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ROTATIONAL VELOCITY DISTRIBUTION OF A STARS: SEARCHING FOR INTRINSIC SLOWLY ROTATING NORMAL A0-A1 STARS

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Abstract. Royer et al. (2007) showed that the distribution of rotational velocities for A0-A1 stars is bimodal although all known peculiar and/or binary stars had been excluded from their sample. We present here the preliminary results of the abundance analysis for 47 A0-A1 "normal" main sequence stars selected with $v \sin i$ slower than 65 km s^{-1}. These high signal-to-noise spectra collected with ÉLODIE and SOPHIE (OHP) will allow us to obtain a clean sample of low $v \sin i$ normal A0-A1 stars and search for intrinsic slow rotators.

Keywords: Stars: early-type, Stars: rotation

1 Introduction

Normal A-type stars are fast rotators on average, and the distributions of their equatorial velocities display a mode between 150 and 220 km s^{-1} (Abt & Morrell 1995; Royer et al. 2007). The bimodality of the equatorial velocity distribution observed for A0-A1-type stars is argued to be due to binaries and chemically peculiar stars (Abt & Morrell 1995). Nonetheless Royer et al. (2007) showed a pronounced double peaked distribution of rotational velocities for A0-A1 stars, although all known peculiar and/or binary stars had been excluded from their sample. Abt (2009) suggested that slowly rotating normal stars could be Ap stars that already underwent a magnetic braking but do not show chemical peculiarity yet.

We present here the preliminary results of an observation programme aimed at understanding these A0-A1 slow rotators. High signal-to-noise spectra were collected with ÉLODIE and SOPHIE (OHP) for 47 A0-A1 "normal" main sequence stars selected from Royer et al.'s sample with $v \sin i < 65$ km s^{-1}. Binary stars and chemically peculiar stars (hereafter CP) are discarded on the basis of spectral synthesis. Signatures of gravity darkening are searched for to disentangle v and i from the projected rotational velocities, and sort out pole-on stars, like Vega (Gulliver et al. 1994), from intrinsic slowly rotating stars.

2 Data

The sample is selected from Royer et al. (2007), using A0-A1 main-sequence stars, not already known as binary or CP stars, with a low $v \sin i < 65$ km s^{-1}. The sample is limited to targets observable from Observatoire de Haute-Provence ($\delta > -15$ °). Six nights were allocated on ÉLODIE (2005, 2006) and four nights on SOPHIE (2009, 2011, 2012). Additional spectra were fetched from the ÉLODIE archive (Moultaka et al. 2004) and the SOPHIE archive.

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3 Classification: selecting normal stars

3.1 Spectroscopic binaries

Radial velocities are derived from the cross-correlation of the observed spectra with a synthetic template ($T_{\rm eff}$ = 9500 K and $\log g = 4$ dex). The variation of the radial velocity (for targets with several spectra) and the shape of the cross-correlation permitted the detection of several spectroscopic binaries: HD6530, HD40446, HD50931 and HD217186.

3.2 Atmospheric parameters and abundance analysis

Effective temperature and surface gravity have been determined for the remaining stars using the calibration of Strömgren photometry from Napiwotzki et al. (1993). An abundance analysis, based on Takeda (1995) minimization procedure, has been carried out to determine the abundances of 16 elements (C, O, Na, Mg, Si, Ca, Sc, Ti, Cr, Mn, Fe, Ni, Sr, Y, Zr and Ba).

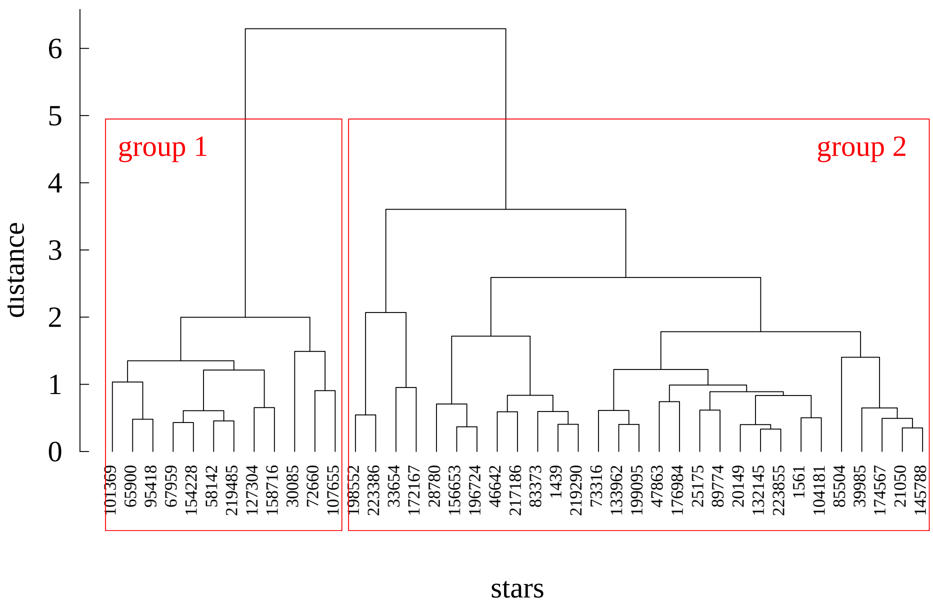

Fig. 1. Dendogram plot of the hierarchical tree resulting from the cluster analysis of the 14-species chemical abundances of the sample. The x-axis gives the HD numbers of the stars and the y-axis represents the Euclidean distance, in the normalized abundance space, between subgroups. The two main groups are identified by the labeled boxes.

3.3 Cluster analysis

These abundances (Na and Mn are only available for a few stars and not taken into account) have been used to perform a hierarchical classification of the sample (Cowley & Bord 2004) into two different groups (Fig. 1). The abundance patterns (medians and standard deviations) of both groups are shown in Fig. 2, confirming that group 1 corresponds to CP stars and group 2 to normal stars.

4 A closer look at HD30085

HD30085, classified as a normal A0 IV by Cowley et al. (1969), is part of our CP group and turns out to be Mn-rich star, possibly a HgMn CP star. We derived a temperature of 11300 K and a surface gravity of 3.95 dex

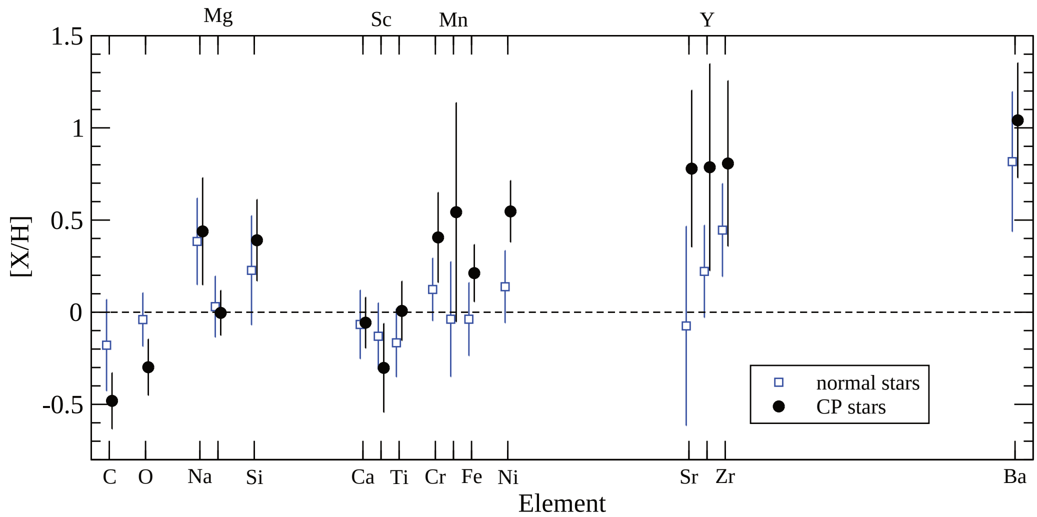

Fig. 2. Abundance pattern for the two groups. For each element, the median abundance is plotted and the error bar corresponds to the dispersion around the median value.

using Napiwotzki et al.'s calibration of Strömgren photometry, which suggests a spectral type reassessment to B8-B9 V.

By iteratively adjusting LTE synthetic spectra to the observed normalized spectrum of HD30085, we have found large overabundances for Mn (Fig. 3.a), Y, Zr (Fig. 3.b), and Sr, about two orders of magnitude larger than solar abundances. Helium is underabundant (−1.1 dex) which appears to be the case in most HgMn stars (Alecian et al. 2009).

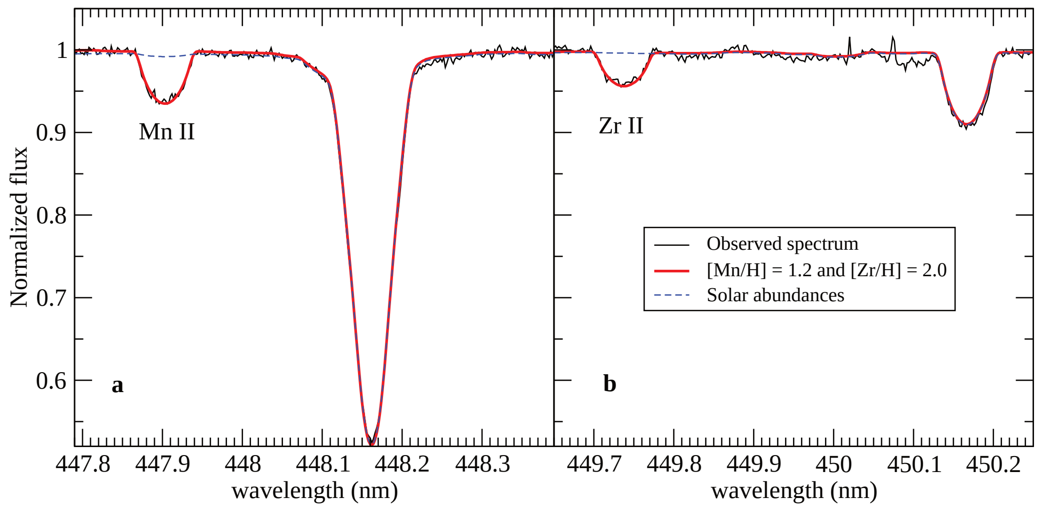

Fig. 3. Spectrum of HD30085 (thin solid line) superimposed to synthetic spectra with different abundances: **(a)** [Mn/H] = 0 dex (dashed line) and [Mn/H] = 1.2 dex (thick solid line), **(b)** [Zr/H] = 0 dex (dashed line) and [Zr/H] = 2.0 dex (thick solid line).

5 Pole-on candidates

The normal group resulting from the aforementioned classification is being carefully studied to disentangle the projection effect from the true equatorial velocity. The spectral signature of fast rotators seen pole-one, due to gravity darkening, can be detected on faint lines. Such features have been detected in the spectrum of Vega by Gulliver et al. (1994), and since, many authors studied the star by spectroscopy (Takeda et al. 2008; Yoon et al.

2008; Hill et al. 2010) and interferometry (Peterson et al. 2006). Using a spectrum of Vega, Takeda et al. (2008) found that, whereas ionized element lines show classical profiles on average, neutral element lines display very characteristic profiles: from flat-bottomed to reversed profiles, due to the effective temperature gradient from the pole to the equator. The quality of our data ($R = 75\,000$; SNR $\sim$ 250–400) does not reach that obtained for Vega by Takeda et al. (2007): $R \sim 100\,000$, SNR $\sim$ 1000–3000. Then we decided to investigate the line profiles globally, using a Least-Square Deconvolution method (Donati et al. 1997; Kochukhov et al. 2010) to enhance the signal and recover the broadening function. Using the line list from Takeda et al. (2008), broadening functions for Fe II lines and Fe I lines separately have been determined for our normal stars. A few among our targets show the characteristic profiles expected for fast pole-on rotators (Fig. 4), i.e. classical shape for Fe II and flat or reversed bottom for Fe I broadening functions.

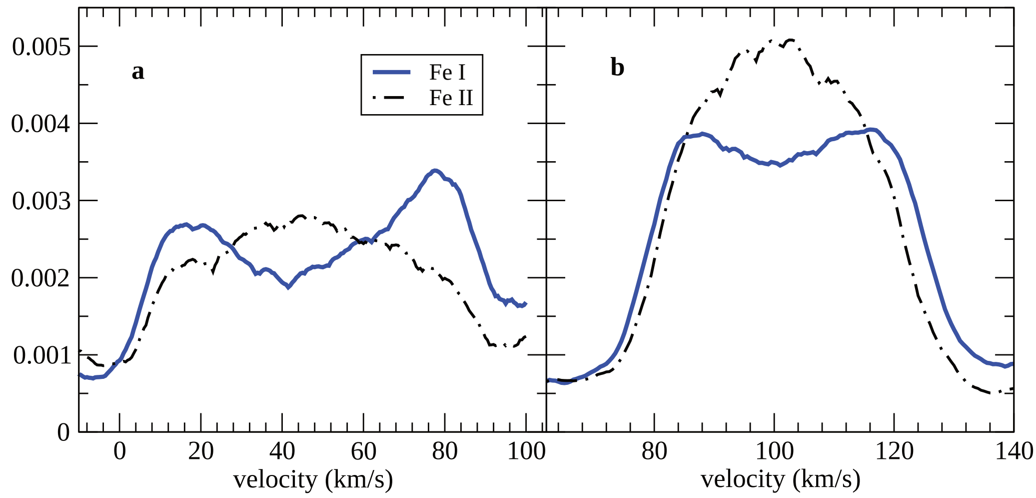

Fig. 4. Broadening functions extracted from Fe II (thick solid line) and Fe I lines (dashed line) for two pole-on candidates in our sample (**a** and **b**).

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