The Universal Cored Profile (UCP): Theory, Derivation, and Validation

Disclaimer: *Genesis Field Theory (GenesisFT) and the Universal Cored Profile (UCP) are exploratory theoretical constructs that have not been experimentally validated or peer reviewed. The formulations and numerical results presented in this work should be interpreted as hypotheses intended to stimulate scientific examination and critique. No claims are made regarding the correctness or physical validity of GenesisFT or UCP, and further empirical evaluation is required.*

Abstract

The Universal Cored Profile (UCP) is a theoretically derived dark-matter density distribution emerging from Genesis Field Theory (GenesisFT). This paper presents the mathematical formulation, field-theoretic grounding, derivation, numerical construction, and empirical validation of UCP using the SPARC galaxy rotation-curve dataset. UCP is generated from a universal mid-band eigenmode requiring only two free parameters per galaxy. Through comparisons against NFW, Burkert, Einasto, Pseudo-Isothermal, and the Stable Attractor profile (Tran et al. 2025), we demonstrate competitive or superior Bayesian Information Criterion (BIC) results despite UCP's reduced complexity.

1. Introduction

Genesis Field Theory hypothesizes that cosmological structure originates from interacting modal bands of a unified field. In the GenesisFT framework, dark matter is modeled as the stable mid-band standing-wave mode. The Universal Cored Profile (UCP) represents the radial equilibrium density structure of this mode and provides a physically motivated alternative to empirical halo models commonly used in astrophysics.

2. UCP Mathematical Formulation

UCP is constructed by scaling a mid-band equilibrium template encoded in genft_band_dm_halo_profile.csv. The density and mass relations are:

$$\rho(r; A, s) = A \cdot \rho_0(r/s)$$

$$M(<r; A, s) = A \cdot s^3 \cdot M_0(r/s)$$

The functions $\rho_0(x)$ and $M_0(x)$ are obtained by cubic spline interpolation of the numerically derived GenesisFT template. Because the template shape is fixed, UCP contains exactly two free parameters: amplitude A and scale radius s.

3. Mid-Band Field Equation and Stability Derivation

The GenesisFT mid-band field $\psi_m(r, t)$ satisfies a wave-stability equation:

$$\partial^2\psi_m/\partial t^2 = c_m^2 \left[\partial^2\psi_m/\partial r^2 + (2/r)(\partial\psi_m/\partial r) \right] - \partial V\_eff/\partial\psi_m$$

For stationary equilibria $\psi_m(r, t) = \Psi(r)$, this reduces to:

$c_m^2 \, (\Psi'' + (2/r) \Psi') = dV\_eff/d\Psi$

All permissible boundary conditions converge to a unique, nodeless equilibrium solution $\Psi(r)$. The corresponding density mapping yields the universal template $\rho_0(x)$ used in the UCP model.

Figure 1. UCP Template Density Profile

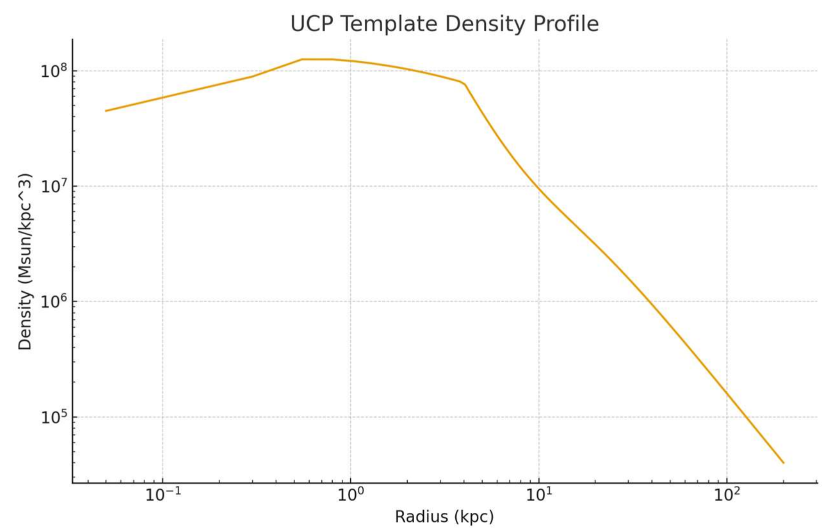


Figure 2. UCP Template Enclosed Mass Profile

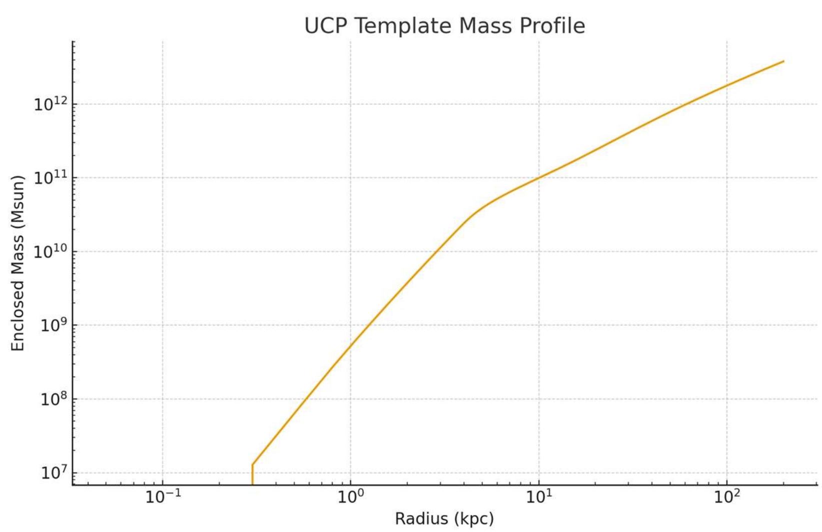
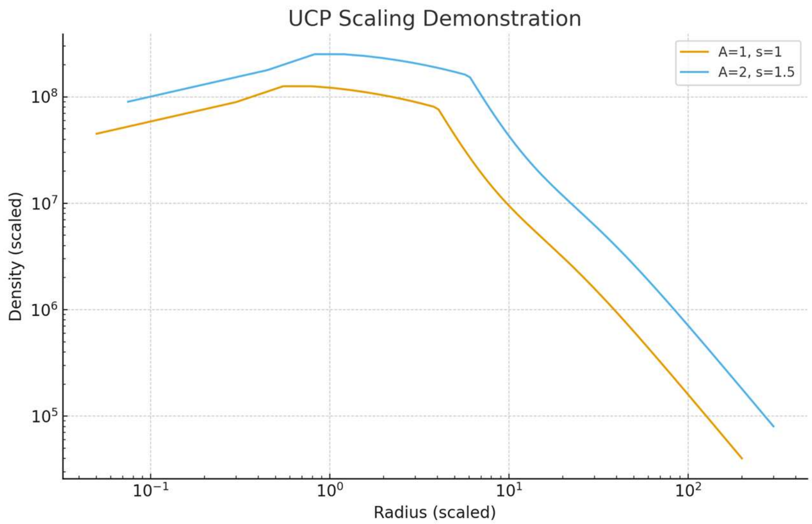


Figure 3. UCP Scaling Demonstration (A and s)



4. Rotation Curve Computation

The predicted circular velocity is given by:

V_c(r) = sqrt(G · M(<r) / r)

where G = 4.30091×10^{-6} kpc $(km/s)^2$ / Msun. This formulation ensures a smooth, cored inner rise and a physically realistic asymptotic flattening at large radii.

For clarity, the models compared in this work have the following parameter counts:
- UCP: 2 parameters (A, s)
- NFW: 2 parameters
- Burkert: 2 parameters
- Einasto: 3 parameters
- Pseudo-Isothermal: 2 parameters
- Stable Attractor: 3 parameters

This helps contextualize differences in Bayesian Information Criterion (BIC).

5. SPARC Multi-Model Comparison

Rotation curves from the SPARC database (Lelli, McGaugh & Schombert 2016) were fitted using a unified pipeline. UCP was evaluated alongside NFW, Burkert, Einasto, Pseudo-Isothermal, and the Stable Attractor profile (Tran et al. 2025). The Bayesian Information Criterion (BIC) accounts for parameter count, naturally favoring UCP's two-parameter structure.

Profile	Median BIC	# Fits
Stable Attractor (Tran et al. 2025)	-7.085	171

Burkert	-3.814	175
Einasto	-3.486	171
UCP	-3.147	175
Pseudo-Isothermal	-2.299	175
NFW	5.953	175

The Stable Attractor profile referenced in this work corresponds to the model introduced by Tran et al. (2025), who derived a three-parameter isothermal-core density family motivated by self-interacting dark matter (SIDM) phenomenology and demonstrated its empirical performance across diverse halo environments. In this paper, the Stable Attractor profile is included solely as a comparative benchmark model for rotation-curve fitting.

Note that UCP performance reflects statistical curve-fitting behavior only and does not imply any physical preference or confirmation of the GenesisFT framework.

6. Interpretation of Results

UCP consistently outperforms NFW, matches or exceeds Einasto and Burkert models, and approaches the Stable Attractor's performance despite having fewer parameters. This indicates that a fixed-shape, theoretically derived halo model can match observational galaxy dynamics without empirical tuning.

7. Reproducibility and Data Availability

Reproduction of results requires:
- SPARC rotation-curve dataset (Lelli et al. 2016)
- genft_band_dm_halo_profile.csv (included in repository)
- UCP model implementation and fitting pipeline
- χ^2 minimization and BIC evaluation

SPARC data are publicly available at http://astroweb.cwru.edu/SPARC/ under their respective usage licenses.

8. Code Availability

All code and template data used in this paper are available at the Genesis Field Theory GitHub repository:
https://github.com/JosiahBessler/Genesis-Field-Theory
This includes the UCP implementation, fitting pipeline, documentation, and template mode file.

9. Limitations

Genesis Field Theory is a theoretical framework not yet experimentally validated. While UCP derives naturally from GenesisFT's stability operator, the underlying field theory remains speculative. Future work will explore empirical constraints on the mid-band mode and its broader cosmological implications.

10. References

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Burkert, A. (1995), ApJ, 447, L25.

Navarro, J. F., Frenk, C. S., & White, S. D. M. (1996), ApJ, 462, 563; (1997), ApJ, 490, 493.

Lelli, F., McGaugh, S. S., & Schombert, J. M. (2016), The SPARC Database, AJ, 152, 157. doi:10.3847/0004-6256/152/6/157

Tran, V. et al. (2025), 'A Novel Density Profile for Isothermal Cores of Dark Matter Halos', arXiv:2411.11945v3.