

V 367 CYGNI

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Abstract. The spectral and photometric investigations of the W Ser-type star V 367 Cyg have been carried out. The comparison of the observed parameters of the stellar components of the system V 367 Cyg with the theoretical ones for the main-sequence stars of the same mass has shown the considerable excesses of the radii and luminosities of both components of the system. The whole complex of the observed characteristics of the bright (at present less massive: $M_1 = 2.3 M_{\odot}$) component is well described by the current evolution theory of close binary systems of medium mass. At the same time, it is shown that the luminosity of the secondary component cannot be explained within the framework of the disc accretion model, suggested by Plavec (1980a) to describe the observed properties of W Ser-type stars.

Key Words: Stars: Binaries: Individual : V 367 Cyg

In 1923, Merrill paid attention to V 367 Cyg (HD 198287-8, BD 38° 4235, SAO 70517, ADS 14314) for the first time. He discovered the strong emission H_{α} line in its spectrum (Merrill, 1923). Ten years later, a spectral variability of the star was found (Christie, 1932). In 1930, Humason classified V367 Cyg as an β Lyr-type eclipsing binary star and determined the photometric elements of its orbit for the first time (Humason, 1930). After that, the star was extensively studied visual, photographic (Kukarkin, 1932; Filin, 1949), photoelectric (Kalv and Pustynnik, 1975; Kalv, 1978; Akan, 1985, 1987; Fresa, 1966; Heiser, 1962, 1966; Lindemann and Hauch, 1973; Walker, 1971; Wood, 1955; Wood and Lewis, 1955; Young and Snyder, 1982), polarimetric (Shakhovskoy, 1964; Appenzeller, 1966; Bidelman and Wolfire, 1981) and spectral (Karetnikov and Perekrestnyi, 1973; Abt, 1954; Aydin et al., 1978; Christie, 1933; Hack et al., 1984; Heiser, 1961; Sanford, 1950; Underhill, 1954) methods. The observations of V 367 Cyg have been obtained at IUE and EINSTEIN (Plavec, 1976, 1979, 1980b, 1981; Guinan et al., 1984; Plavec and Polidan, 1976; Plavec and Koch, 1978).

Photometric investigations. V 367 Cyg has a light curve of β Lyr-type with the different brightness of the maxima and the different depths of the asymmetric minima. In the light curve, there are effects of the ellipticity, reflection and bright lines. The small light fluctuations give an occasion to suspect a physical instability of the star (Wood, 1955; Heiser, 1962; Fresa, 1966). However, the optical pulsations exceeding 1 per cent of the stellar luminosity have not been found (Nevo et al., 1975). The earliest photographic observations already showed the differences of the light curves obtained by the different observers and at different epochs (Heiser, 1962). Later, the photoelectric observations (Akan, 1987) confirmed the existence of the long-term variations of the light curve of V 367 Cyg. The detailed analysis of the variability of the light curve of V 367 Cyg made by Akan (1987) has shown, that the light fluctuations take place not only at the maxima, but exist also at the ascending and the descending branches of both minima, being more pronounced in the blue light. According to Wood and Lewis (1955), the colour of the system changes with phase not significantly (less than 0.04 mag). On the other hand, the detailed photometric analysis of the light variations (Young and Snyder, 1982) has shown a slight increase of the color index (b-y) at the middle of the primary eclipse. This may be a result of the increase of the contribution of the secondary component to the total flux from the system. In (u-b), there was the sure sudden increase in the ultraviolet, synchronized with the primary mid-eclipse. Young and Snyder (1982) interpreted this fact as a manifestation of the hot central source (again either a star, or an accretion zone on a star, or both). The comparison of the color curves obtained within the 25-year interval has shown, that the system V 367 Cyg was redder in 1960, than in 1985 (Akan, 1985; Heiser, 1962).

The peculiarities of the light curve of V 367 Cyg make more difficult to obtain the solution of the light curve and the determination of the elements of the orbit. Nevertheless, the first attempts to obtain the photometric solution had been already made by Kalv and Pustynnik (1975), Heiser (1962), Fresa (1966). The results of these calculations indicate that the both components of the system have a very large sizes, and, at least, one of them overfills its Roche lobe. The analysis of the photoelectric light curve of V 367 Cyg has been made by Li and Leung (1987) by the 'synthesis' method in frame of the Wilson-Devinney (1971) model. Unfortunately, it has not solved the problem of the interpretation of the photometric observations of V 367 Cyg. The obtained parameters (radii, luminosities) are more reliable, but considerably differ from the analogous characteristics of the normal main sequence stars of the same masses. Both components of the system have the considerable excesses of the luminosities and radii (Tab.1). The obtained excesses may be a result of the evolutionary peculiarities of the system. Also, it is possible, that they are the consequence of the simplifications assumed while solving the light curves. There are two main causes, which can change the ratio of the luminosities and of the radii of the components of V 367 Cyg:

1. the discrepancy of the used model with the real geometry of the system.
2. not taking into account the influence of the circumstellar matter on the light curve of the system.

The model of Wilson-Devinney (1971) applied by Li and Leung (1987) for the determination of the absolute elements of V 367 Cyg had represented the forms of the both components of the system as the equipotential surfaces in the Roche model. At the same time, the whole observational data testify that the more bright and now less massive component of the system fills

its Roche lobe and loses matter through the point L1. This matter, coming into the vicinity of the secondary component, forms an accretion disk near it. This accretion disk can seem as a false photosphere around the secondary component. Therefore, the solution of the light curve of V 367 Cyg should be made in a model with a disk-like secondary component. Such a model was elaborated by Antokhina (1988) and was successfully used for the analysis of the photoelectric light curves of the some peculiar binary systems (RY Sct, BM Ori, SS 433). Taking into account the distortion of the light curve by the circumstellar matter, the ratio of the luminosities and the dimensions of the components may be changed. The theoretical analysis of the light curves of close binaries with common scattering envelopes (Pustyl'nik and Einasto, 1984, 1985) had shown, that the ratio of the depths of light curve minima is determined not only by the luminosities of the components. It also depends on the luminosity of the envelope $L(\text{env})$, which is connected with the following parameters: $\tau(\text{env})$, L_2/L_1 , A , q , $l(\text{env})$. While solving the light curves of the binary systems with the developed circumstellar matter, it is necessary to take into account the contribution of the circumstellar matter to the total light curve of the system. However, for V 367 Cyg, this is impossible at present, because of the complicated structure of the circumstellar matter contained in this system.

The light curves have been solved by the synthesis method according to the program elaborated by Antokhina (1988). Two models were used: the system in the frame of the Roche model and the system with a geometrically thick disk around the secondary component. The photoelectric curve obtained by Fresa (1966) from 1957 to 1960 and based on 456 individual observations was used. To solve the light curve in frame of the Roche model, the shapes of the stars were approximated by the equipotential surfaces. The rotational and tidal distortion of the shapes of the components was taken into account. The intensity of the radiation emitted from an elementary surface area was determined according to the stellar temperature, limb darkening, gravity darkening and the reflection. In the model, having a geometrically thick disk, the shape of the primary component was approximated by an equipotential surface in the Roche model. The form of the secondary component was approximated by an ellipsoid with an equatorial semiaxis a and a polar semiaxis b . The temperature distribution along the ellipsoid's surface was computed according to the law:

$$T(r) = T_p (b/a)^{0.5}$$

Close and equivalent accuracy solutions have been obtained both in the Roche model and model with disk-like secondary component. The absolute parameters of V 367 Cyg are collected in Table 1. The obtained radii and luminosities are considerable greater than the same characteristics of the zero-age main-sequence stars of the same masses (as well as in (Li and Leung, 1987)).

Particularly, the luminosity excess of the secondary component can be caused by the influence of the circumstellar matter on the light curve of the system. According to the results obtained by Pustyl'nik and Einasto (1985, 1987), the account of the contribution of the circumstellar matter can decrease the estimated value of the luminosity of the secondary component by 2-3 times. However, it can not explain the observed luminosity excess, which, obviously, indicates the evolutionary peculiarities of the system.

Spectral investigations. The results of the spectral investigations of V 367 Cyg are very contradictory. This is explained by the fact, that the system is surrounded by a significant gaseous envelope, which determines the main features of the observed spectrum. This fact strongly complicates the investigation of the stars of the system. If usually we have to search for the evidence on the existence of the circumstellar matter in a system, for V 367 Cyg the problem is a contradicting one: the most careful investigations are needed to detect the stellar features in the spectrum of V 367 Cyg. In the literature, we have found 12 determinations of the common spectral type of the system from F2 ev (Christie, 1933) to B8 Ia (Wilson, 1974) and 7 determinations of the individual classifications of the stellar components from F2 e + F5 (Polidan, 1970) to A2 + A8 (Gaposchkin, 1953). The elements of the spectral orbit have been determined three times and show a marked difference in the determination of the K and velocities and the functions of masses $f(M)$ (Abt, 1954; Heiser, 1961; Aydin et al., 1978). The masses of the components are still uncertain: from $1.5 M_{\odot} + 1.28 M_{\odot}$ (Abt, 1954) to $19 M_{\odot} + 12 M_{\odot}$ (Li and Leung, 1987).

No one of the investigators of V 367 Cyg could succeed in finding the lines of the secondary component in the spectrum. Therefore, from the curve of the radial velocities, only the function of masses has been determined, from which (and general considerations) the stellar masses have been calculated. In works (Heiser, 1961; Aydin et al., 1978), the blue component in the lines Mg II λ 4481 A was found at some phases. However, because of the absence of the correlation the displacement of this detail with the phase of an orbital period, the authors of these works had concluded, that this component forms in the circumstellar matter.

From 1981 to 1989, we made the spectral observations of V 367 Cyg at the 6-meter telescope of SAO of the Soviet Academy of Sciences, and at the 2-meter telescope of the ROZHEN observatory of the Bulgarian Academy of Sciences. 46 spectrograms were obtained with the dispersion of 9, 18 and 28 A/mm within the range λ 3700 - 6800 A. The results of these investigations were published in the works (Karetnikov and Menchenkova, 1983, 1986, 1987; Menchenkova and Pavlenko, 1989, 1990; Glazunova and Menchenkova, 1989; Menchenkova and Kovachev, 1990; Menchenkova, 1990). It has been shown, that only the line Mg II λ 4481 A and the wings of the hydrogen lines are formed in the atmosphere of the bright star of the system. The stellar component is observed in the line K Ca II λ 3934A, but because of the strong blending by the line

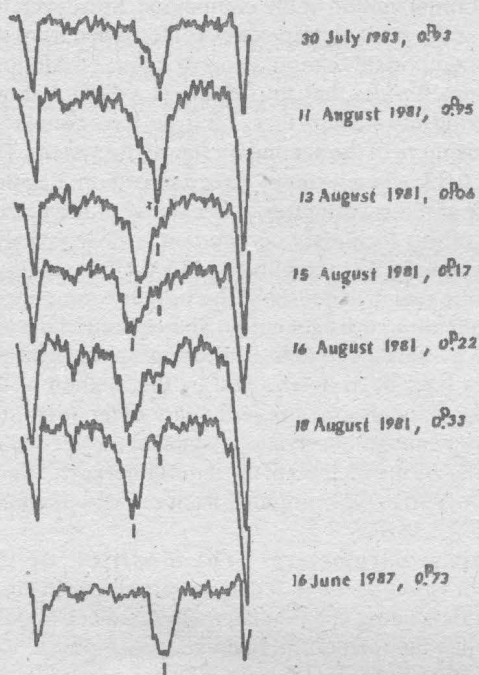


Fig. 1 The spectrum of V 367 Cyg in the region near the line Mg II 4481 Å on the different orbital phases. The positions of the primary and secondary components are marked.

of interstellar calcium and other neighboring lines of the spectrum, it can not be used to study the parameters of the stellar atmospheres.

From the lines Mg II λ 4481 Å and of the hydrogen lines H γ , H δ , H 9 - H 13, the parameters of the atmosphere of the bright star of the system have been determined by the method of model atmospheres. For the comparison with the model calculations, we have used the observations obtained near the phase of the secondary minimum, in order to decrease a possible influence of the secondary component and of the circumstellar matter on the characteristics of the lines. In this time, the secondary component and the area near the point L1 are eclipsed, and, therefore, they make a minimum contribution to the total spectrum of the system. Using the net of the equivalent widths of the line Mg II λ 4481 Å computed by Topilskaya (1987) for the models with 10000 K T (eff) 17000 K, lg g = 3.0, 3.5, 4.0 and V(tr)=2.5 km/s and 10 km/s, we have estimated the effective temperature and turbulent velocity in the atmosphere of the bright star of the system: T (eff) = 12000 K - 14000 K, V (tr) = 10 km/s, if log N (Mg)=log N_O (Mg) and log g = 3.0 - 4.0. We have not considered the models with T(eff) 10000K since the stellar temperature cannot be lower than that of the envelope which is estimated to be about 9500 K (Karetnikov and Menchenkova, 1985).

We estimated the rotational velocity of the bright star of the system V 367 Cyg by using the calibration curve from Zajkova and Udovichenko (1988) and the semiwidth of the line Mg II 4481 Å. This value is V sin i = 50 km/s. It is lower than the mean value for the main sequence stars of the same spectral class.

By using the net of the models calculated by Kurucz (1979) for the stars of the spectral type O -G, we have made comparisons between the observed profiles of the lines H γ and H δ , and the theoretical ones. It was found that the wings of the hydrogen lines H γ and H δ can be equally well described by three models:

- T (eff) = 12000 K, log g = 2.5
- T (eff) = 16000 K, log g = 3.0
- T (eff) = 20000 K, log g = 3.5

For the 'single-value' determination of the parameters of the atmosphere of the bright star of the system, we had to consider the higher terms of the Balmer series. The synthetic hydrogen spectrum for the lines H 8 - H 14 computed by Pavlenko (Menchenkova and Pavlenko, 1989) according to the method of Grim (1967) realized in the ATLAS-5 program (Kurucz, 1970) was used for these three models. It should be noted, that the difference between the wings of the lines in these models is small. For the models with T (eff) = 12000 K, log g = 2.5 and T (eff) = 16000 K, log g = 3.0, this difference does not exceed the errors of observations. Nevertheless, the usage of the additional criteria allows to limit the range of the suggested values T(eff) and log g. The best agreement of the observational data with the theoretical computations has been obtained for models with T(eff) = 12000 K - 16000 K. In this case, the spectral type of the bright star of the system V 367 Cyg is B8 or earlier. From the other side, the absence of the helium lines in the spectrum of the system may argue, that the spectral type of the bright star of the system (with a normal chemical composition) cannot be earlier

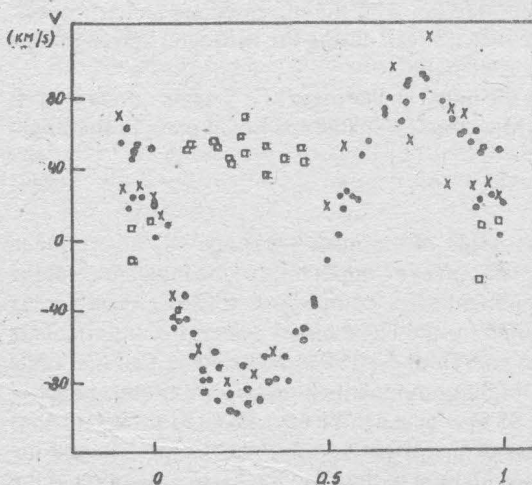


Fig. 2 The curves of the radial velocities for two components of the line Mg II 4481 Å. ○ - the primary component of the line, □ - the secondary component of the line, ● - the data obtained by Heiser (1961), X - the data obtained by Aydin et.al. (1978).

than B8. Summing up the results of the analysis of all stellar features in V 367 Cyg spectrum, we have arrived a conclusion, that the temperature of the bright star of the system is about T(eff) = 12000 K and log g = 2.5. As has been found in the process of our investigations, the line Mg II λ 4481 Å shows the composite profile, which besides the primary component contains a fainter one. The displacement of this faint component agrees with the phase of the orbital motion of the secondary star of the system (Fig.1).

The radial velocity curves for the two components of the line Mg II λ 4481 Å are shown at Fig.2. At the same figure, the radial velocity curves for the bright component obtained by Heiser (1961) and Aydin et al.(1978) are shown. The radial velocity

curve of the secondary component of the line Mg II λ 4481 A agrees with the orbital motion of the companion. Moreover, the ratio of the intensities of the components of this line coincides with the ratio of the stellar luminosities (determined from the photometry) of about $L_2 / L_1 = 0.4$ (Heiser, 1962). The spectral types of the components cannot strongly differ. That follows from the absence of the considerable color variation during the primary minimum. Besides that, the line Mg II λ 4481 A shows a slight dependence on the temperature within the spectral interval B 8 -A 8. Taking into account these facts, we have concluded that the secondary component of the line Mg II λ 4481 A is formed in the atmosphere of the secondary star of the system. The absence of the secondary component of the line Mg II λ 4481 A at the phase 0.73, when it should have a maximum negative displacement, may be caused by an additional absorption by the circumstellar gaseous structures, more dense at the phases near the secondary maximum. However, at the phases 0.93 - 1.0, the line of the secondary component is observed with certainty. The orbital elements have been calculated as follows. The initial values of the K_1 (amplitude) and γ (the velocity of the center of masses of the system) have been determined from the curve of the radial velocities of the primary component. The initial epoch T_0 has been taken equal to the moment of the primary minimum in the light curve. The eccentricity e and the periastron angle ω have been set arbitrary. Then the parameters T_0, e, ω have been defined more precisely with the method suggested by Lavrov (1987). The final values of $K_1, \gamma, T_0, e, \omega$ have been determined by the method of the differential corrections. In order to calculate the theoretical curve of the radial velocities for the secondary component, the same values of the elements γ, e and $\omega + 180^\circ$ have been used (because not enough observational data on the secondary component during the second half of the period). K and T have been determined by the method of the differential corrections. The orbital elements for the primary and secondary components of the system V367 Cyg computed from our observational data, are presented in Table 2. The stellar masses are $M_1 = 2.3M_\odot$ and $M = 3.6M_\odot$.

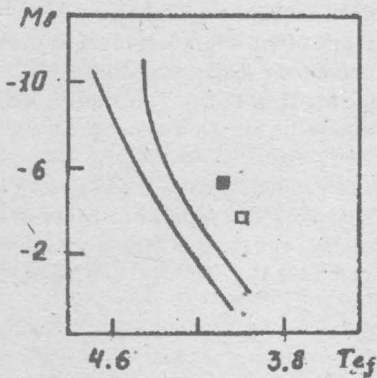


Fig. 3 The positions of the components of V 367 Cyg in H-R diagram.
 ■ - bright component,
 □ - companion.

Evolutionary status and initial parameters. The position of the components of the V 367 Cyg system as well as the H-R diagram are shown in Fig.3. The lines mark the positions of the stars being at the initial main sequence and the positions of the stars, which have just completed the main sequence phase. The excesses of the luminosity and radius of the bright component can be easily explained by the evolutionary theory of close binary systems of intermediate mass.

The bright, initially more massive (at present less massive) component has already evolved, leaved the main sequence, filled its Roche lobe and is losing matter now. The large orbital separation, together with the intermediate stellar masses, indicates, that the mass exchange phase began during the hydrogen burning in the layer source (case B events) or at later stages.

By using the relation between the initial stellar mass M_0 and its remnant mass after the first mass-loss episode M_R , we estimated the initial mass of the bright component of the system M_{10} :

$$M_R / M_0 = 0.1 (M / M_0)^{1.4}$$

$$M_{10} = 9.4 M_\odot$$

As the fast stage of the mass exchange has not yet been finished, this value gives an upper limit of the initial mass of the primary component. The comparison with the evolutionary tracks computed for the close binary systems of intermediate masses (Iben and Tutukov, 1985) has shown, that the initial mass of the bright component should be within the range of $6.95 M_\odot - 9.85 M_\odot$ (Fig.4). We have taken $M_{10} = 8 M_\odot$ as an initial mass of the bright component and determined the main-sequence lifetime of the primary t_{1MS} , the mass of the remnant of the primary after the first mass-loss episode M_{1R} , the mass helium core of this remnant $M_1(\text{He})$ and a time of the first stage of matter exchange t_B .

$$t_{1MS} = 2.76 \cdot 10^7 \text{ years}$$

$$M_{1R} = 1.84 M_\odot$$

$$M_1(\text{He}) = 1.11 M_\odot$$

$$t_B = 1.38 \cdot 10^4 \text{ years}$$

Because the system is being observed during the fast stage of the first mass-loss episode, after the bright component of the system has leaved the main sequence, the age of the system can be estimated 2.76×10^4 yrs. The accepting secondary component of the system has also the considerable excesses of radius and luminosity. However, if the radius excess of the

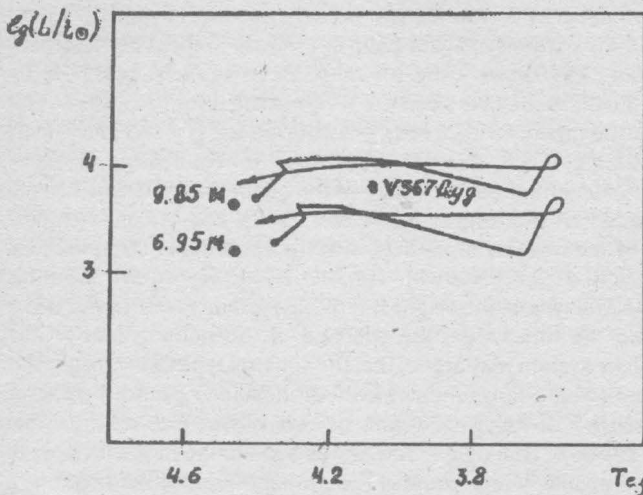


Fig. 4 The comparison between the parameters of the bright component of the system V 367 Cyg and the theoretical evolutionary tracks.

secondary component can be easily explained within the model with the accretion disk near the nondegenerate star, the luminosity excess of the secondary component is impossible to describe by this model. We estimated the accretion luminosity, assuming that the accepting component is a main sequence star with mass $M_2 = 3.6 M_{\odot}$ and radius $R_2 = 3 R_{\odot}$ (the observed size of the secondary component apparently may correspond to the accretion disk). The main-sequence lifetime of the secondary accepting component of the system (now the star with mass $M_2 = 3.6 M_{\odot}$) cannot be less than $t_{2MS} = 2.03 \times 10^8$ yrs. That is ten times more than of the primary star ($M_{10} = 8 M_{\odot}$, $t_{1MS} = 2.76 \times 10^7$ years). Consequently, the time required for the more massive primary component to leave the main sequence and to lose a considerable part of its mass, is shorter than the main sequence lifetime of the secondary component (assuming that only own evolution of the companion is considered, without taking into account the accretion influence). The mass-loss rate of the bright component has been

determined according to the period variation taken from Kreiner and Ziolkowski (1978): $\dot{M} = 6.7 \times 10^{-6} M_{\odot}/\text{yr}$. It can be used as an upper limit for estimating the accretion on the secondary component

$$L_{ac} = G \dot{M} M / R = 251 L_{\odot}$$

As one may see, L_{ac} is of the same order with the own luminosity of the secondary companion ($M_2 = 3.6 M_{\odot}$, $L_2 = 114 L_{\odot}$). The total luminosity of the accepting component (star + accretion disk) is equal to

$$L_{2total} = (L_2 + L_{ac}) = 365 L_{\odot}$$

$$\log(L_{2total} / L_{\odot}) = 2.56$$

That is by a factor of ten less than the observed one. Thus, we are convinced, that the accretion cannot explain the observed luminosity excess of the secondary component. Before that moment, we supposed, that the accretion did not influence on the evolution of the accepting component. In fact, the matter added to the accepting component is not in the thermal balance. The accepting star accretes in the thermal time scale of the losing mass primary component, which differs from its own thermal time scale. It leads to the fast increase of the accepting component sizes, the filling up the Roche lobe with it and creating the contact configuration. The theoretical calculations of the evolution of the accepting component have shown, that its Roche lobe has been filled and the contact configuration has been created after the transfer of about $\sim 0.1 M_{\odot}$ in the systems with masses $5 M_{\odot} + 2 M_{\odot}$ (Benson, 1970) and only $0.05 M_{\odot}$ in systems with masses $1.5 M_{\odot} + 1 M_{\odot}$ (Yungelson, 1973).

As soon as the contact configuration come into existence, the common envelope losing the mass and angular momentum is formed. The fact that V 367 Cyg is closed to a contact configuration is shown by the whole complex of the spectral and photometric investigations testifying the presence of the hot optically dense plasma in the system. Moreover, the results of the analysis of the photometric observations of V 367 Cyg (Li and Leung, 1987) have shown, that the degree of overcontact of the system seems to have been growing from 0.0 % (or 0.6 % undercontact) to 5 % and to 9 % overcontact through the years from 1957 to 1960 and to 1973.

Using the statistical relations, we have estimated the initial parameters of V 367 Cyg. According to the conclusions of Popov (1968), the primary component in the systems with total mass close to $(8-12) M_{\odot}$ loses 75 % of its mass during the matter exchange process. 90 % of this matter go away from the system. Svechnikov (1969) has obtained same results for the stars with $(M_1 + M_2) \sim 11 M_{\odot}$. According to our determinations, the initial mass of the bright component of the system V 367 Cyg is $8 M_{\odot}$. Consequently, it has been lost $\sim 6 M_{\odot}$ during the first Roche-lobe-filling phase and only 10 % of this mass ($0.6 M_{\odot}$) has been added to the secondary component. The main part of this matter has been lost from the system. In this way, the initial mass of the secondary component is $\sim 3.0 M_{\odot}$, and the total initial mass of the system is $8 M_{\odot} + 3 M_{\odot}$.

The main difficulty in calculating the initial orbital elements is to determine the angular momentum loss from the system during the mass transfer event. We have estimated the initial semimajor axis, assuming that (according to Masevich and Tutukov (1988)), the energy required for the matter ejection from the system is taken from the orbital energy of the system:

$$\alpha_{CE} M_{1R} M_2 / A_f = M_{10}^2 / A_0,$$

where A_0 and A_f are the initial and final semimajor axes, respectively, M_{10} and M_{1R} are initial and final masses of the Roche-lobe-filling component, M_2 is the mass of the companion, α_{CE} is the efficiency of the transformation of the orbital energy into the energy required to eject mass from the system, $\alpha_{CE} = 1$. By using the numerical values, we obtained $A_0 = 410 R_{\odot}$, and the initial period of the system (according to the Kepler third law) $P_0 = 293$ days. It should be noted, that due to the considerable uncertainty of the parameters α_{CE} and M_{10} , M_2 , the obtained value A_0 can be some less than in reality. However, even a small increase of the initial semimajor axis can be the reason, that the primary fills its Roche in a case C event with the white dwarf formation after a common envelope phase. While in the case B event, the helium star is formed at first.

Table 1. Absolute dimensions of V 367 Cygni

Parameter	Our results			Results of Li and Leung (1987)	
	Component 1	Component 2		Component 1	Component 2
		Roche model	Disk model		
A, R_{\odot}	53			93	
M, M_{\odot}	2.3		3.6	19	12
R, R_{\odot}	18	19.6	21.5	39	31
$L, \text{erg/s}$	$24 \cdot 10^{37}$	$1.3 \cdot 10^{37}$	$1.7 \cdot 10^{37}$	$9.4 \cdot 10^{37}$	$2.4 \cdot 10^{37}$
T, K	12000	9850	10100	11600	9300
$R(\text{ZAMS}), R_{\odot}$	2		3	6	4
$L(\text{ZAMS})e/s$	$0.9 \cdot 10^{35}$	$0.5 \cdot 10^{36}$		$3.1 \cdot 10^{38}$	$5.1 \cdot 10^{37}$

Table 2. Orbital elements of V 367 Cygni

Parameter	Our results		Abt(1954)	Heiser(1961)	Aydin et al.(1978)
	Component 1	Component 2	Component 1		
$K, \text{km/s}$	86.7	55.2	51.3	93.2	96.5
$\gamma, \text{km/s}$	1.6	1.6	-2.8	-4.6	15.0
ω	65.8	65.8	-	-	-
e	0.06	0.06	0.07	-	0.03
$A_{\text{ini}}, 10^6 \text{ km}$	22.14	14.09	13.1	23.8	24.7
$M \sin^3 i, M_{\odot}$	2.14	3.36	-	-	-
$f(M)$	1.24		0.259	1.56	1.72

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