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A wide-field study of globular clusters in the nearest giant elliptical: Subaru/Suprime-Cam observations of Maffei 1⋆

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ABSTRACT
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Key words: Galaxies: individual: Maffei 1 – Galaxies: star clusters

1 INTRODUCTION

Add some general remarks on globular cluster systems.

Maffei 1 is a giant elliptical galaxy (Maffei 1968; Spinrad et al. 1971) located at only 0.5° North of the Galactic plane. This position implies large obscuration by dust from the Galactic disc which has hampered the measurement of even the most basic parameters of the galaxy.

Give main results from the literature

Its particular relative position has also conspired against the study of its globular clusters (GCs). Studies of its globular cluster system (GCS) have produced only a handful of GC candidates (Davidge 2002; Buta & McCall 2003; Davidge & van den Bergh 2005), whereas for its luminosity ($M_V \sim -20.80$, Fingerhut et al. 2007), the size of its GCS should be comparable to the one of Cen A, hosting $\sim$ 1300 GCs (Harris 2010).

In this paper we present the first wide-field study of the Maffei 1 GCS system using Subaru/SuprimeCam imaging.In Sect. 2 we present the imaging data used, as well as its reduction and photometry. In Sect. 3 we present the GCs selection, together with the derived properties of the GCS. Sect. 4 puts our results on a wider context, while Sect. 5 summarizes the work and give conclusions.

⋆ Based on data collected at Subaru Telescope, which is operated by the National Astronomical Observatory of Japan.

2 SUBARU/SUPRIME-CAM OBSERVATIONS AND DATA REDUCTION

Maffei 1 images were obtained using Suprime-Cam (Miyazaki et al. 2002) located on the Subaru telescope, Mauna Kea, Hawaii. Suprime-Cam comprises 10 CCD detectors separated by $\sim 15''$ covering a field-of-view of $34' \times 27'$ with a pixel scale of $0.2''$. SDSS r', i' and z'-band images were obtained during the night of January 5th, 2011. Several short exposures were taken with a $\sim 1'$ dither pattern, totalling 385, 280, and 280 seconds in the r', i' and z'-bands, respectively.

Suprime-Cam images reduction was conducted within the SDFRED2 pipeline (Ouchi et al. 2004). Reduction steps include bias subtraction, flat-fielding, correction for atmospheric distortions, point spread function (psf) equalization (i.e. the normalization of the psf to a single shape across the detectors and exposures), sky subtraction, image alignment and finally, the combination of all exposures and detectors into single images. Final averaged images have a field-of-view of $\sim 37' \times 31'$ and a seeing quality of $0.72''$, $0.68''$and $0.63''$, for r', i' and z', respectively.

For the z' image set, which is used as the basis for the GC candidates identification given its higher image quality (see Sect. 3.1), a parallel alternative reduction process was adopted. The z' dataset not only provides the reddest band to pierce through the Galactic plane, but also contains the best seeing images. Even though the same SDFRED2 pipeline was mostly used, a couple of the aforementioned reduction steps were skipped in order to mantain image manipulations that could alter the image quality to a minimum. Firstly, given the slight degradation of the psf towards the outer detectors, psf equalization across the chips would imply a lost of

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Figure 1. The Maffei 1 field as seen by Subaru-SuprimeCam. Image size is approximately $37' \times 31'$. North is up and East is to the left.

information on the best chips. For this reason the detectors were reduced independently and not combined into a single image as a final step. As a second difference, we did not apply any correction for atmospheric distorsions, since it resulted in an increase of about 10% of the measured stellar full width at half maximum (fwhm) due to charge shifting to neighbor pixels. Finally, images with psf sizes significantly larger than the mean were excluded from the final image combination. This resulted in the rejection of zero to two exposures per chip.

Coordinate transformations and image combination for the individual detectors were carried out with DAOMASTER/MONTAGE2 (Stetson 1993, 1994), which give more flexibility than SDFRED2 for images with a small overlapping area. Measured fwhm on the combined z' images varies between $0.52''$to $0.58''$from detector to detector, which are noticeably better than the $0.62''$measured on the combined full frame image given by SDFRED2.

As a last step prior to photometry, images presenting large background variations (containing Maffei 1 light or Galactic cirrus), were medianed filtered with 128 pixel boxes; a large size that preserves point-like sources unaltered. Photometry and astrometry were performed on the images fully processed with the SDFRED2 pipeline.

2.1 Stellar(ish) photometry

Aperture and psf-fitting photometry were carried out using the stand-alone DAOPHOT2 photometric suite (Stetson 1987). The psf was modelled selecting $\sim$120–140 bright and isolated stars on each detector. A quadratically varying Moffat function was found to provide the best description of the psf behaviour within the detectors.

Photometry for all the sources was also obtained using SExTRACTOR (Bertin & Arnouts 1996), which additionally provides measurements of the size, orientation and ellipticity of the sources.

3 RESULTS

3.1 Selecting globular clusters candidates

The basic selection criterium for GCs in Maffei 1 rests on the non-stellar shape of their light profiles. This shape, usually smeared out for distant systems or in images with low spatial resolution, should be noticeable for the largest GCs in Maffei 1 given the galaxy's distance and the quality of the imaging. A similar approach has been applied succesfully on ground-based imaging of GCs in the slightly more distant elliptical galaxy Centaurus A (Rejkuba 2001; Gómez et al. 2006; Gómez & Woodley 2007).

Star-subtracted z'-images produced by the psf-fitting algorithm in ALLSTAR, were visually inspected to look for residuals that revealed the presence of extended sources. The light profile of GCs (but also galaxies) would be over-subtracted in the central parts and under-subtracted in the wings, leaving an easily recognizable "ring-shaped" residual (see Fig. 2). A visual inspection of the residuals in the entire SuprimeCam field of view is painstaking proccess, but it was preferred over more automatized procedures such as relying on the star-galaxy separation of SExTRACTOR that could result in a large amount of false detections; a posterior analysis has shown that clearly resolved sources have been assigned a `CLASS_STAR` parameter value as high as 0.98, which on a blind approach would

Figure 2. Two examples of the psf-subtraction technique applied on the final z images to reveal extended sources. The left panels show the original image, while the right panels are the psf-subtracted images. Top panels: A round "Class A" object with fwhm=3.4 pixels. Note the ring-shaped residual. Bottom panels: A somewhat elongated "Class B" object with $\epsilon = 0.12$.

have been classified as stars. Our selected approach revealed the presence of XXX extended sources in the entire field of view.

The extended sources were separated into 3 classes based on the visual appeareance of their residuals in combination with their structural parameters measured with SExTRACTOR: circular residuals with fwhm $< XX$ (class A), symmetric but elongated residuals where the source has $\epsilon < 0.3$ (class B), and finally, elongated residuals with $\epsilon > 0.3$ together with sources with very extended (fwhm$>$ 6 pixels) or asymmetric residuals (class C). In the few cases where the source was not detected by SExtractor (usually because of the proximity of a bright star or the patchy Maffei 1 center), the classification was made only based on their visual appearance. The ellipticity limit of 0.3 was chosen since it contains all the ellipticities found for GCs in Local Group galaxies (e.g. van den Bergh 2008). These classes correlate with the likelihood of the sources being genuine Maffei 1 GCs based on their structure, with the round class-A objects having a higher probability of being genuine Maffei 1 GCs, and the elongated or large class-C sources, being most probably background galaxies.

3.2 Globular clusters color-magnitude diagram

3.3 Globular cluster sizes

4 DISCUSSION

5 SUMMARY AND CONCLUSIONS

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APPENDIX A: GLOBULAR CLUSTER CANDIDATES PHOTOMETRY

This paper has been typeset from a TEX/ LATEX file prepared by the author.

Table A1. Photometry of "Class A" (see main text for its definition) globular cluster candidates.

ID	RA	Dec	r'	i'	z'	ϵ	Notes
GC1	XX:XX:XX.XX	XX:XX:XX.XX	99.99 ± 99.99	99.99 ± 99.99	99.99 ± 99.99	9.99	

Table A2. Photometry of "Class B" globular cluster candidates.

ID	RA	Dec	r'	i'	z'	ϵ	Notes

Table A3. Photometry of "Class C" globular cluster candidates.

ID	RA	Dec	r'	i'	z'	ϵ	Notes