SF2A 2013
L. Cambrésy, F. Martins, E. Nuss and A. Palacios (eds)

NON-LTE IRON ABUNDANCE DETERMINATION OF A SAMPLE OF KEPLER RED GIANTS

Rana Ezzeddine[1], Thibault Merle[2] and Bertrand Plez[1]

Abstract. In the aim of calibrating non-LTE effects in atoms, particularly iron, for which quantum mechanical calculations for collisions with neutral hydrogen do not exist, we re-analyzed a sample of *Kepler* K red giant stars and determined both LTE and non-LTE FeI and FeII abundances, using asteroseismic fundamental atmospheric parameters. 1D, spherical MARCS model atmospheres were used for the abundance determinations. FeI and FeII lines with reliable oscillator strength values were selected. Results show better mutual agreement in abundances between neutral and singly ionized Fe lines as a function of equivalent width and excitation potential in NLTE as compared to that in LTE.

Keywords: Iron abundances, NLTE, Red Giants

1 Introduction

The study of iron abundances in cool stars plays an important role in understanding the Galactic chemical evolution, since there exists a wealth of Fe spectral lines even in metal-poor stars, which makes it a proxy for the total metal content in the star. Iron is also an important opacity contributor in the stellar atmosphere of late-type stars. Moreover, iron lines are used to derive fundamental atmospheric parameters (Effective temperature $T_{\rm eff}$, surface gravity log$g$ and microturbulent velocity ξ) of the star.

In stellar atmospheres, the statistical equilibrium of neutral iron can deviate from thermodynamic equilibrium due to the deviation of the mean intensity of ionizing radiation J_ν from the Planck function B_ν (Mashonkina et al. 2011), and thus it is important to perform non-local thermodynamic equilibrium (NLTE) line formation calculations in order to accurately determine abundances.

In his review, Asplund (2005) described NLTE as the case where "Everything depends on everything, everywhere". And thus in order to correctly synthesize and model stellar spectra to determine NLTE abundances, one has to take into account accurate atomic data including all possible radiative and collisional transitions between the corresponding levels of a model atom of the element under study, especially the collisions with neutral hydrogen which become important in metal poor stars where $\mathrm{n}_H/\mathrm{n}_e \sim 10^5$. However, collisional rates with hydrogen are usually treated using the semi-classical Drawin approximation (Drawin 1969) which is based on classical rather than quantum mechanics, and has been shown to overestimate the collisional rates up to 5 orders of magnitude (Belyaev & Barklem 2003). And since quantum mechanical data are not yet available for iron, we attempt to calibrate these collisional rates by accurately modelling and determining NLTE FeI/FeII abundances.

2 Method

For this study, we selected a sample of bright *Kepler* red giants which have reliable asteroseismic fundamental atmospheric parameters, $T_{\rm eff}$ and log g. We used high resolution (R=67000) spectra (Thygesen et al. 2012) from the FIES (FIber-fed Echelle Spectrograph) spectrograph of the NOT (Nordic Optical Telescope) at La Palma,

[1] Laboratoire Univers et Particules de Montpellier (LUPM), Université de Montpellier 2-CNRS, France.
[2] Institut d'Astronomie et Astrophysique, Université Libre de Bruxelles, Belgique.

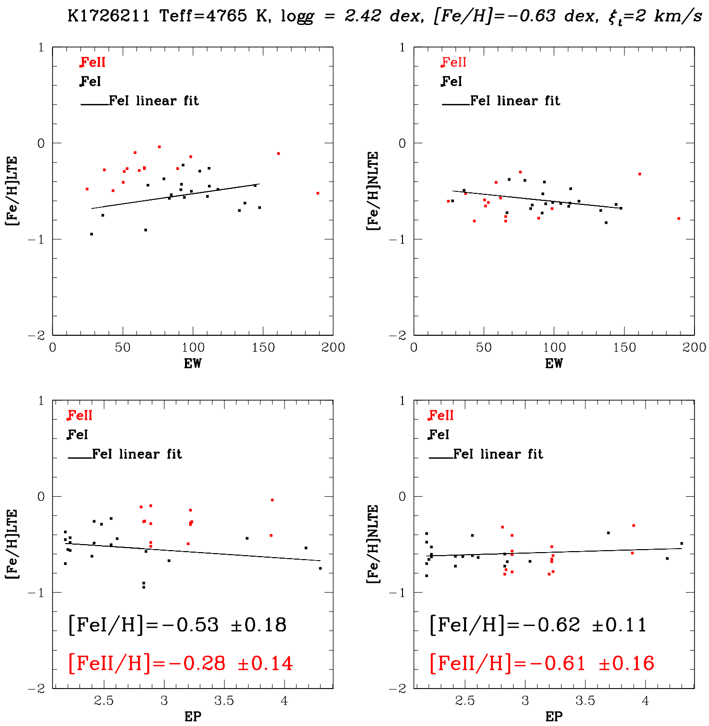

Fig. 1. Diagnostic plots of the results for FeI and FeII in LTE (left column) and NLTE (right column): abundances versus excitation potential and equivalent width for one of the sample stars of KIC ID 1726211.

to measure equivalent widths of a well selected list of non-blended lines from the INSPECT database* (Bergemann et al. 2012). The chosen lines have up-to-date averaged experimental oscillator strengths values from Gehren et al. (2001). Spherical 1D model atmospheres were interpolated† from the MARCS database (Gustafsson et al. 2008) and used with an FeI/FeII model atom (Thévenin & Idiart 1999) to determine NLTE abundances using the spectral synthesis code MULTI2.2 (Carlsson 1986) and a curve-of-growth technique, while LTE abundances were calculated using the TURBOSPECTRUM code (Alvarez & Plez 1998), (Plez 2012).

3 Results and Conclusions

Our LTE results show less deviations with respect to the mean in FeI abundances as a function of excitation potential and equivalent width (~ 0.25 dex) as compared to that of previous work on these stars. Bruntt et al. (2011) calculated LTE abundances and imposed ionization equilibrium between FeI and FeII lines to derive atmospheric parameters ($T_{\rm eff}$, $\log g$ and ξ). The deviations from the mean in their plots are up to 0.5 dex. It is important to note that there is also a difference of up to 400 K in $T_{\rm eff}$, 0.23 dex in $\log g$ and 0.2 dex in metallicity, between our asteroseismic and their spectroscopic values of atmospheric parameters. This can have serious consequences on the further abundance determination using these parameters, and thus they have to be carefully chosen.

Our results also show better mutual agreement between FeI and FeII lines in NLTE as compared to LTE (see Fig.1) as a function of equivalent width and excitation potential, without imposing ionization equilibrium between the singly and ionized iron lines.

Future work aims at improving our results by calculating more accurate NLTE abundances, using a better and more complete iron model atom with up-to-date atomic data, and using the updated version of MULTI

*www.inspect-stars.net
†Masseron code: http://marcs.astro.uu.se/software.php

(MULTI2.3). This will allow us to quantify the effects of collision with neutral hydrogen and electrons, leading to more accurate iron abundance determinations in giant stars.

References

Alvarez, R. & Plez, B. 1998, A&A, 330, 1109
Belyaev, A. K. & Barklem, P. S. 2003, Phys. Rev. A, 68, 062703
Bergemann, M., Lind, K., Collet, R., Magic, Z., & Asplund, M. 2012, MNRAS, 427, 27
Bruntt, H., Frandsen, S., & Thygesen, A. O. 2011, A&A, 528, A121
Carlsson, M. 1986, Uppsala Astronomical Observatory Reports, 33
Drawin, H. W. 1969, Zeitschrift fur Physik, 228, 99
Gehren, T., Butler, K., Mashonkina, L., Reetz, J., & Shi, J. 2001, A&A, 366, 981
Gustafsson, B., Edvardsson, B., Eriksson, K., et al. 2008, A&A, 486, 951
Mashonkina, L., Gehren, T., Shi, J.-R., Korn, A. J., & Grupp, F. 2011, A&A, 528, A87
Plez, B. 2012, Turbospectrum: Code for spectral synthesis, astrophysics Source Code Library
Thévenin, F. & Idiart, T. P. 1999, ApJ, 521, 753
Thygesen, A. O., Frandsen, S., Bruntt, H., et al. 2012, A&A, 543, A160