Globular Clusters in Compact Groups

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Abstract. We have studied globular cluster systems (GCSs) around elliptical galaxies in Hickson compact groups using multi–band deep, high quality images from Keck, VLT and CFHT. Analyzing the luminosity functions, specific frequencies, color and spatial distributions, we could determine the properties of the GCSs of those galaxies and trace their star formation histories. We have found poor populations, concentrated toward the center of the galaxies, with bimodal color distributions. The study of GCSs around galaxies in small groups are a blank on the globular cluster literature.

1 Introduction

Compact groups of galaxies are high density environments with small velocity dispersions where interactions should play a major role on the galaxies’ evolution. A sample of 100 compact groups was selected by Hickson (1982), the Hickson Compact Groups (HCGs). N-body simulations predict a collapse time smaller a fraction of a Hubble time (Barnes, 1989). The fact that they still exist in the Universe, has generated many discussions on its nature. The explanations presented range from chance alignments of galaxies in poor groups to a delay on the group collapse by special distributions of dark matter and kinematics.

In order to address the evolutionary history of galaxies in this kind of environment, we continued the study of globular cluster systems (GCSs), well known as good tracers of major events of star formation. Physical properties as its specific frequency, luminosity, spatial and color distributions, can give us important information about the formation and evolution of their host galaxies (Ashman & Zepf, 1998; Da Rocha et al., 2002), since we expect them to show signatures of the interaction processes.

2 The Sample

In this work we have studied early–type galaxies on three HCGs (HCG 22, 68 and 93) and the loose group Telescopium (Da Rocha, 2002; Da Rocha et al., 2002).

HCG 22A – brightest galaxy of the triplet HCG 22, classified as an E2 galaxy, at 33.1 Mpc, observed with Keck/LRIS in the $B$ and $R$ bands.
HCG 68A/B – two first ranked galaxies at the quintet HCG 68, classified as S0 and E2, at 23.8 Mpc, observed with CFHT/MOS in the R band. Pair in probable interaction, it was not possible to separate the individual GCSs, so we have analyzed it as a single GCS centered at the pair geometric center.

HCG 93A – brightest galaxy of the quartet HCG 93, an E1 galaxy, at 67.0 Mpc, observed with CFHT/SIS in the R band. Clear signs of interaction with other group members like a central dust spiral and a shell around it.

NGC 6868, the brightest galaxy of the loose group Telescopium, an E2 galaxy, at 26.8 Mpc, which has probably suffered a recent merger in its central part (Hansen et al., 1991). This galaxy will be used as our control sample.

3 Data Reduction

The bright galaxies were modeled and subtracted with STSDAS tasks ELLIPSE and BMODEL, and the detection and photometry was performed with SExtractor (Bertin & Arnouts, 1996). We have performed Monte–Carlo simulations to evaluate the images detection limits, completeness fraction function, photometric errors and star–galaxy separation index (see Da Rocha et al., 2002 for a detailed description).

The GC candidates were selected considering: the detection in both bands, for the cases where we have images in B and R; classification as point–source; magnitudes within the beginning of the luminosity function ($M_V \sim -11.0$) and the detection limit of the image and $(B - R)_0$ within 0.7 and 2.1.

4 Analysis and Results

4.1 HCG 22A

The magnitude limits applied to HCG 22A were $22.0 \leq B \leq 25.5$ and $20.0 \leq R \leq 24.0$. Using the radial distribution of selected objects we can notice a high concentration of objects close to the center, where the GC candidates will be selected, and a flat outer region, used to estimate the background level.

The globular clusters luminosity function (GCLF) was defined as a Gaussian with turnover magnitude at $-7.33 \pm 0.04$ and $\sigma = 1.40 \pm 0.05$. To HCG 22A this value are $B = 26.2 \pm 0.3$ and $R = 24.6 \pm 0.3$, which are fainter than our detection limits. For this reason we have left the turnover and the dispersion fixed.

To estimate the total number of objects in the GCS we have applied a radial extrapolation using two radial models: a core model ($\rho \propto (r_0^2 + r^\alpha)^{-1}$) and a power law model ($\rho \propto r^{-\alpha}$). We have obtained specific frequencies of $3.6 \pm 1.8$ and $5.2 \pm 3.2$ using the core and power law models, respectively, showing a normal to poor GCS, considering the error bars. The normal $S_N$ value for an elliptical galaxy is $\sim 3.5$ (Harris, 2001). The high slope fitted to the radial profile ($\alpha = 2.5 \pm 0.3$; see fig [3]) shows a GCS concentrated toward the center of the galaxy (the “regular” values range from 1.0 to 2.0 (Ashman & Zepf, 1998)).
The color distribution of GCs around HCG 22A was analyzed with the KMM (Ashman et al., 1994) which has detected the presence of two sub–populations with peaks at $(B - R)_0 = 1.13 \pm 0.04$ and $1.42 \pm 0.04$ (see fig 1), corresponding to metallicities of $[Fe/H] = -1.45 \pm 0.21$ dex and $-0.55 \pm 0.21$ dex. 62% of the GCs belong to the blue population and 38% to the red one.

**Fig. 1.** The left panels show the radial distribution of GC candidates around HCG 22A with the core model overplotted on dashed lines (panel (a)), the power law model (panel (b)) and the galaxy light on continuous line. The right panel shows the color distribution of the GC candidates with Epanechnikov kernel density estimator and its upper and lower limits overplotted (continuous and dotted lines). Dashed lines represent the color peaks located by KMM.

### 4.2 NGC 6868

To this “control–sample” galaxy the magnitude limits applied were $22.0 \leq B \leq 24.5$ and $20.0 \leq R \leq 23.0$ and the GCLF turnover is located at $B = 25.7 \pm 0.2$ and $R = 24.1 \pm 0.2$. The $S_N$ values found for this galaxy were $1.8 \pm 1.1$ and $1.9 \pm 1.0$, for the core and power law models, respectively, and show a poor GCS around this galaxy. The radial profile has a regular value slope of $1.4 \pm 0.3$.

The color distribution shows two sub–populations with peaks at $(B - R)_0 = 1.12 \pm 0.07$ and $1.42 \pm 0.07$ ([Fe/H] = $-1.48 \pm 0.22$ dex and $-0.55 \pm 0.22$ dex). 51% of the GCs are part of the blue population and 49% of the red population.

Comparing our results of HCG 22A and NGC 6868 with Forbes & Forte (2001) (fig 2), we can see that our results are consistent with those authors’.

### 4.3 HCG 68A/B

The magnitude limits applied to this galaxy pair was $20.0 \leq R \leq 23.5$ and the GCLF turnover is located at $R = 23.8 \pm 0.3$, very close to our detection limit.
Fig. 2. Color–velocity dispersion relation for the early–type galaxies of Forbes & Forte (2001). Panel (a) shows the values for the red peaks and panel (b) for the blue peaks. The solid line represents the color–velocity dispersion relation proposed by those authors. The filled pentagons are the values for HCG 22A and the open ones are the values for NGC 6868.

The high value estimated to the radial profile \(2.8 \pm 0.6\) shows, as in the case of HCG 22A, a GCS very concentrated toward the geometric center of the galaxy pair. The \(S_N\) values are \(1.3 \pm 0.8\) for the two models applied showing a poor GCS. Even if we consider an upper limit case where the whole GCS would belong to the elliptical galaxy, the specific frequency is not superior to \(3.1 \pm 1.7\).

The flattening of the central region, that can be seen in the radial profile (fig 3), can be caused by the projection or by the merger of the GCSs of the two galaxies and turns our \(S_N\) estimated on an upper limit.

4.4 HCG 93A

To this galaxy we have used \(22.5 \leq R \leq 25.5\) as magnitude limits and the GCLF turnover is located at \(R = 26.3 \pm 0.3\). The radial profile of selected objects shows a concentration of objects close to the center and two different flat levels that could be used as background level estimators (see fig 4).

We have performed three cases of analysis: (1) the background level was estimated using the whole flat area, from \(0.69\) (13 kpc) until \(1.59\) (31 kpc); (2) we have estimated the background level using the outer flat region, from \(1.14\) (22 kpc) until \(1.59\); (3) no background estimative was used, all selected objects were considered as GCs. The \(S_N\) values estimated for the three cases are extremely low (see table 1), showing a very poor GCS. The slopes of each case can also be seen in table 1, and indicate a normal to high concentration GCS.
Fig. 3. Radial distribution of GC candidates around HCG 68A/B with the core model overplotted (panel (a)) and power law model (panel (b)).

Table 1. Specific frequency values for HCG 93A

| Model                  | Analysis I   | Analysis II  | Analysis III  |
|-----------------------|--------------|--------------|---------------|
| $S_N$ for core model  | $0.16 \pm 0.11$ | $0.50 \pm 0.11$ | $1.57 \pm 0.11$ |
| $S_N$ for power law   | $0.25 \pm 0.11$ | $0.50 \pm 0.11$ | $1.43 \pm 0.11$ |
| Slope ($\alpha$)      | $2.4 \pm 0.5$  | $1.4 \pm 0.2$  | $0.9 \pm 0.1$  |

5 Summary

In our study we have found poor GCSs in groups, compact or loose, showing low specific frequency values. The GCS of the HCG galaxies are in all cases very concentrated toward the center of the galaxy ($\alpha > 2.0$) and the two multi–band analysis have shown multiple populations of GCs around those galaxies.

A possible cause for those poor systems is the erosion caused by the frequent interactions suffered by the galaxies in such dense environments, which, associated to the expansion suffered by the GCS during the interactions, may create a very efficient effect. Other possible cause would be an inefficiency on forming GCs, comparing to field stars, which may be due to the destruction of the GCs formation loci, as the super giant molecular clouds.

We intent to enhance our studied sample in order to obtain a statistically representative sample, enriching the literature, since there are only a few studies of GCSs on the small groups environment, compact or loose.
Fig. 4. Radial profile of selected objects around HCG 93A. Long dashed line corresponds to the background level estimated with the flat part from 0.
69 until 1.
59 (Analysis I). Short dashed line corresponds to the background level estimated with the flat part from 1.
14 until 1.
59 (Analysis II).

6 Acknowledgments

C.D.R. and C.M.dO acknowledge funding from FAPESP (grant No. 96/08986-5), PRONEX and the Alexander von Humboldt Foundation which made possible the attendance to the conference and also to ESO and the conference organizers for all the support.

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