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Editorial

Editorial to the Special Issue "Feature Papers—Compact Objects"

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Astrophysical studies of compact objects unite very different fields of research: from observations of known sources to sophisticated theoretical models involving new physics. This Special Issue includes eight research papers and four review articles touching upon different subjects, all related to various aspects of modern studies of black holes (BHs), neutron stars (NSs), and white dwarfs (WDs).

Observational data are presented in the paper [1]. The authors analyse a set of long-time monitoring of the famous X-ray binary Her X-1, containing a NS. Data from two instruments are used: the X-ray detector MAXI (on-board of the International Space Station) and Swift/BAT. The main focus is on the 35-day cycle observed in this system. This superorbital cycle is manifested in properties of the X-ray emission of the source, in particular, in the count rate and in the pulse shape. The origin of the cycle is related to precession of the accretion disc, see, e.g., [2] and references therein. However, many details are not well-understood, yet. Thus, new observations and analysis are much welcomed. The authors of [1] found spectral modulations in X-ray emission of Her X-1 which they attribute to changes in the column density depending on the 35-days cycle phase.

Her X-1 belongs to a well-known class of X-ray pulsars. However, new types of close binary systems with NSs are predicted. In [3] the authors analyse the observability of so-called HOFNARS—HOt and Fast Non-Accreting Rotators—with SGR/eROSITA X-ray telescope. NSs in HOFNARs are heated due to the r-mode instability. Their surface temperature can be $\sim 10^6$ K. In the paper, upon applying the population synthesis approach, the authors demonstrate that a few hundred such sources can be detected in the 4-year all-sky survey by eROSITA. Non-detection of HOFNARs will put very stringent limits on the properties of these types of NSs.

The remainder of the original studies in this Special Issue are more theoretical in scope. NSs are of great interest in the physics community due to their numerous extreme properties which enable the probing of physical laws under conditions unreachable in terrestrial laboratories. In particular, the properties of matter deep inside NS interiors is one of the major puzzles in modern nuclear physics. The authors of [4] study the deconfinement phase transition to quark matter. The results obtained by the authors are particularly relevant in the study of NS coalescence.

Exotic types of compact objects—anisotropic strange stars—are studied in $f(T, \mathcal{T})$ gravity in the paper [5]. The authors stability analyses of these models, deriving fundamental parameters of these strange stars and advocate for further studies.

In [6], the authors analyse behavior of relativistic spin-1/2 charged particles in a uniform magnetic field in the Schwarzschild metric. These results are applicable to interiors of NSs and similar objects. Future observations of millisecond radio pulsars orbiting supermassive BHs in galactic centers are discussed in [7]. Millisecond pulsars in such binaries have complex orbital and spin dynamics due to spin–orbit and spin–spin coupling effects. Observations of such sources might be important in the context of future observations with space gravitational wave detectors like the Laser Interferometer Space Antenna (LISA).

Three other theoretical papers in this Special Issue are related to BH physics. Patel et al. [8] modeled and discuss rotational energy extraction via the Penrose process,

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comparing rotating regular spacetimes and singular spacetimes, in particular the rotating Simpson–Visser regular spacetime. Results are compared with the known solution for Kerr BHs (it is found that the energy extraction in rotating Simpson–Visser spacetime is the same as in a Kerr BH). The authors also discuss the prospects of distinguishing between BHs of different types on the basis of astronomical observations. In [9], the deflection angle of a BH and related shadow properties (with and without surrounding plasma) are calculated in non-local gravity. The authors demonstrate that the size of the BH shadow decreases with the non-local parameter. Calculations of BH shadows for various model parameters are of significant interest because of the recent measurements of supermassive BHs from the Event Horizon Telescope Collaboration (EHTC). Potentially, future observations of the shadow size, shape, and temporal BH image properties will provide a strong tool to probe the predictions of different theories of gravity. In this vein, the authors of [10] explore properties of charged dilaton BHs.

Three review papers of this Special Issue also cover a wide range of topics. Mizuno [11] discusses the current status of advanced modeling of jets and accretion in active galactic nuclei (AGN). The review describes modern general-relativistic magneto-hydrodynamics codes developed to simulate jet formation and propagation. The author describes recent results of modeling jet formation in different accretion regimes (with various disc parameters and even without disc formation), also providing comparison with recent astronomical observations.

Magnetic fields are important not only in the collimation and launching of relativistic jets in AGNs. They are even more important in mediating the evolution and observational manifestations of NSs. In [12], the topic of evolution of magnetic fields of NSs is reviewed in detail. The authors discuss physical mechanisms responsible for the magnetic field evolution, present results of recent numerical modeling of these evolutions, and discuss how the field evolution influences observational properties of NSs.

Finally, NSs and WDs can provide crucial new insights into astroparticle physics. Dark matter particles can strongly interact with the interiors of these sources, with axions contributing to the cooling of WDs. Furthermore, axions can be produced due to photon conversion in strong magnetic fields of NSs. These topics are reviewed in [13].

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Abbreviations

The following abbreviations are used in this manuscript:

AGN	Active galactic nuclei
BH	Black hole
LISA	Laser Interferometer Space Antenna
NS	Neutron star
WD	White dwarf

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