

Inner Halo Shapes of Dwarf Galaxies: Resolving the Cusp/Core Problem

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Abstract. We derive inner dark matter halo density profile slopes for a sample of 200 dwarf galaxies by inverting rotation curves obtained from high-quality, long-slit optical spectra. Using simulations to assess the impact of long-slit observing and data processing errors on our measurements, we conclude that our observations are consistent with the cuspy halos predicted by the CDM paradigm.

1. Introduction

While the hierarchical CDM paradigm is very successful at reproducing observations on scales greater than a few Mpc, the agreement between CDM predictions and galaxy halo properties is not as certain. In particular, measured inner halo density profile slopes of dwarf galaxies inferred from long-slit optical spectra tend to be shallower than the cusps obtained from CDM simulations of halo assembly (*e.g.* de Blok, Bosma, & McGaugh 2003, hereafter dBBM; Swaters et al. 2003, hereafter SMBB). The implications of this cusp/core problem in light of observational uncertainties remains unclear: while some authors advocate a genuine conflict between theory and observations (dBBM), others claim consistency between the data and cuspy CDM halos (SMBB). In this paper, we obtain inner density profile slopes for a large sample of dwarf galaxies and investigate the impact of observational and data processing errors on our result with detailed simulations.

2. Sample Selection and Data Analysis

We select 200 low-mass galaxies from the SFI++ catalog, a 4800-object Tully-Fisher database maintained at Cornell University (Catinella et al. 2003). Galaxies in the sample have $V_{rot} < 130 \text{ km s}^{-1}$, archived rotation curves (RCs) from high-quality H α spectroscopy and no evidence for a bulge, bar, or other baryonic distortions as determined by our accurate I-band photometry.

For each rotation curve, the density $\rho(r_i)$ is derived at each RC point r_i assuming a minimal disk and spherical symmetry: $\rho(r_i) \propto 2(V_i/r_i)(dV/dr)_i + V_i^2/r_i^2$. The rotation velocity V_i and RC derivative $(dV/dr)_i$ are obtained from a best-fit smooth curve to the RC points. For $\rho(r) \propto r^{-\alpha}$ at small r , we measure the inner slope α_m from a linear fit to the inner 2–3 points of $\log(\rho(r))$. Fig. 1 shows our results (solid lines): α_m is generally smaller than the intrinsic slope $\alpha_{int} \sim 1$ predicted by CDM simulations.

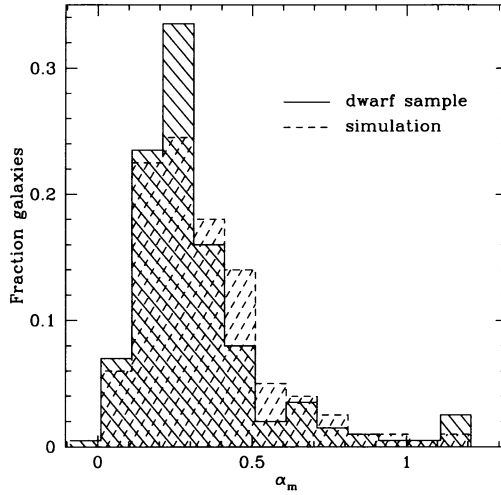


Figure 1. Inner slopes α_m for the dwarf sample (solid lines) and simulated galaxies (dashed lines). See text for details.

3. Dwarf Population Simulations

To investigate the consistency of our findings with CDM predictions, we simulate long-slit observations of 200 dwarf galaxies with intrinsic cusps. We embed infinitely thin, uniform $H\alpha$ disks inside NFW halos ($\alpha_{int} = 1$; *e.g.* Navarro, Frenk & White 1996). The primary observational parameters for each system are random deviates of corresponding distributions derived for the sample. The simulated galaxies are then “observed” (with some error, chosen to match RC folding outputs from the sample) in typical conditions. The resulting RCs are calibrated and α_m is measured using the algorithm described in §2.

Fig. 1 shows the distribution of α_m obtained for the simulated dwarf population (dashed lines) superimposed on the sample distribution (solid lines); on average, the α_m inferred for the simulated halos are shallower than the intrinsic slope $\alpha_{int} = 1$, and resemble those obtained for the galaxy sample. Quantitatively, a Kolmogorov-Smirnov test returns a “P-value” of 0.1, indicating no statistically significant difference between the two distributions. We conclude that these long-slit spectroscopic observations are consistent with cuspy halos predicted by the CDM paradigm without recourse to halo triaxiality, modifications of Newtonian dynamics or other exotic phenomena.

References

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