Chemical abundances in LMC stellar populations

I. The Inner disk sample *

Luciana Pompéia, Vanessa Hill, Monique Spite, Andrew Cole, Francesca Primas, Martino Romaniello, Luca Pasquini, Maria-Rosa Cioni and Tammy Smecker Hane

1 IP&D, Universidade do Vale do Paraíba, Av. Shishima Hifumi, 2911, São, José dos Campos, 12244-000 SP, Brazil
e-mail: pompeia@univap.br
2 Instituto Astronômico e Geofísico (USP), Rua do Matão 1226, Cidade Universitária, 05508-900 São Paulo, Brazil
e-mail: Vanessa.Hill@obspm.fr e-mail: Monique.Spite@obspm.fr
3 Observatoire de Paris-Meudon, GEPI and CNRS UMR 8111, 92125 Meudon Cedex, France
e-mail: Vanessa.Hill@obspm.fr e-mail: Monique.Spite@obspm.fr
4 School of Mathematics and Physics, University of Tasmania, Private Bag 37, Hobart, TAS 7001, Australia
5 Kapteyn Astronomical Institute, University of Groningen, Postbus 800, NL-9700 AV Groningen, Netherlands
e-mail: cole@astro.rug.nl
6 European Southern Observatory, Karl Schwarschild Str. 2, 85748 Garching b. München, Germany
e-mail: fprimas@eso.org e-mail: mromanie@eso.org e-mail: lPasquin@eso.org
7 Edinburg SUPA, School of Physics, University of Edinburgh, IfA, Blackford Hill, Edinburgh EH9 3HJ, UK
e-mail: mrc@roe.ac.uk
8 Department of Physics and Astronomy, 4129 Frederick Reines Hall, University of California, Irvine, CA 92697-4575
e-mail: smecker@carina.ps.uci.edu

Received/Accepted

Abstract. Aims. We have used FLAMES (the Fibre Large Array Multi Element Spectrograph) at the VLT-UT2 telescope to obtain spectra of a large sample of red giant stars from the Inner Disk of the LMC, ~2 kpc from the center of the galaxy. We investigate the chemical abundances of key elements for the understand-
standing of the star formation and evolution of the LMC disk: heavy and light 
\([s\text{-process/Fe}]\) and \([\alpha/\text{Fe}]\) give constraints on the time-scales of formation of the 
stellar population. Cu, Na, Sc and the iron-peak elements are also studied aiming 
to better understand the build up of the elements of this population and the origin 
of these elements. We aim to provide a more complete picture of the LMC’s 
evolution by compiling a large sample of field star abundances.

Methods. LTE abundances are derived using line spectrum synthesis or equivalent 
width analysis. We have used OSMARCS model atmospheres and an updated 
line list.

Results. We have found that the alpha-elements Ca, Si, and Ti show lower 
\([X/\text{Fe}]\) ratios than Galactic stars at the same \([\text{Fe/H}]\), with most \([\text{Ca/Fe}]\) being 
subsolar. \([\text{O/Fe}]\) and \([\text{Mg/Fe}]\) ratios are slightly deficient, with Mg showing some 
overlap with the Galactic distribution. Sc and Na follow the underabundant behavior of Ca, with subsolar distributions. For the light \(s\)-process elements Y and 
Zr, we have found underabundant values compared to their Galactic counterparts. \([\text{La/Fe}]\) ratios are slightly overabundant relative to the galactic pattern showing 
low scatter, while the \([\text{Ba/Fe}]\) are enhanced, with a slight increasing trend for metallicities \([\text{Fe/H}] > -1 \text{ dex}\). The \([\text{heavy-s/light-s}]\) ratios are high, showing a slow increasing trend with metallicity. We were surprised to find an offset for 
three of the iron-peak elements. We have found an offset for the \([\text{iron-peak/Fe}]\) 
ratios of Ni, Cr and Co, with an underabundant pattern and subsolar values, while 
Vanadium ratios track the solar value. Copper shows very low abundances in our 
sample for all metallicities, compatible with those of the Galaxy only for the most 
metal-poor stars. The overall chemical distributions of this LMC sample indicates 
a slower star formation history relative to that of the solar neighborhood, with a 
higher contribution from Type Ia supernovae relative to Type II supernovae.

Key words. Stars: abundances, Galaxies: Magellanic Clouds, Galaxies: abundan-
ces, Galaxies: evolution

1. Introduction

During the last decade, due to the operation of the new class of large telescopes, we 
have witnessed for the first time the analysis of elemental abundances of large samples of 
individual stars in external galaxies. Thanks to new optical technologies, objects fainter 
than supergiant stars, planetary nebulae or HII regions are now possible targets suitable 
for extragalactic research, allowing the study of older objects and the exploration of earlier 
phases of galaxy evolution. The abundance patterns of diverse elements in numerous stars 
in a galaxy give information on different domains such as the kinematic and chemical
evolution, nucleosynthesis channels, the star formation history (SFH) and the initial mass function (IMF) of its stellar population(s).

One of the most interesting extragalactic objects in the study of stellar populations is the Large Magellanic Cloud (LMC), our nearest companion after the Sagittarius dwarf galaxy (that is the process of merging with the Milky Way). The LMC is an irregular galaxy located within 50 kpc from the Sun, with a kinematically-defined disk, a bar and a thick disk or flattened halo (e.g. Westerlund 1997). The almost face-on position of its disk, with a tilt relative to the plane of the sky of $\sim 30^\circ$, gives us the precious opportunity to study stars from its different components.

The star formation (SF) and cluster formation histories of this galaxy have been studied for more than three decades (e.g. Butcher 1977, van den Bergh 1979, Olszewski et al. 1996 and references therein, Cioni et al. 2006 and references therein) although a final picture is far from complete (the current status of the research deals with the detailed SF and cluster formation within the different components and regions of this galaxy, e.g. Geha et al. 1998, Smecker-Hane 2002, Subramaniam 2004, Javiel et al. 2005, Cole et al. 2005). The clusters of the LMC show a ancient population with ages $> 11.5$ Gyr, followed by an hiatus when just one single cluster seems to have formed (ESO 121-SC03) (e.g. van den Bergh 1998 and references therein). Some 2-4 Gyr ago, a new formation event was triggered and some other clusters have been built (e.g. Da Costa 1991). The SF in the disk field shows a different evolution, with nearly constant rate over most of the history of the LMC (Geha et al. 1998). The SFR appears to have been enhanced some 1–4 Gyr ago, with the timing and amplitude of the ‘burst’ seeming to vary between locations (Holtzman et al. 1999; Olsen et al. 1999). The SFH of the bar field appears to more closely track the cluster formation history, with a strong burst $\approx 3$-6 Gyr ago (Smecker-Hane et al. 2002; Cole et al. 2005). The lack of a field star age gap means that field star properties can be used to trace the history of the LMC during the 3-11 Gyr cluster age gap (Da Costa 1999; van den Bergh 1999).

The elemental distributions of the LMC stars are still poorly known, due to the paucity of data, but the present picture is in fast change due to new observational programs (e.g. Evans et al. 2005, Dufton et al. 2006, Johnson et al. 2006). We briefly sumarize here the results on elemental abundances in the LMC (for a detailed discussion see Hill 2004). The abundance analysis of B stars and HII regions (Garnett 1999, Korn et al. 2002, Rolleston et al. 2002) show a deficient abundance of O, Mg and Si relative to their solar neighborhood counterparts\footnote{taking as the solar value log (O/H) $\sim 8.83$ (Grevesse & Sauval 2000)}, with mean log (X/H) - log (X/H)$_\odot$ $\sim$ -0.2 dex for oxygen, -0.2 dex for magnesium, and -0.4 dex for silicon abundances (this last value is only for the B stars, HII regions show a much lower value of $\sim$ -0.8 dex), but compatible to galactic supergiant values. Russell & Dopita (1992), Hill et al. (1995) and Luck
et al. (1998) studied samples of supergiants in the field of the LMC and Hill & Spite (1999) derived abundances for supergiants in clusters. They found a similar behavior for the α-elements when compared to the galactic disk values, while for the heavy elements (those with $Z \geq 56$), the abundance ratios are enhanced by a factor of $\sim 2$. Huter et al. (2007) derived C, Mg, O, Si and N abundances for three globular clusters from the LMC, and found an average value 0.3 dex lower than that of the Galactic Clusters for all the analysed elements, except for N. Red giant branch stars from the field (Smith et al. 2000, hereafter SM02) and from globular clusters (Hill et al. 2000, 2003, hereafter H00 and H03, and Johnson et al. 2006, hereafter JIS06) have also been studied. A general behavior of low [$\alpha$/Fe] ratios compared to the stars of the galactic disk with similar metallicities is detected (with the exception of Si and Mg in JIS06), while for the heavy-elements, the same overabundant pattern found for the LMC supergiants has been derived. JIS06 inferred the [Y/Fe] ratios and found abundances compatible to the solar value. Na abundances are different in field and clusters stars. While SM02 found low [Na/Fe] ratios and [Sc/Fe] ratios close to zero, JIS06 found that [Sc/Fe] and [Na/Fe] ratios are simillar to their galactic counterparts. JIS06 have derived the [iron-peak/Fe] abundances and found that Ni, V and Cu abundances fall bellow their corresponding galactic values.

An observational project aiming at making the full analysis of the elemental abundances of significant samples (∼70-100) of stars from different locations in the LMC has been developed, taking advantage of the FLAMES multiplex facility at the VLT. We have obtained spectra from stars in three different regions of the LMC: the Inner Disk (characterised by a galactocentric radius of $R_C=2kpc$); the Outer Disk (with $R_C=4kpc$); and a field near the optical center of the Bar. Stars have been selected based on kinematics and metallicity data derived from the near-infrared calcium triplet (CaT and CaT metallicities), trying to sample as evenly as possible the whole metallicity range of this galaxy. In the present paper we focus on a sample of Red Giant Branch (RGB) stars on the Inner Disk region, previously studied by Smecker-Hane et al. (2002), who derived the ages, metallicities (CaT) and kinematics of this sample. They have identified two kinematical groups in the Inner Disk field, one with velocity dispersion of $13\pm4$ km/s, characterizing a thin disk, and one with velocity dispersion of $34\pm6$ km/s, probably pertaining to the flattened halo. The metallicities of these two groups are different: the low-dispersion velocity group has metallicities ranging $-0.6 \leq [Fe/H] \leq -0.3$ dex, while the high-dispersion velocity component has $-2 \leq [Fe/H] \leq -0.4$. The ages derived for this Inner Disk population has shown that stars have continuously formed during the last $\sim 1$ to $15$ Gyr, with a possible enhancement in the star formation rate (SFR) some 3 Gyr ago.

As the prototype galaxy of the Magellanic irregular class, to learn the evolutionary history of the LMC is clearly a vital step towards the global understanding of galaxies near the dwarf-giant boundary. Additionally, because the Magellanic Clouds have evolved
in such close proximity to the Milky Way, their histories have been intimately tied to that of our own galaxy. The ongoing impact of the LMC on the structure and kinematics of the Milky Way is manifest in the warp of the Galactic disk and possibly in the presence of the central bar (e.g., Weinberg 1999), while Bekki & Chiba (2005) have used N-body simulations to show that the LMC could have made a significant contribution to the build up of the Milky Way halo as a result of tidal stripping.

According to models of galaxy formation within a hierarchical CDM scenario (D’Onghia & Lake 2004; Moore et al. 1999), the history of the Milky Way depends strongly on its interactions with its environment. It now seems that the abundance patterns in dwarf spheroidal stars are dissimilar to those in Milky Way halo stars (e.g., Shetrone et al. 2001; Tolstoy et al. 2003; Geisler et al. 2005), ruling them out as analogues to the accreting fragments that built up the halo. Study of the LMC takes on added significance in this light, because of the hypothesis by Robertson et al. (2005) that the accretion of LMC-like fragments circumvents this difficulty with the hierarchical accretion scenario. Deeper knowledge of the abundances in the oldest LMC stars therefore has direct bearing on the evolution of our own Galaxy.

In the present paper, we focus on a sample of RGB stars in the Inner Disk field, previously studied by Smecker-Hane et al. (2002, hereafter SMH02), who derived the SFH of the region from Hubble Space Telescope color-magnitude diagrams; they find stars in this field to have formed continuously over the whole life of the LMC, with a slight enhancement in the star formation rate (SFR) \( \approx 3 \) Gyr ago. Smecker-Hane et al. (2007) obtained CaT spectra for a large number of red giants to measure their kinematics and overall heavy element abundances, finding the most metal-rich stars to belong to a kinematically cold population and the metal-poor stars to be more kinematically hot, possibly belonging to a flattened halo or very thick disk population. We focus our work on the Inner Disk region, presenting abundance results for iron-peak, heavy and light s-process elements, and \( \alpha \) elements for a total of 59 stars. With this detailed information in hand, we aim to shed light on the following questions: (i) what are the chemical abundance patterns of the Inner Disk of the LMC?; (ii) what do these elemental distributions tell us about the formation and evolution of the LMC?; (iii) are they similar to any component of the Milky Way?; (iv) or to the populations of other Local Group galaxies?; (v) based on the elemental distributions, is a merging scenario with LMC debris a likely solution for the Galactic Halo formation?

The paper is organized as follows: in Sect. 2 the observations and the reduction procedure are described; in Sect. 3 the calculation of stellar parameters is presented; Sect. 4 describes the abundance determination procedures; Sect. 5 reports the results for the abundance ratios, comparing to Milky Way samples; in Sect. 6 we compare our results to those for the dSph galaxies; we discuss the results in Sect. 7; and finally in Sect. 8 a summary of the work is given.
2. Sample selection, observations and reductions

2.1. Sample selection

To best measure the elemental abundances of the LMC disk and their evolution along time, we selected a field located 1.7° southwest of the LMC Bar, in the Bar’s minor axis direction to ensure a negligible contribution of its stellar populations. An HST color-magnitude diagram study of this field (SMH02) found it to have experienced a rather smooth and continuous history of star formation over the past 13 Gyr, with a possibly increased star-formation rate over the last 2 Gyr. This stands in contrast to the history of the Bar itself, in which significant star-formation episodes are seen to have commenced 4–6 Gyr ago (SMH02; see also Holtzman et al. 1999 and references therein). This field has also more recently been the target of a low-resolution spectroscopy campaign (Cole et al. 2000; SMH), using the CaT to derive its metallicity distribution and break the age-metallicity degeneracy inherent to color magnitude diagram CMD analyses.

We have used these infrared CaT metallicities from SMH to select a sample of red giant branch members of the LMC (based on their radial velocities) distributed uniformly (i.e., with the same number of stars in each metallicity bin) over the whole metallicity range of the LMC disk. In this way, we have been able to sample the lower metallicity bins of the LMC very efficiently. The most metal-poor stars convey essential information on the evolution of the elements of this galaxy, but they are rare, hence their number would have been significantly lower if we had selected our sample by picking stars randomly across the RGB. The final sample consists of 67 stars with CaT metallicities ranging from $-1.76$ to $-0.02$ dex (including 13 stars with metallicities below $-1.0$ dex), drawn from the 115-star sample of SMH. In Fig. I we show the sample stars overplotted on the color-magnitude diagram of the LMC inner disk region (CTIO photometry from SMH). The sample mean magnitude is $V=17.25$ mag, bright enough to allow reasonable S/N high-resolution spectra to be acquired.

2.2. Observations and reductions

The observations were made at the VLT Kueyen (UT2) telescope at Paranal during the Science Verification of FLAMES/GIRAFFE (Pasquini et al. 2000) in January, February and March, 2003, complemented by one night of the Paris Observatory Guaranteed Time Observations in January, 2004. In its MEDUSA mode, GIRAFFE is a multiobject spectrograph with 131 fibers of which 67 were used for the present project. The remaining fibers were allocated to targets of other Science Verification projects in the LMC. The detector is a $2048 \times 4096$ EEV CCD with $15 \mu$m pixels. We used the high resolution grating of GIRAFFE in three different setups: (i) H14 $\lambda 638.3 - \lambda 662.6$ nm with R=28800; (ii) H13 $\lambda 612.0 - \lambda 640.6$ nm with R=22500, and (iii) H11 $\lambda 559.7 - \lambda 584.0$ nm with R=18529.
Exposure times are 6 hours for H14 and H13 setups and 7h30 for H11. The setups were chosen in order to cover the maximum number of key elements such as Fe I and Fe II for spectroscopic calculations of stellar parameters, and α, iron-peak and s-process elements, for the abundance analysis. The average signal to noise ratio of the spectra is S/N∼80 per resolution element.

The data reduction was carried out using the BLDRS (GIRAFFE Base-Line Data Reduction Software http://girbldrs.sourceforge.net/) and consists of bias subtraction, localization and extraction of the spectra, wavelength calibration and rebinning. We have also used the MIDAS packages for sky subtraction and co-addition of individual exposures.

3. Determination of stellar parameters

3.1. Photometric stellar parameters

A first guess of the stellar parameters was made using photometric data of CTIO (V,I from SHM) and 2MASS (J,H,K). Bolometric magnitudes and effective temperatures were derived from calibrations of Bessell, Castelli & Plez (1998, hereafter BCP). The observed CTIO and 2MASS colors were transformed into the corresponding photometric systems using Fernie (1983, V−I Cousins to Johnson) and Carpenter (2001, K, V−K & J−K 2MASS). Photometric data are given in Table 1, while Table 2 gives the derived effective temperatures (T\textsubscript{phot}) and surface gravities (log g\textsubscript{phot}): T\textsubscript{phot} is derived using the BCP calibration of the deredenned V−I and V−K colors, and the surface gravity is computed using the following relation:

$$\log g_{\text{phot}} = 4.44 + \log(M) + 4 \times \log(T_{\text{phot}}/5790.) + 0.4 \times (M_{\text{bol}} - 4.75),$$

where M\textsubscript{bol} is computed from the dereddened K magnitude of the star, the bolometric correction BC\textsubscript{K} taken from BCP, and the mass of the stars (M) are assumed to be 2M\odot. A distance modulus based on Hipparcos data and the period-luminosity relations from LMC Cepheids of 18.44 ± 0.05 mag is assumed (Westerlund 1997, Madore & Freedman 1998). Uncertainties of this value stems from the specific subsets of the Cepheids chosen for the comparison (Madore & Freedman 1998). For the reddening, two values were checked: E(B−V) = 0.03, which was derived by SMH02 for the sample of the Inner Disk, using Strömgren photometry, and E(B−V) = 0.06, a mean value for the whole disk (Bessell 1991). We adopted CaT metallicities from SMH as our initial guesses and reported them in the [Fe/H]\textsubscript{CaT} column of Table 2.

We have derived temperatures from V−I, V−K and J−K colors. We have found some trends when comparing temperatures from different colors: T\textsubscript{eff}(V−I) is 65K hotter than T\textsubscript{eff}(V−K) in the mean, with $\sigma=59K$; T\textsubscript{eff}(J−K) is 21K hotter than T\textsubscript{eff}(V−K) and shows a highly dispersed relation, with $\sigma=118K$ (these numbers vary only slightly when choosing
a reddening of $E(B-V)=0.06$ or 0.03). As initial values of our stellar temperatures we have chosen to use a weighted mean of the estimates from $V-I$ and $V-K$, omitting the less sensitive $J-K$ color. We assign higher weight to the more temperature-sensitive ($V-K$), according to the following expression:

$$T_{\text{eff}} = \frac{(T_{\text{eff}}(V-I) + 2 \times T_{\text{eff}}(V-K))}{3}.$$

In Table 2 the inferred temperatures for the two values of reddening, $T_{\text{photLow}}$ and $T_{\text{phot}}$ for $E(B-V) = 0.03$ and 0.06 respectively, are given.

### 3.2. Spectroscopic parameters

The final stellar parameters used for the abundance determination of the sample stars were derived spectroscopically using abundances derived from the equivalent widths (EW) of iron lines. Although 67 stars were observed, 8 of them have one or two setups with low S/N, compromising the determination of stellar parameters. These stars have not been included in the abundance analysis. Due to low S/N ratios, the H13 setup has not been used for the following stars: RGB,601, RGB,646, RGB,672, RGB,699, RGB,705, RGB,710, RGB,720, RGB,731, RGB,748, RGB,756, RGB,773 and RGB,775; and for RGB,666 the H11 setup has been discarded. We have estimated the stellar parameters as follows: effective temperatures are calculated by requiring no slope in the $A(\text{Fe I})$ vs. $\chi_{\text{exc}}$ (excitation potential) plot ($\chi_{\text{exc}}$ is the excitation potential of the line); microturbulent velocities, $V_t$, are derived demanding that lines of different EW give the same iron abundance, also checking for no slope in the $[\text{Fe/H}]$ vs. log(W/$\lambda$) plot (iron abundance vs. the reduced equivalent width); and surface gravities are determined by forcing the agreement between Fe I and Fe II iron abundances (within the accuracy of the abundance determination of Fe II). For the temperature and surface gravity ranges covered by our current sample of stars, $T_{\text{eff}}$ and log g determinations are well correlated and the calculation of stellar parameters is made iteratively. In Fig. 2 we show an example of the excitation equilibrium calculation for RGB,625, and in Fig. 3 the $[\text{Fe/H}]$ vs. $\lambda$ with the log(W/$\lambda$) check, and the $[\text{Fe/H}]$ vs. EW are given for RGB,710. The spectroscopic and photometric parameters of all our stars are reported in Table 2 together with the barycentric radial velocities calculated from the spectra.

### 3.2.1. Equivalent widths, line list and model atmospheres

The EW of the lines and the radial velocities (RV, in km/s, reported in Table 2 of the stars are computed using the program DAOSPEC written by Stetson (Stetson and Pancino, in preparation). The line list and the atomic data were assembled from the

---

2 The documentation and details about this program can be found in [http://cadcwww.dao.nrc.ca/stetson/daospec/]
literature and the oscillator strengths references are given in Table 3. DAOSPEC has already been used to measure the EW of spectra for different types of stars yielding reliable results (e.g. Pasquini et al. 2004, Barbuy et al. 2006, Sousa et al. 2006). We have made a study of the DAOSPEC EW estimations using GIRAFFE spectra. In the Appendix A we show a comparison of DAOSPEC EW with those made by hand using the Splot - Iraf task for six of our sample stars. We have found a very good agreement between the two methods for the analysis of the GIRAFFE spectra within the expected uncertainties.

MARCS 1D plane-parallel atmospheres models Gustafsson et al. 1975, Plez et al. 1992, Gustafsson et al. 2003) were kindly provided by B. Plez (private communication).

3.2.2. Comparison with UVES analysis

In a previous observing run (066.B-0331), we obtained UVES spectra (in slit mode) for one of our sample stars, RGB\textsubscript{666}. UVES is an echelle spectrograph also mounted on the VLT Kueyen telescope with a higher resolving power: $R = 45000$ (with a slit of 1") and a much wider wavelength coverage (in the case of our chosen set-up, 4800-6800Å), and therefore with a better performance to derive equivalent widths. We have used this spectrum to evaluate DAOSPEC performance to derive EW from low resolution spectra. In Fig. 4, equivalent widths derived with DAOSPEC from UVES spectra from 5800 to 6800Å are compared to those measured also by this program on the GIRAFFE spectra of the same star using the same line list. In the top of the plot, the mean differences between analyses are given together with the dispersion and the number of lines used (lines of all elements are plotted in this comparison). We can see from this plot that GIRAFFE EW are only slightly higher than UVES EW. Such a difference is probably due to a better definition of the continuum for the UVES spectra, as well as the increased blending at the lower resolution of GIRAFFE. Using the EW of this figure, we have inferred the stellar parameters for UVES to compare the analysis from both spectrographs. We have found that the stellar parameters are almost identical to those given for RGB\textsubscript{666} in Table 2 except for $V_t$ for which we have found $V_t = 1.8$ kms\textsuperscript{-1} (a difference of $\Delta V_t = +0.1$ kms\textsuperscript{-1}). Comparing the results from the two spectrographs, we have: $[\text{Fe}/\text{H}]_{\text{UVES}}- [\text{Fe}/\text{H}]_{\text{GIRAFFE}} = -0.11$ dex and $[\text{FeII}/\text{H}]_{\text{UVES}}- [\text{FeII}/\text{H}]_{\text{GIRAFFE}} = 0.00$ dex. Therefore it is possible that a systematic uncertainty of $[\text{Fe}/\text{H}] \sim 0.1$ dex may be present in the following abundance analysis, although robust statements on this uncertainty would require better statistics. Let us further note that this 0.1 dex difference is within the errorbar that we quote for our GIRAFFE metallicities.
3.3. Behavior of stellar parameters

We found good agreement between spectroscopic and photometric temperatures. Our spectroscopic temperatures are hotter than photometric temperatures derived using the low reddening value, $T_{\text{photLow}}$, by 113 K, with $\sigma=91$K, and by 54K than $T_{\text{phot}}$ (higher reddening value) with $\sigma=64$K. An interesting result is depicted in Fig. 5 where we compare the spectroscopic temperatures $T_{\text{eff spec}}$ with those derived from colors, $T_{\text{eff}}(V-I)$ and $T_{\text{eff}}(V-K)$, and from the equation given in Sect. 3.1.1, $T_{\text{eff}}(\text{phot})$, for both values of reddening ($E(B-V)=0.06$ in the upper panels, and $E(B-V)=0.03$ in the lower panels). This figure shows that photometric temperatures inferred using $E(B-V)=0.06$ are in much better agreement with spectroscopic temperatures than those derived with the lower $E(B-V)$. Provided that the photometric temperatures and the excitation temperature scale show a good agreement, this could indicate that $E(B-V)=0.06$ is a better reddening value for this region.

On average, spectroscopic surface gravities are lower than the photometric estimates by $\Delta(\log g_{\text{spec}} - \log g_{\text{phot}}) = -0.38$ dex, as might be expected if NLTE overionization effects are at work (Korn et al. 2003). This systematic effect in log g corresponds to a 0.2 dex difference between FeI and FeII.

The metallicities that we derive differ on average from those derived from the CaT by $\Delta([\text{Fe/H}]_{\text{CaT}} - [\text{Fe/H}]_{\text{spec}}) = +0.13$ dex with $\sigma=0.27$ dex. In fact, most of this effect comes from the high-metallicity end of the sample: for $[\text{Fe/H}]_{\text{CaT}} > -0.6$ dex, CaT seems to overestimate the metallicity systematically by 0.27 dex ($\sigma=0.19$ dex), whereas for the metal-poor end of the sample, there is almost no systematic effect ($\Delta[\text{Fe/H}]_{\text{CaT}} - [\text{Fe/H}]_{\text{spec}}) = -0.04$ dex with $\sigma=0.24$ dex.

Finally, in Fig. 6, abundance ratios of different species, [Cr/Fe], [Ni/Fe] and [V/Fe], against temperatures are plotted in order to check the quality of the spectroscopic temperatures. As can be seen from this picture, there is no trend of the abundances of the elements with temperature, which means that our temperatures are well defined. Our final sample comprises 59 red giant stars within $-1.7 < [\text{Fe/H}] < -0.30$ dex and temperatures ranging from 3900 K to 4500 K.

4. Abundance determination

We have selected a list of lines covering the chosen setups in order to sample as much as possible the most important elements: iron-peak, neutron-capture and $\alpha$ elements. Abundances are derived from EW measurements for eight elements (in parenthesis the average number of lines used in the analysis): Fe (45), Ni (7), Cr (4), V (11), Si (3), Ca (10), Ti (7) and Na (3). We have also derived abundances by using line synthesis for nine elements (in parenthesis the lines used in the synthesis): O ([O I] 6300 Å); Mg I (5711 Å), Co I (5647 Å), Cu I (5782 Å), Sc II (5657 Å), La II (6320 Å), Y II (6435 Å), Ba II
Pompéia et al.: Abundances of Stars in the LMC Disk

(6496 Å), and Zr I (6134 Å). The code used for the abundance analysis was developed by Monique Spite (1967) and has been improved over the years. We note that both model atmospheres and the line synthesis program are in spherical geometry, so errors due to geometry inconsistencies are minimized (Heiter & Eriksson 2006). For the synthesis of the [O I] line in 6300.311 Å, we have taken into account the blend with Ni I 6300.336 Å (line data from Allende Prieto 2001), but no difference have been detected between results with or without such blend. Hyperfine structures (HFS) are taken into account for the following elements (the line sources are given in parenthesis): Ba II (Rutten 1978, and the isotopic solar mix following McWilliam 1998); La II (Lawler et al. 2001 with log gf from Bord et al. 1996); Cu (Biehl 1976), and Co I and Sc II (Procaska et al. 2000). In Fig. 7 the fitting procedure is shown for the Y I 6435 Å line in RGB_752 and the La II line 6320 Å in RGB_690. Abundances are given relative to solar abundances of Grevesse & Sauval (2000). Atomic lines for the synthesis have been chosen according to the quality of the synthetic fit in the Solar Flux Atlas of Kurucz et al. (1984). In Tables 4 to 7 the derived abundances are given.

Errors in the derived abundances have three main sources: the uncertainties in the stellar parameters, the uncertainties in the measurements of the EW (or spectrum synthesis fitting) and the uncertainties on the physical data of the lines (mainly log gf). The errors due to stellar parameters uncertainties have been chosen as the maximum range each parameter could change not to give unrealistic models atmospheres. The errors \( \delta([\text{X}/\text{Fe}])_{\text{model}} \), are given in Table 8, assuming the following uncertainties in each of the stellar parameters: \( \Delta(T_{\text{eff}}) = \pm 100 \text{K} \), \( \Delta(\log g) = \pm 0.4 \text{ dex} \), \( \Delta(V_t) = \pm 0.2 \text{ km/s} \) and \( \Delta([\text{Fe}/\text{H}]) = \pm 0.15 \text{ dex} \).

Errors in the EW measurement are computed by DAOSPEC during the fitting procedure, then propagated into an abundance uncertainty for each line, and then combined into an abundance error on the mean abundance for each element (\( \delta_{\text{DAOSPEC}} \)). Errors due to the combined uncertainties on the line data and line measurement are reflected in the abundance dispersion observed for each element, provided that the number of lines is large enough to measure this dispersion in a robust way (\( N \geq 3 \)). We therefore combined these error estimates in a conservative way as given bellow:

\[
N_X < 3 : \quad \delta([X/H]) = \delta_{\text{DAOSPEC}},
N_X \geq 3 : \quad \delta([X/H]) = \text{Max}(\delta_{\text{DAOSPEC}}, \frac{\sigma(X)}{\sqrt{N_X}})
\]  

(1)

where \( N_X \) is the number of lines of the element X and \( \sigma(X) \) the dispersion among lines.

These errors are calculated for each element and given in Tables 4 to 6 together with the abundances derived from the EW. For elements measured by synthesis spectrum fitting, an error estimate has been carried out of the typical abundance change for which two different synthetic spectra (i.e. computed with two slightly different abundances) still fit satisfactorily the same line. On average, these values are the following for each
5. Abundance Distributions and comparison to Galactic samples

In Figs. 8 to 12 we depict the elemental distributions for the α-elements, the iron-peak group, Na, Sc, Cu and s-elements for our stars compared to different samples of the Galaxy and the LMC. Our data are represented as dots. The references of the disk are: Fulbright 2000 (crosses); Reddy et al. 2003 (open squares); Allende Prieto et al. 2004 (open stars); Prochaska et al. 2000 (open triangles); Burris et al. 2000 (stars - only for the heavy-elements plots); Johnson & Bolte 2002 (open triangles - only for the heavy-elements plots); Simmerer et al. 2004 (open hexagons); Nissen & Shuster 1997 (asterisks, only stars with low [α/Fe] ratios); Nissen et al. 2000 (asterisks - Sc abundances for the low-α stars); and Bensby et al. 2004 (open squares - only for the oxygen plot). LMC globular clusters (GC) stars from Hill et al. (2000, hereafter HI00) for O, and Hill (2004 hereafter HI04) for Na, Mg, Ca and Si are plotted as downward-pointing, open triangles; LMC GC stars from JIS06 are represented as open diamonds; field LMC red giants of SM02 are depicted as open pentagons. Error bars as described in Sect.4.0.1 are shown in the lower left side of the plots.

5.1. Ca, Si and Ti

In Fig. 8, the elemental distributions for Ca I, Si I, and Ti I are depicted. We have found that [Si/Fe] follows roughly the solar ratio with some scatter. [Ca/Fe] shows a slight decrease with metallicity. Compared to the distribution of the galactic halo, both silicon and calcium mean abundances are deficient by a factor of 3. Ti I ratios are also underabundant relative to galactic disk and galactic halo samples, and agree very well with the results of SM02, who derived titanium abundances from neutral lines for a sample of red giants from LMC disk. There is a hint of a decreasing trend of Ti abundances for higher metallicity stars, especially when SM02 datapoints are taken into account together with our sample. Compared to the LMC GC of HI04, we have found that the star of our sample with metallicity similar to those of those of Hill et al. (2004) also has
similar [Ca/Fe] ratio. The JIS06 sample of LMC GC stars seems to overlap our [Ca/Fe] and [Ti/Fe] distributions, while their [Si/Fe] ratios are enhanced.

A very interesting result emerges when comparing our data with those of Nissen & Shuster 1997 (hereafter NS97, asterisks). NS97 discovered a sample of stars from the galactic halo with abnormal abundances: low [α/Fe], [Na/Fe] and [Ni/Fe] ratios compared to “standard” halo stars. Such chemically peculiar or “low-α” halo stars have an important role in elucidating the possible merging history of the galactic halo. Because of their chemical properties, they indicate that this group have formed in another stellar system that evolved separately, and which has been captured or ejected to the halo. Comparing our LMC distribution to the low-α stars, we have found that NS97 stars show a slightly enhanced mean α abundance relative to our LMC stars.

Si, Ca and Ti are predicted to be produced in intermediate mass Type II SNe (SNe II) with a smaller contribution from Type Ia SNe (SNe Ia) (e.g. Tsujimoto et al. 1995, Thielemann et al. 2002), while Fe is mostly produced by SNe Ia (e.g. Thielemann et al. 2001, Iwamoto et al. 1999). The low [α/Fe] ratios observed indicate that SNe Ia have contributed more to the ISM content in the past than the SNe II.

5.2. Mg, O, Na and Sc

In Fig. 9, abundance ratios are given for O, Mg, Sc and Na. Nucleosynthetic predictions attribute the main source of O, Mg and Na to high-mass stars, with M > 25 M_☉, which explode as SNe II (Woosley & Weaver 1995, hereafter WW95), with Na production controlled by the neutron excess. Although WW95 have attributed the origin of Sc to SNe II, the main source of Sc production is still unclear (e.g. McWilliam 1997, Nissen et al. 2000).

As can be seen in the upper panel of Fig. 9, oxygen ratios fall in the lower envelope of the galactic halo and disk distributions. For higher metallicities, it shows a faster decline with metallicity compared to stars from the galactic disk. In the second plot we see that the [Mg/Fe] ratios for the LMC Inner Disk overlap those of the Galaxy, but with smaller mean values. In contrast, Na and Sc behaviors are similar to those of the α-elements Ti, and Si. Both elements are deficient and show smaller values for higher metallicities, while for the metal-poor tail, a match to the Galactic samples is observed. From this figure we see that the different LMC samples agree very well for all elements, Mg, O, Na and Sc, even the LMC globular clusters of H00, H04 and JIS06. A few stars in the NS00 sample of low-α stars show small [Sc/Fe] ratios and overlap our sample, but most of them show solar [Sc/Fe] values, higher than in our LMC sample. Sodium abundances in NS97 sample are similar to our values, although with a higher mean abundance. It is important to notice that sodium abundances in giants are still uncertain. Pasquini et al. (2004) found that [Na/Fe] ratios in giant stars are slightly higher than those from
dwarf stars in the same cluster. High [Na/Fe] ratios were also inferred from giants in M67 (Tautvaišiene et al. 2000). But such results have not been confirmed in the reanalysis of [Na/Fe] in giants and dwarfs of M67 (Randich et al. 2006).

Nissen et al. (2000) also found that Sc behaves similarly to Na, showing lower [Sc/Fe] ratios in their low-\(\alpha\) stars, suggesting a correlation among those elements. In order to test the hypothesis of a correlation among Na and \(\alpha\)-elements, and Sc and \(\alpha\)-elements we have applied a statistical test to check for the existence and significance of such correlation, calculating the linear correlation coefficient, which varies from 1 or -1 (maximum correlation or anti-correlation) to 0 (no correlation). We have found that the correlations are weak: for Na-Ca, a correlation coefficient \(\phi = -0.06\) is found, and for Sc-Ca, \(\phi = 0.39\).

5.3. Iron-peak elements

Abundance distributions for the iron-peak elements are shown in Fig. 10. The iron-peak elements Co, Ni and Cr display a very distinct pattern in the LMC Inner Disk stars, with underabundant values compared to the Galactic distributions and many subsolar ratios. [Co/Fe], [Cr/Fe] and [Ni/Fe] show a flat trend for most of the metallicity range, with mean abundances of \(\sim -0.18\) dex for Cr, \(\sim -0.24\) for Ni, and \(\sim -0.14\) dex for Co. The [V/Fe] ratios are similar to the galactic halo and disk patterns and track the solar value, with a group of stars showing smaller values. Results from the LMC GC of JIS06 seem to agree with our samples for Co, Ni and Cr. Vanadium in their sample shows an offset, with abundance ratios corresponding to the stars with smaller values in our sample. NS97 low-\(\alpha\) stars overlap our sample for Ni and Cr, but lie in the high abundance envelope of the distributions.

According to nucleosynthetic predictions, iron-peak elements are mainly produced in SNe Ia (Iwamoto 1999, Travaglio et al. 2005): while each SN Ia produces \(\approx 0.8\) M\(_{\odot}\) of the solar iron-peak elements, SN II produce \(\approx 0.1\) M\(_{\odot}\) each (Timmes et al. 2003). The difference in the distributions from one environment to the other is an evidence that the production factors for each iron-peak element are not the same in the different types of SNe and depend on the SFH of the parent population. This will be further discussed in Sect. 7.

5.4. Copper

In Fig. 11 we show the plot for Cu. We have found that in the Inner Disk LMC stars, the copper distribution is flat, with a mean value of [Cu/Fe] = \(-0.68\) dex. Comparing to the Galaxy, there is an overlap between the LMC and Halo stars at the metal-poor end ([Fe/H] < \(-1.3\) dex); for the higher metallicity range, the distributions diverge, with LMC stars showing a clear underabundance with respect to the Galactic Disk. JIS06 also found an offset in their [Cu/Fe], compatible to our abundance ratios.
Although originally associated with the iron-peak elements, the origin of copper is still much-debated (e.g. Bisterzo et al. 2004, Cunha et al. 2004, Mishenina et al. 2002). Sometimes its main source is attributed to SNe Ia (Matteucci et al. 1993, Cunha et al. 2002, Mishenina et al. 2002) and sometimes to SNe II, particularly to a metallicity dependent mechanism (Bisterzo et al. 2004; McWilliam & Smecker-Hane 2005). If the elemental behavior of the present sample, with low \( \alpha/Fe \), low [iron-peak/Fe] ratios, is due to a higher contribution from SNe Ia, the overall low [Cu/Fe] pattern indicates that thermonuclear supernovae cannot be the main source of Cu production.

### 5.5. s-process elements

We have found interesting elemental distributions for the s-process elements for our sample stars (Fig. 12). While the light s-process elements (hereafter \( ls \): elements made by the s-process with atomic number lower than \( \sim 45 \)) Zr and Y, show subsolar ratios with mean abundances the heavy s-process elements (hereafter \( hs \): elements made by the s-process with atomic number higher than \( \sim 50 \)) La and Ba show supersolar values with enhanced pattern compared to those of the Galaxy. The underabundance of \( ls \) elements is quite strong, \([Y/Fe] = -0.33 \) dex and \([Zr/Fe] = -0.48 \) dex, and Zr shows a hint of decreasing with increasing metallicities. Of the \( hs \) elements, Ba has a peculiar behavior with a high value for one metal-poor star \([Fe/H] < -1.4 \) dex), mild enhancements until \([Fe/H] \sim -1.15 \) dex, increasing again towards higher metallicities. La shows no trend with metallicity, with mild enhancements everywhere. One star, RGB_1118, has particularly high La and Ba abundances \([Ba/Fe] \) and \([La/Fe] \geq +1.0 \) dex) and could be a star enriched in s-process elements (via mass-transfer from a former AGB companion), although it is not possible from our present data to discriminate between enhancements of s-process or r-process elements. The s-process elements in JIS06 sample are different when compared to our results. While they have found no offset for the \( ls \) elements compared to the galactic distribution, showing therefore a higher abundance compared to our stars, their \( hs \) elements (Ba and La) are less enhanced than ours. Comparing NS97 low-\( \alpha \) stars with our sample, we find that these stars show abundances nearer those of normal disk stars for Ba and Y than the LMC stars.

The \( hs/ls \) ratios are high, showing large scatter, with a mean value of \([hs/ls] = +0.77 \) dex, as can be seen in Fig. 13. This is very different from what is observed for the galactic halo and disk stars, which fall around -0.2 to +0.2 dex (e.g. Pagel & Tautvaisiene 1997; Travaglio et al. 2004). A slow increasing trend with metallicity is observed.

High abundances of elements heavier than Zr were also derived for LMC and SMC supergiants (Russell & Bessell 1989; Spite et al. 1993; Hill et al. 1995). Hill et al. (1995) for example, found that the light s-elements Zr and Y show solar composition in LMC supergiants while heavier s-elements (Ba, La, Nd) as well as the r-process element Eu are
enhanced by +0.30 dex. As discussed by these authors, the overabundance of the heavier s-process and r-process elements seems to be a characteristic of the Magellanic Clouds, and indicate a particular evolution of that galactic system, although no satisfactory explanation was proposed for it.

In order to evaluate the r-process and s-process contributions within our sample we analysed the r-process content of one of our sample stars for which we have UVES spectra that cover the Eu λ 6645 Å line. Eu and Ba abundances were derived from these spectra in the same way as was done for GIRAFFE spectra. For RGB_666 we find respectively [Ba/Fe] = +0.52, and [Eu/Fe] = +0.40 dex. The corresponding [Ba/Eu] ratio of 0.12 (to be compared with the solar r-process [Ba/Eu]=−0.55 and the solar s-process [Ba/Fe]=+1.55, following Arlandini et al. 1999), indicate that this star contains a significant r-process contribution at a value close to the solar s/r mix at intermediate metallicities (RGB_666: [Fe/H]=-1.10).

A high content of r-process elements seems to be in contradiction with the observed low [$\alpha$/Fe] ratios (both being produced in massive stars). More data on Eu abundances are needed to confirm this high content of r-process elements, and in particular, the trend of the s/r fraction (traced by [Ba/Eu]) as a function of metallicity will help to constrain the source of the high content of heavy s-process elements in the LMC disk. We intend to tackle this issue in the two other fields (Bar and Outer Disk) of our LMC program, since one of the MEDUSA wavelength ranges covers the Eu line for these fields.

5.5.1. The NaMg, NaNi relations

In the paper by NS97 the authors found a correlation between Na and Ni for their halo stars (both “normal” and “low-\(\alpha\)” stars). Such correlation has been confirmed for a group of stars in the Dwarf Spheroidal Galaxies (Shetrone et al. 2003, SH03, Tolstoy et al. 2003, TO03, Venn et al. 2004). To evaluate this trend, we plot in Fig. 14 the [Ni/Fe] vs. [Na/Fe] relation for our sample stars (dots) together with NS97 low-\(\alpha\) stars. We see that the LMC stars also show a correlation between Na and Ni, although with a flatter pattern than the increasing trend observed for the NS97 sample. According to Tsujimoto et al. (1995), Ni can be produced in SNe Ia without Na production; therefore, a higher contribution from SNe Ia would flatten the NaNi relation (Venn et al. 2004) and could explain the behavior of the LMC stars. In Fig. 14 we also analyze the correlation between Na and Mg and we find decreasing [Na/Mg] ratios for increasing [Mg/H] ratios. The NS97 low-\(\alpha\) stars seem a continuation of the observed trend.

\(^3\) however Travaglio et al. 2005 found that some Na and Mg are also produced in SNe Ia
6. Comparison to the Dwarf Spheroidal Galaxies

In Figs. 15 and 16 we show a comparison of the chemical distributions of our LMC sample to those of the dSph galaxies of Shetrone et al. (2003) and Tolstoy et al. (2003), and the Sagittarius dwarf galaxy (Sgr) of Bonifacio et al. (2004) and Sbordone et al. (2007). The elemental distributions of most dSph galaxies are more concentrated in the metallicity range for which we have the lowest number of stars, \([\text{Fe/H}] < -1.2\), so the present analysis is not ideal. In Fig. 15 the distributions for the \(\alpha\)-elements Ca, Ti and Si and for Cu are depicted (the description of the different symbols are given in the figure captions). As can be seen from these figures, and observed for also for O, Mg, Na and Sc, there is an overlap among the LMC abundance ratios and those of the dSph galaxies. The same occurs for the iron-peak elements Cr, V and Ni and for Cu (with the exception of Fornax, which shows higher values for Cu). Particularly, the agreement among our data and those of the Sagittarius dwarf galaxy is very good, except that this galaxy shows \([\text{Ti/Fe}]\) and \([\text{Mg/Fe}]\) ratios slightly underabundant relative to our values.

For the \(s\)-process elements, depicted in Fig. 16, the dSph galaxies show enhanced \(hs\) and deficient \(ls\) compared to the Galactic behavior, although the general pattern is less discrepant than that showed by the LMC inner disk stars, except for Sgr, which shows striking similar ratios when compared to our data. Fornax has a more metal-rich star (Fnx21) with high \(s\) content, which may be an \(s\)-enriched star. The \([\text{Ba/Y}]\) ratios show a large offset relative to galactic samples, of the same order magnitude we have found. Venn et al. (2004) attribute such offset to primary \(s\)-process production by low-metallicity AGB stars.

The very similar elemental distributions of the Sgr galaxy indicate that this galaxy must have been very similar to LMC, i.e., with a higher mass content, which may be nowadays hidden in streams and/or dynamically mixed to the Galaxy.

7. Discussion

It is an amazing opportunity to have so much data on the amount of various elements of stars in an external galaxy. With this unique dataset, we can now explore in more detail the SFH and better understand the evolution of the LMC disk. The overall low \([X/Fe]\) ratios indicate that such stars have undergone a global process which is different from that experienced by the average halo and disk stars in the Galaxy. In this section we discuss the possible explanations for such behavior.

We have found an overall low abundance pattern for the \(\alpha\)-elements, in agreement with many previous works with stars in this galaxy (Sect. 1). The heavy \(s\)-elements show an enhancement relative to the Galactic disk distributions, as inferred before for supergiants and red giants in the LMC. New results from the present work include low light-\(s\) abundance ratios \([Y/Fe]\) and \([Zr/Fe]\), with most of the stars showing subsolar
values, and an unexpected offset for the iron-peak elements Ni, Cr and Co, and in some stars, also for V. Na and Sc are deficient with many subsolar ratios relative to iron, and copper shows a very low abundance in all stars from the present sample, with mean $[\text{Cu/Fe}] \sim -0.7$ dex, and no trend with metallicity.

As seen in previous sections, small $[\alpha/\text{Fe}]$ ratios have already been observed in other stellar systems such as the chemically peculiar halo stars (NS97, NS00), the dSph galaxies of the Local Group (Shetrone 2003, Tolstoy 2003), the Sagittarius galaxy (Smecker-Hane & McWilliam 2002, Bonifacio et al. 2004, Monaco et al. 2005, Sobordone et al. 2007), as in samples in the LMC (e.g. Hill et al. 2000, 2003; SM02, Garnett 2000, Korn et al. 2002). It is interesting to notice that the s-process trends in the dSph galaxies (enhanced $hs$ and deficient $ls$ ratios) are the same as for our stars. Correlations between abundances of iron-peak elements and $\alpha$-elements were observed also in other stellar systems. A pattern of slightly deficient Ni and Cr has been observed for the low-$\alpha$ stars of NS97. Bensby et al. (2003) found a correlation among the [iron-peak/Fe] and [Na/Fe] vs. [$\alpha$-elements/Fe] abundance ratios, i.e., slighty higher [Cr/Fe], [Ni/Fe] and [Na/Fe] ratios in thick disk stars with enhanced [$\alpha$-element/Fe] ratios (see their Fig. 13). Sobordone et al. (2007) found subsolar ratios for Na, Sc, Co, Ni and V in their analysis of the Sagittarius dwarf galaxy stars, which has also low $[\alpha/\text{Fe}]$ ratios. Such behavior may tell us interesting details about the formation of these elements and give clues about low-mass galaxy formation.

Many interpretations have been given for the small $[\alpha/\text{Fe}]$ ratios observed. One hypothesis is that the star formation (SF) developed slowly, in short bursts, followed by long quiescent periods without SF, during which the SNe Ia contaminated the ISM and increased the Fe content (e.g. Gilmore & Wyse 1991). Smaller SNe II/SNe Ia ratios, therefore a higher frequency of SNe Ia relative to SNe II, have also been invoked, within a bursty or continuous regime, and with or without galactic winds (e.g. Pagel & Tautvaisiene 1997, Smith et al. 2002); a steepened IMF relative to that of the solar neighborhood has been proposed by Tsujimoto et al. (1995) and de Freitas Pacheco (1998), whereas alpha-enriched galactic winds, which would lower the [$\alpha$/Fe] content, have been suggested by Pilyugin (1996); and finally, a small (low-mass) star-formation event that would effectively truncate the IMF, yieding fewer high-mass SNe II than produced by normal SF events has been suggested (Tolstoy et al. 2003). To find explanations for the behavior of the iron-peak elements is more puzzling, since they are predicted to be basically produced in SNe Ia (e.g. Travaglio et al. 2005). A possible explanation is that the yields of the SNe Ia are metallicity dependent (Timmes et al. 2003).

The abundance distributions observed for the $hs$ and the $ls$ elements, with $hs/ls=[\text{Ba+La/Y+Zr}]$, are in agreement with the hypothesis that the s-process in AGB stars is metallicity dependent (Busso et al. 1999 and references therein; Busso et al. 2001; Abia et al. 2003, Travaglio et al. 2004). It has been noticed that, due to details of the nucleosynthesis of the s-process, $hs$-elements (e.g. Ba, La and Nd) are preferentially pro-
duced by metal-poor AGB stars compared to ls elements (e.g. Y, Zr and Sr), which are most efficiently produced at [Fe/H] ≈ -0.1 (e.g. Fig. 1 of Travaglio et al. 2004). If the SF is slow, low-metallicity AGB stars have enough time to contaminate the ISM, leaving noticeable chemical signatures for the next generations.

Nevertheless, Venn et al. (2004) discuss the possibility that the abundances of these elements (including Y) in dSph cannot be accounted for solely by the s-process, requiring a strong contribution from the r-process. Also, according to Richtler et al. (1989) and Russell & Dopita (1992), the most probable explanation for the high Ba and La abundances observed in the Magellanic Clouds is an additional r-process component. This would mean that hs and ls elements are produced in different rates by the r-process nucleosynthesis, probably in different sites. Therefore, the analysis of the behavior of the s-elements in the given metallicity range is complex and must take into account both the r and the s contributions.

7.1. Galaxy Formation and Evolution

One of the most debated themes about galaxy formation in the Universe under a ΛCDM hierarchical scenario concerns the problem of overprediction of galaxy counts at low-z and underprediction at high-z (Cimatti et al. 2002). One of the consequences for the Local Group is a larger number of small galaxies than is actually observed although the number of dwarf galaxies observed around the Milky Way and M31 has lately grown significantly (eg. Belokurov et al. 2007). According to these models, numerous merging and accretion events play an important role in the formation process of massive galaxies (e.g. Moore et al. 1999), although not all dark matter clumps are predicted to host star formation and thereby become visible galaxies (e.g. Bullock & Johnston 2005). The quest for signatures of possible accreted stars from nearby galaxies in the Galactic halo and disk have been carried out, without definite conclusions (NS97, NS00, Ivans et al. 2003, Venn et al. 2004). A careful inspection of the elemental distributions of the different Galactic components reveals a low dispersion in the abundance ratios at each metallicity bin and smooth transitions between them (see e.g. plots from Venn et al. 2004). This seems to indicate a different process: that the Galaxy, including the halo, has grown in a holistic way, rather than by many independent accreting events, even for the galactic halo (see Gilmore & Wyse 2004). Another possibility is that the merging events occurred very early in the building process of our Galaxy, involving mostly dark matter and primordial gas. Such observational features hint for a common history within the same environment rather than a mix of SFHs. The results from the present work strongly support this idea, showing that an LMC-like SFH results in a quite distinctive elemental pattern not seen in any galactic stellar population.
We have found that the elemental compositions of the LMC Inner Disk stars show a different pattern when compared to their galactic counterparts (if we exclude the low-alpha stars of NS97). This indicates that possible accreting events of LMC and LMC-like fragments (Bekki & Chiba 2005, Robertson et al. 2005), from which our Galactic halo could have been built, are unlikely, but strong conclusions are still not possible because more representative samples are needed, from both halo and LMC stars. However, we stress here that the stellar populations probed in the LMC are mostly intermediate age, and would not have been merged into a Milky Way halo or disk if the accretion of an LMC-like galaxy occurred early on ($z > 1$). Strong conclusions concerning the possible early accretion of LMC-type systems therefore still await detailed analysis of the elemental abundances of representative samples of the oldest populations in the LMC. The elemental distributions of the LMC Inner Disk also hint for a different process of galaxy formation, showing that the galactic local environment is fundamental for the the amount of various elements of its components.

8. Summary

In the present paper we report abundance ratios for a series of elements, including $\alpha$, $s$- and iron-peak elements, Na, Sc and Cu for a sample of 59 RGB stars of the inner LMC disk. We have found a very different behavior for most of the elements relative to stars from the Galaxy with similar metallicity, hinting at a very different evolutionary history. On the other hand, there is a good overall agreement between the elemental distributions of our sample stars and previous results of the LMC GC and field stars of Hill et al. (2000, 2003), Smith et al. (2002) and Johnson et al. (2006) The main results are summarized as follows:

- $[\alpha/Fe]$ ratios show an overall deficient pattern relative to Galactic distributions, in agreement with a slower star-formation history in the LMC, leading to a stronger Type Ia supernovae influence. However, all $\alpha$-elements do not show the same degree of deficiency: while O/Fe and Mg/Fe are hardly different in the LMC and Milky-Way disks, Si, Ca and Ti are strongly underabundant. This illustrates that all $\alpha$-elements are not alike from the nucleosynthesis point of view.

- Cu is strongly depleted with respect to iron, $[Cu/Fe] \approx -0.70$ dex, with no apparent trend with metallicity. This also hints at a strong contribution of Type Ia supernovae to the creation of copper.

- the $[X/Fe]$ deficiency of the $\alpha$-elements is also displayed by Na, Sc, and, in an unexpected behavior, by the iron-peak elements Ni, Cr and Co. The iron peak elements underabundances are not expected in any standard chemical evolution model (i.e. currently not predicted by SNe yields).
we have found relationships between Na-Ni and Na-Mg, in agreement to those derived by Nissen & Schuster (1997) for a sample of low-Å halo stars. As Na is predicted to be mainly produced by SNe II, together with O and Mg, a relationship Na-Mg is expected, although Na production is also controlled by the neutron excess during carbon burning in massive stars (Umeda et al. 2000). The Na-Ni relationship is also expected if Ni is also produced in SN II, with yields dependent on the neutron excess (Thielemann et al. 1990).

Heavy neutron capture elements fall into two well-defined groups: while high-mass s-process elements (Ba and La) present an enhanced pattern, low-mass s-process elements (Y and Zr) are deficient relative to the galactic samples. Such behavior has been observed before in LMC and SMC F supergiants and in dSph galaxy RGB stars. It could reflect a strong contribution of metal-poor AGB stars to the metal-enrichment of these systems, as low-metallicity AGB stars preferentially produce the heavier s-process elements over the lighter ones (see Travaglio et al. 2004 for the theoretical side and de Laverny et al. 2006 for the observation of low-metallicity AGBs).

We have derived Eu abundances for one of our intermediate-metallicity stars (RGB666: [Fe/H] = −1.10), and combined with the measured Ba abundance for this star, this enabled us to disentangle the respective r- and s-process contributions to heavy neutron-capture elements: this star contains a solar mix of r- and s-process elements. Although a single measurement is obviously not enough to conclude, we thereby confirm that the high abundances of ls elements observed at intermediate metallicity should be attributed to the s-process.

For the next two fields of our program (see Introduction) the wavelength range of the spectra covers a Eu line and a better evaluation of such contributions will be possible.

Compared to the dSph galaxies, similar abundance ratios for almost all the elements have been derived, with slight enhancements of La, Ba, Na and Y, although the match in metallicity among our sample and the dSph samples is not ideal. LMC Inner Disk abundances of Ca, Si, Ti and Cu are also similar to those of the Sagittarius dwarf galaxy. The commonalities between the LMC inner disk population and the samples in dSph galaxies indicate that all these galaxies may have undergone similar SFH.

The overall pattern of the elemental distributions for the LMC Inner Disk population can be explained by a higher contribution of Type Ia SNe, indicating that the build up of this population has been slower than that of the solar neighborhood stars. A higher contribution from metal-poor AGB stars is also proposed. The present results support the hypothesis that the elemental distributions of the stars are directly related to galaxy they pertain.

Acknowledgements. L. P. acknowledges CAPES and FAPESP fellowships #0606-03-0 and #01/14594-2. We greatly thank Peter Stetson for the availability of the DAOSPEC program.
References

Abia, C., Domínguez, I., Gallino, R., Busso, M., Masera, S., Straniero, O., de Laverny, P., Plez, B., Isern, J. 2002, ApJ 579, 817
Allende Prieto, C., Barklem, P. S., Lambert, D. L., Cunha, K. A&A 420, 183
Barbuy, B., Zoccali, M., Ortolani, S., Momany, Y., Minniti, D., Hill, V., Renzini, A., Rich, R. M., Bica, E., Pasquini, L., Yadav, R. K. S. 2006, A&A 449, 349
Belokurov, V., Zucker, D. B., Evans, N. W., et al. 2007, ApJ 654, 897
Bensby, T., Feltzing, S., Lundstrom, I. 2003, A&A 410, 527
Bensby, T., Feltzing, S., Lundstrom, I. 2004, A&A 415, 155
Bessell, M.S., Castelli, F. & Plez, B. 1998, A&A 333, 231
Bessell, M.S. 1991, A&A 242L, 17
Biehl, D. 1976, Ph.D. Thesis, Kiel
Bisterzo, S., Gallino, R., Pompeia, L., Cunha, K., Smith, V. 2004, MnSAI v.75, p.741
Bonifacio, P., Sbordone, L., Marconi, L., Pasquini, L., Hill, V. 2004, A&A 414, 503
Bord, D. J., Barisciano, L. P., Cowley, C. R. 1996, MNRAS, 278, 997
Bullock, J.S. & Johnston, K.V. 2005, ApJ 635, 931
Butcher, H. 1977 ApJ 216, 372
Burris, D.L., Pilachowski, C.A., Armandroff, T.E., Sneden, C., Cowan, J.J., Roe, H. 2000, ApJ 544, 302
Busso, M., Gallino, R., Wasserburg, G. J. 1999, ARA&A, 37, 239
Busso, M., Gallino, R., Lambert, D.L., Travaglio, C., Smith, V.V. 2001, ApJ 557, 802
Carpenter, J.M. 2001, AJ, 121, 2851
Cayrel, R. 1988, in in IAU Symp. 132, The Impact of Very High S/N Spectroscopy on Stellar Physics, eds. G. Cayrel de Strobel & M. Spite (Dordrecht: Kluwer), 345
Cayrel, R., Depagne, E., Spite, M., Hill, V., Spite, F., François, P., Plez, B., Beers, T., Primas, F., Andersen, J., Barbuy, B., Bonifacio, P., Molaro, P., Nordstrm, B. 2004, A&A 416, 1117
Cimatti, A., Pozzetti, L., Mignoli, M., Daddi, E., Menci, N., Poli, F., Fontana, A., Renzini, A., Zamorani, G., Broadhurst, T., Cristiani, S., D’Odorico, S., Giallongo, E., Gilmozzi, R. 2002 A&A 391L, 1
Cioni, M.-R., Girardi, L., Marigo, P., Habing, H.J. 2006, A&A 448, 77
Cunha, K., Smith, V.V., Suntzeff, N.B., Norris, J.E., Da Costa, G.S., Plez, B. 2004, AJ 124, 379
Da Costa, G. S. 1991, in IAU Symp 148, ”The Magellanic Clouds”, eds. R. Haynes and D. Milne, Kluwer: Dordrecht, p. 183
Da Costa, G. S. 1999, in IAU Symp 190, ”New Views on the Magellanic Clouds”, eds. Y.-H Chu, N. Suntzeff, J. Hesser, D. Bohlender, ASP: San Francisco, p. 397
de Laverny P., Abia C., Domínguez I., Plez B., Straniero O., Wahlin R., Eriksson K., Jørgensen U., 2006 A&A 446, 1107
D’Onghia, E., & Lake, G., 2004 ApJ 612 628
Dufton, P. L.; Smartt, S. J.; Lee, J. K. et al. 2006, A&A 2006, 457, 265
de Freitas Pacheco, J.A. 1998, Aj 116, 1701
de Vaucouleurs, G. 1980, PASP 92, 576
Kurucz, R.L., Furenlid, I., Brault, J. 1984, National Solar Observatory Atlas, Sunspot, New Mexico: National Solar Observatory, 1, 984
Lawler, J. E., Bonvallet, G., Sneden, C. 2001, ApJ 556, 452
Luck, R.E. & Lambert, D.L. 1992, ApJS 79, 303
Madore, B. F., & Freedman, W. L. 1998, ApJ, 492, 110
Matteucci, F., Raineri, C.M., Busson, M., Gallino, R., & Gratton, R. 1993, A&A, 272, 421
McWilliam, A. 1997, ARA&A 35, 503
McWilliam, A. 1998, AJ 115, 1640
McWilliam, A., Smecker-Hane, T. 2005, ApJ 622, 29
Mishenina, T. V., Kovtyukh, V. V., Soubiran, C., Travaglio, C., & Busso, M. 2002, A&A, 396, 189
Moore, B., Ghigna, S., Lake, G., Quinn, T., Stadel, J., & Tozzi, P. 1999, ApJ, 524, L19
Nissen, P. E., Schuster, W. J. 1997, A&A 326, 752
Nissen, P. E., Chen, Y. Q., Schuster, W. J., Zhao, G., 2000, A&A 353, 722
Olszewski, E.W.; Suntzeff, N.B.; Mateo, M. 1996, ARA&A 34, 511
Pagel, B. E. J., Tautvaisiene, G. 1997, MNRAS 288, 108
Pasquini, L., Avila, G., Blecha, A. et al. 2002, The Messenger, 110, 1
Pasquini, L., Randich, S., Zoccali, M., Hill, V., Charbonnel, C., Nordström, B. 2004, A&A 424, 951
Pilyugin, L.S. 1996, A&A 310, 751
Plez, B., Brett, J.M., Nordlund, A. 1992, A&A 256, 551
Plez, B. 2000, Proc. IAU Symp. 177, 'The Carbon Star Phenomenon', Wing, R.F. ed., Kluwer Academic Publishers, Dordrecht, p.71
Prochaska, J. X., Naumov, S. O., Carney, B. W., McWilliam, A., & Wolfe, A. M. 2000, AJ 120, 2513
Randich, S., Sestito, P., Primas, F., Pallavicini, R., Pasquini, L. 2006, A&A 450, 557
Reddy, B. E., Tomkin, J., Lambert, D. L., & Allende Prieto, C. 2003, MNRAS 340, 304
Richtler, T., Spite, M., Spite, F. 1989, A&A 225, 351
Rolleston, W. R. J., Trundle, C., Dufton, P. L. 2002, A&A 396, 53
Russell, S.C. & Bessell, M.S. 1989, ApJS 70, 865
Russell, S.C. & Dopita, M.A. 1992, ApJ 384, 508
Rutten, R.J., 1978, Solar Physics 56, 237
Sarajedini, A. 1998, AJ 116, 38
Sbordone, L., Bonifacio1, P., Buonanno, R., Marconi, G., Monaco, L., Zaggia, S. 2007, 465, 815
Shetrone, M. D., Venn, K. A., Tolstoy, E., Primas, F., Hill, V., & Kaufer, A. 2003, AJ, 125, 684
Smecker-Hane, T.A., Cole, A.A., Gallagher, J.S.III, Stetson, P.B. 2002, SMH02, ApJ 566, 239
Smecker-Hane T., Cole, A., Mandushev, G.I., Bosler, T. L., Gallagher J., in press
Smecker-Hane, T.A., Cole, A.A., Mandushev, G.I., Bosler, T.L., Gallagher, J.S. 2007, in preparation
Smecker-Hane T., McWilliam, A. 2002, Proc. Symp. ‘Cosmic Abundances as Records of Stellar Evolution and Nucleosynthesis in honor of David L. Lambert” ASP Conf. Series, Thomas G. Barnes III and Frank N. Bash eds., San Francisco, V. 336, 221
Smith, V.V., Hinkle, K.H., Cunha, K., Plez, B., Lambert, D.L., Pilachowski, C.A., Barbuy, B.,
Melendez, J., Balachandran, S., Bessell, M.S., Geisler, D.P., Hesser, J.E., Winge, C. 2002,
AJ 124, 3241
Sneden, C., Gratton, R.G., Crocker, D.A. 1991, A&A, 246, 354
Sousa, S. G.; Santos, N. C.; Israeli, G.; Mayor, M.; Monteiro, M. J. P. F. G. 2006, A&A 458,
873
Smith, V.V., Hinkle, K.H., Cunha, K., Plez, B., Lambert, D.L., Pilachowski, C.A., Barbuy, B.,
Melendez, J., Balachandran, S., Bessell, M.S., Geisler, D.P., Hesser, J.E., Winge, C. 2002,
AJ 124, 3241
Sneden, C., Gratton, R.G., Crocker, D.A. 1991, A&A, 246, 354
Sousa, S. G.; Santos, N. C.; Israeli, G.; Mayor, M.; Monteiro, M. J. P. F. G. 2006, A&A 458,
873
Spite, F., Barbuy, B., Spite, M. 1993, A&A 272, 116
Subramaniam, A. 2004, A&A 425, 837
Tautvaišiene, G., Edvardsson, B., Tuominen, I., Ilyin, I. 2000, A&A, 360, 499
Thielemann, F.-K., Hashimoto M., Nomoto K. 1990, ApJ 349, 222
Thielemann, F.-K., Brachwitz F., Freiburghaus, C., Kolbe, E., Martinez-Pinedo, G., Rauscher,
T., Rembges, F., Hix, W. R., Liebendörfer, M., Mezzacappa, A., Kratz, K.-L., Pfeiffer, B.,
Langanke, K., Nomoto, K., Rosswog, S., Schatz, H., Wiescher, W. 2001, PPNP, 46, 5
Thielemann, F.-K., Argast, D., Brachwitz, F., Martinez-Pinedo, G., Rauscher, T., Liebendörfer,
M., Mezzacappa, A., Hiflich, P., Nomoto, K. 2002, Ap&SS 281, 25
Timmes, F. X., Brown, Edward F., Truran, J. W. 2003, ApJ 590, 83L
Tolstoy, E., Venn, K. A., Shetrone, M. D., Primas, F., Hill, V., Kaufer, A., & Szeifert, T. 2003,
AJ, 125, 707
Travaglio, C., Gallino, R., Arnone, E., Cowan, J., Jordan, F., Sneden, C. 2004, ApJ 601, 864
Travaglio, C. Hillebrandt, W., Reinecke, M., Thielemann, F.-K, 2005, astro-ph/0406281
Tsujimoto, T., Nomoto, K., Yoshii, Y., Hashimoto, M., Yanagida, S., Thielemann, F.-K. 1995,
MNRAS 277, 945F
Umeda, H., Nomoto, K., Nakamura, T 2000, in The First Stars, ed. A. Weiss, T. Abel, & V.
Hill Heidelberg: Springer, 150
van den Bergh, S. 1979, ApJ 230, 95
van den Bergh, S. 1998, ApJ 507, L39
van den Bergh, S. 1999, IAU Simp. 190, "New Views of the Magellanic Clouds", Y.-H. Chu, N.
Suntzeff, J. Hesser, & D. Bohlender (Eds.)
van der Marel, R.P., Cioni, M.-R. L. 2001, AJ 122, 1807
Venn, K.A., Irwin, M., Shetrone, M.D., Tout, C.A., Hill, V., Tolstoy, E. 2004, AJ 128, 1177
Westerlund, B. E. 1997, The Magellanic Clouds Cambridge: Cambridge Univ. Press
Woosley, S.E., Weaver, T.A. 1995, ApJS 101, 181
Fig. 1. V (V−I) color-magnitude diagram of the Disk region (following SMH02), with our sample stars overplotted: asterisks are stars with [Fe/H]_{CaT} ≥ −0.5 dex, triangles−1.0 ≤ [Fe/H]_{CaT} < −0.5 dex, squares [Fe/H]_{CaT} < −1.0 dex.

Fig. 2. Example of the temperature calculation for RGB_625: [Fe I/H] vs. $\chi_{exc}$.

Fig. 3. Examples of microturbulence velocity calculation for RGB_710: [Fe I/H] vs. $\lambda$ (left); and [Fe I/H] vs. EW (right). The different values for the reduced EW in the left panel are given with different symbols: 1) squares: −5.6 ≤ log W/λ ≤ −5.0 and 12<W<50; 2) crosses: −4.8 ≤ log W/λ ≤ −4.0 and 80<W<300; and 3) times: −5.0 ≤ log W/λ ≤ −4.8 50<W<80.
Fig. 4. Comparison between UVES and GIRAFFE spectra analyses for RGB_666.

Fig. 5. Comparison between photometric and spectroscopic temperatures (see text). On the bottom plots, photometric temperatures are derived with E(B−V)=0.03 (SMH02), while on the upper plots, photometric temperatures are derived with a higher reddening value, E(B−V)=0.06 (Bessel 1991). Solid lines represent $T_{\text{eff}}(\text{spec}) = T_{\text{eff}}(\text{phot})$ and $T_{\text{eff}}(\text{spec}) = T_{\text{eff}}(\text{phot}) \pm 100$K.
Fig. 6. Abundance ratios against temperatures. From top to bottom: [Cr/Fe] vs. $T_{\text{eff}}$, [Ni/Fe] vs. $T_{\text{eff}}$ and [V/Fe] vs. $T_{\text{eff}}$.

Fig. 7. Example of the line synthesis procedure for the Y I and La II lines: left panel: Y I $\lambda$6435Å line fitting for RGB$_{752}$; right panel: La II $\lambda$6320 line fitting for RGB$_{690}$. The black circles depict the observed spectra and the lines are the synthetic spectra. Abundances of the synthetic spectra are: $[\text{Y/Fe}] = -0.55$ (dashed line), $-0.45$ (continuous line - best fit), $-0.25$ (dotted line); and $[\text{La/Fe}] = 0.56$ (dashed line), 0.66 (continuous line - best fit), and 0.76 (dotted line).
Fig. 8. Abundance distributions for the Inner Disk LMC stars: $\alpha$/Fe vs. $\text{[Fe/H]}$ (blue dots). LMC samples are depicted with polygons (downward-pointing green triangles - Hill et al. 2000; red pentagons - Smith et al. 2002; magenta diamonds - Johnson et al. 2006); and the remaining symbols (all in blue) are data for the galactic stars (crosses - Fulbright 2000; open squares - Reddy et al. 2003; cyan asterisks - Nissen & Schuster 1997). Error bars depict: a. leftmost side of the plots - errors due to stellar parameter uncertainties (Table 8); and b. more to the right side - errors associated with the abundance analysis - for those derived from the EW, is the mean error of Tables 4, 5, and 6; for those elements with abundances derived from spectrum synthesis, is the value described in Sect. 4.
Fig. 9. Abundance distributions for the Inner Disk LMC stars: [O, Mg, Na, Sc/Fe] vs. [Fe/H] (symbols are the same as in Fig. 8, and we added: blue open stars - Allende Prieto et al. 2004, blue crosses - Bensby et al. 2004 only for oxygen; cyan asterisks - Nissen et al. 2000 for Sc and Nissen & Schuster 1997 for the other elements).
Fig. 10. Abundance distributions for the Inner Disk LMC stars: [Iron-peak/Fe] vs. [Fe/H] (symbols are the same as in Figs. 8 and 9, and the solid downtriangles depict upper limits for our sample stars).
Fig. 11. Abundance distributions for Inner Disk LMC stars: Copper. The symbols are the data from: our sample stars (dots); Mishenina et al. 2002 (blue stars); Prochaska et al. 2002 (open blue triangles); Reddy et al. 2003 (open blue squares); Johnson et al. 2006 (magenta diamonds).
Fig. 12. Abundance distributions for Inner Disk LMC stars: \([s\text{-elements/Fe}]\) vs. [Fe/H]. The large dots (or downtriangles for upper limits) depict our sample stars, while open blue symbols represent galactic samples: symbols as in Figure 8, plus Burris et al. 2000 (blue stars); Johnson & Bolte 2002 (blue triangles); Simmerer et al. 2004 (blue hexagons); Nissen & Schuster 1997 (cyan asterisks).
Fig. 13. Observed abundance ratios \([hs/ls] = [\text{Ba}+\text{La}/\text{Y+Zr}]\).
Fig. 14. The NaNi and NaMg abundance relations. Our sample stars are depicted as dots and NS97 low-α stars as starred symbols.
Fig. 15. Comparison of the Inner Disk LMC stars with stars from the dwarf spheroidal galaxies and the Sgr galaxy. 1. Alpha elements. The symbols are: our sample (dots), Leo I (magenta pentagons), Sculptor (open cyan dots), Fornax (green triangles), Carina (red squares), and Sgr (Bonifacio et al. 2005 - blue stars; Sbordone et al. 2007 - blue asteriks). Solid lines depict mean values of the Galactic distributions for each element.
Fig. 16. Comparison of the Inner Disk LMC stars with stars from the dwarf spheroidal galaxies. 2. s-process elements (symbols are the same as in Fig. 15).
Table 1. Photometric Data

| Star Reference | 2MASS number  | V   | I   | J   | K   |
|----------------|---------------|-----|-----|-----|-----|
|                | mag           |     |     |     |     |
| RGB_{1055}     | 05113508-7112309 | 17.599 | 16.219 | 15.070 | 14.172 |
| RGB_{1105}     | 05125047-7107463 | 17.661 | 16.170 | 14.972 | 13.952 |
| RGB_{1118}     | 05104862-7109301 | 17.628 | 16.278 | 15.298 | 14.258 |
| RGB_{499}      | 05130497-7115406 | 17.023 | 15.699 | 14.624 | 13.905 |
| RGB_{512}      | 05105703-7111340 | 16.994 | 15.539 | 14.452 | 13.489 |
| RGB_{522}      | 05112258-7107277 | 17.005 | 15.537 | 14.360 | 13.420 |
| RGB_{533}      | 05131266-7118005 | 16.958 | 15.537 | 14.562 | 13.571 |
| RGB_{534}      | 05123774-7118119 | 17.111 | 15.890 | 14.807 | 14.045 |
| RGB_{546}      | 05112068-7108113 | 17.041 | 15.619 | 14.546 | 13.639 |
| RGB_{548}      | 05130454-7113055 | 17.095 | 15.680 | 14.502 | 13.573 |
| RGB_{565}      | 05111922-7112564 | 17.061 | 15.585 | 14.468 | 13.489 |
| RGB_{576}      | 05120852-7116597 | 17.132 | 15.806 | 14.668 | 13.631 |
| RGB_{593}      | 05132454-7109519 | 17.168 | 15.688 | 14.484 | 13.529 |
| RGB_{599}      | 05124460-7109195 | 17.174 | 15.756 | 14.574 | 13.663 |
| RGB_{601}      | 05111325-7120037 | 17.112 | 15.673 | 14.633 | 13.772 |
| RGB_{606}      | 05133509-7109322 | 17.152 | 15.791 | 14.694 | 13.850 |
| RGB_{611}      | 05114888-7111492 | 17.122 | 15.603 | 14.478 | 13.589 |
| RGB_{614}      | 05145465-7113031 | 17.023 | 15.492 | 14.459 | 13.375 |
| RGB_{620}      | 05142327-7107446 | 17.205 | 15.790 | 14.608 | 13.845 |
| RGB_{625}      | 05103395-7112074 | 17.144 | 15.614 | 14.473 | 13.440 |
| RGB_{629}      | 05104928-7110057 | 17.140 | 15.766 | 14.723 | 13.792 |
| RGB_{631}      | 05134131-7118477 | 17.054 | 15.655 | 14.638 | 13.638 |
| RGB_{633}      | 05120481-7113402 | 17.131 | 15.647 | 14.527 | 13.702 |
| RGB_{640}      | 05100529-7112259 | 17.154 | 15.772 | 14.747 | 13.791 |
| RGB_{646}      | 05140805-7117297 | 17.071 | 15.674 | 14.653 | 13.922 |
| RGB_{651}      | 05114466-7107176 | 17.152 | 15.713 | 14.672 | 13.729 |
| RGB_{655}      | 05143617-7109412 | 17.202 | 15.674 | 14.521 | 13.616 |
| RGB_{656}      | 05122551-7112106 | 17.191 | 15.758 | 14.637 | 13.743 |
| RGB_{658}      | 05100845-7109582 | 17.229 | 15.797 | 14.728 | 13.643 |
| RGB_{664}      | 05100659-7115514 | 17.156 | 15.529 | 14.438 | 13.336 |
| RGB_{666}      | 05104728-7119320 | 17.167 | 15.833 | 14.763 | 13.977 |
| RGB_{671}      | 05114880-7113428 | 17.197 | 15.705 | 14.555 | 13.585 |
| RGB_{672}      | 05130066-7116289 | 17.193 | 15.611 | 14.460 | 13.407 |
| RGB_{679}      | 05123409-7113324 | 17.203 | 15.653 | 14.481 | 13.578 |
### Table 1. Photometric Data

| Star Reference | 2MASS number | $V$ (mag) | $I$ (mag) | $J$ (mag) | $K$ (mag) |
|----------------|--------------|----------|----------|----------|----------|
| RGB$_{690}$   | 05144229-7110108 | 17.266   | 15.678   | 14.488   | 13.413   |
| RGB$_{699}$   | 05095252-7115084 | 17.214   | 16.058   | 15.243   | 14.399   |
| RGB$_{700}$   | 05113581-7113336 | 17.284   | 15.821   | 14.717   | 13.676   |
| RGB$_{701}$   | 05124208-7110018 | 17.214   | 15.693   | 14.590   | 13.579   |
| RGB$_{705}$   | 05141536-7107463 | 17.215   | 15.886   | 14.866   | 14.026   |
| RGB$_{710}$   | 05110701-7108413 | 17.308   | 15.762   | 14.424   | 13.368   |
| RGB$_{720}$   | 05103055-7116158 | 17.314   | 15.984   | 14.901   | 14.313   |
| RGB$_{728}$   | 05142677-7119303 | 17.249   | 15.836   | 14.777   | 13.955   |
| RGB$_{731}$   | 05120180-7117002 | 17.255   | 15.593   | 14.382   | 13.357   |
| RGB$_{748}$   | 05122530-7119025 | 17.279   | 15.781   | 14.804   | 13.760   |
| RGB$_{752}$   | 05144969-7110095 | 17.320   | 15.801   | 14.566   | 13.621   |
| RGB$_{756}$   | 05143449-7112462 | 17.251   | 15.568   | 14.349   | 13.278   |
| RGB$_{758}$   | 05111461-7118573 | 17.269   | 15.983   | 14.996   | 14.266   |
| RGB$_{766}$   | 05111734-7115235 | 17.343   | 15.861   | 14.726   | 13.779   |
| RGB$_{773}$   | 05115657-7108489 | 17.264   | 15.707   | 14.632   | 13.602   |
| RGB$_{775}$   | 05095756-7116288 | 17.261   | 15.927   | 14.879   | 14.100   |
| RGB$_{776}$   | 05111615-7116401 | 17.287   | 15.877   | 14.826   | 14.033   |
| RGB$_{782}$   | 05104950-7107338 | 17.291   | 15.844   | 14.758   | 13.761   |
| RGB$_{789}$   | 05121657-7108570 | 17.310   | 15.629   | 14.382   | 13.267   |
| RGB$_{793}$   | 05110667-7111205 | 17.319   | 15.843   | 14.751   | 13.783   |
| RGB$_{834}$   | 05112287-7116589 | 17.355   | 15.828   | -        | -        |
| RGB$_{854}$   | 05102155-7118506 | 17.415   | 15.997   | 14.922   | 14.064   |
| RGB$_{855}$   | 05124558-7116301 | 17.393   | 16.001   | 14.901   | 13.981   |
| RGB$_{859}$   | 05112287-7116589 | 17.397   | 15.883   | 14.730   | 13.806   |
| RGB$_{900}$   | 05130400-7113289 | 17.400   | 15.983   | 14.915   | 14.032   |
| Star    | $T_{\text{phot,Low}}$ | $T_{\text{phot}}$ | $T_{\text{spec}}$ | $\log g_{\text{phot}}$ | $\log g_{\text{spec}}$ | $[\text{Fe/H}]_{\text{spec}}$ | $[\text{Fe/H}]_{\text{CaT}}$ | $[\text{FeII/H}]$ | Vt | RV |
|---------|----------------------|------------------|------------------|-------------------------|-------------------------|-------------------------------|------------------------------|-----------------|----|----|
| RGB_1055 | 4066                | 4118             | 4266             | 1.5                     | 0.90                    | -0.96                         | -0.87                        | -0.87           | 1.2 | 177 |
| RGB_1105 | 3921                | 3965             | 4100             | 1.4                     | 0.90                    | -0.71                         | -1.15                        | -0.69           | 1.6 | 243 |
| RGB_1118 | 4102                | 4154             | 4204             | 1.5                     | 1.30                    | -0.57                         | -0.25                        | -0.65           | 1.8 | 208 |
| RGB_499  | 4212                | 4269             | 4242             | 1.4                     | 1.00                    | -0.85                         | -0.44                        | -0.89           | 2.2 | 220 |
| RGB_512  | 4002                | 4051             | 4202             | 1.2                     | 0.80                    | -0.84                         | -0.78                        | -0.89           | 1.7 | 247 |
| RGB_522  | 3971                | 4016             | 4101             | 1.2                     | 1.01                    | -0.70                         | -0.37                        | -0.77           | 2.0 | 270 |
| RGB_533  | 4062                | 4113             | 4112             | 1.2                     | 0.80                    | -0.75                         | -0.43                        | -0.82           | 2.0 | 243 |
| RGB_534  | 4295                | 4359             | 4295             | 1.5                     | 1.20                    | -1.22                         | -1.11                        | -1.12           | 1.6 | 246 |
| RGB_546  | 4055                | 4107             | 4185             | 1.3                     | 0.80                    | -0.96                         | -0.91                        | -0.99           | 1.7 | 260 |
| RGB_548  | 4016                | 4064             | 4066             | 1.2                     | 0.90                    | -0.74                         | -0.31                        | -0.80           | 2.0 | 247 |
| RGB_565  | 3970                | 4016             | 4100             | 1.2                     | 0.70                    | -0.94                         | -0.60                        | -0.96           | 1.9 | 242 |
| RGB_576  | 4064                | 4117             | 4190             | 1.3                     | 0.80                    | -1.24                         | -1.03                        | -1.20           | 1.6 | 305 |
| RGB_593  | 3948                | 3993             | 4088             | 1.2                     | 0.70                    | -1.15                         | -0.58                        | -1.17           | 1.9 | 234 |
| RGB_599  | 4018                | 4066             | 4028             | 1.3                     | 0.80                    | -0.84                         | -0.71                        | -0.81           | 1.8 | 241 |
| RGB_601  | 4071                | 4123             | 4101             | 1.3                     | 1.01                    | -0.55                         | -0.77                        | -0.44           | 2.0 | 242 |
| RGB_606  | 4122                | 4174             | 4320             | 1.4                     | 0.80                    | -1.74                         | -1.63                        | -1.72           | 1.0 | 183 |
| RGB_611  | 3968                | 4010             | 3980             | 1.2                     | 0.70                    | -0.45                         | -0.42                        | -0.55           | 1.6 | 244 |
| RGB_614  | 3756                | 3967             | 4107             | 1.1                     | 0.70                    | -0.87                         | -0.71                        | -0.84           | 2.2 | 241 |
| RGB_620  | 4075                | 4127             | 4197             | 1.4                     | 1.30                    | -0.61                         | -0.28                        | -0.74           | 2.0 | 197 |
| RGB_625  | 3910                | 3951             | 4090             | 1.2                     | 0.70                    | -0.91                         | -0.86                        | -0.91           | 2.2 | 242 |
| RGB_629  | 4099                | 4150             | 4229             | 1.3                     | 0.80                    | -0.91                         | -0.97                        | -0.95           | 1.7 | 188 |
| RGB_631  | 4061                | 4112             | 4061             | 1.3                     | 0.80                    | -0.64                         | -0.90                        | -0.75           | 1.7 | 256 |
| RGB_633  | 4015                | 4067             | 4015             | 1.3                     | 0.90                    | -0.62                         | -1.21                        | -0.55           | 1.9 | 194 |
| RGB_640  | 4089                | 4141             | 4280             | 1.3                     | 0.80                    | -0.93                         | -0.82                        | -0.93           | 1.9 | 219 |
| RGB_646  | 4166                | 4218             | 4216             | 1.4                     | 1.20                    | -0.72                         | -0.69                        | -0.63           | 1.9 | 236 |
| RGB_651  | 4039                | 4091             | 4089             | 1.3                     | 1.10                    | -0.40                         | -0.51                        | -0.46           | 1.8 | 247 |
| RGB_655  | 3948                | 3988             | 4048             | 1.2                     | 0.80                    | -0.57                         | -0.66                        | -0.50           | 1.8 | 226 |
| RGB_656  | 4032                | 4084             | 4082             | 1.3                     | 0.80                    | -0.71                         | -0.56                        | -0.65           | 2.0 | 233 |
| RGB_658  | 3987                | 4033             | 4087             | 1.3                     | 1.10                    | -0.61                         | -0.40                        | -0.57           | 2.0 | 231 |
| RGB_664  | 3840                | 3881             | 3900             | 1.1                     | 0.70                    | -0.54                         | -0.58                        | -0.48           | 1.9 | 251 |
| RGB_666  | 4179                | 4233             | 4279             | 1.4                     | 1.00                    | -1.02                         | -1.02                        | -1.01           | 1.7 | 225 |
| RGB_671  | 3952                | 3996             | 4052             | 1.2                     | 0.90                    | -0.78                         | -0.55                        | -0.70           | 1.9 | 249 |
| RGB_672  | 3866                | 3906             | 3956             | 1.2                     | 0.70                    | -0.68                         | -0.38                        | -0.66           | 1.9 | 251 |
| RGB_679  | 3928                | 3968             | 3998             | 1.2                     | 0.80                    | -0.63                         | -0.34                        | -0.67           | 2.0 | 253 |
| RGB_690  | 3843                | 3883             | 3950             | 1.2                     | 0.90                    | -0.66                         | -0.23                        | -0.70           | 2.0 | 296 |
Table 2. continued

| Star  | T<sub>photLow</sub> | T<sub>phot</sub> | T<sub>spec</sub> | log g<sub>phot</sub> | log g<sub>spec</sub> | [FeI/H]<sub>spec</sub> | [FeII/H]<sub>CaT</sub> | [FeII/H] | Vt | Rv |
|-------|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|---------|----|----|
| RGB_699  | 4458            | 4531           | 4488           | 1.6           | 1.20           | -0.64           | -1.15          | -0.70   | 1.4 | 230 |
| RGB_700  | 3966            | 4011           | 4000           | 1.3           | 1.01           | -0.60           | -0.37          | -0.56   | 2.0 | 282 |
| RGB_701  | 3934            | 3975           | 4125           | 1.2           | 0.70           | -0.73           | -0.33          | -0.65   | 2.1 | 257 |
| RGB_705  | 4182            | 4237           | 4202           | 1.4           | 1.20           | -0.55           | -0.72          | -0.50   | 1.6 | 250 |
| RGB_710  | 3834            | 3870           | 3950           | 1.1           | 0.80           | -0.75           | -0.65          | -0.53   | 1.9 | 265 |
| RGB_720  | 3814            | 4320           | 4370           | 1.6           | 1.40           | -0.82           | -0.90          | -0.85   | 1.7 | 200 |
| RGB_728  | 4102            | 4153           | 4252           | 1.4           | 0.90           | -0.85           | -0.80          | -0.76   | 2.1 | 270 |
| RGB_731  | 3804            | 3844           | 3900           | 1.1           | 0.80           | -0.48           | -0.23          | -0.38   | 1.8 | 278 |
| RGB_748  | 3980            | 4026           | 4186           | 1.3           | 0.90           | -0.35           | -0.17          | -0.32   | 1.5 | 223 |
| RGB_752  | 3915            | 3956           | 3915           | 1.2           | 1.01           | -0.28           | -0.08          | -0.24   | 1.8 | 225 |
| RGB_756  | 3780            | 3813           | 3930           | 1.1           | 0.70           | -0.82           | -0.46          | -0.75   | 2.0 | 254 |
| RGB_758  | 4282            | 4347           | 4442           | 1.6           | 1.20           | -0.95           | -1.22          | -0.92   | 1.7 | 257 |
| RGB_766  | 3971            | 4016           | 4156           | 1.3           | 0.90           | -0.64           | -0.46          | -0.65   | 1.9 | 282 |
| RGB_773  | 3914            | 3954           | 4034           | 1.2           | 0.80           | -0.87           | -0.51          | -0.76   | 2.4 | 232 |
| RGB_775  | 4191            | 4245           | 4271           | 1.5           | 1.01           | -0.82           | -1.28          | -0.82   | 1.2 | 241 |
| RGB_776  | 4118            | 4170           | 4178           | 1.4           | 1.01           | -0.73           | -0.75          | -0.72   | 1.7 | 241 |
| RGB_782  | 3998            | 4045           | 4078           | 1.3           | 0.90           | -0.57           | -0.34          | -0.52   | 1.8 | 249 |
| RGB_789  | 3763            | 3796           | 3923           | 1.1           | 0.60           | -0.56           | -0.36          | -0.58   | 1.8 | 245 |
| RGB_793  | 3982            | 4029           | 4169           | 1.3           | 0.80           | -0.70           | -0.53          | -0.80   | 1.9 | 241 |
| RGB_834  | 3953            | 3993           | 4053           | 1.3           | 0.80           | -0.86           | -0.64          | -0.79   | 2.0 | 197 |
| RGB_854  | 4077            | 4129           | 4157           | 1.4           | 1.20           | -0.70           | -0.10          | -0.82   | 2.0 | 313 |
| RGB_855  | 4065            | 4117           | 4257           | 1.4           | 1.20           | -0.74           | -0.02          | -0.73   | 1.9 | 217 |
| RGB_859  | 3951            | 3992           | 4021           | 1.3           | 1.01           | -0.64           | -0.22          | -0.56   | 1.9 | 244 |
| RGB_900  | 4071            | 4123           | 4131           | 1.4           | 1.01           | -0.69           | -0.27          | -0.64   | 2.1 | 276 |
Table 3. Line List

| Wavelength | Element | $\chi_{exc}$ | log gf | Wavelength | Element | $\chi_{exc}$ | log gf |
|------------|---------|--------------|--------|------------|---------|--------------|--------|
| 6496.900   | BA2     | 0.604        | -0.380 | 6393.610   | FE1     | 2.430        | -1.580 |
| 6572.800   | CA1     | 0.000        | -4.300 | 6344.160   | FE1     | 2.430        | -2.920 |
| 6162.190   | CA1     | 1.900        | -0.090 | 6593.870   | FE1     | 2.437        | -2.420 |
| 6169.560   | CA1     | 2.520        | -0.270 | 5701.560   | FE1     | 2.560        | -2.220 |
| 6169.040   | CA1     | 2.520        | -0.540 | 6609.120   | FE1     | 2.560        | -2.690 |
| 5601.290   | CA1     | 2.520        | -0.690 | 6475.630   | FE1     | 2.560        | -2.940 |
| 6493.790   | CA1     | 2.521        | 0.140  | 6137.700   | FE1     | 2.590        | -1.400 |
| 6166.440   | CA1     | 2.521        | -0.900 | 6322.690   | FE1     | 2.590        | -2.430 |
| 6499.650   | CA1     | 2.523        | -0.590 | 6575.040   | FE1     | 2.590        | -2.710 |
| 6161.300   | CA1     | 2.523        | -1.030 | 6200.320   | FE1     | 2.610        | -2.440 |
| 6455.610   | CA1     | 2.523        | -1.360 | 6180.210   | FE1     | 2.730        | -2.650 |
| 6439.080   | CA1     | 2.526        | 0.470  | 6518.370   | FE1     | 2.830        | -2.300 |
| 6471.670   | CA1     | 2.526        | -0.590 | 6355.040   | FE1     | 2.840        | -2.290 |
| 6508.840   | CA1     | 2.526        | -2.110 | 6411.660   | FE1     | 3.650        | -0.720 |
| 5647.240   | CO1     | 2.280        | -1.560 | 6301.510   | FE1     | 3.650        | -0.600 |
| 6330.100   | CR1     | 0.940        | -2.910 | 6302.500   | FE1     | 3.690        | -0.910 |
| 6362.880   | CR1     | 0.940        | -2.700 | 6336.830   | FE1     | 3.690        | -1.050 |
| 5787.930   | CR1     | 3.320        | -0.080 | 6408.030   | FE1     | 3.690        | -1.000 |
| 5783.070   | CR1     | 3.320        | -0.500 | 5809.220   | FE1     | 3.883        | -1.690 |
| 5782.130   | CU1     | 1.642        | -1.720 | 6188.020   | FE1     | 3.940        | -1.720 |
| 6358.690   | FE1     | 0.860        | -4.470 | 6157.730   | FE1     | 4.076        | -1.110 |
| 6498.950   | FE1     | 0.960        | -4.700 | 6165.360   | FE1     | 4.142        | -1.470 |
| 6574.250   | FE1     | 0.990        | -5.020 | 6380.750   | FE1     | 4.190        | -1.380 |
| 6581.220   | FE1     | 1.480        | -4.860 | 5618.630   | FE1     | 4.209        | -1.260 |
| 6430.860   | FE1     | 2.180        | -2.010 | 5638.270   | FE1     | 4.220        | -0.870 |
| 6151.620   | FE1     | 2.180        | -3.300 | 5635.820   | FE1     | 4.256        | -1.740 |
| 6335.340   | FE1     | 2.200        | -2.180 | 5641.450   | FE1     | 4.260        | -1.180 |
| 6297.800   | FE1     | 2.220        | -2.740 | 5814.810   | FE1     | 4.283        | -1.820 |
| 6173.340   | FE1     | 2.220        | -2.880 | 5717.830   | FE1     | 4.284        | -0.980 |
| 6421.350   | FE1     | 2.279        | -2.010 | 5705.470   | FE1     | 4.301        | -1.360 |
| 6481.880   | FE1     | 2.280        | -2.980 | 5691.500   | FE1     | 4.301        | -1.370 |
| 6392.540   | FE1     | 2.280        | -4.030 | 5619.610   | FE1     | 4.390        | -1.700 |
| 6608.040   | FE1     | 2.280        | -4.030 | 5806.730   | FE1     | 4.607        | -0.900 |
| 6494.990   | FE1     | 2.400        | -1.270 | 5679.020   | FE1     | 4.651        | -0.770 |
| Wavelength | Element | $\chi_{exc}$ | log gf | Wavelength | Element | $\chi_{exc}$ | log gf |
|------------|---------|--------------|--------|------------|---------|--------------|--------|
| 6597.560   | FE1     | 4.795        | -0.920 | 5793.070   | SI1     | 4.930        | -2.060 |
| 6469.190   | FE1     | 4.835        | -0.620 | 6599.110   | TI1     | 0.900        | -2.085 |
| 5633.950   | FE1     | 4.990        | -0.270 | 6126.220   | TI1     | 1.070        | -1.420 |
| 6516.080   | FE2     | 2.890        | -3.450 | 6261.110   | TI1     | 1.430        | -0.480 |
| 6143.68    | FE2     | 2.890        | -3.708 | 6554.240   | TI1     | 1.440        | -1.220 |
| 6149.250   | FE2     | 3.889        | -2.724 | 6303.770   | TI1     | 1.440        | -1.570 |
| 6247.560   | FE2     | 3.890        | -2.329 | 6258.100   | TI1     | 1.443        | -0.350 |
| 6416.920   | FE2     | 3.891        | -2.740 | 6556.080   | TI1     | 1.460        | -1.080 |
| 6456.390   | FE2     | 3.900        | -2.075 | 5648.580   | TI1     | 2.490        | -0.250 |
| 6320.430   | LA2     | 0.170        | -1.520 | 6559.590   | TI2     | 2.048        | -2.190 |
| 5711.090   | MG1     | 4.346        | -1.833 | 6491.560   | TI2     | 2.061        | -1.793 |
| 5688.220   | NA1     | 2.100        | -0.460 | 6606.950   | TI2     | 2.061        | -2.790 |
| 5682.650   | NA1     | 2.100        | -0.700 | 6274.660   | V1      | 0.270        | -1.670 |
| 6160.750   | NA1     | 2.100        | -1.230 | 6285.170   | V1      | 0.280        | -1.510 |
| 6154.230   | NA1     | 2.100        | -1.530 | 6199.190   | V1      | 0.290        | -1.290 |
| 6327.600   | NI1     | 1.680        | -3.150 | 6292.820   | V1      | 0.290        | -1.470 |
| 6128.980   | NI1     | 1.680        | -3.330 | 6224.510   | V1      | 0.290        | -2.010 |
| 6314.670   | NI1     | 1.930        | -1.770 | 6251.820   | V1      | 0.290        | -1.300 |
| 6482.810   | NI1     | 1.930        | -2.630 | 6150.150   | V1      | 0.300        | -1.790 |
| 6532.890   | NI1     | 1.935        | -3.390 | 6135.370   | V1      | 1.050        | -0.750 |
| 6586.320   | NI1     | 1.950        | -2.810 | 6119.530   | V1      | 1.060        | -0.320 |
| 6175.370   | NI1     | 4.090        | -0.530 | 6452.320   | V1      | 1.190        | -1.210 |
| 6300.310   | O1      | 0.000        | -9.770 | 6531.410   | V1      | 1.218        | -0.840 |
| 5657.150   | SC2     | 1.500        | -0.603 | 6357.290   | V1      | 1.849        | -0.910 |
| 5665.560   | SI1     | 4.920        | -1.720 | 6435.010   | Y1      | 0.070        | -0.820 |
| 5690.430   | SI1     | 4.930        | -1.870 | 6134.570   | ZR1     | 0.000        | -1.280 |
Table 4. Abundance ratios of the elements. Iron and Si, Ca, Ti1 and Ti2.

| Star   | [Fe/H]     | [Si/Fe]    | [Ca/Fe]    | [Ti1/Fe]   | [Ti2/Fe]   |
|--------|------------|------------|------------|------------|------------|
| RGB-1055 | -0.96 ± 0.16 | -0.01 ± 0.09 | -0.10 ± 0.05 | -0.21 ± 0.04 | -0.06 ± 0.12 |
| RGB-1105 | -0.73 ± 0.16 | 0.04 ± 0.21 | -0.07 ± 0.11 | 0.10 ± 0.12 | 0.01 ± 0.09 |
| RGB-1118 | -0.57 ± 0.16 | 0.13 ± 0.07 | 0.03 ± 0.12 | 0.00 ± 0.06 | 0.13 ± 0.03 |
| RGB-499  | -0.85 ± 0.16 | 0.18 ± 0.05 | -0.06 ± 0.09 | 0.20 ± 0.05 | -0.06 ± 0.13 |
| RGB-512  | -0.84 ± 0.16 | -0.07 ± 0.08 | -0.06 ± 0.08 | 0.06 ± 0.04 | -0.04 ± 0.03 |
| RGB-522  | -0.70 ± 0.16 | 0.24 ± 0.04 | -0.13 ± 0.07 | 0.09 ± 0.02 | 0.22 ± 0.03 |
| RGB-533  | -0.75 ± 0.16 | 0.07 ± 0.04 | -0.08 ± 0.10 | 0.17 ± 0.04 | -0.06 ± 0.12 |
| RGB-534  | -1.21 ± 0.16 | 0.15 ± 0.13 | -0.02 ± 0.05 | 0.09 ± 0.05 | 0.17 ± 0.14 |
| RGB-546  | -0.93 ± 0.16 | -0.06 ± 0.16 | 0.05 ± 0.09 | -0.08 ± 0.04 | -0.07 ± 0.04 |
| RGB-548  | -0.74 ± 0.16 | 0.08 ± 0.08 | -0.23 ± 0.09 | 0.04 ± 0.04 | -0.09 ± 0.09 |
| RGB-565  | -0.95 ± 0.16 | -0.01 ± 0.03 | -0.16 ± 0.03 | 0.17 ± 0.03 | 0.00 ± 0.06 |
| RGB-576  | -1.24 ± 0.16 | -0.04 ± 0.12 | 0.00 ± 0.04 | -0.03 ± 0.03 | 0.05 ± 0.04 |
| RGB-593  | -1.15 ± 0.16 | 0.06 ± 0.13 | -0.04 ± 0.10 | 0.15 ± 0.05 | 0.00 ± 0.27 |
| RGB-599  | -0.85 ± 0.16 | 0.06 ± 0.05 | -0.14 ± 0.08 | -0.09 ± 0.02 | 0.05 ± 0.14 |
| RGB-601  | -0.52 ± 0.17 | 0.11 ± 0.09 | -0.34 ± 0.11 | -0.11 ± 0.05 | -0.09 ± 0.05 |
| RGB-606  | -1.74 ± 0.16 | - ± -      | 0.13 ± 0.08 | -0.17 ± 0.08 | 0.21 ± 0.25 |
| RGB-611  | -0.45 ± 0.16 | -0.05 ± 0.04 | -0.12 ± 0.14 | 0.01 ± 0.08 | -0.14 ± 0.05 |
| RGB-614  | -0.87 ± 0.17 | - ± -      | -0.07 ± 0.08 | 0.22 ± 0.04 | -0.01 ± 0.11 |
| RGB-620  | -0.61 ± 0.17 | 0.24 ± 0.10 | -0.23 ± 0.08 | 0.08 ± 0.09 | 0.28 ± 0.08 |
| RGB-625  | -0.91 ± 0.16 | 0.09 ± 0.05 | 0.15 ± 0.08 | 0.12 ± 0.04 | 0.09 ± 0.10 |
| RGB-629  | -0.91 ± 0.16 | -0.05 ± 0.09 | -0.19 ± 0.06 | -0.13 ± 0.03 | 0.05 ± 0.06 |
| RGB-631  | -0.63 ± 0.16 | -0.02 ± 0.12 | -0.01 ± 0.12 | -0.05 ± 0.06 | 0.04 ± 0.03 |
| RGB-633  | -0.62 ± 0.16 | -0.01 ± 0.14 | -0.21 ± 0.07 | -0.14 ± 0.06 | 0.06 ± 0.16 |
| RGB-640  | -0.93 ± 0.16 | 0.02 ± 0.11 | 0.08 ± 0.09 | -0.05 ± 0.05 | 0.07 ± 0.08 |
| RGB-646  | -0.69 ± 0.16 | -0.04 ± 0.05 | -0.18 ± 0.15 | -0.15 ± 0.07 | -0.01 ± 0.08 |
| RGB-651  | -0.40 ± 0.16 | 0.07 ± 0.08 | -0.31 ± 0.10 | -0.23 ± 0.04 | -0.11 ± 0.05 |
| RGB-655  | -0.57 ± 0.16 | 0.13 ± 0.03 | -0.24 ± 0.08 | -0.09 ± 0.05 | -0.02 ± 0.09 |
| RGB-656  | -0.71 ± 0.16 | 0.07 ± 0.06 | -0.07 ± 0.09 | 0.03 ± 0.11 | 0.02 ± 0.23 |
| RGB-658  | -0.61 ± 0.16 | - ± -      | -0.24 ± 0.07 | -0.05 ± 0.05 | -0.06 ± 0.26 |
| RGB-664  | -0.54 ± 0.16 | 0.16 ± 0.08 | -0.45 ± 0.07 | -0.22 ± 0.07 | 0.00 ± 0.18 |
| RGB-666  | -1.02 ± 0.16 | -0.08 ± 0.13 | -0.08 ± 0.08 | -0.11 ± 0.09 | -0.06 ± 0.06 |
| RGB-671  | -0.78 ± 0.16 | 0.10 ± 0.08 | -0.11 ± 0.11 | -0.21 ± 0.02 | -0.06 ± 0.03 |
| RGB-672  | -0.65 ± 0.17 | 0.10 ± 0.05 | -0.21 ± 0.22 | -0.04 ± 0.07 | 0.09 ± 0.13 |
| RGB-679  | -0.63 ± 0.16 | 0.14 ± 0.04 | -0.19 ± 0.09 | -0.15 ± 0.07 | -0.08 ± 0.05 |
Table 4. continued.

| Star   | [Fe/H]       | [Si/Fe]    | [Ca/Fe]   | [Ti1/Fe]  | [Ti2/Fe]  |
|--------|--------------|------------|-----------|-----------|-----------|
| RGB-690| -0.66 ± 0.16 | 0.23 ± 0.04| -0.27 ± 0.09| 0.03 ± 0.03 | -0.10 ± 0.05 |
| RGB-699| -0.59 ± 0.16 | -0.04 ± 0.17| -0.10 ± 0.09| -0.18 ± 0.04 | -0.09 ± 0.24  |
| RGB-700| -0.60 ± 0.16 | 0.30 ± 0.14| -0.36 ± 0.10| -0.29 ± 0.03 | -0.10 ± 0.12  |
| RGB-701| -0.73 ± 0.17 | 0.11 ± 0.09| 0.19 ± 0.13 | 0.20 ± 0.07 | 0.00 ± 0.09   |
| RGB-705| -0.52 ± 0.16 | 0.02 ± 0.06| - ± 0.16   | -0.26 ± 0.04 | -0.06 ± 0.05  |
| RGB-710| -0.70 ± 0.16 | 0.09 ± 0.11| -0.34 ± 0.13| -0.29 ± 0.10 | 0.02 ± 0.06   |
| RGB-720| -0.83 ± 0.16 | 0.21 ± 0.10| -0.06 ± 0.08| 0.01 ± 0.04 | 0.15 ± 0.12   |
| RGB-728| -0.85 ± 0.16 | 0.08 ± 0.08| -0.02 ± 0.07| 0.02 ± 0.06 | 0.35 ± 0.13   |
| RGB-731| -0.46 ± 0.17 | -0.07 ± 0.09| 0.36 ± 0.13| -0.17 ± 0.12| -0.11 ± 0.16  |
| RGB-748| -0.31 ± 0.17 | -0.14 ± 0.10| -0.49 ± 0.08| 0.22 ± 0.07 | - ± 0.09     |
| RGB-752| -0.28 ± 0.16 | 0.11 ± 0.04| -0.36 ± 0.09| -0.02 ± 0.07| -0.01 ± 0.08  |
| RGB-756| -0.80 ± 0.17 | 0.08 ± 0.05| -0.07 ± 0.15| 0.26 ± 0.12 | -0.04 ± 0.08  |
| RGB-758| -0.95 ± 0.16 | - ± -     | -0.11 ± 0.08| -0.02 ± 0.10| -0.05 ± 0.14  |
| RGB-766| -0.64 ± 0.17 | 0.13 ± 0.15| -0.18 ± 0.07| 0.05 ± 0.04 | -0.02 ± 0.04  |
| RGB-773| -0.78 ± 0.17 | 0.09 ± 0.09| -0.49 ± 0.13| 0.05 ± 0.07 | 0.15 ± 0.16   |
| RGB-775| -0.82 ± 0.16 | -0.16 ± 0.11| -0.09 ± 0.10| -0.11 ± 0.07| -0.10 ± 0.18  |
| RGB-776| -0.73 ± 0.16 | -0.19 ± 0.08| -0.13 ± 0.08| -0.16 ± 0.05| 0.03 ± 0.03   |
| RGB-782| -0.57 ± 0.16 | 0.08 ± 0.09| -0.24 ± 0.09| -0.11 ± 0.03| -0.07 ± 0.07  |
| RGB-789| -0.56 ± 0.16 | 0.01 ± 0.03| -0.24 ± 0.08| 0.13 ± 0.07 | 0.04 ± 0.09   |
| RGB-793| -0.70 ± 0.16 | -0.07 ± 0.06| -0.16 ± 0.08| -0.06 ± 0.05| 0.01 ± 0.06   |
| RGB-834| -0.86 ± 0.16 | -0.10 ± 0.06| -0.21 ± 0.05| 0.06 ± 0.07 | 0.11 ± 0.03   |
| RGB-854| -0.70 ± 0.16 | 0.10 ± 0.08| -0.08 ± 0.08| 0.12 ± 0.14 | -0.06 ± 0.33  |
| RGB-855| -0.74 ± 0.16 | 0.00 ± 0.09| -0.13 ± 0.09| 0.05 ± 0.06 | 0.11 ± 0.18   |
| RGB-859| -0.64 ± 0.16 | 0.13 ± 0.09| -0.13 ± 0.12| -0.14 ± 0.04| 0.17 ± 0.05   |
| RGB-900| -0.69 ± 0.16 | 0.20 ± 0.05| -0.12 ± 0.09| -0.06 ± 0.03| 0.09 ± 0.10   |
Table 5. Abundance ratios of the elements Na, Sc, Cu and the α-elements Mg and O.

| Star     | [O/Fe] | [Mg/Fe] | [Na/Fe]     | [Sc/Fe] | [Cu/Fe] |
|----------|--------|---------|-------------|---------|---------|
| RGB\_1055 | 0.10   | 0.50    | -0.76 ± 0.05 | 0.20    | -0.57   |
| RGB\_1105 | -      | 0.02    | -0.43 ± 0.07 | 0.04    | -0.78   |
| RGB\_1118 | 0.10   | 0.00    | -0.28 ± 0.10 | -0.16   | -0.84   |
| RGB\_499  | 0.40   | 0.15    | -0.05 ± 0.07 | -0.23   | -0.55   |
| RGB\_512  | -      | 0.32    | -0.42 ± 0.07 | 0.10    | -0.80   |
| RGB\_522  | -      | 0.40    | -0.03 ± 0.15 | -0.18   | -0.46   |
| RGB\_533  | -      | 0.30    | -0.08 ± 0.07 | -0.15   | -0.62   |
| RGB\_534  | -      | 0.28    | -0.25 ± 0.05 | -0.11   | -0.60   |
| RGB\_546  | -      | 0.10    | -0.49 ± 0.13 | 0.22    | -0.94   |
| RGB\_548  | -      | 0.25    | -0.30 ± 0.10 | 0.00    | -0.46   |
| RGB\_565  | -      | 0.32    | -0.15 ± 0.07 | -0.06   | -0.83   |
| RGB\_576  | -      | 0.31    | -0.27 ± 0.05 | 0.03    | -0.84   |
| RGB\_593  | -      | 0.50    | -0.27 ± 0.06 | 0.04    | -0.75   |
| RGB\_599  | -      | 0.30    | -0.41 ± 0.06 | -0.10   | -0.84   |
| RGB\_601  | -      | 0.33    | ± 0.07       | -0.20   | -0.40   |
| RGB\_606  | <0.20  | -       | 0.09 ± 0.08  | -0.10   | -       |
| RGB\_611  | -      | 0.12    | -0.41 ± 0.13 | -0.26   | -0.90   |
| RGB\_614  | <0.15  | -       | -0.09 ± 0.05 | -       | -       |
| RGB\_620  | <0.05  | 0.10    | 0.06 ± 0.17  | -0.12   | -0.30   |
| RGB\_625  | -      | 0.00    | -0.06 ± 0.07 | -0.20   | -0.80   |
| RGB\_629  | 0.30   | 0.14    | -0.46 ± 0.10 | ±0.00   | -0.90   |
| RGB\_631  | -      | 0.20    | -0.03 ± 0.10 | -0.03   | -0.68   |
| RGB\_633  | 0.10   | -       | -0.20 ± 0.07 | -0.50   | -0.50   |
| RGB\_640  | -      | 0.12    | -0.25 ± 0.05 | -0.20   | -0.85   |
| RGB\_646  | -      | 0.17    | -0.39 ± 0.08 | -0.22   | -0.80   |
| RGB\_651  | -      | 0.15    | -0.38 ± 0.14 | -0.20   | -0.44   |
| RGB\_655  | -      | 0.36    | -0.28 ± 0.14 | -0.10   | -0.80   |
| RGB\_656  | -      | 0.30    | -0.06 ± 0.12 | -0.30   | -0.64   |
| RGB\_658  | -      | -       | -0.10 ± 0.09 | -       | -       |
| RGB\_664  | -      | 0.30    | -0.24 ± 0.12 | -0.30   | -0.90   |
| RGB\_666  | -      | 0.22    | -0.37 ± 0.07 | -       | -0.85   |
| RGB\_671  | -      | -       | -0.23 ± 0.08 | -0.10   | -0.50   |
| RGB\_672  | -      | 0.10    | 0.20 ± 0.14  | -0.33   | -0.64   |
| RGB\_679  | -      | 0.00    | -0.36 ± 0.09 | -0.37   | -0.70   |
Table 5. continued.

| Star    | [O/Fe] | [Mg/Fe]   | [Na/Fe]   | [Sc/Fe] | [Cu/Fe] |
|---------|--------|-----------|-----------|---------|---------|
| RGB_690 | -      | 0.36      | -0.18 ± 0.12 | -0.23   | -0.68   |
| RGB_699 | -      | 0.42      | 0.19 ± 0.08  | 0.00    | -0.80   |
| RGB_700 | <0.05  | 0.10      | -0.31 ± 0.11 | <0.20   | -0.67   |
| RGB_701 | -      | 0.30      | 0.08 ± 0.10  | -0.04   | -0.50   |
| RGB_705 | -      | 0.26      | 0.26 ± 0.09  | -0.19   | -0.75   |
| RGB_710 | -      | 0.30      | -0.27 ± 0.08 | -0.08   | -0.58   |
| RGB_720 | <0.35  | 0.20      | -0.29 ± 0.11 | <0.30   | -       |
| RGB_728 | -      | 0.11      | -0.33 ± 0.07 | -0.20   | -0.75   |
| RGB_731 | 0.00   | 0.03      | -0.29 ± 0.08 | -0.32   | -0.76   |
| RGB_748 | <0.00  | 0.20      | 0.53 ± 0.20  | 0.00    | -0.60   |
| RGB_752 | -      | 0.20      | -0.28 ± 0.12 | -0.27   | -0.53   |
| RGB_756 | -      | 0.05      | 0.09 ± 0.08  | <0.30   | -0.75   |
| RGB_758 | -      | -         | 0.08 ± 0.12  | -       | -       |
| RGB_766 | <0.10  | 0.00      | -0.09 ± 0.13 | -       | -0.50   |
| RGB_773 | 0.25   | 0.02      | -0.03 ± 0.07 | -0.32   | -0.57   |
| RGB_775 | -      | 0.20      | -0.41 ± 0.04 | 0.14    | -0.83   |
| RGB_776 | -      | 0.12      | -0.53 ± 0.10 | -0.13   | -0.80   |
| RGB_782 | -      | 0.30      | -0.19 ± 0.13 | -0.28   | -0.80   |
| RGB_789 | -      | 0.04      | -0.28 ± 0.14 | -0.30   | -0.74   |
| RGB_793 | <0.10  | 0.08      | -0.39 ± 0.10 | -0.30   | -0.80   |
| RGB_834 | -      | 0.13      | -0.32 ± 0.04 | -0.25   | -0.76   |
| RGB_854 | -      | 0.30      | -0.20 ± 0.12 | -0.10   | -0.50   |
| RGB_855 | -      | 0.10      | -0.17 ± 0.09 | -0.20   | -0.38   |
| RGB_859 | -      | 0.22      | -0.21 ± 0.10 | -0.22   | -0.42   |
| RGB_900 | -      | 0.34      | -0.13 ± 0.11 | -0.15   | -0.68   |
| Star   | [Cr/Fe]     | [V/Fe]     | [Ni/Fe]    | [Co/Fe]   |
|--------|-------------|------------|------------|-----------|
| RGB\_1055 | -0.47 ± 0.12 | -0.40 ± 0.04 | -0.32 ± 0.08 | <0.00     |
| RGB\_1105 | -0.32 ± 0.11 | -0.06 ± 0.05 | -0.26 ± 0.08 | -0.10     |
| RGB\_1118 | -0.19 ± 0.09 | -0.19 ± 0.08 | -0.20 ± 0.06 | -0.20     |
| RGB\_499  | 0.11 ± 0.12  | 0.14 ± 0.06  | -0.23 ± 0.09 | -0.08     |
| RGB\_512  | -0.18 ± 0.11 | 0.06 ± 0.08  | -0.15 ± 0.06 | -0.05     |
| RGB\_522  | -0.08 ± 0.11 | 0.17 ± 0.06  | -0.07 ± 0.05 | -0.12     |
| RGB\_533  | -0.13 ± 0.10 | 0.15 ± 0.06  | -0.23 ± 0.07 | -0.10     |
| RGB\_534  | -0.29 ± 0.08 | -0.03 ± 0.05 | -0.11 ± 0.05 | 0.00      |
| RGB\_546  | -0.22 ± 0.13 | -0.15 ± 0.05 | -0.30 ± 0.06 | -0.10     |
| RGB\_548  | -0.30 ± 0.10 | -0.06 ± 0.06 | -0.27 ± 0.08 | -0.19     |
| RGB\_565  | -0.15 ± 0.10 | 0.20 ± 0.05  | -0.19 ± 0.04 | -0.10     |
| RGB\_576  | -0.43 ± 0.10 | -0.14 ± 0.05 | -0.14 ± 0.03 | 0.05      |
| RGB\_593  | -0.24 ± 0.15 | 0.00 ± 0.05  | -0.24 ± 0.06 | -0.05     |
| RGB\_599  | -0.25 ± 0.12 | -0.28 ± 0.06 | -0.24 ± 0.09 | -0.10     |
| RGB\_601  | 0.05 ± 0.10  | -0.03 ± 0.04 | -0.21 ± 0.04 | -0.18     |
| RGB\_606  | 0.35 ± 0.12  | ± 0.36      | -0.46 ± 0.07 | <0.10     |
| RGB\_611  | -0.18 ± 0.06 | -0.03 ± 0.08 | -0.28 ± 0.02 | -0.36     |
| RGB\_614  | -0.17 ± 0.07 | 0.24 ± 0.07  | -0.41 ± 0.10 | -         |
| RGB\_620  | -0.07 ± 0.18 | 0.11 ± 0.08  | -0.16 ± 0.11 | <0.00     |
| RGB\_625  | -0.11 ± 0.12 | 0.18 ± 0.08  | -0.18 ± 0.12 | 0.10      |
| RGB\_629  | -0.45 ± 0.12 | -0.34 ± 0.04 | -0.24 ± 0.11 | <0.20     |
| RGB\_631  | -0.12 ± 0.12 | -0.02 ± 0.07 | -0.26 ± 0.06 | -0.14     |
| RGB\_633  | -0.20 ± 0.10 | -0.06 ± 0.02 | -0.23 ± 0.06 | -0.04     |
| RGB\_640  | -0.14 ± 0.14 | -0.02 ± 0.06 | -0.08 ± 0.05 | <0.20     |
| RGB\_646  | -0.38 ± 0.06 | -0.25 ± 0.06 | -0.06 ± 0.03 | -0.10     |
| RGB\_651  | -0.28 ± 0.12 | -0.16 ± 0.06 | -0.26 ± 0.07 | -0.15     |
| RGB\_655  | -0.09 ± 0.12 | 0.12 ± 0.06  | -0.13 ± 0.08 | -0.20     |
| RGB\_656  | -0.21 ± 0.12 | 0.02 ± 0.05  | -0.25 ± 0.10 | -0.09     |
| RGB\_658  | -0.56 ± 0.08 | 0.16 ± 0.07  | -0.04 ± 0.09 | -         |
| RGB\_664  | -0.29 ± 0.09 | -0.24 ± 0.07 | -0.36 ± 0.11 | -0.27     |
| RGB\_666  | -0.43 ± 0.09 | -0.38 ± 0.05 | -0.27 ± 0.06 | -         |
| RGB\_671  | -0.28 ± 0.12 | -0.08 ± 0.06 | -0.23 ± 0.07 | -0.09     |
| RGB\_672  | -0.21 ± 0.12 | -0.17 ± 0.05 | -0.21 ± 0.04 | -0.22     |
| RGB\_679  | -0.25 ± 0.14 | -0.02 ± 0.05 | -0.28 ± 0.06 | -0.14     |
Table 6. continued.

| Star   | [Cr/Fe]   | [V/Fe]   | [Ni/Fe]   | [Co/Fe]   |
|--------|-----------|----------|-----------|-----------|
| RGB_690| -0.12 ± 0.12 | 0.01 ± 0.09 | -0.19 ± 0.05 | -0.22      |
| RGB_699| -0.08 ± 0.06  | - ± 0.06  | -0.50 ± 0.17 | -0.17      |
| RGB_700| -0.48 ± 0.12  | -0.20 ± 0.08 | -0.34 ± 0.09 | -0.20      |
| RGB_701| 0.03 ± 0.07   | 0.23 ± 0.08 | -0.12 ± 0.14 | -0.12      |
| RGB_705| -0.13 ± 0.09  | -0.26 ± 0.04 | -0.25 ± 0.09 | -0.25      |
| RGB_710| -0.24 ± 0.05  | -0.43 ± 0.04 | -0.34 ± 0.06 | -0.20      |
| RGB_720| -0.11 ± 0.06  | 0.05 ± 0.06  | -0.16 ± 0.12 | -0.29      |
| RGB_728| -0.17 ± 0.12  | -0.28 ± 0.08 | -0.20 ± 0.12 | -0.08      |
| RGB_731| -0.17 ± 0.10  | -0.29 ± 0.04 | -0.28 ± 0.02 | -0.20      |
| RGB_748| 0.25 ± 0.15   | -0.18 ± 0.13 | -0.37 ± 0.13 | -0.10      |
| RGB_752| -0.18 ± 0.07  | -0.15 ± 0.07 | -0.31 ± 0.09 | -0.13      |
| RGB_756| -0.02 ± 0.09  | 0.13 ± 0.05  | -0.19 ± 0.09 | -0.10      |
| RGB_758| -0.27 ± 0.09  | -0.08 ± 0.09 | -0.34 ± 0.11 | -          |
| RGB_766| -0.05 ± 0.10  | 0.25 ± 0.07  | -0.08 ± 0.03 | -0.09      |
| RGB_773| -0.10 ± 0.07  | - ± 0.06    | -0.33 ± 0.04 | -0.01      |
| RGB_775| -0.18 ± 0.06  | - ± 0.03    | -0.37 ± 0.03 | -0.22      |
| RGB_776| -0.21 ± 0.14  | -0.26 ± 0.05 | -0.27 ± 0.06 | -0.22      |
| RGB_782| -0.13 ± 0.10  | -0.19 ± 0.07 | -0.22 ± 0.02 | -          |
| RGB_789| -0.19 ± 0.07  | 0.28 ± 0.05  | -0.21 ± 0.06 | -0.20      |
| RGB_793| -0.19 ± 0.13  | -0.14 ± 0.05 | -0.29 ± 0.06 | -0.20      |
| RGB_834| -0.13 ± 0.11  | 0.05 ± 0.05  | -0.26 ± 0.07 | -          |
| RGB_854| -0.15 ± 0.12  | -0.01 ± 0.09 | -0.09 ± 0.05 | 0.12       |
| RGB_855| -0.07 ± 0.14  | -0.04 ± 0.10 | -0.36 ± 0.12 | -0.04      |
| RGB_859| -0.37 ± 0.11  | -0.05 ± 0.05 | -0.15 ± 0.03 | -0.08      |
| RGB_900| -0.14 ± 0.10  | -0.03 ± 0.06 | -0.18 ± 0.05 | -0.12      |
Table 7. Abundance ratios of the elements (continuation). Heavy and light $s$-process elements.

| Star    | [La/Fe] | [Ba/Fe] | [Y/Fe] | [Zr/Fe] | Star    | [La/Fe] | [Ba/Fe] | [Y/Fe] | [Zr/Fe] |
|---------|---------|---------|--------|---------|---------|---------|---------|--------|---------|
| RGB*1055 | <0.05   | 0.40    | <0.40  | -       | RGB*666 | <0.10   | 0.65    | <-0.20 | <-0.30  |
| RGB*1105 | 0.15    | 0.40    | <-0.48 | -0.50   | RGB*671 | 0.15    | 0.70    | <-0.60 | -0.65   |
| RGB*1118 | 1.12    | 1.00    | 0.14   | 0.00    | RGB*672 | 0.20    | 0.60    | -0.30  | -0.62   |
| RGB*499  | 0.48    | 0.35    | 0.27   | 0.00    | RGB*679 | 0.40    | 0.65    | -0.24  | -0.60   |
| RGB*512  | 0.50    | 0.50    | -0.04  | -0.17   | RGB*690 | 0.66    | 0.95    | -0.20  | -0.32   |
| RGB*522  | 0.40    | 0.60    | 0.00   | -0.35   | RGB*699 | 0.12    | 0.60    | <-0.50 | -0.80   |
| RGB*533  | 0.40    | 0.15    | -0.20  | -0.38   | RGB*700 | <0.30   | -0.10   | -0.45  | -0.90   |
| RGB*534  | <0.20   | 0.20    | <0.10  | <0.35   | RGB*701 | 0.24    | 0.30    | 0.00   | -0.24   |
| RGB*546  | 0.62    | 0.65    | -0.20  | -0.20   | RGB*705 | 0.32    | 0.40    | -0.37  | -0.80   |
| RGB*548  | 0.32    | 0.70    | -0.30  | -0.61   | RGB*710 | 0.40    | 0.60    | -0.46  | -0.78   |
| RGB*565  | 0.20    | 0.20    | -0.18  | -0.30   | RGB*720 | -       | 0.35    | -      | -0.60   |
| RGB*576  | 0.32    | 0.45    | <0.20  | -0.28   | RGB*728 | <0.10   | 0.50    | -0.20  | <-0.50  |
| RGB*593  | <0.20   | 0.00    | -0.20  | <-0.45  | RGB*731 | 0.05    | 0.25    | -0.60  | -0.70   |
| RGB*599  | 0.25    | 0.50    | <-0.40 | -0.40   | RGB*748 | <0.30   | 0.4     | -0.3   | <0.8    |
| RGB*601  | -       | 0.80    | 0.00   | -0.43   | RGB*752 | 0.37    | 0.85    | -0.45  | -0.75   |
| RGB*606  | 0.30    | 0.80    | -      | -       | RGB*756 | 0.20    | 0.45    | -0.33  | -0.40   |
| RGB*611  | 0.30    | 0.60    | -0.52  | -0.70   | RGB*758 | -       | -      | -      | -       |
| RGB*614  | -       | 0.40    | 0.00   | -       | RGB*766 | 0.60    | 0.50    | <-0.25 | <-1.00  |
| RGB*620  | <0.50   | 0.50    | -0.10  | <-0.40  | RGB*773 | 0.25    | 0.00    | -0.10  | -0.42   |
| RGB*625  | 0.18    | 0.20    | -0.30  | -0.24   | RGB*775 | 0.30    | 0.60    | <-0.80 | -0.40   |
| RGB*629  | <0.00   | 0.20    | -0.50  | <-0.60  | RGB*776 | 0.40    | 0.55    | <-0.80 | -0.84   |
| RGB*631  | 0.20    | 0.50    | <-0.50 | <-1.00  | RGB*782 | <0.10   | 0.45    | -0.52  | -0.87   |
| RGB*633  | 0.23    | 0.35    | -0.27  | -0.55   | RGB*789 | 0.00    | 0.55    | -0.20  | -0.60   |
| RGB*640  | <0.10   | 0.10    | <-0.50 | <-0.20  | RGB*793 | 0.24    | 0.30    | -0.30  | -0.49   |
| RGB*646  | 0.47    | 0.50    | <-0.50 | <-0.40  | RGB*834 | 0.17    | 0.25    | -0.28  | -0.40   |
| RGB*651  | 0.32    | 0.63    | -0.50  | -0.77   | RGB*854 | <0.35   | 0.40    | -0.25  | -0.50   |
| RGB*655  | 0.40    | 0.70    | -0.32  | -0.38   | RGB*855 | -       | 0.55    | -0.20  | -0.50   |
| RGB*656  | 0.32    | 0.55    | -0.40  | -0.60   | RGB*859 | 0.40    | 0.80    | <-0.50 | -0.56   |
| RGB*658  | -       | 0.80    | -0.30  | -       | RGB*900 | 0.40    | 0.50    | -0.25  | -0.55   |
| RGB*664  | 0.26    | 0.25    | -0.68  | -0.80   |
Table 8. Errors due to stellar parameters uncertainties.

| Element   | $\Delta T_{\text{eff}} = +100$ K | $\Delta \log g = -0.4$ | $\Delta V_t = +0.2$ km/s | $\Delta [\text{Fe/H}] = -0.15$ | $\delta_{\text{tot}}$ |
|-----------|----------------------------------|------------------------|--------------------------|-------------------------------|------------------------|
| [Fe I/H]  | -0.01                            | -0.10                  | -0.12                    | -0.03                         | 0.16                   |
| [O I/Fe]  | 0.04                             | -0.06                  | 0.10                     | -0.02                         | 0.12                   |
| [V I/Fe]  | 0.16                             | 0.06                   | 0.00                     | 0.04                          | 0.17                   |
| [Y I/Fe]  | 0.19                             | 0.08                   | 0.07                     | 0.04                          | 0.22                   |
| [Ca I/Fe] | 0.11                             | 0.11                   | -0.01                    | 0.04                          | 0.16                   |
| [Cr I/Fe] | 0.12                             | 0.07                   | 0.00                     | 0.04                          | 0.15                   |
| [Fe II/Fe]| -0.18                            | -0.16                  | 0.08                     | -0.07                         | 0.26                   |
| [Mg I/Fe] | 0.01                             | 0.06                   | 0.01                     | 0.01                          | 0.06                   |
| [Na I/Fe] | 0.11                             | 0.10                   | 0.06                     | 0.05                          | 0.17                   |
| [Ni I/Fe] | 0.01                             | -0.03                  | 0.05                     | -0.01                         | 0.06                   |
| [Si I/Fe] | -0.07                            | -0.01                  | 0.09                     | -0.01                         | 0.12                   |
| [Ti I/Fe] | 0.15                             | 0.08                   | 0.01                     | 0.04                          | 0.17                   |
| [Ti II/Fe]| -0.05                            | -0.10                  | 0.04                     | -0.04                         | 0.12                   |
| [Zr I/Fe] | 0.19                             | 0.06                   | 0.03                     | 0.03                          | 0.20                   |
| [Ba II/Fe]| 0.04                             | -0.04                  | -0.04                    | 0.00                          | 0.07                   |
| [Co I/Fe] | 0.03                             | -0.01                  | 0.05                     | -0.01                         | 0.06                   |
| [Cu I/Fe] | 0.07                             | -0.04                  | 0.06                     | 0.07                          | 0.12                   |
| [La II/Fe]| 0.04                             | -0.06                  | 0.05                     | -0.04                         | 0.10                   |
| [Sc II/Fe]| -0.01                            | 0.04                   | 0.01                     | -0.01                         | 0.04                   |

Appendix A: Comparison between equivalent width from DAOSPEC and from Splot-Iraf

In order to evaluate the quality of the DAOSPEC estimates, we have derived by eye inspection the EW of six stars, using the Splot Iraf task. We have chosen stars in a range of S/N ratio typical of our total sample in order to better evaluate the errors: S/N = 54 for RGB_522, 59 for RGB_546, 47 for RGB_664, 42 for RGB_666, 26 for RGB_720, and 47 for RGB_1055. The detailed values are given in Table A.1. We have found two problems relative to the DAOSPEC results from GIRAFFE spectra: a) not all blends have been identified, nevertheless all lines with weak blends (which are most of the lines) have been correctly analysed by the iterative process of the program; b) cosmic rays also have not been identified, and those lines too near CR features must be discarded. Therefore the use of DAOSPEC requires spectra and line lists as clear as possible from blends and spectra as clean from cosmic hits as possible. As can be seen in Table A.1, we have found a very good agreement between the program results and those from the Splot manual measurements. The average difference EW(Dao) - EW(Splot) is 0.46 mA for the six stars, with no strong systematic trend in one direction or the other (the mean difference for each star ranges from −3.7 to +5 mA). However, the dispersion of the
Fig. A.1. Difference between the EW derived using the DAOSPEC program and the Iraf task Splot: trends with respect to the EW(Dao) and to the wavelength of the lines for RGB_522 and RGB_546 (left plot) and for RGB_720 and RGB_664 (right plot).

measurements around the mean are higher, between 9.4mÅ for RGB_1055 and 22.2mÅ for RGB_666. These dispersion seem to anticorrelate with S/N as expected (the two stars with the highest dispersion are the two lowest quality spectra), and may also correlate with temperature, although our sample of 6 stars is not quite high enough to investigate these dependencies any further.

We have checked for systematic trends on the EW with wavelength and with the EW strength by plotting the differences EW(Dao) - EW(Splot) vs. wavelength and EW(Dao) - EW(Splot) vs. EW(Dao) for four stars, as shown in Fig. A.1. No trends have been found and confort us in the validity of using DAOSPEC EW measurement for atmospheric parameter determinations (effective temperature and microturbulence velocities).

In Table A.2 we give the differences for the abundances derived from DAOSPEC and Splot, Ab(Dao) - Ab(Splot). As can be seen in this Table, the agreement between the two methods is good for most of the elements, always better than the typical errorbars given for our measurement of the corresponding elements, and usually below 0.10 dex. The differences are higher for those elements with fewer lines (e.g. Na I and Ti I), which increases the weight of the scatter among lines. Let us note in particular that elements such as Ca I or Ti I do not seem to be affected by the method used for equivalent width measurement in a systematic direction, so that the strong underabundances found for these elements (with respect to the galactic trends) are robust against EW systematics.
Table A.1. Comparison of the equivalent widths derived from DAOSPEC and Iraf-Splot task for six of our sample stars.

| Line     | Element | RGB_522 | RGB_546 | RGB_664 | RGB_666 | RGB_720 | RGB_1055 |
|----------|---------|---------|---------|---------|---------|---------|---------|
| 6300.31  | O1      | -       | -       | -       | 96      | 108     | -       |
| 6274.66  | V1      | 173     | 159     | 118     | 85      | 171     | 156     |
| 6285.17  | V1      | 140     | 172     | 92      | 111     | 170     | 159     |
| 6199.19  | V1      | 206     | 205     | 126     | 128     | 193     | 212     |
| 6292.82  | V1      | 167     | 186     | 111     | 116     | 174     | 192     |
| 6245.51  | V1      | 134     | 130     | 77      | 76      | 147     | 135     |
| 6251.82  | V1      | 170     | 184     | 119     | 118     | 165     | 173     |
| 6150.15  | V1      | 167     | 169     | 92      | 91      | 178     | 183     |
| 6135.37  | V1      | 146     | 155     | 74      | 51      | 150     | 138     |
| 6191.53  | V1      | 139     | 153     | 85      | 94      | 136     | 139     |
| 6452.32  | V1      | 103     | 106     | 43      | 44      | 64      | 61      |
| 6531.41  | V1      | 105     | 106     | 41      | 37      | 109     | 109     |
| 6357.29  | V1      | 37      | 40      | -       | -       | -       | -       |
| 6222.58  | V1      | -       | -       | -       | 38      | 54      | -       |
| 6435.01  | Y1      | 78      | 88      | 28      | 44      | 77      | 67      |
| 6613.73  | Y2      | -       | -       | -       | -       | -       | 94      |
| 6496.90  | BA2     | 249     | 267     | 218     | 210     | 239     | 238     |
| 6141.73  | BA2     | 260     | 281     | 220     | 220     | 272     | 268     |
| 6572.80  | CA1     | 216     | 229     | 156     | 156     | 231     | 218     |
| 6162.19  | CA1     | 308     | 334     | 234     | 229     | 312     | 319     |
| 6169.56  | CA1     | 179     | 175     | 140     | 148     | 188     | 173     |
| 6169.04  | CA1     | 162     | 147     | 128     | 111     | 163     | 138     |
| 5601.29  | CA1     | 201     | 204     | 150     | 154     | 206     | 203     |
| 6493.79  | CA1     | 192     | 195     | 165     | 161     | 196     | 195     |
| 6166.44  | CA1     | 144     | 140     | 105     | 84      | 143     | 143     |
| 6499.65  | CA1     | 159     | 161     | 115     | 112     | 153     | 146     |
| 6161.30  | CA1     | 151     | 172     | 129     | 114     | 165     | 158     |
| 6455.61  | CA1     | 126     | 126     | 94      | 88      | 119     | 122     |
| 6439.08  | CA1     | 224     | 227     | 187     | 189     | 241     | 228     |
| 6471.67  | CA1     | 164     | 176     | 140     | 142     | 168     | 149     |
| 6508.84  | CA1     | 72      | 72      | -       | 54      | 74      | 28      |
| 6282.60  | CO1     | 152     | 180     | 109     | 112     | 177     | 177     |
| 6117.00  | CO1     | -       | -       | -       | -       | -       | 44      |
| 5647.24  | CO1     | 80      | 85      | 45      | 43      | 77      | 73      |
| 6330.10  | CR1     | 141     | 152     | 95      | 85      | 148     | 155     |
| 6362.88  | CR1     | -       | 101     | 98      | 168     | 153     | 64      |
| 5787.93  | CR1     | 102     | 107     | 69      | 71      | 110     | 101     |
| 5793.07  | CR1     | 92      | 94      | 60      | 57      | 90      | 88      |
| 5782.13  | CU1     | 199     | 172     | 126     | 113     | 202     | 160     |
| 6358.69  | FE1     | 241     | 186     | 170     | 173     | 214     | 212     |
| 6498.95  | FE1     | 183     | 192     | 156     | 152     | 200     | 184     |
| 6574.25  | FE1     | 160     | 162     | 144     | 153     | 171     | 150     |
| 6581.22  | FE1     | 138     | 114     | 97      | 93      | 150     | 187     |
| 6430.86  | FE1     | 243     | 244     | 201     | 194     | 257     | 250     |
| 6151.62  | FE1     | 140     | 149     | 118     | 121     | 136     | 135     |
| 6335.34  | FE1     | 217     | 211     | 183     | 174     | 220     | 215     |
| 6297.80  | FE1     | 180     | 191     | 147     | 151     | 193     | 205     |
| 6173.34  | FE1     | 169     | 189     | 149     | 159     | 170     | 165     |
| 6421.35  | FE1     | 214     | 221     | 187     | 189     | 222     | 215     |
| 6481.88  | FE1     | 151     | 157     | 132     | 125     | 163     | 149     |
| 6392.54  | FE1     | 88      | 86      | -       | 90      | 79      | 32      |
### Table A.1. Comparison of the equivalent widths derived from DAOSPEC and Iraf-Splot task for six of our sample stars.

| Line        | Element | Dao 522 | Dao 546 | Dao 664 | Dao 866 | Dao 720 | Dao 1055 |
|-------------|---------|---------|---------|---------|---------|---------|---------|
| 6392.54     | Fe1     | 88      | 86      | -       | -       | -       | -       |
| 6608.04     | Fe1     | 99      | 110     | 80      | 67      | 128     | 119     |
| 6494.99     | Fe1     | 261     | 283     | 229     | 232     | 274     | 270     |
| 6393.61     | Fe1     | 234     | 229     | -       | -       | 235     | 232     |
| 6444.16     | Fe1     | 201     | 185     | 154     | 160     | 201     | 180     |
| 6593.87     | Fe1     | 181     | 191     | 154     | 164     | 192     | 197     |
| 5701.56     | Fe1     | 174     | 170     | 146     | 139     | 185     | 174     |
| 6609.12     | Fe1     | 155     | 163     | 136     | 148     | 168     | 157     |
| 6475.63     | Fe1     | 134     | 132     | 108     | 113     | 142     | 132     |
| 6137.70     | Fe1     | 261     | 264     | 211     | 197     | 268     | 261     |
| 6322.69     | Fe1     | 153     | 165     | 136     | 135     | 156     | 166     |
| 6575.04     | Fe1     | 167     | 179     | 133     | 147     | 179     | 167     |
| 6200.32     | Fe1     | 160     | 162     | 131     | 120     | 150     | 146     |
| 6180.21     | Fe1     | 141     | 152     | 114     | 117     | 133     | 153     |
| 6518.37     | Fe1     | 132     | 141     | 114     | 121     | 144     | 126     |
| 6355.04     | Fe1     | -       | -       | 141     | 128     | 183     | 170     |
| 6411.66     | Fe1     | 161     | 164     | 153     | 146     | 156     | 160     |
| 6301.51     | Fe1     | 152     | 165     | -       | -       | 175     | 194     |
| 6302.50     | Fe1     | 128     | 138     | 105     | 112     | 129     | 134     |
| 6336.83     | Fe1     | 159     | 149     | 136     | 134     | 154     | 158     |
| 6408.03     | Fe1     | -       | -       | 122     | 114     | 131     | 140     |
| 5809.22     | Fe1     | 105     | 111     | 74      | 83      | 92      | 94      |
| 6188.02     | Fe1     | 84      | 90      | 69      | 71      | 90      | 80      |
| 6157.73     | Fe1     | 126     | 132     | 102     | 94      | 141     | 142     |
| 6165.36     | Fe1     | 79      | 83      | 68      | 57      | 72      | 67      |
| 6308.75     | Fe1     | 87      | 85      | 61      | 73      | 89      | 67      |
| 6380.75     | Fe1     | 87      | 85      | 61      | 73      | 89      | 67      |
| 5618.63     | Fe1     | 107     | 121     | 68      | 60      | 97      | 96      |
| 5638.27     | Fe1     | 121     | 104     | 96      | 89      | 128     | 114     |
| 5635.82     | Fe1     | 81      | 52      | 48      | 42      | 80      | 64      |
| 5641.45     | Fe1     | 115     | 95      | 93      | 84      | -       | -       |
| 5814.81     | Fe1     | 65      | 54      | -       | -       | 39      | 33      |
| 5717.83     | Fe1     | 112     | 104     | 90      | 85      | 115     | 104     |
| 5705.47     | Fe1     | 72      | 66      | 48      | 42      | 74      | 54      |
| 5691.50     | Fe1     | 90      | 94      | 56      | 60      | 79      | 73      |
| 5619.61     | Fe1     | -       | -       | 41      | 37      | 76      | 70      |
| 5806.73     | Fe1     | 86      | 83      | 66      | 82      | 83      | 75      |
| 5679.02     | Fe1     | 83      | 77      | -       | -       | 83      | 79      |
| 5697.56     | Fe1     | 53      | 65      | 37      | 35      | 83      | 68      |
| 6469.19     | Fe1     | 128     | 138     | 75      | 213     | 109     | 100     |
| 5633.95     | Fe1     | 87      | 92      | 64      | 63      | 83      | 78      |
| 5616.08     | Fe2     | 61      | 98      | 57      | 59      | 58      | 68      |
| 6432.68     | Fe2     | 33      | 27      | 40      | 37      | 51      | 38      |
| 6149.25     | Fe2     | -       | -       | -       | -       | -       | -       |
| 6247.56     | Fe2     | 46      | 55      | 43      | 41      | 41      | 46      |
| 6456.39     | Fe2     | 51      | 57      | 62      | 58      | 56      | 66      |
| 6320.43     | La2     | 100     | 84      | 83      | 72      | 90      | 75      |
| 6390.48     | La2     | 67      | 86      | 65      | 85      | 72      | 63      |
| 5711.09     | Mg1     | 148     | 134     | 119     | 116     | 155     | 149     |
| 5688.22     | Na1     | 190     | 137     | 125     | 82      | 198     | 146     |
Table A.1. Comparison of the equivalent widths derived from DAOSPEC and Iraf-Splot task for six of our sample stars.

| Line  | Element | RGB_522 | RGB_546 | RGB_664 | RGB_666 | RGB_720 | RGB_1055 |
|-------|---------|---------|---------|---------|---------|---------|----------|
| 5682.65 | NA1 | 159 | 148 | 82 | 64 | 159 | 159 | 57 | 68 | 68 | 54 | 45 | 45 |
| 6160.75 | NA1 | 88 | 67 | - | - | 94 | 79 | 32 | 42 | - | - | - | - |
| 6154.23 | NA1 | 59 | 69 | - | - | 78 | 67 | 24 | 20 | - | - | - | - |
| 6327.60 | NI1 | 139 | 135 | 102 | 106 | 131 | 135 | 84 | 110 | - | - | 73 | 71 |
| 6128.98 | NI1 | 109 | 127 | 78 | 75 | 116 | 122 | 68 | 70 | - | - | 60 | 56 |
| 6314.67 | NI1 | 139 | 150 | 122 | 125 | 150 | 133 | 116 | 165 | - | - | 73 | 31 |
| 6482.81 | NI1 | 124 | 117 | 94 | 98 | 127 | 127 | 89 | 88 | 112 | 118 | 77 | 77 |
| 6532.89 | NI1 | 74 | 83 | 53 | 53 | 89 | 84 | 33 | 36 | 49 | 36 | - | - |
| 6586.32 | NI1 | 110 | 117 | 99 | 94 | - | - | 105 | 125 | 88 | 106 | 82 | 96 |
| 6175.37 | SC1 | 68 | 72 | 40 | 51 | 44 | 27 | 36 | 57 | - | - | - | - |
| 6305.67 | SC1 | 209 | 266 | 86 | 101 | 212 | 219 | 58 | 60 | - | - | 29 | 28 |
| 6604.60 | SC2 | 91 | 102 | 82 | 80 | 115 | 88 | 31 | 48 | 125 | - | 60 | 53 |
| 5640.99 | SC2 | 113 | 97 | 82 | 77 | 124 | 110 | 85 | 79 | 85 | 103 | 72 | 68 |
| 5669.04 | SC2 | 136 | 138 | 114 | 127 | 140 | 144 | 93 | 96 | 85 | 104 | 82 | 87 |
| 5667.15 | SC2 | 84 | 85 | 58 | 59 | 86 | 79 | 69 | 53 | 60 | 72 | 54 | 51 |
| 6245.62 | SC2 | 95 | 85 | 66 | 69 | 101 | 112 | 76 | 101 | - | - | 57 | 64 |
| 6655.56 | SI1 | 66 | 75 | 28 | 28 | 54 | 57 | 32 | 41 | 35 | 42 | 31 | 16 |
| 6590.43 | SI1 | 55 | 56 | 31 | 32 | 59 | 54 | 29 | - | 49 | 45 | 36 | 39 |
| 5793.07 | SI1 | 49 | 40 | 36 | 36 | 48 | 51 | 39 | 39 | - | - | 25 | 30 |
| 6599.11 | TI1 | 128 | 142 | 82 | 86 | 147 | 138 | - | - | - | - | 34 | 44 |
| 6126.22 | TI1 | 152 | 170 | 114 | 121 | 166 | 170 | 81 | 130 | - | - | 72 | 92 |
| 6261.11 | TI1 | 235 | 248 | 151 | 156 | 231 | 234 | 75 | 120 | - | - | 103 | 104 |
| 6504.24 | TI1 | 140 | 134 | 83 | 86 | 146 | 123 | 68 | 66 | 84 | 56 | 61 | 64 |
| 6303.77 | TI1 | 110 | 131 | 59 | 58 | 114 | 109 | 50 | - | - | - | - | - |
| 6258.10 | TI1 | 221 | 182 | 139 | 152 | 232 | 233 | 114 | - | - | - | 108 | 110 |
| 6556.08 | TI1 | 152 | 150 | 100 | 94 | 169 | 151 | 83 | 71 | 90 | 81 | 64 | 58 |
| 5648.58 | TI1 | 82 | 73 | 34 | 31 | 77 | 68 | - | - | 36 | 31 | 23 | 18 |
| 6559.59 | TI2 | 83 | 86 | 61 | 65 | 84 | 52 | 60 | 49 | 88 | 70 | 57 | 48 |
| 6491.56 | TI2 | 103 | 107 | 75 | 79 | 91 | 87 | 67 | 81 | 83 | 86 | 59 | 63 |
| 6606.95 | TI2 | 46 | 57 | - | - | 71 | 83 | - | - | - | - | - | - |

Table A.2. Absolute differences Ab(Dao) - Ab(Splot) and the average value (see text).

| Element | RGB_522 | RGB_546 | RGB_664 | RGB_666 | RGB_720 | RGB_1055 | Average Difference |
|---------|---------|---------|---------|---------|---------|---------|---------------------|
| CA1     | -0.03   | 0.13    | -0.04   | 0.03    | -0.06   | -0.09   | -0.01 ± 0.08        |
| CR1     | -0.08   | 0.03    | 0.10    | -0.05   | -0.05   | 0.11    | 0.01 ± 0.08         |
| FE1     | -0.11   | 0.01    | 0.10    | -0.01   | -0.06   | 0.00    | -0.02 ± 0.07        |
| FE2     | -0.13   | -0.06   | -0.02   | 0.04    | -0.05   | -0.10   | -0.05 ± 0.06        |
| NA1     | 0.08    | 0.09    | 0.18    | -0.06   | 0.06    | -0.06   | 0.05 ± 0.09         |
| NI1     | -0.03   | -0.06   | 0.09    | 0.04    | -0.12   | -0.09   | -0.03 ± 0.08        |
| SI1     | -0.05   | 0.01    | -0.01   | 0.07    | 0.20    | -0.03   | 0.03 ± 0.09         |
| TI1     | -0.06   | 0.00    | 0.14    | 0.02    | -0.16   | -0.10   | -0.03 ± 0.10        |
| TI2     | -0.18   | -0.07   | 0.13    | 0.0    | 0.13    | 0.06    | 0.01 ± 0.12         |
| V1      | -0.05   | 0.02    | 0.10    | -0.22   | -0.10   | -0.09   | -0.06 ± 0.11        |
