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# THE MULTIPLE STELLAR POPULATIONS OF GLOBULAR CLUSTERS IN EARLY-TYPE GALAXIES

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**Abstract.** It is now well-established that all Galactic globular clusters display multiple stellar populations. These stellar populations are characterized among other things by unique chemical signatures, similar to what is observed in the massive early-type galaxies centers. Here we present the effects of multiple stellar populations on the integrated properties of their host early-type galaxies. We specially focus our study on their impact on the stellar $M/L$ that have been used to infer variations in the stellar initial mass function in the center of these massive galaxies.

Keywords: galaxies: stellar content, galaxies: abundances, galaxies: star clusters: general

## 1 Introduction

In the past decades, spectroscopic studies of globular clusters (GCs) provided evidence of strong star-to-star variations of the light element abundances leading to think that these stellar clusters are not composed of a unique simple stellar population as always thought but consist at least of two stellar populations. One of these stellar populations (1P) displays the same chemical abundance patterns as field stars in the neighbourhood, following the standard galactic chemical evolution. The second one (2P) displays He-, N-, Na-, Al-enrichment and C-, O- Mg-depletion (e.g. Gratton et al. 2012) compared to the 1P. GCs are composed of stars formed out of the same molecular cloud at the same time, thus these abundance variations are not expected to be the results of standard stellar evolution. The He-enrichment of stars has a strong impact on their evolution, and in turn, on the observed properties of their host GCs. Thus it should also affect the properties of their galaxy host.

Meanwhile, many massive early-type galaxies (ETGs) show higher far UV-luminosities than would be expected for this metal-rich stellar population (e.g. O'Connell 1999). This UV-excess is correlated to the stellar $M/L$ and mass of the host galaxy (e.g. Zaritsky et al. 2015). These massive ETGs also display in their center abundance gradients which is unlikely to be the result of a classical galactic chemical enrichment. Finally, the $M/L$ variation in the $r$-band among ETGs can be interpreted as an IMF variation towards a bottom-heavy distribution (Cappellari et al. 2012). The chemical features observed in massive ETGs are similar to the chemical patterns found in GCs. Similarly, the bright UV luminosities of GCs with hot horizontal branches due to their multiple stellar populations (MPs) are also reminiscent of the UV-excess in ETGs. Finally, the variation of stellar luminosities and stellar mass of the multiple stellar populations might lead to a variation of the $M/L$ between the different stellar populations in GCs. It would then be interesting to investigate if He rich stars of GCs would be an alternative explanation for the observed $M/L$ variations in massive ETGs.

Here we present the contribution of GCs to the stellar populations of massive ETGs and we explore the effects of the peculiar abundance pattern of MPs (i.e. enhanced He, N, Na, Al and depleted C and O) on the integrated properties of their host galaxy, focusing specially on the mass-to-light ratio.

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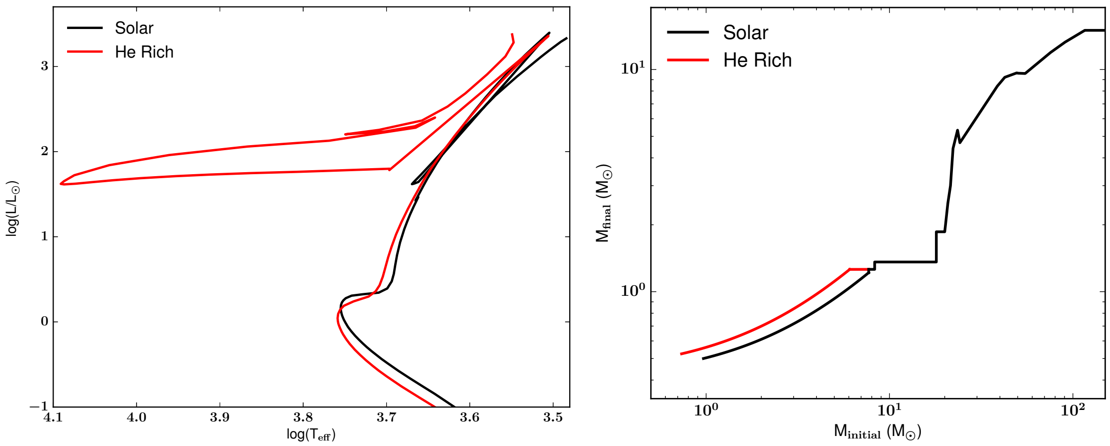

**Fig. 1.** Isochrones (**left**) and initial-final mass relationships (**right**) at $Z_\odot$ and 12.6 Gyr for He normal and He rich populations (black and red respectively). Figures from Chantereau et al. (2018).

## 2 Multiple stellar population models

To explain the presence of these multiple stellar populations in the ETGs core, we find that disrupted globular clusters (which hosted these stellar populations) in the center of ETGs may contribute to $\sim$ 35% of stars with 2P chemistry to the field population. In addition, $\sim$ 5% of these 2P stars would be strongly He enriched (for details, see Chantereau et al. 2018).

Stellar population models have been computed at $Z_\odot$ and an age of 12.6 Gyr for a solar He content and for an enhanced He content of 0.4 (mass fraction). For the He rich stellar population (2P), we also took into account the typical abundance variations of light elements observed such as a depletion of [C/Fe] and [O/Fe] (-0.6 dex) and an enrichment of [N/Fe] and [Na/Fe] (+1.0 dex, see Fig. 1, left panel). From these two stellar population models, we have also created a population more representative of the center of ETGs (ETG mixture) consisting of a mixture between the 2P stars ($\sim$ 35%) and the 1P stars (for details, see Chantereau et al. 2018). We have finally computed self-consistent stellar model atmospheres and synthesized stellar spectra with ATLAS12 and SYNTHE (Kurucz & Avrett 1981; Kurucz 2005).

The final mass of our 2P stars is $\sim$10% higher with respect to the final mass of He normal stars (see e.g. Karakas 2014; Shingles et al. 2015; Althaus et al. 2017; Chantereau et al. 2017), their initial-final mass relations are displayed in Fig. 1 (right panel). We note that the minimum initial mass needed to form neutron stars through electron-capture supernovae from He rich progenitors is dramatically shifted down compared to the He normal stars. Thus the neutron stars formation rate is increased in the framework of multiple stellar populations.

## 3 Mass-to-light ratio

The $M/L$ for our different models are displayed in Fig. 2. Despite the total remnant mass is higher for the He rich population, it is counterbalanced by the lower mass of stars still in the nuclear burning phase. Thus the total mass of both He normal and He rich populations are very similar. It is then the same for the ETG mixture population. Therefore the difference of $M/L$ for these populations comes mainly from differences in the light contribution. The He-rich model is brighter than the He-normal model at wavelengths bluer than 5000 Å, but fainter at redder wavelengths. This is mainly due to the stars from the hot horizontal branch (see Fig. 1, left panel).

Note that the ETG mixture and He rich population lead to a near-UV luminosity $\sim$2 and $\sim$20 times higher respectively than for the He normal population. This strengthens the idea that He rich populations in ETGs could play an important role in the observed UV-excess (e.g. Chung et al. 2017).

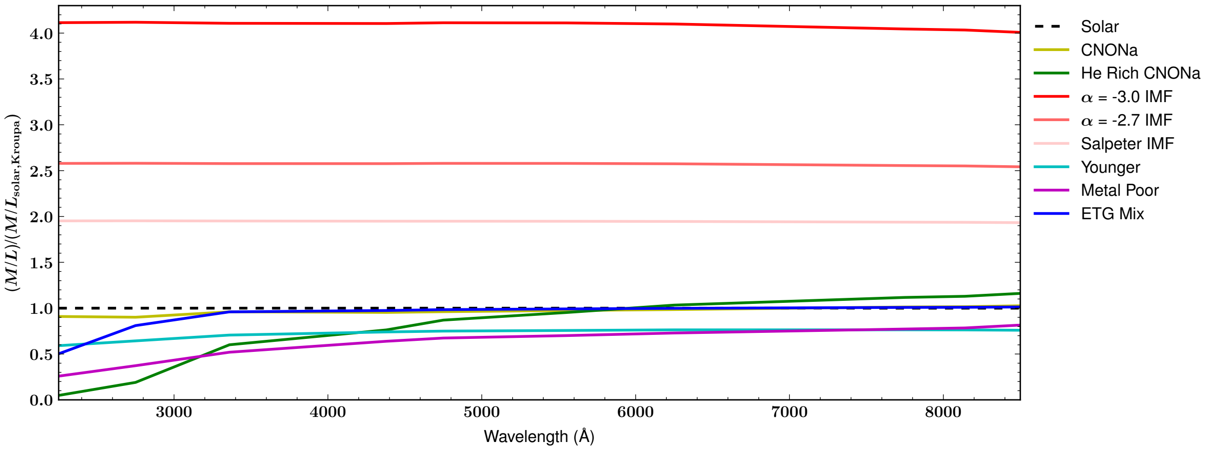

**Fig. 2.** $M/L$ as a function of wavelength. We focus our study here on the solar composition, Milky Way-like IMF model (black), the bottom heavy IMF model (red), and the ETG mixture model (blue). Figure from Chantereau et al. (2018).

Thus the He rich population has a negligible effect on the $M/L$ in the $r$-band (Fig. 2). This is very different from the high $M/L$ observed in the $r$-band of massive ETGs that could be expected from a stellar population with a bottom-heavy IMF (Cappellari et al. 2012). Thus, we can safely rule out the He rich population as the source of the $M/L$ variations in $r$-band in massive ETGs.

## 4 Conclusion

In this study, we find that disrupted GCs can supply a significant number of He, N and Na enhanced, C and O depleted stars to the field star population of ETGs; explaining the chemistry observed in the center of the most massive ones. In addition, the stars of these multiple populations are strong UV sources and can at least partially explain the UV-excess found in massive ETGs. However, we conclude that He enhancement cannot mimic the observational signatures of a bottom heavy IMF observed in these ETGs.

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