HOW NEWTON'S LAW (THE LAW OF TWO-BODY GRAVITATION) BECAME CALLED THE LAW OF UNIVERSAL GRAVITATION.

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Abstract. *This article attempts to dispel the biggest myth surrounding Newton's law of gravitation for over 300 years. It explores the history of the term "law of universal gravitation" in physics and the consequences of its unjustified application to the law of two-body gravity. This term was preceded by Robert Hooke's term "universal attraction," which referred not to the law of gravity between two bodies, but to the attraction between all bodies in the universe. This "substitution" of terms led to kept Hooke's contribution in the shadows for over three centuries. In science, this led to the true law of universal gravitation, as Robert Hooke envisioned it, never being discovered.*
Keywords: *Robert Hooke; Isaac Newton; astronomy; Newton's law of gravitation*

1. Introduction

Isaac Newton's discovery of the law of universal gravitation became the foundation of classical physics. The term "law of universal gravitation" is usually associated with Newton [1]. But Robert Hooke was the first to speak of "*universal attraction*" long before the publication of *Philosophiae Naturalis Principia Mathematica.* It is well known that Robert Hooke, with his remarkable intuition and broad interests, served as the intellectual catalyst for Newton's discovery of the law of gravitation. Hooke viewed the force of universal gravitation as a gravitational force exerted on all bodies by all other celestial bodies.

In a letter to Newton in 1679, Robert Hooke pointed out that the law of universal gravitation must take into account the elliptical orbits of the planets and the inverse-square law. This was the first verbal formulation of the law of universal gravitation in the history of science. It was Hooke's fateful 1679 letter that changed Newton's thinking and pushed him to discover the law of gravity.

In 1687, Newton presented his verbal formulation of the law of gravitation, which included the inverse-square law. However, the parameters of the elliptical orbit discussed by Hooke were not included in his law of gravitation. Instead of orbital parameters, Newton introduced mass into his law. As a result, instead of a law of universal gravitation for all bodies in the universe based on the orbital motion of bodies, Newton proposed a law of two-body [2, 3, 4] gravitation based on the mass of the gravitating body. This radically differed from Hooke's verbal formula. Newton's two-body law of gravitation did not take into account the additional attractive force of all other bodies in the universe. The law of two-body gravity, described by a proportional relationship, did not take into account the additional force of attraction of all other bodies in the Universe.

The euphoria of Newton's supporters over the discovery of the law of gravitation was so great that they began to unjustifiably call the law of two-body gravitation the law of universal gravitation. Although this was Hooke's term (*universal attraction),* it referred not to the law of gravitation between two bodies, but to the attraction between all bodies in the universe. This "substitution" of terms led to Hooke's contribution remaining in the shadows for a long time. But the most destructive consequence of this “substitution” of terms was that the ***real law of universal gravitation***, as Robert Hooke envisioned it, was never discovered.

2. Two different verbal formulas for the law of universal gravitation.

In the history of science, there have been two different verbal formulas for the law of universal gravitation. The first verbal formula for the law of universal gravitation in the history of science was given by Robert Hooke in a letter to Newton [5]. This occurred in 1679, seven years before the publication of Philosophiae Naturalis Principia Mathematica. In his verbal formula, Robert Hooke indicated that the law of universal gravitation must take into account the orbits of the planets and the inverse-square law. Hooke did not mention mass as a parameter in the law of gravitation in the verbal formula.

Newton's verbal formula was different. Newton pointed out the proportionality of force to the masses of bodies and the inverse-square law. The symbolic representation of Newton's law of gravity looks like this:

$$F_N \propto \frac{mM}{r^2} \qquad (1)$$

Where: F_N is the force, m, M are the masses of the bodies, r is the distance, ∝ is the proportionality sign.

Newton didn't assign any numerical value to the gravitational force. This wasn't a precise law of gravity, but a proportional relationship. In this incomplete form, Newton's law existed for almost 200 years (!). It became a precise equation in the form:

$$F=GmM/r^2 \qquad (2).$$

This happened only after the introduction of the gravitational constant G into formula (1) [6-9].

Formulas (1) and (2) describe the attraction of only one local source of gravity and do not take into account that bodies simultaneously gravitate toward all other bodies. Formulas (1) and (2) describe the local gravity of two bodies and do not take into account the additional gravitational force that actually exists as a result of the gravitational action of all bodies in the Universe. The law of gravitation $F = GmM/r^2$ is the law of two-body gravitation, applicable to closed, strictly elliptical orbits, which do not actually exist in the Universe.

3. Real planetary orbits are not closed.

Planetary orbits are not strictly closed in the sense of a perfect, unchanging ellipse, but form a complex shape reminiscent of a "spiral rosette" (a flower with many petals). In 1859, U. Le Verrier discovered an anomalous shift in Mercury's perihelion [10]. This shift in Mercury's perihelion could not be explained by Newton's law of gravitation. S. Newcomb discovered a shift in the perihelion not only for Mercury but also for other planets [11]. This indicates that some additional force is acting on the planets. U. Le Verrier strongly believed in the correctness of Newton's law and believed that the extra shift was caused by another unknown planet located even closer to the Sun. He even gave it a name: *Vulcanus*. By the beginning of the 20th century, it became clear that there was no planet inside Mercury's orbit, meaning that Newton's physics was failing somewhere. The discovery of planetary perihelion shifts demonstrated that the planets' actual trajectories are not closed. With the advent of General Relativity (1915), Einstein demonstrated that this is a fundamental property of gravity, making planetary orbits non-closed.

4. Why did Hooke emphasize the orbital motion of the planets?

In a letter to Newton in 1679, Hooke emphasized the need to take into account the orbital motion of the planets in the law of gravitation. Hooke persistently studied the orbital motion of the planets [5]. He discovered the main secret of gravity: *the orbital motion of the planets occurs under the action of gravitational forces from all bodies in the universe*. He believed that the orbital motion of the planets is determined by the force of universal gravitation and that this force of universal gravitation forms the real orbits of the planets and acts on all bodies from all other celestial bodies. Even before 1679, Hooke spoke of "*universal attraction*". He understood gravity as a general attraction of everything to everything. He distinguished between the local gravity of two bodies and universal attraction. Hooke knew that the force of universal gravitation is "*encoded*" in the orbital motion of the planets. Hooke shared this knowledge with Newton in 1679. Newton did not accept Hooke's hint [5]. Newton did not use orbital parameters in his law of gravitation; He was looking for a solution to the problem of two-body gravity and used mass as a parameter.

In his letter to Newton, Hooke expected Newton to formulate a universal law of gravitation that takes into account the orbital motion of bodies. But instead of a law of universal gravitation based on the orbital motion of bodies, Newton proposed a proportional relationship $F_N \propto mM/r^2$, based on the mass of the gravitating body. As a result, instead of a law of gravity that takes into account the gravity of all bodies, Newton formulated a law of gravity of two bodies.

The law of gravity $F = GmM/r^2$ still remains the law of gravity of two bodies [2, 3, 4]. It applies only to closed orbits, whereas real planetary orbits are not closed. This is precisely the point where Newton's mathematical justification of gravity collided with the harsh "*physical reality*" of the universe. Ideal ellipses (closed orbits) are possible only in Newton's two-body problem. Planets do not move in closed orbits. The real Universe does not consist of two bodies.

5. Hooke's terminology as applied to universal gravitation.

Hooke first discussed gravity as a universal force that gives celestial bodies their spherical shape in 1665 in his book "*Micrographia*". In *Micrographia,* he does not yet use the precise formulation "*universal attraction*," but he lays the foundation for this idea by discussing gravity as a universal property of matter to aggregate into spheres. In his "*Observation VI*", Hooke makes a bold proposition for his time: "*...Attraction is common not only to the Earth, Sun, Moon, and Planets, but to every minute body in the Universe...*" [12].

In 1674, in his work "*An Attempt to Prove the Motion of the Earth from Observations*," Hooke already wrote about "*attraction which is universal*." He asserted that all celestial bodies exert a force of attraction toward their centers and that they also attract all other celestial bodies. Instead of "*universal gravitation,*" he used the term "*universal attraction*." At that time, the word gravitas was used to describe the weight of an object. It was also used figuratively to describe a person's qualities: seriousness, dignity, importance, and authority.

Newton found a solution to the two-body gravity problem that only approximates the actual gravitational force of the entire Universe. The force of gravitational interaction between two bodies is only a part of the force of universal gravitation. In the universe, there is no isolated gravitational interaction between two bodies. All bodies in the universe participate in gravitational interaction. This discovery is due to Robert Hooke. The gravitational force of two bodies always has an "*addition*." This "*addition*" is the gravitational force of all other bodies in the Universe. The Law of gravity $F = GmM/r^2$ "*doesn't see*" these "*additions*." Therefore, the two-body model is only a useful approximation in physics. The law of gravitation $F = GmM/r^2$ is applicable only on small scales, for small masses, where the contribution of the force F to the total gravitational attraction significantly exceeds the gravitational force of all other bodies in the Universe.

Thus, the problem of discovering the real law of universal gravitation, as set out by Hooke in his verbal formula, remains unsolved. In the minds of scientists and laymen, the formula for the gravitational force of all bodies in the universe has been replaced by the formula for the gravitational force of two bodies: $F = GmM/r^2$. This reinforced the illusion *that the law of universal gravitation had been discovered and there was nothing more to discover*. The formula for the gravitational force of two bodies, $F = GmM/r^2$, unjustifiably replaced the formula for the force of universal gravitation. All of the above shows that calling the law of gravitation of two bodies ($F = GmM/r^2$) the law of universal gravitation is a exaggeration. The real Law of Universal Gravitation remains undiscovered.

6. To what law of gravity did Hooke's verbal formulation lead?

To what law of gravitation could Hooke's verbal formulation, taking into account the orbital motion of bodies, lead? Based on Hooke's verbal formulation, it must be a completely different law, unlike Newton's law. It must not include a gravitating mass. It must include the orbital parameters.
Hooke's verbal formulation, when using real, open orbits of bodies, can lead to a real law of universal gravitation. To do this, it is necessary to know the parameters of real, open orbits of bodies. This same verbal formulation by Hooke, when using closed Keplerian orbits, leads to a new law of two-body gravitation [5]:

$$F = mR^3/T^2r^2 \qquad (3)$$

Where: m is the mass of the body, R and T are the orbital parameters, and r is the distance.

Equation (3) is a more precise two-body law of gravity than Newton's law. The new two-body law of gravity does not include the constant G. The insufficient accuracy of the constant G ceases to be a limiting factor in gravity. The law of gravity $F = mR^3/T^2r^2$ is a worthy replacement for the formula $F = GmM/r^2$.

7. The N-body gravitational problem as an attempt to provide a realistic description of the gravity of the Universe.

The N-body gravitational problem is an attempt to provide a realistic description of the gravity of the Universe by moving from the two-body problem to a real system where each body attracts all others. The N-body gravitational problem is based on Newton's law of gravitation, $F = GmM/r^2$. This is a vicious circle: an attempt to find a realistic description of the gravity of the Universe using the two-body law as a basis. A mathematical impasse arose immediately for $N \geq 3$. A complete description of gravity requires taking into account the gravitational influence of billions of bodies in the Universe. Henri Poincoré proved that the N-body gravitational problem for N ≥ 3 has no analytical solution. Attempts to provide a realistic description of the gravity of the Universe using the N-body gravitational problem have been unsuccessful.

Other attempts to give a realistic description of the gravity of the Universe have been based on modifications of Newton's law [13–19]. No modifications to the two-body law of gravity $F = GmM/r^2$ have yielded results. Neither the N-body gravity problem nor modifications of the two-body law of gravity led to the discovery of a Law of Gravity that takes into account the gravity of all bodies in the Universe.

In [20] the problem of finding the law of universal gravitation based on the integral parameters of a system of N bodies was first formulated. This is the inverse N-body problem. Unlike the unsolvable direct N-body problem, the inverse N-body problem has a solution. All solutions to the inverse N-body problem are given in [20]. One solution to the inverse N-body problem is the law of universal gravitation without the gravitational constant G [21]:

$$F_U = \frac{mR^3}{T^2 r^2} + mc^2\sqrt{\Lambda} \qquad (4)$$

Where: m is the mass of the body, R and T are the orbital parameters, and r is the distance, **c** is the speed of light in vacuum, **Λ** is the cosmological constant.

The law of universal gravitation without the gravitational constant G has two components [14]. The additivity of the forces allows us to obtain the resulting force of universal gravitation as the vector sum of all individual forces. The first component describes the attraction between two bodies and is represented by the Hooke-Kepler law of universal gravitation [5]. The second component describes the attraction of all other bodies in the universe using the integral parameter of the universe—the cosmological constant Λ [14].

The law of universal gravitation (4) describes the real, non-closed orbits of bodies, which corresponds to the real motion of bodies in the universe. The path to this real law of universal gravitation was outlined by Robert Hooke in his verbal formula as early as 1679.

8. How the law of gravity of two bodies came to be called the law of universal gravitation.

To Newton's credit, he did not call his proportional relationship $F_N \propto mM/r^2$ the law of universal gravitational attraction. Moreover, Newton believed that it was impossible to discover the law of universal gravitation, which takes into account the gravity of all bodies in the universe. Here is what Newton wrote in 1684 in a text [22] known as the "Copernican Scholium":"...*the planets neither move exactly in ellipses nor revolve twice in the same orbit. Each time a planet revolves it traces a fresh orbit, as in the motion of the Moon, and each orbit depends on the combined motions of all the planets, not to mention the action of all these on each other. But to consider simultaneously all these causes of motion and to define these motions by exact laws admitting of easy calculation exceeds, if I am not mistaken, the force of any human mind*."

Therefore, instead of searching for a realistic description of gravity, instead of using the hint given to him by Hooke, Newton solved a simplified problem: the two-body gravity problem [2, 3, 4]. Using mass «M» as a parameter in the law of two-body gravity is equivalent to considering the motion of planets along a closed trajectory, which does not correspond to the actual motion of planets. How then did the laws of two-body gravity ($F_N \propto mM/r^2$, $F = GmM/r^2$), which do not take into account the gravity of all bodies in the Universe, come to be called the laws of universal gravitation?

Newton didn't do this. Others did. Roger Cotes, the editor of the second edition of "Philosophiae Naturalis Principia Mathematica" (1713), did. In the preface, he emphasizes the universality of Newton's law of gravitation. Voltaire, in his Philosophical Letters (1734), explained Newton's ideas using Hooke's concept of "*universal attraction*." Thus, the law of two-body gravity began to acquire an unjustifiably exaggerated status. Voltaire failed to mention that "*universal attraction*" is Robert Hooke's term, and it refers not to the law of gravitation between two bodies, but to the attraction between all bodies in the universe. Thus, Voltaire also authored the historical injustice that kept Hooke's contribution in the shadows for over three centuries.

Calling the law of two-body gravity, $F = GmM/r^2$, the law of universal gravitation, we are repeating not the words of Newton, but the words of Roger Coates, who, being a great admirer of Newton, unjustifiably called the law of two-body gravitation the law of universal gravitation.

But what about the real law of universal gravitation? This unjustified renaming of the law of two-body gravity to the law of universal gravitation did not advance scientific progress. This created the illusion that the law of universal gravitation had been discovered and that no other law of gravity existed. The true law of universal gravitation, which takes into account the fact that every body in the universe attracts every other body, as Robert Hooke said about it, was never discovered.

9. Consequences of silencing Robert Hooke's contribution and of the "innocent" substitution of terms.

The unjustified assignment of the name "*law of universal gravitation*" to the law of two-body gravitation had its negative consequences. This seemingly "*innocent*" substitution of terms cost science dearly. First, it resulted in a historical injustice, as a result of which the contribution of Hooke, England's Leonardo, remained in the shadows for more than three centuries [23, 24].

Even greater harm was done to physical science. The unjustified designation of the law of two-body gravitation $F = GmM/r^2$ as the law of universal gravitation gave rise to a blind faith in its omnipotence. This seemingly "*innocent*" substitution of terms gave rise to the illusion that the sought-after law of universal gravitation had been discovered and should be used to explain observations. The consequence of such blind faith and illusion was the emergence of false ideas and false concepts in science.

Mercury was the first to "*rebel*." It "*refused*" to obey the law of two-body gravity. U. Le Verrier, relying on Newton's law of universal gravitation, attempted to explain the anomalous precession of Mercury's perihelion [25]. He proposed the existence of an invisible planet, *Vulcanus*, located closer to the Sun, which turned out to be a mistake. V. Le Verrier's conviction in the infallibility of Newton's law of gravity led him to *Vulcanus*.

The history of dark matter's emergence in science is similar to the emergence of *Vulcanus*. In the 1930s, Fritz Zwicky noticed that galaxies were moving too fast—as if there was much more mass there than we could see. A dilemma arose: either the galaxy was "wrong," or Newton's law was incorrect. Newton's law, $F = GmM/r^2$, was traditionally understood, in accordance with its name, as the law of universal gravitation, not the law of two-body gravity. The change of terminology played a destructive role. Therefore, Fritz Zwicky confidently called the invisible mass dunkle Materie [26]. Fritz Zwicky reached this conclusion relying on Newton's law.

Even earlier, in 1904, blind faith in Newton's law as the law of universal gravitation failed Lord Kelvin [27]. While attempting to estimate the mass of the Milky Way, he concluded that there exist "*dark bodies*" that we cannot see but that create additional gravity. The existence of these "*dark bodies*" was inferred from Newton's law of universal gravitation to balance the calculations. French mathematician and physicist H. Poincare criticized Kelvin's assumption. His verdict was: "*There is no dark matter, or at least not as much of it as visible matter*" [28].

Vera Rubin's research in the 1970s showed that the outer parts of spiral galaxies rotate too rapidly, contrary to Newton's laws of mechanics [29]. Vera Rubin concluded that dark matter exists. This conclusion was reached by the same attempt to apply the law of two-body gravity, $F = GmM/r^2$, to the galaxy, beyond its applicability. Once again, the substitution of terminology played a destructive role. Vera Rubin was confident that Newton's law, $F = GmM/r^2$, was the law of universal gravitation and therefore applicable to the galaxy.

How many more scientists will be distracted by false ideas because the two-body law of gravity is still considered the law of universal gravitation? This will continue until the true law of universal gravitation, as envisioned by Robert Hooke, is discovered, taking into account the gravity of all bodies in the universe.

10. Conclusions.

1. In the history of science, there have been two different verbal formulas for the law of universal gravitation. The first verbal formula for the law of universal gravitation was given by Robert Hooke seven years before the publication of Philosophiae Naturalis Principia Mathematica. Hooke emphasized the orbital motion of bodies. Newton's verbal formula differed from Hooke's. Newton emphasized the masses of bodies.

2. Hooke discovered the main secret of gravity: *the orbital motion of the planets occurs under the influence of gravitational forces from all bodies in the universe*. He believed that the orbital motion of the planets is determined by the force of universal gravitation and that this force of universal gravitation shapes the actual orbits of the planets and acts on all bodies from the side of all other celestial bodies.

3. Newton solved the two-body gravitational problem. Newton's verbal formula was further developed and, after the introduction of the gravitational constant G, became the law of two-body gravitation $F = GmM/r^2$, which became known as the "*law of universal gravitation*." It so happened that Hooke's term "*universal attraction*" was applied to the law of gravitation between two bodies. However, Hooke used it not to refer to the attraction between two bodies, but to the attraction between all bodies.

4. The formula F = GmM/r² describes the local gravity of two bodies and does not take into account the additional gravitational force that actually exists as a result of the gravitational action of all bodies in the universe. The law of gravitation F = GmM/r² applies to closed, strictly elliptical orbits, which do not actually exist in the universe. The actual orbits of the planets are not closed.

5. Calling the law of two-body gravitation (F = GmM/r²) the law of universal gravitation is an exaggeration. Newton, having solved the two-body problem, did not call his law of gravitation the law of universal gravitation. This was done by his popularizers, who were too far removed from understanding of gravity.

6. Attempts to provide a realistic description of the gravity of the Universe by modifying Newton's law and by moving from the two-body problem to the N-body gravitational problem did not lead to the discovery of a new law of gravity that accounts for the gravity of all bodies in the Universe.

7. The unfounded designation of the law of two-body gravity F = GmM/r² as the law of universal gravitation gave rise to a blind belief in its omnipotence. Attempts were made to apply it on a universal scale. This resulted in the emergence of false ideas and false concepts in science.

8. The unjustified renaming of the law of two-body gravity to the law of universal gravitation did not contribute to scientific progress. This created the illusion that the law of universal gravitation had been discovered and that no other law of gravity existed. In science, this led to the fact that the true law of universal gravitation, as envisioned by Robert Hooke, *was never discovered*.

9. None of the above diminishes the significance of Newton's discovery. In 1687, it was a monumental scientific breakthrough. Newton's discovery became the foundation of classical physics. Although the Law of Gravitation F = GmM/r² is a two-body law of gravity and describes idealized closed orbits, it is applicable on small scales, for relatively small masses, where the contribution of the force F to the total gravitational attraction significantly exceeds the gravitational force of all other bodies in the Universe.

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