METROLOGY, QUALITY, STANDARDIZATION AND CERTIFICATION

PROBLEM OF THE COSMIC GRAVITY MEASUREMENT

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Abstract. Based on Newton's adapted law of universal gravitation in the case of moving masses, taking into account the finite velocity of gravity, differential equations of motion of celestial bodies are obtained. The transient process of the precession of the planet's perihelion was simulated for the first time. A new physical interpretation of the celestial phenomenon due to the discovered new component of force in addition to the Newtonian and Lorentz (gravitomagnetic) is given. The problem of measuring a new force has been formed. The results of computer simulation of the precessing perihelion of the planet considering a new force component are discussed.

Key words: Equation of motion of celestial bodies; Precession of the planets perihelion; Component of the physical force of motion; Problem of measurement of a new component of gravity; Simulation of the transition process.

1. Introduction

The precession of Mercury's orbit is measured at 5.600 “arcs per century. Newton's equation, considering the effects all the effects from other planets (as well as the very slight deformation of the Sun due to its rotation) and the fact that the Earth is not an inertial frame of reference, assumes a precession of 5.557” arcs per century. There is a discrepancy of 43 “arcs per century. Attempts to improve the Newtonian law of gravity began in the middle of the XVIII century. Models were proposed without dependence and with dependence on the speed of motion. But they all lack strict mathematical support from the equations of gravity. A. Lorentz and G. Poincare dealt with the problem, and we dwell on four characteristic results [1–7].

2. Shortcomings

Models without speed dependence. 1. The improvement of I. Newton's law S. Newcomb in 1895 have interpreted as follows

$$F = G\frac{mM}{R^{2+\delta}}, \qquad (1)$$

where F is the force of gravity of the masses m, M ; R is the distance between the masses; G is gravitational constant; δ is adjustment factor. The precession of the perihelion per revolution in (1) is equal to

$$\delta\varphi = \frac{2\pi}{R^{2+\delta}} = 2\pi\left(1+\frac{\delta}{2}\right). \qquad (2)$$

2. Soon H. Zeeliger and K. Neumann have proposed another modification of the law of universal gravitation:

$$F = G\frac{mM}{R^2}e^{-\lambda R}, \qquad (3)$$

In it, an additional multiplier provides faster than I. Newton, the decrease in gravity with distance.

Models with speed dependence. 1. P. Gerber have proposed in 1898 a formula for the gravitational potential:

$$V = \frac{4\pi^2 A^3}{RT^2\left(1-\frac{1}{c}\frac{dR}{dt}\right)^2}, \qquad (4)$$

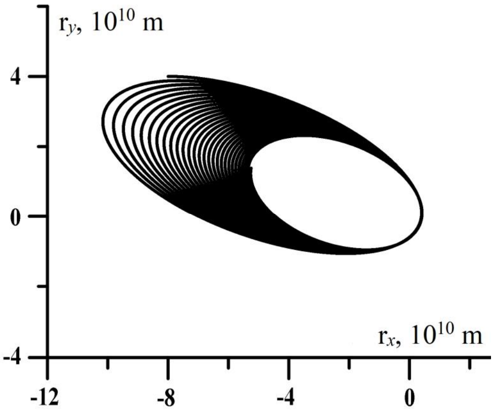
where T is the period of rotation; A is the major half-axis of the ellipse; c is the speed of light.

3. A. Einstein in 1915 have calculated (approximately) this deviation and obtained an almost exact coincidence with the observed 43” of arc per century

$$\delta\varphi = \frac{24\pi^3 A^2}{c^2T^2\left(1-\varepsilon^2\right)}, \qquad (5)$$

here ε is an eccentricity of an ellipse trajectory. For Mercury, this formula gives 42.98” per century, which is consistent with observations [6, 7]. The exact solution of the general theory of relativity equations obtained by K. Schwarzschild in spherical coordinates two months later has revealed that the perihelion of the planets really must undergo an additional precession compared to Newton's theory. Although there is a caveat: in a spherically symmetric space, such a precession can not exist.

This brief review suggests that all these recommendations, obtained by approximating the trajectory of a particular planet in a particular quasi-stationary orbit, are not based on physical laws and do not correspond to other orbital moving celestial bodies. In addition, they are obtained under conditions $R = const$ or $\varepsilon = const$, that are far from true (see Figure).



Hodograph of the distance of the gravitational planet at times close to the Sun under initial conditions:
$v_x(0) = 25000;\ v_y(0) = 0;\ r_x(0) = -0.8 \cdot 10^{11};\ r_y(0) = 0.4 \cdot 10^{11}$

3. Purpose of Work

The aim of the article is the study of the precession phenomenon of the planets' perihelion based on differential equations of celestial bodies motion by simulating a phenomenon in dynamics.

4. Modeling the dynamics of the precession of the planets' perihelion

Successful modeling in the dynamics of the precession of the planets' perihelion in Euclidean space and physical time is possible only based on equations of celestial mechanics, which applies Newton's adapted law for the case of moving masses [8, 9]:

$$\mathbf{F} = G\frac{mM}{r^2}\left(1 + \frac{v^2}{c^2} + 2\frac{v}{c}\mathbf{r}_0 \cdot \mathbf{v}_0\right)\mathbf{r}_0, \tag{6}$$

where $\mathbf{F}$ is the vector of gravity of the masses m, M; is v the mutual instantaneous speed of movement; r is the distance between the masses; $\mathbf{r}_0, \mathbf{v}_0$ are unit vectors of distance and trajectory. The equation of moving mass is obvious:

$$\mathbf{F} = m\frac{d\mathbf{v}}{dt}. \tag{7}$$

Most of the practical problems of celestial mechanics can be successfully solved in 2D space due to the logical orientation of the coordinate system. The balance of forces (6) and (7) is described in Cartesian coordinates [3]:

$$\frac{dv_x}{dt} = -\frac{GM\,r_x}{r^3}\left(1 + \frac{v^2}{c^2} + 2\frac{r_x v_x + r_y v_y}{cr}\right);$$
$$\frac{dv_y}{dt} = -\frac{GM\,r_y}{r^3}\left(1 + \frac{v^2}{c^2} + 2\frac{r_x v_x + r_y v_y}{cr}\right). \tag{8}$$

They must be supplemented by coordinate equations:

$$\frac{dr_x}{dt} = v_x; \quad \frac{dr_y}{dt} = v_y, \tag{9}$$

and

$$r = \sqrt{r_x^2 + r_y^2}; \quad v = \sqrt{v_x^2 + v_y^2}. \tag{10}$$

Expressions (8)–(9) are the differential equations of celestial mechanics in Euclidean space and physical time. The uniqueness of the solution is provided by the initial conditions. It can be emphasized that the real course of the transition process is over-sensitive to the initial conditions!

The results of the joint solution of (8)–(9) by the numerical method are demonstrated in Figure, at constant parameters corresponding to the Sun. Based on real graphical and temporal resolution capabilities, judging the course of the transition process, close to the actual conditions, is not necessary. Therefore, Figure shows a transition process in which the considered gravitational mass approaches the mass of the Sun. Now it becomes clearer not only the precession of aphelion (and at the same time perihelion) in the direction of rotation of the planet but also the gradual convergence of the planet with the star.

A more meticulous analysis of the transitional process based on simulation is shown in Table, where the limit values of the distance of the planet from the center of the Sun and the limit linear orbital velocities in open elliptical orbits are given.

The computed data of the transitional process

No	$r_{min} \cdot 10^{-9}$	$r_{max} \cdot 10^{-9}$	v_{min}	v_{max}
1	3,989	70,420	14200	251016
2	3,903	109,422	9139	256254
3	3,903	109,422	9139	256191
4	3,989	70,420	14200	251029

Hodograph of Figure and tabular data indicate that the transient process is not over. Data in Table are taken from the last revolutions of the planet at the physical time of the process in the time interval (0–80)–10^6 s. Data of Table and Figure have been computed under the same initial conditions:

$$v_x(0) = 25000;\ v_y(0) = 0;\ r_x(0) = -0.8 \cdot 10^{11};$$
$$r_y(0) = 0{,}4 \cdot 10^{11}.$$

Moreover:

– the data of the first line are obtained as a result of the integration of equations (8)–(9);

– the data of the second line correspond to the data of the first line in the absence of the third component in (1), strikingly affect the process of transition of the planet perihelion (about it later);

– the data of the third line are calculated by Newtonian mechanics (in the absence of the second and third component in (1)); the obtained result coincides almost with the previous one;

– the data of the fourth line correspond to the data of the first line in the absence of only the second term v^2 / c^2 in (1), which presents relativistic gravitomagnetic forces; the data of both lines almost coincide. This was to be expected. It was known in the second half of the 19th century that relativistic forces make a small contribution to the perihelion precession (in the case of Mercury no more than 6–7” per century). It is important to note that as the planet “falls” on the star, the eccentricity of its quasi-elliptical trajectory decreases:

$$\varepsilon = \frac{r_{\max} - r_{\min}}{r_{\max} + r_{\min}} \tag{11}$$

In this process, if the integration time is increased by $40 \cdot 10^6$ s, it decreased from 0.8947 (at $80 \cdot 10^6$ s) to 0.8634 (at 120.106 s). Therefore, the statement that “Mercury makes a complete revolution of the perihelion every 260 thousand years” is not true [2].

Thus, according to the analysis of the Table, we come to the unequivocal conclusion that the third component of the force responsible for the precession of the perihelion of the planets is equal to:

$$F_v = G\frac{mM}{r^2}\left(2\frac{v}{c}\mathbf{r}_0 \cdot \mathbf{v}_0\right)! \tag{12}$$

The search for the causes of the perihelion precession of planetary trajectories, ranging from the interaction of neighboring moving bodies, relativistic gravitomagnetic forces, etc. up to the properties of the vacuum, cannot withstand criticism, as it is unfounded physically and mathematically. In particular, those that are reduced to the approximation of ready-made artificially closed trajectories of celestial motion.

The force (12) closes the triune force of gravity in addition to the two known ones: Newton’s force F_n and gravitomagnetic force (like Lorentz force in electricity). In a stationary state and for a circular orbit of a moving planet: $F_v = 0$. When moving along the centers of interacting masses, it is maximum: $-2F_n \le F_v \le 2F_n$.

In the process of the perihelion precession of the planets, a new component of the force associated with motion in the gravitational field dominates the relativistic gravitomagnetic component and is crucial. Plausibly, it is involved in the effect of I. Shapiro [5] that consists in the gravitational delay of the signal. According to it, electrical signals propagate more slowly in the gravitational field than in the absence of this field.

No less a problem of gravimetry is the measurement of the “fall” of the planet on the parent star. Experimentally confirmed such a “fall” may raise the question of another possible evolution of the Solar system.

5. Conflict of interests

The authors claim that there are no possible financial or other conflicts over the work.

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7. Conclusions

1. The phenomenon of transient precession of the perihelion of a moving planet is mathematically substantiated and simulated in 2D Euclidean space and physical time.

2. The existence of a new force related not only to the speed of the gravitational mass but also to the spatial orientation of its trajectory is substantiated. This force in the precession of the perihelion of the planets dominates over the relativistic (gravitomagnetic) and at the same time leads to the “fall” of the planet on the gravitating star. This fact requires immediate experimental measurement of the new force.

3. Experimentally confirmed “fall” of the planet to the star may contribute to the development of another possible variant of the evolution of the solar system.

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