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The V_c–σ_c relation in high and low surface brightness galaxies

A. Pizzella[1], E.M. Corsini[1], E. Dalla Bontà[1], M. Sarzi[2], L. Coccato[3], and F. Bertola[1]

[1] Dipartimento di Astronomia, Università di Padova, Padova, Italy
[2] University of Oxford, UK
[3] Kapteyn Astronomical Institute (RUG), The Netherlands
e-mail: pizzella@pd.astro.it

Abstract. We investigate the relation between the asymptotic circular velocity, V_c, and the central stellar velocity dispersion, σ_c, in galaxies. We consider a new sample of high surface brightness spiral galaxies (HSB), low surface brightness spiral galaxies (LSB), and elliptical galaxies with H I-based V_c measurements. We find that:
1) elliptical galaxies with H I measurements fit well within the relation;
2) a linear law can reproduce the data as well as a power law (used in previous works) even for galaxies with σ_c< 70 km/s;
3) LSB galaxies, considered for the first time with this respect, seem to behave differently, showing either larger V_c values or smaller σ_c values.
If the V_c–σ_c relation is equivalent to one between the mass of the dark matter halo and that of the supermassive black hole, these results suggest that the LSB galaxies host a supermassive black hole with a smaller mass compared to HSB galaxies of equal dark matter halo. On the other hand, if the fundamental correlation of SMBH mass is with the halo circular velocity, then LSBs should have larger black hole masses for given bulge dispersion.

1. Introduction

Recently, a tight correlation between the bulge velocity dispersion σ_c and the galaxy asymptotic circular velocity V_c has been found for a sample of elliptical and spiral galaxies (Ferrarese 2002). The validity of this relation has been also confirmed by Baes et al. (2003), who enlarged the spiral galaxy sample. The fact that such a tight relation exists between two velocity scales that probe very different spatial regions (the bulge and the dark matter halo), is a strong indication of a fundamental correlation in the structure not only of spirals but also of ellipticals. On the other hand, it may be interesting to investigate whether the V_c–σ_c relation holds also for less dense objects characterized by a shallow potential well in their core. This is the case of LSB galaxies.

2. The sample

We studied the V_c–σ_c adding to previous studies new data for HSBs, Es, and LSBs. In particular, we consider a sample of 41 HSB spirals (17 from Ferrarese (2002), 7 from Baes et al. (2003), 17 from Pizzella et al. (2004)), 11 LSB spirals from Pizzella et al. (2003), 19 Es from Kronawitter et al. (2000), and five Es with H I-based V_c measurements.

Send offprint requests to: A. Pizzella

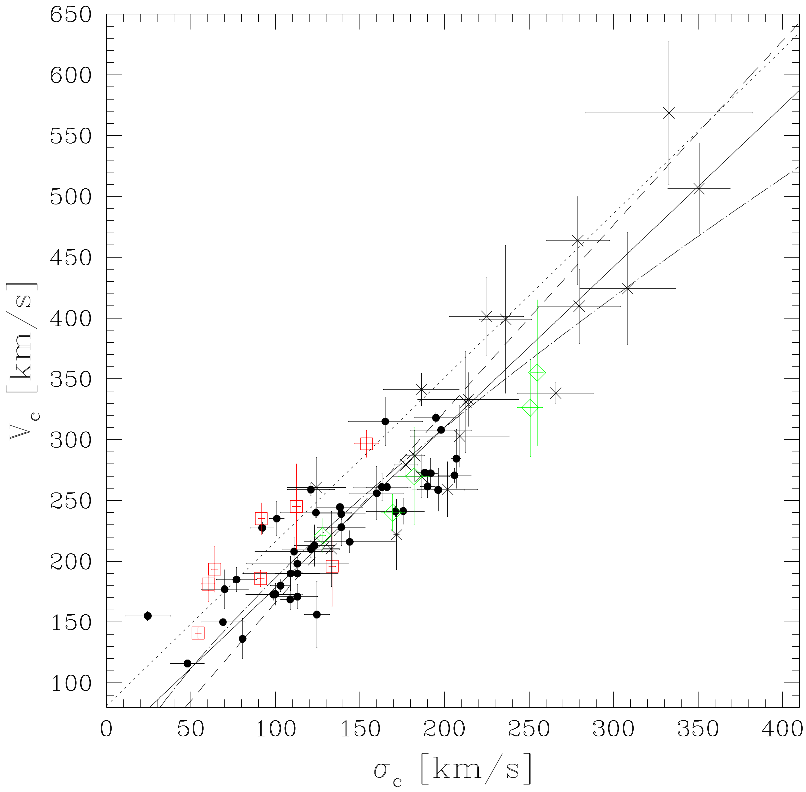

Fig. 1. The correlation between the circular velocity V_c and the central velocity dispersion of the spheroidal component σ_c for elliptical and disc galaxies. The data points corresponding to HSB galaxies (*filled circles*), LSB galaxies (*squares*), elliptical galaxies with V_c obtained from H I data (*diamonds*), and elliptical galaxies with V_c obtained from dynamical models (*crosses*) are shown. The *continuous* and *dash-dotted line* represent the linear (Eq. 1) and power-law fit to HSB and elliptical galaxies. The *dotted line* represents the linear-law fit (Eq. 2) to LSB galaxies. For a comparison, the *dashed line* corresponds to the power-law fit to spiral galaxies with $\sigma_c > 80$ $\mathrm{km s^{-1}}$ by Baes et al. (2003).

2.1. The HSBs sample

Concerning the HSB sample we check that all galaxies have extended rotation curves which are flat in the last region. The flatness of each rotation curve has been checked by fitting it with a linear low $V(R) = AR + B$ for $R \geq 0.35 R_{25}$. The radial range has been chosen in order to avoid the bulge-dominated region of the rotation curve (e.g., IC 724 and NGC 2815). The rotation curves with $|A| \geq 2$ km $\mathrm{s^{-1}}$ $\mathrm{kpc^{-1}}$ within 3σ have been considered not to be flat. In this way a total of 40 HSB galaxies resulted to have a flat rotation curve. V_c has been then derived as the average of the last measured points. The resulting V_c–σ_c diagram is plotted in Fig. 1 (dots).

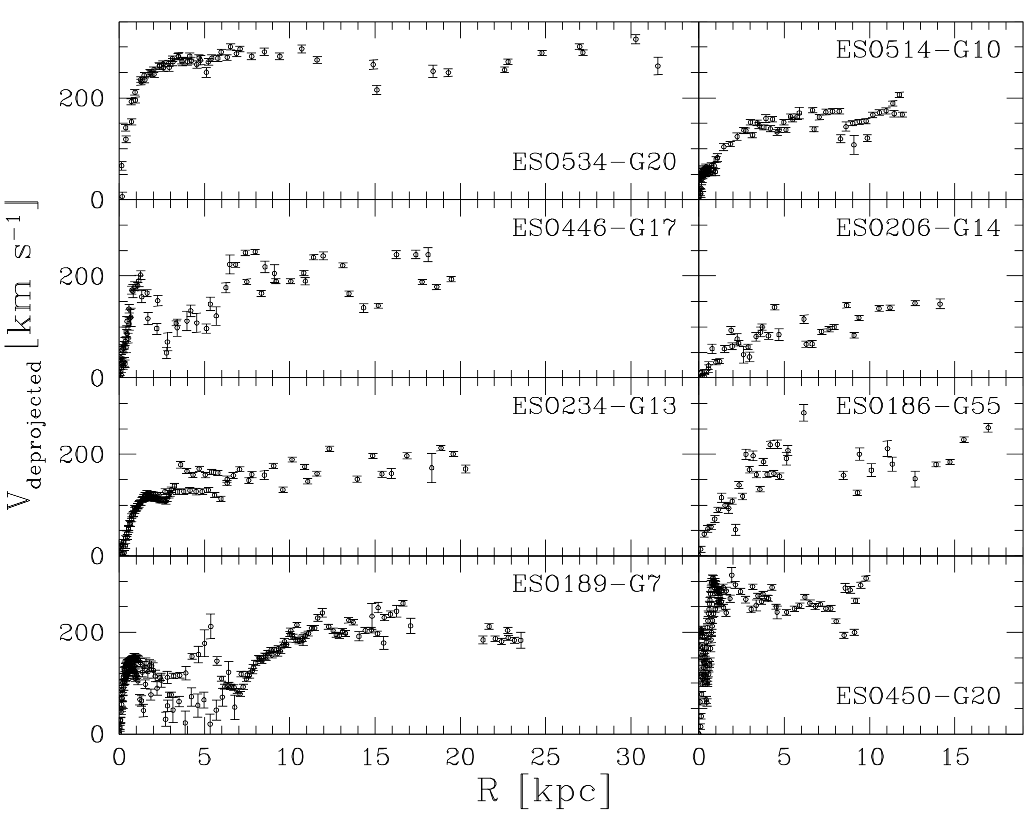

Fig. 2. Deprojected rotation curves of the eight LSB galaxies of the final sample.

2.2. The H I-based Es sample

In the previous works elliptical galaxies V_c measurements were based on the dynamical modeling studies by Kronawitter et al. (2000) who used the stellar kinematics to derive the mass distribution of a sample of bright, not rotating ellipticals. The resulting V_c–σ_c relation matches the one derived for HSB galaxies (Ferrarese 2002). This result may suffers of some bias introduced by the dynamical modeling or by the limited extension of the kinematical data. In fact, stellar kinematical measurements are generally extended to a fraction of R_{25}. To check whether a bias exists, we added data-points for ellipticals with V_c measured directly from H I kinematical measurements. In the literature we found five ellipticals for which V_c may be directly derived from the flat portion of their H I rotation curves. In all cases the H I velocity are measured at radii much larger than R_{25}. The resulting V_c–σ_c diagram is plotted in Fig. 1 (diamonds).

2.3. The LSBs sample

Out of the sample of 11 LSBs for which we have kinematical measurements (Pizzella et al. 2003, 2005b), only eight objects are characterized by a flat rotation curve as defined in sect. 2.1. The eight curves are plotted in Fig.2.

3. Results and conclusions

The data-points of HSB and E galaxies can be represented both with power law with an exponent near to 1 (see Pizzella et al. 2005a,for a more detailed analysis) (Fig.1 dash-dotted line). For this reason we decided to adopt a linear law instead. The best fit to the HSB+E data is given by the equation

$$V_c = (1.32 \pm 0.09)\,\sigma_c + (46 \pm 14) \quad (1)$$

Ellipticals with H I data are well represented by the relation and share the same V_c–σ_c as the other Es. Contrarily, LSBs data points appear to fall in a region of the V_c–σ_c plane offset with respect to HSB galaxies. For this reason we did not include the LSB sample in the sample fitted by 1. All (but one) LSB fall above the relation for HSB+E, having higher V_c for a given σ_c(or a smaller $\sigma_c$for a given V_c). A linear fit the the eight LSB is given by

$$V_c = (1.35 \pm 0.19)\,\sigma_c + (81 \pm 23) \quad (2)$$

The main conclusion of this work can be summarized as follows:

1. a linear law can reproduce the data as well as a power law (used in previous works) even for galaxies with $\sigma_c < 70\,\mathrm{kms}^{-1}$;
2. elliptical galaxies with H I measurements fit well within the relation;
3. LSB galaxies, considered for the first time with this respect, seem to behave differently, showing either larger V_c values or smaller $\sigma_c$values.

If the V_c–σ_c relation is equivalent to one between the mass of the dark matter halo and that of the supermassive black hole, these results suggest that the LSB galaxies host a supermassive black hole with a smaller mass compared to HSB galaxies of equal dark matter halo. On the other hand, if the fundamental correlation of SMBH mass is with the halo circular velocity, then LSBs should have larger black hole masses for given bulge dispersion.

Although statistical tests applied to HSB+E and LSB data indicate that they are different at a 3σ confidence level and thus that LSBs do not follow the same V_c–σ_c relation as HSB and E galaxies, we need more data points for LSB galaxies to confirm such discrepancy and characterize it.

Confirming this result will highlight yet another aspect in the different formation history of LSBs. Indeed, LSBs appear to have a central potential well less deep than HSB spirals of the same halo mass. If the collapse of baryonic matter cause a compression of the dark halo as well, for LSB galaxies such process may have been less relevant than for HSBs. Again LSBs turn out to be the best tracers of the original density profile of dark matter halos and therefore in pursuing the nature of dark matter itself.

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