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Spectroscopy of globular cluster systems

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Abstract. We compare [α/Fe], metallicity, and age distributions of globular clusters in elliptical, lenticular, and spiral galaxies, which we derive from Lick line index measurements. We find a large number of globular clusters in elliptical galaxies that reach significantly higher [α/Fe] values (> 0.5 dex) than clusters in lenticular and spiral galaxies. Most of these highly α-enriched globular clusters are old ($t > 8$ Gyr) and exhibit relatively high metallicities up to solar values. Given the lower [α/Fe] ratios of the diffuse stellar population in early-type galaxies, our results suggest that the extremely α-enhanced globular clusters are members of the the very first generation of star clusters formed, and that their formation epochs likely predate the formation of the majority of stars in giant early-type galaxies.

Keywords. galaxies: star clusters, abundances, stellar content, formation, evolution

1. Introduction

Since they survive a Hubble time, globular cluster systems provide important information on the assembly history of their parent galaxy and the physical conditions in the star formation episodes during which they formed. Today's 8m-class telescopes allow us to access the chemical composition of individual extragalactic globular clusters in massive early-type galaxies which can provide insight on the enrichment histories and timescales of their parent massive gas clouds.

Because of the different progenitor lifetimes of type II and type Ia supernovae (SNe; e.g. Tornambé & Matteucci 1986) and the different chemical composition of their ejecta (e.g. Nomoto *et al.* 1997), the progenitor gas clouds will exhibit different chemical signatures depending on whether they were enriched on short timescales predominantly by type II SNe, or on extended timescales by both type II and Ia SNe. Ages and chemical compositions of globular clusters can be used to reconstruct the early assembly histories of globular cluster systems and their host galaxies, since all but perhaps the most massive globular clusters ($> 10^6\,M_\odot$, e.g. ω Cen) are not able to retain their own SN ejecta (Recchi & Danziger 2005). Together with accurate ages and metallicities, the chemical composition of globular clusters can be used to reconstruct the early assembly histories of globular cluster systems and their host galaxies. Here, we investigate [α/Fe], metallicity, and age distributions of globular cluster systems as a function of environment: in elliptical, lenticular, and spiral galaxies based on high-quality spectroscopic data from the literature.

2. Results

The majority of our analysis is based on the spectroscopic dataset presented in Puzia *et al.* (2004), who obtained high-S/N spectra for globular clusters in seven early-type galaxies with the FORS multi-object spectrograph at VLT and augmented the sample with high-quality index measurements from the literature. In terms of calibration quality

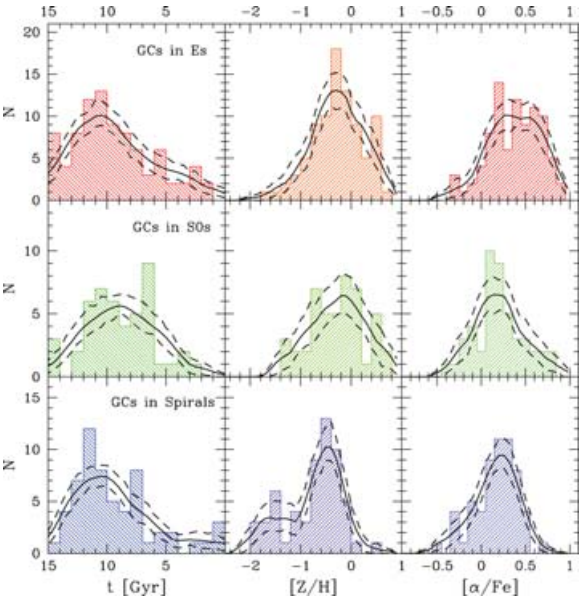

Figure 1. Age, metallicity, and [α/Fe] distributions of globular clusters in elliptical (upper row), lenticular (middle row), and spiral galaxies (bottom row). Solid curves are non-parametric probability density estimates with their 90% confidence limits indicated by dashed lines.

and signal-to-noise, it is, to our knowledge, the best-quality spectroscopic dataset of extragalactic globular clusters currently available.

Ages, metallicities, and [α/Fe] ratios are derived with an iterative χ^2-minimization approach of diagnostic grids taking into account index measurement errors and systematic uncertainties of the Lick index system, following the technique described in Puzia *et al.* (2005). Figure 1 shows the corresponding distributions. It is important to realize that the very high [α/Fe] ratios for old globular clusters in elliptical galaxies are not mirrored in the diffuse-light stellar populations of their host galaxies (typically 0.25 dex, e.g. Thomas *et al.* 2005). This strongly suggests that the formation of massive globular clusters with extremely high [α/Fe] ratios predates the formation of the majority of stars in elliptical galaxies. High-multiplexity spectrographs at future 30m-class telescopes will be able to refine this picture.

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