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Future-Mass Projection with a Constant Dark-to-Baryon Background: A Renormalized FMP Variant Preserving $\Omega_{\rm DM}/\Omega_b = 5.4$

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Abstract

We develop a renormalized variant of *Future–Mass Projection* (FMP) in which the cosmological dark-to-baryon matter ratio is held fixed at all redshifts, $R(z) \equiv \Omega_F/\Omega_b = R_0 = 5.4$, thereby preserving the ΛCDM background inferred from precision probes. The key step removes the spatial zero mode of the FMP response and reinstates a fixed homogeneous term $R_0\,\bar{\rho}_b(a)$; only inhomogeneous fluctuations δ_F contribute to structure. We formulate the model, derive its linear response, prove that the background expansion $H(a)$ and CMB/BAO/SNe distance relations remain unchanged, and place phenomenological priors on the fluctuation transfer $T_F(k,a)$ using weak lensing and redshift-space distortions. The resulting *constant-R FMP* (cFMP) acts as a scale-localized, baryon-tethered enhancement to clustering without introducing new particles or altering gravitational-wave propagation. We outline decisive tests: (i) baryon–mass co-variations in galaxies and groups (dynamics *and* lensing with the same kernel), (ii) the rarity of truly baryon-free subhalos in strong lenses, (iii) null signals in non-gravitational dark-matter searches, and (iv) merger chronologies in Bullet-like clusters. All references cited are peer reviewed.

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1. Introduction

The ΛCDM model successfully accounts for background expansion and large-scale structure across cosmic time. The *Planck* 2018 legacy analysis constrains the baryon and cold-dark-matter densities to $\Omega_b h^2 \simeq 0.0224$ and $\Omega_c h^2 \simeq 0.120$ [1], implying a background ratio

$$R_0 \equiv \frac{\Omega_c}{\Omega_b} \simeq \frac{0.120}{0.0224} \approx 5.4. \tag{1}$$

Distance probes (BAO, SNe Ia) and growth information (RSD, cosmic shear) broadly support this background when systematics are controlled [2–5].

Non-particle alternatives must therefore preserve the *background* while allowing modified *inhomogeneous* dynamics. We present such a construction for Future–Mass Projection (FMP), recasting it as an effective source that leaves $R(z) = R_0$ invariant while modifying structure through a scale- and time-dependent response tightly coupled to baryons.

2. Original FMP and Constant-R Renormalization

2.1. Schematic FMP

In FMP, beyond baryonic density $\rho_b(\boldsymbol{x},t)$ one introduces a gravitationally active field ρ_F obtained by a temporal projection of baryon trajectories:

$$\rho_F^{\rm raw}(\boldsymbol{x},t) = \int_0^\infty K(\Delta t)\,\Pi\big(\boldsymbol{x}, t+\Delta t \,\big|\, I_t\big)\,{\rm d}\Delta t, \tag{2}$$

where K is a causal kernel and Π symbolically denotes a coarse-grained forecast of baryon mass based on information I_t. The modified Poisson equation reads

$$\nabla^2\Phi(\boldsymbol{x},t) = 4\pi G\left[\rho_b(\boldsymbol{x},t) + \rho_F(\boldsymbol{x},t) + \rho_\Lambda\right]. \tag{3}$$

2.2. Background–Fluctuation Renormalization

We decompose $\rho_b = \bar{\rho}_b + \delta_b$ and define a spatial average $\langle\rho_F^{\rm raw}\rangle(t)$. Our renormalized model sets

$$\delta_F(\boldsymbol{x},t) \equiv \rho_F^{\rm raw}(\boldsymbol{x},t) - \langle\rho_F^{\rm raw}\rangle(t), \tag{4}$$
$$\rho_F(\boldsymbol{x},t) \equiv R_0\,\bar{\rho}_b(t) + \delta_F(\boldsymbol{x},t). \tag{5}$$

Equivalently, in Fourier space we impose a zero-DC condition on the kernel,

$$\tilde{K}(\boldsymbol{k}=\boldsymbol{0},\omega) = 0, \tag{6}$$

and add the fixed homogeneous term $R_0\,\bar{\rho}_b$. Then

$$\bar{\rho}_F = R_0\,\bar{\rho}_b \quad \Rightarrow \quad R(z) = \frac{\Omega_F}{\Omega_b} = R_0 \;\; \forall z, \tag{7}$$

so $H(a)$ and background distances remain those of ΛCDM for the same (Ω_b, Ω_c, h) [1–3].

Proposition 1 (Background invariance)**.** *With Eqs.* (4)–(5) *the Friedmann equation retains the standard form* $H^2(a) = H_0^2\left[\Omega_r a^{-4} + \Omega_b(1+R_0)a^{-3} + \Omega_\Lambda\right]$*, and all background distance indicators (CMB peak positions, BAO scales, SNe Hubble diagram) are unchanged* by construction.

Proof. Spatial averaging of (3) with (5) gives $\bar{\rho}_{\rm tot} = \bar{\rho}_b + R_0\bar{\rho}_b + \rho_\Lambda$, since $\langle\delta_F\rangle = 0$ by definition. Hence the homogeneous energy density equals the ΛCDM one with $\Omega_m = \Omega_b(1+R_0)$. The background solution and comoving sound horizon are unaffected. □

2.3. Fluctuation Response and Scale Localization

Only δ_F appears in the inhomogeneous sector:

$$\nabla^2\Phi = 4\pi G\Big[(1+R_0)\bar{\rho}_b + \delta_b + \delta_F + \rho_\Lambda\Big]. \tag{8}$$

At linear order we parameterize

$$\tilde{\delta}_F(\boldsymbol{k},a) = T_F(k,a)\,F(k)\,\tilde{\delta}_b(\boldsymbol{k},a), \tag{9}$$

with a smooth high-pass $F(0) = 0$; e.g.

$$F(k) = \frac{k^2}{k^2 + k_c^2}, \tag{10}$$

or a band-limited generalization. The comoving scale k_c^{-1} confines cFMP to galaxy–cluster regimes, mitigating conflict with large-scale growth [2,4,5].

3. Linear Growth and Effective Coupling

Defining $\Omega_m = \Omega_b(1+R_0)$, the effective matter fluctuation is

$$\delta_{\rm eff} \equiv \frac{\delta\rho_b + \delta_F}{\bar{\rho}_m} = \frac{\Omega_b}{\Omega_m}\Big[1 + T_F(k,a)F(k)\Big]\delta_b. \tag{11}$$

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In a growth-equation form one may write

$$\delta''_{\text{eff}} + \left(2 + \frac{H'}{H}\right)\delta'_{\text{eff}} - \frac{3}{2}\,\Omega_m(a)\,\mu(k,a)\,\delta_{\text{eff}} = 0, \tag{12}$$

with an effective modification $\mu(k,a)$ determined by the baryon fraction and T_F.[1] Current shear and RSD data bound any sizeable, broad-band deviation [2,4,5]. cFMP therefore adopts T_F that is localized in k and (optionally) limited in redshift.

4. Nonlinear Phenomenology

4.1. Galaxies: Dynamics and Lensing

Because δ_F is baryon-tethered, the same kernel parameters must describe rotation curves and lensing deflection for a given galaxy. The tight radial acceleration relation (RAR) [9] suggests precisely such a baryon–gravity linkage. Joint lensing–dynamics fits thus provide a stringent, object-by-object test.

4.2. Clusters and the Baryon Fraction

Relaxed-cluster gas mass fractions f_{gas} constrain the background and show near-constancy with redshift after calibration [6,7]. Since cFMP fixes $R(z) = R_0$, it preserves these results at the background level; residual effects arise only through inhomogeneous physics already considered in ΛCDM analyses.

4.3. Substructure in Strong Lenses

Strong-lensing "gravitational imaging" detects low-mass subhalos [15,16]. cFMP generically predicts a *lower* incidence of truly baryon-free subhalos than particle CDM due to baryon tethering. A statistically significant population of dark, baryonless subhalos would therefore challenge the mechanism.

4.4. Merging Systems

In Bullet-like mergers, lensing mass peaks offset from X-ray gas are well established [17]. cFMP predicts that the lensing pattern should be reconcilable with the time-integrated baryon flow; failure to achieve such consistency with plausible baryon end-states would falsify cFMP on these scales.

5. Consistency with High-Energy and Solar-System Tests

cFMP is an effective source within the Poisson sector of GR; it does not modify the tensor kinetic term or GW propagation speed. Consequently, the GW170817/GRB170817A constraints are automatically satisfied [10,11]. Parametrized post-Newtonian bounds are likewise respected, since no new long-range force is introduced.

6. Relation to Known Small-Scale Issues

Baryon–DM small-scale tensions (cores, satellites, too-big-to-fail) have various proposed resolutions within baryonic astrophysics and/or new DM physics [12]. cFMP offers an alternative effective description: extra, baryon-tied mass that can mimic some small-scale trends while remaining invisible to non-gravitational searches.

7. Observational Program and Falsifiability

We highlight four decisive tests:

1. **Joint fits in galaxies:** For spirals and ellipticals, fit dynamics *and* lensing with a common $(A_F, k_\star, \Delta \ln k)$ entering T_F. Failure to fit both with the same parameters would disfavor cFMP.

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[1] For context on μ, Σ parameterizations in modified-gravity tests see [1,18].

2. **Subhalo demographics:** Use strong-lensing samples to measure the abundance of baryon-free subhalos [15,16]. A high fraction at $M \lesssim 10^9\,M_\odot$ would be problematic for cFMP.
3. **Growth tomography:** RSD $f\sigma_8(z)$ and weak lensing two-point statistics constrain broad-band $\mu(k,a)$ [2,4,5]. Detection of a large, wide k-range enhancement would force T_F to be narrow or small; a contradictory requirement from galaxy scales would challenge viability.
4. **Merging clusters:** Test whether lensing peaks can be matched by reasonable forward models of the baryon flow over merger timescales in systems like 1E 0657−56 [17].

8. Conclusions

We presented a constant-R renormalization of FMP that leaves the ΛCDM background intact while enabling baryon-tethered, scale-localized modifications to structure. The construction removes the kernel DC mode and adds a fixed homogeneous term $R_0\,\bar{\rho}_b$, guaranteeing $R(z) = R_0 = 5.4$ consistent with CMB/BAO/SNe [1–3]. The remaining degrees of freedom enter through $T_F(k,a)$, to be constrained by shear and RSD [4,5]. cFMP is falsifiable via joint galaxy lensing–dynamics fits, subhalo statistics, and merger chronologies, and it predicts null results in non-gravitational DM searches.

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References

1. Planck Collaboration (N. Aghanim *et al.*), "Planck 2018 results. VI. Cosmological parameters," *Astronomy & Astrophysics* **641**, A6 (2020). doi:10.1051/0004-6361/201833910. Source.
2. S. Alam *et al.* (eBOSS Collaboration), "Completed SDSS-IV extended Baryon Oscillation Spectroscopic Survey (eBOSS): Cosmological implications" *Phys. Rev. D* **103**, 083533 (2021). doi:10.1103/PhysRevD.103.083533. Source.
3. D. Brout, D. Scolnic *et al.*, "The Pantheon+ Analysis: Cosmological Constraints," *Astrophys. J.* **938**, 110 (2022). doi:10.3847/1538-4357/ac8e04. Source.
4. DES Collaboration (T. M. C. Abbott *et al.*), "Dark Energy Survey Year 3 results: Cosmology from cosmic shear," *Phys. Rev. D* **105**, 023520 (2022). doi:10.1103/PhysRevD.105.023520. Source.
5. M. Asgari *et al.* (KiDS Collaboration), "KiDS-1000 Cosmology: Cosmic shear constraints and comparison between two-point statistics," *Astron. Astrophys.* **645**, A104 (2021). doi:10.1051/0004-6361/202039070. Source.
6. S. W. Allen, D. A. Rapetti, R. W. Schmidt, H. Ebeling, G. Morris, A. C. Fabian, "Improved constraints on dark energy from Chandra X-ray observations of the largest relaxed galaxy clusters," *Mon. Not. R. Astron. Soc.* **383**, 879–896 (2008). doi:10.1111/j.1365-2966.2007.12610.x. Source.
7. A. B. Mantz *et al.*, "Cosmology and astrophysics from relaxed galaxy clusters II: Cosmological constraints," *Mon. Not. R. Astron. Soc.* **440**, 2077–2098 (2014). doi:10.1093/mnras/stu368. Source.
8. M. Bartelmann, P. Schneider, "Weak gravitational lensing," *Physics Reports* **340**, 291–472 (2001). doi:10.1016/S0370-1573(00)00082-X. Source.
9. S. S. McGaugh, F. Lelli, J. M. Schombert, "The Radial Acceleration Relation in Rotationally Supported Galaxies," *Phys. Rev. Lett.* **117**, 201101 (2016). doi:10.1103/PhysRevLett.117.201101. Source.
10. B. P. Abbott *et al.* (LIGO Scientific Collaboration and Virgo Collaboration), "GW170817: Observation of Gravitational Waves from a Binary Neutron Star Inspiral," *Phys. Rev. Lett.* **119**, 161101 (2017). doi:10.1103/PhysRevLett.119.161101. Source.
11. V. Savchenko *et al.*, "INTEGRAL Detection of the First Prompt Gamma-Ray Signal Coincident with the Gravitational-Wave Event GW170817," *Astrophys. J. Lett.* **848**, L15 (2017). doi:10.3847/2041-8213/aa8f94. Source.
12. J. S. Bullock, M. Boylan-Kolchin, "Small-Scale Challenges to the ΛCDM Paradigm," *Annu. Rev. Astron. Astrophys.* **55**, 343–387 (2017). doi:10.1146/annurev-astro-091916-055313. Source.
13. A. Cooray, R. K. Sheth, "Halo models of large scale structure," *Physics Reports* **372**, 1–129 (2002). doi:10.1016/S0370-1573(02)00276-4. Source.

 doi:10.20944/preprints202510.0416.v1

14. M. P. van Daalen, J. Schaye, C. M. Booth, C. Dalla Vecchia, "The effects of galaxy formation on the matter power spectrum," *Mon. Not. R. Astron. Soc.* **415**, 3649–3665 (2011). doi:10.1111/j.1365-2966.2011.18981.x. Source.
15. S. Vegetti *et al.*, "Gravitational detection of a low-mass dark satellite galaxy at cosmological distance," *Nature* **481**, 341–343 (2012). doi:10.1038/nature10669. Source.
16. S. Vegetti, O. Rau, L. V. E. Koopmans, M. W. Auger, C. D. Fassnacht, "On the density profile of dark matter substructure in gravitational lenses," *Mon. Not. R. Astron. Soc.* **442**, 3598–3609 (2014). doi:10.1093/mnras/stu1284. Source.
17. D. Clowe *et al.*, "A Direct Empirical Proof of the Existence of Dark Matter," *Astrophys. J. Lett.* **648**, L109–L113 (2006). doi:10.1086/508162. Source.
18. K. Koyama, "Cosmological tests of modified gravity," *Rep. Prog. Phys.* **79**, 046902 (2016). doi:10.1088/0034-4885/79/4/046902. Source.