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SPECTROSCOPIC STUDY OF LONG PERIOD ECLIPSING BINARY 32 CYGNI[1]

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ABSTRACT

Spectra of the ζ Aurigae type eclipsing binary system 32 Cygni were taken at the Asiago Observatory. Using the Gaussian fitting method we can estimate the radial velocity and equivalent widths of some metalic lines.

1. INTRODUCTION

32 Cygni is a typical ζ Aurigae type eclipsing binary which consists of a late type supergiant (K5 Iab) as one component and the other as an early type star (B4 IV-V). The period is estimated as 1147 days with the totality duration of 13 days (Wilson 1960). Eccentricity is 0.301 and the orbital inclination is 72° (Wellmann 1957). Even this star shows the atmospheric eclipse of the ζ Aurigae type binary we can not expect the total eclipse because of its orbital inclination.

Photometric observations of 32 Cygni were made by many observers (Bloomer and Wood 1974, Griffiths and Stencel 1972, Guinan and McCook 1974, Doherty *et al.* 1974, Johansen *et al.* 1970). The apparent magnitude is $4^m.14$ and the distance is estimated as 383 pc. The mass of a supergiant is 9.6 solar mass and the mass ratio is 2.0.

During the eclipse period of 1984 to 1987 at the Okayama Astrophysical Observatory, Saito and Kawabata (1988) observed CaII H and K line spectrum and found their daily variations. This phenomenon was interpreted as the existence of the discontinuous variation of the opacity source in the atmosphere of the supergiant. They concluded that there exist transitions between the upper and lower atmosphere in the K-type giant star.

Spectroscopic study by Wright (1952) indicates the large scale prominence activity in K-type star. He also suggested that the radiation effect from the early type star is more effective to the outer atmosphere.

In this paper we calculated radial velocities and equivalent widths of 32 Cygni from the observed spectrum.

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2. OBSERVATION AND REDUCTION

2.1 Observed materials

Spectroscopic observations were made at Asiago Observatory using a Cassegrain A spectrograph. The used plates are 103a-O with the size of 9cm x 12cm. The linear dispersion at Hγ is 42 Å/mm and FeI arc was used as the comparison light source. The plate number and the exposure time are listed in Table 1.

Table 1. Observed materials.

Plate number	Date	U.T	Exposure
18231	Aug. 1, 1989	21^h32^m	10^m
18232	Aug. 1, 1989	21^h53^m	30^m
18236	Aug. 2, 1989	22^h58^m	30^m

2.2 Reductions

Observed plates were scanned from the use of the microdensitometer (Perkin Elmer PDS1010A) with the scan speed of 10mm/sec. Comparison line identification was made using 24 FeI arc lines. Using these 24 comparison lines we made the 4th order polynomial non-linear least square method calibration to get the correlation between the PDS coordinate and the actual wavelength. Figure 1 shows this correlation. The residual errors between the real wavelength and the calculated one is less than 1Å.

The relative intensity of absorption lines was made from the normalization of continuum level. We made this process through the calculating mean intensity values for each wavelength regions. Figure 2 shows mean intensity values for each wavelength regions. Using these mean values we estimated intensities from the non-linear least square method. The normalization intensity was defined as the ratio value of the observed intensity to the calculated one.

We plotted these normalized intensities of 32 Cygni in Figures 3a-d. From these figures we can see that some heavy element lines are prominent as like ZrI, VI, ScI, FeII and CoI.

3. RADIAL VELOCITY AND EQUIVALENT WIDTHS

3.1 Radial velocity

To get the radial velocity of 32 Cygni we used FeI lines which are relatively symmetric sharp and strong. Gaussian fitting method was used and Figure 4 shows this fitting to a FeI line. Table 2 is the radial velocity calibration from some FeI lines with reference wavelengths and observed ones.

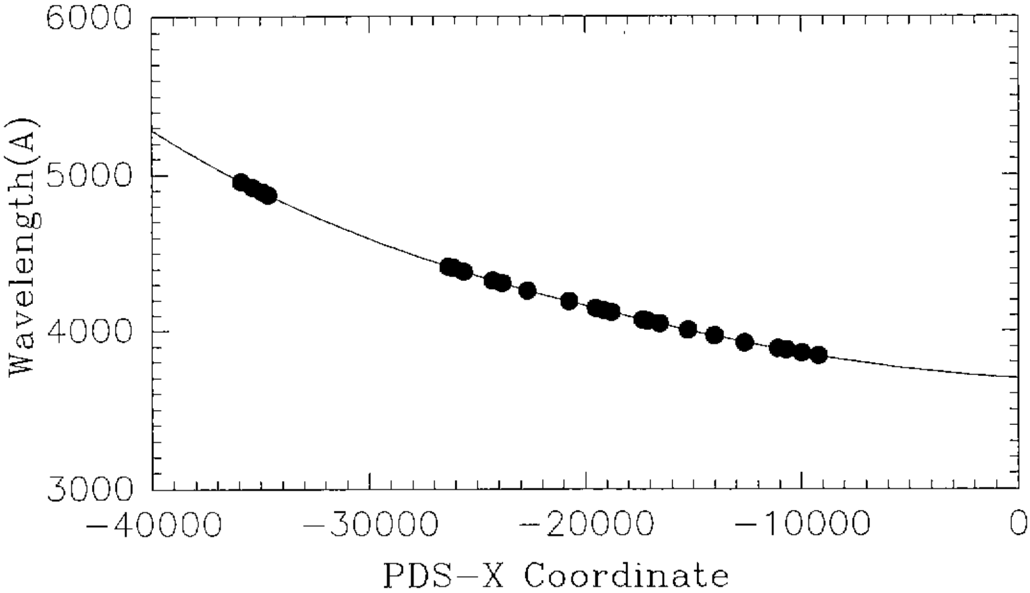

Fig 1. The correlation curve between the PDS coordinate and the actual wavelength.

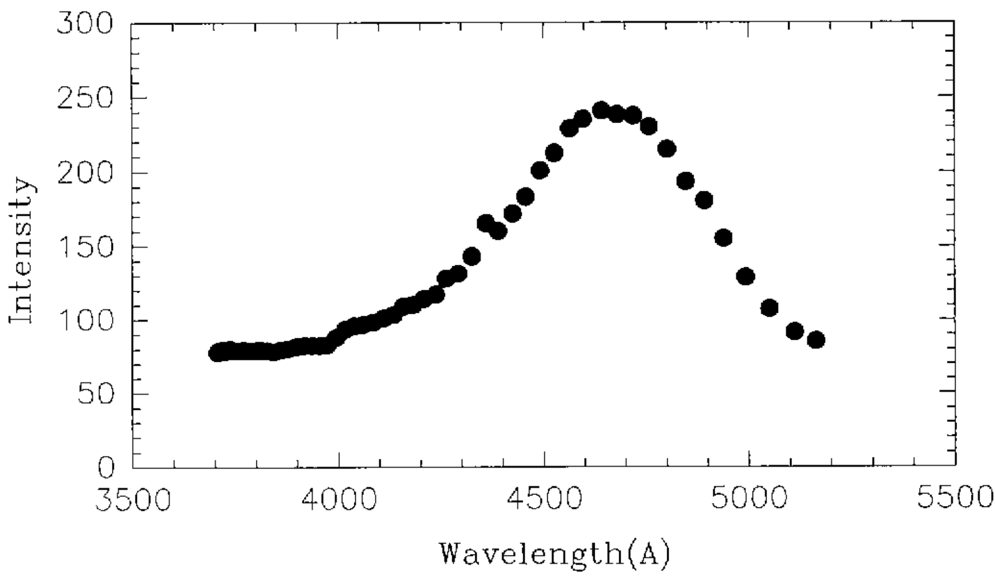

Fig 2. Mean intensity values for each wavelength regions.

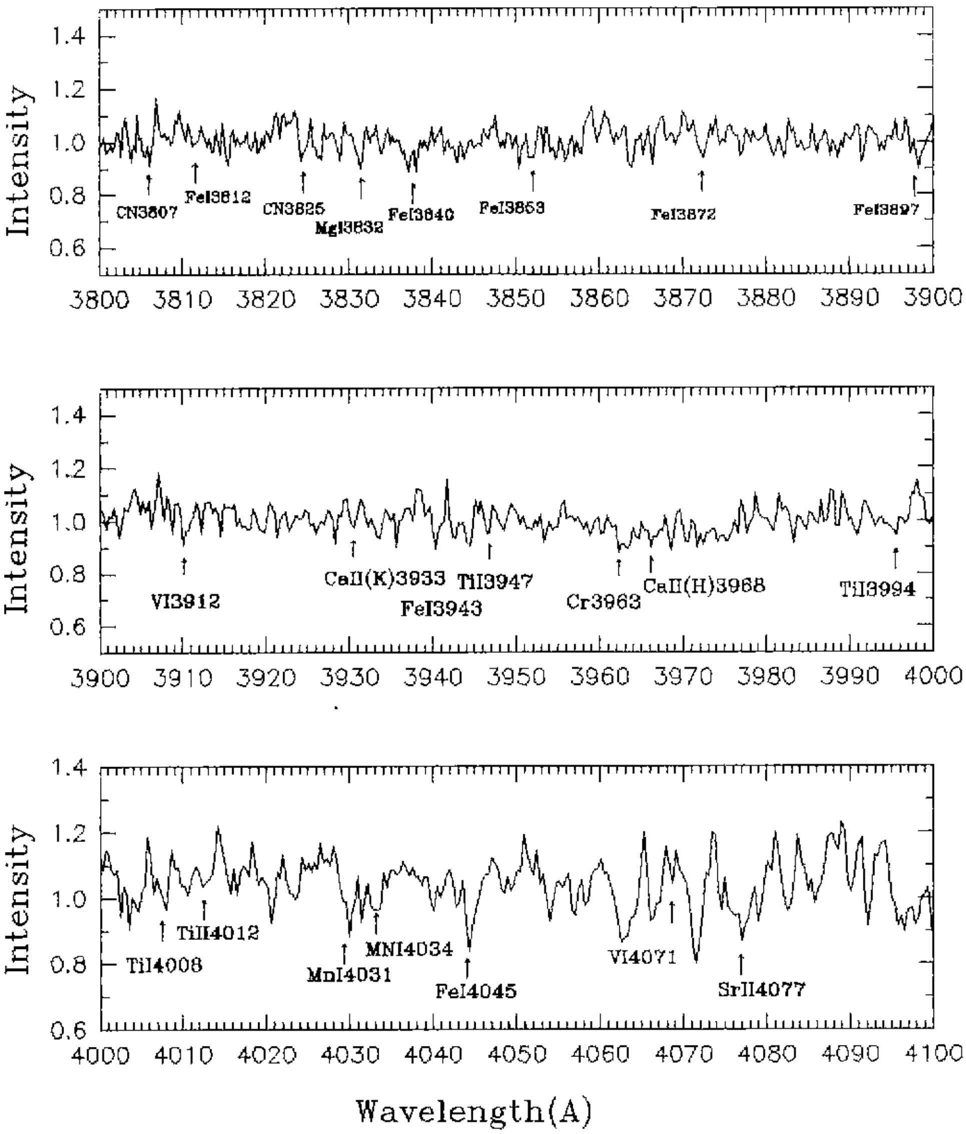

Fig 3a. Normalized intensity of 32 Cygni.

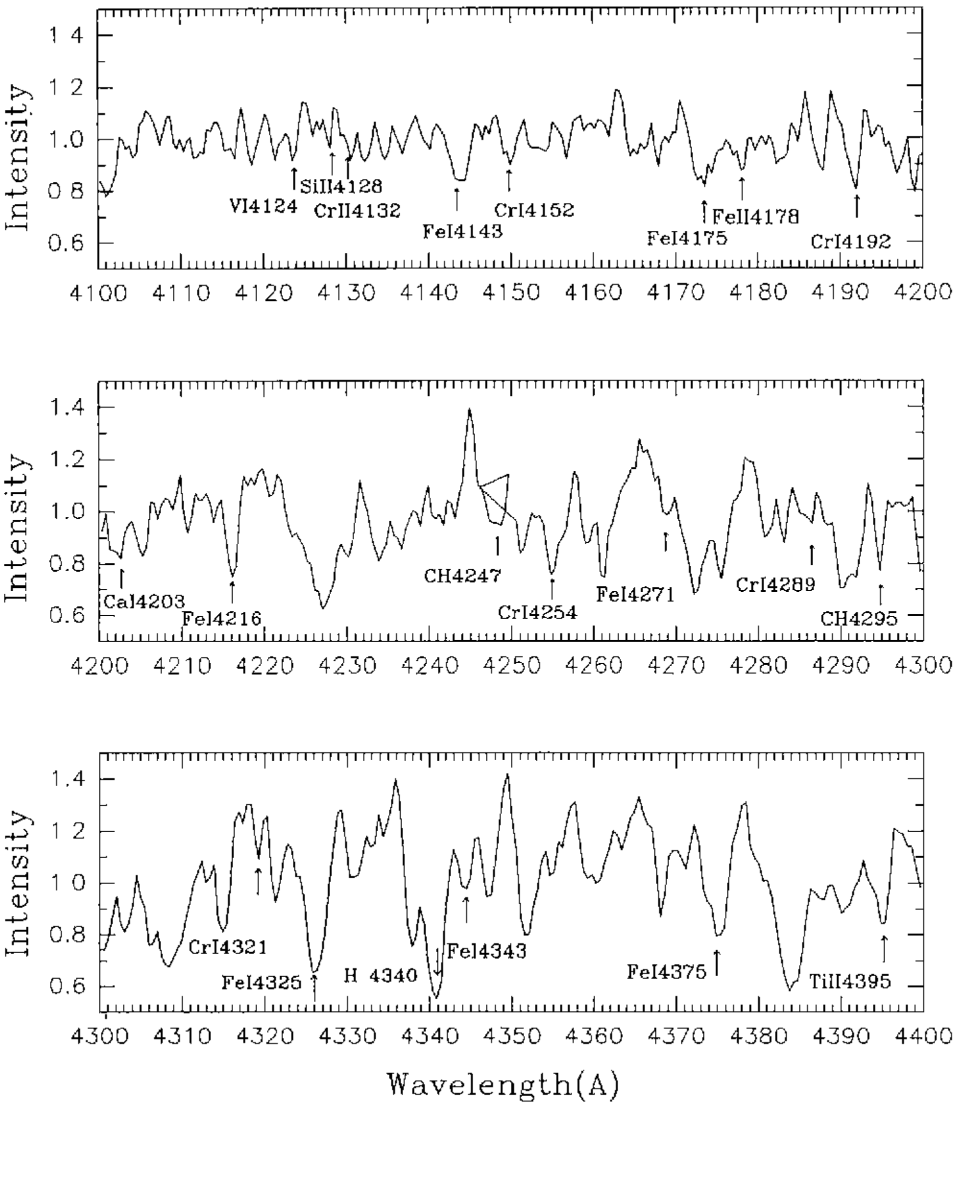

Fig 3b. Normalized intensity of 32 Cygni.

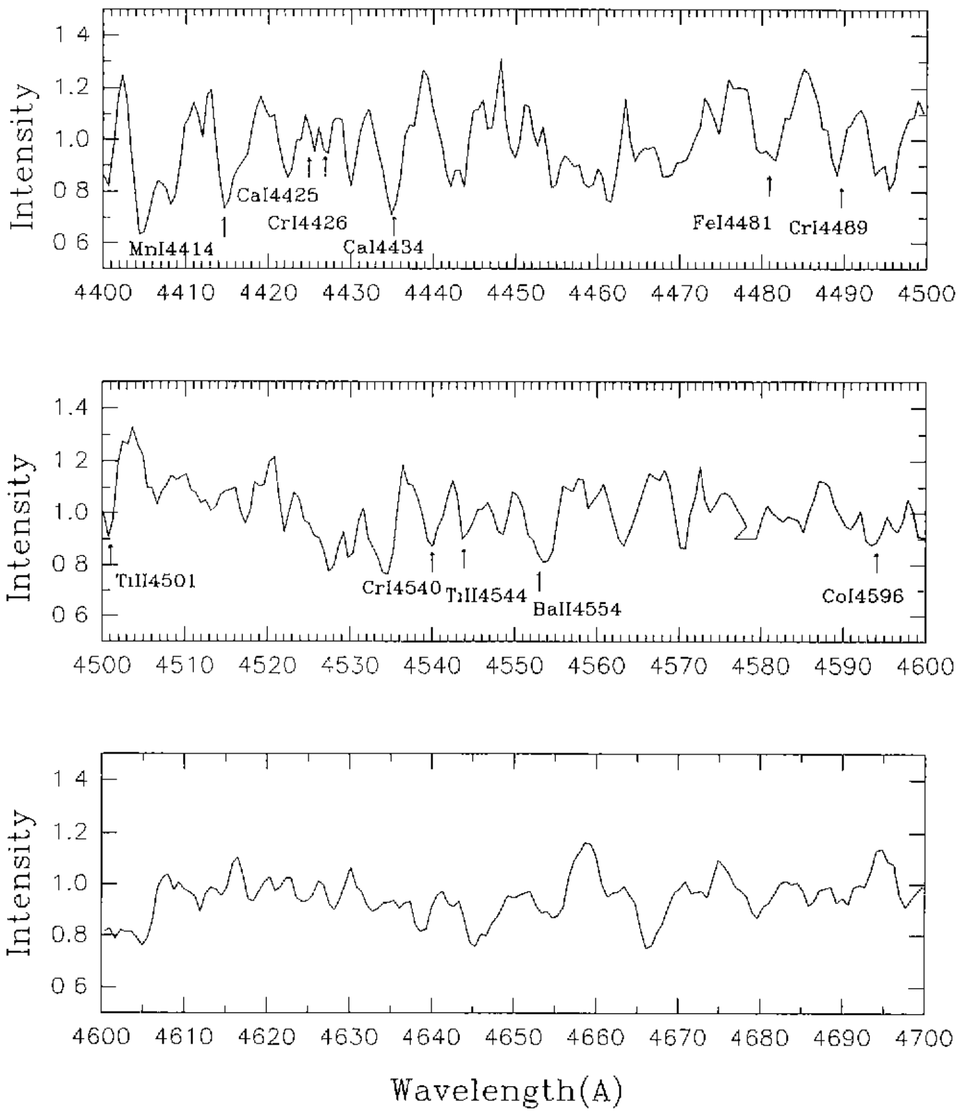

Fig 3c. Normalized intensity of 32 Cygni.

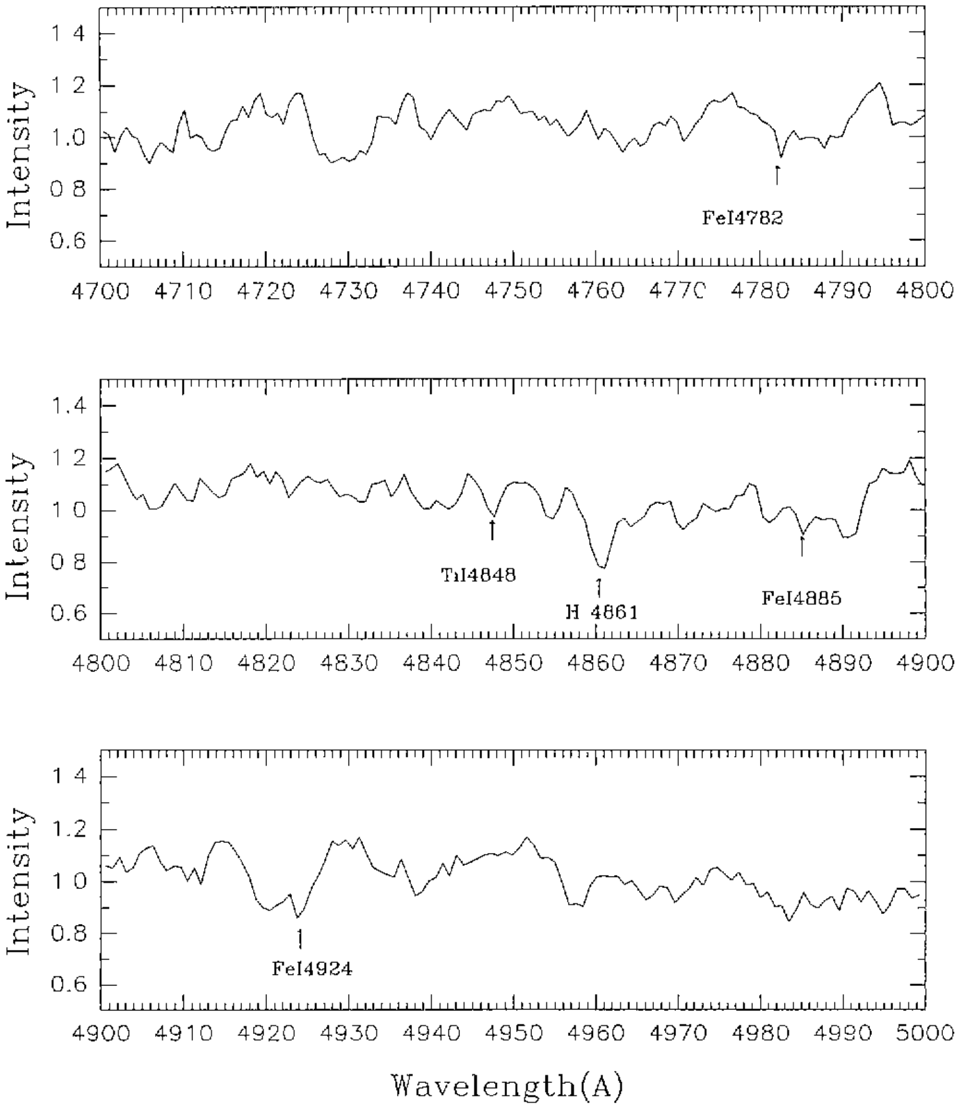

Fig 3d. Normalized intensity of 32 Cygni.

The observed phase is 0.6 which is the period of the out of eclipse. We fitted the calculated radial velocities to the radial velocity curve of the full phase as in Figure 5. The fitting is good within the error bar.

Table 2. Radial velocity calibration from some FeI lines.

Reference Å	Observation Å	Radial Velocity(km/sec)
3840.45	3839.97	-13.5
3843.71	3843.61	16.2
3845.17	3844.17	-54.0
3854.37	3854.14	6.1
3867.92	3867.01	-46.6
3872.51	3872.08	-9.3
3887.05	3886.68	-4.6
3888.42	3888.22	8.6
3891.93	3891.95	25.5
3897.45	3896.95	-14.5
3943.18	3942.64	-17.1
3945.12	3944.67	-10.2
3994.01	3993.35	-25.6
4018.27	4017.90	-3.6
4265.26	4264.71	-14.7
4279.49	4278.97	-12.5
4556.93	4556.61	2.9
4885.43	4885.42	23.4

3.2 Equivalent widths

From the less blended absorption lines we can estimate equivalent widths using the Gaussian fitting method. Table 3 listed these calculated values. First column is the identification of element, the second and third are the reference and observed wavelength. Calculated equivalent width was divided with the reference wavelength and are listed in column 4 as log scale. These values can be comparable with the solar values in column 5.

The typical characteristics of 32 Cygni can be made from this equivalent width calculation as

i) Ca II K line is very weak during this observing run, which is the common characteristic during the outside eclipse of the ζ Aurigae type eclipsing binary.

ii) Neutral metal lines like MnI, NiI, TiI, VI, CrI and CaI are very strong, which reflect that the primary star is the late type K-giant.

iii) Ionized metal lines like TiII, BaII, SiII and SrII are relatively strong and appeared as blended lines. This indicates that the primary K-type star is a normal supergiant.

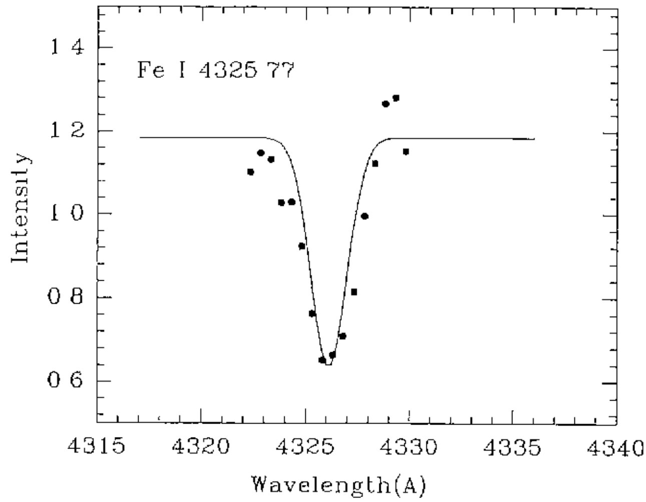

Fig 4. Gaussian fitting to a FeI absorption line.

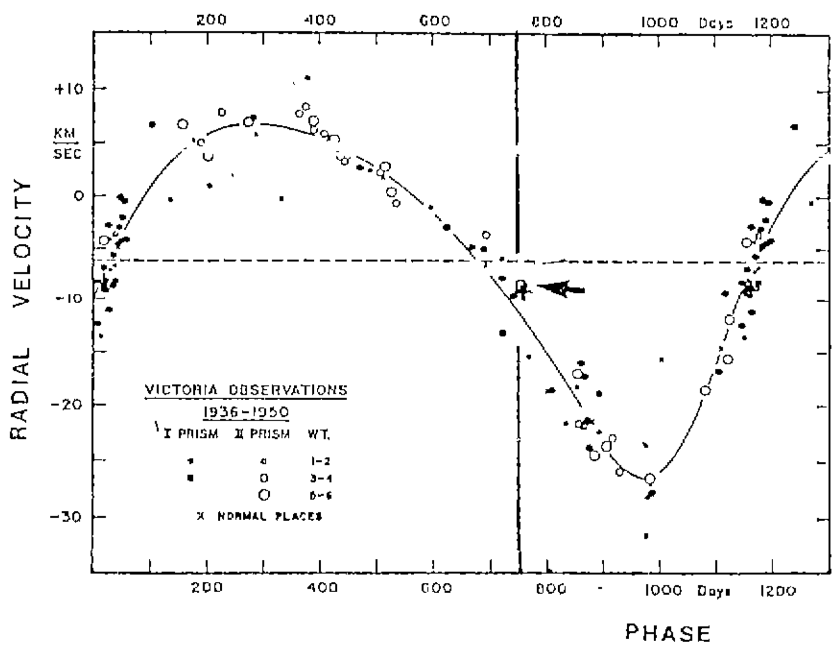

Fig 5. Fitting the calculated radial velocities (marked with arrows) to the radial velocity curve of the full phase.

Table 3. Calculated equivalent widths of some absorption lines.

	Reference Å	Observation Å	-log(W/λ)*	-log(W/λ) ⊙
Neutral metal lines				
CaI	4434.96	4434.35	3.65	4.41
CrI	3917.59	3917.38	4.99	5.23
CrI	4089.59	4089.58	4.54	6.13
CrI	4192.10	4191.50	3.11	5.28
FeI	3812.98	3812 62	4.67	4.07
	3849.97	3849.76	4.50	3.80
	9859.92	3859.86	5.19	3.40
	3927.92	3927.67	4.15	4.32
	3937.33	3937.14	5.86	5.02
	4007.27	4007.24	4.24	4.67
	4091.55	4091.60	4.50	4.83
	4143.87	4143.42	4.20	3.95
	4180.40	4180.64	4.62	4.96
	4187.81	4187.33	4.33	4.27
	4325.77	4325.72	3.59	3.59
	4429.20	4429.40	4.05	5.47
	4821.60	4822.08	4.20	6.08
MgI	3829.36	3829.20	4.72	3.64
MnI	3926.45	3926.24	4.81	5.06
	4031.79	4031.83	4.51	4.63
	4034.49	4034.40	4.37	4.28
NiI	3946.20	3946.53	4.56	6.20
	3993.95	3993.75	4.95	4.81
TiI	4052.94	4053.08	5.17	5.10
	4394.85	4394.32	3.47	4.94
	4547.85	4547.67	4.34	4.79
	4781.72	4781.66	4.19	5.50
VI	3912.20	3912.08	5.42	5.42
	4570.38	4569.89	3.87	6.36
Ionized metal lines				
SrII	4077.72	4077.46	3.87	3.98
TiII	4330.24	4330.40	4.00	5.06
Molecular lines				
CH	4210.96	4210.97	4.11	4.62
CH	4254.84	4254.83	3.75	5.55
CH	4296.21	4296.62	6.30	5.09
CH	4303.08	4303.03	4.92	5.13
CH	4375.20	4374.35	3.59	4.90
CH	3866.24	3866 26	4.16	5.27
CH	3871.39	3870.58	4.40	3.70

4. CONCLUSION

Medium dispersion spectra were used to get the radial velocity and equivalent widths of 32 Cygni. Gaussian fitting method was applied to calculate these parameters. The estimated mean radial velocity was -9.3 ± 4.8 km/sec at the phase of 0.67, which value is the well fitted one to the radial velocity curve.

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