ABSTRACT

This thesis presents a comprehensive study on compact stars, black holes and wormholes, exploring their physical characteristics, formation processes and theoretical implications. By synthesizing current theoretical frameworks with observational constraints, this work aims to enhance understanding of these enigmatic cosmic entities and their roles in the broader structure of the universe. The thesis is embodied into the following chapters, each dedicated to explore different aspects and theoretical models related to these cosmic phenomena.

First chapter elucidates the transition from special to general relativity, explores modified gravity theories and discusses their impact on compact objects. It also covers the observational signatures of these objects, such as strong lensing and shadows and the role of Bose-Einstein condensation setting the stage for the detailed analysis in later chapters.

Second chapter constructs a compact star model incorporating Bose-Einstein Condensate (BEC) matter, governed by a polytropic equation of state with $\gamma = 2$ and a specific energy density. It evaluates the model's physical viability, stability and alignment with constraints from the GW 170817 event. Key findings include how the parameter κ affects central density, compactness and the likelihood of gravitational collapse, suggesting BEC stars could mimic neutron stars.

Third chapter explores relativistic quintessence anisotropic solutions within the $f(T)$ gravity framework, employing Tolman-Kuchowicz metric potentials. It analyzes how anisotropy and a quintessence field with parameter ω_q, along with $f(T)$ gravity parameter α, influence stellar characteristics. The study demonstrates that varying α from 0.5 to 2.5 affects density, pressure and compactness of the compact star Her X-1, with higher values of α yielding a more compact star. The chapter also evaluates the hydrostatic equilibrium and mass-radius relationship for the model emphasizing the impact of α on the star's structural and stability attributes.

Fourth chapter provides an exact solution to the Einstein field equations for a static, spherically symmetric, anisotropic stellar fluid sphere with non-zero complexity, using specific metric potentials and ensuring boundary continuity; stability is assessed through stan-

dard conditions and validated against pulsar data.

Fifth chapter explores a Reissner-Nordström+ Λ black Hole in a (2+1) dimensional Friedmann-Robertson-Walker universe. It presents new exact solutions and finds that the cosmological constant Λ is negative inside the black Hole. The chapter demonstrates that Λ depends on the black Hole's radius R, charge Q and the universe's scale factor $a(v)$. It shows that the black Hole's mass and charge increase with cosmic contraction and decrease with cosmic expansion.

Sixth chapter explores the astrophysical consequences of black holes in quadratic gravity. To evaluate the physical validity of black hole like solutions in quadratic gravity, their shadow and gravitational lensing properties are analyzed in the strong field regime.

Seventh chapter examines three new wormhole solutions with Yukawa gravitational potential, focusing on geometry, energy conditions, stability and shadow. Stability is assessed using the Tolman-Oppenheimer-Volkov equations, with parameters β, a and γ influencing wormhole properties.

Eighth chapter, investigates identifying wormholes through their shadows by analyzing the effects of rotating wormhole parameters on photon orbits, using Event Horizon Telescope (EHT) data to constrain shadow size and spin, aiming to potentially reveal wormholes in galactic regions.

Finally, **Ninth chapter** encapsulates the crux of the research, emphasizing the nuanced impacts of parameter variations on the attributes and detectability of cosmic entities. It outlines prospective research trajectories to further elucidate theoretical constructs and refine observational methodologies for these enigmatic phenomena.

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