

On Thermodynamic-Gravitational Scalar Couplings and Brans-Dicke Constraints on the Chandrasekhar Mass

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Abstract

Can we link local thermodynamic states directly to spacetime curvature to modify stellar stability? We explore this question by looking at a specific thermodynamic-gravitational parameter, the Chattaraj Constant (C_S). After proving its dimensional consistency, we derive a classical collapse-radius relation under a Newtonian limit. To make the framework covariant, we treat this parameter as a local scalar field, $\chi(x)$, non-minimally coupled to the Ricci scalar via $S_g = \frac{c^3}{16\pi G} \int d^4x \sqrt{-g}(1 + \beta\chi)R$. Adding the necessary covariant kinetic term maps this model straight into Brans-Dicke scalar-tensor gravity. Solving the weak-field, quasi-static field equations gives an effective Newtonian constant $G_{\text{eff}}/G = (4 + 2\omega_{BD})/(3 + 2\omega_{BD})$. Moving to the Einstein frame to enforce the ghost-free vacuum condition ($\omega_{BD} > -3/2$) reveals a strict constraint: the induced scalar force has to be universally attractive. Because of this, canonical non-minimal curvature couplings evaluated in the stable domain suppress the Chandrasekhar mass limit rather than enhance it. Imposing Solar System bounds from Cassini tracking ($\omega_{BD} \gtrsim 4 \times 10^4$) caps this mass shift at an unobservable $|\Delta M_{\text{Ch}}| \lesssim 10^{-5} M_{\odot}$. Real super-Chandrasekhar enhancements under this coupling only appear in the ghost-unstable regime ($-2 < \omega_{BD} < -3/2$). This effectively rules out canonical scalar-tensor mechanisms for overluminous progenitors, pushing the focus toward non-canonical derivative theories instead.

Keywords: White dwarfs; Chandrasekhar mass; Scalar-tensor gravity; Brans-Dicke theory; Modified gravity; Compact stars; Thermodynamic-gravitational coupling.