Beware of darkness: A cuspy dark matter halo from stellar kinematics where gas shows a core
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Abstract
N-body simulations of galaxy formation with aCDM inputs have long predicted Navarro-Frenk-White (NFW) dark matter (DM) halo profiles (Navarro et al. 1996a), or similar parameterizations, over many decades of scale with a cusp near the centers. Low surface brightness (LSB) and late-type dwarfs galaxies have been choice targets in which to measure such profiles as they appear to be more dark matter dominated than giant ellipticals and spirals (de Blok & McGaugh 1997). Most measurements and mass models of late type dwarfs suggest cored DM halos (e.g. Flores & Primack 1994, Moore 1994, Moore 1994, Moore 1995, Van den Bosch et al. 2008; Simon et al. 2005). Simulations can produce cored DM halos by adding a number of effects from baryons most often relying on feedback prescriptions (Navarro et al. 1996b, Weinberg & Katz 2002, Governato et al. 2010). We here present measurements and anisotropic Jeans models for late-type dwarfs obtained from stellar kinematics. Until recently, DM mass profiles in such systems have been obtained exclusively from atomic or ionized gas. The nearby member of the M81 group, NGC 2976 (SAc), has been measured in ionized gas to have a DM core with a strong constraint on the DM power law index of α<0.17 (Simon et al. 2003), where α=1 corresponds to the center of an NFW profile. In our first work on NGC 2976, we confirm that the simplest models from gas kinematics reveal a cored DM halo but find that the stellar kinematic are most consistent with an NFW profile. We advocate the stellar kinematics as more robust due to the tracer's collisionless nature while the gas is subject to more uncertainties from radial motion, warped disks, and pressure support. We are making an ongoing study by which the type, strength, and conditions of feedback can be constrained from new measurements and comparison to simulations.

18 hours of VIRUS-P data

Anisotropic Jeans models

Results and future work
- Mass models from new stellar kinematics are made for NGC 2976, a system thought to have a DM core by ionized gas measurements
- NGC 2976 is measured to either have a DM cusp or be baryon-dominated to large radius from the stellar kinematics alone
- The loose SED-based τ∗ constraint combined with the kinematics makes NGC 2976 most consistent with a NFW profile
- We also measure the ionized gas kinematics (unshown here) and discuss how different modeling assumptions can yield either a DM core or cusp
- 10 more late-type dwarf galaxies are being measured with a new R=8600 wide field-of-view integral-field unit spectrograph named VIRUS-W with results coming soon

Update: Confirmation with R=8600 data

Figure 1: Left The SINGS R-band image of NGC 2976 overlayed with the VIRUS-P (Hill et al. 2008) fiber positions. The numbered squares show the spatial bins used in the extraction of the stellar kinematics. The arrow indicates the major axis with scale of 120” (2 kpc at our assumed distance). Right Spectra and line-of-sight-velocity distribution (LOSVD) fits to two select bins (bins 56 and 38). The data have R=2400 and a mean S/N per pixel of 30.

Figure 2: Without some loose constraint on the stellar mass-to-light ratio (τ∗), the Jeans models for cores and cusps can be very degenerate. We have fit the spectrophotometric data with a large range of two-population stellar population synthesis (SPS) models. The dominant uncertainty is from the Initial Mass Function (IMF), but for our τ∗ uncertainty considering Salpeter and Chabrier IMFs. Left We show the best-fit model and confidence interval with various two-component SPS models. The best-fit model shown prescribes τ∗=0.64 and τ∗=0.18 with luminosity weighted fractions of 0.67±0.33 for a Z=0.22, E(B-V)=0.40, instantaneous burst, 100 Myr age model, and a Z=0.22, E(B-V)=0, instantaneous burst, 2.5 Gyr age model, respectively. Right Fits to the SINGS spectra with the SPS models appropriately broadened. The displayed best-fit model prescribes τ∗=0.90 with a similar set of populations. The 68% confidence interval for both IMFs is τ∗=1.1±0.8. Recent studies (Bershady et al. 2010, 2011) are finding disk galaxies to be submaximal at this level.

Figure 3: Projected velocity maps. Top Column 1 Rotation velocity. Bottom Column 1 Dispersion. Columns 2-4 Second-moment velocities. The models are made with five parameter fits through the Jeans Anisotropic-Multi-Gaussian Expansion (JAME) software (Cappellari 2008). The parameters are τ∗, inclination (i), anisotropy parameter (β), dark matter density at 1 pc (ρ), and dark matter power law index (α). Top Column 2 Data. Bottom Column 2 Data uncertainty. Columns 3-4 Models and residuals. Column 3 The least-squares minimum model with the figure 2 prior on τ∗ at (1.158, 65.0°, 0.450, 45.7 Mpc−1, 0.90) with χ2=77.1. Column 4 A model with τ∗=1.1 and α=0.1 with χ2=93.9. This represents the class of DM dominated and DM cored models that can be excluded solely by our kinematic data. The combination of τ∗ prior and kinematics suggests the DM is cuspy.