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Modified Gravity and the Complexity of Compact Stellar Structures

This work investigates anisotropic compact stellar models in the framework of modified $f(R, T)$ gravity using the Vaidya-Tikekar metric ansatz. A linear functional form, $f(R, T) = R + \beta T$, is adopted, where β represents the matter-geometry coupling parameter. By imposing the vanishing complexity condition on an anisotropic matter distribution, an exact interior solution is obtained. The stellar interior is smoothly matched with the exterior Schwarzschild spacetime through the continuity of the metric functions and the vanishing of radial pressure at the boundary.

The pulsar 4U 1608-52 is used as the primary case study for graphical analysis, while several other observed compact stars are examined numerically to assess the applicability of the model. The influence of the coupling parameter β and the spheroidal parameter K is studied independently. The resulting solutions exhibit regular metric potentials, positive and monotonically decreasing energy density and pressures, and a vanishing radial pressure at the stellar surface. A positive anisotropy factor provides additional support against gravitational collapse.

The model satisfies the null, weak, strong, and dominant energy conditions and fulfills the essential criteria for physical acceptability. Stability is verified through the causality condition, Herrera's cracking criterion, the adiabatic index, and the Tolman-Oppenheimer-Volkoff equilibrium equation. The analysis indicates that negative values of the coupling parameter β lead to denser and more compact stellar configurations while maintaining stability. Stable solutions are also obtained for different values of the spheroidal parameter K , demonstrating the robustness of the proposed model.

Overall, the developed solutions are physically viable and consistent with current observational data, emphasizing the potential of modified $f(R, T)$ gravity as a framework for describing realistic compact stellar objects.

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