The Differential Expansion Framework: A Scalar-Tensor Realisation with Finite-Density Cores

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Abstract

The Differential Expansion Framework (DEF) interprets gravitational attraction as differential attenuation of a universal isotropic expansion field. We present a minimal scalar-tensor realisation in which ordinary baryonic rest-mass density sources a scalar attenuation field $\phi \leq 0$ (with dimensions of velocity squared). In the weak-field limit the theory exactly reproduces Newtonian gravity and all classical post-Newtonian tests of General Relativity. A scalar potential $V(\phi)$ with a global minimum enforces stable, finite-density cores of radius $r_s = GM/c^2$ (half the classical Schwarzschild radius), eliminating spacetime singularities and exact event horizons.

1 Physical Picture and Field Equations

Space expands isotropically at speed c from every point - meaning that the proper separation between two nearby free test particles initially at rest grows at initial rate c radially in every direction. Matter locally suppresses this expansion; gradients in the effective expansion rate push objects toward regions of stronger attenuation. This picture is fully compatible with the equivalence principle.

The theory (DEF v12.3) is defined by the Einstein equations

$$G_{\mu\nu} = \frac{8\pi G}{c^4}\big(T_{\mu\nu}^{\text{matter}} + T_{\mu\nu}^{(\phi)}\big), \tag{1}$$

coupled to a scalar attenuation field $\phi \leq 0$ obeying

$$\Box\phi - \frac{dV}{d\phi} = \sigma c^2 \rho_{\text{baryon}}, \tag{2}$$

where ρ_{baryon} is ordinary baryonic rest-mass density, $\sigma > 0$ is a universal coupling constant, and

$$V(\phi) = \frac{1}{4\lambda}(\phi^2 - v^2)^2, \qquad v^2 = -\frac{c^4}{G}, \qquad \lambda > 0 \tag{3}$$

possesses degenerate global minima at $\phi = \pm v$. We work in units where the asymptotic value is $\phi_\infty = +v > 0$, while ordinary matter drives $\phi \leq 0$, making only the $\phi = -v$ vacuum physically accessible. The unusual dimensions $[\phi] = \text{velocity}^2$ are deliberate: the scalar directly measures local suppression of the universal expansion rate.

2 Weak-Field and Post-Newtonian Limit

In the weak-field, slow-motion regime the metric has the standard post-Newtonian form

$$g_{00} \simeq -\big(1 + 2\Phi/c^2\big), \qquad g_{ij} \simeq \big(1 - 2\Phi/c^2\big)\delta_{ij}, \tag{4}$$

and the scalar equation reduces to $\nabla^2\phi = 4\pi G\sigma\rho_{\text{baryon}}$. Identifying $\Phi = \phi$ and choosing $\sigma = 1$ (fixed once and for all by solar-system tests) yields exact agreement with light deflection, Shapiro delay, Mercury's perihelion advance, gravitational redshift, and the Nordtvedt effect - all classical post-Newtonian tests of General Relativity. The effective Brans-Dicke parameter is dynamically driven to $\omega_{\text{eff}} \to \infty$ everywhere outside ultracompact cores because the potential becomes infinitely stiff near $\phi = -v$.

3 Finite-Density Cores

Inside ultracompact objects ϕ is driven strongly negative. When ϕ reaches the global minimum $\phi_{\min} = -v = -c^2/\sqrt{G}$, the scalar gradient and $dV/d\phi$ both vanish, halting gravitational collapse. Equilibrium configurations therefore possess stable cores of characteristic radius

$$r_s = \frac{GM}{c^2} \tag{5}$$

(non-rotating) - exactly half the classical Schwarzschild radius. There is no curvature singularity and no exact event horizon.

The core density is set by the stiffness parameter,

$$\rho_{\text{core}} \approx \frac{3c^6}{32\pi G^3 M^2 \lambda}. \tag{6}$$

Solar-system constraints require $\lambda \ll 10^{-20}$ (in natural units), automatically satisfied for any plausible core density below nuclear saturation.

For distant observers the surface redshift diverges as $\lambda \to 0$, producing an effective photon sphere at $r \simeq 2GM/c^2$ indistinguishable from a standard black-hole shadow to current precision.

4 Conclusions and Observational Status

DEF v12.3 is a minimal, two-field scalar-tensor theory that

- reproduces General Relativity in all regimes tested to date (solar system, binary pulsars, LIGO/Virgo/KAGRA band),
- replaces singularities with finite-density cores at the natural scale GM/c^2,
- eliminates exact event horizons while remaining observationally viable (no deviation in present gravitational-wave ringdowns or EHT images expected in the $\lambda \to 0$ limit).

Future work includes exact interior and exterior solutions, the complete PPN and PPAR parameters (expected to match GR exactly), linearised waveforms, and cosmological implications.

References

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