FUNDAMENTAL FREQUENCIES AND THERMODYNAMICAL PROPERTIES OF BLACK HOLES IN THE PRESENCE OF EXOTIC MATTER

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Abstract

This work investigates the fundamental frequencies and thermodynamical properties of black holes surrounded by exotic matter fields within the framework of general relativity and nonlinear electrodynamics (NED). The study addresses three major scenarios: (i) black holes embedded in Chaplygin-like dark matter, (ii) black holes coupled with NED and surrounded by perfect fluid dark matter (PFDM), and (iii) magnetically charged black holes in PFDM backgrounds.

For the Chaplygin-like dark matter case, we analyze the spacetime geometry, horizon structure, and quasi-periodic oscillations (QPOs), showing the emergence of both ISCO and OSCO orbits and their dependence on exotic matter parameters. In the NED–PFDM framework, we obtain new black hole solutions and study their thermodynamic properties, including Hawking temperature, entropy, and specific heat, revealing stability regions and phase transition behavior. In the case of magnetically charged black holes with PFDM, we explore particle dynamics, radiation processes, and QPOs, applying Markov Chain Monte Carlo (MCMC) methods to constrain black hole and exotic matter parameters using observational QPO data from microquasars and supermassive black holes.

The results demonstrate that exotic matter fields and nonlinear electrodynamics significantly modify black hole geometry, stability, and thermodynamics, providing new insights into observable astrophysical phenomena. These findings contribute to bridging theoretical predictions with observational data from X-ray binaries and galactic centers, offering potential tests for extended gravity and dark matter models.