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Fast bars in early-type barred galaxies

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Abstract. We measured the bar pattern speed of a sample of 6 SB0 galaxies using the Tremaine-Weinberg method. We derived the ratio, $\mathcal{R}$, of the corotation radius to the length of the bar semi-major axis. For all the galaxies, $\mathcal{R}$ is consistent with being in the range from 1.0 and 1.4, i.e. that they host fast bars. This represents the largest sample of galaxies for which $\mathcal{R}$ has been measured this way. We compared this result with recent high-resolution N-body simulations of bars in cosmologically-motivated dark matter halos, and conclude that these bars are not located inside centrally concentrated dark matter halos.

Key words. galaxies: halos – galaxies: kinematics and dynamics

1. Introduction

The pattern speed of a bar, Ω_p, is its main kinematic observable. When parametrized by the distance-independent ratio $\mathcal{R} \equiv D_L/a_B$ (where D_L is the Lagrangian/corotation radius, at which a star is at rest in the bar's rest frame, and a_B is the bar semi-major axis), it permits the classification of bars into fast ($1.0 \leq \mathcal{R} \leq 1.4$) and slow ($\mathcal{R} > 1.4$) ones. If $\mathcal{R} < 1.0$ orbits are elongated perpendicular to the bar, so that self-consistent bars cannot exist in this regime (Contopoulos 1980).

A model-independent method for measuring Ω_p directly was obtained by Tremaine & Weinberg (1984, hereafter TW). The TW method is given by the simple expression $\mathcal{X}\,\Omega_p \sin i = \mathcal{V}$, where $\mathcal{X}$ and $\mathcal{V}$ are luminosity-weighted mean position and velocity measured along slits parallel to the line-of-nodes. If a number of slits at different offsets from the major-axis are obtained for a galaxy, then plotting $\mathcal{V}$ versus $\mathcal{X}$ for the different slits produces a straight line with slope $\Omega_p \sin i$.

We have started a program to measure pattern speeds measured with the TW method in galaxies of various bar strength, environment, luminosity, inclination etc. Here we present results for 6 SB0 galaxies.

2. Pattern speed measurements

For each sample galaxy we measured surface photometry and stellar kinematics in order to estimate $\mathcal{R} \equiv D_L/a_B$ (see Debattista, Corsini & Aguerri 2002; Aguerri, Debattista & Corsini 2003, hereafter ADC03). The length of the bar, a_B, was

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derived from the analysis of the surface brightness distribution. The corotation radius, $D_L \equiv V_{\rm c}/\Omega_p$, is the ratio of the circular velocity, $V_{\rm c}$, to the pattern speed, Ω_p. We derived $V_{\rm c}$ by applying the asymmetric drift correction to stellar velocities and velocity dispersions. We measured Ω_p by applying the TW method. To compute the mean position of stars, $\mathcal{X}$, along the slits, we extracted the intensity profiles from the spectra. To measure the luminosity-weighted line-of-sight stellar velocity, $\mathcal{V}$, for each slit position, we collapsed each two-dimensional spectrum along its spatial direction to obtain a one-dimensional spectrum. The value of $\mathcal{V}$ has been derived by fitting the resulting spectrum with the convolution of a template stellar spectrum and a Gaussian line-of-sight velocity profile. We derived $\Omega_p \sin i$ for the bars by fitting a straight line to the values $(\mathcal{X}, \mathcal{V})$ obtained from the available slit positions.

3. Conclusions

Our 6 SB0's represent the largest sample of barred galaxies, with Ω_p measured by means of the TW method. For all of them, $\mathcal{R}$ is consistent with being in the range 1.0 to 1.4, within the errors, i.e. with each having a fast bar. The unweighted average for the sample is $\overline{\mathcal{R}} = 1.1$. The fact that some of the values of $\mathcal{R}$ are nominally less than unity leads us to suggest that the large range of $\mathcal{R}$ is a result of random errors and/or scatter in the measurements.

Debattista & Sellwood (2000) argued that bars this fast can only survive if the disc in which they formed is maximal. Recent high resolution N-body simulations with cosmologically-motivated dark matter halos produce bars with $\mathcal{R}$ in the range between 1.2 and 1.7 (Valenzuela & Klypin 2002). Even discounting our argument above in favor of a more restricted range of $\mathcal{R}$, Fig. 1 shows that $\mathcal{R} = 1.7$ is possible only for the bars of IC 874, NGC 1440, NGC 3412 and, marginally, NGC 936, while the bars of ESO 139-G009, NGC 1023, NGC 1308 and NGC 4596 never reach this value of $\mathcal{R}$. Note, moreover, that 3 of the galaxies that do reach $\mathcal{R} = 1.7$ have amongst the largest fractional errors in $\mathcal{R}$. Therefore we conclude that the N-body models of Valenzuela & Klypin (2002) probably produce slower bars than the observed.

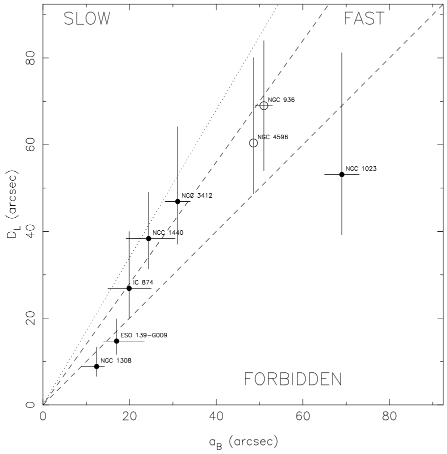

Fig. 1. The corotation radius, D_L, and the bar semi-major axis, a_B, for the sample galaxies. The open circles represent galaxies which are not part of our sample: NGC 936 (Merrifield & Kuijken 1995) and NGC 4596 (Gerssen et al. 1997). Dashed lines corresponding to $\mathcal{R} = 1$ and $\mathcal{R} = 1.4$, separate the fast-bar, slow-bar and forbidden regimes. The dotted line corresponds to $\mathcal{R} = 1.7$ (adapted from ADC03).

References

Aguerri, J. A. L., Debattista, V. P., & Corsini, E. M., 2003, MNRAS, 338, 465 (ADC03)

Contopoulos, G. 1980, A&A, 81, 198

Debattista, V. P., & Sellwood, J. A. 2000, ApJ, 543, 704

Debattista, V. P., Corsini, E. M., & Aguerri, J. A. L. 2002, MNRAS, 332, 65

Gerssen, J., et al. 1997, MNRAS, 288, 618

Merrifield, M. R., & Kuijken, K. 1995, MNRAS, 274, 933

Valenzuela, O., & Klypin, A., 2002, MNRAS, submitted (astro-ph/0204028)