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Stellar parameters with FASMA: a new spectral synthesis package

M. Tsantaki[1], **D. T. Andreasen,**[2] **G. D. C. Teixeira,**[2] **S. G. Sousa,**[2]
N. C. Santos,[2] **E. Delgado-Mena,**[2] **and G. Bruzual**[1]

[1]Instituto de Radioastronomía y Astrofísica, UNAM,
Campus Morelia, A.P. 3-72, C.P. 58089, Michoacán, Mexico
email: `mtsantaki@crya.unam.mx`

[2]Instituto de Astrofísica e Ciências do Espaço, Universidade do Porto,
CAUP, Rua das Estrelas, Porto, 4150-762, Portugal

Abstract. Current Galactic surveys, including the Gaia mission, rely on the efficiency of the spectral analysis techniques to provide precise and accurate spectral information (i.e. effective temperature, surface gravity, metallicity, and chemical abundances) in the shortest computational time. In this work, we present a new package to preform complete spectral analyses based on the spectral synthesis technique (Tsantaki *et al.* 2017, submitted). We focus on deriving atmospheric parameters for FGK-type stars using both high and medium resolution (GIRAFFE) spectra. This method is implemented on the Gaia-ESO benchmark stars to confirm its validity, achieving similar accuracy for the two resolution setups.

Keywords. techniques: spectroscopic, stars: atmospheres, fundamental parameters

1. Introduction

In the last decades, due to the growing number of spectroscopic surveys dedicated to the study of the Galactic stellar populations, the number of high quality spectra has increased to several hundreds of thousands mainly owing to ground-based surveys, such as APOGEE, the Gaia-ESO Survey (GES), the GALAH survey, to name a few. The success of the above surveys depends on the efficiency of the spectral analysis techniques to provide precise and accurate spectral information in the shortest computation time.

Motivated by that, we developed a new package to derive the fundamental atmospheric parameters using the spectral synthesis technique. We named this package 'FASMA' which is built around the spectral synthesis code, MOOG (version 2014, Sneden 1973). FASMA includes other spectral functionalities, among them the analysis of spectra based on the equivalent width which is described in detail in Andreasen *et al.* (2017). In this work we describe a new additional driver of FASMA for the derivation of atmospheric parameters using the spectral synthesis technique. Among the advantages of this work is its applicability for both high and medium resolution regimes and the wide coverage of the stellar parameter space including high rotational velocities.

2. Methodology

Model atmospheres. The model atmospheres included in FASMA are the grid generated by the ATLAS program (Kurucz 1993), the grid of MARCS models (Gustafsson *et al.* 2008) and the grid for the APOGEE survey based on ATLAS9 (Mészáros *et al.* 2012).

Line list. The line list covers a wide range in the optical and therefore can be applied to spectra obtained by various spectrographs. It includes the regions of HR10 and HR15n set-ups of the GIRAFFE spectrograph (5399–5619 Å and 6470–6790 Å, respectively). We queried for all atomic and molecular lines inside intervals of ±2Å around mainly iron lines. From the 249 unique lines bigger than 10 mÅ (of the Sun) of our line list, 159 are iron. We used the NSO Atlas and the typical solar parameters to improve the transition probabilities ($\log gf$ values) in an inverted analysis.

Minimization procedure. FASMA performs local normalization for the adopted intervals and includes the parameter optimization procedure based on the Levenberg-Marquardt algorithm to solve the nonlinear least-squares problem, yielding the parameters that minimize the χ^2, namely T_{eff}, $\log g$, $[M/H]$, and $v \sin i$.

The code is written in python and the complete package is provided freely here: `https://github.com/MariaTsantaki/fasma-synthesis`. It is run either from the terminal or through a GUI interface for a more user-friendly approach.

3. Results

We explore how our parameters are affected by different characteristics: 1) the choice of initial conditions, 2) the different signal-to-noise values, 3) the different resolution set-ups, and 4) different rotational velocities. Moreover, to check the performance of our code, we select the GES benchmark stars as our comparison sample. The sample (excluding the M stars) contains 29 stars and is described in Heiter *et al.* (2015). We added the latest metal-poor benchmark stars suggested by Hawkins *et al.* (2016), reaching a total of 34 stars. The spectra in high resolution are taken from Blanco-Cuaresma *et al.* (2014) (95 spectra in total). For medium resolution, we query the GES archive for spectra taken with the GIRAFFE spectrograph.

4. Conclusion

With our spectral package, we provide stellar parameters for a wide range of spectral types and luminosity classes and can be used to analyse large samples in a reasonable amount of time. Our parameters show almost no dependence on the choice for initial parameters. Signal-to-noise deviations should be considered for very noisy spectra (below 50). The effects of rotational velocities become visible after 35 km s^{-1}. We compare our results with the GES benchmark stars using spectra both in high and medium resolution and we find very good agreement for metallicities for both resolutions. When we have better external estimations of surface gravities (e.g. using parallaxes), we can improve the temperature determinations.

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