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Extension of the Ca II Triplet Calibration as a Metallicity Indicator to Young and/or Metal-rich Systems: Application to the LMC

R. CARRERA[1], C. GALLART[1], R. ZINN[2], E. PANCINO[3], and E. HARDY[4]
(1) Intituto de Astrofisica de Canarias, La Lguna, Spain
(2) Yale University, New Haven, USA
(3) Universita di Bologna, Bologna, Italy
(4) National Radio Astronomy Observatory, Santiago, Chile

Abstract

The Ca II triplet is one of the most frequently measured features for deriving stellar metallicities from moderate resolution spectroscopy of red giants in old and metal poor systems. With the advent of 8m class telescopes, this indicator becomes of invaluable help in deriving metallicities for large samples of faint stars in the Local Group, and beyond. Its application to intermediate-age or young and/or metal rich stellar populations, however, is still uncertain, due to the lack of metal rich and intermediate-age calibrators and to the (still unexplored) behavior of this indicator in conditions of varying [Ca/Fe] ratios. In this poster we discuss the extension of the calibration of the Ca II triplet to intermediate-age and young stellar populations and to higher metallicity and present the preliminary results of observing 11 open clusters in December 2002. We also discuss the main objective of this project: to use this revised calibration to estimate the chemical enrichment of the Large Magellanic Cloud and its variation with position in the Cloud.

1.1 Introduction

The Ca II triplet lines at λ8498, 8542 and 8662 Å are the strongest feature in the IR spectra of most late-type stars, and thus their equivalent widths can be measured with reasonable accuracy for faint objects with moderate resolution spectroscopy. A pioneering study by Armandroff & Zinn (1988) showed that, in the integrated light of globular clusters, the Ca II equivalent width is correlated with metallicity (Figure 1.1), indicating that this feature could be a fair metallicity indicator for old (and approximately coeval) stellar populations. Subsequent work in this field concentrated on individual red giants in globular clusters and empirical relations between the cluster metallicity and the reduced equivalent width of the Ca II lines were derived by several authors (e.g. Rutledge et al. 1997a, b; hereafter R97a, b). Sometimes, this technique has been applied to composite stellar populations, such as dwarf spheroidal companions of the Milky Way and the Magellanic Clouds (Cole et al. 2000; Tolstoy et al. 2001), with the justification that the age sensitivity ought to be low. The existing calibrations, however, are valid for old, relatively metal-poor populations only, and it is not clear that they provide an accurate metallicity ranking for red giants near solar composition and for ones spanning a wide range in age.

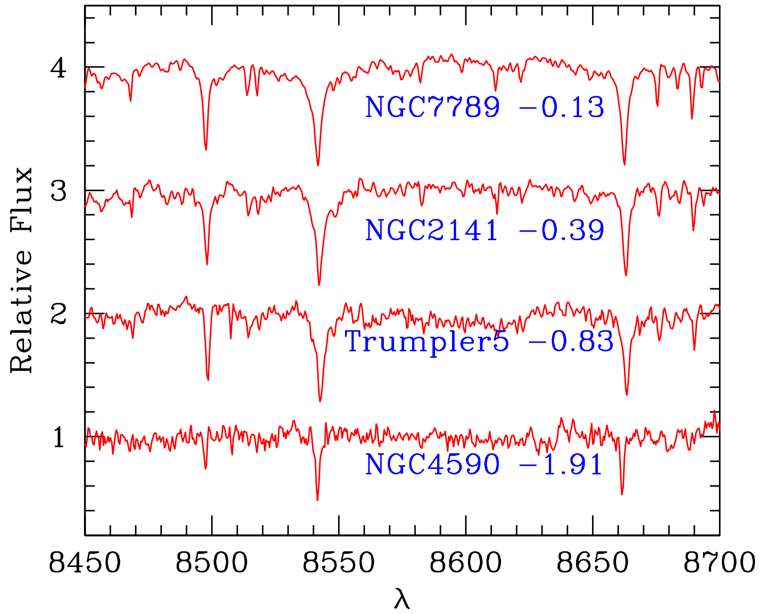

Fig. 1.1. Comparison of the spectra of stars in different clusters. The stars have nearly the same M_V (∼-0.5), but differ in [Fe/H].

It is usually assumed that the strengths of absorption lines, W(Ca II), are mainly determined by abundance, effective temperature Te and surface gravity, g. Consequently, to relate abundances to the measurable parameter W(Ca II), the parameters Te and log g must be fixed in some way. It was found empirically (Armandroff & Da Costa 1991; Olszewski et al. 1991) that for globular clusters, a plot of ΣCa (the combined equivalent width W(Ca II) of the Ca II triplet lines) against absolute V or I magnitude or against V-V_{HB}, produces and accurate ranking of globular clusters by metallicity. In each one of these diagrams, the red giants in globular clusters define separate linear sequences of very similar slope. However, our purpose is to apply this relation to composite stellar systems, and therefore we must extend this relation to intermediate-age and young stellar populations, as well as to higher metallicities regimes.

Pont et al. (2004) have argued from modeling the age and metallicity effects on the Ca II triplet lines and from a few observations of young and intermediate-age open clusters that the absolute magnitude-*Sigma*Ca diagram is only mildly sensitive to age between 12.6 and 1 Gyr. This conclusions need to be investigated further using a larger number of open clusters that span ranges in both age and metallicity and that have reliably determined abundances from high dispersion spectroscopy.

It is also necessary to investigate the behavior of the Ca II triplet in conditions of varying [Ca/Fe] ratios. The ratio is approximately constant at ∼+0.3 for globular clusters, but is very different for open clusters (for example [Ca/Fe]=-0.04 for NGC6819; Bragaglia et al. 2001).

Table 1.1. *Open clusters observed to extend the Ca II triplet calibration as a metallicity indicator for young and/or metal rich systems.*

Cluster	Other Name	Age (Gyr)	[Fe/H]
NGC 188		4	–0.05
NGC 2141		1.5	–0.26
Trumpler 5		4	–0.83
Collinder 110		1.25	–0.55
Berkeley 32		3	–0.58
NGC 2420		1	–0.27
NGC 2506		1	–0.38
NGC 2682	M67	2.5	0.00
NGC 6705	M11	0.2	+0.14
NGC 6819		1.5	+0.07
NGC 7789		1.5	–0.08

1.2 Clusters Sample Selection and Observations

The open clusters that have been observed in order to calibrate the Ca II triplet are listed in table 1.1. These clusters are selected to cover a wide range of age and metallicities. Also the most metal poor ones are chosen to overlap in metallicity with the globular clusters of the R97a sample in these range, and to study the influence of age in the calibration. Also, in order to transform our measurements to the R97b scale, we observed M68, a globular clusters of R97a's sample. These clusters have already been observed with the IDS spectrograph at the INT telescope (Roque de los Muchachos observatory, La Palma, Spain). A number of stars (5-12) were observed in each cluster with grating R1200R, which provides a dispersion of 0.45 Å/pix.

The reduction is currently underway, and we show in Figure 1.2 a preliminary result. The equivalent widths of the Ca II triplet lines, W(Ca II) were measured following the procedure described by R97a. We used their definitions of the feature and continuum passbands and employed a Moffat function of exponent 2.5 to fit the line profiles. In practice we used the weighted sum of the widths ΣCa, as defined by R97a: $\Sigma Ca = 0.5W_{8498} + W_{8542} + 0.6W_{8662}$

Our ΣCa measurements were transformed to the R97a scale with an accuracy of about 0.03 dex. Most previous investigations that used the Ca II triplet as a metallicity indicator have plotted ΣCa against V-V_{HB} because this quantity is independent of the reddening and the distance modulus of the system. However, in open clusters (and in systems with composite populations), it is not trivial to define the position of the HB. For this reason, we use M_V instead of V-V_{HB}. In the M_V-ΣCa diagram, all clusters define linear sequences of approximately similar slope, which are offset from each other in order of their metallicities (Figure 1.2).

Due to the poorly known metallicities of open clusters, as a part of our project, we plan to obtain high resolution spectra in all open clusters in the sample. This, in addition to provide their abundances, will give us information of the influence of the [Ca/Fe] ratio in the calibration.

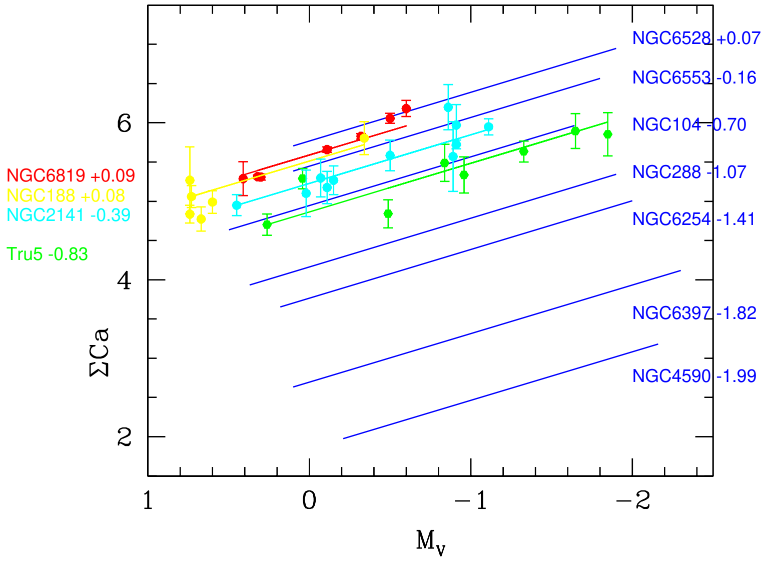

Fig. 1.2. Positions of the sequence of some open clusters in the M_V-ΣCa plane, with respect to the sequence of globular clusters.

1.3 The Large Magellanic Cloud Project

The nearest dwarf galaxies companions of the Milky Way offer an excellent opportunity to test galaxy evolution, since their star formation (SF) history can be derived with great accuracy from deep color-magnitude diagram (CMD), their masses can be accurately calculated from the velocity dispersion of their stars, and the metallicities and metallicity distribution can be obtained from spectroscopy of their individual stars. One of the nearest Milky Way satellites, the LMC, is an ideal laboratory for the study of galaxy evolution. Despite decades of work, there are still significant gaps in our knowledge of the LMC's SF and chemical enrichment (CE) histories (Olszewski et al. 1992). The most recent studies suggest that the SF history of the LMC disk has been more or less continuous with some increase of SF rate in the last few Gyr (Aparicio 2001). Even less is known about the CE history. The widely cited work of Dopita et al. (1997), based on α-elements in planetary nebula, showed that there was little evolution at all until 2 Gys ago, when abundances doubled, but only ten nebulae were used. Olszewski (1993), based on Ca II triplet spectra of RGB stars, found an excess of stars between -1.5 and -0.8 as compared with the stars in clusters. Cole et al. (2000), also using Ca II triplet spectroscopy, found marked differences in metallicity between fields observed in both studies. Our purpose is to investigate the CE history and metallicity gradients in the LMC with Ca II spectra. As a starting point, we have deep CMD of four fields situated at 2.8, 4.0, 5.3 and 6.7 Kpc from the center of LMC. Deep CMDs of these fields are plotted in Figure 1.3 (only 1/8 of the stars in each field are plotted), which were used to select a sample of red giant branch stars that were observed with low resolution spectroscopy in the Ca II region in December 2002, using Hydra at the CTIO 4m. The wide range in age and metallicity observed in these diagrams justify the extension of Ca II triplet indicator to high metallicities populations, and to verify its behavior for younger stars.

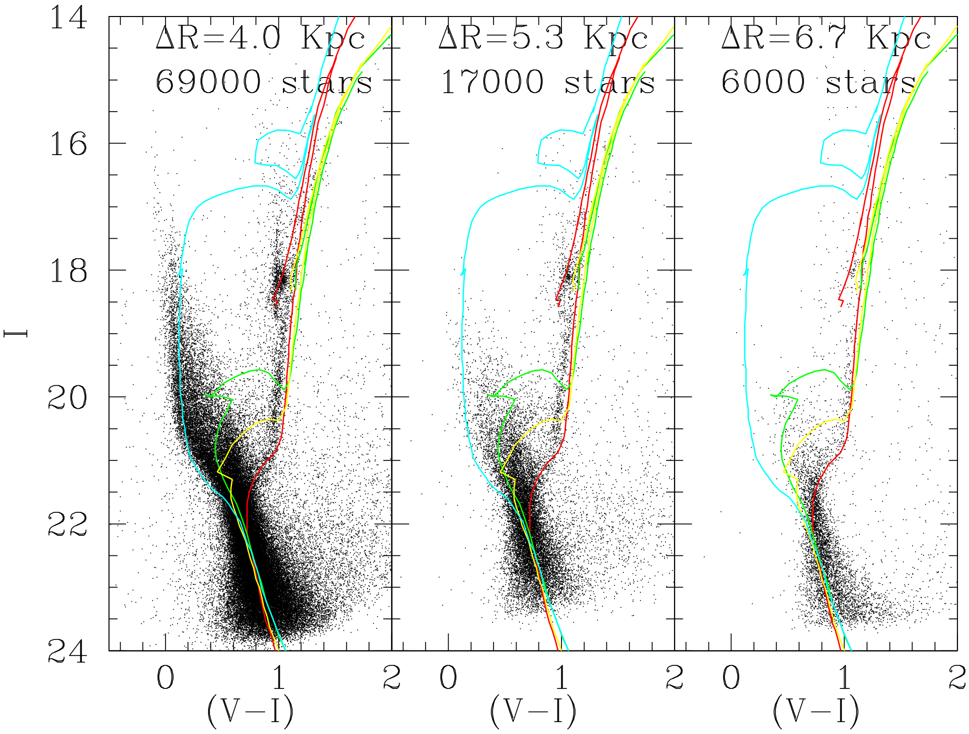

Fig. 1.3. CMD of three of the four fields used to select stars for the spectroscopic study of the LMC. Note that even in the outermost field there are traces of intermediate-age population. Isochrones from Bertelli et al. (1994) of [Z, Gyr]=[0.0004,10.0],[0.001,4.0],[0.004,1.5],[0.004,0.2] have been superimposed.

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