KINEMATIC CONSTRAINTS ON THE STELLAR AND DARK MATTER CONTENT OF SPIRAL AND S0 GALAXIES

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SUMMARY

By comparing the predicted kinematics of mass models of 28 disk galaxies to their observed stellar kinematics, we constrain their K_S-band stellar mass-to-light ratios and dark matter fractions. The median $(M/L)_{Ks}$ for the sample is 1.17 with an rms scatter of 0.36. The median dark matter fraction is 16% within one effective radius and 50% within R_{25}. The S0s in our sample are systematically fainter for a given circular velocity, a finding that is consistent with models of galaxy evolution in which S0s are the faded descendents of spirals.

1 INTRODUCTION

This work has two principal goals: to constrain the near-infrared mass-to-light ratios and stellar masses of a sample of local disk galaxies, and to constrain the fraction of the total mass of those galaxies that is dark matter.

We present mass models of 14 spiral and 14 lenticular (S0) galaxies. By comparing the predicted kinematics of the models to observed stellar kinematics, we constrain their stellar and dark matter content.

Each mass model is comprised of an axisymmetric stellar component based on observed K_S-band photometry (Bureau et al. 2006) and an NFW halo (Navarro et al. 1997). The stellar component is assigned a constant mass-to-light ratio, $(M/L)_{Ks}$. The halo is assumed to follow a correlation between halo mass M_{DM} and concentration c_{vir} (Macció et al. 2008).

The Jeans equations for the corresponding potential are solved under the assumption of constant anisotropy in the meridional plane, β_z (Cappellari 2008).

This yields a prediction of the second velocity moment, which we compare to observed stellar kinematics (Chung & Bureau et al. 2004) to constrain the three parameters of the model, $(M/L)_{Ks}$, M_{DM} and β_z. An example model for one of the 28 galaxies is shown in Fig. 1.

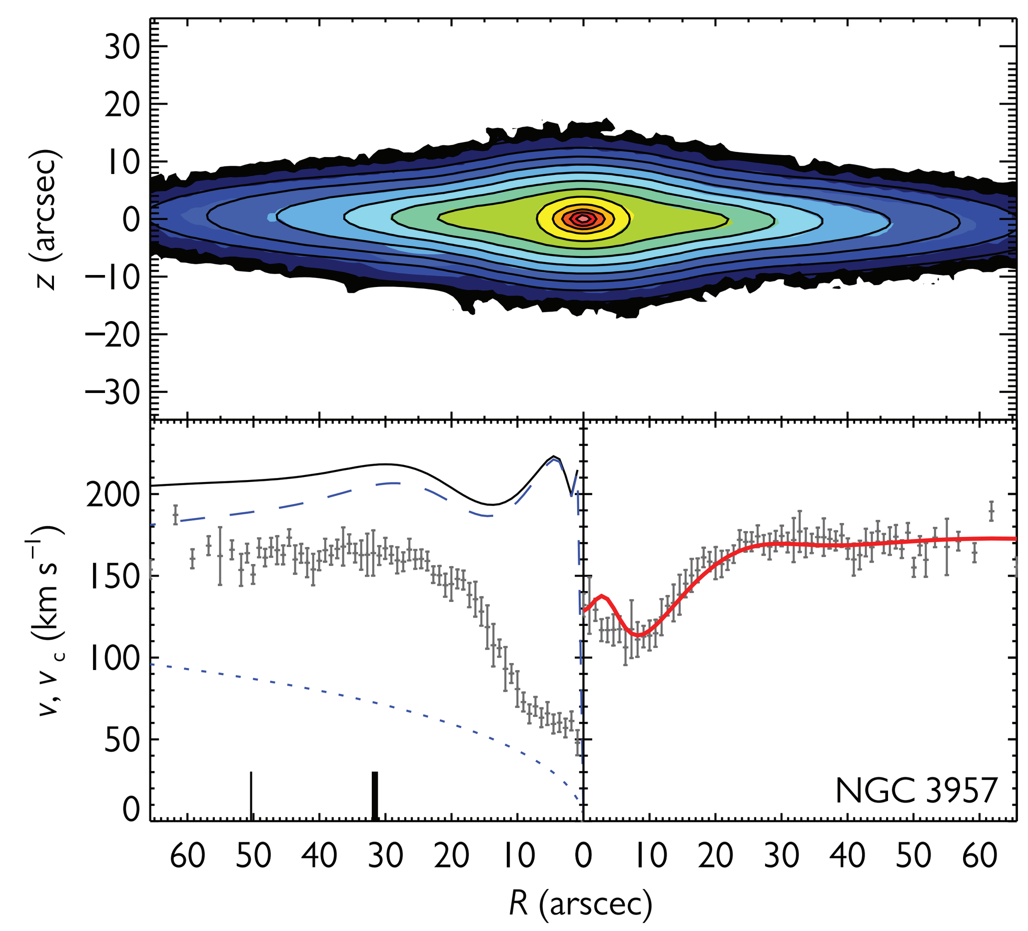

FIGURE 1

Example data and model (NGC 3957). The top panel shows the observed K_S-band image (filled contours) and the model of the stellar component (lines). The bottom left panel shows the observed line-of sight velocity (points) and the circular velocities of the total mass model (solid line) and its stellar and dark components (dashed and dotted lines). The bottom right panel shows the second velocity moment of the model (red line). The model is adjusted to reproduce the observed second velocity moment (points).

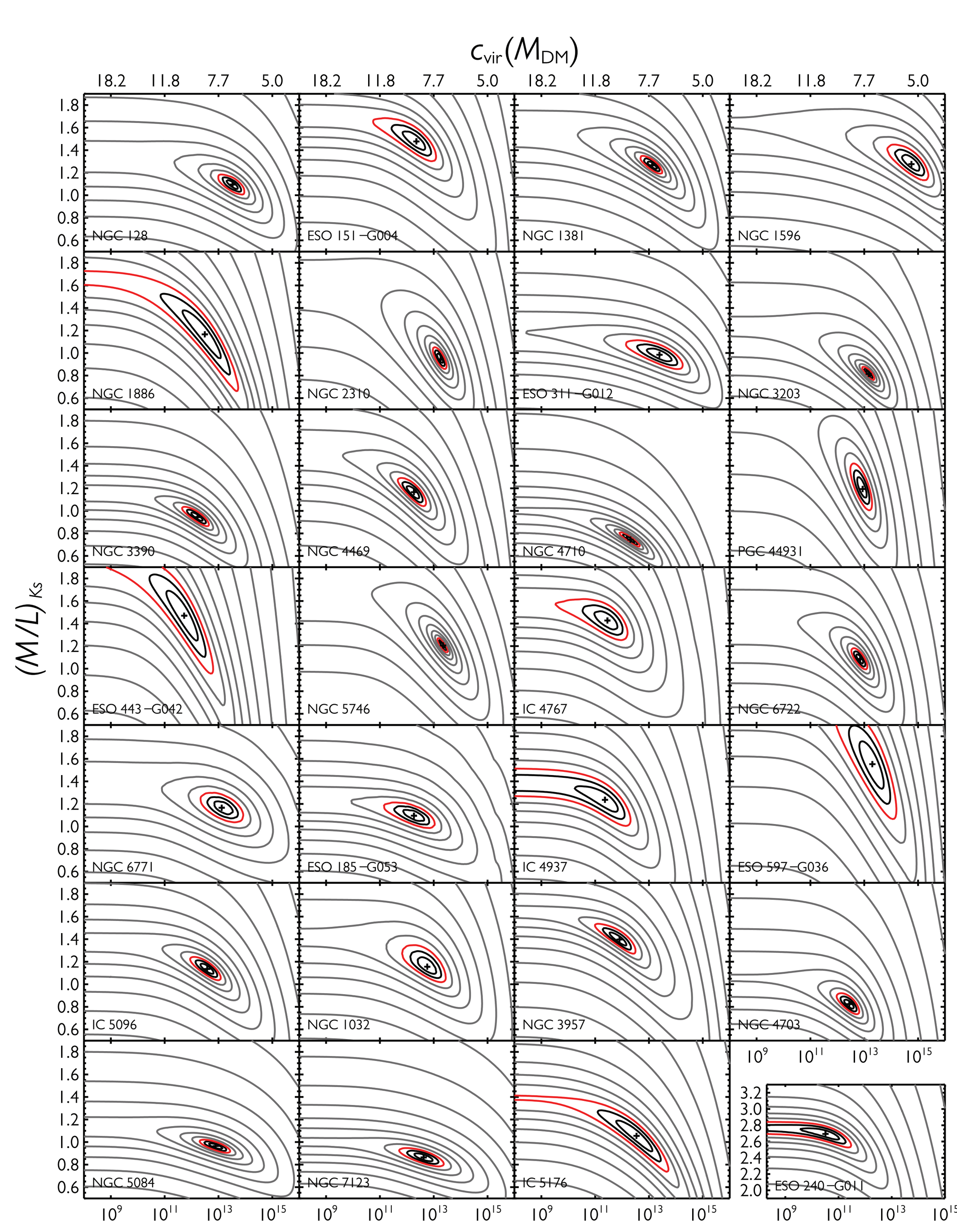

FIGURE 2

Contours of χ^2 for the complete sample. χ^2 is defined in terms of the difference between the observed and model second velocity moment. The red contours are the 3σ confidence levels.

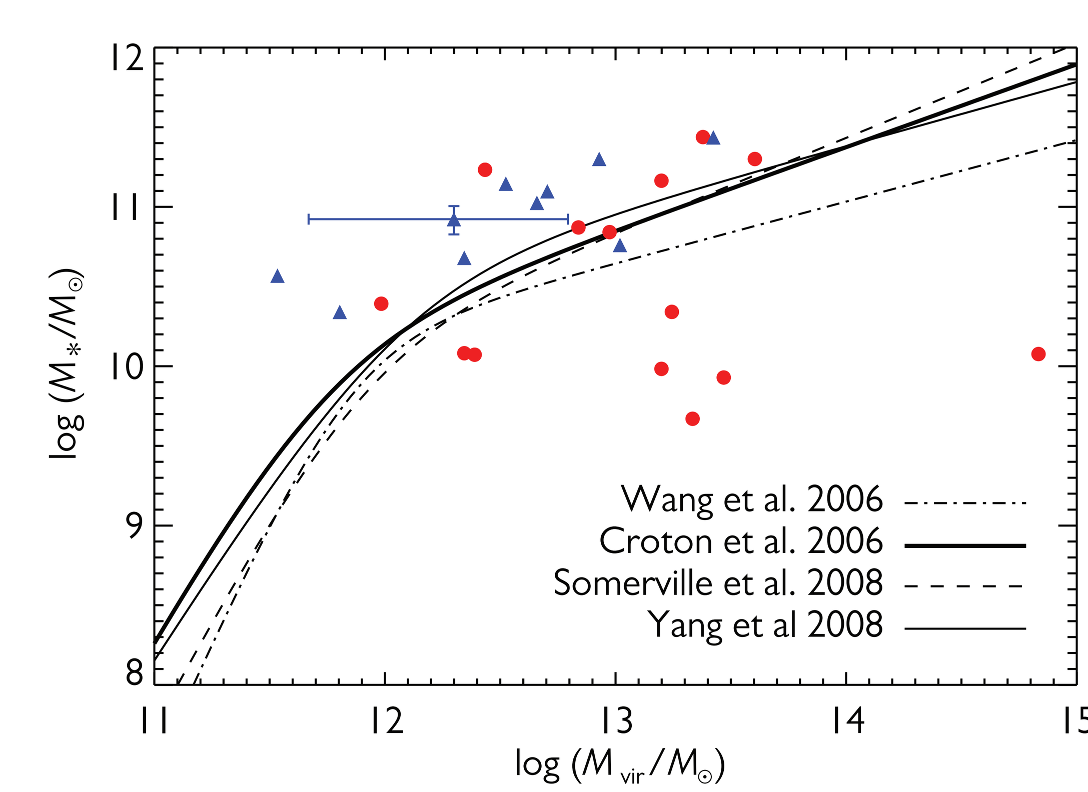

FIGURE 3

Stellar and virial masses of the mass models. Spiral galaxies are blue triangles and S0s are red circles. The predictions of a number of semi-analytic models are shown for comparison.

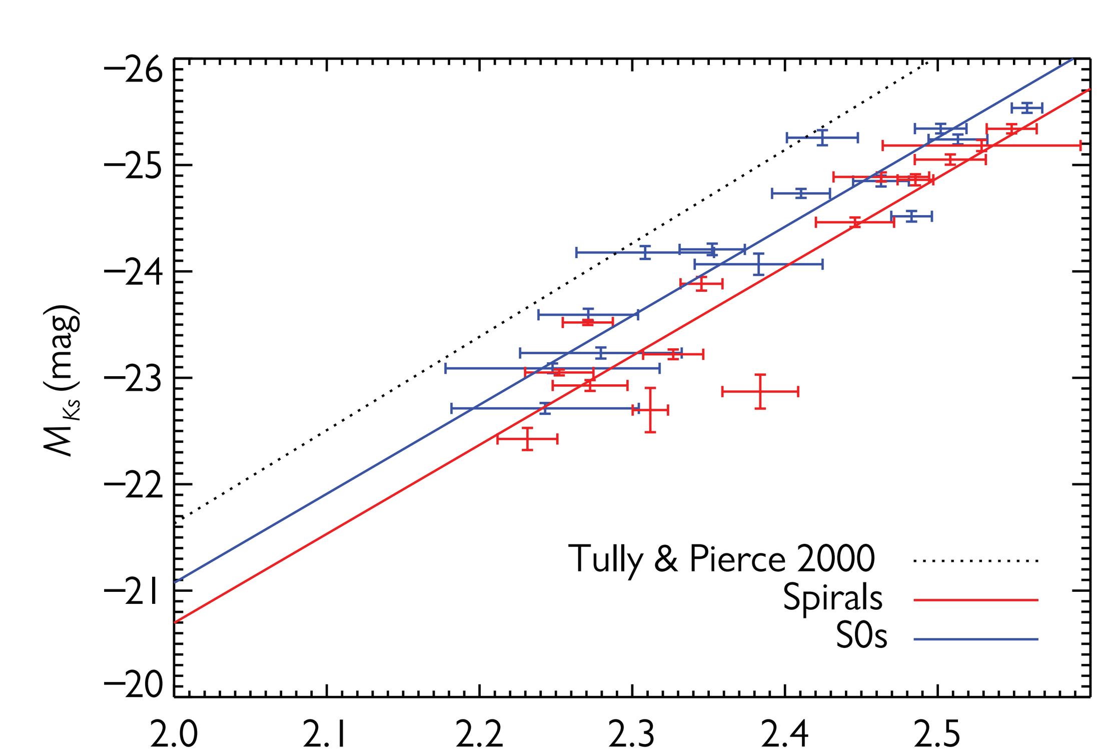

FIGURE 4

The Tully-Fisher relations of the early-type spirals and S0s in our sample. S0s (red points) are systematically fainter than spirals (blue points) at a given circular velocity. The late-type spiral TFR of Tully & Pierce (2000) is shown for comparison

2 RESULTS

In all cases, these simple models are able to reproduce the wide range of observed stellar kinematics, which extend to 2-3 effective radii or, equivalently, 0.5-1 R_{25}.

In Fig. 2 we show contours of χ^2 for the sample. This demonstrates the constraints we are able to place on $(M/L)_{Ks}$ and M_{DM} for each galaxy (χ^2 is not a strong function of β_z in these rotationally supported galaxies).

The median $(M/L)_{Ks}$ for the sample is 1.17 with an rms scatter of 0.36. Our preliminary comparisons show this is consistent with the predictions of two stellar population models (Bell & de Jong 2001, Maraston 2005).

The median M_{DM} for the sample is $10^{12.85}$ $M_\odot$ with an rms scatter of 0.7 dex. This is equivalent to halo concentrations between 7 and 9. The mass models contain a median dark matter fraction of 16% within one effective radius and 50% within R_{25}.

Models without a dark halo are 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.

4 DISCUSSION

NEAR-INFRARED M/L RATIOS

Near-infrared mass-to-light ratios are particularly useful because it is at these wavelengths that the effects of dust are minimized and light most closely corresponds to stellar mass. Unfortunately, the calibration of stellar population synthesis models in the near-infrared is particularly uncertain because of the difficulty of modelling the thermally pulsing asymptotic giant branch (in addition to the usual uncertainties about the IMF). Dynamical estimates of the stellar mass-to-light ratio that correctly account for dark matter are therefore of great interest This work is the largest sample of dynamically determined stellar population mass-to-light ratios at K_S-band and avoids the assumption of a maximal disk. In a future work we will compare in detail these dynamical estimates to the predictions of population models.

DARK HALOES

Our mass models are constrained by kinematics only within the optical parts of the galaxy. The parameter M_{DM} of our mass models is therefore entirely model dependent. Despite this, a preliminary comparison demonstrates that it appears to correspond well with the predictions of semi-analytic models constrained by the local stellar mass function (see Fig. 3)

TULLY-FISHER RELATIONS OF EARLY-TYPE DISKS

The Tully-Fisher relation (TFR, Tully & Fisher 1977) relates the global HI line width to the luminosity of spiral galaxies. Previous authors have demonstrated that S0s lie at fainter magnitudes for a given line width (see, e.g., Bedregal et al. 2006 and references therein). They did this by using the stellar kinematics of S0s to estimate their maximum circular velocity, which is statistically related to the global line width used in the normal TFR.

Our mass models allow us to determine the circular velocity profile directly for both the spirals and S0s in our sample, eliminating the possibility of systematic differences between kinematic tracers of rotation. We confirm the finding that S0s lie at fainter magnitudes for a given circular velocity (0.4 mag at K_S-band, see Fig. 4). This is consistent with models of galaxy evolution in which S0s are the faded descendents of spirals.

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