

Extragalactic GCs in the near-infrared: genuinely old in E/S0's?†

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Globular cluster (GC) systems are powerful probes to study the evolutionary histories of galaxies, being tracers of major star formation episodes (Brodie & Strader 2006). They are found around all major galaxies and are easy to see far beyond the local group. Age dating GCs therefore helps pinpoint epochs of major star forming events. Spectroscopic age dating though (Strader *et al.* 2005) is extremely time consuming and can only access the few brightest clusters. An alternative is to combine near-infrared (NIR) and optical photometry, and therefore have a better chance in lifting the age metallicity degeneracy than with optical colours alone. This approach relies in testing GC colours against simple stellar population (SSP) models. The first studies following this technique showed the possible existence of a high percentage of intermediate age (2-3 Gyrs) GCs in early-type galaxies known to contain old stellar populations from integrated light studies. Two strong cases can be listed: NGC 4365 (Puzia *et al.* 2002, Larsen *et al.* 2005) and NGC 5846 (Hempel *et al.* 2003). In the present study we combine NIR deep photometry obtained with the WHT/LIRIS instrument and archival HST/ACS optical images to determine $g(F475W)$, $z(F840LP)$ and $K(2.2\mu)$ magnitudes and colours of GCs in 14 early-type galaxies.

In Fig. 1, in the right and middle panels 2-colour diagrams for the GC systems observed are shown: $(g - k)$ vs. $(g - z)$. In the left panel a model grid from Maraston (2005) is over plotted whereas in the middle panel a model grid of Padova SSPs with Marigo *et al.* (2008) isochrones where there is a new treatment for the TP-AGB phase is plotted. According to Maraston (2005) models all galaxies exhibit a significant population of GCs that would fall in the intermediate age regime (2-3 Gyrs) as does NGC 4365. This is unlikely as these galaxies are known to contain old stellar populations (eg. Sauron survey). Charlot & Bruzual (2009) preliminary models yield basically the same conclusion: the $(g - k)$ SSPs are $\sim 0.2 - 0.3$ mag too blue. This offset is a generic feature of all older SSP models. According to Padova models with Marigo *et al.* (2008) isochrones (middle panel), the older tracks (~ 14 Gyr) fall where the intermediate age GCs would be located and old ages are implied for the GC systems. It is found that the data spread along $(g - k)$ cannot be attributed to stochastic effects, being either intrinsic or most probably due to observational errors. Whether the GCs presented here are "in fact" old depends on which set of models is chosen. If Padova models with Marigo *et al.* (2008) isochrones are considered old ages are derived. Finally, in the right panel the 2-colour plot $(g - k)$ vs. $(z - k)$ for GCs of M87 and NGC 4649 is shown. A SPoT-Teramo 14 Gyr SSP with a realistic treatment of horizontal branch morphology (Raimondo *et al.* 2005) is over plotted. Note the wavy feature the data presents around $(g - k) \sim 3.2$ and $(z - k) \sim 2$. This feature is also present in the SPoT-Teramo SSP model. Other SSP models (Charlot

† The data for NGC 4382 and NGC 4473 GC systems should be taken with caution as they were observed in highly extinguished conditions.

& Bruzual 2009, Maraston 2005 and Padova) that do not take into account the horizontal branch morphology do not show this behaviour. If the $(z - k)$ colour distribution (the best metallicity proxy) was unimodal and the $(g - k)$ still bimodal, this feature seen here could be indicative of the Yoon *et al.* (2006) scenario for colour bimodality.

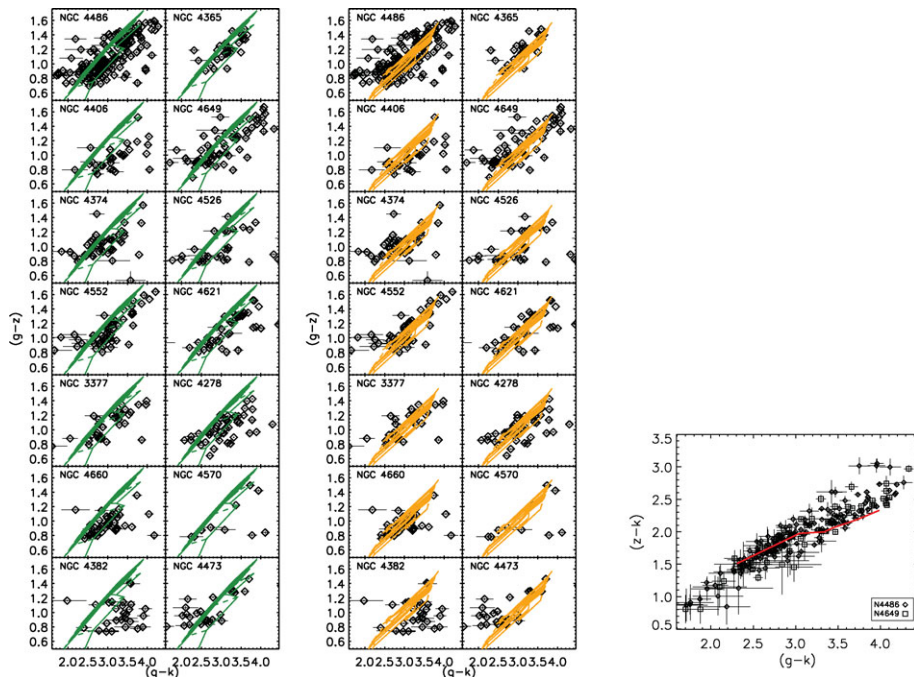


Figure 1. *Left panel:* 2 colour diagrams for the high quality data GCs for the 14 galaxies. $(g - k)$ vs. $(g - z)$. A model grid from Maraston (2005) is over plotted with model sequences of constant age as solid lines: 2, 3, 4, 5, 6, 8, 11, 14 Gyrs. *Middle panel:* same as left panel, now a model grid of Padova SSPs with Marigo *et al.* (2008) isochrones is over plotted with ages as in previous panel. *Right panel:* $(g - k)$ vs. $(z - k)$ for GCs of M87 and NGC 4649. The line is the SPoT-Teramo 14 Gyr SSP.

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