RAS, G.31
Groombridge, S., 1814. Letter to William Herschel, 8 February. RAS, G.30
Groombridge, S., 1813. Letter to William Herschel, 6 November. RAS, G.29
Groombridge, S., 1812. Letter to William Herschel, 28 October. RAS, G.28
Groombridge, S., 1811. Letter to William Herschel, 26 July. RAS, G.27
Groombridge, S., 1810. Letter to William Herschel, 7 September. RAS, G.32
In the next hundred thousand nebulae and clusters of stars.


Herschel, W., 1805b. Letter to William Watson, 25 August. RAS, W1/1, 247-250.

Herschel, W., 1805c. Letter to Caroline Herschel, 25 August. RAS, W1/1, 247-250.

Herschel, W., 1805d. Letter to Giuseppe Piazzi, 29 October. RAS, W1/1, 244.

Herschel, W., 1805e. Letter to Samuel Vince, 15 January. RAS, W1/1, 9-95.


Herschel, W., 1805g. Observations of the new Planet. Published in *Dreyer (1912)*, Volume 1, cix-xci.


Herschel, W., 1805i. Letter to Joseph Banks, 10 June. *Dawson Turner Collection* 13, 163-164.


Herschel, W., 1805k. Letter to Johann Schröter, 2 May. RAS, W1/1, 191.

Herschel, W., 1805l. Letter to Giuseppe Piazzi, 29 October. RAS, W1/1, 244.

Herschel, W., 1805m. Letter to Caroline Herschel, 25 August. RAS, W1/1, 247-250.

Herschel, W., 1805n. Letter to William Watson, 25 April. RAS, W1/1, 247-250.

Herschel, W., 1805o. Letter to Joseph Banks, 10 June. *Dawson Turner Collection* 13, 163-164.

Herschel, W., 1805p. Letter to Giuseppe Piazzi, 29 October. RAS, W1/1, 244.

Herschel, W., 1805q. Letter to Johann Schröter, 2 May. RAS, W1/1, 191.

Herschel, W., 1806a. Account of the changes that have happened, during the last twenty-five years, in the relative situation of double stars; with an investigation of the cause to which they are owing. *Philosophical Transactions*, 93, 339-382.

Herschel, W., 1806b. Letter to Joseph Banks, 10 June. *Dawson Turner Collection* 13, 163-164.

Herschel, W., 1806c. Letter to William Watson, 25 April. RAS, W1/1, 247-250.

Herschel, W., 1806d. Letter to William Watson, 25 April. RAS, W1/1, 247-250.

Herschel, W., 1806e. Letter to Giuseppe Piazzi, 29 October. RAS, W1/1, 244.

Herschel, W., 1805b. Ueber den 7 Nebelfleck der 1sten classe des Herschel'schen Verzeichniss, und uebert Ceres and Pallas, vom Herrn Doctor HERSCHEL, aus zwey Briefen desselben. Astronomisches Jahrbuch, 211.

Herschel, W., 1807a. Observations on the nature of the new celestial body discovered by Dr. Olbers, and of the comet which was expected to appear last January in its return from the Sun. Philosophical Transactions, 97, 260-266.

Herschel, W., 1807b. Letter to Joseph Banks, 1 June. RAS W.1/1, 269-270.


Huth, J., 1802. Letter to Herschel, 10 September. RAS, H.33.


International Astronomical Union (IAU), resolution 5A, Definition of Planet. 24 August 2006.


La Belle Assemblee or, Bell’s Court and Fashionable Magazine, 2, January issue, 89 (1807).
Laplace, P.S., 1784. Theorie du Mouvement et de la Figure Elliptique des Planetes. Ph.-D. Pierres, Paris.
Laplace, P., 1802. Letter to Herschel, 17 June. RAS, L.34.
Lee, S., 1802. Letter to Nevil Maskelyne, 14 April. RGO 4/123/34.
Lofft, C., 1801. The Monthly Magazine, 12, October issue, 192.
Lynn, W.T., 1892. Herschel and Schröter. The Observatory, 15, 345-346.
Mackay, A., 1809. The Theory and Practice of Finding the Longitude at Sea or Land. Printed for and sold by the author, London.


Maskelyne, N., 1801. Letter to unknown recipient, undated. RGO 35/35.


Maskelyne, N., 1802b. Letter to William Herschel, 16 March. RAS, M.64.


Maskelyne, N., 1802g. Letter to Joseph Banks, 28 May. DTC 13/52.

Maskelyne, N., 1802h. Letter to William Herschel, 2 June. RAS, M.67.

Maskelyne, N., 1802i. Letter to William Herschel, 18 June. RAS, M.68.


Maskelyne, N., 1803. Letter to Joseph Banks, 13 April. RGO 35/73.


Maskelyne, N., 1807a. Letter to William Herschel, 28 April. RAS, M.73.

Maskelyne, N., 1807b. Letter to William Herschel, 13 May. RAS, M.74.

Maskelyne, N., 1807c. Letter to William Herschel, 20 May. RAS, M.75.


Monthly Correspondence, 1802b. Letter from Banks to Zach, July issue, 90.


Mosely, W.M., 1823b. The Philosophical Magazine and Journal, 61, 31 March issue, no. 301, 375.


Olbers, W., 1797. Abhandlung ueben die leichteste und bequemste Methode die Bahn eines Cometen aus einigen Beobachtungen zu berechnen. Verlag des Industrie-Comptoirs, Weimar.

Olbers, W., 1802a. Letter to Joseph Banks, 4 May. RAS, O.1

Olbers, W., 1802b. Letter to Gauss, 8 May. Göttingen Archives.

Olbers, W., 1802c. Letter to Gauss, 23 May. Göttingen Archives.

Olbers, W., 1802d. Letter to Lalande, 24 May. Bremen University Archives.

Olbers, W., 1802e. Letter to William Herschel, 17 June. RAS, O.2.

Olbers, W., 1802f. Letter to Gauss, 14 July. Göttingen Archives.

Olbers, W., 1802g. Letter to Gauss, 6 August. Göttingen Archives.

Olbers, W., 1802h. Letter to Gauss, 10 October. Göttingen Archives.

Olbers, W., 1802i. Manuscript of 25 October. Bremen University Archives.

Olbers, W., 1804. Letter to Gauss, 26 September. Göttingen Archives.

Olbers, W., 1805. Letter to Gauss, 4 April. Göttingen Archives.


Oriani, B., 1802b. Letter to Piazzi, 1 September. Brera Observatory Archives.


Pearson, W., 1802a. *A Journal of Natural Philosophy*, 1, 284-295.


The London Literary Gazette and Journal of Belles Lettres, no. 707, 7 August issue, 514 (1830).
The London Mechanics Register, 4, 54 (1826).
The Mechanics' Magazine, 6, no. 164, 14 October issue, The Lost Comet, 382-384 (1826a).
The Mechanics' Magazine, 6, no. 165, 21 October issue, The Lost Comet, 382-384 (1826b).
The Mechanics' Magazine, 13, no. 349, 110-111 (1830a).
The Monthly Anthology and Boston Review, 2, 388 (1805).
The Monthly Magazine, 12 (1), A New Planet. 1 August, 88 (1801a).
The Monthly Magazine, 12 (3), Particulars relative to the New Planet, discovered on the first Day of this Century, 1 November, 317-320 (1801b).
The Monthly Magazine, 13 (5), 1 April, Further Account of the New Planet, 205 (1802b).
The Monthly Magazine, 13 (6), 1 May, An Account of the Discovery of ANOTHER NEW PLANET, by Dr. Olbers, of Bremen; and Further Particulars of Piazzi’s New Planet, called Ceres Ferdinandea, 406 (1802c).
The Monthly Magazine, 13 (7), Further account of the last new Planet, Pallas, 1 June, 514 (1802d).
The Monthly Magazine, 14 (1), 1 August, 67 (1802e).
The Monthly Magazine, 14 (2), An Account of a NEW PLANET (PALLAS), lately discovered by Dr. Olbers, of Bremen, 1 September, 117-122 (1802f).
The Monthly Magazine, 14 (6), 1 January, 479 (1803a).
The Monthly Magazine, 15 (1), 1 February, 64 (1803b).
See: Lalande, 1802c.
The Monthly Magazine, 16, 1 September, 164 (1803e).
The Monthly Magazine, 18, 1 November, 334 (1804b).
The Monthly Magazine, 19, 1 July, 534 (1805).
The Monthly Magazine, 22, 1 July, 505 (1806a).
The Monthly Magazine, 22, 1 December, 481 (1806b).
The Monthly Magazine, 23, 1 June, 472 (1807a).
The Monthly Magazine, 24, 1 July, 583 (1807b).
The Monthly Magazine, 36, 100-103 (1813).
The New Jerusale Magazine, 204-206 (1827).
The New Monthly Magazine, 8, 144 (1817).
The Philosophical Magazine (Tilloch’s Journal), 1 March, 54-83 (1802a).
The Philosophical Magazine, 1 May, 53-62 (1802b).
The Philosophical Magazine, 15, XXXIV. Intelligence and Miscellaneous Articles: Astronomy, 190 (1803a).
The Philosophical Magazine, 15, Astronomy, 288 (1803b).
The Philosophical Magazine, 16, Astronomy, 95 (1803c).
The Philosophical Magazine, 21, 188 (1805).
The Philosophical Magazine, 3, 380 (1824).
The Philosophical Magazine, 3, 380 (1828).
The Quarterly Journal of Science, 11, 184 (1821).
The Quarterly Journal of Science, 13, 208 (1822).
The Quarterly Review, 49, 1-33 (1833).
The Quarterly Review, 61, 501 (1838).
The Repertory of Arts, 1(1), second series, 1 June, 151 (1802).
The Saturday Magazine, 14, February, 75 (1839).
The Scots Magazine and Edinburgh Literary Miscellany, 101-103 (1804a).
The Scots Magazine and Edinburgh Literary Miscellany, 46, June, 408 (1804b).
The Scots Magazine and Edinburgh Literary Miscellany, 46, August, 608 (1804c).
The Scots Magazine and Edinburgh Literary Miscellany, 46, October, 735 (1804d).
The Scots Magazine and Edinburgh Literary Miscellany, 46, December, 894-896 (1804e).
The Scots Magazine and Edinburgh Literary Miscellany, 67, 207 (1805).
The Scots Magazine and Edinburgh Literary Miscellany, 69, June, 408 (1807).
The Scots Magazine and Edinburgh Literary Miscellany, 70, 751 (1808).
The Times, 9 May (1804a).
The Times, 12 May (1804b).
The Universal Magazine, 4, 40-41 (1805a).
The Universal Magazine, 3, 260 (1805b).
Thoelden, A.F., 1804. A Journal of Natural Philosophy, 9, October issue, 143.
http://www.census.gov/population/international/data/worldpop/table_history.php
Vince, S., 1811. The Elements of Astronomy, Designed for the Use of Students in the University. Kimber and Conrad, Philadelphia.
Walker, W., 1802a. The Monthly Magazine, 13, 1 April, 272-273.
Walker, W., 1802d. The Scots Magazine, 64, 421.
Watson, W., 1801. Letter to William Herschel, 21 October. RAS, W.72.
Watson, W., 1802a. Letter to William Herschel, 26 February. RAS, W.74.
Watson, W., 1802b. Letter to William Herschel, 27 April. RAS, W.76 (1).
Watson, W., 1803. Letter to William Herschel, 2 March. RAS, W.77 (1).
Wilson, P., 1802b. Letter to Herschel, 20 February. RAS, W.133.
Wilson, P., 1802c. Letter to Herschel, 9 March. RAS, W.134 (1).
Wilson, P., 1802d. Letter to Herschel, 12 April. RAS, W.136.
Wilson, P., 1802e. Letter to Herschel, 27 July. RAS, W.139 (2).
Wilson, P., 1804. Letter to Herschel, 19 May. RAS, W.145 (1).
Young, T., 1802a. An Account of some cases of the production of colours, not hitherto described. *Philosophical Transactions*, 92, 12-48.
Young, T., 1802b. An Account of some cases of the production of colours, not hitherto described. *Philosophical Transactions*, 92, 387-397.
Zach, F.X., 1802n. Letter to Nevil Maskelyne, 4 May. RGO 119/x.
Zach, F.X., 1802r. Letter to Oriani, 26 June. Brera Observatory Archives.
Zach, F.X., 1818. *Correspondence Astronomique*, 1, 524-525.
APPENDIX A: William Herschel’s Papers Concerning the Asteroids

William Herschel’s first paper about the asteroids was read before The Royal Society on 18 February 1802, but it was never published in the *Philosophical Transactions*, likely because it was quickly superseded by the 6 May paper and thus deemed to be out of date information. Here is the text as printed in Dreyer (1912: cix-cx).

The discovery of an additional planet of the solar system by Mr. Piazzi of Palermo, must undoubtedly be highly interesting to all astronomers. Before the elements of its orbit could be well settled, the planet was lost for some time, and when I was upon the look out for it about the place where by calculation it was likely to be, and where we are now assured it really was, I could perceive no star with any visible disk, whereby I might have distinguished it from the rest. Hence I surmised that it would require fixed instruments to rediscover it; and not being in possession of any, I requested my much esteemed friend Dr. Maskelyne, to give me the earliest notice of its situation, as soon as he should have observed it at Greenwich. Accordingly, the 5th of this month, I received his account of the place where he had seen it early in the morning of the 4th, and, by directing my telescopes to the star thus pointed out I obtained the following observations.

Feb. 7. 1802. 13h.

With a ten-feet reflector and a magnifying power of 600 I viewed the place where I expected the new planet to be, in hopes of distinguishing it from the neighbouring stars by its visible disk. Being sufficiently used to direct my telescope to any given part of the heavens, I immediately perceived a star which appeared sufficiently different from another at no great distance, to occasion a supposition that it was the planet. In order to verify my suspicion I put on a magnifier of 1200, and comparing the supposed planet with the same fixed star, I found a doubt still remaining that there might be a mistake.

The 20 feet telescope with a power of 300 and of 600, would not resolve the doubt; but the supposed planet being still too low for very distinct vision, with such high powers, I intended to examine it when in, or near the meridian, as soon as the air should be sufficiently pure.

The following days, though cloudy, afforded every now and then an opportunity of ascertaining, by its change of place, that the star I had examined must be the new planet.

Feb. 13. 1802 5 o’Clock in the morning.

Having long been disappointed by cloudy weather, a favourable change enabled me to see it with great distinctness. When I examined it with a magnifying power of 600, I found, by comparing it alternately many times with the star I had chosen as a standard, that there was a sufficient difference in their appearance, and that a very minute planetary disk might be perceived in the one, which was not to be seen in the other. After having clearly satisfied myself of the planetary nature of the new star, I wished to ascertain its magnitude. The advanced time of the morning, and an apprehension of clouds coming on, would not permit me to apply the lamp and lucid disk micrometers. I therefore had recourse to a comparative view of the Georgian planet, and the newly discovered one, as their situation was such that I could easily change the direction of my telescope from one to the other.

When I turned from the new planet to the Georgium Sidus, and compared its diameter with that of the former, I judged it to be apparently from four to six times as large. Immediately after this I directed the telescope again to the new planet, and as the last of luminous objects in succession is apt to make proportionally the strongest impression, its diameter appeared to me now to be nearly one fourth of the diameter of the Georgian planet. On viewing again our known planet, in order to compare it once more with the new one, I estimated its diameter to be not less than 5 or 6 times as large as that of which I was desirous to ascertain the magnitude.
Apprehensive of not having soon again so fair an opportunity, I examined the new planet with an attention to its appearance, and found its colour is faintly ruddy. Perhaps it appeared rather the more so, on account of my viewing it after the Georgian planet which is of a mild bluish tint.

There was no appearance, nor indeed the least suspicion, of any ring surrounding it; its disk, though very minute, being perfectly well defined all round.

Herschel’s second paper on the asteroids was presented nearly three months later:

PHILOSOPHICAL
TRANSACTIONS.

VIII. Observations on the two lately discovered celestial Bodies.
By William Herschel, LL. D. F. R. S.

Read May 6, 1802.

In my early account of the moving star discovered by Mr. Piazzi, I have already shewn that it is of a remarkably small size, deviating much from that of all the primary planets.*

It was not my intention to rest satisfied with an estimation of the diameter of this curious object, obtained by comparing it with the Georgian planet, and, having now been very successful in the application of the lucid disk micrometer, I shall relate the result of my investigations.

But the very interesting discovery of Dr. Olbers having introduced another moving star to our knowledge, I have extended my researches to the magnitude, and physical construction, of that also. Its very particular nature, which, from the observations I shall relate, appears to be rather cometary.

* By comparing its apparent disk with that of the Georgian planet, it was estimated, that the real diameter of this new star could not amount to half of that of our moon.
than planetary, will possibly throw also considerable light upon
the circumstances belonging to the other celestial body; and,
by that means, enable us to form some judgment of the nature
of both the two last-discovered phenomena.

As the measures I have taken will oblige me to give a result
which must appear extraordinary, it will be highly necessary
to be particular in the circumstances of these measures, and to
mention the condition and powers of the telescopes that were
used to obtain them.

Magnitude of the new Stars.

April 1, 1802. Having placed a lucid disk at a considerable
distance from the eye, but so that I might view it with perfect
distinctness, I threw the image of Mr. Piazzi’s star, seen in a
7-feet reflector, very near it, in order to have the projected
picture of the star and the lucid disk side by side, that I might
ascertain their comparative magnitudes. I soon perceived that
the length of my garden would not allow me to remove the
disk-micrometer, which must be placed at right angles to the
telescope, far enough to make it appear no larger than the star;
and, not having disks of a less diameter prepared, I placed the
smallest I had, as far from me as the situation of the star would
allow. Then, bringing its image again by the side of the disk,
and viewing, at the same time, with one eye the magnified star,
while the other eye saw the lucid disk, I perceived that Ceres,
which is the name the discoverer has given to the star, was
hardly more than one third of the diameter of the disk, and
certainly less than one half of it.

This being repeated, and always appearing the same, we
shall not under-rate the size of the star, by admitting its diameter to have been 4.5 hundredths of the lucid disk.

The power of the telescope, very precisely ascertained, by terrestrial geometrical measures properly reduced to the focus of the mirror on the stars, was \(370.42\). The distance of the lucid disk from the eye, was 2131 inches; and its diameter 3.4 inches. Hence we compute, that the disk was seen under an angle of 5' 29''.99; and Ceres, when magnified 370 times, appearing, as we have shewn, 45 hundredths of that magnitude, its real diameter could not exceed 0''.40. Had this diameter amounted to as much as was formerly estimated, the power of 370 would have made it appear of 6' 10'', which is more than the whole lucid disk.

This extraordinary result, raised in me a suspicion, that the power 370 of a 7-feet telescope, and its aperture of 6.3 inches, might not be sufficient to shew the planet's feeble light properly. I therefore adapted my 10-feet instrument to observations with lucid disks; which require a different arrangement of the head of the telescope and finder: I also made some small transparencies, to represent the object I intended to measure.

April 21. The night being pretty clear, though perhaps not quite so proper for delicate vision as I could have wished, I directed my 10-feet reflector, with a magnifying power of 516.54, also ascertained by geometrical terrestrial measures reduced to the focus of the instrument on celestial objects, to Mr. Piazzi's star, and compared it with a lucid disk, placed at 1486 inches from the eye, and of 1.4 inch in diameter. I varied the distance of the lucid disk many times; and fixed at last on the above-mentioned one, as the best I could find. There was, however, a haziness about the star, which resembled a faint
cometa; and this, it may be supposed, must render the measure less satisfactory than it would otherwise have been.

From these data we compute, that the disk appeared to the natural eye under an angle of $3'\ 14''\ 33''$; while Ceres, when magnified $516\frac{1}{2}$ times, was seen by the other eye of an equal magnitude; and that consequently its real diameter, by measurement, was only $6'', 38$.

April 22. 11$^{h}\ 38'$, sidereal time. I used now a more perfect small mirror; the former one having been injured by long continued solar observations. This gave me the apparent diameters of the stars uncommonly well defined; to which, perhaps, the very favourable and undisturbed clearness of the atmosphere might contribute considerably.

With a magnifying power of $881, 51$, properly ascertained, like those which have been mentioned before, I viewed Dr. Olearis's star, and compared it with a lucid disk of $1/4$ inch in diameter, placed at $1514$ inches from the eye, measured, like the rest of the distances, with long deal rods. The star appeared to me so ill defined, that, ascribing it to the eye-glass, I thought it not advisable to compare the object, as it then appeared, with a well defined lucid disk. Exchanging the glass for that which gives the telescope a magnifying power of $516\frac{1}{2}$, I found Pallas, as the discoverer wishes to have it called, better defined; and saw, when brought together, that it was considerably less in diameter than the lucid disk.

In order to produce an equality, I removed the disk to $1942$ inches; and still found Pallas considerably less than the disk.

Before I changed the distance again, I wished to ascertain whether Ceres or Pallas would appear under the largest angle, especially as the air was now more pure than last night. On
comparing the diameter of Ceres with that of the lucid disk, I found it certainly less than the disk. By proper attention, and continued examination, for at least an hour, I judged it to be nearly \( \frac{3}{4} \) of the lucid disk.

Then, if we calculate as before, it appears by this observation, in which there is great reason to place confidence, that the angle under which this star appeared, was only \( \alpha'' 22 \). For, a lucid disk of 1.4 inch diameter, at the distance of 1948 inches, would be seen under an angle of \( 2' 28'' 7 \); three quarters of which are \( 1' 51'' 52 \). This quantity, divided by the power 516,54, gives \( \alpha'' 21 59 \), or, as we have given it abridged, \( \alpha'' 22 \).

19th 7. I removed the micrometer to the greatest convenient distance, namely, 2196 inches, and compared Dr. Olbers’s star, which, on account of its great altitude, I saw now in high perfection, with the lucid disk. It was, even at this distance, less than the diameter of the disk, in the proportion of 2 to 3.

When, by long continued attention, the appearance of Pallas was reduced to its smallest size, I judged it to bear no greater proportion to the diameter of the lucid disk of the micrometer, than as 1 to 2.

In consequence of these measures, it appears that the diameter of Pallas, according to the first of them, is \( \alpha'' 17 \); and, according to the last, where the greatest possible distinctness was obtained, only \( \alpha'' 13 \).

If it should appear almost incredible that these curious objects could give so small an image, had they been so much magnified as has been reported, I can say, that curiosity led me to throw the picture of Jupiter, given by the same telescope and magnifying power, on a wall at the distance of 1818 inches, of which it covered a space that measured 12 feet 11 inches. I do not
mention this as a measure of Jupiter, for the wall was not perfectly at right angles to the telescope, on which account the projected image would be a little larger than it should have been, nor was I very attentive to other necessary minute circumstances, which would be required for an accurate measure; but we see at once, from the size of this picture, that the power of the telescope exerted itself to the full of what has been stated.

As we generally can judge best of comparative magnitudes, when the measures are, as it were, brought home to us; it will not be amiss to reduce them to miles. This, however, cannot be done with great precision, till we are more perfectly acquainted with the elements of the orbits of these stars. But, for our present purpose, it will be sufficiently accurate, if we admit their mean distances from the sun, as the most recent information at present states them; for Ceres 2,602.4; and for Pallas 2,8. The geocentric longitudes and north latitudes, at the time of observation, were, for Ceres, about $\mu 20^{\circ} 4'$, $15^{\circ} 20'$; and for Pallas, $\mu 28^{\circ} 40'$, $17^{\circ} 30'$. With these data, I have calculated the distances of the stars from the earth at the time of observation, partly by the usual method, and, where the elements were wanting, by a graphical process, which is sufficiently accurate for our purpose. My computed distances were 1,634 for Ceres, and 1,833 for Pallas; and, by them we find, that the diameter of Ceres, at the mean distance of the earth from the sun, would subtend an angle of $\sigma''35127'$; and that, consequently, its real diameter is 161.6 miles.

It also follows, that Pallas would be seen, at the same distance from the sun, under an angle of $\sigma''3199'$; and that its real diameter, if the largest measure be taken, is 147 miles; but, if we take the most distinct observation, which gives the
smallest measure, the angle under which it would be seen from
the sun, will be only 0",2399; and its diameter, no more than
110\(\frac{1}{2}\) miles.

Of Satellites.

After what has just now been shewn, with regard to the size
of these new stars, there can be no great reason to expect that
they should have any satellites. The little quantity of matter
they contain, would hardly be adequate to the retention of a
secondary body; but, as I have made many observations with
a view to ascertain this point, it will not be amiss to relate them.

Feb. 25. 20-feet reflector. There is no small star near Ceres,
that could be supposed to be a satellite.

Feb. 28. There is no small star within 3 or 4 minutes of
Ceres, that might be taken for a satellite.

March 4. 9\(h\) 45', sidereal time. A very small star, south-
preceding Ceres, may be a satellite. See Plate V. Fig. 1. where
C is Ceres, S the supposed satellite, a b c d e f, are delineation
stars, c and d are very small. S makes nearly a right angle with
them; e is larger than either c or d. There is an extremely faint
star f, between e and d.

14\(h\) 16'. Ceres has left the supposed satellite behind.

March 5. There are two very small stars, which may be
satellites; see Fig. 2. where they are marked, 1st S, 2d S. The
rest, as before, are delineation stars.

March 6. The two supposed satellites of last night remain
in their situation, Ceres having left them far behind.

10\(h\) 16'. There is a very small star, like a satellite, about 75°
south-following Ceres. See Fig. 3. It is in a line from C to b
of last night.
11° 20'. Ceres has advanced in its orbit; but has left the supposed satellite behind.

March 30. 9° 35'. A supposed 1st satellite is directly following Ceres: it is extremely faint. A 2d supposed satellite is north-following. See Fig. 4. The supposed satellites are so small, that, with a 20-feet telescope, they require a power of 300 to be seen; and the planet should be hidden behind a thick wire, placed a little out of the middle of the field of view, which must be left open to look for the supposed satellites.

12° 17'. Ceres has changed its place, and left both the supposed satellites behind.

March 31. 9° 20'. There is a very small star, on the north-preceding side of Ceres, which may be a satellite.

11° 50'. Ceres has moved forwards in its path; but the supposed satellite remains in its former situation. The nearest star is 20" of time from Ceres; so that, within a circle of 40" of time, there certainly is no satellite that can be seen with the space-penetrating power of this instrument.

It is evident, that when the motion of a celestial body is so considerable, we need never be long in doubt whether a small star be a satellite belonging to it, since a few hours must decide it.

May 1. 12° 51'. I viewed Pallas with the 20-feet reflector, power 300; there was no star within 3", that could be taken for a satellite.

Of the Colour of the new Stars.

Feb. 19. The colour of Ceres is ruddy, but not very deep. April 21. Ceres is much more ruddy than Pallas. April 22. Pallas is of a dusky whitish colour.
Of the Appearances of the new Stars, with regard to a Disk.

Feb. 7. Ceres, with a magnifying power of $516\frac{1}{2}$, shews an ill defined planetary disk, hardly to be distinguished from the surrounding haziness.

Feb. 13. Ceres has a visible disk.

April 22. In viewing Pallas, I cannot, with the utmost attention, and under the most favourable present circumstances, perceive any sharp termination which might denote a disk; it is rather what I would call a nucleus.

April 28. In the finder, Pallas is less than Ceres. It is also rather less than when I first saw it.

Of the Appearances of the new Stars, with regard to an Atmosphere, or Coma.

April 21. I viewed Ceres for nearly an hour together. There was a haziness about it, resembling a faint coma, which was, however, easily to be distinguished from the body.

April 22. I see the disk of Ceres better defined, and smaller, than I did last night. There does not seem to be any coma; and I am inclined to ascribe the appearance of last night to a deception, as I now and then, with long attention, saw it without; at which times, it was always best defined, and smallest.

April 28. Ceres is surrounded with a strong haziness. Power 550.

With $516\frac{1}{2}$, which is a better glass, the breadth of the coma beyond the disk may amount to the extent of a diameter of the disk, which is not very sharply defined. Were the whole coma and star taken together, they would be at least three times as MDCCCLII.
large as my measure of the star. The coma is very dense near the nucleus; but loses itself pretty abruptly on the outside, though a gradual diminution is still very perceptible.

April 30. Ceres has a visible, but very small coma about it. This cannot be seen with low powers; as the whole of it together is not large enough, unless much magnified, to make up a visible quantity.

May 1. The diameter of the coma of Ceres, is about 5 times as large as the disk, or extends nearly 2 diameters beyond it.

13$^h$ 19$. 20-feet reflector; power 477. The disk of Ceres is much better defined than that of Pallas. The coma about it is considerable, but not quite so extended as that of Pallas.

May 2. 13$^h$ 20$. Ceres is better defined than I have generally seen it. Its disk is strongly marked; and, when I see it best, the haziness about it hardly exceeds that of the stars of an equal size.

Memorandum. This may be owing to a particular disposition of the atmosphere, which shews all the stars without twinkling, but not quite so bright as they appear at other times. Jupiter likewise has an extremely faint scattered light about it, which extends to nearly 4 or 5 degrees in diameter.

April 22. Pallas, with a power of 881$^{1/2}$, appears to be very ill defined. The glass is not in fault; for, in the day time, I can read with it the smallest letters on a message card, fixed up at a great distance.

13$^h$ 17$. The appearance of Pallas is cometary; the disk, if it has any, being ill defined. When I see it to the best advantage, it appears like a much compressed, extremely small, but ill defined, planetary nebula.

April 28. Pallas is very ill defined: no determined disk can
be seen. The coma about it, or rather the coma itself, for no star appears within it, would certainly measure, at first sight, 4 or 5 times as much as it will do after it has been properly kept in view, in order to distinguish between the haziness which surrounds it, and that part which may be called the body.

May 1. Pallas has a very ill defined appearance; but the whole coma is compressed into a very small compass.

13\textdegree\ 5'. 20-feet reflector; power 477. I see Pallas well, and perceive a very small disk, with a coma of some extent about it, the whole diameter of which may amount to 6 or 7 times that of the disk alone.

May 2. 13\textdegree\ 5'. 10-feet reflector. A star of exactly the same size, in the finder, with Pallas, viewed with 516\textdegree, has a different appearance. In the centre of it is a round lucid point, which is not visible in Pallas. The evening is uncommonly calm and beautiful. I see Pallas better defined than I have seen it before. The coma is contracted into a very narrow compass; so that perhaps it is little more than the common aberration of light of every small star. See the memorandum to the observation of Ceres, May 2.

On the Nature of the new Stars.

From the account which we have now before us, a very important question will arise, which is, What are these new stars, are they planets, or are they comets? And, before we can enter into a proper examination of the subject, it will be necessary to lay down some definition of the meaning we have hitherto affixed to the term planet. This cannot be difficult, since we have seven
Dr. Herschel's Observations on

patterns to adjust our definition by. I should, for instance, say of planets,

1. They are celestial bodies, of a certain very considerable size.

2. They move in not very excentric ellipses round the sun.

3. The planes of their orbits do not deviate many degrees from the plane of the earth's orbit.

4. Their motion is direct.

5. They may have satellites, or rings.

6. They have an atmosphere of considerable extent, which however bears hardly any sensible proportion to their diameters.

7. Their orbits are at certain considerable distances from each other.

Now, if we may judge of these new stars by our first criterion, which is their size, we certainly cannot class them in the list of planets: for, to conclude from the measures I have taken, Mercury, which is the smallest, if divided, would make up more than 135 thousand such bodies as that of Pallas, in bulk.

In the second article, their motion, they agree perhaps sufficiently well.

The third, which relates to the situation of their orbits, seems again to point out a considerable difference. The geocentric latitude of Pallas, at present, is not less than between 17 and 18 degrees; and that of Ceres between 15 and 16; whereas, that of the planets does not amount to one half of that quantity. If bodies of this kind were to be admitted into the order of planets, we should be obliged to give up the zodiac; for, by extending it to them, should a few more of these stars be discovered, still farther and farther deviating from the path of the earth, which
is not unlikely, we might soon be obliged to convert the whole firmament into zodiac; that is to say, we should have none left.

In the fourth article, which points out the direction of the motion, these stars agree with the planets.

With regard to the fifth, concerning satellites, it may not be easy to prove a negative; though even that, as far as it can be done, has been shewn. But the retention of a satellite in its orbit, it is well known, requires a proper mass of matter in the central body, which it is evident these stars do not contain.

The sixth article seems to exclude these stars from the condition of planets. The small comas which they shew, give them so far the resemblance of comets, that in this respect we should be rather inclined to rank them in that order, did other circumstances permit us to assent to this idea.

In the seventh article, they are again unlike planets; for it appears, that their orbits are too near each other to agree with the general harmony that takes place among the rest; perhaps one of them might be brought in, to fill up a seeming vacancy between Mars and Jupiter. There is a certain regularity in the arrangement of planetary orbits, which has been pointed out by a very intelligent astronomer, so long ago as the year 1772; but this, by the admission of the two new stars into the order of planets, would be completely overturned; whereas, if they are of a different species, it may still remain established.

As we have now sufficiently shewn that our new stars cannot be called planets, we proceed to compare them also with the other proposed species of celestial bodies, namely, comets. The criteria by which we have hitherto distinguished these from planets, may be enumerated as follows.
1. They are celestial bodies, generally of a very small size, though how far this may be limited, is yet unknown.

2. They move in very excentric ellipses, or apparently parabolic arches, round the sun.

3. The planes of their motion admit of the greatest variety in their situation.

4. The direction of their motion also is totally undetermined.

5. They have atmospheres of very great extent, which shew themselves in various forms of tails, coma, haziness, &c.

On casting our eye over these distinguishing marks, it appears, that in the first point, relating to size, our new stars agree sufficiently well; for the magnitude of comets is not only small, but very unlimited. Mr. Pigott’s comet, for instance, of the year 1781, seemed to have some kind of nucleus; though its magnitude was so ill defined, that I probably over-rated it much, when, November 22, I guessed it might amount to 3 or 4″ in diameter. But, even this, considering its nearness to the earth, proves it to have been very small.

That of the year 1783, also discovered by Mr. Pigott, I saw to more advantage, in the meridian, with a 20-feet reflector. It had a small nucleus, which, November 29, was coarsely estimated to be of perhaps 3″ diameter. In all my other pretty numerous observations of comets, it is expressly remarked, that they had none that could be seen. Besides, what I have called a nucleus, would still be far from what I now should have measured as a disk; to constitute which, a more determined outline is required.

In the second article, their motions differ much from that of comets; for, so far as we have at present an account of the
orbits of these new stars, they move in ellipses which are not very excentric.

Nor are the situations of the planes of their orbits so much unlike those of the planets, that we should think it necessary to bring them under the third article of comets, which leaves them quite unlimited.

In the fourth article, relating to the direction of their motion, these stars agree with planets, rather than with comets.

The fifth article, which refers to the atmosphere of comets, seems to point out these stars as belonging to that class; it will, however, on a more particular examination, appear that the difference is far too considerable to allow us to call them comets.

The following account of the size of the comas of the smallest comets I have observed, will shew that they are beyond comparison larger than those of our new stars.

Nov. 29, 1781. Mr. Pigott's comet had a coma of 5 or 6' in diameter.

Nov. 29, 1783. Another of Mr. Pigott's comets had a coma of 8' in diameter.

Dec. 22, 1788. My sister's comet had a coma of 5 or 6' in diameter.

Jan. 9, 1790. Another of her comets was surrounded by haziness of 5 or 6' in diameter.

Jan. 18, 1790. Mr. Mechain's comet had a coma of 5 or 6' in diameter.

Nov. 7, 1795. My sister's comet had a coma of 5 or 6' in diameter.

Sept. 8, 1799. Mr. Stephen Lee's comet had a coma of not less than 10' in diameter, and also a small tail of 15' in length.
From these observations, which give us the dimensions of the comas of the smallest comets that have been observed with good instruments, we conclude, that the comas of these new stars, which at most amount only to a few times the diameter of the bodies to which they belong, bear no resemblance to the comas of comets, which, even when smallest, exceed theirs above a hundred times. Not to mention the extensive atmospheres, and astonishing length of the tails, of some comets that have been observed, to which these new stars have nothing in the least similar.

Since, therefore, neither the appellation of planets, nor that of comets, can with any propriety of language be given to these two stars, we ought to distinguish them by a new name, denoting a species of celestial bodies hitherto unknown to us, but which the interesting discoveries of Mr. Piazzi and Dr. Olbers have brought to light.

With this intention, therefore, I have endeavoured to find out a leading feature in the character of these new stars; and, as planets are distinguished from the fixed stars by their visible change of situation in the zodiac, and comets by their remarkable comas, so the quality in which these objects differ considerably from the two former species, is that they resemble small stars so much as hardly to be distinguished from them, even by very good telescopes. It is owing to this very circumstance, that they have been so long concealed from our view. From this, their asteroidical appearance, if I may use that expression, therefore, I shall take my name, and call them Asteroids; reserving to myself, however, the liberty of changing that name, if another, more expressive of their nature, should occur. These bodies will hold a middle rank, between the two species that
were known before; so that planets, asteroids, and comets, will in future comprehend all the primary celestial bodies that either remain with, or only occasionally visit, our solar system.

I shall now give a definition of our new astronomical term, which ought to be considerably extensive, that it may not only take in the asteroid Ceres, as well as the asteroid Pallas, but that any other asteroid which may hereafter be discovered, let its motion or situation be whatever it may, shall also be fully delineated by it. This will stand as follows.

Asteroids are celestial bodies, which move in orbits either of little or of considerable excentricity round the sun, the plane of which may be inclined to the ecliptic in any angle whatsoever. Their motion may be direct, or retrograde; and they may or may not have considerable atmospheres, very small comas, disks, or nuclei.

As I have given a definition which is sufficiently extensive to take in future discoveries, it may be proper to state the reasons we have for expecting that additional asteroids may probably be soon found out. From the appearance of Ceres and Pallas it is evident, that the discovery of asteroids requires a particular method of examining the heavens, which hitherto astronomers have not been in the habit of using. I have already made five reviews of the zodiac, without detecting any of these concealed objects. Had they been less resembling the small stars of the heavens, I must have discovered them. But the method which will now be put in practice, will completely obviate all difficulty arising from the asteroidal appearance of these objects; as their motion, and not their appearance, will in future be the mark to which the attention of observers will be directed.

A laudable zeal has induced a set of gentlemen on the MDCCXII.
Continent, to form an association for the examination of the zodiac. I hope they will extend their attention, by degrees, to every part of the heavens; and that the honourable distinction which is justly due to the successful investigators of nature, will induce many to join in the meritorious pursuit. As the new method of observing the zodiac has already produced such interesting discoveries, we have reason to believe that a number of asteroids may remain concealed; for, how improbable it would be, that if there were but two, they should have been so near together as almost to force themselves to our notice. But a more extended consideration adds to the probability that many of them may soon be discovered. It is well known that the comas and tails of comets gradually increase in their approach to the sun, and contract again when they retire into the distant regions of space. Hence we have reason to expect, that when comets have been a considerable time in retirement, their comas may subside, if not entirely, at least sufficiently to make them assume the resemblance of stars; that is, to become asteroids, in which state we have a good chance to detect them. It is true that comets soon grow so faint, in retiring from their perihelia, that we lose sight of them; but, if their comas, which are generally of great extent, should be compressed into a space so small as the diameters of our two asteroids, we can hardly entertain a doubt but that they would again become visible with good telescopes. Now, should we see a comet in its aphelion, under the conditions here pointed out, and that there are many which may be in such situations, we have the greatest inducements to believe, it would be a favourable circumstance to lead us to a more perfect knowledge of the nature of comets and their orbits; for instance, the comet of the year 1770, which
Mr. Lexell has shewn to have moved in an elliptical orbit, such as would make the time of its periodical return only about \( 5\frac{1}{2} \) years: if this should still remain in our system, which is however doubtful, we ought to look for it under the form of an asteroid.

If these considerations should be admitted, it might be objected, that asteroids were only comets in disguise; but, if we were to allow that comets, asteroids, and even planets, might possibly be the same sort of celestial bodies under different circumstances, the necessary distinction arising from such difference, would fully authorise us to call them by different names.

It is to be hoped that time will soon throw a greater light upon this subject; for which reason, it would be premature to add any other remarks, though many extensive views relating to the solar system might certainly be hinted at.

Additional Observations relating to the Appearances of the Asteroids Ceres and Pallas.

May 4, 12h 40'. 10-feet reflector; power 516\frac{1}{2}. I compared Ceres with two fixed stars, which, in the finder, appeared to be of very nearly the same magnitude with the asteroid, and found that its coma exceeds their aberration but in a very small degree.

12h 50'. 20-feet reflector; power 477. I viewed Ceres, in order to compare its appearance with regard to haziness, aberration, atmosphere, or coma, whatever we may call it, to the same phenomena of the fixed stars; and found that the coma of the asteroid did not much exceed that of the stars.
I also found, that even the fixed stars differ considerably in this respect among themselves. The smaller they are, the larger in proportion will the attendant haziness shew itself. A star that is scarcely perceptible, becomes a small nebulosity.

10-feet reflector. 13h 10′. I compared the appearance of Pallas with two equal fixed stars; and found that the coma of this asteroid but very little exceeds the aberration of the stars.

14h 5′, 20-feet reflector. I viewed Pallas; and, with a magnifying power of 477, its disk was visible. The coma of this asteroid is a little stronger than that which fixed stars of the same size generally have.
The text of Herschel’s 1803 paper that briefly mentions the asteroids:

XV. **Account of the Changes that have happened, during the last Twenty-five Years, in the relative Situation of Double-stars; with an Investigation of the Cause to which they are owing.**

*By William Herschel, LL. D. F. R. S.*

Read June 9, 1803.

*In the Remarks on the Construction of the Heavens, contained in my last Paper on this subject,* I have divided the various objects which astronomy has hitherto brought to our view, into twelve classes. The first comprehends insulated stars.

As the solar system presents us with all the particulars that may be known, respecting the arrangement of the various subordinate celestial bodies that are under the influence of stars which I have called insulated, such as planets and satellites, asteroids and comets, I shall here say but little on that subject. It will, however, not be amiss to remark, that the late addition of two new celestial bodies, has undoubtedly enlarged our knowledge of the construction of the system of insulated stars. Whatever may be the nature of these two new bodies, we know that they move in regular elliptical orbits round the sun. It is not in the least material whether we call them asteroids, as I have proposed; or planetoids, as an eminent astronomer, in a letter to me, suggested; or whether we admit them at once into the class of our old seven large planets. In the latter case, however, we must recollect, that if we would speak with precision,

* See Phil. Trans. for 1802, p. 477.*
they should be called very small, and exzodiacal; for, the great inclination of the orbit of one of them to the ecliptic, amounting to 35 degrees, is certainly remarkable. That of the other is also considerable; its latitude, the last time I saw it, being more than 15 degrees north. These circumstances, added to their smallness, show that there exists a greater variety of arrangement and size among the bodies which our sun holds in subordination, than we had formerly been acquainted with, and extend our knowledge of the construction of the solar, or insulated sidereal system. It will not be required that I should add any thing farther on the subject of this first article of my classification; I may therefore immediately go to the second, which treats of binary sidereal systems, or real double stars.
The text of Herschel’s 1805 paper that deal with the asteroid Juno:

Phil Trans, 1805, pg. 31. Read December 6, 1804.

Experiments for ascertaining how far Telescopes will enable us to determine very small Angles, and to distinguish the real from the spurious Diameters of celestial and terrestrial Objects; with an Application of the Result of these Experiments to a Series of Observations on the Nature and Magnitude of Mr. Harding’s lately discovered Star.

The discovery of Mr. Harding having added a moving celestial body to the list of those that were known before, I was desirous of ascertaining its magnitude; and as in the observations which it was necessary to make I intended chiefly to use a ten-feet reflector, it appeared to me a desideratum highly worthy of investigation to determine how small a diameter of an object might be seen by this instrument.

[Most of the paper then relates these experiments in detail. The conclusion of the paper, dealing with Juno, is printed here.]
disks, whether spurious or real, of the instrument I used on this occasion, has been sufficiently investigated by the foregoing experiments, there could be no difficulty in the observation, with resources that were then so well understood, and have now been so fully ascertained.

"Mr. Harding's new celestial body precedes the very small star in Fig. 3, between 29 and 33 Piscium, and is a little larger than that star; it is marked A. fgh are taken from Fig. 1. I suppose g to be of about the 9th magnitude, so that the new star may be called a small one of the 8th."

With the 10-feet reflector, power 496·3, I viewed it attentively, and comparing it with g and h, Fig. 3, could find no difference in the appearance but what might be owing to its being a larger star.

By way of putting this to a trial, I changed the power to 879·4, but could not find that it magnified the new one more than it did the stars g and h.

"I cannot perceive any disk; its apparent magnitude with this power is greater than that of the star g, and also a very little greater than that of h; but in the finder and the night-glass g is considerably smaller than the new star, and h is also a very little smaller."

I compared it now with a star which in the finder appeared to be a very little larger; and in the telescope with 879·4 the apparent magnitude of this star was also larger than that of the new one.

"As far as I can judge without seeing the asteroids of Mr. Piazzi and Dr. Olbers at the same time with Mr. Harding's, the last must be at least as small as the smallest of the former, which is that of Dr. Olbers."
"The star k, Fig. 1, observed Sept. 24, is wanting, and was therefore the object I was in search of, which by computation must have been that day in the place where I saw it."

"The new star being now in the meridian with all those to which I am comparing it, and the air at this altitude being very clear, I still find appearances as before described: the new object cannot be distinguished from the stars by magnifying power, so that this celestial body is a true asteroid."

Mr. BOKE's stars 19, 25 and 27 Ceti are marked 7m, and by comparing the asteroid, which I find is to be called Juno, with these stars, it has the appearance of a small one of the 8th magnitude.

With regard to the diameter of Juno, which name it will at present be convenient to use, leaving it still to astronomers to adopt any other they may fix upon, it is evident that, had it been half a second, I must have instantly perceived a visible disk. Such a diameter, when I saw it magnified 879.4 times, would have appeared to me under an angle of 7' 19.7, one half of which, it will be allowed, from the experiments that have been detailed, could not have escaped my notice.

Oct. 1. Between flying clouds, I saw the asteroid, which in its true starry form has left the place where I saw it Sept. 29. It has taken the path in which by calculation I expected it would move. This ascertains that no mistake in the star was made when I observed it last.

Oct. 2, 7'. Mr. HARDING's asteroid is again removed, but is too low for high powers.

8h 30'. I viewed it now with 220.3, 288.4, 410.5, 496.3, and 879.4. No other disk was visible than that spurious one which such small stars have, and which is not proportionally magnified by power.

With 288.4, the asteroid had a larger spurious disk than a star which was a little less bright, and a smaller spurious disk than another star that was a little more bright.

Oct. 5, with 410.5. The situation of the asteroid is now as in Fig. 4. I compared its disk, which is probably the spurious appearance of stars of that magnitude, with a larger, an equal, and a smaller star. It is less than the spurious disk of the larger, equal to that of the equal, and larger than that of the smaller star. The gradual difference between the three stars is exceedingly small.

"With 496.3, and the air uncommonly pure and calm, I see so well that I am certain the disk, if it be not a spurious one, is less than one of the smallest globules I saw this morning in the tree."

The diameter of this globule was 0.2. It subtended an angle of 0'7.420, and was of sealing-wax; had it been a silver one, it would have been still more visible.

With 879.4. All comparative magnitudes of the asteroid and stars, remain as with 496.3.
I see the minute double star \( q \) Ophiuchi * in high perfection, which proves that the air is clear, and the telescope in good order.

The asteroid being now in the meridian, and the air very pure, I think the comparative diameter is a little larger than that of an equal star, and its light also differs from star-light. Its apparent magnitude, however, can hardly be equal to that of the smallest globule I saw this morning. This globule measured \( 0.01358 \), and at the distance of 9620.4 inches subtended an angle of \( 0.214 \).

When I viewed the asteroid with \( 879.4 \) I found more haziness than an equal star would have given: but this I ascribe to want of light. What I call an equal star, is one that in an achromatic finder appears of equal light.

Oct. 7. Mr. Harding's asteroid has continued its retrograde motion. The weather is not clear enough to allow the use of high powers.

Oct. 8. If the appearance resembling the spurious disks of small stars, which I see with 410-5 in Mr. Harding's asteroid, should be a real diameter, its quantity then by estimation may amount to about \( 0.3 \). This judgment is founded on the facility with which I can see two globules often viewed for this purpose.

The angle of the first is \( 0.429 \), and of the other \( 0.214 \); and the asteroid might be larger than the latter, but certainly was not equal to the former.

With 495-3, there is an ill defined hazy appearance, but nothing that may be called a disk visible. When there is a glimpse of more condensed light to be seen in the centre, it is so small that it must be less than two-tenths of a second.

To decide whether this apparent condensed light was a real or spurious disk, I applied different limitations to the aperture of the telescope, but found that the light of the new star was too feeble to permit the use of them. From this I concluded that an increase of light might now be of great use, and viewed the asteroid with a fine 10-feet mirror of 24 inches diameter, but found that nothing was gained by the change. The temperature indeed of these large mirrors is very seldom the same as that of the air in which they are to act, and till a perfect uniformity takes place, no high powers can be used.

The asteroid in the meridian, and the night beautiful. After many repeated comparisons of equal stars with the asteroid, I think it shows more of a disk than they do, but it is so small that it cannot amount to so much as 3-tenths of a second, or at least to no more.

It is accompanied with rather more nebulosity than stars of the same size.

The night is so clear, that I cannot suppose vision at this altitude to be less perfect on the stars, than it is on day objects at the distance of 800 feet in a direction almost horizontal.

Oct. 11. By comparing the asteroid alternately and often with equal stars, its disk, if it be a real one, cannot exceed \( 2 \), or at most 3-tenths of a second. This estimation is founded on the comparative readiness with which every fine day I have

* See Cat. of double Stars, I. 87.
seen globules subtending such angles in the same telescope, and with the same
magnifying power.

"The asteroid is in the meridian, and in high perfection. I perceive a well
defined disk that may amount to 2 or 3-tenths of a second; but an equal star
shows exactly the same appearance, and has a disk as well defined and as large as
that of the asteroid."

RESULT AND APPLICATION OF THE EXPERIMENTS AND OBSERVATIONS.

We may now proceed to draw a few very useful conclusions from the ex-
periments that have been given, and apply them to the observations of the star
discovered by Mr. Harding; and also to the similar stars of Mr. Piazzi and
Dr. Olbers. These kind of corollaries may be expressed as follows.

(1.) A ro-foot reflector will show the spurious or real disks, of celestial and
terrestrial objects, when their diameter is \( \frac{1}{2} \) of a second of a degree; and when
every circumstance is favourable, such a diameter may be perceived so distinctly,
that it can be divided by estimation into two or three parts.

(2.) A disk of \( \frac{1}{4} \) of a second in diameter, whether spurious or real, in order to be
seen as a round, well defined body, requires a distinct magnifying power of 5 or 6
hundred, and must be sufficiently bright to bear that power.

(3.) A real disk of half a second in diameter will become so much larger by the
application of a magnifying power of 5 or 6 hundred, that it will be easily distin-
guished from an equal spurious one, the latter not being affected by power in the
same proportion as the former.

(4.) The different effects of the inside and outside rays of a mirror, with
regard to the appearance of a disk, are a criterion that will show whether it is real
or spurious, provided its diameter is more than \( \frac{1}{4} \) of a second.

(5.) When disks, either spurious or real, are less than \( \frac{1}{4} \) of a second in diameter,
they cannot be distinguished from each other; because the magnifying power will
not be sufficient to make them appear round and well defined.

(6.) The same kind of experiments are applicable to telescopes of different sorts
and sizes, but will give a different result for the quantity which has been stated at
\( \frac{1}{4} \) of a second of a degree. This will be more when the instrument is less perfect,
and less when it is more so. It will also differ even with the same instrument,
according to the clearness of the air, the condition, and adjustment of the mirrors,
and the practical habits of the observer.

With regard to Mr. Harding's new starry celestial body, we have shown, by
observation, that it resembles, in every respect, the two other lately discovered ones
of Mr. Piazzi and Dr. Olbers; so that Ceres, Pallas, and Juno, are certainly three
individuals of the same species.

That they are beyond comparison smaller than any of the seven planets cannot
be questioned, when a telescope that will show a diameter of $\frac{1}{6}$ of a second of a degree, leaves it undecided whether the disk we perceive is a real or a spurious one.

A distinct magnifying power, of more than 5 or 6 hundred, has been applied to Ceres, Pallas, and Juno, but has either left us in the dark, or at least has not fully removed every doubt upon this subject.

The criterion of the apertures of the mirror, on account of the smallness of these objects, has been as little successful; and every method we have tried has ended in proving their resemblance to small stars.

It will appear, that when I used the name asteroid to denote the condition of Ceres and Pallas, the definition I then gave of this term * will equally express the nature of Juno, which, by its similar situation between Mars and Jupiter, as well as by the smallness of its disk, added to the considerable inclination and eccentricity of its orbit, departs from the general condition of planets. The propriety therefore of using the same appellation for the lately discovered celestial body cannot be doubted.

Had Juno presented us with a link of a chain, uniting it to those great bodies, whose rank in the solar system I have also defined,† by some approximation of a motion in the zodiac, or by a magnitude not very different from a planetary one, it might have been an inducement for us to suspend our judgment with respect to a classification; but the specific difference between planets and asteroids appears now by the addition of a third individual of the latter species to be more fully established, and that circumstance, in my opinion, has added more to the ornament of our system than the discovery of another planet could have done.

Slough, near Windsor,
Dec. 1, 1804.

* See Phil. Trans. for 1802, p. 229
† Ibid. page 224 of the same Paper
The text of Herschel’s 1807 paper on Vesta:

*Observations on the Nature of the new celestial Body discovered by Dr. Olbers, and of the Comet which was expected to appear last January in its return from the Sun.*

[Phil. Trans., 1807, pp. 260–266.]

Read June 4, 1807.

The late discovery of an additional body belonging to the solar system, by Dr. Olbers, having been communicated to me the 20th of April, an event of such consequence engaged my immediate attention. In the evening of the same day I tried to discover its situation by the information I had obtained of its motion; but the brightness of the moon, which was near the full, and at no great distance from the object for which I looked, would not permit a star of even the 5th magnitude to be seen, and it was not till the 24th that a tolerable view could be obtained of that space of the heavens in which our new wanderer was pursuing its hitherto unknown path.

As soon as I found that small stars might be perceived, I made several delineations of certain telescopic constellations, the first of which was as represented in figure 1, and I fixed upon the star A, as most likely, from its expected situation and brightness, to be the one I was looking for. The stars in this figure, as well as in all the other delineations I had made, were carefully examined with several magnifying powers, that in case any one of them should hereafter appear to have been the lately discovered object, I might not lose the opportunity of an early acquaintance with its condition. An observation of the star marked A, in particular, was made with a very distinct magnifying power of 460, and says, that it had nothing in its appearance that differed from what we see in other stars of the same size; indeed Dr. Olbers, by mentioning in the communication which I received, that with such magnifying powers as he could use it was not to be distinguished from a fixed star,* had already prepared me to expect the newly discovered heavenly body to be a valuable addition to our increasing catalogue of asteroids.
The 25th of April I looked over my delineations of the preceding evening and found no material difference in the situation of the stars I had marked for examination; and in addition to them new asterisms were prepared, but on account of the retarded motion of the new star, which was drawing towards a period of its retrogradation, the small change of its situation was not sufficiently marked to be readily perceived the next day when these asterisms were again examined, which it is well known can only be done with right-glasses of a very low magnifying power.

A long interruption of bad weather would not permit any regular examination of the situation of small stars; and it was only when I had obtained a more precise information from the Astronomer Royal, who, by means of fixed instruments, was already in possession of the place and rate of motion of the new star, that I could direct my telescope with greater accuracy by an application of higher magnifying powers. My observations on the nature of this second new star discovered by Dr. Olbers are as follows.

April 24. This day, as we have already seen, the new celestial object was examined with a high power; and since a magnifier of 460 would not show it to be different from the stars of an equal apparent brightness, its diameter must be extremely small, and we may reasonably expect it to be an asteroid.

May 21. With a double eye-piece magnifying only 75 times the supposed asteroid A makes a right-angled triangle with two small stars /g/. See fig. 2. With a very distinct magnifier of 460 there is no appearance of any planetary disk.

May 22. The new star has moved away from /g/, and is now situated as in fig. 3. The star A of figure 1 is no longer in the place where I observed it the 24th of April, and was therefore the asteroid. I examined it now with gradually increased magnifying powers, and the air being remarkably clear, I saw it very distinctly with 450, 577, and 636. On comparing its appearance with these powers alternately to that of equal stars, among which was the 463d of Bode's Catalogue of the stars in the Lion of the 7th magnitude, I could not find any difference in the visible size of their disks.

By the estimations of the distances of double stars, contained in the first and second classes of the catalogues I have given of them, it will be seen that I have always considered every star as having a visible, though spurious, disk or diameter; and in a late paper I have entered at large into the method of detecting real disks.
from spurious ones; it may therefore be supposed that I proceeded now with Vesta (which name I understand Dr. Olbers has given the asteroid), as I did before in the investigation of the magnitudes of Ceres, Pallas, and Juno.

The same telescopes, the same comparative views, by which the smallness of the latter three had been proved, convinced me now that I had before me a similar fourth celestial body. The disk of the asteroid which I saw was clear, well defined, and free from nebulousness. At the first view I was inclined to believe it a real one; and the Georgian planet being conveniently situated so that a telescope might without loss of time be turned alternately either to this or to the asteroid, I found that the disk of the latter, if it were real, would be about one-sixth of the former, when viewed with a magnifying power of 460. The spurious nature of the asteroidal disk, however, was soon manifested by an increase of the magnifying power, which would not proportionally increase its diameter as it increased that of the planet; and a real disk of the asteroid still remains unseen with a power of 636.

May 23. The new star has advanced, and its motion is direct; its situation with respect to the two small stars / g, is given in figure 4. Its apparent disk with a magnifier of 460 is about 5 or 6-tenths of a second; but this is evidently a spurious appearance, because higher powers destroy the proportion it bears to a real disk when equally magnified. The air is not sufficiently pure this evening to use large telescopes.

May 24. With a magnifying power of 577 I compared the appearance of the Georgian planet to that of the asteroid, and with this power the diameter of the visible disk of the latter was about one 9th or 10th part of the former. The apparent disk of the small star near β Leonis, which has been mentioned before, had an equal comparative magnitude, and probably the disks of the asteroid and of the star it resembles are equally spurious.

The 20 feet reflector, with many different magnifying powers, gave still the same result; and being already convinced of the impossibility, in the present situation of the asteroid, which is above two months past the opposition, to obtain a better view of its diameter, I used this instrument chiefly to ascertain whether any nebulousness or atmosphere might be seen about it. For this purpose the valuable quantity of light collected by an aperture of 18½ inches directly received by an eye-glass of the front-view without a second reflection, proved of eminent use, and gave me the diameter of this asteroid entirely free from all nebulous or atmospheric appearances.

The result of these observations is, that we now are in possession of a formerly unknown species of celestial bodies, which by their smallness and considerable deviation from the path in which the planets move, are in no danger of disturbing, or being disturbed by them; and the great success that has already attended the pursuit of the celebrated discoverers of Ceres, Pallas, Juno, and Vesta, will induce us to hope that some further light may soon be thrown upon this new and most interesting branch of astronomy.
APPENDIX B: William Herschel’s Notes about his Asteroid Observations


[Image of William Herschel’s notes on asteroid observations]

September 16, 1801.
I examined the plains south of Aries in order to find, whether a principal star might be seen. No. 101 is at the south of the line of the is one after which a planet may exist.

Oct. 3, 1801.
No. 102, the last star, I saw from 11 till 6 in the place where it is not included in the line of the is one after which a planet may exist.

Oct. 4, 1801.
No. 103. The planet discovered by 11 till 6 in the place. I examined the plains east of Aries in order to find, whether a principal star might be seen. The air was very clear and the stars show many globes of the smaller size of which one might be seen in the plane of the is one after which a planet may exist.

Jan. 1, 1802.
No. 104, the planet discovered by 11 till 6 in the place. I examined the plains east of Aries in order to find, whether a principal star might be seen. The air was very clear and the stars show many globes of the smaller size of which one might be seen in the plane of the is one after which a planet may exist.
210
for a long time. But on the other side, where a lot of light was shining, the light seemed to be coming from a window. This was confirmed by the fact that there were many windows that were open, and the light seemed to be coming from them.

In conclusion, the object in question was a window, and the light was coming from it. It was a beautiful sight, and I was able to see the entire street through it.

May 4, 1843.

213
215
Table of the mean of the apparent diameters, in 80, as the average.

August 14th, 1773.

Table.

<table>
<thead>
<tr>
<th>Date</th>
<th>Diameter (in 80)</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 14th, 1773</td>
<td>80</td>
</tr>
</tbody>
</table>

Mean diameter: 80.

---

The table above shows the mean diameter of the Sun's disk, observed in 80, on August 14th, 1773, which was 80.

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Note: The table provides the mean diameter of the Sun's disk observed through a telescope in 80, on August 14th, 1773.
APPENDIX C: Papers by Pearson

Two extensive articles by William Pearson (Section 5.8) were published in *A Philosophical Journal* (Nicholson’s Journal) in April and May of 1802. Together they show the extraordinary level of information and detail that was being offered to the British reading public about the discovery of Ceres.

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IX.

Concerning the new Planet Ceres. *In a Letter from the Rev. William Pearson, including an Extract of a Letter from the Baron de Zach to Mr. Edward Troughton.*

To Mr. NICHOLSON.

SIR,

Parson’s Green, March 9, 1802.

As the discovery of the new planet Ceres is an event which has already engaged the attention of the principal astronomers of Europe, and will continue to be a subject of discussion until
ON THE PLANET CERES.

until the elements of its orbit shall be accurately assigned, it may be acceptable to many readers of your journal to have a popular detailed account laid before them of the manner of applying observations to determine the whole period and form of the orbit, in order that they may comprehend, and consequently feel an interest in, the perusal of the different notices which will, most probably, be published from time to time in different countries.

When a heavenly body is first suspected to be a planet, the suspicion arises either from its apparent aspect compared to a star when viewed in a telescope, as was the case with Geo. Sidus, or otherwise on account of an observed change of relative situation, as was the case with the new planet Ceres when compared with some small stars in its neighbourhood: the first thing to be done after the supposed discovery of a new planet is, to ascertain its right ascension and declination, and from thence its geocentric longitude and latitude; the means used for doing which need not be described here.

A series of observations, and corresponding calculations, Subsequent observations. are usually continued at successive intervals, until the newly discovered body has advanced or receded through such a portion of the ecliptic as to afford data for estimating its daily velocity when compared to that of the earth: now, if a series of observations could be made by an observer in the sun, the arc passed through by the planet would bear the same proportion to the interval of time elapsed between the first and last observations, that a circle does to the whole period, provided the motions were equable: and, if the motions were unequal, the observed progress at equal intervals would shew whether the inequalities were increments or decrements, and consequently whether the planet was approaching the perihelion or aphelion point. But the observed places are geocentric, and must therefore be converted into heliocentric, to gain those observations which an observer placed in the sun would make; for which purpose the proportion to be used will be, by the Manner of doing simple case in plane trigonometry, as the distance of the planet (to be at first assumed) from the sun: is to the sine of its observed elongation, or angular distance from the sun (or its supplement) :: [to be filled in] to the sine of an angle which is the difference between the heliocentric and geocentric places, and which is called the parallax of the orb.

The
The heliocentric arc, which the planet has passed through in given time, being thus nearly ascertained, the whole approximate period is next found on a supposition of equal arcs being passed through in equal times; which will afford data for determining a somewhat more accurate distance of the planet from the sun, by the well known law of Kepler, by which the squares of the periodic times are analogous to the cubes of the mean distances of the earth and any other planet respectively. An approximate distance being thus obtained may, in the next place, be substituted for the assumed distance, and the parallax of the orb be determined a second, and even a third time in this way; by means of which repetitions an approximate period, and a corresponding approximate distance, will be obtained. These will vary more considerably from the truth the greater the distance of the observed arc is from one of those two points of the orbit where the planet has a mean motion; these points are always nearer to the aphelion than to the perihelion point, by a quantity which depends upon the eccentricity. If therefore it should so happen that a new planet, at the time of its first discovery, were at, or very near, its mean distance, the whole period and distance obtained from a few of the first observations would be pretty accurate.

The next step to be taken is to determine the increments or decrements of motion, when a number of geocentric are changed into heliocentric places, and thus to trace the points in the ecliptic where the velocity is a maximum, where it is a minimum, and where it is a mean. These will show where the perihelion and aphelion points are, and also the place of equated anomaly at an instant when the equation is a maximum; these data afford the means of calculating the greatest equation and corresponding eccentricity; but before they can be ascertained with accuracy, a considerable time must elapse to afford the astronomer an opportunity of observing a few successive oppositions or conjunctions and stationery points, for the purpose of correcting the approximate elements, and of determining the true shape and position of the orbit.

In the mean time the geocentric latitudes, gained by observation, must be also converted into heliocentric latitudes, in order to determine the nodes or points where the two opposite sides of the orbit cross the ecliptic. For doing this the analogy
ON THE PLANET CERES.

is—As the sine of the planet's elongation from the sun is to the angle of commutation (or difference between the heliocentric longitudes of the planet and of the earth)—So is the tangent of the geocentric lat: is to the tangent of the heliocentric latitude.

From this account of the means necessary to be used in ascertaining the precise nature of the orbit of a newly discovered planet, it will be naturally inferred that the elements already assigned to the orbit of the new planet Ceres cannot be very accurate, allowing them to be duly proportioned to one another, because an error in any one of its elements renders all the rest erroneous; and there has not yet elapsed, probably, much more than one-fourth of an entire period since its discovery, nor has it yet been in the most essential portions of its orbit for affording the best data. Hence a continuation of accurate reports concerning this planet ought to be publicly recorded from time to time, in order that a comparison of different and distant observations may afford the requisite data for ultimately settling its elements with accuracy. I shall therefore make no apology for laying before your readers an extract from a letter of Baron Von Zach to his friend and correspondent, Mr. Edward Troughton, mathematical instrument-maker, of Fleet Street, who has very obligingly put it into my hands, with permission to make what use of it I may think proper. The letter is unusually long, and full of interesting matter; but I shall confine myself, in this communication at least, to those parts of it which principally relate to the new planet, and the subjects connected with it.

Extract of a Letter from the Baron Von Zach to Mr. Edward Troughton.

Gotha, January 28, 1802.

"********* YOU have heard perhaps, dear friend, Re-discovery of that I was so lucky as to discover again Mr. Piazzi's planet, the planet Ceres, called now, in honour of the king of Naples, Ceres Ferdinandea. I found this little planet first on the 7th of December last year, juft between the head and the north wing of Virgo, in 178° 33½ right ascension, and 11° 41½ declination N. An astronomical friend of mine, Dr. Olbers, in Bremen, found
found the planet on the 2nd of January between the N. 40° E. and S. Virginis. I have not heard that this little planet, which resembles a star of the ninth magnitude in size, has been seen in France and England. I have already given information of my discovery to the president of the Royal Society, Sir Joseph Banks. I have the honour to send you here my observations of this planet.

Table of observations.

<table>
<thead>
<tr>
<th>Date</th>
<th>Mean Time</th>
<th>Ap. Right Asc.</th>
<th>Declination</th>
</tr>
</thead>
<tbody>
<tr>
<td>1801. 7 Dec.</td>
<td>18° 48' 10.3'</td>
<td>178° 33' 30.6&quot;</td>
<td>11° 41.5' N.</td>
</tr>
<tr>
<td>31</td>
<td>17 38.5' 44'</td>
<td>184° 44' 11' 5'</td>
<td></td>
</tr>
<tr>
<td>1802. 11 Jan.</td>
<td>17 3 17.4</td>
<td>186° 45' 49.95'</td>
<td>11° 15'</td>
</tr>
<tr>
<td>16</td>
<td>16 46 25.6</td>
<td>187° 27 53.25'</td>
<td>11° 26'</td>
</tr>
<tr>
<td>22</td>
<td>16 25 23.9</td>
<td>188° 6 25.8</td>
<td>11° 44'</td>
</tr>
<tr>
<td>23</td>
<td>16 14 32.9</td>
<td>188° 20 39.15'</td>
<td>11° 54'</td>
</tr>
<tr>
<td>25</td>
<td>16 10 53.7</td>
<td>188° 24 49.5</td>
<td>11° 57'</td>
</tr>
</tbody>
</table>

If you, or your astronomical friends, wish to look at the new planet Ceres, which is rather difficult, this heavenly body being so small, I send you here a little ephemeris, which will direct you in the research of this planet. With my eight feet transit instrument, by the late Mr. Ramget, and with 200 magnifying power, I could not perceive the least mark of a disk. Perhaps Mr. Herschel will see more; perhaps he will discover some satellites to Ceres.

Ephemeris.

Position of the Ceres Ferdinanda for Midnight, in the Seeberg Observatory.

<table>
<thead>
<tr>
<th>Right Asc.</th>
<th>Decl.</th>
<th>R. A. in Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1802. Feb</td>
<td>0° 8° 43'</td>
<td>12° 31' 12° 34' 53'</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>47 12 35 1</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>24 12 34 55</td>
</tr>
<tr>
<td>31</td>
<td>31</td>
<td>22 12 34 33</td>
</tr>
<tr>
<td>11</td>
<td>11</td>
<td>41 12 33 57</td>
</tr>
<tr>
<td>17</td>
<td>17</td>
<td>3 12 33 5</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
<td>21 12 31 59</td>
</tr>
<tr>
<td>23</td>
<td>23</td>
<td>42 12 30 49</td>
</tr>
<tr>
<td>26</td>
<td>26</td>
<td>3 12 29 8</td>
</tr>
<tr>
<td>March</td>
<td>16 6 50 15</td>
<td>24 12 27 22</td>
</tr>
</tbody>
</table>

Difficulties in the observations.

How much I want your four feet circle in my observatory, my present perplexity will show you. Hitherto I have observed all my zenith distances with a four feet Dollond's quadrant,
quadrant, and a circle of two feet from Cary; the telescopes have little aperture, so that I cannot see the new planet Ceres, and consequently I cannot observe the zenith distances: as the air all January was very hazy and cold, I had much ado to see the planet in my very excellent transit instrument. I must therefore wait till the planet shall increase in brightness, which yet will not go farther than to a star of the seventh magnitude. In the mean time I hope that by very clear weather I may distinguish the planet in my old quadrant, or in my little circle, and that this faint body will support the illuminating of wires, which has not been the case hitherto. This is the reason that I could not obtain one exact declination, but my right ascensions of Ceres are extremely exact. This difficulty will certainly never take place in my observatory when I once get your four feet circle. * * * * * * 

"As soon as the instruments arrive, I shall give you notice of it: in the mean while I have the honour to subcribe myself, with the greatest regard and highest esteem, which the reigning Duke of Saxe Gotha very sincerely shares with me,

Most honoured Friend,

Your most obedient Servant,

And devoted Friend,

Francis Baron de Zach,

Lieutenant-Colonel, and Director of

Seeberg Observatory.

"Before I finished this letter, I had two observations more: viz.

\begin{tabular}{|c|c|c|}
\hline
Date & Time & Alt. & Decl. Ceres. \\
\hline
28 Jan. 16\° 3' 29" M. T. & 188\° 31' 57,85" & 12\° 9' 41,3" \\
29 & 15 & 59 & 43,7 188 34 18,13 12\° 14' only guessed. \\
\hline
\end{tabular}

This extract affords me an opportunity of illustrating the Application of account, which has been just given, of the application of two observations, before detailed, to the observations of a planet for determining the heliocentric to the observatory that has been run through in a given time: if I take the right ascension of Ceres for the 1st of Jan. 1801, as given by Piazzi's
Piazzi's first observation, and also for the 26th of Jan. 1802, as given by the last observation of Von Zach in the present extract, and project the orbits of the earth and Ceres according to the eccentricity, mean distance and place of the apogee of Ceres, as given in the extract from the Moniteur in the different journals, we shall have the figure represented in Plate XIII. Fig. 1, which is thus constructed, viz.

Supposing the point $S$ to be the sun, describe, with any radius, the circle marked $\varphi$, $\psi$, $\pi$, &c. for the ecliptic, and conceive it to be at an infinite distance; draw an occult line from $S$ to $\varphi 9\frac{1}{2}^{\circ}$, the earth's aphelion, and another to $\varphi 26\frac{1}{2}^{\circ}$, the aphelion of Ceres; take 10 from a scale of equal parts, and describe with that radius the innermost circle $A \oplus P$ from a point $\varphi 5^{\circ}$ of the radius from $S$ towards $A$ in the occult line, and another circle with a radius of 27.6 of those equal parts from the point $\varphi 4^{\circ}$ of the said radius from $S$ in the second occult line, and these circles, which are eccentric with respect to the sun at $S$, will very nearly represent the required orbits of the earth and Ceres, in both which $A$ represents the aphelion, and $P$ the perihelion points. In the next place find the two points in the earth's orbit, which are diametrically opposite the sun's place for Jan. 1, 1801, at 9th P. M. and Jan. 27, 1802, at 4th A. M. which will be $\cong 11^\circ 1' 33''$ and $\cong 6^\circ 35'$ respectively, and mark them as in the figure with their dates; after this mark the geocentric right ascensions of Ceres (denoted by the letter $C$ with a cross beneath) for Jan. 1, 1801, and $G$ at $\cong 21^\circ 47' 48''$, according to Piazzi, and for Jan. 26, 1802, at $G$ at $\cong 8^\circ 24'$, according to Von Zach, and draw the two dotted lines from $S$ to each; then if dotted lines be drawn parallel to these two lines from the earth ($O$) in Jan. 1801 and 1802 respectively, until they touch the orbit of the planet Ceres, these last lines will mark the geocentric apparent places of this planet in its orbit, of which the dotted lines from $S$ to the ecliptic denote the measure; and, lastly, if lines be drawn from $S$ through the geocentric places to the ecliptic to $H$ and $H$, they will indicate the Heliocentric longitudes, and the arcs contained between the Heliocentric and Geocentric measures will be on each day the measure of what is called the parallax of the orbit.—This method of converting Geo-centric into Heliocentric places by Projection is capable of great accuracy, and is, so far as I know, original.

The method of converting Geo-centric portions into Heliocentric
ON THE PLANET CERES.

The reason of drawing the occult parallel lines, which may not occur to the reader, is this; as the ecliptic is considered to be an infinite distance, so that the whole orbit of the earth, if seen from it, would appear only as a point, a line drawn to it from the sun, and another parallel thereto from the circumference of the earth's orbit, will, to an eye placed in the ecliptic, even if it were only at the distance of a star, appear coincident on the same line; hence if a line be drawn from the earth to the planet in its orbit, let their respective situations be what they may, another line drawn parallel to that from the sun, till it reaches the ecliptic, will shew the geocentric measure therein the same as if that measure were taken in a graduated ecliptic described from the earth as a center, and having all its divisions exactly parallel to those of the ecliptic described from the sun as a center.

Indeed, I have tried this projection with the geocentric and heliocentric places of some of the other planets taken from an ephemeris, and find it extremely accurate as well as easy.

From this projection of the heliocentric and geocentric places of Ceres, it appears evident that the distance from the earth to it was much greater last summer when the earth was at P, than it is at present, and it is equally evident, that as the velocity of the earth is greater than that of the new planet, and as they were both moving in the same direction at the latter period in the projection, the distance will continue to diminish until both the planets are in the same straight line as seen from the sun, agreeably to what is said in the extract from Von Zach's letter; for the apparent magnitude is in an inverse ratio of the distance, so that as the distance diminishes, the apparent disk increases. The reason also appears clear, why there was very little apparent motion of the new planet in the last month as seen from the earth, for in this part of the earth's orbit Ceres would appear to have a retrograde motion, provided it were at Cref, but its forward motion in a certain degree balanced that, and produced the effect of little or no apparent motion at all;—on the 6th or 7th of Feb. last it was stationary, and has been since retrograde in a small degree.
ON THE PLANET CERES.

In order to ascertain by calculation the heliocentric arc passed through in 390,3 days, the time contained between Jan. 1, 1801, at 9 P. M. and Jan. 27, 1802, at 4 A. M., the heliocentric longitudes of the new planet may be ascertained thus:

<table>
<thead>
<tr>
<th></th>
<th>1801, Jan. 1st</th>
<th>9th sun's long.</th>
<th>:</th>
<th>9</th>
<th>11 1 33</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right ascension of Ceres</td>
<td>1 21 47 48</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elongation</td>
<td></td>
<td>7</td>
<td>19 13 45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Then at 27 (supposed distance)</td>
<td>1,43136</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is to fine of 49° 14'</td>
<td>9,87931</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>So is 10 (earth's distance)</td>
<td>1,00000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10,87931</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,43136</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To fine of paral. of orb. 16° 17'</td>
<td>9,44795</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Again 1802, Jan. 26th 15th sun's long. | : | 10 | 6 35 |
| Right ascension of Ceres | 6 8 24 |
| Elongation | | 3 | 28 11 |
| Then as 27 | 1,43136 |
| Sine of 61° 49' (supplement) | 9,94519 |
| So is 10 | 1,00000 |
| | 10,94519 |
| | 1,43136 |
| To fine of paral. of orb. 19° 3' | 9,51383 |

Geocentric place of Ceres. | : | 1 21 47 48 |
| Parallax | 16 17 |
| Jan. 1, 1801 | | 6 8 24 49 |
| Ditto | 19 3 |
| Jan. 26, 1802 | | 35 20 |
| Whole geocentric arc | 4 16 37 1 |
| Deduct sum of parallaxes | 1 5 20 |
| Whole heliocentric arc | 3 11 17 1 |

In 390,3 days.

Now, if the motion of the planet were equable throughout its orbit, we should have the whole tropical period from this ratio, as 101° 17 1" : 390,34 : 360° : 1987,27 days, but the portion
ON THE PLANET CERES.

portion of a circle, which has been past since Jan. 1, 1801, is that in which the velocity has been above a mean velocity; therefore the period thus obtained is shorter than the true period by a quantity which depends upon the equation of the center, which has not yet been examined. At present want of leisure, and the length of this paper, render it necessary that I should defer entering upon the other particulars, which remain to be discussed, some of which, it is presumed, will be found interesting; for I propose to show that some of the elements assigned by Gauss, which are considered as the most accurate, are not in due proportion to one another. This discussion will therefore constitute the subject of another communication. In the mean time we may infer, either that the whole period is shorter than has been prematurely determined, or otherwise that the greatest equation should be much greater than the eccentricity at present assigned requires. Indeed, it will hereafter appear that the eccentricity, given from the excised which the assigned eccentricity requires, Moniteur in the different journals, is almost two-thirds too little to correspond to the equation which has been attributed to the new planet.

I am, SIR, as usual,

Your's very respectfully,

W. PEARSON.

The early observations of Professor Piazzi, to which Mr. Pearson refers, are given by the professor in the following tables. The computations in the latter table were made from elements which, at the present time, would require to be greatly amended; but I have not chosen to omit them. W. N.
Table of the Mean Time, Right Ascension, and Declination of the new Star as observed; together with the Longitude of the Sun, and the Logarithm of its Distance from the Earth.

<table>
<thead>
<tr>
<th>Days of the Month</th>
<th>Two Thirds of the Day in mean Time</th>
<th>Right Ascension</th>
<th>Declination</th>
<th>Sun's Place</th>
<th>Log. Distance of ((\oplus)) from Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3621</td>
<td>51° 47' 42.7&quot;</td>
<td>15° 47' 41.5&quot;N</td>
<td>9' 12&quot; 3' 33.1&quot;</td>
<td>9.9994417</td>
</tr>
<tr>
<td>4</td>
<td>3628</td>
<td>43° 47' 27.1&quot;</td>
<td>41° 5' 5.5&quot;</td>
<td>12 2 31.2&quot;</td>
<td>9.9992562</td>
</tr>
<tr>
<td>3</td>
<td>3677</td>
<td>39° 36.1&quot;</td>
<td>44° 30.8&quot;</td>
<td>13 3 30.2&quot;</td>
<td>9.9992583</td>
</tr>
<tr>
<td>4</td>
<td>3647</td>
<td>35° 47.7&quot;</td>
<td>47° 59.5&quot;</td>
<td>14 4 29.0&quot;</td>
<td>9.9992585</td>
</tr>
<tr>
<td>10</td>
<td>3274</td>
<td>23° 14.4&quot; 16</td>
<td>10 32.0&quot;</td>
<td>20 10 29.5&quot;</td>
<td>9.9992688</td>
</tr>
<tr>
<td>11</td>
<td>3250</td>
<td>22° 26.0&quot;</td>
<td>14 30.1&quot; eff.</td>
<td>21 11 59.5&quot;</td>
<td>9.9992794</td>
</tr>
<tr>
<td>12</td>
<td>3205</td>
<td>22° 34.5&quot;</td>
<td>23 40.5&quot;</td>
<td>23 14 28.0&quot;</td>
<td>9.9992848</td>
</tr>
<tr>
<td>13</td>
<td>3168</td>
<td>22° 55.8&quot;</td>
<td>27 5.7&quot;</td>
<td>24 14 57.5&quot;</td>
<td>9.9992863</td>
</tr>
<tr>
<td>14</td>
<td>3132</td>
<td>27 35.1&quot;</td>
<td>40 13.0&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>3094</td>
<td>28 43.1&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>3059</td>
<td>38 34.0&quot;</td>
<td>49 1.4&quot;</td>
<td>29 19 14.1&quot;</td>
<td>9.9993400</td>
</tr>
<tr>
<td>17</td>
<td>3023</td>
<td>48 21.3&quot;</td>
<td>58 35.9&quot;</td>
<td>10 1 21.5&quot;</td>
<td>9.9993153</td>
</tr>
<tr>
<td>18</td>
<td>3009</td>
<td>46 45.5&quot;</td>
<td>6 21.5&quot;</td>
<td>2 5 54.7&quot;</td>
<td>9.9993296</td>
</tr>
<tr>
<td>19</td>
<td>3084</td>
<td>3 41.4&quot;</td>
<td></td>
<td></td>
<td>3 54 40.4&quot;</td>
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<td>20</td>
<td>3039</td>
<td>52 43.3&quot;</td>
<td>32 54.8&quot;</td>
<td>8 46 45.5&quot;</td>
<td>9.9993282</td>
</tr>
<tr>
<td>21</td>
<td>2994</td>
<td>37 21.2&quot;</td>
<td>43 11.0&quot;</td>
<td>10 28 10.6&quot;</td>
<td>9.9993445</td>
</tr>
<tr>
<td>22</td>
<td>2960</td>
<td>34 18.9&quot;</td>
<td>48 21.5&quot;</td>
<td>11 38 55.5&quot;</td>
<td>9.9993708</td>
</tr>
<tr>
<td>23</td>
<td>2923</td>
<td>41 45.01&quot;</td>
<td>53 36.5&quot;</td>
<td>12 29 36.6&quot;</td>
<td>9.9993773</td>
</tr>
<tr>
<td>24</td>
<td>2889</td>
<td>49 45.9&quot;</td>
<td>58 57.5&quot;</td>
<td>13 30 17.0&quot;</td>
<td>9.9993851</td>
</tr>
<tr>
<td>25</td>
<td>2855</td>
<td>53 44.11&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>2821</td>
<td>25 40.5&quot;</td>
<td>18 25 10&quot;</td>
<td>16 32 13.9&quot;</td>
<td>9.9994083</td>
</tr>
<tr>
<td>27</td>
<td>2759</td>
<td>44 37.5&quot;</td>
<td>31 23.2&quot;</td>
<td>19 35 2.1&quot;</td>
<td>9.9994388</td>
</tr>
<tr>
<td>28</td>
<td>2702</td>
<td>54 16 31.7&quot;</td>
<td>47 58.8 N</td>
<td>22 35 41.3&quot;</td>
<td>9.9994388</td>
</tr>
</tbody>
</table>

N. B. The observations marked with two points (‡) are a little doubtful; those marked with (‡‡) vary uncertain.
This concludes the article in the April edition. The article in the May edition follows. It includes a letter from Zach to Banks of 20 February 1802. This letter is included in Appendix D of this thesis, so it is omitted here. Pearson follows the Zach letter with his own “Remarks”, which conclude the article. In all about 23 pages of text and a Figure comprise the articles from these two months, giving the public as much information as any professional had about the new object Ceres.
ON THE NEW PLANET CERES.

X.

On the new Planet CERES.

To Mr. NICHOLSON.

SIR,

Parson's Green, April 3, 1802.

The subject refused.

At the conclusion of the memoir concerning the new planet Ceres, which you did me the honour to publish in your last number of the Philosophical Journal, a want of leisure, and the length of the communication, were alleged as reasons for my not concluding, at that time, the whole of the observations which I had to offer on the subject: I beg leave, therefore, now to resume the examination and detail of those particulars which remain yet to be treated of.

About four years ago, when I was inventing a mechanical contrivance, by which the equation of the center and true distance of a planet, or any number of planets, might be exhibited in an orrery, I discovered that the natural sine of half the greatest equation of any planet, is equal, or very nearly equal, to the decimal figures which represent the value of a vulgar fraction, composed of the eccentricity and mean distance of that planet: For instance, if we take the mean distance of the earth from the sun at 100000, and the eccentricity, according to Lalande, at 1681.393, the fraction \( \frac{1681.393}{100000} \), converted into a decimal expression of the same value, is \( 0.01681393 \); and, omitting the decimal point and three last figures, we shall have 0.168 for the natural sine of \( 0^\circ 57' 47.6'' \), which arc differs only about half a second from one half of the greatest equation, as given in the tables of the third edition of Lalande's Astronomy.

The process, in the form of an analogy, will be thus: As the mean distance is to unity :: so is the eccentricity :: to the natural sine of \( \frac{1}{4} \) the greatest equation.

This analogy will apply to all the other planets, as may be seen in the subjoined table, which I have calculated from the mean distances and eccentricities given in Lalande's Astronomy, and copied by Mr. Vince, except in the instance of Ceres, the data of which planet are taken from the elements of Gauss.

Planets.
ON THE NEW PLANET CERES.

<table>
<thead>
<tr>
<th>Planets</th>
<th>Vulgar Fractions</th>
<th>Decimals, or Nat. Sines</th>
<th>Correspondent Area</th>
<th>Half the greatest Equation, 1750</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>(\frac{1}{3}1\frac{1}{12})</td>
<td>20551</td>
<td>0</td>
<td>0 50 0</td>
</tr>
<tr>
<td>Venus</td>
<td>(\frac{1}{12}1\frac{1}{3})</td>
<td>00588</td>
<td>0 23 38,3</td>
<td>0 23 40</td>
</tr>
<tr>
<td>Earth</td>
<td>(\frac{1}{3}1\frac{1}{3})</td>
<td>01581</td>
<td>0 37 47,6</td>
<td>0 37 48,2</td>
</tr>
<tr>
<td>Mars</td>
<td>(\frac{1}{12}1\frac{1}{12})</td>
<td>09308</td>
<td>5 20 26,9</td>
<td>5 20 20</td>
</tr>
<tr>
<td>Ceres</td>
<td>(\frac{1}{12}1\frac{1}{12})</td>
<td>02981</td>
<td>1 42 28,96</td>
<td></td>
</tr>
<tr>
<td>Jupiter</td>
<td>(\frac{1}{12}1\frac{1}{12})</td>
<td>04807</td>
<td>2 45 18,6</td>
<td>2 45 19,15</td>
</tr>
<tr>
<td>Saturn</td>
<td>(\frac{1}{12}1\frac{1}{12})</td>
<td>05222</td>
<td>3 13 22,7</td>
<td>3 13 21</td>
</tr>
<tr>
<td>Georgian</td>
<td>(\frac{1}{12}1\frac{1}{12})</td>
<td>04733</td>
<td>2 42 45,5</td>
<td>2 43 38</td>
</tr>
</tbody>
</table>

In this table the greatest difference between the arcs contained in the same line of the two last columns, is that in the line of Mercury; but it may be worthy of remark, that half the greatest equation of this planet, according to Dr. Halley's tables, is 11° 31' 18''; and also that Lalande himself made a new determination of the elements of Mercury's orbit, as related in the "Memoires de l'Institute Nationale" of Paris for the "fourth year of the Republic;" in which the grand equation is given 25° 40' 45''.

Here, then, it appears, that the greatest equation of the new planet Ceres, which corresponds to the eccentricity assigned by Gauss, and copied into the different journals, is about 3° 25'', instead of 9° 27' 41''; so that, as I hinted before, either the eccentricity is almost two thirds too little, or the greatest equation almost two thirds too much. I mean not at present to enter into a geometrical demonstration of the analogy which I have used in procuring the above tabulated results; but leave it to exercise the ingenuity of your mathematical readers, some of whom will probably be induced to favour you and the public with a demonstration, as a separate article. I will, however, just prove to the reader the accuracy of the inference I have made with respect to Ceres, by means of the elliptic hypothesis of Ward, which is generally allowed to be a convenient approximation to be used for finding the equation of a planet, instead of either the direct or tentative methods, which are more accurate, but much more intricate.

Vol. II.—May, 1802. E By
ON THE NEW PLANET CERES.

By the elliptic hypothesis, the analogy for converting mean into equated anomaly is simply this: As the aphelion distance is to the perihelion distance :: so is the tangent of half the mean anomaly to the tangent of half the equated anomaly; and the difference between these two anomalies constitutes the equation itself. Now, it is well known to all who are conversant in the theory of planetary motion, that in the projection of any elliptic orbit, a circle, described from the focus in which the sun is supposed to be, with a radius that is a mean proportional between the major and minor semi-axes, will cut the ellipse in two points, which shall be the points of mean distance; or, which is the same thing, the points where the equation becomes stationary, and consequently where it is a maximum.

It is also equally well known to practical astronomers, and calculators of an ephemeris, that the equation varies very slowly for many degrees both before and after the points of mean anomaly corresponding to the greatest equation; and likewise that these points fall a little beyond the first quadrant from the aphelion, or three degrees of mean anomaly, by a quantity which depends upon the eccentricity of the orbit. In the orbit of Mercury the point of mean anomaly, when the equation is greatest, is nearly at 105° from the aphelion; in that of Venus it is between 90° and 91°; in that of the Earth about 91°; in that of Mars about 97°; in that of Jupiter and Georgian between 93° and 94°; and in that of Saturn about 94°. Hence it may be inferred, that if the greatest equation of Ceres be 3° 25′, the said point of mean anomaly will be about 92°; but that if the equation be 9° 27′ 41″, it will be about 96°; namely, somewhat short of that of Mars, the greatest equation of which is 10° 40′ 40″.

Let us try now what the greatest equation will be upon both suppositions successively, according to the simple elliptic hypothesis.

<table>
<thead>
<tr>
<th>Log.</th>
<th>As the aphelion distance (27673 + 825) 28498</th>
<th>4,45481</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Is to the perihelion dist. (27673 — 825) 26848</td>
<td>4,42891</td>
</tr>
<tr>
<td></td>
<td>So is the tangent of 46° (92°) 1/2 mean anom.</td>
<td>10,01516</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14,44407</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4,45481</td>
</tr>
<tr>
<td></td>
<td>To the tangent of 1/2 eq. anom. 44° 17′ nearly</td>
<td>9,98926</td>
</tr>
<tr>
<td></td>
<td>Then 92° — 88° 34′ = 3° 26′ is the greatest equation.</td>
<td></td>
</tr>
</tbody>
</table>

Again,
ON THE NEW PLANET CERES.

Again, supposing the point of mean distance to be at 96°,
we have in that case,

As the aphelion distance, 28498 - - - - - 4,45431
Is to the perihelion dist. 26848 - - - - - 4,42891
So is the tangent of 48° - - - - - 10,01536

14,47447
4,45431

To the tangent of 46° 17' nearly - - - - - 10,01966
Then 96° - 82° 34' = 5° 26' is the greatest equation, as be-
fore.

Hence it is indubitably proved, that the equation, as given
by Gauss, is much too great for the eccentricity; and it ap-
pears also, according to what has been already asseried, that
the equation at 92° and 96° of mean anomaly is nearly the
same; that is to say, the difference will only be in the sec-
onds.

But the greatest equation of a planet is usually determined
from a series of observations antecedently to the calculation of
the eccentricity; therefore the error which has been detected
may be in the eccentricity, and not in the equation; in which
case, by reverting the analogy already used, we shall have
this calculation, viz. As unity : mean distance 27673 :: na-

The equation
given by Gauss
is too great for
the eccentricity;
or the eccentric-
ity is faulty.

tural sine of 4° 43' 30" or 03247,4 : 2282,2 for the requisite
eccentricity. But it will be most easy to determine in which
of the two elements the error has been committed, when the
whole period has been accurately ascertained.

When it was mentioned in the former paper on this subject,
that oppositions and conjunctions were of importance to be
observed, the reason was omitted to be explained; which is,
that when a superior planet is in opposition, or an inferior one
in conjunction, the observed geocentric longitudes are also
heliocentric longitudes, without calculation or reference to
distance and eccentricity; because in such relative situations
there is no parallax of the orb: and it is well known to astro-
nomers, that when an opposition happens at the place of mean
distance of a superior planet, half the difference between the
heliocentric place, by calculation of mean motion, and of the
place as observed at that time, is equal to the greatest equation.
The 13th of March ult. was the day on which the astronomers
on the continent predicted that an opposition of Ceres would
occur;
ON THE NEW PLANET CERES.

occur; but it must have happened on the 23d, as I calculate from Von Zach's little ephemeris continued forwards; viz. when the geocentric plane was about 182°. The astronomer who has an observatory, and has noted the exact time, will do well to make the observation public.

The mean time which elapses between two successive oppositions or conjunctions of a planet, as seen from the earth, is called a synodic revolution, and is determined by dividing 360° by the difference of the mean daily motions of the earth and other planets. Thus: taking the mean daily motion of Ceres at 770,7376", according to Gauss, and of the earth at 58° 8', 33", according to Lalande, we have \( \frac{360\degree}{770,7376\" - 466,6}\) days nearly for the whole synodic period, on an assumption that the motions are both equable throughout their orbits; but their respective distances from their aphelia at the time of opposition must be made the argument of a correction, either additive or subtractive, as the case may be, to determine what a synodic period would be if both motions were equable. Now, if we reverse this process, we can just as easily gain the difference of the daily motions between that of the earth and other planets, and consequently the whole period of the latter, from having only the earth's daily motion, and observed synodic period; for 360°, divided by this period in days, gives the difference wanted at once, which, subtracted from the daily motion of the earth, gives that of the other, if it be a superior planet; but if an inferior one, that difference must be added; and the more nearly the two daily motions approximate to each other, the longer will be the respective synodic revolution. In the instance before us, if we suppose the whole corrected synodic revolution of Ceres to be 466,6 days from observation, we shall have \( \frac{360\degree}{466,6}\) for the difference to be subtracted from 3548,33" the earth's mean daily motion, which will leave 770,7376" for the mean daily motion of Ceres, as before; by which if we divide 360°, we shall have the whole tropical period = 1681° 12' 8" 49". But it remains to be observed what a whole synodic period of Ceres may prove in reality.

Supposing the epoch, or mean heliocentric longitude of Ceres to have been 2 S. 17° 36' 34" on January 1, 1801, the day of its discovery, as is stated by Gauss, and the place of the aphelion 10 S. 26° 27' 38", the mean anomaly must, on 4
ON THE NEW PLANET CERES.

this supposition, have been at that time 3 S. 21° 8' 56'', so that it had passed the place of mean motion about either 19° or 15°, accordingly as we make the greatest equation 3° 25' or 9° 27' 41'': therefore the daily motion was nearer a mean motion than it has been ever since; and it will be yet some months before it arrives at its place of mean motion in the opposite half of its orbit; which place is either 2° or 6° short of the ninth sign of anomaly, accordingly as we take the eccentricity. Let us suppose now the whole period to be upwards of 1881 days, as has been, perhaps prematurely, determined; one fourth of this time had elapsed on the 24th of February last; on which supposition, the mean anomaly must then have been advanced just three signs from the original situation; namely, it must have been upwards of 65. 21°, at which rate the planet had passed the perihelion by a space of time answering to 21° of mean motion, which is about 98 days: therefore the 18th of November, 1801, must have been the day on which it was at the perihelion, or place of greatest velocity; but at that time the planet was lost, and we are not in possession of any observation of it nearer that time than the 7th of December following, when Baron Von Zach re-discovered it.

The continuance of any planet in the first quadrant from aphelion is longer than in the second quadrant, by a space of time which corresponds to the whole equation, taken at three signs of mean anomaly; in which situation, it has been already observed, that the equated or apparent motion is also, as nearly as may be, a mean motion; if therefore the equation at three signs be divided by the mean daily rate of motion, we shall have a space of time, which, added to one fourth of the whole period, and subtracted from another fourth, will give nearly the respective times of continuance in the first and second quadrants of anomaly: Hence arises this rule for finding the two semicircles, respectively bifeeted by the perihelion and aphelion points, viz. divide four times the equation at three signs of anomaly, (which may be the greatest equation where the eccentricity is small), by the mean daily motion, and the quotient will be the number of days that the planet continues longer in the semicircle from nine to three signs of anomaly than from three to nine. For instance, if we take the equa-
tion of Ceres at 3° 25', we shall have \(3\frac{1}{4} \times 4 = 63,83\) days for the time of continuance in the semicircle embracing the aphelion, longer than in the semicircle which is bisected by the perihelion: but if we take the equation at three signs = 9° 25', somewhat less than the greatest equation, in this case, by reason of the increased eccentricity, we shall have the excess of continuance 9° 25' \(\times 4 = 175,93\) days.

This suggestion may be worthy the notice of the practical astronomer; for when a variety of observations are taken of the new planet in the different quadrants of its orbit, and the corresponding times recorded, it will be no difficult task, when equidistant geocentric longitudes are converted into heliocentric longitudes, to observe what semicircle of the ecliptic corresponds to that half of the orbit in which the planet has continued longest: the middle of that semicircle will be the aphelion, and the two extremities will be three and nine signs of anomaly: Also, the excess of duration, above the time occupied by the other semicircle, multiplied by the mean daily motion, will be four times the equation at three and nine signs of anomaly very nearly; and as this equation is very little short of the greatest equation, the eccentricity may likewise be found by either of the methods already described; thus the form and elementary points of the orbit may be gained by a series of observations converted into heliocentric places, even by the projection proposed in the last memoir on this subject, and these determinations may be corrected by a comparison of them with the results deduced from the properties of an ellipse, which are here purposely omitted, lest a more minute and scientific description of intricate calculations should rather puzzle than inform the generality of readers *.

It remains yet that some observations be made relative to the position of the orbit of a planet. There are many methods of ascertaining the nodes of a planet's orbit, from calculation grounded upon observations; but the simplest, when it is practicable, is to convert the geocentric into the heliocentric place at the time when there is no latitude by observation, for

* See Lalande's and Mr. Vince's Astronomy; and also Professor Robison on the Geo. Sidus, in the Edin. Trans. vol. I. 1788.
ON THE NEW PLANET CERES.

the heliocentric place will be the place of the node, ascending or descending, as the case may be, which will appear by a subsequent observation; but when the place of a planet, when crossing the ecliptic, cannot be observed, the middle point between two equal north and south latitudes, gained by observation, will give the node.

The heliocentric latitude, when a planet is just 90° from each node, is the measure of the inclination of its orbit, and is easily obtained from the observed geocentric latitude, taken in that situation, by the analogy already described; or, otherwise, the greatest heliocentric latitude may be acquired from an observation of a geocentric latitude and longitudinal distance from the node, thus: When the earth is in the line of the nodes, the analogy will be, as the sine of the difference of the longitudes of the sun and planet seen from the earth : radius :: tangent of the geocentric latitude : tangent of the inclination.

The two days on which the earth will be in the line of the nodes of Ceres will be June 12 and December 13, this year. But it is beyond the prepared intention of this popular memoir to enter into all the minutiae of calculation, were the requisite data before me; but only to point out the methods of applying observations for determining the size, form, and position of a planet's orbit: it may not, however, be unworthy of notice, before I conclude, to remark, that the astronomers on the continent, who availed themselves of the earliest observations only for determining an approximate set of elements of Ceres, were enabled to do this from noticing that this planet became stationary between the 10th and 11th of January, 1801, when its elongation was known by observations; for it has been known by writers on astronomy, that, upon a supposition of circular orbits, the tangent of the elongation is equal to the semi-diameter of the orbit, divided by the square root of that semi-diameter + 1.

Yours, &c.

W. P.

REMARKS.

1. The distance which corresponds to the logarithm of ¾ axis major, viz. 0.4424742, is 2,769,964, the earth's radius being unity.

2. The whole tropical period from the mean daily heliocentric tropical motion, 769.7924', is 1683° 13' 41' 56.5'.

3. The
ON THE NEW PLANET CERES.

3. The synodic revolution corresponding to this motion is $456^\circ 10^\circ 22^m$.

4. The time of opposition could not be on the 17th of March as stated in this letter, but about the 23d, as has been mentioned before, because it was on that day that the difference of the right ascensions of the sun and Ceres was $180^\circ$, even according to the Baron's own table; the error seems to have arisen from reckoning the point diametrically opposite Ceres to be nearly two degrees short of the equinoctial point, instead of the same quantity ever, when the right ascension of Ceres was about $182^\circ$; the other circumstances also dependent on the moment of opposition must therefore be attributed to the 23d instead of the 17th.

5. On receiving these last corrections of Dr. Gauss I was at first surprised to find such a trifling alteration made with the greatest equation and corresponding eccentricity, after the error which I was confident I had detected; but I have now found out the cause of the apparent discrepancy, which some lines has been laid upon; the mean distance and eccentricity, I now perceive are, contrary to the usual mode of expression, given in terms of different denominations: the mean distance has been given in terms which suppose the radius of the earth's orbit to be unity, and the eccentricity is given in terms which suppose the radius of the orbit of Ceres to be unity, instead of its proportional radius 2.76964. Professor Robison on the contrary, in his approximate elements of Georgian expressed the mean distance and eccentricity in terms of the same denomination, which is also done by Lalande, Vince, and other eminent astronomers with respect to the other planets. Let us try now what the greatest equation will be by the elliptic hypothesis, when unity is made the radius of the orbit:

As the aphelion distance ($1 + 0.08140$) $1.08140 - 4.03383$
Is to perihelion distance ($1 - 0.08140$) $0.9186 - 3.96913$
So is tang: of $46^\circ 2^\prime 33.6''$ mean anom: $- 10.0458$

\[
\begin{array}{c}
\text{To tang: } \frac{1}{2} \text{ eq. anom: } 43^\circ 20^\prime 33.6'' \quad - \quad 4.00669 \\
\end{array}
\]

\[
\begin{array}{c}
\text{Then } 48^\circ 20^\prime 33.5'' + 2 = 86^\circ 41^\prime 72''; \text{ and } 92^\circ - 86^\circ 41^\prime 7.2'' = 9^\circ 10^\prime 5.23'' \text{ is the greatest equation.}
\end{array}
\]
Also by the tabulated method we have \( \frac{3140}{\text{error}} = 0.8140 \), which is the natural sine of \( 4^\circ 40' 8.27'' \), or half the greatest equation \( 9^\circ 20' 16.51'' \), which is not \( 9'' \) above the correction of Dr. Gauss.

6. Hence it appears, that the eccentric point in the projection of the orbit of Ceres should be a little less than \( \frac{1}{12} \) of the radius from the central point \( S \) (Plate XIII. Fig. 1.) which represents the sun.

W. P.
APPENDIX D: A Compilation of British Correspondence Relating to the Asteroids 1801-1818

The following table lists all the British letters relating to the first four asteroids from 1801-1818, along with their archival location. Many of these letters were used throughout the thesis in an analysis of various topics. Whenever a letter was used in the thesis, it is given a separate entry in the References. The letters involving Joseph Banks, Nevil Maskelyne, William Herschel and Stephen Groombridge are given in this Appendix, with footnotes where warranted.

Table D1: The Asteroid-related correspondence with dates and archival locations.

<table>
<thead>
<tr>
<th>Letter from</th>
<th>Letter to</th>
<th>Date sent</th>
<th>Location code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sastres</td>
<td>Herschel</td>
<td>May 2, 1801</td>
<td>RAS, S7</td>
</tr>
<tr>
<td>Bode</td>
<td>Herschel</td>
<td>June 6</td>
<td>RAS, B.117</td>
</tr>
<tr>
<td>Herschel</td>
<td>C. Herschel</td>
<td>Aug. 25</td>
<td>RAS, W.1/8.18</td>
</tr>
<tr>
<td>Piazzi</td>
<td>Herschel</td>
<td>Sept. 1</td>
<td>RAS, P.18</td>
</tr>
<tr>
<td>Watson</td>
<td>Herschel</td>
<td>Oct. 21</td>
<td>RAS, W.72</td>
</tr>
<tr>
<td>Herschel</td>
<td>Bode</td>
<td>Oct. 27</td>
<td>RAS, W.1/1, 242</td>
</tr>
<tr>
<td>Herschel</td>
<td>Watson</td>
<td>Oct. 27</td>
<td>RAS, W.1/1, 243</td>
</tr>
<tr>
<td>Herschel</td>
<td>Piazzi</td>
<td>Oct. 29</td>
<td>RAS, W.1/1, 244</td>
</tr>
<tr>
<td>Herschel</td>
<td>Lalande</td>
<td>Nov. 10</td>
<td>RAS, W.1/1, 245</td>
</tr>
<tr>
<td>Maskelyne</td>
<td>Piazzi</td>
<td>Nov. 16</td>
<td>Piazzi</td>
</tr>
<tr>
<td>Lalande</td>
<td>Herschel</td>
<td>Nov. 26</td>
<td>RAS, L.28</td>
</tr>
<tr>
<td>Seyffer</td>
<td>Herschel</td>
<td>Jan. 4, 1802</td>
<td>RAS</td>
</tr>
<tr>
<td>Zach</td>
<td>Banks</td>
<td>Jan. 14</td>
<td>Royal Soc. L&amp;P.XII.4</td>
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Notes: The Royal Greenwich Observatory (RGO) manuscripts, and the Dawson Turner Collection (DTC) manuscripts are now held at Cambridge University. The Royal Astronomical Society (RAS) manuscripts are in London in the Herschel Collection; all letters to Herschel are in W.1/13. The 22 May 1802 letter from Herschel to Méchain is not extant, but was published in *The Moniteur*. (BL) denotes the British Library. The
letter of 16 November 1801 from Maskelyne to Piazzi is mentioned in section 18 of Piazzi (1802a) but the text is lost. The letter of 11 March 1802 from Maskelyne to Piazzi is excerpted in section 30 of Piazzi (1802a). Göttingen is: Department of Manuscripts of the State and University Library of Göttingen.

The material in this Appendix is organised as follows:

D.1 The Joseph Banks Correspondence  
D.2 The Nevil Maskelyne Correspondence  
D.3 The William Herschel Correspondence  
D.4 The Stephen Groombridge Correspondence  
D.5 Articles in British Magazines from 1801-1805.

The contents of D.5 are of magazine articles too lengthy to include in the main body of the work. Included here is the important article by Brougham (1803) that criticizes Herschel for creation of the word ‘asteroid.’ It also includes Brewster (1802c) where he goes into great detail about what distinguishes planets from comets. In this article he argues that Pallas is a comet, not a planet. Other entries include an early report on Ceres in The Monthly Magazine (1801b), Lalande’s address to the French National Institute on the discovery of Pallas (Lalande, 1802c), and several reports about the discovery of Juno.
The complete extant correspondence of Banks as it relates to the asteroids follows, showing what great detail was being transmitted to Banks, and from him to Herschel and others. Most of the letters received by Banks were from Baron von Zach, who kept him fully apprised of asteroid observations made by him and others on The Continent. Zach stayed in London from late 1783 through 1784, where he became well acquainted with Banks, Maskelyne and Herschel. Letters from Maskelyne to Banks are in this Section, while other letters to and from Maskelyne are included in Section D.2.

On 14 January 1802 Zach wrote to Banks:

I have herewith the Honour of transmitting to you the Information of the Discovery of the new Planet, Discovered first a Year ago in Palermo by Mr. Piazzi\(^1\), and called by him, Ceres Ferdinandea. I detected this planet first, in my Observatory at Seeberg December 7\(^{th}\) 1801 at 18\(^{h}\) 48\(^{m}\) 10\(^{s}\) 3 Mean time. Apparent Right Ascension = 178\(^{º}\) 33\(^{º}\) 30\(^{º}\),6 very exact. Declination 11º 41\(^{º}\)½ N. only by Estimation, having not observed the Planet with the quadrant, but only with my 8 feet Transit Instrument.

The 31 December, I saw the planet again, and had the certitude that it had changed its place according to an elliptical motion, that suits with a Planet existing between the orbits of Mars & Jupiter, as was supposed immediately after the first discovery made in Palermo 1 Jan. 1801.

The 11 January 1802, I saw the planet again, and had full Conviction, that it really was the supposed Planet Ceres Ferdinandea. I observed the planet again in the Meridian 11 Jan. 1802 at 17\(^{h}\) 3\(^{º}\) 17\(^{º}\),4 Mean time App. AR = 186\(^{º}\) 45\(^{º}\) 49,95 exact to a second. Declin. N. 11º 10\(^{º}\) by Estimation.

These Positions agree to a half a degree in AR, and to 9 Minutes in Declination, with the account of its Motion, which I have printed in my Journal Monatliche Correspondenz December.

My first observation is printed in my Journal for January, but without knowing then, that this star was really the planet sought for. I take the liberty to send you here the printed sheets thereof.

Dr. Olbers in Bremen, discovered the same planet (not having had any Notice of my Discovery) January the 2.\(^{d}\) His observations, made in a gross manner, are as follows:

\[
\begin{array}{ccc}
\text{AR} & \text{1802 Jan. 2. 11h 58' 26'' M. time Bremen...} & 185\,9' \text{.... Decl. 11° 7' N} \\
\text{----- 5. 17 30 0 ------ -----------....} & 185\,43' \text{..... 11 8.'--}
\end{array}
\]

Letters from Paris, from Mr. La Lande, and Mechain, as far as 1 January, mention nothing about this planet, it therefore has not been discovered in France at that time. I can't tell, whether it has been seen anywhere before 7 December.

The planet appears to be a star of 9 magnitude. I looked at it with a magnifying Power of 120, but could not discover the least appearance of a Disc; the planet appears to me rather like a tarnished Star.

I leave it to your favor, whether this Discovery is thought worth your while, to give the Royal Society, the English Astronomers Information thereof. For it is very likely that Mr. Herschel, has discovered this planet already for his own part. Notwithstanding I take the liberty, to send you here annexed an Ephemeris of the Position of this heavenly Body [see Figure D.1, below], to facilitate the Research, if perhaps an unfavorable sky has not permitted to make the Discovery in England. (Zach, 1802a, his underlining).
Zach’s next letter to Banks was penned on 30 January 1802, telling him that only he and Olbers had seen Ceres:

In pursuance of what I had the honor of intimating to you in my last, and in the supposition my notices will not be disagreeable to you, I take the liberty to send you the continuation of my observances of the New Planet Ceres Ferdinandea.

The RA are very exact, the Declinations only guessed at my transit instrument, for the planet appears so faint, that it was impossible to distinguish in the telescope of my 4 foot meridian quadrant, notwithstanding I got twice the zenith distances of the planet, marked with an x Viz., the 25th and 28th January. But I scarcely could see the wires as the little planet permits very little illuminating, and the state of air being very foggy all the time.

<table>
<thead>
<tr>
<th>Seeberg Obsvr</th>
<th>Mean time</th>
<th>App. RA Ceres</th>
<th>App. Declinat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1801 Decbr</td>
<td>18h 48m 10.3</td>
<td>178 33 30.60</td>
<td>11 41 1/2 N</td>
</tr>
<tr>
<td>1801 Decbr</td>
<td>17 38  ::</td>
<td>184 44  ::</td>
<td>11 5</td>
</tr>
<tr>
<td>1802 Jan</td>
<td>16 46 25.6</td>
<td>187 27 53.25</td>
<td>11 26</td>
</tr>
<tr>
<td>1802 Jan</td>
<td>16 25 23.9</td>
<td>188 6 25.80</td>
<td>11 44</td>
</tr>
<tr>
<td>1802 Jan</td>
<td>16 14 32.9</td>
<td>188 20 39.15</td>
<td>11 56 23x</td>
</tr>
<tr>
<td>1802 Jan</td>
<td>16 10 53.7</td>
<td>188 24 49.50</td>
<td>11 57</td>
</tr>
<tr>
<td>1802 Jan</td>
<td>16 3 29.0</td>
<td>188 31 37.85</td>
<td>12 9 41.3x</td>
</tr>
<tr>
<td>1802 Jan</td>
<td>15 59 43.7</td>
<td>188 34 18.15</td>
<td>12m 14</td>
</tr>
</tbody>
</table>

The Ceres has hitherto been observed by no other astronomer but by me, and by Dr Olbers of Bremen; this latter made a little mistake in reducing his observations, I had the honor to send to you. I make it a duty, so give you here a corrected copy of these observations, this gentleman sent to me in his last letter. The mistakes took place in noting the AR of 20 Virginis, 3 minutes too little, with which he compared the planet. His observations stand thus now.

<table>
<thead>
<tr>
<th>Bremen</th>
<th>Mean time</th>
<th>App. RA Ceres</th>
<th>App. Dec N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1802 Jan</td>
<td>11h 58' 36&quot;</td>
<td>185 7' 40&quot;</td>
<td>11 6' 30&quot;</td>
</tr>
<tr>
<td>1802 Jan</td>
<td>17 30 0</td>
<td>185 43 7</td>
<td>11 7 56</td>
</tr>
<tr>
<td>1802 Jan</td>
<td>12 25 41</td>
<td>186 34 52</td>
<td>11 13 10</td>
</tr>
<tr>
<td>1802 Jan</td>
<td>11 53 38</td>
<td>187 1 56</td>
<td>11 18 56</td>
</tr>
<tr>
<td>1802 Jan</td>
<td>11 9 3</td>
<td>187 10 11</td>
<td>11 20 57</td>
</tr>
<tr>
<td>1802 Jan</td>
<td>12 8 9</td>
<td>187 18 27</td>
<td>11 23 25</td>
</tr>
<tr>
<td>1802 Jan</td>
<td>13 8 0</td>
<td>187 55 0</td>
<td>11 37 18</td>
</tr>
<tr>
<td>1802 Jan</td>
<td>12 26 40</td>
<td>188 5 45</td>
<td>11 43 55</td>
</tr>
</tbody>
</table>

These observations are all made with the circular micrometer which wants no illuminations of wires. It is only a perfect circular diaphragm in the focus of the telescope. The immersions and emissions of the planet, and the star compared with, are obscured. And so AR and Decl. are
deduced, but this method of observing gives not a very great precision, especially for Declination
upon which 1 or 2 min cannot be depended.

Till 15th January the planet has not yet been discovered in France. A letter from Mr Piazzi, Palermo 9th last December mentions that he had not discovered yet the planet. I long to know, whether the English astronomers had been happier. Perhaps Mr Herschel will discover some satellites in Ceres. Mr Harding of Lilienthal sends me words, that looking at the Ceres with a Power of 288, he distinguished a little disc, of the size of the I or II satellite of Jupiter; he esteems therefore the diameter of Ceres about 2 seconds. He saw also two lucid points near the planet (11 January) both to the west of the planet, the one about 20” the remoter 30” or 35”. Dr Herschel will best tell us, if these lucid pointers are satellites or not.

Here I have the honor to send you another ephemeris for Ceres, which will agree better than my former, because I corrected it upon my observations. (Zach, 1802b).

Footnote by C. Cunningham:

1 Karl Harding (1765-1834) discovered the third asteroid, Juno, in 1804. He worked as an assistant to Johann Schröter in Lilienthal at the time this letter was written. He later moved on to a professorship at Göttingen.

Two weeks later, on 16 February 1802, Banks (1802a) passed to Herschel some of the information in the last paragraph in Zach’s letter:

By a letter from Zach [this is the January 30 letter] I learn that Mr. Harding of Lilienthal looking at Ceres with a power of 288 distinguished a little disc of the size of the I or II satellite of Jupiter whence he concludes the diameter of the planet to be about 2”. He saw also 2 lucid points near the planet both on the west side on the 11th of January. The one about 20” the other about 30” or 35” distant which he suspects to be satellites.

In fact, Harding’s full report is published in the February 1802 issue of the Monthly Correspondence, page 170. He used a 7-foot Herschel telescope for these observations (see Cunningham, 2001: 324). A little over a week after writing his previous letter Zach (1802d, his underlining) sent Banks another missive on 8 February 1802:

  I take the liberty to send you here, the first approximated Elements of an elliptical orbit of the new Planet Ceres Ferdinandea, which Dr Gauss corrected upon my first Observation of this Planet Decb. 7 1801, and 16 Jany. 1802. These Elements will want some farther corrections, but in the mean While they will agree with the Heaven for a considerable time about half a minute.

<table>
<thead>
<tr>
<th>Midnight at Seeberg</th>
<th>RA</th>
<th>Decl N</th>
<th>RA in time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1802 30 Jan</td>
<td>188 37</td>
<td>12 16</td>
<td>12 34 30</td>
</tr>
<tr>
<td>1802 2 Feb</td>
<td>188 43</td>
<td>12 31</td>
<td>12 34 53</td>
</tr>
<tr>
<td>1802 5 Feb</td>
<td>188 45</td>
<td>12 47</td>
<td>12 35 11</td>
</tr>
<tr>
<td>1802 8 Feb</td>
<td>188 44</td>
<td>13 4</td>
<td>12 34 55</td>
</tr>
<tr>
<td>1802 11 Feb</td>
<td>188 38</td>
<td>13 22</td>
<td>12 34 33</td>
</tr>
<tr>
<td>1802 14 Feb</td>
<td>188 24</td>
<td>13 41</td>
<td>12 33 57</td>
</tr>
<tr>
<td>1802 17 Feb</td>
<td>188 16</td>
<td>14 1</td>
<td>12 33 5</td>
</tr>
<tr>
<td>1802 20 Feb</td>
<td>187 59, 25</td>
<td>14 21</td>
<td>12 31 59</td>
</tr>
<tr>
<td>1802 23 Feb</td>
<td>187 40</td>
<td>14 42</td>
<td>12 30 40</td>
</tr>
<tr>
<td>1802 26 Feb</td>
<td>187 17</td>
<td>15 3</td>
<td>12 29 8</td>
</tr>
<tr>
<td>1802 1 March</td>
<td>187 51</td>
<td>15 24</td>
<td>12 27 22</td>
</tr>
</tbody>
</table>

Epocha Mean Long. 1801 for Palermo ........................77° 24’ 55,9”

--- --- --- --- 1802 --- ---------------------------155 33 35,1

Dayly mean tropick heliocentric motion...........770,"7376
Tropick Revolution........................................1681 Days 12 h 9 Min
Log. ½ axis..................................................0.4421189
Aphelium…………………………………………… 326° 14′ 45″
Node………………………………………………… 80° 58′ 55″
Excentricity………………………………………… 0.08086253
Greatest Equation of the Center……………………… 9° 16′ 23″
Inclination………………………………………….. 10° 37′ 51″

My Observations agree with this Elements thus:

<table>
<thead>
<tr>
<th>Seeberg</th>
<th>Calculated AR</th>
<th>Distance from observation</th>
<th>Calculated Declin.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decb 1801 7</td>
<td>178 33° 33′ 6″</td>
<td>+ 3°, 0</td>
<td>11° 47′ 33°</td>
</tr>
<tr>
<td>Jany 1802 11</td>
<td>186 46 9,3</td>
<td>+19°, 3</td>
<td>11 15 41</td>
</tr>
<tr>
<td>Jany 1802 16</td>
<td>187 28 3,1</td>
<td>+ 9°, 9</td>
<td>11 26 40</td>
</tr>
<tr>
<td>Jany 1802 22</td>
<td>188 6 45,9</td>
<td>+ 20°, 1</td>
<td>11 45 18</td>
</tr>
<tr>
<td>Jany 1802 25</td>
<td>188 21 6,5</td>
<td>+ 27°, 3</td>
<td>11 56 49</td>
</tr>
</tbody>
</table>

You’ll find my Subsequent Observations of the Planet in the annexed printed Sheets pag. 15. The Planet was stationary from Febr 4th to 5th.

To facilitate the Calculation of the Position of Ceres by the above Elements, I calculated the following formulae

1) for the Equation of the Center

\[-33330°.972 \text{ Sin. Anon. med} + 1681°. 843 \text{ Sin 2 Anon med} - 117°.670 \text{ Sin 3 Am} + 9°.408 \text{ Sin 4 A.m} - 0°.8148 \text{ Sin 5 A.m} \]

2) For the Radius Vector = r

\[r = \frac{7. 61007}{2.767700 + 0.2238032 \text{ Cos. Anom. ver}}\]

3) for the heliocentric Latitude = λ

\[\log \sin \lambda = 9. 2659499 + \log \sin \text{ Arg. Latit.}\]

4) for Reduction to the Ecliptick = ε

a) \[\log \text{ Tang. } \phi = 9.9924811 + \log \text{ tang. Arg. Latit.}\]

b) \[\text{Arg Latit - } \phi = \varepsilon\]

Mr Schroeter from Lilienthal measured the Planet’s disk

Jany 25 = 1°.815 but the planet appears to him wrapt up in a very great nebulosity. The Diameter with this Nebulosity was = 2″, 514

the 26 Jany ……= 2, 687

Mr Harding found the same to be = 2″,330

Then on 20 February, Zach (1802e, his underlining) sent Banks his latest observations of Ceres:

I had the honor to send to you my observations of the new Planet Ceres Ferdinandea made in January: here I take the liberty to send the continuations of them made in February.

<table>
<thead>
<tr>
<th>1802</th>
<th>Mean time in Seeberg</th>
<th>Apparent RA observed</th>
<th>App. Declin. Obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Febr 3</td>
<td>15h 40′ 35.8″</td>
<td>188 42 13′ 05″</td>
<td>12° 40′ 5″N</td>
</tr>
<tr>
<td>Febr 4</td>
<td>15 36 41.4</td>
<td>188 42 36.30</td>
<td>……………………..</td>
</tr>
<tr>
<td>Febr 5</td>
<td>15 32 45.1</td>
<td>188 42 31.15</td>
<td>12 50 25</td>
</tr>
<tr>
<td>Febr 9</td>
<td>15 16 43.7</td>
<td>188 38 3.90</td>
<td>13 14 18</td>
</tr>
<tr>
<td>Febr 19</td>
<td>14 34 46.7</td>
<td>187 58 27.90</td>
<td>14 20 3</td>
</tr>
</tbody>
</table>
Dr Gauss has corrected his elliptical Elements of the orbit upon my observations. Here is what he has found since my last letter to you.

Epoch for the Beginning of the Year to the Meridian of Seeberg    77° 27' 36.5"
Epoch 1801 for the Seeberg Meridian    77° 27' 36.5"
Mean diurnal mot. helioc. and tropical 769°.792 log 2.4463726
Log. semi major axis 0.4424742 number 2.769965
Eccentricity 0.0814064
Aphelion 1801 stationary 325° 57' 15"
Node 80 58 40
Equation of the orbit 9 20 8
Inclination 10 37 56.6

With these Elements of the orbit, all the observations made by Mr Piazzi in Palermo from Jan'y 1 till Feb'y 11 1801, agree perfectly well, and within a few seconds. And my observations are represented by them thus:

<table>
<thead>
<tr>
<th>Seeberg Obser.</th>
<th>RA calculated</th>
<th>Difference</th>
<th>Declin. Calcul.</th>
<th>Diff°</th>
</tr>
</thead>
<tbody>
<tr>
<td>1801 Decembr 7</td>
<td>175 33' 29.2&quot;</td>
<td>-1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1802 January 11</td>
<td>186 45 47.6</td>
<td>-2.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1802 January 16</td>
<td>187 27 38.8</td>
<td>-14.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1802 January 22</td>
<td>188 6 18.2</td>
<td>-7.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1802 January 25</td>
<td>188 20 37.2</td>
<td>-2.0</td>
<td>11° 56' 58.4&quot;</td>
<td>+35.4</td>
</tr>
<tr>
<td>1802 January 26</td>
<td>188 23 37.0</td>
<td>-12.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1802 January 28</td>
<td>188 31 25.7</td>
<td>-12.1</td>
<td>12 9 55.6&quot;</td>
<td>+14.3</td>
</tr>
<tr>
<td>1802 January 29</td>
<td>188 34 14.1</td>
<td>-4.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1802 January 30</td>
<td>188 36 38.4</td>
<td>-5.5</td>
<td>12 19 19.8&quot;</td>
<td>+19.1</td>
</tr>
<tr>
<td>1802 January 31</td>
<td>188 38 38.3</td>
<td>-7.1</td>
<td>12 24 15.3</td>
<td></td>
</tr>
<tr>
<td>1802 Febry 3</td>
<td>188 42 7.8</td>
<td>-5.2</td>
<td>12 39 53.6&quot;</td>
<td>-11.4</td>
</tr>
</tbody>
</table>

As these elements agree hitherto so well with the heavens, the following ephemeris calculated upon them for the next month will probably do the same, so I annex it here, to point to our English observers the place, where they have to look for the Ceres.

This planet will come in opposition with the Sun March the 17th afternoon. In the same time this heavenly body will be in its greatest proximity to the Earth = 1.6025 and therefore the most favourable time, to look for its satellites, if there are any. About this time the planet will also be in the greatest geocentric Latitude = 17° 9', and a little later, he will have his greatest retrograde motion, about 13 min in Right Ascension per day. The North Declination will increase till to the beginning of April, about the 9th of the same month, the motion in Declination will commence to be South.

| Position of the Ceres for the Midnight Mean time in Seeberg Observatory |
|-----------------------------|-----------------|-----------------|-----------------|
| 1802 | RA in degrees | Decl N | RA in time |
| March 1 | 186° 41' | 15° 30' | 12h 26' 45" |
| March 4 | 186 11 | 15 50 | 12 24 45 |
| March 7 | 185 39 | 16 10 | 12 22 36 |
| March 10 | 185 5 | 16 29 | 12 20 18 |
| March 13 | 184 28 | 16 47 | 12 17 53 |
| March 16 | 183 51 | 17 4 | 12 15 24 |
| March 19 | 183 13 | 17 19 | 12 12 50 |
| March 22 | 182 34 | 17 33 | 12 10 15 |
| March 25 | 181 55 | 17 44 | 12 7 40 |
| March 28 | 181 17 | 17 54 | 12 5 7 |
| March 31 | 180 39 | 18 1 | 12 2 37 |
| April 3 | 180 3 | 18 6 | 12 0 12 |
| April 6 | 179 29 | 18 10 | 11 57 54 |

It appeared to me that the Ceres has some change of light. I imputed it first to our hazy atmosphere this winter, but Mr Schröter from Lilienthal, and Mr Olbers from Bremen sent me
words, that they have observed the same, and they believe that it is the planet, which is subject to such changes of light. Mr Herschel will tell us best, whether it is so.¹

I have some hopes to find the Planet, in ancient Catalogues of Stars. Mr Messier² was very near it in the Year 1779. The famous comet of this year ran just over the northern Wing of Virgo, as now, and the new planet was not very far. If the comet had two months sooner reached the wing of Virgo, Mr Messier must infallibly have observed the Ceres then, because he determined all the little stars in the vicinity of the Comet; the Planet had been in the way of the comet, and so of course he would have caught this little planet in 1779. [This point is given some more detail in a letter by Olbers, published in the March 1802 issue of the *Monthly Correspondence*.]

If my informations are acceptable to you, Dear Sir, only a little hint, and I shall continue with pleasure to give you further intelligence.

Footnotes by C. Cunningham:

1. Any changes in the light of Ceres observed by Zach, Schröter and Olbers were mistaken. A combination of poor optics and atmospheric conditions misled them. Its true amplitude is only 0.04 magnitude, far too small for visual detection.

2. Charles Messier, the famous French astronomer. He co-discovered comet Bode on 19 January 1779.

Banks replied to this letter on 12 March 1802 but it is no longer extant. Zach also sent a copy of this letter to Edward Troughton, and subsequently it was published in *A Journal of Natural Philosophy* (Nicholson’s Journal; 1802e). Zach’s next letter to Banks is dated 15 March 1802:

I had the honor of your letter 12th inst. and was very much flattered to see, that you accepted so well, and pay’d some attention to my letters, which I took the liberty to address to you concerning the Ceres Ferdinandea. This very kind reception imbolden’s me to send you here, the continuation of my observations of this new Planet. Very good observations of this heavenly body, are still very scarce, and I hope the English astronomers will find the mine so. There are hitherto only three places, where Ceres is observed with great accuracy, in Greenwich, in Paris, and in Seeberg. All other astronomers in Europe have either not the means, and the power to observe this delicate Planet with great precision; or the intelligence of the discovery of this heavenly body, has not reached them yet. So Mr. Oriani astronomer in Milan sent me words Febr’ 10th, that to this date, no tidings of Ceres came to Italy, and yet I sent to him the intelligence in the begining [sic] of January, but very unfortunately, Mr. Oriani was not in Milan by this time, he was then as Deputy of the Cisalpine Republic in Lyons, so my first letter to him was delayed. From Palermo neither no news; so I can’t tell when Mr. Piazzi (who is very able to make excellent observations) began first to observe the Ceres Ferdinandea. Mr. Mechain was so kind, as to send me two observations of Ceres, of the Astronomer Royal, and I was much satisfied, to see, that my observations agree’d perfectly with the Doctor's. But as my friend Mr. Mechain sent me words, that the Doctor wished not, to have his observations published, so I have made no use of them in the *Monatliche Correspondenz*, tho’ a greater, and a divers set of observations wou’d have been very acceptable to the calculators of the Planet’s orbit. I do not communicate to you either the observations from Paris, because Mr. Mechain assured me in his letter, that he has already done it. Here are all my observations [see Figure D.2, below], made in the present Month of March, they prove, that the ephemeris of the Planet’s Track, which I took the liberty to send you, still agrees tolerably well with the Heaven.

At the bottom of this table is an * with another observation made on 15 March.

To the right of the table, Zach wrote this paragraph:

"*An observation just made the night before this letter was sent off, which will set a puzzling some astronomers, for the Ceres fell just in, with a star of 7 magn. and it was difficult to distinguish, which was the Planet. I observed them both, and so I found out, that the Planet followed the star 7″.52 in time, and was the northern most. The mean position of the star 1 January 1802 is AR 184° 0′ 21″.23 Declinat 16° 56′ 46″.2 N."
After this aside, Zach now resumes the letter:

I shall take the liberty, to send you in my next (letter), the first proof of a celestial map, which is engraving just now, & upon which I delineated the Track of the new Planet during its visibility in the present Year. This map will be of great utility to astronomers, in observing the planet out of the meridian, for in May the Twilight will not permit this kind of observation, and we must take recourse to equatorial sectors, or parallactic instruments, in comparing the little Planet with fixed stars in its Parallel.

In order to do this with great accuracy, I have set down in this map, all the little stars, even the telescopicks, which come in the Planet’s Way, and which are not lay’d down in Mr. Bode’s great maps he published last year. I have to this Purpose not only calculated the positions of these little stars, observed by the nephew of Mr. de LaLande, in his Histoire celeste francaise, but as he has only observed the zenith distances, I have determined with great care, with my 8 feet transit instrument of late Mr. Ramsden, the mean Right Ascensions of them. And as I took to my standard, the late corrected positions and AR of Regulus, β Leonis, β Virginis and Spica, from the Royal Astronomer, communicated to me by Mr. Mechain; and as referred in No. 1 Jan. 1802 p. 60 of my Monthly Correspondence, I hope all these little stars, are determined as exactly, as in the Doctor’s Catalogue of the 36 principal stars.

If the Astronomer Royal will take the trouble to examine how far my attention deserves credit, I put down here some of my determinations, that will enable him to judge, whether these AR, will be to any service to astronomers, in comparing the new Planet with them.

The following two paragraphs were written to the right of the table of star positions that are reproduced in Figure D.3:

All the time, I observed the new Planet, I also observed carefully the Sun, in order to find out the error of our solar tables, on purpose to get the heliocentric places of the planet as pure and unmixed with errors of our own motion, Planet as pure, and unmixt with the errors of our own motion. This caution is by no planets more necessary, as by Ceres and Mars, as astronomers, who aspire to modern delicacy in practical astronomy will understand best. For our best solar tables, can yet be erroneous to a quarter of a minute, in some cases. Some equations of the Sun’s longitude depending on the Planet’s actions, and on the higher powers of the excentricity of their orbits, had been neglected hitherto, tho’ the joint actions of these neglected terms can amount to 10 or 12″ in space. Mr. de LaPlace, wrote to me lately, that he had also found out, that the mean solar motion has a secular diminution of about 20″.

To correct now the elements of the orbit of Ceres, the action of Jupiter and Mars upon this little planet must needs be computed, for these Perturbations will be considerable enough. I expect only the observation of the opposition, and as soon, as I shall have done it, I’ll immediatly [sic] set about this calculation (Zach, 1802g, his underlining).
Footnotes by C. Cunningham:

1. Zach refers here to Bode’s famous *Uranographia* star atlas.
2. Michel Lefrançois. He was a cousin, not a blood nephew of Lalande, but was always referred to as Lalande’s nephew. Michel married Lalande’s daughter Amelie. He began working with Lalande in 1781.
3. Maskelyne’s 1790 catalogue gave the proper motions of 36 stars. From these data, Herschel determined the Sun’s motion in space.
Zach’s next letter to Banks is dated 30 March 1802:
I promised you in my last letter, that I shall have the honor to send to you, the observation of the opposition of the new Planet Ceres Ferdinandea, which as you know, is of a great moment for the Theory of this new heavenly body, and as I was so lucky to get these observations with full success, I take the liberty to communicate to you the results of them.

The 15, 16, 17, 18, 19 March the sky was very favorable; these days include exactly in their middle the opposition of the Planet with the Sun. I had the honor to tell you in my former letter that my purpose first was, to find out the errors of our Solar Tables, upon which a nice observer cannot rely; to attain which, I made the following observations of the Sun, which I compared with my own Solar Tables, published in Gotha 1792, and corrected hereafter in 1798. These observations stand thus [see Figure D.4]:

![Figure D.4: Zach's observations of Ceres (after Zach, 1802).](image)

The mean error from 17 to 21 March is therefore +4″.4 which my Solar Tables give the longitude of the Sun too great; and to be employed in the calculations of the opposition of Ceres Ferdinandea. As to the planet, I compared my observations with the Elements VII of its orbit, as referred in my journal, March page 272, viz:

- Epocha of long. 1801 Seeberg meridian: 77° 27' 36.5″
- Mean daily heliocentric tropical motion: 769°.7924
- Log. ½ great axis: 0.4424742
- Eccentricity: 0.0814064
- Aphelion: 325° 37' 15″
- Equinox: 80° 58' 40″
- Greatest equation of the orbit: 9° 20' 8″
- Inclination: 10° 37' 56.6″

According to these Elements my observations are represented thus, as in the following [see Figure D.5 and D.6]:

![Figure D.5 and D.6](image)

It appears therefore, that the mean error of the elements of the orbit is -31″.1 in Longitude and +27″.2 in Latitude, excluding the error of Latit. of the late observation, marked doubtfull [sic]. The heliocentric Elements of the calculus for the above observations will stand as follows [see Figure D.7]:

![Figure D.7](image)
With these data I then found, that the Ceres Ferdinandea came into opposition with the Sun, March y°17th at 4°18’ 0” mean time in Seeberg. For this moment, the true corrected Longitude of the Sun by -4",4 and +20",0 from appar. Equinox is 11° 26’ 21’’ 26",6
the geocentric. long. of Ceres corrected by +31”,1 is 5° 26’ 21’’ 26,5
the geocentric. long. of Ceres by the elements is 5° 26’ 21’’ 7,7

error of Elements in Long -18”.8

The geocentric. Latit. of \( \varphi \) corrected by -27",2 is \( \ldots = \) 17° 8’ 9",0 North
Hence the heliocentric lat. will be .................. = 10  34  54,8
The same by the elements calculated .................. = 10  35  12,2

error of Elements in latit  +17",4

So then, the main result is: That Ceres Ferdinandea was in opposition with the Sun 1802 March 17th at 4h 18' 0" mean time in Seeberg in geo- and heliocentrick Longitude from the
Apparent equinox        = 5Z  26° 21' 26",55
In geocentr. latitude  =,......  17  8  9,00 North
In heliocentr. latitude =,......  10  34  54,80 North

All my observations shall agree with the above Elements of Dr. Gauss. The comparison which he has made, with the whole series of my observations in AR, and Declination, is as annexed here [see Figures D.8 and D.9].

By inspection of this Table it appears, that all the negative Errors in AR, turned into positives, and are increasing, and very likely will continue so: But there is no correction of Permanence to hope, till the Equations of Perturbation shall be calculated. The Planet Jupiter has a very great action upon our little Planet, and Mr. De la Place wrote to me, that the summ [sic] of all the Perturbations, to which Ceres is liable, amount to half a Degree. My Disciple Dr. Burckhardt, has already done this (?). He sends me Words, that all Equations of the Perturbation come chiefly from Jupiter, and amount to 27 minutes. Mars produces not 1 seconde, and Saturn as much as nothing. Taking therefore, these quantities in Account he finds the following corrected Elemens of the Orbit.

Figure D.8: The ephemeris for Ceres based on Gauss’ elements (after Zach, 1802i).
Figure D.9: An evaluation of Zach’s observations based on Gauss’ ephemeris (after Zach, 1802).

| Epocha Longit. | Meridian Paris | 77° 19’ 17” |
| Aphelium in 1801 | 326 42 32 |
| Annual Motion | +2 5 |
| ☊ 1801 | 81 5 35 |
| Annual Motion | as much as nothing |
| Inclination | 10 36 52 |
| Half great-Axis | 2.76587 |
| Excentricity | 0.0788725 |
| Tropick Revolution | 1679 days, 84 |

[To the right of these elements, Zach writes the following]:

Mr. Burckhardt has already constructed planetary Tables, upon these principles, but I shall not insist upon, as I suppose, that Mr. Mechain, will acquaint, the Astronomer Royal with this matter. For the present Moment Dr. Gauss Elements are more then sufficient to point out the Planet, and so I send here the continuation of an Ephemeris (7) Dr. Gauss has calculated at my Request.

[The letter then continues below.]

Here I have the Honor of Sending you the Continuation of my Observations of the Ceres Ferdinandea [see Figure D.10].

Figure D.10: Zach’s observations of Ceres made in March 1802 (after Zach, 1802).

To the left of this table, Zach writes the following:

As Several Astronomers wished for the Position of Stars, with which they had compared the Ceres, I upon this occasion have constructed the following Catalogue of Stars (*) which are new, or had been laid down very erroneous [see Figure D.11]. I hope the competent Judges will find these Positions very exact.
From Mr. Piazzi I received lately two letters from Feb’ 2\textsuperscript{nd} and Feb’ 17\textsuperscript{th}. He just tells me in a Postscript, that he received by newspapers the intelligence of the discovery of his New Planet, but expects [sic] now, to hear by his correspondents, where to look for the Ceres Ferdinandea. He wishes not, that the name he has given to the Planet in honor of his King might be altered, but it seems, that the French prefer the name of Juno. Mr. LaPlace in all his letters to me, always used the name of Juno. Mr. LaLande employed the name, Planète de Piazzi, as he does with, Planète de Herschel. In my journal Monthly Correspondence I applied to it the symbol $\mathcal{P}$, till a better shall be found out. The symbol of Saturn $\mathcal{H}$, represents a scythe, so the symbol of Ceres $\mathcal{P}$ may represent a sickle, as Ceres is the Goddess of corn and tillage.

But it is time to finish my epistle, in offering you of the highest Regard & Esteem. (Zach, 1802i, his underlining).

The somewhat confusing layout of Page 2 of this letter is reproduced here as Figure D.12.
Zach's next letter to Banks is dated 5 April 1802, and informs him of the surprise discovery of yet another object (Pallas):

In haste I have the honour to acquaint you, with a most extraordinary Discovery¹, which will as much astonish you, as it will surprize all english Astronomers. My Friend Dr. Olbers in Bremen discovered, March yᵉ 28ᵗʰ in the northern Wing of Virgo besides the wellknown Ceres Ferdinandea, an other little moveable celestial Body, resembling in Magnitude and Light to Ceres, with a retrograde motion like Ceres except that its northern Declination is increasing quicker. This new heavenly Body looks like a star of the ⁷ᵗʰ magnitude, without the least appearance of a Nebulosity. Here is the history of this very extraordinary Discovery. As Dr. Olbers is not provided with fixed instruments, but now observes the Ceres to his amusement with a loose Refractor, and a circular micrometer he is bought, to look out for Ceres with a nightglas, and to be in quest of her amongst the little stars, the more thorough. Doing this the 28ᵗʰ March, he found, that he could compare our new Planet’s brilliancy with the star Nᵒ 3 Coma Berenices. Having done with this observation, he made with his nightglas a Review of this part of the Heaven, in the Purpose, to get better acquainted with all the little stars scattered thereabout, to the end that he might with greater easiness find out the Ceres in his future observations. Sweeping by chance the spot where stands Nᵒ 20 Virginis, he is with some surprise remarked a star of the ⁷ᵗʰ Magnitude which with Nᵒ 191 of Mr. Bode’s Catalogue formed very nearly an equilateral Triangle[sic]. As this was the very same spot, where Dr. Olbers saw first, January yᵉ 1, the Ceres Ferdinandea, this part of the Heaven was thoroughly known to him, and he recollected very well, that in January & February no such star had been visible there. His first surmise, was therefore, that this star might be, in the number of
these, called Stellae mirabilis, like Mira Ceti, or other of the kind discovered in the latter time, in
greater multitude, by Mr. Goodrike\(^5\), and Mr. Pigott\(^5\). In the mean while Dr. Olbers compared this
new guest with No 20 Virginis and continued\(^\text{sic}\) so from 8¾ o’clock till 11 o’clock, when the weather
began to be overcast. But this little Interval of time was sufficient to shew, that the subsequent
observations of the Right Ascension grew shorter, and the Declination greater. These Alterations
were too regular, as to impute them to the Errors of the observations, & thus Dr. Olbers was
convinced the same evening, that his new Guest, was a Vagrant, and certainly had a proper motion.
Very fortunately the following Day March \(y^\circ\ 29^{\text{th}}\) the weather cleared up, and Dr. Olbers with as
much Pleasure as surprise perceived at the first glance of the Eye that this heavenly Body had
considerably changed its Place; he compared it with No. 20 \(\rho\), and found that he had moved 10
minutes in AR; and 20 minutes in Declination to the North.

March the 30\(^{th}\) the weather favoured again. The new Rambler was already too remote from No.
20 \(\rho\) to be compared with this star, Dr. Olbers took therefore his Refuge to two little stars of Mr. La
Lande’s great Catalogue, in Connaissance des tems Anneé X, page 254, the two last stars of the
page. By this means Dr. Olbers found these three rough Positions:

<table>
<thead>
<tr>
<th>Bremen</th>
<th>mean time</th>
<th>AR</th>
<th>Declin. N.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1802 March 28</td>
<td>9h 25’</td>
<td>184°57’</td>
<td>11°33’</td>
</tr>
<tr>
<td>29</td>
<td>8 49</td>
<td>184°46</td>
<td>11°53</td>
</tr>
<tr>
<td>30</td>
<td>8 3</td>
<td>184°36</td>
<td>12°13</td>
</tr>
</tbody>
</table>

The 31 March Dr. Olbers was so kind, to send me this Intelligence, beging \(\text{sic}\) that I might
endeavour to catch this new star, and observe it with accuracy with my fixed Meridian Instruments,
which he could not do. I received his letter Sunday morning, April \(y^\circ\ 4^{\text{th}}\), and the very same
evening, being very fortunately favoured by a very fair & clear sky, I immediately found after the
first Dusk with my nightglas, our strange Host. I then, without delay prepared for a carefull, and
nice meridian observation, and was indeed so lucky to get the first very good, I dare say, very
excellent, observation of the Right-Ascension, and Declination of this new vagabond. I had the
moral certainty, that it was Dr. Olbers new star, but I wished to get the physical conviction of its
being the very same Body, in comparing its diurnal proper motion, and so I expected, (as you will
easily guess), with the greatest eagerness the following night, which very happily turned again very
clear and serene. Looking to the place where I saw the day before, the star I had observed, the bird
was flown, and I observed with Delight \(\text{sic}\), that it had moved just according Dr. Olbers
Indication; I again had a very nice meridian observation, and having thus two very accurate
Positions of this new Rambler, and to day being postday for England, I do not longer putt off, to
give you, Dear Sir, this most extraordinary Intelligence taking the liberty to send to you here, my
two very good observations, in hopes, you will take this attention to you kindly of me.

<table>
<thead>
<tr>
<th>1802 mean time Seeberg RA D’ Olbers Star</th>
<th>Declin. D’ Olb. *</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 4</td>
<td>11h 24° 51°,9</td>
</tr>
<tr>
<td>---- 5</td>
<td>11 20 17,3</td>
</tr>
</tbody>
</table>

I hope this will be sufficient to point out to the english Astronomers this new Guest, and that
they will find him out soon, this letter being by this season only 12 days upon the Road.

To my opinion it appears to me, that this new Body looks just as Ceres in magnitude, but a little
bit brighter as Ceres. Dr. Olbers on the contrary estimates Ceres brighter then the new star. Dr.
Schröter in Lilienthal who gazed at it with his 13 feet Reflector and a magnifying Power of 288,
finds the star greater, brighter and better terminated then Ceres, he found the new Ramblers
Diameter the 30 March = 4°,635 and this of Ceres the 28 March = 4°,831.

But now, pray Sir, what do you think, of this strange heavenly body? Is it a Comet? The
appearance and the constant regular motion is against this opinion. Is it a Planet? What an
imense and paradoxical inclination must this orbit not have! Where to range this Planet? Is it
perhaps Lexell’s Comet of 1770, that has a Period of 5 years? This opinion is contradicted by the
little Inclination of this comet’s orbit, which is only 1° ¾ … I don’t know, what to say, to this
strange appearance. Time will tell us, what it is; let us observe now with great Accuracy and
Exactness this curious Body, which Dr. Olbers wishes to call (to abridge the Denomination) in the
meanwhile, Pallas. I shall exert all my Power and Industry in observing this new candidate for
Planetisme; and I shall have the honor to give you from time too [sic] time my Report of the success.

Ceres is not neglected by this new occurrence [sic]; and here I take the liberty to send the following observations of this Planet [see Figure D.13]. (Zach, 1802), his underlining).

Footnotes by C. Cunningham:

1. Olbers discovered Pallas, the second asteroid. See Cunningham (2006) for a full account.
2. The English astronomer John Goodricke (1764–1786) was the first to notice that some variable stars are periodic.
3. The English astronomer Edward Pigott (1753–1825) published a list of 50 variable stars in 1786.

Mechanics’ Magazine (1826) printed a letter and a rejoinder regarding the role of the comet of 1770 in imparting an atmosphere to Ceres and Pallas. The rather bizarre idea was given its stamp of approval by David Brewster, who is quoted from his *Edinburgh Encyclopedia* article. A correspondent signed F. M. wrote derisively about the idea in the following issue. “Mr. Comet must have been the very tiniest of his species, not to have been able to take them [Ceres and Pallas] both off in his pocket!” (See Subsection 3.2.3). Zach’s next letter to Banks is dated 8 April 1802 and includes observations of Ceres and Pallas on the same night:

The great importance of the object, will make my Apology for teasing you thus, with my correspondence. But your ardent affection in promoting Sciences, which are so much indebted to you, is a sure warrant of your indulgence.

The very extraordinary heavenly body, who’s existence, and discovery I had the honor a few days ago to signify to you, is certainly a Primary Planet, that moves according to the general Laws of Gravitation in a very inclined orbit round the Sun, between the orbits of Mars and Ceres. Its Revolution is about 3 years, the mean distance 2.1. The ascending node 5° 20’. The 6th April the weather was overcast. The 7th April I had again a very exact observation of

<table>
<thead>
<tr>
<th>Pallas</th>
<th>Mean Time</th>
<th>Appar. RA</th>
<th>App. Decl.</th>
<th>N.</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 7</td>
<td>11° 11’ 10^&quot;.6</td>
<td>183° 15’ 38^&quot;.5</td>
<td>14° 49’ 2^&quot;.1</td>
<td></td>
</tr>
</tbody>
</table>

The same night observation of Ceres

| April 7 | 10^h 55 21,3 | 179° 17 39,7 | 18° 9 47,1 |

Dr. Olbers observations of Pallas are as follows [Figure D.14] (Zach, 1802k):
On 9 April 1802 Banks informed Herschel of the discovery of Pallas:
Dr. Olbers has discovered another Ceres, on the 20th of March, it is to appearances larger than the Georgium. Messrs. Schroeter and Harding have seen it since April the 2nd. Mr. Harding saw a star near it which he believes will prove a satellite. (Banks then prints the positional data for March 28, 29 and 30). The two first observations by Olbers, the 3rd by Harding. (Banks, 1802b).

Charles Blagden sent Maskelyne another letter from Paris 14 April 1802:
At the desire of Mr. Laplace, and in conformity to my own wishes, I send you the enclosed observations of the new star discovered by Dr. Olbers, made at the Observatory of Paris by Mr. Mechain and Bouvard; the former taking the zenith distances by the mural quadrant (of Bird) and the latter taking the passage over the meridian by the transit instrument.

<table>
<thead>
<tr>
<th>Mean time</th>
<th>apparent RA</th>
<th>appar. Decl.</th>
<th>Appar long.</th>
<th>Appar. Latitude N.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr. 10</td>
<td>13h 58′ 40″</td>
<td>182 45′ 10″</td>
<td>15° 41′ 30″</td>
<td>176° 6′ 58″</td>
</tr>
<tr>
<td>12</td>
<td>10 48 34</td>
<td>182 32 31.5</td>
<td>16 10 58</td>
<td>175° 42 47</td>
</tr>
</tbody>
</table>

These observations are not corrected for parallax or aberration.

Mr. Bouvard has given me the last of these observations and that of last night, April 13, in the following form

April 12 RA 12h 10′ 10″.2) sidereal time (32° 39′ 10″.5) zenith
13 12 9 39.4 ) (32 24 2.5 ) distance

You will see how far they agree. If this star be a planet, they have rudely calculated its distance from the sun as 1.9, somewhat more distant than Mars; but the great obliquity of its orbit to the plane of the ecliptic raises doubts. It appears here as nearly as possible of the same brightness as Piazzi's planet (Blagden, 1802b).

Blagden also wrote a letter to Banks from Paris, dated 12/13 April 1802:
On Saturday last a letter arrived here from Dr. Olbers of Bremen, mentioning that as he was looking at some stars near which Ceres had been last year, he discovered a new star of nearly the same magnitude, which appeared to have a proper motion, and being without nebulosity or tail, or any of the common appendages of a comet, but rather exhibiting a defined disc, though very small, he was inclined to consider it as a real planet. The night between Saturday and Sunday being tolerably clear here, most of the astronomers employed themselves in searching for this new heavenly body, and yesterday evening three of them read to the Institut a notice of their having found it, nearly in the place where they expected it according to the account of its motion given by Dr. Olbers; but somewhat less distant from the place where he observed it, because it is now retrograde, and approaching to its stationary point. M. de Lambre's notice, read to the Institut, is, that when it passed the meridian in the night between the 10th and 11th April, its right ascension was 12h 11′ 15″.9, and its declination 15° 38′ to 40′ North. About 4 o'clock in the morning of April 11th its RA was found to be about 17′ less, and its declination had increased 4′. These gentlemen could perceive no disc: it looked to them like a star of between the 7th and 8th magnitude, less luminous than they expected: it was near the 6th star of Berenice's hair, which is of the 5th magnitude. If I learn any thing more of this before the post goes away to-morrow, you shall have
it.... [section about Buerg's Tables of the Moon]. Laplace thinks them [the Tables] much more exact than any former ones. He wishes this to be communicated to Dr. Maskelyne, as also the observations of Olbers's new star (which De Lambre proposes to call Juno) and likewise to Dr. Herschel. Both these astronomers, no doubt, have Dr. Olbers's own observations already. I believe M. Mechain will send the French ones, by this post, to Sir H. Englefield and perhaps to others.

Mr. Bouvard has just sent me from the Observatory the following observations of Olbers's new star. It passed the Meridian of the Observatory at 12h 10′ 8″½ sidereal time: its distance from the Zenith by the great mural quadrant was 32º 38′ 34″5. From these observations and the latitude and longitude of Paris, the RA and Declination are easily calculated; but I have no book here to do it. Mechain and Bouvard say it appears of the same magnitude as Piazzi planet, but they do not here venture to assert, as yet, that it is a planet. (Blagden, 1802a: 65-66, and 70).

Stephenson Lee (elected eight years later in 1810 as assistant secretary to the Royal Society) wrote Maskelyne from his residence at Grove Hackney on 14 April 1802:

Sir Joseph Banks having obligingly written to inform me, that Dr. Olbers had discovered another erratic star on the 28th March last, I looked for it on Sunday night, but without success. On Monday, I looked for it again, and in RA 182° 36′ Decl. 16° 17′N by estimation discovered a small star, which from its appearance and position being certain I had not seen one in that place before, led me to suspect it must be the one in question. I was prevented from repeating by observations, as I intended to have done, two or three hours afterwards, by the cloudiness of the weather, but last night saw it again at 11h 50′ 48″ mean time in RA 182° 24′ Decl. 16° 27′ North. It is of the 7th magnitude, of a dull red colour, but appears brighter sometimes than at others, being from its faint light more easily observed by vapours floating in the air than the fixed star (Lee, 1802).

Banks sent Herschel a letter 16 April 1802 with news from France:

The news of the new planet reached Paris on Saturday the 10th inst. On Sunday the 11th 3 memoirs were read to the Institut which happened to meet on the day by persons who had seen it; by desire of M. Laplace I communicate to you the following observations from Paris.

The planet which M. Delambre proposes to call Juno was when it passed the meridian on the night between April 10th and 11th in RA 12. 11. 15.9 North Dec. 15. 38 to 40. About 4 in the morning of the 11th its RA was found to be about 7″ less and its declination had increased 4″.

On the night between the 12th and 13th of April it passed the meridian at the Paris Observatory at 12° 10′ 8″.2 sidereal time observed by the planet its distance from the zenith was 32° 38′ 34″.5 by mural quadrant (Banks, 1802c).

Banks informed Herschel on 16 April 1802 that two other astronomers had seen Pallas:

Mr. Gilpin saw the new planet on the 9th and has kept it ever since. Mr. Lee saw it on the 12th. No one else has seen it here as far as I know. [The next section repeats the last two paragraphs of the letter he wrote to Maskelyne on this date.] (Banks, 1802c).

Maskelyne wrote to Banks on 19 April 1802 about Pallas observations in Germany and France:

Thank you for the use of Mr. Schroeter's letter concerning the discovery of a new planet by Dr. Olbers on the 28th of March with 2 observations made of it by him & a third by Mr. Harding at Lilienthal, & other particulars. It is a pity he did not stay to put in the observation Mr. Harding had made on the 1st of this month, as it would have conduced much to the finding it here. I thank you also for your favor of the 16th with the places of the planet by the observations of the French astronomers on the 10th and 12th. Here on the 15th & 16 its places were as follows:

| April 15 | 9h 37′ 41″ | 182° 9′ 26″ | 16° 49′ 35″ |
| April 16 | 12 1 48 | 182 1 25 | 17 6 24 |

The declinations are only by the divisions of the meridian circle, corrected by a known fixt star. Be so good, when you write to M. Laplace, to return my thanks to him. (Maskelyne, 1802c).
Banks followed up his 16 April letter to Herschel on 23 April 1802: 
Mr. Best has received another letter from Mr. Schroeter in which he says Dr. Olbers wishes his 
new star to be called Pallas.  
From further observations he believes that this new heavenly body moves between Jupiter and 
Mars as Ceres does, is bigger than Ceres, about the size of Ceres including its nebula, and like 
Ceres has an orbit more oblique than the planets.  
On the 2nd of April he measured the diameter 3 days and made it as follows  

<table>
<thead>
<tr>
<th>April</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.735</td>
<td>4.671</td>
<td>4.680</td>
</tr>
</tbody>
</table>

It seems remarkable to me that two objects similar to each other moving nearby on the same path 
should differ from all other Primary Planets so much, the nebula with which both of them are 
surrounded is quite different from what has been observed in those Primary Planets.  The 
inclination of their orbits also resemble those of comets.  Their size also is so trifling that I cannot 
help thinking that on mature consideration and new identified observed stars, astronomers will not 
consider these strangers as Primary Planets but as another sort of revolving body such as have in 
fact before been discovered and of which many more here after be found (Banks, 1802d).  
According to Lynn (1904), Herschel suggested the asteroid family may number 30,000. 

Blagden wrote again to Banks on 24 April 1802:  
Burckhardt was been engaged in calculating the orbit of Olbers’s new star; but, not having found 
any circle or nearly circular ellipsis which answered to the observations, he had recourse to a 
parabola, and found the following elements.  Inclination of the orbit 54° 58’ 30”; Node 5s 26° 45’ 
34”; Perihelion 3s 23° 52’ 3”; the 29th Sept. 1801 16h 48’; perihelion distance 1.8432; motion direct.  
Burckhardt is, however, still trying to find an ellipsis which will agree with the observations; and 
the astronomers here do not yet absolutely declare it to be a comet, as they have not great 
confidence in the first observations of Dr. Olbers.  I hope before this letter must be closed to 
receive the last observations made here upon this star, and will add them [see Figure D.15].
Zach wrote to Banks on 1 May 1802 about the relationship between Ceres, Pallas and comets:

Here I also take the liberty to send you the promised map of the Part of the Heaven, where Ceres Ferdinandea and Olber’s Pallas are rambling now. I have described upon, the apparent Path of both. The Ceres from 7 Decb. 1801 where I discovered her first, described till June 29th 1802 a sort of Epicyclus, being in this Period of time just direct, then stationary, and afterward retrograde. She will become stationary again in a few days, about 9 May in AR the 2 May in Longitude. The Path of Pallas marked blue upon the map, is represented in a straight line. She crossed the Track of Ceres the 19 April. This latter heavenly body is a very remarkable one, and certainly a Middle-Thing between a Planet and a Comet. For it is a Fact now, that the observations and Positions of this star cannot be represented by a circular orbit, a Parabolical orbit has been therefore tried, but with as little success, and we are pretty sure that a Parabola will not do, it remains only the ellipse, and it seems that a very excentric Ellipsis will agree best with the motions of this remarkable body. The Pallas cannot be deemed a comet, if we understand by a comet a hairy blazing star, moving in a parabolical orbit. For she has not all the appearance of a nebula, or a dark gloomy star, not the least Trace of a tail, Bush, or Pencil of spurious Light. She looks rathar clearer than Ceres; is about of the same size. She moves not in a parabolical curve. The Pallas cannot be deemed a Planet, if we understand by Planets, heavenly bodies revolving in little excentric ellipses round the Sun, and pursuant to the law of distances, compleated now by the Discovery of Ceres, and extending to the Georgian Planet, & perhaps beyond. The Pallas has no assigned Place as a Planet according to this law in our solar système. She moves in a too excentric ellipsis, and has a too great inclination of the orbit, as that she might be ranked amongst our Primary-Planets. This Body gives us therefore the indication of a new species, that we might call PlanetoComet, so we’ll have, fixed Stars, Primary-Planets, Secondary-Planets, and Planeto-Comets.¹

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¹ Zach wrote to Banks on 1 May 1802 about the relationship between Ceres, Pallas and comets:

Here I also take the liberty to send you the promised map of the Part of the Heaven, where Ceres Ferdinandea and Olber’s Pallas are rambling now. I have described upon, the apparent Path of both. The Ceres from 7 Decb. 1801 where I discovered her first, described till June 29th 1802 a sort of Epicyclus, being in this Period of time just direct, then stationary, and afterward retrograde. She will become stationary again in a few days, about 9 May in AR the 2 May in Longitude. The Path of Pallas marked blue upon the map, is represented in a straight line. She crossed the Track of Ceres the 19 April. This latter heavenly body is a very remarkable one, and certainly a Middle-Thing between a Planet and a Comet. For it is a Fact now, that the observations and Positions of this star cannot be represented by a circular orbit, a Parabolical orbit has been therefore tried, but with as little success, and we are pretty sure that a Parabola will not do, it remains only the ellipse, and it seems that a very excentric Ellipsis will agree best with the motions of this remarkable body. The Pallas cannot be deemed a comet, if we understand by a comet a hairy blazing star, moving in a parabolical orbit. For she has not all the appearance of a nebula, or a dark gloomy star, not the least Trace of a tail, Bush, or Pencil of spurious Light. She looks rather clearer than Ceres; is about of the same size. She moves not in a parabolical curve. The Pallas cannot be deemed a Planet, if we understand by Planets, heavenly bodies revolving in little excentric ellipses round the Sun, and pursuant to the law of distances, compleated now by the Discovery of Ceres, and extending to the Georgian Planet, & perhaps beyond. The Pallas has no assigned Place as a Planet according to this law in our solar système. She moves in a too excentric ellipsis, and has a too great inclination of the orbit, as that she might be ranked amongst our Primary-Planets. This Body gives us therefore the indication of a new species, that we might call PlanetoComet, so we’ll have, fixed Stars, Primary-Planets, Secondary-Planets, and Planeto-Comets.¹

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The Annals of Astronomy and the Records of time, even since the discovery of the Telescopes, never mentioned a comet, without a Nebula, a hairy bushy Tail, Beams, or Rays of Light. The Denomination of such celestial Bodies itself is taken from Hairs, or Curls, and the greek word κομή denotes Hairs, or a bush of a Hair, from whence comes the name of κομήτης.

Mr. De la Lande says in his Astronomie XIX Book, that a Tail, Beams, Hairs, are not a distinctive character of a comet, and in order to support this assertion he quotes several comets, which to his Report had no such visible Distinction. But in this he is greatly mistaken. For instance he says the Comet of 1585 was perfectly round and without a Tail. But the Landgrave of Hesse Cassel who first observed this comet, in a Letter to Tycho de Brahe makes the following description of it: "Exquosest, et unduque crinitus, ut erem etc., Tycho himself in his Astronom. pg. 752 says of this comet, "quedi fibris quimbusdam refrubus juxta circumferentiam extitit, minusque illic turebat. Some other authors compared this comet, with the Nebula or Praesepe of Cancer.

LaLande says the comet of 1665 was clear, and had no Tail, and almost no Beams. But Hevelius who observed this Comet in his Cometographia Lib XI p.775 speaks of a Tail. "Loci ad quam cauda porrecla fuit, and he gives Angulum Deviationis caudae.

According to LaLande's Astronomy the Comet 1682 was as round and as clear as Jupiter to the report of Cassini. But in the Histoire de l'Acad. Roy. Tome I p. 350 it is plainly spoken of a kernel of the Body, and of a Head. Flamsteed observed the same Comet, and he describes it in his I Vol. of Hist. coelestis Brittan. p. 108 with these words: “Caput autem tubo pedum 16 considgatatum exile apparut, sed spioso inde emanante capillito, five cauda longa 5 grad &… Hevelius in the Aolis Eruditorum 1632 pg. 291 gives in Tab. XX a Draught of the appearance of this comet, which is represented with a large and bushy Tail, and he says, “Initio cauda 12 five grades etc.

I have turned over Lubeniecki Pingré, and all cometical chronicles, but I found not one example of a comet reported of an appearance like a fixed star, or like our Pallas, as we behold her now. But why should we not make classifications? To the famous Halleyan Comet of 1531, 1607, 1682, 1759, and which again will become visible in 1835 not such a Middle-Thing? Why should we not distinguish the elliptical, the parabolical, and the hyperbolical comets? What a body is that very remarkable comet 1770, that moves in 5 years round the Sun, and has only once been seen? Where are the comets of 1680, 1729, 1742, 1744, 1763, 1773, 1779 to be ranked? The denomination of comet is too loose, too indefinite, and I hope Mr. Olbers’s Pallas will make us acquainted with a new species of heavenly Bodies, and as you observe very well, the Heavens seem to be more peopled than we believed them to be. Perhaps several Stars, which are deemed to be lost’ have been such comets as our Pallas. Dr. Herschel and Mr. La Lande have a catalogue of nearly 200 such forlorn stars, certainly the greatest part of ‘em arisen from errors of observation; or of the Print, or from slips of the Pen. But it is equally possible that Dr. Olbers Pallas, & perhaps one or two such deities more might have been amongst them. Future time, our Progress in practical Astronomy, and the augmentation of observatories will learn (teach) us more.

But, bless me! What a lucky star that ever shined upon the astronomers! Indeed a great luck! For let us suppose, an astronomer in looking out for Ceres, should first have met with Pallas. Would he not have taken it for the Ceres Ferdinandea? One to hundred thousand he would’! Pallas look’s exactly as Ceres, Piazza himself would’ve been mistaken by the appearance. She moves like her in the Environs and adjacent parts, where the Ceres was expected. She moves like her very regularly, in an elliptical orbit, certainly every astronomer would have been mistaken, and no wonder! But what would have been the consequence of such a mistake? An unexampled Perplexity and confusion! All astronomers would have pursued the supposed and spurious Ceres. The calculations, the conjectures, and hypotheses would have been endless, and inextricable. For they would have attempted, to adjust, and to make agree Mr. Piazza’s observations of the true Ceres, with our supposed one. The case would have been inexplicable [sic], and Perhaps a whole century might have passed before [sic] this intricate case could have been explained and unfolded. For if this misfortune had happened, surely the Perquisition [sic] of Ceres would have been neglected; In the mean while the astronomers had put themselves to the Trouble to calculate these paradoxical observations, and the Prophanes [sic] had took the pleasure to laught at the credulous astronomers, who believed into the Messiah of a Planet (here without doubt I should have had my good share of Derision, as I was one of the most tenacious astronomers in this Belief since 30
years) the true Ceres might have gone, perhaps forever, for if we had missed or lose the opportunity to observe the true Ceres, in amusing ourselves with the Pallas larvata certainly nobody would have looked for her in 1803, and if we did, would not Pallas have led us astray? No Doubt Ceres was left, and God knows when she might have been discovered again? Let us therefore make an oblation to Urania, that she preserved us from this Danger.7

There is one example in astronomy of a like confusion, which nearly imbroiled the astronomers, but very favourably they escaped the Perplexity. It was in the year 1664 Febr. the 18th that Hevelius mistook a Nebula, or some little cloud for the comet, & produced an observation, which thoroughly did not agree with the precedent observations. Hevelius came into controversy with the french astronomer Auzout8, who impugned this observation, but Hevelius supported it with obstinacy, and admitted not the Fault. Very fortunately other astronomers in Italy, Spain and England observed the comet the same day, and so Hevelius was unexpealably [sic] convinced. Auzout makes therefore the just remark saying “That what is most disagreeable in this incident is, that if the sky would have been overcast until Feb.18 so that no-one could have observed the comet after that day, he (the comet) would have embarrassed the present and future astronomers by such an odd observation”. The same Thing might have been say’d from Ceres & Pallas, for if Pallas had been discovered first, and before Ceres, Truly this would have perplexed for ever the present and the future astronomers.

Permit me an other reflexion. It is a long time that the astronomers wished to observe a comet of a so determinate appearance; that it might be observed with great accuracy; For if such a comet should come to pass in a Distance from the Earth, half as this of the Planet Mars, or Venus in its Perihelion, such nice observations of this comet woul’d give us the means to determine the Parallaxe of the Sun, with greater Precision, as the renowned Passages of Venus before the disk of the Sun, which happen so seldom.12 Indeed this requires a concurrence of accidents very difficult to exspect, for such a comet must be observed in two very different places in the same time in order to get a very great trigonometrical Basis, and Pingré in his Cometographie Part II p. 151 says himself. “He assumed that we would have little basis for expecting the combination of these favourable circumstances”. But perhaps Pallas will present the Reunion of such circumstances. If this so well defined Body revolves in an ellipsis whose Period will be determined, its future appearances can be calculated, and if it should take its way between the Earth and Mars, or the Earth and Venus, two different observers in this case will have the time to bespeake to this Purpose corresponding observations, which if all circumstances concur to be propitious will give us the Knowledge of the Sun’s Parallaxe with as great a Precision as Passages of Venus over the Sun. But this is only a conceit fancy. The Elements of the elliptical orbit of Pallas will sole decide, whether such a supposal [sic] can take Place.9 In the meanwhile our Duty is, to gather materials, and to observe with as much accuracy as possible this remarkable celestial Body, before we can pass our Judgment. This I have done with as much care, and constant application in my Power, and here I have the honor to send you all my observations of Pallas, adding to them those made of the planet Ceres Ferdinandae (Zach, 1802m, his underlining).

Footnotes by C. Cunningingham:

1. Compare this discussion about comets with what Zach published in the May, 1802 issue of the Monthly Correspondence.
3. Tycho Brahe (1546–1601), the famous Danish astronomer.
4. Giovanni Cassini (1625–1712), Director of Paris Observatory from 1671.
5. Stanisław Lubieniecki (1623–1675), Polish astronomer, and author of Theatrum Cometicum, 1668.
7. See Wagman (2003).
8. Adrien Auzout (1622–1691), French astronomer. He believed comets followed elliptical or parabolic orbits, a view opposed by Johannes Hevelius (1611–1687).
9. Even though Pallas did not offer this opportunity, the asteroid Eros was closely tracked in 1900 and again in 1931 in an effort to determine the solar parallax.

Blagden wrote to Banks on 3 May 1802 about whether or not the French regarded Pallas as a comet:

My last letter to you, which was of the 24th of April, contained observations of Olbers’s new star down to that time, together with the parabolic elements of its orbit, as calculated by Dr. Burckhardt on the supposition that it is a comet; and in a letter written to Count Rumford the 27th of April, I gave the elliptical elements of its orbit, as calculated by the same gentleman. The astronomers here are still undecided whether to call it a planet or a comet; but I think they are most inclined to the latter opinion. M. Laplace is decidedly so. (Blagden, 1802d, his underlining).

Olbers wrote Banks on 4 May 1802, and this letter was given by Banks to Herschel.

It is important as it includes a diagram of interlocking rings, denoting the orbits of Ceres and Pallas. This was drawn first by Gauss in a letter of 4 May 1802 that he sent to Olbers; thus Olbers quickly included this and the elements of Pallas derived by Gauss, and sent them to Herschel the very same day. In the following 31 May 1802 letter from Zach to Banks, the same interlocking ring diagram is included. Here is the relevant portion of the letter to Banks:

With much pleasure, as you can well believe, I send you full and certain information that our Pallas is a planet; the own sister to Ceres, not inferior to her in dignity and importance, and perhaps on that account another remarkable discovery; as she gives rise to many speculations regarding the origin and history of our Planetary system. With this I send the elements calculated by Dr. Gauss. [Olbers here prints elements of 31 March 1802].

The orbit [of Pallas] is therefore only as eccentric as that of Mercury. But what a great unexpected inclination! And how curious its position with regard to that of Ceres! The two cross each other like the interlocked rings of a chain. (Olbers, 1802a; his italics).

To my great surprise, and surely to your too, I hear that Dr. Herschel allows Ceres a diameter of only 1 second. (Olbers, 1802a; his italics).

Maskelyne wrote Banks on 14 May 1802. At the conclusion of the letter, he said:

I do not think Dr. Burckhardt’s notion of a periodic time of 12 years to the new planet Pallas to be probable.

Zach wrote to Banks on 31 May 1802 that the orbits of Pallas and Ceres are so close to one another they may touch:

Having prosecuted Dr. Olber’s Pallas from April 4th till to May 11th in the Meridian, Dr. Gauss upon this set of my observations calculated the Elements of an elliptical orbit of this very remarkable heavenly Body, which represent with great accuracy all Seeberg observations [see Figure D.17]. It appears in general by these calculations, that:

Pallas is a planetary heavenly Body, that moves between the orbits of Mars & Jupiter, with a very great Excentricity and Inclination, and whose orbit comes very near, to the orbit of the Planet Ceres, perhaps touches it, perhaps even cut’s it, like two links of a chain in this Way, which cannot yet be attested with certainty, the observed arc run over by this planet being too small.

Notwithstanding, it appears already that the distances of Pallas and Ceres in the Line of Nodes of their orbits, in very nearly equal. In the descending Node ☉, the Distance of Pallas from the Sun is 2,86 and the same Distance of Ceres = 2,93. In the ascending node ☉, these distances are of a greater Inequality. Another very remarkable circumstance is, that the mean motions of Pallas and Ceres are very near the same, perhaps absolutely the same, which cannot yet be attested; the Period of the observations of both Planets being by far too short. But as much appears already, that these mean motions will not differ very much, and in this case, as little as the masses of ☉ and ☉ may be, they will, nevertheless exact a very sensible action one upon the other, and give therefore occasion
to very curious & interesting Investigations in the Mechaniks of the Heaven. The new Planet Pallas will also call forth the utmost Exertion of our Analytical Powers.

Hitherto the two Elements of a planetary orbit, viz, the Excentricity, and the Inclination, had been considered, as an infinite little quantity, and so it could be, as these two Elements in all our old Planets are very small; so then, the higher Powers of them could be neglected without Danger in calculating their Mutual Action, as they produced no sensible Term in the approximating series. But this is not the case more by Pallas, where the Excentricity of the orbit and the Inclination are so very great.

Here are the elements of the orbits of the planet Pallas calculated by Dr. Gauss.

Epocha March 31 at Noon in Seeberg………161° 12’ 43”,2
Aphelium ------ ------ -- … 300 5 4,0
Node ------ ------ =…172° 34’ 35,0
Inclination …………………………….. 35 0 42,0
Mean daily heliocentr. tropick motion ………75”,166
Logarithm of half the great axis ………….0,4472636
Excentricity……………………………0,2591096.
By these Elements the whole series of my observations are represented thus.

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Figure D.17: Zach's observations of Pallas made from 4 April to 11 May 1802 (after Zach, 1802a).

Pallas and Ceres are now come too near to the Sun, and the Twilight permits no Meridian observation. But the astronomers who are provided with Equatorials of great Perfection, as for instance are, in Greenwich, Oxford, Richmond, and of Sir George Schuckburgh, will be able to prosecute these two Planets a longer time. The observations of Pallas will chiefly be of a very great value; as the series of Meridian observations is not above 5 Weeks. If more observations are not procured, it will be with some difficulty we shall find again Pallas next Year, for the Elements of an orbit calculated upon so little an arc as 7½, can be in Fault of some degrees till in January 1803. You will do, most honoured Sir, a great Benefit to Science in general, and to Astronomy in particular, if you engage the English Astronomers, who have so very excellent, and fixed Equatorial Sectors, to prosecute Pallas out of the Meridian as far as they can, to this Purpose I take the liberty to send you here an Ephemeris of this Planet's Motion calculated by Mr. Gauss, this will enable and facilitate to the Astronomers the Research, and the observations of Pallas.

Ephemeris of the Position of Pallas for Midnight in Seeberg Observatory [see Figure D.17]. (Zach, 1802a, his underlining).
Footnotes by C. Cunningham:

1. This letter was reprinted in full in A Journal of Natural Philosophy, Chemistry and the Arts (popularly known as Nicholson’s Journal) Vol. 2, 213-215.
2. The symbols for Pallas and Ceres, respectively.
3. Sir George Shuckburgh-Evelyn (1751–1804), English politician and amateur astronomer. He had a private observatory on his estate in Warwickshire. He was elected Fellow of the Royal Society in 1774.

Piazzi wrote to Banks on 7 July 1802, finally sending copies of his treatise on Ceres:
I take the liberty of addressing to you six copies of the enclosed pamphlet upon the new Planet Ceres Ferdinandea, which I have published only for the satisfaction of the people of this place, and I beg you will be so good as to accept one for you, to present one to the Royal Society, to deliver one for each to Dr. Maskelyne, to Mr. Herschell, and to the Neopolitan Ambassador [Sastres]; and lastly to forward one through Mr. Young’s means to Mr. Loft of Troston in Suffolk, which I do at the particular request of my friend Mr. Balsamo (Paolo Balsamo, a teacher). I hope your love and zeal for the advancement of the sciences, and your goodness for me and my former works will plead my excuse for troubling you on this occasion (Piazzi, 1802e).

Zach wrote to Banks on 1 March 1803 on the path of Ceres in the sky:
I take the liberty to inform you, of the appearance of the new Planet Pallas. Mr. Harding in Lilienthal saw it first Febr. 19th at 15 o’clock near the star No. 36 of Taurus Poniatowski of Mr. Bode’s Catalogue. This little Planet is very difficult to be seen, and not visible by a Refractor of 3 Feet. Mr. Harding discovered it with a Reflector of 7 Feet, and esteems the magnitude to be, like a star of the 13th magn. I saw this heavenly body with my Refractor of 10 Feet, and I can assign no magnitude, methinks the Planet appears quite as a telescopic star. Dr. Olbers looked at Pallas, with his 5 Feet Refractor, and saw it perfectly, to his opinion the Planet looks quite as the 4th satellite of Saturn. The Reason and the Possibility of discovering this little Planet so soon, is to be ascribed to the Exactness of the Elements of the orbit calculated by Dr. Gauss, and to the Precision of the Ephemeris given in the Monatliche Correspondence, October 1802, which placed the Planet exactly upon the spot, where Mr. Harding found it. There is therefore no Difficulty more to find this Planet, who ever pleases to look for; he has only to follow the Ephemeris, of which I have the honnor [sic] to join here a copy. I have also had engraved a map for my Month. Corresp, upon which the supposed Path of Pallas has been described, in order to facilitate the search for this
Planet, but beyond every expectation [sic] this map is become now an exact Representation of the Way, which this heavenly Body takes in Reality. I take therefore the liberty to send it to you annexed. It represents [sic] the motion from 3 to 3 days [ie at 3-day intervals] of the Planet from Febr. y° 4th till April y° 17th. In my next Letter, I shall have the honor to send to you the second Part of this map, which contains the Track of this Planet from April 5th till June 28th. By these Means it is impossible to miss this nearly imperceptible point, which allways [sic] will be traced by these Maps, and by the Ephemeris.

Good observations are yet very difficult to be made considering the Meanness of this little body. In the mean time some course [coarse] observations have been made in order to evince, that this heavenly Body is realy [sic] our Pallas. 1803 Febr. 20 at 15° 30′ 13″ mean time in Lilienthal AR ♂ = 272° 38′ 27″ Declin. ♀

No tidings yet from Ceres. But there is no Doubt, she will presently [sic] make her Appearance upon the spot assigned by the Ephemeris of this planet, I add here. Her very low Position, and great south Declination is probably the Reason, she has not been seen yet, in the vapours of the Horizon (Zach, 1803a, his underlining).

Blagden wrote Banks on 19 March 1803 that Pallas had been spotted from Paris: M. Laplace desires me to inform you, that the planet Pallas has been seen here, nearly in the place calculated from Gauss's last elements, as laid down in Zach's journal; so that no doubt now remains as to the general form & situation of its orbit. (Blagden, 1803a).

On 22 March 1803 Banks wrote to Herschel about Pallas:
By letters received this evening I learn that Pallas was rediscovered by Harding at Lilienthal on the 19th of Feb. & has since been seen at Paris nearly in the place where according to Gauss's calculation she was expected. No news has been received of Ceres she is still very faint. (Banks, 1803a).

Zach sent Banks a letter on 23 March 1803, enclosing a map of the path of Pallas in the sky:
According to my last Promise, I have the honor to send you here, the Continuation of the celestial map, that represents the path of Pallas till Jun. 28th. Tho' this map has been performed long before the Planet has been discovered again in Febr.° of the present Year, the Elements of the Orbit had been so well ascertained by Dr Gauss, that the difference is but a Trifle, not even to be represented upon the scale, on which the map is drawn. Nevertheless the nice astronomical observations will shew a little Difference, but which Dr Gauss has already corrected by mending the Elements of the Orbit, which he has calculated last Year, upon the series of my observations of this planet, in conjunction with these made at the Royal Observatory in Greenwich. Only such most exact observations, strained to the highest Pitch of astronomical Exertion could produce Elements so near to the Truth after so long a Period of near 7 months, this little Planet vanish'd out of sight. Dr. Gauss's old Elements had been published in my Monthly Correspondence Decemb.° 1802 p. 581.

The new now corrected, upon a few observations, you will find in the present printed sheets, which make part of my Journal April 1803, which comes late to your Hand. I only add that the Last observation of this Planet is thus represented by these Elements.

Diff. with observation

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<td></td>
<td>8°58 18,1 N</td>
<td>-- 4°9</td>
</tr>
</tbody>
</table>

The little printed Ephemeris of the Planet, which I had the honor of sending to you in my last, are calculated upon the old Elements quoted above, in Order to reduce them to the present Elements annexed here, and marked VI, it is only necessary to subtract in the Beginning of every Right Ascension 2 ½ min. and Avg up ye 9°...9′ 6" in the middle time proportionally. From the declinations only subtract thoroughly 1 min. so this Ephemeris shall be reduced to these new Elements, and will exactly agree with the Heaven, which by so a little and nice heavenly Body is so much the more necessesary [sic], to avoid mistakes, & not to confound the Planet with the multitude of little stars which might surround her.

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Dr. Gauss has calculated since a new Ephemeris for Pallas by his new (VI) Elements from August 9th down to Octb 23rd. Which very likely will be the last Term of visibility. I have the honor to submit here a copy (Zach, 1803b, his underlining).

Maskelyne sent Banks a letter about Pallas on 13 April 1803. It shows they were sharing information from Zach:

I thank you for the communication of Dr. Zach’s letter, ephemeris of Pallas’s place from Aug. 9 to Oct. 25 last, & the celestial chart representing its motion. I have copied what I wanted, and now return the papers, except that the ephemeris is only a copy, but an exact one, of what you sent, the original having been mislaid. Yesterday morning & this morning I had very good observations of Pallas as follows

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean time</th>
<th>Right ascension</th>
<th>Declination North</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 11</td>
<td>15h 26' 41&quot;</td>
<td>282' 44' 12&quot;</td>
<td>15° 3' 38&quot;</td>
</tr>
<tr>
<td>April 12</td>
<td>15 31 5</td>
<td>283 2 30</td>
<td>15 13 47</td>
</tr>
</tbody>
</table>

The correction of the Ephemeris sent before, and serviceable as it makes the observations agree almost exactly with it. Thus this morning the right ascension agreed exactly & the declination differed only 13" which is not to be reckoned any thing, as the ephemeris was only set down to minutes. The observation made here on the 1st instant was only taken by the divisions of the instrument & therefore less exact, but agreed nearly with the ephemeris corrected. Thus it seems that Dr. Gauss’s 6th sett [sic] of elements of the planet’s orbit is pretty exact, & likely to represent the planet’s place, probably within a minute during the remainder of the year. Astronomers are much obliged to him for his indefatigable labors, which are of great service to ascertain whether we observe the planet or a fixt star, as so many are scattered throughout the heavens. We shall, I think, have no difficulty about finding it in future. I am glad to learn that such grand operations are carrying on in the mensuration way in the North of Germany. When you write to Dr. Zach, be so good as to make my complements to him, and impart to him my two observations, & inform him I used the star of 6 Magnitude No. 170 of Aquila according to Bode’s Catalogue, & took its Right ascension for the present time 18h 46' 30" of time, and its declination 14° 9' 13" North. (Maskelyne, 1803).

D.2. The Nevil Maskelyne Correspondence

George Gilpin wrote Maskelyne on 4 February 1802:

Your servant being here I embrace the opportunity of acquainting you that the President [Sir Joseph Banks] has received a Letter from Mr. Zach dated 14th Jan. 1802, acquainting him that he had detected the new Planet on the 7th December last; when it appears by his observation at 18h 48' 10".3 Mean time its appt. RA was 178° 33' 30".6 very exact and its Decl 11° 41½' N by estimation not having observed it at the Quadrant but by the 8 feet transit. On the 11th January 1802 he observed it again at 17h 3' 17".4 M. time its RA 186° 45' 49.95 very exact to a second and its decl. 11° 10'N by estimation—he mentions having letters from Paris as late as the 1st January but no mention was made of their having seen it, therefore he concludes that they had not at that time. Mr. Zach’s letter is to be read tonight at the (Royal) Society. (Gilpin, 1802a).

George Gilpin was Secretary of the Royal Society. Zach’s letter that mentions Ceres was read to the Royal Society on 4 February, along with one from Maskelyne saying he had also observed Ceres.

Gauss wrote Maskelyne on 20 February 1802:

Your kindness, and the common interest of science will I hope excuse a stranger’s intruding upon You with this letter. I flatter myself, that You would not be displeased with the communication of an Ephemeris of the New Planet, which is constructed upon elements corrected after some new observations of Mr. de Zach’s, and may perhaps contribute to facilitate farther observations of this faint-lighted Planet. The elements themselves are to be printed in the Monthly Correspondence, March. I hope, this ephemeris shall not deviate above One minute of degree from the true places.
Mr. de Zach has already furnished me with a considerable number of very precise Right Ascensions, but hitherto he could get but very few exact declinations. You would lay me under the greatest obligation, if you would hereafter honour me with the communication of some exquisite unparalleled excellence of the Greenwich-Instruments. If you should please to grant me this favour, I certainly will make of it the best use I am able. (Gauss, 1802a).

Maskelyne replied to Gauss on 11 March 1802:

On the 7th of this month I received your favour of the date 20th last month, for which I am much obliged to you, particularly for the ephemeris of the place of the new planet, which we call Ceres Ferdinanda according to the discoverer Mr. Piazzi; and apply to it the symbol \( \mathcal{C} \) expressive of the discoverer till a better shall be found out. Agreeable to your desire, I have sent you some of my observations, and will do myself the pleasure to send you more occasionally if you shall desire it. The first was taken with the equatorial instrument of 5 feet, the telescope having an aperture of 4.1 inches, by differences from 34 Virginis, whose place I have since settled by the meridian instruments. The three others were taken on the meridian. Taking your meridian to be 10° 52′ E of this, I find the RA corresponding to my observation should by your calculations be 185° 48′ 52″ and declination 16° 3′ 50″ which agree perfectly with your calculation. The Astronomers of Europe, and, I may say, Astronomy itself, is much obliged to you for having taken the pains to investigate elements of the orbit of the planet from Mr. Piazzi’s observations of only 6 weeks, sufficiently exact to find the lost planet by, without which I fear it would not have been found again soon, for neither Mr. Piazzi’s circular orbit nor Dr. Burckhardt’s elliptic orbit were nearer enough to the truth; and I have undergone much labour in searching for it, but all in vain. It appears to me in a fine clear night to be of 8th Magnitude, and of an indifferent night of the 9th Magnitude. I divide the stars less than the 6th magnitude, which are visible to my equatorial of 4.1 inches, into 6 classes or gradations from 7th to 12th Magnitude, the last of which is to the telescope what the 6th Magnitude is to the naked eye. On February 4th I observed the planet to have a well defined disc; but at the same time 34 Virginis had the same. This appearance I see, tho’ but rarely, in the stars, on a very fine night. Its diameter appears to me about 2″. On the 6th being a very fine night at 3 hours distance from the meridian, it was just ready to disappear with an aperture of half an inch, while 34 Virginis a star of 6M. required an aperture of 3 inch to reduce it to the same degree of faintness as that of the planet with the half inch aperture. Hence the light of the planet is about 3rd of that of a star of the 6th M. It will require a good ephemeris to follow the planet when it is approaching to its conjunction with the Sun, as it will be very liable to be confounded with small stars. I have found it to be the case now with respect to stars of the same magnitude as itself. It is a pity a person so capable as Mr. Zach, should not have better wires put to his instrument. I use wires of 1/1000 inch in thickness; they might be made much smaller in one direction by flattening them with a stroke of a hammer. (Maskelyne, 1802a).

Maskelyne sent Herschel a letter on 16 March 1802:

I have the pleasure to send you some places of Ceres Ferdinanda sent me by Dr. Gauss, true to a minute. I see you acknowledged my letter about the planet to the Royal Society. Hope you will determine the app. diameter of it with your telescope, which will show it the smallest. [Maskelyne means here that Herschel’s large telescopes will hopefully be able to resolve Ceres, even though it is the smallest of the planets. He includes an ephemeris from 16 March to 18 April.] (Maskelyne, 1802b).

Gauss wrote Maskelyne on 3 April 1802:

Your kind letter of March 11th and all the interesting communications You have honoured me by, have caused to me the greatest pleasure, and I say You my most respectful thanks for them. Of Your observations of Ceres Ferdinanda I have compared two with my last elements (signed VII in Mr. Zach’s Monthly Corr. March); the 6th March the error of the computed place was +5′0 in RA and +34″0 in Decl. (both being too great by this difference). But Your RA of February 19 which You make 187° 44′ 17″6 does not agree neither
with the elements nor with the cotemporal observations of other Astronomers, if I may presume, that the minute only is erroneously written and ought to be 58', this RA will agree exactly with Mr. Zach’s observation of the same day 187° 58' 27"9; the RA calculated for Your observation was 187° 58' 13"2, for Mr. Zach’s obs. 187.58.23"8, therefore error of the elements - 4"4 by Your, -4"1 by Mr. Z’s observation [ed: the figure 187° 44 17"6 was wrongly converted from time to space. 12h 31' 53' of time corresponds to 187° 58' 15".3]. The error in decl. of the same day was by Your obs. +35"3. (I must remark, that when I computed my VIIth elements, I had not yet any declinations and of consequence could not adapt the elements to them; as notwithstanding this the error of the elements in decl. is only ½ minute, this certainly is the most convincing proof of the high exactness of Mr. Piazzi’s observations). As without doubt, no other observations can more effectually contribute to the farther correction of the elements (which I am already going to make preparations for, though I shall not entirely finish it, till no observations more may be made before the Conjunction of this year), I shall be extremely happy to receive the farther Greenwich observations You are so kind as to promise to me.

I take the liberty to join hereunto a continuation of the ephemeris of the new planet till ultim. Jun., constructed after the same (VII) elements and for the same meridian of Seeberg 42' 54" time E. of Greenwich. As the orbit of Ceres is not an exact ellipsis, the effect of the perturbations caused by Jupiter being considerable, I do not doubt, but this ephemeris will not conspire with the true places equally exactly during this whole time, as it has done hitherto. However I trust, this circumstance will not lessen the utility of it; for as the error calculi must, by necessity, increase only by slow degrees, one may always provide [sic] it with all necessary exactness, by comparing the preceding observations with the ephemeris. The error calculi in RA was on the 19 March according to Mr. Zach’s obs. +15", the error in Decl. appears to be nearly constant. I should hardly imagine, the error might go upwards of 5 minutes in the month of June.

I am informed, the French Mathematicians have already calculated the perturbations of Ceres by Jupiter, corrected the elliptical elements and constructed tables thereby. But, in my opinion, this is a pain not yet very necessary. For as it is at present of very great importance with respect to the certainty and precision of the calculated orbit, whether the series of observations taken for basis of it, be several months longer or shorter, those tables will enjoy but a short life. For it will be absolutely necessary to make a new computus, when the observations of this year shall be entirely finished. Then I also, but no sooner, will neglect no pains, to determinate the elements as accurately as it shall be in my power.

According to Mr. Schroeter’s mensuration at Lilienthal, the true diameter of Ceres in only the fifth part of the diameter of earth; of consequence the planet is much smaller than our Satellite. But, comparatively, its atmosphere is prodigiously high. Certainly one may not wonder, that this puny celestial body has escaped so long to the astronomers.

[Gauss encloses an ephemeris of the equatorial co-ordinates of Ceres dating from 2 1 April to 2 9 June 1802, calculated for midnight on the meridian of Seeberg]. (Gauss, 1802b).

Gilpin wrote Maskelyne on 7 April 1802:
By a happy accident the present letter has been detained one post day. I say happy, for this delay gives me an opportunity to join to it an advertisement which appears to be of the highest importance, viz. nothing less than another New Planet discovered by Dr. Olbers at Bremen. As he has charged me expressly to inform you if it and in the same time assure you of his most perfect regard, I transcribe here the import of his letter of April 2, which I received in this moment.

“Since March 28 I observe in the northerly wing of the Virgin, besides Ceres, another moving small star, perfectly similar to Ceres with respect to its light and exterior appearance. In my extremely good refractor of Dollond, magnifying 180 times, it may not be distinguished from a fixed star of the 7th magnitude, without any nebula, retrograde as Ceres, the northerly declination motion only increasing much faster.”

Since March 28 Dr. Olbers has made the 4 observations following:
[these are 28 March through 1 April 1802]
Mr. Schroeter at Lilienthal observed this new star (which Dr. Olbers proposes to denominate “Pallas” if it should prove to be really a new planet) since March 28; he distinguishes its disc still better than that of Ceres; also he estimates the first somewhat greater than the second.

Dr. Olbers wishes ardently, that astronomers provided with fixed instruments (which he is not) may commence as soon as possible to observe this new star, as it has already past its opposition. It will hardly be observable longer than June. However, I hope we shall get a number of observations sufficient to compute its orbit, nearly enough to find it again in 1803 if it shall prove to be a “course rentrante.” I do not doubt, but this important discovery will obtain all your attention, and you will oblige me infinitely, if to your observations of Ceres you will join your observations of Pallas.

[Appended are three observations of Pallas by Zach made on 2, 3 and 7 April 1802.] (Gilpin, 1802b).

Olbers also wrote a similar letter to Burckhardt on 2 April.

On 9 April Banks wrote to Herschel:

Dr. Olbers discovered on the 28th of March another Ceres apparently larger (in brightness) than the Georgium (Uranus). Mr. Schroeter and Harding saw it on the 30th and on April the 2nd Harding saw a star near it which he thinks may prove a satellite. [Here he prints the data from 28 March to 30 March.]

The two first observations by Dr. Olbers, the 3rd by Mr. Harding. (Banks, 1802b).

Banks wrote an identical letter to Maskelyne on 9 April.

On 14 April 1802 Blagden wrote Maskelyne from Paris:

At the desire of Mr. Laplace, and in conformity to my own wishes, I send you the enclosed observations of the new star discovered by Dr. Olbers, made at the Observatory of Paris by Mr. Méchain and [Alexis] Bouvard; the former taking the zenith distances by the mural quadrant (of Bird) and the latter taking the passage over the meridian by the transit instrument.

<table>
<thead>
<tr>
<th>Mean time</th>
<th>apparent RA</th>
<th>appar. Decl.</th>
<th>Appar long.</th>
<th>Appar. Latitude N.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr. 10</td>
<td>13h 58′ 40″</td>
<td>182 45′ 10″</td>
<td>15° 41′ 30&quot;</td>
<td>176° 6′ 58&quot;</td>
</tr>
<tr>
<td>12</td>
<td>10 48 34</td>
<td>182 32 31.5</td>
<td>16 10 58</td>
<td>175 42 47</td>
</tr>
</tbody>
</table>

These observations are not corrected for parallax or aberration.

Mr. Bouvard has given me the last of these observations and that of last night, April 13, in the following form

April 12 RA 12h 10′ 10″.2) sidereal time (32° 39′ 10″.5) zenith 13 12 9 39.4 ) (32 24 2.5 ) distance

You will see how far they agree. If this star be a planet, they have rudely calculated its distance from the sun as 1.9, somewhat more distant than Mars; but the great obliquity of its orbit to the plane of the ecliptic raises doubts. It appears here as nearly as possible of the same brightness as Piazzi's planet (Blagden, 1802b).

Maskelyne sent Herschel a letter 23 April 1802 with news from Paris:

Yesterday I received the ephemeris of the new planet Ceres Ferdinandea from Dr. Gauss who calculated its elements, which perhaps you may not have received, therefore I present you with a copy of them. They will probably find its place within a minute. Mr. Mechain in his letter of 27 January expressed his wish that you might make some discoveries about it with your great telescopes; and mentioned that the same of theirs was not yet finished. In his letter of 16 March, received only yesterday, he asks me whether you have measured the diameter of the planet, or seen anything remarkable about it, its disc or atmosphere, or any satellite of which there is some suspicion? The new planet, discovered by Dr. Olbers at Bremen, appears like to and of equal brightness with Ceres. I have sent you its places below, observed here, in the hope you will make some discoveries concerning it also. There is a suspicion of a satellite about it. [Positions from 15 to 22 April are printed here.] Considering this star as a planet Mr. Mechain writes that they have calculated its distance from the sun as 1.9; but its great inclination raises doubts. They mention the observation on April 10 was 15° 19′ 16″ and 12h 15′ 49′ 11″ both North. [An ephemeris of Ceres from 21 April to 29 June ends this letter.] (Maskelyne, 1802d).
In the sole surviving letter from Zach to Maskelyne (4 May 1802), Zach evinces a perfect model of precatory eloquence while at the same time congratulating himself on the coincidence of their observations:

I was very much flattered by the few lines, you were so kind to send to me, and I return you my sincere thanks for all the favours which I experience from you; I shall always acknowledge it with the greatest Gratitude; if you will be so kind to send me over your Nautical Almanac, which is so difficult to get by own German booksellers.

I thank you also, for your kind communication of the observations of the new Planet Ceres Ferdinandea. I was very happy to see that my observations agree so well with yours. The difference in AR is as much as nothing, allowing for the difference of meridians; but in declination there are some times diversities of 10 seconds, which differences are certainly deficiencies upon my account. For it is impossible to enter into competition with my 4 feet Dollond's quadrant, with your 8 feet mural quadrants.

I was only so lucky to get from late Mr. Ramsden an 8 feet transit instrument, aperture 4 inches. This instrument of a most perfect kind, can certainly rival with any other existant, but Mr. Ramsden had not finished my 8 feet whole circle, for which he has got an advance of 200 £, which money is very likely lost now. I entertain no hopes at all, to get this instrument done, by his successor Mr. Berge, so I commanded a whole circle to Mr. Troughton, of which I hope to come in possession the present year; in the meanwhile I am confined to the 4 feet Dollond's quadrant for observations in declination, and with all care & dexterity it is impossible to determine the error of collimation within 4 or 5 seconds, let as much be the error of the observation, a conspiration of both will of course produce an error of 10″. I in all my instruments so make use of spider's web, instead of silver wires, and I find no other inconvenience to them, unless that by faint celestial objects, as for instance Ceres was, when I discovered her first, Decb 7th. An. present. These so very thin wires are a little difficult to illuminate, but this inconvenient [sic] is only owing to the extreme fineness of these wires, and I find them not at all transparent, and they project themselves even upon the Sun's disk as black and dark as silver wires. They bisect a star of 4th magnitude so perfectly as the most opack [sic] wire will do. It is only and chiefly in my quadrant that I find these thin wires difficult to illuminate in observing faint objects. I applied therefore according to your advice (Astr. Obser. at Year 1786 Observat. of the Comet 1786 with the Equat. Sector page 35) some thicker supplementary wires, of which I make use by faint objects. So in the beginning I made use of such a thick supplementary silver wire in observing Ceres, but as she grewd brighter towards her opposition, I returned to the spider wire, as it supported the illumination without prejudice to this little Planet, but now in May I shall again be compelled to take recourse to the thicker silver wire. I am pretty sure that my differences of declinations with yours are not owing to these spider wires, but to other imperfections of my old quadrant, which was constructed in the year 1764. The aperture of the telescope is only ½ inch, the nonius gives only 12″, the micrometer screw the single second, so you will now judge best, how far my accuracy can go.

All the Elements and Equations of the Moon's Orbit are inserted in my Monthly Correspondence; which I very regularly have the honor to send over to the President of the Royal Society. If I knew that a copy of my Journal should be acceptable to you, I with the greatest pleasure should send it you over, and deem it an Honour, if you will accept it. You will find in this Journal all Novelties in Astronomy, observations, calculations, and interesting Results. So, for instance, I have the honor to send you here annexed a Proof Sheet of the Equations of Perturbation of Ceres by the action of Saturn, Mars and Jupiter, which Mr. Oriani from Milan has calculated, and just sent me over. I also take the liberty to send you here my observations of Ceres from the last month, and the whole lot of observations of Pallas. I hope that you have also observed this very remarkable heavenly body. It continued to move in an elliptical orbit very regularly. Her orbit is between Mars and Jupiter's but so exentrick that she traverses the orbit of Ceres. Her Aphelial-distance is twice so great from the Sun, as on her Perihelial-distance, which is about 2.0. The revolution is between 5 and 6 years. What a various and strange phenomenon! No doubt that several other such Planeto-Comets might exist in the heavens, especially in the great and immense spaces between Jupiter and Saturn, Saturn and the Georgian Planet. But as most of 'em must appear as very little stars, hic labor, hoc opus est (this is labor, this is work), to find them out. Chance can only be the best helper in finding out such telescopic Planets.

I shall now very soon be forced to take leave from Ceres and Pallas, as the meanness of these
Planets, and the increasing Twilight will forbear to confine the observations to the meridian. I must commit now these observations to such astronomers who are provided with Equatorial Sectors. Notwithstanding I shall try my good luck with a Dollond parallactic-instrument, but I am much afraid, these heavenly bodies will quickly decrease in light, as their distances from the Earth, and the Twilight increase rapidly (Zach, 1802n, his underlining).

Footnotes by C. Cunningham:
1. Matthew Berge (1753–1819), was Ramsden’s workman during the last decade of the eighteenth century. He succeeded Ramsden, and from 1809 to 1819 supplied many of the surveying instruments ordered by Giuseppe Piazzi for the trigonometric survey of Sicily (McConnell, 2007: 259).
2. Determining the positions of the asteroids and their comparison stars required observers to take transit measurements. The method in use at the Royal Observatory Greenwich was the ‘eye and ear’ method of James Bradley (Astronomer Royal from 1742 to 1762). In this method, when a star or asteroid is about to make a transit, the observer reads off the time from a clock and continues to count the second-beats while watching the movement of the object. As it approaches the central wire, he fixes in his mind its position at the first beat before it crosses the wire and its position at the first beat after; from the distances of these points from the meridian, he estimates by eye the time of the crossing in tenths of seconds. The problem, therefore, is to determine the correct tenth of the relevant second. It was assumed the accuracy achieved was one-tenth or two-tenths of a second. Maskelyne believed this error could be reduced even further by averaging the measurements for the different wires in the focus (Brooks, 1979).
3. James Rennell, a cartographer, elected Fellow of the Royal Society in 1781.

Gauss wrote Maskelyne on 19 May 1802 with his initial calculations of the orbit of Pallas:
As the new star discovered by Dr. Olbers engages at present the attention of all astronomers of Europe, I hope you will receive with kind indulgence the first results of my endeavours about its true orbit, especially as its motion appears to put it already almost beyond doubt, that it is really another planet betwixt Jupiter and Mars whose orbit has the most extraordinary inclination and will, perhaps, give us in a few years, explanations of a very unexpected nature.

As soon as the observations of Pallas were continued through a few days only, it was already decided, that its orbit could not be a circle, the motion being always too fast, whatever distance from the Sun might be supposed. When the series of observation had increased to a fortnight, Dr. Olbers attempted to compute a parabola, but soon found, that it was equally impossible to represent the observations by it; for when he computed again the mean observation, he found an error calculated of 11′ in longitude.

When I had received Dr. Olbers’ observations till April 17, for curiosities’ sake I attempted to apply to them the same method, which I had made use of in my calculations about Ceres Ferdinandea, and which without any hypothetical supposition yields the true conic section as exactly as the nature of the problem and the projection of the observations will permit. Indeed in the present case I could not exspect [sic], that the result would be very near the truth, as Dr. Olbers’ observation had not the necessary precision, nor was their duration long enough, and besides the fear was accidentally in a very unfavourable position. However the result, which I concluded from those observations agreed generally speaking well enough with that which I afterwards, when all those circumstances had altered for the better, found by the observations of Baron de Zach. The
orbit I found was an ellipsis between Mars and Jupiter of an eccentricity greater indeed than that of any other planet (viz. 0.3), however not so great as to deprive Pallas of the right of being called a planet.

The elements which I afterwards have found by Baron Zach’s observations from April 4 till May 1, and which differ from this whole series only a few seconds, are the following; I omit the minutes because it is evident they may not yet be depended upon, and I shall soon endeavour to correct them by more observations.

Mean longitude
in the meridian of Seeberg 161° 1¼ 161° 12′ 43″ 2
Diurnal tropical motion 12′ 37″ 757.166
Excentricity 0.259 .02591096
Mean distance from the Sun 2.80 2.80068
Aphelium 300° log 0.4472636
♀ 172 ½ 172° 34′ 35″
Inclination 35° 35 0 42
Aphel. 300 5 4

From these elements it is easy to derive two very extraordinary conclusions (supposing they do not differ very much from the truth)

1° that the times of revolution of Pallas and Ceres are nearly or perhaps exactly the same
2° that the orbits of these two planets do nearly coincide in one point at the ascending node of the orbit of Ceres on the orbit of Pallas. This circumstance has yielded an ingenious idea to Dr. Olbers, viz that perhaps Ceres and Pallas might be only fragments of one greater planet, once dashed to pieces by the percussion of a Comet; indeed, the exterior appearance of the two stars and their very variable light seems to countenance such a supposition and to indicate, that their shape is not spherical but considerably irregular; however farther observations and a more exact and certain knowledge of the true orbits will be necessary to decide these highly interesting questions.

Meanwhile I have computed, by the above elements which I design by II, a little ephemeris, which, perhaps, will facilitate the farther observations before Pallas approaches too near the sun. I hope it will differ from the observations only a few minutes, and by the best observations of Mr. Zach from May 2—till May 11 (from which the greatest difference has been 15″) I am inclined to guess, that the calculated RA will be too small about 3 or 4 minutes towards the end of June, yet this estimation may not be depended upon. The declinations also probably will prove somewhat too small, but this presumption is still more precarious and uncertain, as the last declinations observed at Seeberg with a quadrant of 4 feet are not very exact nor harmonizing with each other.

[ Gauss now encloses an ephemeris for Pallas from 24 May to 29 June.]

As the above elements shall not be exact enough to find Pallas again easily, when it emerges again from the rays of the sun in the beginning of 1803 in the constellation of Ophiuchus, it will be of great importance to get still, before its disappearance, as great a series of good observations as shall be possible. I am sure that I shall attain considerably better elements, if you will have the kindness to communicate to me for that use your observations, than I should be able without them. And I have hopes that if you will grant me this favour, I shall have it in my power to determinate the orbit exactly enough, that the planet may be found out again without pain (Gauss, 1802c, his underlining).

Maskelyne wrote to Gauss on 21 May 1802:

On the 21st of April I received your letter of the 3rd of that month, with a further ephemeris of Ceres Ferdinandea from the 21st of April to the 29th of June next, for which accept my best thanks. You were right with respect to my observation of the right ascension of Ceres on the 19th of February; it was wrong reduced; it should have been 12h 31′ 53″ 2 of time=187° 58′ 15″.3 of right ascension. I have now the pleasure of sending you all my observations made on the meridian both of this planet, and of the other new planet called Pallas, discovered by your friend Dr. Olbers on the 28th of last March, as he had before rediscovered Ceres on the 1st day of this year. Having compared together the right ascensions of the Sun found by my transit instrument (assuming that of alpha Aquila by which the others were settled in right ascension) with the right ascensions of the Sun computed from his declinations about the opposite equinoxes, for

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some years past, I have found the latter right ascensions were greatest, and consequently the right ascensions of my Catalogue required an increase [Astronomical Observations made at the Royal Observatory at Greenwich, 4 vols, London 1787-1800]. But having taken the observations last year, with particular care not to open the shutters to let in the Sun’s rays till the very moment of observing his Zenith distance, I prefer the corrections from them, and have added 3°.8 to the right ascension of the 36 stars of my catalogue. Therefore 3°.8 must be added to the right ascensions of Ceres, sent you before. However I have here sent you all the right ascensions corrected, and the declinations from the first. I have moreover found from my observations of the summer solstitial Zenith distances of the Sun for some years past, the obliquity of the ecliptic no less than 5° greater than I had computed it by carrying it on as settled in 1786 by a supposed annual diminution of the Obliquity. Hence it is necessary to increase the appt. Obliquity set down at the beginning of the nautical almanac of 1802 by 5°.4. I desire to recommend to you my folio Tables, as likely to be useful to you in your calculations, and desire you will do me the favour to accept a copy of them which I will have the pleasure of sending. I shall now observe Ceres and Pallas with the Equatorial Sector, of evenings, till they shall be lost in the rays of the Sun.

[He encloses a list of 13 observations, made with his transit instrument between 4 February and 13 May 1802, of the apparent equatorial co-ordinates of Ceres, and 12 between 23 April and 16 May 1802 of Pallas]. (Maskelyne, 1802e).

**Maskelyne wrote Herschel 24 May 1802 about his own observations of Ceres and Pallas:**

Here are a few of the last observations of Ceres and Pallas made here. But the ephemeris for Ceres is always exact within ½ a minute.

<table>
<thead>
<tr>
<th>Date</th>
<th>RA</th>
<th>Decl. N.</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 13</td>
<td>11h 45m 12s</td>
<td>16° 1 49s (on the meridian)</td>
</tr>
<tr>
<td>May 21</td>
<td>14h 46m 49s</td>
<td>15° 2 18s (near midnight)</td>
</tr>
<tr>
<td>May 22</td>
<td>14h 47m 8s</td>
<td>14° 55m 0 (near midnight)</td>
</tr>
</tbody>
</table>

Ceres

Dr. Zach writes by date May 4 that the orbit of Pallas is so eccentric it traverses the orbit of Ceres, and the aphelion distance is twice the perihelion distance, which latter is about 2.0, the revolution between 5 and 6 years (Maskelyne, 1802f).

**Maskelyne sent Banks a letter 28 May 1802 about Zach’s letters, which Banks had loaned him:**

I thank you for sending Baron Zach’s two letters, together with a third, which third I now return to you enclosed.

The map of the track of the two new planets in the heavens is a mere curiosity of no real use in astronomy. I will keep it till next week, and then return it to you. Baron Zach wants to class the two new planets by themselves, from the circumstance of these motions, as Dr. Herschel does from their smallness. He seems to think that the orbit of Pallas might be so eccentric that it might in a part of its course come as near to us as Venus does in her transits over the Sun, but the letter you favoured me with yesterday from Dr. Olbers to Mr. Schroeter, shows the contrary: consequently we cannot expect to get at the Sun’s parallax this way, not even so well as by the planet Mars in opposition to the Sun (Maskelyne, 1802g).

**Maskelyne wrote Herschel on 2 June 1802 with Olbers’ hypothesis that the asteroids resulted from the collision of a comet with a primordial planet:**

I have just received your favor dated May 1, for June 1, yesterday. I was going to write to you by this post, Dr. Gauss of Brunswick by date May 19 has sent me fresh elements of Pallas and an ephemeris of its place till 29th this month, as follows. He thinks the calculated RA may turn out 3°
or 4′ too small toward the end of June, and the declination also too small, but both these are uncertain. He derives some extraordinary conclusions from these elements, supposing they do not differ much from the truth.

1. The periodic times of Pallas and Ceres are nearly, or perhaps exactly, the same.

2. Their orbits nearly coincide in one point at the ascending node of the orbit of Ceres on the orbit of Pallas. Hence, Dr. Olbers conjectures, "they were once but one planet, which was divided into two by the percussion of a comet; indeed the exterior appearance of the two stars and their very variable light seems to countenance such a supposition and to indicate that their shape is not spherical, but considerably irregular."

[The 3rd elements of Pallas, and an ephemeris from 24 May to 27 June.] (Maskelyne, 1802h).

Maskelyne wrote Herschel 18 June 1802 about the calculation of the diameter of Pallas:

It has occurred to me that as the elements of the orbit of Pallas found by Dr. Gauss give the mean distance 2.8 whereas I believe you took it considerably less, I believe 2.1 according to what was reported to you from a communication I received from France, in computing the real diameter from the apparent diameter you had observed, that the real diameter would require to be augmented. I thought you would like to make their alteration before it is printed. I spoke to Dr. Gray about it, yesterday, who will stop the printing your paper, till he receives your directions. From Dr. Gauss’ elements the distance in parts of the orbit may be readily computed, and thence the real magnitude inferred. I shall have the authority to compute it myself as soon as I get home tomorrow, and send you the result which you may compare with your own calculations. I shall compute for the 22nd of April for the most exact apparent diameter of Pallas which you mentioned to me 0″.13 (Maskelyne, 1802i).

Maskelyne wrote Herschel again 23 June 1802 with his estimate of the diameter of Pallas:

I now fulfill my promise in the letter of June 19th. I have calculated the distance of Pallas from the earth on April 22nd at midnight by Dr. Gauss’ elements which I sent you, and find it to be 1.976
whence as you measured the app. diameter of the planet 0”.13 its appt. diam. at the mean distance of the earth from the sun should be 0”.2568 and taking the mean distance of the sun at 93606000 English miles the true diameter of Pallas will be 116.56 or say 116 English miles, which approaches nearer to that of Pallas [he meant Ceres] which I think you said was 162 miles. I hope this will save you some trouble as it has given me a good deal, principally owing to the greatness of the excentricity of the orbit. You will be pleased to send what directions you think proper to Dr. Gray about altering the number for real diameter of Pallas or convey me your directions, and I will impart them to him. On the 20th I observed Ceres and Pallas, the 1st is reduced to a star of 10th magnitude and in the last observations of the evening between 11 and 12, the first was in RA 12h 4’ 9” Decl. 10’.26’N. The 2nd in RA 12h 25’ 2” Declin. 19’.49’N. The difference from Mr. Gauss’ elements is exactly what he supposed they would be. The obs. were made about midnight. I have this day received a letter from M. Mechain who had received the account I gave him of your observations of the two new planets. He writes that they are impatient to see your paper upon the subject (Maskelyne, 1802).

Maskelyne wrote Gauss about Pallas on 20 July 1802:

On May 31st I received your favor of May 19, with your elements of the orbit of Pallas, and an ephemeris of its right ascension and declination from May 24 to June 29th for which I return you my best thanks. I observed Ceres on this meridian till May 13th and Pallas till May 16th. I have since observed them with an equatorial Sector of 5 feet length of telescope, having an aperture of 4 1/10 inches. On the 20th of this month (2 days ago) at 10h 37’ 38” mean time I observed a star of 11 magnitude in the RA 193.46.5 and declination 17.2.55 N it followed 38 Comae Berenices by 3’.41’’.62 of time, and being 1’ 9” South of it. I take the mean place of the star from Wollaston’s Catalogue in RA 12h 51’ 22”.73 time and 18’.11’ 55” north declination. I take this to be the planet Pallas, but I am not sure; but shall know on searching the heavens another night. There were other small stars near it.

When I can no longer see the planet Pallas, I will send you the whole of my observations. I found the right ascensions of Pallas in your ephemeris too little towards the end of June as you supposed, but the declinations rather greater [see Figure D.20] (Maskelyne, 1802k).

Maskelyne wrote Gauss again 10 days later, 30 July 1802, giving him magnitude estimates of Pallas from April through June:

On the 26th I received your letter dated July but without the day of the month. It contained your elements of Pallas’ orbit No. III. Your calculation of the place on May 7th points out an error in my observations that day of 2”1/2 of time in the RA=37”1/2 of the Equator owing to a mistake of 10” at one of the wires, which divided by 4, as the middle wire was missed, to observe the Zenith distance, produces the 2”1/2. The corrected RA=12h 3’ 45”.60 = 6s 0’ 56’ 24”.0 from which your computation differs +1”.8, which agrees very well with the other observations. I addressed a line to you on the 20th by the post, but since find reason to think that it was a fixt star I had observed on the 18th and that the planet could not be seen. However if you have computed its place on the 18th I should be glad if you would send it to me.

Pallas on April 21 appeared of 9M. April 22 9M May 17th 9M June 14th 9M June 18 11M.
June 20 11th to 12M. June 28 10M. I began a new set of magnitudes with my Equatorial sector, calling the 1st or brightest but less than a star of 6th Magnitude to be of 7th M and calling the smallest that is visible with the telescope of the 12 Magnitude the following one and brightest of the two stars (it being a double star?)

On May 4 I found Ceres with aperture 4 inch
Pallas with " 5
Uranus with " 15
95 or 0 Leonis 6M with " 2
in each case just visible or barely visible with great difficulty. From this you may judge of the relative brightness of Ceres and Pallas and of their visibility in future, considering also their altitude as on Bouger’s Table in his traite optique. (Maskelyne, 1802).

Gauss (1802f; his underlining) replied to Maskelyne’s 20 July letter ten days later:
Your favour, dated Jul 20 I received on the 26 of this month. I regret very much, that I had been induced, by the early conclusion of the German observations of the New Planets, to think a continuation of their ephemeris unnecessary. As I now see, that your superior instruments permit a considerably longer series of observations, I instantly have done, what was still in my power to do:
I have constructed by the III\textsuperscript{d} elements of the planet Pallas, sent you in a letter of July 9\textsuperscript{th}, a new ephemeris, which I hasten to send you. I am afraid, that, after the arrival of this letter, the planet will be exceedingly faint, this ephemeris perhaps will serve at least, so decide, whether the planet at any time has been confounded with a fixt star or no. You have sent me an observation, which you say was made “the 20\textsuperscript{th} of this month (two days ago)”. It is evident, that an error is committed either in the date of your letter or in the day of the observation. [ed:see note below] I cannot but make the latter supposition, as your letter could hardly come from Greenwich to Brunswick in three days (it being arrived here already July 23 in the evening.) According to the III\textsuperscript{d} elements the computed place of Pallas was July 18. 10h 37’ 38” m.t. Greenwich RA 193° 44’ 59” D. 17° 2’ 1” which tolerably agrees with your observation, which, perhaps, still may suffer some change after a more accurate reduction, as the position of 38 Comae Ber., you made use of, seems to be only that settled by Flamsteed. But perhaps this reduction cannot be made, before the star shall culminate again by night. In a letter I wrote yesterday to Mr. Zach I have enquired if he is in possession of any later determination of 38 Comae Ber.

By passing to me Taylor’s Logarithms, you will make me greatly your debtor. They will rightly abridge all my calculations and spare me much time and labor, which I may employ otherwise. As soon as I shall have corrected once more the elements of Ceres and Pallas by the last observations I am to compute an ephemeris for the year to come for both planets. Before hand I found by the III\textsuperscript{d} elements of Pallas

1803 June 28 midnight RA= 275° 45’
at Seeberg, about one Decl. = 23° 12’ North
day before the opposition Longit. = 9° 7’ 42’
Latit. = 46° 31’ North
Distance from the earth = 2.56

Note: This point of chronology was examined by Forbes (1971:228). Despite his incredulity, the letter did indeed take only five days to travel from Greenwich to Brunswick; Gauss actually received it on the morning of the sixth day. Forbes confused the issue further when he stated in this note ‘Another reason for doubting Gauss’ own words…’ when he actually meant ‘Another reason for doubting Maskelyne’s own words…’. It was Maskelyne, not Gauss, who made the date error in the 20 July 1802 letter from Maskelyne to Gauss.

Maskelyne submitted four observations of Pallas to Zach, but as Zach relates the data had to be corrected

“... since he used, as already mentioned in the case of the observations of Ceres, only the mean position of the star compared taken from Wollaston’s star catalogue, disregarding the aberration and nutation. Since this star is known, the original observations can be restored and calculated anew.
This star is no. 24 Coma Berenices, whose position we already gave in the August issue on page 189. But this star is a binary star, a fact that Dr. Maskelyne did not notice and thus it remains unknown which he used for comparison; their ascensional difference is 15°.2. We took the mean value and thus notice that if the first of these stars is meant, one has to add 7″.6 to our calculated positions of the planet and on the contrary, if the following star is meant the same amount has to be subtracted. In Wollaston this star is according to Flamsteed only given as a single star. Accordingly, the observations of Pallas from Greenwich were calculated (Figure D.21):

Also the error, which was mentioned in the July issue p. 85, in the observation of Pallas of May 7 from Greenwich was discovered. Dr. Maskelyne observed Pallas only at four hairs of the passage instrument (1st, 2nd, 4th, 5th); for one the time was given erroneously by 1″, thus the sum and the quotient by 10/4 = 2.″5 in time = 37.″5 in arc too small. The correct RA is accordingly 180° 56′ 24.″0 and the error of Gauss’ III elements +1.″8. (Zach, 1802x).

Olbers was also communicating directly with Maskelyne, as evidenced by this letter of 6 August he wrote to Gauss, which also reveals the admiration of the English instruments used in the study of Ceres and Pallas.

I haven’t received anything about the two planets for a long time, other than a letter from Maskelyne who still observed Pallas on the 18th, although he was uncertain whether or not it was Pallas. It was “of the 11th magnitude.” He’s promised me his complete set of observations as soon as he can no longer see the planets. I’ve also sent him, at his request, an ongoing ephemeris of Pallas, a copy of which is enclosed. [This ephemeris is no longer extant.] What a nice prospect for the rediscovery in the coming year when it will come noticeably nearer than on July 18. Maskelyne’s eyes and instruments are unrivalled. His equatorial telescope is 5 feet and has a 4 1/10 inch aperture. (Olbers 1802e)

Gauss wrote to Maskelyne on 18 November 1802 about new elements of Pallas:

I owe to you still my best thanks for the kind communication of all your observations of the two new planets and for your welcome and useful present of your folio tables, which I received by favour of Mr. Tatter in the month of August. I must beg your kind forgiveness for paying my due acknowledgements so lately. My last letter written July 30th, which contained the calculated positions of Pallas for the months of July and August, I hope you have received. Since that time I have calculated, twice more, elements of Pallas. The first (IV) after the last observations of Dr. Olbers are printed in the October issue of Baron Zach’s Journal; the latter after the last observations of Mr. Oriani conducted August 8 at Milan, which are Vth in order, I have the honour to communicate here following as they are not yet published but will appear in the December issue of the Monthly Correspondence.

These elements I had already computed, when I was informed that Mr. Mechain has been so fortunate as to observe Pallas till the end of August; but till now I have not yet received any of his observations posterior to the last of Mr. Oriani’s, which agree very well with the cotemporeal observer Mr. Mechain. To my very great surprise Mr. Messier at Paris has observed Pallas till 21 Sept.; his last observ. is

Sept 21 7h 58′ RA Pallas 215° 48′ 46″
Decl. 8° 59′ 28″

Supposing the time to be mean time, the place of the planet calculated after my Vth elements is

215. 49. 14 Difference +28″ (Distance from earth 3.518)
9. 0. 16 +48″ (Altitude above the horizon 13° 10′)

281
There are already extant two ephemerides for the course of Pallas in the year to come, one constructed by Dr. Olbers after my III\textsuperscript{a} elements (Zach’s M.C. September) the other by myself after the IV\textsuperscript{th} elements (ibidem October). I have now the honour to send you a new one computed after my last above elements (V), continued above a month further than the two preceding ones, which I hope will be near enough to the truth to find the planet out again, though I am afraid, that the faintness of its light and the innumerable little stars which lie in its way in the galaxy will be very untimely circumstances. The last column of the table expresses the value of the quantity

\[
\frac{1}{(\text{distance of Pallas from the sun } \times \text{dist. of Pallas from earth})^2}
\]

and may be considered as the measure of the planet’s apparent quantity of light, neglecting its elevation above the horizon. The same expression yields for this year

\[
\begin{array}{ccc}
1802 & \text{April 4} & 0.08997 \\
     & \text{May 16} & 0.04740 \\
     & \text{August 10} & 0.01455 \\
     & \text{Sept. 25} & 0.01030 \\
\end{array}
\]

I have also corrected my VII\textsuperscript{th} elements of Ceres after the observations of the last season and introduced the perturbations caused by the action of Jupiter. The result of these researches is exhibited in the \textit{Monthly Corr.} November, but till now I have not calculated any ephemeris for 1803 by the new elements, because the course of Ceres 1803 after my VII elements is already calculated by Mr. Triesnecker and Bode in their respective astronomical ephemerids, which I hope will be sufficient to find the planet out. The difference between the VII elements and the new ones (VII) towards the opposition is by a calculation made somewhat hastily.

- Longitude 10\textdegree
- Latitude 3 1/2\textdegree

If I should undertake the calculation of a more correct and extensive ephemerid, I shall not fail to send it you as soon as it is finished (Gauss, 1802h, his underlining).

Gauss wrote to Maskelyne on 30 January 1803:

Your great present of Taylors Tables I have received already in the month of December of the last year, for which inappreciable work I ought sooner to have acknowledged my gratitude. The cause of my delay was my wishing to give You at the same time some account of the last researches I have made on the orbit of Piazzi’s planet. I have once more subjected the whole series of the observations which have been made till now, to a scrupulous examination, but the result has been, that it is not yet possible to give the elements a high degree of precision; indeed I have convinced myself that different elements may be assigned agreeing with each other to a few seconds, for all the observations from January 1, 1801 till August 5, 1802, but differing 10\textdegree or even more in longitude for the next opposition July 1 of this year. I have taken pains, to bring out such elements as make the calculated places coincide as nearly as possible with the observed places, and computed thereafter an ephemeris for 6 months which I have the honour to send You here enclosed. Though, by the above reasons, I cannot pretend to warrant this ephemeride to one single Minute. Yet I trust that the planet may be found out thereafter without any difficulty, and as soon as the error of the reckoning out the rate of its increase or variation have once been settled by good observations, the deviation will be no more of any consequence. The places of Ceres calculated by Mr. Triesnecker and Bode after my VII elements differ very little from these new ones, however I hoped that an ephemeris for Right Ascension and Declination would be more commodious for immediate application, than the longitudes and latitudes. The last column contains the value of \[
1 / (\text{dist. } \theta \times \text{dist. } \varphi \times \Delta \theta)^2
\]

which is considered as proportional to the apparent brightness [i.e. the illumination received by Ceres from the Sun, and that reflected from Ceres on to the earth, in each case the square of the distance between the bodies concerned]. But to make a just estimation, it will be necessary to take also into consideration, that will start much lower in this year than in the two years past. The value of the above formula is

\[
\begin{array}{ccc}
\text{for 1801} & \text{January 1} & 0.03637 \\
     & \text{Feb. 11} & 0.02409 \\
     & \text{Dec. 7} & 0.02494 \\
\end{array}
\]
1802
Feb. 26  0.05633
May 17  0.03608
Aug. 5   0.01543

My researches upon this subject has led me to detect an error in one of your meridional observations
Viz. the declination of May 11, which You make 16° 21’ 41”.8 ought to be about 2’ 30” greater or
nearly = 16° 15’ 12” and therefore the longitude about 1’ smaller, the latitude about 2’+
greater. Perhaps You will be able to make out the cause of this difference, which comes out not only
from the calculation but is confirmed also by two observations made on the same day by Cesaris at
Milan and Mechain at Paris—At least this circumstance will be worth examination, as all your
other Meridian observations are of an admirable exactness and agree among themselves to one or a
few seconds. [Rough notes by Maskelyne contain a reference to a letter from Méchain dated
27 January 1802, in which Méchain said that his initial observation of Ceres on 24 January
yielded a ‘declination 17’ more than Zach’s computation; RGO 4/120/xi].

In the month of March I hope You will find out one of the planets if not both, by Your
equatorial Sector. I flatter myself, that, when You have got some observations of them, You will
honour me with the communication. I am completely prepared to convert any new observations into
immediate use for correcting the orbit, and I have already experienced, what uncommon
abridgement in calculation is derived from the excellent works Your bounty has furnished me
with. The ephemeris for Pallas which I had the honour to send you in the month of November of
the last year, I hope is come to your hands. Both planets are in an unfavourable position this
year; Pallas for her great distance from earth and Sun, and the faintness of her light resulting
thence; Ceres partly for the same reasons though in a more moderate degree, partly from her
great south declination, which in our northern latitudes scarcely will permit her to emerge from the
vapours of the horizon. Probably therefore the astronomers of Italy will sooner be able to find her
out, than those of the more northern countries, and in St. Petersburg and Stockholm she
will not be seen at all.

[Appended to this is an ephemeris entitled “Geocentric motion of Ceres Ferdinandea in the year
1803,” containing the equatorial co-ordinates (correct to the nearest minute of arc) and corresponding
values of the ‘force of light’ derived from the equation quoted in the text of this letter, from 4
February to 9 August 1803] (Gauss, 1803a).

Gauss wrote Maskelyne 24 April 1803 about Pallas:
Though, probably, you are already fully informed of every essential point concerning Mr.
Harding’s at Lilienthal finding out again Dr. Olbers’ new planet: yet I hope, that perhaps some of
the following particulars will be not without interest to you.

Mr. Harding saw Pallas, for the first time, again February 18 and became sure of his discovery
the following night. But Dr. Olbers, the discoverer of the planet, who immediately had intelligence
thereof and accordingly found out his planet Febr. 21, is, at least in Germany, the only one who
makes due observations of it. He is only provided with a 5 feet refractor of Dollond (but an
excellent one, 4 in clear aperture), the campus of which serves to him as micrometer. However so
great is his skill in this kind of observations, that those made by him have a degree of precision,
which hardly could be expected from this manner. The result of them is that my last ephemeris,
which I had the honour to send you Nov. 18 (if I am right) of the last year, gave the Right
Ascension too great by 2½ min., the declination too small by ½ or 1 min. This is to be understood
for his first observations; at present the error of the Right Ascension has increased to 3 min. or
some seconds more, which are to be subtracted from the place given in the above mentioned
ephemeris; the error of the declination has remained nearly the same. With this correction the
ephemeris serves to find out the planet at every time with all facility, that can be attained under the
particular difficulties caused by the extremely faint light of the planet and the vast number of
telescopical stars in this zone of the heavens. Probably you will have found out also the planet at
present, and make yourself all the preceding remarks by your own observations.

As soon as I had received the two first observations of Dr. Olbers, I computed thereby the
following new elements which I shall not touch anew, before the observations of this season shall
be finished.
Mean longit. 31 Dec. 1801) noon in the mer. of (143° 28′ 17′′

283
31 Dec. 1802) Seeberg  
(221. 28. 54.0  
Therefore, for the meridian of Greenwich  

<table>
<thead>
<tr>
<th>Epocha 1802</th>
<th>143° 28' 40&quot;,1</th>
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<tbody>
<tr>
<td>1803</td>
<td>221° 29' 16&quot;,9</td>
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Aphelion 1803 (supposed to be at rest sidereally) 301° 24' 13"  
Ascending node, at supra  
Mean diurnal tropical motion 769°4161  
Logarithm of the semi axis major 0,4426160  
Excentricity 0,245619  
Inclination of the orbit 34° 38' 19",8

With these elements I have compared all the hitherto-made observations of Dr. Olbers, which stand thus [Gauss writes here a table of observations from 21 February through 13 April.]

My ephemeris of the course of Pallas in this year expiring with August 9, I have continued it from the new elements till Oct. 20, which certainly will be more than sufficient, as the faintness of the planet’s light will much sooner impose an end to the observations. Here I have the honour to transcribe the Continuation of the Ephemeris of Pallas. [Gauss prints the ephemeris from 9 August to 20 October.]

As to the other new planet, Ceres Ferdinandea, I have not yet, till this hour, received any new observations. I am only informed that Baron Ende at Celle in company with Mr. Harding found the planet without difficulty March 21 and perceived its motion the following nights, but I could not get any precise observations of it. I am for this reason still ignorant, what corrections my ephemeris, which I sent you about the 31 of January last, may stand in need of.

![Figure D.22: The cover of Taylor's Logarithms.](image)

I acknowledge with high pleasure that I am mostly indebted to the precision of your excellent observations of Pallas, for the exact agreement of its foretold course with the real, as likewise I am for the facility with which I now make all my calculations to your precious present of Taylor’s Tables [Figure D.22]. I hope, you will farther grant your favour to my endeavours, to bring the theories of those remarkable celestial bodies nearer to perfection, by continuing to communicate to me your future observations of them. (Gauss, 1803b, his underlining).
Gauss wrote Maskelyne on 25 September 1804 about the discovery of Juno:
A fortnight ago I had the honour to send you a short warning of the discovery of a new moving star, which by every appearance was supposed to be a third new planet. I now am happy to give you a more full account of this extraordinary phenomenon.

Since Sept 12 I observed myself this remarkable star, the brightness of which surpasses still the light of Ceres and Pallas. Here you receive the list of all my hitherto-made observations.

[Gauss here prints his data from 12 to 24 September.]

Though the interval of all existent observations be much too short and their precision too small, to found upon them even an approximate determination of the orbit of this star; yet I have thought it would not be without use, for estimating the course which it will hold in the next weeks. The result of my researches has been, that all my observations together with those of Dr. Olbers and a few communicated to me by Baron de Zach of 13.14.15 Sept. may be represented by the following elements

Mean long. Sept. 9 0h m.t. at Seeberg 24° 53′ 2″
Aphelion 244. 51. 36
Ascending node 171. 48. 24
Mean diurnal motion 12′ 5″ 2′
Log. of semimajor axis 0.459706
Mean dist. 2.8821
Excentricity 0.31376
Inclination of the orbit 15° 12′ 39″

The mean motion therefore seems to be much the same as that of Ceres and Pallas, and perhaps future observations will yield a still greater coincidence. I shall not fail to communicate to you the results of my future researches, which soon will get a greater certainty. At present I hasten to send you an ephemeris of the course of the planet, which, though it may deviate very considerably from the true positions, nevertheless shall be sufficient, to find it out, if perhaps you should not yet have succeeded in your researches.

[Gauss prints an ephemeris from 27 September to 8 November.]

I beg you, to communicate these particulars to the illustrious R.S., if you shall find them worthy of this honour. Also I repeat my entreaties, that your kindness might give me an opportunity of making use of your future observations of the planet for determining more exactly its orbit, than I should be able without them.

As there seems to be little doubt, that this star is really a permanent planet, a denomination soon must be thought of. I have proposed the name of Hebe to Mr. Harding on account of the bright and fair light of the planet, not unworthy of the goddess of Youth. If this name should be accepted (of which naturally Mr. Harding the discoverer must remain arbiter), a flower would not be an unbecoming symbol (Gauss, 1804a).

Maskelyne wrote Banks on 26 September 1804 about the discovery of Juno:
Last night I observed Mr. Harding’s new planet of 8th magnitude discovered on the 1st & at 11h 36′ 50″ mean time its right ascension was 358° 47′ 38″ & declination 4° 31′ 48″S. Its motion at present is 10′ 18″ a day in right ascension going westward or retrograde, & its motion in declination 14′ a day southward. This obs. was on the meridian. It is likely to be seen same time. (Maskelyne, 1804a).

Maskelyne wrote Gauss on 1 October 1804:
[First part of the letter deals with asteroid Juno]. I thank you also for the mention of the errors of the ephemerides of Pallas and Ceres in the places of those planets as set down in Mr. Zach’s journal. I have, however, never seen Zach’s Journal [the Monthly Correspondence], nor have I made any further observations on the two planets, which I should have done, if I had received intimation of its place, such as you kindly favoured me with before. I have been so busy, that prevented me computing them by the elements you sent. When you have made out elements of its orbit, I shall be obliged to you for the communication of them, and also for any ephemeris you may have of Ceres and Pallas. I should think it particularly useful to observe them near the opposition. Perhaps it would be the shortest way to send the letters you may favour me with by
Gauss replied to Maskelyne 16 October 1804, with further observations of Juno:

On the 14th I received your favour of Oct. 1 with your information, that you happily have found out Mr. Harding’s new planet, and your observations of Sept. 25 and 29, for which I am highly obliged to you. I continue to lay before you what results from the further observations and calculations concerning this remarkable discovery. Mr. Harding has chosen for his planet the denomination Juno; at the same time he proposes the symbolic sign representing a scepter with a star on its top: ♀ without doubt, no astronomer will refuse to embrace these proposals.

In my former letter I sent you the first coarse essay to determinate the elements of Juno from my own observations: I now am happy to communicate to you new ones, which are principally founded on Mr. Zach’s meridian observations and, I hope, much superior to the first. The mean motion, which before came out smaller than that of Ceres and Pallas now results considerably greater, and I presume, the uncertainty which may still affect these elements can hardly be so great as the difference between this new mean motion of Juno and that of the other two planets. I therefore am inclined to pronounce, that the time of revolution and of consequence the mean distance from the sun too are really smaller than the revolution and distance of Ceres and Pallas. Here follow the new elements, which for distinctions sake I design with (II)

Mean longitude 1804 Sept. 30.0 in the meridian of Seeberg

<table>
<thead>
<tr>
<th>Element</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean longitude</td>
<td>21° 17' 47&quot;</td>
</tr>
<tr>
<td>Mean diurnal motion</td>
<td>836,&quot;89</td>
</tr>
<tr>
<td>Longit. of the aphelium</td>
<td>231. 18. 1</td>
</tr>
<tr>
<td>Excentricity</td>
<td>0.25496</td>
</tr>
<tr>
<td>Logar. of semi-major axis</td>
<td>0.418225</td>
</tr>
<tr>
<td>Semi-major axis</td>
<td>2.61954</td>
</tr>
<tr>
<td>Longit. of the asc. node</td>
<td>170. 46. 41</td>
</tr>
<tr>
<td>Inclination of the orbit</td>
<td>12. 19. 43</td>
</tr>
</tbody>
</table>

I am impatient to get a longer series of your observations by which soon I shall be able to give the elements a much higher degree of precision.

I have till now continued my own observations of Juno, but as they must be much inferior in precision to meridian observations, they would be of no value to you. More acceptable, I hope, will be to you, an ephemeris of Juno, calculated, after the above elements, which though probably it will deviate much from the truth, in the latter positions, yet may be of some use to facilitate the observations, as the error in these positions will increase only by degrees. I immediately join to this ephemeris those of Ceres and Pallas, as they are set down in Mr. Zach’s Journal.

[Gauss includes here the ephemeris of Ceres, Pallas and Juno for the period 18 October to 29 December.]

Nota

1) The declinations are all south
2) The hour for all positions is 12h mean time at Seeberg
3) The ephemeris of Pallas gave on October 9
   the RA  7’ too small
   the Decl. 2’ too small
4) The ephemeris of Ceres gave on Sept. 15
   the RA  8’ too small
   the Decl. 4’ too great
5) The errors of Juno I cannot yet guess at.

About September 18 Ceres and Juno will be very near each other. I wished Dr. Herschel might profit of this favourable occurrence, to compare their apparent diameters and brightness—I hope, dear Sir, you will make a rich series of observations of all the three planets, the kind communication of which shall highly oblige (Gauss, 1804b).

Maskelyne wrote Gauss on 18 October 1804 about an observing strategy to discover more asteroids. It was this method that led him to discover Vesta three years later:

On the 8th instant I received your second favour dated Sept. 25th & thank you for the elements you have sent me of its [Juno’s] orbit, & the ephemeris of its motion….I shall continue to observe the
new planet at intervals, as I have began, & I will send you the results. I here send you three other observations of it. [Maskelyne then gives data for 5, 9 and 17 October.]

These 3 new planets will disturb one another’s motion, sensibly, I expect, tho’ they are so small, on account of the equality or near equality of their periodic times, which will afford us a means of determining their quantities of matter. Mr. Piazzi, Astronomer Royal at Naples, has published a large folio volume of his Catalogue of all stars in Wollaston’s Catalogue and determined each from 3 or 4 to 80 observations of his own. In doing this, he discovered Ceres. If astronomers would observe on two successive nights, they would run a chance of discovering new planets. Of it they observed stars twice in the same night, with an interval of 1, 2 or 3 hours, with a good equatorial instrument, they would find them out by their motion in the interval. (Maskelyne, 1804c).

Gauss wrote to Maskelyne about a more precise set of elements for Juno on 7 December 1804:

As, since my last letter, in which I sent you elements of Mr. Harding’s new planet, founded on observations of one month’s duration, the interval has increased to thrice that time, I have been able, to give the elements a much greater precision though the last observations, which I made use of, being of my own, cannot equal in exactness to meridian-observations. My new elements, corrected yesterday after my obs. of Dec. 4 are these:

Mean longitude 1804 Dec. 31.0° in the merid. of Seeberg

\[
\begin{array}{l}
\text{mean diurnal motion} & 42' 41' 34'' \\
\text{Aphelium} & 812.5'091 \\
\text{Excentricity} & 233' 23' 47'' \\
\text{Logar. of mean distance} & 0.256841 \\
\text{Ascending node} & 0.426935 \\
\text{Inclination of the orbit} & 171 4 12 \\
\text{Right Ascension} & 13 4 9
\end{array}
\]

The mean diurnal motion of 812" I hope is exact to a very few seconds; wherefore it is decidedly greater than the mean motions of Ceres and Pallas.

For the commodity of the observers, I have calculated a new ephemeris that I have the honour to communicate to you. The ephemeris of Ceres, sent you in my last letter, gave on Dec. 4 the Right Ascension too small 6', the declination too great almost 4'. Therefore Juno and Ceres will on Dec. 21 come so near one another, that the distance is less than ¼ degree. Juno now is considerably fainter in light than Ceres, though still brighter than Pallas, which Dec. 3 was very near ζ Aquarii.

[Gauss prints here an ephemeris from 5 December 1804 to 31 January 1805.]

I expect with impatience the continuation of your observations of Juno, as those which you shall have made of Ceres and Pallas: and I shall be happy, to send you the further results of my investigations on these three remarkable planets (Gauss, 1804c, his underlining).

Gauss wrote Maskelyne on 2 April 1805:

In my last letter [dated 25 October 1804, but now lost] I promised you an early communication of the results of my researches on the three new discovered planets. I now have the honour to make good my engagement, and to send you as well the last elements of all three, as an ephemerid for their course in their next apparition. I trust to your friendship that you will give me an early notice, when you shall succeed to find them out again, and by the kind communication of your precious observations enable me, to give my results a still greater perfection; also I should be very happy to get what observations you have made of any of the new planets since October 17, 1804. Ceres and Pallas will be so bright that they must fully equal stars of the 7th order, and therefore they may be easily found out and observed.

[Gauss enclosed a list of the elements for Ceres, Pallas and Juno; also ephemerides for each of the asteroids dating from 28 July 1805 to 24 May 1806, and 30 April 1806 for Ceres and Pallas respectively, and from October 1805 to 23 July 1806 for Juno]. (Gauss, 1805).
Maskelyne wrote his final letter to Gauss on 8 May 1805:

I return you many thanks for your elements of all the three planets, and the ephemerides of their motions. I shall lay your communication of the elements and places of the planets before the Royal Society. I believe Dr. Zach’s journal does not find its way to this country, at least only to particular persons and that irregularly. I wish I knew how to get it by the help of our booksellers.

[Maskelyne lists 3 pairs of equatorial co-ordinates for Ceres obtained on 22 and 26 November, and 3 December 1804.] (Maskelyne, 1805).

The following letter shows how Maskelyne was a conduit of information about the asteroids to other astronomers in Great Britain. This was written by John Brinkley (1763–1835), Royal Astronomer, Dunsink Observatory to J. A. Hamilton, Director of Armagh Observatory. It reads in part:

I have just received from a friend in London the improved elements and ephemeris for the three new planets, Ceres, Pallas and Juno which Dr. Gauss very lately sent to England, I believe to Dr. Maskelyne, and they were communicated to the Royal Society about a fortnight ago. I think that you will be glad to have them and I have therefore sent them on the other side. I was extremely glad of them as otherwise there would have been the great trouble of computing the places. Ceres and Pallas at their appearance will be fully equal to stars of the 7th magnitude but Juno will be very faint. (Brinkley, 1805).

Maskelyne (1807b) wrote Herschel 13 May 1807 about Vesta:

Last Monday the 11th the RA of Dr. Olbers new planet at passing the meridian was 11h 53’ 42" and declination 12° 11’ 27" N. It is now about stationary in RA. It moved 17’ 5 ½" South in 4 days or at a rate of 4’ 16" a day, but only 5.4 of time retrograde or 1.3 of time a day.

A week later Maskelyne (1807c), on 20 May 1807, wrote Herschel about Vesta again:

…We think you have seen the planet since I wrote to you on the 13th. I have observed the planet on the meridian on the 18th & 19th.

<table>
<thead>
<tr>
<th>RA</th>
<th>Declin.</th>
</tr>
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<tbody>
<tr>
<td>h</td>
<td>°</td>
</tr>
<tr>
<td>18 May</td>
<td>11 54 40</td>
</tr>
<tr>
<td>19</td>
<td>11 54 55</td>
</tr>
</tbody>
</table>

Some observations have been sent from Dr. Olbers at Bremen.

[Maskelyne then appends data from 29 March to 12 April]

By Mr. Bode at Berlin  [Maskelyne then appends data from 13 April to 4 May]

D.3. The William Herschel Correspondence

As mentioned in Section 5.3, Herschel was first informed of the discovery of Ceres in a letter of 2 May 1801 from Francesco Sastres:

I yesterday received a letter from Palermo, acquainting me that Father Piazzi had discovered a comet, and that he requested of you the favour of informing him, through me, whether you have observed the same. (Sastres, 1801).

The following month Herschel received a letter from Johann Bode:

I would like to ask you to give the Royal Society of Sciences on my behalf the following astronomical news. On March 20 I received a letter, dated January 24, from Mr. Piazzi in Palermo.

While reading the letter I immediately noticed the peculiar appearance and motion of this alleged comet and after the first observations I considered the assumption justified that this little star is not a comet but rather a planet and to be precise that one of our solar system that has been announced by me since 1772 and has not been discovered yet. If I assume its distance from the sun...
approximately 2.90, the accuracy of Mr. Piazzi’s communicated observations and the fact that it came to a standstill on January 11, it corresponds extremely well to this assumption. On March 23 I wrote Mr. Piazzi and asked for some more observations, but until today I have not received those or a response to my letter of March 23. The other day I got a second letter from Mr. Piazzi, dated April 10 but he only mentions he had followed the comet discovered in January until February 11. But then he fell ill and had not fully recovered yet, but he intended to send me as soon as possible the orbital elements. If Mr. Piazzi had determined the star’s position for February 11, its orbit could be derived already and my assumption of it be confirmed. As soon as I have some more observations I will inform the Royal Society about the results of my observations. (Bode, 1801).

William Herschel, while on a visit to Worcester, wrote to his sister Caroline:
I want very much to look over the ecliptic again, to see for another planet, and to find whether Piazzi’s star is a real planet, and if so whether it be furnished with satellites. For this reason my 10 feet telescope shall have all possible distinctness. (Herschel, 1801a).

Herschel’s friend William Watson was particularly scathing in his opinion of Piazzi, and in a letter dated 21 October 1801 sarcastically supposed that Piazzi did not communicate sooner because he was deceased:
I wish to be informed whether there is any foundation for the rumour that the deceased Mr. Piazzi of Palermo has discovered a new planet between the orbit of Mars and Jupiter. If that should be the case the astronomers will be the more intent to make a fresh scrutiny of the Heavens particularly of the zodiac to see whether there may not be many more. (Watson, 1801).

Herschel replied to Watson on 27 October 1801:
By the same post that brought me your letter I received one from the deceased, as your letter styles him, Mr. Piazzi, relating to his discovery. He wishes me to search for the lost planet, comet, or moving star which he observed last January. Before his letter came I had already examined that part of the heavens where, supposing it to be a planet, it should be found; but hitherto no astronomer, I hear has had any success in the rediscovery of the erratic phenomenon. Mr. Bode now thinks it might be the comet of Mr. Lexell. I have also anticipated your surmise that “astronomers will be more intent to make a fresh scouting of the Zodiac.” This has been my employment since our return from north Wales. (Herschel, 1801b).

Herschel (1801c, his italics) replied to Piazzi on 29 October:
I have been searching for the new star that you discovered and of which he announced to me in his Risultati delle osservazioni della nuova stella etc. which I read with the greatest pleasure. In case you find that star again, do me the pleasure to inform me first.

Less than two weeks later, on 10 November, Herschel (1801d, his italics) wrote to Lalande:
I have been searching for the star that Piazzi discovered and of which he announced to me in his Risultati delle osservazioni della nuova stella, but until now I have not seen any trace of it.

Lalande replied to Herschel from Paris:
I also have received the observations of Piazzi, but I do not believe at all the period of four years. The observed arc is very small, and the degree of the attraction cast too many doubts it may be a comet. (Lalande, 1801).

After Ceres had been discovered, on 20 February 1802 Herschel’s friend Patrick Wilson asked him to help with the preparation for an article for Tilloch’s Journal:
I have this moment, just at post hour, received a note from Mr. Tilloch Editor of the Philosophical Magazine, very respectfully entreating some short account of Gauss’ paper about the new Planet, to appear on the 1st March—and such an account as may appear to be communicated by one who attended the meeting—he says it he receives it on Monday it will be in time for insertion—so I have
acquainted him that probably I may get something drawn up that would be correct and particular; so as to do justice to Gauss’ paper—I wish much however that you yourself would draw up such an abstract and send it to me for tomorrow’s post, and which I could transcribe for Mr. Tilloch; so as you should not appear. (Wilson, 1802b, his underlining).

Just six days later, another close friend, William Watson (1802a), held out great hopes for Herschel’s investigations of Ceres:

You sent me word in your last [letter] that you were diverted from the pursuit of the new planet by some other object of attention, and that you had met with great success. I am informed also you have sent an account of the new planet, as has also Dr. Maskelyne and Mr. Aubert. If it has any moon or moons you will be the first to discover them.

Despite his deliberate neglect of Herschel in 1801, Piazzi (1802b) then had the unmitigated gall to ask Herschel to keep him informed about any discovery Herschel might make about Ceres:

In your very kind reply to my letter about the new planet, you had indicated your wish to be informed if I found it. It is to fulfil this obligation that I take the liberty to write you. I have no doubt that by now you have seen it more than once, and possibly have even improved on my discovery. So I found it on January 23, having not been able to make any observation before then. Its position was fairly in keeping with the ellipse provided by Mr. Gauss. I will follow it continuously until its immersion into the rays of the sun.

Please make sure, with the goodness that is so natural to you and so much to your credit, to keep me informed of everything that you discover about this new star with your great means and your great intelligence.

Even though outwardly Herschel maintained cordial relations with Piazzi, one can only imagine what he thought of such effrontery at the time.

On 9 March Wilson (1802c) also communicated to Herschel about a visit to Sir Joseph Banks:

Last Sunday’s evening I was at Sir Joseph’s rooms when he inquired kindly about you, and expressed some hopes of hearing farther from you as to the new Planet by Thursday, in consequence of our having lately, some intervals of a clear starry heavens.

PS. I have received back Piazzi’s and Baron Zach’s schedules upon the new Planet – pray shall I send them out to you in a parcel by coach? Mr. Tilloch has been greatly obliged by them.

Three days later, Alexander Aubert wrote Herschel:

I saw the Ceres Ferdinandea Saturday night the 6th instant, it had at 9h 17’ mean time 185° 50′ RA and 16° 3′ Dec. N.

The 9th March near midnight it had 185° 55′ RA and 16° 22′ Dec. N., so it alters very little in RA and much more in Dec. I hope you received my line advising you of my first sight of it (Aubert, 1802a).

Aubert (1802b) wrote to Herschel again on 20 April, providing him two observations by Olbers, which were communicated to him by Maskelyne and Lee. He goes on:

I judge the motion of Dr. Olbers’s planet to be diminishing in AR daily about 32 seconds of time & increasing in Dec. North near 17 min. of a degree daily. The above observations of Dr. Olbers’s planet in the first I have been able to get it having passed already for several nights before; the moon does not hinder the observation of it. It is larger than the Ceres of a reddish hue and rather more distinct in it’s [sic] appearance.

This is an important letter as it represents the views of one of only five observers in England on the question of asteroid colour, the others being Herschel, Maskelyne, Lee and Walker (Table 3.1). Like Herschel, it seems Aubert was fond of reddish hues (Section 3.3).

George Best was a conduit of information between Herschel and Schröter. Here is
the letter about the discovery of Pallas (Schröter, 1802a) mentioned in Section 5.14:

On 1802 March 28, Dr. Olbers after having observed the planet Ceres, accidentally casting a look upon the star No. 20 in the northern wing of the Virgin, (near which he had rediscovered the Ceres the 1st of January last), discovered, to his great surprise, a star of the 7th magnitude, forming nearly an equilateral triangle with No. 19 and 20 of the Virgin, and which he was persuaded had not been visible there at that time. He compared it several times with the 20th of the Virgin, but always found the right ascension less and less and the declination greater. The new star appeared to him as perfectly resembling Ceres in his Dollond telescope, without either atmosphere or nebula and could not be distinguished from a fixed star. What a singular circumstance!

March 30: With magnifying power of 288 applied to the 13 feet reflector, I saw it much more striking and planet-like than Ceres, with something of a planetary disc, and tho’ not altogether sharply defined, but rather hazy, yet with its limb more distinct than that of Ceres, so that I was able to measure its diameter. With the disc-micrometer with which I had measured the apparent diameter of Ceres on the 28th of March to be 4″.391, I found the diameter of the new planet to be 4″.635, consequently much larger than that of Ceres and Georgium Sidus, the diameter of which last I found on the 20th of March to be 3″.973.

The light of the Olbersian star was in comparison with that of Ceres pale and white but rather more intense, because its disc remained visible in the midst of the illumined disc of projection, and less of the hazy boundaries became invisible. Notwithstanding all this, I was not able to see the last trace either of this or of Ceres with the naked eye, although I could always see the Georgium Sidus as hitherto I had always done, even in a low situation.

The planet was followed westward by a very small darkish star, only visible in the 13 feet reflector. On the 1st of April it was again accompanied by a small dark star, from which it lay S.W. exactly as on the 30th of March, and seemed to be the same, which I suspect to be a satellite.

It is remarkable that the moveable & principal star, perhaps on account of the heavy dew, had no longer the planet-like appearance of the 30th of March; it appeared with the magnifying power of 288 in the 13 feet reflector, less in a stronger light, and could not well be distinguished from a fixed star. When it appeared with a small disc its apparent diameter was only 3″.244 instead of 4″.635 as on the 30th of March.

After the discovery of Pallas, Wilson (1802d, his underlining) forwarded Herschel a letter from an unknown person, who was most curious about the new planet:

When I returned about 9 in the evening I was greatly surprised and pleased at hearing of Another new Planet just discovered:

congrsequence which you had written Mr. Herschel in Your Letter of Sunday—I should be highly obliged were you to bestow a few minutes, as soon as ever you find time, in writing me what notices you may be at liberty to mention concerning this cur[ious] matter.

Herschel wrote to Méchain on 22 May 1802. This is the extremely important “chain letter” that announced the word ‘asteroid’ (see Subsection 4.2.3.1):

Regarding the two celestial bodies which were last discovered I am giving you a summary of my observations. In a memorandum, read to the Royal Society in London on the 6th and 13th of this month, I explained in detail my measurements of the diameters of these stars and I believe to have proven that that of Ceres, seen from the earth on April 22, was only 0″.216; and that of Pallas according to an equally good measurement 0″.17; but according to another even more accurate measurement only 0″.13.

Calculating with these as much as our still imperfect knowledge of the orbits of these stars allows, I found that Ceres’ diameter is about 162 English miles and that of Pallas only 70.

I explained with the help of all my observations that these bodies cannot be called planets because of their small size and because they are beyond our zodiac. And, as I prove as well, they are not comets either and thus can only be regarded as a species between comets and planets which has been unknown to us and demands a name of its own. Since they resemble small stars and they are difficult to distinguish even with the best telescopes, I called them *asteroids.*
Here follows the definition of this word: “Asteroids are small celestial bodies that revolve around the sun on ellipses more or less eccentric and whose plane can be inclined towards the ecliptic at any angle. Their motion can be direct or retrograde. They may or may not have considerable atmospheres, very small comas, disks or nuclei.”

You see, sir, that this definition leaves us a great deal of space and with tolerating these three species of heavenly bodies, planets, asteroids and comets, we make it much easier to classify future discoveries.

On this date, Herschel also sent nearly identical letters to Lalande, Laplace, Bode, Zach, Olbers, Seyffer, Schröter and Piazzi; Herschel (1802d; his italics).

On 10 Sep 1802, Huth wrote Herschel an impassioned letter urging him to reconsider placing Ceres and Pallas in a new category. This was considered in Subsection 4.2.2.3:

Although I enjoyed reading your nice observations and ways of measuring the diameters of planets and could convince myself of the correctness of both, I still doubt the conclusion you are drawing “that Ceres and Pallas cannot be planets” and I believe that the smallness of these celestial bodies does not exclude them from being planets, if I may say so.

I believe planets have always been defined as celestial bodies revolving around the Sun in the same direction on slightly elliptical orbits. This kind of motion can be found in the case of Mercury, Venus, Earth, Mars, Jupiter and the George’s planet, and furthermore that their orbits intersect at small angles. In the case of Ceres and Pallas we have the described motion but not the position. Their orbits intersect the orbits of those celestial bodies moving with them around the sun at greater angles. Consequently, Ceres and Pallas give us the following new experience: There are celestial bodies moving around the Sun on unchangeable and slightly elliptical orbits with a common direction but with a greater inclination of their orbits than those of the others or Ceres and Pallas teach us that there are planets beyond our zodiac, in which the known planets are visible.

But why should stars with planetary motion (and it is the motion that is characteristic for planets and not the size, not the positioning of their orbits, not the existence of satellites, rings or atmospheres, not the differences of distances from the Sun, all these things are minor facts and allow a great variety) outside the zodiac, I am asking you, not be called planets? I think it unwise to introduce new names especially a general one, if we can avoid it. New categories entice us to see differences where there are none. The fact that Ceres and Pallas are smaller than the other planets cannot hinder us to expel them from the set of planets, especially in regards of their consistent nature and planetary motion. That their orbits are this close cannot deceive us because their size is similar and most likely their density as well, that is why their momenta come almost to a balance with the gravitation against the Sun. They cannot become each other’s satellites because they are partly similar in mutual gravitation and partly because they are too small and too far apart to provoke a mutual approximation, at least for the time being. Maybe the characteristic of our planetary system is the following: that there are many such small celestial bodies of similar size and density. Maybe when the planets formed, there also developed from a certain quantity of planetary matter a certain amount of planetary grains of similar size, but where Earth, Venus, Jupiter, Saturn and George’s planet developed, the matter formed larger spheres that attracted neighbouring smaller ones thus building satellites. It does not seem unlikely to me that in a very short time between Mars and Jupiter, but closer to Mars, there will be found more bodies like Ceres and Pallas. And more of those might be seen in our zodiac. But all of them will be planets if they show planetary motion just as Ceres and Pallas. (Huth, 1802).

Thomas Young wrote Herschel on 18 April 1807 about the newly-discovered Vesta:

I have just received a letter from Dr. Olbers of Bremen, of which, according to his request, I send you an extract – it is dated the 2nd of April.

“I take the liberty to ask your Honour most obediently to announce with due respect to the adorable Royal Society that I had the luck to again discover a new planet on March 2 of this year [1807], I found this one in the northern wing of the Virgin, a sky area which, after my hypothesis on these asteroids, all these little heavenly bodies have to pass and which I observe with a comet seeker regularly. The new planet appears as a star between the 5th and 6th magnitude and is not
distinguishable in the telescope from a fixed star with the magnifications I can use. Here are two positions of the stranger which will be adequate to find him again.

March  29  8h 21 m  M.Z.  AR  184° 8  Decl. 11° 47  Bor. 30 12 33 183 52 11 54

I request you to announce this message to the gentlemen Maskelyne and Herschel with my most obedient recommendation quite urgently. I would have given myself the honour to write to these gentlemen if the correspondence with England would not be so very aggravated now."

I doubt not but that your superior instruments will enable you to give us some further account of this newly discovered body before next Thursday, when I shall communicate Dr. Olbers’ letter to the Royal Society (Young, 1807b).

Herschel wrote to Banks on 1 June 1807 about his paper on Vesta:

As cloudy weather has prevented an immediate continuation of my observations of Dr. Olbers’s new star, and its increasing distance from us will soon put it out of the reach of telescopes that are directed to it for no other purpose than an examination of its physical condition, I have sent you the inclosed paper, which indeed appears to me quite sufficient to determine that the new star is a fourth Asteroid. In hopes that it will soon be honoured with a reading at the R.S’s meeting, I remain with the highest respect, Sir… (Herschel, 1807b).
D.4. The Stephen Groombridge Correspondence

Stephen Groombridge appears to have made his first asteroid observations in 1807, and he was brought to the attention of Herschel by Maskelyne:

I have the pleasure to send you my obs. of the planet [Vesta] last night & two of my neighbour Mr. Groombridge, who first discovered it on Saturday night; they were all taken on the meridian.

RA in time

<table>
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<th>Date</th>
<th>H</th>
<th>M</th>
<th>S</th>
<th>In deg</th>
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<tbody>
<tr>
<td>April 25</td>
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<td>50</td>
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<td>27</td>
<td>11</td>
<td>56</td>
<td>2</td>
<td>179 0 28</td>
</tr>
</tbody>
</table>

Mr. Groombridge found it by a 42 inch achromatic of Dollond on an equatorial stand. Mr. Groombridge spoke of it as a star of 6th magnitude, which would very well bear illuminating, and equal to the Georgium Sidus. To me it appeared only of between the 9th & 10th magnitude; but that might be owing to the haziness of the night; and it varied its appearance very much while it was passing thro’ the telescope. It was near its opposition when discovered by Dr. Olbers. (Maskelyne, 1807a).

It was Groombridge who was in the forefront of communicating information about the newly-discovered Vesta to British readers, and he did so through The Philosophical Magazine, popularly known as Tilloch’s Journal.

The discovery of the planet Vesta, on the 29th of March 1807, having been communicated to this country by Dr. Olbers; on the 26th of April I found its place, and observed the same on the meridian. I obtained a series of observations to the 20th of May; after which, from the increase of daylight, it was no longer visible on the meridian. The observations which were afterwards made were with equatorial instruments; and these cannot be depended on, for sufficient accuracy in calculating the elements. I have, however, used some of these, from the 29th of March to the 22nd of June, to determine the eccentricity; those which were made on the meridian producing nearly the same radius. I thence discovered, that the planet was decreasing in radius, and therefore conjecture that it was in aphelion about the time it was first seen. When the planet was discovered by Dr. Olbers on the 29th of March, it appears to have been about seven days past the opposition; and it is well known, not having that point of the orbit for a datum, the difficulty of calculation is increased. I was therefore anxious to observe the planet before the ensuing opposition, to obtain sufficient materials for ascertaining all the elements. For this purpose, I assumed a mean radius of the extreme observations; which, if I was right in my conjecture of the aphelion, would prove too great; and therefore the planet should be further advanced in the ecliptic. On the 30th of July, the evening being clear, and the moon not risen, I observed the difference of right ascension of several stars of the sixth magnitude, compared with those laid down in Bode’s Catalogue; but in particular five stars, about two degrees advanced in longitude, from the computed place of the planet; not one of which was to be found in that Catalogue; the latitude being nearly the same: I therefore suspected one of these to be Vesta. On the 1st of August the same five stars being brought into the field of the telescope, it was instantly apparent that one had changed its place, southward and retrograde in right ascension: this was the object of my research. I could not obtain a meridional observation till the 11th, having been disappointed by the intervention of clouds or vapour. The following were the places as observed on the meridian, from which its course may be discovered.

<table>
<thead>
<tr>
<th>Date</th>
<th>Mean Time</th>
<th>App. R.</th>
<th>Dec. S.</th>
<th>Long.</th>
<th>Lat. S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug. 11</td>
<td>14 24 32</td>
<td>356 30 2</td>
<td>12 0 40</td>
<td>351 58 35</td>
<td>9 37 15</td>
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<td>14</td>
<td>14 11 20</td>
<td>356 8 51</td>
<td>12 23 44</td>
<td>351 29 56</td>
<td>9 50 1</td>
</tr>
<tr>
<td>19</td>
<td>13 48 50</td>
<td>355 25 57</td>
<td>13 3 40</td>
<td>350 34 51</td>
<td>10 9 22</td>
</tr>
<tr>
<td>21</td>
<td>3 39 40</td>
<td>355 6 14</td>
<td>13 20 2</td>
<td>350 9 42</td>
<td>10 16 44</td>
</tr>
</tbody>
</table>

From the observations in last year, I have ascertained part of the elements; which agree very well with those now made.

Inclination of the orbit 7 8 20
Ascending node - - - - 104 38
Period - - - - - - - - - 3.182
Mean radius -- - - - - 2.163

The eccentricity appears to be considerable, from the increased angular motion in its orbit; but I have not at present sufficient data to determine the quantity. However, I do conjecture, that Vesta will be nearer to the Earth, about one-fifth the radius of the latter, at the ensuing than at the preceding opposition: which will enable astronomers, viewing the planet with high powers, the better to ascertain its diameter.

The opposition will happen about the 9th of September. (Groombridge, 1808d).

He contributed a second article about Vesta later the same year:

I now send for your insertion an ephemeris of Vesta for the ensuing two months; with a diagram of its motion in right ascension and declination, as seen from the Earth. The configuration with the four stars, on July 30th and Aug. 1st, was the appearance, as described in my last. The ecliptic opposition was Sept. 8th, at 7 ½ hours, in longitude 345°54'26". The aphelion, long. 183. Eccentricity, 0.0953 of the Earth's radius. The planet will be stationary in longitude, Oct. 21st, and in right ascension, Oct. 23. (Groombridge, 1808e).

Groombridge kept William Herschel apprised of his asteroid observations in a series of letters written between 1808 and 1818. In the first of these Groombridge says:

Being in this road, returning from Oxfordshire, I have had the honour to call on your house, to communicate my observations of the Planet Vesta, which I have again discovered at my Observatory, Blackheath, on 30th ultimo. The ensuing opposition will happen about 9th Sept. and as the Planet at the former opposition was near the Aphelium, it will now be about the Perihelium. I have not determined the eccentricity; but the Planet will certainly be nearer to the Earth, one fifth of the Radius of the latter, than at the preceding opposition. This, I am assured, will induce you to ascertain the diameter of this small body; which, as I am informed, you think is about 150 miles only: the present distance scarcely exceeds, the mean of the Earth from the Sun.

The Elements which I have determined from my observations of last year, agree with those made at this time; from which it appears, that Vesta is nearer to Mars than the three previously discovered.

Inclination of the orbit     7° 8' 20"
Ascending node             104 38
Period          years 3.182
Mean radius     2.183

[Groombridge then prints his four observations of August 1808.] (Groombridge, 1808a).

His second letter (Groombridge, 1808b) was penned a little over one week later, and also referred to Vesta:

It was not till Sunday night that I succeeded to obtain a meridian observation of Vesta, therefore have not previously troubled you with a letter. It has now a convenient position with ο1 & ο2 Aquarii, and is proceeding retrograde in RA, nearly one minute of time in 24 hours.

RA Dec. S.
Sept. 4 12h 33' 25"  352°17'37"  15°13'22"
5 11  30 ------  352° 4 30  15° 21 0

The latter observation was before its passage over the meridian; it was then obscured. Vesta is the same apparent magnitude with the above stars; but has not an equal sparkling light.

Almost exactly one month later, Groombridge (1808c) sent Herschel a third letter, again reporting observations of Vesta:

I was favoured with your letter of 19 ultimo, but from a series of cloudy weather, and the present moonlight, I have been prevented making a reply. On 21st I observed the stars in the annexed diagram [see Figure D.23], and having understood that Ceres would bear the illumination of the wires, I concluded the star A of 6 mag. to be the object: of this I observed the meridian transit. On
1st instant I had again a sight of the same stars, but observing it on the meridian, I found its place the same as before. The moonlight prevented my seeing the smaller stars, which are of 8 mag. till the 5th when I found that marked a was missing, and conjectured 1.0 to be Ceres; last night I could just discover the whole before it became cloudy, when it appeared as 2.0, having advanced 13′ of time in RA. This is therefore the Asteroid, which I hope you will be able to see; although its great zenith distance, makes it appear very faint; therefore I can make no useful observation of the same, on the meridian.

The two last observations of Vesta on the meridian were
Oct. 1   RA  346′34′41″ Dec. S. 17°34′16″
      5   345 57 37   17 41 10

I shall be happy to have your opinion of the diameters of these Asteroids; and at all times thank you for any communication.

His observations of Vesta were printed in Germany (Groombridge, 1809) and his observations of Ceres and Vesta in 1811 were also published in Germany (Groombridge, 1813b). About two and a half years later Groombridge (1811) sent Herschel a further letter about his observations of Vesta:

I have the pleasure to send you the observed place on the meridian of Vesta [see Figure D.24, below], the Planet is less than 7s from the perihelion which will render it convenient for the observation of its magnitude.
More than a year later Herschel received yet another letter, also about Vesta:

I send you the following ephemeris [Figure D.25] of Vesta in opposition tomorrow (25th). I could have wished to have communicated this, at an earlier date, having had an observation on the meridian on 16th, but the weather has been so unfavourable, that I could not ascertain whether it was the Planet, till last night. (Groombridge, 1812).

Groombridge’s next letter to Herschel was written on 6 November 1813, but this time it referred to Juno:

I have made two observations of Juno on the meridian, to verify my Ephemeris [Figure D.26]. The opposition will be on 19th 12h. The star appears 7.8 magnitude; and will be preceded tomorrow night by a star 7 magnitude, about 40° RA and 5° north dec. I shall be happy to hear that you have made observations of Juno, it being favourably situated about the perihelion distance: which in its great eccentricity is a very fortuitous circumstance. (Groombridge, 1813a).

Just three months later, Groombridge (1814) wrote Herschel again, but this time about ‘his old favourite’, Vesta:

Annexed is an Ephemeris of Vesta at midnight [see Figure D.27]. I observed it last night on the meridian. Opposition 13th at 18h. Magnitude 7. True anomaly 73°, therefore exceeds in distance the semi axis major, but is very brilliant.
His observations on the asteroids from 1812-1815 were published in Germany (Groombridge, 1816). Groombridge's next letter to Herschel was written more than three years later, and referred to three different asteroids, Ceres, Pallas and Vesta:

Mr. Lee informed me that you wished for some observations of the new Planets: the above were those I made at the last oppositions [Figure D.28]. Pallas was very faint, but exceeding a star of 9th magnitude. Ceres was in opposition about the same time, but its distance, being greater than that of Pallas, I did not discover it. Juno was in opposition on 3rd June, but its true anomaly being 20º and distance 3.2 of the Earth’s radius, I could not succeed in finding it. I computed the places from the elements in Bode’s Jahrbuch, & have always observed these Planets within a small error.
When I have computed the next oppositions, I will communicate the news; should they be so situated as to have a chance of observing them. (Groombridge, 1817a).

Figure D.28: Groombridge’s observations of Pallas and Vesta in 1816 (after Groombridge, 1817a).

Just two months later Groombridge (1817b) wrote Herschel again, but this time about just Ceres and Pallas:

I have annexed my computed Ephem. for the ensuing opposition of Pallas & Ceres at midnight [see Figure D.29]; and that you may be enabled to compare the correctness of the same, have copied the whole process of 13 July, from which you will discover wherein we disagree.

I very much doubt whether Pallas will be seen, having so great eccentricity, and near its aphelion. I yet have generally discovered Ceres, although her southern declination is favourable.

D.29a: Groombridge’s data on Pallas and Ceres in 1817 (after Groombridge, 1817b).
A month and a half later Groombridge (1817c) wrote the following brief letter to Herschel, along with an ephemeris for Juno:

I take the opportunity of my servant passing through Slough, to send the ephemeris of Juno at the opposition [Figure D.29] which I expect will be visible, being in the lower part of her orbit. I could not observe Pallas, being so very small, nor Ceres, having so great southern declination: neither would bear the illumination of the wires.
Figure D.30: An ephemeris for Juno in 1817 (after Groombridge, 1817c).

More than a year later, Groombridge (1818) supplied Herschel with ephemerides for Ceres and Pallas in 1818:

I had intended to have sent you the Ephemeris of Pallas [Figure D.31], some few days since, but having been cloudy from 2nd to last night, I could not put my computation to the test; as this body is so small (about 9th magnitude) that it will scarcely bear any illumination of the wires. I found the computed & true RA to differ 21″, which error having applied, the Ephemeris is correct for the meridian transit: the Declination agrees with the computation. The distance of the Planet is unfavourable, the true anomaly being this day 43° 9′. I hope the computed place of Ceres will be sufficiently near to find it; not having yet made an observation.
Figure D.31: Ephemerides for Ceres and Pallas in 1818 (after Groombridge, 1818).

Even though letters to Herschel seem to have ceased at this date, Groombridge kept observing the asteroids. His observations from 1820-1823 were published in the Bode’s Astronomical Yearbook (Groombridge, 1825). That there was continuing English interest in the orbit of Vesta is shown by two articles in Tilloch’s Journal (The Philosophical Magazine 1821 a and b), and T. M. Moseley's contribution in 1832:

Having amused myself, during the autumn of 1821, in calculating the place of Vesta, at intervals between the beginning of April and the end of July 1822, from Daussy’s Tables (in Connaissance des Temps 1820), with a design of making some observations on the meridian; I was mortified, on receiving Bode’s Ephemeris for 1824, to find that my calculations differed considerably from those given by the author for certain days in the above months. However, when Mr. Groombridge...
communicated to the Astronomical Society an Ephemeris for the opposition of the four small planets in the summer of 1822, (and which was inserted in the Philosophical Magazine for January of that year, page 28). I was in some degree relieved from my embarrassment by a remark which that gentleman made respecting the above-mentioned Tables of M. Daussy; viz, “that the orbit of Vesta having been found, from later observations, less than at first computed, the mean longitude given by them has become nearly twenty minutes in arrear.” But upon looking over Bode’s Jahrbuch for 1825, lately received, a new difficulty has arisen. In page 181, a number of observed places of Vesta, during the month of June last, are given by Professor Encke, and the opposition is stated to have taken place on the 15th, at 22h 53’ 29”,5 Paris time.

<table>
<thead>
<tr>
<th>Mean time</th>
<th>RA</th>
<th>Dec.</th>
<th>Long.</th>
<th>Lat. N.</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 14</td>
<td>12</td>
<td>8</td>
<td>4.2</td>
<td>264 0 0.6</td>
</tr>
<tr>
<td>17</td>
<td>15</td>
<td>3</td>
<td>11.3</td>
<td>263 57 28.8</td>
</tr>
</tbody>
</table>

I have assumed -7’2 for the parallax in declination, and 23° 27’ 53”.0 for the apparent obliquity of the ecliptic; whence the above will be found the geocentric longitude and latitude: the opposition appears to be, on June 15th, at 22h 48’ 59”.2 mean time, in longitude 264° 39’ 3”.4; latitude N 4° 18’ 53”.8. Applying 9’ 20”, for the difference of the meridians of Paris and Blackheath, will show the opposition to have taken place at Paris on June 15th, 22h 58’ 19”, being 4’ 50” later than the time given by Professor Encke.
These different results will appear in the following comparison:

It therefore appears that I had supposed the mean longitude of the orbit about 3′ in excess. The Ephemeris of Professor Encke gives a mean error in RA -2′ 36″.7 and in Dec. +14°.5; my Ephemeris gives an error in RA +3′ 16″.5, and in Dec. +8°.7. The difference in the time of opposition may arise from the use of different reductions of the earth’s longitude; yet the Connaissance des Temps, preceding the Nautical Almanack 22″ in the longitude of the sun, being equal to the distance of the meridians of Paris and Greenwich, should not affect the deduction. The difference 13″.7 in the true geocentric latitude of the planet, will partly arise from the later time of the opposition, as the latitude was decreasing; or it may be also affected by not having applied the same parallax in the reduction: the refraction was probably the same in both cases; the mean of which, in my Tables, agrees with those of the French.

This detailed explanation by Groombridge elicited a grateful response from Moseley (1823b: 375; his italics):

I avail myself of your valuable publication, to express my obligations to Mr. Groombridge for the satisfactory explanation of the difficulty which I stated in your Magazine for March, respecting the computed and observed places of Vesta in July 1822. Soon after I had transmitted the letter, it struck me that some passages in it seemed to call too strongly upon Mr. Groombridge to defend the assertion he had previously made, regarding the orbit of the planet having been found less than at first supposed; but I beg leave to assure him, that nothing was more distant from my thoughts at the
moment than such a design. I fear, however, from the prompt and explicit manner in which Mr. G. has answered the inquiry in your last Number, that he really did view my communication as directed to himself,—an impression I am very anxious to efface.

The circumstance which Mr. Groombridge mentions in regard to his method of applying only the equation of the centre in forming his Ephemeris of Vesta, affords a reason for the discordance which I had found between his positions and mine. I used the whole panoply of Daussy's Tables, taking out the small equations of longitude, where directed, to three decimal figures. These minor equations sometimes amount to upwards of 50′, the omission of which must produce a considerable difference in the final result. The planet, however, may be found, in a telescope with large field, by a less intricate process. In was very unfortunate, that after preparing, with great trouble, many calculations of the place of this little planet, during last summer, the weather was so perplexing that I had not one opportunity of comparing the apparent transit with the computed on those particular days which were selected. How often have observers, in this climate, occasion to regret the mortifying disappointments which occur from our turbid atmosphere—"Dum latet obscura condita nube dies!"

Moseley resided at Winterdyne House, near Bewdley, Worcestershire. From his brief obituary in 1828, we learn that

… he possessed several valuable instruments, and is said to have left behind him a series of observations of transits and north polar distances, and some measures of double stars confirmatory of their changes. (The Philosophical Magazine, 1828).

D.5. Articles in English Magazines

The Monthly Magazine (1801b) included a comprehensive report on Ceres:

The celebrated Astronomer M. von Zach, had communicated to Dr. Olbers, of Bremen, M. Piazzi's observations of the 1st and 23rd of January; and on the 30th of May received from him a calculation of new elements of the planet's orbit. These elements, however, could not be determined with any great exactness, as the observations are only twenty-two days distant from one-another, and are only given in minutes. Dr. Olbers found, however, from all the data then known, the Diameter of the orbit 2,947465—Longitude of the ascending node, 2° 21′ 55′′ 10″—Inclination of the orbit, 7° 54′ 38″—Heliocentric longitude on the 1st of January, 1801, 2° 7′ 40′′ 36″—Sidereal Revolution, 1841.24 days = 5.04096 years—Diurnal heliocentric motion, 11′ 43.3′′ 87—Annual motion, 71′ 24′ 57′′ 6′—With these elements it would have been difficult to calculate before-hand the course of the planet, so as to be able to find it again on its re-appearing in the morning in August, if it be not at first light distinguishable from a star of the 8th magnitude; “for, probably, (says Dr. Olbers) it has a considerable eccentricity. In opposition it may, perhaps, increase in luminousness, so as to equal a star of the 6th magnitude. I have little doubt that it will be found in La Lande's Catalogue."

On the 16th of May Professor Bode writes to M. von Zach, “That it gave him great pleasure to find, that M. von Zach agreed with him in opinion respecting the Piazzian comet, and that Oriani and Piazzi himself incline towards the same opinion.—How often (continues he) have I wished that I might live to witness this discovery—I have been several times laughed at by others about my ideas of the harmonic progression in the distances of the planets. Adopting 2.75 for the distance, I find the heliocentric difference of longitude, betwixt the 1st and 23rd of Jan. very well corresponding with the observations; the planet goes to its node, which I placed in Taurus: its inclination must exceed 6°; and this I think was one of the causes why it was not sooner discovered.”

Till towards the end of May M. von Zach received no farther accounts relative to this star. He had communicated to his friends the Parisian astronomers the observations and elements calculated: and, not doubting that La Lande, to whom Piazzi had sent the first account of the discovery of the comet, had likewise been made acquainted with the subsequent observations and conjectures, he requested him to send to him an account of all the particulars that had come to his knowledge relative to the new planet.

But to his no small surprise he received, in the beginning of June, several letters from Paris; one from the Senator La Place, dated the 29th of May; from La Lande and Burckhard [sic], of the 26th of May; from De Lambre, of the 24th of May’ from Méchain, of the 26th of May; from Henry, of the
28th of May; in which none of the six astronomers, who had communicated several important observations and new discoveries, writes even a single syllable about the new planet! Méchain only makes mention of Piazzi’s comet;—from which it appears, that so late as the end of May they knew nothing of the conjecture of its being a planet; although the astronomers in Germany had been made acquainted therewith by Professor Bode already in the month of March.—Méchain in his letter to M. von Zach, of the 26th of May, merely says, ”Have you seen the comet, which the journals announce to have been discovered at Palermo last January? No one here has yet found it. Our astronomers have not discovered any since that of the month of December, 1799. I sometimes look out for them, but without success.”

On the 10th of June, M. von Zach received another letter from Professor Bode, in which he says, “Piazzi’s first letter I received on the 20th of March, and on the next post-day, the 23d, I answered it. But he did not wait for my reply; and—conceive my joy and at the same time my vexation!—I received a second letter from Piazzi, in which I found only the following few words relative to the newly-discovered planet: ‘I wrote to you in January, informing you that I had discovered a comet in Taurus, which comet I continued to observe till the 11th of February, when I was attacked by a dangerous disease, from which I have not entirely recovered. As soon as the state of my health will permit, I shall calculate elements for it, and send them to you. In the mean time I have communicated my observations to M. La Lande.” It is remarkable that he still calls the star a comet, as in his first letter.”

On the 18th of June, M. von Zach received a letter from Dr. Burckhardt, in which we learn the following particulars: La Lande had received Piazzi’s observation on the 31st of May, when Dr. Burckhardt immediately began to calculate its orbit. Two days later they received Von Zach’s and Oriani’s investigations, which gave them cause to hope that the supposed comet would prove to be a planet. Dr. Burckhardt had already found that the arc described by it was not considerable. The small geocentric and heliocentric motion of the comet gave him a great deal of trouble in calculating its orbit. He had first chosen for this purpose the observations of the 14th, 21st, and 28th of January; but from this circumstance found himself under the necessity of selecting the observations most distant in time from one another, viz. those of the 1st and 21st of January, and of the 11th of February. During these 42 days the geocentric longitude of the comet varied only 3′, and the heliocentric longitude only 10½. On attempting to correct, by Laplace’s methods, the parabola found by his method, he discovered that nothing in this respect could be effected by the conditional equations. He then tried Laplace’s method of approximation, but with as little success: the unavoidable errors of observation having too great an influence on the differences of the geocentric longitudes and latitudes. He now proved eight hypotheses by means of Laplace’s method of correction, but without approximating nearer to the truth. He then calculated the following orbit which agrees with the three observations to within ±2½ minutes:

|-----------------------------|-------------------------------|-----------------------------|---------------------------|-------------------------------|

However various the trials that had been made: yet, as it did not thence follow, that it was impossible to find a parabola for these observations, he determined to apply a method, which had often proved successful, when all other methods of interpolation failed. Putting the logarithm of the distance from the sun equal 0,378, the smallest error was ±8; then putting the logarithm of the distance 0,378, the smallest error was ±4. It was therefore necessary still more to diminish the distance; and after 20 hypotheses he found the following parabola:

<table>
<thead>
<tr>
<th>Place of the ascending node, 2° 20’ 50’ .</th>
<th>Inclination of the orbit, 9° 41’.</th>
<th>Place of the perihelium, 4° 8’ 38’ 25”.</th>
<th>Smallest distance from the sun, 2,21883, its log 0,3461250.</th>
<th>Logarithm of the diurnal motion, 9,4409408.</th>
<th>Time of the passage through the perihelium, 1801, 30th June, 19h, 1’.</th>
</tr>
</thead>
</table>

Dr. Burckhardt is of opinion, that there is no other parabola that more nearly agrees with these three observations. The errors in the longitude are on the 14th and 28th of January—1’ 47” and ±38. But Piazzi had not mentioned any thing respecting the accuracy with which he was able to observe the comet.

On the 21st of June M. von Zach received the promised continuation of Dr. Burckhardt’s researches. He had calculated an ellipsis for the comet, although the arc it had run through was too small for us to expect great accuracy, but he thought he should thereby facilitate the finding of the star.
Place of the ascending node, 2, 20° 58’ 30″.—Inclination of the path, 10° 47’ 0″.—Place of the aphelium, 2° 8’ 59’ 37″.—Time of the passage through the aphelium, January, 1801, 1,3328. — Excentricity, 0,0364.—Logarithm of half the great axis, 0,4106586.—Period of sidereal circumvolution, 4,13 years.

This ellipsis represents, within a few seconds, the longitudes and latitudes of five observations. It would have been easy to obtain a greater degree of accuracy, but he thought it quite superfluous, as the arc run through is so small.” The above ellipsis gave Dr. Burckhardt the following

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<tr>
<td>20° June</td>
<td>13h 4’</td>
<td>101 45’</td>
<td>30 26 N.</td>
</tr>
<tr>
<td>17° July</td>
<td>1 43</td>
<td>113 3</td>
<td>4 6</td>
</tr>
<tr>
<td>12° August</td>
<td>10 54</td>
<td>124 21</td>
<td>4 51</td>
</tr>
<tr>
<td>7° Sept.</td>
<td>16 19</td>
<td>135 28</td>
<td>5 52</td>
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<td>12°</td>
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<td>137 40</td>
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<td>18°</td>
<td>3 ---</td>
<td>139 50</td>
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<td>23d</td>
<td>8 ---</td>
<td>141 58</td>
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<td>28°</td>
<td>13 ---</td>
<td>144 5</td>
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<td>3d Oct.</td>
<td>17 41</td>
<td>146 9</td>
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<td>8°</td>
<td>22 ---</td>
<td>148 12</td>
<td>6 53</td>
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<td>11 ---</td>
<td>154 8</td>
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<tr>
<td>29°</td>
<td>14 45</td>
<td>156 3</td>
<td>7 53</td>
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<tr>
<td>3d Nov.</td>
<td>18 ---</td>
<td>157 56</td>
<td>8 9</td>
</tr>
<tr>
<td>8°</td>
<td>22 ---</td>
<td>159 48</td>
<td>8 26</td>
</tr>
</tbody>
</table>

Here is what Brewster (1802c, his italics) wrote in an article dated 22 June 1802:

Having transmitted to you, on former occasions, all the information respecting the two newly-discovered planets, which my situation enabled me to collect, I now trouble you a third time, with some additional notices on the same subject, and with a few loose observations calculated to disprove the prevailing opinion, that the two stars lately discovered belong to the planetary system.

“The excentricity of Pallas, it appears, is a little greater than that of Mercury; the inclination of its orbit to the ecliptic 33°..39; its mean distance a little less than that of Ceres, and its periodic time four years and five months, about two months less than that of Ceres. But the most remarkable circumstance concerning it is, that it crosses the orbit of Ceres, approaching the sun nearer in its perihelium, and receding further from him in his aphelium than Ceres does. Dr. Herschel has made some curious observations on the apparent diameters both of Ceres and Pallas, from which he infers the real diameter of Pallas to be 95 miles and that of Ceres 162 miles. He considers them a different species from the known planets. In their smallness and motion they resemble comets; but in the clearness of their light, they resemble the other planets.” (footnote: see the Montly Magazine for May 1802, from which the above paragraph is extracted.) [This is an error, as the article was in the June issue: The Monthly Magazine, 1802d]

From these facts we shall now deduce a few conclusions to support the opinion which has already been advanced; and though our arguments will be drawn chiefly from analogy, the only source to which we can at present apply, yet they should nevertheless have their due influence in the formation of our opinion, till certainty and experience can be substituted in their place. For it must be recollected, that, with respect to the present question, we are in a situation where the maxim of Terence most pointedly applies:

“Dum in dubio est animus, paulo momento huc illuc impellitur.”
[While the mind is in doubt, a very little sways it one way or another.]

By attending to the facts which have already been made known respecting Pallas, the star discovered by Dr Olbers, we will find many circumstances of resemblance between it and comets, and many marks of dissimilarity to the bodies of the planetary system.

1. Its excentricity is said to be greater than that of Mercury, the ellipticity of whose orbit is almost double that of any other planet. But as very excentric orbits are peculiar to comets, it is reasonable to believe that Pallas has no connection with the planetary system. This argument would be more powerful, if, on account of Mercury’s proximity to the Sun, we could assign for his superior excentricity, as final cause that would not apply to bodies situated at a greater distance.

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2. The next circumstance of dissimilarity to the planets, is the inclination of its orbit. The orbits of all these bodies are inclined to the ecliptic at very small angles, and may all be comprehended between two planes situated at the distance of only fourteen degrees, but on the supposition that Pallas is a planet, these planes, in order to comprehend its orbit, must be removed to the enormous distance of 67°18′, its inclination being 33°39′. This circumstance affords a strong presumption that this star should be numbered among the comets whose orbits are inclined to the plane of the ecliptic at various angles, and are often perpendicular to each other.

3. The next circumstance of dissimilarity is the smallness of its diameter. As all the planets of our system are bodies of immense magnitude, the diameter of the least of them amounting to several thousand miles, is it not a striking breach of the uniform regularity which pervades that system, to suppose that a star 95 miles in diameter, and infinitely less than the smallest secondary, should revolve round the Sun as a planet; while it has a nearer resemblance to comets whose general characteristic is the smallness of their diameters.

4. Before the discovery of Piazzi, or Ceres, astronomers suspected the existence of a star between Mars and Jupiter, as the distances of the other planets would then increase in a regular progression; and after a star was discovered in that situation, the very same argument, drawn from an idea on uniformity in the system, strengthened them in the belief that this star should be ranked among the number of the planets. Now, by the very same argument, with this difference only, that in the present case it comes with tenfold force, might it be proved, that Ceres cannot be a planet. Can there be a greater breach of uniformity, than to suppose two heavenly bodies revolving round the Sun almost at equal distances? Can there be a greater breach of uniformity, than to suppose the orbits of two planets crossing one another, one of them being nearest the Sun in its perihelium, and farthest from him in his aphelion? Would they not run the risk of meeting each other in the heavens? Or if this did not happen, would not their reciprocal action, increased by their frequent proximity, produce in their movements the most enormous irregularities? It may be said, however, that the great inclination of Pallas’s orbit is intended to prevent those effects which might otherwise arise from the necessary proximity of these planets. It is true indeed, that this circumstance must prevent, in a great degree, the effects that will result from their mutual action; but if the line of Pallas’s nodes should coincide at any time with the nodes of the crossing orbits, i.e. the points where the orbits of Pallas and Ceres cross each other, and if the two planets should happen to be in or near these points, the greatest irregularities would still be produced, and the two planets would actually run counter to each other.

5. The opinion of Dr Herschel also strengthens these arguments. He “considers them of different species from the known planets. In their smallness and motions they resemble comets; but in the clearness of their light they resemble the other planets.” But in these words there is an objection to the opinion which we have advanced, as well as a strong confirmation of the reasoning which has been employed to support it. They resemble the other planets, it is said, in the clearness of their light. Now, in order to obviate this objection, we must enquire whether or not any comets have existed which resembled the other planets in the “clearness of their light;” and if this question can be decided in the affirmative, the objection must completely fall to the ground.

Comets are generally believed to be opaque bodies, illuminated by the Sun, and surrounded by large atmospheres, by means of which their tails are produced. There are comets, however, which have no tails, and which, as Mr [Patrick] Brydone [1741–1818] remarks, “seem to be of a very different species from those which have tails, having a less resemblance to these than to the other planets.” Here then seems to be a species of comets without tails, having a considerable resemblance to the other planets. But in addition to this we are informed by other observers, that the light and apparent bigness of comets are sometimes like those of a small clouded star, and sometimes like the satellites of Jupiter. And Cassini, in particular, affirms, that he has seen through a glass, comets whose disc was a pure, big, and clear, as that of Jupiter. Such was the second comet of 1665, and that of 1682. From these facts, then, we actually see that comets do resemble the other planets in the “clearness of their light;” and since the star Pallas resembles a comet in its motion, in its smallness, in its orbit, and in the inclination of that orbit, we are authorized to rank it among the number of these heavenly bodies, till astronomers, who are of a contrary opinion, shall have actually traced it through the different parts of its orbit round the Sun.

Several of the arguments which we have used for proving Pallas to be a comet, authorize, in some measure, the same conclusion respecting Piazzi, or Ceres. On this point, however, we shall
quiries were, as might be expected, extremely "the great difference" dery variety of position, and e size and small eccentricity of orbit, eater than the diameter of the nucleus, and in the new stars is only a foremost place amongst English critical journals (Sydney, 1898: 228) the word 'asteroid'

upon the Doctor's theory; premising, that we rely with the most implicit confidence on the accuracy proceed to the more invidious, but equally necessary part of our office, atmo spheres, very small comas, disks, or nuclei. whatsoever. eccentricity, round the Sun, the plane of which may be inclined to the ecliptic in any angle class of comets nor planets, but he gives them the name of Asteroids, which he thus few times greater. whatsoe ver.

circumstances of the new stars, it differs in that of the atmosphere, which, in the comets, is at the being discovered to have any. this is consistent wit

Henry Brougham’s article in The Edinburgh Review (1803) criticises Herschel for adopting the word ‘asteroid’. (see Subsection 4.2.2.1). The Review, founded in 1802, rapidly assumed the foremost place amongst English critical journals (Sydney, 1898: 228):

Our astronomical readers are acquainted with the interesting discoveries which have, within the space of a few months, introduced to our acquaintance two new celestial bodies; the one names Ceres, by its discoverer Piazzi; the other called Pallas, by its discoverer Olbers. Our own indefatigable astronomer Dr. Herschell [sic], who has himself, by his numerous and accurate observations, so far extended the bounds of human knowledge, appears to have directed his attention, without loss of time, to the new and interesting field of observation opened to him by his brethren on the Continent. The results of his first inquiries were, as might be expected, extremely interesting. He found that the magnitude of these supposed stars, or, as he calls them, moving stars, was much inferior to that of the other primary planets, or even of their satellites. Thus he found that Ceres has a diameter only three eighths the diameter of the moon. In the present paper, besides extending the same observation, and the same conclusions to Pallas also, this excellent astronomer has given us a set of new and accurate observations, tending to establish some very singular and interesting facts. We hold it to be a duty indispensably incumbent on us to present our readers with a sketch of this valuable paper.

The first remarkable circumstance that strikes us in all the observations, is the great difference between the real magnitudes and the lucid disks. By one measurement with the most delicate micrometer, expressly adapted for the purpose of such experiments, the real diameter of Ceres was found to be only three fourths of the lucid disk; and that of Pallas only two thirds. The angle which the former subtends, was found to be only 0°.38; that of the latter no more than 0°.13. He calculates by a rough estimate, that the diameter of Ceres is only 161.6 miles, and that the diameter of Pallas is no more than 110½ miles.

From the very small quantity of matter which these bodies contain, we cannot expect that they can have any satellites; accordingly various observations concurred to convince Dr. Herschell that this is consistent with truth. He also determined that Ceres has a visible disc, but that Pallas cannot be discovered to have any. The last set of observations are extremely important for ascertaining the precise nature of the two new bodies. By them it is ascertained, that both the stars have at all times a small coma or haziness, which grows denser near the nucleus.

Our author next proceeds to make his observations upon the results of these inquiries. He begins by defining planets to be celestial bodies of a considerable size and small eccentricity of orbit, moving in planes not very different from that of the earth, in direct curves at considerable distances from each other, with no atmospheres that bear any proportion to their diameters, and of bulk sufficient to retain satellites in their orbits. It is evident that, with this definition, the new stars but ill agree. Our author then defines comets to be very small celestial bodies, moving in directions wholly undetermined and in most eccentric orbits, situated in every variety of position, and having very extensive atmospheres. Although the definition agrees in most particulars with the circumstances of the new stars, it differs in that of the atmosphere, which, in the comets, is at the very least a hundred times greater than the diameter of the nucleus, and in the new stars is only a few times greater. Dr. Herschell therefore maintains, that these bodies are neither referable to the class of comets nor planets, but he gives them the name of Asteroids, which he thus defines:—

Asteroids are celestial bodies, which move in orbits either of little or considerable eccentricity, round the Sun, the plane of which may be inclined to the ecliptic in any angle whatsoever. Their motion may be direct or retrograde, and they may or may not have considerable atmospheres, very small comas, disks, or nuclei.

Having thus followed the Doctor through his very interesting speculations, we must now proceed to the more invidious, but equally necessary part of our office, and offer a few remarks upon the Doctor’s theory; premising, that we rely with the most implicit confidence on the accuracy
of his observations, from long experience of his great skill, patience, and fidelity, and from our knowledge of the unrivalled excellence of his instruments. It is to his conclusions alone that we object; and, with all possible reverence, we hold ourselves as well qualified to judge of the truth of these, as if we had ourselves made or verified the observations upon which they are founded.

And, first, we must positively object to the unnecessary introduction of new terms into Philosophy. The science of Astronomy is, beyond any other branch of the mixed mathematics, loaded with an obscure and difficult technology. As all nations have been observers of the heavenly bodies, so all languages have contributed to form the nomenclature of the astronomer. Not only are the same bodies indifferently known by a variety of names, but, so defective is the phraseology, that no one list can be given in two or three languages, or according to two or three systems of mythology. To a person who had resided in ancient Italy and Greece, on the banks of the Nile, of the Ganges and Euphrates, in modern Europe, and amongst the Gothic nations, the astronomical technology might be natural and simple, as it is composed of all the languages spoken, all the mythologies received, and many of the court calendars published in these various countries and distant ages. Knowing, as we do, the great power of words in misleading and perplexing our ideas, we cannot allow the unnecessary introduction of a new term to escape unnoticed. Where a new object has been discovered, we cheerfully admit the right of the discoverer to give it a new name; but we will not allow a needless multiplication of terms, or an unnecessary alteration in the old classification of things, to be either justifiable or harmless, a substitute for real discovery, or a means of facilitating the progress of invention. It remains, therefore, to inquire, whether the circumstances of Ceres, or of Pallas, distinguish them from the bodies formerly known?

We cannot admit the difference of magnitude to be of any importance, while the largest and the smallest planets, Jupiter and Mercury for instance,—the largest and smallest satellites,—the largest and smallest comets, between which the difference of magnitude is still more remarkable,—while all these bodies are severally arranged under the same class, from considerations wholly independent of their size, it is but a clumsy and cumbersome invention, to arrange a new body under a separate class, from the mere difference of its bulk. The same remark applies, though certainly with diminished force, to the other criterion assumed by the Doctor, the difference in the position of the planes of motion; and, most unquestionably, the mere circumstance of wanting satellites, is no distinguishing mark, while so many of the acknowledged planets have none; nor, indeed, is it by any means certain that, as the Doctor seems to think, the mass of matter in the new planets is insufficient to retain secondary bodies in their orbits. The proportion of their distances from the centre of the system, or their proximity to each other, is evidently no better criterion.

In short, it if shall be admitted that comets move in ellipses; that the chief difference between those bodies and planets, consists in the greater eccentricity of the cometic orbits, in the perceptible atmosphere which accompanies them, and in the state of ignition which we have every reason to believe is the cause of that atmosphere; the more philosophical view of the subject would certainly be, to consider both planets and comets as bodies of the same nature, forming different parts of one great system. Indeed, Dr. Herschell himself admits the probability of the comets cooling in the process of time; and their atmosphere diminishing, so as to reduce them to a state of planets in every thing but their magnitude and eccentricity; and he applies the same remark to the case of the new bodies. Such an observation is obviously destructive of the principle of arrangement for which he contends. But whatever may be our opinion upon this subject, or however much we may be disposed to admit the propriety of distinguishing comets from planets; in the present state of our knowledge, the grand circumstance of concentricity is evidently sufficient to authorise a classification of the new bodies under the head of planets; and the discovery of them is chiefly valuable, on account of their coincidence, in certain particulars, with the nature of comets, and their differing from those bodies in the extent of their atmospheres, probably in decreased ignition. If it shall be found demonstrated, that the cometary orbits are elliptical, and not parabolic, these new planets will form a sort of link in the system, in consequence of an intermediate step between the greater and the smaller, the concentric and eccentric heavenly bodies. In the mean time we must enter our protest to the formation of a separate class, distinguished by a new and uncouth name.

Such being our opinion, it is of much less consequence to inquire, whether the new name of Asteroid is the most appropriate that could be imagined. To us, that name presents the idea of some body resembling fixed stars; whereas the two new planets have no one circumstance in common with those distant bodies. If a new name must be found, why not call them by some appellation

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which shall, in some degree, be descriptive of, or at least consistent with, their properties? Why not, for instance, call them Concentric Comets, or Planetary Comets, or Cometary Planets? Or, if a single term must be found, why may we not coin such a phrase as Planetoid or Cometoid?

Dr. Herschell’s passion for coining words and idioms, has often struck us as a weakness wholly unworthy of him. The invention of a name, is but a poor achievement in him who has discovered whole worlds. Why, for instance, do we hear him talking, on page 220 of this volume, of the space-penetrating power of his instrument - a compound epithet and metaphor which he ought to have left to the poets, who, in some future age, shall acquire glory by celebrating his name? The greatest discoverers have scarcely ever immortalized their deeds by efforts of nomenclature. Columbus, Cabral, Gama, and Cook, left the honour of being attached to the regions which they had penetrated, to the impostors who succeeded them, or the princes and saints whom they served. [The paper concludes with two paragraphs that attack Herschel’s other recent papers in the Philosophical Transactions]. (Brougham, 1803).

The Journal of Natural Philosophy (Nicholson’s Journal) printed in full an English translation of Lalande’s 5 July 1802 address to the French National Institute, on the discovery of Pallas:

When we announced, in the last public sitting, the discovery of a planet by M. Piazzi of Palermo, we were far from thinking that, in three months, we should have to make known a discovery of the same kind. It was also by a fortunate accident that this tenth planet was discovered; but accident could favour none but an intelligent and indefatigable astronomer.

On the 28th of March, at nine in the evening, Dr. Olbers of Bremen was observing Piazzi’s planet, with which astronomers have been engaged for a year. He was examining with his telescope all the small stars in the Virgin’s wing, to ascertain their positions, that he might be better able to establish the place of the planet, and had come to the 20th star of the Virgin, near which he had observed the planet in the month of January. He was surprised to see near this star, which is of the 6th magnitude, another smaller of the 7th magnitude. He was very certain that it had not been there at the time of his first observations: he therefore hastened to determine its position; and, having continued to view it for two hours, he perceived that it had changed its place in the course of that interval. The two following nights afforded him the means of being certain of its motion, which was 10 minutes per day. On the 28th of March, at 9h 25′ mean time, at Bremen, it had 184 56′ right ascension, and 11 33′ north declination.

Astronomers have been accustomed to consider as comets, all stars that have motion. This was the case with the planets of Herschel and Piazzi at the time when they were discovered. That of Dr. Olbers had no more resemblance to a comet than the rest. With an achromatic telescope, the magnifying power of which was 180, it could not be distinguished from stars of the 7th magnitude. It was better defined than the planet of Piazzi; and, with a telescope of 13 feet, which magnified 288 times, it seemed to have a diameter of 4 seconds: but this was an effect of irradiation, or of the dispersion of the rays of light, which always makes the diameters appear too large; for the satellites of Jupiter appear much larger than the new planets, and yet we know that their apparent diameter is not a second.

Dr. Maskelyne, by means of diaphragms placed before the object-glass of his telescope, ascertained that the light of Piazzi’s planet is stronger by one half than that of the new planet.

Dr. Olbers having observed the new star for four days, he sent notice to different astronomers; and on the 10th of April, C. Burckhardt, when he received his letter, went immediately to the military school to search for it, and next day sent his observation to the Institute.

He began to calculate its orbit, trying first a circle, and then a parabola known to be that of comets; but, at the end of three days, his elements were found to err 30 seconds. He tried also ellipses of different dimensions.

On the 15th of May we were informed, by a letter from baron von Zach, the celebrated astronomer of Gotha, that Dr. Gauss, an astronomer of Brunswick, had found an ellipse which corresponded to the first observations. On the 22nd we received the details. He found the revolution to be four years seven months, and the inclination 3°. This great inclination seemed to remove it from the order of planets, and some astronomers called it a comet; but its proximity, and continual appearance, will not allow of its being placed among the number of those stars of which we often lose sight for so long a time, and which go to enormous distances.
C. Burckhardt, on his part, made similar researches; he made several trials with ellipses very much elongated, which gave him a result very near that of Dr. Gauss. On finding that this planet, like that of Piazzi, was between Mars and Jupiter, and that its motion must be affected by the attraction of Jupiter, C. Burckhardt undertook to calculate these perturbations. The calculation is long and difficult, but it is indispensably necessary to obtain the orbit with more exactness.

At last, on the 4th of June, he finished these laborious calculations, and found the following elements:
Distance 2.791, or 95,890,000.
Revolution, 4 years, 8 months, and 3 days.
Eccentricity, 0.2463; equation of the orbit, 28° 25′.
Epoch of 1802, 4Z 23° 50′; aphelion 10Z 2° 3′;
Node 5Z 22° 28′; inclination 34° 50′ 40″.

These elements corresponded to five observations of the 4th, 16th, and 27th of April, and the 7th and 20th of March; the last two made by C. Burckhardt, and Lalande’s nephew, who, as well as C. Méchain, Messier and Delambre, continued to observe it as long as it could be seen in the meridian, because such observations are the surest. After the 21st of May, other instruments and other stars were necessary; but it still passed through some included among the 15,000 stars which we have published. On the 15th of June these elements corresponded, within a few seconds, with the observations of Méchain and Messier; which confirms the exactness of the elements found by C. Burckhardt, and assures us, that the motion of the new planet is already known. Baron von Zach has published a great many observations respecting it in his Journal.

C. Cabrol de Murol [see note below] has calculated for us an ephemeris, which gives the situation of this planet to the 21st of October, on which day it will have 227° 7′ of right ascension, and 6° 8′ of declination. It will then set at 7h 51′: there is therefore reason to think that it may be still observed. It will be above Libra near the Serpent, after passing the legs of the Cow-herd (Aquila). He finds that, in 1806, it will have 33½° of south declination, and that it will then be difficult to see it at Paris; but C. Vidal, who has already observed it this year, will then be better able than we to follow it.

Its greatest northern declination will not exceed 26½ degrees, a term at which it will be a year hence. It will be easier to be seen, but its distance will be double, and its light four times less than the present year. In the month of March 1804, it will be at three times the distance; its light will be nine times less, and, in all probability, it will be difficult to observe it.

As the orbit of this new planet intersects that of Piazzi, I was curious to know whether the two planets might not meet; but I found that, when they are in the same plane, there will be an interval of about 19 millions of leagues between them.

The planet of Dr. Olbers is very small. If we suppose its apparent diameter to be half a second, I find that its real diameter cannot be more than 100 leagues. Dr. Herschel, in a paper which he read before the Royal Society on the 7th of May, makes it be four times less. He says, that on the 22nd of April Piazzi’s planet was only 22 hundredths of a second, and that of Olbers 13 hundredths; but it appears to me, that we have no means of determining, with certainty, quantities so small.

Dr. Olbers calls his new planet Pallas; but, as I see no sufficient motive for this fabulous denomination, I prefer giving it the name of the person to whom we are indebted for this valuable discovery.

Dr. Olbers distinguished himself in 1797 by an excellent treatise on comets, and was worthy of the good fortune with which his labours have been crowned. (Lalande, 1802c).

Note: Michel Chabrol de Murol was born in Riom, France, on 18 November 1777 and worked as an astronomer at the Paris Observatory. He published a method to calculate eclipses. It is not known where or when he died (Zach, 1818: 525).

Continuing its report of asteroid observations from France, The Philosophical Magazine (Figure D.33; 1803d) informed readers of a unique occurrence, an account which did not appear in any other English publication:
The new planets discovered by Piazzi and Olbers continue to engage the attention of astronomers. Notwithstanding the smallness of the arc which they have passed through in our sight, and notwithstanding the considerable perturbations which they experience from Jupiter, we have already obtained the elements of their orbits with sufficient precision to find again these bodies in the place indicated by calculation, when they become visible, after having been several months lost in the rays of the sun. The greatest difficulty arises from their extreme smallness, which sometimes causes us to doubt whether we have them in the field of the telescope. This is true in regard to Pallas in particular, which appears sometimes like a star of the 10th or 11th, or even the 12th magnitude, while Ceres appears of the 7th or 8th. But as there is something too arbitrary in this distribution of the stars according to the order of their magnitudes, it will be better to say with Messier, that Pallas is the smallest object that can be distinguished with an excellent telescope. An extraordinary circumstance has given to this imperceptible star for a moment a more sensible diameter and a stronger light. On the 25th of May, the weather being very fine, C. Messier was surprised to find in it a light double to that which it had been before; and yet, according to calculation, the distances of the sun and moon being nearly the same, the brightness of the planet ought not to have changed. The cause of this appearance was soon discovered. The small planet in its course met with a star, to which it appeared to be so close that the least interval could not be observed between them. Forty-two minutes after, a separation took place, and, according to the known motion of the planet, the interval must have been 15″. The position of the small star may be determined at leisure; and from the repeated observations which may be made of it, there will result for the moment of the observation of Messier a determination of the place of the planet more exact than any of those which could have been procured in a direct manner. Those observations known under the name of appulses are exceedingly rare. However numerous the small stars may appear, the intervals which they leave between them are sufficiently large for the planets to make the tour of the heavens without concealing one of them, or at least any of those which can be observed.

A table of geocentric motions of Pallas and Ceres for the month of August was printed after this paragraph.

In 1803 Seyffer published a monograph that reprinted Piazzi’s memoir on the discovery of Ceres together with his own reflections about Ceres. This publication was summarized in The Monthly Magazine (1804a).

This is a translation of the “Resultate der Beobachtungen des neuen Sterns,&”— and contains the history of the discovery of the Ceres Ferdinandae, together with the original Observations, as well as the Calculations of M. Piazzi. The additions made by M. Seyffer comprehend the labours of the other Astronomers, as well as Observations on the nature of this Star, concerning which there is some dispute, relative to its particular denomination, some contending that it is a Planet, while others assert that it is Comet, the arch [sic] of its orbit being too small to determine this question with any degree of certainty.

M. Seyffer proposes to distinguish the new Star, by means of a sign analogous to the others, such as the Caduceus of Mercury, the Buckler and Lance of Mars, the Mirror of Venus, &c. It is accordingly recommended to choose for Ceres, a flambeau, the head of a poppy, or an ear of corn. Dr. Olbers of Bremen lately announced to the Royal Society of Sciences, that he saw, on the first day of January, 1802, precisely a year after its discovery, a Star which he took to be the Ceres Ferdinandaea of M. Piazzi; that on the second, he distinguished its motion, and that on the morning of the sixth, he was perfectly assured that it was the new Planet. On the last of these days, he perceived it to have advanced below No. 20, of the Virgin, in conformity to the theory of its movements, It is his opinion, that M. Piazzi has made the apparent diameter two [sic] large.
Early reports on the discovery of Juno were widely covered in the English periodicals. The Scots Magazine (1805) gave a detailed report about Juno’s orbital elements:

The New Planet lately discovered by Mr Harding of Lilienthal, had not been seen for the space of a month on account of the badness of the weather. It was observed, however, on the 21st of December, by Burckhardt, who has determined anew the following elements of its orbit:

- Ascending node: 171° 6’ 0"
- Inclination: 13 5 0
- Perihelion in 1805: 45 49 33
- Epoch 31st Dec. 1814, At noon: 42 17 23
- Eccentricity: 0.25096
- Larger semiaxis: 2.657
Periodical revolution  1582 days.
From these elements the following places of the Planet have been calculated. [The article then
gives eight positions from 21 December 1804 to 15 February 1805.]

From these elements it appears that its periodical revolution, which is four years and four
months, is nearly equal to that of Pallas or Ceres, and that the eccentricity of its orbit is greater than
that of any of the other planets of the system. The effect of this eccentricity is so sensible, that the
time employed by the planet to pass over the first part of its orbit, the middle of which is occupied
by its aphelion, is the double of the time necessary for completing the second half. In like manner,
greatest distance from the sun is almost double the least distance. In absolute measures, the
difference between these two distances is 45 millions of leagues, or equal to one and a third of the
distance of the earth from the sun. The Planet passed its perihelion on the 15th of February.

The Christian Observer (1804) also reports this discovery:
M. Harding, of the Observatory at Lilienthal near Bremen, who has been employed on at atlas of
all the stars down to those of the eighth magnitude, which lie within and near the orbits of the two
new planets Ceres and Pallas, discovered on the 1st of September a THIRD NEW PLANET. Its
place, as settled by Dr. Olbers, on September 8, was at M.T. 8h. 11m. 20 deg. A.R. 1 deg. 29 min.
39 sec. declin. south 0 deg 47 min. 19 sec.: its motion in A.R. is about 7 min. 56 sec., or 31 min. 7 sec.
in time retrograde, and in declin. about 12 min. 34 sec. south per diem. It is similar to Ceres in
light and apparent magnitude. Nothing nebulous can be distinguished around it; and, in all
probability, it is another of a considerable body of small planets, of which this is the third recently
discovered. In the Philosophical Magazine for October last, a chart is given, representing the
apparent path of this New Planet, laid down from Observation.

Tilloch's Journal (1805) has this report:
M. Harding, of Lilienthal, near Bremen, has discovered a new planet, to which he has given the
name of Juno. While comparing with the heavens the fifty thousand stars observed by Messrs.
Lalande, he saw one of the eighth magnitude, which appeared to him to have a motion of its own.
He observed it several days, and soon found that it was a planet. On the 5th of September, its right
ascension was 1° 52′. Its north declination 0° 11′. M. Burckhardt observed it on the 23d of
September, at 359° 7′, and 4° 6′, and thence concluded that the duration of its revolution is five
years and a half. Its inclination is 21°. Its excentricity is a quarter of its radius. Its mean distance
from the sun is three times that of the earth, that is to say, it is about a hundred millions of leagues;
it is consequently a little farther distant from the sun than Ceres and Pallas, which are only ninety-
six millions of leagues. Its diameter has not yet been measured, but it appears like a star of the
eighth magnitude. Its size appears nearly equal to that of Ceres, or of the planet discovered by
Piazzi. As astronomers daily observe it, more precise elements of it may be obtained. Juno is the
12th planet discovered within a small number of years. Herschel discovered Uranus, and its six
satellites; he discovered also two new satellites to Saturn; Piazzi discovered Ceres; Olbers
discovered Pallas; and Harding has discovered Juno.

Even though Herschel claimed to have discovered six moons of Uranus, only the first
two were real, the others being spurious. It took several decades to establish this.

This official account of the Proceedings of The Royal Society covers the period
November 1801 to July 1802, with an addendum for 1807. It was printed in Young
(1807: 671-677):
The meeting of the 10th of December (1801) was occupied by an abridged translation of a pamphlet
of Mr. Piazzi, on the supposed planet, which he discovered at Palermo, and which he has named
Ceres Ferdinandeae. Its apparent diameter was seven seconds, its distance from the sun is nearly
three times that of the earth, and its period somewhat more than five years. It does not, however,
appear to be by any means fully ascertained, that it deserves to be considered as a true planet. The
paper was communicated by Dr. Maskelyne.

On the 4th of February (1802), a letter from Dr. Maskelyne announced that he had observed the
new planet of Mr. Piazzi passing the meridian between three and four o'clock in the morning,
having about 18° 43′ right ascension, and 12° 38′ north declination, appearing like a star of the
eighth magnitude.

Another letter, from Mr. von Zach, was read, informing the Society that he had observed this
planet at Seeberg on the 7th of December, within half a degree of the place before determined in his journal. Mr. Olbers saw it at Bremen on the 2nd of January. With a power of above 120, it presented no observable disc.

On the 11th, a second letter from the Astronomer Royal informed the Society that he had repeated his observation of the new planet, so as fully to ascertain its motion. It appeared to have a visible disc when on the meridian, and viewed with a power of 50. When the air was very clear the disc was round and well defined, but somewhat smaller than that of the 34th of Virgo, a star of the 6th magnitude near it. Dr. Maskelyne observes that the smallness and roundness of the appearance of the disc of the fixed stars is a good criterion of the clearness of the air.

Another letter, from Alexander Aubert, Esq. F.R.S. was also read. Mr. Aubert discovered the planet Ceres on Sunday morning, having about 188° 41’ right ascension and near 13° declination, its motion at present being retrograde.

On the 18th of February a letter from Mr. von Zach was read, containing a continuation of his observations on the planet Ceres, and mentioning an account from Mr. Harding that two faint spots had been seen, at the distances of 20 and 35 seconds from this planet, which it was conjectured might possibly be satellites: although the fact had not by any means been ascertained.

Dr. Herschel sent an account of the appearance of the new planet, as viewed through his telescopes. He had sought for it in vain, until he received Dr. Maskelyne’s determination of its place. When viewed with powers of 600 and 1200, it could not be decidedly distinguished from a star, until it was found to change its place. Its apparent diameter was not large enough to be directly determined, but it was certainly not larger than one fourth of that of the Georgian planet, and perhaps equal only to one sixth. From a rough computation of its magnitude, Dr. Herschel concludes that its real diameter is about 1/40 of that of the moon: its light is of a reddish hue.

Mr. Gilpin also gave the Society an account of observations on the 8th and 12th of February. He found the planet’s right ascension from 188° 41’ to 188° 30’, while its declination increased. Mr. Gilpin observes that its light resembles that of the planet Mars.

Thursday, 25th February. A letter from Mr. Schroeter of Lilienthal, respecting the planet Ceres Ferdinandea, informed the Society that Mr. Schroeter had observed a nebulosity around the planet, somewhat resembling that of a comet: the diameter of the true disc being 1.8″, and that of the nebula 2.0′, but the distinction was not always equally observable. Mr. Schroeter considers this body as of a hybrid nature, or a medium between a planet and a comet; but he imagines the apparent nebulosity to be owing to an atmosphere, the light reflected from the planet is either white, bluish, or reddish.

A table of observations of the same planet was also communicated by Mr. Méchain, through Sir Henry Englefield.

A letter was also read on the 11th March, from Mr. von Zach, confirming Mr. Schroeter’s observation of the changeable light of the planet Ceres, which Mr. von Zach had at first attributed to the haziness of our own atmosphere, until he found that MM. Olbers and Schroeter were agreed in deriving it from a real change in the light reflected.

Some observations of the place of the planet Ceres, by Professor Bode, of Berlin, were also communicated on the 8th April by Dr. Herschel.

On the 6th of May, Dr. Herschel’s observations on the two lately discovered celestial bodies were read.

Dr. Herschel begins with stating the result of his attempts to measure the diameter of the stars discovered by Piazzi and Olbers. He employed the lucid disc micrometer, which consists of an illuminated circle, viewed with one eye, while the other compares with it the magnified image formed by the telescope; and he concludes, that the apparent diameter of Ceres was .22″, and of Pallas .17″ or .13″, at the distance of nearly 1.634, and 1.187 from the earth respectively, whence the apparent diameters at the distance of the earth from the sun would be .35″ and .21″ or .16″ respectively; and that their real diameters are about 163 and 90 or 71 English miles. There is no probability that either of these stars can have a satellite. The colour of Ceres is more ready than that of Pallas. They have generally more or less of a haziness, or coma, but sometimes, when the air is clear, this nebulosity scarcely exceeds the scattered light surrounding a very small star. From a view of all these circumstances, Dr. Herschel proceeds to consider the nature of the new stars. He thinks that they differ from the general character of planets, in their diminutive dimensions, in the great inclination of their orbits, in the coma surrounding them, and in the mutual proximity of
their orbits; that they differ from comets in the want of eccentricity, and of a considerable nebulosity. Dr. Herschel, therefore, wishes to call them asteroids, a term which he defines as a celestial body, which moves round the sun in an orbit either little or considerably eccentric, of which the plane may be inclined to the ecliptic in any angle whatever, the motion being either direct or retrograde, and the body being surrounded or not by a considerable atmosphere, or a very small coma. This definition is intended to include such other bodies of the same kind as, Dr. Herschel supposes, will, in all probability, be hereafter discovered. Some additional observations show, that the apparent comas, surrounding Ceres and Pallas, scarcely exceed those, which are caused by aberration, round the images of minute fixed stars.

In 1807, the minutes record two sessions dealing with Vesta:

May 28. A short paper was read on the magnitude and situation of Dr. Olbers’s new planet called Vesta, whose orbit, it appears, is between Mars and Venus [sic]. The brightness and smallness of Vesta are such as to make it be considered a true asteroid.

June 4. Dr. Herschel communicated his observations on the new planet Vesta, which differ little from those previously reported from the astronomer royal.

Here is the full text by the anonymous author of Essay on the System of the Earth (1811) that was considered on page 34:

The difference of mean distance from the sun of the two asteroids Ceres and Pallas, is stated in Vince’s Astronomy to be as the difference between 276.74 and 276.759 or about .019, the distance of the earth being the standard at 100. Taking the real mean distance of the earth from the sun at about 95,000,000 miles, according to the table of Dr. Maskelyne before referred to, the distance between these asteroids must be about 18,000 miles. At this distance I cannot suppose it possible that they can permanently keep asunder, or that they could now be separate if this had been their original relative position. The difference of the inclinations of their orbits may for a time keep them separate when they are in the same position in longitude as to the sun, and if they are approaching to Jupiter with different velocities, it is possible that they may heretofore have been and may again become sufficiently separated to preserve their separate existence, before the chance of their being both in the nodes or points of mutual intersection of their respective orbits at the moment of their being also in conjunction or in the same meridian of longitude as to the sun, must otherwise bring them together, if within 18,000 miles of each other. If we suppose the present position of Ceres to be in part the effect of a late accession of a comet, this might afford a second possible explanation of the present separate existence of this asteroid. But we cannot suppose four comets all fixed so near to each other in the places of their new courses, as asteroids.

It may also here be remarked that if these asteroids shall fall into Jupiter, as I have supposed to be presumable, they must be expected to affect the inclination as well as eccentricity of the orbit of the increased planet in a proportion adequate to the difference of the two bodies; and if moving in an orbit at a considerable angle of inclination to the orbit of Jupiter, they must be expected also to produce a change in the position of the axis and of the poles of the aggregate planet. Thus if all the planets be aggregations of numerous asteroids, a second possible explanation is afforded of that phenomenon which we find in almost all the planets, of the axis not being perpendicular to the orbits.

Before I proceed to consider other consequences of this view of the asteroids, I will here take the opportunity of remarking, that this explanation of their origin will account for the plane of the orbit of Ceres being at so much greater an angle to the plane of the sun’s equator, than any of the aggregate planets. (Anon, 1811: 193-194).
## TABULAR VIEW OF THE SOLAR SYSTEM.

<table>
<thead>
<tr>
<th>Planet's Name</th>
<th>Mean solar rev. in Mean Solar Days</th>
<th>Mean Distance from Sun in Eng. miles</th>
<th>Relative mean dist. from Sun, that of Earth being = 1</th>
<th>Eccentricity of orbit in parts of the mean dist.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>87.962980</td>
<td>36,880,485</td>
<td>0.3970950303</td>
<td>0.33054149</td>
</tr>
<tr>
<td>Venus</td>
<td>224.706789</td>
<td>69,314,653</td>
<td>0.725331765</td>
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<tr>
<td>Earth</td>
<td>365.259744</td>
<td>96,277,898</td>
<td>1.000000000</td>
<td>0.000000000</td>
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<tr>
<td>Mars</td>
<td>686.376948</td>
<td>145,168,695</td>
<td>1.623699292</td>
<td>0.0833070</td>
</tr>
<tr>
<td>Vesta</td>
<td>1285.743100</td>
<td>220,016,782</td>
<td>2.351380000</td>
<td>0.0001200</td>
</tr>
<tr>
<td>Juno</td>
<td>1809.094800</td>
<td>324,387,803</td>
<td>3.608161896</td>
<td>0.0378458</td>
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<tr>
<td>Ceres</td>
<td>1821.349100</td>
<td>353,646,156</td>
<td>4.278443935</td>
<td>0.0745496</td>
</tr>
<tr>
<td>Pallas</td>
<td>1866.538800</td>
<td>384,183,767</td>
<td>4.985915183</td>
<td>0.0916490</td>
</tr>
<tr>
<td>Jupiter</td>
<td>4326.541612</td>
<td>490,303,437</td>
<td>6.159134114</td>
<td>0.0601001</td>
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<tr>
<td>Saturn</td>
<td>10786.315817</td>
<td>598,717,375</td>
<td>7.327950061</td>
<td>0.0561566</td>
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<tr>
<td>Herschel</td>
<td>30885.968260</td>
<td>1,027,050,388</td>
<td>11.188280012</td>
<td>0.0667204</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Planet's Name</th>
<th>Time of Rotation on axis</th>
<th>Inclination of axis to orbit</th>
<th>True equatorial diameter in Eng. miles</th>
<th>Relative diameter ; Earth's = 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>24h. 23m. 59s.</td>
<td>88° very nearly</td>
<td>3,984</td>
<td>0.379656</td>
</tr>
<tr>
<td>Venus</td>
<td>23 50 54</td>
<td>15° nearly</td>
<td>7,921</td>
<td>0.302818</td>
</tr>
<tr>
<td>Earth</td>
<td>23 56 4</td>
<td>66° 32' 50&quot;</td>
<td>7,994</td>
<td>1.000000</td>
</tr>
<tr>
<td>Mars</td>
<td>24 36 21</td>
<td>0° 29' 0&quot;</td>
<td>4,222</td>
<td>0.439738</td>
</tr>
<tr>
<td>Vesta</td>
<td>unknown</td>
<td></td>
<td>0.965</td>
<td>0.095685</td>
</tr>
<tr>
<td>Juno</td>
<td>87 probability</td>
<td></td>
<td>1.365</td>
<td>0.176589</td>
</tr>
<tr>
<td>Ceres</td>
<td>1,302</td>
<td></td>
<td>1,302</td>
<td>0.395644</td>
</tr>
<tr>
<td>Pallas</td>
<td>9,085</td>
<td></td>
<td>9,085</td>
<td>0.304529</td>
</tr>
<tr>
<td>Jupiter</td>
<td>9 58 57</td>
<td>82° 34' 38&quot;</td>
<td>89,655</td>
<td>10.88353</td>
</tr>
<tr>
<td>Saturn</td>
<td>10 16 2</td>
<td>61° 30' 0&quot;</td>
<td>81,584</td>
<td>9.34339</td>
</tr>
<tr>
<td>Herschel</td>
<td></td>
<td></td>
<td>34,393</td>
<td>3.65585</td>
</tr>
<tr>
<td>Sun</td>
<td>95d. 14h. 23m.</td>
<td>88° 44' 9&quot;</td>
<td>1,087,983</td>
<td>112.08484</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Planet's Name</th>
<th>Relative bulk, that of Earth being = 1.</th>
<th>Quantity of matter, that of Earth being = 1.</th>
<th>Density, that of Earth being = 1.</th>
<th>Gravity as surfer, that at Earth's surface = 1.</th>
<th>Comparative light and heat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>0.3329</td>
<td>0.1300</td>
<td>2.585</td>
<td>1.70</td>
<td>6.72828</td>
</tr>
<tr>
<td>Venus</td>
<td>0.29574</td>
<td>0.1043</td>
<td>1.004</td>
<td>0.38</td>
<td>1.01396</td>
</tr>
<tr>
<td>Earth</td>
<td>1.00000</td>
<td>1.0000</td>
<td>1.000</td>
<td>1.00</td>
<td>1.00000</td>
</tr>
<tr>
<td>Mars</td>
<td>0.31523</td>
<td>0.0656</td>
<td>0.656</td>
<td>0.34</td>
<td>-0.29686</td>
</tr>
<tr>
<td>Vesta</td>
<td>0.00804</td>
<td>unknown</td>
<td>unknown</td>
<td>unknown</td>
<td>unknown</td>
</tr>
<tr>
<td>Juno</td>
<td>0.03443</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceres</td>
<td>0.00796</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pallas</td>
<td>0.00004</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jupiter</td>
<td>1989.10000</td>
<td>382.06</td>
<td>0.301</td>
<td>2.33</td>
<td>-0.72839</td>
</tr>
<tr>
<td>Saturn</td>
<td>1104.00000</td>
<td>113.97399</td>
<td>0.103</td>
<td>1.00</td>
<td>-0.08299</td>
</tr>
<tr>
<td>Herschel</td>
<td>81.27000</td>
<td></td>
<td>0.022</td>
<td>0.05</td>
<td>-0.72839</td>
</tr>
<tr>
<td>Sun</td>
<td>14880.1269</td>
<td>35493.00</td>
<td>0.282</td>
<td>27.00</td>
<td></td>
</tr>
</tbody>
</table>

**Hourly motion in the Orbit at the mean distance, in English miles.**

<table>
<thead>
<tr>
<th>Planet's Name</th>
<th>Venus</th>
<th>Earth</th>
<th>Mars</th>
<th>Vesta</th>
<th>Juno</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>109,700</td>
<td>80,288</td>
<td>53,833</td>
<td>44,435</td>
<td>41,700</td>
</tr>
<tr>
<td>Ceres</td>
<td>41,601</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pallas</td>
<td>Jupiter</td>
<td>Saturn</td>
<td>Herschel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41,600</td>
<td>39,943</td>
<td>29,111</td>
<td>15,592</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure D.34: Tabular View of the Solar System (after The Ladies' Diary, 1839)
APPENDIX E: Nevil Maskelyne's Memoranda

Nevil Maskelyne wrote several memoranda about the asteroids, some of which served as the basis for articles that he published in *The Monthly Magazine*. The first article that was likely written by Maskelyne, in the August 1801 issue of *The Monthly Magazine*, is included in Section 5.2. There is no corresponding memorandum for this early article. Both the memoranda and the subsequent articles are reproduced in this Appendix. All of the underlining and strikeouts are in the original memoranda.

Memorandum by Maskelyne  
22 October 1801  
and 28 January 1802

1801 Oct 22 Rec. a letter & memoir on the new planet from Mr. Piazzi.—Jan. 28 Account in the Moniteur of Jan 24 1802 of the new planet having been found again by Dr. Olbers at Bremen on 6th of Jan.—Dr. Burckhardt’s elliptic elements—Mr. Gauss’s elements—their errors—astron. have labored much in search of it, the Astr. Royal not the least owing to the defectiveness of the elements deduced from Piazzi’s observations. Fortunately Mr. Gauss of Brunswick had investigated [and his results] are nearer the truth by means of which it was found. Dr. Zach saw it 7th December last. Dr. Olbers 1st of January.

Memorandum by Maskelyne  
23 February 1802

Looked at planet Ceres with telescope of equatorial sector in the time from its passing the meridian till a quarter past ten with powers 50 & 200. The planet & star which preceded it 25″ was about 5′ N of it, seemed nearly of equal size colour and brightness; the planet rather the least possible larger brighter and whiter. The planet nearly white very little reddish. There was a little red the least possible reddish cast. A star of Virgo appeared tolerably well defined, not perfectly so. The sky was pretty tolerably clear, but the moon light strong. The star appeared in the telescope of the transit instrument rather smaller than the wire or less than 2″ in diameter; as the planet appeared rather larger with the telescope of the equatorial sector, it may be reckoned 2″ in diameter. T.F. [Thomas Firminger] from the observations he has made of it with the quadrant, reckon it 2 1/2″ in diameter. Perhaps in a very fine clear air it may appear larger than this morning when at the time of passing the meridian the air was hazy & overcast with thin clouds.

Maskelyne’s article for *The Monthly Magazine* (1802b) was dated 27 February 1802. It was signed by his pseudonym, Astrophilus:

The Planet having been lost through M. Piazzi’s illness, on the 11th of February, 1801, after he had observed it for six weeks; and it never having been seen out of his observatory, the astronomers were reduced to the necessity of endeavouring to find it, after eight months, by elements of its orbit deduced from his observations. He had given elements in a circular orbit, and Dr. Burckhardt, at Paris, and Mr. Gauss, at Bremen, elliptical elements. Baron Zach published calculations of its place from Dr. Burckhardt’s elements, in his monthly journal, and the astronomers of Europe have laboured to find it by these calculations and their own, but in vain. Mr. Gauss, of Brunswick, probably excited by this disappointment to try to produce more exact elements, succeeded in the attempt, and calculations made upon them have been also published in the same monthly journal, and fortunately been the means of finding the planet again, which was observed by Baron Zach, at Gotha Observatory, on the 7th of December last year, and by Dr. Olbers, at Bremen, on the 1st day of January this year, as it had been discovered by M. Piazzi on the 1st of January of the preceding year. Dr. Olbers observed the planet, without knowing it, making a right angle with two stars in the right wing of the constellation of the Virgin; and, looking again the next night, was struck with the appearance of the figure of the triangle being changed, which shewed a motion that pointed out the planet to him. He thought he was the first who had observed it since it had been lost, but Baron Zach afterwards published an account of his having seen it before, on the 7th of December; but, not being certain of its being the planet, waited before he published any thing till he could verify his observation by the return of fine weather, which was not till the latter end of the month. Thus these two learned gentlemen may both by considered as discoverers, since each found it without the
assistance of the other; and if either of the observations had been wanting, we should have been in possession of the planet by the observation of the other. We must, however, always gratefully acknowledge our principal obligations are to M. Piazzi, the original discoverer, though he let it afterwards slip through his fingers, and by withholding an early, free, and ample communication of his discovery from the learned world, hazarded the total loss of it to the present generation, to be discovered again, perhaps by accident, in some future age. We are, however, now in full possession of it, without fear of losing it again, except only in the sun’s rays, in like manner as the other planets, to emerge from them again on the contrary side of the sun, and from an evening star turned into a morning one.

Mr. Gauss’s elements of the orbit of the planet in an ellipse, are as follows:

Epoch of 1801
Place of aphelium
Ascending node
Inclination
Mean distance
Periodic time
Mean daily heliocentric motion
Eccentricity
greatest equation of centre

These elements give the longitude greater by a degree than Dr. Olber’s observations; while Dr. Burchhardt’s elements give it near 8° less, and M. Piazzi’s circular elements near 11° less.

The planet was first observed by M. Mechain, the astronomer of the National Observatory at Paris, on the 23d of January, who sent an account hither: and it was observed at the Royal Observatory at Greenwich, on the third of this month. It has been also observed by Alexander Aubert, Esq. at Highbury Place; by Stephen Lee, jun. Esq. at Hackney; George Gilpin, Esq. at the Royal Society apartments, Somerset Place; and by Dr. Herschel, at Slough; who have communicated their observations to the Royal Society. It will take some time to determine its apparent diameter with any exactness, it being so small. Although M. Piazzi reckoned it 7″ when it was farther off than at present, it appears here much smaller. The Astronomer-royal has estimated it at 2″; Dr. Herschel, at one second, which may be the case with his ten-feet reflecting telescope. It is expected to be in opposition to the sun the latter end of March.

The first reference to Mr. Gauss as being from Bremen is a mistake. Maskelyne certainly meant to say Dr. Gauss, at Göttingen.

Early in March Maskelyne wrote a memorandum about Ceres:

Memorandum by Maskelyne 6 March 1802
At 9h 50′ planet appeared excessive faint, with an aperture of 1/2 inch in diameter. I saw 34 Virginis very faint with 1/3 inch aperture, but not so faint as the planet before with 1/2 an inch aperture. Then looked at with an aperture of .3 inch and it was scarcely distinguishable and much fainter than the planet appeared before. This was a fine night, and stars of 6 magnitude were visible. Perhaps with an aperture of 1/3 inch, the star 34 Virginis might have appeared equally faint as the planet with an aperture of half an inch. According to this the light of the planet is to that of the star as 9 to 25 or near three times less. The planet appeared of 8th magnitude.

His next logbook entry for March came three weeks later. The symbol θ denotes the Earth:

Memorandum by Maskelyne 27 March 1802
The planet [Ceres] was in opposition to the sun the 17th of March, 1802, of the size and appearance of a star of 8 magnitude, its apparent diameter about 2″. When in At the time of opposition to the sun it was near its northern limit of latitude, and about 30′ past its perihelion, and was nearly in as favourable a position as for being seen as it ever will be. Its apparent diameter at the distance of θ (Earth) at opposition = 3″.16. Its diameter probably 1/6 1/7 of that of the earth, & its bulk 1/343 of that of the earth. Subtracting 1/12″ for imperfection of telescope, its corrected app. diameter in March = 1″ 1/2; at mean distance of θ to sun = 2″.37. Its diameter to diam θ :: 1:77.36 and its bulk 1/398.7 of that of θ or 1/400 of that of the earth. Dr. Gauss to whom we are indebted for the recovery of the planet is a young man of extraordinary mathematical genius, who was taught mathematics under Zimmerman [Eberhard August Wilhelm von Zimmermann, 1743–1815], at the expense of
the Duke of Brunswic [sic], had read Newton’s *Principia* at 18, and now only 22; and has published a very learned treatise on the higher parts of arithmetic, written in a very perspicuous stile, in good Latin, which he has dedicated to his generous patron the Duke of Brunswic [sic].

Here is the revised text that was printed in *The Monthly Magazine* (1802c), which has a different date of 28 April:

**Further particulars of PIAZZI’s New Planet, called Ceres Ferdinandea**

The planet was in opposition to the sun on the 17th of March. It was then near its northern limit of latitude, and about 30° past its perihelium; and was nearly in as favourable a position for being seen, as it ever will be. Taking its correct apparent diameter to be a second and a half, its real diameter will be about one-seventh of that of the earth, or half that of the moon. Its apparent place in the heavens, from April 30, to June 29, has been computed by Dr. Gauss, from his elements, as follows [see Figure E.1 below], for midnight in the meridian of Seeberg, or Saxe-gotha:

![Figure E.1: Observations of Ceres in 1802 (after The Monthly Magazine, 1802c).](image)

Dr. Gauss, to whom we are indebted for his calculations, by which the planet was re-discovered by Baron Zach and Dr. Olbers, is a young man, of Brunswick, of 22 years of age, of extraordinary mathematical genius, who was taught mathematics by Zimmerman, at the expence of the Duke of Brunswick, and had read Newton’s *Principia* through at eighteen. He has published a very learned treatise on the higher parts of arithmetic, written in a very perspicuous stile, in Latin; which he has dedicated to his patron the Duke of Brunswick. April 28th, 1802.

Likewise, Maskelyne’s article about Pallas first appeared in his logbook:

**Memorandum by Maskelyne**

On the 20th of March 1802 Dr. Olbers of Bremen accidentally looking at the star N°. 20 in the Northern wing of the Virgin, near which he had rediscovered Ceres on the 1st day of January last, to his great surprise saw a star of 7th magnitude, which had not been there before, by which means and attending to its motion he found it was another new planet. It appeared to him, with his Dollond’s telescope, perfectly resembling Ceres, without either atmosphere or nebula, and not to be distinguished from a fixed star. Mr. Schröter of Lilienthal on the 30th looked at it with his 13 feet reflector, and thought it more striking than Ceres, with something of a planetary disc, and measured its apparent diameter 4″.635, whereas on the 28th of March he had found that of Ceres only 4″.021, and on the 20th of March that of Georgium Sidus 3″.973. The light of the Olbersien planet was paler and whiter than that of Ceres, but rather more intense; yet he could not see either of them with the naked eye, tho’ he had never failed to see Georgium Sidus so, even in a low situation. Both on 30th of March and 1st of April, the Olbersien star was followed by a very small darkish star, which he suspects to be a Satellite, from which it lay S.W.-- Here at Greenwich it has appeared of a dullish light, less bright than Ceres, but not so bright as Georgium Sidus. At the Paris Observatory, from 10th to 13th April, it has appeared, as near as possible, of the same brightness as Georgium Sidus Ceres. Considering this star as a planet, they have roughly calculated its distance from the
sun as 1.9 that of ours, consequently more distant than Mars; but the great obliquity of its orbit to
the ecliptic (for its latitude on the 12th was 15°.49N) raises doubts.

Here is the much-altered text, which was published on the same page as the
information about Ceres:

On the 28th of March 1802, Dr. Olbers, accidentally looking at the star No. 20 in the northern wing
of the Virgin, near which he had rediscovered Ceres Ferdinandea, on the first of January last, to his
great surprise he saw a star of 7th magnitude, forming an equilateral triangle with No. 19 and 20, of
the Virgin; which he was persuaded had not been visible there at that time; by which circumstance,
and by tracing its motion, he found it was another new planet. It appeared to him, with his
Dollond’s telescope, perfectly resembling Ceres, without either atmosphere or nebula, and not to be
distinguished from a fixed star. Supposing it to be a planet moving in a circular orbit, they have
calculated its distance from the sun to be twice and one tenth our distance from the sun, and its
periodic time, about three years. The inclination of its orbit to the ecliptic must be very
considerable, as on the 12th of this month, its observed latitude was nearly 16°. Dr. Olbers has
named it Pallas. (The Monthly Magazine, 1802c, italics in article).

Two months later Maskelyne wrote another memorandum about Pallas:
Memorandum by Maskelyne 29 May 1802
Further account of the new planet, Pallas
Dr. Olbers, who discovered it on the 28th of March, after observing it for six five weeks, was fully
persuaded of its being a true planet. Dr. Gauss has determined its elements as near as could be
done from so small a part of its orbit, and its eccentricity is a little greater than that of Mercury, the
greatest equation of the center 24°.46′, the inclination of its orbit 33° 39′, and its mean distance a
little less than that of Ceres. But the most remarkable circumstance concerning it is, that it crosses
the orbit of Ceres, approaching the sun nearer than Ceres in its perihelium and receding farther
from it in its aphelion than Ceres does. Dr. Herschel has made some curious observations of the
apparent diameters both of Pallas and Ceres, from which he infers the real diameter of Pallas to be
95 miles & that of Ceres 162 miles. He thinks them to be a different species from the
known planets and proposes to give them. In their motions and smallness they resemble
comets, but in the clearness of their light the other planets.

Here is the text as published in The Monthly Magazine (1802d):
Dr. Olbers, who discovered it on the 28th of March, after observing it for five weeks, was fully
persuaded of its being a true planet. Dr. Gauss has determined the elements of its orbit, as near as
could be done from so small a part of it. Its eccentricity is a little greater than that of Mercury; the
inclination 33° 39′; its mean distance a little less than that of Ceres; and its periodic time four years
and five months, or two months less than that of Ceres. But the most remarkable circumstance
concerning it is, that it crosses the orbit of Ceres, approaching the sun nearer in its perihelium and
receding further from him in his aphelion, than Ceres does. Dr. Herschel has made some curious
observations of the apparent diameters both of Pallas and Ceres, from which he infers the real
diameter of Pallas to be 95 miles, and that of Ceres 162 miles. He considers them of a different
species from the known planets. In their smallness and motions they resemble comets, but in the
clarity of their light they resemble the other planets.

Maskelyne’s final memorandum was written about Juno:
Memorandum by Maskelyne 11 September 1804
Mr. Schroeter’s Account
Mr. Harding who superintends the Observatory at Lilienthal, discovered on the 1st Sept. in Pisces a
new moving star of the 8th magnitude evidently a new planet of a fine white light, defined like a
planet without any nebula, and in every other respect like the two last discovered new planets Ceres
and Pallas. Its motion is retrograde towards the southwest. Mr. Harding’s measurements are stated
in the annexed paper and Dr. Olbers’ measurements agree with them.

According to Mr. Schroeter’s previous measurement and observations the planet has a measurable
diameter of at least two seconds.

On the 10th Sept. its station was between two stars of Lalande of the 8th magnitude, but by
removing part of their irradiations the two fixed stars were soon reduced to small spots less than a
second in diameter, whereas the planet with the reflected light of the sun only retained its
magnitude; and remained faintly visible when the fixed stars could no more be seen.