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EDITED BY
Orlando Luongo,
University of Camerino, Italy

REVIEWED BY
Yeinzon Rodriguez Garcia,
Industrial University of Santander, Colombia

*CORRESPONDENCE
Elmo Benedetto,
ebenedetto@unisa.it

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# Editorial: Experimental predictions in general relativity: what now?

Fabiano Feleppa[1,2], Elmo Benedetto[3]*, Gerardo Iovane[3], Fabrizio Tamburini[4] and Ignazio Licata[5]

[1]Dipartimento di Fisica "E.R. Caianiello", Università di Salerno, Fisciano, Italy, [2]Istituto Nazionale di Fisica Nucleare, Sezione di Napoli, Napoli, Italy, [3]Dipartimento di Informatica, Università di Salerno, Fisciano, Italy, [4]Rotonium Quantum Computing, Padua, Italy, [5]Institute for Scientific Methodology (ISEM), Palermo, Italy

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Editorial on the Research Topic
Experimental Predictions in General Relativity: What Now?

In 1915, Einstein revolutionized our understanding of space, time, and gravity with his theory of general relativity, first confirmed in 1919 through the observed deflection of starlight during a solar eclipse. Over the following decades, systematic tests—from Solar System experiments in the 1960s to binary pulsar observations in the 1970s—demonstrated its remarkable accuracy in the weak-field regime (Will et al., 2018).

In the last two decades, breakthroughs in observational capabilities have revolutionized this area of research, offering novel ways to examine general relativity and alternative theories both on cosmological scales (Ishak, 2019) and in the strong-field regime around black holes and neutron stars (Berti et al., 2015), potentially allowing us to address previously unsolved puzzles.

This Research Topic brings together contributions in which the authors propose solutions to some of these puzzles or suggest tests of alternative theories.

In the research article *Solution of the Dark Matter Riddle within Standard Model Physics: From Black Holes, Galaxies, and Clusters to Cosmology*, Nieuwenhuizen suggests that the energy of the quantum vacuum serves as both dark energy and dark matter. This energy condenses around mass concentrations, forming "electro-aether-energy", offering a potential explanation for the dark matter mystery without introducing new physics. The author further explains how the theory could help address other cosmic puzzles, including galaxy formation, the Hubble tension, and black hole growth.

In the research article *Gravitational orbits in the expanding Universe revisited*, Vavryčuk explores the application of modified Newtonian equations for gravitational orbits in an expanding universe, comparing results obtained in the Friedmann-Lemaître-Robertson-Walker (FLRW) metric and the conformal cosmology (CC) metric. According to a previous study by the same author (Vavryčuk, 2022), the CC metric is shown to be more accurate in predicting cosmic time dilation and fitting Type Ia supernova observations without requiring dark energy. While the FLRW metric suggests that local gravitationally bound systems like galaxies or planetary systems are unaffected by the expansion of the Universe, the CC metric indicates that local systems expand in sync with the Hubble flow. The paper thus models the evolution of spiral galaxies, demonstrating that their size grows in agreement with observational data, and predicts flat rotation curves without invoking dark matter.

The review article *A review on analytical studies in gravitational lensing* by Chowdhuri et al. focuses on analytical studies of gravitational lensing by black holes (Bozza, 2010). It begins by discussing lensing in the spherically symmetric Schwarzschild spacetime and then moves to the rotating Kerr metric. The review also explores lensing in black-bounce spacetimes (Lobo et al., 2021), examining how various parameters can be constrained using astrophysical data.

Finally, in the review article *Testing parity symmetry of gravity with gravitational waves*, Qiao et al. examine the role of parity symmetry in gravitational interactions. While Einstein's general relativity preserves parity, various theories of parity-violating (PV) gravity have recently been proposed across different theoretical frameworks, driven by diverse motivations. In this review, the authors summarize recent advancements in these theories, focusing specifically on the observable effects of PV terms in gravitational waves (GWs), particularly the differences between left-hand and right-hand polarization modes. The authors emphasize the implications of these theories for GWs produced by compact binary coalescences and primordial GWs from the early universe. Deviations in the GW waveforms or the primordial power spectrum can be characterized by the energy scale at which parity violation occurs in each theory. By analyzing current and future observations from laser interferometers and the cosmic microwave background radiation, they present both the existing and potential constraints on the energy scale of PV. These constraints suggest that the parity symmetry of gravity can be tested at high energy scales in the emerging era of gravitational wave research.

These four papers collectively provide a broad perspective on active research directions—some focusing on the dark energy and dark matter problem, while others explore potential deviations from general relativity. Gravitational lensing and gravitational wave physics are among the most promising avenues for detecting such deviations. Hopefully, the ideas presented in these papers will help refine our understanding and enhance our ability to identify these signatures.

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