# CLASSICS OF SCIENCE: Mystery of Mercury's Orbit

*Astronomy*

How the inequality of Mercury's orbit was discovered, how the only hypothesis allowed by Newton's laws of gravitation was found inadequate, and how the solution of the mystery came from an unexpected quarter.

## *The First Hypothesis*

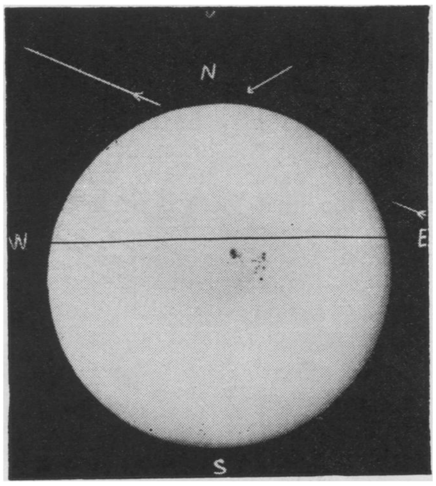
*LE VERRIER'S LETTER ON THE INTERMERCURIAL PLANETS; and Faye's Remarks upon its application to the case of the Total Eclipse of July 17 (Astron. Time), 1860. Cambridge (England), 1860.*

In my first researches on Mercury, published in 1842, the observations of the transits were not produced with such great accuracy. [One second of arc—*Ed.*] There might be observed, among many other errors, in relation to the transits of the month of May, a somewhat remarkable progressive error, which amounted to 9 seconds of arc in 1793. Such discrepancies could not be attributed to errors of observation. But, not having then revised my theory of the Sun, I thought it best to refrain from drawing any conclusion from this fact.

The use of the corrected tables of the Sun, in my new work, has not caused the errors above described to disappear entirely; systematic errors, which could not be ascribed to the observations without supposing that astronomers, such as LALANDE, CASSINI, BOUGUER, &c., had committed errors of several minutes of time, having even a progressive variation from one epoch to another,—an impossibility!

But it is worthy of remark, that an addition of thirty-eight seconds to the secular motion of the perihelion is sufficient to represent all the observations of the transits within less than a second, and even the greater part within less than half of a second. This neat result, which immediately gives to all the comparisons a precision superior to that hitherto arrived at in astronomical theories, shows that this increase of the motion of the perihelion of Mercury is indispensable, and that with it the tables of Mercury and the Sun possess all the accuracy required.

The necessity for adding thirty-eight seconds to the secular motion of the perihelion of Mercury being once admitted, let us inquire to what conclusions it will lead us. As the motion originally adopted for the perihelion proceeded from received values of the masses of the disturbing planets, we ought first to inquire what changes it would be necessary to apply to these masses in order to increase the computed motion by thirty-eight seconds. Now we perceive that this would only be possible upon one condition, namely, to increase the mass assigned to Venus *by at least a tenth* of its value. Is this alteration admissible?




*MERCURY TRANSITING THE DISK OF THE SUN. The arrows show the position of the planet and the direction in which it is moving. The larger dark patches are sunspots*

If we derive the mass of Venus from the periodic perturbations which that planet occasions to the Earth's motion, we find, from the discussion of numerous meridian observations of the Sun, made between 1750 and 1810, that this mass is the *four-hundred-thousandth* part of that of the Sun. We reach the same result by taking into account the observations made between 1810 and 1850. It is the mass which we have adopted, and which it would be necessary to increase by *a tenth*, according to the discussion of the transits of Mercury over the Sun.

The perturbative action of Venus is again perceptible in the secular variation from the seven solstices observed with the greatest accuracy, from the time of BRADLEY to the present day, we find that the mass of Venus, which we have just quoted, is *a little too great,—a result contrary to that given by Mercury*. This contradiction is the point to which we are to give our attention. . . To fix our thoughts, let us consider a planet which would be situated between Mercury and the Sun, and, as we have not observed a variation in the motion of the node of the orbit of Mercury similar to that of the perihelion, let us conceive that the supposed planet moves in an orbit but little inclined to the orbit of Mercury. Let us even conceive, on account of the indeterminateness of the problem, that the orbit is circular.

As the hypothetical planet must produce a secular motion of thirty-eight seconds in the perihelion of Mercury, it follows that there is a relation between its mass and its distance from the Sun, such that, in proportion as we assume the distance to be smaller, the mass will increase, and inversely. For a distance a little less than half of the mean distance of Mercury from the Sun, the mass sought for will be equal to that of Mercury.

But is it possible such a body could exist without having ever been noticed? Assuredly it would be endowed with great brilliancy. Is it to be believed that in consequence of its slight elongation it would be always lost in the diffused light of the Sun? How conceive that we have never been struck with its brilliant light during some one of the total eclipses of the Sun? How does it happen that we have never discovered it passing over the disc of the Sun?

All these difficulties vanish upon the admission, in the place of a single planet, of the existence of a series of small bodies (corpuscles) circulating between Mercury and the Sun.

Under the *mechanical* aspect, the influence of all these small bodies would be united to produce the required motion of the perihelion of Mercury; and, supposing always that they moved in circles, they would exert no effect upon the eccentricity of the orbit of this planet. As they would form, the periodic influences which each one would exert upon Mercury would mutually destroy each other.

Under the *physical* aspect, it would not be astonishing if the regions which border on the Sun should be found to be less free than the remainder of the planetary system. Since there circulates between Jupiter and Mars a ring of small bodies, of which the largest alone have been seen in our telescopes; since everything leads us to the belief that the vicinity of the orbit of the (*Turn to next Page*)

# The Mystery of Mercury's Orbit—*Continued*

Earth is furrowed by innumerable groups of asteroids, it is altogether natural to suppose that the same formation may be reproduced within the orbit of Mercury. Could any of these bodies be sufficiently noticeable to be perceived in their transits over the disc of the Sun? Astronomers, already so observant of all the phenomena which exhibit themselves upon the surface of this star, will undoubtedly find, in these reflections, an additional motive for following with attention the smallest and best defined spots. Some minutes of observation will be usefully employed in deducing their nature from observing their motions.

### *The Hypothesis Doubted*

*ASTRONOMY FOR EVERYBODY, A Popular Exposition of the Wonders of the Heavens, by Simon Newcomb. New York,* 1902

Observations of transits of Mercury since 1677 have brought out one of the most perplexing facts of astronomy. The orbit of this planet is found to be slowly changing its position, its perihelion moving forward by about 43 seconds per century farther than it ought to move in consequence of the attraction of all the known planets. This deviation was discovered in 1845 by Le Verrier, celebrated as having computed the position of Neptune before it had ever been recognized in the telescope. He attributed it to the attraction of a planet, or group of planets, between Mercury and the sun. His announcement set people to looking for the supposed planet. About 1860, a Dr. Lescarbault, a country physician of France, who possessed a small telescope, thought he had seen this planet passing over the disk of the sun. But it was soon proved that he must have been mistaken. Another more experienced astronomer, who was looking at the sun on the same day, failed to see anything except an ordinary spot. It was probably this which misled the physician-astronomer. Now, for 40 years, the sun has been carefully scrutinized and photographed from day to day at several stations without anything of the sort being seen. . . .

It therefore seems certain that there can be no intramercurial much brighter than the eighth magnitude. It would take hundreds of thousands of such planets as this to produce the observed motion of Mercury. So great a number of these bodies would produce a far brighter illumination of the sky than any that we see. The result therefore seems to be conclusive against the view that the motion of the perihelion of Mercury can be produced by intramercurial planets. In addition to all these difficulties in supposing the planet to exist we have the difficulty that, if it did exist, it would produce a similar though smaller change in the position of the nodes of either Mercury or Venus, or both.

Altogether, the evidence seems conclusive against the reality of any bodies whose attraction could produce the observed deviation, which still remains unexplained. The most recent supposition on the subject is that the force of gravitation deviates slightly from the law of the inverse square. But this requires further investigation.

### *The Solution*

*RELATIVITY, the Special and General Theory, by Albert Einstein, Translated by Robert W. Lawson. New York,* 1920.

If we confine the application of the theory to the case where the gravitational fields can be regarded as being weak, and in which all masses move with respect to the co-ordinate system with velocities which are small compared with the velocity of light, we then obtain as a first approximation the Newtonian theory. Thus the latter theory is obtained here without any particular assumption, whereas Newton had to introduce the hypothesis that the force of attraction between mutually attracing material points is inversely proportional to the square of the distance between them. If we increase the accuracy of the calculation, deviations from the theory of Newton make their appearance, practically all of which must nevertheless escape the test of observation owing to their smallness.

We must draw attention here to one of these deviations. According to Newton's theory, a planet moves round the sun in an ellipse, which would permanently maintain its position with respect to the fixed stars themseves and the action of the other planets under consideration. Thus, if we correct the observed motion of the planets for these two influences, and if Newton's theory be strictly correct, we ought to obtain for the orbit of the planet an ellipse, which is fixed with reference to the fixed stars. This deduction, which can be tested with great accuracy, has been confirmed for all the planets save one, with the precision that is capable of being obtained by the delicacy of observation attainable at the present time. The sole exception is Mercury, the planet which lies nearest the sun. Since the time of Leverrier, it has been known that the ellipse corresponding to the orbit of Mercury, after it has been corrected for the influences mentioned above, is not stationary with respect to the fixed stars, but that it rotates exceedingly slowly in the plane of the orbit and in the sense of the orbital motion. The value obtained for this rotary movement of the orbital ellipse was 43 seconds of arc per century, an amount ensured to be correct to within a few seconds of arc. This effect can be explained by means of classical mechanics only on the assumption of hypotheses which have little probability, and which were devised solely for this purpose.

On the basis of the general theory of relativity, it is found that the ellipse of every planet round the sun must necessarily rotate in the manner indicated above; that for all the planets, with the exception of Mercury, this rotation is too small to be detected with the delicacy of observation possible at the present time; but that in the case of Mercury it must amount to 43 seconds of arc per century, a result which is strictly in agreement with observation.

**Urbain Jean Joseph Leverrier** (1811-1877) elaborated Laplace's conception of the structure of the heavens, and revised the theories of all the planets. By calculation from perturbations in the orbit of Uranus he predicted the discovery of Neptune.

**Simon Newcomb** (1835-1909) carried out the revision of the planetary constants on a homogeneous basis, so that all astronomical results could be expressed in a comparable manner.

**Albert Einstein** (1879- ) published the Special Theory of Relativity at the age of 26, and the General Theory ten years later.

**Mercury** is the smallest planet, and the nearest the sun. It is seen low in the morning or evening sky, near Venus. Its mean distance from the sun is about 36 million miles, but its orbit has greater eccentricity than that of any other planet. Its year is only 88 of our days, and its day is believed to be of the same length. This, and the improbability of any atmosphere, would make conditions on Mercury similar to those on the moon, but enormously hotter.

*Science News-Letter, April 27, 1929*

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**Pellagra, a disease of man, and black tongue, a disease of dogs, are found to be due to the same kind of dietary deficiencies.**