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Note

Spectroscopic State of the Be Star ζ Tauri in 1976–1986

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Abstract

The long-term variations of the radial velocities (RV) of the shell absorption lines and the violet-to-red ratio (V/R) of the emission double peaks of ζ Tau are examined, based on spectrograms taken at the Okayama Astrophysical Observatory. It is found that the pseudo-periodic variation was terminated around 1982 and that ζ Tau seems to have entered a new quiet phase in its long-term activity.

Key words: Be stars: ζ Tau – Line profile: V/R — Radial velocity

ζ Tau (HD 37202, B2 IVpe, $V \sin i = 310$ km s^{-1}) is a well-known spectroscopic Be binary with an orbital period of 132.9735 d (Harmanec, 1984). Delplace (1970a) first found a pseudo-periodic long-term variation in the radial velocities (RV) of the hydrogen shell absorption lines. This behavior has been studied by Delplace and Chambon (1976) up to 1974 and by Harmanec (1984) up to 1976. Harmanec (1984) summarized the long-term variation of this star in the RV, as reproduced in figure 1, where we can see that the pseudo-periodic long-term variation started in the late 1950's after a long stable state, and repeated an oscillating variation of changing period and changing amplitude. Hubert-Delplace et al. (1983) showed from their observations during 1978–1980 that ζ Tau has revealed high RV's in 1978, as a continuation of the pseudo-periodic variation. Ballereau et al. (1987) observed the Hα emission profiles in 1983.

In this note we present the results of our measurements of the long-term variations of the RV's of shell lines as well as the V/R values of the Balmer emission lines. We used coudé spectrograms obtained at the Okayama Astrophysical Observatory during the epoch of 1969–1986. The spectral dispersion is 10 Å mm^{-1} for the Hβ and blue regions and 20 Å mm^{-1} for the Hα region. The results are shown in figure 2, where the upper and lower panels give the RV variation and the V/R variation, respectively. In plotting the RV data, we have made a correction in order to remove the orbital motion of ζ Tau and, thus, facilitate an inspection of the long-term pseudo-periodic variation. For this correction we used the ephemeris of Harmanec (1984) :

$$T \text{ (primary eclipse)} = \text{JD } 2415549.638 + 132.9735 \text{ E d}, \quad (1)$$

setting the revolution velocity to $K_1 = 10$ km s^{-1} and the systemic velocity to $\gamma = 22$ km s^{-1}. In figure 2a, the RV data of Delplace and Chambon (1976), Abt and Levy (1978), Hubert-Delplace et al. (1983), as well as Ballereau et al. (1987), are also plotted. A series of our Hβ line profiles are illustrated in figure 3.

Our particular attention has been aimed at understanding the spectroscopic state of ζ Tau after completion of the last pseudo-periodic variation around 1980. Based on the above figures we can make the following remarks:

1) The RV values in our measurement are smoothly connected to those of previous observations, as can be seen in figure 2a. The last pseudo-periodic variation in 1976 through 1980 is remarkable due to its large amplitude of the RV curve and the V/R values.

2) It seems that the pseudo-periodic phenomenon disappeared in 1982 and that ζ Tau entered a new quiet phase around 1984.

3) The Hα and Hβ profiles presented by Delplace (1970b) have revealed a strong phase-related V/R variation in the pseudo-periodic variation during its first period (1960–1967), though they often showed a complicated multi-peaked structure. In the V/R variation shown in figure 2b, although observed points were scarce before 1978, its phase-related feature seems to have continued up to the termination of its pseudo-periodic variation. In particular, a high V/R ratio that appeared at the end of 1978 is remarkable, as is shown in figure 3. In the quiet phase, which seems to have started in 1984, the V/R variation has also disappeared, while maintaining a nearly constant value of V/R that is slightly greater than

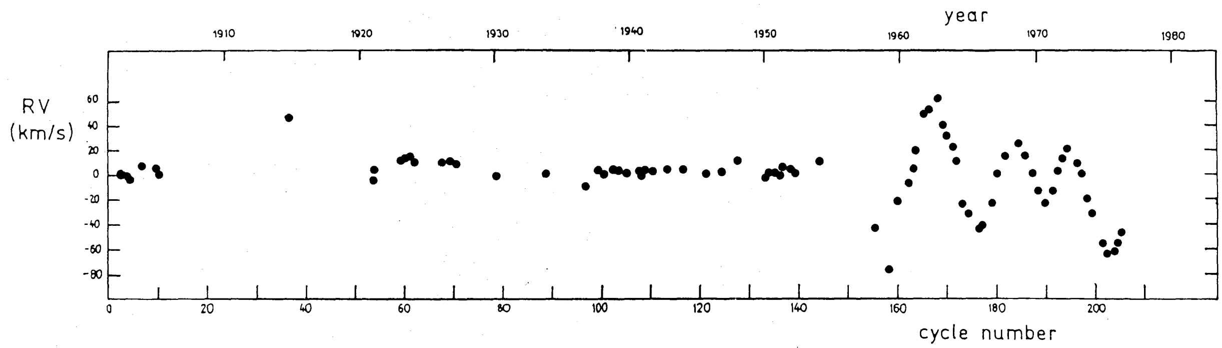

Fig. 1. Long-term variation of ζ Tau in the RV's of the hydrogen shell lines (adopted from Harmanec 1984).

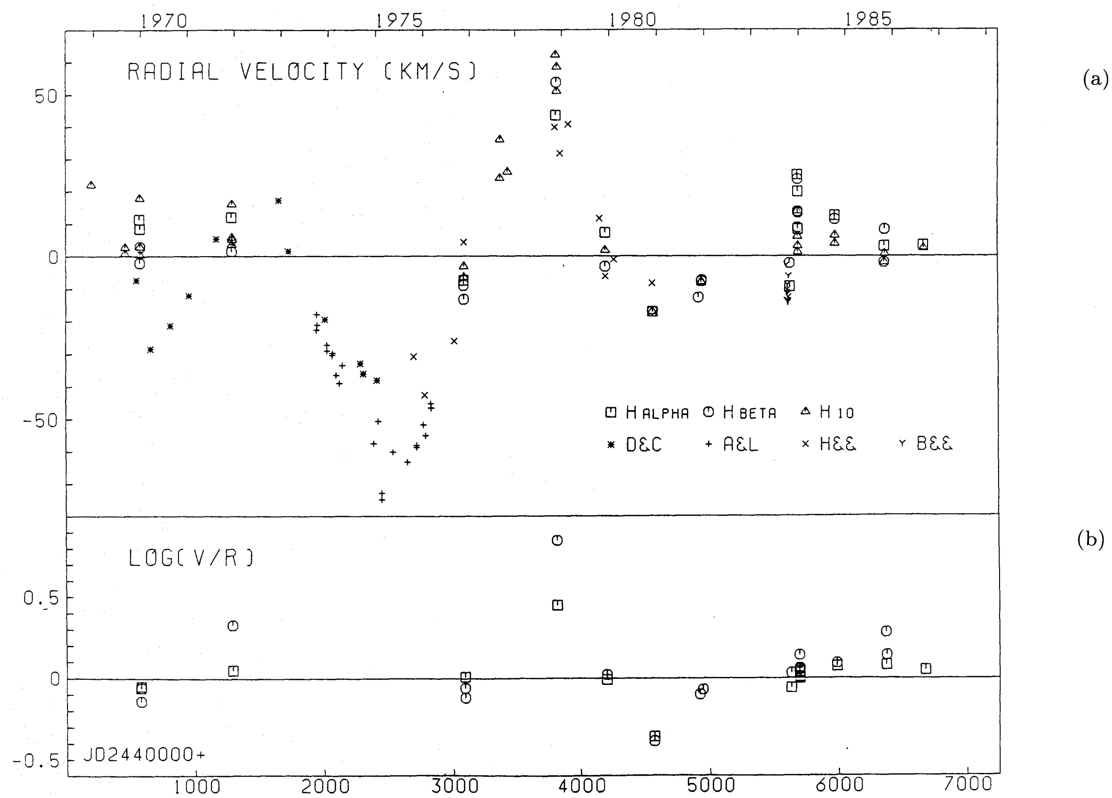

Fig. 2. Long-term RV and V/R variations of ζ Tau in 1970–1986. (a) RV values for the shell absorption components of the Hα, Hβ, and H10, after removal of the binary motion. The RV data by Delplace and Chambon 1976 (D&C, Hγ, Hδ and Hε), Abt and Levy 1978 (A&L, hydrogen), Hubert-Delplace et al. 1984 (H&&, Hγ, Hδ and Hε), and Ballereau et al. 1987 (B&&, Hα) are also plotted. (b) V/R values for the Hα and Hβ emissions.

unity. The V/R variation of Be stars has so far been interpreted the form of either an elliptical disk model or a pulsation-rotation model, though the problem is still unsolved. The relationship between RV and V/R in pseudo-periodic variation causes a farther constraint in modelling the Be envelopes.

Results concerning detailed spectrophotometric measurements will be given in the next paper.

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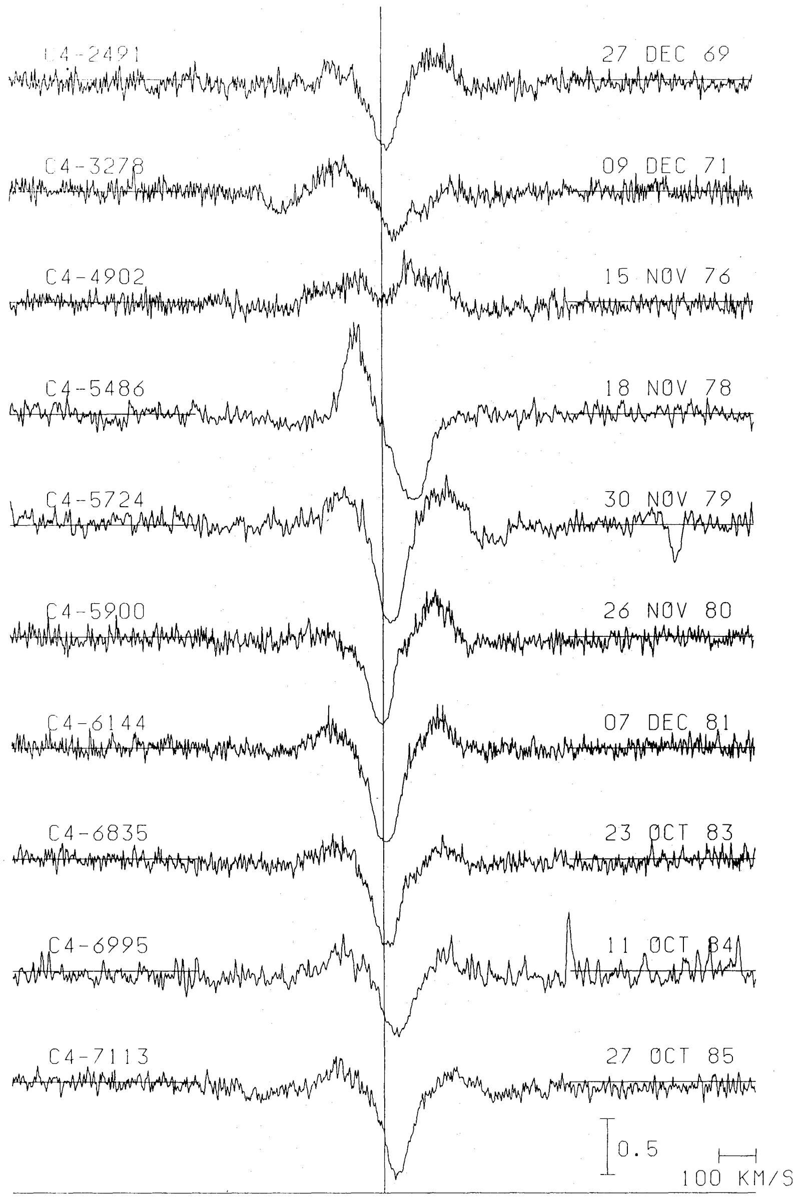

Fig. 3. Series of Hβ line profiles. The plate number of the spectrograms at the Okayama Astrophysical Observatory and the date of observation are shown on each of the profiles.

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