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Kinematical decomposition of stellar populations in disc galaxies

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Abstract

Understanding how different stellar populations evolve in different regions is a key to understand the evolution of galaxies. Traditionally the kinematics and stellar populations in galaxies have been obtained separately and unrelatedly, sometimes ignoring the other one. In this pilot study we simultaneously disentangle the stellar populations (characterizing their age and metallicity) and associate them with the stellar kinematics (velocity and velocity dispersion) in the bulge of three very different disc galaxies using high resolution IFS data.

1 Introduction

Secular processes are believed to influence the formation of bulges, by rearranging both mass and angular momentum. However, results are still not clear, owing to the intrinsic complexity of bulges, which are not the simple components that were thought to be a few years ago, but complex systems which are indeed formed by several subcomponents[9]. Knowing how those components behave is a very important step to the understanding of how bulges form and evolve.

Simulations also predict these subcomponents in bulges. [5] shows that in cosmological simulations, at least two stellar components (with different ages, metallicities and kinematics) form the bulge in Milky Way like galaxies.

The decomposition has been tried in several works before, but the methodology and observations only allowed to decouple bulge and disc [8, 4] or kinematically very different components, like counter rotating discs [2]. [8] used full spectral fitting to decouple a disc and a bulge from the integrated light of NGC 4030, decoupling the kinematics and the age of the stellar populations. However, the metallicity had to be fixed.

We present here a new technique, which will allow us, for the very first time, to obtain complete information (age, metallicity and kinematics) simultaneously of the stellar subcomponents present in bulges.

2 Sample

Our study is based on the analysis of three very different galaxies in terms of stellar populations. We chose galaxies in which the bulge has different contribution to the total luminosity of the galaxy, and with different complexity and morphological features (bulge, disc, rings, etc.). The galaxies are selected from Hyperleda, taking into account parameters such as radial velocity ($cz \leq 3500$), central surface brightness ($B \leq 12$) and inclination ($i \leq 45°$). Our three final candidates are the following:

- NGC 5701 is a barred spiral which is supposed to have no disc [3], and a round bulge. We expect this galaxy to be dominated by old stars.
- NGC 6753 is an unbarred galaxy, in which the contribution of the bulge is intermediate in our sample. A disc is clearly present, but the bulge is not negligible. From the results in [13] the velocity dispersion is extremely large. A star formation ring is also present.
- NGC 7552 is the most complex galaxy in our sample. It is dominated by the disc, with a very tiny bulge and lots of dust and star formation, which makes us suspect that the galaxy is dominated by young metal-poor stars.

These galaxies were observed with a high resolution mode ($R = 7000$) in the WiFeS integral field spectrograph on the 2.3 m telescope in the Siding Spring Observatory in a dark night, covering a filed of $38'' \times 25''$. Our aim was to obtain a high SNR (~ 100), but, due to bad weather, the SNR decreased considerably. Owing to this issue, we cannot make use

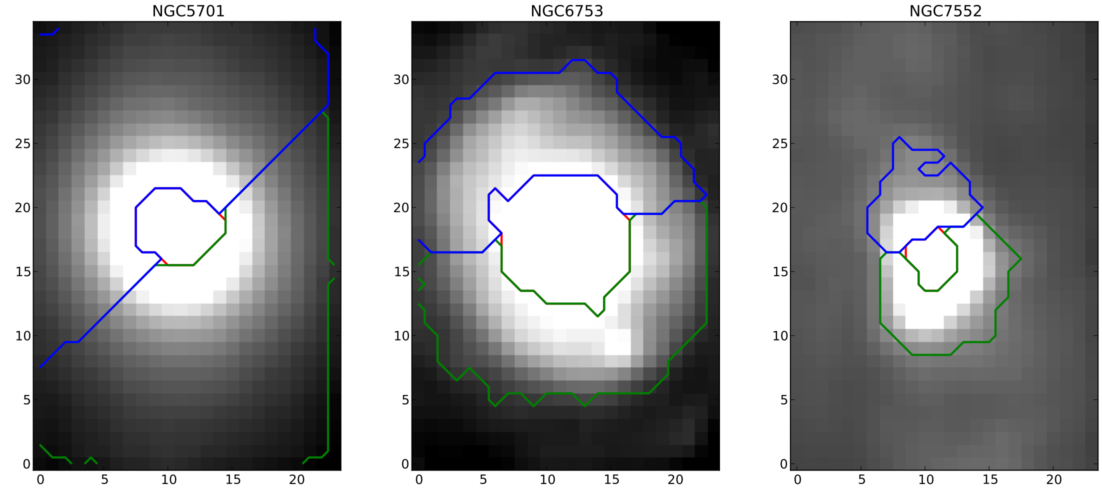

Figure 1: Regions in which the spectra were collapsed to increase the signal-to-noise ratio to a minimum, which allows to apply our methodology, in the three galaxies, from left to right, NGC 5701, NGC 6753 and NGC 7552. Region surrounded in red is the inner region and regions surrounded in blue and green are regions 1 and 2, respectively.

of the high spatial resolution of the instrument and had to bin the spaxels in three regions (shown in Fig. 1), one covering the very central regions and the other two, symmetric respect to the kinematical axis we obtained in [13].

3 Results

3.1 NGC 5701

Left upper panel in Fig. 2 shows the age-velocity and age-metallicity diagrams for the three regions (from top to bottom, outer region 1, inner region and outer region 2) in NGC 5701. In this galaxy we have detected three populations. Two of them are compatible with being bulge population, with old stars (~ 10 Gyr) and broad velocity distributions ($\sim 100\,\mathrm{km\,s^{-1}}$) centred on zero. The third population, however, is much younger (10 Myr), and is rotating with a velocity of $\sim 75\,\mathrm{km\,s^{-1}}$, as indicates the symmetry in the outer regions. This population is explained by star formation in a region close to the centre of the galaxy, which presents Hα emission [12].

3.2 NGC 6753

The diagrams corresponding to NGC 6753 can be found in right upper panel in Fig. 2. The three regions in this galaxy show three very different populations. There is an old population, which can be split in two subcomponents (more evident than in NGC 5701), corresponding to the bulge, with very large velocity dispersion, as was also found in [13]. Similarly as in NGC 5701 star formation (present in this galaxy as a ring) is recognized in the form of very young stars. As expected in a ring, this young population is more important in the outer regions. As a difference with NGC 5701, in this galaxy we detect a disc population, with intermediate of those of bulge and recently formed stars in terms of age, metallicity and kinematics.

3.3 NGC 7552

Lower panel in Fig. 2 shows the diagrams for NGC 7552. This galaxy is dominated by young stars, but a disc and a bulge are still visible. The disc, in this case, is formed by several bursts, as can be seen in the diagrams on the right panels. The lack of rotation in the diagrams owes to the inclination of the galaxy, which does not allow to appreciate it.

4 Conclusions

In this work we study the kinematics and stellar population simultaneously in three very different galaxies, obtaining results which are compatible with the results that we obtained, using a different methodology, in [13].

We demonstrate that the spectroscopic decomposition is possible, but it has some limitations. High spectral resolution and signal-to-noise ratio are needed to be able to decouple the components. We want to emphasize that the results are robust and, even when the three regions in each galaxy are analysed independently, without including information of one region in any of the others, the results are compatible and into agreement for the three regions in each galaxy.

Finally, we have confirmed and characterized empirically that bulges are complex structures conformed by several substructures which have different properties, as predicted by cosmological simulations.

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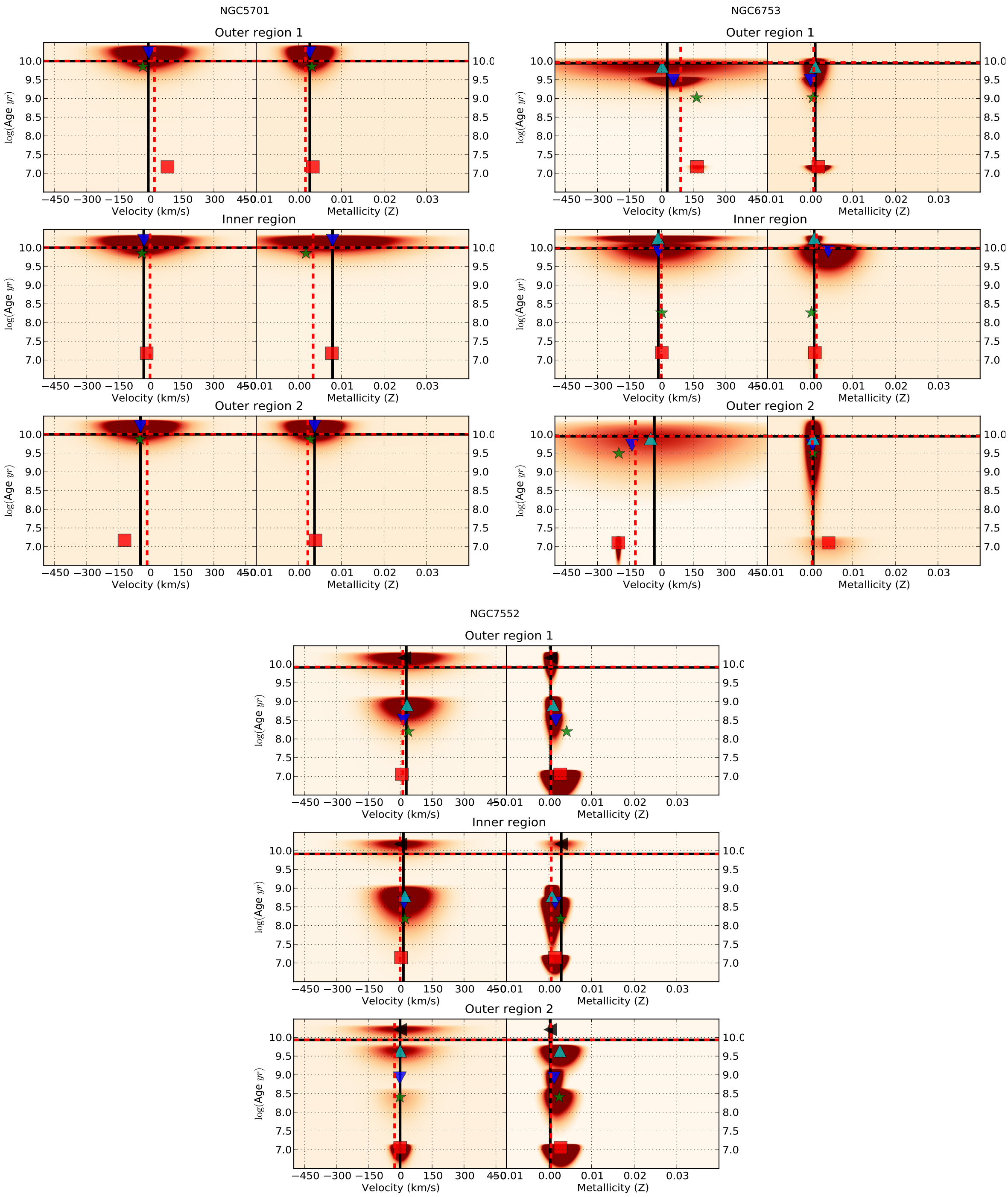

Figure 2: Age-velocity (*left* panels) and age-metallicity (*right* panels) for the outer region 1 (*upper* panels), inner region (*central* panels) and outer region 2 (*lower* panels) in NGC 5701 (*top left*), NGC 6753 (*top right*) and NGC 7552 (*bottom*). Red shadows represent the distributions of the populations, with intensity representing the contribution. Symbols of different shape and colour represent different stellar populations. Red dashed lines represent the mean values obtained with STECKMAP in a "classical" way, and black solid lines represent the mean values obtained with the new methodology.

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