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The Perturbation of Venus

In Chapter 3 it was mentioned that Einstein had proposed a small modification to Newton's law of gravitation. There were problems confronting the simple law of gravitation which Newton bequeathed to science. Close study of the motions of the planets had indicated that whilst they were moving approximately in elliptical orbits, their orbits as a whole were moving very slowly themselves. On Newtonian theory such progression will arise from the perturbing effects of other planets. Indeed, it was by using Newton's law that Leverrier (1811–1877) predicted the existence of the planet Neptune from observations of perturbations of the planet Uranus. J. G. Galle at Berlin then discovered the planet Neptune within one degree of the place Leverrier predicted (1846). From observations on the orbit of the planet Mercury, Leverrier also predicted the existence of another perturbing body. It was named Vulcan. Sir Robert Stawell Ball writing in his *The Story of the Heavens*, 1897, calls it 'the planet of romance'. He comments:*

> The existence of a planet much closer to the sun than those hitherto known has been asserted by competent authority. The question is still unsettled, and the planet cannot with certainty be pointed out.

For Mercury there is an unaccountable rate of advance of the perihelion. The discrepancy is as little as an advance of 43 seconds of arc per century, but it exists and cannot be traced to inaccuracies in observation. Now, the laws of planetary motion under perturbation conditions depend upon the assumed equivalence of inertial and gravitational mass. Eotvos in 1891 sought to check this assumption. It was established that at least in the laboratory inertial mass and gravitational mass were

* Page 122, book published by Cassell.

exactly equal. Thus it was indicated that the gravitational properties of a body are essentially of the same nature as its inertial properties. At the end of the nineteenth century it was then evident that unless Vulcan could be found we needed a new law of gravitation.

But let us examine the problem more closely. In calculating the perturbation effects it was necessary to know exactly the masses of the various bodies involved, excepting that whose perturbation was under study. Since its inertial mass is the same as its gravitational mass the accelerating forces acting on it develop forces in proportion to its mass and the orbit is therefore substantially independent. The sun is such a large central body as to be effectively fixed for the purpose of these perturbation studies. If a planet has a visible satellite its mass can be calculated. Neither Mercury nor Venus have satellites. Therefore, to find their masses we work backwards from a study of their perturbing effects on other bodies, assuming, of course, that Newton's law is valid. Since there are more orbits to observe than planets with unknown masses this process provides an effective check on the theory. It is the discrepancies which suggest unknown planets as needing recognition.

Let us next examine some of the results of Doolittle (1925)* calculated for the planet Venus. Calculation on Newtonian law gives the following perturbation components of perihelion motion. The assumed masses of the disturbing bodies are tabulated as reciprocal fractions of the solar mass.

Planet	*Secs arc/century*	*Solar mass/Planet mass*
Mercury	− 118·9242	7,500,000
Earth + Moon	− 564·1755	327,000
Mars	+ 74·5865	3,093,500
Jupiter	+ 656·06924	1,047·879
Saturn	+ 7·92070	3,501·6
Uranus	+ 0·277671	22,800
Neptune	+ 0·110304	19,700
	+ 55·86460	

* *Trans. American Phil. Soc.*, 22, p. 37, 1925.

In theory, therefore, the perihelion should be advancing by 55·86 seconds of arc per century, provided our masses are correct. Experimental observation, however, shows an advance of 43·055 seconds of arc per century, according to Doolittle.*

Note that these data were calculated before the later discovery of the planet Pluto in 1930. Pluto is more remote than Neptune and has a mass smaller than that of the earth. Its effect on Doolittle's figures can, therefore, be ignored.

At that time the mass of Venus was known with more assurance than was the mass of Mercury. Also, because Mercury has a highly elliptical orbit and describes its orbit more frequently, being the closest planet to the sun, it provides a better test for Newton's theory than does Venus. For Mercury it was found that the perihelion advanced by 43 seconds of arc per century faster than was calculated. There is an anomalous advance of perihelion. For Venus, Doolittle's data show an anomalous retardation of nearly 13 seconds of arc per century.

These anomalies were, of course, already well known by the men who began to question Newton's laws in the early years of this century. Planck (1907) asserted that all energy must gravitate. Einstein (1911) followed this by contending that since light is a form of energy light must gravitate. Thus a ray of light passing the sun must be curved and the velocity of light must depend upon the gravitational field. Einstein (1915) then presented a new gravitational theory incorporating his concept of a space–time metric in four dimensions. It incorporated a modification of Newton's law. From Einstein's new law of gravitation the planet Mercury would have an added perihelion advance of 43 seconds of arc per century, a remarkable agreement with the observed value. For Venus, Einstein's theory gives about 8 seconds of arc per century as an additional perihelion advance rate to that given by Newton.

Unfortunately, however, Einstein's theory is as inflexible as Newton's. The perihelion advance of Mercury has to be 43 seconds of arc per century plus whatever Newton's theory says it is. The values calculated depend upon the masses of the

* It is merely coincidental that this observed advance for Venus is almost the same as the anomalous advance for Mercury.

perturbing bodies. It is now believed that the oblateness of the sun, not accounted for in these early calculations, can reduce the theoretical perihelion advance by 3 seconds of arc per century. This makes Einstein's result less remarkable. Furthermore, there has been progress in working out the mass of Mercury and the test by Venus looks possible. By analysis of the motion of the minor planet Eros, one of the asteroids which approaches the earth very closely at perihelion and can afford more accurate data, Rabe (1951) has found the mass of Mercury to be one 6,120,000 part of that of the sun. This changes the figure of −118·9242 in the Doolittle data to one more likely to be −145·5. The anomalous retardation of 13 seconds of arc per century on Newton's theory becomes an advance of 14 seconds of arc per century instead. This is closer to Einstein's value of 8. But there are difficulties posed by our knowledge of the mass of the earth and moon system relative to that of the sun. Astronomers accept that there are discrepancies in the data they use. Indeed, they use different values for different purposes in order not to add confusion before resolving it. Nevertheless, the sun's mass appears to be about 333,430 times that of the earth, as far as we can judge from the earth's motion about the sun. This is the figure usually seen in most reference works. The mass of the earth is well known to be 81·53 times that of the moon. Therefore, the earth–moon system should be smaller than that of the sun by the factor 329,380. Doolittle's value was only 327,000. Also, many reference works suggest a value of the order of 328,400 as best for some purposes.*

This is not very assuring. If Doolittle's calculations are based on the value of 329,380 a further 4·1 seconds of arc per century have to be added to the theoretical advance, and this cuts the anomaly to 9 seconds of arc, which looks close to Einstein's value. But, did Rabe use Einstein's law in analysing the orbit of Eros? If he used Newton's law he has the wrong mass if Einstein's law is the correct one. Such are the problems!

Einstein's theory reduces gravitation to a geometrical condition; what has been called the curvature of space–time produced by the presence of matter. This compares with a pre-Einstein

* *Science Journal*, H. Aspden, August 1965, p. 28.

concept of Fitzgerald (1894) that gravity is due to a change in the structure of the aether produced by the presence of matter. This question of whether there is or is not an aether has importance even to Einstein's theory. The motion of a planet according to Einstein is not an ellipse even when other perturbing bodies are absent. It is an ellipse modified by progressive rotation as if the radial oscillations of the planet from the sun as centre are at different frequency to that of the planet about the orbit. It is as if the momentum properties of the planet are different for radial motion and the orbital motion. Of course, if we imagine a pendulum with a fixed spherical bob we have exactly this. The momentum properties are different for linear motion and swinging motion. The mass of the bob governs the linear momentum but the physical size of the fixed bob is involved as well, increasing effective momentum, for the swinging action. The planet can be likened to a system with a pivotally mounted bob, since it rotates independently of its orbital motion. The planet should, therefore, have the same effective mass for the two types of motion. But what if there is an aether medium? If the aether in the planet rotates with the planet, then this will not cause any discrepancy. But what about the aether surrounding the planet? We have to add the effect of moving a spherical hole through a fixed medium. This sounds absurd but it has sound physical basis, since we are dividing an argument into two parts. A hole can move through a medium if the medium can transfer itself across the void. Such a hole would have a negative linear momentum exactly balancing that due to the planetary aether. But such a hole could not be moved around in an orbit without changing its effective negative mass, because a hole can be said to move in a line but cannot be said to turn. This means that if there is an aether medium there will be an angular momentum effect to take into account. The angular velocity of the planet in an elliptical orbit changes as the planet traverses the orbit. Thus, the angular momentum of the aether will change as well. This angular momentum will be drawn from the orbital motion of the planet so modifying its orbit. It is then to be expected that the existence of an aether will cause anomalies in the motions of planets. The calculations are straightforward, as the author has shown* elsewhere, and the quantitative results support the thesis in this work that an astronomical body is enveloped in an aether which rotates with it.

* See footnote ref. on page 11.