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A New Outburst Stage of the Symbiotic Triple-Star System CH Cygni

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Abstract. We present the HST imaging, the VLA radio map (5 GHz), plus optical high-resolution (echelle) spectroscopy and the U photoelectric photometry of the symbiotic star CH Cyg obtained during its 1998-2000 active phase. The HST image shows the central stars are embedded in a nebula extended to $\sim$620$\pm$150 A.U. The nebula is a product of the recent 1998 outburst. The flux contours of the radio VLA observation follow well the shape of the optical HST image. Photometric observations revealed an eclipse of the active star in the inner binary (the symbiotic pair) by the cool giant on the outer, 14.5-year period orbit. Evolution of the spectrum and variation in the hydrogen line profiles result from an irregular, high-velocity ($\sim$1 200 km s^{-1}) mass outflow from the central star.

1. Introduction

CH Cyg is the most enigmatic object among other symbiotic stars. Symbiotic activity was recorded for the first time at the beginning of the 1960s. Since 1963 CH Cyg has displayed a series of active phases, starting with a sudden 2-3 mag brightening in the U band (Fig. 1). During stages of activity CH Cyg develops a low excitation line spectrum and exhibits different types of mass outflows.

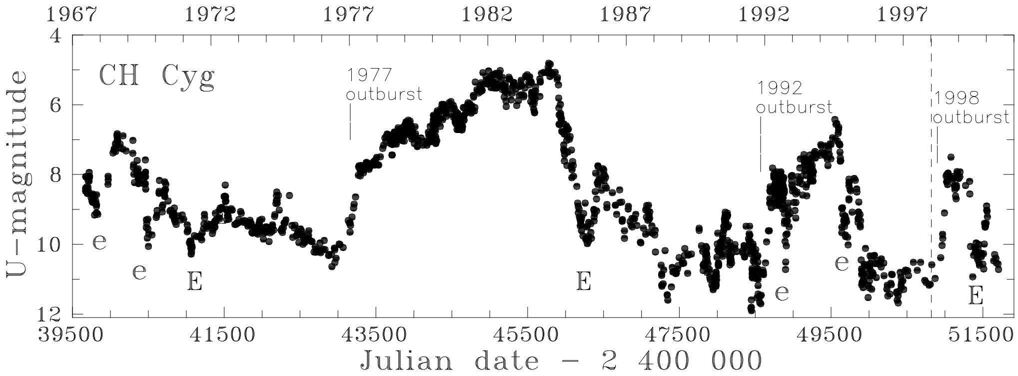

Figure 1. The U light-curve of CH Cyg during its symbiotic life. Eclipses in the outer and the inner binary are denoted by **E** and **e**, respectively.

During quiescent phases the symbiotic phenomenon practically disappears, the spectrum resembling that of an M giant.

Recent studies suggest that CH Cyg is an eclipsing triple-star system consisting of the inner, 756-day period binary (the symbiotic pair, which is responsible for the observed activity) and another cool giant revolving around it on the long, 14.5-year period orbit (Skopal et al. 1996, 1998b; Iijima 1998; original suggestion of a triple-star model was set by Hinkle et al. 1993).

In our contribution we present the optical observations (HST image, high-resolution spectroscopy and the U photometry) and the VLA 5 GHz radio observation obtained during the latest, 1998-2000, active phase of CH Cyg.

2. Observations and results

2.1. Optical photometry

New photoelectric photometry covering the recent 1998-2000 outburst of CH Cyg was performed at the Skalnaté Pleso and Stará Lesná Observatories. Figure 1 shows the U light-curve recorded during the symbiotic life of CH Cyg, which demonstrates best its activity. The recent outburst began in 1998 May and ended in the spring of 2000. Between 1999 June and 2000 January we detected about 2-mag deep minimum in the U band. Its *position* (it appeared close to the inferior conjunction of the giant in the outer orbit), its *duration* for 6-7 months and *colours* were similar to those observed in 1971 and 1985. Therefore we suggest that the minimum was caused by the *eclipse* of the active star in the symbiotic pair (i.e. the inner binary) by the giant star on the outer long-period orbit. Positions of these minima (Fig. 1) determine their ephemeris as

$$JD_{\rm Min}(Phot.) = 2\,435\,985 + 5\,147(\pm 3.2) \times {\rm E}. \qquad (1)$$

2.2. Optical spectroscopy

Our high-dispersion spectroscopy was secured at the Asiago and Nizhnij Arkhyz Astrophysical Observatories. Here we present spectra obtained on 1998 Septem-

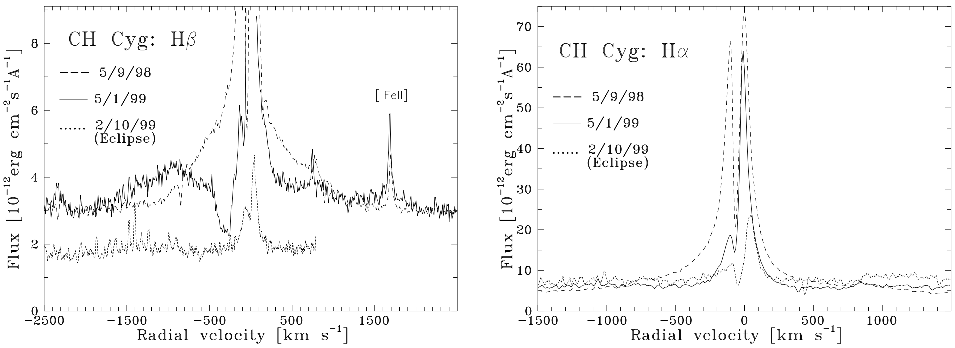

Figure 2. Variation in the Hβ (left) and Hα (right) profiles. Two types of the mass outflow from the active star were present: (i) Radiative driven high-velocity hot star wind (5/9/98), and (ii) a massive outflow indicated through the P-Cygni type of the profile (5/1/99).

ber 5, 1999 January 5 and 1999 October 2. The last one was taken during the eclipse in the outer orbit (Sect. 2.1). The recent active phase of CH Cyg was characterized again by a low excitation shell spectrum with prominent H I emission lines in the optical domain. Figure 2 displays significant variations in the Hβ and Hα lines. On 1998 September 5 we observed double-peaked profiles, symmetric with respect to the central absorption, superposed on a broad emission extended to about $\pm 1\,200\,\mathrm{km\,s^{-1}}$. The very broad emission suggests the presence of a high velocity hot star wind, while the double-peaked central part of the profile is probably connected with an accretion disk around the hot star. The latter is in agreement with previous work of Skopal et al. (1998a). On 1999 January 5 we detected a dramatic change in the hydrogen profiles. A complex absorption/emission structure, basically of the P-Cygni type, had developed on the blue side of Balmer lines. Such massive outflow, which entirely destroyed the blue wing of the emission profile resembles that currently observed during outbursts in other symbiotics. At present, the physical nature of such activity is rather uncertain. This evolution reflects an *irregular* mass outflow from the central star. Finally, on 1999 October 2, emission in the hydrogen lines significantly decreased and the profiles lost the main characteristics observed on previous spectra. This was due to the eclipse effect.

2.3. HST and VLA observations

Our HST and VLA observations of CH Cyg were made during its recent activity on 1999 August 12 and 1999 September 26, respectively. Figure 3 shows an example of the nebula surrounding the CH Cyg system exposed by the HST through the F502N WFPC2 filter, which is dominated by the [O III]4959+5007 Å lines. The inner part of the nebula is rather spherical, while its outer parts are more irregular, generally elongated in the ~N-S direction. Shaping of the HST nebula is in very good agreement with the radio VLA emission measured at 5 GHz. The nebula has a complex density structure. The most distant clump is located around $\alpha = 19^h\,24^m\,33^s.1$, $\delta = 50^\circ\,14'\,28''.0$, in the south.

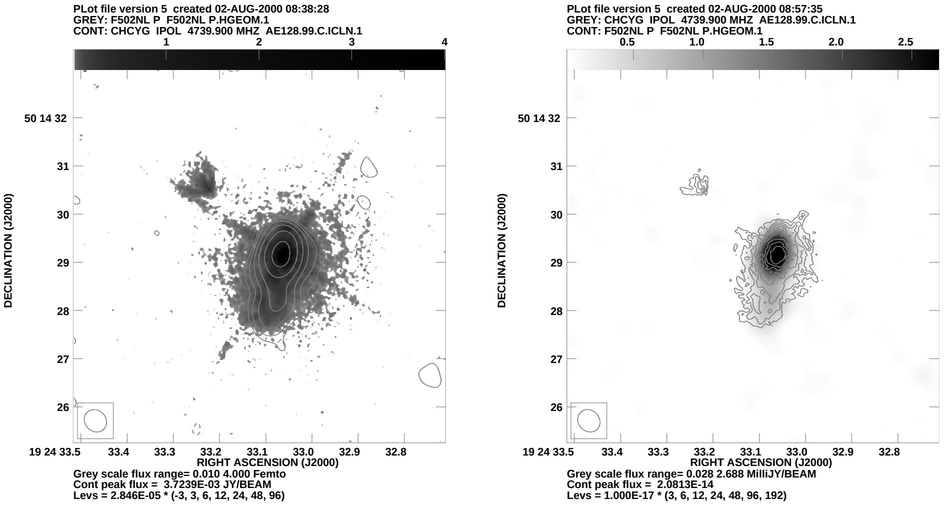

Figure 3. Left: The HST image made on 12/8/99 in the F502N filter (around the [O III]4959+5007 Å lines). Fluxes are in $\log(\mathrm{erg\,cm^{-2}\,s^{-1}\,arcsec^{-1}})$. Superimposed are the flux contours of the VLA 5 GHz radio observation made on 1999 September 26. Right: The same as left, but the flux contours of the HST image are superimposed on the radio emission. The feature to the NE of the main nebula is an artifact of the F502N filter.

The measured extension of the nebula, $\sim$2.3 arcsec, corresponds to its real dimension of $\sim$620$\pm$150 A.U., for the distance to CH Cyg of 270$\pm$66 pc (Viotti et al. 1997). The mass outflow at $\sim$1 200 km s^{-1} (Fig. 2.) suggests that the nebula around CH Cyg seen on our HST image is the product of the recent 1998 outburst. If the outer radius of $\sim$310 A.U. is extrapolated backward at this velocity, an ejection epoch of 1998 May/June is obtained, which coincides with photometric detection of the outburst. This is valid if the physical boundary of the nebula is equal to the ionization boundary.

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