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Search for rapid *V/R* variability in η Cen

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Summary. In order to search for rapid V/R variability in the Be star, η Cen, a series of Hα profiles of this star were observed on three nights between 1986 May 28 and June 3. A method of estimating the standard deviation value (σ) of V/R ratio measurements is described. From the results of the Hα profiles it was found that few profiles displayed rapid V/R variations which were beyond the 3σ limit, with no rapid variations of equivalent widths and peak separations of the two emission components. It was also found that rapid V/R and radial velocity variations of the Hα profiles were in close agreement. Low-amplitude night-to-night variations of the V/R ratio were also present in η Cen during the interval of our observations.

1 Introduction

One of the most important features of the emission line variability is the variation of V/R, the ratio of the violet to the red emission peaks. Variability of the V/R ratio on a time-scale of years and months is well known (see Doazan 1982 and references therein). Night-to-night V/R variations of low amplitude have been reported for several Be stars (Dachs *et al.* 1981, 1986). Also, rapid profile variations on a time-scale of hours and minutes were claimed by different authors (for references see Ghosh *et al.* 1988). However, there are many authors who have reported negative results regarding rapid variability of emission lines of Be stars (Chalabaev & Maillard 1983; Fontaine, Lacombe & Wesemael 1983). Thus the reality of this variability on a time-scale of hours and minutes has been a subject of much debate. In this connection it is important to mention that the detection of rapid variations in an individual star depends on the detection limit of the detector, i.e. spectral resolution, time resolution, signal-to-noise ratio (S/N) and the state of variability of the Be star – because a Be star exhibits different amplitude variations at different epochs. In order to search for such rapid variability, we observed the Be star η Cen, on three nights in 1986 and the results are presented in this paper.

2 Observations and analysis

Spectrograms in the Hα region were obtained on three nights between 1986 May 28 and June 3 with Carl-Zeiss UAGS using a grating of 651 lines mm^{-1} and a 170-mm camera, at the Cassegrain focus of the 102-cm reflector of Vainu Bappu Observatory, India. All the spectrograms were obtained on Kodak III-aF emulsion with a reciprocal dispersion of 82 Å mm^{-1} and they were digitized using a PDS-1010 M microdensitometer, at a speed of 2 mm s^{-1}, using a spacing interval of 5 μm. The transformation to intensities was done with the help of calibration plates (which were developed along with the stellar spectrograms) obtained by using an auxiliary calibration spectrograph. Reductions of all the spectrograms were carried out using the RESPECT software package (Prabhu, Anupma & Giridhar 1987). Smoothing by low-pass filter (cut-off frequency ~8 cycles mm^{-1}) and conversion of density to intensity scale were done interactively using RESPECT. While converting from density to intensity of the stellar spectrum, special care was taken to check each observed Hα profile and it was found that all the studied Hα profiles were well within the linear part of the photometric calibration curve. We normalized the stellar spectra by dividing by a spline fit to manually selected continuum points.

Wavelength conversions of the stellar spectra were carried out by fitting a third order polynomial to the measured positions of about 20 to 30 laboratory comparison lines (Fe + Ar or Fe + Ne hollow cathode source) per spectrogram. With this dispersion curve we rebinned the stellar spectra in equidistant wavelength steps. In order to measure the radial velocities of the Hα profiles it is very important to locate the line-centre of the profiles. However, it is difficult to find the line-centres of emission lines of Be stars, because they are generally double peaked and asymmetric. For our present study, the line-centres of the observed Hα profiles were obtained by Gaussian profile fitting and measuring the centroid wavelength of the fitted profile. Total measuring error of the line-centres of the Hα profiles is estimated to be around 12 km s^{-1}.

Equivalent widths of the emission components of Hα profiles [$W(\alpha)$] of η Cen can be measured by following the method of Andrillat & Fehrenbach (1982), which defines a different pseudo-continuum (located at the minimum of the emission core) for each profile. But this method may introduce some errors for rapid variability study. Therefore we measured the $W(\alpha)$ values of the emission lines which lie above the adjacent stellar continuum only.

3 Error estimation

To determine the reality of rapid variations of the V/R ratio, we have to detect the observational error in V/R measurements for our program star. The error estimation cannot be made from another star(s), because this error depends on the shape, strength and fine structure of the emission line, as well as on the noise and photometric calibration of each spectrum. So, the error on V/R must be estimated from the program star. In order to estimate this error we performed the following procedure.

The standard deviation value of the intensity of the violet emission component (in units of mean continuum intensity) of an unsmoothed normalized Hα profile was measured from the scattered intensity values around the mean intensity value of the violet component of that

Table 1. Average values of different parameters of Hα profiles. For explanation of abbreviations used in the table, see Sections 2 and 3.

Date of obser-vation (1986)	No. of profiles observed	$\Delta\lambda$ (Å)	$W(\alpha)$ (Å)	S/N	ΔV_{peak} (Å)	V/R	$\sigma(V/R)$	$\sigma_T\{W(\alpha)\}$ (Å)
May 28	15	29	5.47	55	7.85	1.04	0.048	0.63
June 02	7	28	6.59	58	7.87	0.88	0.047	0.63
June 03	4	30	7.13	52	7.92	0.98	0.051	0.68

profile [$\sigma(V)$ – the uncertainty in measuring the intensity value of the V-component of a single Hα profile]. Similarly, we measured the $\sigma(1/R)$ value of the same profile, where R is the mean intensity of the red emission component. Then, the value of $\sigma(V/R)$ of each Hα profile was obtained from the $\sigma(V)$ and $\sigma(1/R)$ values [$\sigma(V/R)=\{\sigma(V)\ \sigma(1/R)\}^{1/2}$].

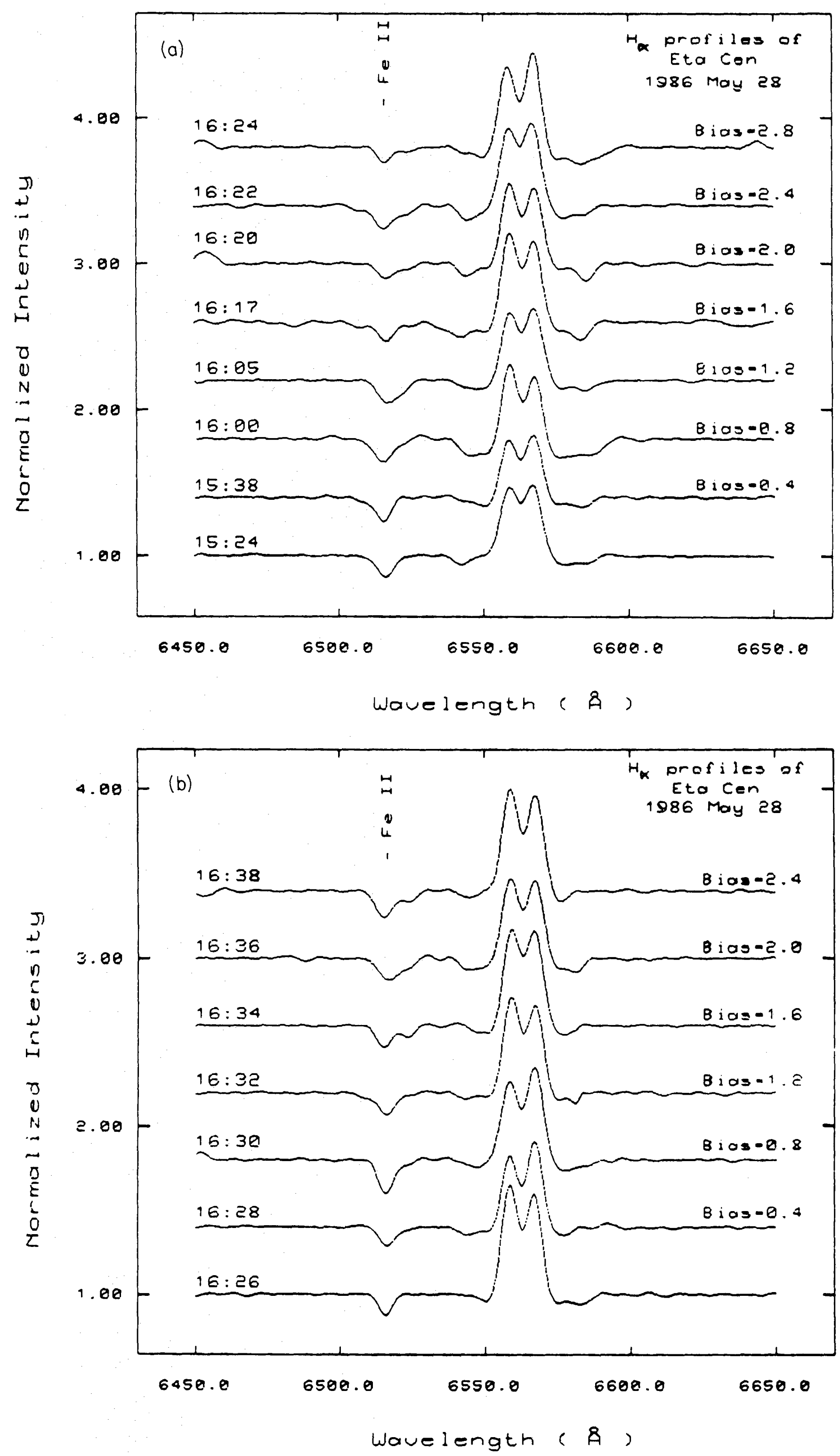

Figure 1. Observed Hα profiles of η Cen for different observing dates. UT of observations are shown to the left and the bias values to the right. Plate defects are marked by X.

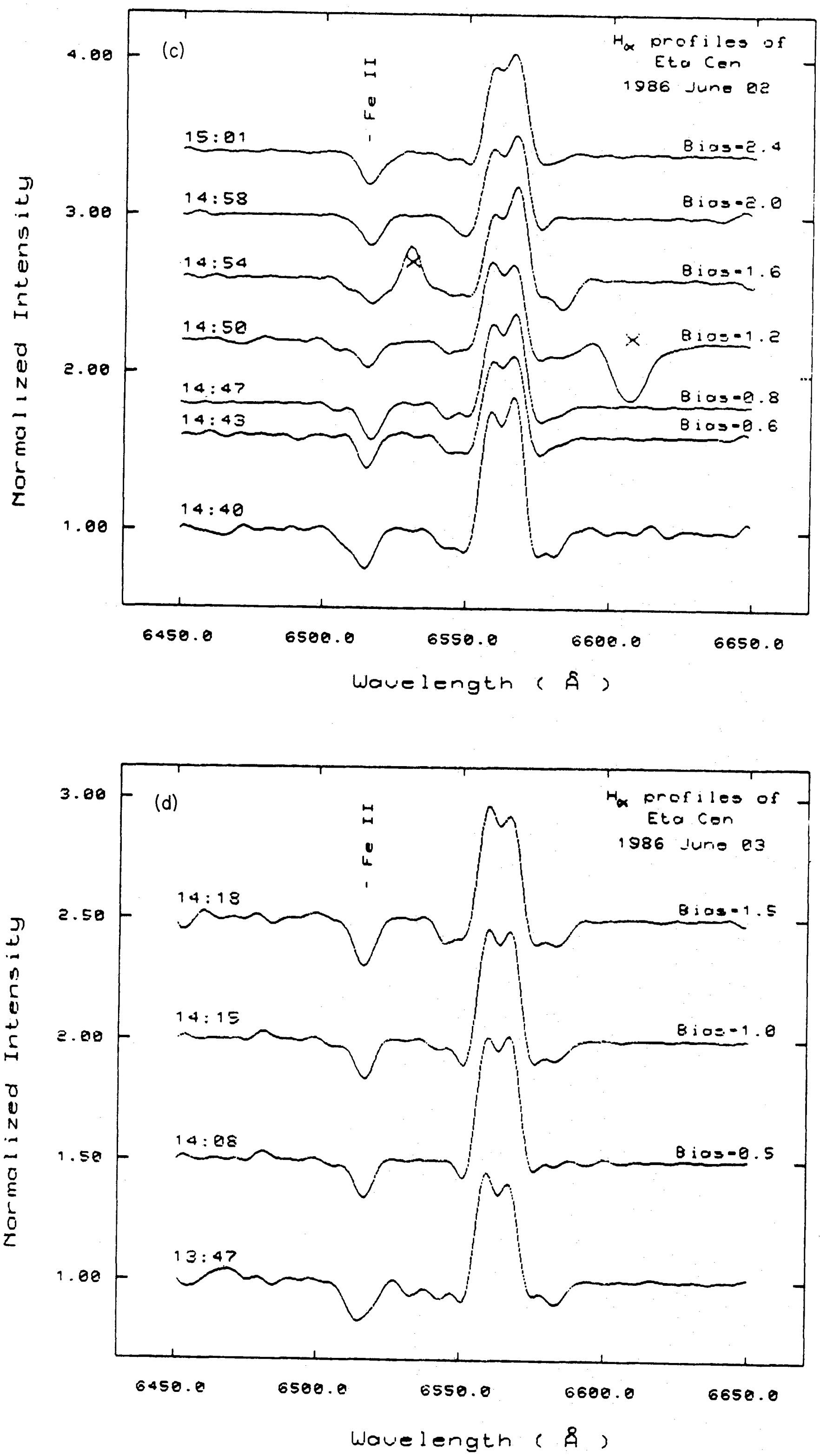

Figure 1 – *continued*

The average of all the $\sigma(V/R)$ values of the Hα profiles for one night provides us with the nightly mean value of $\sigma(V/R)$ and these values are shown in Table 1 for different nights.

Chalabaev & Maillard (1983) have shown that the value of the standard deviation (σ_T) of the equivalent width of the Hα profile depends on the value of $W(\alpha)$. Thus we cannot determine the observational errors in $W(\alpha)$ measurements for the program star (which may be a variable star) from the measured $W(\alpha)$ values of the standard star or any other stable shell star (for detailed discussion see Ghosh 1988). But this error can be estimatd from the σ_T values. Using the theoretical expression of Chalabaev & Maillard (1983) for σ(EW) (expression A10 of their paper) we have obtained the estimated σ_T [$W(\alpha)$] values for η Cen.

Total observational errors in V/R and $W(\alpha)$ measurements may be fixed as ± 3 $\sigma(V/R)$ and ± 3 σ_T [$W(\alpha)$], respectively (canonical values).

4 Results and discussion

η Cen is an interesting Be-shell star showing emission lines centrally divided by shell absorption core. This star entered into a new shell phase in early 1983 (Baade 1983). Our observed Hα profiles of η Cen consist of two emission components at the centre of the broad stellar absorption line and they are presented in Fig. 1(a)–(d). Mean Hα profiles of May 28 (from 15 profiles), June 2 (from seven profiles) and June 3 (from four profiles) are shown in Fig. 2. Table 1 presents the average values of different parameters of Hα profiles of η Cen. Measured values of violet and red emission intensities (in units of mean continuum intensity), the V/R ratio and its variations [in units of $\sigma(V/R)$, with respect to the nightly mean value of V/R], peak separation (ΔV_{peak}), $W(\alpha)$ and its variations [in units of σ_T $\{W(\alpha)\}$, with respect to the nightly mean

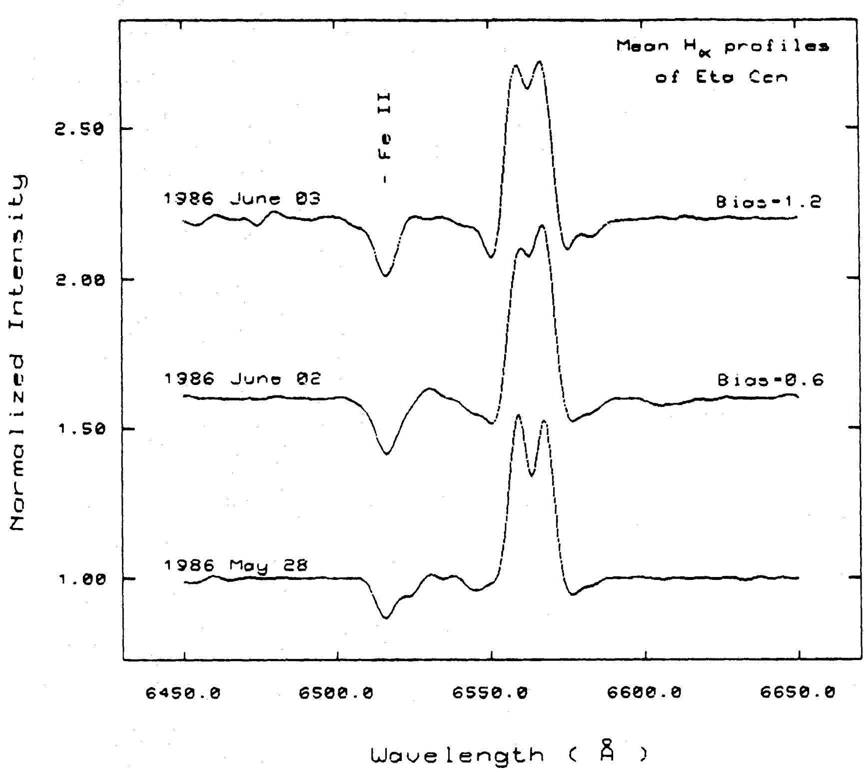

Figure 2. Nightly mean Hα profiles of η Cen.

value of $W(\alpha)$] and the corresponding radial velocities of the Hα profiles are listed in Table 2. In addition to the above observations, the following details are worth mentioning:

(i) Observed variations, in units of $\sigma(V/R)$, of V/R ratios of Hα profiles with respect to their nightly mean values are shown in Fig. 3. It can be seen from this figure and from Table 2 that few profiles displayed rapid changes of V/R which were beyond the observational error limit [$\pm 3\ \sigma(V/R)$].

(ii) Nightly mean values of ΔV_{peak} are given in Table 1. Comparison of the data for this star from Tables 1 and 2 shows that the rapid variations of ΔV_{peak} were absent during the interval of our observations.

(iii) No rapid variations of $W(\alpha)$ were observed in η Cen between 1986 May 28 and June 3 (Table 2 and Fig. 4).

Table 2. Observed parameters of Hα profiles of η Cen. For an explanation of the abbreviations used in the table, see Sections 2 and 3.

UT	V	R	V/R	Variations of V/R in units of $\sigma(V/R)$	ΔV_{peak} (Å)	$W(\alpha)$ (Å)	Variations of $W(\alpha)$ in units of $\sigma_T(W(\alpha))$	Radial Velocity (km/s)
1986 May 28								
15:24	1.47	1.49	0.96	−1.67	7.81	5.37	−0.16	−4.26
15:38	1.39	1.42	0.93	−2.29	7.86	5.94	0.75	−5.34
16:00	1.51	1.42	1.21	3.54	7.94	5.22	−0.40	19.43
16:05	1.47	1.49	0.96	−1.67	7.80	5.34	−0.21	7.61
16:17	1.61	1.54	1.13	1.87	7.82	5.31	0.25	7.14
16:20	1.54	1.52	1.04	0.00	7.88	5.42	−0.08	3.61
16:22	1.52	1.56	0.93	−2.29	7.79	5.81	0.54	−5.25
16:24	1.55	1.64	0.86	−3.75	7.87	5.77	0.48	−16.77
16:26	1.64	1.59	1.08	0.83	7.80	5.19	−0.44	−11.31
16:28	1.42	1.51	0.82	−4.58	7.86	5.22	−0.40	−18.29
16:30	1.46	1.55	0.84	−4.17	7.81	5.95	0.76	−21.64
16:32	1.56	1.51	1.10	1.25	7.88	5.34	−0.21	9.33
16:34	1.57	1.56	1.02	−0.42	7.83	5.27	−0.32	7.14
16:36	1.47	1.46	1.02	−0.42	7.89	5.79	0.51	7.25
16:38	1.60	1.56	1.07	0.62	7.84	5.16	−0.49	8.61
1986 June 02								
14:40	1.75	1.85	0.88	0.00	7.96	7.23	1.02	−19.31
14:43	1.47	1.51	0.92	0.82	7.91	6.44	−0.24	−12.04
14:47	1.51	1.57	0.89	0.20	7.80	6.31	−0.44	−21.67
14:50	1.50	1.49	1.02	2.86	7.87	6.07	−0.82	−16.15
14:54	1.41	1.59	0.69	−3.96	7.85	6.72	0.21	−22.59
14:58	1.42	1.52	0.81	−1.43	7.79	6.48	−0.16	−11.42
15:01	1.55	1.63	0.87	−0.21	7.91	6.85	0.41	−20.24
1986 June 03								
13:47	1.46	1.41	1.12	2.74	7.94	7.34	0.31	5.74
14:08	1.52	1.52	1.00	0.39	7.88	7.27	0.21	6.37
14:15	1.45	1.44	1.02	0.78	7.98	7.04	−0.13	7.81
14:18	1.45	1.40	1.12	2.74	7.89	6.87	−0.41	9.25

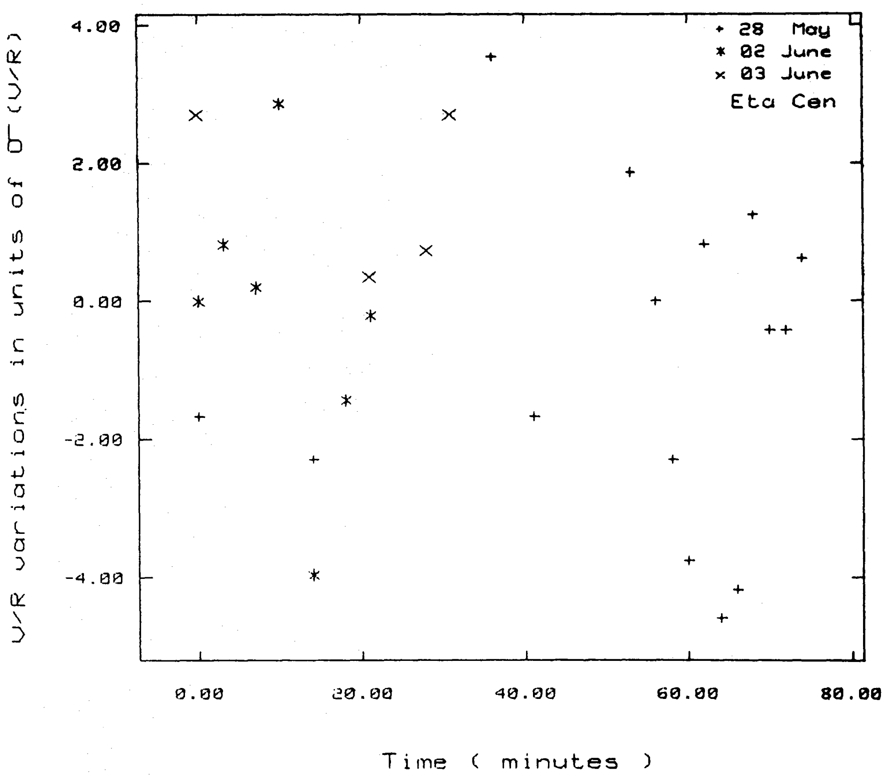

Figure 3. Plot of V/R variations, in units of $\sigma(V/R)$, with respect to their nightly mean value. X-axis represents the elapsed time in minutes from the time of first observation.

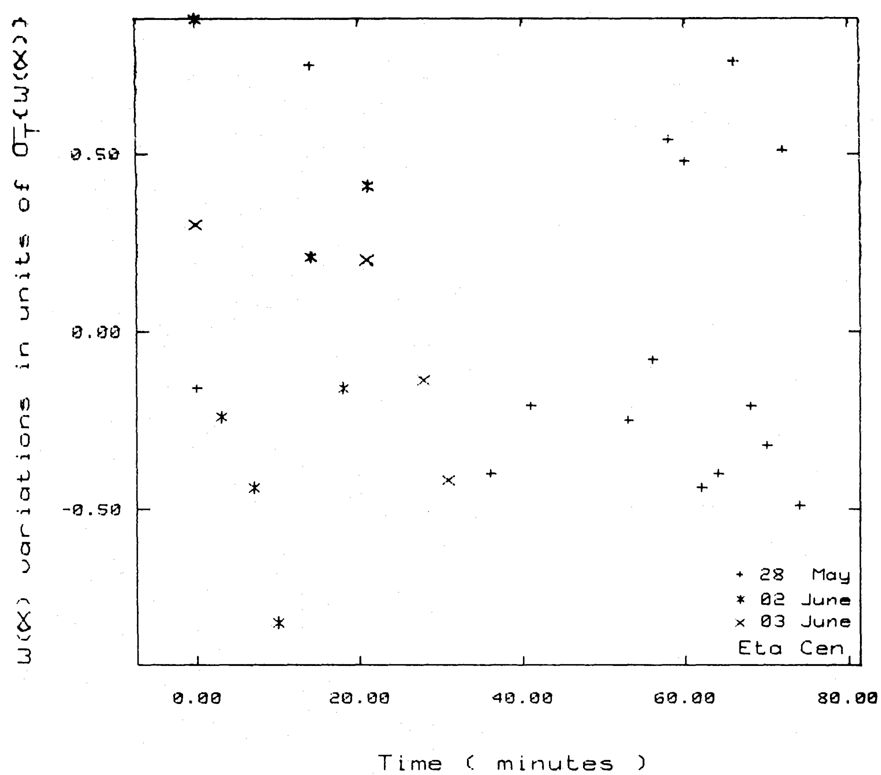

Figure 4. Observed variations of $W(\alpha)$, in units of $\sigma_T\{W(\alpha)\}$, with respect to the nightly mean value of $W(\alpha)$. X-axis is the same as in Fig. 3.

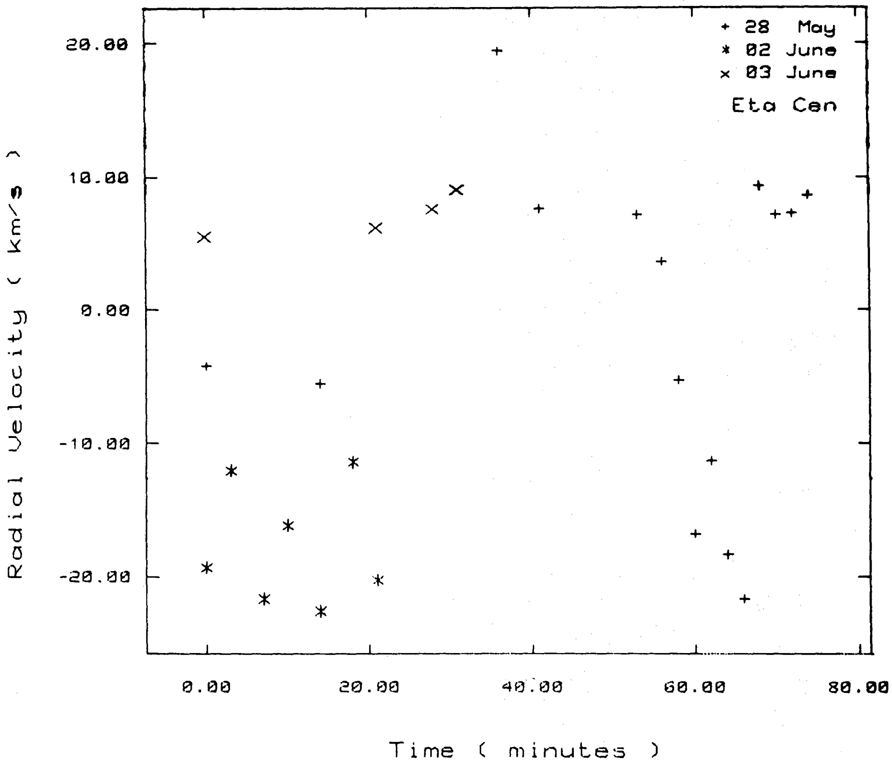

Figure 5. Plot of radial velocities of Hα versus time. Time axis is the same as in Fig. 3.

(iv) Observed radial velocities of Hα profiles are shown in Fig. 5, and this, together with Table 2, shows that rapid and irregular radial plasma motions (beyond the limit of total measuring error) were present in the envelope of η Cen during the time of our observations.

(v) Fig. 2 shows the nightly mean profiles of Hα. This figure and Table 1 suggest that night-to-night variation of V/R between 1988 May 28 and June 2 was beyond 3 $\sigma(V/R)$, whilst that between June 2 and 3 was within the 3 σ limit (Table 1).

It is well known that varying line profiles must yield variable radial velocities of their line-centres or wings or both, and that whichever one is higher shows the more pronounced variations. From the results of our observations we also found that rapid variations of V/R of Hα profiles of η Cen were in close agreement with the radial velocity changes of those profiles (see Table 2). This suggests that the observed variations may be due to the material circulation in the envelope of η Cen, as was already suggested by Dachs *et al.* (1986) for their observed variations in certain other Be stars. Low-amplitude night-to-night variations of V/R of η Cen, which we observed during the interval of our observations, were also detected by Dachs *et al.* (1986) (see fig. 37 of their paper) and they suggested that such variations are possibly due to the rotational motion of an inhomogeneous envelope containing bright line-emitting condensations.

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