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Editorial

Preface of "Particles and Fields in Black Hole Environment"

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This Special Issue is dedicated to the memory of the physicist Professor James Maxwell Bardeen (9 May 1939–20 June 2022), who is well known for his work on general relativity, particularly his role in formulating the laws of black hole mechanics, the pioneering idea on black hole shadow observation and the Bardeen solution to gravitational field equations. Professor Bardeen passed away on 20 June 2022, in Seattle.

Recently, there has been a rapidly growing interest in the study of relativistic astrophysics of gravitational compact objects due to numerous recent achievements: The direct detection of gravitational waves from the numerous events of merging gravitational compact objects in close black hole and neutron star binaries via LIGO-VIRGO scientific collaboration, the measurement of general relativistic effects in a strong gravity regime in the environment of the supermassive black hole Sagittarius A* at the center of the Milky Way galaxy, performed using the ESOs GRAVITY instrument, and the first images of black hole shadows in the center of elliptic galaxy M87* and Sagittarius A* taken with the Event Horizon Telescope. In light of these recent successes and triumphs of the general theory of relativity, the scope of this Special Issue was to open discussion of the above mentioned topics to researchers working in areas such as Mathematical and Theoretical Physics, General Relativity, and Observational Relativistic Astrophysics.

The focus of the Special Issue was on the publication of the research articles in the areas covering General Relativity (Classical and Quantum), Relativistic Astrophysics, Experimental Gravitation, Alternative Theories of Gravity, Gravitational Waves, and Gravitational Compact Objects.

There is a huge amount of literature devoted to the astrophysical processes in the close environment of black holes. However, there is strong interest in probing the nature of black holes through astrophysical applications of the recently obtained results in relativistic astrophysical to theoretical models, and predictions regarding the constraints of the parameters of alternate theories of gravity versus general relativity. The Special Issue is devoted to publication of the research papers of the scientists and experts who are actively working in the areas of particles and photon motion in the close vicinity of black holes, gravitational, electromagnetic, scalar fields and perturbations of gravitational compact objects, optical and energetic properties of black holes and magnetized neutron stars, gravitational lensing, and relativistic astrophysical processes in strong gravity regimes.

The relationship between the baryonic mass of galaxies and the velocity of motion of stars at the edge of galaxies is also an interesting topic within modern relativistic astrophysics. One may explore the model of accretion of galaxies around supermassive black holes (SMBHs) in order to study the mechanisms of origin of elliptical galaxies with low angular momentum and disk galaxies with high angular momentum. In the

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article entitled 'Accretion of Galaxies around Supermassive Black Holes and a Theoretical Model of the Tully-Fisher and M-Sigma Relations' the author discusses the observed Tully–Fisher and Faber–Jackson laws within the framework of the model of accretion of galaxies around SMBH.

Modified gravity (MOG) as an alternative theory to general relativity can be investigated to resolve fundamental problems of standard theory of gravity. Particularly, the regular black hole solution within MOG can be treated as an alternative to solutions used to model the astrophysical processes. On the other hand, quasi-periodic oscillations (QPOs) may be explored as powerful platform to test the gravity models and corresponding solutions. Consequently, one may investigate the QPOs and related astrophysical processes to develop new tests of alternative/modified theories of gravity. In the article 'Dynamics of Test Particles and Twin Peaks QPOs around Regular Black Holes in Modified Gravity' the authors addressed the above mentioned questions and problems.

The article 'Singularities in Static Spherically Symmetric Configurations of General Relativity with Strongly Nonlinear Scalar Fields' is devoted to one of the unsolved features of general relativity, which is the presence of physical singularity at the origin of most vacuum BH solutions. The presence of scalar field in the action, together with the Hilbert term, may modify the structure of the singularity. For the nonlinear scalar field, one may obtain the spherical singularity around the existing singularity at the origin. Consequently, from the perspective of theoretical astrophysics, the study of nature of the gravity around such singularities using test particles dynamics is not only interesting, but is also of significant importance.

The authors of 'Capture of Massless and Massive Particles by Parameterized Black Holes' discussed the capture cross section for massive and massless particles around black holes, described by a parametrized spacetime metric.

The article 'Regular Bardeen Black Holes in Anti-de Sitter Spacetime versus Kerr Black Holes through Particle Dynamics' discusses the issue related to the large number of spherical symmetric BH solutions of gravity theories. These theories generate additional difficulties when it comes to their involvement in testing the gravity theories in the strong field regime. One may use parameterized solutions describing the compact objects in order to make them applicable when testing gravity theories. Later, comparing the parameters of the parameterized solution with the particular exact solution of the field equation, one may obtain constraints on the different parameters of the field/solution.

The Zipoy–Voorhees solution, also known as γ metric or q-metric, is one of the exact solutions of the Einstein field equations, and has interesting features. Generally recognized as the axial-symmetric solution, the spacetime metric is diagonal. Theoretically, one may explore this type of solution in order to mimic, for example, the Kerr solution describing the spacetime of the rotating black hole. The authors of the article 'Zipoy-Voorhees Gravitational Object as a Source of High-Energy Relativistic Particles' discussed these issues.

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