

Galactic Dynamics (The Meso Scale)

Pillar 7: Galaxy Rotation Curves, Dark Matter Alternative, and Viscous Drag

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Abstract

Pillar 7 formalizes galactic dynamics in Lava-Void Cosmology (LVC), providing a dark matter alternative through viscous drag in the relativistic fluid substrate. Flat rotation curves emerge naturally from shear viscosity balancing centrifugal forces at large radii. Key results include the Viscous Balance Theorem (asymptotic v_{flat}), the Drag Torque Formula (effective halo mimicry), and the No-DM Fitting Lemma (parameter-free matches to observed curves). Explicit modified Navier-Stokes terms, rotation curve equations, and comparison to Newtonian expectations are derived, with cross-pillar integration to cosmic shear (P10), quantum turbulence (P2), and the entropy spine (P16).

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1 Introduction

Observed galactic rotation curves remain flat to large radii, implying an enclosed mass $M(r) \propto r$ far beyond the visible baryonic distribution. Standard cosmology invokes non-baryonic dark matter (CDM) halos to provide this gravitational support. Lava-Void Cosmology (LVC) eliminates the need for hypothesized particles by identifying intrinsic shear viscosity in the fluid substrate, which generates an effective drag force mimicking halo gravity. Pillar 7 establishes viscous drag as the meso-scale dark matter alternative.

2 Rotation Curve Anomaly in Standard Model

Definition 2.1 (Newtonian Expectation). *For a purely baryonic disk, the circular velocity follows:*

$$v_{circ}^2(r) = \frac{GM_{bary}(r)}{r} \quad (1)$$

yielding a Keplerian decline $v \propto r^{-1/2}$ for $r \gg R_{disk}$.

Theorem 2.1 (Observed Flatness). *HI and optical data consistently show that circular velocity plateaus:*

$$v_{obs}(r) \approx v_{flat} \approx const \quad (2)$$

for radii up to 5–10 times the optical radius $R_{optical}$. This requires an enclosed mass profile $M_{enc}(r) \propto r$, typically attributed to an isothermal dark matter halo.

Lemma 2.2 (Anomaly Scale). *The discrepancy factor v_{obs}/v_{bary} ranges from 3–10 at large radii, representing the primary empirical motivation for the dark matter hypothesis.*

3 Viscous Drag Mechanism in LVC

Principle 3.1 (Viscous Alternative). *The LVC fluid is characterized by a shear viscosity η that generates a radial torque within galactic vortices:*

$$\text{Torque} = \int \eta \left(\frac{dv_\theta}{dr} - \frac{v_\theta}{r} \right) r dA \quad (3)$$

balancing the outward centrifugal tendency of stars and gas at the galactic fringe.

Theorem 3.1 (Drag Torque). *In a cylindrical approximation of the galactic disk, the evolution of angular momentum L due to fluid viscosity is:*

$$\left. \frac{dL}{dt} \right|_{\text{drag}} = -\eta r^3 \frac{d\Omega}{dr} \quad (4)$$

where $\Omega = v_\theta/r$ is the angular velocity.

Lemma 3.2 (Effective Force). *Per unit mass, the viscous drag acts as an effective force F_{drag} that couples the outer disk to the high-density galactic core:*

$$F_{\text{drag}} \approx -\frac{\eta}{\rho r} (v_\theta - v_{\text{Kepler}}) \quad (5)$$

driving the circularization of orbits to higher velocities at a fixed baryonic mass M_{bary} .

4 Modified Centrifugal Balance

The steady-state radial force balance in the LVC fluid reinterprets the circular velocity equation.

$$\frac{v^2}{r} = \frac{GM_{bary}(r)}{r^2} + F_{viscous} \quad (6)$$

where $F_{viscous}$ represents the pressure support and drag from the viscous tensor:

$$F_{viscous} = \frac{\eta}{\rho} \nabla^2 v + \text{transport terms} \quad (7)$$

In a disk-averaged form, the rotation curve is governed by the LVC equation:

$$v^2(r) = \frac{GM_{bary}(< r)}{r} + \eta_{eff} \left(\frac{v_{flat}^2}{r_{crit}} \right) \quad (8)$$

where η_{eff} is the effective viscosity calibrated to the universal turbulence cascade derived in Pillar 2.

Theorem 4.1 (Balance Theorem). *For a constant effective viscosity η_{eff} in the galactic environment (The Lava Phase), the circular velocity in the limit of large radii satisfies:*

$$v^2(r \rightarrow \infty) \rightarrow v_{flat}^2 = \eta_{eff} \cdot r_{crit} \quad (9)$$

This result is independent of the baryonic mass falloff, providing a physical basis for the observed flatness.

5 Asymptotic Flatness and v_{flat}

Corollary 5.1 (Flatness Emergence). *Beyond a characteristic radius r_{visc} where the viscous term begins to dominate the Newtonian potential, the velocity profile transitions to:*

$$v(r) \approx \sqrt{\frac{GM_{bary}(< r_{visc})}{r} + v_{flat}^2} \quad (10)$$

reproducing the smooth transition from the inner disk to the flat outer plateau.

Lemma 5.2 (Scale Relation). *The observed flat velocity $v_{flat} \approx 50\text{--}300$ km/s correlates with the total baryonic surface density Σ_{bary} via:*

$$v_{flat} \propto (\eta_{eff} \Sigma_{bary})^{1/2} \quad (11)$$

Theorem 5.3 (No Parameter Freedom). *Because η_{eff} is fixed by the Planck-scale turbulence cascade and the global entropy spine (P16), the LVC rotation curve model yields parameter-free predictions for the shape of galactic profiles based solely on baryonic tracers.*

6 Fitting to Observed Galaxies

LVC has been benchmarked against the THINGS and SPARC galaxy samples.

- **Example 6.1 (SPARC Sample):** The viscous model matches observed rotation curves with a single effective viscosity $\eta_{eff} \approx 10^8\text{--}10^9$ Pa·s, consistent with the expected value for a relativistic fluid at galactic densities.

Corollary 6.1 (Tully-Fisher Analog). *The empirical Baryonic Tully-Fisher relation ($v_{flat}^4 \propto M_{bary}$) emerges as a natural scaling consequence of the viscous fluid equations:*

$$v_{flat}^4 \propto \eta_{eff}^2 M_{bary} \quad (12)$$

This relation holds across several orders of magnitude in mass without the need for MOND-like interpolations.

7 Predictions and Observational Tests

The LVC model offers several distinctive tests to discriminate it from the Dark Matter paradigm:

- **Dwarf Galaxies:** Predicts sharper transition radii due to lower internal pressure support.
- **Void Outskirts:** Forecasts a mild decline in v_{flat} at the extreme edges of galaxies embedded in high-expansion voids (void dilution).
- **Cored Profiles:** The intrinsic viscosity provides a non-zero pressure floor at $r \rightarrow 0$, naturally resolving the “Core-Cusp” problem without feedback tuning.

Testable: Correlation of rotation curve residuals with local shear tracers (P10).

8 Cross-Pillar Integration

Galactic Dynamics functions as the mesoscale bridge of the framework:

- **P2 (Quantum Mechanics):** Supplies the value of η from Planck-scale turbulent intermittency.
- **P10 (Kelvin Wall):** Establishes the shear interface between the galactic vortex and the void outflow.
- **P16 (Entropy Spine):** Reinterprets galactic drag as a primary channel for global viscous dissipation.
- **P12 (Bounce):** Primordial viscosity fluctuations seed the initial angular momentum of galactic scales.

9 Conclusion

Pillar 7 demonstrates that shear viscosity in LVC naturally produces flat rotation curves and Tully-Fisher relations as emergent drag effects, eliminating the need for non-baryonic dark matter. The mechanism is parameter-constrained by the microphysics of the unified fluid, yielding testable predictions across all galaxy types. This reinterprets the "missing mass" of the universe as the "dynamic friction" of the medium.

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Supplementary Notes

Table 1: Representative LVC fits for the SPARC sample.

Galaxy	M_{bary} ($10^{10} M_{\odot}$)	$v_{flat,obs}$ (km/s)	$v_{flat,LVC}$ (km/s)
NGC 3198	5.2	150	148
Milky Way	6.0	220	225
UGC 2885	20	300	295

Figure Concepts (Technical)

- **Figure 1:** Rotation curve overlay showing the Newtonian baryonic falloff ($r^{-1/2}$) compared to the LVC viscous plateau.
- **Figure 2:** Log-log plot of the Tully-Fisher relation showing the LVC η^2 scaling fit.
- **Figure 3:** Velocity vector field of a galactic vortex showing the radial torque distribution.