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# VIMOS@VLT photometric and spectroscopic survey of the Sagittarius dwarf Spheroidal Galaxy

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**Abstract.**
The closest neighbour of the Milky Way (MW), the Sagittarius dwarf Spheroidal Galaxy (Sgr dSph) is being tidally destroyed by the interaction with our Galaxy, losing its stellar content along a huge stream clearly detectable in the Galactic Halo. The stellar content and internal dynamics of Sgr dSph are marginally known due to its large dimensions ($\simeq 20^\circ \times 10^\circ$ in the sky). We undertook a spectrophotometric survey of Sgr dSph with VIMOS@VLT, in order to derive detailed colour magnitude diagrams and radial velocities across the entire extension of the galaxy. We observed 8 fields along the major and minor axis of the galaxy (along $7^\circ$ and $2^\circ$ respectively), plus 6 globular cluster belonging to the Sgr main body or likely associated with its tidal streams (NGC 4147, Pal5, Pal12, Arp2, Ter7, Ter8). All of them were observed in V and I bands. The photometric catalogue was then used to select targets for VIMOS-MOS high resolution mode. We obtained spectra for about 1200 stars. This turns out to be one of the richest photometric and spectroscopic homogeneous catalog of the stellar content of Sgr dSph . The survey led to the discovery of an anomalous spatial distribution of the stars in Sagittarius. We confirm that the centre of the galaxy appears located around the Globular Cluster M54, while an asymmetryc distribution of stars is observed along the major axis of the dwarf galaxy.

**Key words.** Stars: Populations – Galaxy: globular clusters – Cosmology: Dwarf Galaxies

## 1. Introduction

In 1994 Ibata, Gilmore & Irwin, during the course of a spectroscopic study of the Bulge

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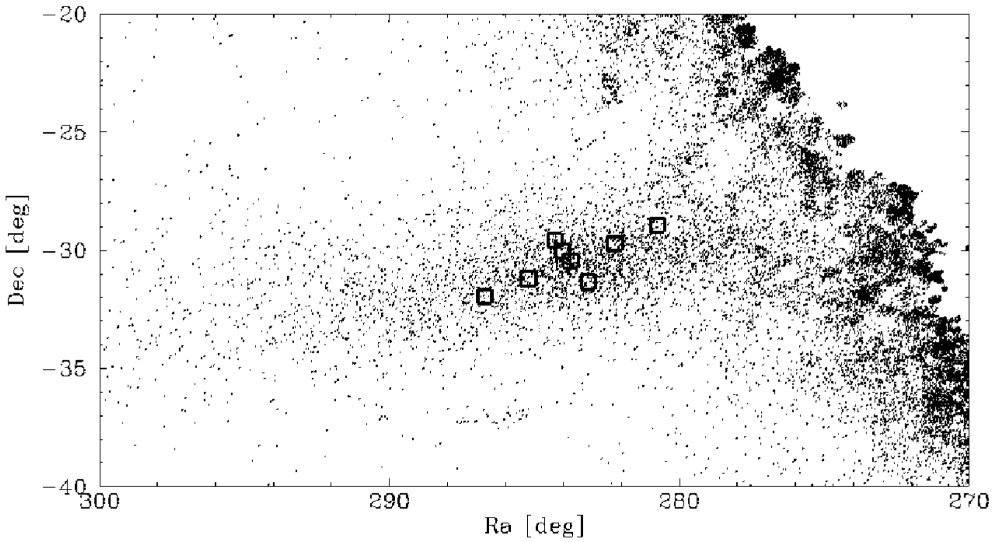


**Fig. 1.** Map of the Sgr dSph galaxy obtained from 2MASS and UCAC catalog selected in K, J-K, and E(B-V) (E(B-V)< 0.555, 0.95 <$(J\text{-}K)_0$ < 1.10, 10.5 < $K_0$ < 12, see Majewski et al. 2003). The boxes shows the position of our fields

of the Milky Way, discovered a new Dwarf Spheroidal Galaxy (dSph) at only 25 Kpc from the Sun, the Sagittarius dSph, hereafter Sgr. This object is orbiting around the Milky Way with a period of about 1 Gyr, and probably was captured about 10 Gyr ago Ibata et al. (1997). This long interaction between Sgr and the Milky Way is a clear on-going accretion event which is strongly modifiying the stellar content of the galactic Halo: Sgr appears to contribute more than 75 % of the high latitude halo M giants Majewski et al. (2003), and, with few exceptions, all the high latitude AGB Carbon stars come from the tidal disruption of Sgr Mauron et al. (2005). However, although Sgr seems to be an ideal "building block" for the galaxy Halo, its chemical pattern Bonifacio et al. (2004) is largely different from that of standard halo members like globular clusters. This makes Sgr an unlikely "source" for the Halo field stars and poses serious questions about the hierachical merging scenario formation of the Galaxy. A detailed study of the Sgr dSph is therefore fundamental in order to understand the building process of the Milky Way.

Despite all efforts gone in studying the nature of this object, actually only the regions near the M54 globular cluster (coincident with the core of Sgr) have been studied in details, with few exceptions Marconi et al. (1998); Bellazzini et al. (1999); Bellazzini et al. (2006). Photometric studies revealed that the main population surrounding M54 (Layden & Sarajedini , 2000; Bellazzini et al. , 2006, hereafter LS00) shows a large spread in metallicity with the mean around [Fe/H]= $-1.3$ while spectroscopic studies revealed that the bulk of the stellar population is older than 5 Gyr with a surprisingly high mean metallicity around [Fe/H]= $-0.5$ Further studies showed a large spread in metallicity which ranges from [Fe/H]= $-3$ to [Fe/H]$\simeq$ 0.0 Zaggia et al. (2004); Bonifacio et al. (2004); Sbordone et al. (2005, 2007); Monaco et al. (2005). However at the moment we don't know whether the same mix of populations is present in the peripheral regions of Sgr: is there any metallicity gradient? Do Sgr peripheral stars share the same chemical pattern of the central ones? Is there a metal poor tail and how much is it?

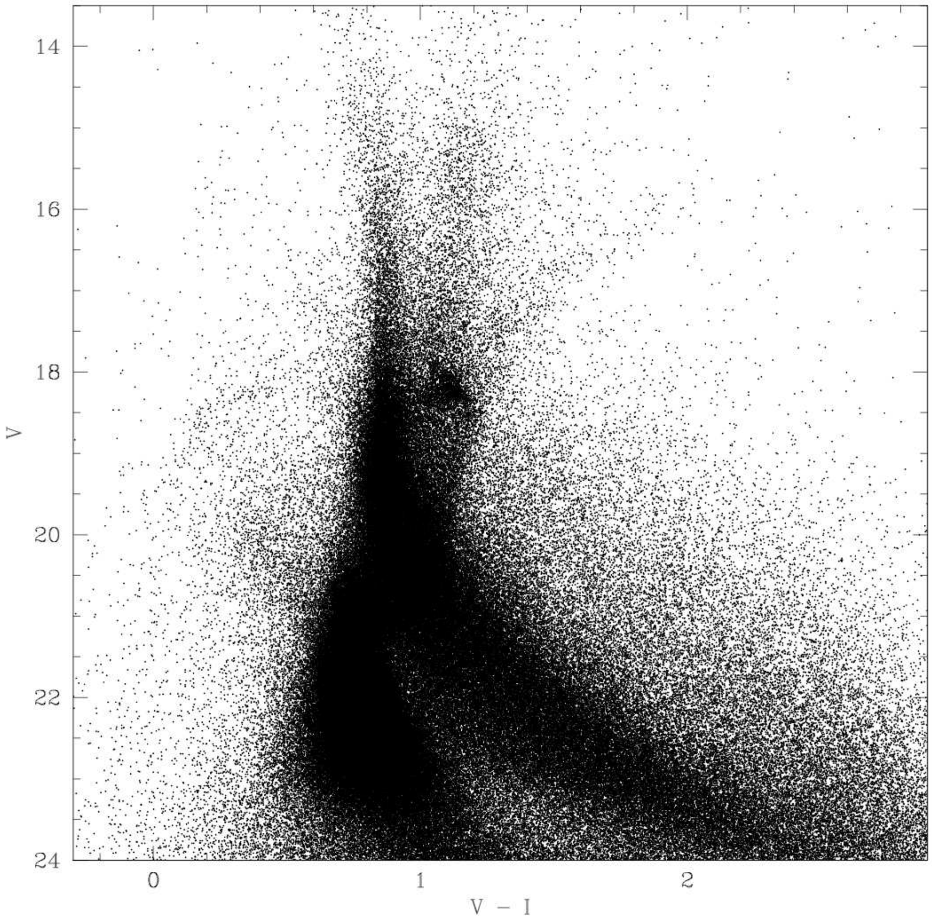


**Fig. 2.** Colour-magnitude diagram for all the stars detected the 7 sgr's fields + the M54 field. The final catalogue counts about 370000 stars

We present here an homogeneous photometry of 7 peripheral fields of the Sgr dSph (see Fig. 1), along with photometry of M54 and of 6 globular cluster likely associated with the galaxy. These data have been used to select a sample of "bona fide" Sgr stars candidate, and this sample has been used as targets for VIMOS spectroscopy in high resolution mode (R=2500). Radial velocities have been obtained for a sample of about 1200 stars (815 out of which in Sgr's main body). Using colors, magnitudes and radial velocities, we selected a sample of Sgr's stars for further investigations on the chemical abundance of Sgr components. Here we will limit to present the photometric data of Sgr dSph so far obtained.

## 2. Observation and data reduction

The frames have been overscan corrected, bias subtracted and trimmed with the ESO-VIMOS pipeline; fringing correction on I band

**Table 1.** Field list with RA, DEC in degree and covered area in arcmin

| Field name | RA | DEC | $arcmin^2$ |
|---|---|---|---|
| M54 | 283.748 | -30.4614 | 4 X 7’ X 8’ |
| Sgr0 | 284.023 | -30.0231 | 4 X 7’ X 8’ |
| Sgr1 | 280.752 | -28.9509 | 4 X 7’ X 8’ |
| Sgr2 | 282.217 | -29.7033 | 4 X 7’ X 8’ |
| Sgr3 | 285.199 | -31.2037 | 4 X 7’ X 8’ |
| Sgr4 | 286.719 | -31.9393 | 4 X 7’ X 8’ |
| Sgr5 | 284.287 | -29.5905 | 4 X 7’ X 8’ |
| Sgr6 | 283.145 | -31.3392 | 4 X 7’ X 8’ |

frames was performed using IRAF tasks imcombine and ccdproc. Photometry has been performed using DAOPHOTII/ALLFRAME packages Stetson (1994), psf stars have been selected in a semi-interactively mode: a first sample of bright stars has been selected from aperture photometry, an automatic procedure has been used to select only stars isolated and distributed along the entire frame. After that, daophot task ”psf” has been used to calculate a first rough psf model, and with this model a first fit over the stars detected by DAOPHOT with the ”find” task has been performed. Subsequently the catalogue has been used to select a new sample of psf stars and to calculate a more accurate psf model. The exposures of the same region has been matched with DAOMATCH/DAOMASTER and ALLFRAME has been used to perform a new photometry simultaneously in all the frames. Finally DAOMASTER has been used to obtain a single catalogue for every field.

Photometric calibration was obtained using Zero points calculated by ESO QC team for our nights, colour terms have been obtained using standard frames taken during the nights. The following correction was finally applied:

$M = 2.5 * Log(Flux[e/sec]) - cterm * Colour + cext * Airmass + Zp.$

## 3. Discussion

Figure 2 shows the CMD of all the stars in the seven Sgr’s peripheral fields plus the M54 field (see Table 1). The CMD shows clearly some of the well known features of SGR:

1. The Milky Way disk contamination produces a slightly vertical sequence at V−I= 0.8 from V= 20.5 to V= 13.5. The giant branch of the old Bulge population, instead, is visible as a nearly parallel sequence at V−I= 1.0.
2. The turn off of the Sgr main population is detectable at a magnitude of about V= 20.5 and color V−I= 0.8.
3. An well populated Red Clump at a magnitude of V≃ 18.0 and V−I≃ 1.2 is detected.
4. The multiple RGB of the main body Sgr population is clearly present.
5. An extended blue plume is visible from V−I= 0.4 to V−I= 0.8 and from V= 19 to V= 21.

Figure 3 shows the spatial distribution of Sgr stars along the major axis. Sgr stars have been selected on the RGB which is clearly visible. Having selected only the brightest RGB stars, we are confident that only a few, if any, MW stars are present in our sample. Milky Way bulge and disk stars are plotted for comparison. We confirm that Sgr dSph is clearly centered around the globular cluster M54 Monaco et al. (2005) Bellazzini et al. (1999), we also observe that a strong asymmetry exists in the distribution of the stars along the major axis: the density is higher in the direction of the Milky Way. The figure shows that bulge stars are more concentrated toward the galactic plane than disk stars, as expected.

## 4. Conclusions

We collected data from a large area along the major and the minor axis of the Sgr dSph. A first analysis reveals an asymmetry of the stellar distribution along the major axis and confirms that the Sgr dSph is centered around M54 Monaco et al. (2005), Bellazzini et al. (1999). However, our data doesn’t allow to conclude whether M54 could be classified as the old nucleus of the Sgr dSph, or it is simply a globular clusters attracted by dynamical friction on that position Monaco et al. (2005). Comparison of the CMDs of the different fields with synthetic population models is ongoing. The spectrophotometric catalogue so far obtained allowed us

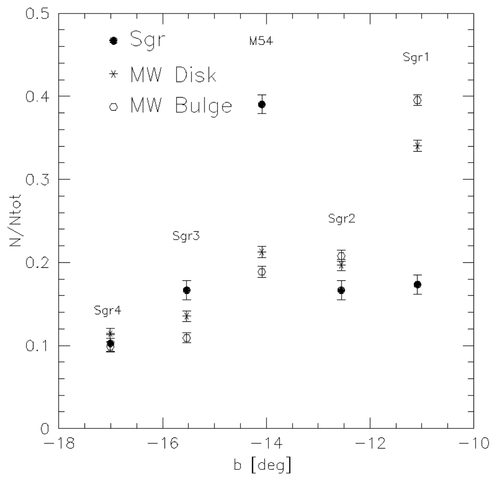


**Fig. 3.** Sgr dSph spatial distribution along its major axis. Bulge and Disk distribution are plotted for comparison

to select about 1600 good Sgr's stars candidate for FLAMES and their analysis is in progress. This sample of stars is at the same time extended across the whole galaxy and it covers a good range in atmospheric parameters. Hopefully this analysis will give the answer to several questions of this intriguing companion of the Milky way:

- How cospicuous is the metal poor population in Sgr and, then, in other dSphs?
- Which is the age of the metal poor component?
- Are the most metal-poor stars also the oldest in Sgr, as expected by age-metallicity arguments?
- How low is the metal content in the metal-weak tail of Sgr?
- Do there exist stars even more metal-poor than the two so far found?
- Does it contain also survivors zero-metal stars?
- What is the precise run of $[\alpha/\mathrm{Fe}]$ for Sgr ?
- Do the under-enhancement persists at the lowest metallicities ?

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