Stellar Populations as Building Blocks of Galaxies
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Galaxies with nested bars: constraining their formation scenarios

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Abstract. Secular evolution theory predicts that spheroidal components are formed thanks to bars that can transport gas to the central regions of the galaxies. This activity would trigger the star formation needed to generate galactic bulges. According to this idea, bars at smaller scales may carry material to the galactic center and feed active galactic nuclei. For the first time, we have carried out a complete kinematical and stellar population analysis of a double-barred galaxy (NGC 357) to determine if this system of two bars is efficient enough to cause that kind of effects. We have measured suitable line-strength indices on high quality spectra to obtain the relative ages and metallicities for the different structural components and thus constrain the star formation history. First results seems to indicate that in the case of NGC 357 the nuclear bar hasn't played an important role in fueling the star formation in the center.

Keywords. galaxies: bulges, galaxies: evolution, galaxies: formation, galaxies: kinematics and dynamics

1. Introduction

Bars are intended to be the key structural components of the galaxies to clarify the formation of the bulges. This is because they are thought to drive material to the inner parts of the galaxies triggering intense star formation. Moreover, most of the spiral galaxies in the Universe present large-scale bars and this fraction seems to be constant independently of the distance. However, these main bars are unable to transport gas to the very central regions, so a system formed by two or more nested bars is needed (Shlosman *et al.* 1990). These systems are also very common, as they appear in $\sim 1/3$ of the barred galaxies. To check if such nested bars are efficient enough to drive the material to small radii it is necessary to analyze the dynamics and the stellar populations of the galaxies, and really high quality spectra are needed for this purpose. We present here this kind of study for the double-barred S0 galaxy NGC 357, from spectra of resolution ~ 1.3 Å obtained with EMMI at the NTT telescope (La Silla, Chile).

2. Kinematics

Kinematical analysis was performed along both the nuclear bar axis and the semi-major axis, showing that the bulge is pressure-supported since its $v_r/\sigma \sim 0$. Moreover, σ is nearly constant along the nuclear bar decreasing outwards. The mean velocity dispersion σ is 180 km s^{-1} for the bulge, 165 km s^{-1} for the nuclear bar and $\sim$100 km s^{-1} for the outer bar and the semi-major axis.

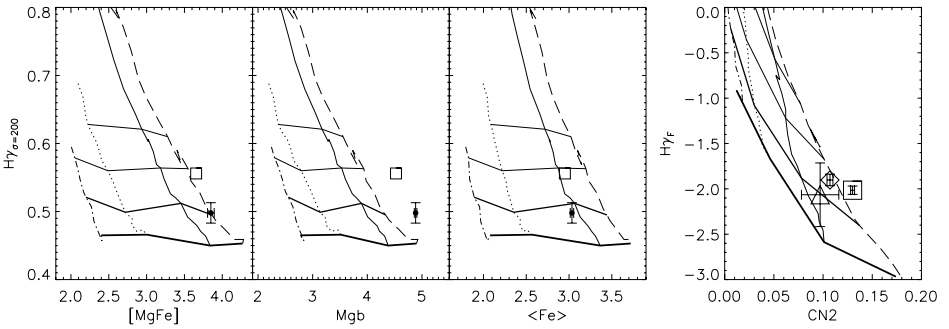

Figure 1. The age indicators Hγ_σ (Vazdekis & Arimoto 1999) and Hγ_F vs. the metallicity indicators [Mg/Fe], Mg, Fe and CN2 of the Lick system. The grids were obtained by using the Vazdekis (1999) stellar population models, smoothed to match the σ measurements for the bulge of this galaxy (i.e. $\sim$180 km s^{-1}). The solid lines represent different ages (from top to bottom: 4, 6, 10 and 18 Gy). The metallicity increases from left to right ([Fe/H] -0.7, -0.4, 0.0 and 0.2). The symbols represent the structural components of NGC 357: the bulge (square), the nuclear bar (diamond), the outer bar (triangle) and a reference Virgo galaxy of similar σ: NGC 4473 (filled dot; Yamada *et al.* 2006).

3. Stellar populations

Several line strength indices were measured on the NGC 357 spectra and compared with those corresponding to the stellar population synthesis models (see Figure 1). Comparing the values for the different structural components it seems to be no significant age difference among them. Moreover, the obtained values for the bulge of NGC 357 and a prototype elliptical galaxy of similar central σ of the Virgo cluster are rather similar and supersolar. Finally, we obtain the [Mg/Fe] $\sim$0.4 and [CN/Fe] $\sim$0.4 overabundances, that are equivalent to those ratios for elliptical galaxies of similar masses.

4. Conclusions

Our analysis suggests that the typical formation timescale for the bulk of the stellar population of this galaxy was lower than 1 Gy. Several features, like bulge's [Mg/Fe] or [CN/Fe] overabundances, are similar in NGC 357 and in field elliptical galaxies of similar σ, suggesting that their formation histories cannot be significantly different. Moreover, NGC 357 is younger than the Virgo's galaxy, as expected for field galaxies (Kuntschner *et al.* 2002). The large age and the obtained [Mg/Fe] overabundance ratio suggest that the nuclear bar does not play an important role in fueling star formation in the center of NGC 357. However, further double-barred galaxies will be analyzed this way in order to obtain a more general result.

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