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Review Article

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The Physical Cause of Planetary Perihelion Precession

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Abstract
According to the revised gravitation formula, the gravitational force on planets in the solar system is mainly provided by the sun, and only when the planet is far enough from the sun to treat the sun as a particle, the gravitational force on the planet coincides well with Newton's gravitational formula. The closer the planet is to the sun, the more the gravitational force on the planet deviates from (greater than) the value calculated by Newton's universal gravitation formula. The precession of the planet's perihelion is due to this property of gravity.

Keywords: Mercury Precession, Planetary Precession, Perihelion precession, Gravity, Law of Gravity, Gravity Modification, Astrophysics

Introduction

Astronomical observations found that Mercury's orbit around the sun revolve against the clock, and the orbit is not closed, this is the precession of Mercury. The precession of Mercury's perihelion calculated by Newton's law of universal gravitation is not consistent with the observed value. In 1859, the French astronomer Urbain Le Verrier found that the observed value of the perihelion precession of Mercury was 38" per century faster than the theoretical value calculated by Newton's laws, and speculated that this might be caused by the attraction of a planet closer to the sun than Mercury. But after years of painstaking searching for the suspected planet, there was no sign of it. The American astronomer, Newcomb, S., calculated that Mercury's anomalous precession rate was 43"/century, and later put forward some theories to explain Mercury's anomalous precession, but none of them succeeded. So Newcomb suspects that the law of square inversion in the law of gravity is problematic. For the purpose of explaining the actual motion of several inner planets at the same time, Newcomb worked out that the gravitational force should be inversely proportional to 2.1574 power of the distance. At the end of the 19th century, Weber, Riemann and others, at the early stage of the development of electromagnetic theory, tried to explain the precession of Mercury's perihelion with electromagnetic theory, but they failed to get satisfactory results.

The purpose of this paper is to give the physical reason behind the phenomenon of perihelion precession of planets and to explore the nature of universal gravitation.

Analysis of the cause of perihelion precession of planets

For a planet with a gravitational mass of m in the solar system, according to the modified universal gravitation formula (2.9), the magnitude of the universal gravitation on the planet is [1]:

$$F = G_0 m \sum_{i=1}^{n} \frac{M_i}{r_i^2} \qquad (2.1)$$

In formula (2.1), G_0 is a constant, M_i is the gravitational mass of any celestial body in the universe, r_i is the distance between the center of mass of the planet and the center of mass of the celestial body with gravitational mass of M_i, and the sum sign is the sum of all celestial bodies in the universe. Since the sun is the closest massive celestial body to the planet, in order to simplify the calculation, we only retain the solar term in the sum term on the right side of Equation (2.1), and discard all other terms, and replace G_0 with the gravitational constant G:

$$F = G_0 m \sum_{i=1}^{n} \frac{M_i}{r_i^2} \approx Gm\frac{M}{r^2} \qquad (2.2)$$

In the above equation, M is the gravitational mass of the sun, and r is the distance between the center of mass of the planet and the center of mass of the sun. Because the sun is close to the planet and can't be regarded as a particle, in order to improve the accuracy of the calculation, we divide the sun into n small pieces. According to the revised law of gravity, the gravity between the planet and the sun is [1]:

$$F \approx Gm \sum_{i=1}^{n} \frac{m_i}{r_i^2} \quad (2.3)$$

In the above equation, mi is the gravitational mass of any small piece after the sun is divided into n small pieces.

$$M = \sum_{i=1}^{n} m_i \quad (2.4)$$

r_i is the distance between the center of mass of the planet and the center of mass of the small piece with gravitational mass of m_i, and the sum sign is the sum of all the n small pieces that divide the sun. Since the gravitational mass of the sun can be regarded as a continuous distribution, the sum of Equation (2.3) can be changed to an integral:

$$F = Gm \iiint \frac{\rho(R)dv}{r^2} \quad (2.5)$$

In the above formula, ρ(R) is the gravitational mass density distribution of the sun, and v is the volume of the sun. When the planet is far from the sun and can treat the sun as a particle, we have:

$$F = Gm \iiint \frac{\rho(R)dv}{r^2} \approx \frac{Gm}{r^2} \iiint \rho(R)dv = G\frac{mM}{r^2} \quad (2.6)$$

and:

$$\frac{m_I v^2}{r} \approx G\frac{mM}{r^2} \quad (2.7)$$

where, m_I is the inertial mass of the planet. In this case, the gravitation of the planet is in good agreement with Newton's universal gravitation formula and the motion of the planet is in good agreement with Newton's motion equation. When the planet is close to the sun and the sun can't be regarded as a particle, we have:

$$Gm \iiint \frac{\rho(R)dv}{r^2} > G\frac{mM}{r^2} \quad (2.8)$$

and:

$$\frac{m_I v^2}{r} > G\frac{mM}{r^2} \quad (2.9)$$

In this case, the gravity of the planet deviates from Newton's gravitational formula, the motion of the planet deviates from Newton's equation of motion, and the closer the planet is to the sun, the greater the deviation.

To sum up, Newton's universal gravitation formula can be well established only when two interacting objects are far away from each other and can be regarded as particles. When two objects are too close to each other to be regarded as particles, if these two objects are still regarded as particles and Newton's universal gravitation formula is used to calculate the universal gravitation between these two objects, then the obtained universal gravitation will deviate from the relationship inversely proportional to the square of the distance:

$$F = G\frac{mM}{r^{2+\alpha}} \quad (2.10)$$

In formula (2.10), α>0. Moreover, the closer two objects are to each other (the smaller the ratio of the distance to the object radius), the greater the α is. Therefore, the relationship between gravity and the 2.1574 power of distance, or α=0.1574, obtained by Newcomb, S. should not be the universally satisfied value of all planets in the solar system, nor is it the universal value of Newton's law of gravity. Therefore, a planet with an elliptical orbit at perihelion would have a precession greater than that calculated by Newton's universal gravitation formula; And the closer perihelion is to the sun, the farther aphelion is away from the sun, the greater the deviation. Since Mercury's perihelion is closest to the sun and its elliptical orbit has the largest eccentricity among all the planets in the solar system, the actual precession of Mercury at perihelion has the largest deviation from the precession calculated by Newton's universal gravitation formula.

The calculation of the perihelion precession of the planet

Any planet orbiting the sun strictly satisfies the following formula:

$$Gm \iiint \frac{\rho(R)dv}{r^2} = \frac{m_I v^2}{r} \quad (3.1)$$

In formula (3.1), G is the gravitational constant, m is the gravitational mass of the planet, m_I is the inertial mass of the planet, ρ(R) is the gravitational mass density distribution of the sun. If we take the gravitational mass equal to the inertial mass, there is:

$$G \iiint \frac{\rho(R)dv}{r^2} = \frac{v^2}{r} \quad (3.2)$$

Using Equation (3.2) and using computer, the path of any planet of the solar system can be modeled, and the precession of the perihelion of each planet should be calculated accurately.

References

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