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Editorial

Current Problems and Recent Advances in Wormhole Physics

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Wormholes are hypothetical space-time tunnels with nontrivial topologies capable of connecting either two distant regions of the same universe or two different universes [1–3]. From the theoretical point of view, the possibility of their existence is problematic but cannot be ruled out. If wormholes do exist, many unusual phenomena can be expected. Among them, probably the most exciting ones are shortcuts providing interstellar, intergalactic or inter-universe trips and even time machines.

At present, wormholes are extremely attractive and popular objects for research, it is sufficient to mention that the word "wormhole" is found in the titles of 1614 articles on the resource ArXiv.org for all years and 175 articles for the last 12 months (as of 19 January 2023). Although many mathematical and physical properties of these objects have been discovered and studied in recent decades, there remain multiple unsolved problems and opportunities of interest to be explored.

The present Special Issue "Recent Advances in Wormhole Physics" is aimed at enlightening some recent results in selected areas of wormhole physics. The issue is a collection of fourteen papers [4–17] that fairly well characterizes the diversity of subjects and methods of wormhole physics.

Very roughly, wormhole studies may be classified as follows:

- A search for wormhole solutions in general relativity and other theories of gravity, investigations of their properties and conditions of their existence.
- Studies of mathematical, physical, metaphysical and philosophical consequences of possible wormhole existence.
- Assuming that wormholes do exist in the Universe, studies of their astronomical and astrophysical manifestations, in particular, their possible observational distinctions from black holes.

Needless to say that many studies combine some or all of these trends. Nevertheless, it can be more or less conditionally observed that the first trend is represented by the papers [4,13,14,16], the second one by [5,7,11,15], and the third one by [6,8–10,12,17].

Two of the papers are brief reviews [4,9]. Thus, Takafumi Kokubu and Tomohiro Harada [4] consider different physical aspects of thin-shell wormholes, both in GR and in Einstein—Gauss—Bonnet gravity, including spherical, planar and hyperbolic symmetries of space-time and the stability issues. Cosimo Bambi and Dejan Stojkovic [9] describe astronomically observable effects of wormholes as possible substitutes of black holes, including gravitational lensing and shadows, possible orbiting star trajectories, accretion disk spectra, and gravitational waves emitted at merges of compact objects, of which one or both are wormholes.

Some of the papers evidently go beyond the traditional subjects of wormhole physics, concerning classical traversable wormholes. Thus, Sergey Bondarenko [11] considers their quantum counterparts, called quantum wormholes, and, in particular, their possible role

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in the origin of a small cosmological constant favoured by observations. Elias Zafiris and Albrecht von Müller [15] discuss the possible role of Planck-scale wormholes in the so-called "ER = EPR" conjecture in quantum entanglement. Alexander Kirillov and Elena Savelova [16] discuss the conditions under which Planck-scale virtual wormholes may be converted into macroscopic and observable ones. The present authors together with Pavel Kashargin [13] discuss wormholes that can emerge in the framework of general relativity without any exotic matter in nonstatic space-times.

The outstanding progress of observational astronomy and cosmology, above all, the discovery of gravitational waves and the pictures obtained by the Event Horizon Telescope, are apparently reflected in the wealth of studies devoted to possible observable effects due to wormholes. In the present issue, we see the discussions of high-energy particle collisions in wormhole space-times [6], gravitational lensing by wormholes with unusual topologies [8], peculiar features of accretion flows [10] and nearby stellar orbits [12,17] and possible manifestations of a fractal distribution of primordial wormholes [11].

It should be noted that, with the whole diversity of wormhole studies presented in this Special issue, some areas turned out to be almost unmentioned. These are axially and cylindrically symmetric wormholes with or without rotation (though, some effects of rotation are discussed in [6]), so we would here refer to the reviews [18,19] and references therein. These are also stability studies concerning all kinds of perturbations of static or stationary wormholes (note that Ref. [4] only discusses the stability of thin-shell wormholes with respect to shell motion), so please see, e.g., [20,21] and references therein for more general studies.

Concluding, we would like to say that the study of wormholes is far from being complete, and one can expect many new interesting physical and mathematical results in this relevant and promising area of physics.

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