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Unraveling the physical and chemical proprieties of globular clusters in dwarf galaxies

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Abstract. Dwarf galaxies (DGs) are galactic structures with stellar masses below $10^{9.5}$ M$_\odot$. These objects exhibit various morphological types and can be studied at different redshifts. To probe the properties of DGs, we use globular clusters (GCs), ancient stellar systems associated with the epoch of galaxy formation and of subsequent merger events. While important features of GCs in massive galaxies are known, these relationships and properties in DGs are not well-constrained. In this context, we present an analysis of the properties of globular cluster systems in dwarf irregular galaxies in the local universe (D < 20 Mpc), located in low-density regions. The initial analysis revealed a bimodal color distribution in some objects in the sample, an unexpected finding in DGs. Additionally, we investigate the relationship between the number of GCs and the virial mass of the dark matter halo.

Resumo. Galáxias anãs (GAs) são estruturas galácticas com massas estelares inferiores a $10^{9.5}$ M$_\odot$. Esses objetos apresentam diferentes tipos morfológicos e podem ser estudados em vários "redshifts". Para investigar as propriedades das GAs, utilizamos os aglomerados globulares (AGs), sistemas estelares antigos associados à formação da galáxia e eventos subsequentes de fusão. Conhecemos características importantes dos AGs em galáxias massivas, no entanto, essas relações e propriedades dos AGs nas GAs não estão bem restritas. Neste cenário, apresentamos uma análise das propriedades dos sistemas de aglomerados globulares em galáxias anãs irregulares no universo local (D < 20 Mpc), localizadas em regiões de baixa densidade. A análise inicial revelou uma distribuição de cor bimodal em alguns objetos da amostra, o que é uma descoberta inesperada em GAs. Além disso, investigamos a relação entre o número de AGs e a massa virial do halo de matéria escura.

Keywords. Dwarf Galaxies - Globular Clusters - Extragalactic Astrophysic

1. Introduction

Dwarf galaxies (DG) are the most abundant structures at all redshifts. The wide variety of morphologies and their significance in understanding the universe's evolution make these objects important laboratories for exploring cosmic evolution (Mateo 1998). Globular clusters (GC) are old stellar structures that formed alongside galaxies during their formation. As a result, they are remnants of the physical and chemical primordial environment Brodie & Strader (2006). While these objects trace important scale relations with their host galaxies, these relations are well-constrained for massive galaxies. However, in DGs, these relations are not clear. With this in mind, the main objective of this research is to extend the principal relations and parameters of GC systems in DGs. Therefore, we have defined a sample of 15 galaxies in the southern hemisphere and have searched for GC candidates within them. This project is in the stage of consolidating methodology. We have already worked with 5 of the 15 objects in the sample and have found GC candidates in all of them. Another crucial aspect of this research is to understand the dark matter, an essential component in galaxy formation and evolution. It is a topic of great importance in cosmological studies, impacting various aspects of the universe (Natanael et al. 2023). Therefore, understanding the relationship between GCs and the dark matter halo is crucial to explain Forbes et al. (2018).

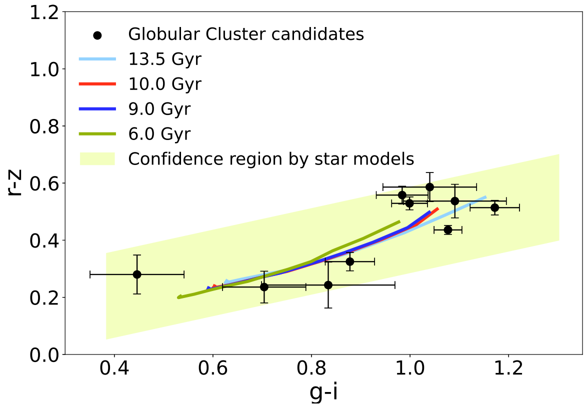

Figure 1. Colour bimodality in ESO410-018 GC populations.

2. Sample selection and data sets

We defined a sample of 15 dwarf irregular galaxies in the southern hemisphere. These galaxies have been selected from the S^{4}G survey (Sheth et al. 2010), they have masses ranging from 10^7 to 10^9 M$_\odot$ and maximum distance $d < 20$ Mpc. These objects have optical (*griz*) and radio (21-cm) observations from the DELVE Drlica-Wagner et al. (2022) and HIPASS (Barnes 2001) surveys, respectively. The average point spread function (PSF) of the optical images for each band is $\sim 1\farcs1$, and 5σ point-source magnitude limits of $g = 24.3$, $r = 23.9$, $i = 23.5$, $z = 22.8$ mag (Drlica-Wagner et al. 2022).

3. Methodology

To identify globular clusters (GCs) in the dwarf galaxies (DGs) of the sample, we first subtracted an unsharp mask, smoothing the original images with a Gaussian filter with $\sigma = 3.5$ pixels. Then we employed SExtractor (Bertin & Arnouts 1996), an astronomical software that generates a catalog containing all the sources in the image. Subsequently, we measured the photometry using an aperture of 2.″1, considering a mean PSF of 1.″1.

To reduce the contamination of background galaxies, we applied additional criteria based on the geometry of the sources (point sources should be nearly circular with small ellipticities, $e < 0.2$) and the light concentration within the central pixels of the PSF. Foreground contamination from Milky Way stars is removed using astrometric data from Gaia DR3 (Gaia Collaboration 2023). Lastly, the final GC candidates are obtained after applying colour cuts based on models of simple stellar evolution with ages older than 6 Gyr and metallicity [Fe/H] ≥ -2 (Girardi et al. 2000, see Fig.1).

Galaxy ID	d [Mpc]	$\log(M_*)$ [M$_\odot$]	R_{eff} [arcsec]	ΔV_{20} [km s^{-1}]	$\log(M_{200})$ [M$_\odot$]
ESO410-018	19.0	8.8	29.7	85.1	9.2
ESO362-009	10.2	8.9	69.0	98.5	9.1
ESO249-026	9.5	7.7	31.7	147.9	10.9
ESO159-025	11.8	8.1	28.4	127.7	10.2
NGC2101	13.3	9.0	47.8	127.2	10.5

Table 1. Main properties of the dwarf irregular galaxies analysed in this work.

4. Results

4.1. GC luminosity function

Globular clusters (GCs) display a distinct luminosity curve. The average value for this characteristic in a GC is -7.4 mag, as demonstrated by **?**. In this study, we present a histogram encompassing all GCs from various Dwarf Galaxies (DGs), revealing a peak around $M_V = -7.54$ mag, consistent with the literature (Fig. 2).

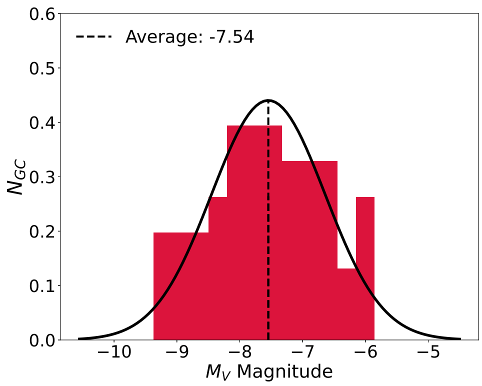

Figure 2. Luminosity curve of the GCs in all DGs.

4.2. GC colour bimodality

We identified two subpopulations of globular clusters (GCs) in our sample - a bluer and a redder one - which is unexpected according to the literature (Rejkuba 2012) and warrants further investigation through a spectroscopic follow-up, a future objective of this project.

4.3. The GC systme mass - DM halo mass relation

We explored the scaling relation between the mass of globular clusters and the dark matter (DM) halo mass (M_{200}) of the host

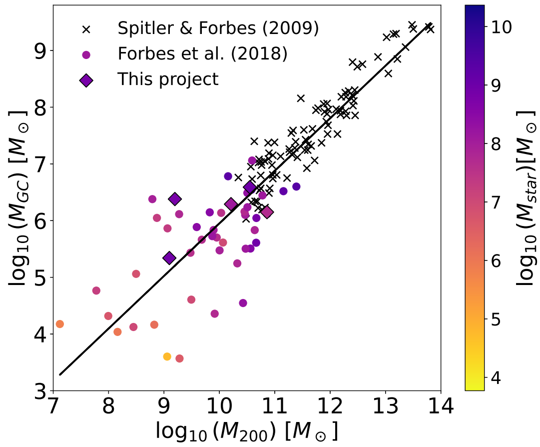

Figure 3. The GC system mass -DM halo mass relation.

galaxy (Navarro, Frenk & White 1996). The halo mass was estimated from the velocity width of the 21-cm line (Tab. 1), corrected for galaxy inclination, following (Forbes et al. 2018).

The GC - DM halo connection was first introduced by Spitler & Forbes (2009). A linear relation implies a co-evolution between the DM halo and the galaxy GC system. All our targets exhibit values closely aligned with a linear trend (Fig. 3). An additional noteworthy observation is the scattering of objects, particularly noticeable in low-mass galaxies. This phenomenon is not well-constrained in the existing literature and may be attributed to various factors, including tidal effects (Georgiev 2010).

5. Conclusions:

We presented preliminary results on the selection and characterization of GC candidates in a sample of dwarf irregular galaxies in line with expectations for GCs in DGs. Surprisingly, we found colour bimodalities in the GC populations of some of our targets that need further investigation. We derived the GC - DM halo mass relation for our sample and we found that our dwarfs follow the linear trend consistently with previous studies. Ongoing refinements in the methodology are being implemented to enhance the reliability of the GC selection method. We plan to expand this analysis to the whole galaxy sample to improve statistical results and to better constrain the properties of GCs in dwarf galaxies.

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