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Globular Cluster Systems in the Hydra I Galaxy Cluster

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Abstract. In this contribution, first results of deep VLT (V,I) photometry in the central region of the Hydra I galaxy cluster are presented. Many star clusters have been identified not only around several early-type galaxies, but also in the intra-cluster field, as far as 250 kpc from the cluster center. Outside the bulges of the central galaxies NGC 3311 and NGC 3309, the intra-cluster globular cluster system is dominated by blue clusters whose spatial distribution is similar to that of the (newly discovered) dwarf galaxies in Hydra I. The color distributions of globular clusters around NGC 3311 and NGC 3309 are multimodal, with a sharp blue peak and a slightly broader distribution of the red cluster population.

1. Introduction

The study of globular clusters (GCs) in the center of galaxy clusters always has been of special interest due to their extraordinary rich abundance around the central (often cD) galaxy. Whether all central GCs belong to the bulge of the central galaxy or to the cluster as a whole is under discussion. Kinematic studies of GCs around NGC 1399 in the Fornax cluster (Richtler et al., this volume; Kissler-Patig et al. 1999) and M87 in the Virgo cluster (Bridges et al., this volume; Cohen & Ryzhov 1997) seem to indicate that most GCs outside a certain radius follow the gravitational potential of the galaxy cluster rather than that of the galaxy. Also the detection of GCs far outside the center of NGC 1399 (Dirsch et al., this volume) seems to confirm the existence of intra-cluster globular clusters, as predicted by some authors (e.g. West et al. 1995, and references therein). However, the process that is responsible for the formation of a very rich central GCS as well as a cD halo has not been understood yet. The main scenarios are *i)* a multi-phase *in situ* formation within a common host halo (Forbes et al. 1997), *ii)* stripping of GCs from nearby galaxies (Kissler-Patig et al. 1999), or *iii)* formation in small sub-halos and the subsequent assembly into a giant elliptical, as for example the accretion of a large number of dwarf galaxies (e.g. Côté et al. 1998; Hilker et al. 1999). In order to decide which one of the processes is dominant, further observational constraints are needed.

The availability of 8m-class telescopes has made it possible for the first time to investigate globular cluster systems in cluster of galaxies in great detail beyond the nearby Virgo and Fornax cluster. At the distance of the Hydra I cluster ($\simeq 44$ Mpc or $(m - M)_V \simeq 33.2$ mag; Struble & Rood 1991), only a few CCD fields are needed to cover a wide range in radius from the cluster core to the outside.

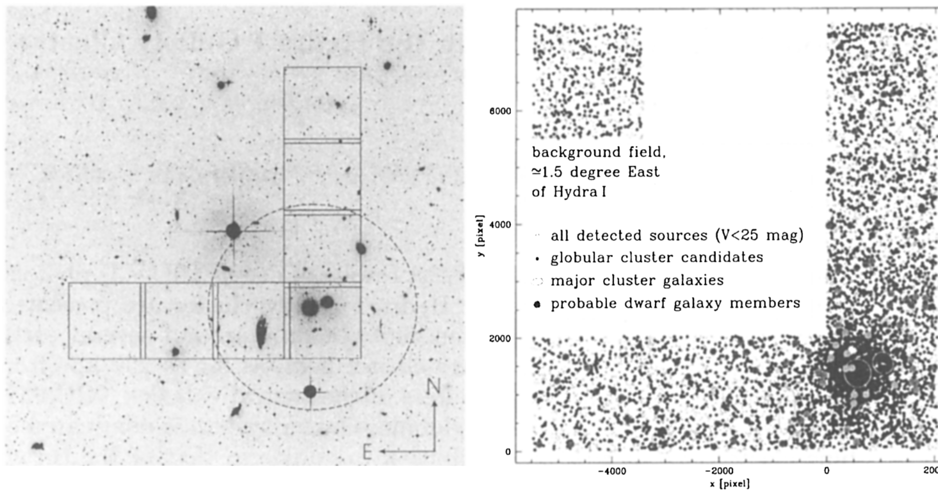

Figure 1. On the left, a DSS image of the central region of the Hydra I galaxy cluster is shown. The squares mark the position of the observed fields, the dotted circle the core radius of the cluster. In the right panel, the distribution of all detected sources, globular cluster candidates, major galaxies, and probable dwarf galaxy members are shown. Note the large extent of the central globular cluster system.

With good seeing conditions and moderate exposure times, globular clusters can be easily detected down to the peak of their luminosity function ($V \simeq 26$). Moreover, dwarf galaxies as faint as the Local Group dwarf spheroidals ($\mu_V \simeq 25$ mag/arcsec^2) can be resolved and morphologically classified, and their properties can be related to those of the globular clusters. The same is true for the extended stellar halo of the central cD galaxies whose light can be followed out to faint surface brightnesses. Such a dataset enables us to study not only the GCSs of individual galaxies, but the GCS of the galaxy cluster as a whole.

In this contribution, I present first results on globular clusters in the Hydra I galaxy cluster. This cluster has a compact regular core shape and a pair of bright galaxies in the center, whose brighter component, NGC 3311, possesses a cD halo and a extraordinary rich globular cluster system (e.g. McLaughlin et al. 1995).

2. Observation, reduction, and candidate selection

Images of seven fields in the Hydra I cluster (see L-shape configuration in Fig.1) and one background field have been taken through V and I filters. The observations have been performed in a service mode run in April 2000 with UT1/FORS1 at ESO/Paranal. All exposures were taken during dark time and with a seeing between $0\farcs5$ and $0\farcs7$. The exposure times for V and I were 3×8 min and 9×5.5 min, respectively.

On the combined images, the light of the main elliptical galaxies has been subtracted by ellipse fitting before applying SExtractor for the finding and photometry of the objects. Point sources have been measured through an aperture

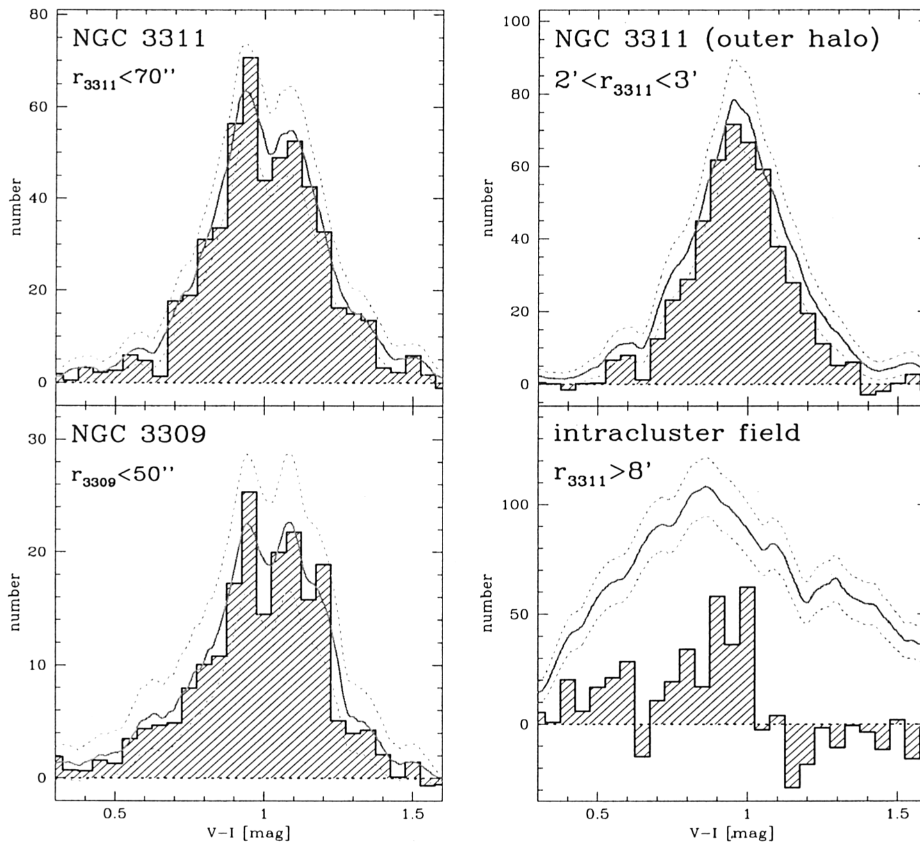

Figure 2. In this plot color distributions of globular cluster candidates brighter than $V = 25.5$ mag are shown. The hashed histograms are the background corrected distributions. The solid curves show the uncorrected distributions using a density estimation technique (Epanechnikov kernel). Whereas the histograms of NGC 3311 and NGC 3309 (left panels) indicate a clear separation between red and blue globular clusters, the globular clusters in the outer halo of NGC 3311 and the intra-cluster field are dominantly blue.

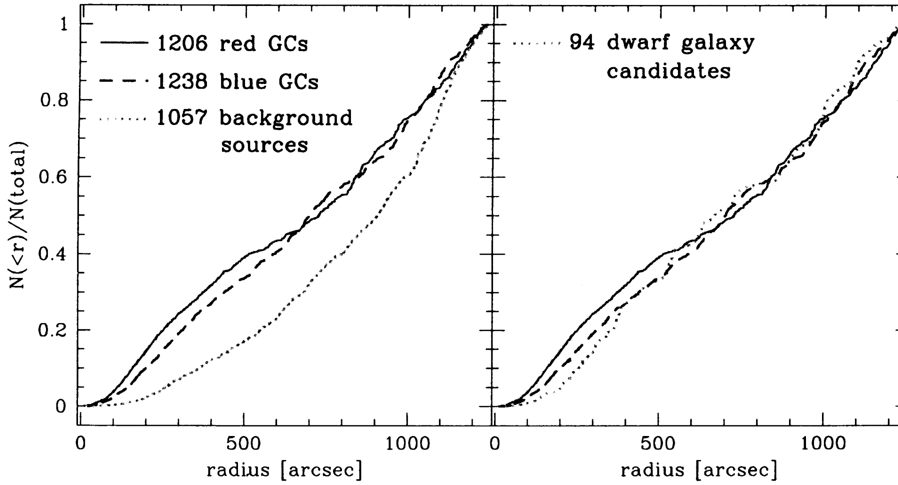

Figure 3. This plot shows the cumulative radial distribution of red and blue globular cluster sub-populations in Hydra 1. Additionally, the radial distribution of background sources (left panel) and dwarf galaxy candidates (right panel) are plotted. Within a 10′radius the red clusters are more concentrated than the blue ones. The dwarf galaxies follow the distribution of the blue cluster population.

of 2″diameter, and then corrected for the total magnitude and photometric zero points from the ESO standard calibration plan.

All objects that have a FMHM$\leq$2″and a color $0.4 < (V-I) < 1.6$ mag have been defined as globular cluster candidates. The adopted reddening throughout the analysis was $E_{V-I} = 0.10$ mag, the average of the values given by Schlegel et al. (1998) and Burstein & Heiles (1984).

3. Globular Cluster color and spatial distribution

Some years ago it was thought that there is a lack of metal-poor, blue GCs in the central galaxy NGC 3311. Using Washington photometry, only red GCs with a mean metallicity of [Fe/H]$=-0.31$ dex were found (Secker et al. 1995). Only recently, this surprising result has been overruled by HST photometry, which shows a normal color distribution of the GCS, comparable to that of other giant ellipticals (Brodie el al. 2000). This has also been confirmed by our analysis (see Fig.2). For the color distribution in Fig.2, only point sources with $V < 25.5$ mag and a photometric error less than 0.1 mag have been selected. Applying the same selection criteria for the control field, the color distribution of background sources has been subtracted statistically. NGC 3311 as well as NGC 3309 possess a blue globular cluster sub-population with a well defined peak at about $(V-I) = 0.93$ mag ([Fe/H]$\simeq -1.5$ dex). The red sub-population has a broader distribution peaking around $(V-I) = 1.08$ mag. Most probably, this reflects a superposition of several red sub-populations of different metallicities. The existence of an extended blue tail in the color distributions points either to a population of

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very metal-poor globular clusters ([Fe/H]< -2.0 dex) or a population of young clusters of a rather recent star formation event (that might be related to the central dust lane in NGC 3311).

In the outer halo of NGC 3311 (beyond 16 kpc from the galaxy center) blue globular clusters start to dominate the distribution. The lower right panel of Fig.2 shows that (mainly blue) globular clusters exist out to very large distances from the cluster center (< 250 kpc). In this plot all globular cluster systems of the major galaxies in Hydra have been excluded.

The dominance of blue globular clusters in the halo and the large extent of the intra-cluster GCS is also reflected in the radial distribution of the different sub-populations. Figure 3 shows the high concentration of red clusters ($1.0 < (V - I) < 1.2$) within a radius of $10'$. Interestingly, the distribution of dwarf galaxy candidates (see Fig.1) closely follows the distribution of blue globular clusters ($0.7 < (V - I) < 0.9$), except a possible deficiency in the very center of the cluster.

4. Future Analysis

The study of the color and spatial distribution has shown that the investigation of globular clusters in galaxy clusters should not only be restricted to the analysis of GCSs around individual member galaxies, but all the intra-cluster GCs have to be taken into account. The next steps for further analyses of the presented data are:

- Constructing a density and color map for the sub-populations of the intra-cluster GCS in order to define its center and compare it to that of the central galaxy and the X-ray gas halo.
- Modelling the cD halo light and study the specific frequency as a function of centro-cluster distance.
- Studying the individual GCSs for all member galaxies down to the dwarf galaxy regime (colors, density profiles, specific frequency, etc.).
- Confirming the membership of dwarf galaxies and bright compact objects by follow-up spectroscopy (Magellan I data in hand).

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Discussion

C. Grillmair: Has anyone ever found an offset between centers of globular cluster systems and the centers of their host galaxies/galaxy clusters?

M. Hilker: No, but our data set enables us to examine this for the first time. It would be of special interest to investigate this issue in clusters that show an X-ray halo whose center is displaced with respect to the position of the central galaxy.

J. Gallagher: Have you compared the radial distributions of blue GCs in Hydra with that of the dEs?

M. Hilker: First analysis seems to indicate that the spatial distribution of both populations are closely related (see Fig.3). However, the membership of the individual dwarf galaxy candidates has to be confirmed (by our follow-up spectroscopy for example) and their globular cluster systems have to be identified, before further interpretations can be made.