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A spectroscopic view of stellar populations in bulges of low surface brightness galaxies

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Abstract. We present the radial profiles of the age, metallicity and α/Fe enhancement of the stellar populations in the bulge-dominated region for a sample of eight spiral galaxies with a low surface-brightness stellar disc and a bulge. Almost all the sample bulges are characterized by a young stellar population, a solar α/Fe enhancement, and a metallicity spanning from high to sub-solar values. No signicant gradient in age and α/Fe enhancement is measured, whereas a negative metallicity gradient is found only in a few cases. The stellar populations of the bulges hosted by low-surface-brightness discs result to share many properties with those of high surface-brightness galaxies. Therefore, they are likely to have common formation scenarios and evolution histories.

Key words. galaxies : abundances – galaxies : bulges – galaxies : evolution – galaxies : stellar content – galaxies : formation – galaxies : Kinematics and Dynamics

1. Introduction

Galaxies with a central face-on surface brightness fainter than 22.6 mag arcsec^{-2} in the B band are classified as low surface-brightness (LSB) systems. Although they are more difficult to be identified than high surface-brightness (HSB) galaxies, LSB galaxies do not occupy a niche in galactic astrophysics. Indeed, they constitute up to 50 per cent of the galaxy population and, consequently, represent one of the major baryonic repositories in the Universe (see Bothun et al. 1997, for a review). Nevertheless, LSB galaxies are characterized by different morphologies (ranging from dwarf irregulars to giant spirals) and cover a wide range of colors ($0.3 < B - V < 1.7$) suggesting that they can follow a variety of evolutionary paths. The typical gas surface density of LSB discs is below the critical threshold necessary for star formation, despite the

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fact that they have an higher content of neutral hydrogen with respect to their HSB counterparts (van der Hulst et al. 1993). This inability to condense atomic gas into molecular gas results in a very low star formation rate and in a significantly slower evolution of the galaxy. Although most of the LSB galaxies are bulge-less, there are also galaxies with a LSB disc and a significant bulge component (Beijersbergen et al. 1999; Pizzella et al. 2008). It is not known whether these bulges are similar to those of HSB galaxies and whether their properties do depend on the LSB nature of their host discs. An invaluable piece of information to understand the processes of formation and evolution of bulges in LSB galaxies is imprinted in their stellar populations. To this aim, the central values and radial profiles of age, metallicity, and α/Fe enhancement of the stellar component can be used to test the predictions of theoretical models, as already done for the bulges of HSB galaxies (see Rampazzo et al. 2005; Jablonka et al. 2007; Zhao 2012).

Gas dissipation toward the galaxy centre, with subsequent star formation and blowing of galactic winds, produces a gradient in the radial profile of metallicity. Therefore, a metallicity gradient is expected in bulges formed by monolithic collapse (Kobayashi 2004) while the metallicity gradient is expected to be very shallow (or even absent) in bulges built by merging (Bekki & Shioya 1999). In fact, mergers of galaxies poor of gas mix up the galaxy stars, erasing the pre-existing population gradients and only rarely metallicity gradient is enhanced by the secondary events of star formation, which eventually occur in mergers of objects rich of gas. If this occurs, a clear signature can be observed in the age radial profile for several Gyr (Hopkins et al. 2009). The predictions for bulges assembled through long time-scale processes, such as the dissipationless secular evolution of the disc component, are more controversial. According to this scenario, the bulge is formed by the redistribution of disc stars and gradients that are eventually present in the progenitor disc could either be amplied, because the resulting bulge has a smaller scalelength than the disc, or they could be erased as a consequence of disc heating (Moorthy & Holtzman 2006). We present a short summary of the detailed photometric and spectroscopic study of a sample of eight bulges hosted in LSB discs that we have done in Morelli et al. (2012b). The analysis of the spectral absorption lines has allowed us to derive the age and metallicity of the stellar populations and to estimate the efficiency and timescale of the last episode of star formation in order to distinguish between the early rapid assembly and late slow growth of the bulge.

2. Sample selection

All the sample galaxies were selected to be spiral galaxies with a bulge and a LSB disc. It should be noted that these galaxies have central surface brightnesses that place them on the low side of normal spirals, but are not examples of typical LSB galaxies. Nevertheless, the LSB nature of their discs was confirmed by a detailed decomposition of the surface-brightness distribution.

To this aim we derive the photometric parameters of the bulge and disc applying a detailed decomposition of the surface brightness of the galaxy. We adopted the galaxy surface photometric 2D (GASP2D) code by Méndez-Abreu et al. (2008). The structural parameters of the galaxies were derived assuming the galaxy surface-brightness distribution to be the sum of the contributions of a bulge, a disc and, if necessary, a bar. We fitted iteratively the model of the surface brightness to the pixels of the galaxy image using a non-linear least-squares minimisation.

Therefore, the final sample is made by 8 LSB spiral galaxies with a morphological type ranging from Sa to Sm and including some barred galaxies. Their optical images are shown in Fig. 1.

3. Long-slit spectroscopy

The galaxies were observed with the UT1 unit mounting the FOcal Reducer and low dispersion Spectrograph 2 (FORS2). For each galaxy long-slit spectra on the major and minor axis were usually taken using the grism GRIS_1400V+18 in combination with either

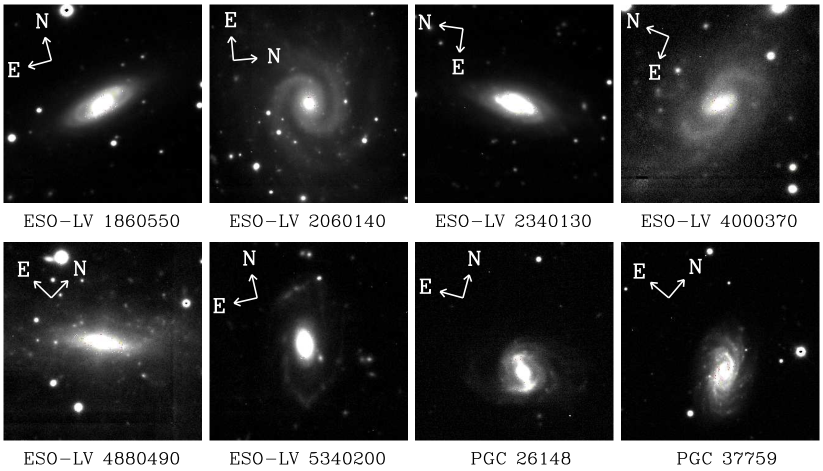

Fig. 1. Optical images of the sample galaxies. The orientation is specified by the arrows indicating north and east in the upper-left corner of each image. The size of the plotted region is about 80 arcsec × 80 arcsec.

the 0.7 arcsec slit that guarantees an instrumental velocity resolution of $\sigma_{\rm inst}$ = 33 km s^{-1} at 5000 Å. The stellar kinematics was measured from the galaxy absorption features present in the wavelength range centred on the H$_\beta$(λ 4861 Å) line and Mg I line triplet ($\lambda\lambda$ 5164,5173, 5184 Å) by applying the Penalized Pixel Fitting (pPXF, Cappellari & Emsellem 2004) and Gas AND Absorption Line Fitting (GANDALF, Sarzi et al. 2006) IDL packages adapted for dealing with the FORS2 spectra.

4. Properties of the stellar populations

The models by Thomas et al. (2003) predict the values of the line-strength indices for a single stellar population as function of the age, metallicity, and [α/Fe] ratio. The central values of Mg$_2$, Mg$_b$, H$_\beta$, and $\langle$Fe$\rangle$ were obtained by a weighted mean of all the measured data points within an aperture of radius $0.3\,r_{\rm e}$ along the radial profile. From the central values of the Lick indices we derived the mean age, total metallicity, and total /Fe enhancement of the stellar population in the central region of the bulge of the sample galaxies (Fig. 2). The studied bulges are characterized by a very young stellar population, with a distribution of ages peaked at the value of 1.5 Gyr. The metallicity of the sample bulges spans a large range of values from high ([Z/H] = 0.30 dex) to sub-solar metallicity ([Z/H] = −1.0 dex). Most of them display solar α/Fe enhancements.

The gradients of the properties of the bulge stellar population (Fig. 2) were derived from the values of age, metallicity, and α/Fe enhancement in the radial range out to $r_{\rm bd}$, the radius where the bulge and disc give the same contribution to the total surface brightness (Morelli et al. 2008). Most of the sample galaxies show no gradient in age and [α/Fe] radial profiles. This is in agreement with the earlier findings by Jablonka et al. (2007); Morelli et al. (2012a) for the bulges of HSB galaxies.

5. The common nature of bulges in LSB and HSB galaxies

In this paper, we have highlighted the fact that bulges hosted by LSB galaxies share many structural and chemical properties with the bulges of HSB galaxies. Such a similarity suggests that they possibly had common formation scenarios and evolution histories. Our findings are in agreement with, and also extend, the previous results inferred by McGaugh et al. (1995) and Beijersbergen et al. (1999), who compared

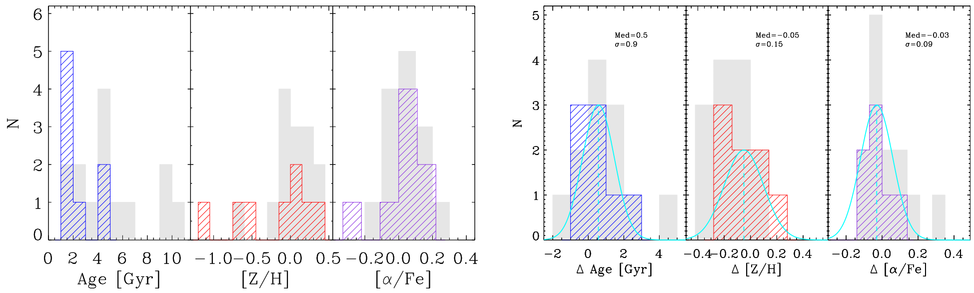

Fig. 2. Distribution of the central values (left) and gradients (right) of the mean age (left-hand panel), total metallicity (central panel), and total α/Fe enhancement (right-hand panel) for the stellar populations of the bulges of the sample galaxies. The distribution of the same quantities obtained by Morelli et al. (2008) for the bulges of HSB discs are plotted in grey for sake of comparison.

the photometric properties of the bulges of LSB and HSB galaxies, and by Coccato et al. (2008), who performed a detailed analysis of the kinematical and mass-distribution properties of the bulge of the LSB galaxy ESO 323-G064. The fact that bulges hosted in galaxies with very different discs are remarkably similar rules out a relevant interplay between the bulge and disc components and it gives further support to earlier ndings (Thomas & Davies 2006; Morelli et al. 2008).

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