VLT SPECTROSCOPY OF GLOBULAR CLUSTERS IN DWARF GALAXIES

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ABSTRACT

Faint Low Surface Brightness Dwarf Galaxies (LSBDG) down to $M_V \sim -12^m$ have long been thought to be free of globular clusters because they have insufficient mass to trigger their formation. We report here on Very Large Telescope FORS2/MXU observations of twenty GCs from the list of Sharina, Puzia and Makarov (2005) in five dwarf galaxies outside the Local Group. We review our algorithms of spectroscopic analysis and possible perspectives of future observations.

Key words: Technique: spectoscopic; Virtual Observatory.

1. INTRODUCTION

A main goal of our project is to measure the chemical composition of globular clusters (GCs) in dwarf galaxies and to compare these data with globular clusters in massive galaxies. GCs are composed of stars of one age and chemical composition, and the study of them help us to understand how galaxies form and evolve. The spectroscopic survey of GCs in five nearby low surface brightness dwarf galaxies (LSBDGs) is based on a photometric study of GC candidates identified by us in 30 LSBDGs using HST/WFPC2 photometry in V and I bands (Sharina et al. , 2005). Our sample galaxies are faint, with absolute blue magnitude in the range $M_B = -11^m$ to -13^m. The spectroscopic confirmation of the existence of GCs in such small galaxies, and their particular chemical compositions might provide important constraints for hierarchical galaxy formation models.

Our spectroscopic observations were performed with the FORS2 instrument at the Very Large Telescope (VLT) with the 600B grism in the MXU mode (Multi-object spectroscopy with exchangeable masks). In the following we summarize the information available in the literature on the strategy of the FORS MXU data reduction and describe our approaches to the data reduction.

2. OBSERVATIONS

FORS2 is the visual and near-UV Focal Reducer and low-dispersion Spectrograph for the VLT. FORS2 offers the possibility to insert in the focal plane a mask in which slits of different length, width and shape can be cut with a dedicated laser cutting machine. The masks are based on pre-imaging and slits are placed on objects visible on these images.

To complete our program, the pre-imaging in B and I was obtained i) to obtain accurate astrometry in order to prepare optimal slit masks, ii) to select representative GC candidates that might reside outside the field of view of the HST photometry. The FORS Instrumental Mask Simulator (FIMS) tool [1] (Hummel , 2000) was used to define the slit positions. In order to derive a calibration for each object spectrum flat-field and arc-lamp exposures were obtained trough the science masks in th

3. DATA REDUCTION APPROACHES

A large number of objects which can be observed simultaneously with multi-slit mode by modern spectrographs demands the availability of automatic reduction software. Such software is very important for the preparation of large science products, to be stored in Virtual Observatory archives. Currently there are no public software reduction packages available for the FORS2 MXU mode, and we have developed our own software pipelines to cope with these large datasets.

One problem for the data reduction of FORS2/MXU data arises due to the existence of optical field distortions in the field-of-view of the spectrograph. The distortions bend spectra which lie away from the optical axis. This effect complicates the wavelength solution and accurate sky subtraction. To solve the problem the aXe software was developed by Kuntschner, Kummel, Larsen, & Walsh (Kuntschner et al. , 2005). It provides science-quality

[1]http://http.hq.eso.org/observing/p2pp/OSS/FIMS/FIMS-tool.html

spectra for the slit-less modes of the ACS instrument aboard HST. The aXe concept was applied then by the authors to reductions of the FORS2-MXU spectra. The essence of this approach is in the accurate knowledge of the trace and wavelength solution as a function of the frame position.

A different approach to the reduction of distorted spectra was formulated by Sharina, Afanasiev, and Puzia (Sharina et al. , 2006), who observed GCs in dwarf galaxies and the Lick standard stars with the multi-slit unit of the SCORPIO spectrograph at the Special Astrophysical observatory of Russian Academy of Sciences. The authors used small gaps between spectra to correctly determine edged of the spectra and to obtain a two-dimensional high order polynomial fit for trace calibration. We cannot use this strategy for the reduction of the FORS2-MXU spectra due to a tight location of GC candidates in the field of view.

The data reduction and subsequent analysis were performed in MIDAS (the European Southern Observatory Munich Image Data Analysis System). After cosmic-ray removal and subtraction a bias all frames were divided by a normalized flat-field image. For each slit a 2-dimensional subsection of the CCD was automatically extracted using the accurate slit position stored in a frame descriptors. Then the subsection was treated as a long-slit observation.

An optimum extraction method of Horne (Horne , 1986) was used to average the rows for each object. The extraction of each GC spectrum was performed by tracing the spectra along the wavelength direction. This was done by fitting a Gaussian to the spatial distribution in each point of a spectrum. The limits of the objects were taken at a distance from the center of the object where the Gaussian fit has an intensity of a given fraction of the central intensity, typically 10-15%. The sky region is determined up to 2 pixels away of these limits.

Due to the aforementioned problems with spectra bent by the optical field distortion, we investigated the methods of obtaining the wavelength solution for our spectra. The first one was developed by Puzia et al. (Puzia et al. , 2004). In this method a wavelength solution was calculated for each pixel row from arc lamp spectra and rectified all slit spectra according to this distortion mask. After this transformation into wavelength space all spectra were optimally extracted. The second approach is identical to one used for reductions of tilted long-slit spectra.
1. Extract a one-dimensional spectrum from the appropriate comparison arclamp exposure using the identical aperture and trace used for the corresponding object spectrum,
2. determine the dispersion solution for this comparison spectrum,
3. use the dispersion solution to put the object spectrum on a linear wavelength scale. We compared the spectra obtained by applying of these two approaches and found that the results are fully consistent with each other, and that the second way can also be used for reductions of the FORS2-MXU spectra. We compared our wavelength predictions with the observations of relatively isolated and strong night sky lines with known wavelength. The systematic errors appear to be less then 0.1 nm, and may be reduced by adopting global shifts based on measurements of skylines. A typical accuracy of the two-dimensional dispersion solution was < 0.02 nm. Note that the average dispersion is 0.074 nm/pixel.

4. BRIEF SUMMARY OF OUR SPECTROSCOPIC RESULTS

We measure absorption line Lick indices, compare the obtained values with predictions of simple stellar population models (Thomas et al. , 2003), and, finally, estimate age, metallicity, and alpha-element abundance ratios (Puzia & Sharina , 2007). The obtained metallicity is low ($[Fe/H] \simeq 1.0$ dex) and [α/Fe] is about solar for most of our sample GCs. These results likely imply low star formation rates and a significant contribution of type-Ia supernovae in contrast to GCs in more massive galaxies.

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