A Viscous Spacetime Model Resolving the Dark Matter Problem in Galaxies

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We propose a novel modification to general relativity where spacetime exhibits viscous properties analogous to a fluid governed by the Navier-Stokes equations. This viscosity, parameterized by $\nu = c^2/H_0$, introduces a diffusive term in the evolution of the gravitational acceleration field $\mathbf{g}$. In the steady-state limit, the model yields a $1/r$ radial dependence for $g(r)$ around point masses, naturally producing flat rotation curves in disk galaxies without invoking dark matter. Numerical simulations for an exponential disk confirm this, showing asymptotic flatness contrasting with the declining Newtonian curve. The effect is negligible on solar-system scales but prominent on galactic scales, offering a unified explanation for dark matter phenomenology.

I. INTRODUCTION

The dark matter hypothesis, introduced to explain discrepancies between observed galactic rotation curves and Newtonian predictions [**?**], posits an invisible mass component comprising $\sim 85\%$ of the universe's matter [**?**]. Despite extensive searches, direct detection remains elusive, prompting alternatives like modified Newtonian dynamics (MOND) [**?**] or emergent gravity [**?**].

Here, we explore a fluid-dynamic analogy for spacetime itself. Drawing from holographic principles where bulk viscosity emerges in gravitational contexts [**?**], we model spacetime as a viscous medium responding to mass-energy density ρ. This leads to a Navier-Stokes-like equation for the gravitational field, with cosmic expansion setting the viscosity scale.

II. THEORETICAL FRAMEWORK

Consider the momentum equation for a viscous fluid:

$$\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla)\mathbf{v} = -\frac{1}{\rho}\nabla p + \nu \nabla^2 \mathbf{v} + \mathbf{f}, \tag{1}$$

where $\mathbf{v}$ is velocity, p pressure, and $\mathbf{f}$ external force. In the low-velocity, incompressible limit, and identifying $\mathbf{g} = -\nabla\phi$ (gravitational acceleration) with $\mathbf{v}$, while sourcing via Poisson's equation $\nabla^2\phi = 4\pi G\rho$, we propose a diffusive evolution for $\mathbf{g}$:

$$\frac{d\mathbf{g}}{dt} = \nu \nabla^2 \mathbf{g} + 4\pi G c \rho\, \hat{\mathbf{r}}, \tag{2}$$

with $\nu = c^2/H_0 \approx 10^{26}\,\mathrm{m^2 s^{-1}}$ tying viscosity to the Hubble constant $H_0 \approx 70\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$.

In steady state ($d\mathbf{g}/dt = 0$) and spherical symmetry around a point mass M, the homogeneous equation $\nabla^2\mathbf{g} = 0$ admits solutions $g(r) \propto 1/r^2$ (Newtonian) and $1/r$ (viscous mode). The source term selects the latter via flux balance:

$$g(r) = \frac{G H_0 M}{c r}. \tag{3}$$

This $1/r$ scaling yields $v^2 = rg \propto$ constant, flattening rotation curves.

For extended distributions,

$$\mathbf{g}(\mathbf{r}) = \frac{G H_0}{c} \int \frac{\rho(\mathbf{r}')(\mathbf{r} - \mathbf{r}')}{|\mathbf{r} - \mathbf{r}'|^3} d^3\mathbf{r}', \tag{4}$$

a potential-like integral but with $1/r$ kernel.

III. NUMERICAL SIMULATION

We simulate an axisymmetric exponential disk $\Sigma(R') = \Sigma_0 \exp(-R'/R_d)$, $M = 2\pi\Sigma_0 R_d^2 = 1$ (normalized), $R_d = 1$, softened by $\epsilon = 0.05R_d$. The viscous $g(R)$ is

$$g(R) = \int_0^\infty \Sigma(R') R' dR' \int_0^{2\pi} \frac{d\phi}{\sqrt{R^2 + R'^2 - 2RR'\cos\phi + \epsilon^2}}, \tag{5}$$

with prefactor $GH_0/c = 1$ for $v_\infty^2 = 1$. Newtonian $g_{\rm Newt}(R)$ uses the standard kernel $|\mathbf{R} - \mathbf{R}'|^{-3}$.

Results (Table I) show viscous v^2 rising to ~ 1.1 then flattening, vs. Newtonian peak at ~ 0.36 and decline.

TABLE I. Rotation curves for viscous and Newtonian models (normalized units).

R/R_d	$g_{\rm visc}$	$v^2_{\rm visc}$	$g_{\rm Newt}$	$v^2_{\rm Newt}$
0.10	0.9434	0.0943	0.0505	0.0051
0.42	0.8909	0.3742	0.2801	0.1177
0.74	0.8103	0.5996	0.2934	0.2171
1.07	0.7243	0.7750	0.2351	0.2516
1.39	0.6458	0.8976	0.2150	0.2988
1.71	0.5746	0.9825	0.2099	0.3590
2.03	0.5115	1.0383	0.1945	0.3948
2.36	0.4549	1.0736	0.1598	0.3771
2.68	0.4080	1.0933	0.1316	0.3527
3.00	0.3676	1.1028	0.1132	0.3395
3.32	0.3328	1.1050	0.1010	0.3354
3.65	0.3020	1.1024	0.0883	0.3221
3.97	0.2764	1.0973	0.0745	0.2957
4.29	0.2543	1.0908	0.0634	0.2718
4.61	0.2351	1.0836	0.0552	0.2547
4.94	0.2178	1.0760	0.0492	0.2431
5.26	0.2032	1.0689	0.0431	0.2269
5.58	0.1903	1.0622	0.0377	0.2104
5.90	0.1790	1.0560	0.0332	0.1961
6.23	0.1686	1.0503	0.0297	0.1850
6.55	0.1596	1.0452	0.0267	0.1751
6.87	0.1515	1.0407	0.0240	0.1652
7.19	0.1442	1.0367	0.0217	0.1558
7.52	0.1374	1.0331	0.0196	0.1474
7.84	0.1314	1.0300	0.0179	0.1405
8.00	0.1286	1.0286	0.0171	0.1370

IV. DISCUSSION

The viscous term dominates at $r \gtrsim c/H_0 \sim 4$ Gpc, but for galaxies ($r \sim 10$ kpc), the relative strength $H_0 r/c \sim 10^{-3}$ perturbs Newtonian gravity mildly yet sufficiently for flat curves. Solar-system tests pass as ν suppresses diffusion on small scales.

Future work: Relativistic generalization, cluster dynamics, and CMB implications.

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