THEORETICAL SUBSTANTIATION OF THE RESULTS OF MEASURING ANOMALIES OF SPACECRAFT TRAJECTORIES

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Abstract. t is about the solar acceleration of spacecraft. The prevailing opinion that classical properties of the fundamental laws of statics can be successfully used in the celestial mechanics of low speeds (v << c) has been refuted because the involvement of relativistic methods does not improve the situation due to the smallness of the gravity magnetic acceleration. The essence of the problem is that the known classic methods of the theory of motion operate solely on the transverse component of the velocity vector concerning the orientation of the radius vector of the gravitational interaction. In the article, an insufficient longitudinal component was introduced into the electrogravity theory of motion, the effect of which turned out to be an order of magnitude higher than the effect of the transverse one.

Key words: Electrogravity, Additional solar acceleration of spacecraft, Adapted Newton's law of gravity for motion.

1. Introduction

First of all, let's make a small excursion into the problem known in scientific publications as the "Pioneers anomaly".[2-4]. Pioneer 10 is a NASA space probe designed primarily to study Jupiter and the heliosphere. Launched on March 3, 1972, Pioneer 10 became the first spacecraft to fly by Jupiter and photograph the planet, and the first to develop enough speed to overcome the Sun's gravity. After him, on April 6, 1973, "Pioneer-11" was launched, designed to study Jupiter and Saturn.

For the first time, the anomaly of the flight path of space probes was discovered in the 1980s, when they passed about 20 AU, that is, 20 distances from the Earth to the Sun, on a trajectory outside the Solar System. By this point, the probes have already fulfilled their main mission. Pioneer 10 flew by Jupiter in December 1973, determining its mass and measuring its magnetic field. "Pioneer-11" approached the planet exactly one year later: in December 1974. After taking detailed pictures, it went to Saturn. In 1979, the apparatus transmitted images of the planet and its satellite Titan to Earth. The main mission ended, but they decided to use the monitoring data of the flight path of the Pioneer-10 device to search for what was then supposed to be the tenth planet in the Solar System. And now it's the ninth (after the demotion of Pluto). If there was a deviation in the trajectory, then, as scientists believed, it would be a consequence of the gravity of an as-yet-undiscovered planet. Deviations were found, but the cause of this anomaly was by no means a planet at the edge of the solar system. But, what is most interesting is that the anomaly was also found in the twin probe. Today, the devices are flying in different directions. "Pioneer-10" is moving to the edge of the Milky Way, in the direction of the constellation Taurus. Its twin, on the contrary, flies toward the center of the Galaxy, in the direction of the constellation Shield. Both probes are now in free flight. Only previously obtained acceleration and external forces (gravitational and non-gravitational) affect the flight of spacecraft.

Among the non-gravitational forces is, for example, solar radiation pressure, which causes acceleration directed away from the Sun. The Sun's gravity, on the contrary, pulls the devices towards the star, causing an acceleration directed toward the Sun, that is, it slows them down. All forces that can affect the flight of space vehicles are calculated and taken into account. Except for one. One unknown and incomprehensible force pulls the probes back. It is she who is the cause of the "Pioneers" mystery. The power is tiny, but it is there. The latest calculations, obtained before 2002, say that the magnitude of the unexplained negative acceleration was (8.74 ± 1.33).10-10 ms-2 (at a certain fixed distance and a certain speed). This has already led to the deviation of the devices by approximately 400,000 km from the calculated trajectory. It would seem that the probes have flown billions of kilometers. At the time of losing contact with Pioneer-10 (January 23, 2003), it flew away from us by more than 12 billion kilometers. This is 82 AU. Communication with Pioneer-11 was lost on September 30, 1995, the device was already at a distance of 6.5 billion kilometers, or 43 AU, from the Sun. We read in [3]: "And what are these hundreds of thousands compared to billions of kilometers? But for science, these tiny values can be of great importance. Deviations from the norm, from the trivial understanding of things, that is, anomalies can indicate the presence of something significant, but still undiscovered, especially in astrophysics." An anomaly in the movement of Uranus led to the discovery of a new planet – Neptune. Anomaly in the motion of Mercury, discovered in 1859, was explained based on differential equations of motion only recently by us [1]. Or else: "The solution to the "Pioneers" anomaly may revolutionize modern physics or, on the contrary, will be completely trivial. That is why it does not give rest to many scientists."

Some argue that the boundary of the Solar System is defined as the point where the Sun's gravity ceases to affect an object. But gravity, as you know, de ter mines the universe on a huge scale. This point is 50,000 times greater than the distance from the Sun to the Earth. Yes, "Voyager-1" covered 123 AU. and it will take another 14,000 years to leave the Sun's gravitational grip at its current speed.

2. Drawbacks

For all the years devoted to the search for a solution to the problem of the "Pioneers" anomaly, many assumptions have been put forward. The first is errors in observations and interpretation of the received data. But he was rejected almost immediately. The anomaly was explained by various reasons, including the brake outs of the interplanetary environment (dust, gas clouds, etc.), the gravitational attraction of Kuiper belt objects, leakage of gas, such as helium, used as a working medium in radioisotope generators. The reason was also sought in the electromagnetic forces caused by the accumulated probes of electric charges. And, of course, they attributed it to the influence of dark matter or dark energy. They turned to the effect of clock acceleration, caused by the expansion of the universe, and thus by the increase in the background "gravitational potential", which in turn accelerates cosmological time; by changing inertia due to interaction with vacuum energy; by the possible non-equivalence of atomic and astronomical time. The background space-time described by the Friedman-Lemaitre-Robertson-Walker cosmological metric, which is not flat according to Minkowski, was not left out. But one of the most common explanations was thermal radiation – a thermoelectric generator. It was not without proposals to adjust the existing physics. Thus, in 1983, was proposed the so-called theory of modified Newtonian dynamics, according to which "Newtonian mechanics needs corrections" to describe the movement of bodies with extremely low acceleration. All this demonstrates an interesting epistemological situation, how the human mind in a state of helplessness searches for the way to the Truth, the essence of which will be discussed separately at the end of the book.

Since the Pioner-10 and Pioner-11 spacecraft flew almost without additional stabilization of the engines during the "cruise", the density of the environment of the Solar System can be characterized by the strength of its influence on the movement of the spacecraft. In the outer solar system, this effect can be easily calculated based on ground-based measurements of the distant space environment. When these effects were taken into account, along with all other known effects, the Pioneers' calculated position did not agree with measurements based on the return times of radio signals from the spacecraft. They consistently showed that both spacecraft were closer to the inner solar system than they should be. The Pioneers were uniquely suited to detect the effect because they flew for long periods without additional course adjustments. Most of the deep space probes launched after the Pioneers have either stopped on one of the planets or used the engines to run throughout their mission.

The line of thought of the opponents of the revision of gravitational physics is as follows. If the "Pioneer Anomaly" was a gravitational consequence of some long-range modifications of the known laws of gravity, why did it not affect the orbital motion of large natural bodies in the same way? Therefore, for a gravitational explanation, it is necessary to violate the principle of equivalence, which states that the force of gravity acts on all objects equally. Therefore, some argued that increasingly accurate measurements and simulations of the motion of the outer planets and their satellites rejected the possibility that the "Pioneer Anomaly" is a phenomenon "Pioneer Anomaly" of gravitational origin, while others believed that our knowledge of the motion of the outer planets and the dwarf planet Pluto was insufficient to refute gravitational nature of the anomaly.

Regarding the search for the cause of a possible cosmological origin, gravitationally bound objects such as the Solar System or even the Milky Way should not participate in the expansion of the Universe – this is known from conventional theory and by direct measurement

Finally, let us say that in this interesting story, attempts to establish contact with "Pioneer-10" on February 7, 2003, were unsuccessful. NASA experts consider the depletion of the radioisotope power source to be the reason for the loss of radio communication. It is assumed that the device continues its flight. Its speed is sufficient to leave the Solar system, and the course lies towards the star Aldebaran. If nothing happens to Pioneer 10 along the way, its flight to the outskirts of this star will take more than two million years.

Among the unsolved problems of theoretical physics is the following: "What causes additional acceleration in the direction of the Sun of space vehicles, which is not described by classical theory." The first thing that came to my mind was that in light of my latest theoretical developments [1. 8], it is possible to tackle the successful solution of this problem. But here there is a big risk since I do not have quantitative raw data, which is necessary in such a case for confident movement forward, secured by the necessary feedback (what kind of additional acceleration?). But it was not possible to pass by the problem either, because that would be an escape into the shadow of irresponsibility. That's why I'm putting everything below on the discussion table because even when I'm wrong, I'm sure that such mistakes will only accelerate someone's difficult steps forward.

3. Goal

Based on the theory of electrogravity, substantiate the results of live measurements of the "anomaly" of the trajectory of spacecraft movement in the solar gravitational field using the example of the Pioneer-10 space probe, thus showing that the movement occurs following the fundamental laws of the universe, as also based on the theory of gravity explain the observed natural phenomenon of the appearance additional heliocentric acceleration, which slows down the movement of spacecraft leaving the space of the solar system.

4. Consideration of spacecraft movement

The classical celestial mechanics of the free movement of spacecraft at non-relativistic velocities in

the coordinates of the conventionally motionless Sun is completely derived from I. Newton's law of universal gravitation:

$$\mathbf{F} = G\frac{mM}{r^2}\mathbf{r}_0, \qquad (1)$$

where **F** is the force vector; m is the mass of the mobile device; M is the mass of the Sun; r is the instantaneous distance between the centers of the rotating masses; $\mathbf{r}_0$ is the unit space vector; $G = 6{,}67438\cdot10^{-11}\text{m}^3\text{kg}^{-1}\text{s}^{-2}$ *and* is a global constant.

The appearance of additional acceleration of space vehicles is still due to their motion even in the range of pre-relativistic speeds. Classical law (1) is a law of statics, not dynamics. Due to this, a problem arises. Therefore, the law (1) adapted to the case of movement based on the theory of electrogravity [1] is suggested here:

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

where v is the mutual instantaneous mass movement speed; c is the speed of light in a vacuum; $\mathbf{v}_0$ is a unit velocity vector. The first term in (2) presents the ever-present static force (1), and the second – the so-called gravity(electro)magnetic force, which is a prolonged Lorentz force from electricity to mechanics caused by transverse motion. It is responsible for the relativistic effect in the gravitational field, similar to the magnetic field in the electric field. The third term corresponds to the force caused by the longitudinal movement, oriented along the radius-vector of the force interaction.

The modulus of the force vector (2) we describe in component form:

$$F_N = G\frac{m_1m_2}{r_{12}^2}, \qquad (3)$$

$$F_L = G\frac{m_1m_2}{r_{12}^2},\frac{v^2}{c^2}, \qquad (4)$$

$$F_T = 2G\frac{m_1m_2}{r_{12}^2},\left(\frac{v}{c}\mathbf{r}_0\cdot\mathbf{v}_0\right), \qquad (5)$$

where F_N is Newton's force; F_L, F_T are gravitational force is the tangential and radial components of the gravitational force of velocity. It is clear that $v\to 0$ the modulus of force interaction (4), {5) degenerates to (3).

The limiting share in the force interaction of components (4) and (5), based on the speed and orientation characteristics, is the next:

$$\mathbf{F}_L = (0\div1)\mathbf{F}_N; \qquad \mathbf{F}_T = ((-2)\div(+2))\mathbf{F}_N. \qquad (6)$$

It is proved in [3] that the force component (4) is due to the tangential velocity component. In the electric field, it completely coincides with the Lorentz force, which in classical electrodynamics presents the force of the magnetic field or the so-called relativistic effect in the electric field. Prolonged to mechanical interaction, it presents the corresponding gravitomagnetic force (4) [5–7].

The functional dependence of (5) on the velocity of motion is higher than that of (4), because if the factor (4) is elevated to the second degree, and in (5) – to the first. It is component (5) that finishes the hitherto unknown triune essence of gravitational forces and makes it possible to solve the problem on a rigorous mathematical basis. Let's write the obvious equations of the moving mass in the classical notation of Newton's second law:

$$\mathbf{F} = m\frac{d\mathbf{v}}{dt}, \qquad \frac{d\mathbf{r}}{dt} = \mathbf{v}, \qquad (7)$$

Let us remind you that in the current issue, the mass does not depend on the speed of its movement! This is one of the fetishes of the special theory of relativity. Only the force of mass interaction depends on the speed of movement [1]!

The balance of forces (2), (7) in the field of the gravitational mass m_2 according to (7) is written in coordinate terms:

$$\frac{dv_k}{dt} = -G\frac{m_2r_k}{r^3}\left(1+\frac{v^2}{c^2}+2\frac{r_xv_x+r_yv_y+r_zv_z}{cr}\right);$$
$$\frac{dr_k}{dt} = v_k; \quad k = x,y,z, \qquad (8)$$

where r *and* v are the modules of the vectors of radius **r** and velocity **v**

$$r = \sqrt{r_x^2+r_y^2+r_z^2}; \qquad v = \sqrt{v_x^2+v_y^2+v_z^2}, \qquad (9)$$

Expressions (8), and (9) produce a complete system of algebraic-differential equations for the analysis of transient processes in the gravitational field in 3D Euclidean space and physical time. The unambiguity of the solution is ensured by the initial conditions:

$$r_x(0),\ r_y(0),\ r_z(0), v_x(0), v_y(0), v_z(0).$$

Thus, in the process of movement of a certain mass, we possess all parameters of movement **r** and **v**.

Note that based on (8), and (9) the perihelion shift of Mercury [1] and the mutual influence of the planets of the solar system on their orbits were simulated for the first time [1].

If we consider

$$\frac{d\mathbf{v}}{dt} = \mathbf{a}, \qquad (10)$$

Here **a** is the acceleration vector, then the right-hand parts of the first three differential equations (8) are the required accelerations.

For example, let's choose a fixed spatio-temporal position of the spacecraft in the gravitational field of the

Sun with a mass around the Earth $m_2 = M$. Orient the Cartesian coordinate system so that their origin coincides with the center of the stationary Sun. Then, based on (4) – (6), we can write down the expression for the additional solar longitudinal incident as

$$a = 2G\frac{M}{r^2}\frac{v}{c}\mathbf{v}_0 \cdot \mathbf{r}_0 \qquad (11)$$

Since our problem deals with the non-relativistic speeds of space vehicles, due to the ratio of speeds $v << c$, the gravitomagnetic force as a transverse force is practically negligible. The longitudinal force (2) is much greater. Therefore, we look for the reason for the appearance of additional acceleration in the Sun's gravitational field.

We base on Newton's second law $\mathbf{F} = m\mathbf{a}$, where $\mathbf{a}$ is an acceleration vector. The module based on (2) can be written as:

$$a = G\frac{M}{r^2}\left(1 + \frac{v^2}{c^2} + 2\frac{v}{c}\mathbf{v}_0 \cdot \mathbf{r}_0\right), \qquad (12)$$

From expression (12), let's select the third term. It will be the expression of the sought-after additional heliocentric acceleration

$$a = 2G\frac{M}{r^2}\frac{v_r}{c}; \quad v_r = v\,\mathbf{v}_0 \cdot \mathbf{r}_0, \qquad (13)$$

where v_r is the radial velocity component. At a great distance from the Sun, it is enough to take $v_r = v$.

In the field of the Solar System, for all dimensions in SI:

$$G = 6{,}67438.10^{-11};\ M = 1{,}9891.10^{30};\ c = 2{,}99792.10^{8};\ \text{AU} = 1{,}49598.10^{11},$$

formula (9) can be simplified (for $r = n$ AU) [8]:

$$a = 0{,}39575\frac{v_r}{n^2}10^{-10}. \qquad (14)$$

Example. Let's calculate additional heliocentric accelerations a slow down the speed of the Pioneer-10 (start 02.03.1972) space probe. Available starting data, obtained based on the results of space contacts on the specified dates [2]:

1. Calculation option – $n = 25.00$; $v_r = 12500$ ms^{-1};
2. Contact 01.23.2003 – $n = 82.19$; $v_r = 12224$ ms^{-1};
3. Contact 01.23.2012 – $n = 106.96$; $v_r = 12048$ ms^{-1};

Substituting the initial data in (14), provided that at a sufficient distance $v_r = v$, we obtain the desired fixed additional accelerations:

$a_1 = 7.915\cdot10^{-10}$; $a_2 = 0.716\cdot10^{-10}$; $a_3 = 0.417\cdot10^{-10}$.

As for the additional acceleration a_1, it fits perfectly into the result of the experiment $(8.74 \pm 1.33)\cdot10^{-10}$:

$$7.41\cdot10^{-10} < 7.92\cdot10^{-10} < 10.07\cdot10^{-10},$$

although the result of a logical assumption was introduced into the starting data in this version.

For a preliminary assessment of the quantitative ratios of the component action of the Sun's gravity, we calculate the total acceleration based on (12)

$$a = 9.492\cdot10^{-6}(1 + 0.174\cdot10^{-8} + 0.8339\cdot10^{-4}) = 9.492\cdot10^{-6} + 1.650\cdot10^{-14} + 7.915\cdot10^{-10}\ (\text{ms}^{-2})$$

As we can see, the coefficient of gravitomagnetic acceleration $0.174\cdot10^{-8}$ is small, so it can be neglected in practice, which cannot be done with the coefficient of additional solar acceleration $0.8339\cdot10^{-4}$, and therefore this acceleration is also noticeable in space practice.

In conclusion, let us confirm an important position: theoretical propositions of electrogravity [1] logically fit into the theory of cosmic inflation [9].

6. Conflict of interests

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

7. Gratitude

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Conclusions

1. The dominant opinion that classical properties of the fundamental laws of statics can be successfully used in the celestial mechanics of low speeds (v << c) does not always satisfy the practice of operating artificial space vehicles. The involvement of relativistic methods also does not improve the situation, because the gravitomagnetic acceleration is too small. Therefore, it is time to look for new approaches to get out of this theoretical impasse.

2. The analysis of the problem showed that the known classical methods of the theory of motion operate only with the transverse component of the velocity vector concerning the orientation of the radius-vector of the gravitational interaction. For the first time, we introduced the missing longitudinal component into the theory of motion, the effect of which turned out to be an order of magnitude higher than the effect of the transverse component.

3. The appearance of experimentally perceptible additional solar acceleration in the practical problem of the flight of space vehicles only confirms the trinity of force gravitational interaction – static, transverse, and longitudinal dynamic.

4. The new results obtained in the work are not only of purely scientific interest but also epistemological in favor of the unity of the universe at all its levels – mega-, macro-, and microworld.

5. Without looking at the 40-year history of the existence of the problem of the anomaly of the flight speed of space probes, its mathematical solution was carried out for the first time, based on the theory of electrogravity – there is no anomaly of the flight trajectories of space vehicles. On the contrary, the movement occurs in the basic laws of the universe.

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