DISK MASS FROM LARGE-SCALE DYNAMICS

J. A. SELLWOOD
Rutgers University
Dept. of Physics & Astronomy, PO Box 849, Piscataway, NJ 08855, USA

1. Introduction

The radial distribution of mass in a disk galaxy is strongly constrained by its rotation curve. The separate contributions from the individual stellar populations and dark matter (DM) are not easily disentangled, however, especially since there is generally no feature to indicate where the component dominating the central attraction switches from luminous to dark matter. Here I summarize three recent thesis projects at Rutgers University which all suggest that DM has a low density in the inner parts of bright galaxies, and that most of the mass therefore resides in the disk. In addition, I present some preliminary work on the Milky Way. If we are able to determine the M/L of a typical disk stellar population, it should provide a useful constraint on the numbers of low mass stars.

2. Masses of galactic disks

Palunas & Williams (1997) have I-band surface photometry and 2-D kinematic maps of 76 southern disk galaxies. They calculate the gravitational field in each case, assuming a constant M/L for the disk and bulge, and find that the shape of the inner rotation curve is very well reproduced by the light distribution for $M/L_I \sim 2 - 3$ in most cases (for $H_0 = 75$ km s^{-1} Mpc^{-1}). Mass discrepancies indicative of the dark halo contribution become noticeable only in the outer parts of some galaxies.

Weiner (1997) models the 2-D flow pattern of gas in the barred galaxy NGC 4123 by calculating gas flows in a model potential derived from the I-band photometry. He finds that a $M/L_I \sim 2.5$ is again required for the predicted flow pattern to match that observed. As a result, almost all the mass in the inner galaxy must be distributed as the luminous component, else the rotation curve in the outer disk would be too high.

Debattista & Sellwood (1997) use fully self-consistent simulations of barred disks embedded in halos to verify Weinberg's (1985) prediction that the rotation rate of the bar should quickly decrease through dynamical friction. In even a moderate density halo, the bar slows dramatically as it loses angular momentum and the ratio of corotation radius to bar semi-major axis quickly becomes inconsistent with observed properties of barred galaxies. Only if the central halo density is low, and the disk is massive, can rapid braking be avoided.

3. The Milky Way

Both Spergel et al. (1996) and Freudenreich (1997) have proposed models for the 3-D luminosity density in the Milky Way that are based on the all-sky multi-color photometry obtained by the DIRBE instrument on the COBE satellite. Both groups take extinction by dust into account, but in different ways, and then fit parameters of an idealised model to the projected sky brightness. While the volume luminosity density distributions are different in the two models, the integrated luminosities for the Milky Way in the different IR color bands (see Mulhotra et al. 1996) are very similar. Freudenreich gives a useful conversion to bolometric luminosity for the whole galaxy: $L_{bol} = 2.3 \times 10^{10}$ $L_\odot$ ($\pm 20\%$).

We can use these models to derive a mass density for the light distributions, provided a constant M/L assumption is valid. I make this assumption in the present work, but it should be borne in mind that localized excesses of supergiant stars may cause features in the IR light distribution that

J. Andersen (ed.), Highlights of Astronomy, Volume 11A, 410–411.

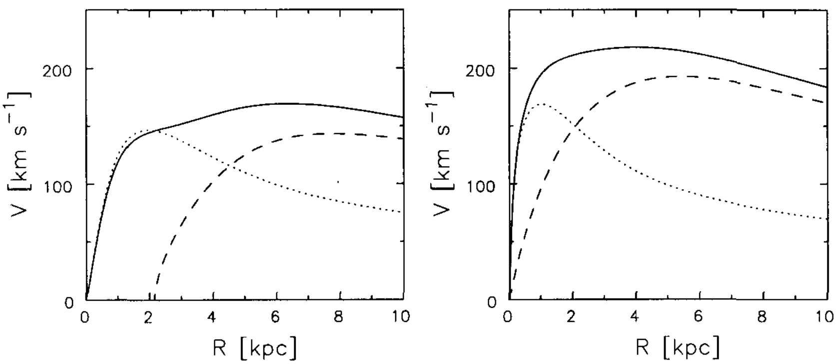

Figure 1. Axially symmetrised "rotation curves" derived from the photometric models of the Milky Way proposed by Freudenreich (left) with $M/L_{bol} = 2$ and Spergel et al. (right) $M/L_{bol} = 3$. The dotted (dashed) curve shows the bar/bulge (disk) contributions, the full curve is their sum.

have no counterparts in the mass; one such feature may be the IR bright ring at 3 kpc where the molecular gas density is high, which could be responsible for the apparently short scale length for the disk. It is also questionable whether the disk and bulge/bar should be assigned the same M/L.

I determine my single free parameter, the M/L for the Milky Way, by requiring that the surface density of luminous mass at the Sun be approximately 50 $M_\odot$ pc^{-2}, in accordance with recent determinations (Kuijken & Gilmore 1991). A safer normalization can be made by modelling the gas flow in the barred region (Englmaier & Gerhard, this meeting) and it is encouraging that they also find that the mass of the inner galaxy is dominated by luminous material.

Both models have two stellar components, the bulge/bar and a disk. The rotation curve obtained by solving for the gravitational field is shown in Figure 1; the inner "rotation curve" of these barred galaxy models is simply derived from the azimuthal average of the central attraction. Freudenreich's model S has a hole in the disk; setting $M/L_{bol} = 2$ gives a surface density of 46 $M_\odot$ pc^{-2} at $R = 8$ kpc. The model preferred by Spergel et al. has not yet been published, but Binney, Gerhard & Spergel (1997) give one fit which has almost the same total light as Freudenreich's, even though the disk in this model does not have a hole. The circular velocity curve shown in Figure 1(b) results from setting $M/L_{bol} = 3$ to give a local surface density of 49 $M_\odot$ pc^{-2}. The central brightness, extrapolated inwards from 3 kpc, is very high in this model and clearly overstates the disk light in this region; a greater fraction of the light probably should be attributed to the bar.

4. Conclusions

Both studies of external galaxies, as well as of the Milk Way, suggest that the disk component contains most of the mass in the bright inner parts of high luminosity galaxies. The data seem to suggest a $M/L_I \sim 2-3$ for the stellar population in typical galaxy disk. Very preliminary fits of constant M/L models for the Milky Way suggest $M/L_{bol} \sim 2-3$ (a value that also indicates little DM in the inner Galaxy).

This work was supported by NSF grant AST 93/18617 and NASA Theory grant NAG 5-2803.

References

Binney, J., Gerhard, O. E. & Spergel, D. (1997) *MNRAS*, **288**, 365
Debattista, V. P. & Sellwood, J. A. (1997) *ApJ Lett*, to appear
Freudenreich, H. T. (1997) astro-ph/9707340
Kuijken, K. & Gilmore, G. (1991) *ApJ Lett*, **367**, L9
Mulhotra, S., Spergel, D. N., Rhoads, J. E. & Li, J., (1996) *ApJ*, **473**, 687
Palunas, P. & Williams, T. B. (1997) *ApJ Suppl*, to appear
Spergel, D. N., Mulhotra, S. & Blitz, L. (1996) In *Spiral Galaxies in the Near-IR*, ed. D. Minnitti & H-W. Rix (Berlin: Springer) 128
Weinberg, M. D. (1985) *MNRAS*, **213**, 451
Weiner, B. (1997) PhD Thesis, Rutgers University