SPECTROPOLARIMETRY OF β*Cephei* TYPE STAR γ*Pegasi*

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ABSTRACT. Results of an intensive spectropolarimetric study of the small-amplitude purely radial pulsating β Cephei-type star γ Pegasi are presented. It was shown that residual intensity, full width at half maximum and equivalent width of the He I 6678 line vary during 0.15-day pulsation period and reach its maximal value when the temperature of the star is highest. The line parameter variations due to pulsation were explained as a temperature effect. Although no strong signatures appear in the individual longitudinal magnetic field measurements, its probable coherent variation with the well-known 0.15-day pulsation period is an indication of the presence of a weak magnetic field in γ Pegasi. The values of γ-velocity and $2K$-amplitude of the pulsation velocity curves are presented as well as the results of its variations due to the 6.83-day orbital period.

Key words: stars: atmospheres, early-type; oscillations; stars: binary: spectroscopic; stars: individual: γ Pegasi; magnetic field

1. Introduction

The β Cephei-type star γ Pegasi (HR 39, B2 IV) has one of the smallest amplitude variations in radial velocity $2K = 7\ km\ sec^{-1}$ (McNamara, 1953), light $\Delta m_v = 0.017$ (Sareyan et al., 1975) and short pulsation period $P \sim 0.15$ day. The star is believed to pulsate in a low-order, purely radial mode. De Jager et al. (1982) show that γ Pegasi has a virtually zero rotational velocity component i.e. the star is seem rotation pole-on.

Small-amplitude pulsating stars have not often been an object of intensive high-resolution study for variation of spectral line parameters due to pulsations. In this paper the results of high-accuracy study of variation of the He I 6678 line parameters due to the radial pulsation of γ Pegasi are presented. Photosphere displacement curves were calculated for different pulsation cycles. The difference between amplitudes of the individual curves was analysed.

Results of a number of attempts to detect magnetic field on this star (Babcock, 1958; Rudy and Kemp, 1978; Landstreet, 1982, Butkovskaya and Plachinda, 2004) left this problem unsolved. However, magnetic field with polar strength of several hundred gauss were detected on four early B-type pulsating stars: β Cep (Donati et al., 2001), ζ Cas, ω Ori and V 2052 Oph (Neiner et al., 2003a,b,c). It was shown (Butkovskaya et al., 2006) if rotation axis of γ Pegasi and line of sight are almost coincide, and the star hosts a dipole magnetic field then dipole axis would be situated near rotation equator plane and longitudinal component can be equal to some dozens. Using our high-accuracy measurements of the magnetic field of γ Pegasi the variation of its longitudinal component due to pulsation cycle was studied here.

Harmanec et al. (1979) have determined the 6.83-day period of variation of the γ-axis of the pulsation velocity curves and concluded that the star is a spectroscopic binary. Ducatel et al. (1981) clearly detected day-to-day variation of the γ-velocity, but they assumed that the γ-axis probably varies due to the stellar oscillations. Today Butkovskaya et al. (2006) after careful analysis of possible origins of the 6.83-day periodic variation of the γ-velocity have concluded that the variation occurs owing to orbital motion of the star. Results of the measurements of the γ-velocity and $2K$-amplitude of the pulsation velocity curves are presented as well as the results of its variations due to the orbital period.

2. Observations

An intensive study of γ Pegasi has been performed in the line He I 6678.149Å during 23 nights from 1997 to 2005, and 405 high-accuracy spectra were obtained using coude spectrograph of the 2.6-m Shajn telescope at the Crimean Astrophysical Observatory. Signal-to-noise ratios of a single spectrum were typically 350-600 with resolving power of spectra approximately 2.2×10^4.

3. Discussion and conclusions

3.1. Pulsation

The phases of the basic pulsation period have been computed from the ephemeris $JDh = 2451060.461 \pm$

0.15175039 (Butkovskaya and Plachinda, 2004).

In Figure 1a,c,d,e radial velocity (RV) as well as core residual intensity (RI), full width at half maximum (FWHM), equivalent width (EW) of the line He I 6678 as a function of the pulsation period phase are presented. The mean pulsation cycle values of both radial velocity and all three spectral line parameters were subtracted.

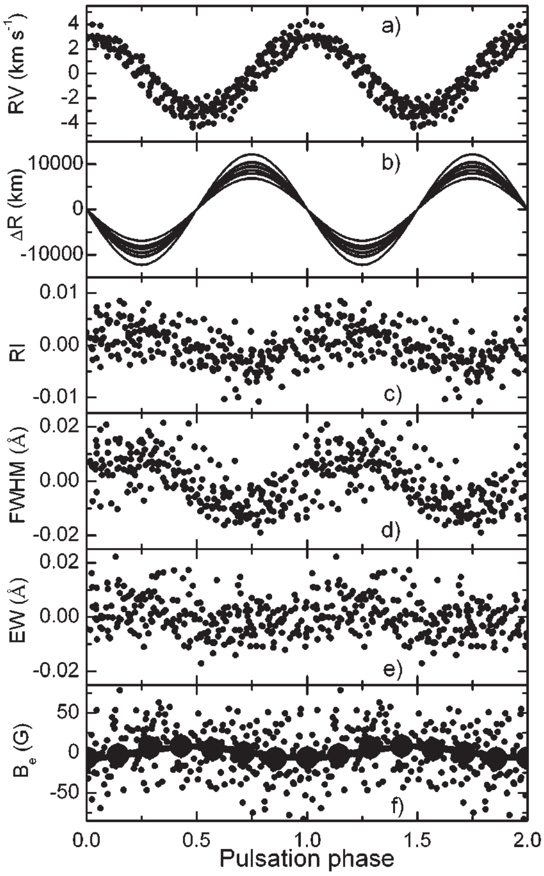

Figure 1: Pulsation

The RI, FWHM and EW of the helium line rich its maximal values in maximum compression phase when the temperature of the star is highest. The line parameter variations due to pulsation would be explained as a temperature effect.

The photosphere displacement curves calculated in standard manner (see Mathias et al., 1991, Appendix B) are presented in Figure 1b. The amplitude of photosphere displacement differs from one pulsation cycles to another. The star is an open thermodynamic system, and the discrepancy between the individual curves occurs because these values are determined in a highly non-linear fashion by the physical conditions in and above the He ionization zones in the star, so that small variations in the structure of the outer layers of these stars could easily lead to significant changes in pulsation properties (Christy, 1966). γ Pegasi is a spectroscopic binary and the instability in the ionization zone can be owing to tidally effect of the secondary component.

In the Figure 1f longitudinal magnetic field against pulsation phases is presented (small filled circles) as well as the same data binned into 7 bins (large filled circles). The least-square sinusoidal fitting is shown by solid line As it has been estimated by Butkovskaya et al. (2006) that owing to frizzing of magnetic field into plasma the longitudinal magnetic field variation due to the radial pulsation of γ Pegasi would be less than 1 G. But in the Figure 1f the longitudinal magnetic field shows periodic variation with amplitude of about 7 G, moreover, the reverse of its polarity exists. Therefore, in the case of γ Pegasi the variation of the magnetic field due to the radial pulsations of the star could not be explained only in the frame of the pulsation motion of stellar atmosphere. Additional data, which will require further precise observations are needed in order to confirm these results.

3.2. Binarity

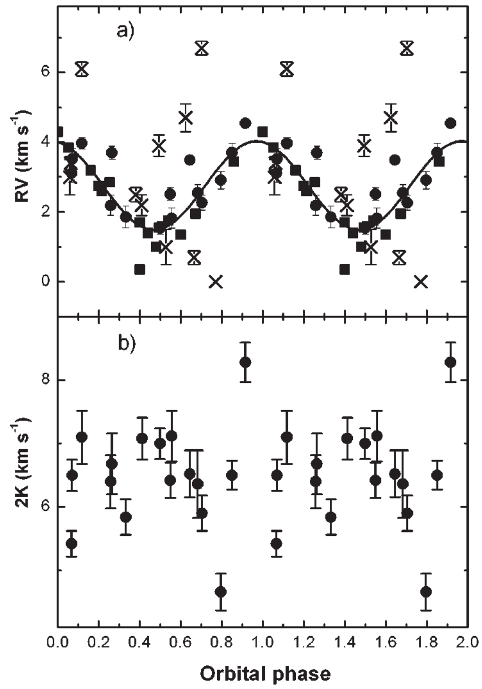

Figure 2: Orbital motion

McNamara (1955) pointed out a possibility that γ-axis of the 0.15-day velocity curve of γ Pegasi varies. Harmanec at al. (1979) have determined the 6.83-day period for the variations of the γ-axis and concluded that the star is a spectroscopic binary. Later, Ducatel et al. (1981) also clearly detected day-to-day variation of γ-axis, but they supposed that the variation can be associated with stellar oscillation. Recently Butkovskaya et al. (2006) after careful analysis of possible origin of the 6.83-day periodic variation of the γ-axis concluded that the star is a spectroscopic binary as it was claimed by Harmanec et al. (1979). In the Figure 2a,b γ-velocities and $2K$-amplitude of the pulsation velocity curves folded with the orbital period phase are presented. In the Figure 2a filled circles represent our γ-velocity data, filled squares are data taken from Figure 1 in paper of Harmanec et al. (1979), and crosses are data of Ducatel et al. (1981). The γ-velocity and $2K$-amplitude values are given in Table 1 (columns 2 and 3). Here the column labeled JDh indicate the Heliocentric Julian Date.

Table 1: γ-velocity and $2K$-amplitude

JDh	γ ($km\ s^{-1}$)	$2K$ ($km\ s^{-1}$)
2451060.481	2.27 ± 0.22	5.90 ± 0.28
2451061.480	3.71 ± 0.26	6.50 ± 0.23
2451088.430	2.91 ± 0.25	4.66 ± 0.29
2451171.218	4.54 ± 0.13	8.28 ± 0.31
2451172.251	3.11 ± 0.27	5.42 ± 0.20
2451488.272	1.86 ± 0.32	5.84 ± 0.28
2452217.366	3.52 ± 0.30	6.50 ± 0.25
2453280.317	2.55 ± 0.23	6.36 ± 0.53
2453283.283	3.97 ± 0.17	7.10 ± 0.42
2453284.284	3.70 ± 0.19	6.68 ± 0.48
2453598.455	2.19 ± 0.29	6.40 ± 0.42
2453600.448	2.52 ± 0.18	6.42 ± 0.28
2453627.426	1.54 ± 0.18	7.00 ± 0.24
2453628.421	3.49 ± 0.08	6.52 ± 0.37
2453688.308	6.49 ± 0.24	7.08 ± 0.33
2453689.294	1.82 ± 0.29	7.12 ± 0.40

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