SHAPING OF NOVA SHELLS - THE CASE OF NOVA V 1974 CYGNI

D. Chochol, T. Pribulla
Astronomical Institute of the Slovak Academy of Sciences
059 60 Tatranská Lomnica, Slovakia
E–mail: chochol@auriga.ta3.sk, pribula@auriga.ta3.sk

ABSTRACT. Expanding shell of Nova V 1974 Cygni consists of two major components: an outer fast low-mass envelope and an inner slow high-mass envelope. The outer envelope, detected in diffuse enhanced spectra and on radio images, is shaped and accelerated by the fast wind consisting of spherical and polar components. The inner envelope, detected in nebular spectra and on the HST images, consists of equatorial ring and polar blobs. Common envelope phase and strong magnetic field of the O-Ne-Mg white dwarf play an important role in shaping of the inner envelope. Both envelopes are prolate.

Key words: Stars: novae, circumstellar matter, Nova V 1974 Cygni

Introduction

Exact mechanism which shapes the nova shells is unclear. Spectroscopy during the early phases of the outburst and high resolution radio and HST imaging, which is able to resolve the structures in the ejecta as rings, clumps, blobs and bipolar outflows allow to study the mechanism of ejection and shaping. Components of the expanding shell appear to reflect processes which take place on the scale of binary system during the outburst. Livio (1994) discussed the importance of the common envelope phase for shaping of nova shells. The mass loss which results from orbital energy deposition occurs preferentially in the orbital plane. The coupling of the nova wind and the magnetic field could also shape the nova shell (Orio et al. 1992). According to Chevalier and Luo (1994) the magnetic field in the wind from a magnetized rotating star become increasingly toroidal with the distance from the star. Toroidal magnetic tension can constrain the flow in the equatorial region, while not interfering with the flow in polar region. Slavin et al. (1996) showed the connection between the speed class of novae and shaping. The faster novae with $t_3 < 17$ days produce inhomogenous approximately circular shells with discrete randomly distributed knots of brighter emission. The slower novae tend to produce remnants having polar blobs/equatorial ring morphologies. Slower novae spend a longer time in a common envelope, so their remnants are affected more by the orbital motion of the binary than in faster novae.

Shaping of the envelope of Nova V 1974 Cyg

a) wind

Wind was detected spectroscopically in early UV spectra as double absorptions in P Cygni profiles of Mg II lines (Shore et al., 1993). Very broad absorption centered at about 2400 km/s was caused by the spherical wind, the absorption at about 4000 km/s was caused by the polar wind. Radial velocities of the components of the wind seen in UV region correspond to the radial velocities of the broad double absorptions in the HI profiles of the Orion spectrum detected in the optical region (Chochol et al., 1993) about 50 days after the outburst.

b) outer low mass envelope

The optical diffuse enhanced spectra taken a few days after the maximum light showed double absorptions in P Cygni line profiles of HI, HeI, Ca II, Fe II and Mg II lines. Each absorption can be considered to be produced in a different region of the outer envelope approaching the observer. An increase of blue-shift of double absorptions with time suggests that the outer envelope was accelerated by the wind. Radial velocities of double absorptions caused by the wind and parts of the outer envelope approaching the observer are depicted in Fig. 1. The ratio of radial velocities of absorptions caused by the spherical and polar components of the wind is the same as for the components of the outer envelope (0.596 ± 0.007), so the spherical and polar components of the outer envelope were shaped by the spherical and polar winds, respectively. The first two radio images of the outer envelope were taken by Eyres et al. (1996) at 6cm by MERLIN on days 154 and 172. The envelope was elliptical, with major to minor axis ratio 1.37 ± 0.05.

c) inner massive envelope

Chochol et al. (1993) found in the high resolution tracings of the H_β line in the nebular stage of the nova (which started 79 days after outburst) a splitting of the emission line profile into a few components corresponding to approaching and receding parts of an expanding equatorial ring and polar blobs. The same

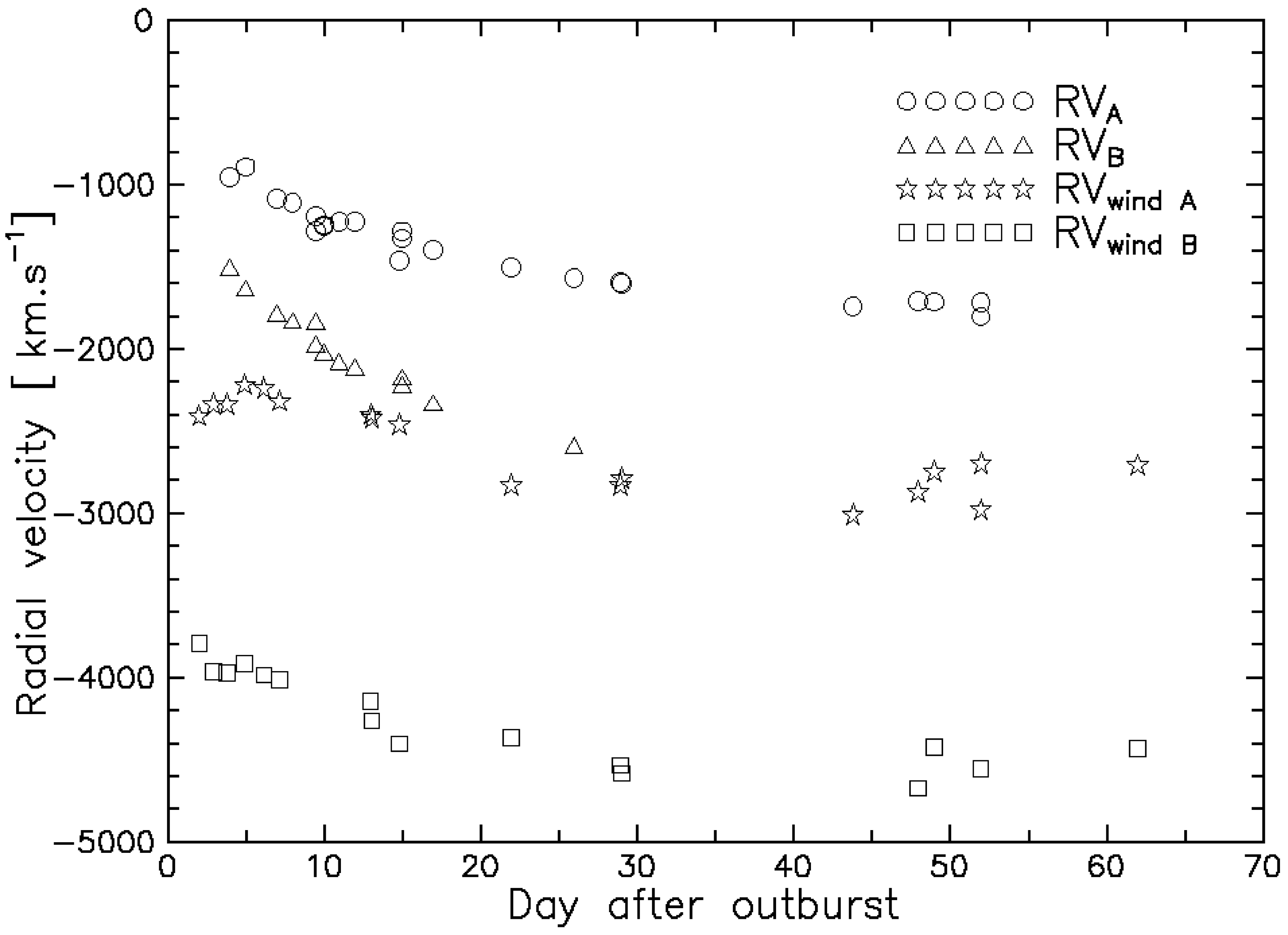

Figure 1: Radial velocities of the spherical (A) and polar (B) wind, the spherical (A) and polar (B) component of the low-mass outer envelope.

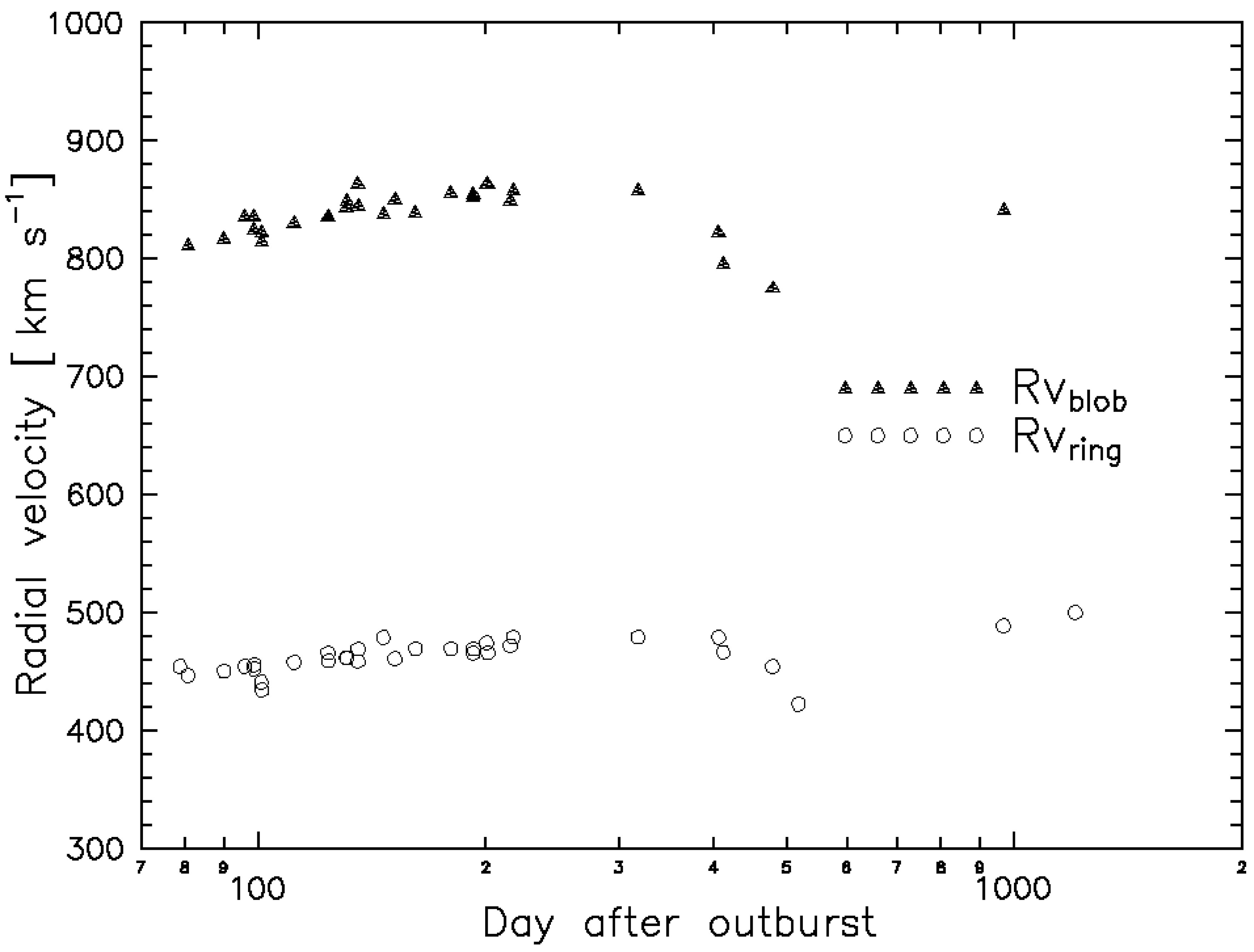

Figure 2: Mean radial velocities of ring and blobs of the inner envelope.

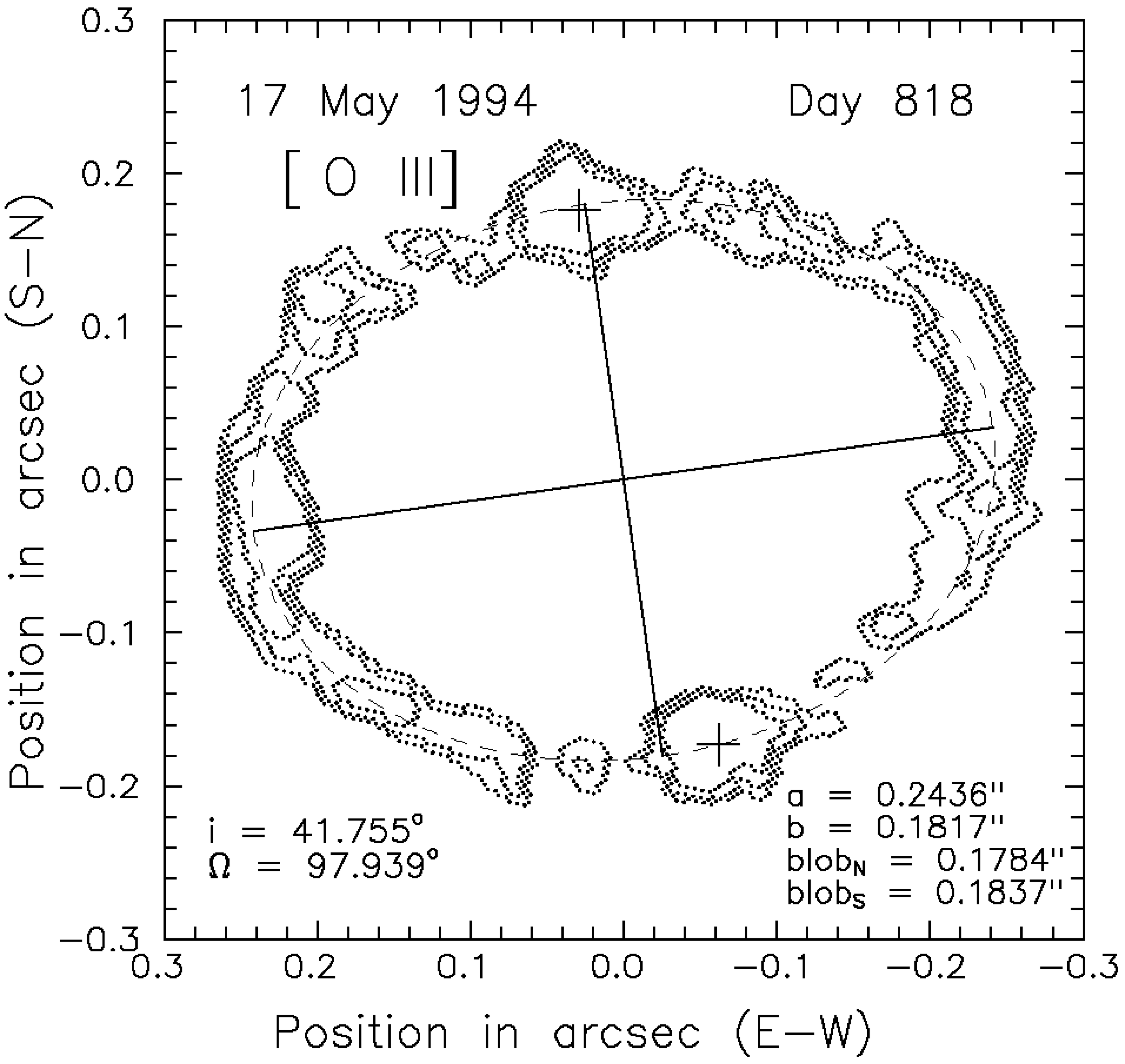

Figure 3: Ring and blobs (marked by crosses) of the inner envelope - isophotes of the HST image.

features can be seen also in [O III] lines as well as C III] and N III] lines in UV region (Chochol et al., 1996). Mean radial velocities of the ring and blobs of the inner envelope are plotted in Fig. 2. A decrease of expansion velocities of the ring and blobs after day 318 could be caused by the deceleration of the envelope due to the interaction with the preoutburst ejecta. The HST image of the expanding envelope taken 818 days after outburst clearly shows presence of the ring and two polar blobs (Fig. 3). An elliptical shape of the ring is caused by the projection of the circular ring onto a celestial sphere. The equatorial ring formed during the common envelope phase expands in the orbital plane. Superposition of the HST images in [Ne V] and [O III] lines lead to the discovery of magnetic fountain, which originates in the polar region. Interaction of the particles flowing from the blobs in meridional arcs (flux tubes) with expanding spherical inner envelope is responsible for the origin of observed bright spots. We can conclude that the shaping of the inner envelope is largely affected by the magnetic field of the white dwarf.

d) true expansion velocities and 3D model

Radial velocities of the components of the inner and outer envelopes and their expansion rates in the plane of the sky (found from radio and the HST images) were used to determine the inclination of the polar ejecta with respect to the observer. The resulting value of i = $38.^{\circ}7 \pm 2.^{\circ}1$ enabled us to determine the true expansion velocities of the components of the expanding envelope. Polar component of the outer envelope expands two times faster (about 3600 km/s) than the spherical component. The true velocity of the blobs of the inner envelope (about 1100 km/s) is 1.2 times larger than the velocity of the ring. Both envelopes are prolate.

Acknowledgements. This research has been supported through the Slovak Academy of Sciences grant No. 1282/1996.

References

Chevalier R.A., Luo D., 1994, *Astrophys. J.* **421**, 225

Chochol D, Hric L., Urban Z., Komžík R., Grygar J., Papoušek J., 1993, *Astron. Astrophys.* **277**, 103

Chochol D., Grygar J., Pribulla T., Komžík R., Hric L., Elkin V., 1996, *Astron. Astrophys.* (in press)

Eyres S.P.S., Davis R.J., Bode M.F., *Mon. Not. Roy. Astron. Soc.* **279**, 249

Livio M., 1994, in H. Nussbaumer and A. Orr (eds.): Interacting Binaries, Springer, Berlin, p. 135

Orio M., Trussoni E., Ögelmann H., 1992, *Astron. Astrophys.* **257**, 548

Shore S.N., Sonneborn G., Starrfield S.G., Gonzales-Riestra R., Ake T.B., 1993, *Astron. J.* **106**, 2408

Slavin A.J., O'Brien T.J., Dunlop J.S., 1995, *Mon. Not. Roy. Astron. Soc.* **276**, 353