THE SHELL ACTIVITY OF Be/SHELL STAR ζ TAURI IN 1985 - 1997

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ABSTRACT. The study results of high-resolution CCD-spectra of the V/R variable Be-shell star ζ Tauri covering 1985 - 1997 obtained at the 2.6-m telescope of the Crimean Astrophysical Observatory are present. Tthe equivalent width, the violet and red intensities and V/R ratio of the Hα emission line and equivalent width and central depth of the HeII 6678 line were measured. The shell activity was low in 1985-1988: the equivalent width Hα emission line were about 7-12 Å, V/R ratio fluctuated in an irregular manner. The active shell phase started in 1989 and then equivalent width of Hα emission line increased to 19-26 Å in 1992 - 1995; V/R cyclic changes and compound structure of Hα emission line profiles reappeared. In 1996 - 1997 the equivalent wight of Hα line slightly lessened, but compound profiles structure remained.

Key words: line: profiles - stars: activity - stars: emission line, Be-stars: individual: ζ Tauri

Introduction

The star ζ Tauri (123 Tauri, HD 37202) is one of the brightest and most extensively studied Be/shell stars of northern sky. It is singlelined spectroscopic binary with an orbital period of 132.9735 days (Harmanec, 1984) and cyclic variations of intencities of violet and red peakes the Balmer emission lines (V/R). Its opticl spectrum is characterized by rotationlly widened HI and HeI lines of an early-B spectral type, by double emission component of lower members of Balmer series, and by the present of many strong shell lines corresponded to an A2 Ia spectral type. The strength of the shell lines, the V/R ratio of the double emissions and the radial velocities of the shell lines ll exhibot long-term cyclic variatoins in some epochs. (Hubert-Delplace at al, (1983), Bahng (1976), Slettebak at Reynolds (1978)). Sometimes the cyclic variatoins dispeared completely (Yang at al (1995)), but the emission and shell spectrum was observed always during century of observations of the star.

The equivalent width of Hα emission changed in bredth limits: it was 26-35 Å in 1961-1967 (Delplace, 1970), 19-23 Å in 1973 (Bahng, 1976) and decreased to 12-15 Å in 1984 - 1987 (Guo at al,1995) In last paper are given parameter variations of Hα line from 1978 to 1994 and possible shell models are discussed. In connection with Quirrenbach at al (1994) work as to the reconstruction of ζ Tauri shell in OLBI MarkIII experiment in september - november 1992 into Hα line, study parameters of this line obtain special meaning.

Observations

Observations ζ Tauri were obtained by A.E.Tarasov with the specrograph attached in coude focus of the 2.6-m telescope of the Crimean Astrophysical Observatory. The spectra were registrated on GEC CCD P8600 (576 $\times$ 580 pixels) before 1995 and on Elektronix CCD (1024 $\times$ 260 pixels) after 1995. In each observation was registrated the spectrum part length

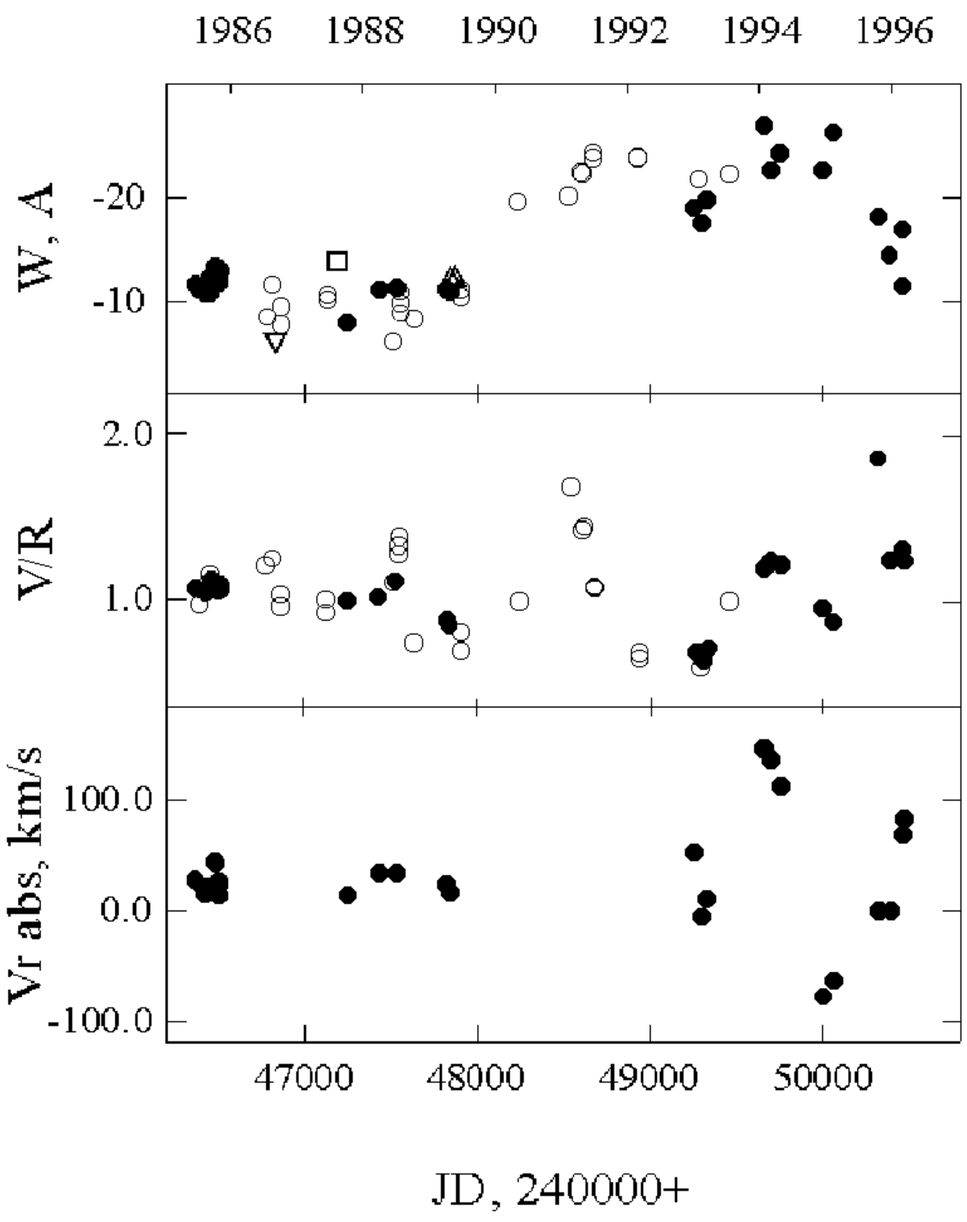

Figure 1. On Fig.1 the our significances of equivalent width of line, V/R ratio, and radial velisity of absorption component intencities are shown as filled circles and:
- circles - Guo at al, (1995);
- square - Mennickent at al, (1994);
- triangles - Kunjaya, Hirata, (1995)

near 60 Å. The exposure times was from 10 to 37 minutes; the signal to noise ratio S/N was 100-200. Whole 29 Hα and 11 HeII 6678 was got in 1985 - 1997. The reduction of dates was held in standard manner. Reduction to the lengths waves scale was realized both of the telluric water lines before 1988 and of comparison thorium-argon spectrum; then the fasten lengths wave scale to Solar system barycenter was done. The mean fasten error did not exceed 0.5 km/s.

Line profile variations

We measured equivalent width, the violet and red intensities and V/R ratio of the Hα emission line, radial velocity it's emission end absorption component and equivalent width and central depth of the HeII 6678 line. The results are given Tab.1 2 accordingly.

Table 1. Measured parameters of Hα emission lines ζ Tauri.

JD 2400000+	W (Å)	I_V	I_R	I_A	V/R
46374.58	11.61	2.31	2.16	1.01	1.07
46405.42	11.01	2.32	2.19	0.93	1.06
46407.41	11.26	2.34	2.20	0.98	1.06
46428.45	10.67	2.24	2.15	0.96	1.04
46460.39	10.75	2.35	2.22	0.88	1.06
46463.30	11.39	2.45	2.26	0.95	1.08
46466.47	12.16	2.52	2.25	1.01	1.12
46490.38	12.21	2.36	2.16	1.25	1.09
46491.35	13.25	2.44	2.26	1.32	1.08
46509.29	12.99	2.38	2.19	1.23	1.09
46510.23	12.48	2.36	2.17	1.28	1.09
46514.29	11.80	2.33	2.20	1.22	1.06
47253.25	7.89	1.85	1.85	0.80	1.00
47436.43	10.98	2.09	2.08	1.38	1.00
47537.50	11.19	2.23	2.01	0.77	1.11
47828.59	11.12	1.93	2.21	0.85	0.87
47846.38	10.79	1.94	2.29	0.75	0.85
49263.61	19.03	2.43	3.56	1.54	0.68
49304.57	17.54	2.26	3.58	1.69	0.63
49340.56	19.78	2.60	3.70	1.70	0.70
49671.29	27.10	3.73	3.13	2.71	1.19
49708.58	22.67	3.40	2.70	2.45	1.23
49762.35	24.40	3.62	2.97	2.53	1.22
50005.61	22.63	2.70	2.85	2.37	0.95
50069.44	26.44	3.70	4.30	2.56	0.86
50326.59	18.16	3.90	2.11	1.90	1.85
50393.63	14.42	2.24	1.81	1.67	1.24
50466.28	17.01	2.73	2.08	1.56	1.31
50472.40	11.42	2.00	1.61	1.49	1.24

The our significances of equivalent width, V/R ratio and radial velocity of absorption component of line are shown on Fig. 1 as filled circles, where the other authors resultes are shown too (circles - Guo at al, 1995; square - Mennickent at al, 1994; triangles - Kunjaya, Hirata, 1995).

The shell activity of ζ Tauri was low in 1985-1988:

- the equivalent width Hα emission line were about 7-12 Å, V/R ratio fluctuated in an irregular manner.

The active shell phase was begun in 1989:

Table 2. Measured parameters of HeI 6678 line ζ Tauri.

JD 2400000+	W (Å)	I_A	FWHM (Å)
47199.46	1.6	0.68	3.7*
47436.43	1.8	0.64	3.6*
47537.61	1.32	0.70	1.90
47828.72	1.47	0.69	3.89
47846.53	1.37	0.76	4.50
49263.56	1.29	0.65	1.86
49304.54	1.27	0.69	1.71**
49671.30	1.22	0.81	5.65
50069.46	1.20	0.75	4.00
50393.61	1.55	0.60	2.49
50466.29	1.39	0.60	2.76

* Note: W and FWHM was measured by dispersion
0.0536 Å/pix whithout comparison srectrum.
** 0.1057 Å/pix.

-V/R began cyclic changed with slight amplitude at the minimum meanings of equivalent width of Hα emission line.

- then equivalent width Hα emission line increased to 19-26 Å in 1992 - 1995, the amplitude of V/R cyclic changes increased too and compound structure Hα emission line profiles reappeared. Complementary peaks intensity arose. The helium line form and it's radial velocity fluctuated too.

Hα emission lines profiles referred to the continuum level are shown on Fig. 2. Three upper profiles relate to low active phase of the shell, and others - to high active phase. That we can see as variety of profiles with it's compound structure.

The similar structures are indicated in the van der Welt work (1970) at the significances W from 28 Å in 1964 to 17 Å in 1966 and there is specified, that H-α radial velocity is remarkable, being reversed with respect to the other hydroger lines. He assumes positive radial velocity of absorption component as hydrogen ejection from the inner layers. In 1996 - 1997 the equivalent width Hα emission line decreased, but compound structure wiht complemen-

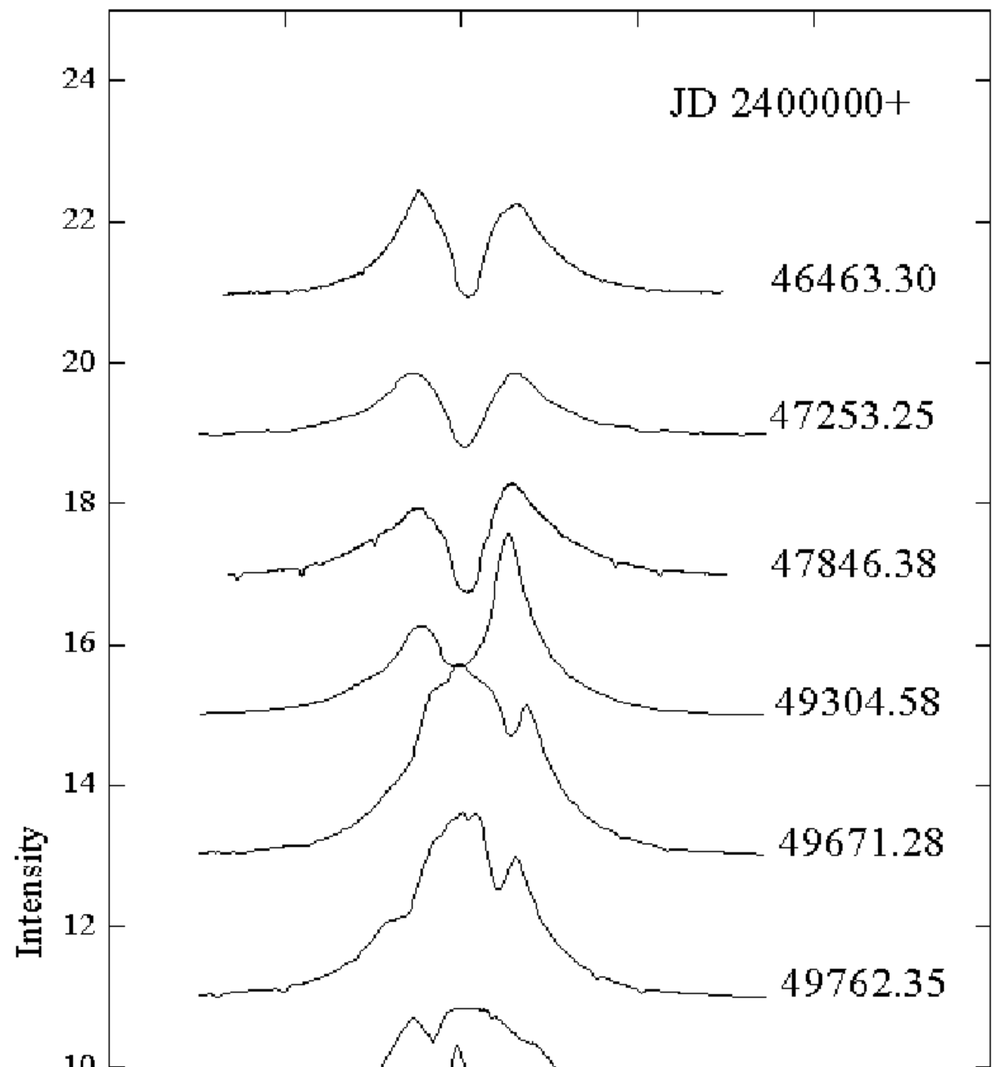

Figure 2. On Fig.2 H-alpha emission lines profiles referred to the continuum level are shown. Three upper profiles relate to low active phase of the shell, and others - to high active phase. Julian dates show of the right.

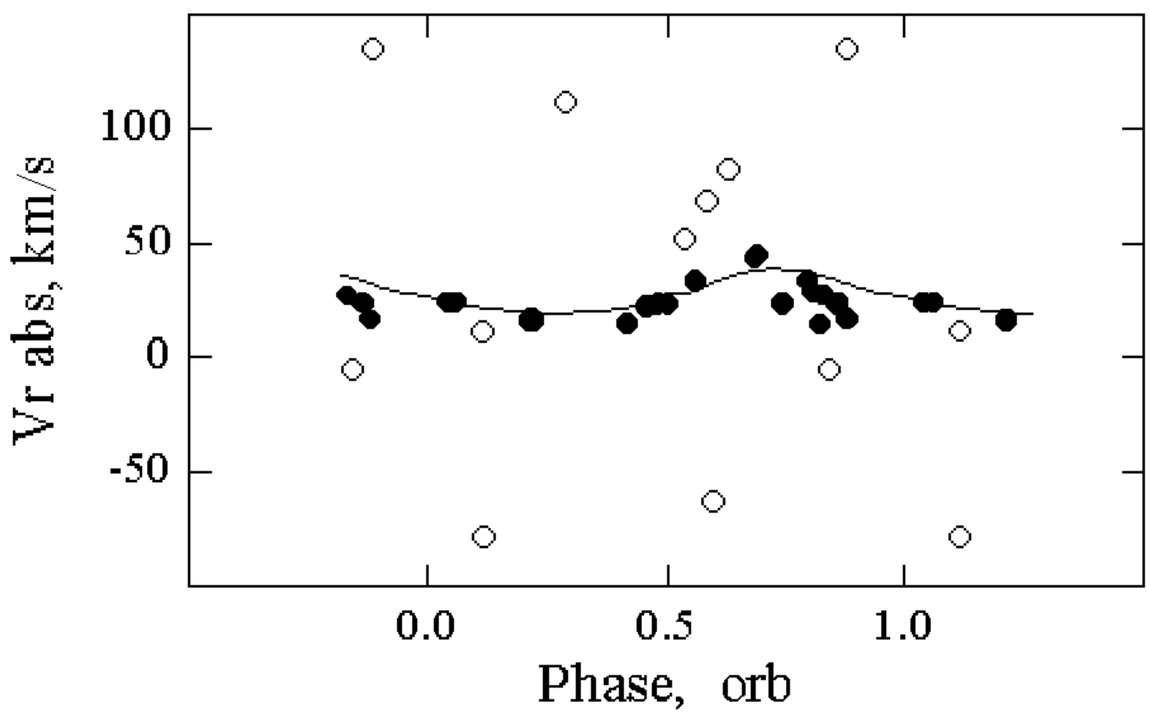

Figure 3. On Fig.3 the radial velocities of absorption component are compared with the orbital movement of ζ Tauri.
- full circles related to calm phase
- circles - active phase
- line - radial velocity of star

tary peaks intensity Hα emission remained.

The radial velocity of absorption component also displays dependence from shell activity. At comparison radial velocity of absorption component with the orbital movement of ζ Tauri (the parameters are taked out of paper Harmanec, 1984) we see, that in calm phase radial velocity of absorption component liked to radial velocitiy of star and changes within 50 km/sec (Fig. 3, full circles). In the active phase the desperse meanings of radial velocity of absorption component achieves 230 km/sec and don't display correlation with the star orbital movement.

Conclusion

The variations of shell size and mass we can observe as variations Hα emission and others shell lines. Absorption component is formed in the part of the shell projected aginst the stellar disk and the Balmer emission lines originate in n extended cool envelope round the underlying star. Therefore, the variations of the radil velocity of shell lines and V/R ratio reflect the the behavior of the extended envelope. In a active phase it is possible to assume availability unstable and non-continious of flows of matter between invisible companion and Be-star.

Existing at present time the shell model of ζ Tauri a most approximate but longtime observations in the different length of the waves of the with allowance for planned repetition of experiment as to the reconstruction of shell will let create more accurate model.

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References

Bahng J.D.R.: 1976, in: *Proc. IAU Symp.* **70**, *Be and shell stars,* ed. A. Slettebak, Reidel, Dordrecht, 41

Delplace A.M.: 1970, *As. Ap.,* **7**, 459

Guo Y., Huang L., Hao J., Cao H., Guo Z., Guo X.: 1995, *As. Ap. Suppl.*, **112**, 201

Harmanec P.: 1984, *Bull. Astron. Inst. Czech.,* **35**, 164

Kunjaya C., Hirata R.: 1995, *PASJ,* **47**, 589

Mennickent R.E., Vogt N., Barrera L.H., Covarrubias R., Ramirez A.: 1994, *As. Ap. Suppl.,* **106**, 427

Quirrenbach A., Buscher D.F., Mozurkewich D., Hummel C.A., Armstrong J.T.: 1994, *As. Ap.,* **283**, L13

van der Welt T.: 1970, *As. Ap.,* **4**, 341