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Search for rapid spectral variability in Be stars: α Columbae, p Carinae and η Centauri

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Abstract. — A series of Hα profiles (in total 1006 spectra in the Hα region) with the time resolution around 45 s were obtained on six nights between 1988 January 29 and February 07 to search for rapid spectral variability in the Be stars – α Col, p Car and η Cen. We could not detect any rapid variations of F_c and $W(\alpha)$ in α Col and ρ Car, but such variations of F_c were present in η Cen on the night of February 02 and absent on other nights. Also it was found that F_c and L_{6563} of η Cen slowly increased from 1988 January 29 and reached to a maximum (by a factor of 1.29 at continuum and a factor of 1.30 at 6563 Å) on 1988 February 02 with a subsequent gradual decay, without affecting the equivalent width of Hα. Changes of F_c and L_{6563} were in close concert which may be attributable to the mass loss episode of η Cen.

Key words : Be stars — emission line profiles — rapid variability.

1. Introduction

Emission line variability of Be stars on the time scales of hours, minutes or less has been a subject of vivid debates for years. On the basis of results obtained so far, it cannot be ruled out that some Be stars occasionally show such a variability (for detailed references see Ghosh *et al.*, 1988). In order to have more conclusive data, it is essential to have high time resolution, high signal-to-noise ratio and long base-line observations at different epochs of the stars. Also, careful data analysis is equally important for rapid variability studies. In order to search for rapid spectral variability in Be stars, α Col (HR 1956), p Car (HR 4140) and η Cen (HR 5440) were monitored in the range of Hα on six nights. In total 1006 profiles of the Hα line of those stars were recorded with high time resolution (45 sec) and a good signal-to-noise ratio (93–152 at continuum around Hα).

2. Observations and data analysis.

The series of Hα emission profiles of the program stars (Tab. I) were obtained on six nights between 1988 January 29 and February 07, with a rapid scanning grating spectrometer attached to the 102 cm Cassegrain reflector of Vainu Bappu Observatory, Kavalur, India. Four standard stars (at different hour angles) and sky background plus dark counts were also observed (in the Hα region) on each night using the same instrument. This provided the values of the atmospheric extinction coefficients. It was found that the variations of these coefficients were negligible within a night.

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Details of the scanner instrument were described by Bappu (1977). Actual operating mode and performance of this instrument for the study of Hα emission line variability were described in details in a previous paper (Ghosh, 1988). Width of the exit slot of the scanner instrument corresponds to 3 Å (nominal resolution). Forward scans were recorded over a wavelength range of 180 Å centered on Hα. The signal-to-noise ratio at continuum (S/N) around Hα usually averages about 93 to 152 (Tab. I). Wavelength dependence of the instrumental sensitivity was obtained from the standard stars. Instrumental and extinction corrections were applied to the observed values to obtain instrumental and extinction free counts. Each observed Hα profile was normalized by a linear continuum fit to fifteen continuum points which were obtained from three continuum regions around 6485, 6500 and 6610 Å. Parameters of the linear fit were used to compute the continuum counts at 6563 Å (F_c) and the standard deviation of the linear fit was used as the statistical uncertainty of F_c measurements [$\sigma'(F_c)$]. Average of all the F_c values of a star obtained during the night provides the nightly mean value, $\bar{F}_c$, of that star. Nightly mean value of the standard deviation of F_c, $\sigma(F_c)$, was computed using the following relation :

$$\sigma(F_c) = \left[\sum_{i=1}^{N} \{\sigma_i'(F_c)\}^2 / N \right]^{1/2} \quad \dots (1)$$

where N is the total number of Hα profiles observed for that particular star in a night. Computed $\sigma(F_c)$ values of the program stars are presented in table I. An estimate was made to find out the uncertainly in F_c measurements implied by the measured variations of the atmospheric extinction and it was found that the continuum level variations were within less than one sigma limit.

Standard deviation of all F_c $[\sigma_1(F_c)]$ of a star measured during the night was computed and compared with that obtained from the linear fit. From the comparison it was found that the values of $\sigma_1(F_c)$ were slightly larger than $\sigma(F_c)$ for α Col and p Car and were much larger for η Cen, especially on the night of 02 February. The differences between the two standard deviations $[\sigma_1(F_c)$ and $\sigma(F_c)]$ may be due to the variations of transparency, response stability, guiding errors, etc. or stellar variability. Contribution due to atmospheric and instrumental variations in F_c measurements can be estimated from the standard stars and it was found from the results of the observed standard stars that F_c variations were within two sigma limit. Therefore, by caution, the total observational error limit in F_c measurement for our program stars was fixed as $\pm\, 5\, \sigma\, (F_c)$.

Measurement of $W(\alpha)$ of two program stars (α Col and η Cen whose emission components were embeded in absorption lines) were made following the method of Andrillat and Fehrenbach (1982) (see Fig. 1 of their paper) which defines a pseudo-continuum located at the minimum of the emission core. Expected values of the standard deviation of equivalent widths of Hα, $\sigma_T\{W(\alpha)\}$, cannot be estimated from the standard stars [for detail discussion see Chalabaev and Maillard (1983)] but can be calculated using the theoretical expression for σ_T of Chalabaev and Maillard (1983) (expression (A10) of their paper). However, in their calculation they have considered only the photon statistics error. Therefore, we shall follow the method of Lacy (1977) who has considered both photon statistics and scintillation errors. Using equation (3) of Lacy's paper we have computed the $\sigma_T\{W(\alpha)\}$ values of each Hα profile and the nightly mean value of $\sigma_T\{W(\alpha)\}$ of the individual stars was computed using a similar type of relation given in equation (1) and they are presented in table I. By caution, the total observational error limit in $W(\alpha)$ measurements for the program stars was fixed as $\pm\, 5\, \sigma_T\, \overline{\{W(\alpha)\}}$ respectively.

TABLE I. — *Observed nightly mean values of different parameters of Hα profiles of the program stars. N, number of Hα profiles observed on each night. For explanation of abbreviations used in the table see sections 2 and 3.*

Star	Epoch (1988)	N	Mid UT	$\bar{F}_c^*$	$\sigma(F_c^*)$	$\bar{F}_{6563}^*$	$\overline{W(\alpha)}$ (Å)	S/N	$\sigma_T\{\overline{W(\alpha)}\}$ (Å)
Col	Jan 30	5	16:57	2793	24	3130	5.67	116	± 0.43
HR 1956	Jan 31	135	16:22	2806	25	3189	5.58	112	± 0.45
	Feb 02	55	17:14	2801	24	3120	5.55	117	± 0.45
	Feb 03	82	16:48	2857	25	3214	5.74	114	± 0.45
p Car	Jan 31	151	21:19	1449	15	2657	18.69	96	± 0.93
HR 4140	Feb 02	34	20:49	1483	16	2788	18.65	93	± 0.92
	Feb 03	147	21:33	1425	15	2601	18.16	95	± 0.94
	Feb 03	47	20:40	1466	15	2758	19.06	98	± 0.97
Cen	Jan 29	43	23:40	3051	26	3513	7.65	117	± 0.54
HR 5440	Jan 31	104	23:26	3530	26	4037	7.59	136	± 0.52
	Feb 02	138	22:51	3946	26	4562	7.91	152	± 0.56
	Feb 07	56	22:48	3088	23	3567	7.52	134	± 0.53

* All the values have been scaled down by dividing by 10.

3. Results and discussion.

3.1 α COLUMBAE. — The Hα profiles of α Col have shown almost constant emission strength between 1974 and 1983 (Dachs *et al.*, 1986 and Refs. therein) and during this interval the Hα line was in pure emission. But our observed Hα profiles of this star which were obtained between 1988 January 30 and February 07 (in total we obtained 277 spectra in the Hα region), display an emission component embedded on a broad photospheric absorption (Fig. 1). Due to the poor resolution (3 Å) of our scanner instrument we are unable to study the profile variations. Only one Hα profile of each star is shown in figure 1.

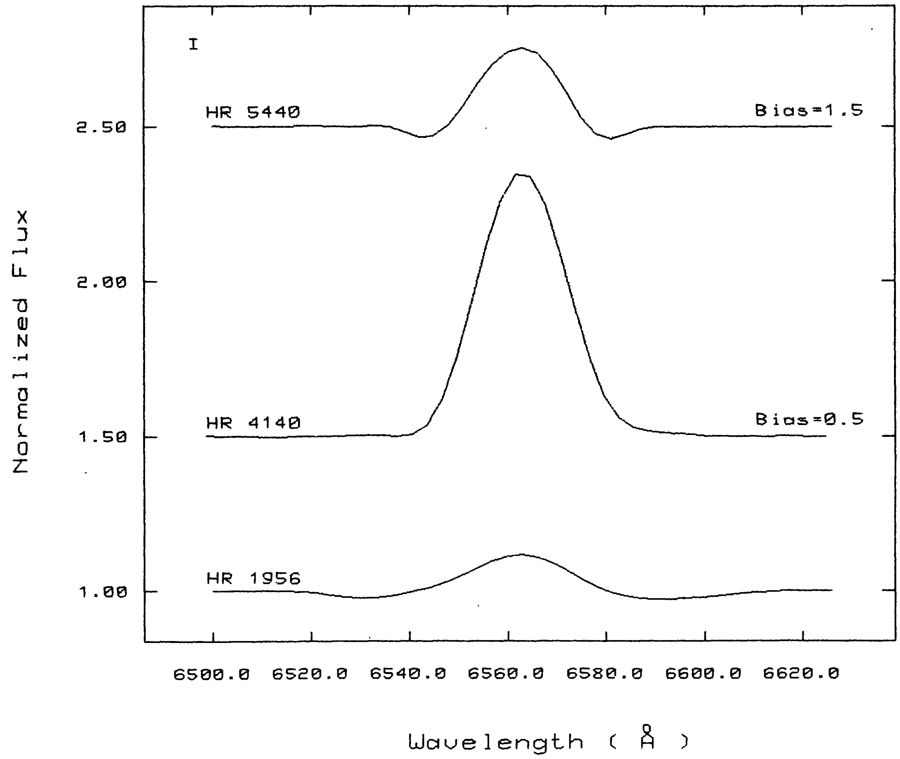

FIGURE 1. — Observed Hα profiles of the program stars. Name of the stars are shown to the left and the bias values to the right. The vertical bar in the top left corner indicates the one sigma value of the local continuum.

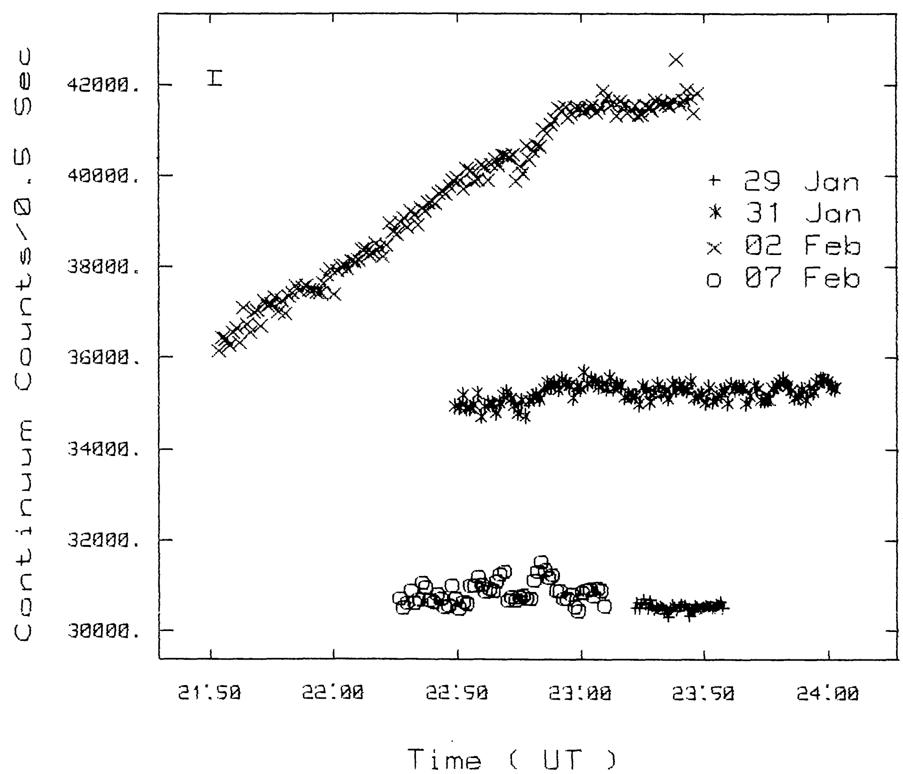

FIGURE 2. — Continuum counts / 0.5 sec *versus* time [in U.T.]. Different symbols used in the figure are for different observing dates. One sigma value of the continuum counts measurements is shown by the top left vertical bar.

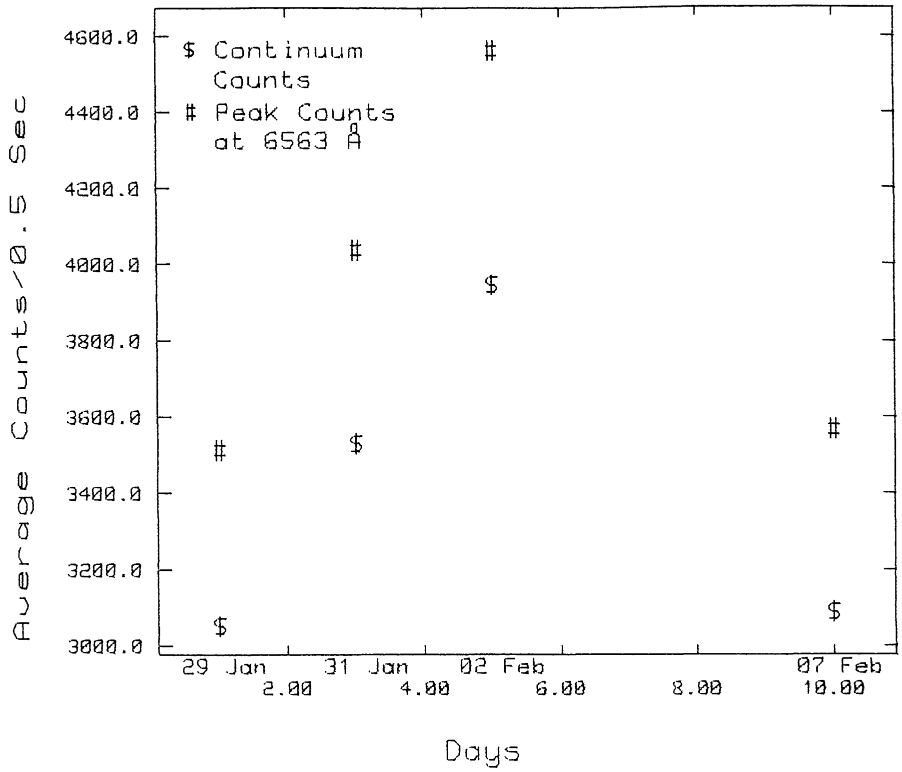

FIGURE 3. — Plot showing the average counts of continuum and peak emission at 6563 Å of different nights. X-axis represents the elapsed days from the day of first observation (1988, January 29).

Table I presents the nightly mean values of F_c, $\sigma(F_c)$, peak emission counts at 6563 Å (F_{6563}), S/N, $W(\alpha)$, and $\sigma_T\{W(\alpha)\}$ of the program stars. Observed rapid and night-to-night variations of F_c and $W(\alpha)$ of α Col with respect to their nightly mean values, were within the observational error limit. But this star displayed rapid Hβ profile variations in 1976 (Bijaoui and Doazan, 1979). Possible explanation for such contradictory results is that the rapid variations in the spectra of Be stars may be present only during isolated short periods of activity (Chalabaev and Maillard, 1983).

3.2 p CARINAE. — Results of p Car are presented in table I and the Hα profile of this star is shown in figure 1. Comparison with the results of Dachs *et al.* (1986) shows that a decrease of $W(\alpha)$ values occurred since 1983. The star has already displayed this type of variations between 1970 and 1977 (Dachs *et al.*, 1986, see Fig. 57d of their paper). Rapid and nightly variations of F_c and $W(\alpha)$ were absent in p Car, at least between 1988 January 31 and February 07.

3.3 η CENTAURI. — This is a Be-shell star (Baade, 1983); and the variability of Balmer lines of this star has been discussed in details by Dachs *et al.* (1986). The star was observed on four nights between 1988 Jan 29 and Feb 07. In total 341 Hα profiles were obtained. The Hα line of η Cen shows an emission component embedded on a broad photospheric absorption (Fig. 1). Observed values of F_c are plotted in figure 2.

It can be seen from table I that the average continuum counts of η Cen on 1988 Jan 29 and Feb 07 were 3058 and 3101 respectively, whereas this value increased to 3521 on January 31 and reached maximum (3959) on February 02 (Fig. 3). As is evident from table I and figure 3, the L_{6563} appear to change in close concert with F_c. On February 02, the flux of η Cen increased by a factor of 1.29 at continuum and by a factor of 1.30 at 6563 Å with respect to January 29, and then decreased by same factors by February 07.

In addition to the above described results of our observations, the following details are worth mentioning:

1) Most spectacular changes of F_c were observed on the night of February 02 during the interval of our observations. On this night the starting F_c value was around 36000 (per scan per 0.5 sec) and at the end of our observations this value reached to 42000 (per scan per 0.5 sec)(Fig. 2).
2) Close inspection of figure 2 suggests that the rapid variations of F_c on the time scales of hours which were beyond the limit of $\pm$ 5 $\sigma(F_c)$, were present in η Cen only on February 02 and on other nights they were within $\pm$ 5 $\sigma(F_c)$.
3) From the plots of $W(\alpha)$ variations (figures are not presented here) it was found that the rapid variations of $W(\alpha)$ of all the four nights were very much within $\pm$ 5 $\sigma_T\{W(\alpha)\}$.

Hourly variations of F_c which were observed February 02, may be due to the density inhomogeneity in its envelope and this density inhomogeneity may be the effect of mass loss episode of the star which we shall discuss below.

From optical continuum linear polarimetry and optical continuum (6585 Å) and Hα line photometry of w Orionis, Hayes and Guinan (1984) have found that the changes in continuum flux and Hα emission flux were in close concert (see Fig. 2 of their paper). They attributed this observed phonomena as due to the transient mass loss episode of w Orionis. Our observations also show the same type of phenomena in η Cen. Perusal of figure 3 indicates the changes of continuum flux and line flux at 6563 Å. Simultaneous increase in F_c and L_{6563} suggests that the free-free, bound-free (for continuum emission) and bound-bound (for line emission) emission increased in η Cen during the interval of our observations. One of the possibilities for this emission enhancement may be the addition of extra mass which may be provided by the star itself due to mass loss mechanisms, into the envelope of η Cen as was suggested by Hayes and Guinan (1984) for w Orionis. On the basis of present observations (since we could not observe this star in every night before and after February 02) it is very difficult to estimate the time scale of this emission episode, but it can be clearly seen from figure 3 that the temporal profile (both continuum and line emission at 6563 Å) of the event is triangular with a short rise time and a gradual subsequent decay.

The main results of this study may be summarised as follows. α Col and p Car did not display any variations of F_c and $W(\alpha)$ during the interval of our observations. The high correlation of continuum and line (6563 Å) flux changes [without changes of $W(\alpha)$] is attributable to the mass loss episode of η Cen. Hourly variations of F_c were observed in this star only on February 02 which may be due to the density inhomogeneity in the envelope of the star caused by the mass loss episode.

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