Abstract

We construct mass models of 28 S0–Sb galaxies. The models have an axisymmetric stellar component and an NFW dark halo and are constrained by observed $K_s$-band photometry and stellar kinematics. The median dark halo virial mass is $10^{12.8} M_\odot$ and the median dark/total mass fraction is 15% within one effective radius and 50% within $R_e$.

We compare the Tully-Fisher relations of the spirals and S0s in the sample and find that S0s are 0.5 mag fainter at $K_s$-band than spirals for a given rotational velocity. We use this result to rule out scenarios in which spirals are transformed into S0s by processes which truncate star formation without affecting galaxy dynamics or structure, and raise the possibility of a break in homology between spirals and S0s.

1 Mass models

In Williams et al. (2009), we present mass models of 28 edge-on early-type disk galaxies (S0–Sb). These were found by solving the Jeans equations for an axisymmetric stellar component of constant mass-to-light ratio, $(M/L)_K$, and an NFW halo (Navarro et al. 1997) assuming constant anisotropy in the meridional plane, $\beta_2$ (Cappellari 2008). This gives a prediction of the second velocity moment, which we compare to the observed stellar kinematics (Chung & Bureau 2009) to constrain the three parameters of the model, $(M/L)_K$, halo mass $M_{\text{halo}}$ and $\beta_2$. An example model for one of the 28 galaxies is shown in Figure 1. These simple models are able to reproduce the wide range of observed stellar kinematics, which extend to 2-3 effective radii. In Figure 2, we show contours of $\chi^2$ for the sample. This demonstrates the constraints we are able to place on $(M/L)_K$ and $M_{\text{halo}}$ for each galaxy.

2 Model halo properties

The median $(M/L)_K$ for the sample is 1.09 (solar units) with an rms scatter of 0.33. The median $M_{\text{halo}}$ for the sample is $10^{12.8} M_\odot$ with an rms scatter of 0.7 dex. This is equivalent to halo concentrations between 7 and 9. The mass models have a median dark/local mass fraction of 15% within one effective radius and 50% within $R_e$. But all two are maximal.

Models without a dark halo are also able to reproduce the observed kinematics satisfactorily in most cases. The improvement when a halo is added is statistically significant, however, and the stellar mass-to-light ratios of mass models with dark haloes match the independent expectations of stellar population models better.

3 The Tully-Fisher relation and the origin of S0s

Using the circular velocity of the models, we constructed Tully-Fisher Relations (TFRs) as functions of luminosity, stellar mass, and dynamical mass for the S0s and spirals separately (see Figure 2, Williams et al. in preparation. Preprints available).

We find that S0s are 0.5 mag fainter at $K_s$-band than spirals for a given rotational velocity. For truncated star formation stellar population synthesis models, this fading would take ~ 1 Gyr, but we know that the processes which form S0s began at earlier times (Dressler et al. 1997, Fasano et al. 2000). We therefore rule out scenarios in which spirals are transformed into S0s by an environmental or secular process which simply truncates star formation, without affecting the dynamics or structure of the galaxies.

The offset of the S0 TFR could be explained by recent star formation in S0s, but we find that the offset of the S0 TFR persists as a function of stellar and dynamical mass. This is consistent with a small (10–20%) but systematic contraction of spirals as they transform to S0s, consistent with the morphological dependence of the local size—luminosity relation (Courteau et al. 2007).

References