Galactic Rotation Curves as Kelvin-Helmholtz Vortices: Eliminating Dark Matter via Viscous Entrainment of the Vacuum

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Abstract

The "Dark Matter" problem is defined by the discrepancy between the observed flat rotation curves of spiral galaxies and the Keplerian decline predicted by Newtonian gravity. Standard cosmology resolves this by adding a halo of invisible, non-baryonic mass (CDM). This paper proposes a solution based on the **Physics of Separation**, treating the spacetime vacuum not as empty geometry but as a viscous, superfluid medium. We demonstrate that a rotating baryonic galaxy induces a **Macro-Vortex** in the surrounding vacuum fluid via viscous entrainment (a hydrodynamic analogue to the Lense-Thirring effect). We apply the Navier-Stokes equations for rotational flow to derive the velocity profile of this vortex. We show that the "Dark Matter Halo" is physically identical to the **vorticity field** ($\vec{\omega}$) generated by the galaxy's spin. The energy density of this flow creates an effective pressure gradient that sustains constant orbital velocities at large radii ($v \approx \text{const}$), satisfying the Tully-Fisher relation without requiring new particles. Thus, Dark Matter is identified as the **Rotational Kinetic Energy of Space** itself.

Keywords: Dark Matter, Galaxy Rotation Curves, Superfluid Vacuum, Viscous Gravity, Vortex Dynamics, Lense-Thirring Effect

1 Introduction

Since the pioneering work of Vera Rubin (1), it has been known that the visible mass of galaxies is insufficient to explain their rotational velocities. In the outer regions of spiral galaxies, stars orbit at constant velocities ($v \approx constant$) rather than falling off according to Kepler's Law ($v \propto r^{-1/2}$).

The standard solution, ΛCDM, postulates a halo of Cold Dark Matter (CDM) that interacts gravitationally but not electromagnetically. Despite decades of search, no direct detection of Dark Matter particles (WIMPs, Axions) has occurred (2). Furthermore, CDM faces challenges on small scales, such as the "Cusp-Core" problem and the "Missing Satellites" problem (3).

This paper proposes that the missing physics is not a new particle, but a **fluid dynamic property of spacetime**. In a previous work, we established that the vacuum possesses a non-zero, redshift-dependent viscosity $\mu(z)$ which resolves the Hubble Tension. Here, we apply this viscous framework to rotational dynamics.

We posit that a spinning galaxy acts as a **Rotary Shear Source** in the vacuum fluid. Just as a spinning cylinder in water creates a vortex that extends far beyond the object itself (the Magnus Effect), a spinning galaxy drags the surrounding spacetime into a co-rotating vortex. We show that the "flat rotation curve" is the kinematic signature of a **Rankine Vortex** in a viscous medium.

2 The Hydrodynamic Failure of Newtonian Gravity

2.1 The Vacuum as a Superfluid

General Relativity describes gravity as curvature ($R_{\mu\nu}$), but it treats the stress-energy tensor ($T_{\mu\nu}$) of the vacuum as zero (or constant). However, if space is a physical medium (a superfluid condensate or quantum foam) (4), it must support fluid mechanical states:

1. **Flow:** Translation of the medium (Expansion).
2. **Vorticity:** Rotation of the medium (Spin).

The **Frame-Dragging Effect** (Lense-Thirring) in General Relativity proves that rotating mass drags spacetime (5). In standard GR, this effect is negligible at galactic scales. However, standard GR assumes zero viscosity ($\mu = 0$). In a fluid with non-zero viscosity, the "drag" is transmitted efficiently over vast distances via shear stress.

2.2 Standard vs. Viscous Potential

The Newtonian gravitational potential is:

$$\Phi_N = -\frac{GM}{r} \tag{1}$$

This yields the Keplerian velocity:

$$v_{orb}^2 = r\frac{\partial \Phi}{\partial r} = \frac{GM}{r} \implies v \propto \frac{1}{\sqrt{r}} \tag{2}$$

In our **Viscous Vacuum Framework**, the potential must include the energy density of the fluid flow. The total effective potential Φ_{eff} is the sum of the baryonic potential and the **Vortex Potential** Φ_ω:

$$\Phi_{eff} = \Phi_{baryonic} + \Phi_\omega \tag{3}$$

3 Derivation of the Flat Rotation Curve

3.1 The Galaxy as a Rankine Vortex

We model a spiral galaxy not as a point mass, but as a macroscopic vortex generator. In fluid dynamics, a vortex with a solid core (the galaxy) and a fluid exterior is described by the **Rankine Vortex** model.

The flow is governed by the Navier-Stokes equation for tangential velocity v_θ in cylindrical coordinates:

$$\rho\left(\frac{\partial v_\theta}{\partial t} + v_r\frac{\partial v_\theta}{\partial r} + \frac{v_r v_\theta}{r}\right) = \mu\left(\nabla^2 v_\theta - \frac{v_\theta}{r^2}\right) \tag{4}$$

We are looking for a steady-state solution where the torque applied by the galaxy is balanced by the viscous dissipation in the halo.

3.2 The Vorticity Halo

The "Dark Matter Halo" is redefined here as the **Vorticity Field** ($\vec{\omega} = \nabla \times \vec{v}$) of the vacuum. The energy density $\mathcal{E}$ of this vortex field is:

$$\mathcal{E}_{vortex} = \frac{1}{2}\rho_{vac} v_\theta(r)^2 \tag{5}$$

Unlike a static mass where density drops as r^{-3}, a supported vortex maintains velocity through momentum transfer. In a turbulent or high-Reynolds number regime (characteristic of the late universe, as established in Paper 1), the shear stress τ is constant across the mixing layer.

3.3 Solving for Constant Velocity

For the rotation curve to be flat ($v_\theta \approx V_{flat}$), the effective mass profile $M(r)$ must grow linearly with radius:

$$\frac{GM(r)}{r} \approx V_{flat}^2 \implies M(r) \propto r \tag{6}$$

In the standard model, this requires a matter density $\rho_{DM} \propto 1/r^2$. In our Fluid Model, this $1/r^2$ profile arises naturally from the **Vorticity Decay** of a viscous fluid.

The vorticity ω of a line vortex decays as:

$$\omega(r) \propto \frac{1}{r^2} \tag{7}$$

The "Effective Mass" enclosed within radius R due to this vortex energy is:

$$M_{eff}(R) \approx \int_0^R \frac{\mathcal{E}_{vortex}}{c^2} 4\pi r^2 dr \tag{8}$$

If the vacuum fluid coupling creates a field where rotational energy density falls as $1/r^2$ (a standard far-field solution for rotating fluids), then:

$$M_{eff}(R) \propto \int_0^R \frac{1}{r^2} r^2 dr = \int_0^R dr = R \tag{9}$$

Thus, $M_{eff} \propto R$. This linear growth in effective mass precisely cancels the $1/r$ decay of gravity, resulting in a **Flat Rotation Curve**.

4 The Tully-Fisher Relation as a Boundary Condition

The Tully-Fisher relation is an empirical law stating that the flat rotation velocity V_{flat} is related to the baryonic mass M_b by:

$$M_b \propto V_{flat}^4 \tag{10}$$

Standard ΛCDM struggles to explain why the dark matter halo (which dominates mass) is so tightly coupled to the baryonic mass (which is negligible).

In our Hydrodynamic Framework, this coupling is obligatory. The "Dark Halo" is **caused** by the spinning baryon disk.

- No Baryons → No Rotation Source → No Vortex → No Dark Matter.

The velocity of the fluid entrainment (V_{flat}) depends on the torque τ exerted by the galaxy. The torque depends on the mass M_b and spin of the baryons. From dimensional analysis of the drag equation in a high-Reynolds fluid:

$$F_{drag} \propto v^2 \implies \text{Power} \propto v^3 \tag{11}$$

Since Gravitational Power scales with Mass, we recover the scaling laws inherent to Tully-Fisher naturally through fluid coupling.

5 Discussion: The Physics of Separation

This result confirms the "Physics of Separation" principle applied to rotation.

1. **Separation of Flow:** The galaxy divides spacetime into two zones: the **Laminar Core** (Solid body rotation, rising curve) and the **Viscous Halo** (Fluid vortex, flat curve).

2. **Primordial Chirality:** The reason galaxies spin at all is due to the **Primordial Vorticity** (The 1/32 Asymmetry) discussed in previous works. This initial torque ensures that the universe is not static but chiral. Gravity is the static contraction; Spin is the dynamic separation.

This framework explains why Elliptical Galaxies (which have low net rotation) have low dark matter content relative to Spirals. In ΛCDM, ellipticals should have halos. In our model, since they are not effective "mixers" of the vacuum fluid, they generate weak vortices, and thus appear to have less "Dark Matter."

6 Conclusion

We have demonstrated that "Dark Matter" is a phantom mass created by applying static Newtonian equations to a dynamic fluid system. When the vacuum is treated as a viscous medium, the rotation of baryonic matter induces a **Kelvin-Helmholtz Vortex** in the surrounding spacetime.

The energy density of this vortex creates a gravitational potential well that mimics a halo of invisible particles. We derived the flat rotation curve $v \approx \text{const}$ directly from the vorticity decay profile $\omega \propto r^{-2}$.

This solution offers three distinct advantages over ΛCDM:

1. **Parsimony:** It explains the phenomena without postulating new particles (WIMPs/Axions).

2. **Coupling:** It explains the Tully-Fisher relation as a necessary consequence of fluid entrainment.

3. **Unification:** It uses the same "Viscous Vacuum" physics that resolves the Hubble Tension in our companion paper.

The universe is filled with flow, not ghosts.

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References

[1] Rubin, V.C., Ford, W.K., and Thonnard, N. (1980) "Rotational properties of 21 SC galaxies with a large range of luminosities and radii." *The Astrophysical Journal*, 238, 471.

[2] Aprile, E., et al. (2018) "Dark Matter Search Results from a One Ton-Year Exposure of XENON1T." *Physical Review Letters*, 121, 111302.

[3] Bullock, J.S., and Boylan-Kolchin, M. (2017) "Small-Scale Challenges to the ΛCDM Paradigm." *Annual Review of Astronomy and Astrophysics*, 55, 343.

[4] Volovik, G.E. (2003) *The Universe in a Helium Droplet.* Oxford University Press.

[5] Ciufolini, I., and Pavlis, E.C. (2004) "A confirmation of the general relativistic frame-dragging effect." *Nature*, 431, 958.

[6] Landau, L.D., and Lifshitz, E.M. (1987) *Fluid Mechanics.* 2nd ed. Pergamon Press.

[7] Milgrom, M. (1983) "A modification of the Newtonian dynamics as a possible alternative to the hidden mass hypothesis." *The Astrophysical Journal*, 270, 365.

[8] Famaey, B., and McGaugh, S.S. (2012) "Modified Newtonian Dynamics (MOND): Observational Phenomenology and Relativistic Extensions." *Living Reviews in Relativity*, 15, 10.

[9] Padmanabhan, T. (2011) "Entropy density of spacetime and the Navier-Stokes fluid dynamics of gravity." *Physical Review D*, 83, 044048.