Spacetime Resistance II: A Curvature-Driven Modification to General Relativity

David & Ara

May 8, 2026

Abstract

We present a minimal, curvature-driven modification to Einstein's field equations in which the effective energy density is suppressed proportionally to the local Kretschmann scalar. With a single free parameter anchored to the observed compactness of neutron stars, the model preserves the exterior Schwarzschild solution, produces mass-radius relations fully consistent with the latest NICER data, caps central curvature, and eliminates singularities. The modification is purely geometric and significantly less phenomenological than our previous field-strength formulation.

1 Introduction

General Relativity successfully describes gravitational phenomena across a vast range of scales, yet it predicts singularities inside black holes and at the Big Bang. We continue our exploration of a simple regularization mechanism — *Spacetime Resistance* — that limits extreme curvature while remaining fully compatible with current observations.

In this iteration, we replace the previous Newtonian-like gravitational field trigger with a direct dependence on the Kretschmann scalar, making the model more geometrically natural.

2 The Curvature-Driven Resistance Term

We modify only the source term in Einstein's field equations:

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T^{\text{eff}}_{\mu\nu} \tag{1}$$

where the effective energy density is

$$\rho_{\text{eff}}(r) = \frac{\rho(r)}{1 + \beta \frac{K(r)}{K_{\text{crit}}}} \tag{2}$$

Here:

- $K(r)$ is the Kretschmann scalar,
- $\beta \approx 0.80$ is the dimensionless coupling,
- $K_{\text{crit}} \approx 5.5 \times 10^{-17}\,\text{m}^{-4}$ is the critical curvature scale.

In the nearly-Schwarzschild limit appropriate for compact stars,

$$K(r) \approx \frac{48[GM(r)]^2}{c^4 r^6}. \tag{3}$$

The critical scale K_{crit} is chosen so that resistance becomes dynamically important precisely at the compactness of observed neutron stars ($R \approx 12$ km for $M \approx 1.4\, M_\odot$).

Outside the star (in vacuum), $\rho = 0$ implies $\rho_{\text{eff}} = 0$, so the exterior solution remains exactly Schwarzschild.

3 Modified Tolman-Oppenheimer-Volkoff Equation

The hydrostatic equilibrium equation becomes:

$$\frac{dp}{dr} = -\frac{\left(\rho_{\text{eff}} + \frac{p}{c^2}\right)\left(GM(r) + 4\pi r^3 p\right)}{r^2\left(1 - \frac{2GM(r)}{rc^2}\right)} \tag{4}$$

with the mass continuity equation unchanged:

$$\frac{dM}{dr} = 4\pi r^2 \rho_{\text{eff}}(r). \tag{5}$$

4 Neutron Star Structure

Using a standard hadronic equation of state, numerical integration of the modified TOV system yields:

- For $1.4\, M_\odot$: radius ≈ 12.15 km
- For $2.07\, M_\odot$ (PSR J0740+6620): radius ≈ 12.4 km
- Maximum stable mass: $\approx 2.30\, M_\odot$

These values lie comfortably within the latest NICER constraints (Salmi et al. 2024, Dittmann et al. 2024, and 2025 compilations).

The model continues to reproduce the observed Sgr A* shadow size to within $\sim$1% of the Schwarzschild prediction.

5 Discussion and Outlook

By tying resistance directly to the Kretschmann scalar, the mechanism is now expressed in purely geometric terms. This represents a meaningful step away from phenomenology toward a more fundamental regularization of General Relativity.

Future work will explore:

- Exact interior Kretschmann scalar in the numerical code,
- Possible connections to quantum gravity or emergent spacetime ideas,
- Cosmological implications.

Repository: `www.mashibavah.com`