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SEARCH FOR RAPID SPECTRAL VARIABILITY IN Psi^9 AURIGAE

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ABSTRACT

In order to search for rapid spectral (both continuum and total emission strength) variability in Be stars, we observed ψ^9 Aur on five nights between 1988 January 29 and February 3, and a series of Hα profiles (in total 253 spectra in the Hα region) were obtained for this star with a time resolution around 45 s. A method has been described to find out the standard deviation in continuum counts (F_c) measurements. The estimated value of the standard deviation of measured equivalent widths of Hα profiles ($W(\alpha)$) was calculated using the theoretical expression of Chalabaev and Maillard (1983). From the results of our observations we find that the rapid variations (on time scales of around a few minutes) of F_c and $W(\alpha)$ were absent (within a 3-σ limit) in our program star during the interval of our observations. But we have detected a few hourly variations of F_c (beyond the 3-σ limit) which are not due to the random noise in a long series of observations. Also, night-to-night variations of F_c of ψ^9 Aur were observed on two nights.

Key words: stellar atmospheres–Be stars

1. Introduction

Variability of Be stars with time scales of years, months, and days is well known in the astronomical community (Doazan 1982; Slettebak 1988 and references therein). However, regarding rapid variability on the time scales of hours, minutes, or less has been a subject of spirited debate for years. On the basis of the results obtained so far, regarding the rapid emission-line variability (profile as well as total emission strength) of Be stars, it can be summarized that certain stars have shown such variability in their spectra (Slettebak and Snow 1978; Bijaoui and Doazan 1979; Ghosh *et al.* 1988 and references therein) and others did not display such variations (Lacy 1977; Chalabaev and Maillard 1983; Fontaine, Lacombe, and Wesemael 1983). Therefore, in the present situation it is very important to collect more observations on Be stars at different epochs of those stars with high time resolution and high signal-to-noise ratio, to resolve the lively debates on the rapid emission-line variability of Be stars. Also, it has been suggested by Chalabaev and Maillard (1983) that the search for rapid continuum level variability of these stars, if it can be detected, will be very interesting in understanding the Be phenomena.

In order to search for such variability in Be stars, ψ^9 Aurigae (HR 2568; HD 50658: $V_{mag} = 5.87$; B8 IIIe) was observed on five nights between 1988 January 29 and February 3. Hubert (1973) observed this Be-shell star (ψ^9 Aur) regularly between 1953 and 1970, and from his observations it was found that this star displayed envelope emission variability on a time scale of about 16 years. High resolution and high signal-to-noise ratio Hα profiles of this star were also obtained by Andrillat and Fehrenbach (1982) between March and December 1980. During the interval of their observations, Hα profiles (two emission components separated by a central absorption core) have shown V/R variability (V/R values were between 0.85 and 1.30) with almost constant emission strength ($W(\alpha) = 7.06$ Å). Therefore, the study of rapid variability of continuum level and equivalent widths of Hα profiles of this star will be interesting. Results of such a study are presented in this paper. The observational details are given in Section 2 and the data analysis and error estimation are discussed in Section 3. Finally, in Section 4 we present the results and discussion.

2. Observations

Photoelectric scans of the Hα emission profiles of ψ^9 Aur were obtained on five nights between 1988 January 29 and February 3 with a rapid scanning grating spectrometer attached to the 102-cm Cassegrain focus of Vainu Bappu Observatory, Kavalur, India. Different spectrophotometric standard stars and sky background plus dark counts were also scanned in the Hα region using the same instrument (sky background plus dark counts were obtained to be subtracted from the results of the Hα scans). Technical details of the grating spectrometer have been described by Bappu (1977). Actual operating mode and performance of this spectrometer which was used for the study of rapid emission-line variability have been described in detail in previous publications (Ghosh *et al.* 1988; Ghosh 1988). Nominal bandwidth of the instrument is 3 Å. Scans of the Hα profiles were obtained over a wavelength range of 180 Å centered at 6563 Å. The signal-to-noise ratio (S/N) at the continuum around Hα usually averages about 71 to 78 (Table 1). Instrumental and extinction corrections which were obtained from the standard stars were applied to the observed values to obtain instrumental and extinction-free counts.

3. Data Analysis and Error Estimation

Each observed Hα profile (instrumental and extinction free) was normalized at (6500 ± 6) Å and (6610 ± 6) Å. Thus, we obtained two profiles for each observed profile, and the average of these two profiles gives us the final normalized Hα profile.

Mean continuum counts (F_c) for each profile were obtained from the average of the two continuum counts, F'_c and F''_c, at (6500 ± 6) Å and (6610 ± 6) Å, respectively: $F_c = [(F'_c + F''_c)/2]$. An average of all the F_c values obtained on a particular night provides us the nightly mean value of F_c ($\bar{F}_c$) of ψ^9 Aur. Similarly, the standard deviation value of F_c of each Hα profile [$\sigma(F_c)$] was obtained from the average of the two standard deviation values of continuum counts at (6500 ± 6) Å [$\sigma(F'_c)$] and (6610 ± 6) Å: [$\sigma(F''_c)$] [$\sigma(F_c)$] = [$\sigma(F'_c) + \sigma(F''_c)$]/2. The nightly mean value of $\sigma(F_c)$ [$\sigma(\bar{F}_c)$] was obtained from the average of all the $\sigma(F_c)$ values of a night.

Equivalent widths of Hα profiles [$W(\alpha)$] of ψ^9 Aur were measured following the method of Andrillat and Fehrenbach (1982) (see their Fig. 1). An estimated value of the standard deviation of $W(\alpha)$, ($\sigma_T[W(\alpha)]$), may be calculated using the theoretical expression for σ_T of Chalabaev and Maillard (1983) (expression (A10) of their paper). Before using their theoretical expression we have to find out its adaptability with our instrumental system. In order to do that we measured the equivalent widths of Hα profiles of different standard stars which were observed using the same scanner instrument and obtained the standard deviation value of $W(\alpha)$, {$\sigma[W(\alpha)]$}. Also, we calculated the estimated values of the standard deviation of

$$W(\alpha)\,\{\sigma_T\,[W(\alpha)]\}$$

for those standard stars using the theoretical expression for σ_T of Chalabaev and Maillard (1983). From the comparison of σ [$W(\alpha)$] and σ_T [$W(\alpha)$] values, which are almost equal, of the standard stars we find that the above-mentioned theoretical expression can be adapted for our instrumental system. So, we calculated the σ_T [$W(\alpha)$] values for each Hα profile of our program star using that theoretical expression of Chalabaev and Maillard (1983) and from the average of all these values we obtained the nightly mean value of σ_T [$W(\alpha)$].

Data analysis of all observed Hα profiles of ψ^9 Aur was performed on the VAX-11/780 computer of Vainu Bappu Observatory, using the spectrophotometric package developed by A. V. Raveendran. All the figures presented in this paper were plotted using the RESPECT software package (Prabhu, Anupama, and Giridhar 1987).

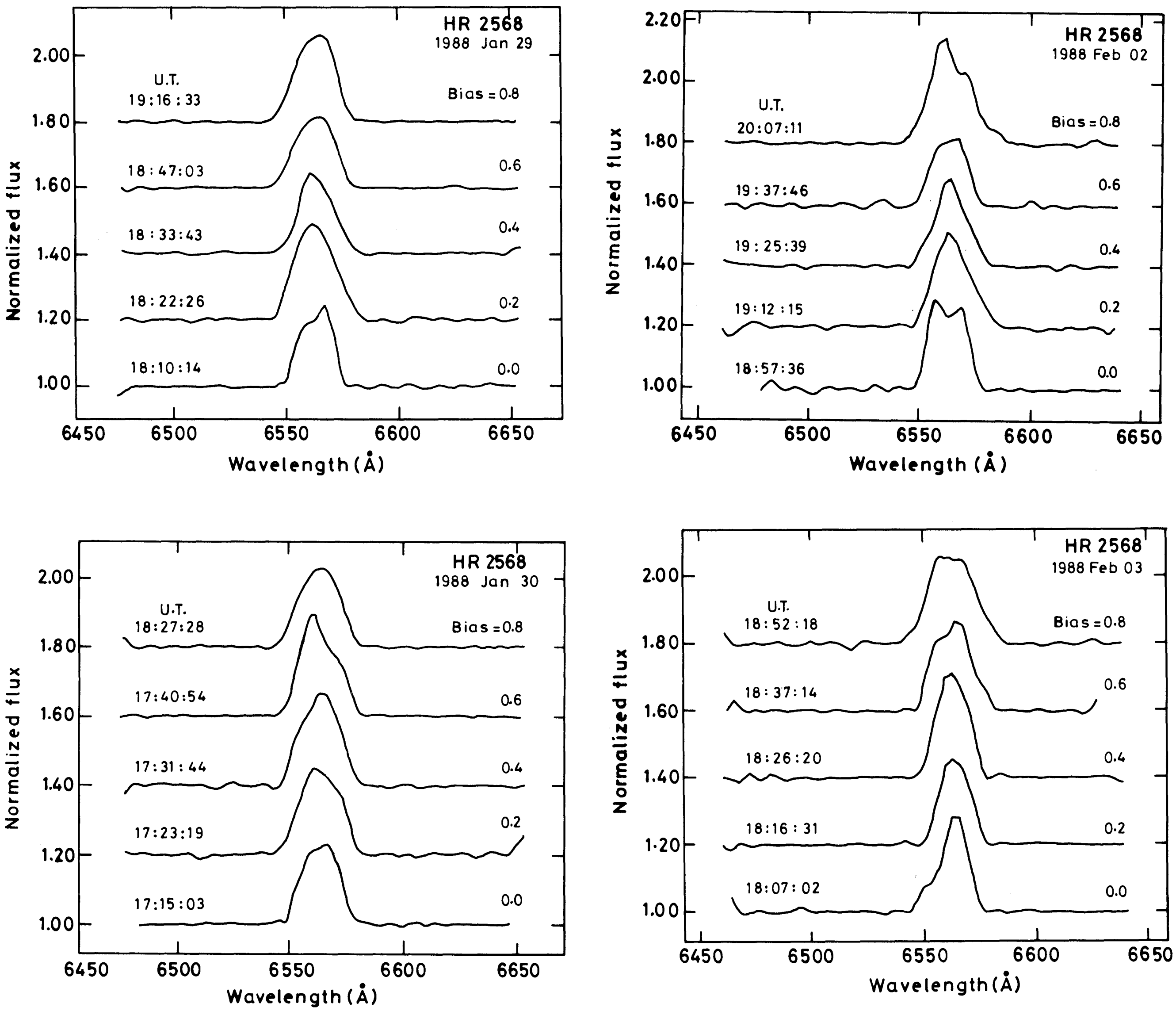
(F_c) and $W(\alpha)$ variations of the standard stars were within the 2-σ limit. Therefore, to be on the safe side, the total observational error in (F_c) and $W(\alpha)$ measurements of ψ^9 Aur may be fixed as ± 3 σ ($\bar{F}_c$) and ± 3 σ_T [$W(\alpha)$], respectively.

4. Results and Discussion

In total we obtained 253 Hα profiles of ψ^9 Aur on five nights between 1988 January 29 and February 3, and five Hα profiles of each night are presented in Figure 1a–e. Due to the poor resolution (3 Å) of our scanner instrument, we could not resolve the emission components of Hα (if emission components are present there in Hα). In Table 1 we present the nightly mean values of F_c, $\sigma(F_c)$, $W(\alpha)$, S/N, $\sigma_T[W(\alpha)]$, and the starting and end times of Hα scans. Comparison of data for this star in Table 1 with the results of Andrillat and Fehrenbach (1982) shows the decrease of average $W(\alpha)$ values which has occurred since 1980.

Close inspection of Table 1 shows that small changes of average F_c values occurred on the nights of January 30 and February 3 which were beyond ±3 $\sigma(\bar{F}_c)$ with respect to the other three nights. Variations of continuum counts of all the nights, in units of $\sigma(\bar{F}_c)$, with respect to their nightly mean values, are plotted in Figure 2 which shows that rapid variations (on time scales of minutes) of F_c for most of the profiles were within ±3 $\sigma(\bar{F}_c)$. But, there are a few variations of F_c which are beyond ±3 $\sigma(\bar{F}_c)$, and they are on the time scale of half an hour or so. These variations of F_c which are beyond the 3-σ limit may be by chance (random noise) in a long series of observations. Assuming a Gaussian distribution for the random noise, we computed the probability of F_c variations, in units of sigma, for our program star which was observed for a relatively longer time on 1988 January 31 and is shown in Figure 3. Perusal of this figure shows that the probability of those variations (due to the random noise) beyond the 3-σ limit is extremely low. Therefore, the observed variations of F_c are not by chance and they may be considered as intrinsic phenomena of the star. This fact suggests that hourly variations of F_c were present in ψ^9 Aur. Also, night-to-night variations of F_c were observed in this star (see Table 1).

Continuum emission (free-free and bound-free) emanates from the inner part of the envelope of Be stars (Hayes and Guinan 1984) and changes in free-free and bound-free transition rates may produce variability of continuum emission. Again, temperature and density variations of the inner part of the envelope may lead to changes of free-free and bound-free transition rates. But, looking at the models of Be stars (Poeckert and Marlborough 1978), it appears difficult to envisage how such



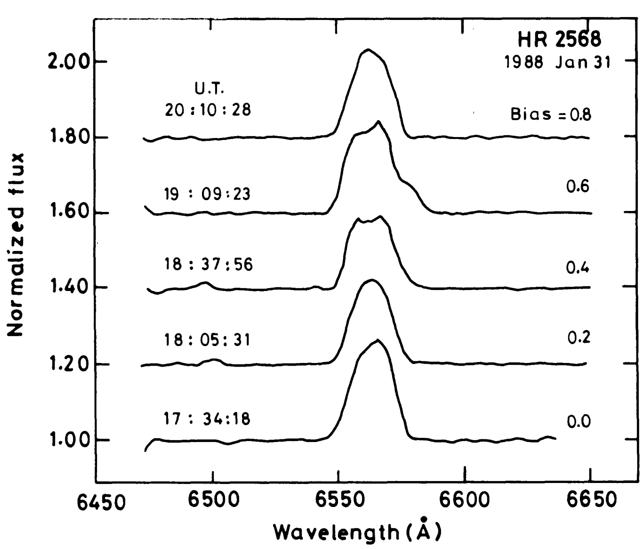


FIG. 1a–e–Observed Hα profiles of ψ^9 Aur. Observing date is given at the top. UTs of observations are shown to the left and the bias values are to the right.

hourly variations of temperature can occur in the envelope of those stars. Therefore, it is suggested that the observed hourly variations of F_c may be due to density variations in the inner part of the envelope of ψ^9 Aur. Again, those density variations may be caused by density inhomogeneities in the winds of the star. From Table 1 and Figure 4 it can be clearly seen that night-to-night and rapid variations of $W(\alpha)$ were absent in ψ^9 Aur during the interval of our observations.

On the basis of the obtained results it can be concluded that during the interval of our observations we could not detect any rapid variations of $W(\alpha)$, but the presence of hourly and night-to-night variations of F_c were present in ψ^9 Aur. Also, it may be suggested that rapid variations in the spectra of Be stars may be present only during isolated

TABLE 1

Average values of different parameters of Hα profiles of ψ^9 Aurigae[a]

Date (1988)	Observed profiles	Starting time (in UT)	Ending time (in UT)	$\bar{F}_c$	$\sigma(\bar{F}_c)$	W(α)	S/N	$\sigma_T\{W(\alpha)\}$ (Å)
Jan. 29	43	18:10:14	19:16:33	4405	62	5.00	71	± 0.46
Jan. 30	39	17:15:03	18:27:18	4593	59	4.58	78	± 0.41
Jan. 31	100	17:34:18	20:10:18	4379	58	4.67	76	± 0.42
Feb. 02	41	18:57:36	20:07:11	4371	61	4.69	72	± 0.42
Feb. 03	30	18:07:02	18:52:18	4731	61	4.91	78	± 0.41

[a]For explanation of abbreviations used in the table, see sections 2 and 3.

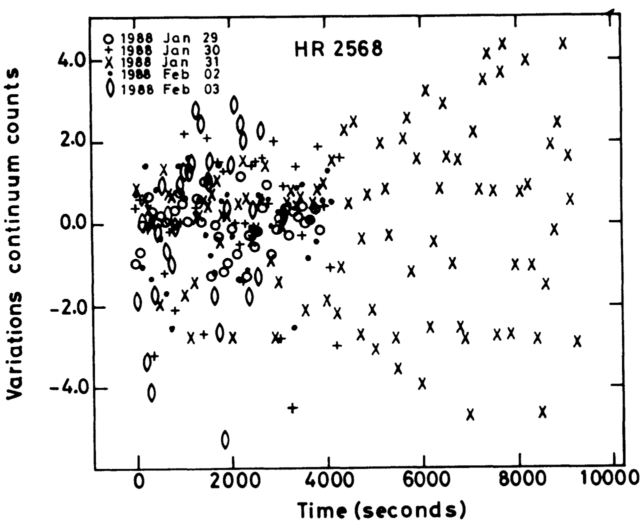


FIG. 2–Plots of variations of continuum counts (in units of $\sigma(\bar{F}_c)$) with time for different nights. The time axis represents the elapsed time in seconds from the starting time of observations.

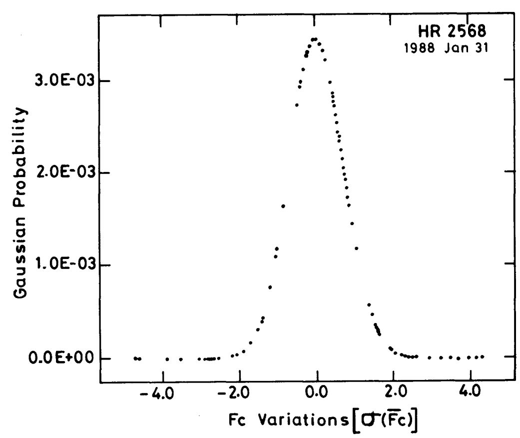


FIG. 3–The Gaussian probability distribution of F_c variations of ψ^9 Aur which were observed on 1988 January 31. The X axis represents the variations of F_c in units of $\sigma(\bar{F}_c)$.

short periods of activity such as was recently observed in one Be star—η Centauri (Ghosh *et al.* 1989).

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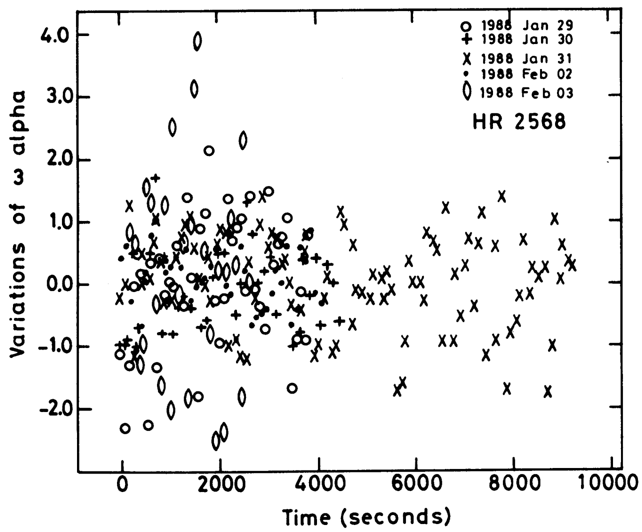

FIG. 4–Plots of $W(\alpha)$ variations (in units of σ_T $[W(\alpha)]$) versus time for different observing nights. The time axis is the same as in Figure 2.

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