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FORMING GLOBULAR CLUSTER SYSTEMS SEMI-ANALYTICALLY

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RESUMEN

Describimos el escenario para la formación de sistemas de cúmulos globulares en galaxias elípticas utilizando un modelo semi-analítico de formación de galaxias. En una cosmología de tipo ΛCDM, asumimos que los cúmulos globulares de baja metalicidad se forman a altos corrimientos al rojo en fragmentos pre-galácticos, y que la consiguiente fusión rica en gas de estos fragmentos conduce a la formación de los cúmulos globulares de alta metalicidad. Comparamos nuestros resultados con datos contemporáneos y estudiamos el caso particular de las funciones de distribución de metalicidad estelar y de los cúmulos globulares de la galaxia elíptica cercana Centaurus A.

ABSTRACT

We describe a scheme for the formation of globular cluster systems in early-type galaxies using a semi-analytic model of galaxy formation. Operating within a ΛCDM cosmology, we assume that metal-poor globular clusters are formed at high-redshift in pre-galactic fragments, and that the subsequent gas-rich merging of these fragments leads to the formation of metal-rich clusters. We compare our results with contemporary data, and look at the particular case of the globular cluster and stellar metallicity distribution function of the nearby elliptical Centaurus A.

Key Words: **STARS: STAR CLUSTERS — GALAXIES: ELLIPTICAL**

1. GENERAL

Globular clusters (GCs) are long-lived tracers star formation, ranging from ancient, metal-poor stellar populations (e.g., Galactic halo GCs) to young, solar-metallicity stellar populations created during interactions (e.g., Schweizer et al. 1996). Due to their relatively "simple" nature (they are idealised simple stellar populations), the ages and metallicities of GCs can in principle be unambiguously determined. Hence, the study of GC systems affords a unique insight into the formation histories of galaxies.

We have investigated the formation of the GC systems of elliptical galaxies using the fiducial semi-analytic model of Cole et al. (2000). We (Beasley et al. 2002a) assume GC formation occurs in two modes; in pre-galactic fragments with GC formation truncated at high redshift, and during the dissipative merging of these fragments.

With these assumptions, we produced 450 realisations of elliptical galaxy GC systems of over a range of halo masses i.e., $1.0{\times}10^{13}h^{-1}M_\odot \leq \mathrm{M_h} \leq 1.3 \times 10^{15}h^{-1}M_\odot$.

Using simple stellar population models (Kurth, Fritz-v. Alvensleben & Fricke 1999), we can transfer our predictions into the observable plane. We have

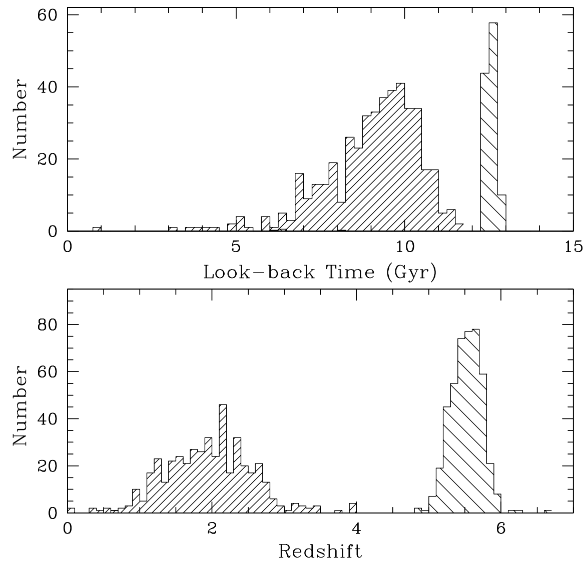

Fig. 1. The distribution in mean ages for 450 model GC systems. *Top panel:* Distribution in look-back time for the metal-rich GCs (dark histogram) and metal-poor GCs (light histogram). The metal-poor GC histogram has been scaled down by a factor of 6 for display purposes. *Bottom panel:* Distribution in formation redshifts for the GC sub-populations.

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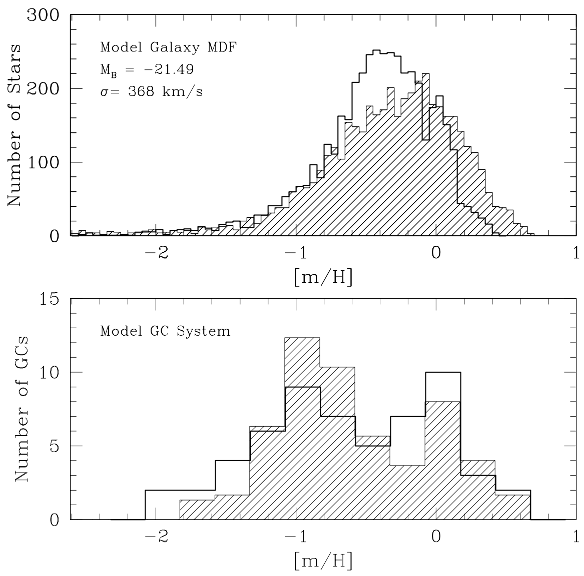

Fig. 2. *Upper panel:* Comparison between the semi-analytic model stellar metallicity distribution function (solid line), and the observed MDF of old stars in NGC 5128 from Harris & Harris (2002; shaded histogram). *Lower panel:* Comparison between the model GC MDF (solid line) and the observed NGC 5128 GCs (Held et al. 2002 private comm; shaded histogram).

compared our model results to contemporary data for the GC systems of elliptical galaxies, and the principle results from our study are as follows:

(i) The total number of GCs (N) scales with host galaxy luminosity as N $\propto L^{1.25}$, rather than the expected N $\propto L^{1.0}$ for constant GC formation efficiencies. This scaling is very similar to the observational data, and in the model is due to a $\mathcal{M}/L \propto L$ dependence for L_* ellipticals.

(ii) The formation of metal-rich GCs in low-redshift mergers does not significantly alter the S_N (number of GCs per unit starlight) of the host elliptical. This reflects the small gas-fractions of merger progenitors at later epochs.

(iii) The metal-poor GCs have *mean* ages of ~ 12 Gyr, whilst the metal-rich GCs have *mean* ages of ~ 9 Gyr (e.g. Fig 1). However, the age range of the metal-rich GCs in many individual galaxies is significant ($5 \sim 12$ Gyr) with a small fraction forming at the present epoch.

Our results suggest that metal-rich GCs may directly trace the merger history of their host galaxy whenever star formation occurs. Therefore, the metal-rich GCs are remnants of both star formation at later times and the dynamical assembly of their host galaxies, possibly providing a key to probing the formation epoch of elliptical galaxies.

Furthermore, our model provides explicit information on the ages and abundances of both the GCs and the "field" stars which aggregate to produce the final galaxy. Recently, Harris & Harris (2002) have constructed a metallicity distribution function (MDF) for the nearest giant elliptical galaxy Centaurus A (NGC 5128) using *HST*. By selecting model ellipticals occupying similar environments to this galaxy, we can directly compare its predicted and observed stellar content (see Beasley et al. 2002b).

Such a comparison is shown in Fig 2 for the stellar MDF of NGC 5128 and its GC system. The model MDFs are qualitatively similar to those observed; both model and data have stellar components which are predominantly metal-rich ($\sim 0.8 Z_\odot$), but possess a small number of metal-poor stars extending down to $0.002 Z_\odot$. Early gas infall in the model ameliorates the so-called "G-dwarf" problem (e.g. Kauffmann 1996).

Interestingly, we find that the model MDFs harbour a greater fraction of stars at $Z > Z_\odot$ than the observations, yielding a broader (by ~ 0.1 dex), more metal-rich MDF. This is possibly a result of the fact that these outer-bulge observations are missing some of the highest-metallicity stars in NGC 5128. Such a comparison facilitates the possible reconstruction of the star formation history of this nearby elliptical galaxy.

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