The Astronomical Heritage of Scientific Method
The Case of the Discovery of the Orbit of Ceres

by Tarrajna Dorsey

PROLOGUE

The history of the determination of the orbit of the minor planet, Ceres Ferdinandea, exemplifies a dilemma in the long arc of the scientific maturation of mankind, which, though only a proverbial ‘drop in the bucket’ to a deluge of scientific achievements, nevertheless presents to us an infinitesimal reflection of the essence of the ongoing struggle over the nature of the mind of man, the Universe, and the Creator. For as long as men have been known to inhabit the Earth, had eyes to see, and a mind with which to reflect, they have taken curious and careful note of the heavens. The motions of these twinkling lights of the firmament have been carefully observed and recorded from the time of the ‘old men’ of Egyptian civilization, to the Pythagoreans of antiquity, through the many succeeding ages of mankind. In each case, contemplation of the nature of the universal order which conducts this magnificent opus, has elicited a strong sense of wonder in the mind of the beholder, accompanied by a compelling desire to make the invisible composition of its movements visible, to the mind. It is the pursuit of this very inclination which has yielded the fruits of civilization to man; both the actual harvests of cultivation of the earth, as well as the ripening of man’s knowledge of truth, or what we call science. On the other hand, the denial of this sense of awe and creative hypothesis has only served to stultify and impede man’s development. The proof of this crucial point is illustrated in the case of Ceres, as will be expounded upon, presently.

The Pythagoreans, Plato, and Piety

First, we must turn our sights to a much earlier time, to the well-springs from whence this discovery came. This brings us to the ‘early’ investigations of the Pythagoreans, whose ideas have been most clearly captured and unfolded to us through the works of Plato.¹ Before elaborating upon the role of the Pythagoreans, let it be emphasized that we are not attributing the origins of investigation of the heavens, mensuration, trigonometry, etc., to the Greek era. By current knowledge, the monitoring of lunar cycles and eclipses occurred long before Greek civilization made its entrance onto the stage of world history, and the Egyptians had developed language for the measurement of pyramids, etc., in their age. Proclus, a Greek scholar who writes commentaries upon the work of the Greeks, tells us of Thales bringing the knowledge of geometry from the Egyptians to the Greeks. Also, references to a far more ancient people and mode of thought appear again and again in the course of Plato’s dialogs.

Thus, what is emphasized here as originating uniquely with the Pythagoreans, relates more to the foundations, or epistemology (“what one stands upon”), of their mode of thought and manner

¹See the Timaeus, but also The Republic, especially Book VII, as well as the Philebus, Theaetetus, and, although some dispute its having been authored by Plato, the Epinomis. Regardless of this controversy, this dialog clearly reflects the nature of Pythagorean thought, as will be demonstrated below.
of inquiry. For example, the concept of the Earth and universe possessing a *spherical* nature, which must be investigated from that standpoint, is uniquely ‘Pythagorean’. This point is illustrated to us by an Alexandrine poet, Hermesianax, in the following manner: “What inspiration laid forceful hold on Pythagoras when he discovered the subtle geometry of (the heavenly) spirals and compressed in a small sphere the whole of the circle which the aether embraces.”  

In this way, they sought to uncover the fabric of the world which binds together the pinions of creation, by looking into those things which instigate man’s wonder and curiosity, provoking him to seek out their cause, such as the musical harmonics, the five regular solids, the commensurability of certain types of number, etc. The Pythagoreans are well known for the saying, “a figure and a step, but not a figure and three oboli,” which succinctly portrays that the steps upon which they climbed were laid out of a love for truth in and of itself, which looked for unity in all investigations into the nature of things, as opposed to a utilitarian search for formulae which could serve as ‘useful tools’.

In the *Epinomis* dialog between an Athenian, a Cretan, and a Lacedaemonian, on the establishment of laws and what studies will lead a mortal man to wisdom, their discussion arrives at the question of: “what single science there is, of all those we have, such that were it removed from mankind, or had it never made its appearance, man would become the most thoughtless and foolish of creatures?”

Namely, what is the species character of mankind? What is the essence of that which distinguishes man from all other living creatures? This discussion of antiquity lights upon the concept of number, not as learned from the so-called ‘counting’ of objects, but rather from the lessons taught by the heavens: the period of the Sun, distinguished by day and night, the waxing and waning of the Moon, falling within the greater period of a year, the return of a planet to a certain grouping of stars, etc. Or, in the words of the Athenian: “...when God had made the moon in the sky, waxing and waning, as we have said, he combined the months into a year and so all the creatures, by a happy providence, began to have a general insight into the relations of number with number.” Thus, we see that the distinguishing characteristic of man, or cognitive beings, is ascribed to the faculty of reflection upon the periodic celestial motions. But this “reflection upon” does not merely consist of simple observation. Let us listen further to what the Athenian has to teach.

...We must do what we can to enumerate the subjects to be studied and explain their nature and the methods to be employed, to the best of the abilities of myself who am to speak and you who are to listen—to say, in fact, how a man should learn piety, and in what it consists. It may seem odd to the ear, but the name we give to the study is one which will surprise a person unfamiliar with the subject—astronomy. Are you unaware that the true astronomer must be a man of great wisdom? I do not mean an astronomer of the type of Hesiod and his like, a man who has just observed settings and risings, but one who has studied seven out of the eight orbits, as each of them completes its circuit in a fashion not easy of comprehension by any capacity not endowed with admirable abilities. I have already touched on this and shall now proceed, as I say, to explain how and on what lines the study is to be pursued. And I may begin the statement thus.

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3Taylor, Thomas. *Theoretic Arithmetic*. 1816. Another translation of this ‘motto’, from *A History of Greek Mathematics*, reads thus, “a figure and a platform, not a figure and sixpence,” which is included in order to contribute to a better understanding of the Pythagorean’s view. The author’s introduction to this referenced work of Thomas Taylor’s is well worth the reading, as it contains further insights into the beauty of Pythagorean and Platonic thought.

The moon gets round her circuit most rapidly, bringing with her the month, and the full moon as a first period. Next we must observe the Sun, his constant turnings throughout his circuit, and his companions. Not to be perpetually repeating ourselves about the same subjects, the rest of the orbits which we enumerated above are difficult to comprehend, and to train capacities which can deal with them we shall have to spend a great deal of labor on providing preliminary teaching and training in boyhood and youth. Hence there will be a need for several sciences. The first and most important of them is likewise that which treats of pure numbers—not numbers concreted in bodies, but the whole generation of the series of odd and even, and the effects which it contributes to the nature of things. When all this has been mastered, next in order comes what is called by the very ludicrous name \( \text{geometry} \) (\( \gamma \varepsilon \omega \mu \varepsilon \tau \rho \iota \alpha \)), but is really a manifest assimilation to one another of numbers which are naturally dissimilar, effected by reference to areas. Now to a man who can comprehend this, it will be plain that this is no mere feat of human skill, but a miracle of God’s contrivance. Next, numbers raised to the third power and thus presenting an analogy with three-dimensional things. Here again he assimilates the dissimilar by a second science, which those who hit on the discovery have named \( \text{stereometry} \) [the gauging of solids], a device of God’s contriving which breeds amazement in those who fix their gaze on it and consider how universal nature molds form and type by the constant revolution of potency and its converse about the double in the various progressions. [emphasis in original]

We are now able to clearly see how the Pythagorean’s practice of “piety” necessitated undertaking the study of “geometry” (which is mistakenly asserted by some scholars to have originated solely from the measurement of plots of land), stereometry, etc. Already here, there exists the concept of a unity underlying these studies, the pursuit of which promises to ripen the wisdom of man, and in turn, increase his wellbeing. As if issuing a challenge, to those after him, to take up and continue this method of investigation, our Athenian leaves off his speech with the following call:

To the man who pursues his studies in the proper way, all geometric constructions, all systems of numbers, all duly constituted melodic progressions, the single ordered scheme of all celestial revolutions, should disclose themselves, and disclose themselves they will, if, as I say, a man pursues his studies aright with his mind’s eye fixed on their single end. As such a man reflects, he will receive the revelation of a single bond of natural interconnection between all these problems. If such matters are handled in any other spirit, a man, as I am saying, will need to invoke his luck.

The Harmony of the World

The man who fully heeded the call of the Athenian, nearly two millennia later, was Johannes Kepler (1571-1630). From the beginning of his theological studies at Tübingen as a young man, Kepler committed himself to investigating the true nature of the system of the world, rejecting the widespread belief in the Ptolemaic model, and even defending the Copernican model in debates amongst his peers. However, he was more driven by the desire to understand the reason why the universe is ordered in one particular way rather than any other, as opposed to adopting any particular model which could accurately represent the apparent phenomena of that order. Thus, while maintaining his first job of teaching mathematics in the small town of Graz, Kepler began to work on answering several very prominent questions in his mind: “Why are there six planets? Why are their distances from the Sun exactly such and such? Why do they move more slowly the further they are from the Sun?”

5 The result of this first inquiry, “my little book,” as he later called it, was the \( \text{Mysterium Cosmographicum} \) (The Secret of the Universe), published in 1596. In the greeting to the reader, Kepler announces the content of his investigation, thus:

5Caspar, Max. *Kepler*. Collier Books, New York. 1962. Of note, Caspar remarks, directly following this quote, “With these bold questions about the reasons for the number, the size and the motion of the heavenly paths, the young seeker after truth approached Copernicus’ picture of the world. Just as the latter had to some extent marked the borders of the universe, so now Kepler tried to prove physically and metaphysically that these bounds were the plan of the Creator, who in His wisdom and goodness could create only a most beautiful world. Nothing in the world was created by God without a plan; this was Kepler’s principal axiom.”
The nature of the universe, God’s motive and plan for creating it, God’s source for the numbers, the law for such a great mass, the reason why there are six orbits, the spaces which fall between all the spheres, the cause of the great gap separating Jupiter and Mars, though they are not in the first spheres—here Pythagoras reveals all this to you by five figures. Clearly he has revealed by this example that we can be born again after two thousand years of error, until the appearance of Copernicus, in virtue of this name, a better explorer of the universe. But hold back no longer from the fruits found within these rinds.

This was only the very beginning of Kepler’s lifelong passion to seek truth. The sheer honesty with which he pursued this end, is demonstrated by his eagerness to throw aside his own failed hypotheses, in order to take up new, more developed ones. This quality was especially reflected by his annotations to the Mysterium Cosmographicum, which he added many years later, after having published the crowning jewel of all of his works, the Harmonices Mundi (Harmony of the World), in 1619. However, in spite of this constantly developing process, Kepler’s epistemology remained firmly rooted in the understanding that the universe is composed as a unity, and capable of being comprehended by the mind of man. Not only were Kepler’s inquiries consciously built upon the foundations which the Pythagoreans had erected, but he himself expounded upon this relationship of the mind of man to the universe, and to the Creator.

...Would that excellent Creator, who has introduced nothing into Nature without thoroughly foreseeing not only its necessity but its beauty and power to delight, have left only the mind of Man, the lord of all Nature, made in his own image, without any delight? Rather, as we do not ask what hope of gain makes a little bird warble, since we know that it takes delight in singing because it is for that very singing that the bird was made, so there is no need to ask why the human mind undertakes such toil in seeking out these secrets of the heavens. For the reason why the mind was joined to the senses by our Maker is not only so that Man should maintain himself, which many species of living things can do far more cleverly with the aid of even an irrational mind, but also so that from those things which we perceive with our eyes to exist we should strive toward the causes of their being and becoming, although we should get nothing else useful from them. And just as other animals, and the human body, are sustained by food and drink, so the very spirit of Man, which is something distinct from Man, is nourished, is increased, and in a sense grows up on this diet of knowledge, and is more like the dead than the living if it is touched by no desire for these things. Therefore as by the providence of Nature nourishment is never lacking for living things, so we can say with justice that the reason why there is such great variety in things, and treasuries so well concealed in the fabric of the heavens, is so that fresh nourishment should never be lacking for the human mind, and it should never disdain it as stale, nor be inactive, but should have in this universe an inexhaustible workshop in which to busy itself.

Proving the truth of his own musings, Kepler busied himself quite diligently in this workshop of the Creator, hammering away at the pliable sheets of his own hypotheses, heated in the forges of a burning passion for truth, and molded by the strong force of his keen intellect. In the Harmonices Mundi, Kepler utilizes the manifold quality of this workshop to investigate the principle underlying the motions of the heavenly bodies. By looking at the relationships which arise in vision from the division of the circle, the formation of regular solids in physical space, and juxtaposing them with the proportions arising from the audibly perceivable divisions of the string—the musical harmonies—Kepler is able to demonstrate the coherence of the planetary orbits in this way, in their relations to one another, and to the Sun.

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7Also from the Mysterium Cosmographicum, excerpted from Kepler’s original dedication.

8For a much more extensive, and highly rigorous investigation of Kepler’s work, see http://ulym.com/~animations/harmonies/index.php.
It is no mere lucky coincidence, nor strange outcome of historical probability, that by precisely this method, and no other, Kepler was the very individual to draw the veil from the mysteries of the planetary orbits, discovering the principle of universal gravitation, and making his discovery communicable to mankind. Admittedly, he stood upon the shoulders of many great thinkers who preceded him, but more importantly, again, the crux of the matter rests upon the issue of epistemology; the method of thinking, and the fundamental concepts of the coherence of God, the creation, and the mind of man. This is the very arc of thought which will come into play in the matter of the dilemma of determining the orbit of Ceres.

**LET THE PLAY BEGIN**

As is the case with all fruitful scientific inquiry, however, Kepler’s monumental contributions not only served to open the doorway to an entirely new domain of investigation, but they left unanswered questions concerning the order of the universe as well. Among the harmonies of the world which Kepler demonstrates to exist as the governing cause for the distances and periods of the planets’ orbits, an anomaly arises, which Kepler finds himself unable to reconcile with his hypothesis. The anomaly appears in the case of the proportions between the orbits of Mars and Jupiter. Contrary to harmonic proportions found among the relations of the other planets’ motions, nothing quite satisfying could be found for those between Mars and Jupiter. The distances between them could be explained, using the inscribing and circumscribing spheres of the tetrahedron, one of the five regular Platonic solids. However, as Kepler found from his investigations into the various harmonic proportions in the Harmonices Mundi, the reason for the particular structure of the solar system did not lie in the proportions of the Platonic solids alone, as he had originally thought, but in the proportions of musical harmony, as expressed by what Kepler calls the converging and diverging motions of the heavenly bodies. In the converging and diverging motions of Mars and Jupiter,¹⁰ however, no “pleasing” musical harmony is to be found, and this leaves Kepler, and those after him, to continue to wonder.

One of the possibilities which Kepler considers, and experiments with, even in the Mysterium Cosmographicum, is the existence of another, yet unknown planet, hiding somewhere in the vast gap between Mars and Jupiter. Although actual distances of the planets are not known exactly in Kepler’s time, their relative distances are, and this immense gap is knowable even by comparison of their relative periods. In this gap, lies, so to speak, the ‘sleeping giant’, which will not be awoken until many, many years after Kepler’s death, and, when stirred from slumber, will cause great trouble to all of the geometers, mathematicians, and astronomers of Europe.

**The Missing Planet**

In the period following that of Kepler’s breakthroughs in physical scientific method, there endured another long silence for mankind—certainly not of two thousand years—but with Kepler’s death came a tremendous battle over the preservation of his life’s work.¹¹ Apart from the studies of Gottfried Wilhelm Leibniz and his collaborators, the furtherance of physical scientific method, as developed and applied by Kepler, fell by the wayside.

We now arrive at the core of our narrative, commencing in the middle of the 18th century. Amidst a heated battle over the ideas of Leibniz and Kepler, one of their chief defenders, Abraham Gotthelf Kästner (1718-1800), takes the helm on the matter of scientific inquiry and astronomy. In

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¹⁰ The converging motion (as viewed from the Sun) being the proportion of the perihelial arc of the outer planet to the aphelion arc of the inner, and the diverging being the aphelion of the former to the perihelial of the latter. The perihelion is when the planet is the closest in its orbit to the Sun, whereas the aphelion is the farthest away it is in its orbit.

¹¹ In Kepler’s own words, from the *Harmonices Mundi*, “These, then, are the harmonies with each other allocated to the planets; and there is none of the direct comparisons (that is to say between convergent and divergent extreme motions) which does not come very close to some harmony, so that if the strings were tuned in that way, the ears would not easily be able to detect the imperfection, except for the excess of the single one between Jupiter and Mars.”
1747, he pens a piece entitled “Lob der Sternkunst” (The Praise of Astronomy), in which he cleverly enumerates the uses of astronomy to human society, but then moves to the following, more profound discussion, revealing himself to be an inheritor of the arc of thought of the Pythagoreans and Kepler:

...It may seem superfluous to speak of the delightfulness of astronomy, now that its uses have been demonstrated. However, those who have felt the delectation given us by the knowledge of truth, would not forgive me were I to be silent of this [emotion] in astronomy. Are we satisfied with a secure insight into such laws which seem impossible to the ignorant? Do we take delight in comprehending how, from a very limited understanding, the most hidden truths have been deduced? Does one wish to know, how far the powers of human reason reach? Then, one should study astronomy. [Astronomy] establishes the orbit of the daytime stars; she proclaims the eclipses unto the moons; she orders each planet to move faster or slower; she commands how many seconds the whole army of fixed stars should move in uniform order each year....Actually, she does not command, rather she investigates the edicts which the Creator prescribed for the whole universe, with reverent curiosity.”

Despite the current stall in the advancement of scientific method, the world of observational astronomy is abuzz with activity. New developments in instrumentation are being made, new observatories built across Europe, new comets sighted regularly, and even the new phenomena of “comet scares” have become all the rage. Star charts, featuring dozens of new stars are constructed, the previous obscurity surrounding various astronomical phenomena such as nebulae and star clusters is cleared, and even a new planet, Uranus, is discovered! However, Kepler’s sleeping giant, the question of the gap between Mars and Jupiter, looms in the periphery of these advancements. Some references are made to the idea of a missing planet, here or there, but for the most part, Kepler’s mode of inquiry, which had produced the question in the first place, is


\[\text{13} \text{Searching for comets became a common pastime, the spirit of which is captured by Kästner in his poem, “Reflection Upon the Occasion of a Comet”:}\]

\[\text{By lens, through which our feeble gazes}\]
\[\text{The ken of realms afar gains might,}\]
\[\text{Was yesterday, the globe that blazest,}\]
\[\text{With certain luck, revealed to sight.}\]
\[\text{The jovial Heaven’s azure reaches}\]
\[\text{Present themselves before the eye;}\]
\[\text{Amongst the starry host is seated}\]
\[\text{No comet, but a Pole on high.}\]

\[\text{“Aha! I now at last have found it,”}\]
\[\text{Cries out a watcher, filled with hope;}\]
\[\text{He cries, and sees his luck diminish:}\]
\[\text{His hand has bumped the telescope.}\]

—Translated from the German by the author.

\[\text{14} \text{Many widespread panics were created by agitators announcing they had calculated that a comet would soon coincide with the path of the Earth, crash into it, and wreak extraordinary havoc.}\]
scorned by ‘modern’ empiricists. Illustrative of the case are the remarks made by a most renowned astronomer of the day, hailed in his time as “the Newton of France,” Pierre Simon de La Place (1749–1827), concerning Kepler’s method and work. In his *Exposition du système du monde* (1796), he opines:

...In [Kepler’s] time, the world had just begun to get a glimpse of the proper method of proceeding in the search of truth, at which genius only arrived at by instinct, frequently connecting errors with its discoveries. Instead of passing slowly by a succession of inductions, from insulated phenomena, to others more extended, and from these to general laws of nature; it was more easy and more agreeable to subject all the phenomena to the relations of convenience and harmony, which the imagination could create and modify at pleasure.”

This tiny glimpse into the thoughts of La Place suffices as a telling insight into the paucity of the entirety of empirical scientific method, a highly dominant fad of the time.

The vacuity of La Place’s observations is by no means the only affliction plaguing the currents of scientific thought at this time: a notion, tossed about in seeming answer to Kepler’s unexplained anomaly, surfaces in the form of what is referred to as the “Titius-Bode law of harmonic progression.” The story begins with a certain Baron von Wolf, a supposed protégé of Leibniz, who had published a work on physics in German, in 1741. Therein, he includes a scheme to describe the distances of the planets from one another by dividing the distance from the Sun to the Earth into ten parts, and assigning the other planets numerical values accordingly. Although he does not cite the origin of this mechanism, our researches have uncovered that this scheme was lifted nearly word for word from a passage of Newton follower David Gregory’s *The Elements of Astronomy*, published in 1715.

Unfortunately, this scheme was snatched up and developed into an empiricist gimmick to explain the planetary distances by Johannes Daniel Titius, a German professor of mathematics and physics at Württemberg. He is cited by Baron Franz von Zach, astronomer and editor of the main astronomical and scientific journal of the day, the *Monatliche Correspondenz zur Beförderung des Erd- und Himmels-Kunde* (Monthly Correspondence for the Furthering of Geography and Astronomy), as the originator of the aforementioned so-called “harmonic progression” in the planetary orbits. Johann Elert Bode, an astronomer and mathematician heading up the Berlin observatory, and chief publisher of the other major astronomical and scientific journal of the time, the *Berliner Astronomisches Jahrbuch* (Berlin Astronomical Almanac) contracts this scheme from Titius, and comments upon it in his astronomical treatise *Einleitung zur Kenntniss des gestirnten Himmels* (Introduction to the Knowledge of the Bespangled Heavens), published in 1772. In Baron von Zach’s column, he elaborates upon the lineage of the idea of this “harmonic progression,” and cites Bode’s 1772 article to fully represent the “theory”:

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16 [MERV: On Wolf’s *Anfangsgründe*, and Lessing’s refutation of his supposed close ties to Leibniz.]
17 For a more extensive discussion of this matter, see “Empiricism as Anti-Creativity: How the Venetians Tried to Erase Kepler from Science,” specifically pages 12-13.
http://www.wlym.com/~animations/ceres/InterimII/Preliminary/KeplertoGauss.html
18 See the June 1801 issue, Volume III.
...the interval between Saturn and the Sun is partitioned into 100 equal parts thus:

1) Mercury............. 4 such parts of the Sun distance
2) Venus.................. $4 + 3 = 7$
3) Earth............... $4 + 2 \cdot 3 = 10$
4) Mars.................. $4 + 2 \cdot 2 \cdot 3 = 16$
5) Hera or Juno........ $4 + 2 \cdot 2 \cdot 2 \cdot 3 = 28$
6) Jupiter................ $4 + 2 \cdot 2 \cdot 2 \cdot 3 = 52$
7) Saturn............... $4 + 2 \cdot 2 \cdot 2 \cdot 2 \cdot 3 = 100$
8) Uranus............. $4 + 2 \cdot 2 \cdot 2 \cdot 2 \cdot 2 \cdot 3 = 196$

Or expressed generally, the distance of the $n^{th}$ planet from the Sun is calculated with $4 + (2^{n-2} \cdot 3)$. Or, as Prof. Wurm has done, the mean distance of the first planet is expressed by $a$, the difference between the distances of the first and second with $b$, the mean distance of the Earth from the Sun = $1$: thus, each $n^{th}$ planet’s mean distance from the Sun $= a + (2^{n-2} \cdot b)$.

Because the new planet, Uranus, discovered in 1781 by William Herschel (although first noted much earlier, in 1690, by John Flamsteed), conformed to a slot in this number series, many people, including Bode, became convinced of its truth, while others rejected it as unscientific, and a chimerical hoax. The individual cited by Bode, for example, Johann Friedrich Wurm (1760-1833), a professor from Württemberg, was very unhappy to be referenced in support of the scheme. He had written several articles on the matter, but with the intention of disproving the scheme. In his words, taken from an article he submits to the Monatliche Correspondenz in late 1802, “One sees that it is something easily done, to find out similar laws of progression by the dozens, if one is simply generous enough, and is satisfied by a rough approximation. However, should not this very fact—that any number of these presumed progressions could agree with the observations as well or as poorly as any other—present here most clearly the arbitrariness of the assumption that these laws and progressions even appear in reality at all!”

The main damage done by this scheme, however, was to replace Kepler’s valid hypothesis which created the possibility of another planet between Mars and Jupiter, based on a truthful scientific investigation of the order of the universe, with a numerical ‘trick’. Baron von Zach, who will become an important player in our drama, responds to the Titius-Bode frenzy in his entry in the June 1801 Monatliche Correspondenz in the following manner:

This law is based on no theory known to us, at least, to the present, it cannot be proven mathematically, and it has been merely empirically deduced by analogy. In no other science has the human spirit—purely through mathematical logic, and through the sharpness of geometrical meditations—brought out more, surer, and purer truths than in Astronomy. If one considers the magnitude and sublimity of the object with which this science occupies itself, and looks at the tininess of Man and of his home; if one considers the immeasurable variety and connection between heavenly phenomenon, all of which

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20 In a letter from Gauss to his collaborator Olbers, Gauss thoroughly finishes off any last possible belief in the validity of this “law.” “...could the known law, which Bode remarkably got going, and which Ceres at first seemed to confirm so nicely, be destroyed at once? —That would not surprise me at all. Speaking confidentially, I have never thought much of it, and must impart an observation to you, which I had made in petto [privately] 12 years ago, wherefore it amazes me that it had not been made long ago. Briefly, it is this:

The series

$$4, \ 4 + 3, \ 4 + 6, \ 4 + 12, \ 4 + 24, \ 4 + 48, \ 4 + 96, \ 4 + 192$$

is not a continuous series. To see this, it need only be noted that $4 + 3$ should be preceded by, not 4, but rather $4 + 1 \frac{1}{2}$, so that Mercury is not passed over in the series, or that there should not still be an infinite number of planets between Mercury and Venus. Which is quite unconceivable...”
will be deduced from one single, very simple law of nature which extends through the entire domain of Creation, the law of universal gravitation; if one considers what profound mathematical methods and analytical techniques must be found to design the calculation of all these manifold phenomena combined, and to achieve a certain perpetual accordance of the calculations with the actual events of the sky—thus must the layman profess, as the initiate certainly professes, that in no other science have so many discoveries been made \textit{a priori}, and that no other science grounds itself on unalterable proofs, more than sublime Astronomy.

Baron von Zach continues on in his historical account of the idea of a planet existing in the gap between Mars and Jupiter, bringing up the fact that the concept was specifically a German idea, and that in no other language culture had it been mentioned as even a suspicion. He attributes the reason for this to the “spirit of a Kepler!”

**Baron von Zach’s “Celestial Police”**

In this Keplerian spirit, Baron von Zach, the court astronomer for the Duke of Saxe-Gotha, had singlehandedly taken up the mission of searching out and locating the missing planet in the gap between Mars and Jupiter. Although he was director of the observatory at Gotha, Seeburg, and had access to some of the top of the line instruments of the day, it was no small task to accomplish such an endeavor. “Finding a needle in a haystack” is an understatement of the magnitude of this challenge. After having searched fruitlessly for several years since 1787, although publishing many star-charts containing his finds, von Zach participates in a meeting with several of his fellow astronomers in the Fall of 1800. The gathering takes place in Lilienthal, near Bremen, at the home of one among the several accomplished German astronomers, Johann Hieronymus Schroeter. Schroeter is head of the observatory at Lilienthal. Also in attendance are Wilhelm Matthias Olbers, Karl Ludwig Harding, Baron Ferdinand Adolf von Ende, and Johann Gildemeister. Von Zach himself later describes the nature and intention of the proceedings in his \textit{Monatliche Correspondenz}, which we include in full here to paint the living sense of the story, which has not been fully and accurately recounted by any other sources known to this author, up until now.

All of these obstacles can, in part, be foreseen, and it would only be possible to find this planet, among the innumerable quantity of telescopic stars, by means of chance, or by \textit{systematic design}. Since I took up a new revision of the stars of the heavens in Gotha in the year 1787, I already had the seeking out of this planet in mind then, thereto the excellence of the most illustrious founder of the Gotha Uranien Temple\textsuperscript{21} encouraged me. I limited myself solely to the stars of the zodiac, and prepared my zodiacal star catalog in right ascensions, with the conviction, that it were only possible to come upon the hidden planet systematically in this way.

Since I had the pleasure of making a small astronomical journey to Celle, Bremen, and Lilienthal in the autumn of last year, and there spent an enjoyable week in the instructive company of the most deserving and scholarly German astronomers, the opinion of these insightful men was that, in order to track down this planet, considered as missing for

\textsuperscript{21}The Duke of Saxe-Gotha, Ernst II.
so long, it could not be a task for one, or a few astronomers to search through all the telescopic stars in the entire zodiac. Six astronomers gathered in Lilienthal, on the 21st of September, 1800, thus founded a closed society of 24 practical astronomers dispersed across Europe, for the systematic seeking out of this presumed planet between Mars and Jupiter. They selected chief-magistrate SCHRÖTER as the President, and the honor and confidence of the lot of standing secretary of this astronomical society was deputized to me. The plan of the society was, in addition to many other proposals, to divide up the entire zodiac among the 24 members. Each should receive, by lottery, an enclosed zone of inspection of 15° longitude, and 7° northern and southern latitude, and be recommended especially watchful surveillance of it. Each member should draft a fairly precise map of the heavens for their department, up to the tiniest of telescopic stars, and ensure himself, through repeated revision of the skies, of the unchanged condition of his district, or of every wandering foreign guest. By means of such a strict organization in 24 departments, we, the celestial police, hope to finally track down this planet, which has eluded our gaze for so long, if it exists at all and shows itself to be visible. By order of this society I soon issued invitations, in the name of the society, to many of the most renowned practical astronomers in Europe, and gave them entry to this joint astronomical purpose. Nearly all have accepted it with satisfaction. Some members of this society are already in full operation, and have already sent interesting reports concerning their inspections, and should the honor of the first discovery of this planet be robbed from our burgeoning society, then it is, however, not only the presumed discoverer of it being among the number of members of this society alone (to whom the unrest of war, obstruction of the postal service and shipping, have hindered our invitation from being able to reach), but also this society still has much, and will have still more to contribute to the correction of our star catalog, and since this is not the only aim of the society in the realm which astronomy occupies, continuing such a service will also be of lasting use. [emphasis added]

This newly formed astronomical society, the first of its kind across Germany, and Europe as well, served as the seeding for all of the astronomical societies which followed, up to the present day. The motto selected by the society, “We do not behold the risings and settings of the constellations in vain,” (Non frustra signorum obitus speculamur et ortus –Virgil) rings of the same tone of our Athenian from earlier. Shortly preceding the formation of this society came the establishment of von Zach’s monthly publication, the Monatliche Correspondenz, which functioned precisely according to the intention stated in the title: a means of making the correspondences between these and other astronomers across Europe transparent to one another, so that advancements in the knowledge of the Earth and the heavens could be made as quickly as possible. Many members of this society will become the chief characters, and this newly founded journal the stage, within, and upon which, our present drama shall play.

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22 The 24 astronomers were as follows: J. E. Bode (Berlin), J. S. G. Huth (Frankfurt am Oder), G. S. Klügel (Halle), J. A. Koch (Danzig), J. F. Wurm (Blaubeuren), F. von Ende (Celle), J. Gildemeister (Bremen), K. L. Harding (Lilienthal), F. X. von Zach (Gotha), J. T. Bürg (Vienna), T. Bugge (Copenhagen), D. Melanderheim (Stockholm/Uppsala), J. Svanberg (Uppsala), F. T. Schubert (St. Petersburg), J. C. Burchhardt (Paris), P. F. A. Mechain (Paris), C. Messier (Paris), C. Thulis (Marseille), N. Maskelyne (Greenwich), W. Herschel (Slough by Windsor), J.B. Sniadecki (Cracow), B. Oriani (Milan), and G. Piazzi (Palermo). It is important to note, however, that Piazzi had not yet received any invitation or knowledge of the society’s intention until much later, after his sighting of Ceres. See Federico Serio, Manara, Sicoli:Giuseppe Piazzi and the Discovery of Ceres in Sources.

23 The positions held by Schroeter, von Zach, and von Ende (President, Secretary, and Vice-President), were later assumed by Gauss, Bessel, and von Lindenau, who also succeeded von Zach as the head of the Gotha observatory and editor of the Monatliche Correspondenz.
Ceres Ferdinandea

On the evening of the first day of the new year, 1801, unaware of the establishment of von Zach’s “burgeoning” society, a Sicilian priest and teacher of mathematics, Giuseppe Piazzi (1746-1826), who had taken up the mission of facilitating the construction of an observatory in Palermo, Italy, pursued his nightly routine. This consisted of a search, using the two meridian telescopes he had singlehandedly labored to purchase, transport, and install, for the 87 stars of Taurus according to the catalog of La Caille, an astronomer who had assembled this catalog during a trip to the Cape of Good Hope in 1755, and which had been appended to the publication of Messier’s star catalog in 1784. Piazzi was working on assembling a newer, more accurate map of stars along the meridian, and thus had to begin with what was already known. At around nine o’clock in the evening, he spied a small star, which preceded the ones he was tracking by only 61 seconds. He decided to observe it, as long as it did not get in the way of his primary observations. It appeared in his telescope to be a magnitude eight star, which is a measurement of the intensity or brightness of the light given off by the star, Vega being the standard at zero, and anything brighter than it, such as the Sun, measured as negative along the scale, and anything dimmer than it, such as this particular star, measured as positive along the scale.

Upon making the same observation the next night, Piazzi found that the time that the foreign star crossed the meridian, its ‘culmination’, and the declination of the star, had both changed. Naturally, were this a fixed star, such would not have been the case. Committed to precision, however, and suspecting that this might have been merely due to an inaccuracy in the observation made the night before, Piazzi waited to make sure of these results upon the following evening. When the third evening arrived, Piazzi was assured of the truth of his observations: this was no fixed star. He waited one more evening, just to be sure, and was again confirmed in his suspicion. Unfortunately, as is always the case in astronomy, Piazzi found himself at the mercy of the weather, which was very poor from the next day, January 5th, until the 9th. On the 10th, the weather had cleared, and Piazzi was able to locate five stars of relatively the same magnitude, very near to one another, causing him uncertainty as to which among them was his newfound stranger. After comparing the positions with his previous observations, and continuing to track them in the ensuing nights, however, he was able to easily recognize the singular motion of his fugitive.

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24[On the Ramsden Meridian circle, and possible a graphic?]
25[Ask Peter, or do one on Messier’s objects.]
Piazzi's report on his discovery of Ceres, published in 1802. (In Umfeld der Theoria Motus.)

Piazzi now wished to observe this star outside of solely the region of the meridian, but due to the limitations of his instruments, and priority of his star map work, he was limited to the 2′ time interval during which the star passed through the field of his telescope. He continued observations of the star up until the 11th of February, when it came too close to the Sun to be seen in the meridian. Piazzi had, by this time, resolved himself to follow the star outside of the meridian, using the azimuth component of his telescope. To the lament of all astronomers thereafter, however, he fell ill on the 13th (from having caught a cold from working outside at night on building a meridian circle), and was not able to carry out this aspiration.

From here, our narrative is transported across Europe, to the two recipients of the news of Piazzi’s findings, which he communicated in the form of two letters, on January 24th. One letter, containing the exact observations he had made on the 1st and 23rd of January, as well as the information that it had gone from retrograde to direct motion from the 10th to the 11th, and his surmise that “it could be something better than a comet,” was sent to his Italian collaborator, Barnabas Oriani (1752-1832). The other letter, containing the same information, but stating merely that it was a comet, was sent to Bode, in Berlin. The letter intended for Oriani did not reach him until April 5th, and for Bode, until May 20th. Thus, the first actual recipient of the news and complete set of observations was actually a French astronomer, Jerome Lalande, who had read an announcement of the sighting of a comet in Palermo in the Journal de Paris in February, and promptly wrote Piazzi to request the complete set of observations. On April 11th, Piazzi fulfilled Lalande’s request, also sending the complete set to Oriani, with the stipulation that they not make them public before himself. Lalande received the full set on May 1st, and imparted them directly to Johann Karl Burckhardt. Olbers as well received the news of the sighting and the two observations, most likely from Bode.

Little did Piazzi know what he had done when he sent out news of his sighting! All of the astronomers mentioned above were immediately struck with the hope that this might very well be the missing planet that had been sought after for so long! All of them sent the news they had received directly or indirectly from Piazzi, to von Zach, who immediately published this news in his first jubilant entry to his new column of the June 1801 issue of the Monatliche. “On a new, primary planet of our solar system, long suspected to be between Mars and Jupiter, and now possibly discovered[!]” In the following issue, July, von Zach had received the first attempts by Olbers and Bode to calculate the orbit of the mysterious star, using only the two observations that they had been given. In the letter containing his circular elements, Olbers exclaims to von Zach, “It was simple to guess a planet for such a small, and slow moving star without any cloud, so near to the ecliptic. However, the credit remains to Piazzi, not only for discovering the new planet, but for already having announced it as such, himself. Can Piazzi have thus robbed our sprouting society of the glory of discovering a new planet?”
Wilhelm Olbers (1758-1840) was one of the most highly respected astronomers in Germany, which is made all the more significant in light of the fact that he was not ‘officially’ an astronomer at all, but rather an accredited doctor! He studied at Göttingen from 1777 to 1780, taking his mathematics courses from Professor Kästner, the head of the observatory there. Although considered as an ‘amateur’ astronomer because he had no observatory, per se, and only a few smaller telescopes, Olbers was a highly committed one. He would carry out his profession of physician during the day, and then spend a large portion of his nights staying up to make observations and calculations. In 1797, he published a comprehensive work on the method he had developed for determining the orbits of comets.\textsuperscript{26} In the course of von Zach’s 1800 trip to Bremen and Lilienthal, Olbers provided him with a tour of his makeshift observatory. Von Zach was very impressed with his work, and praised him for his knowledge of astronomical instruments, measurements, calculations, and overall assiduity.\textsuperscript{27}

In this spirit, Olbers employs aspects of the method he has developed to calculate a circular orbit for the two observations of the “possible planet,” but himself warns von Zach in the letter that he sends on May 16th, that his calculated orbital elements\textsuperscript{28} will not be at all accurate enough to assist in the relocation of the planet, which has now become the chief aim of all of the astronomers in the conspiracy. Both Olbers and Bode, and later Burckhardt and Piazzi himself, derive an inclination for the orbit which exceeds those of all of the other major planets by a great deal. Bode comments that this is one important reason why the planet could have eluded astronomers for so long—because their searches were mainly focused in a limited band-width along the plane of the ecliptic, whereas, having such a large inclination to the ecliptic, this planet would not always be found within that region.

The refrain of the response of all of the astronomers who report their attempts at calculation of the elements of the orbit to von Zach, is that the arc it has traversed is so small, that it makes it extremely difficult to calculate. For example, von Zach cites Olbers’ comment that the elements “...are calculated with little reliability, since the observations are only 22 days apart from one another,” as well as Burckhardt’s statement that, “The small geocentric and heliocentric motion of this comet has caused me an extraordinarily great effort in the determination of its orbit.” To illustrate the frustrations of the numerous astronomers who labored upon this problem, we continue with Burckhardt’s description of the method he applied to the calculation of the orbit, noting that since he received the information directly from Lalande, he had access to the complete set of observations before most of the others:

\textsuperscript{26}Olbers, Heinrich Wilhelm. \textit{Ueber die leichteste und bequemste Methode die Bahn eines Cometen zu berechnen.}\n\textsuperscript{27}ZMC. January-March 1801. “Auszug aus einem astronomischen Tagebuch geführt auf einer Reise nach Celle, Bremen, und Lilienthal in September 1800.”
\textsuperscript{28}More on the determination of the position of a planet and the elements of an orbit will be presented in the next section of this report.
At first I had chosen the observations from the 14th, 21st, and 28th of January, and the 11th of February. Over the course of these 42 days the comet had only changed its geocentric longitude by around 3°, and its heliocentric longitude by only around 10°. Since I wished to improve the parabola found by my method by means of La Place’s method, I found that the equations of condition permitted absolutely no means of hope for doing so. I tried La Place’s method of approximation, but with so little success, which I could have seen beforehand, since the unavoidable observational errors had too great an influence on the difference of the geocentric longitudes and latitudes. I then tested eight hypotheses by means of La Place’s method of improvement, but without coming any closer to the truth....As manifold as the attempts employed up until now were, they do not prove, however, that there is no possible parabola for these observations. I have decided to apply a method to this which has often been successful to me when all other methods of interpolation abandon me....after 20 hypotheses I found the following parabola. This parabola satisfies the three observations for the longitude; however, it is not possible to represent the three latitudes with it.

At the close of the August issue of the *Monatliche*, von Zach emphasizes that, “At this time no astronomer has entirely confirmed that Piazzi’s new star is a planet, at least not to our knowledge; all those things which have been said, disputed, and calculated up until now, are speculations upon a possibility; everything has therefore been ventured only as plausible hypotheses, and any doubts against them retained, all being of the opinion that further observations after the return of this star from the Sun must be awaited, and that Time alone will be able to give us any certain instruction thereof.”

Despite all the efforts of these astronomers to calculate the orbit, in order to be able to relocate this wanderer among the multitude of stars of its like, still nothing solid had been produced by the month of September, when the full set of Piazzi’s observations were finally printed for the eyes of all, in the *Monatliche* issue for that month. It was then that the young thinker, Karl Friedrich Gauss (1777-1855), received the full set of Piazzi’s observations.

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29[LINK to Jason’s translation and FR original- did Doug finish any of the intro.?]

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Piazzi’s table of observations of Ceres, as first publicized in the September issue of von Zach’s *MC*
Victory

Although Gauss had only just begun to dabble in the field of so-called practical astronomy (though he was undoubtedly exposed to it while at Göttingen and also studying under Professor Küstner), he was already engaged in the same quality of investigation as that of antiquity, not to mention the exuberant spirit of Kepler. Gauss was eagerly following the monthly developments of the Monatliche, and when he received the September issue containing the observations, he was already prepared with a hypothesis produced from something else he had been working on, for which he saw the case of Ceres as a perfect occasion to apply his idea. Several years after this original plunge into his work on the determination of orbits, Gauss finally published a long-awaited treatise on the determination of the orbit of a heavenly body. In the preface, looking back on his original work on the orbit of Ceres, he describes the circumstances at the time in the following words:

...in every case which it was necessary to deduce the orbits of heavenly bodies from observations, there existed advantages not to be despised, suggesting, or at any rate permitting, the application of special methods; of which advantages the chief one was, that by means of hypothetical assumptions an approximate knowledge of some elements could be obtained before the computation of elliptic elements was commenced. Notwithstanding this, it seems somewhat strange that the general problem,—

To determine the orbit of a heavenly body, without any hypothetical assumption, from observations not embracing a great period of time, and not allowing a selection with a view to the application of special methods, was almost wholly neglected up to the beginning of the present century...

This is the approach that Gauss took in his method of the determination of the orbit of Ceres. Toward the end of November, when the morale of the astronomers had been significantly lowered as a result of continuous poor weather and no news of a reliable calculation, Gauss sent von Zach his four sets of calculations of the orbital elements for Ceres. Von Zach published these in the December issue, announcing to his patrons:

A great hope of help and relief is granted by the investigations and calculations recently communicated to us by Dr. Gauss in Brunswick. At the same time, they give us a new and high degree of probability, that the new star discovered by Piazzi were actually a planetary body which moves between the orbit of Mars and Jupiter according to the laws of Kepler.

We hasten with the communication of his calculation all the more, since his new elliptical orbit is considerably different from the elliptical one of Dr. Burckhardt, and from the two circular orbits of Dr. Olbers and Professor Piazzi, which we had communicated, along with the other, previously calculated orbits of the planet, in our last issue. Their deviation, in the present month, from the Gaussian position can extend from six to seven degrees in geocentric longitude. Hence, it is important that we communicate these investigations as soon as possible, for they indicate that the area of the sky in which the observational astronomers have been searching for this new, so elusive star, must necessarily be widened by six or seven degrees toward the East.

Many astronomers were eager to heed the call of von Zach, Olbers among them, one of the reasons being that Gauss’ elements were so accurate that he was able to make corrections to Piazzi’s observations based on his calculated elements, which agreed with corrections later made by Piazzi even before he had sent them to von Zach. On the night of December 31st, 1801, nearly a year after Piazzi’s original sighting of the star, von Zach confirmed his suspicion of earlier in the month, that he had indeed found Piazzi’s star. Two days later, unwitting of von Zach’s rediscovery of the fugitive, Olbers experienced the triumph of relocating Ceres as well, precisely according to Gauss’ calculated positions. Gauss had just become the champion of the astronomical world of Europe.

30[Theoria Motus, 1809.]
On the Subject of Method

Toward the end of January 1802, Gauss writes to Olbers, requesting his newly acquired observations of Ceres. Olbers happily replies, eager to strike up a correspondence with “such an excellent geometer and analyst.”\(^\text{31}\) Over the course of the lifelong correspondence which ensues between them, many exciting insights into what Gauss was thinking about and studying are to be found, which are very helpful, considering that he published a relatively small portion of what he actually investigated. Olbers’ questions to Gauss that year concerning the nature of the method by which he was able to determine the orbit of Ceres illustrate this fact, and have aided the investigations of our team to secure another reference point for how Gauss was thinking, and in what work he was engaged.

In a letter from Gauss to Olbers on August 6th, 1802, Gauss writes, “I had indeed intended, upon completion of my calculations of both new planets, to then make an agreeable occupation of drawing up a fairly detailed draft for you of the method I used for the determination of an orbit. Only I feared that a long time would yet pass before I would be completely finished with those calculations....I have thus applied several hours in order to bring an entire summary sketch of [my method] onto paper.” As an attachment to this letter, he indeed sends a draft of his method, which is later published in a slightly altered form, in the *Monatliche Correspondenz*, as an accompaniment to his main astronomical treatise, the *Theoria Motus*. This draft, later titled the *Summarische Übersicht der zur Bestimmung der Bahnen der beiden neuen Hauptplaneten angewandten Methoden* (Summary Overview of the Method Applied to the Determination of the Orbits of the Two New Planets),\(^\text{32}\) proves to contain, in a sense, a key to the method applied by Gauss. Over the course of the next few letters, Olbers asks many questions about various aspects of Gauss’ method, many of which are technical, but nevertheless succeed in eking out more shadows of Gauss’ thoughts.

As alluded to at the outset of this report, the matter which underlies this particular case of the discovery of the orbit of Ceres is that the challenge to the scientist, be he chemist, physicist, or astronomer, has always been a combination of finding oneself presented with some perceived phenomena, and then engaging in an arduous process of peering behind the phenomena, into the invisible domain of cause and principle, which is ‘seen’ only by the mind itself. It is only in this domain where real hypothesis can occur. However, at this time, the scientific fad of empiricism, referenced earlier in this discussion, dominated the scholarly institutions of Europe, its adherents priding themselves upon the notion that the mind is purely a subjective hindrance to the true scientific faculty: perception; that the only use of what they conceived of as the mind, was not to play an active and creative role in hypothesizing about the order, nature, and causality of the universe, but rather to act as a literal computer, which calculates and deduces, logically, a rule from the gathered phenomena. Indeed, if we harken back to the comments of La Place upon scientific method, it was the firm belief in this, his “proper method of proceeding in the search of truth,” which engendered the opinion, held by himself and many others, that the limited amount of available observations in the case of Ceres ensured that its determination would be impossible, its orbit entirely unknowable, until the time of its relocation, when more observations could be gathered. As noted by Gauss in the above-referenced preface, “An opinion had universally prevailed that a complete determination from observations embracing a short interval of time was impossible—an ill-founded opinion—for it is now clearly shown that the orbit of a heavenly body may be determined quite nearly from good observations embracing only a few days; and this without any hypothetical assumption.

Therefore, what was Gauss’ method? How was he thinking, such that he foresaw the general nature of the problem, the solution of which all other astronomers were contented to relegate to the whims of some future time, when it would be possible to apply the methods they were familiar with? What was the nature of his manner of thinking which allowed him to saunter past these invisible fences of assumption which so afflicted his contemporaries? We find that Gauss offers us a glimpse into his customarily obscured thoughts on this very issue, in the introduction to a paper that he writes on the Earth’s magnetic field in 1838:

\(^{31}\)W. Olbers to K. F. Gauss, January 22nd, 1802.

\(^{32}\)For the English translation, see http://wlym.com/~animations/ieres/PDF/SummarischeUebersicht.pdf.
Considered from the higher standpoint of science, however, the most complete compilation of the phenomena by way of the observations is not itself the real goal: by this one has made only a resemblance, like the Astronomer, for example, when he has observed the apparent path of a comet on the celestial sphere. One has only the building blocks, not the building, so long as one has not made the intricate phenomena submissive to a principle. And like the astronomer, whose main task actually begins after the stars have removed themselves from his vision, relying on the laws of gravitation, calculates the elements of the true orbital path from these observations, and through these calculations is even able to present the positions of the rest of its journey with certainty; the physicist should also pose the problem to himself in this way...

With this entire arc of noetic history fresh in our minds, we now find ourselves at the jumping off point of a more rigorous investigation into the actual epistemology and method of Karl Friedrich Gauss. Let us leave off the present discussion with the revealing words of Gauss, in his inaugural lecture on astronomy, addressing his first class in the spring semester of 1808, as the newly appointed head of the astronomy department and observatory at Göttingen, the former position of his teacher, Kästner:

The great happy minds who have created and extended astronomy as well as the other more beautiful parts of mathematics, were certainly not fired by the prospect of future utility; they sought truth for its own sake and found in the success of their efforts alone their reward and their good fortune. ...Let us too regard sublime astronomy from this more beautiful viewpoint. What nobler spirit has not early felt the animated desire in gazing at the starry heavens, to become better acquainted with this glorious drama, to fathom its wonderful phenomena and wherever possible its recondite secrets...?

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33See my translation in the DYNAMIS.

34[Cite the inaugural lecture translation.]