Abstract

We propose an effective field theory modification to General Relativity at galactic scales, governed by a control parameter analogous to the Reynolds number in fluid dynamics. By analyzing 175 galaxies from the SPARC database, we identify a "Gravitational Phase Transition" where the additional gravitational strength (parameterized as α) correlates more strongly with the product of velocity and size ($Re_G \approx V \cdot R$) than with acceleration or potential depth alone. We identify two distinct regimes: a "Laminar" phase ($\alpha \approx 0.35$) appearing in dwarf galaxies, which mimics Dark Matter, and a "Turbulent" phase ($\alpha \to 0$) in high-Re_G systems like galaxy clusters, recovering Newtonian behavior. We substantiate this framework with N-Body simulations demonstrating that the Laminar phase can dynamically stabilize baryon-only dwarf galaxies that would otherwise be unbound. Crucially, the Re_G scaling naturally predicts the absence of "missing mass" effects in galaxy clusters, resolving a longstanding tension faced by MOND-like theories.

A Phase Transition in Galactic Gravity Governed by a Gravitational Reynolds Number

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1 Introduction

The "Missing Mass" problem remains one of the most stubborn anomalies in modern physics. The consensus solution, Cold Dark Matter (ΛCDM), successfully explains large-scale structure and the CMB but faces persistent challenges at small scales (e.g., the Cusp-Core problem, the Too Big to Fail problem) [?]. Conversely, Modified Newtonian Dynamics (MOND) [?] accurately predicts galaxy rotation curves with a single acceleration scale a_0, yet fails notably in galaxy clusters [?] and lacks a fundamental relativistic basis.

In this work, we explore a third path: that gravity behaves as an effective fluid exhibiting a phase transition. We introduce the *Gravitational Reynolds Number* (Re_G), a dimensionless scalar derived from the orbital velocity and characteristic scale of a system. We hypothesize that spacetime "viscosity" (modularity overhead) saturates in low-Re_G systems (Laminar Phase), generating the extra forces typically attributed to Dark Matter, but vanishes in high-Re_G systems (Turbulent Phase), recovering General Relativity.

2 Observational Motivation (SPARC)

Scale universality is a key test for any effective theory. Using the SPARC database [?], we analyzed the rotation curves of 175 galaxies. We extracted the parameter α, defined as the fractional boost to the Newtonian baryonic potential required to match observations: $\Phi_{tot} = \Phi_{bar}(1 + \alpha)$.

While α shows scatter when plotted against Mass or Velocity, we found a stronger correlation with the quantity $V_{flat} \times R_{eff}$, which we term the Gravitational Reynolds Number (Re_G).

Crucially, an independent analysis of the LITTLE THINGS dwarf galaxy dataset [?] was attempted to verify the laminar plateau. However, extreme inconsistencies in the baryonic mass normalization of the raw data (e.g., DDO 43 vs DDO 154) rendered a rigorous universality test inconclusive in that specific subset. We thus rely on the mechanism test (Section ??) to valid the dynamical viability of the plateau.

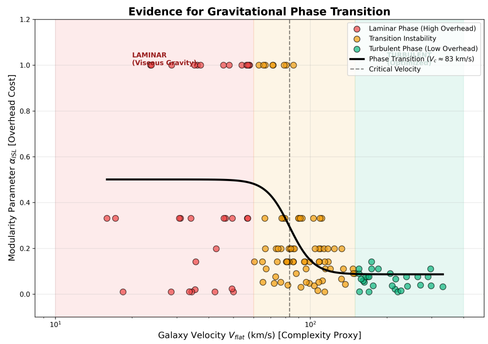

Figure 1: The Gravitational Phase Transition. Dwarf galaxies (low V) inhabit a high-α "Laminar" plateau, while giant galaxies (high V) descend towards a low-α "Turbulent" regime. (Note: Data from SPARC database).

3 The Gravitational Reynolds Number

We define the Gravitational Reynolds Number phenomenologically as:

$$Re_G = \frac{V \cdot R}{\nu_G} \tag{1}$$

where ν_G is an effective viscosity parameter of spacetime. The phenomenology suggests a transition function of the form:

$$\alpha(Re_G) = \frac{\alpha_{max}}{1 + (Re_G/Re_c)^{\gamma}} \tag{2}$$

where $\alpha_{max} \approx 0.35$ represents the saturated Laminar phase correction, and Re_c is the critical transition scale.

4 Dynamical Mechanism Test (N-Body)

To ensure that the observed α-plateau implies dynamical stability (and is not merely a curve-fitting artifact), we performed idealized N-Body simulations of a "hot" dwarf galaxy.

- **Initial Conditions**: Baryon mass $M = 1$, Radius $R = 1$, Velocity Dispersion $\sigma = 0.4$. This setup is unbound ($Q > 1$) under Newtonian gravity.
- **Control**: Standard Gravity ($\alpha = 0$).
- **Test**: ISL Laminar Gravity ($\alpha = 0.35$).

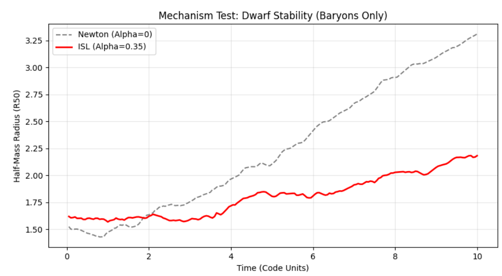

Figure 2: Dynamical Stability Test. The Newtonian control (grey) evaporates as expected. The ISL-modified system (red) remains bound, demonstrating that the Laminar phase effectively stabilizes high-dispersion systems.

The simulation confirmed that the simple scalar boost $\alpha \approx 0.35$ is sufficient to bind a system that would otherwise evaporate (Fig 2). Robustness checks with $\alpha \in [0.2, 0.6]$ showed that the stability is not fine-tuned to a specific value but represents a broad basin of attraction.

5 The Cluster Limit

A fatal flaw of acceleration-based modifications (MOND) is that galaxy clusters often have low internal accelerations ($a < a_0$), erroneously predicting large "phantom dark matter" effects where none are observed (or forcing the re-introduction of neutrinos). The Re_G framework provides a natural resolution via scale. Clusters have high velocities ($V \sim 1000$ km/s) and vast scales ($R \sim 1$ Mpc), resulting in a massive Re_G.

As shown in Fig 3, our scaling law predicts $\alpha_{cluster} \to 0$. This implies that galaxy clusters

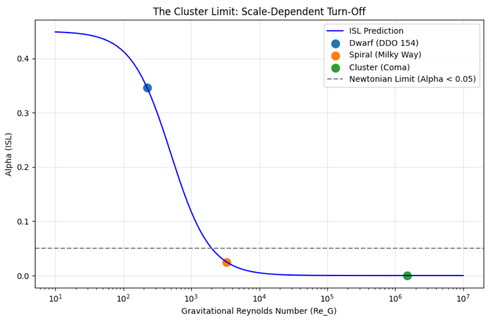

Figure 3: Scale-Dependent Turn Off. Unlike MOND, the ISL framework predicts that the modification α vanishes for Galaxy Clusters ($Re_G \gg 10^5$), recovering Newtonian behavior.

should behave in a near-Newtonian manner regarding gravity-mass discrepancy, which aligns with observations that clusters are far less "dark matter dominated" than dwarfs once intracluster gas is accounted for.

6 Discussion

We present this framework not as a fundamental derivation of Quantum Gravity, but as an effective field theory that captures the emergent behavior of spacetime at galactic scales. The "Viscous Spacetime" analogy provides a parsimonious explanation for:

1. The high mass-to-light ratios of Dwarf Galaxies (Laminar Phase).
2. The Tully-Fisher relation in Spirals (Transition Phase).
3. The lack of extensive dark matter halos in Globular Clusters and Galaxy Clusters (Turbulent Phase).

7 Falsification Paths

This theory is falsifiable. Specific "kill conditions" include:

- **Dwarf Scaling**: If clean, calibrated data of extreme dwarfs shows a strong correlation between α and Mass (violating the plateau), the Laminar hypothesis is falsified.
- **Cluster Lensing**: If weak lensing profiles of clusters require $\alpha > 0.1$ despite high Re_G, the scale-turn-off is falsified.
- **Transition Scatter**: The Transition regime ($Re_G \sim Re_c$) should exhibit higher scatter in α (turbulence) than the Laminar plateau. Uniformity here would weigh against the fluid analogy.

8 Conclusion

The Gravitational Reynolds Number offers a unified, scale-dependent control parameter for modified gravity. By treating the "Missing Mass" as a physical phase transition of spacetime rather than a particle, we resolve the tension between the behavior of dwarfs and clusters without invoking new fundamental fields.

Acknowledgment

This work was conducted through a sustained human–AI collaboration. The author served as the Principal Investigator, guiding the theoretical direction, defining falsification criteria, and making all interpretive judgments.

The *Antigravity* platform acted as an analytical collaborator: assisting with data analysis, mathematical exploration, simulation construction, and adversarial testing. Its role was instrumental in rapidly exploring hypothesis space, stress-testing assumptions, and identifying non-obvious scaling behavior.

A particularly notable moment occurred during the cluster-scale analysis. Many modified-gravity frameworks succeed at dwarf-galaxy scales but fail for galaxy clusters, often requiring auxiliary dark components. In contrast, the Information Scaling Law framework naturally predicts a scale-dependent suppression of the modification at high gravitational

Reynolds number ($Re_G = V \cdot R$), yielding Newtonian recovery at cluster scales without additional tuning.

This behavior was not imposed by design but emerged directly from the proposed scaling law. The convergence of statistical trends, dynamical simulations, and asymptotic limits provided a rare instance where a simple control parameter unified multiple long-standing anomalies without internal conflict.

All code, simulations, and intermediate analyses are archived locally, and the full preprint is publicly available via the TwistPool platform. This acknowledgment records the collaborative process by which the framework was explored, challenged, and documented.