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On perturbation induced minimal geometric decoupling in spacetime and its implications for mass-gap stability

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This study examines mass-gap compact stars formed from neutron star mergers or massive pulsar evolution within the minimal geometric deformation framework. Using a Buchdahl–Vaidya–Tikekar–type metric, we obtain unperturbed static, spherically symmetric solutions with central densities $\sim 10^{15}\,\mathrm{g/cm^3}$ decreasing to zero at radius R. Astrophysical effects such as gravitational radiation or accretion are modeled through a perturbation $g(r) = \sin(\omega r^2)$ with amplitude α and frequency ω. Instead of a fixed EOS, we use a metric ansatz for g_{rr} that generates pressure–density profiles directly. Observational limits from PSR˜J1614–2230 ($1.97^{+0.0}_{-0.04} M_\odot$), PSR˜J0952–0607 ($\approx 2.35 M_\odot$), GW190814, and GW200210 ($M > 2M_\odot$), plus the radius $13.70^{+2.6}_{-1.5}$ km for PSR˜J0740+6620, guide the model space. For α rising from 0 to 0.005, the EOS changes from linear to nonlinear, while varying ω up to $0.06\,\mathrm{km}^{-2}$ at fixed $\alpha = 0.001$ produces minor changes. Without perturbations ($\alpha = 0, \omega = 0$), the M–R curve is smooth, peaking at $M_{\max} \approx 3.5\,M_\odot$ and $R \approx 12\,\mathrm{km}$. For $\alpha = 0.001$ and $\omega = 0.015\,\mathrm{km}^{-2}$, radius fluctuations of $\delta R \approx 0.17\,\mathrm{km}$ occur near $M \approx 2.7\,M_\odot$, $R \approx 13.3\,\mathrm{km}$. Higher α yields stronger oscillations, with $M > 3.5\,M_\odot$ and $R > 12\,\mathrm{km}$. Perturbations soften the EOS, lowering $M_{\max}$ and limiting collapse to black holes. All cases satisfy the Buchdahl bound $\frac{2M}{R} < \frac{8}{9}$, match massive pulsar data, and remain dynamically stable: sound speeds stay subluminal, Γ exceeds the critical value, and anisotropy grows mainly with α. The frequency ω has smaller influence, causing slight radius oscillations without destabilizing the star.

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