THE ASTROPHYSICAL JOURNAL, 360:239–241, 1990 September 1

EXPANDING SHELL AND P CYGNI PROFILES OF 27 CANIS MAJORIS

K. K. GHOSH
Indian Institute of Astrophysics, Vainu Bappu Observatory
Received 1989 August 10; accepted 1990 February 7

ABSTRACT

Results of high-resolution (0.17 Å) and high signal-to-noise ratio (S/N ~ 150–200) CCD spectra of the Be star 27 CMa obtained between 1989 April 16–26 are presented. Observed spectra displayed P Cygni profiles of He I (5876 Å) and Hα with variable velocities of absorption and emission components. Equivalent widths of different components were almost constant except the variable red emission component of Hα. Regular Hα observations of this star between 1985 and 1989 reveal that it entered into the Be-shell phase in 1986 and had a transition to Be phase in mid-1987 which continued until 1989 February. Recent (1989 October) CCD spectra clearly show that this star has again entered into a new shell phase after the major episodic mass loss in 1989 April.

Subject headings: line profiles — stars: Be — stars: individual (27 CMa)

I. INTRODUCTION

From optical observations of Be stars it is well known that these stars display a variety of emission-line profiles in their spectra, and variability of emission lines is an outstanding property of Be stars. It is also known that the same star may show a Be spectrum, a Be-shell spectrum, and a normal B-type spectrum at different epochs (Doazan *et al.* 1989 and references therein). These types of variations have been observed for a large number of Be stars so that one cannot escape the conclusion that these three spectra do not define three different types of objects, but rather, the same object observed at different phases of observations. The differences in the spectra could be due to differences in the geometry of the extended atmospheres of these stars, or in their density, velocity, or temperature structure. These different geometries or structures could in turn be the sign of different evolution stages in the interior of the stars. Therefore, the study of these stars at different epochs may be of special interest to understand the cause of Be phenomenon.

27 CMa is an extremely interesting star among the many peculiar Be stars which display radial velocity variations up to 230 km s^{-1} (presumably the largest one presently known of any Be star; Baade 1981). This star was extensively observed by Struve (1927, 1931, 1946) but did not yield a conclusive explanation of the star's behavior and unfortunately, nobody continued regular monitoring of this star and the available measurements are very scattered (Danks and Houziaux 1978 and references therein).

We started regular observations of 27 CMa in the Hα region (6400–6800 Å) from 1985 January. Preliminary results show that this star, which was in Be phase, entered into the shell phase in 1986 and persisted until mid-1987 and then again came back to Be phase, which was clearly visible until the end of 1989 February. However, recent CCD spectra of 27 CMa which were obtained in the Hα and He I (5876 Å) region between 1989 April 16 and 26 show that the observed profiles exhibit P Cygni type absorption and emission features of Hα and He I (Bhattacharyya and Ghosh 1989. The very recent (1989 October 14–21) CCD profiles show that this star has entered into a new shell phase. Radical, abrupt changes in the spectra of certain other Be stars (γ Cas [Galkina 1987], FY CMa, HR 2855 [Peters 1988], 59 Cyg [Peters 1987], λ Eri [Peters 1989; Baade 1989], μ Cen [Peters 1986; Baade *et al.* 1988]) were also observed on time scales from days to months, and those transient emission events were explained in the framework of different models. But, to the best knowledge of the author, the above-mentioned changes in the spectra of 27 CMa, which has undergone phase switching from Be to Be-shell phase via P Cygni profiles, are not known in the literature of Be stars. In this paper we report the results of such observations of 27 CMa.

I. OBSERVATIONS

Spectra of 27 CMa in the Hα region were regularly obtained between 1985 January and 1989 February. The Bhavanagar spectrograph, a 125 mm camera and 1800 grooves mm^{-1} grating were used at the Cassegrain focus of the 77 cm reflector of Vainu Bappu Observatory (VBO), India. All the spectrograms were obtained on Kodak O9802 emulsion with a reciprocal dispersion of 18 Å mm^{-1}, and they were digitized using PDS-1010M microdensitometer. Reductions of all the spectrograms were done using RESPECT software package (Prabhu, Anupama, and Giridhar 1987) following the same procedure which has been described in details in a previous paper (Ghosh, Apparao, and Tarafdar 1989). CCD observations of Hα and He I (5876 Å) profiles were carried out with the echelle spectrograph at the coudé focus of 102 cm reflector of VBO, India, during 1989 April 16–26 and October 14–21 using Photometrics CCD detector (Ram Sagar and Pati 1989) with 254 mm camera (about seven to nine different orders of spectra were covered in each CCD frame and April 16–17, the grating position was for red regions from Hα onward). The reciprocal dispersion of the spectrometer was 7.4 Å mm^{-1} at Hα (0.17 Å per pixel); the total wavelength region covered by each order of CCD spectrum was 70 Å. The typical S/N around continuum level at Hα attained in the 30 minute exposures made was in the range 150 to 200 except the first spectrum of April 16 (S/N = 90). The data were reduced using the revised version of the RESPECT software package. The steps followed for the reduction scheme were: Correction of the raw data for read-out and dark noise; flat-field correction; wavelength calibration (error was around ±0.05 Å), normalized to continuum intensity; conversion of velocity scale with respect to the star's frame of reference (using photospheric absorption lines of Fe II).

III. RESULTS AND DISCUSSION

Hα and He I (6678 Å) profiles of 27 CMa which were obtained between 1985 January and 1989 February are shown in Figure 1. P Cygni profiles of He I (5876 Å) and Hα are shown in Figures 2 and 3, respectively. Measured radial velocities (with respect to the star's frame of reference) of violet emission and absorption and red emission centers of the P Cygni profiles are presented in Figure 4. Figure 5 shows He I and Hα profiles of this star which were obtained between 1989 October 14 and 21.

Results of our observations may be summarized as follows.

1. Velocities of blue absorption and red emission components of Hα were different from that of He I. This suggests that the regions of formation of Hα and He I were different in the expanding shell of 27 CMa (Fig. 4).

2. Velocities of all the components of Hα were variable between 1989 April 16 and 18. But, from April 18 when the blue emission velocities were almost unchanged, the blue absorption and red emission velocities were decreasing and that for He I components were increasing (Fig. 4).

3. Equivalent widths of blue emission (0.09 Å) components of He I lines were almost constant during the interval of our observations. But the red emission strengths of Hα profiles displayed weak variations (1.33–1.63 Å) between April 16 and 26.

4. He I and Hα profiles of Figure 5 clearly exhibit that 27 CMa has entered into a new shell phase.

From Figure 1 it is clearly evident that 27 CMa which was in Be phase (double-peak Hα profile), entered into the shell phase in 1986. Hα profiles of 1986 show a typical shell profile whose narrow and deep absorption core went much below the local continuum, and the shell indications were present until mid-1987. Scattered blue region observations of this star obtained between 1985 February and 1987 June also indicate some activity of 27 CMa during this period (Mennickent and Vogt 1989). However, they could not detect any phase transition of this star. Spectra obtained between mid-1987 and 1989 February show that this star has come back to the Be phase. Also, large-amplitude radial velocity variations and strong V/R variations ($V/R > 1$ to < 1) were displayed by this star between 1985 and 1989.

P Cygni profiles of He I (5876 Å) (Fig. 2) display intense blueshifted absorption components and weak redshifted emission components. But the Hα profiles (Fig. 3) display type III P Cygni profiles without photospheric absorption wings (Beals 1951) i.e., blueshifted absorption and redshifted emission components with additional emission on the blue side of the absorption feature.

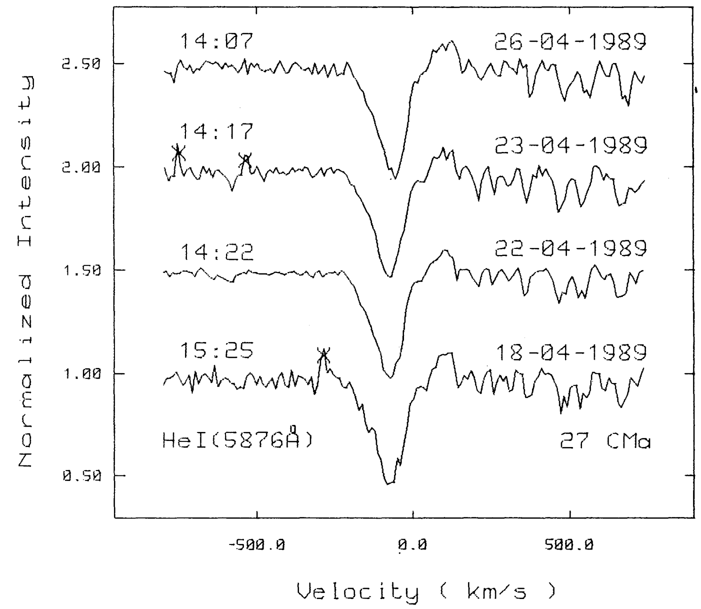

FIG. 2.—Observed P Cygni profiles of He (5876 Å) of 27 CMa. Some of the profiles are contaminated by cosmic ray, X.

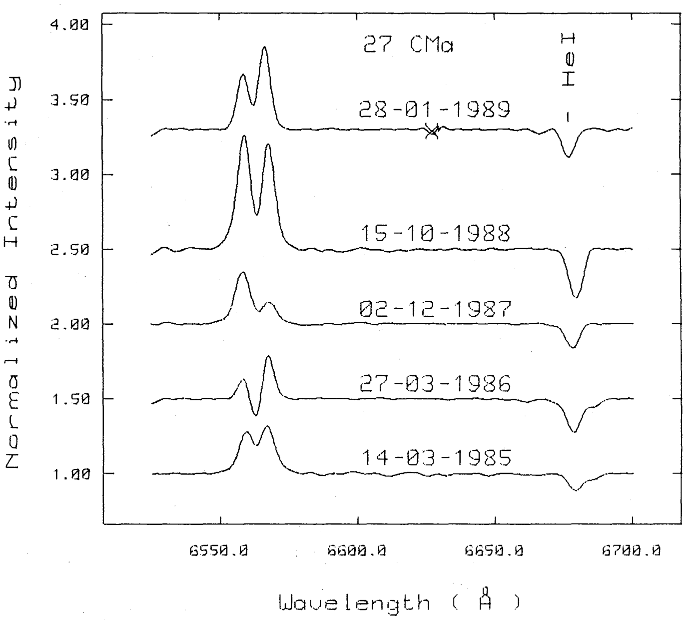

FIG. 1.—Hα and He I (6678 Å) profiles of 27 CMa. Plate defects have been marked by X.

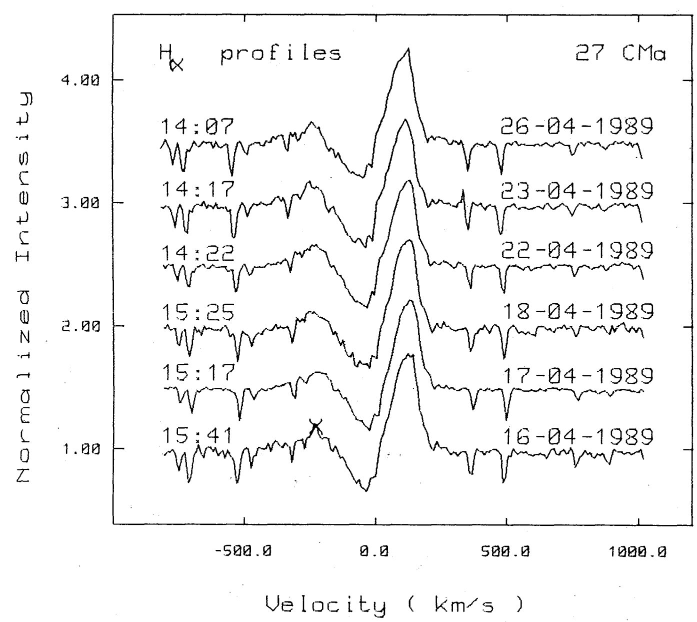

FIG. 3.—Same as Fig. 2, but for Hα profiles

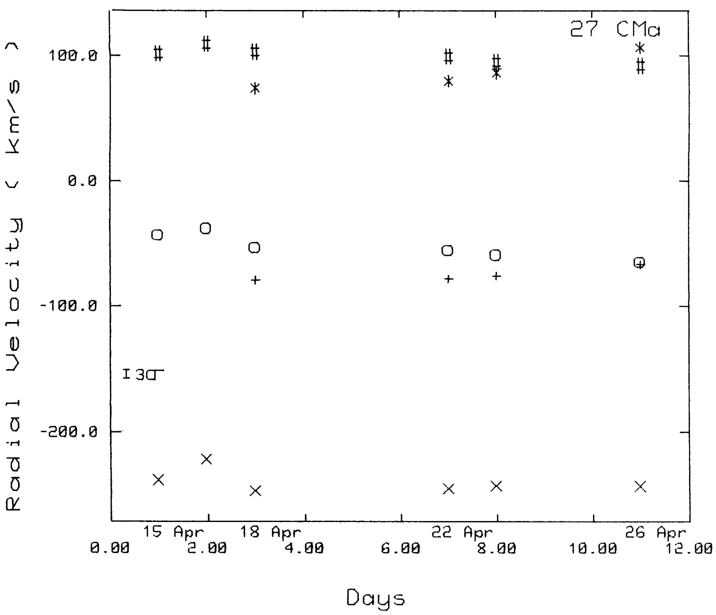

FIG. 4.—Radial velocity plots of different emission and absorption components of Hα and He I (5876 Å) lines. Different symbols used in the figure are: + = He I blue absorption, * = He I red emission, × = Hα blue emission, ○ = Hα blue absorption, # = Hα red emission.

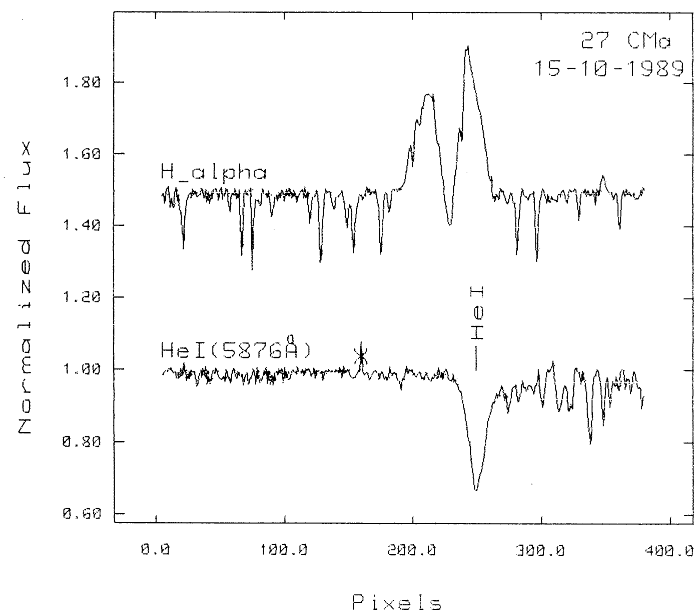

FIG. 5.—Hα and He I shell profiles of 27 CMa

P Cygni profiles are perhaps the best indicators of mass loss and such profiles come from an expanding shell around the star. Therefore, the observed P Cygni profiles of 27 CMa suggest that the mass-loss episode has taken place in this star whose envelope was expanding. On the basis of the spectroscopic observations of this star, Struve and Kao (1948) and Burbidge and Burbidge (1954) concluded that the spectrum and radial velocity variations are due to a variable absorption shell. From the close inspections of the radial velocity curve and the highly asymmetric absorption lines of Hβ and He I of 27 CMa, Baade (1981) suggested that occasional perturbations (some kind of motions within the star which were not purely radial) were present in this star. But this star is not known as a nonradial pulsator.

As mentioned in § I, certain Be stars have displayed spectacular changes in their spectra which were transient emission events on time scales from days to months. But the observed changes in the spectra of 27 CMa are due to the transition of this star from Be to Be-shell phase via the mass-loss episode. It may be important to point out one weak spectral feature in the He I (6678 Å) line which exhibited inverse P Cygni profile in the spectra of this star during 1989 January (see the top spectrum of Fig. 1). Since we have used photographic plates, the S/N was poor and therefore the weak feature found in He I line may be just at 3 σ level. If this inverse P Cygni profile of He I is real, it may be the possible cause for the episodic outburst of 27 CMa before the phase transition to Be-shell phase. Whatever the physical process(es) is involved for the mass-loss event, it is clearly evident from our observations that the phase switching of 27 CMa has taken place via strong ejection of matter from the star to the envelope.

Sincere thanks to Prof. N. K. Rao and Drs. S. Giridhar and S. G. V. Mallik for their kind support to obtain few spectra of 27 CMa during their observations. Sincere thanks to K. Kuppuswamy for his help during observations. Valuable suggestions of Drs. D. C. V. Mallik, T. P. Prabhu, M. Parthasarathy, and A. K. Pati are highly acknowledged. The author is also grateful to Dr. T. P. Prabhu for his support in the reduction of the CCD spectra. I would like to express my appreciation to Prof. J. C. Bhattacharyya for encouragement. Finally the author thanks an anonymous referee for many helpful comments.

REFERENCES

Baade, D. 1981, in *Workshop on Pulsating B Stars*, ed. C. Sterken, p. 267.
———. 1989, *Be Star Newsletter*, No. 20, 14.
Baade, D., Dachs, J., Van de Weygaert, R., and Steeman, F. 1988, *Astr. Ap.*, **198**, 211.
Beals, C. S. 1951, *Pub. Dominion Ap. Obs.*, **9**, 1.
Bhattacharyya, J. C., and Ghosh, K. K. 1989, *IAU Circ.*, No. 4777.
Burbidge, E. M., and Burbidge, G. R. 1954, *Ap. J.*, **119**, 496.
Danks, J., and Houziaux, L. 1978, *Pub. A.S.P.*, **90**, 453.
Doazan, V., Barylak, M., Rusconi, L., Sedmak, G., Thomas, R. N., and Bourdonneau, B. 1989, *Astr. Ap.*, **210**, 249.
Galkina, T. S. 1987, *Be Star Newsletter*, No. 15, 9.
Ghosh, K. K., Apparao, M. V. K., and Tarafdar, S. P. 1989, *Ap. J.*, **344**, 437.
Ghosh, K. K., Kuppuswamy, K., and Pukalenthi, S. P. 1989*a*, in preparation.
Mennickent, R. E., and Vogt, N. 1989, *Astr. Ap. Suppl.*, **74**, 497.
Peters, G. J. 1986, *Ap. J.* (*Letters*), **301**, L61.
———. 1987, *Be Star Newsletter*, No. 16, 15.
———. 1988, *Ap. J.* (*Letters*), **331**, L36.
———. 1989, *Be Star Newsletter*, No. 20, 12.
Prabhu, T. P., Anupama, G. C., and Giridhar, S. 1987, *Bull. Astr. Soc. India*, **15**, 98.
Ram Sagar., and Pati, A. K. 1989, *Bull. Astr. Soc. India*, **17**, 6.
Struve, O. 1927, *Ap. J.*, **65**, 273.
———. 1931, *Ap. J.*, **73**, 301.
———. 1946, *Ap. J.*, **104**, 459.
Struve, O., and Kao, S.-K. 1948, *Ap. J.*, **108**, 537.

K. K. GHOSH: Indian Institute of Astrophysics, Vainu Bappu Observatory, Kavalur, Alangayam, T.N. 635701, India