Asociación Argentina de Astronomía
BAAA, Vol. 48, 2005
E.M. Arnal, A. Brunini, J.J. Clariá Olmedo, J.C. Forte, D.O. Gómez, D. García Lambas, Z. López García, S. M. Malaroda, & G.E. Romero, eds.

INFORME INVITADO – INVITED REVIEW

Eta Carinae

Zulema Abraham

Instituto de Astronomia, Geofísica e Ciências Atmosféricas, Universidade de São Paulo, PO Box 3386, 01060-970, São Paulo, Brazil

Abstract. Even after more than a century of intensive studies, little is known about η Carinae as a star. Its high luminosity and the observed episodes of mass ejection suggest that it is a LBV (Luminous Blue Variable) star. Periodicities in the historical light curve and in the radial velocity of the recombination lines are strong indication of the binary nature of the system, although the characteristics of the sharp dip in the light curve are typical of shell-like events. The periodicity and dips in the light curves are found at all wavelengths, from radio to X-rays. The strong X-ray emission at 2-10 keV is also easy to explain in a binary system, if it is produced by wind-wind collisions. However, the duration and magnitude of the dip depend strongly on the wind and orbital parameters. The continuum radio emission is due to free-free emission from an almost edge-on disk, its internal density, close to 10^7 cm^{-3} produce maser emission in the H recombination lines. The periodic dips can be explained by the recombination of the ionized plasma, when the UV ionizing photons cannot reach the disk. In June 2003 occurred the last low excitation event in Eta Carina, and a large number of closely spaced data became available. I will review the contribution that these data brought to our understanding of the physical and orbital parameters of the binary system.

Resumen. Aún después de más de cien años de estudios intensivos poco se conoce sobre la estrella η Carinae. Su alta luminosidad y sus episodios de eyección de masa sugieren que es una Variable Azul Luminosa. Las periodicidades en la curva de luz histórica y en la velocidad radial son fuertes indicadores de la naturaleza binaria del sistema, si bien las características de los mínimos en su curva de luz son típicas de eventos de tipo "cáscara". En todas las longitudes de onda se observan mínimos y periodicidad, desde ondas de radio hasta rayos X. La fuerte emisión de 2 a 10 keV tambin es fácil de explicar en un sistema binario, si es producida por colisiones entre dos vientos. Sin embargo, la duración y magnitud del mínimo depende en gran medida de las características del viento y de los parámetros orbitales. La emisión en el continuo de radio es producida por emisión libre-libre en un disco visto casi de canto; su densidad interna, cercana a 10^7 cm^{-3}, produce emisión máser en líneas de recombinación del hidrógeno. Los mínimos periódicos pueden ser explicados por la recombinación del plasma ionizado, cuando los fotones UV ionizantes no pueden alcanzar el disco. En junio de 2003 ocurrió el último de los eventos de alta excitación en η Carina, y se hizo público un gran número de datos. Resumiré la contribución que estos datos trajeron a nuestro entendimiento de los parámetros físicos y orbitales de η Carinae.

1. Introduction

η Carinae is a variable star that underwent a series of mass ejection episodes, the most dramatic occurred around 1840, when the star ejected large amounts of material that formed an expanding nebula: the Homunculus. Variable emission from the star and its surrounding was detected at wavelengths ranging from radio to X-rays, and a 5.52 years periodicity in the high excitation lines was found by Damineli (1996). Subsequent events in 1998.9 and 2003.5 confirmed the periodicity (Fernández Lajús et al. 2003, van Genderen et al. 2003, Whitelock et al. 2004, Corcoran 2005, Abraham et al. 2005a). Damineli, Conti & Lopes (1997) suggested the existence of a binary companion star, although the spectroscopic events could be better explained by episodes of shell ejection, making the binary hypothesis controversial (Zanella, Wolf & Stahl 1984, Davidson et al. 2000). This review is divided in five parts, the first concentrates in the star itself and its wind, the second addresses the expanding Homunculus, the third describes the observed 5.52 year periodicity at all wavelengths, the fourth confronts the binary hypothesis with the shell ejection events and discuss a solution to this controversy and the fifth describes our knowledge about the orbital parameters of the binary system.

2. η Carinae as a star

The evolutionary state of the star η Carinae is only speculative, since no photospheric lines are visible in its spectrum, which is completely dominated by the surrounding strong wind. According to its bolometric luminosity (5×10^6 $L_\odot$, van Genderen & Thè 1984), the mass of η Carinae should be larger than 120 $M_\odot$, making it the most massive star in our Galaxy. Its complete photometric light curve, starting in 1596, was compiled and discussed by several authors (e.g. van Genderen & Thé 1984, Davidson & Humphreys 1997, Humphreys, Davidson & Smith 1999, Frew 2004). Only three observations are available before 1800 and they are compatible with a very slow brightening, around magnitude $m_V \sim 3$. In 1837 occurred the "Great Eruption", a nova-like event, after which η Carinae became one of the brightest stars in the sky, with $m_V \sim 0$; it lasted until 1856, when the brightness started a fast decline, probably as a consequence of dust condensation that gave rise to the formation of the Homunculus nebula. A second and much smaller brightening event occurred in in 1887, known as the "Lesser Eruption" that lasted until 1895. Between 1900 and 1920 its brightness remained constant, at $m_V \sim 7.6$ and around 1940 started a continuous increase at a rate of about 0.030 mag yr^{-1} (Smith et al. 2000, Martin & Koppelman 2004). Superposed to the secular brightening, short term variations are also observed.

This general behavior led to the hypothesis that η Carinae is a Luminous Blue Variable (LBV) star (Conti 1984, Humphreys & Davidson 1994). This type of stars, with masses larger than 50 $M_\odot$, are very luminous ($M_{Bol} \sim -9.6$) and undergo violent mass-loss events. During the quiescent state they lose about $10^{-4} - 10^{-5}$ $M_\odot$ yr^{-1}. In a typical eruption, they eject about 1 $M_\odot$, their photospheres expand and their temperatures decrease, but the bolometric luminosity remains constant. The exact mechanism that produces these events is still not fully understood, but it must be related to radiation pressure and/or dynamical instabilities in the outer layers, as the star evolves from the main sequence. During the outburst phase, the enhanced mass outflow leads to the formation of an extended atmosphere, the envelope expands with a velocity of 100-200 km s^{-1} and becomes very cool (7000-9000 K) and dense ($N \sim 10^{11}$ cm^{-3}). In the quiescent state, the LBV is a normal high temperature star, with $T > 15000$ K and a lower mass loss rate. Although η Carina presents similar behavior, its actual surface temperature is not known and during the large outbursts its luminosity increased in at least two magnitudes instead of remaining constant. The total mass ejected by η Carinae during the Great Eruption, which formed the Homunculus nebula, was estimated as 2.5 $M_\odot$ based on visual extinction (Davidson & Humphreys 1997). Recent measurements of the total mass of the Homunculus, obtained from IR dust emission observations, gave the much larger value of 15 $M_\odot$ (Morris et al. 1999, Smith et al. 2003). This new result, together with the fact that during the Great Eruption η Carinae reached $M_{\rm Bol} \sim -14$ mag, with a total radiated energy of about 10^{49} erg, comparable to the energy released in a supernova explosion, lead to the speculation that maybe what really occurred during this event was a supernova explosion in which the central star survived.
The spectrum of η Carinae does not show photospheric lines. When observed from the ground, with angular resolution of about 1" (Hillier et al. 1992, Damineli et al. 1998), it presents narrow permitted and forbidden emission lines (FWHM $\sim 20 - 80$ km s^{-1}), on top of much broader components (FWHM ~ 500 km s^{-1}). At optical and IR wavelengths, Hα is the strongest line, followed by HeIλ10830. Many FeII and [FeII] lines are present, as well as a group of highly excited lines of [NeIII], [FeIII], [ArIII] and [SIII]. Numerous faint lines of FeII, TiII, CrII and NI are also present. Observations from the $HubbleSpaceTelescope$ (HST) allowed the extraction of the central source with ten times better resolution. Its spectrum presents mainly the broad permitted emission. Hillier et al. (2001) derived a mass loss rate of about 10^{-3} M$\odot$ yr^{-1} and solar abundances of species like Fe and Mg to within a factor of 2, N is at least a factor of 10 overabundant while C and O are depleted. The narrow lines are formed in dense condensations, known as the Weigelt blobs.

3. The Homunculus

η Carinae is surrounded by the Homunculus, a bipolar expanding nebula with nearly circular and hollow lobes. At visual wavelengths, the Homunculus is essentially a reflection nebula, although some intrinsic emission lines are present in its spectrum (Meaburn et al. 1987, 1993, Hillier & Allen 1992). The emission line profiles change with position and the scattered light shows P Cygni profiles in HI, HeI, FeII and the Na D lines, implying that the central object is related to P Cygni type of stars.

The Homunculus presents a patchy structure; proper motions of its components was measured by Curie et al. (1996) and Morse et al. (2001) using images obtained with the HST. The outward velocity at the poles is about 650 km s^{-1} and the tilt angle between the polar axis and the line of sight is $57° \pm 10°$. Assuming that the expansion velocity is ballistic, the derived ejection date was extrapolated to 1840, coincident with the Great Eruption.

Some features are also seen outside the Homunculus, they were probably ejected earlier (Walborn, Blanco & Tackerary 1978, Hillier & Allen 2001), suggesting that a number of episodic outbursts occurred before the Great Eruption. Matter inside the Homunculus, with velocity around 200 km s^{-1} and probably ejected in the 1890 eruption, was first identified by Ishibashi et al. (2003) and named the "Little Homunculus". Smith (2005) performed a Doppler tomography in the [Fe II]λ16435 line that revealed its complete structure. He found that the expansion velocity is not the same in all directions: at low latitudes it is consistent with linear expansion starting in 1910, but the velocity at the polar caps imply ejection dates around 1920-1930. However, it is possible that the wind was accelerated and the ejection consistent with the 1890 eruption. In any case, the total kinetic energy and ejected mass were much smaller that those of the Great Eruption.

At 10 and 20 μm infrared wavelengths, the Homunculus is the brightest extrasolar system object in the sky (Westphal & Neugebauer 1969). Its emission is due to starlight absorbed and re-emitted by dust. Smith, Gehrz & Krautter (1998) review all previous IR images of the Homunculus and inferred that it contains at leas 2.5 $M_\odot$ for a dust-gas ratio of 100. Morris et al. (1999) presented a 2-200 μm spectrum obtained with ISO that revealed much higher far-IR emission than what would be expected from mid-IR data. They attributed the excess far-IR emission to a 110 K dust component, located in a compact and very massive torus, containing about 15 $M_\odot$. Smith et al. (2003), using data from the Baade 6.5 m Telescope of the Magellan Observatory at 4.8-25 μm, derived similar mass for the Homunculus, although they believe that it is located in the polar lobes.

The Homunculus was also detected in soft X-rays by the $EINSTEIN$, $ROSAT$ and $CHADRA$ instruments (Chlebowski et al. 1984, Weis et al. 2001, 2004), while the central source presents harder spectrum. The morphology and properties of the X-ray nebula are the result of shocks from the fast clumps moving into a pre-existing denser circunstellar medium, with additional contribution from interactions between the clumps. Spectra from $CHANDRA$ revealed gas temperatures of 0.6-0.76 keV.

4. The 5.52 yr periodicity

Whitelock et al. (1994) reported infrared (1.25-3.5 μm) light curves covering a 20 year period, in which a 5 yr quasi-period variability was superposed to a clear secular brightening . Damineli (1996) found a very well defined 5.52 yr periodicity in the HeIλ10830 high excitation line, its luminosity light curve was characterized by sharp dips that lasted for about a month, anticorrelated with the infrared luminosity. Further, better sampled IR broad band observations, showed the same sharp dips in the light curves as those seen in the high excitation optical lines (Feast, Whitelock & Marang 2001). Similar periodicity was found in the radial velocity of the Paδ and Paγ lines, compatible with the existence of a binary system in a highly eccentric orbit (Damineli et al. 1997, 2000, Davidson 1997), the sharp minima in the light curve occurring close to periastron passage. Interferometric observation with the Australian Compact Array (ATCA) at 3 and 6 cm , with 1" resolution, were able to separate the central source from the nebula emission (Duncan, White & Lim 1997, Duncan & White 2003). The central source is optically thick at these wavelengths, it varies with the same 5.52 yr periodicity, although the light curve is almost sinusoidal and does not present the sharp minima seen at optical and IR wavelengths. The high resolution observations showed also variability in the shape of the emitting region, which changed from a non resolved point source during the minima to an elongated 4" diameter disk-like structure at the maximum. Periodicity was also found in the continuum at millimeter wavelength, with the source remaining optically thick up to 1 mm wavelength (Cox et al. 1995a, Abraham & Damineli 1999). Duncan & White (2003) interpreted the continuum spectrum as free-free emission from a dense disk, the changes in geometry and luminosity would be produced by changes in the available ionizing UV radiation . Millimeter-wave recombination lines were also observed, its intensity clearly shows strong departure from LTE, requiring densities of the order of 10^7 cm^{-3} both for a spherical wind (Cox et al. 1995b) and for a disk model (Abraham et al. 2002).

X-ray observations provide the probably best sampled light curve for the η Carinae system; the periodic sharp dip occurs after a continuous brightening and lasts for more than a month (Ishibashi et al. 1999). The X-ray intensity is several orders of magnitude larger than what is expected from a single star and it is attributed to free-free emission from a high temperature shock formed by wind-wind collision (Prilutskii & Usov 1976, Pollock 1987, Zhekov & Skinner 2000). Both theoretical and numerical simulations confirm this hypothesis (Chlebowski 1989, Usov 1992, Pittard et al. 1998) Since the X-ray flux density depends on the separation between the stars, the light curve provides a good estimation of the binary orbital parameters (Corcoran et al. 2001; Pittard & Corcoran 2002). The first predicted low excitation event occurred in 1997.8, it was recorded at all wavelengths, although the optical observations were affected by the solar proximity to η Carinae. The observing conditions were better during the second predicted event, which occurred in 2003.5 (Fernández Lajús et al. 2003, van Genderen et al. 2003, Whitelock et al. 2004, Corcoran 2005, Abraham et al. 2005a). Two new detections resulted from these observations. First, the HeIIλ4686 line was identified by Steiner & Damineli (2004), with radial velocities that varied between -100 and -400 km s-1 close to periastron passage. Stahl et al. (2005) reported observations of this line through reflected light in the Homunculus nebula. The HeIIλ4686 was seen in the spectrum of the SE lobe, consistent with viewing the polar region, with significantly smaller equivalent width than seen on the star directly. If corrected for light-travel time delay, the polar emission appears to peak earlier than closer to the equator. The second detection occurred at 7 mm, during the daily observations performed with the Itapetinga radiotelescope, near periastron passage, in which a well defined and short duration peak was superposed to the declining flux density (Abraham et al.

2005a). This excess emission was interpreted as produced by free-free emission in the dense, optically thick shock material, near periastron passage.

5. Binary system versus shell events

Shell-like events in η Carinae were already already observed in 1892-1893, when a dramatic change from emission to absorption lines was reported (Canon 1901, Whitney 1952). Further spectroscopic monitoring detected this kind of behavior in other occasions (Gaviola 1953, Viotti 1968, Thackerary 1967, Rodgers & Searle 1967), which we now know occur with a 5.52 yr periodicity. Zanella et al. (1984), based on changes observed in the 1981 spectrum, concluded that additional material, situated close to η Carinae and with velocities smaller than 600 km s^{-1}, was brought into the line of sight. Moreover, the observed fading of the high energy lines could be explained by assuming that not enough high energy photons were available to ionize the elements with high ionization energies. Based in these considerations, they proposed the ejection of a dense shell as the explanation for the changes of the 1981 spectrum.

With the discovery of the 5.52 yr periodic variation in the radial velocity of the hydrogen recombination lines and its interpretation as a consequence of binary system orbital motion (Damineli et al. 1997), the shell ejection hypothesis seemed to be not longer necessary to explain the periodic photometric and spectroscopic events. The binary system hypothesis also explains the strong X-ray flux density and its temporal variation, under the assumption that it is generated in the shock produced by the wind-wind collisions (Pittard et al. 1998). In fact, after the 1997.9 event, Ishibashi et al. (1999), using the orbital parameters derived by Davidson (1997), and the wind absorbing hydrogen column density was able to reproduce the general behavior of the observed X-ray light curve. However, some discrepancies were found when the system approaches periastron, especially the predicted duration of the minimum, which was much shorter than what it is actually observed. The existence of a dense, geometrically thin disk around η Carinae was proposed as a possible mechanism to produce the large duration eclipses. Corcoran et al. (2001) obtained a better agreement between the observed X-ray light curve and the shock models by reducing the mass loss rate of η Carinae and increasing the eccentricity, but they still had to assume an increase by a factor of 20 in the mass loss rate after periastron passage, to reproduce the faint phase duration.

Neither a thin disk around the primary star nor an increase in the stellar mass loss rate seem to be appropriate to explain the spectroscopic low excitation events (Martin & Koppelmann 2004). This fact, together with high-resolution $Hubble Space Telescope$ (HST) spectroscopic observations (Davidson et al. 2000), which showed that although the radial velocity of the emission lines formed close to the star were variable, they were incompatible with the ground based observations of Damineli et al. (1997), casted doubts on the binary system hypothesis. Recently, Falceta-Gonçalves, Jatenco-Pereira & Abraham (2005) showed that as the secondary star moves in its orbit close to periastron passage, the dense shock cools down in timescales of hours and dust is formed in a shell, which explains the spectroscopic events maintaining the binary hypothesis. As the shell moves away from η Carinae with a velocity of about 100 km s^{-1}, the

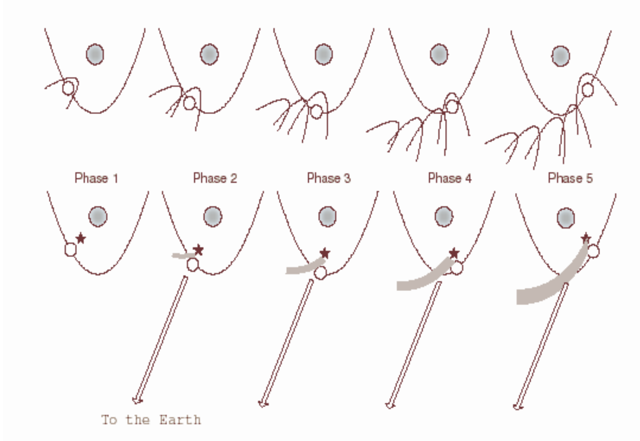

Figure 1. Evolution of the gas accumulated behind the shock, near periastron passage.

accumulated material in the direction of the line of sight to the shock is enough to explain the X-ray absorption. For this process be effective, the secondary star should be located between η Carinae and the observer near periastron, in agreement with the *HST* observations of Davidson et al. (2001). An schematic view of this situation can be seen in Figure 1.

6. The orbital parameters

The orbital parameters of the η Carinae binary system are still an open question. Damineli et al. (1997) derived an eccentricity $e = 0.63$, using the newly discovered periodic variability in the radial velocity of the Paδ and Paγ lines; the ephemerides of periastron passage being close to the epoch of the spectroscopic events. Davidson (1997) analyzed the same data and found a better agreement with and eccentricity $e = 0.80$, although latter raised doubts on the real existence of the binary system, because of the differences in the line profiles obtained from ground and from the Hubble Space Telescope (Davidson et al. 2000). Better determinations of the orbital parameters were obtained from X-ray observations since, as the stars approach each other close to periastron passage, the intensity of the X-ray emission increases together with the increase in the density of the shocked material. Unfortunately, the sharp absorption in the X-ray light curve occurs before the maximum of emission, and the exact ephemerides for periastron passage remains uncertain. Other parameters were better determined by the photometric and spectroscopic X-ray data, like the eccentricity $e \sim 0.9$ and $\eta = \dot{M}_s v_s / \dot{M}_p v_p \sim 0.2$, where $\dot{M}_p$ and $\dot{M}_s$ are the mass loss rates of η Carinae and the companion star, v_p and v_s their respective wind velocities.
As mentioned before, the 2003.5 event was followed daily at 7 mm with the Itapetinga radiotelescope and weekly at 1.3 mm with SEST (Abraham et al. 2005a). The closely spaced observations provided not only the light curves with great precision as can be seen in Figure 2, but they also showed an unexpected increase in flux density, which could not be explained by variable free-free emis-

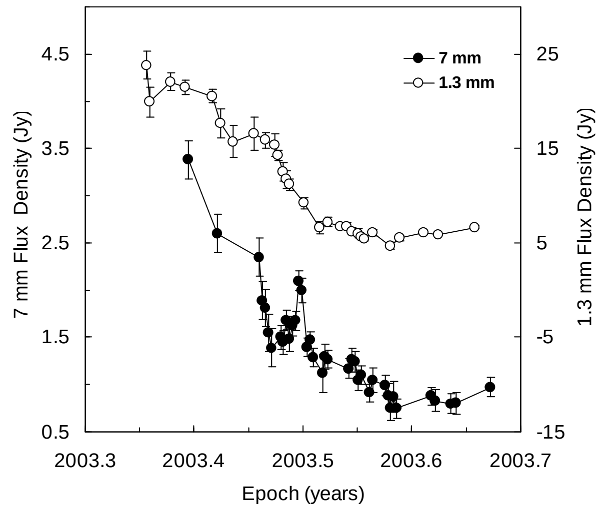

Figure 2. mm-wave light curves of η Carinae during the 2003.5 low excitation phase.

sion from the individual stellar winds. Abraham et al. (2005b) showed that the excess emission could be produced by free-free emission from an optically thick plasma at the wind collision site. The 7 mm light curve was explained as the superposition of the contribution of a fading disk and the emission from an optically thick cone, representing the shock surface, whose projected area into the plane of the sky changes as the secondary star moves in its orbit close to periastron, as can be seen in Figure 3.

The shape of the light curve is very sensitive to the orbital parameters, the eccentricity e and the aperture angle of the conic surface β determine the width of the peak, the phase of conjunction Φ determines the asymmetry in its shape and the epoch of periastron passage t_p defines its position in the light curve. The epoch of conjunction t_c is determined directly from the other parameters. The orbital parameters that can reproduce the observations are presented in Table 1. The first column shows the orbital parameters, the second the parameters interval for which a fair fitting was found and the third column presents the parameters that best fit the data. Notice the short parameter range in eccentricity, an illustration of the sensitivity of the light curve to this parameter is shown in Figure 4, where emission models for eccentricities 0.9 and 0.95 are compared to the observed 7 mm light curve, from which the contribution of the disk surrounding η Carine was subtracted.

Table 1
Orbital parameters of the binary orbit

β (degrees)	$40 - 60$	56
e	$0.92 - 0.95$	0.95
t_p (since 6/29/2003)	$1.5 - 3.2$	1.5
t_c (since 6/29/2003)	$-1 - 0.1$	0.1
Φ (degrees)	$(-30) - (-50)$	-30

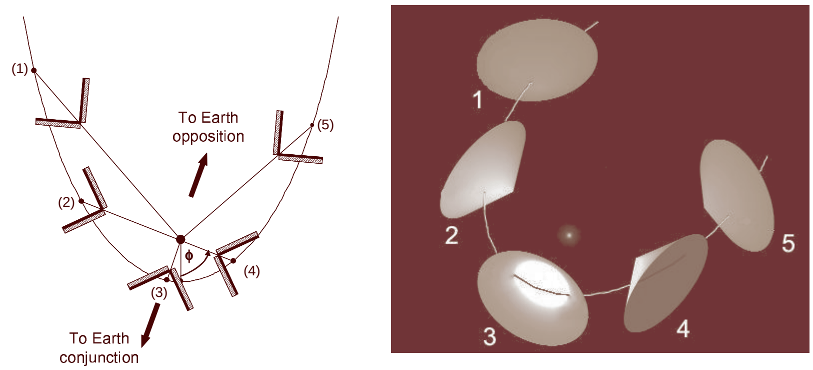

Figure 3. Shock surface seen by the observer at different positions of the secondary orbit, near periastron passage.

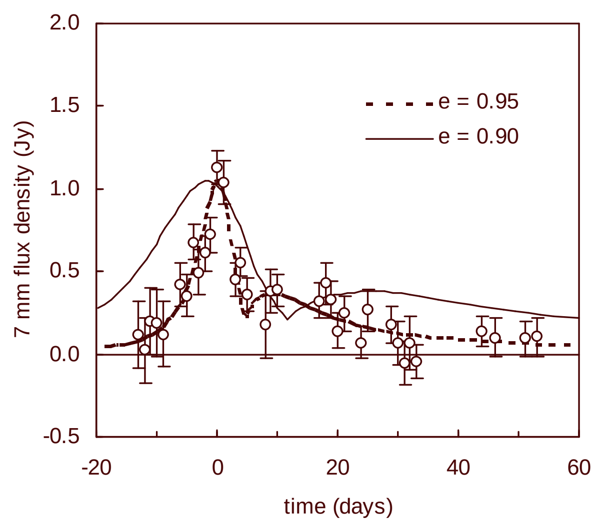

Figure 4. Observed 7 mm light curve and emission models for eccentricities 0.8 and 0.95

Acknowledgments. This work was partially supported by the Brazilian agencies FAPESP and CNPq

References

Abraham, Z., Damineli, A., 1999, in ASP Conf. Ser. Vol. 179, η Carinae at the Millenium. Ast. Soc. Pac. San Francisco, p. 263

Abraham, Z., Damineli, A., Durouchoux, P., Nyman, L-Å, McAuliffe, F. 2002, in Cosmic Masers: from proto-stars to black holes, San Francisco, ASP Conf. Ser. 206, 234

Abraham, Z., Falceta-Gon calves,D., Dominici, T. P. et al. 2005a, A&A, 437, 977

Abraham, Z., Falceta-Gon calves,D., Dominici, T. P., Caproni, A., Jatenco-Pereira, V. 2005b, MNRAS, 364, 922

Cannon, A. J. 1901, Harvard Ann. 28, 135

Chlebowski, T. 1989, ApJ, 342, 1091

Chlebowski, T., Seward, F. D., Swank, J., Szymkowiak, A. 1984, ApJ, 281, 665

Conti, P. S., 1984, in Observational Tests of Stellar Evolution Theory, IAU Symposium No. 105, ed. A. Maeder and A. Renzini (Dordrecht, Reidel), p. 233

Corcoran, M, F. 2005, AJ, 129, 2018

Corcoran, M., Ishibashi, K., Swank, J., Petre, R. 2001, ApJ 547, 1034

Currie, D. G., Dowling, D. M., Shaya, E. J. et al. 1996, AJ, 112, 1115

Cox, P., Mezger, P. G., Sievers, A. et al. 1995a, A&A, 297, 168

Cox, P., Martin-Pintado, J., Bachiller, R. et al. 1995b, A&A, 295, L39

Damineli, A. 1996, ApJ, 460, L49

Damineli, A., Conti, P., Lopes, D. 1997, New Astr., 2, 107

Damineli, A., Stahl, O., Kaufer, A. et al. 1998, A&ASS, 133, 299

Damineli, A., Kaufer, A., Wolf, B. et al. 2000, ApJ, 528, L101

Davidson 1997, New. Astron., 2, 397

Davidson, K., Hunphreys, R. M. 1997, ARA&A, 35, 1

Davidson, K., Ishibashi, K., Gull, T. R., Humphreys, R. M., Smith, N, 2000, ApJ, 530, L107

Duncan, R. A., White, S. M., Lim, J. 1997, MNRAS, 290, 680

Duncan, R. A., White, S. M. 2003, MNRAS, 338, 425

Falceta-Gonçalves, D., Jatenco-Pereira, V., Abraham, Z. 2005, MNRAS, 357, 895

Feast, M., Whitelock, P., Marang, F. 2001, MNRAS, 322, 741

Fernández Lajús, E., Gamen, R., Schwartz, M. et al. 2003, Inf. Bull. Var. Stars, 5477

Frew, D. J. 2004, Jour. Astr. Data, 10, 6

Gaviola, E. 1950, ApJ, 111, 408

Gaviola, E. 1953, ApJ, 118, 234

van Genderen, A. M., Thé, P. S. 1984, Space Sci. Rev., 39, 317
van Genderen, A. M., Sterken, C., Allen, W. H., Liller, W. 2003, A&A, 412, L25
Hillier, D. J., Allen, D. A. 1992, A&A, 262, 153
Hillier, D. J., Davidson, K., Ishibashi, K., Gull, T. 2001, ApJ, 553, 837
Humphreys, R. M., Davidson, K. 1994, PASP, 106, 1025
Humphreys, R. M., Davidson, K., Smith, N. 1999, PASP, 111, 1124
Ishibashi, K., Corcoran, M. F., Davidson, K. et al. 1999, ApJ, 524, 983
Ishibashi, K., Gull, T., Davidson, K. et al. 2003, AJ, 125, 3222
Martin, J. C., Koppelman, M. D. 2004, AJ, 127, 2352
Meaburn, J., Wolstencroft, R. D., Walsh, J. R. 1987, A&A, 181, 333
Meaburn, J.,Walsh, J. R., Wolstencroft, R. D. 1993, A&A 268, 283
Morris, P. W., Waters, L. B., F., M., Barlow, M. J. et al. 1999, Nature, 402, 502
Pittard, J. M., Stevens, I. R., Corcoran, M., F., Ishibashi, K. 1998, MNRAS, 299, L5
Pittard, J. M., Corcoran, M. 2002, A&A, 383, 636
Prilutskii, O., Usov, V. 1976, Sov. Astron., 20,2
Pollock, A. 1987, ApJ, 299, 265
Ringuelet, A. E. 1958, A.f.Astrophys., 46S, 276
Rodgers, A. W., Searle, L. 1967, MNRAS, 135, 99
Smith, N. 2005, MNRAS, 357, 1330
Smith, N., Morse, J. A., Davidson, K., Humphreys, R. M. 2000, AJ, 120, 920
Smith, N., Gehrz, R. D., Hinz, P. M. et al. 2003, AJ, 125, 1458
Smith, N., Gehrz, R. D., Krautter, J. 1998, AJ, 116, 1332
Smith, N., Gehrz, R. D., Hinz, P. M. et al. 2003, AJ, 125, 1458
Steiner, J. E., Damineli, A. 2004, ApJ, 612, L133
Stahl, O., Weiss, K., Bomans, D. J. 2005, A&A, 435, 303
Thackeray, A. D. 1967, MNRAS, 135, 51
Usov, V. 1992, ApJ, 389, 635
Viotti, R. 1968, Mem. Soc. Astron. Italiana, 39, 105
Walborn, N. R., Blanco, B., Thackery, A. D. 1978, ApJ, 219, 498
Weis, K., Duschl, W. J., Bomans, D. J. 2001, A&A, 367, 566
Weis, K., Corcoran, M. F., Bomans, D. J. Davidson, K. 2004, A&A, 415, 595
Westphal, J. A., Neugebauer, G. 1969, ApJ, 156, L45
Whitelock, P. A., Feast, M. W., Koen, C., Roberts, G., Carter, B. S. 1994, MNRAS, 270, 364
Whitelock, P., Feast, M. F., Marang, F., Breedt, E. 2003, MNRAS, 352, 447
Whitney, C. A. 1952, Harvard Bull. 921, 8
Zanella, R., Wolf, B., Stahl, O. 1984, A&A, 137, 79
Zhekov, S., Skinner, S. 2000, ApJ, 538, 808