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Detecting extragalactic globular clusters in early-type galaxies in J-PLUS images

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Abstract. J-PLUS and S-PLUS are photometric surveys that can revolutionize the study of extragalactic globular clusters (GC). These objects will not be detected *a priori* by the data reduction pipeline of the surveys. In order to fill this gap, here we present a study for developing a pipeline to detect GC candidates, exploring methods for galaxy subtraction as well as objects selection. In our preliminary runs, the number of detected globular clusters candidates in NGC1023 is 188 ± 20 and the number of GC candidates in NGC3384 and M105 is 93 ± 15.

Resumo. J-PLUS e S-PLUS são surveys fotométricos que podem revolucionar o estudo de aglomerados globulares extragalácticos (AG). Esses objetos não serão detectados *a priori* pela pipeline de redução de dados dos surveys. Para suprir tal carência, neste trabalho apresentamos um estudo para desenvolver uma pipeline para detectar candidatos a AG, explorando métodos para subtração de galáxias, bem como seleção de objetos. Nesse estudo preliminar, o número de candidatos a aglomerados globulares detectados na NGC 1023 foi 188 ± 20 e o número de candidatos a AG na NGC3384 e na M105 foi 93 ± 15.

Keywords. Galaxies: star clusters: general

1. Introduction

Globular Clusters are found in most galaxies and are among the oldest radiant objects in the universe (Larsen 2001). The study of these objects is a powerful way to recover the history of galaxy formation and evolution.

J-PLUS (http://jplus.cefca.es) and S-PLUS (http://splus.iag.usp.br) are photometric surveys that together will observe about 15 000 square degrees of the sky. However, globular clusters will not be detected *a priori* by the data reduction pipeline of J-PLUS and S-PLUS. Therefore, being capable of detect GC in an automatized and efficient way is important to explore all the potential of the surveys for GC studies.

Here we show our preliminary results on detecting extragalactic GC in a semi-automatized way.

2. Developing the pipeline

We started working on J-PLUS images of the galaxies NGC1023 (S0), NGC3384(S0) and M105(E1) interactively. Due to the fact that NGC3384 and M105 appear very close to each other in the images, we worked with it as a single system.

J-PLUS (as well as S-PLUS) data are composed of observations in 5 broad-band filters based on SDSS filters plus 7 narrow-band filters that cover the major stellar indices from 3 700 to 9 000 Å. The galaxies were observed using the JAST/T80 telescope (diameter of 80 cm) and T80Cam (pixel scale of 0.55"/pixel).

With the aim of detecting point-like objects inlaid in the extended galaxy halo light, we first removed the smooth galaxy light profiles from the individual images. To execute this step we performed numerous tests with different software, among them: CHEFs (Jimènez-Teja & Benìtez 2012), ELLIPSE (Tody 1993) and ISOFIT (Ciambur 2015); in order to establish optimal input parameters. An example of a residual image after subtracting the bright galaxies of the field is presented in Fig. 1.

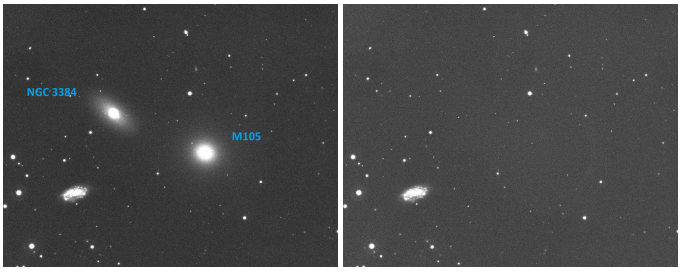

Figure 1. Left: NGC3384 and M105. Right: Residual image of NGC3384 and M105.

From the best residual images obtained using ISOFIT, the detection of point-like objects was performed using SExtractor (Bertin & Arnouts 1996). In order to select GC candidates, we adapted part of the methodology presented in Cho et al. (2016) and Kartha et al. (2014). We adopted criteria based on magnitude, color, data quality and shape. We started working on the detected objects of g and i bands.

The i band magnitude selection was $i \geq 18.9$ mag, because considering the distances of the galaxies (about 11 Mpc; Kartha et al. 2014, Bergond et al. 2006), objects brighter then this value would likely be ultra compact dwarfs (Kartha et al. 2014). The color range adopted was $0.65 \leq (g\text{-}i) \leq 1.3$ mag, as also presented by Kartha et al. (2014).

As a data quality criteria, we selected only objects with the SExtractor parameter *FLAGS* < 4 with the aim of excluding objects that are close to the edge of the images. We also selected only objects with a S/N > 5 relation by setting *MAGERR_ISO* < 0.2 mag (Cho et al. 2016) as shown in Fig. 2.

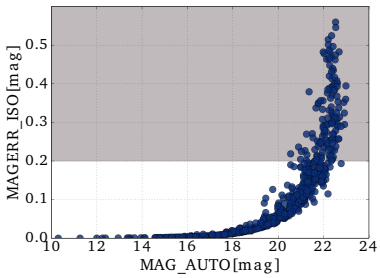

Figure 2. *MAGERR_ISO* adopted for NGC1023. Objects in gray regions were excluded.

Considering the shape of the detected objects, we required our GC candidates to be compact, so we were interested in objects with *CLASS_STAR* > 0.5. We also set limits for *FWHM* to select faint point-like sources (Cho et al. 2016). These criteria are illustrated in Fig. 3.

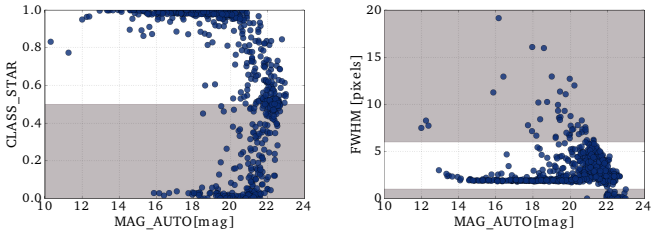

Figure 3. Left: *CLASS_STAR* adopted for NGC1023. Right: *FWHM* adopted for NGC1023. Objects in gray regions were excluded.

The remaining objects of this selection were considered to be the GC candidates of the *g* and *i* bands. In order to select the GC candidates of the other bands, we matched the positions of the GC candidates of *g* and *i* bands with the detected objects of the extra bands within a matching radius of 2 arcsec. As a sanity check, we also applied the selection of data quality and shape on the data of the new catalogs. By the end of the process, we obtained a catalog of GC candidates for each band and dataset.

3. Results

In these preliminary runs, we detected 188 ± 20 GC candidates in NGC1023, and 93 ± 15 GC candidates in NGC3384 and M105.

The numbers of detected GC candidates were compared to what is reported in literature for HST/ACS and VLT data (Cortesi et al. 2016; Bergond et al. 2006), as illustrated in Fig. 4. We are currently comparing the coordinates of the objects we detected with information found in published catalogs. We matched the position of about 20 % of the candidates within a matching radius of 2 arcsec.

Possible reasons for the different number of detections between our images and literature are currently being investigated. That can be at least partially explained by different magnitude limits, the large pixel size of the CCD used in J-PLUS (0.55"/pixel), and the relatively bad weather condition of some of our observing nights.

4. Conclusions and Perspectives

Our pipeline is able to partially retrieve the GC candidates, in comparison to studies reported in literature. Those literature

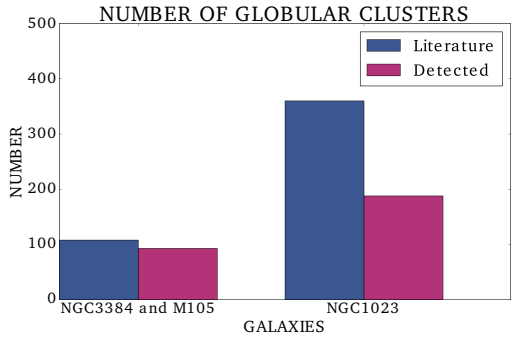

Figure 4. Comparison between our detection and literature.

studies were performed with better observing conditions and higher spatial resolutions, as such we consider that our preliminary partial match already illustrates the capabilities of J-PLUS for GC studies.

We plan to expand this work in the following ways:

1) Improve our methodology, exploring other software and criteria to increase the number of matches.

2) Apply what we have learned interactively to more datasets.

3) Automatize the methodology presented in this work, either making it available as a `python` script or as a scientific workflow like a script in Apache Taverna, a platform which has already being used for astronomical applications (see Benson & Walton 2009).

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