Dark Matter in Galaxies
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Amplitude of Spiral Arms and Dark Matter

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Abstract. Relative amplitudes and pitch angles for the main two-armed spiral structure in a sample of 54 non-barred spiral galaxies were estimated from K band photometry. A lack of strong, tight patterns was observed which may be caused by non-linear dynamic effects. Assuming that the upper envelope corresponds to a relative radial forcing of ~5%, one can estimate the perturbation of the total potential. This suggests that a maximum disk solution is adequate to account for the force perturbation and that no additional dark matter is required.

1. Amplitudes and pitch angles of spiral arms

A sample of 54 ordinary spiral galaxies was observed in the K' band with SOFI at the 3.5m NTT telescope, La Silla (Grosbøl et al. 2003). The data had a typical seeing of 1″ and a limiting magnitude, at a signal-to-noise level of 3, below 20 mag/arcsec^2. The galaxies were nearby and selected with inclination angles to allow a detailed study of their spiral structure. The K band was used to better estimate perturbations in the old stellar disk population. The radial range of the main two-armed spiral pattern in the galaxies was identified visually and average pitch angle i and relative amplitude A_2 of the m=2 Fourier component were computed.

The A_2–tan(i) distribution (see Fig. 1) suggests a lack of strong, tight spiral arms. It is difficult to identify patterns with $i < 5°$ but there is no observational bias against detecting strong spiral arms. There may also be a deficiency of weak open spirals although it is less clear. Although the attenuation by dust is insignificant in the K band, population effects still plays a role. Especially in the arm regions one frequently observes bright knots and other sharp features which are likely to be associated with young objects, which leads to an overestimate of the relative amplitude of the spiral pattern.

The upper envelope could be caused by strong, tight patterns having such a strong relative radial force perturbation ΔF_r that non-linear effects would be important and damp such waves. From studies of periodic orbits in realistic potentials of spiral galaxies, Grosbøl (1993) estimated that non-linear effects started to be important for $\Delta F_r > 5\%$. For galaxies with a constant circular velocity, a simple two-armed spiral potential yields that $\Delta F_r \propto A_2/\tan(i)$ and

[1]Based on observations collected at the European Southern Observatory, La Silla, Chile

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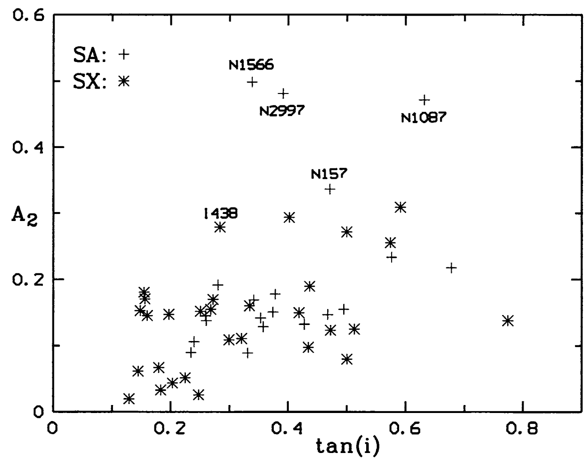

Figure 1. The relative amplitude A_2 of the main two-armed spiral as a function of its absolute pitch angle i is shown.

that the upper envelope of the A_2–tan(i) distribution could be approximated with the line $A_2 = f \tan(i)$ if the limiting value of ΔF_r is constant.

To estimate the factor f from the distribution in Fig. 1, one needs to correct for effects due to strong concentrations of young objects in the arm regions. The two galaxies, NGC 1566 and NGC 2997, with the highest estimated relative amplitudes have indications of strong star formation in their arms. Omitting these two galaxies, one finds that f is in the range of 0.5-0.7 where the low limit is more likely as most galaxies will have some star formation in their arms.

2. Dark Matter Implications

An estimate of ΔF_r can be obtained using the potential-density pair for a 3D spiral perturbation provided by Cox & Gómez (2002). Typical values for ΔF_r were calculated for a galaxy consisting of an exponential disk with a maximum circular speed of 200 km/s, a disk scale length of 3 kpc and scale height of 0.2 kpc. This gave a relative force $\Delta F_r(r = 8\text{kpc}) \approx 0.042$ for a relative amplitude $A_2 = 0.10$ and a pitch angle $i = 15°$.

Comparing this value with the A_2–tan(i) distribution, most galaxies would have $\Delta F_r < 5\%$ depending on corrections for young objects in the arm regions. Thus, a significant contribution from dark matter to the potential within the region of the main spiral pattern is not required.

References

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