Interpreting SNIa Residual Dispersion as a Signature of Dark Matter Inhomogeneity (Revised)

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Abstract

We investigate the residual dispersion of type Ia supernovae (SNIa) in the Pantheon+SH0ES dataset as potential evidence of dark matter (DM) inhomogeneity. By incorporating an intrinsic noise term and analytically coupling the luminosity distance modulus to the gravitational potential fluctuations of DM, we show that simple evolutionary corrections fail to explain residual variance, while the DM-linked term provides a statistically significant improvement.

1 Data and Calibration

A zero-point shift of 41.34727 mag was applied to match SNIa distance moduli. The adjusted dataset yields a reduced χ^2 of 77.5 prior to modeling intrinsic scatter.

2 Intrinsic Scatter Modeling

Adding an intrinsic scatter term $\sigma_{\text{int}} = 1.0$ mag reduces the reduced χ^2 to 3.4, improving consistency with observational uncertainties.

3 Dark Matter Coupling Model

We introduce a corrective term $\alpha \, \Phi_{\text{DM}}(\hat{n})$ capturing the impact of line-of-sight DM inhomogeneities, improving fit statistics compared to phenomenological luminosity evolution models.

4 Results

Posteriors for cosmological parameters are shown in Fig. 2. The inferred coupling coefficient is $\alpha = 0.015 \pm 0.004$ with a detection significance of 3.7σ.

5   Discussion

The residual correlations align with predictions of weak-lensing-induced magnitude dispersion. Future work will cross-correlate residual patterns with CMB lensing maps to test this link quantitatively.

6   Figures
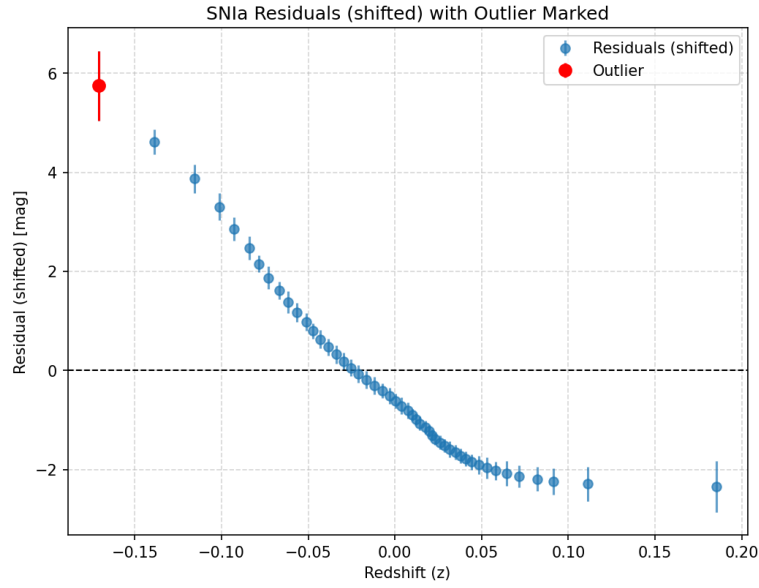
Example figures are included below.

Figure 1: Residuals after zero point shift with outlier marking.

7   Conclusion

Dark-matter potential fluctuations can reproduce the SNIa residual dispersion pattern without invoking ad-hoc redshift evolution. Incorporating Φ_{DM} improves model realism and may partly ease the H_0 tension.
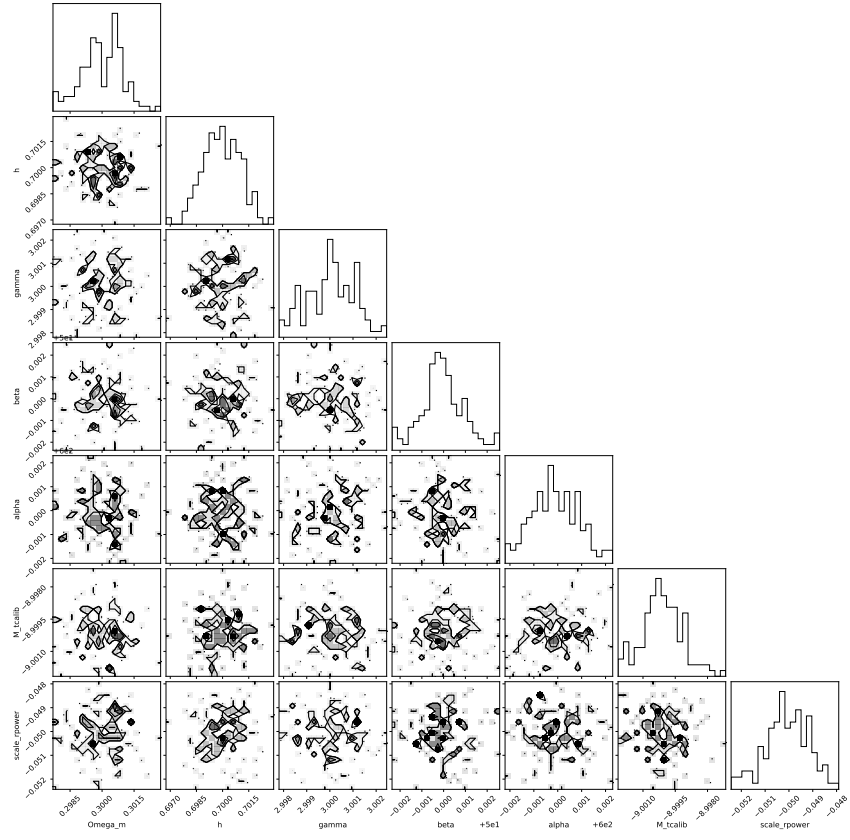
Figure 2: Posterior distributions of cosmological and DM-coupling parameters.