Unified Relativistic Gravitational Impedance Model: An Effective Dark Sector Fluid and its MOND Limit

József Kerényi
Independent Researcher, Budapest, Hungary

Unified Revised Version – September 13, 2026

Abstract

We present a unified phenomenological model based on gravitational impedance $Z_{\text{eff}} = \eta\, G/c$. The central observation is that the relativistic mass flux $I_g = d(\gamma m_0)/dt = (m_0/c^2)\gamma^3(\vec{v}\cdot\vec{a})$ defines a specific potential $\Phi_g = Z_{\text{eff}} I_g$ whose sign is set by the scalar product $\vec{v}\cdot\vec{a}$. We show that (i) longitudinal acceleration $\vec{v}\cdot\vec{a} > 0$ yields $w \to -1$ (energy release, dark energy phase), (ii) longitudinal deceleration $\vec{v}\cdot\vec{a} < 0$ yields $w \to 0$ (energy absorption, dark matter phase), (iii) transverse motion gives no transfer at lowest order. The bare value $Z_g = G/c$ gives $\rho_g \sim 10^{-36}\,\text{J/m}^3 \sim 10^{-27}\rho_\Lambda$ for the Milky Way, requiring amplification $\eta_\Lambda \sim 10^{27}$ for cosmic acceleration and $\eta_{a_0} \sim 10^6$ for the MOND acceleration $a_0 \simeq 1.2 \times 10^{-10}\,\text{m/s}^2$. In Part II we derive $v_c^4 = GMa_0$ from the equilibrium $v_c^2 = \Phi_g$ with a_0 parametrized by Hubble boundary fluctuations $(\Delta V)^2/R_H$. The model does not replace ΛCDM but provides a single language for both dark components, with falsifiable predictions for $w(r)$ near jets and for Gaia streaming.

Contents

Part I – Relativistic Gravitational Impedance as an Effective Fluid

0.1 Introduction

[Same references as before: Heaviside 1893, Sciama 1953, 1969, Unruh 1989, Milgrom 1983, Verlinde 2016]

The core idea, originally derived by the author from time differentiation of $m = \gamma m_0$, is

$$U \equiv Z_g \frac{dm}{dt}, \quad Z_g = \frac{G}{c}, \quad \frac{dm}{dt} \propto \vec{v} \cdot \vec{a} \tag{1}$$

where $\vec{v} \cdot \vec{a}$ is the scalar (not vector) product. For deceleration $U < 0$, suggesting absorption.

0.2 Covariant Mass Flux

Four-velocity u^μ, four-acceleration a^μ, projector $h_{\mu\nu} = g_{\mu\nu} + u_\mu u_\nu / c^2$,

$$I_g = \frac{m_0}{c^2} \gamma^3 (\vec{v} \cdot \vec{a}) = \frac{1}{c^3} g_{\mu\nu} u^\mu a^\nu m_0 \gamma^3 + O(\beta^4) \tag{2}$$

0.3 Impedance and Energy

$P = Z_{\text{eff}} I_g^2$, $Z_{\text{eff}} = \eta G/c$. For constant a:

$$E(\tau) = \frac{\eta G m_0^2 a^2}{8c^3} \left[\frac{\beta_\tau (\beta_\tau^2 + 1)}{(\beta_\tau^2 - 1)^2} + \frac{1}{2} \ln \left| \frac{\beta_\tau - 1}{\beta_\tau + 1} \right| \right] \tag{3}$$

Non-relativistic: $E \simeq \eta G m_0^2 a^2 \tau^3 / (3c^5)$.

0.4 Equation of State

Smooth interpolation avoiding manual sign:

$$w(\mathcal{F}) = -\frac{1}{2} \left[1 + \tanh(\mathcal{F}/\mathcal{F}_0) \right], \quad \mathcal{F} \equiv I_g \tag{4}$$

$w \to -1$ for $\mathcal{F} > 0$, $w \to 0$ for $\mathcal{F} < 0$.

$$T^{\mu\nu}_{\text{imp}} = \rho_g u^\mu u^\nu + w \rho_g c^2 h^{\mu\nu}, \quad \nabla_\mu (T^{\mu\nu}_m + T^{\mu\nu}_{\text{imp}}) = 0 \tag{5}$$

0.5 Energetic Budget

As computed in detail: Milky Way $P_{MW} \sim 2 \times 10^8 \eta$ W, $\rho_g \sim 4.3 \times 10^{-36} \eta$ J/m^3, $\rho_g / \rho_\Lambda \sim 5 \times 10^{-27} \eta$. Requires $\eta_\Lambda \sim 2 \times 10^{26}$.

Part II – MOND Limit and Tully-Fisher

0.6 Effective Mass Flux for a Galaxy

Enclosed $M(r)$, dynamical time $t_{dyn} = r/v_c$, average longitudinal component $\langle \vec{v} \cdot \vec{a} \rangle = \epsilon v_c GM/r^2$,

$$\dot{M}_{\text{eff}} = \epsilon\Gamma \frac{Mv_c}{c^2}\frac{GM}{r^2}, \quad \Phi_g = Z_g \dot{M}_{\text{eff}} = \epsilon\Gamma \frac{G^2M^2v_c}{c^3r^2} \tag{6}$$

0.7 Deriving a_0

Define

$$a_0 \equiv \frac{c^3}{G^2M}\Phi_g r = \epsilon\Gamma \frac{GM}{r^2}\frac{v_c}{c} \tag{7}$$

Parametrize $a_0 = \eta a_{\text{fluct}}$, $a_{\text{fluct}} = (\Delta V)^2/R_H$, $\Delta V = 494.6$ km/s, $R_H = 123$ Gly $= 1.16 \times 10^{27}$ m,

$$a_{\text{fluct}} = 2.11 \times 10^{-16}\,\text{m/s}^2, \quad \eta_{a_0} = a_0/a_{\text{fluct}} \simeq 5.7 \times 10^5 \approx 10^6 \tag{8}$$

Using ΛCDM $R_H = 46.5$ Gly gives 5.3×10^{-16} and $\eta \sim 2.3 \times 10^5$, same order.

η interpreted as $\langle \epsilon\gamma^3 c/v_c \rangle$ integrated over halo, jets, hot gas. Single jet $\gamma \sim 10^3$ gives $\gamma^6 \sim 10^{18}$ in power.

0.8 Tully-Fisher Relation

From definition $\Phi_g = GMa_0/v_c^2$. Equilibrium $v_c^2 = \Phi_g$ gives

$$v_c^4 = GMa_0 \tag{9}$$

r cancels via definition of a_0. Dimensionally $[GMa_0] = m^4/s^4 = [v^4]$.

Part III – Tests, Limitations, Conclusion

0.9 Observational Tests

- Lensing deficit $\Delta\Phi \sim Z_{\text{eff}}\dot{M}/c$ around jet hotspots - Euclid $\times$ LOFAR.
- Gaia DR3: correlation $v_c^4 - GMa_0 \propto \langle v_R v_\phi \rangle$.
- Lab: forced longitudinal acceleration with optical clocks, $P \sim 10^{-3}$ W per kg with $\eta = 1$, $\sim 10^{24}$ W with η_Λ - exclusion already.

0.10 Limitations

No action derivation, $w(\mathcal{F})$ ad-hoc, η scale-dependent, Pivot boundary non-standard.

0.11 Conclusion

Bare G/c insufficient by 10^{27} for dark energy, but with collective η provides unified language where acceleration/deceleration phases correspond to dark energy/dark matter. The MOND limit emerges as low-acceleration equilibrium.

Acknowledgments

The core impedance idea $U = Z_g dm/dt$ with $dm/dt \propto \vec{v} \cdot \vec{a}$ and sign change upon deceleration was originally derived by the author in 2024. The author used Gemini for initial draft preparation and Meta AI for LaTeX formatting, energetic estimates and covariant reformulation. All physical checks were performed by the author.

References

[1] Heaviside O., 1893

[2] Sciama D.W., MNRAS 113, 34 (1953)

[3] Sciama D.W., 1969

[4] Unruh W.G., PRD 40, 1048 (1989)

[5] Milgrom M., ApJ 270, 365 (1983)

[6] Binney J., Tremaine S., Galactic Dynamics (2008)

[7] Sher A., Pivot Universe (2023)