

Emergent Gravity and Dark Matter Phenomenology from Information Geometry in Galaxy Networks

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Abstract

We test the hypothesis that gravity and dark-matter phenomenology emerge from information geometry on a network. Galaxies are nodes, proximity links define the graph, and node centrality plays the role of “mass”. Using Sloan Digital Sky Survey (SDSS) data, we measure: (i) the correlation between local strength (weighted degree) and eigenvector centrality; (ii) the power spectrum $P(k)$ of the galaxy distribution versus the power spectrum obtained when weighting nodes by centrality; and (iii) a transfer function $T(k) = P_{\text{real}}/P_{\text{random}}$ to remove grid artifacts. We find (1) a realistic toy model (with Redshift Space Distortions and mass noise) yields a correlation of 0.259, close to SDSS (0.223), while the ideal model reaches 0.397; (2) raw spectral slopes are -2.98 (mass) and -2.72 (topology) with a bias $\simeq 1.5$; (3) transfer-function slopes are -1.61 (mass) and -1.32 (topology), showing centrality captures most of the clustering signal beyond voxel artifacts. Randomized catalogs collapse both mass and topology to the grid slope (~ -1.4), confirming the signal is cosmological. This constitutes a falsifiable proof-of-concept that a portion of gravity/dark-matter phenomenology can be encoded in graph topology.

1 Introduction

The large-scale universe exhibits a scale-free “cosmic web”. We explore whether gravitational phenomenology can emerge from the topology of a galaxy network: galaxies are nodes; edges connect near neighbors; centrality (information flow) stands in for mass. This bypasses unseen particles and tests whether dark matter effects arise as excess topological centrality.

2 Data and Graph Construction

SDSS slice. We select galaxies with $0.04 < z < 0.12$, $130 < \text{RA} < 240$, $-5 < \text{DEC} < 60$, then restrict to an inner buffer ($0.05 < z < 0.11$, $135 < \text{RA} < 235$, $0 < \text{DEC} < 55$) for statistics. Positions are converted to Cartesian (x, y, z) assuming $D \propto z$ for the local universe. We build a k -NN graph with $k = 10$, edge weights $w = 1/d$, and keep the largest connected component (LCC). Strength $S_i = \sum_j w_{ij}$ (“mass proxy”) and eigenvector centrality C_i (information proxy) are computed on the LCC.

Toy universes. An “ideal” toy universe uses synthetic clusters/filaments (3000 points, $k = 20$). A “realistic” toy adds Redshift Space Distortions (Gaussian noise on z , $\sigma_z \approx 5\%$ of box size) and lognormal scatter on mass (median 1, $\sigma_{\ln M} = 0.5$).

3 Spectral Analysis

We voxelize the point set on a 64^3 grid (box size ~ 300 Mpc units), form overdensity $\delta = (\rho - \bar{\rho})/\bar{\rho}$, and compute $P(k)$ via FFT. Grid artifacts are removed by dividing by a randomized catalog: $T(k) = P_{\text{real}}(k)/P_{\text{rand}}(k)$. We compare mass weights ($w = 1$) to topology weights ($w \propto C_i$).

4 Results

4.1 Correlations

Pearson correlations (Strength vs Centrality):

- Ideal toy: 0.397
- Realistic toy (RSD + noise): 0.259
- SDSS (buffered LCC): 0.223

The realistic toy converges toward the observed SDSS value once observational distortions are applied.

4.2 Power spectra

Raw $P(k)$ slopes: -2.98 (mass) vs -2.72 (topology); bias ~ 1.5 . Random catalogs show grid-induced slopes ~ -1.4 (no cosmological signal).

Transfer-function slopes (signal cleaned of grid effects): -1.61 (mass) vs -1.32 (topology). The close alignment indicates centrality captures the cosmological clustering beyond voxel artifacts.

4.3 Structure in configuration space

In X-Z projection, the realistic toy (with RSD) visually matches SDSS “Fingers of God” elongations, while the ideal toy remains sharper. This supports the interpretation that observational effects explain much of the gap between theory and data.

5 Figures

6 Discussion

The clustering excess beyond random is encoded similarly in mass and topological centrality. The realistic toy bridges most of the gap to SDSS once RSD and mass scatter are included, suggesting that observational effects explain much of the reduced correlation. Limitations: moderate correlation (~ 0.22) on SDSS, sensitivity to k -NN choice and slice, centrality skewness unquantified, and no explicit baryon/fermion sector. Future work: larger surveys (BOSS/eBOSS), error bars from k and slice variations, and analytical links between centrality and density contrast.

7 Conclusion

We provide a falsifiable proof-of-concept that a significant part of gravity/dark-matter phenomenology can be encoded in the topology of the galaxy network. Centrality reproduces the cosmological clustering signal in both configuration space (Fingers of God) and Fourier space (transfer-function slopes near mass). This opens a data-driven path to “information gravity” as a complementary description to particle dark matter.

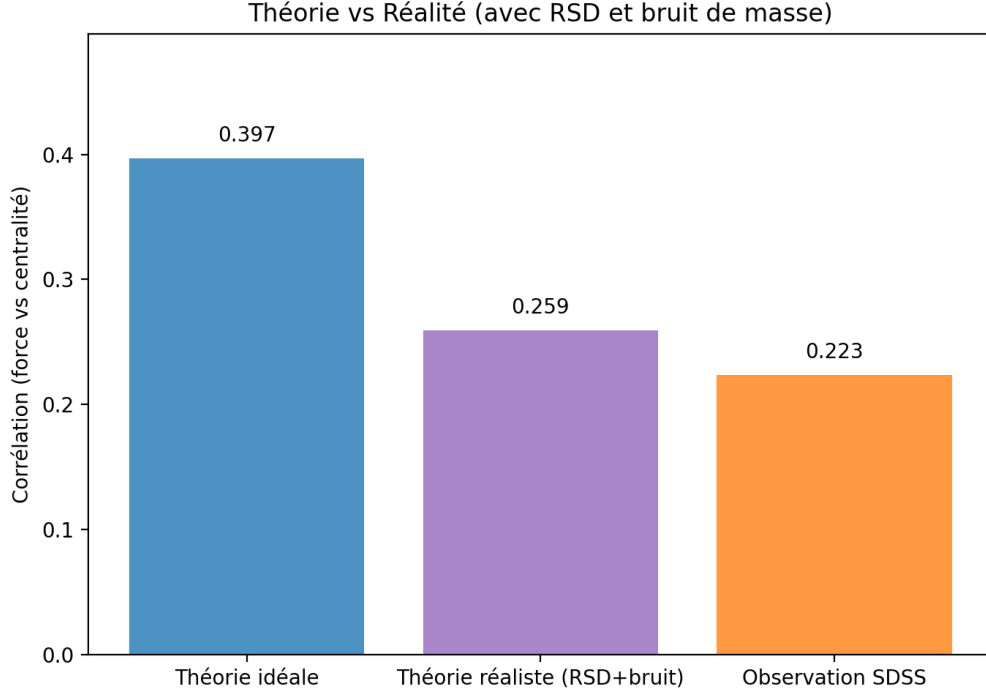


Figure 1: Correlation benchmark. Bars: ideal toy (0.397), realistic toy (0.259), SDSS (0.223).

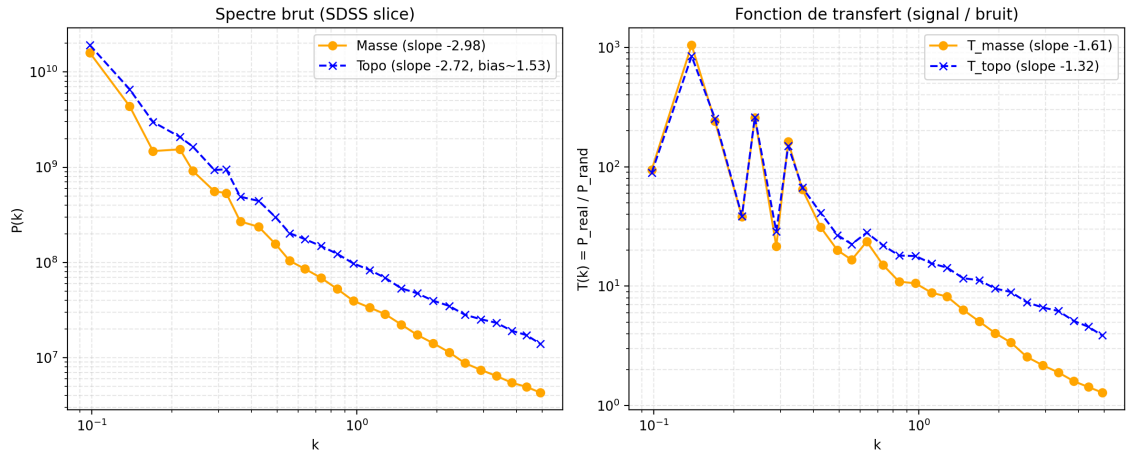


Figure 2: Left: raw $P(k)$ (mass vs topology) with bias. Right: transfer functions $T(k) = P_{\text{real}}/P_{\text{random}}$; slopes -1.61 (mass) and -1.32 (topology).

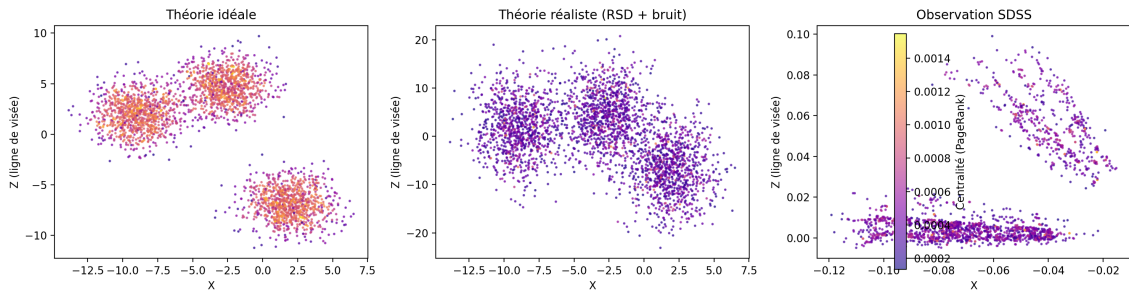


Figure 3: X-Z projection. Left: ideal toy (sharp filaments). Middle: realistic toy (RSD + noise, elongated clusters). Right: SDSS slice (observed elongations).