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Is the mass of celestial bodies, the Sun and the Earth, heavier than previously estimated?

Sankar Palchoudhury

Independent Researcher, Retired W. B. S. Govt. Employee, 101/673/A, College Para, P.O. Kharia, Ward No. 21, Dist. Jalpaiguri, Pin Code -735101, West Bengal, India

sankarpalchoudhury@gmail.com

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ABSTRACT

This paper explores the influence of a buoyancy-like force within the gravitational field on the orbital and rotational behavior of celestial bodies. Drawing an analogy from fluid mechanics, it is proposed that all matter, when immersed in a gravitational field, experiences a buoyant force similar to that observed in liquids. This gravitational buoyancy may play a significant role in the motion of celestial bodies. Through comparative analysis of orbital parameters involving the Earth, Moon, and Sun, the study suggests that the actual masses of the Earth and the Sun could be greater than current estimates. A mathematical model incorporating surface area and the inverse-square law is introduced to describe this additional force. The concept offers a potential extension to classical gravitational theory and may contribute to a deeper understanding of celestial mechanics.

Keywords: Gravitational buoyancy, orbital dynamics, celestial mass, gravitational field

INTRODUCTION

For centuries, celestial bodies have been observed to move in well-defined paths across the universe. According to Newton's law of universal gravitation, all masses attract each other with a force proportional to their masses and inversely proportional to the square of the distance between them. This interaction gives rise to what is commonly known as the gravitational field, which permeates all of space.

Any object within this field is subject to gravitational forces. In this context, every physical body is effectively immersed in a gravitational field and continuously experiences such forces. The motion of celestial bodies, such as the Moon orbiting the Earth and the Earth orbiting the Sun, can be understood in terms of resultant forces that maintain their orbital paths. While both lighter and heavier bodies are subject to the same gravitational interaction, it is typically the lighter body that orbits the heavier one due to the difference in inertia.

This paper introduces a novel interpretation of the resultant force involved in orbital motion. In particular, the gravitational attractive force is considered one component of a more complex interaction.

Figure 1 illustrates two celestial bodies, A and B. Body B is more massive than body A, yet the gravitational force between them is mutual.

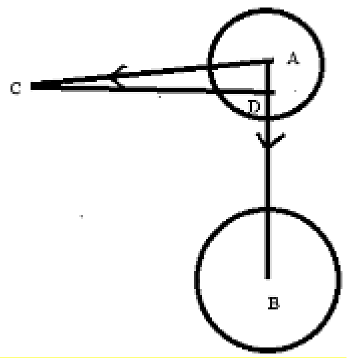

Figure 1: Diagram illustrating orbital motion between two celestial bodies, A and B. Body B is more massive, while body A orbits it under the influence of gravitational attraction and a resultant force vector AC. The angle ∠CAD = θ determines orbital stability.

However, as observed in nature such as the Moon orbiting the Earth smaller bodies tend to revolve around larger ones. The angle ∠CAD, denoted as θ, represents the trajectory-related parameter that influences the stability of the orbit. If θ exceeds 90°, the smaller body may escape the gravitational domain of the larger body. Conversely, if θ is significantly less than 90°, the smaller body may fall toward the larger one. The resultant force vector is labeled AC, while the component AD corresponds to the gravitational attraction. Comparative analysis using orbital parameters and data shown in Table 1 and Table 2 suggests that both the Earth and the Sun may possess greater actual mass than currently estimated. This discrepancy prompts further investigation into the forces involved in orbital motion, potentially including additional effects not accounted for in classical Newtonian mechanics.

Table 1: Orbital Parameters Between Earth and Moon and the Newly Assessed Mass of the Earth

Gravitational Constant (G)	Orbital Position	Distance (d) [m]	Orbital Velocity (v) [m/s]	Angle (θ)	cos(θ)	New Assessed Mass of Earth [kg]
6.67×10^{-11}	Apogee	4.07×10^{8}	990.2023	88.34163°	0.02894	7.10×10^{28}
6.67×10^{-11}	Perigee	3.59×10^{8}	1053.9167	88.00000°	0.03490	7.10×10^{28}

Table 1 presents the relationship between the Earth and the Moon at apogee and perigee, using key orbital parameters to compute a revised estimate of the Earth's mass.
The gravitational constant (G) is taken as 6.67×10^{-11} Nm²/kg². The variable d represents the Earth-Moon distance at each position, while v denotes the Moon's orbital velocity relative to the Earth. The angle θ, corresponding to ∠CAD in Figure 1, is used along with its cosine to resolve the force components relevant to the proposed model. The newly assessed mass of the Earth remains consistent across both orbital positions, indicating that the model yields stable estimates despite changes in distance and velocity, thereby supporting the underlying theoretical framework.
Table 2 presents the rotational motion parameters of the Earth at aphelion and perihelion. The newly assessed mass of the Earth is used to compute the linear momentum (Mv), taking into account the corresponding orbital velocities and distances from the Sun. The angle θ, consistent with the model introduced earlier, is used to determine the component of force along the direction of motion. The results support the hypothesis that orbital mechanics may be influenced by additional factors beyond classical gravitational attraction.

Table 2: Rotational Motion Parameters of the Earth Using Newly Assessed Mass

Gravitational Constant (G) [Nm²/kg²]	New Assessed Mass of Earth [kg]	Orbital Position	Distance from Sun (d) [m]	Orbital Velocity (v) [m/s]	Mv (N·s)	Angle (θ)	cos(θ)
6.67×10^{-11}	7.09663×10^{28}	Aphelion	1.521×10^{11}	29,543.29483	2.09658×10^{33}	88.34163°	0.02894
6.67×10^{-11}	7.09663×10^{28}	Perihelion	1.470×10^{11}	30,041.16428	2.13191×10^{33}	88.00000°	0.03490

The parameters used in Table 2 are defined as follows: G is the universal gravitational constant, with a value of 6.67×10^{-11} Nm²/kg². The variable d represents the distance between the Earth and the Sun, measured at two key orbital points aphelion and perihelion. **v** refers to the Earth's orbital velocity at these positions. The product Mv denotes the Earth's linear momentum, calculated as the multiplication of its mass and orbital velocity. Finally, the angle θ corresponds to the orbital inclination as introduced in the theoretical model (see Figure 1), and its cosine value is used to resolve the velocity vector along the direction of the resultant force.
Table 3 summarizes the interaction between the Earth and the Sun, incorporating both gravitational attraction and a proposed buoyancy-like force within the gravitational field.
Here, GAF represents the gravitational attractive force between the two bodies, while BFGF denotes the buoyancy force acting at a lever arm distance a, as illustrated in Figure 2. The new assessed mass of the Sun is taken as 3.40×10^{35} kg

based on the model's predictions. The consistent lever arm value suggests that the torque caused by the buoyancy force contributes to the observed rotational velocity of the Earth.

The inclusion of BFGF provides a novel interpretation of celestial rotation, potentially complementing or extending Newtonian gravitational theory.

Table 3: Gravitational and Rotational Parameters of the Earth-Sun System Using the Newly Assessed Solar Mass

Gravitational Attractive Force (GAF) [N]	New Assessed Mass of the Sun [kg]	Buoyancy Force in Gravitational Field (BFGF) [N]	Lever Arm Distance a [m]	Rotational Velocity [m/s]
*6.96832×10^{31}	3.40×10^{35}	6.96832×10^{31}	2.11	465
*7.44026×10^{31}	3.40×10^{35}	7.09×10^{31}	2.11	473

*(Williams, 2024, 2025)

The interaction between the Earth and the Sun involves not only gravitational attraction but also an additional force proposed in this study: gravitational buoyancy. At aphelion (1.521×10^{11} meters), the computed buoyancy force is approximately 6.96832×10^{31} N. At perihelion (1.470×10^{11} meters), it increases to around 7.09×10^{31} N.
These estimates are based on orbital data mass, velocity, and distance sourced from NASA's *Sun Fact Sheet* and *Planetary Fact Sheet*(Williams, 2024). Building on earlier calculations, this section introduces the concept of a buoyant force that acts on bodies submerged in the gravitational field analogous to how objects experience buoyancy in a fluid like water. In fluid mechanics, the buoyant force is equal to the weight of the displaced liquid, acting over the object's surface.
Similarly, in a gravitational field, it is proposed that matter experiences a distributed force over its surface area, influenced by its spatial relationship with another body. This gravitational buoyancy force is modeled to vary directly with the product of the actual surface areas of two bodies and inversely with the square of the distance between them. The relationship is expressed mathematically as:

$$B = P \cdot \frac{S \cdot s}{d^2} \quad (1)$$

In this expression, B is the gravitational buoyancy force between the two bodies, P is a constant of proportionality, S and s are the actual surface areas of the two interacting bodies, and d is the distance between them. The term "actual surface area" refers to the portion of a body's outer boundary that directly interacts with external forces. It excludes internal voids and molecular free spaces, which are minimal in solids, greater in liquids, and even more pronounced in gases.
Since these free spaces do not contribute to surface-level pressure or interaction, they are not included in the force calculation. This buoyant force model complements the Newtonian gravitational framework. Based on the orbital motion of celestial bodies, the following relation can be derived:

$$mv\,cos\theta = F = G\,\frac{M\,m}{d^2} \quad \text{or} \quad M = \frac{v\,cos\theta\,d^2}{G} \quad (2)$$

This formulation enables a recalculation of a celestial body's mass by incorporating the velocity component aligned with the resultant force direction, offering a novel method to reassess planetary mass within the gravitational buoyancy framework.

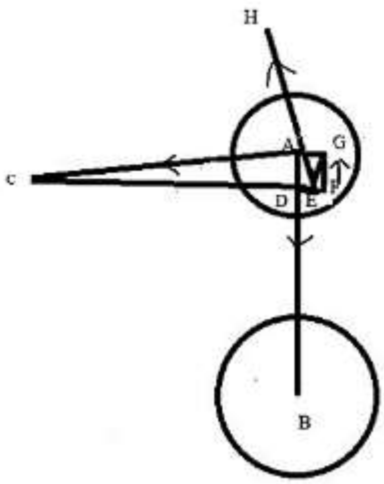

Figure 2: Conceptual Representation of Buoyancy Force Acting in a Gravitational Field

Figure 2 illustrates the effect of gravitational buoyancy on a rotating celestial body. The force vector AC represents momentum (mv), while the gravitational attractive force (GAF) is projected along AD, which equals $AC \cdot cos(\theta)$. The buoyancy force acts at a distance 'a' from the center of mass, contributing to rotational motion.
In Figure 2, the vector AC represents the linear momentum of a body, defined as mv, where m is mass and v is velocity. The gravitational attractive force (GAF) is the projection of this momentum along the direction AD, given by ($AC \cdot cos\theta$). That is, $mv\ cos\theta = F = G(M\ m)/d^2$.
Here, the point G lies at a distance a from point A, indicating where the buoyancy force acts, on the side opposite the gravitational force vector. Since AD and FG are parallel and equal, the buoyancy force (FG) is conceptually equivalent to the gravitational attractive force (AD).
However, the key difference lies in where the force acts. Because the buoyancy force acts at a distance from the center of gravity, it generates rotational torque, contributing to the

celestial body's spin. Thus, the rotational power is dependent on the product of the buoyancy force and the moment arm a. This leads to a refinement in interpreting gravitational force. In Newtonian mechanics, the gravitational force does not account for the surface area of bodies. As a result, Newton's model may underestimate the actual attractive force, especially when distributed surface-level effects are involved. To represent this difference, the following equations are proposed:

$$F_n = F_a - B \qquad F_a = F_n + B \tag{3}$$

Where F_n is the Newtonian attractive force, F_a is the actual total attractive force and B is the buoyancy force in the gravitational field. This distinction explains natural phenomena such as why water, with $F_n > B$, remains grounded, while vapor, where $F_n < B$, tends to rise or stay suspended. Such behavior supports the idea that the actual surface area of matter plays a measurable role in gravitational interactions, reinforcing the concept of gravitational buoyancy (Palchoudhury, 2016).

CONCLUSION

In nature, two fundamental forces may influence the motion and behavior of matter within a gravitational field:
1-Gravitational Attractive Force (GAF), as described by Newtonian mechanics.
2-Buoyancy Force in the Gravitational Field ($BFGF$), as proposed in this study. These two forces collectively impact a wide range of phenomena, including orbital motion, rotational dynamics, free-fall trajectories, and even evaporation processes. Recognizing and integrating the buoyancy effect into gravitational models opens new avenues for understanding celestial mechanics and may lead to significant theoretical advancements.

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