GLOBULAR CLUSTERS and X-RAY SOURCE POPULATIONS in NGC4261

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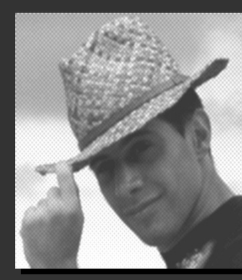

Introduction

The X-ray point-source population of elliptical galaxies consists of Low Mass X-ray Binaries (LMXBs) associated with old stellar population, and in particular to Globular Cluster (GC) counterparts (~50%; Fabbiano 2006, and references therein). One of the open debates about LMXBs formation is whether the GCs are the sole birthplaces of all the LMXBs (e.g. White, Sarazin, & Kulkarni 2002) or if they form independently also in the field (e.g. Juett 2005).

NGC4261 is a nearby (32Mpc) early-type galaxy in the Virgo cluster. Apart from "boxy" isophotes, this galaxy does not show any evidence of recent interaction, e.g. shells, ripples, rings or tidal tails, resulting in a very low fine structure parameter (Σ=1.0; Schweizer & Seitzer 1992). In such an environment, the X-ray sources are expected to be distributed uniformly, but the results from Zezas et al. (2003) and Giordano et al. (2005) suggested an interesting asymmetric distribution.

NGC4261 offers therefore a unique opportunity: proving that LMXBs and GCs indeed have a similar spatial distribution would be a strong evidence in favour of the hypothesis that GCs are the main birthplaces of LMXBs.

Method

The dataset is composed of a 100 ksec Chandra exposure and a collection of 6 HST WFPC2 pointings in the wide *B, V* and *I* filters (namely F450W, F606W and F814W), with a minimum exposure of 800 seconds per pointing.

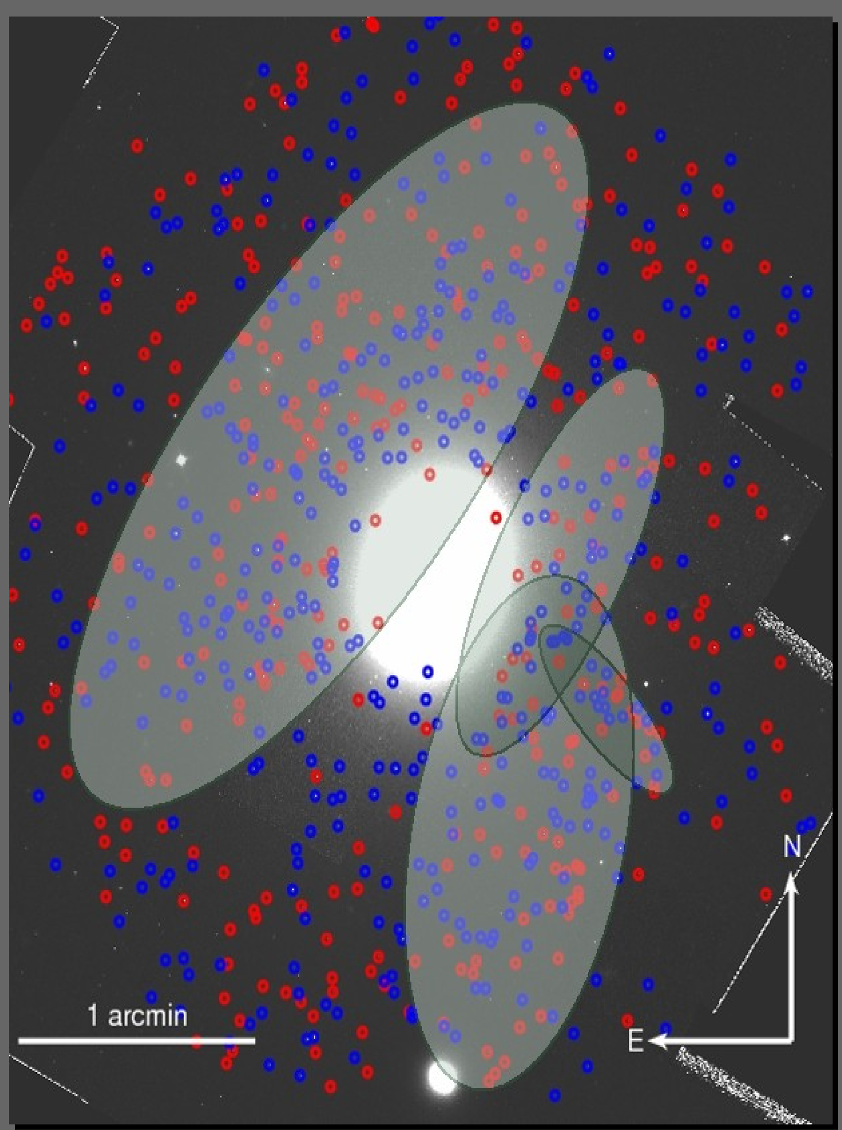

Figure 1. HST-WFPC2 (F814W) mosaic of NGC4261 with the red and blue GCs shown with red and blue points. The shaded ellipses show local enhancements in the distribution of GCs detected with the VTP algorithm. Each clustering is represented by an ellipse whose axes are 3 times the σ of the distribution of its GCs.

Figure 2. Adaptively smoothed Chandra image (in the 0.3-8.0 keV band). In this dataset, the asymmetry distribution of X-ray sources appear less dramatic than in Zezas et al. (2003). This is partly due to source variability, since we detect new bright objects in regions previously considered devoid of X-ray sources.

HST data

The sources in each HST band have been identified with SEXTRACTOR and GCs have been selected on the basis of FWHM, colour, and low ellipticity (Figure 1). *B*, *V*, *I* magnitudes have been calculated using the conversion factors by Holtzman et al. (1995). The *V* and *I* band source lists (the most populated) have been cross-correlated to give the final GCs candidate list (~760 objects with S/N higher than 5 and photometric error less than 0.3 mag).

In order to evaluate the incompleteness of the GCs sample, an artificial source test has been run. Fake GCs have been simulated convolving King profiles with the instrument PSF (generated using *TinyTim*). These objects have been added to the HST mosaics and their [known] characteristics have been measured with SEXTRACTOR using the same setup as for the real data. This analysis supported the criteria used for the identification of the GCs.

CHANDRA data

X-ray source detection has been performed using CIAO *wavedetect* in the 0.3-8.0 keV band. We identify 66 sources at the 3σ level, down to L~ 7×10^{37} erg/sec (assuming an absorbed power law with Γ=1.7, and Galactic N_H; Figure 2).

The candidate GCs and X-ray source lists have been cross-correlated within a search radius of 0.7", producing 30 matches. Monte Carlo simulations have been run to establish a match chance coincidence rate of 1%.

Results

Magnitudes and Colors

> We detect GCs candidates as faint as *V* ~ 25 mag (Figure 3).

> The GC color distribution shows a bimodality (Figure 4), in agreement with the typical GC color distribution in early-type galaxies (e.g. Ashman & Zepf). The distributions of the blue and the red sub-populations peak at *V-I* ~ 1.0 mag and *V-I* ~ 1.2 mag respectively.

X-ray sources – GC association

> In agreement with studies of other ellipticals (e.g. Sivakoff 2007, Fabbiano 2006 and references therein), X-ray sources are preferentially found in redder and brighter GCs (Figure 3 and Figure 5). We measure an association ratio of 3:1 with the red and blue clusters respectively, in agreement with the result of Kundu, Maccarone, & Zepf (2002) for NGC4472.

Radial Profiles

> The radial distribution of the GCs sub-populations are significantly different: blue GCs seem to follow a flatter profile, while the red ones are more peaked towards the center and more similar to the light profile of the galaxy (cf. Brodie & Strader 2006).

Azimuthal distribution

> A Voronoi Tasselation and Percolation (VTP) test has been used to determine local enhancements of GCs (Figure 1).

> The GCs density within radial wedges (Figure 7) show a significant (> 1 σ) peak around ~250° from the P.A. of the galaxy (-20°) for both the sub-populations.

>These results are compatible with the excess of X-ray sources found by Zezas et al. (2003).

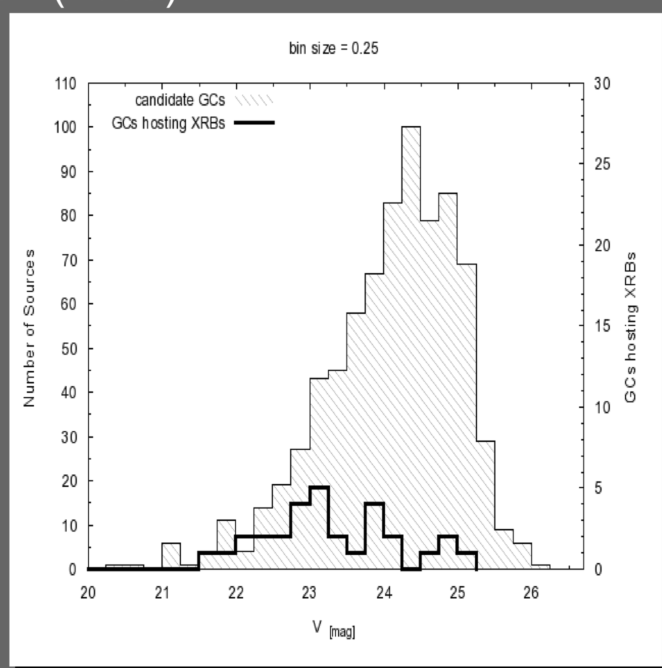

Figure 3. *V* mag histogram for all the GC candidates. The dark line represents the GCs associated to an X-ray source. The plot is affected by incompleteness at the faint end (*V* > 25 mag).

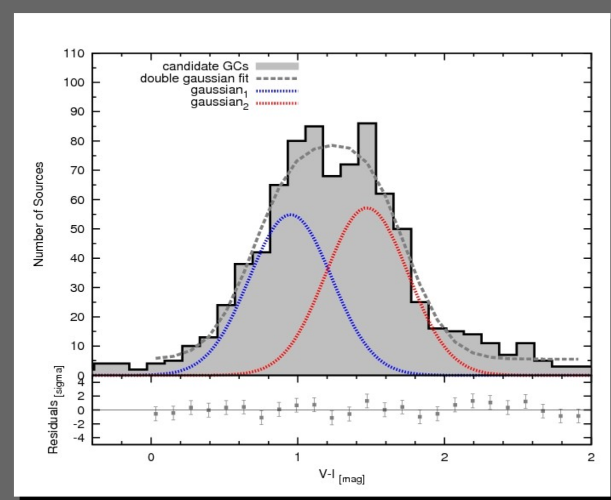

Figure 4. GCs color histogram. The distribution is clearly bimodal. The two gaussians represent the color distribution of the red and blue GC sub-population.

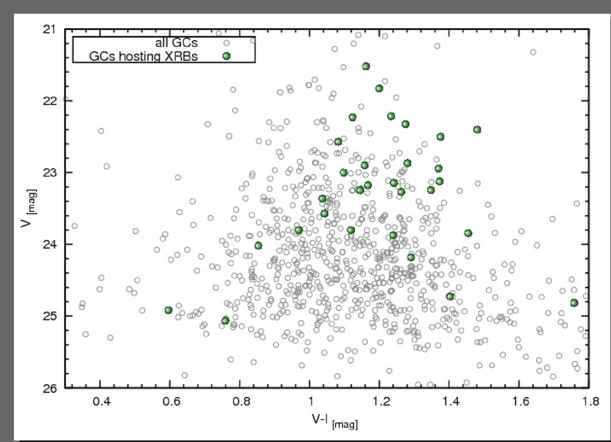

Figure 5. GCs color-magnitude scatter plot. X-ray sources are preferably found in redder and brighter Gcs (top right area).

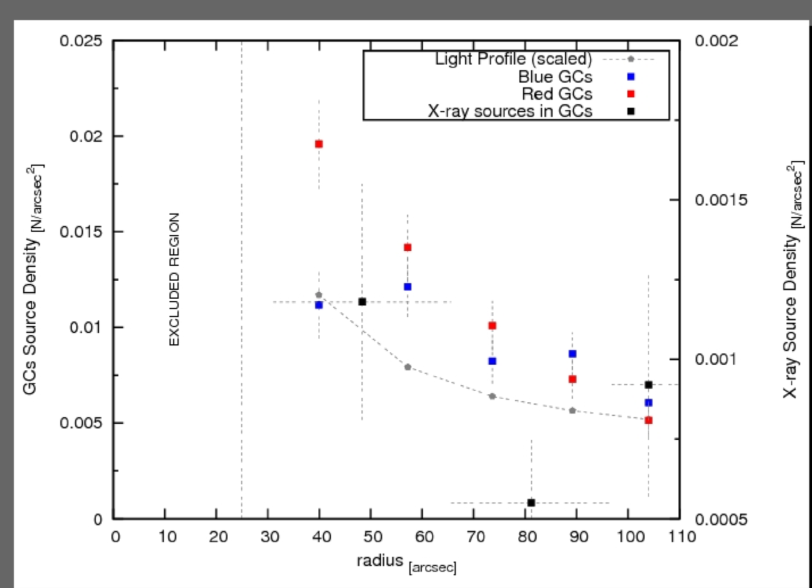

Figure 6. Source density radial profiles. Due to the small number of X-ray sources associated with GCs (30), their distribution has been evaluated on larger bins (horizontal bars). The starlight profile has been normalized for presentation purposes.

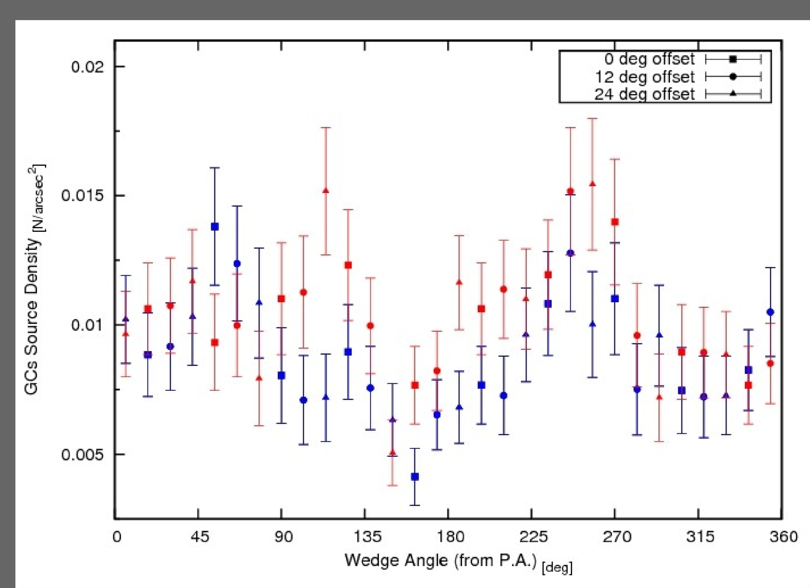

Figure 7. Source density azimuthal profile. The data points represent the density of GCs within wedges of 36° for the red and blue sub-populations. The measurement has been repeated for different rotations of the wedges in order to address the significance of the excess. The galaxy P.A. is ~ -20°.

Conclusions

> We detected ~ 760 GCs in NGC4261 down to *V* ~ 26 mag.

> We identified a red and blue GC sub-population whose colors peak at *V-I* ~ 1.0 mag and *V-I* ~ 1.2 mag respectively.

> 30 LMXBs have GC counterparts (preferably red and bright GCs).

> The radial distribution of the blue GCs is flatter than the one of the red GCs.

> The azimuthal distribution of both red and blue GCs shows evidence for asymmetry at the same P.A. at which the LMXBs cluster.

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