CH CYGNI - A WHITE DWARF AND M-GIANT BINARY WITH TRANSIENT ACCRETION DISK

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The unusual variable star CH Cygni was an object of numerous investigations over past ten years. The aim of the present paper is to give a summary of the most important observational data and to discuss briefly a double star model of CH Cygni which is in general accordance with observational facts.

1. Review of observations. In Fig. 1 the UBV light-curve is given according to the observations by Cester (1972) and Luud et al. (1977, 1979). The light-curve in the filter V is one of the semiregular red giant variables with unusually long period about 700 days. The U-B curve

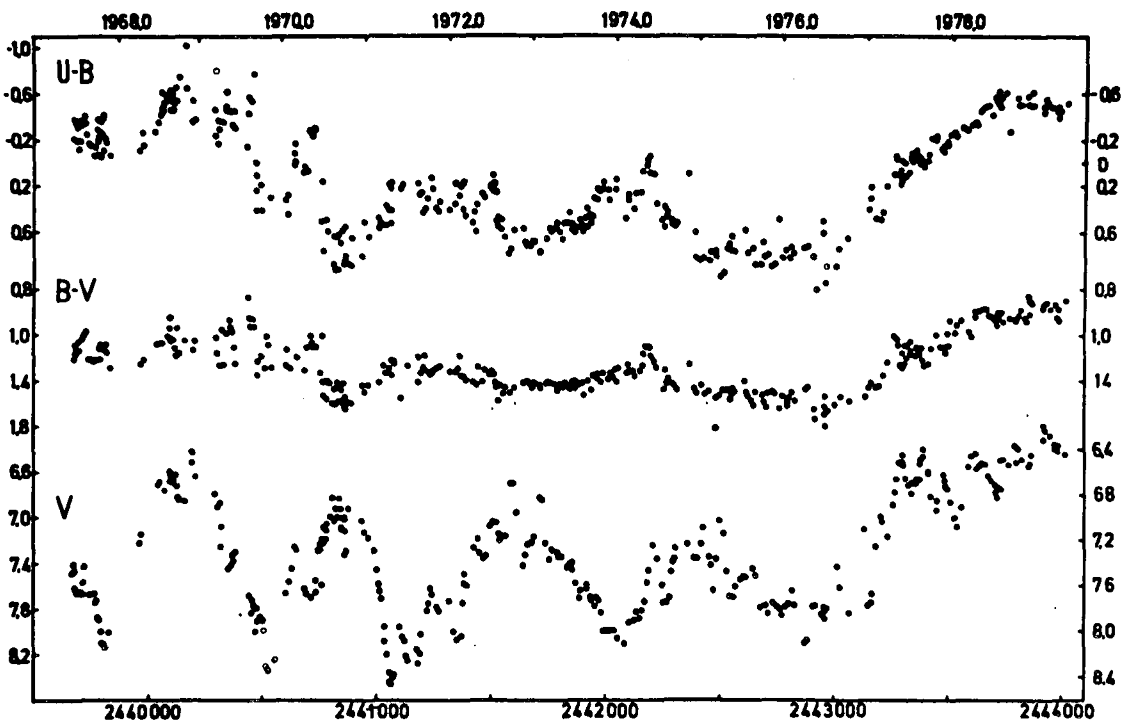

Fig. 1.

https://doi.org/10.1017/S0252921100076375 Published online by Cambridge University Press

shows the varying presence of strong ultraviolet excess. On the two colour diagram CH Cygni occupies the area of composite objects consisting of a M-giant, a hot continuum source and gas (Luud et al. 1977). The behaviour of colour of CH Cygni during maxima without ultraviolet excess is similar to the normal M-giant variable.

When U-B $\leq$ -0.2 the rapid flickering of ultraviolet flux is present (Luud 1970, Luud et al. 1977, Slovak and Africano 1978 and references given in the cited papers). Radio flux from CH Cygni is below the limit of detection (Kazés 1968 and Sun Kwok 1978).

In the periods of ultraviolet excess presence the spectrum of CH Cygni is a combination of gM6 star spectrum, hot continuum and emission lines of H, HeI, FeII, [FeII]. During the periods without colour excess the spectrum is a pure gM6, even Hα is in absorption.

An unsuccessful attempt to find out periodical changes of radial velocities was made by Deutsch et al. (1974), the range of nonperiodical changes found was 30 km/s. The intensities of Balmer lines permit approximate evaluation of physical characteristics of emitting gas (Fig. 2). The intensities of red and violet components of hydrogen lines were contrary during 1967-69 and 1977-79 active periods (Fig. 3). The separation of hydrogen line components was approximately 140 km/s.

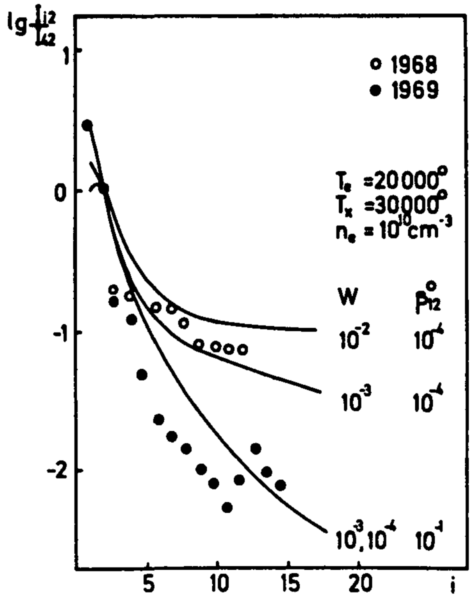

Fig. 2.

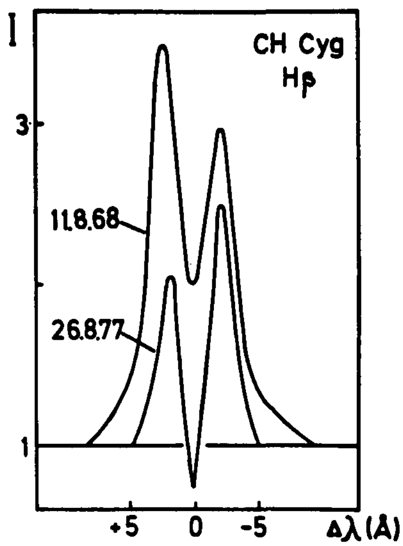

Fig. 3.

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2. Possible single star models. Two kinds of single star models can be proposed: a) multiple flares and b) hot corona excited by shock waves. Case a) must be turned down, since the observable radio flux is absent (Luud et al. 1977) and case b) must be rejected since the bolometric variability of CH Cygni is not in accordance with such a model (Luud 1979 a,b).

3. Double star model. What is the hot companion? According to the spectroscopic and photometric data the cold component is a semiregular M6III star. The hot star cannot be luminous because during the inactive minima it is not detectable. The spectrum of CH Cygni is similar to the spectrum of a symbiotic star, but the hot component must be less luminous than the classical hot component of a symbiotic star since then the emission lines from the Strömgren sphere of the hot component must always be present as strong lines, even when the hot component eclipses. Only a white dwarf or even a less luminous star has a Strömgren sphere small enough to remain nondetectable in emission lines (Luud 1979 a,b). According to Mullan (1978) the mass loss of gM6 semiregular star is $3\times10^{-8} m_{\odot}$ /yr. Assuming that the splitting of Balmer lines is caused by their formation in the accretion disk, it is possible to evaluate that its radius equals to $\sim 200\ R_{\odot}$. To maintain such a disk we need approximately $1.5\times10^{-8} m_{\odot}$/yr. Therefore, nearly all the mass lost by red giant must come to the hot component. This is possible only during the brighter maxima when the red giant fills its Roche-lobe and the mass is transported to the accretion disk by a gas stream.

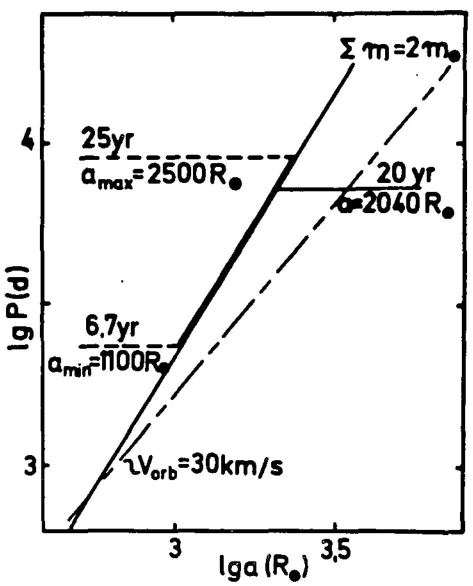

Fig. 4.

Assuming that the cold component is during active maxima $0^{m}.5$ brighter than during inactive ones, we can evaluate that $L_{hs} \approx 2\times10^{36}$ erg/s. According to the formula of gravitational energy supply $L = \eta \dot{m} c^2$ we obtain $\eta \approx 2\times10^{-4}$. According to Sunyajev and Shakura (1974) $\eta \leq 3\times10^{-4}$ for accretion to white dwarfs. Energetics are balanced for CH Cygni model.

4. Geometry of CH Cygni model. The maximal orbital velocity is in the range of 30 km/s. On the lg P versus lg a diagram the v = 30 km/s. line of orbital velocity and $\Sigma m = 2 m_{\odot}$ from Kepler's law define a possible locus of CH Cygni (Fig. 4). The radius of CH Cygni according to Gusev

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(1977) equals 410 $R_\odot$, which is in good accordance with Tsuji's (1978) scale for M6-7 III. Therefore, the pair must be wider than the minimum allowed by dynamics, because the close pair must give permanent mass overflow. The only way to go ahead in solving our crossword puzzle is to assume that during the 1967-69 activity with large variations of ultraviolet flux the hot spot was seen, but during 1977-79 activity it was not seen. Therefore, the pair was seen from opposite directions and the time interval $\sim$ 10 years is probably multiple of a half-period. The estimates of possible half periods are the following: 20, 6.7, 4, 2.8 and 2.2 years. This corresponds to the distances between the stars 2040 $R_\odot$ and 750 $R_\odot$. If the ratio of masses is 1, the radius of Roche-lobe equals to 0.37 of the distance between the stars. Adopting $R_{M6III} = 410 R_\odot$, we have that $a > 1100\ R_\odot$ and $P > 6.7$ years. It is improbable that the period of 6.7 years can cause triggering between overflow and non-overflow maxima. This is possible only in the case when the red giant's radius is moderately smaller then the Roche-lobe, hence the maximal possible period is $\sim$25 years and we may believe that the estimated period $\sim$20 years is a real one. This model is presented on Fig. 5.

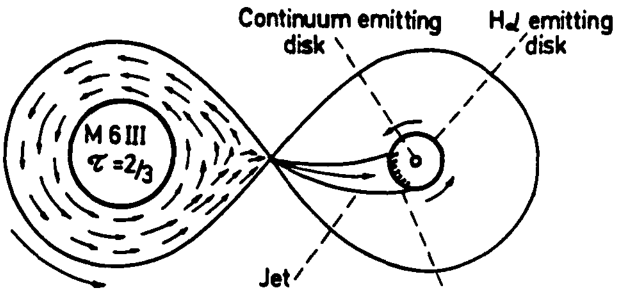

Fig. 5.

5. Some predictions for prospective observations. There exist possible mechanisms to produce X-ray radiation from CH Cygni. Assuming that the inner part of the accretion disk which emits continuously has a spectral distribution of energy which accords to the calculated accretion disk energy distribution by Sunyajev and Shakura (1974) the flux in soft X-rays may be $\sim$ 0.1 Jy in the presence of strong ultraviolet excess (the flux in hard X-rays is $\sim$ 100 times lower). The X-rays may be also emitted by the hot spot. Following Shklovski's (1967) scheme, we find that in the 10 keV range the flux equals $10^{-3} - 10^{-6}$ Jy and it is present during rapid ultraviolet variations.

The distance between the components, 2000 $R_\odot$, and the distance to the star, 330 pc, (Luud 1979 a,b) give for the maximum angular separation 0".03, detectable by speckle interferometry.

The author is grateful to his colleagues whose assistance made the long-lasting investigation of CH Cygni possible.

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