AXISYMMETRIC MASS MODELS OF S0 AND SPIRAL GALAXIES WITH BOXY BULGES: MASS-TO-LIGHT RATIOS, DARK MATTER AND BARS

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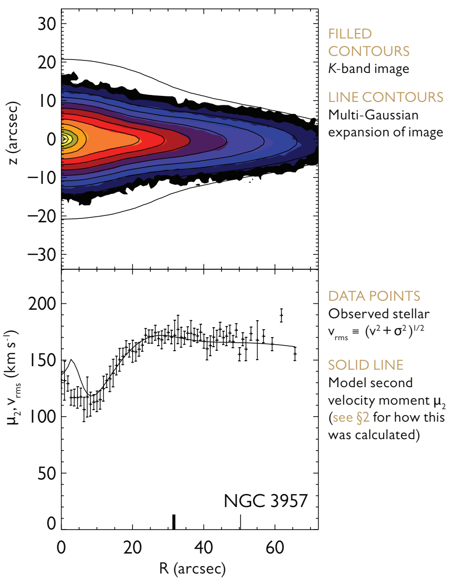

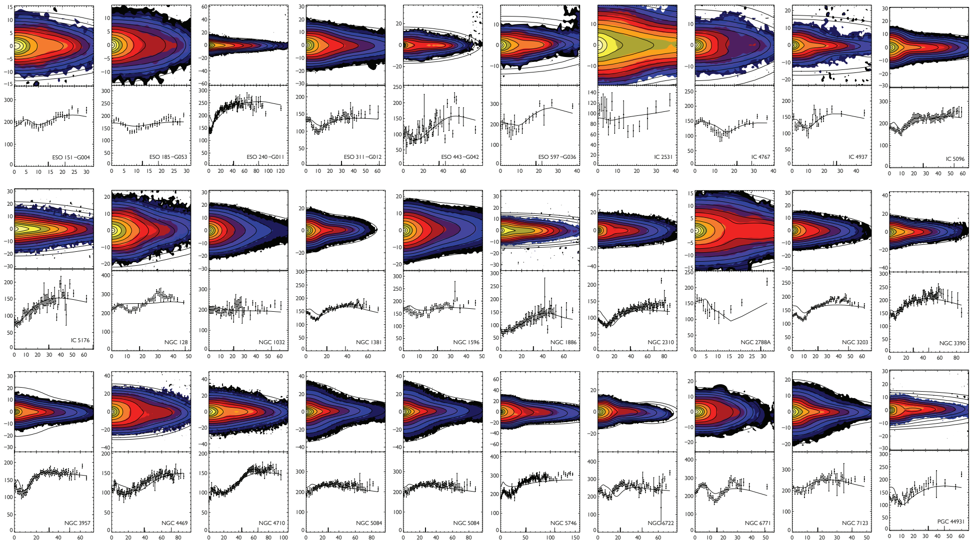

FIGURE 1

Stellar dynamical models of a sample of 30 spiral and S0 galaxies. Mass models are first generated with multi-Gaussian expansions of *K*-band images. The stellar kinematics are then computed by solving the Jeans equations while assuming a constant mass-to-light ratio and anisotropy, and neglecting non-axisymmetries (see §2). The models contain only one free parameter: the mass-to-light ratio. The striking accuracy of the fits suggests that dark matter is not a significant component by mass within 0.5–1 R_{25} or 2–4 R_e (see §4). The thick notches on the *R*-axes are at 1 R_e and the thin notches are at 0.5 R_{25}.

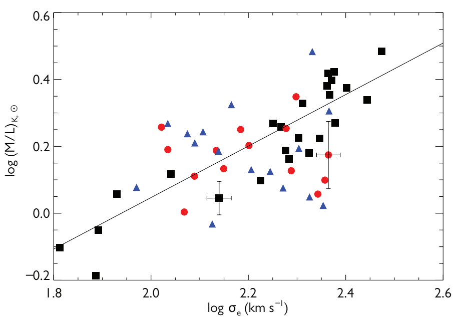

FIGURE 2

Mass-to-light ratio as a function of the effective stellar velocity dispersion for the S0s (red circles) and spirals (blue triangles) in our sample, and the SAURON sample of ellipticals and S0s (black squares; Cappellari et al. 2006). Error bars are representative for the two samples.

1 MOTIVATION

Previous studies indicate with some certainty that there is no significant dark matter within the optical radius, R_{25}, of disk galaxies (e.g. Palunas & Williams 2000; Bell & de Jong 2001; Kassin et al. 2006). Similar studies of ellipticals find little evidence for significant dark matter within the effective radius, R_e (e.g. Gerhard et al. 2001; Romanowsky et al. 2003; Cappellari et al. 2006; Thomas et al. 2007). However, degeneracies in the modelling mean that the dark matter content of ellipticals is more uncertain. Moreover, $R_e \ll R_{25}$.

Non-axisymmetric galaxies make it possible to lift degeneracies in the contributions from luminous and dark matter by ascribing non-circular motions to luminous matter only (e.g. Englmaier & Gerhard 1999; Weiner et al. 2001). Fast observed pattern speeds also constrain dark matter in barred disks (e.g. Debattista & Sellwood 2000; Aguerri et al. 2003; Gerssen et al. 2003).

In this study we used the sample of thirty S0 and spiral galaxies with a boxy or peanut-shaped bulge of Bureau & Freeman (1999) to constrain the dark matter content of these galaxies. From previous numerical and observational work, such galaxies are thought to be barred disk galaxies viewed edge-on (e.g. Kuijken & Merrifield 1995; Bureau and Freeman 1999; Chung & Bureau 2004; Méndez-Abreu et al. 2008).

2 METHOD & ASSUMPTIONS

We modelled the stellar kinematics of the sample galaxies by making two key assumptions, one which we would like to test (that dark matter is an insignificant dynamical component) and one which we know is false (that these galaxies are axisymmetric). In this way, we were able to establish the dark matter content while simultaneously seeking independent confirmation that boxy bulges are bars viewed side-on.

We first parametrized the apparent light distributions of the galaxies using *K*-band images and the multi-Gaussian expansion method (Emsellem et al. 1994). We deprojected these light distributions by assuming that the galaxies are axisymmetric. We then converted the intrinsic light distributions to intrinsic mass distributions by assuming constant mass-to-light ratios. This is equivalent to assuming either that there is no significant dark matter, or that the dark matter distribution follows the visible matter in shape and scale (which would be inconsistent with CDM).

We then computed predictions of the stellar second velocity moments integrated along the line-of-sight by solving the Jeans equations under the assumption of constant anisotropy in the meridional plane (see Cappellari 2008 for details).

3 RESULTS

Results for the entire sample are shown in Figure 1. As can be seen for almost all galaxies, the model second moments are strikingly accurate representations of the kinematic data. There is a slight but systematic deviation of the models within the central 10 arcsec or so, a region which roughly corresponds to the boxy bulges (and thus the non-axisymmetric barred regions).

4 CONCLUSIONS

We find no evidence for dark matter within 0.5–1 R_{25} or 2–4 R_e in a sample of thirty S0 and spiral galaxies. Indeed, because our models are so accurate and depend on only a single free parameter (the mass-to-light ratio), we argue that this absence of evidence is also evidence of the absence of dark matter.

This is consistent with previous studies of spiral galaxies. However, because the sample contains many S0s, which have been demonstrated to be observationally equivalent to fast-rotating ellipticals (e.g. Emsellem et al. 2007; Cappellari et al. 2007), our results also radially extend and place on firmer ground the equivalent statement about the absence of dark matter in ellipticals.

As shown in Figure 2, the *K*-band mass-to-light ratios that we measure are consistent with those of the SAURON sample (Cappellari et al. 2006) (and the single stellar population models of Maraston 2005). Furthermore, the spirals and S0s seem to share the same range in mass and mass-to-light ratio. This is consistent with the claim that S0s are merely strangulated or gas-stripped spirals which contain few young stars.

We are limited by the small size of our non-boxy control sample, but the slight but systematic deviation of the models within the bulge is consistent with the claim that boxy bulges are bars viewed edge-on.

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