CRIRES Science Verification Proposal

The chemical composition of the evolved population in the young LMC cluster NGC 1866: a pilot project

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Abstract:
This proposal is part of a coordinated long-term spectroscopic project devoted to obtain a complete screening of the chemical composition and define a new homogeneous metallicity scale for a representative sample of Large Magellanic Cloud (LMC) stellar clusters. In order to derive accurate abundances and abundance patterns of young (age $\leq$200 Myr) stellar clusters, dominated by massive red supergiant or AGB stars, the use of high-resolution spectra in the IR spectral range is mandatory. Here we propose a pilot project to measure 5 bright giant stars located in the young LMC cluster NGC 1866, in order to derive accurate chemical abundances for Fe, CNO and other α-elements.

Scientific Case:

The globular cluster system of the Large Magellanic Clouds (LMC) covers a wide range of both ages (Searle, Wilkinson & Bagnuolo 1980, ApJ, 239, 803, SWB) and metallicities (e.g. Sagar & Pandey 1989, A&AS 79, 407). It thus represents a fundamental laboratory to perform a number of crucial tests on star formation theories, stellar and galaxy evolution, stellar and gas dynamics, age-metallicity relation, Initial Mass Function etc. The LMC globular clusters also provide the best empirical templates of Simple Stellar Populations (SSPs, *i.e.* a coeval and chemically homogeneous stellar aggregate). The integrated spectral energy distribution (SED) of a SSP continuously changes because its stellar content is evolving: massive stars progressively die and other, less massive replace them in contributing to the integrated light (Renzini & Buzzoni 1986, in *Spectral evolution of Galaxies*, Bruzual & Charlot 1993, ApJ, 405, 538; Maraston 1998, MNRAS, 300, 872; Brocato et al 1999, A&AS, 136, 65; Raimondo et al. 2005). Stellar evolution theory predicts that red stars dominate the bolometric luminosity of a SSP after its first evolutionary stages. In this respect, the SED of a SSP and its most evident color glitches are thus ideal tools for dating distant stellar systems, once a suitable empirical calibration in terms of age be available. To do it, it is mandatory to have template SSPs for which both integrated colors (over a wide spectral range) and precise age (through direct Turn-Off measurements) are available. However, it must be taken into account that *accurate ages require accurate estimates of metallicity and abundance pattern distribution*, since the stellar clock is extremely sensitive to the chemical composition. Actually, despite its importance, the accurate and systematic determination of chemical abundances of the LMC clusters is still lacking. Up to date, only a few and quite inhomogeneous datasets of abundances exist, most of which rely on photometric (see e.g. Dirsch et al. 2000, A&A, 360, 133) or low resolution spectroscopic data (see e.g. Olszewski et al. 1991, AJ, 101, 515) and they can be affected by a quite large uncertainty (up to $\approx$0.5 dex). Very recently, abundances from high resolution spectroscopy became available for a bunch of stars in a few stellar clusters (Hill et al. 2000, A&A, 364, L19; Johnson et al., 2006, ApJ, 640, 801; Ferraro et al. 2006,ApJ, 645, L33).

Given the above scenario, we started an ambitious project devoted to derive a new metallicity scale and a complete screening of abundance patterns for the LMC clusters, based on high resolution spectroscopy. We have observed and analyzed a sample of low mass giant stars in 4 intermediate-age LMC clusters (1-3 Gyr) using high resolution spectra obtained with FLAMES@VLT, deriving for each cluster up to 20 abundance ratios sampling the main chemical elemental groups, i.e. light, α, iron-peak and neutron-capture elements (Ferraro et al. 2006, ApJ, 645, L33 and Mucciarelli et al., 2007, in preparation).
Massive red supergiant and AGB stars are suitable targets to obtain abundances and abundance patterns of young ($\leq$200 Myr) stellar clusters (Ferraro et al. 2004, ApJ, 603, 772; Mucciarelli et al. 2006, ApJ, 646, 939). Indeed, these stars are bright and full of metal lines compared to the blue population of MS stars. However, the chemical analysis of these stars in the optical spectral range is difficult to impossible, given the very low effective temperatures and gravities, and as a consequence the presence of strong molecular features (i.e. TiO, CN). At variance, the near-infrared spectral range is ideal to derive accurate chemical abundances of Fe, CNO and other α-elements.
Here, we propose a pilot project aimed at obtaining IR spectra and accurate chemical abundances of 5 massive giants in the young LMC cluster NGC 1866 ($\sim$140 Myr, Brocato et al., 2003, AJ, 125, 3111). Our spectroscopic analysis of UVES/FLAMES spectra suggests a provisional iron abundance [Fe/H]=-0.58 dex (see also Hill et al., 2000, A&A, 364, L19).
CRIRES spectra are crucial for two reasons. *1)* They will provide an independent iron abundance estimate, also allowing to cross-calibrate the optical and IR scales. Such a check of consistency between the two analysis, based on different abundance indicators, represents a fundamental step to obtain the first homogeneous and reliable metallicity scale for the LMC stellar cluster system over the full range of ages and metallicities. *2)* They will provide accurate abundances of C and O from CO and OH lines, which are difficult to impossible to obtain from optical spectra of these cool stars. These elements are fundamental to trace the chemical enrichment history and nucleosynthesis of a stellar system.

Required observing time

Target	RA	DEC	Wavelength Band	Magnitude	DIT	NDIT
#1	05 13 36.253	-65 28 35.73	1.5326-1.5705	H=9.95	240s	6
#2	05 13 41.405	-65 28 28.35	1.5326-1.5705	H=10.50	240s	6
#3	05 13 46.424	-65 27 43.44	1.5326-1.5705	H=10.96	240s	8
#4	05 13 37.179	-65 28 04.85	1.5326-1.5705	H=12.00	240s	20
#5	05 13 36.206	-65 28 09.17	1.5326-1.5705	H=11.67	240s	20
Hip32602	06 48 04.700	-44 18 58.40	1.5326-1.5705	H=8.5	120s	2

We select the 36/-1/i setup to measure Fe, Ti, OH and CN lines and deriving accurate iron, CNO and α-element abundances. Accordingly to CRIRES ETC, with no AO correction, for stars of T=4000K, and seeing=0.8", airmass=1.1, DIT=240s, slit=0.8", an average on source integration time of 30 min for H=11 and 90 min for H=12 is needed to get S/N$\approx$25 - 30 per pixel. To observed the five stars plus the telluric standard listed in the table above, a total of 4 slit configurations are required:
config.A: slit onto stars #1 and #2, **config.B**: slit onto stars #4 and #5,**config.C**: slit onto star #3, **config.D**: slit onto the telluric standard star Hip32602. A nodding on slit with an average throw of 10" will be also used. In summary, by including overheads we required 40 min for config.A, 120 min for config.B, 60 min for config.C and 20 min for config.D, i.e. **4 hours**. Note that we consider the configurations A, B and D as first priority.