HOT SPOT IN THE SYMBIOTIC STAR CH Cyg?

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ABSTRACT. A model of the "hot spot" emission region in the symbiotic star CH Cyg during the maximum of activity (1981 - 1984) is presented. The possibility of this emission region in a such extensive system (P_{orb}=5700 days) can be very important for study of the mass transfer problem in the symbiotic stars.

1. INTRODUCTION

The observed spectroscopic and photometric characteristics of the symbiotic stars indicate complicated displacement, dynamics and evolution of the circumstellar matter in these long period interacting binaries. The radial velocity curves are a typical example. Their false shape and phase shift (e.g. Chochol and Vittone, 1986; Mikolajewska, Kenyon and Mikolajewski, 1989) as well as the sudden changes of the radial velocities which are sometimes phase dependent (e.g. Chochol and Grygar, 1987; Skopal, Mikolajewski and Biernikowicz, 1989; Skopal et al., this volume) are currently observed. Very complicated behaviour of the radial velocities shows especially, emission line spectrum.

The symbiotic star CH Cyg is a very good example of that. Recently, Skopal, Mikolajewski and Biernikowicz (1989) summarized and analysed the radial velocities of the observed spectral lines in CH Cyg. Approximative quantitative interpretation of the radial velocities of the emission Fe II lines have been made by Skopal (1990).

Present work is continuation of the paper last mentioned. The author have elaborated more accurate mathematical description of the radiation of the region of the collision of the mass transfered from the cold component with the accretion material. For the sake of brevity, the term "hot spot" is used for this region.

2. APPROXIMATION OF THE EMISSION REGIONS

In a view of the complexity of the Fe II emission line profiles, they will be assumed to be formed in different regions of the CH Cyg system during the last phase of the activity (1977-1984). As the main emission regions for this model were considered: 1. The outer parts of the accretion disk-envelope around the hot component; 2. The stellar wind from the cool M giant in the vicinity of the hot component and 3. The region of the collision of the mass transferred from the cool component with the accretion disk-envelope, so called "hot spot". Their evolution during the phase of the activity and action in the model have been discussed by Skopal (1990). Schematically it is shown in Fig. 1. U light curve during these period should characterize the size of the accretion disk-envelope, and then the interaction intensity in the system. Therefore, based on its behaviour, a consideration about the action of the individual emission regions have been provided.

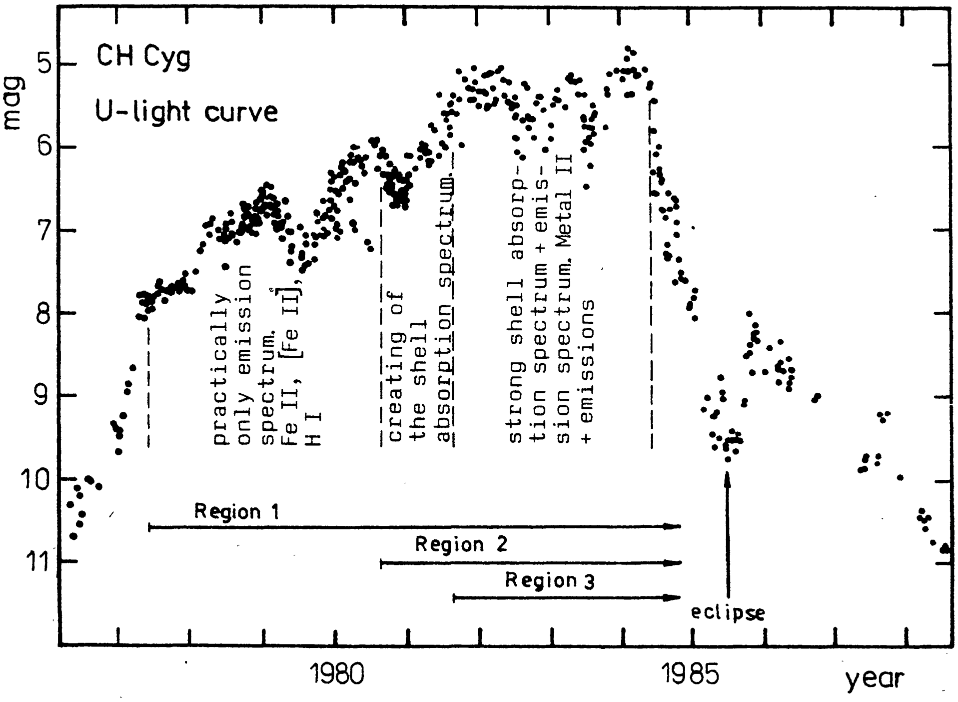

Fig. 1. U light curve of CH Cyg during the period of the last outburst. The action of the individual emission regions is schematically shown.

The resulting line profile is given by the sum of the individual region contributions. For the sake of simplicity, the line profiles of the emission regions 1 and 2 has been approximated by a Gauss curve:

$$I_{1/2}(\lambda) = (I_{1/2}(t)/(\sigma_{1/2}\sqrt{2\pi}))\exp[-(\lambda - a_{1/2}(t))^2/2\sigma^2_{1/2}] \quad (1)$$

$I_{1/2}$ representing the relative intensities and $\sigma_{1/2}$ their halfwidths. The shifts $a_{1/2}$ at wavelength λ_0 of these curves represent their radial velocities and are expressed by relations:

$$(2)\qquad \begin{aligned} a_1(t) &= \lambda_0(RV_{orb}(t) + \gamma + K)/c \\ a_2(t) &= \lambda_0(W\cos\varphi(t) + \gamma)/c \end{aligned}$$

$RV_{orb}(t)$ is the radial velocity of the hot component in orbit, γ is the gamma velocity, constant K = -5 km/s was determined from observations, vector W represents the stellar wind from the cool to the hot component and c is the light velocity. The relative positions of the components in the binary is determined by the phase angle

$$(3)\qquad \varphi(t) = \omega_c + \nu + \frac{1}{2}\pi$$

where ν is the proper anomaly and ω_c (2.426 rad) the length of the periastron of the cool component. ($\varphi(t) = 0$ corresponds to the eclipse of the hot component by the cool component).

The radiation of the region 3 is generated by the collisional ionisation of the accretion disk-envelope with the particles of the matter transfered from the cool component (stellar wind?). Geometry of the "hot spot" is schematically shown in the Fig. 2. Its total radiative contribution depends on its size (defined by angle θ_0), its visible part (S_v), its radiative substantiality per unit surface (I_0) and its limb darkening (parameter u).

Further, we introduce the inertial (fixed) system of Cartesian coordinates (x, y, z) with the origin at the centre of the hot component mass, the x-axis coincides with the line of sight, while the z-axis is perpendicular to the plane of the orbit. The rotating system (x', y', z') with the same origin, z'= z, and x'-axis of which coincides with the line joining the centres of the two components. Spherical coordinates $r(\equiv 1)$, θ, i and $r(\equiv 1)$, ϑ, ε are introduced to express easily the "hot spot" geometry (Fig. 2). Transformation between these two systems is defined by the Eulerian angles. Fixed Eulerian angles (between the z and z' axis and, between the x-axis and the line of nodes) are possible to be assumed 0 (eclipsing system). Consequently, the angle defining the cold component position (in our case) is given by phase angle φ (relation 3).

Let us assume that the radiation intensity of the "hot spot" surface element $ds = \sin\theta\, di\, d\theta$ can be expressed by the same relation as the continuum radiation. Then the intensity in the direction (θ, i) is

$$(4)\qquad dI(\theta,i) = I_0(1 - u - u\cos\alpha)\, ds$$

where α is the angle between the normal of the "hot spot" surface and x-axis. Resulting radiation flux of the visible part, S_v, of the "hot spot" is then

$$(5) \qquad I_3(\lambda) = \int_{S_v} \Psi(\lambda,\theta,i)\,dI(\theta,i) \quad .$$

The condition of the visibility of the "hot spot" surface element is determined by the unequality

$$\cos\alpha > 0.$$

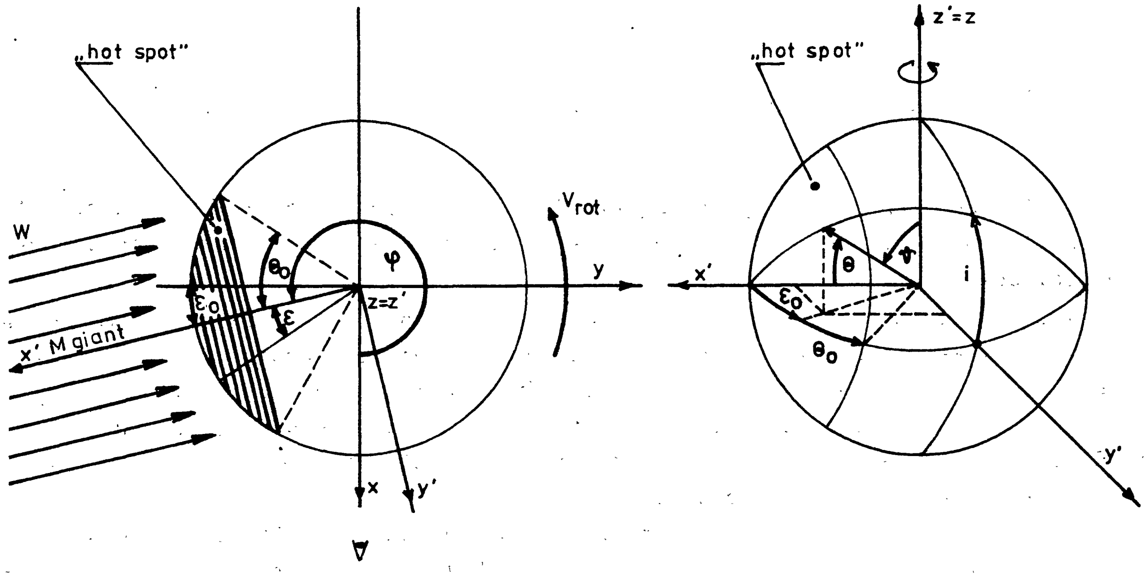

Fig. 2. Schematic picture of the emission "hot spot" region. The rotating system (x',y',z') with this region and the fixed system (x,y,z) of Cartesian coordinates are introduced. Spherical coordinates $r(\equiv 1)$, θ, i and $r(\equiv 1)$, ϑ, ε are introduced to express easily the "hot spot" geometry. Its position is determined by the phase angle φ. The mass transferred from the cool to the hot component is represented by the vector W. Vector V_{rot} represents the rotational velocity of the accretion disk-envelope.

The element line profile is assumed to be approximated by Gauss curve:

$$(6) \qquad \Psi(\lambda,\theta,i) = 1/(\sigma_3\sqrt{2\pi})\exp(-(\lambda - \frac{\lambda_0}{c}(RV(\theta,i) + RV_{orb} + \gamma))^2/2\sigma_3^2)$$

where RV(θ,i) is the vector's field of the radial velocities of the "hot spot" defined by the relation:

$$(7) \qquad RV(\theta,i) = V_{rot}\sin\vartheta(\theta,i)\cos(\varepsilon_0 + \varepsilon(\theta,i))$$

where

$$(8) \qquad \begin{aligned} \vartheta(\theta,i) &= \arccos(\sin\theta\sin i) \\ \varepsilon(\theta,i) &= \mathrm{arctg}(\sin\theta\cos i/\cos\theta) \end{aligned}$$

and V_{rot} is its "equatoreal" rotational velocity and angle $\varepsilon_0 = \varphi - \frac{3}{2}\pi$ (see Fig. 2 and relation (3)).

3. RESULTS AND DISCUSSION

The resulting theoretical profile (the sum of the relations 1 and 5) has been analysed numerically. The maximum of the profile corresponds to the spectral line intensity and its shift to the radial velocity. Radial velocity has been determined from the points of intersection of the profile with the dispersion parallel line. This was described by Skopal (1990) in more detail.

Table 1

RESULTING PARAMETERS OF THE MODELLING LINE PROFILE

Parameter / Region	I	σ	θ_0 [rad]	V_{rot} [km/s]	W [km/s]	u	R [1)]
accretion disk-envelope (1)	0.1	0.2	-	-	-	-	-
stellar wind (2)	0.25	0.2	-	-	13	-	-
"hot spot" (3)	-	0.4	0.7	80	-	0.5	0.9

1) $R = I_0/(\sigma_3\sqrt{2\pi})$

The result of this analysis is the set of parameters characterising the theoretical profile of the spectral line (Tab. 1). Comparison of the theoretical profile of the selected emission Fe II 423.3 nm lines, their intensities and radial velocities to the observed values is shown in Figs. 3, 4 and 5.

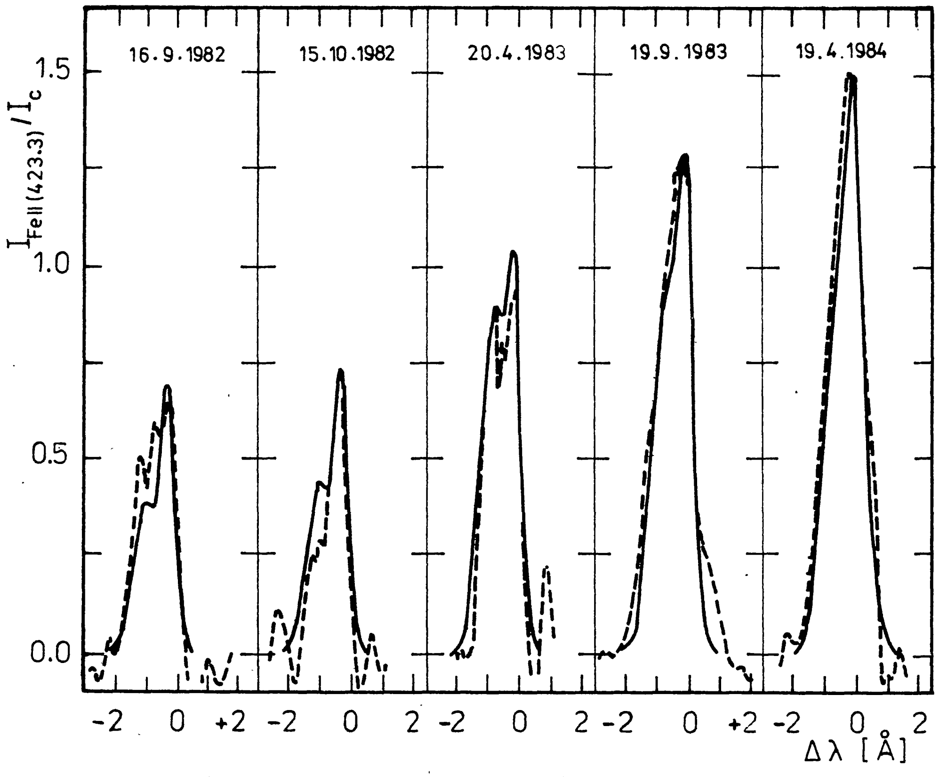

Fig. 3. Calculated (full line) and observed (broken line) profiles of the emission Fe II 423.3 nm line for the selected observations during the maximum of the star's activity.

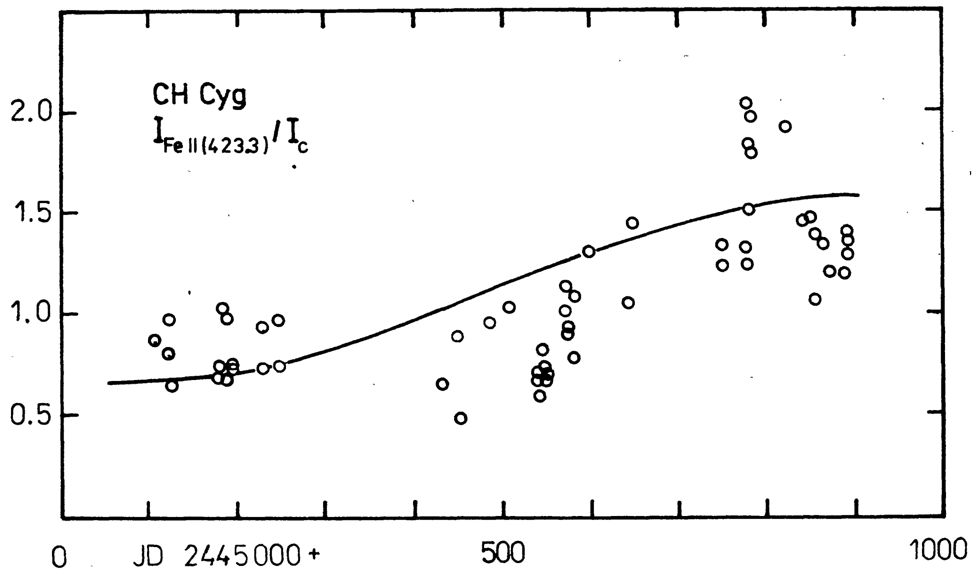

Fig. 4. Relative intensities of the emission Fe II 423.3 nm line. Values were taken from Skopal et al. (1989) and full line represents the model. I_c is the local continuum intensity.

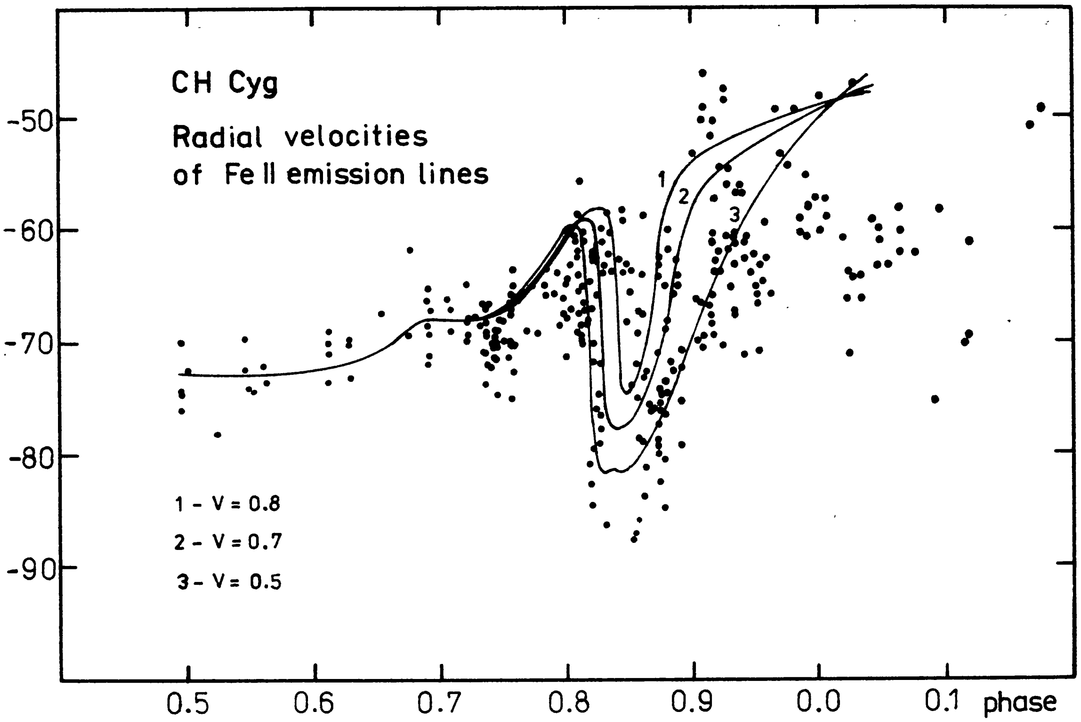

Fig. 5. Radial velocities of the emission Fe II lines and their model computed for three cuts of the spectral line (curve 1 - cut in high 0.5, 2 - 0.7 and 3 - 0.8).

The possibility of the "hot spot" existence in such an extensive system (P_{orb}= 5700 days) can be very important for understanding of the mass transfer problem in the symbiotic stars generally. If we accept the mass transfer by the stellar wind, a problem between the rather small value of the wind-driven mass loss rates and an energetic strong interaction, can arise. On the contrary, the mass transfer by the gaseous stream needs the closer system to contain a lobe-filling giant, as it is now generally considered. Earlier (Skopal, 1988) showed that the red giant in the symbiotic star CH Cyg can fill its Roche's limit in the case of asynchroneous rotation and elliptical orbit. So there is a possibility to solve this problem. In the case of CH Cyg, a model of the concentrated stellar wind between the binary components, might be the probable cause of the "hot spot" creation during the star's maximum activity.

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