Bulgarian Journal of Physics **27** No 2 (2000) 20--23

HIGH–VELOCITY OUTFLOWS IN SYMBIOTIC SYSTEMS

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Abstract. Some peculiar symbiotic and symbiotic-like systems showing different levels of activity demonstrate occasional high-speed bipolar jets and/or centrifugal outflows. Recently, the existence of a new subclass of interacting binaries – *propellers* – was proposed. The supposed prototypes – CH Cyg and MWC 560 – are among the most intensively investigated now peculiar symbiotic binaries. We present some results concerning the high-velocity outflows in both symbiotic systems. Some parameters of the outflows in both systems are given.

1. Introduction to the symbiotic propellers

The later catalogue [1] lists 188 symbiotic stars (SSs) and 28 suspected SSs. Their spectra show absorption patterns typical, usually, for late type M-giants – neutral and single ionised metals and molecular bands; strong emission lines of HI and HeI; permitted and forbidden emission lines of moderate ionization potential; when in outburst, a relatively hot continuum resembling that of an A–F type photosphere together with some nebular emission lines appears in the SSs spectra. The peculiarity of the SS spectrum is well understood in the frame of a model of an interacting wide binary system containing a red evolved giant that transfers matter to a white dwarf (WD). Both components interact in their common evolution exchanging mass and angular momentum. The wide separation between the components of the systems determines the mass transfer to be via stellar wind. WD in the SS having mass of 0.5–1 solar masses (M_s) and the mass-ratio M_{RG}/M_{WD} is up to 2–3. Two main types of SSs are distinguished: a "starlike" S-type (resembling the normal red giants) and a "dusty" D-type (like Mira giants with dusty envelopes and with an excess in IR). The orbital period in the D-symbiotics is larger (10 to 100 y) than this in the S-symbiotics (1–15 y). Nevertheless of the differences, both types of symbiotic stars show similar events that indicate the commonness of the processes in all SSs.

The WD captures of about 1–2 % of the total streaming wind. The falling onto the WD surface abundant in hydrogen material usually causes TNR-release of the accumulated energy. However, for some systems where the accreted matter has a great enough angular momentum, it is possibly an accretion disk (AD) to be formed around the WD.

A few of SSs show peculiarities like a rapid variability of the brightness (flickering) and appearance of high-velocity outflow. Such an activity can be connected with the accretion. Conditions appear there for manifesting of different physical mechanisms: stellar wind; jet outflows or ejection of separate "clouds" or "blobs" of matter; etc. The model of the gravimagnetic rotator (GMR) advanced earlier for these SSs [2] explains many of their peculiarities. In such a system the WD possibly is magnetic (the known magnetic WDs have a dipole field B~10^6–10^8 Gs). The rapidly rotating *as a rigid structure* WD magnetosphere interacts efficiently with the accreting plasma and we can observe the expelled matter as blobs, as well as a flickering. It was proposed such system to be called "propellers" [2]. The different accretion rate possibly determines the different activity as a result of an interaction between the accreting flow and the GMR. Until the ram pressure of the flow ($\sim\rho V^2$) does not exceed the magnetic pressure ($\sim B^2$) the magnetosphere efficiently expels matter out of the accretion complex and there is not accretion on the WD surface. Reaching the critical values for the pressure, the accumulated matter penetrates the magnetosphere and an accretion through the magnetic lines onto the WD surface begins. The released energy grows rapidly as well. Different kinds of ejection – winds, jets or centrifugal outflows – provide efficient releasing mechanisms. The accelerating mechanisms are still not entirely clear but it is out of doubt that the magnetic field can canalise and accelerate the plasma.

2. Prototypic stars for symbiotic propellers

The shape of the spectral lines can be indicator for outflows. We present here examples of the line profiles in the spectra of the prototypic propeller stars: the S-type symbiotic stars CH Cyg and MWC560. Both systems are among the most widely studied SSs during the last decade and demonstrate common characteristics. They present complemented examples: the eclipsing binary CH Cyg is observed in the orbital plane while the orbital plane of MWC560 is almost perpendicular to the line of sight [2]. The most frequently cited parameters (see [2]) of both systems are as follows. For CH Cyg: distance d = 300 pc; $P_{orb} \approx 5700^d$ (15.5 y); eccentricity $e \approx 0.3–0.5$; i = 90°; cool star – M6-M7III with M_{RG} = 0.8 – 2 M_S; a WD of 0.7 M_S; outburst luminosity L $\approx$ 300 L_S. For MWC 560: d = 1–2 kpc; $P_{orb} \approx 2000^d$ (5.5 y) (probably); eccentricity - high (?); i < 10°; cool star – M4-5III, hot companion – WD; maximum outburst luminosity 300 – 1000 L_S. Both systems are wide separated binaries. Their giants do not fill its Roche lobes, that determines an accretion from stellar wind. The GMR-geometry of both stars, however, differs: the inclination between the rotational and magnetic axes probably is less than 5° for MWC 560, while in CH Cyg this angle can reach 45° [2].

For CH Cyg the bipolar high-velocity outflows are hardly detectable due to the low jet brightness and the coincidence of the emission components and the central line structure from the hot stellar component. The jets in CH Cyg were observed in radio [3] and in optics [4]. Recently the nebula was directly observed in optics [5]. Spectroscopic evidences for presence of mass ejection with different radial velocities (from hundreds to thousands of km/s) were also reported [6]. The visibility of MWC560 orbit impedes to study the orbital elements but affords an ideal opportunity to register the rapidly moving ejection directed toward us. They are projected as an absorption column on the pseudo-photosphere of the hot source. The Doppler shift separates the spectral components from the central structure and allows the detail investigation of their speed-shape.

3. Extremely high-velocity jets from MWC560

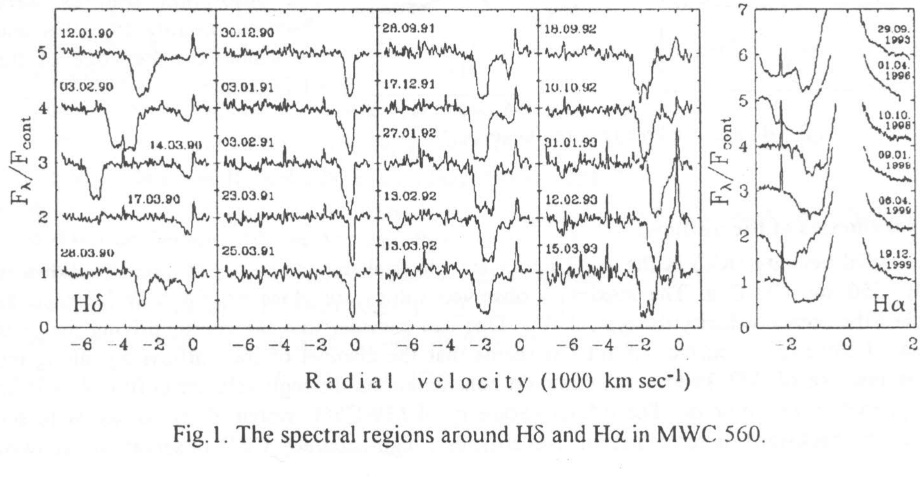

Fig.1. The spectral regions around Hδ and Hα in MWC 560.

Examples of the Balmer line Hδ and Hα are presented in Figure 1. The study of the star in NAO "Rozhen" began since Jan 1990. Until 1994 the spectral data (region 3500-5000 ÅÅ) from the coude- spectrograph of the 2-m telescope were obtained photographically, while since that time we use CCD-cameras in selected spectral intervals, mostly around Hα and Hβ. The different regimes of outflow are well established: *"discrete"* high-velocity (up to 7000 km/s) jets during January – April 1990; *"quasi-stationary" regime of outflow*, with low speed (~200 km/s) jets during December 1990 – March 1991 and, since the autumn of 1991 and still now, jets with velocities 1000 – 2000 km/s. In the same time a week absorption of P Cyg type presents when the low-speed strong component absent. This slow absorption indicates a presence of *stellar wind* from the hot source formed around the WD.

4. Jets and centrifugal outflows from CH Cyg

Our observations of the forbidden line [NII] 6584 Å in 1994 detected bipolar outflow at some distance from the central object [6]. Recently the jets were registered directly [5]. The propeller's action that causes an expelling of the matter can be also observed. High-velocity (up to 2000 km/s) short-living (hours) blue- and red-shifted emission components of Hβ and blue- shifted Hα and Hβ absorptions were registered – Fig.2. They can be explain as throwing off clouds of accreting matter from the propeller [6]. The emission components can be observed more frequently than the absorption features that are visible only when are "projected" on the hot component.

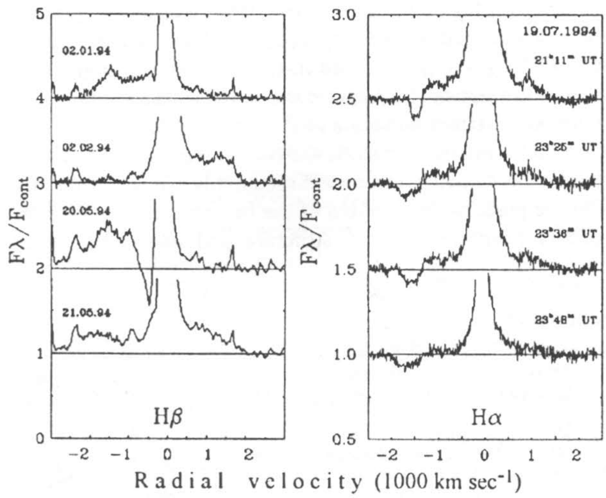

Fig.2. Emission components (in the left panel) and absorption components (in the right panel) displaying the presence of centrifugal outflows in CH Cyg. The absorption features were observed on July 19, 1994 and are visible on the edge of the CCD-frames.

5. Parameters of the outflows

The radial velocity (RV) is the most important physical parameter of the rapid outflows in MWC560 and CH Cyg. The maximum observed values are close or, for MWC 560, even exceed the escape velocity for typical WD. One can consider that the energy driving the jet is released close to the surface of WD. It seems that the channel of the outflow lies along the rotational axis of WD. From most common considerations the high-velocity outflows must be axisymmetric, i.e., *bipolar*. The orbital geometry of MWC560 system does not allow to see easily the backward directed stream. Nevertheless, high-accuracy CCD-observations allowed us to detect a week *red*-shifted *emission* component of Hα having RV equal to that of the *blue*-shifted *absorption* component [6].

The physical parameters of the outflow remain rather uncertain. The directly observed quantities are the RVs and the time-scales of the rapid photometric variability (connected to the propeller activity by the rotational period of the WD). The observed RVs (~ 1000 km/s for CH Cyg and 2000-7000 km/s for MWC 560) can be attributed to distances equal to the radius of the magnetosphere, R_m, for CH Cyg and, respectively, for R_m and R_{WD} – in the case of MWC560 [2]. The mass loss rate from the *cool stars* of both systems is estimated to a few 10^{-7} M_S [2], [8], a value, typical for the symbiotic stars. In the same time, a twice more massive can be the stellar wind from the *hot source* in MWC 560, reaching a value of about 2.10^{-6} M_S [8]. The estimations of the length of the rapid jets in MWC 560 give 10^{10}–10^{12} cm and the hydrogen concentration of 10^{11}–10^{12} cm^{-3} [7], [8]. The steep trapezoidal shape of the high-velocity absorptions testifies to high degree of collimation for the jets in MWC 560. The estimated in [7] angle of ~ 40° for the jet opening in the same star can be consider as an upper limit. The estimation for CH Cyg gives a cone angle about 10° [8].

6. Conclusions

The presence of high-velocity centrifugal and bipolar outflow in CH Cyg and MWC 560 brings up the problem of the formation of such class objects among the SSs as well as the existence of related objects. The small quota of the magnetic WD possibly justifies the expectation for the rarity of the propellers among SSs. Recently discovered high-velocity outflow in another symbiotic star, Hen3-1341 [9] and the presence of a magnetic WD in the "classic" symbiotic star Z And [10] show some promise to extend the number of such stars. In the same time the propeller-action is suspected as well in other types of binaries such as X-ray source Aquila X-1 [11] or the cataclysmic variable AE Aqr [12] making the mechanism to be natural in wide area of astrophysical conditions.

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