The secret of planets' perihelion between Newton and Einstein

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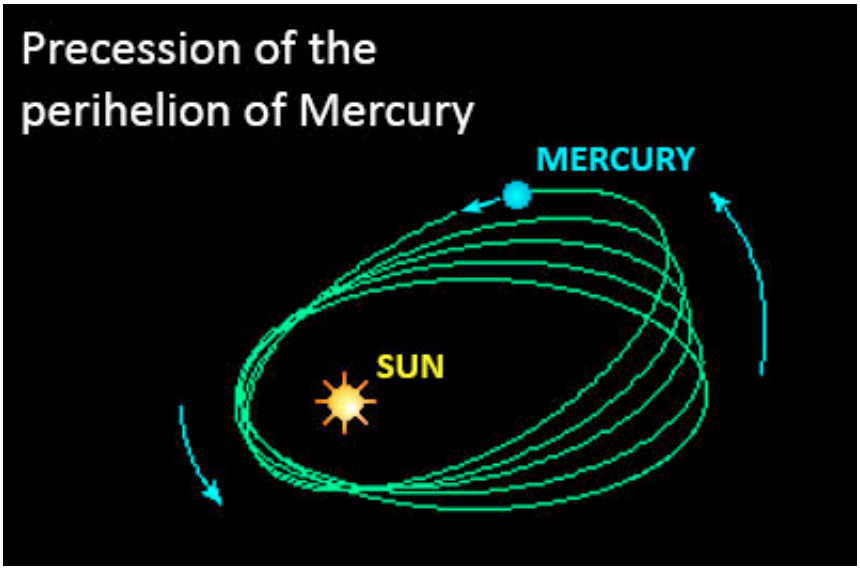

Precession of the perihelion of Mercury Credit: http://www.eniscuola.net/mediateca/la-precessione-del-perielio-di-mercurio/

In the early 1600s, based on astronomical observations, Kepler established that the orbit described by a planet in the solar system is an ellipse, with the sun occupying one of its foci. Assuming that a planet is subject only to the gravitational attraction of the sun, Kepler's result is easily obtained mathematically in Newton's theory. But the other planets also have a gravitational attraction on the planet in question. What is the effect of their presence?

If one repeats the calculation taking into account this complication, the result is that the attraction exerted by all the other planets of the solar system on the planet in question induces an advance (precession) of the perihelion (the point of maximum approach to the sun of the orbit of the planet), orbit after orbit. The precession of the Earth's rotation axis also gives rise to the same effect. For example, Mercury's perihelion moves slightly at the speed of 5,600 arcseconds per century, in the same direction in which the planet rotates around the sun.

However, removing the contribution of the Earth's precession (5,025 arcseconds) does not correctly predict what happens in reality, due to the attraction of the other planets as calculated according to Newtonian physics. The balance indeed misses 43 arcseconds. It is a general conviction, supported by centennial computations, that this deviation of Mercury's orbit from the observed precession cannot be achieved by Newtonian theory. This is the famous anomalous rate of precession of the perihelion of Mercury's orbit. It was originally recognized by the French Astronomer Urbain Le Verrier in 1859 as being an important astronomical problem.

Starting from 1843, Le Verrier reanalyzed observations of the perihelion of Mercury's orbit from 1697 to 1848, by showing that the rate of the precession of the perihelion was not consistent with the previsions of Newtonian theory. This discrepancy of 38" arcseconds per tropical century, which was corrected to 43" by the Canadian-American astronomer Simon Newcomb in 1882, seemed until now impossible to be accounted through Newton's theory. Various ad hoc and unsuccessful solutions have been proposed, but these introduced more problems. The most famous approach by 19th-century astronomers was an attempt to explain this discrepancy through the perturbing effect of a hitherto undiscovered planet, Vulcan, smaller than Mercury and even closer to the sun. However, the search for this planet turned out to be unfruitful. The solution of the problem was provided by Albert Einstein through his

general theory of relativity in 1916. Recent analyses using MESSENGER data and the Cassini mission gave a value of about 42.98'' to the general relativistic contribution to the precession of the perihelion of Mercury per tropical century.

My recent results

In a paper published in *Physics of the Dark Universe* 100834 (2021), using three different approaches, I showed that, contrary to the above cited longstanding conviction of more than 160 years, the advance of Mercury's perihelion can be achieved in Newtonian gravity with a very high precision by correctly analyzing the situation without neglecting Mercury's mass. The first approach concerns the approximation in which one considers Mercury's orbit as being circular instead of elliptical. The second approach is realized by considering Mercury's orbit in terms of harmonic oscillator. The third approach arises from Kepler's third law.

Overall, the general theory of relativity remains more precise than Newtonian physics, but my approach shows that the Newtonian framework is more powerful than researchers and astronomers were thinking before this paper, at least for the case of Mercury. On the other hand, my Newtonian formula of the advance of planets' perihelion breaks down for the other planets. The predicted Newtonian result is indeed too large for Venus and Earth. Therefore, in my paper it is also shown that corrections due to gravitational and rotational time dilation, in an intermediate framework that analyzes gravity between Newton and Einstein, solve the problem. By adding such corrections, I found a result consistent with the one of general relativity.

Thus, the most important results of this paper are: (1) It is not correct that Newtonian theory cannot predict the anomalous rate of precession of the perihelion of planets' orbit. The real problem is instead that a pure Newtonian prediction is too large. (2) Perihelion's precession can be

achieved with the same precision of general relativity by extending Newtonian gravity through the inclusion of gravitational and rotational time dilation effects. This second result is in agreement with a couple of recent and interesting papers of Hansen, Hartong and Obers. By contrast with these papers, my work considers the importance of rotational time dilation. Finally, it is important to stress that a better understanding of gravitational effects in an intermediate framework between Newtonian theory and general relativity, one of the goals of this paper, could, in principle, be crucial for a subsequent better understanding of the famous dark matter and dark energy problems. In the future, I will attempt to use a similar approach in the framework of the galaxy rotation problem.

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Bio:
I received my Ph.D. degree in physics from the Pisa University, Pisa, Italy in 2008. I am the Editor-in-Chief of Journal of High Energy Physics, Gravitation and Cosmology and of Theoretical Physics. I am also Editorial Board Member of other five international peer-reviewed journals. In addition, I am Habilitated as Professor of Astrophysics and Theoretical Physics at the Italian Department for University and Research (MIUR). I have been Professor of Theoretical Physics at the Istanbul University from 1/1/2020 till 2/28/2020. I am Contract Professor of Astrophysics of the Research Institute for Astronomy and Astrophysics of Maragha (RIAAM), P.O. Box 55134-441, Maragha, Iran. Three of my Essays on gravitation were Honorable Mention Winners at the 2009, 2012 and 2018 Gravity Research Foundation

Awards. I have been Community Rate Winner of the 2013 FQXi ssay Contest with a paper which solves the black hole information paradox which has been subsequently published in Annal of Physics.
In October 2013 I have been awarded with a Certificate of Honor by the Nagpur University in recognition and grateful appreciation for his research contributions in the fields of black holes and gravitational waves. In September 2014, at the 12th International Conference of Numerical Analysis and Applied Mathematics, I have been awarded by the European Society of Computational Methods in Sciences, Engineering and Technology with its Highest Distinction of Honorary Fellowship for his outstanding results in Applied Mathematics. I am author and/or co-author of more that 150 scientific papers published in international peer reviewed specialistic journals in the fields of mathematics, theoretical physics, astrophysics and cosmology.

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