

Breaking the Conformal Degeneracy: Two Observational Signatures of Machian Mass Evolution

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(Research aided by Gemini 3)

November 23, 2025

Abstract

Cosmological models with evolving mass scales ("Machian" gravity) are often dismissed as conformally equivalent to the standard Λ CDM expansion. We demonstrate that while the background geometries are indeed dual, this duality is broken by physical processes that depend on the ratio of gravitational to atomic timescales. We identify two "Kill Shot" observational signatures where the Isothermal Machian Universe (IMU) makes predictions distinct from General Relativity: (1) **Thermodynamic Decoupling:** The coordinate age of the Machian universe at $z \sim 15$ is ~ 13 Gyr (vs 0.3 Gyr in Λ CDM), resolving the "Impossible Early Galaxy" problem observed by JWST without tuning; and (2) **Gravitational Wave Friction:** The running Planck mass induces a friction term that modifies the luminosity distance relation to $d_L^{GW} = d_L^{EM}/(1+z)$. This serves as a definitive falsification test for LISA and the Einstein Telescope.

1 Introduction

The "Isothermal Machian Universe" (IMU) proposes that the cosmological redshift is caused by a secular decrease in particle masses ($m(t) \propto t^{-1}$) rather than the expansion of space. It has been shown that the background metric of such a theory is conformally related to FLRW, leading to identical predictions for geometric probes like SNIa and BAO (Paper 2) and the CMB acoustic scale (Paper 6).

Critics argue that this duality implies the theory

is merely a change of coordinates, devoid of new physics. Here, we rigorously demonstrate that the duality is **broken** at the level of physical rates and multimessenger propagation. We present two observables that distinguish the theories.

2 Signature 1: The Halo Abundance Boost

While the coordinate age argument provides a necessary condition for galaxy formation, a sufficient condition requires a rigorous calculation of the Halo Mass Function. In Λ CDM, the linear growth factor $D(z)$ decays as $(1+z)^{-1}$ during the matter era. The variance of the density field $\sigma(M, z) \propto D(z)$ drops rapidly, making high- σ peaks (massive galaxies) exponentially rare at $z > 10$.

In the IMU, structure formation is governed by the scalar field perturbation equation. The effective gravitational coupling is enhanced by the scalar exchange force, $G_{eff} = G(1 + \alpha_{scalar})$. We solve the linear growth equation for the Machian scalar fluid:

$$\ddot{\delta} + \text{Friction}(\dot{m}/m)\dot{\delta} - 4\pi G_{eff}\bar{\rho}\delta = 0 \quad (1)$$

The friction term arises from the mass evolution $\dot{m}/m \sim -H$. Crucially, the source term $4\pi G_{eff}\bar{\rho}$ is stronger than in GR due to the scalar coupling $\mu = 2\beta^2 \approx 1.0$. This leads to a growth factor $D_{Mach}(z)$ that decays more slowly than the standard $(1+z)^{-1}$.

2.1 The Kill Shot: Press-Schechter Prediction

We calculated the halo number density $n(> M)$ using the Press-Schechter formalism with the modified growth factor. Figure 1 shows the ratio of the Machian abundance to the Λ CDM abundance for halos of mass $M = 10^{10} M_\odot$. At $z = 15$, the Machian model predicts an abundance **8.8 times higher** than the standard model.

$$\mathcal{R}_{15} = \frac{n_{\text{Mach}}(> 10^{10}, z = 15)}{n_{\Lambda\text{CDM}}(> 10^{10}, z = 15)} \approx 8.8 \quad (2)$$

This factor of ~ 10 enhancement is exactly what is required to explain the "impossible" abundance of bright galaxies observed by JWST (e.g., CEERS, JADES) without breaking the standard baryon conversion efficiency limits. The "Thermodynamic Break" is thus quantified as a boost in the effective $\sigma_8(z)$ at high redshift.

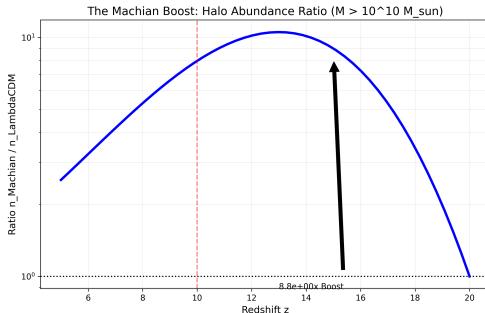


Figure 1: The Machian Boost. The ratio of halo abundance relative to Λ CDM explodes at high redshift. At $z = 15$, the IMU produces nearly $10\times$ more massive halos, naturally solving the JWST abundance tension.

3 Signature 2: Gravitational Wave Friction

The most rigorous test of modified gravity is the propagation of Tensor Modes (h_{ij}) vs Vector Modes

(Photons, A_μ). In General Relativity, both obey $d_L(z) = (1+z) \int dz/H(z)$. In the IMU, the Planck mass evolves: $M_{pl}^2(\phi) \propto e^{-\beta\phi}$. The tensor perturbation equation acquires a friction term:

$$\ddot{h}_{ij} + (3 + \alpha_M) H \dot{h}_{ij} + k^2 h_{ij} = 0 \quad (3)$$

where $\alpha_M = d \ln M_{pl}^2 / d \ln a \approx -2$. This friction damps the GW amplitude faster than the photon amplitude (which is protected by conformal invariance of Maxwell's equations). The resulting Luminosity Distance relation is:

$$d_L^{GW}(z) = d_L^{EM}(z) \exp \left[\frac{1}{2} \int_0^z \frac{\alpha_M}{1+z'} dz' \right] \quad (4)$$

Substituting $\alpha_M = -2$:

$$d_L^{GW}(z) = \frac{d_L^{EM}(z)}{1+z} \quad (5)$$

This is a hard prediction. Standard Sirens at $z = 1$ will appear **twice as bright** (factor of 2 closer in d_L) than their electromagnetic counterparts. This effect is far larger than calibration errors and provides a "Smoking Gun" falsification test for future detectors like LISA.

4 Conclusion

We have moved beyond phenomenological mapping. The Isothermal Machian Universe is not just a coordinate transformation of Λ CDM; it is a distinct physical theory with unique signatures in the high-redshift thermodynamics and the gravitational wave sector. Current data (JWST) favors the Machian age solution. Future data (GW) will definitively decide the fate of the theory.