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The Sagittarius dwarf galaxy as seen by the VLT/FLAMES facility ⋆

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Abstract. This is the first report of the use of the VLT FLAMES facility on the local group dwarf galaxy Sagittarius (SGR). The observing program aimed at collecting a large sample of high-resolution spectra with two main goals: (1) to obtain a detailed description of SGR metallicity distribution, and (2) to study the internal dynamics of SGR, its Mass and Mass to Light ratio (M/L). With the present work, we confirm the existence of a metal-rich population, extending above solar metallicity. The main component of SGR stars is peaked at [Fe/H]~ -0.5, while we found evidence, for the first time, of a metal-weak tail in the SGR populations, considerably more metal-weak than M54 ([Fe/H]~ -1.5). Our direct measure of the central velocity dispersion of SGR give $\sigma = 8.2 \pm 0.3$ km s^{-1} which translates in an M/L= 12.5 using current values of the SGR structural parameters. This new value is in good agreement with the accretion self-consistent "model II" of Helmi & White (2001).

Key words. Dwarf Galaxies – Kinematics – Chemical Abundances

1. Introduction

The SGR dwarf is one of the nearest galaxies companion of the Milky Way and its study is important since it gives us a unique opportunity to look in detail a Searle & Zinn (1978) galactic fragment formed in the outer halo, later captured by the inner Galaxy and actually under its final stages of disruption.

SGR was known since its discovery to posses a rather large metallicity spread, which could be inferred from the wide RGB displayed by the galaxy (Marconi et al. 1998; Bellazzini et al. 1999). However the precise metallicity range and the shape of the distribution were quite uncertain. With the present work, we confirm the existence of a metal-rich population, extending even above solar metallicity. We also found evidence, for the first time, of the existence of a metal-weak tail in the SGR populations, considerably more metal-weak than M54.

Actually no detailed observational studies have been performed on the dynamics of SGR which is actually little known. Ibata

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et al. (1997) using radial velocity measurements from low resolution spectra gave a $\sigma \simeq 11.5\ \mathrm{km\,s^{-1}}$ claiming an M/L of as much as $\simeq$ 50 which implies the presence of a big dark halo in order to explain the present survival of SGR. Majewski et al. (2003) revised the total luminosity and dimensions of SGR and proposed an M/L$\simeq$ 25. Our direct measure of the central velocity dispersion of SGR give $\sigma = 8.2 \pm 0.3\ \mathrm{km\,s^{-1}}$ which translates in a M/L= 12.5. This value is in good agreement with the accretion self-consistent "model II" of Helmi & White (2001).

2. The Ital-FLAMES GTO Observations

In 1999 four INAF Observatories (Bologna, Cagliari, Palermo and Trieste) formed the *Ital-FLAMES* consortium, to collaborate with ESO at the development, construction and installation of the VLT FLAMES facility (Pasquini et al. 2000). FLAMES is composed by a fiber positioner, *OzPoz*, which feeds the GIRAFFE and UVES spectrograph. The facility has a multiplex capability of up to 132 single fibers with GIRAFFE (in the MEDUSA mode) and 8 fibers with UVES, over a large field of view of $\simeq$ 28 arcmin in diameter. The *Ital-FLAMES* consortium in exchange for their participation in the construction of FLAMES received from ESO 11 nights of guaranteed observing time (GTO). The GTO time were divided in a number of programs and the equivalent of one night have been allocated in May 2003 to the observation of the SGR galaxy.

We used FLAMES with both GIRAFFE, at a resolution of $\sim$ 20000, and UVES, at a resolution of 40000. We aimed at obtaining a S/N ratio of the spectra of better than $\simeq$ 20. Such S/N would allow us to reliably: *a)* determine chemical abundances for several elements; and *b)* obtain radial velocities with a precision better than 0.5 $\mathrm{km\,s^{-1}}$.Two different GIRAFFE setup were chosen: HR09 centered at 515 nm and HR14 at 650 nm. In total over 280 stars were observed with Giraffe, both in the SGR field and in the Globular Cluster M54; of these 149 turn out to be radial velocity members of SGR.

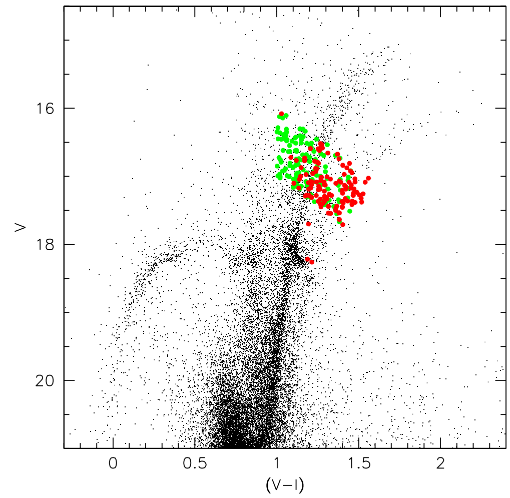

Fig. 1. SGR color magnitude diagram from Monaco et al. (2002). Dark (red) filled dots show SGR FLAMES targets with radial velocity membership ($120 < v_r < 165\mathrm{km\,s^{-1}}$); light (green) filled dots are SGR radial velocity non-members.

Two FLAMES fields were chosen: one centered on the cluster M54 (which lies in the center of SGR, Monaco et al. 2004 and Majewski et al. 2003), and a second field at 12 arcmin West of the center. Being FLAMES a "blind" instrument (it has no pre-imaging capabilities) it needs a very high precision astrometric catalog for the input targets. The selection of the targets were performed on the Monaco et al. (2002) V, I photometric and astrometric catalog (based on EIS Pre-FLAMES images of Zaggia et al. 2001) which contains nearly half-million objects over 1 square degree around the center of SGR. We selected objects with magnitude in the range 16 ÷ 17.5 in a diagonal strip in the (V-I) color which cross the RGBs of M54 and SGR in order to search for populations of any possible metallicity. The color-magnitude selection box is shown in Fig. 1.

The reduction of the GIRAFFE multi-spectra have been performed using the FLAMES data reduction pipeline developed by the Geneva Observatory (Blecha et al. 2001)

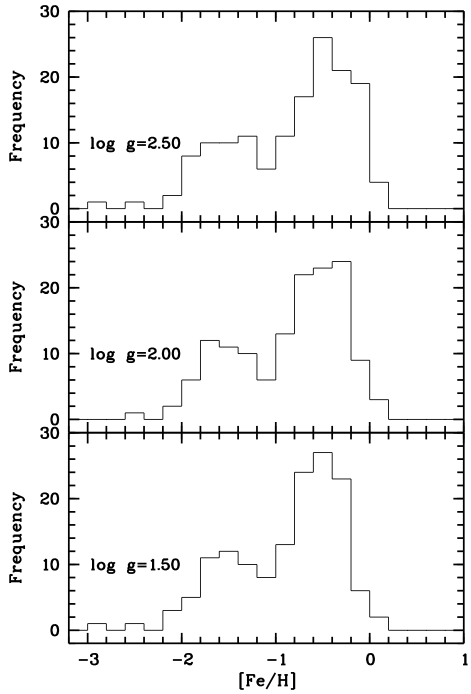

Fig. 2. Metallicity distribution for confirmed radial velocity members of SGR. Our automatic code has been run assuming three different values of surface gravity: log g=1.5,2.0,2.5; the general picture emerging is largely independent of the adopted gravity, since the [Fe/H] measurement relies on neutral iron lines, which are only weakly sensitive to gravity.

while UVES spectra have been reduced with a modified UVES pipeline (Mulas et al. 2002).

3. SGR Metallicity Distribution

Right from the discovery of SGR it was obvious that it was characterized by a rather large metallicity spread, which could be inferred from the wide RGB displayed by the galaxy (Ibata et al. 1995; Marconi et al. 1998; Bellazzini et al. 1999). However the precise metallicity range and the shape of the distribution were quite uncertain and differed from author to author. The first high-resolution spectroscopic observations of SGR by Bonifacio et al. (2000) revealed the existence of a population with almost solar metallicity, considerably higher than the photometric estimates. The existence of such a metal–rich population was later confirmed by other high resolution observations (Bonifacio et al. 2004). However, up to now the number of SGR stars for which high resolution spectra are available has been too small to understand what is the metallicity distribution of SGR. Also previous high resolution observations were quite probably highly biased in favor of the more metal-rich population. Our sample of stars observed with GIRAFFE is large enough to provide, for the first time a clear picture of what this metallicity distribution is. The GIRAFFE spectra have been analyzed with our automatic code Bonifacio & Caffau (2003), assuming three values of log g, the resulting histograms are shown in Fig. 2. Our preferred value is log g=2.0, based on isochrones, however Fig. 2 clearly shows that the main conclusions are independent on the adopted gravity, as long as this is in a reasonable range.

The existence of the metal-rich population, extending even above solar metallicity is indeed confirmed. The broad metal–poor peak is centered at [Fe/H]= -1.5 and includes also stars of the globular cluster M54 with a [Fe/H]= -1.54. The main component of SGR stars is instead peaked at [Fe/H] ~ -0.5, consistently with the results of Monaco et al. (2002). In the present sample is also evident, for the first time, the existence of a metal-weak tail in the SGR populations, considerably more metal-weak than M54.

At this stage it is not clear what is the metal–weak limit of this population, a much larger sample is needed to sample adequately these minority populations. Our data shows convincingly that SGR has experienced a prolonged star formation history and has produced stars which range from 1/200 solar up to 3 times solar.

4. SGR Central Dynamics

The dark matter content of the SGR dwarf remains controversial. Early investigations (Ibata et al. 1997) postulated that *"SGR is being tidally distorted and is tidally limited, but is*

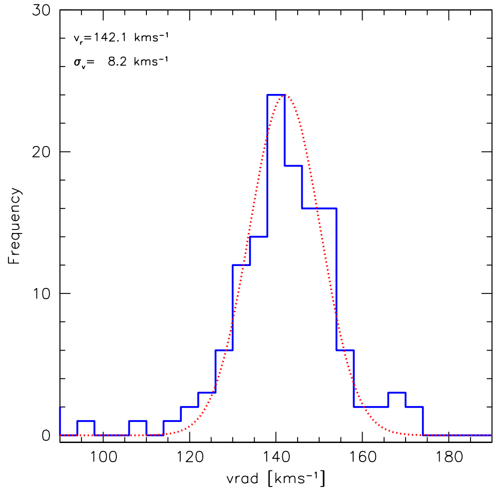

Fig. 3. Histogram of the SGR radial velocities measurements. Over-plotted a gaussian with mean and dispersion as illustrated in the figure.

not disrupted as yet", and derived a central M/L$\simeq$ 50, implying a dark matter-dominated, prolate but tidally-limited galaxy with a not much larger extension than observed today. The later discovery of substantial tidal debris of SGR clearly indicated a dwarf in the process of being tidally disrupted and assimilated into the Milky Way.

The derived M/L of SGR depends on the structural parameters of the galaxy and on its central radial velocity dispersion. Recently, Majewski et al. (2003) performed an all sky analysis of the SGR M-giants using the 2MASS database. They obtained new values for the core radius, tidal radius and total luminosity of the galaxy and used them to calculate a new value of M/L, with the standard King method. The value obtained is M/L= 25 which is based on an *inferred* central velocity dispersion of 11.5 $\mathrm{km\,s^{-1}}$ from the Ibata et al. (1997) field "f7" near the SGR core.

Our high precision radial velocity measurements permitted us to perform a preliminar first analysis of the central radial velocity dispersion of the SGR galaxy. The member selection is relatively simple since radial velocity of SGR is well isolated from the field distribution. M54 have been removed from the sample. Fig. 3 show the radial velocity histogram of 123 SGR members ($120 < v_r < 165 \mathrm{km\,s^{-1}}$). The measured radial velocity dispersion in the SGR galaxy core is $\sigma_v = 8.2 \pm 0.3\ \mathrm{km\,s^{-1}}$. This value is significantly lower than the Ibata et al. (1997) value and imply a M/L= 12.5 calculated using the Majewski et al. (2003) structural parameters. This low value of M/L is now compatible with the self-consistent "Model II" of Helmi & White (2001) which assumes an initial mass for SGR of $1.7\times10^9\ \mathrm{M_\odot}$ that, when evolved for a Hubble time, reproduce all the data currently available for SGR.

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