Heavy Bars and Light Spirals – Taking Advantage of Asymmetries in Galaxies

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Abstract. I summarize a series of studies where the underlying theme is to exploit non-axisymmetry disk structures such as bars and spiral arms. By measuring the strength of gravitational forces from these structures we can measure the mass in them. The advantage of this approach is that mass to light ratios can be constrained in a way independent of the dark matter profile. By examining a variety of types of galaxies it appears that a correlation between morphology and dark matter fraction emerges.

1. Examples of Using Assymmetries in Galaxies to Constrain the Disk Mass

Axisymmetric fits to rotation curves in disk galaxies and velocity profiles in elliptical galaxies allow a large range of freedom in choosing the mass to light (M/L) ratio of the stellar population. This is because there is little observational constraint on the actual form of the dark matter profile. Here we introduce a different approach. By measuring the strength of non-axisymmetric structures we can constrain M/L in disk galaxies in a way that is independent of any assumptions about the dark matter profile.

1.1. Resonant Orbits Outside a Bar

In Quillen & Frogel 1997 we studied the affect of the mass of the bar on the shape of the resonance R1 orbits at the Outer Lindblad resonance. By modeling the shape and velocity field of the outer ring in NGC 6782 we found that the mass of the bar must be quite massive, nearly that of a maximal disk (implying little dark matter within the bar).

1.2. Gas response to spiral structure

A strong spiral gas response results from a gravitational perturbation strong enough to produce shocks. When strong spiral structure is observed in HI we can then place a lower limit on M/L. If velocity perturbations are small then there the mass in spiral structure cannot be large. This lets us place an upper limit on M/L. In Quillen & Pickering 1997 we place upper and lower limits on M/L of the spiral arms in two low surface brightness galaxies. We find that they have normal stellar populations. Since the current star formation rates of these galaxies is very low they must have had much higher star formation rates previously. These galaxies are therefore good examples of old but faded...
galaxies. This technique can also be used to infer the presence of a dim or quiescent stellar disk from the HI morphology (e.g. Quillen 1998).

1.3. Moderate Redshift Galaxies

In Quillen & Sarajedini 1998, we consider distant galaxies observed by HST which have clearly evident spiral structure. Since they display spiral structure they must have disks that are cold and massive enough to support and respond to spiral density waves and yet not fragment. We use the Toomre Q parameter to place both lower and upper limits on the ratio of the mass to light ratio to the stellar velocity dispersion, our two unknowns.

The maximal disk mass to light ratio places an upper limit on $M/L$ of these galaxies. We find that they have low maximal disk mass to light ratios and so are probably young with elevated star formation rates compared to local galaxies. The most likely values for the mass to light ratios and velocity dispersions suggest that they are dark matter dominated.

1.4. When Isochromes Differ from Isophotes

In Quillen et al. 1996 we showed that in a disk galaxy with both a radial color gradient and non-circular motion, isochromes or iso-color contours should follow the shape of closed stellar orbits, and the ellipticity of the isophotes should vary as a function of wavelength. While we initially proposed this model to search for triaxial galaxy halos, this phenomenon is observed in barred galaxies and could be used to place constraints on the orbit distribution in them.

2. A Pattern?

Our ring galaxy work supports studies (either of gas dynamics or of dynamical friction) by Sellwood and collaborators that also suggest that early type barred galaxies are likely to be nearly maximal disk. This would suggest that high surface brightness systems with high stellar densities have low dark matter fractions. On the other hand our constraints on $M/L$ for the distant spiral galaxies suggest that these galaxies have somewhat submaximal disks. The low surface brightness, though they have normal stellar populations are highly dark matter dominated. This suggests that a ‘dark matter’ conspiracy, (where the dark matter profile depends on the history of merging and star-formation in the galaxy) rather than dark matter domination at all radii, is a more likely explanation for the Tully-Fisher relation.

References

Quillen, A. C. & Sarajedini, V. L. 1998, AJ, 115, 1412
Quillen, A. C. & Pickering, T. 1997, AJ, 113, 2075
Quillen, A. C. & Frogel, J. A. 1997, ApJ, 487, 603
Quillen, A. C., Ramírez, S. V., & Frogel, J. A. 1996, ApJ, 470, 790
Quillen, A. C. 1998, xxx.lanl.gov/astro-ph/9801217