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Testing Evolutionary Population Synthesis models with Early Type Galaxies in the Near Infrared

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Abstract. We employed Apache Point Observatory TripleSpec near infrared spectra (NIR, ∼1.0μm-2.4μm) of 6 early-type galaxies, and one spiral galaxy, to test 5 evolutionary population synthesis models in the near infrared. We used 3 low spectral resolution and 2 high spectral resolution bases of simple stellar populations (SSPs) and found that, when using bases with low spectral resolution, the result depends more on the base used than on the galactic properties themselves. For high spectral resolution bases, the same result could not be tested because these bases do not include SSPs younger than 1 Gyr. However, these two bases produced different results, with differences up to 70 percent in one object.

Keywords : galaxies: stellar content – stars: AGB and post-AGB – infrared: galaxies

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1. Introduction

To study the stellar content of astronomical objects not resolvable by modern telescopes (e.g. galaxies), several methods can be employed. One of the main methods to identify the stellar content is by comparing their observed spectra with combinations of simple stellar population (SSPs) libraries. The libraries can be empirical (in this case being limited by the properties of nearby stellar clusters) or can be constructed by appealing to knowledge about stellar evolution, a technique called evolutionary population synthesis (EPS, e.g. Bruzual & Charlot 2003; Maraston 2005; Conroy, Gunn & White 2009; Meneses-Goytia et al. 2015, Röck et al. 2016, hereafter BC03, M05, C09, MG15 and MIUSCAT, respectively).

According to Chen et al. (2010), in the optical region different bases tend to give similar results. However, for the NIR, poorly known evolutionary stages (e.g. Thermally Pulsing Asymptotic Giant Branch Stars) display a significant contribution compared to the optical region. This happens because some processes of stellar evolution (mass-loss, changing opacities, dredge-up events, etc.) are not well understood, and receive a different treatment in each model flavour.

The main goal of this project was to compare the stellar population fits derived using NIR spectra of different sets of EPS models for the central region of 6 local early-type galaxies (ETGs) and one spiral galaxy. ETGs were chosen because they contain relatively homogeneous old stellar populations (Rickes, Pastoriza & Bonatto 2009, and references therein).

2. Sample and Methodology

For this work we chose 5 different sets of EPS models: BC03, M05, C09, MG15 and MIUSCAT. The first three have $R \sim 300$ and the latter two have $R \sim 2000$ in the NIR. The spectra were obtained using Apache Point Observatory TripleSpec NIR (10000–24000 Å). The objects used for the comparison were NGC 4636, NGC 5905, NGC 5966, NGC 6081, NGC 6146, NGC 6338 and UGC 08234.

The spectral fitting of the spectra was carried out using the STARLIGHT code (Cid Fernandes et al. 2004, 2005). The code attempts to fit the observed spectrum with a combination of SSPs in different proportions by minimising the χ^2. It also searches for the reddening that best describes the observed spectrum. We divided our stellar populations into young ($t \leqslant 50$Myr), intermediate ($50\text{Myr} < t \leqslant 2\text{Gyr}$) and old ($t > 2$Gyr). We also added a featureless continuum (FC) to represent the emission from an AGN, plus black bodies (BB) with temperatures between 700 and 1400 K to account for hot dust emission.

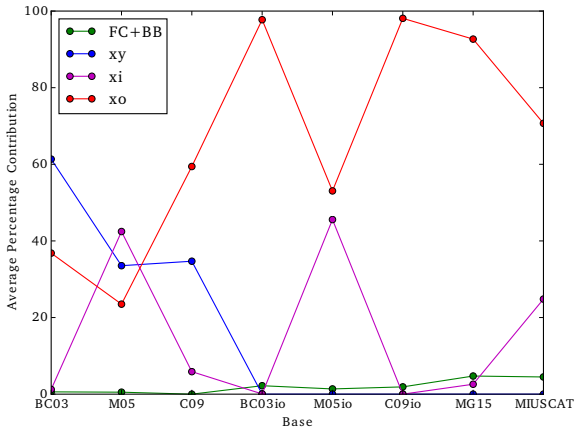

Figure 1. Average percentage contribution for each base. Young populations are displayed in blue, intermediate-aged populations in magenta and old stellar populations in red. Green shows the summed contributions from featureless continua and black bodies.

3. Results

For spectral synthesis using bases with low spectral resolution, the results were more linked to the base used than to the object properties themselves. Fits performed with the BC03 base appear dominated by young populations, with a mild contribution from old populations and a higher reddening. When M05 is used, the sample shows a dominance of intermediate age populations, with significant amounts of young and old populations. When C09 base was used, STARLIGHT found a dominance of old stellar populations, with mild contribution coming from young populations.

In order to be able to compare the results with high-resolution bases that do not include populations younger than 1 Gyr, we removed the young (t < 1 Gyr) SSPs from these bases and performed the fitting again. We labelled these bases BC03io, M05io and C09io, where 'io' stands for intermediate-old. BC03io and C09io models resulted in a ~97% contribution from old populations for all the objects, with the other 3% coming from FC and BB. With these bases, no contribution from intermediate-age populations was found. On the other hand, when using M05io models, 3 objects (NGC 4636, NGC 5905 and NGC 6081) appeared dominated by intermediate-age populations, whereas the rest of the sample were dominated by old stellar populations but with a moderate (>21 %) contribution from intermediate SSPs in all cases.

With high-resolution bases, since they do not include SSPs younger than 1 Gyr, a dominance of old populations was found. Also, higher contributions from FC and BB were found compared to low-resolution bases. Although the results have improved compared to low-resolution bases, when using MIUSCAT then higher contributions

from intermediate-age SSPs were found compared to results obtained with MG15. On three objects (NGC 6338 and UGC 08234 and NGC 5905), MIUSCAT finds higher contributions from intermediate age populations (70, 54 and 31 % respectively). For these objects, no contribution was found using MG15. For a better visualisation of these differences, we plotted the average contribution from young, intermediate and old populations plus the summed contributions of the FC and BB on Figure 1.

The absorption bands were not fitted well when using low-resolution bases, though a slight improvement was obtained when young populations were included. Trials to fit the H and K band absorption features performed much better when we used high-resolution bases. Given the low S/N of the J band, even with high-resolution bases the absorptions could not be fitted well.

Considering that our sample was composed mainly of ETGs, the fact that the dominance of old populations only appeared after removing the young ages shows that the results are more influenced by the base than by the properties of the object. This scenario repeated for high-resolution models, even considering that they do not include ages younger than 1 Gyr. These results imply that a better understanding of stellar evolution is needed in order to construct NIR bases, since the biggest difference between the bases is the different treatment of the short evolutionary stages.

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