Mem. S.A.It. Vol. 84, 261

Memorie della

Fundamental parameters of red giants in 47 Tucanae

A. O. Thygesen[1] and L. Sbordone[1,2]

[1] Zentrum für Astronomie der Universität Heidelberg – Landessternwarte, Königstuhl 12, 69117 Heidelberg, Germany, e-mail: `a.thygesen@lsw.uni-heidelberg.de`

[2] GEPI, Observatoire de Paris, CNRS, Univ. Paris Diderot, Place Jules Janssen, 92190, Meudon, France.

Abstract. In these proceedings we present initial results of a spectroscopic analysis of a small sample of evolved K-giants in the globular cluster 47 Tucanae. We derive the effective temperature, surface gravity and microturbulence of all targets using standard methods. Further we derive LTE abundances of [Fe/H] and [O/Fe] as well as the abundance of sodium, using NLTE corrections. We find a mean metallicity for the cluster of [Fe/H]= -0.75 ± 0.10, in excellent agreement with several other studies. Also, we confirm the sodium-oxygen anticorrelation previously reported by a number of other authors. Finally, we see indications of the sodium enriched stars also being enriched in heavy magnesium isotopes.

Key words. Stars: abundances – Stars: atmospheres – Galaxy: globular clusters

1. Introduction

Studying elemental abundances in globular clusters is a key to understand the chemical evolution of stellar populations, due to the confined environment in which the different stellar generations are born. By now it is well established that most, if not all, globular clusters show multiple stellar populations, both on the main sequence as well as on the red giant branch, indicating a more complex history than previously thought (see e.g. Carretta et al. 2004).

The multiple populations are visible in e.g. different chemical abundance patterns and different photometric colors. This is believed to be caused by cluster self-pollution from a previous generation of stars, but the exact nature of these stars is still debated. Recently, multiple sequences were discovered in 47 Tucanae (Milone et al. 2012), one of the most extensively studied globulars.

We have analysed high resolution (R=110000) high signal-to-noise ($\geq$ 160) spectra of a number of evolved K-giants in this cluster obtained with the VLT UVES spectrograph. From these we determine the effective temperature, T_{eff}, surface gravity, $\log g$, microturbulence, ξ_t, and derive elemental abundances of O, Na and Fe to investigate the Na-O anticorrelation observed in all globular clusters. The abundances have been derived from standard equivalent width measurements.

This work is part of the initial analysis to derive accurate Mg-isotopic ratios for all stars in our 47 Tucanae sample.

Send offprint requests to: A. O. Thygesen

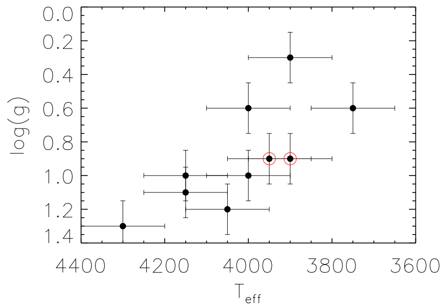

Fig. 1. Basic parameters of the giants in the sample investigated in this work. Two giants with very similar parameters are indicated with red circles (See Figs. 2 and 3)

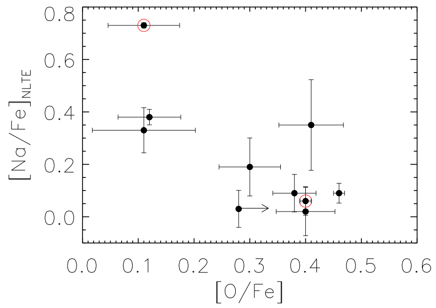

Fig. 2. The anti-correlation of Na and O in our sample. As can be seen, the stars appear to separate in two groups, potentially indicating membership of two different populations.

2. Spectroscopic analysis

From the high-resolution spectra we performed a standard spectroscopic analysis. The atomic lines were carefully selected to have reliable atomic data as well as being reasonably free of strong blends. For all relevant lines we manually measured equivalent widths (EW) using the standard IRAF `splot` task, including deblending when needed. The hereby measured EW's were subsequently analyzed with the spectral analysis package MOOG[1]. The stellar parameters were derived in the standard way of requiring no correlation of iron abundance vs. EW (ξ_t), abundance vs. excitation potential ($T_{\rm eff}$) and ionization equilibrium between Fe I and Fe II ($\log g$).

We employed interpolated model atmospheres from a grid of α-enhanced 1D ATLAS9 atmospheric models in the analysis (Castelli & Kurucz 2004). Using the best-fitting model, the abundance of sodium was determined by fitting the measured EW's. For the Na lines we applied NLTE corrections on a line-by-line basis, using the values from Lind et al. (2011). The corrections were based on our derived stellar parameters, or the closest match in the grid calculated by Lind et al. if no exact match was available[2].

[1] available from `http://www.as.utexas.edu/chris/moog.html`

[2] see `http://inspect-stars.net/`

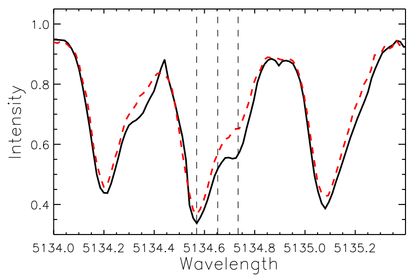

Fig. 3. Plot of the observed spectra of two giants from our dataset with identical $\log g$, and $T_{\rm eff}$ only differing by 50K. Both stars are indicated in Figs. 1 and 2. The star plotted with a black line is strongly enriched in Na and depleted in O. The opposite is the case for the star shown with the red dashed line. Shown is the region around one of the MgH bands typically used for isotopic measurements. The line-centers of ^{24}MgH, ^{25}MgH and ^{26}MgH are indicated with vertical, dashed lines (left to right).

After applying the corrections, a mean abundance was derived. To measure the oxygen abundance we performed spectral synthesis (again using MOOG) of the forbidden transition O-line at 6300Å as well as the O-line at 6363Å. However, the latter could not be synthesized succesfully in all cases due to the presence of atmospheric emission lines. For one target we could only put a lower limit on the oxygen abundance, due to emission lines be-

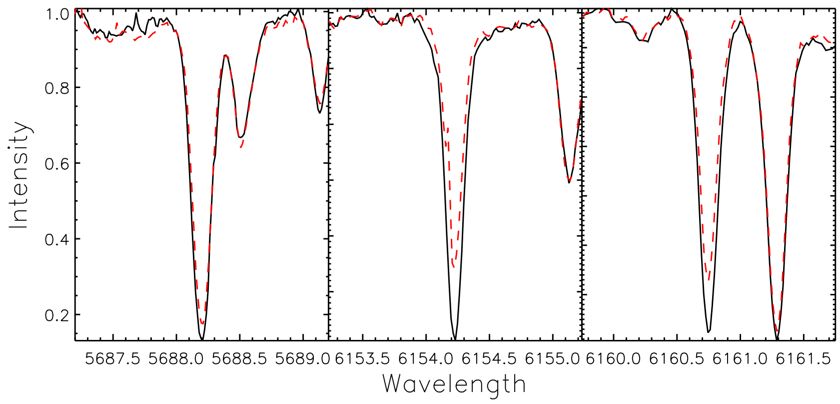

Fig. 4. The Na-lines for the same two stars as in Fig. 3. The difference in sodium abundance is evident.

ing present in both available lines (marked with an arrow in Fig. 2). The abundances of all elements were measured relative to the Sun, using the Lodders & Palme (2009) solar abundances, but including the recent updates from Caffau et al. (2011).

3. Results

In Fig. 1 is shown the position of our giants in a $\log g$ vs. T_{eff} diagram and as can be seen, we sample a set of very evolved giants, with the most extreme case being a potential AGB star. We find good agreement between our spectroscopic temperatures and those derived from broadband photometry, using the calibration of Ramírez & Meléndez (2005), with a deviation of only 40 ± 86 K. From our [Fe/H] measurements we derive a mean metallicity for the cluster giants of [Fe/H]= -0.75 ± 0.10 which is in excellent agreement with the recent study of Koch & McWilliam (2008), as well as several other studies of 47 Tuc (e.g. Carretta et al. 2004; Alves-Brito et al. 2005). In Fig. 2 we present the abundances of sodium and oxygen, relative to the iron abundance of the stars. The Na-O anticorrelation found in all globular clusters is clearly present in our sample of giants from 47 Tuc, confirming the results of Carretta et al. (2009) and Koch & McWilliam, where the latter saw an indication of this in their sample of 9 giants. However, the anticorrelation is significantly more pronounced in our sample, compared to Koch & McWilliam. We note that the Na-O anticorrelation has also been observed in a sample of dwarf stars in 47 Tuc (D'Orazi et al. 2010) showing that this is a general property of the cluster, not related to the giant nature of the stars in our work. Interestingly, we see an indication that the giants may fall in two discrete subgroups, rather than along a continuous distribution of Na/O ratios, with one being strongly enriched in Na compared to the O-enriched stars. However, a larger sample will need to be studied before any firm conclusions can be made.

The final goal of this project is the study of magnesium isotopic ratios from the MgH bands around 5130Å, so it is natural to look for differences in the molecular bands simply by visually inspecting the observed spectra. In Fig. 3 is shown spectra of two giants with almost identical parameters (identical $\log g$ 50K difference in T_{eff}, marked with red in Fig. 1 and 2), but one being strongly enriched in Na and O depleted (black line), while the other is O-rich and Na-poor (red dashed line, see also Fig. 4). As is immediately obvious, the Na-enriched star is also strongly enhanced in the heavy magnesium isotopes. If this is the case also for the remaining sample of Na-enriched stars this implies that the nucleosynthesis of heavy Mg isotopes takes place in the same kind of polluters who produce the enrichment of sodium.

4. Conclusions

We have determined the fundamental parameters for a sample of giants in the globular cluster 47 Tucanae. Using 1D atmospheric models, we derive the abundances of Fe, Na and O, confirming both the metallicity of the cluster ([Fe/H]= -0.75 ± 0.10) as well as the Na-O anticorrelation found by several other authors. It is found that our targets appear to separate into two groups, one being Na enriched and oxygen depleted, whereas the other is found to be rich in oxygen, but with a much lower sodium abundance. Visually inspecting spectra of two representative stars, one from each sample, we see a clear difference in the enrichment of heavy magnesium isotopes. As the Na-enriched giant show much higher abundances of the heavy magnesium isotopes this indicates that they are created in the same polluters who are responsible for creating the overabundance of Na. However, detailed study of the Mg istopic ratios for all stars in the sample will be needed to quantify this further.

Acknowledgements. AOT acknowledges support from Sonderforschungsbereich SFB 881 ”The Milky Way System” (subproject A5) of the German Research Foundation (DFG).

References

Alves-Brito, et al., 2005, A&A,435, 657A
Caffau, E. ,et al. 2011, Sol. Phys., 268, 255
Carretta, E. ,Bragaglia, A. ,Gratton, R. and Lucatello, S., 2009, 505, 139C
Carretta, E. et al. 2004, A&A, 416, 925C
Castelli, F. ,Kurucz, R. L., 2004, ArXiv Astrophysics e-prints
D’Orazi, V. ,et al. 2010, ApJ, 713L, 1D
Koch, A. ,McWilliam, A., 2008, AJ, 135, 1551K
Lind, K. ,Asplund, M. ,Barklem, P. S. ,Belyaev, A. K.,A&A, 2011, 528A, 103L
Lodders, K. ,Palme, H., 2009, Planetary Science Supplement, 72, 5154L
Milone, A. P et al., 2012, ApJ, 744, 58M
Ramírez, I. ,Meléndez, J., 2005, ApJ, 626, 465R