The Open Cluster Chemical Abundances from Spanish Observatories Survey (OCCASO)


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Abstract. We present the motivation, design and current status of the Open Cluster Chemical Abundances from Spanish Observatories survey (OCCASO). Using the high resolution spectroscopic facilities available at Spanish observatories, OCCASO will derive chemical abundances in a sample of 20 to 25 OCs older than 0.5 Gyr. This sample will be used to study in detail the formation and evolution of the Galactic disk using OCs as tracers.

1. Introduction

Stellar clusters are crucial in the study of a variety of topics including the star formation process, stellar nucleosynthesis and evolution, dynamical interaction among stars, and the assembly and evolution of galaxies. In particular, Open Clusters (OCs), which cover large ranges of ages and metallicities, have been widely used to constrain the formation and evolution of the Milky Way disk (e.g. Pancino et al. 2010). This is because some of their features, such as ages and distances, are more accurately determined in comparison with field stars. They provide information about the chemical patterns and the existence of radial and vertical gradients and an age-metallicity relation. However, all these investigations are hampered by the fact that only a small fraction of clusters has been studied homogeneously.
Galactic surveys performed from the ground such as the APO Galactic Evolution Experiment (APOGEE; Frinchaboy et al. 2013), the Gaia-ESO Survey (GES; Gilmore et al. 2012), or the GALactic Archaeology with HERMES (GALAH, Anguiano et al. 2014) include OCs among their targets, providing radial velocities and chemical abundances. OCs are also sampled from space by the Gaia (e.g. Perryman et al. 2001) and Kepler missions. The first will provide accurate parallaxes, from which distances will be derived, and proper motions, and the second is providing accurate photometry.

2. Survey design

The GES was designed to use the FLAMES (Pasquini et al. 2002, GIRAFFE+UVES) capabilities at one of the VLT units in order to complement the Gaia mission. The GES clusters survey includes 20-25 OCs older than 0.5 Gyr. For them, GES is using the GIRAFFE fibers to derive radial velocities and abundances in stars at any evolutionary stage brighter than V \( \sim \) 17 with a resolution lower than 20000. The six UVES fibers, which cover a wavelength range between 480 and 700 nm with a resolution of 47000, are being used to measure accurate radial velocities and detailed chemical abundances only in red clump stars. The UVES observations of old OCs have been designed to obtain a homogeneous sample of chemical abundances in order to study the Galactic disk. Using stars in the same evolutionary stage ensures the homogeneity of the sample.

Unfortunately, GES is sampling only the Southern hemisphere. However, several key OCs such as the most metal-rich, NGC 6791, and the oldest, Berkeley 17, together with several systems towards the Galactic anticenter or those observed by the Kepler mission are only visible from the North. APOGEE is the only survey that is sampling Northern clusters and it observes in the \( H \) band with a resolution of 22500. However, APOGEE is sampling OC stars at any evolutionary stage, like GES-GIRAFFE. Moreover, APOGEE is not observing a minimum of stars in each cluster. In fact, six or more cluster members have been analyzed only in 7 of the OCs observed, those selected for calibration purposes (Frinchaboy et al. 2013).

The Open Cluster Chemical Abundances from Spanish Observatories survey (OCCASO) has been designed to complement from the North the GES-UVES observations of intermediate-age and old OCs in the South before the arrival of WEA VE (Dalton et al. 2012). OCCASO is being developed in parallel with GES. Like GES-UVES, OCCASO is observing a minimum of six red clump stars in a sample of 20 to 25 OCs older than 0.5 Gyr. Red clump stars are selected because they are easily identified even in the sparsely populated color-magnitude diagrams and their spectra are less line crowded and therefore easier to analyze than those of brighter giants. Moreover, targeting objects in the same evolutionary stage avoids measuring anomalous abundances for some elements due to the effects of stellar evolution. Therefore, at the end we will double the sample of OCs with homogeneous chemical abundance determinations. To ensure obtaining abundances in the same scale as GES we are observing several stars in common and we are using some of the analysis methods also used in GES. APOGEE is the only spectrograph with similar multi-object capabilities to UVES in the North but with lower resolution (~22500) and in the infrared. However, at Spanish observatories there are available several echelle high-resolution spectrographs with resolutions and wavelength coverage ranges similar to or larger than UVES. In particular for this project we have selected CAFE@CAHA 2.2 m (Aceituno et al. 2013, 396 < \( \lambda \) < 950 nm, R~60000), FIES@NOT 2.5 m (Telting et al. 2014, 370 < \( \lambda \) < 750 nm, R~67000) and
HERMES@Mercator 1.2 m (Raskin et al. 2011, 377 < \( \lambda \) < 900 nm, \( R \sim 60000 \)). Although only one star can be observed at once in each of them, the fact that we have distributed our observations among three different telescopes/instruments is allowing us to develop OCCASO in a timeline similar to GES. The brightest targets (\( V \leq 12.5 \)) are being observed with MERCATOR/HERMES, those stars with 12 \( \leq V \leq 14 \) are being observing with CAFE/CAHA 2.2 m, and the faintest objects with FIES/NOT. For sake of homogeneity, we are observing stars in common in all telescopes.

3. Observations, data reduction, radial velocity determination and Chemical abundance determination

OCCASO obtained 5 nights on both the NOT and Mercator telescopes in semester 13B, and it was selected as a large program on the same telescopes from semester 14A which ensured 5 nights per semester and telescope over 4 semesters, till semester 15A. Moreover, it has regularly obtained allocations of Director’s Discretionary and Spanish Guaranteed Time at the CAHA 2.2 m telescope from semester 14A. Unfortunately, due to problems with the instrument, most of the data acquired with CAFE is not useful.

Until May of 2015 we have completed a total of 55 observing nights with about 20% of them lost by bad sky conditions. Moreover, the sky conditions of several of the observing nights were not good enough and we had to observe brighter stars than expected. In total, we have acquired \( \sim 550 \) spectra for \( \sim 100 \) stars belonging to 20 OCs. A minimum of 6 stars have been observed in 13 clusters.

The FIES and HERMES spectrographs have dedicated pipelines which perform the bias subtraction, flat-field normalization, order trace and extraction, wavelength calibration, and order merge. For spectra acquired with CAFE we are using the pipeline developed by J. Maiz-Apellaniz. After this basic reduction, the spectra of the three telescopes are handled in the same way. Firstly, the sky emission lines are subtracted using a sky spectrum acquired during each run. Next, each spectrum is normalized by fitting the continuum with a polynomial function using DAOSPEC (Stetson & Pancino 2008). The degree of the polynomial function changes from instrument to instrument. The telluric absorption lines are removed in the normalized spectra using a telluric star spectrum acquired in each run. The wavelength calibration is corrected of the heliocentric velocity. All the spectra of the same star and instrument are combined to reach the required signal-to-noise ratio. Finally, the radial velocity of each star is computed from the combined spectra using DAOSPEC and the same linelist used in the chemical abundance determination.

The OCCASO goal is to derive abundances for more than 20 chemical species. In order to ensure the reliability of the derived chemical abundances, these will be derived using different analysis techniques.

- **DAOPSPEC+GALA**: GALA (Mucciarelli et al. 2013) determines the best model atmosphere and abundances by optimizing temperature, surface gravity, micro-turbulent velocity and metallicity from the equivalent widths determined by the automated wrapper DAOSPEC Option Optimizer (DOOp Cantat-Gaudin et al. 2014))

- **iSpec**: (Blanco-Cuaresma et al. 2014) compares an observed spectrum with synthetic ones generated on-the-fly, using a least-squares algorithm but only in specific regions of the spectrum to minimize the computation time.
• **FERRE**: (Allende Prieto 2004) identifies the model parameters that best reproduce the observations by means of an optimization algorithm that uses the chi-square as metric.

• **MATISSE**: The MATrix Inversion for Spectral Synthesis (MATISSE) algorithm (Recio-Blanco et al. 2006) determines the atmosphere parameters on the basis of a linear combination of a grid of theoretical spectra.

One of the OCCASO requirements is homogeneity between telescopes, method and model atmospheres used, and in the same scale as the GES-UVES abundances, and several tests are being performed to ensure this.

4. **OCCASO and WEA VE**

OCs are included among the targets that WEA VE, the new multi-object spectrograph for the 4.2 m William Herschel Telescope, will study in its Galactic survey. The WEA VE features are similar to those of GIRAFFE (e.g. R~20000). Like GIRAFFE in GES, WEA VE will provide radial velocities and abundances for a few elements in a large number of stars at any evolutionary stage belonging to each studied OCs. OCCASO will complement WEA VE observations by providing detailed chemical abundances and radial velocities from a much higher spectral resolution that can be used as reference for WEA VE measurements.

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**References**

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