SPECTRAL LINE PROFILES VARIATIONS IN THE roAp STAR ALPHA CIRCINI*

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ABSTRACT. We analyse behavior of the line profile variations of the brightest known roAp star αCircini based on the high-resolution spectra obtained with the HARPS spectrometer. The rapid variations of Nd and Pr line profiles are similar to other roAp stars.

Key words: line: profiles - stars: chemically peculiar - stars: oscillations - stars: individual:αCircini.

1. Introduction

αCircini (HD 128898, HR 5463, HIP 71908, V = 3.2 mag) is the brightest known rapidly oscillating Ap star. It was for the first time reported as a roAp variable by Kurtz (1982). The author reports photometric variability with a period of 6.8 min at a few mmag level. More recent photometric studies reveal four additional low amplitude oscillation modes (Kurtz, 1994).

roAp stars is a class of variable stars pulsating in high-overtone, low-degree p-modes. The oblique pulsator model is used to describe them. The model assumes that pulsation axis alignes with the magnetic axis which in turn is inclined to the rotation axis of the star (e.g., Kurtz, 1982; Kurtz, 1994; Shibahashi & Takata, 1993). An amplitude modulation of the main pulsation mode allowed to estimate rotation period of the star to Prot=4.4790 d (Kurtz, 1994). Several further non-radial modes have been detected by means of the photometric analysis of WIRE satellite data (Brunt, 2007).

A strong magnetic field suppresses convection in outer layers of atmosphere(Michaud, 1970). The diffusion leads to stratification of some chemical elements (Babel & Lanz, 1992). The first spectroscopic analysis of the star αCircini showing Ap-star characteristics was performed by Kupka et al. (1996). Recent spectroscopic analysis performed by Bruntt et al. (2008) confirmed remarkable overabundances of Co, Y, Nd and Eu (Bruntt et al., 2008). Similar to other chemically peculiar (CP) stars, αCircini shows abundance spots on its surface (Kochukhov & Ryabchikova, 2001). Ryabchikova et al. (2007) carried out reconstruction of vertical distribution of pulsation amplitude and phase. The derived effective temperature of 7420 K and surface gravity of 4.1 dex agree with the stratified model (Kochukhov et al., 2009) and with the interferometric measurements (Bruntt et al., 2009). Chemical stratification analysis showed inhomogeneous distribution of some chemical elements. spectroscopic The pulsational variability in roAp stars is dominated by the lines of rare-earth elements (REE), especially those of Pr and Nd.

In this paper we present analysis of LPVs focusing on a single Nd III spectral line at 6145Å. The line shows remarkable variations with the rotation phase which is characteristic of roAp-type stars and is probably linked to the stellar surface inhomogeneities. We adopt the same methodology as used in Kochukhov et al.(2004) for roAp star HR 3831.

*Based on observations collected at the European Southern Observatory, Chile (program 081.D-0008).

2. Observations and analysis

We base our analysis on high-resolution spectra obtained with the HARPS (High Accuracy Radial velocity Planetary Search) spectrograph attached to th 3.6-m telescope at La Silla. All spectra were downloaded from ESO archive. Principal investigator and co-investigators of the proposal 081.D-0008 were A. Hatzes, D. Mkrtichian and H. Saio. The two HARPS fibres produce a resolving power of 115000. This accuracy is enough to resolve a radial velocity of an order of 1 $m\,s^{-1}$. The data have been reduced using dedicated ESO pipeline. Reduced spectra were normalized using accurate calculation of a continuum level.

The two data sets of correspondingly 1600 and 3000 spectra have been obtained in February and April 2008. Typical exposure time was from 15 to 70 sec. We rejected 17 spectra with exposure time over 30 sec because this time range does not correspond with selected

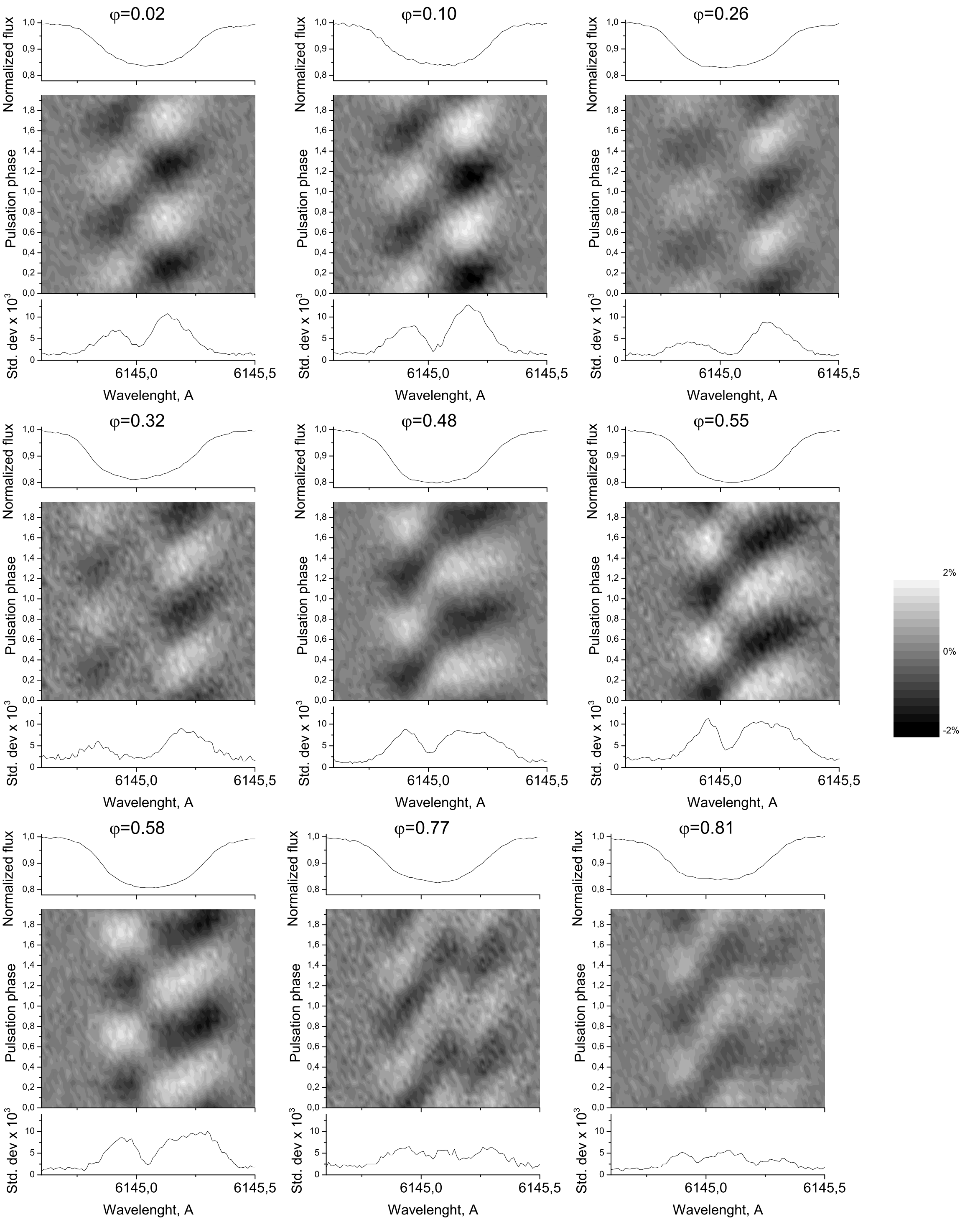

Figure 1: Illustration of the Nd III6145.07Å line profile variation at different rotation phases of the star αCircini. Upper panel of each plot show averaged spectra during the night. The middle greyscale plots show time evolution of the difference between averaged spectrum and phased spectra with the main pulsation frequency. The scale for the greyscale 2.5% of the continuum intensity. Bottom panels show standard deviation. All plots sorted by phase.

step of pulsational phase (see below). The rotational phase has been computed using the following equation *phi*=(HJD-2400000.0)/4.4792, where HJD- Heliocentric Julian Date, 4.4792 - rotational period determined by Bruntt et al. (2009). Following step of reduction was averaging of all spectra from each set of observation during main pulsational phase. For this step we took main frequency 2442μHz determined by Bruntt et al. (2009). Each set was divided by 20 pulastional phases. We could not increase accuracy because maximum exposure time 30 sec occupy 0,07 of pulsational phase.

3. Pulsational behavior of Nd and Pr spectral lines

High precision spectra enable to detect line profile variations in rare earth elements spectral lines. The upper panels in Fig.1 represent the average of all spectra acquired during single night in a small wavelength range centered at Nd III 6145.07 AA spectral line. The line shows obvious modulation with the rotation phase. The difference in the average profile can be explained by magnetic field modulation during rotation. Also it can be explained by inhomogeneous distribution of Nd in the atmosphere of αCircini. The line reaches its maximum depth at φ_{rot}=0.48 whereas minimum in equivalent width appears at φ_{rot}=0.02. The grayscale plots in Fig.1 illustrate time evolution of the residuals obtained by subtracting the mean profile from phased (according to the main pulsation period) individual spectra in every single night. Maximum deviation does not exceed 2% level relative to the mean spectrum Obviously, the red wing of the line is more sensitive to the pulsations which is confirmed by the standard deviation shown in the bottom panel of each plot in Fig.1. Amplitude of the standard deviation reaches maxima at φ_{rot}=0.10 and φ_{rot}=0.58. The two low-resolution figures at φ_{rot}=0.77 and φ_{rot}=0.81 show nonstandard behavior of the line.

We adopt the same methodology for few other Nd III and Pr III lines. The behavior of LPVs does not not show significant difference from the Nd III 6145Å spectral lines.

4. Conclusions

A clear modulation of the line with rotation phases implies the need of Doppler Imaging (DI) (Kuschnig et al., 1999) and Magnetic Dopler Imaging (MDI)(Kochukhov & Piskunov, 2002) mapping. The detailed analysis of the behavior of the Nd III 6145Å spectral line is a subject of the future research.

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