STRUCTURE AND PARAMETERS OF THE CIRCUMSTELLAR MATTER IN THE INTERACTING BINARY SYSTEM V367 CYG

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In the numerical modelling of the evolution of close binaries the most uncertain factor remains the estimation of the quantity of mass and angular momentum loses out of the system. In connection with this the investigation on parameters and structure of the circumstellar matter in the interacting binaries is of great interest. They are in a stage of rapid matter exchange, when the rate of mass transfer is very high and the greater part of the matter can be ejected off the system. The aim of our investigation is to make a detailed analysis of the structure and parameters of the circumstellar matter in V367 Cyg (W Ser-type). According to the present evolutionary conceptions the stars of W Ser-type are younger objects than Algols and are at the end of the rapid phase of the first mass transfer in case B.

Our investigation is based on 46 spectrograms obtained from 1981 to 1989 by the 6-meter telescope of SAO of Academy of Sciences of USSR (0.9 and 1.4 nm/mm) and by the 2-meter telescope of Rozhen Observatory of Bulgarian Academy of Sciences (0.9 and 1.8 nm/mm).

The spectrum of V367 Cygni at all phases of the orbital period shows emissions in the first members of the Balmer series (including H_γ). Emission components of H_δ only appear near the minima of light and are practically invisible during the maximum of light. Synchronous variations of the equivalent widths (Fig. 1) and profiles of the Balmer emission components (H_β, H_γ, H_δ) (Fig. 2) confirm the fact that these lines are generated in close layers of the common envelope. The parameter $J = (V-R)/(V+R)$ describes the relative intensity of the components of the emission lines (V, R are the intensities of the blue and the red emission line components expressed in units of a nearby continuum).

The comparison between the observed and the theoretical Balmer decrement shows that the observed Blamer decrement is steeper than theoretical one and cannot be described by any calculated Balmer decrement taking both radiative and collisional mechanism of atom excitation into account (Fig. 3). Variations of the Balmer decrement relative to the orbital period or during different seasons of observation were not found.

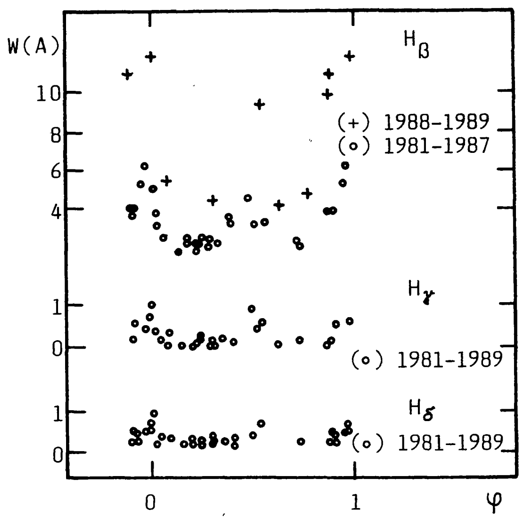

Fig. 1

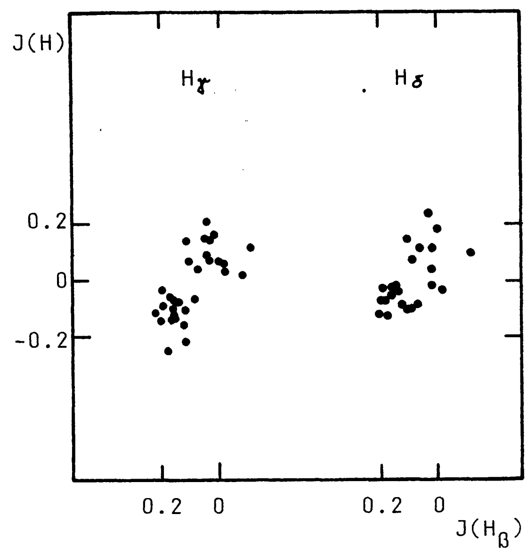

Fig. 2

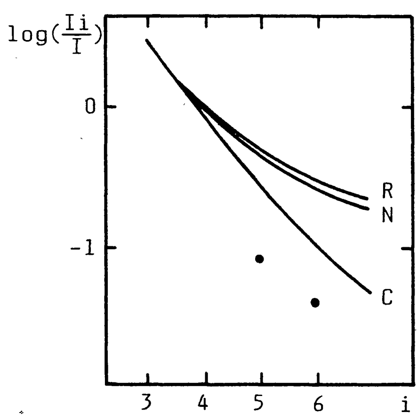

Fig. 3

The comparison between the observed (•) and the theoretical Balmer decrement (line) C - collisional mechanism of atoms excitation: T_e=10000 K, $n_e=10^{10} cm^{-3}$, $\beta^0_{21}=10^{-8}$. R - radiative mechanism of atoms excitation: T=10000 K, T_e=10000 K, $\beta^0_{21}=5 \times 10^{-3} \div 10^{-4}$, =0.1. N - nebula.

Emission components in hydrogen lines are clearly distinguished only at the first members of the Balmer series. The profiles of the higher members of the Balmer series have simpler form: a narrow absorption line (formed as a result of an additional absorption of radiation in the common envelope of the system) is superposed upon a wide absorption line formed in the atmosphere of the bright star. From the additional absorptions in H_9 and H_{10} the number of absorbing atoms for the column of matter per 1 cm^2 of the envelope was determined: $n_2 l = 1.2 \times 10^{15}$. Then using Bolzman formula with $T = T_{L\alpha} = T_e$ and assuming that photoionization processes in the envelope itself cannot influence significantly the ionization state of matter in the envelope, we obtain $\log(n_e^2 l) = 34.1$ (with $n_e \approx n^+$). The size of the envelope was determined from the radial velocity curve of absorption shell lines supposing Kepler orbits of the envelope matter around the mass centre of the system and the envelope mass is negligible compared to the mass of two stars

$$(l/a)^3 = (1 + m_1/m_2)^2 (u/v)^2 ,$$

u - orbital velocity of the primary star, v - orbital velocity of the envelope matter, a - radius of the orbit of the primary star, l - radius of the common envelope of the system. Size of the common envelope of the system $l = 8.24 \times a = 1.9 \times 10^{13}$ cm, mean electron concentration in the common envelope $\log \bar{n}_e = 10.41$ and mass of the common envelope

$$M_{env} = m_H n^+ \times l \times 4 \times R_*^2 = 0.3 \times 10^{-7} M_\odot \ (R_* = 18\ R_\odot).$$

The peculiarities in motion of the outer layers of the envelope of V367 Cyg are manifested in a complicate behaviour of "Balmer progress". Because of the asymmetrical profile of the hydrogen absorption line the radial velocities measured from different parts of the profile have different values and different correlation between V_r and n. The radial velocities of the centre of the deepest part of an absorption core of the Balmer lines vary as follows: the first members of the Balmer series (up to n=15) tend to show decrease in radial velocity with increasing line number, i.e. inverse "Balmer progress". From n = 15 to n = 30 there is observed some "progress", characteristical for supergiant atmospheres but considerably slower. Such a behaviour is observed in all phases of the orbital period.

A more complicated dependence has been observed of the deepest part of the absorption cores of the Balmer lines. The radial velocity variation measured from the deepest point of an absorption cores of the Balmer lines is shown in Fig. 4. The observed "Balmer progress" confirm the fact that the layers in which the deepest part of the hydrogen lines is formed, i.e. the outer layers of the common envelope, are motionless relatively to the star or expand with a velocity not exceeding 10 km/s. One should pay attention to the increase of radial velocity fluctuation in 1987 and 1989 compared to 1983. It might be due to increasing instability of the outer part of the envelope in 1987 - 1989. In 1983 the radial velocities of the Balmer lines at phases 0.06 and 0.17 are practically equal, and a systematical decrease of the radial velocities have been observed at phase 0.28. For detailed studies of the variations of the "Balmer progress" at different phases of the orbital period a great number of spectrograms, covering the near ultraviolet region is necessary. Using our material one can get only to the a conclusion that a small variability of the expansion in a homogeneous outer layers of the envelope takes place.

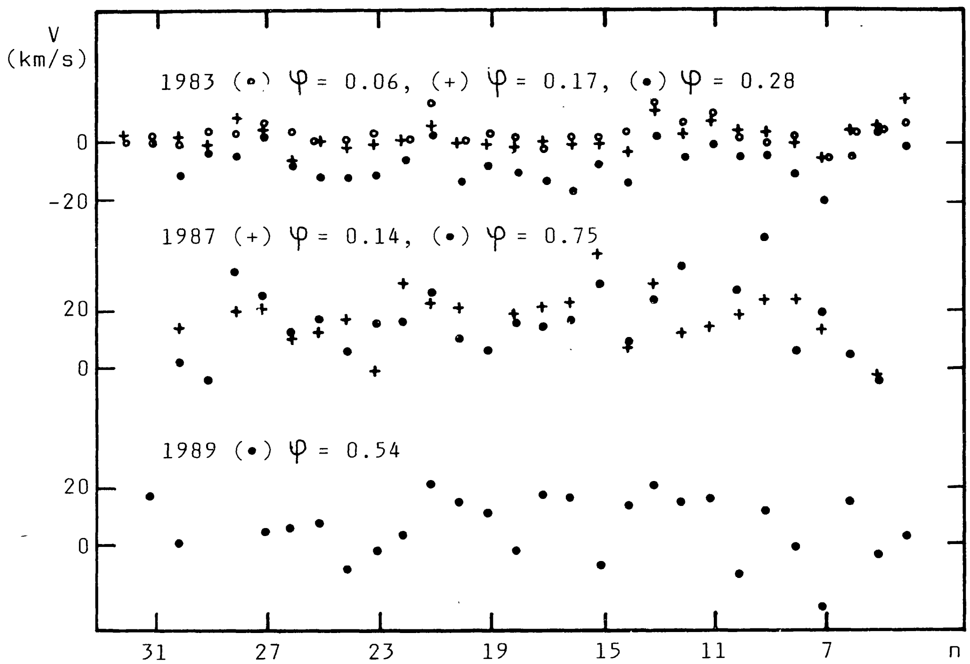

Fig. 4

We can estimate the velocity of the radial motion of the matter by using the "radial velocity - excitation potential" relation. It is clearly seen in Fig. 5 that the radial velocity V_r does not depend on the excitation potential of the line ε . This fact confirms the expansion of the outer layers of the envelope of V367 Cyg with a small velocity.

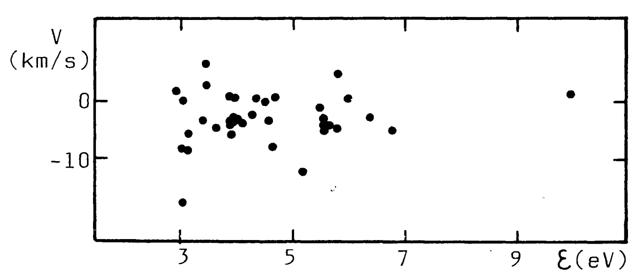

Fig. 5

The mass loss rate of the common envelope can be estimated by following considerations: the expansion velocity of the envelope amounts to $\sim 10^6$cm/s, the size of the envelope is $l = 1.9 \times 10^{13}$ cm, therefore the envelope matter will be dispersed within the time of $\Delta t = 1.9 \times 10^7$ s. Hence the rate of mass loss by the envelope equals to $M_{env}/\Delta t = 0.5 \times 10^{-7}$ $M_\odot$/year.