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# Editorial: Current challenges of compact objects

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Editorial on the Research Topic
Current challenges of compact objects

## 1 Introduction

Celestial bodies, like black holes (BHs) and neutron stars, are known as compact objects. White dwarfs serve as research hubs where fundamental studies take place. The principles of gravity and quantum physics are subject to testing and experimentation. They probe the origins of stars, tracing back to their formation through the collapse process, engaging with the world around them. These items offer a wealth of knowledge regarding the characteristics and operations of spacetime. The end of the life cycle of stars is known as gravitational collapse. This process transforms materials into forms that represent an evolutionary progression. Researchers have been captivated by the studies of Oppenheimer. In addition, Snyder, in his research on the creation of BHs exploring these captivating subjects, has unveiled opportunities, including exploring the realms of relativity and quantum mechanics (Oppenheimer and Snyder, 1939).

In general, BHs have gained much attention from the scientific community as well as the public with the recent advancement in observational technologies, such as witnessing the first-ever image of the black hole in the center of M87 in 2019 (Akiyama et al., 2019). This development signaled the start of a new era of precision in the study of BHs. Several important phenomena, such as the study of gravitational lensing, shadows of BH event horizons, particle dynamics, as well as the accretion process, provide unique possibilities for testing not only Einstein's theory of general relativity but also the modified theories of gravity. Furthermore, the exploration of particle behavior and thermodynamics in the vicinity of BHs has raised important challenges regarding the spacetime singularities as well as the unification of gravitational theories with quantum field theories (Misner et al., 1973).

Compact objects such as white dwarfs and neutron stars play a major role in the study of dense matter physics. The disclosure of pulsars (Hewish et al., 1968) not only yields substantial observational data but also probes the general theory of relativity. Such objects offer valuable insights into the interior structure of compact stars and the stellar evolution (Glendenning, 2000). These objects are crucial for understanding the complicated interaction between gravity and nuclear physics. The study of pulsars could unveil states of matter that are complex to produce in laboratories.

The emergence of the astronomy of gravitational waves has unlocked the bounds of the research of compact objects. The detection of gravitational waves from the mergers of binary BH mergers (Abbott et al., 2016) has reformed our knowledge of such events. It simulated a chain of inquiry to the emergence and evolution of compact binary systems. Recently, mergers of neutron stars produced gravitational waves that provide important information regarding the equation of state (Baiotti, 2019).

This Research Topic, entitled "*Current Challenges of Compact Objects*," is devoted to demonstrating the latest progress in this vigorous area of research. In this issue, we invite contributions that explore research topics such as the stability of compact objects, particle dynamics around BHs, thermodynamics, accretion processes, and the study of compact stars within modified theories of gravity. Moreover, we pursue research that posits compact objects through the wider perspective of relativistic astrophysics. This Research Topic encloses the topics from the analysis of gravitational waves to the early and late time cosmology. These contributions reinforce the existing challenges and provide intriguing opportunities in the field. Hence, this Research Topic provides the significance and foundation of compact objects, their cosmology, and their astrophysics.

# 2 Overview

## 2.1 Article 1

This research article explores the dynamics of filamentary objects in the framework of $f(R,T)$ gravity. The authors explore the collapse at the boundary of the filamentary structures using the Darmois junction condition. They showed that the radial pressure is related to the time-dependent field. They discussed the influence of dark source terms that employ the propagation of gravitational waves. Their analysis explains how the dark matter affects the cosmic structure within the framework of modified theories such as $f(R,T)$. In general, the article yields useful information about the influence of dark matter on gravitational collapse and the distortion and emission of gravitational waves.

## 2.2 Article 2

This article investigates the relativistic polytropes that explain the behavior of compact objects. The authors used the Karmarkar condition and found the Lane–Emden equation by considering the spherically symmetric distribution of fluid. They considered both non-isothermal and isothermal conditions. Two different cases of mass and density are analyzed using the complexity factors. The analysis includes numerical simulations showing the effect of complexity factors on the structure of compact stars. Furthermore, the graphical results explain the linkage between these models and the astrophysical phenomena. Overall, this article represents a good approach to discussing the properties of compact objects, such as temperature and density, using complexity factors.

## 2.3 Article 3

This article demonstrates a convenient approach to neutron stars via correspondence between their subatomic structure and large-scale properties. The authors describe the tetrahedral configuration of neutron quarks under the influence of high gravitational pressure, using SU(3) to represent baryon arrangements. This technique explains multiple useful features of neutron stars, such as variations in density, rotational behavior, and magnetic fields. The authors proposed the sudden shift in the structure as well as spin due to an increase in the pressure. This happened in view of the phase transition in the interaction of a quark and a neutron pairing. This article also explains important phenomena, such as irregularities in magnetic field, abrupt spin-ups, and transients, in neutron stars. This article shows significant insights into stellar astrophysics.

## 2.4 Article 4

This research concentrates on binary system GZ, WUMA type, constituting the observation of ADS 1693, a multiple star system. The physical parameters of the binary system of stars are determined by collecting the data from the t*ransiting exoplanet survey satellite (*TESS) satellite and the ground base observations, and the light and radial velocities are analyzed. The results showed a noticeable transfer of mass from a massive star to a comparatively less massive companion star. This mass transfer prompted the apparent modifications in the orbital time period. This study also suggests a common origin of the stars in ADS 1693. The relationship between the stars is explained using Gaia astronomic data, which enhances the comprehension of multiple star system dynamics. This article effectively incorporates theoretical and observational techniques, providing a comprehensive picture of contact binaries and their significance in both astrophysics and stellar evolution.

Overall, these articles provide valuable insights into the concept of compact objects. These articles comprise several important phenomena, such as the complexity of stellar objects, the study of theoretical models via gravitational collapse, the relationship of stellar phenomena with subatomic physics, and the dynamics and development of binary systems. These research works present the main challenges in the comprehension of compact objects as well as their importance in the universe.

# 3 Final remarks

The analysis of compact objects offers a deep understanding of several interesting phenomena, such as the evolution of the universe, the nature of gravity, quantum mechanics, and testing of modified theories of gravity. The purpose of this Research Topic is to incorporate a range of innovative research studies, including topics like gravitational collapse, stellar model complexity in the structure of neutron stars, and the dynamics of contact binary systems. The featured articles emphasize the essential role of compact objects as they serve as natural laboratories to probe the classical and modified theories of gravity. These objects also underline the new techniques to explain the intricate interaction among the fundamental forces in extreme environments.

Our understanding of compact objects could make remarkable strides with the help of recent observations, such as the detection of gravitational waves, advanced telescopes, and profound theoretical knowledge. The research work carried out in this issue demonstrates the current challenges in the scientific field and provides future directions that can help enhance our understanding of astrophysics, gradational theories, and cosmology. We hope that the contributions in this Research Topic will pave the way for future exploration and encourage new collaborations. This will lead to a better understanding of the vital role of compact objects in the cosmos.

## Author contributions

SI: writing–original draft, writing–review and editing, formal analysis, and supervision. ZY: conceptualization and writing–review and editing. RM: methodology and writing–review and editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



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