From Spirals to Low Surface Brightness galaxies

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Abstract. We show that simple models of the chemical and spectrophotometric evolution of galaxies can be used to explore the properties of present-day galaxies and especially the causes of the observed variety among disc galaxies. We focus on the link between "classical" spirals and Low Surface Brightness galaxies.

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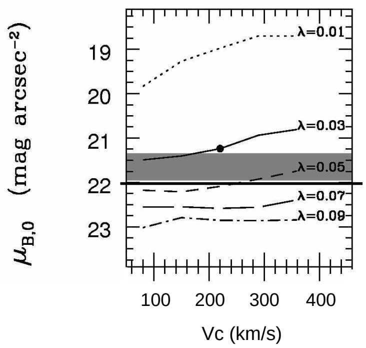
1. Introduction

In the last decades, a considerable amount of observations has been collected on Low Surface Brightness galaxies (LSBs), which are characterised by a central surface brightness well below the Freeman disc centre value ($\mu_{B,0}$=21.65 mag arcsec^{-2}). In a related contribution in the present Volume (Monnier Ragaigne et al.), the samples of LSBs used for comparison with our models are presented. LSBs are relevant for the study of the formation and evolution of galaxies in general, as well as for observational cosmology, since some studies suggest that they may be responsible for a significant fraction of the high redshift quasar absorbers in which gas densities and abundances can be measured on cosmological scales (e.g. Boissier et al., 2002 and references therein).

In section 3, we will compare the properties of the observed samples with the predictions of models of their chemical and spectrophotometric evolution based on reliable models of spirals (presented in section 2).

2. Models

In the contribution by N. Prantzos, it is shown that the properties of nearby spiral galaxies are in good agreement with a grid of simple models of their chemical and spectrophotometric evolution. These



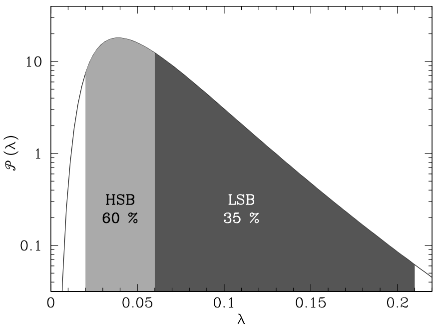


Figure 1. Left: B-band central disc surface brightness as a function of rotational velocity. Each line corresponds to a different value of the spin parameter λ. The Freeman value, typical of "normal"spirals is indicated by the shaded area, while the limit of LSB galaxies we adopted is indicated by the horizontal line. Right: distribution of the spin parameter λ. Models with $\lambda \sim 0.04$ correspond to spirals with Freeman's surface brightness, models with $\lambda > 0.06$ to LSBs.

models are based on: i) a calibration on the Milky Way, ii) scaling relationships obtained in the context of the cold dark matter theory (Mo et al., 1998), and iii) an empirical calibration of infall time-scales: massive galaxies accreting gas more rapidly than low mass galaxies (Boissier and Prantzos, 2000).

The second point is the most relevant for the study of LSBs, as the scaling relations link the structural properties of the disc (scalelength and central surface density) to those of the dark halo (circular velocity V_C and spin parameter λ):

$$R_d = R_{d,MW} \times \frac{V_C}{V_{C,MW}} \times \frac{\lambda}{\lambda_{MW}} \; ; \; \Sigma_0 = \Sigma_{0,MW} \times \frac{V_C}{V_{C,MW}} \times \left(\frac{\lambda}{\lambda_{MW}}\right)^{-2} .$$

The index MW refers to the corresponding value in the Milky Way. The spin parameter λ is a dimensionless quantity measuring the specific angular momentum of the dark halo.

Dalcanton et al. (1997) already suggested that LSBs could be the large angular momentum equivalents of "normal" spirals, an idea also used in the chemical evolution models of Jimenez et al. (1998). Here, we will take advantage of the existence of a grid of models that are well calibrated for spiral galaxies. Figure 1 shows the surface disc brightness obtained with the spiral galaxy models, where, indeed, models with $\lambda > 0.06$ are found to be LSBs ($\mu_B > 22$ mag arcsec^{-2}). Integrating over a distribution of the spin parameter, this correspond to 35 % of

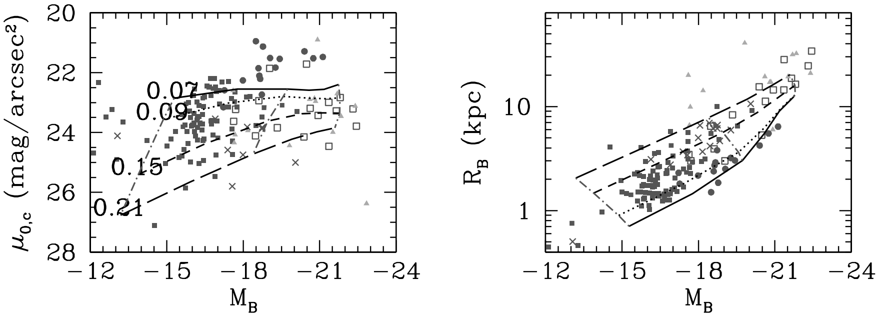


Figure 2. *B*-band central disc surface brightness (left) and scalelength (right) as a function of the absolute magnitude of the disc component for various observational samples (see Monnier Ragaigne et al., this Volume). The lines indicate models for LSB galaxies, i.e. with large spin parameter values, as indicated in the left panel.

all galaxies (in number). In the next section, we extend the models to larger values of the spin parameter (0.07, 0.09, 0.15, 0.21) and compare the results with some of the available observations for LSBs.

3. A comparison of models with observations

3.1. Central disc surface brightness and scalelength

The central disc surface brightness and the scalelength of the models obtained with large values of the spin parameter are presented in Figure 2 as a function of the absolute magnitude of the disc component (all in the B band), for a number of samples of objects of low and intermediate surface brightness, chosen to represent the wide variety among LSBs. The comparison between the two shows that these very simple models (and especially the scaling relationships) provide a sound basis for the study of LSBs.

LSBs could then well be disc galaxies with larger spin parameter than spirals. As a consequence, for similar masses (and thus similar absolute magnitudes, assuming that the mass-to-light ratio does not vary drastically), the scalelengths of LSBs are expected to be larger than for spirals. Indeed, the sample with intermediate surface brightness is characterised by smaller scalelengths than the samples with very low surface brightness galaxies.

3.2. Chemistry

Observational evidence on the chemical evolutionary state of LSBs is relatively scarse. Their H I mass-to-light ratios, on average larger than in spirals, seems to indicate that LSBs are less evolved. This is indeed what is found in the models, the star formation efficiency being much smaller because of the smaller gas densities (see Monnier Ragaigne et al., this Volume).

For the same reasons, chemical abundances of heavy elements are lower. In "normal" spirals, a clear relation between mass and metallicity is observed (e.g. Zaritsky et al., 1994), which is reproduced in the models owing to the mass dependence of infall timescales. The observational situation is less clear for LSBs (see Figure 3). However, contrary to the case of spirals, metallicity in LSBs is measured in only a few H II regions located at various radii in different galaxies: these data cannot be corrected for the unknown underlying abundance gradients. The abundances obtained in the LSB models, weighted by a distribution of velocity, spin parameter and star formation rate (to take into account the need for massive stars to produce observable H II regions) are presented as the grey-scales in Figure 3. A relatively large range of abundances is expected, in rough agreement with the measurements.

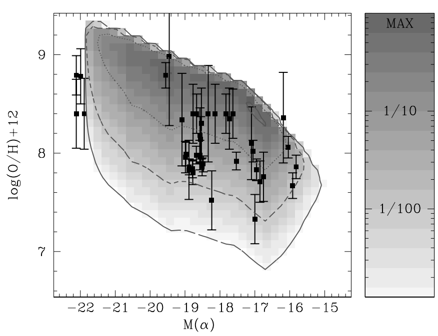


Figure 3. Oxygen abundances in LSBs as a function of the absolute blue magnitude of the disc component. Data are from Mc Gaugh (1994). The grey-scale indicates expected values from the models, weighted by a distribution of velocity, spin parameter, and star formation rate.

3.3. Colours

The main difficulty for these "simple" models (with a smooth star formation history) is their inability to explain the wide range of colours observed (Monnier Ragaigne et al., this Volume). Adding to the models starbursts and truncations of the star formation histories seems a promising way to cure this problem (Boissier et al., in preparation).

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