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## CN2020A-63

Galactic panel
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# Low-luminosity globular clusters in the Milky Way bulge: characterizing a new population

### Abstract

Thanks to wide-field area photometric surveys, the number of the Milky Way globular cluster has substantially increased in the last few years. We propose to perform a follow-up using FEROS observations to characterize four recently discovered low-luminosity globular clusters candidates located in the inner regions of the Milky Way. These objects, detected in the Gaia DR2 data as spatial and dynamical overdensities, represent part of the faint end of the globular cluster luminosity function expected to be found in the Galactic bulge. Due to their physical projection on the sky (less than 100 pc), and their location in the Galaxy, it is unknown how they survive in a very hostile environment and how massive were its progenitors. For each candidate, the observations will allow us to characterize in high-resolution the clusters chemical abundance fingerprints and trace orbits to recreate its past events, and also give clues to find stripped stars within the bulge.

### Observing Blocks

| Instrument/Telescope | Req. time | Min. time | $1^{st}$ Option | $2^{nd}$ Option |
|---|---|---|---|---|
| FEROS/MPG 2.2-m | 3 nights | 1 nights | May Any | June Any |

### CoIs

| Name | Institution | e-mail | Observer? |
|---|---|---|---|
| Manuela Zoccali | PUC | mzoccali@astro.puc.cl | True |
| Rodrigo Contreras Ramos | PUC | rcontrer@astro.puc.cl | True |
| Alvaro Rojas | PUC | arojas@astro.puc.cl | True |
| Ivo Saviane | OCL | ivo.saviane@eso.org | True |

### Status of the project

- Past nights: 0
- Future nights: 0

- Long term: False
- Large program: False
- Thesis: True

## List of Targets

| ID | RA | DEC | Mag |
|---|---|---|---|
| CL-0010 | 18:00:00 | -32:00:00 | G=14.5 |
| CL-0061 | 17:00:00 | -35:30:00 | G=14.5 |
| CL-2217 | 18:10:00 | -28:40:00 | G=14.5 |

**Low-luminosity globular clusters in the Milky Way bulge: characterizing a new population**
**PI: Felipe Gran, Ph.D. student, PUC/MAS/ESO**

Abstract:

Thanks to wide-field area photometric surveys, the number of the Milky Way globular cluster has substantially increased in the last few years. We propose to perform a follow-up using FEROS observations to characterize four recently discovered low-luminosity globular clusters candidates located in the inner regions of the Milky Way. These objects, detected in the Gaia DR2 data as spatial and dynamical overdensities, represent part of the faint end of the globular cluster luminosity function expected to be found in the Galactic bulge. Due to their physical projection on the sky (less than 100 pc), and their location in the Galaxy, it is unknown how they survive in a very hostile environment and how massive were its progenitors. For each candidate, the observations will allow us to characterize in high-resolution the clusters chemical abundance fingerprints and trace orbits to recreate its past events, and also give clues to find stripped stars within the bulge.

Scientific aim and rationale:

As the oldest objects in our Galaxy, globular clusters (GCs) have a crucial role in the characterization of the early phases of its formation as they encapsulate the fossil record of the early stages of Milky Way. While most halo clusters have been extensively studied both photometrically and spectroscopically, GCs close to the plane of the Milky Way have not been equally explored, mostly due to a large amount of gas and dust in the disk and bulge line-of-sights. No consensus has been reached on the absolute number of clusters comprising the Milky Way GCs system. GCs towards the bulge, in particular, comprise more than the ~40% (Bica et al. 2016) of the total Milky Way GCs population, nevertheless have been avoided until recently when wide-field photometric surveys start imaging the central areas of our Galaxy. Mainly, but not limited to near-infrared surveys, numerous GCs detections have been contributed by the 2MASS (Skrutskie et al. 2006) and the VVV (Minniti et al. 2010) surveys. These surveys have vastly contributed to explore this complex area in terms of its GCs population. As an example, only in the direction of the Galactic bulge, in the last few years the number of candidate star clusters reported in the literature has risen significantly (e.g., Davidge 2001; Valenti et al. 2007; Valenti et al. 2010; Chun et al. 2010; Minniti et al. 2011; Moni Bidin et al. 2011; Borissova et al. 2014; Bica et al. 2016; Minniti et al. 2017c; Minniti et al. 2017a; Minniti et al. 2017b; Cohen et al. 2017).

Although several clusters have been discovered in lines of sight towards the bulge, extinction, differential reddening, and crowding conspire against the full census of this area, especially close to the Galactic plane. Recently, the Second Data Release of the Gaia survey (Gaia DR2, Brown et al. 2018) became available, adding another set of all-sky observations, this time with kinematic measurements for more than 1.3 billion stars. Despite the optical nature of its observations, which presents a more shallower view towards the plane (with almost no detections within |b| ≤ 1.5º), this catalogue comprises the most homogeneous and comprehensive survey of the Galactic bulge. Although parallaxes are not reliable at the bulge distance, proper motions are still statistically robust and provide a unique opportunity to enhance and complement efforts of finding clusters as overdensities.

Helmi et al. (2018) and Vasilev (2019) illustrated the potential of Gaia to characterize known GCs, including several in the bulge area. Aside from the confirmation the known ones, Gaia data was not used to search for new GCs in the inner Galaxy. New star clusters can be initially identified as overdensities, and the only way to confirm their cluster nature is to verify that their stars move coherently in space, i.e., they are gravitationally bound. This can be performed by measuring either radial velocities or proper motions (PMs) of stars in a region concentrated at the middle of the spatial overdensity.

We have used data from the Gaia DR2 to search for new GCs in the Milky Way bulge, using the full dynamical information available for most of the stars in the dataset. This method identifies unusual concentrations of stars simultaneously in the plane of the sky, in the vector point diagram (VPD) and in the color-magnitude diagram (CMD), recovering most of the known GCs of the bulge, only missing a few of them located in the plane (|b| ≤ 1.5º, Gran et al. 2019). Applying a clustering algorithm, we discover several candidates GCs that are absent from other catalogues (Harris 1996 online version, Kharchenko et al. 2016) and span the entire Galactic bulge as can be seen in **Figure 1** (Gran et al. in preparation). These candidates may represent several of the low luminosity GCs that are still missing in our Galaxy. This observations will help us to better understand the GC survival in the very hostile environment of the Galactic bulge, and also trace cluster orbits to reconstruct its past dynamical processes within the inner bulge (James & Adler 1982, Harris et al. 2013, Minniti et al. 2017, Alonso-Santiago et al. 2017).

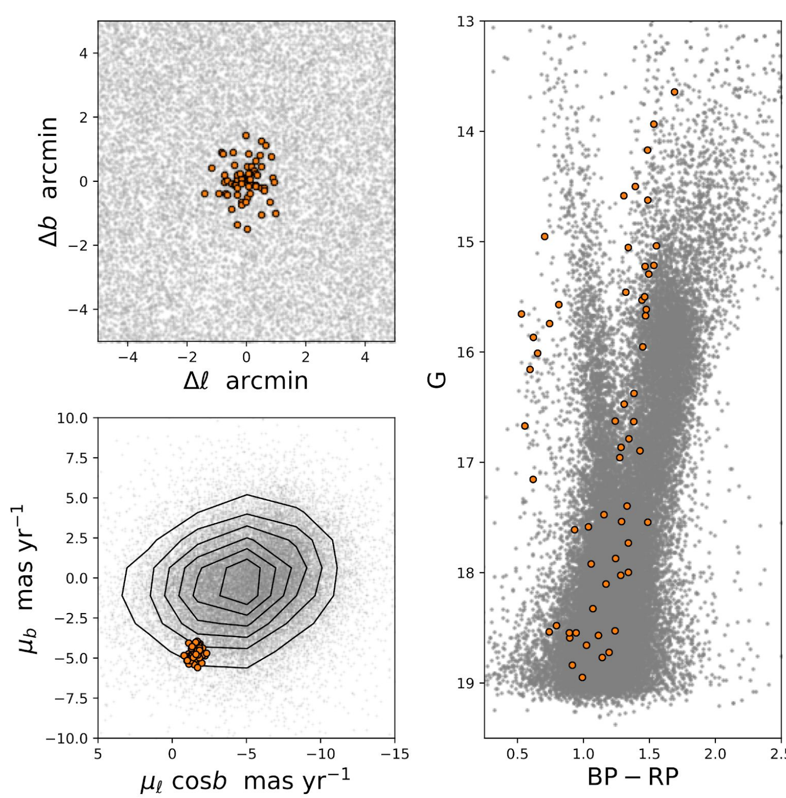


**Figure 1:** shows the spatial **(upper left)**, and dynamical properties of one of our GC candidates (CL2217) by means of color-magnitude diagram **(right)**, and vector-point diagram **(lower left**). As can be noticed, there is a clear overdensity (marked orange points) with an old distribution of its stars in an red-giant branch, clustered in space, and with space motion different than the surrounding field given by the contours.

We propose to perform a spectroscopic FEROS follow up to characterize in high-resolution the clusters chemical abundance fingerprints and trace the GC orbits to recreate its past events, and also give clues to find stripped stars within the bulge.

Description of the project:

As described above, we are currently exploiting Gaia DR2 data to perform a complete and a comprehensive search for missing clusters hidden in the highly extinct and crowded regions towards the inner Galactic bulge. The second data release of the Gaia survey provides us with an unprecedented catalog with positions, proper motions and optical colors for most of the bulge stars outside the plane (|b|>1.5°). An important part of the Ph.D. thesis of Felipe Gran is based on the characterization of the inner parts of the Galaxy in terms of its proper motions, in which interesting results have been discovered recently. Searching for unknown globular clusters in this area of the Galaxy, we have detected several overdensities highly grouped in the sky and proper motion space that resembles the typical behavior of an old red-giant branch. We pretend to constraint the chemical abundances and orbits of four (4) GC candidates initially detected in the Gaia DR2 catalog as shown in **Figure 1**. A high-resolution characterization will allow us to break the age-metallicity relation that the CMD imposes, disentangle the clusters past dynamical events within the bulge, give clues about the survivability of small clusters in the Galactic bulge and serve as a cornerstone to trace stars that may be stripped from the original GC applying a chemical and dynamical tagging approach.

Technical description:

We have selected 10 red-giant branch stars in four (4) of our GC candidates based on the spatial and dynamical information (Figure 1) to perform a complete characterization in terms of precise radial velocities (up to 0.2 km $s^{-1}$) and elemental abundances (C, N, O, Na, Mg, Al, Si, Ca, Sc, Ti, Cr, Mn, Co, Ni, Y, Zr, Ba, La, Ce, Br, Nd, and Eu at the ~0.1-0.2 dex level). We request FEROS observations with an exposure time of 106 minutes per star, splitting the observing time into 2 sub-exposures, each one 53 minutes long. According to the FEROS ETC, the resulting spectra will reach S/N~40 for a G=14.5 magnitude star, after the stacking process. This signal will allow us to calculate [Fe/H] via the equivalent width method, and the wide wavelength coverage of FEROS is optimal to perform full spectral fitting or data-driven models to recover elemental abundances (e.g. The Cannon, Ness et al. 2015). We simulate an observing block with the same information given in the manual to obtain a realistic measure of the overheads involved in the observation execution. Including the overheads, we need **120 minutes per star**, for each of the 10 stars spread in four (4) GC summing up to a total of **20 hours** for this proposal. Therefore we request 3 nights. As a minimum viable time to complete this project, we can select to observe half of the most statistically significant candidate clusters and perform the analysis using only 1 night.

References: Alonso-Santiago et al.  2017, MNRAS, 469, 1330; Bica et al. 2016, PASA, 33, 28; Borissova et al. 2014, A&A, 569, 24; Chun et al. 2010, A&A, 518, 15; Davidge 2001,AJ, 121, 3100; Harris 1966, AJ, 112, 1487; Harris et al. 2013, ApJ, 772, 82; Janes & Adler 1982, ApJS, 49, 425; Kharchenko et al. 2016, A&A, 585, A101; Minniti et al. 2010, NewA, 15, 433; Minniti et al. 2011, A&A, 527, 81; Minniti et al. 2017, ApJ, 849, 24; Minniti et al. 2017b, RNAAS, 1, 16; Minniti et al. 2017c, RNAAS, 1, 54; Moni Bidin et al. 2011, A&A, 535, 33; Ness et al. 2015, ApJ, 808, 16; Skrutskie et al. 2006, AJ, 131, 1163; Valenti et al. 2007, AJ, 133, 1287; Valenti et al. 2010, MNRAS, 402, 1729; Valenti et al. 2018, A&A, 616, 83; Watkins et al. 2015, ApJ, 812, 149.