# Studying colors of extragalactic globular clusters using J-PLUS images

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**Abstract.** From J-PLUS images of the galaxies NGC 3384, M105 and NGC 1023 we selected globular cluster candidates using the pipeline GCFinder (Globular Cluster Finder). We studied the color distribution of these objects in order to investigate if color bimodality could be observed using colors not previously studied in the literature. The preliminary results show that color bimodality can be observed in 19 out of 57 color-magnitude diagrams of globular clusters in NGC 1023 and in 9 out of 15 color-magnitude diagrams of globular clusters in NGC 3384 and M105.

**Resumo.** A partir de imagens do J-PLUS das galáxias NGC 3384, M105 e NGC 1023 selecionamos candidatos a aglomerados globulares usando a pipeline GCFinder (Globular Cluster Finder). Nós estudamos a distribuição de cor desses objetos com o objetivo the investigar se bimodalidade de cor pode ser observada usando cores não estudadas antes na literatura. Os resultados preliminares indicam que há bimodalidade de cor em 19 dos 57 diagramas cor-magnitude de aglomerados globulares da galáxia NGC 1023 e em 9 dos 15 diagramas cor-magnitude de aglomerados globulares das galáxias NGC 3384 e M105.

**Keywords.** Galaxies: individual: NGC 1023, NGC 3384, M105 – Galaxies: star clusters: general – Galaxies: evolution

## 1. Introduction

Globular clusters (GCs) are found in most galaxies and the study of these objects is a powerful way to recover the history of galaxy assembly (Brodie & Strader 2006; Larsen 2001).

J-PLUS (http://jplus.cefca.es) and S-PLUS (www.splus.iag.usp.br) are photometric surveys composed by a set of original filters: 5 broad-band filters based on SDSS filters and 7 narrow-band filters. This novel set of filters can benefit the study of extragalactic globular clusters, since it is possible to perform an investigation of these objects using colors not previously studied in the literature.

In this work we present an overview of the pipeline GCFinder – a code created in order to select candidates of extragalactic GCs in J-PLUS and S-PLUS images –, and a preliminary color study of the obtained GC candidates.

## 2. Data and instruments

We studied J-PLUS images of the galaxies NGC 1023 (SB0), NGC 3384 (S0) and M105 (E1), observed using the JAST/T80 telescope (diameter of 80 cm) and T80Cam (pixel scale of 0.55"/pixel). NGC 3384 and M105 were studied as a single system, given their apparent proximity in the images.

## 3. The pipeline GCFinder

Extragalactic GCs will not be detected *a priori* by the data reduction pipeline of J-PLUS or S-PLUS. Therefore, in a previous phase of this work, we explored methods for galaxy subtraction as well as selection of objects in order to develop a pipeline to detect extragalactic GCs on images of these surveys. The structure of the current version of the pipeline GCFinder is presented in Figure 1 as a flux diagram.

Some details about GCFinder are presented below:

– The detection is performed using optimal input parameters in *SExtractor* (Bertin & Arnouts 1996).
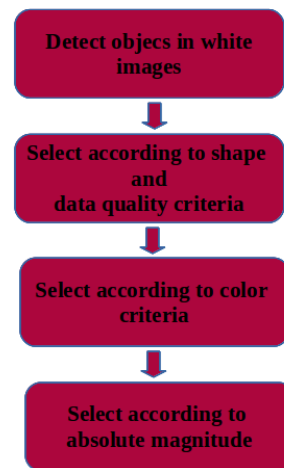


**Figure 1.** Flux diagram of the structure of GCFinder.

– The data quality criteria adopted is MAGERR_ISO < 0.2, in order to select only objects with S/N > 5 and FLAGS < 4 in order to exclude objects with bad photometry.
– The shape criteria adopted is limiting values of CLASS_STAR and FWHM in order to exclude extended objects (Cho et al. 2016; Kartha et al. 2014).
– We set color limits and magnitude limits in order to clear out obvious stellar contaminants.

## 4. Colors of GC candidates

We studied the color distribution of the GCs through color-magnitude diagrams (CMDs). Examples of CMDs can be seen in Figures 2, 3 and 4. We observed that the color distributions could be grouped in three cases:
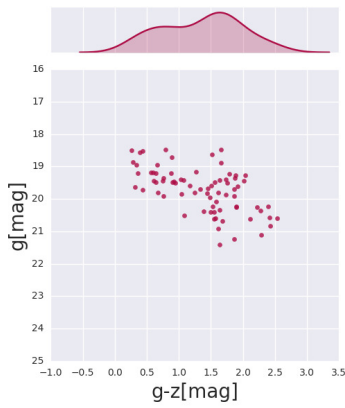
**FIGURE 2.** Possible bimodal color distribution of GCs in NGC 3384 and M105 (Case 1). The galaxies were studied as a single system, given their apparent proximity in the images.



**FIGURE 4.** Possible unimodal color distribution of GCs in NGC 1023 (Case 3).



**FIGURE 3.** Color distribution of GCs in NGC 3384 and M105 showing an ambiguous tail (Case 2). The galaxies were studied as a single system, given their apparent proximity in the images.

- Case 1: Possible bimodal color distribution
  In this case (Fig. 2), we have evidence of a bimodal color distribution of GCs, which might indicate 2 subpopulations of GCs (Brodie & Strader 2006).
- Case 2: Distribution with an ambiguous tail
  In this case, the density plots show an unimodal distribution with a tail and the data distributions on the CMDs indicate a possible color bimodality (Fig. 3).
- Case 3: Possible unimodal color distribution with a tail
  In this case, the density plots show an unimodal distribution with an extended tail and the distributions of the data on the CMDs show no evidence of color bimodality (Fig. 4).

## 5. Possible color bimodality

We visually investigated 57 CMDs for NGC 1023 data and 15 CMDs for NGC 3384 & M105 data and evaluated the percentage of each case of color distribution. The results are presented in Figure 5.

Our preliminary results show that color bimodality is observed only in a minor percentage of the studied colors. It is still necessary to improve the current version of GCFinder to obtain more accurate results, since there is still a possible contamination from stellar objects in the list of GC candidates.
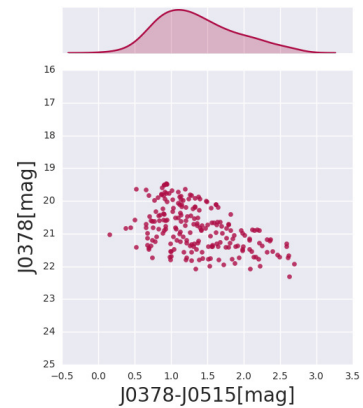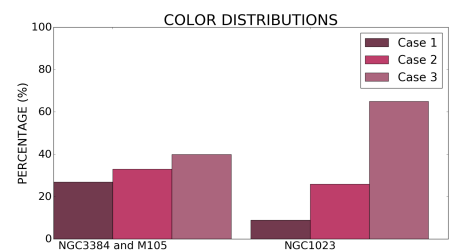


**FIGURE 5.** Percentage of each case of color distribution.

For our present data, we suggest that the colors $J0410 - J0660$, $g - i$ and $g - z$ are the best ones to identify the bimodal distributions of GCs.

## 6. Conclusions and perspectives

We observed that using the broad band filters of J-PLUS as well as its narrow-band filters, we can see evidence of color bimodality in some colors such as $J0410 - J0660$, $g - i$ and $g - z$, but the biggest part of the studied colors show unimodal distributions. The fact that we were able to identify colors that show bimodal distributions is an evidence that the studied galaxies are formed by more than one subpopulation of GCs and it is also an evidence that the galaxies likely passed through interaction events (Brodie & Strader 2006). We plan to expand this work in the following ways:

1. Improve GCFinder.
2. Delve into the study of subpopulations of GCs and stellar populations in other galaxies using the color distribution results.

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