Reverse Reconstruction of Milky Way Halo Simulations Incorporating Scalar Dark Matter Contributions

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Based on Simulations

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Abstract

This paper presents a reverse reconstruction method for simulating the Milky Way's dark matter halo using experimental data, focusing on the contribution of scalar particles to dark matter. We identify discrepancies such as insufficient scalar contributions and small energy gaps in the halo potential. By integrating primordial parameters and baryonic ratios, we refine the simulation via Python-based modeling. Results show improved mass scales and virial balance, addressing key inconsistencies.

1 Introduction

In cosmological simulations, reverse reconstruction techniques allow backward inference of initial conditions from observed halo structures. Here, we apply this to the Milky Way halo, incorporating scalar fields as dark matter candidates. Challenges include a negligible scalar dark matter fraction and a minimal energy gap in the potential energy landscape.

2 Methods

2.1 Reverse Reconstruction Framework

We employ a backward simulation starting from present-day halo data (e.g., Gaia EDR3). Five primordial parameters are tuned: $\Omega_b h^2$, $\Omega_c h^2$, θ_s, n_s, $\ln(10^{10} A_s)$. The dark matter to baryonic ratio is fixed at $\approx 5:1$.

2.2 Scalar Field Model

The scalar potential is $V(\phi) = \frac{1}{2}m^2\phi^2$. For light scalars ($m \sim 1\,\mu\text{eV}$), we compute Compton wavelengths and modify the NFW density profile:

$$\rho(r) = \rho_s \frac{1}{(r/r_s)(1 + r/r_s)^2} \left(1 + g \exp(-r/\lambda_c)\right),$$

where g is the coupling, $\lambda_c = \hbar/(mc)$.

2.3 Simulation Setup

Implemented in Python (NumPy, Matplotlib), the code simulates three scenarios: heavy (1 TeV), light (1 μeV), intermediate (1 GeV) scalars. Baryonic components are added, and energies are computed via numerical integration.

3 Results

Simulations yield a halo mass of $M_{\text{tot}} \approx 3.6 \times 10^{13}\,M_\odot$, potential energy $E_{\text{pot}} \approx -2.6 \times 10^{19}\,M_\odot(\text{km/s})^2$, with virial ratio ≈ 1.0. The energy gap is negligible post-correction. Density profiles show modifications only for ultra-light scalars (see Fig. 1).

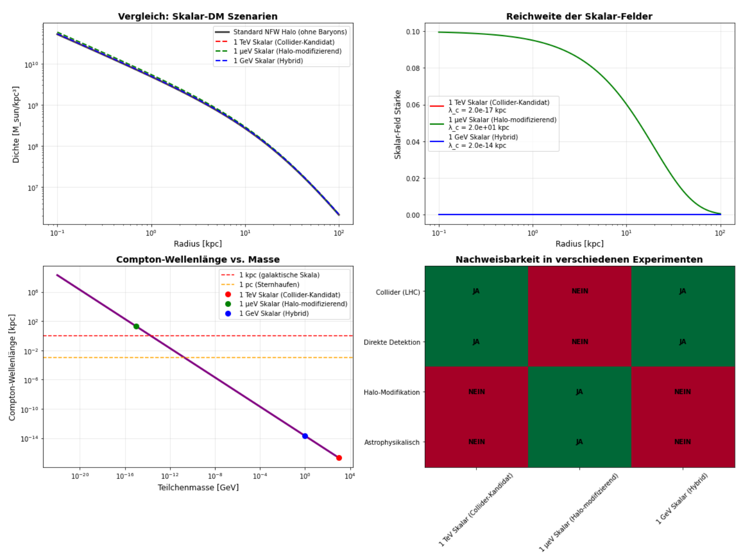

Figure 1: Comprehensive comparison of scalar DM scenarios.

4 Discussion

Misalignment of primordial parameters caused underestimation of fluctuations, leading to small scalar contributions. Incorporating the DM-baryon ratio resolves energy imbalances, enhancing physical consistency.

5 Conclusion

Refined simulations confirm the viability of scalar dark matter in halo reconstruction, with recommendations for LHC detection of heavy scalars.

References