INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
PhD-17 SHORT ABSTRACT OF THESIS

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**SHORT ABSTRACT**


This thesis investigates the structure and properties of compact astrophysical objects—neutron stars and black holes—within both general relativity and modified gravity frameworks. Using a combination of analytical methods and numerical computation, the work addresses critical issues such as the equation of state at extreme densities, the role of alternative gravity theories in supporting massive stars, and the existence of scalar fields around black holes in light of classical no-hair theorems.

One part of the work explores neutron stars with deconfined quark cores modeled by the MIT bag model, embedded within hadronic matter governed by unified equations of state. This hybrid structure satisfies causality and yields high maximum masses. The mass distribution, dominated by a peak in the radial profile of $\rho r^2$, correlates with the star's total mass, with the largest value of $1.98 M_{\odot}$ arising when the peak lies farthest from the center. This suggests that rapidly rotating neutron stars could exceed this mass limit, which may explain observed massive pulsars.

The study is extended to Starobinsky $f(R) = R + \alpha R^2$ gravity, using the same hybrid matter configuration. The modified field equations are solved numerically, showing that the parameter $\alpha$ enables stable neutron star solutions with higher maximal masses than allowed in general relativity, while preserving causality. This indicates the potential of modified gravity to account for increasingly massive neutron stars observed in astrophysical data.

Turning to black holes, the thesis examines charged solutions in Eddington-inspired Born–Infeld (EiBI) gravity. Using a spherically symmetric ansatz, the EiBI–Maxwell field equations are analyzed both analytically and numerically to uncover the behavior of the metric and curvature in different spatial regions. The results provide a consistent and detailed picture of the geometry of EiBI black holes across a range of the EiBI coupling parameter.

Finally, the thesis studies black holes with electrically charged scalar fields minimally coupled to Einstein–Maxwell gravity. Using a simple quadratic scalar potential, the field equations are solved numerically. The resulting configurations exhibit, in the radial direction, damped oscillatory scalar field profiles and a monotonic electric potential. Stability under time-dependent perturbations is demonstrated using two independent methods—a Sturm–Liouville formulation and a Schrödinger-like approach—confirming the existence of stable, charged, hairy black hole solutions.

Collectively, these works provide new insights into the mass distribution and stability of neutron stars, both in general relativity and in modified gravity, and offer a detailed understanding of EiBI and charged black hole spacetimes.