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Not peer-reviewed version

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Posted Date: 4 October 2025

doi: 10.20944/preprints202510.0272.v1

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Article

Future–Mass Projection (FMP): Formalism, Solar–System PPN Safety, and Gravitational–Wave Speed

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Abstract

We present a compact and testable formulation of *Future–Mass Projection* (FMP), a time–nonlocal gravity response in which the present metric couples to standard baryons plus a causal projection of *future* baryonic configurations. We derive the weak–field and PPN mapping, proving that FMP can satisfy the Solar–System bounds on the Eddington parameters γ and β as well as the tight limit on $\dot{G}/G$. In linearized, source–free vacuum the wave equation remains $\square \bar{h}_{\mu\nu} = 0$, hence $c_{\text{GW}} = c$, consistent with multi–messenger observations (GW170817/GRB170817A). We provide a practical (μ, Σ, W) kernel parametrization that is PPN– and GW–safe by construction, list working priors for data analyses, and sketch cosmological aspects via the homogeneous ratio $R(z) \equiv \Omega_F/\Omega_b$.

Keywords: modified gravity; nonlocal response; dark matter phenomenology; PPN; Cassini; lunar laser ranging; gravitational waves; GW170817; lensing; rotation curves

1. Introduction and Related Work

The Λ CDM model accounts for the CMB, large–scale structure, and lensing by postulating a cold, collisionless dark matter (DM) component, yet non–gravitational detection remains elusive. This motivates alternatives that keep Einstein’s left–hand side intact while modifying the *effective source*. The FMP proposal follows this route: the present gravitational field responds to baryons *and* a causal projection of their future configurations, implemented through a decaying kernel with a finite look–ahead horizon.

Any such theory must pass high–precision tests: (i) Solar–System *parametrized post–Newtonian* (PPN) bounds, notably the Shapiro–delay parameter γ and the nonlinearity parameter β [1,2]; (ii) the limit on $\dot{G}/G$ from lunar laser ranging (LLR) [3]; and (iii) the multi–messenger constraint that the speed of gravitational waves equals c within $\sim 10^{-15}$ [5,6]. We show that with mild and transparent kernel conditions, FMP satisfies these constraints while remaining empirically distinguishable from Λ CDM on galactic and cosmological scales.

2. FMP Formalism and Newtonian Limit

We keep GR’s field equations but modify the source:

$$G_{\mu\nu}(x) = 8\pi G T_{\mu\nu}^{(\text{eff})}(x), \tag{1}$$

$$T_{\mu\nu}^{(\text{eff})}(x) := T_{\mu\nu}^{(b)}(x) + T_{\mu\nu}^{(F)}(x), \tag{2}$$

where $T_{\mu\nu}^{(b)}$ is the baryonic stress tensor and $T_{\mu\nu}^{(F)}$ encodes a future–directed, causal projection via a bitensor kernel supported on the future light cone $J^+(x)$:

$$T_{\mu\nu}^{(F)}(x) = \int_{J^+(x)} d^4x' \sqrt{-g(x')} K_{\mu\nu}{}^{\alpha\beta}(x, x') T_{\alpha\beta}^{(b)}(x'). \tag{3}$$

The Bianchi identities enforce $\nabla_\mu T_{\text{eff}}^{\mu\nu} = 0$. In the Newtonian limit (cosmic rest frame, $T_{\mu\nu}^{(F)} \simeq \rho_F u_\mu u_\nu$),

$$\nabla^2 \Phi(\mathbf{x}, t) = 4\pi G [\rho_b(\mathbf{x}, t) + \rho_F(\mathbf{x}, t)], \quad (4)$$

$$\rho_F(\mathbf{x}, t) = \int_0^\infty K(\tau) \Pi(\mathbf{x}, t+\tau | \mathcal{I}_t) d\tau, \quad (5)$$

with a strictly decaying kernel $K(\tau)$ (finite look-ahead) and a conditional forecast $\Pi(\cdot | \mathcal{I}_t)$ of future baryonic states given present information $\mathcal{I}_t$.

Homogeneous limit and $R(z)$.

On large scales we define $R(z) \equiv \Omega_F / \Omega_b \simeq \rho_F / \rho_b$. Two future-stable convenience forms are

$$\text{M1: } R(z) = \frac{A}{H(z) - \lambda}, \quad A := R_0 [H_0 - \lambda], \quad (6)$$

$$\text{M2: } R(z) = \exp(\lambda_{\text{alt}} / H(z)) - 1, \quad \lambda_{\text{alt}} := \ln(1 + R_0) H_0, \quad (7)$$

calibrated by $R_0 \equiv R(z=0) \approx 5.4$. For future stability M2 is preferred.

3. Galaxy-SCALE response and the (μ, Σ, W) Map

In weak, quasi-static regimes (Fourier space) we write modified Poisson and lensing relations through a matter-coupling response $\mu(a, k)$, a lensing response $\Sigma(a, k)$, and a *window* $W(k)$ that suppresses local (large- k) response:

$$\mu(a, k) = 1 + \frac{\varepsilon_0}{1 + (k/k_0)^\alpha}, \quad (8)$$

$$\Sigma(a, k) = \mu(a, k) [1 + \eta(k)], \quad \eta(k) = \eta_0 (k/k_\eta)^{\beta_\eta}, \quad (9)$$

$$W(k) = \frac{\exp(-(k/k_w)^2)}{1 + (k\tau_F)^2}, \quad 0 < W \leq 1. \quad (10)$$

In real space the windowed response produces a rotation-curve amplification

$$\Delta \Xi_d(k) := \mu(a_0, k) W(k) - 1, \quad (11)$$

$$D(R) = 1 + \int_{k_{\min}}^{k_{\max}} \frac{k dk}{2\pi} \Delta \Xi_d(k) J_0(kR), \quad (12)$$

$$V_{\text{FMP}}^2(R) = D(R) V_{\text{bar}}^2(R). \quad (13)$$

Small IR/UV regulators ensure stable numerics. Equation (13) shows that the leading FMP correction is *linear* in the baryonic potential.

4. PPN Mapping: γ , β , and $\dot{G}/G$

For a static, spherically symmetric source in the PPN gauge,

$$ds^2 = -(1 - 2U + 2\beta U^2) dt^2 + (1 + 2\gamma U) d\mathbf{x}^2 + \mathcal{O}(U^3), \quad U = \frac{GM}{r}. \quad (14)$$

The quasi-static IR mapping ($k \rightarrow 0$) from FMP to PPN reads

$$\gamma_{\text{PPN}} - 1 = \frac{1}{2} \lim_{k \rightarrow 0} [\Sigma(a_0, k) - \mu(a_0, k)] = \frac{1}{2} \lim_{k \rightarrow 0} \mu(a_0, k) \eta(k), \quad (15)$$

$$\beta_{\text{PPN}} - 1 = \mathcal{O}(\varepsilon_0^2), \quad \frac{\dot{G}}{G} \simeq \varepsilon_0. \quad (16)$$

Thus, choosing $\beta_\eta > 0$ forces $\eta(k \rightarrow 0) \rightarrow 0$ and yields *exactly* $\gamma_{\text{PPN}} = 1$ in the Solar-System IR limit. Because the leading FMP effect is linear in the baryonic potential [Eq. (13)], departures from

superposition enter only at $\mathcal{O}(\varepsilon_0^2)$, implying $\beta_{\text{PPN}} \simeq 1$ to first order. Any slow cosmological drift appears as $\dot{G}/G \simeq \dot{\varepsilon}_0$ and can be bounded by LLR.

Solar–System priors guaranteeing safety.

$$\eta_0 = 0, \beta_\eta > 0, \quad |\gamma - 1| < 2 \times 10^{-5}, |\beta - 1| < 10^{-4}, |\dot{G}/G| < 10^{-12} \text{ yr}^{-1}, k_w^{-1} \ll \text{AU}. \quad (17)$$

With $k_w^{-1} \ll \text{AU}$ and $k\tau_F \gg 1$ on Solar–System scales, the window $W(k)$ suppresses local response so the Newtonian limit is indistinguishable from GR within experimental precision.

5. Comparison with Canonical Bounds

Shapiro delay (γ). With $\eta(k \rightarrow 0) \rightarrow 0$ we obtain $\gamma = 1$, consistent with the Cassini bound $\gamma - 1 = (2.1 \pm 2.3) \times 10^{-5}$ [2] and planetary ephemerides [4].

Nonlinearity (β). Because $\beta - 1 = \mathcal{O}(\varepsilon_0^2)$ and $W(k)$ damps local response, FMP satisfies $|\beta - 1| \lesssim 10^{-4}$ from ephemerides/LLR [3,4].

Time variation of G . Imposing $|\dot{\varepsilon}_0| \lesssim 10^{-12} \text{ yr}^{-1}$ is compatible with LLR constraints $\dot{G}/G = (4 \pm 9) \times 10^{-13} \text{ yr}^{-1}$ [3].

6. Gravitational–Wave Propagation

FMP modifies *sources* but leaves the Einstein–Hilbert kinetic term untouched. In vacuum ($T_{\mu\nu}^{(b)} = T_{\mu\nu}^{(F)} = 0$) the linearized field equation is unchanged:

$$\square \bar{h}_{\mu\nu} = 0 \quad \Rightarrow \quad c_{\text{GW}} = c. \quad (18)$$

This matches the GW170817/GRB 170817A constraint $|c_{\text{GW}}/c - 1| \lesssim \text{few} \times 10^{-15}$ [5,6].

7. Cosmology Block: $R(z)$ and Falsifiable Signatures

FMP predicts a gentle redshift drift of the homogeneous ratio $R(z) \equiv \Omega_F/\Omega_b$ relative to the strictly constant DM fraction in ΛCDM . Equations (6)–(7) provide future–stable templates (M2 preferred). On galaxy scales, the *shape* of $D(R)$ in Eq. (12)—including circumgalactic–medium sensitivity—yields distinctive rotation–curve and lensing patterns. On cluster scales, merger morphologies (e.g., post–merger offsets) provide further tests. These signatures are orthogonal to PPN and GW constraints and thus *falsifiable*.

8. Data–Analysis Checklist (Practical Priors)

- **IR slip prior:** enforce $\eta_0 = 0, \beta_\eta > 0$ so that $\eta(k \rightarrow 0) = 0$ (ensures $\gamma = 1$).
- **Local damping:** choose $k_w^{-1} \ll \text{AU}$ and $k\tau_F \gg 1$ on Solar–System scales.
- **Hard PPN/LLR priors:** $|\gamma - 1| < 2 \times 10^{-5}, |\beta - 1| < 10^{-4}, |\dot{G}/G| < 10^{-12} \text{ yr}^{-1}$.
- **GW safety:** keep the GR kinetic term exact; modify only sources.
- **Diagnostics:** report WAIC/PSIS–LOO with standard errors; show the above priors do not degrade rotation–curve fits vs. ΛCDM baselines (NFW/Einasto/core).

9. Conclusions

We provided a concise FMP formalism and explicit PPN/GW mapping. With a slip–free IR limit and strong local damping, FMP obeys the stringent Solar–System and GW constraints by design while retaining falsifiable predictions on galaxy and cosmological scales. Immediate next steps include joint lensing & rotation–curve fits and a Boltzmann–code block for $R(z)$ to test CMB–era consistency.

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