# Project VeSElkA: Abundance analysis of chemical species in CP stars HD41076 and HD148330

Khalack[1] V., Gallant[1] G., Thibeault[2] C.

[1] Département de Physique et d'Astronomie, Université de Moncton, Moncton, Canada

[2]Département de Physique, Université de Montréal, Montréal, Québec, Canada

Viktor.Khalack@umoncton.ca

## Abstract

A new semi-automatic approach is employed to carry out the abundance analysis of high-resolution and high signal-to-noise spectra of HD41076 and HD148330 obtained recently with the spectropolarimetre ESPaDOnS at the Canada-France-Hawaii Telescope. This approach allows to prepare the input data for the modified ZEEMAN2 code in a semi-automatic mode and to analyse several hundreds of line profiles in sequence during a single run. It also provides more information on abundance distribution for each chemical element at the deeper atmospheric layers through estimation of the contribution of blends to the studied line profiles. Our analysis of the Balmer profiles observed in the spectra of HD41076 and HD148330 has resulted in the estimates of their effective temperature, gravity, metallicity and radial velocity. The respective models of stellar atmosphere have been calculated with the code PHOENIX and used to carry out abundance analysis employing the modified ZEEMAN2 code.

## Introduction

Competition between the radiative and gravitational forces in a hydrodynamically stable stellar atmosphere can lead to an appearance of vertical stratification of chemical abundances due to the atomic diffusion mechanism. To verify the presence of atomic diffusion in the atmosphere of the CP stars HD41076 and HD148330, we have analysed high resolution ESPaDOnS spectra obtained at CFHT employing the code ZEEMAN2 (Landstreet 1988) and using the semi-automated approach developed by Khalack et al. (2017).

## Fundamental stellar parameters

The effective temperature, gravity and metallicity of the studied stars has been derived from the best fit of observed Balmer line profiles with the help of FITSB2 code (Napiwotzki et al. 2004) using the grids of synthetic fluxes calculated with PHOENIX15 code (Khalack & LeBlanc 2015). The obtained values are consistent with the results for $T_{eff}$ derived from the $c_1$ (Napiwotzki et al. 1993) and $(B-V)_0$ (Netopil et al. 2008) photometric temperature calibrations (see Table 1).

**Table 1**. Fundamental stellar parameters

| Object | Photometric calibrations | | Fit of Balmer line profiles | | | |
|---|---|---|---|---|---|---|
| | $T_{eff}$ [$c_1$], K | $T_{eff}$ [$(B-V)_0$], K | $T_{eff}$, K | log(g) | [M/H] | $\chi^2/\nu$ |
| HD41073 | 9579±60 | 9669±210 | 9483±100 | 3.69±0.10 | -0.5±0.1 | 0.6213 |
| HD148330 | 9292±20 | 9322±180 | 9303±100 | 3.70±0.10 | 0.0 | 0.6286 |

## First approach

The first approach assumes that each line profile selected for analysis is formed mainly due to a contribution of only one chemical element. Selection procedure is performed manually when a researcher chooses mainly unblended line profiles for analysis. From the simulation of each line profile that belongs to a specific ion, we can obtain its abundance at a particular layer of stellar atmosphere, where its line optical depth is $\tau_l=1$ (Khalack et al. 2008). In this way, we can study the vertical distribution of an element's abundance from the analysis of large number of line profiles that belong to the same ion (see Fig.2).

## Second approach

The second approach uses an automatic procedure to select all the line profiles located in the spectral regions with well visible continuum for analysis. It then compiles a list of spectral lines that contribute to each selected line profile and belongs to a set of chemical elements specified in the configuration file. From the simulation of a selected line profile we can derive abundances of different chemical elements that contribute to this profile (see Fig. 1). Combination of all the results obtained from analysis of all selected line profiles allows us to simultaneously study the vertical distribution of element's abundance for different chemical species.

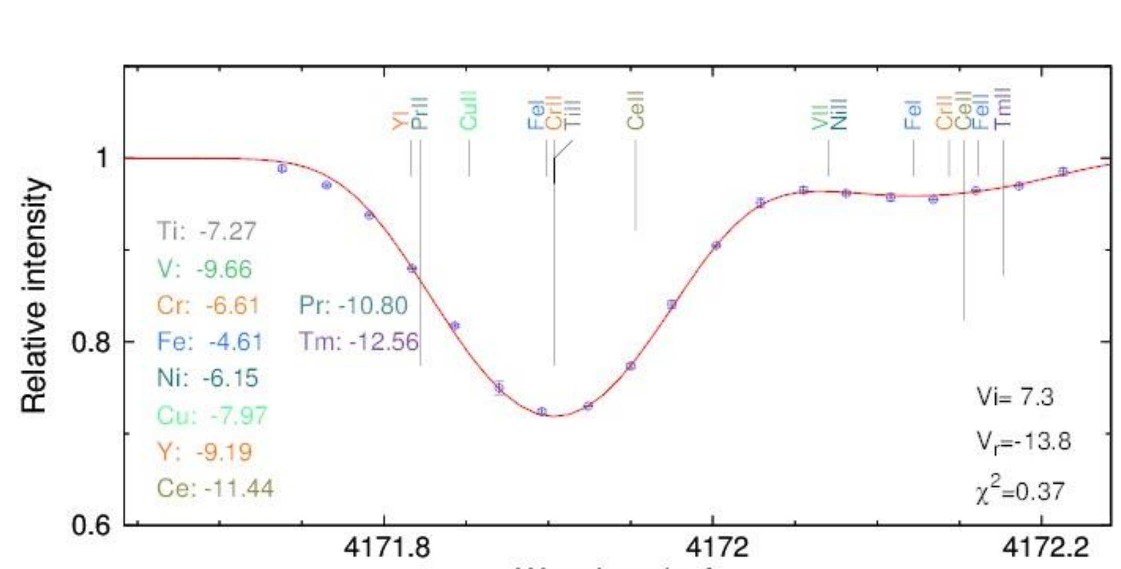


**Figure 1**. The observed spectrum of HD41076 (open circles) is well fitted by synthetic spectrum (solid line). The best fit results for abundance of studied chemical species are shown at the left side of the graph, while the results for Vsin(i), Vr and $\chi^2$ are presented at the bottom right corner.

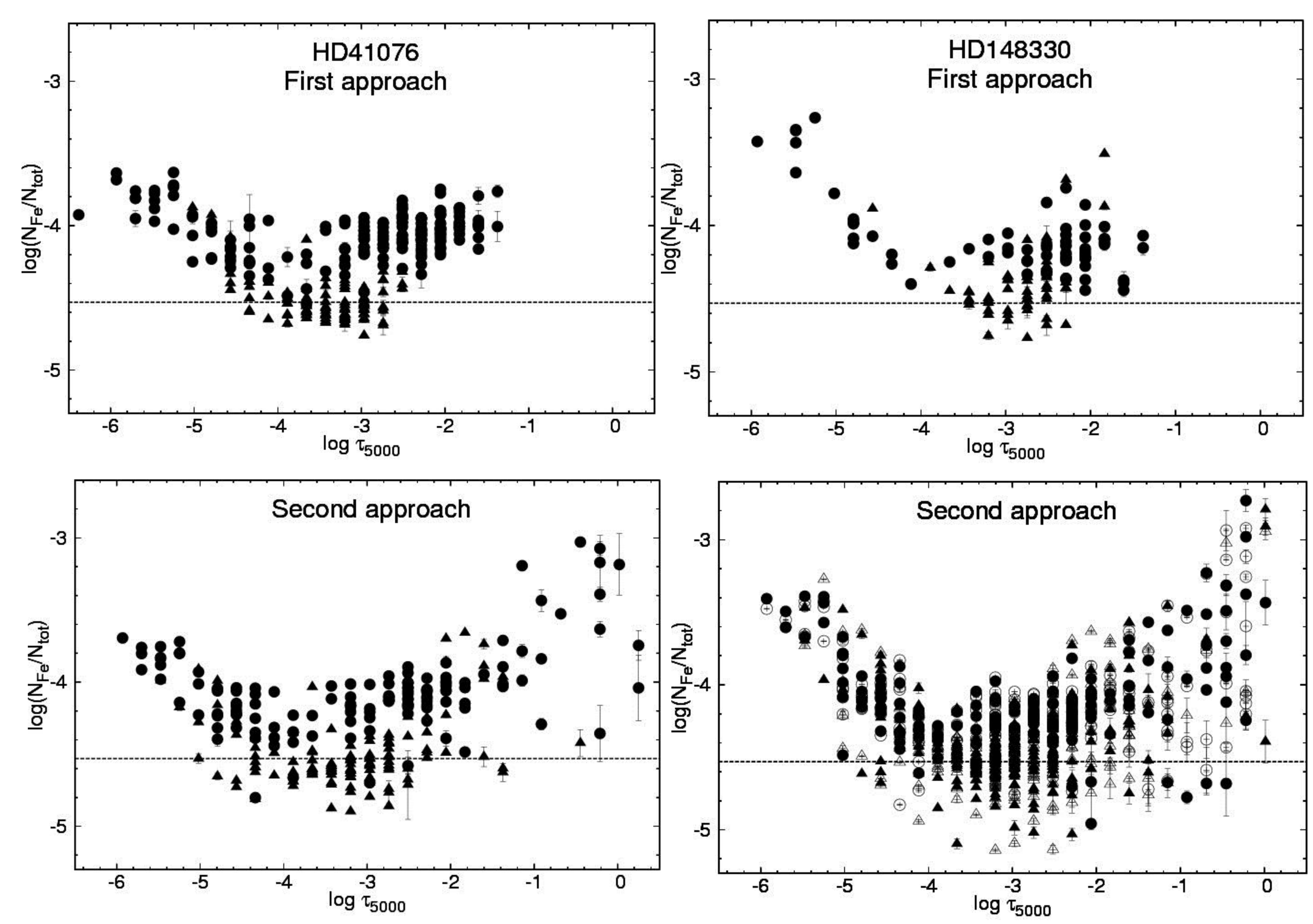


**Figure 2**. Distribution of iron abundance with optical depth in HD41076 and HD148330 based on the best fit results obtained for FeI (triangles) and FeII (circles) line profiles.

## Results

In both approaches, each line profile is simulated separately using the modified ZEEMAN2 code (Khalack et al. 2017). For each analysed line profile we have derived the best fit parameters (abundances, Vr, Vsin(i)) and the fit quality $\chi^2$ (see Fig. 1).

Employing these two approaches we have found similar results for the vertical distribution of iron abundance in stellar atmospheres of HD41076 and HD148330 (see Fig. 2). In both stars the iron reaches its minimum abundance, which is close to its solar abundance, in the area of optical depth log $\tau_{5000}$= -4.0 – -3.6 and tends to increase towards the upper and deeper atmospheric layers. We can see at the Fig.2 that in the area of optical depth log $\tau_{5000}$= -4.0 – -3.6, the FeI is statistically less abundant that the FeII for both HD41076 and HD148330.

## Conclusion

The second approach allows semi-automatic preparation of the input data for the modified ZEEMAN2 code for each line profile. Consequently, we are then able to analyse several hundred of those profiles in a sequence during a single run of the modified ZEEMAN2 code (Khalack et al. 2017). The second approach is sensitive to the contribution of weak lines and therefore provides more data for the deeper atmospheric layers. Both approaches provide very similar results of abundance analysis for iron in HD41076 and HD148330.

## References

Khalack V., LeBlanc F., behr B.B., Wade G. A., Bohlender D., 2008, *A&A*, 477, 641

Khalack V., LeBlanc F., 2015, *AJ*, 150, 1, id. 2

Khalack V., Gallant G., Thibeault C., 2017, *MNRAS*, submitted

Landstreet J. D., 1988, *ApJ*, 326, 967

Napiwotzki R., Schönberner D., Wenske V., 1993, *A&A*, 268, 653

Napiwotzki R., Yngelson L., Nelemans G. et al., 2004, *ASP Conf. Ser.* Vol.318, p. 402

Netopil M., Paunzen E., Maintzen H.M., North P., Hubrig S., 2008, *A&A*, 491, 545