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DETECTION OF MAGNETIC FIELD VARIATIONS OVER THE PULSATION PERIOD OF THE roAp STAR γ Equ FROM Fe II 6149 LINE

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Several attempts recently have been made to investigate which magnetic variations occur over the pulsation cycle in roAp stars (Hubrig et al., 2003; Leone & Kurtz, 2003). For the first time we tried to find these variations from observations of the resolved Zeeman split Fe II λ 6149.2 Å spectral line in order to diagnose the line-intensity weighted average of the modulus of the magnetic field over the visible stellar hemisphere.

In our investigations we used spectra with a resolution of R=120000 obtained with the Coude Echelle spectrometer MAESTRO (Musaev et al., 1999). It was fed by the 2 meter telescope of the Observatory at Terscol Peak (Northern Caucasia). A Wright Instruments CCD 1242×1152 matrix camera with pixel size of 22.5 μm was used. Reduction of the spectra was done using the DECH code (Galasutdinov, 1992). 45 exposures of 80 s each were obtained at JD=2452103. The total time of one cycle was equal to 110 sec. S/N ratio of one spectrum was between 40–60. All details of our data reduction procedure, measurements of RV, etc. can be found in Malanushenko et al. (1998) and Savanov, Malanushenko & Ryabchikova (1999).

Basic results of our investigation are illustrated in Figure 1. Upper and middle panels of Figure 1 (left side) show phase diagrams for the RV variations of the Nd III λ 6145 Å and the Pr III λ 6160 Å lines. RV variations were fitted by a cosine curve using an IDL routine based on the non-linear least-squares Marquardt method (Bevington, 1969). Semi-amplitudes of RV variations are equal to 260 m/s for the Nd III line and 500 m/s for the Pr III line (with errors about 40–50 km/s).

Periods P were taken from a periodogram analysis which was performed with the PERDET code (Breger, 1990) (right panels of Figure 1). The highest peaks for the radial velocity data for Nd III, Pr III and magnetic data are at 1.37, 1.33 and 1.33 mHz, respectively. With our dataset we cannot resolve frequencies mentioned in our RV investigations (Savanov, Malanushenko & Ryabchikova, 1999) and in the photometric investigations by Martinez et al. (1996). The difference in the values of pulsation periods found from Nd III and Pr III lines is small but the same effect was also mentioned by Kochukhov & Ryabchikova (2001).

We also measured the difference ($\delta\lambda_c$) in wavelength between the central parts of the two components of the Fe II λ 6149.2 line and determined the corresponding magnetic field H_c (mean magnetic field modulus) derived from the relation

$$H_c = \delta\lambda_c/(g\ \delta\lambda_Z),$$

where g is the Lande factor and $\delta\lambda_Z$ is the Lorenz unit (see Mathys 1990 for details).

From our observations we found that the mean value of the difference in wavelength between the central parts of the two components of the Fe II line is equal to

$$\delta\lambda_c = 0.1808 \pm 0.0067$$

and the mean magnetic field modulus is equal to

$$H_c = 3792 \pm 140G.$$

These values can be compared with results published by Mathys (1990) for JD = 2447637.917: $\delta\lambda_c = 0.171$ and H_c= 3.6 kG.

Another estimation of H_c yields values in the region of 3.4–3.6 kG and can be found in Mathys & Lanz (1992).

The bottom panels of Figure 1 illustrate the results on the variability of H_c. According to our estimations the amplitude of H_c variations is equal to 99 $\pm$ 53 G. The frequency of the oscillations coincides with the one of the RV variations of the Pr III λ 6160.24 Å line and is equal to 1.33 mHz (close to one of the photometric periods found by Martinez et al., 1996).

We confirm the existence of a small phase difference between the radial velocity variations and the magnetic variations at an order of 0.20-0.25 cycles (0.15 $\pm$ 0.05 cycles by Leone & Kurtz, 2003).

The RV variations of each of the Zeeman components of the Fe II λ 6149.2 Å line are below the limit of our detection (100-120 m/s). This is in agreement with the result by Kochukhov & Ryabchikova (2001) who found that the average of the component's semi-amplitude of RV variations is equal to 64 m/s and that the phase shift between RV variations of Fe II and Pr III, Nd III is about 0.5 of a cycle.

We suggest that oscillations of the mean magnetic field modulus determined from the components of the Fe II λ 6149.2 Å line cannot be connected with oscillation in spots or thick layer as in the case of double-ionized rare earth elements.

In the paper by Hubrig et al. (2003) first theoretical considerations of the magnetic field variations for magnetic roAp stars were presented. These estimations in the particular case of γ Equ imply magnetic field variations at a level of 8%. From their own observations Hubrig et al (2003) were only able to give an upper limit of 175 G. From polarimetric observations Leone & Kurtz (2003) detected magnetic variations over a pulsation cycle of γ Equ with an amplitude in the range of 112–240 G for the Nd lines. This is in agreement with theoretical models expecting 10% variations of the effective field strength which equal to 145 G.

From our analysis we have found that the amplitude of H_c is about 200 G which is 5% of the obtained mean magnetic field modulus H_c. However, an estimate for the expected field variations is tightly connected with the adopted RV data. In general, the available radial velocity data range implies the magnetic field variations in the atmospheres of roAp stars at a level of approximately 1 to 14 % (Hubrig et al., 2003).

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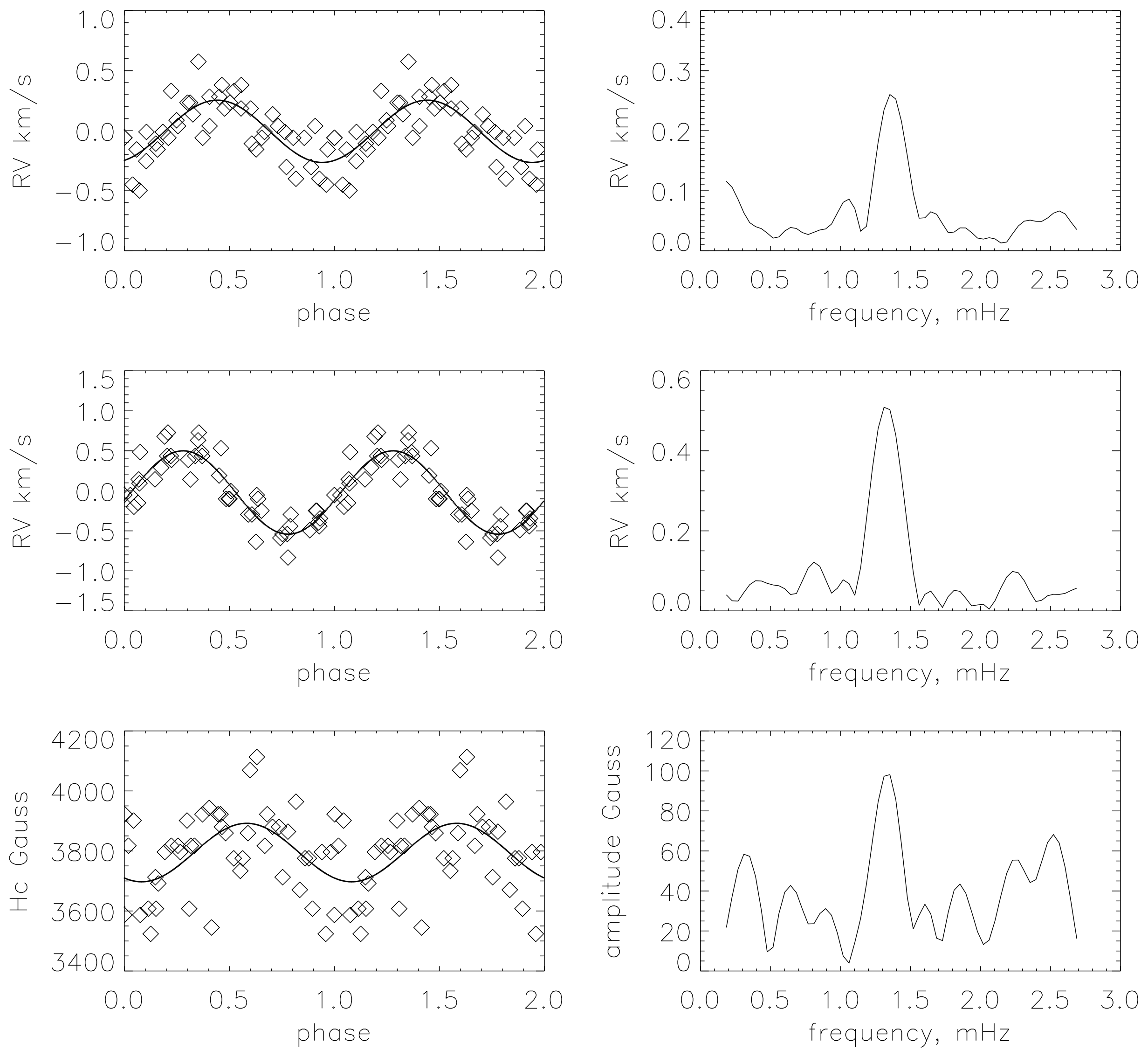

Figure 1. Left side: phase plots of the variability of the radial velocity from the Nd III λ 6145 Å , Pr III λ 6160 Å lines and the mean magnetic field modulus H_c (from top to bottom). Right side: the amplitude spectra for the radial velocity of the Nd III λ 6145 Å , Pr III λ 6160 Å lines and the mean magnetic field modulus H_c (from top to bottom).

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ERRATUM FOR IBVS 5407

We noticed an error in the minima of ET Leo which should be corrected as:

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Mean time 52726.2809, Mean error 0.0004  Min I (BVR)
Mean time 52726.4513, Mean error 0.0002  Min II(BVR)
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