FLARE-LIKE ACTIVITY IN Be STARS HR 7403 AND .8762

K. K. GHOSH

Indian Institute of Astrophysics, Vainu Bappu Observatory, Kavalur, Alangayam, N.A., T.N., India

(Received 22 December, 1988)

Abstract. Rapid spectrophotometric observations of two Be stars were carried out on several nights between November 1984 and December 1985. During the interval of our observations we could not detect any ultra-rapid variations in the spectra of the studied stars except a few flare-like events. The flare-like event of HR 7403 was recorded only at Hα and that for HR 8762 (*o* And) was observed (two events) from Hα photometric observations. Time-scales of these emission events were around few minutes and the total energy liberated by the events were of the order of 10^{34} to 10^{37} ergs.

1. Introduction

Variability in brightness, colour, and emission line profiles of Be stars on time-scales of years, months, and days is well known. A few Be stars have displayed episodic outbursts in their spectra (Peters, 1986; Baade *et al.*, 1988, and references quoted therein; Ghosh, 1988) and it was suggested that the outbursts may be due to the non-radial pulsations of those stars. Also, certain other Be stars have shown sudden changes in their spectra on time-scales of hours (Boyarchuk, 1958; Bakos, 1968; Page and Page, 1970; Slettebak and Snow, 1978; Bartolini *et al.*, 1983; Waelkens *et al.*, 1983) which looks like 'flare'. But not much of information is available in the literature about the flare-like events in Be stars. Therefore, studies of such events may be important to understand the cause(s) of the Be phenomenon. In this paper we present the results of sch flare-like events which were observed in two Be stars: HR 7403 and 8762 (*o* And).

2. Observations and Error Analysis

Photoelectric scans of the Hα profiles of HR 7403 were obtained using the rapid scanning grating spectrometer attached to the 102-cm reflector of the Vainu Bappu Observatory, India. Technical details of the grating spectrometer was described by Bappu (1977). Actual operating mode and performance of this instrument have been described in details in a previous publication (Ghosh *et al.*, 1988). Also four standard stars were scanned on each night which provided the nightly extinction values, the wavelength dependence of instrumental sensitivity and atmospheric variations. The sky background plus dark counts were measured immediately preceding and following the star scans and subtracted from the results of the scans.

o And was observed with one channel fast Hα photometer using an Hα filter of bandpass 10 Å centered at 6563 Å, with an automated photon counting system. Along with *o* And, different standard stars and sky background were also observed.

Astrophysics and Space Science **155**: 311–317, 1989.

Scanner and Hα photometric data reductions were done using the spectrophotometric package developed by A. V. Raveendram, to yield normalized flux (for detail analysis see Ghosh, 1988a) and extinction free-photoelectron counts of Hα, respectively.

Hα profiles of HR 7403 were obtained using the scanner instrument. All the Hα profiles were almost the same with maximum and minimum variations within $3\sigma_T$ (σ_T is the estimated standard deviation value of $W(\alpha)$ which was calculated using the theoretical expression of Chalabaev and Maillard, 1983, see expression A10 of their paper), except one Hα profile (central reversal) of 1 September, 1985 (17 : 16 : 03 UT) which displayed very strong emission strength. Since we have observed only one such profile so, immediately it appears that this may be due to some instrumental problem, e.g., temporary saturation of the photomultiplier tube (PMT). Such saturation of PMT may occur due to the limitations of the photon-counting system for a very bright source. But the observed peak counts of HR 7403 were much less than the limit of the photon-counting system. Also, immediately after our observations of the program star we scanned the mercury source (Hg) which was relatively brighter than the program star, using the same instrument and same set-up for about three hours and we could not detect any such central reversal phenomena. Therefore, considering the other details of the strong central reversal Hα profile (for details see the results of HR 7403 in Section 3) of HR 7403 (Be-shell star) it may be concluded that the observed phenomena is intrinsic to the star.

From the Hα photometric observations of different standard stars which were observed on seven nights along with *o* And, it was found that the maximum and minimum variations of the extinction free photoelectron counts with respect to their average counts were within $\pm 5\%$. *o* And has also shown almost the same percentage of variations on all the nights except for two occasions on the night of 13 September, 1985. On this night the average photoelectron counts (excluding the counts of the two occasions) of *o* And were almost the same with that of other nights and no appreciable amount of variations were observed for the standard stars and the sky background immediately before and after the two emission events of 13 September, 1985. Therefore, these two events may also be considered as real phenomena of *o* And.

3. Results

3.1. HR 7403

HR 7403 which is known to be a Be-shell star, was observed only on five nights between August and November 1985. This star has shown no rapid variations in $W(\alpha)$ during the period of our observations. But, it displayed a flare-like event which was observed on the night of 1 September. On this night we have obtained nine Hα profiles and four of them are shown in Figure 1 and the measured values of $W(\alpha)$ are given in Table I with σ_T values and Figure 2 shows the plot of $W(\alpha)$ values.

The mean value of $W(\alpha)$ obtained between August and November 1985 (excluding the Hα profiles of 1 September) is 18.11 Å for HR 7403. On the night of 1 September,

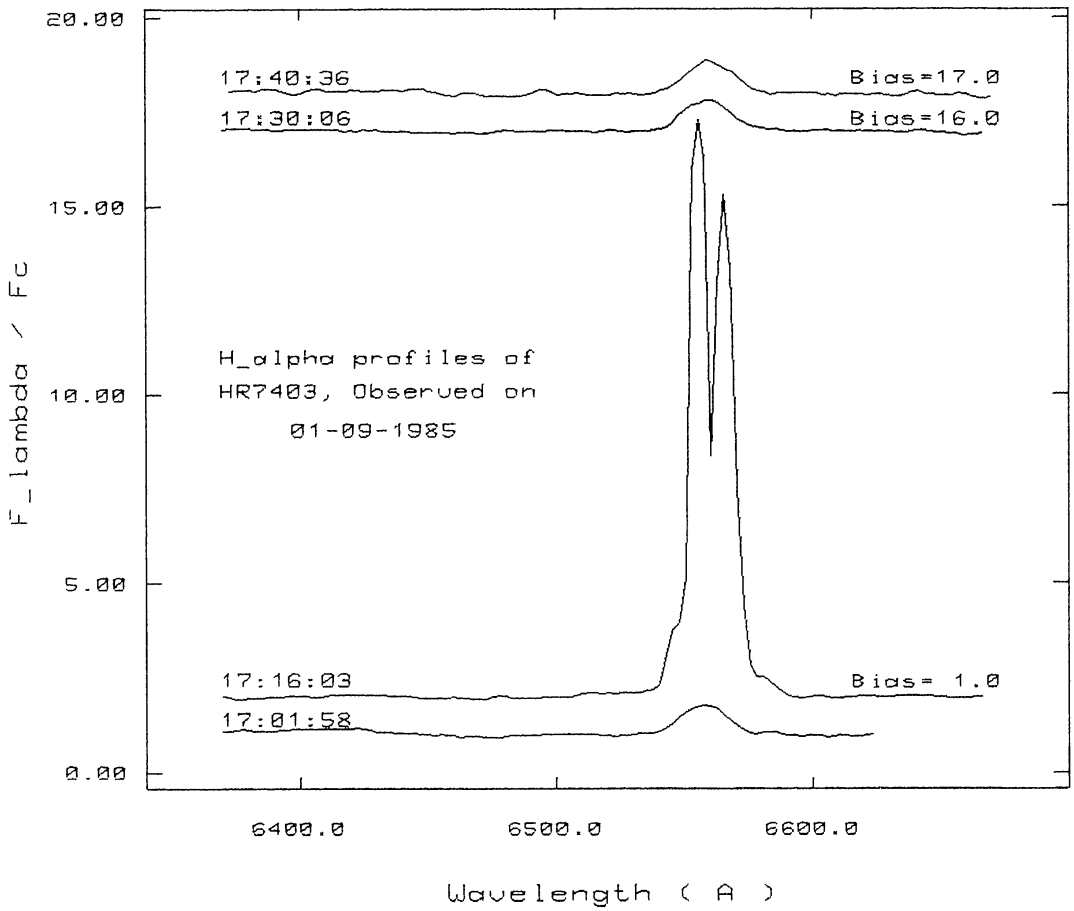

Fig. 1. Observed Hα line profiles of HR 7403.

all the Hα profiles show almost the same $W(\alpha)$ values except one profile (17 : 16 : 03 UT) which has shown a very strong emission strength. This rapid emission event (flare-like event) took place within 29 min. In addition to the above observations the following

TABLE I

Equivalent widths and estimated luminosities of Hα profiles for HR 7403. For explanations of abbreviations, see Sections 2 and 4.

UT (1 September, 1985)	$W(\alpha)$ (Å)	$L_*(\alpha)$ (ergs s^{-1})
16 : 02 : 44	17.94 ± 0.63	1.38 + 33[a]
16 : 17 : 05	18.09 ± 0.63	1.39 + 33
16 : 33 : 25	17.81 ± 0.63	1.37 + 33
16 : 49 : 33	18.27 ± 0.63	1.41 + 33
17 : 01 : 58	17.99 ± 0.63	1.39 + 33
17 : 16 : 03	274.77 ± 4.19 ± 0.63	2.12 + 34
17 : 30 : 06	17.13 ± 0.62	1.32 + 33
17 : 40 : 36	18.06 ± 0.63	1.39 + 33
17 : 56 : 15	18.40 ± 0.63	1.42 + 33

[a] $x + n$ means $x \times 10^n$.

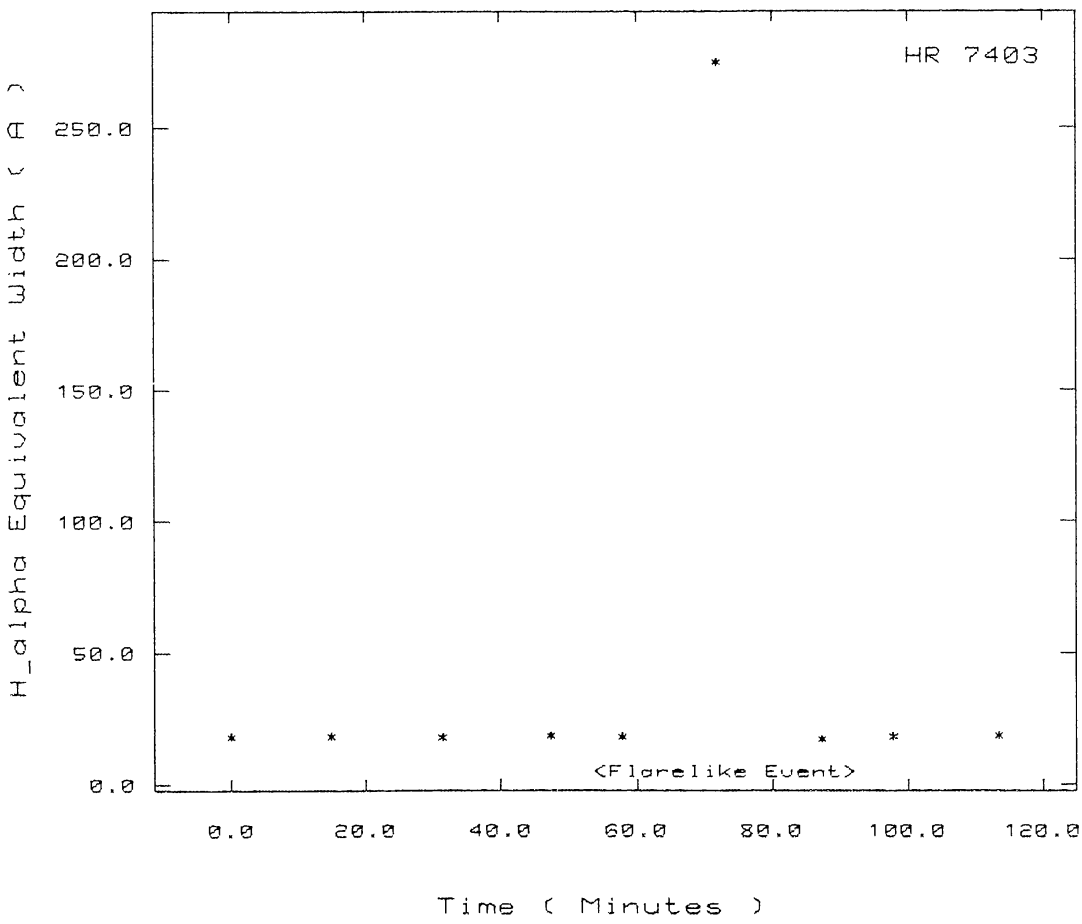

Fig. 2. Plot of $W(\alpha)$ of HR 7403 versus elapsed time in minutes from the time of first observation (UT of first observation is 16^h02^m).

important details are worth mentioning:

(1) During the time of Hα episode the continuum level increased by a factor of 3.

(2) Before and after the episode all the profiles show single-emission peak (even if two emission components would have been there, we were not able to resolve that because of the poor resolution (3 Å) of our scanner instrument), but during the episode the Hα profiles shows two emission components with 10 Å peak separation.

(3) V/R ratio of the Hα profile is greater than one (1.15) during the episode.

(4) Before the episode, the full width at zero intensity (FWZI) of the Hα profiles were around 40 Å and that during the episode increased to 83 Å which decreased (FWZI = 49 Å, 43 Å, ...) very fast after the episode.

(5) After the episode, the continuum emission flux decreased slowly; but the line emission flux decreased very fast.

3.2. HR 8762 (*o* And)

o And is a well-studied object which is having a long history of spectrum variations. It was observed on 7 nights between November 1984 and December 1985. Here we shall

present the results of observations which were obtained on 13 September, 1985 using the Hα photometer. The integration time was 1 s and the duration of the total scan was around 3 hours. During the interval of our observations two flare-like events were observed and they are shown in Figure 3. Average photoelectron counts during the whole scan were 18 000 ± 600 except for two occasions (17 : 01 : 35 and 17 : 35 : 00 UT) when the peak counts increased to 22 400 and 28 900, respectively. Duration of the first event was only 1 min and that for the second one was around 5 min (see Figure 3).

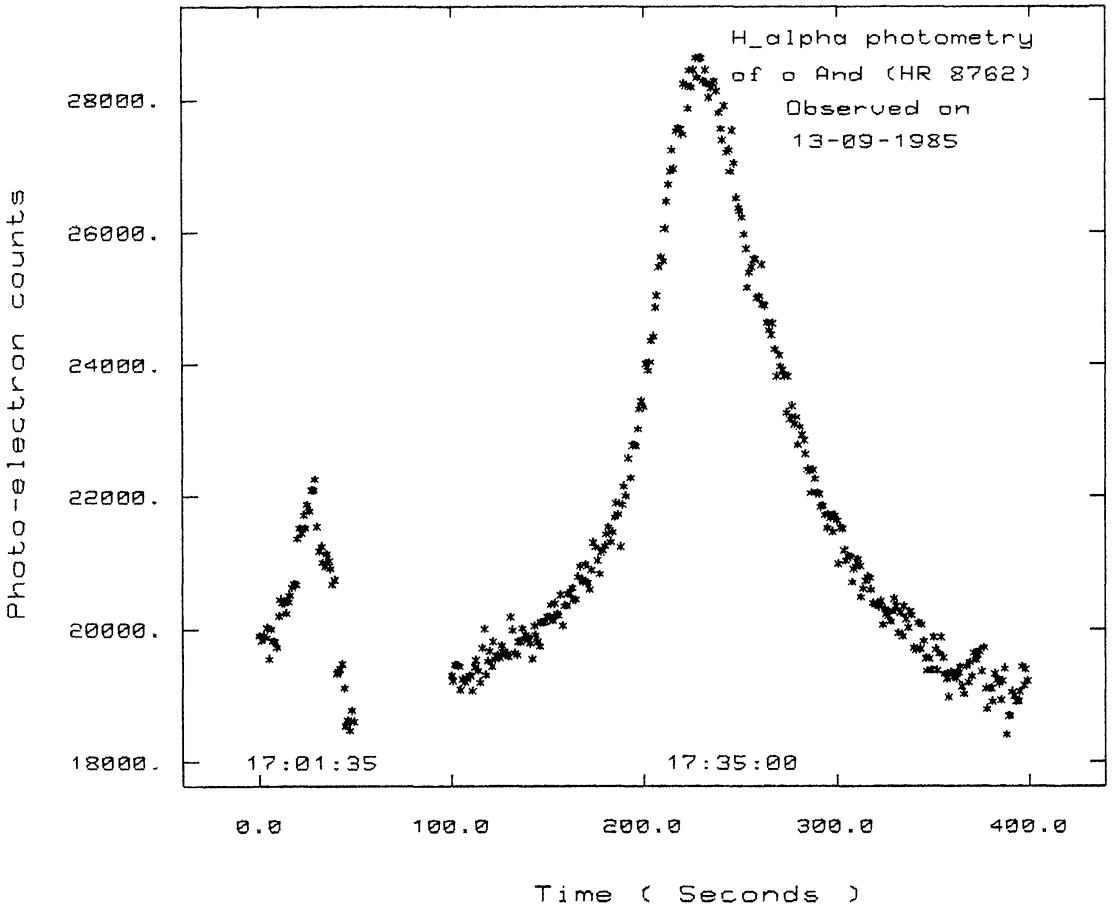

Fig. 3. Plot of Hα photometry of *o* And as a function of time during the flare-like event. Time axis represents the elapsed time in seconds.

Apparently, the second flare-like profile looks symmetric, but from the center of the baseline of the profile it is clearly evident that the rise of the event is very sharp and steep whereas the decay of the event is relatively slow and flat (rise time = 105 s and decay time = 195 s).

4. Discussion

In Table I we list the estimated luminosities in Hα [$L_*(\alpha)$]. The maximum value of $L_*(\alpha)$ was 2.12×10^{34} ergs s^{-1} during the flare-like event and integrating under the

flare-like profile (Figure 2), we find that the total energy liberated in Hα by the flare-like event of 1 September, 1985 (see Figure 2) was 1.7×10^{37} ergs.

o And is a B6III star and we estimate that its luminosity in Hα (from the average equivalent width of 31 Hα profiles of September 1985) is 1.2×10^{32} ergs s^{-1}. Integrating under the flare-like profiles (see Figure 3), we find that the total energy liberated by the flare-like events of 13 September, 1985 were 4.8×10^{32} ergs (17 : 01 : 35 UT) and 1.1×10^{34} ergs (17 : 35 : 00 UT).

Slettebak and Snow (1978) also observed a flare-like event in γ Cas and they suggested two mechanisms for the emission phenomena which are:

(a) density perturbation flowing out through the wind; and

(2) sudden dumping of matter from γ Cas on to a degenerate companion which may result in such outburst.

Though our program Be stars are not known of having any degenerate companion, but the presently known number of X-ray sources associated with Be stars is twenty (van den Heuvel and Rappaport, 19896). Of course, this cannot be taken as a rule that Be stars may have compact companions. But, when the present observations cannot be explained with the existing models of Be stars (Poeckert and Marlborough, 1978), we also suggest the two speculations of Slettebak and Snow (1978) as the probable cause(s) for the observed emission events. The first mechanism is of course supported by recent IUE observations which suggest the variability in the winds of many Be stars (Grady *et al.*, 1988; and references quoted therein). But no detailed calculation has been made so far to find out the total amount of energy liberated by the flare-like event due to density perturbation and thus we do not know whether this mechanism will be able to release energy in Hα as high as 10^{37} ergs. The second mechanism looks reasonable at least from energetic point of view – X-ray fluxes (10^{34} ergs s^{-1} to 10^{39} ergs s^{-1}) were observed in many Be stars which are known to contain compact objects (White *et al.*, 1982). These emitted X-rays can ionize the gas of the envelope of Be stars, resulting the enhanced emission in Balmer lines (flare-like events) and also in optical continuum.

Acknowledgements

The author gratefully acknowledges helpful discussions and correspondences with Prof. M. V. K. Apparao and K. E. Rangarajan for carefully reading the manuscript. Sincere thanks to Dr T. P. Prabhu and G. C. Anupama for various help in using their RESPECT package and to plot the figures.

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