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Eta Carinae: a long period binary?[☆]

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Abstract

We present new observations of η Carinae, strongly suggesting that it is a binary system. High dispersion measurements of the broad Paγ emission line show periodic radial velocity variations that are nicely explained by a star in a highly eccentric orbit. Velocity characteristics of the system imply massive components, in accord with the luminosity and spectral characteristics. Strong and variable wind–wind interactions are predicted to take place in η Car on the basis of the orbital elements and physical characteristics of the components. The low excitation event predicted for the end of 1997 is underway, confirming the high coherence of the 5.52 year cycle and adding confidence to η Car as a binary system. We associate this event with periastron passage. A conclusive demonstration of the binary orbit is still pending, but the present work has the advantages of bringing this mysterious object within a stellar evolution framework, and, for the first time in its history, predictions suitable for testing against future observations. © 1997 Elsevier Science B.V.

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1. Introduction

It has been 170 years since a series of outbursts made η Car one of the brightest objects in the sky. The energy released in the 30 year episode was equivalent to that of a supernova explosion. Huge amounts of outflowing gas and dust created the beautiful bipolar flow known as the Homunculus. The bolometric luminosity returned to pre-burst level, indicating that the event was non-terminal. However, in spite of the fantastic development of telescopes and detectors since then many puzzles remain.

The distance of η Car is not yet completely settled, although it does appear to be a member of the Carina OB association. Distances spanning the ranges 2.3–3.2 kpc have been found in the literature (Massey & Johnson, 1993; Allen & Hillier, 1993; Walborn, 1995; Van Genderen et al., 1994), leading

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to a luminosity in the range (3–5) $\times 10^6 L_\odot$. η Car is classified as a luminous blue variable (LBV), given its outburst history (Humphreys & Davidson, 1994). In the last 50 years, the overall spectrum of the star has remained more or less the same, being rich in forbidden, permitted, and recombination emission lines, with narrow components superimposed on broader ones. Both permitted and forbidden lines show this pattern, except permitted lines of very low excitation potential (e.g., Na D) do not have a narrow component.

Many lines exhibit P Cygni profiles but no *photospheric* absorption lines are seen (Viotti, 1995). The temperature might be lower than that of P Cyg, 20 000 K (De Groot & Lamers, 1992), as P Cyg exhibits optical (permitted) lines of SiIV and FeIII, compared to SiII and FeII in η Car. Optical forbidden lines show ions of ionization potential as low as 6–8 eV, such as [NiII] and [FeII], along with those of up to 40 eV, such as [NeIII], that cannot be accounted for by a single source of ionizination. Damineli et al. (1995) showed IUE spectra of η Car in which the continuum is rapidly dropping towards wavelengths shorter than 1300 Å, corresponding to an energy distribution of a 22 000 K star (Kurucz, 1979). Ebbets et al. (1997) presented GHRS HST spectra in which a mix of stellar lines with both high and low temperatures suggests a *composite* contribution from a B2Ia plus a B8Ia star (22 500 K and 12 500 K). Based on HST spatially resolved (0″.22) UV spectra, Davidson et al. (1997) showed that the broad FeII lines come exclusively from the central object and the narrow components from an extended region. These authors assigned a nebular origin to the narrow components (forbidden and permitted) and a stellar nature to the broad ones. A similar analysis has not yet been performed in the visible and near-infrared spectral regions, but the same behavior is expected, as the radial velocities and line widths are very close to that in the UV range. STIS spectra with a 0″.1 aperture will be collected in Cycle 7 of HST, ranging from the UV to the near-infrared, enabling a definitive statement about the stellar and nebular origin of the line components to be made.

Changes have been seen in the η Car spectrum, initially called *shell events*. During these short-lived phenomena, the lines of highest excitation energy disappear completely ([NeIII], [ArIII], [SIII], [FeIII] and [NII]), and the others decrease in intensity more or less in proportion to the energy of the upper level from which they are formed. The narrow components of the permitted lines behave in a similar way as forbidden lines, being much more variable in intensity than the broad ones. The broad components of the permitted lines (FeII, HI, HeI) have more or less constant intensities, with the exception of the HeI 10830 line that is strongly variable and in the place of narrow emission has a narrow shell absorption (Damineli et al., 1993).

These events have been associated with S Doradus phenomena by some authors. S Dor variability, small amplitude *irregular* photometric variations (Δmag ~ 0.5–2.5), has been found in almost all LBV stars. This kind of variability does not seem to occur at constant bolometric luminosity (Leitherer, 1997) but no large departure from constancy is expected. Most of the variability seen in the optical window is due to the shift of photon energy towards longer wavelengths, when the line excitation becomes lower and the star redder and in the opposite sense, when the star returns to hotter phases. The *shell events* in η Car were initially attributed to S Dor type variability because the near-infrared and optical light-curve display peaks in coincidence with the minima in line excitation. However, in the case of η Car there are important differences from S Dor cycles such as (Damineli, 1997): a) the peaks in the near-infrared light curve are not compensated by for a corresponding fading in the ultraviolet; b) the line variability is mainly in the nebular components of the lines, not in the stellar ones; c) the variability of the HeI 10830 Å line requires a source of energy not accounted for the stellar radiation field; and d) the 5.52 year cycles (see Section 3) have a high degree of coherence. In this way, the 5.52 year cycle mimics partially the S Dor type variability, but its mechanism is of a completely different nature. We will label them *low excitation events* instead of *shell events* because there are no indications of sudden ejection of material.

The photometric history of η Car in the last 50 years also shows a secular increasing brightness that has been attributed to dust dissipation (Van Genderen et al., 1994; Whitelock et al., 1994). However, the stellar flux increased by the same amount at all wavelengths in the range 0.45–2.2 μm, indicating that there is another mechanism in operation, for example, to explain the secular decrease in the HeI 10830 Å strength, as seen in Section 3.

The concept of a binary η Car has emerged in some earlier work – Van Genderen et al. (1994) and references therein – but without firm observational support. We have pursued this idea on the basis of two new observational facts: a) a 5.52 year cycle that appears to be strictly periodic, and b) our newly discovered associated *periodic* radial velocities shown in a *broad line* component, which we believe represents the orbital motion of a star.

2. Observations and data reduction

Spectroscopic observations of η Car were carried out with the 1.6 m telescope of the **National Astrophysical Laboratory (LNA/CNPq, Brazil)**[5] between 1989 and 1996. A GEC CCD at the Coudé focus resulted in a dispersion of $\lambda/\Delta\lambda = 27\,000$ ($11\,\mathrm{km\,s^{-1}\,pixel^{-1}}$) at 10 900 Å. All data reduction was accomplished using IRAF[6]. The continuum near the Paγ line was recorded at S/N ~ 20 to 60 by co-adding three consecutive exposures of 10 minutes. The projected slit aperture was 2″.0 around the central object. Other lines, at shorter wavelength, were observed at higher S/N but we decided to concentrate efforts in this spectral region because spectra could be taken even during twilight, allowing a more regular sampling throughout the year. Paγ has a narrow emission line (FWHM $\simeq 20\,\mathrm{km\,s^{-1}}$) superimposed on a broad component (FWHM $\simeq 185\,\mathrm{km\,s^{-1}}$). The narrow line component was recorded at an intensity up to 40 times the stellar continuum but almost disappeared during the low excitation event of June 1992. The broad component, on the other hand, displayed a variable shaped profile with but little variation in intensity. Representative line profiles of Paγ and Pa-12 in the epoch of large variability are shown in Fig. 1a, Fig. 1b.

Deblending the Paγ line components was straightforward. First we removed the narrow line and then estimated the radial velocity of the broad component by two alternative procedures: gaussian fitting and measuring the line profile baricenter, with identical results. The same procedure was followed with the Paδ line and HeI 6678 Å. The resultant heliocentric radial velocities are presented in Table 1. Column 1 displays the Julian date of the observation, column 2

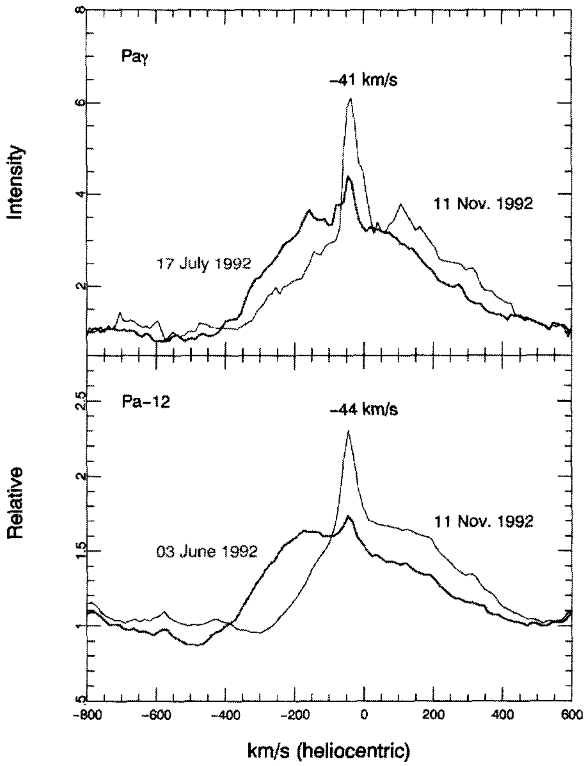

Fig. 1. Representative line profiles around the epoch of low excitation; a)[upper] Paγ, heavy line is for 17 July 1992 and light line for 11 November 1992; b)[lower] Pa-12, heavy line is for 3 June 1992 and light line for 11 November 1992.

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[5] http://www.lna.br/

[6] IRAF is distributed by the National Optical Astronomy Observatories.

the orbital phase using $P = 2014$ days and $T = 2\,448\,800$ (JD) – see Section 3; heliocentric radial velocities of Paγ are in column 3, Paδ in column 4 and HeI 6678 in column 5. The average velocity of the Paγ narrow line component is $V_{nar} = -40 \pm 2\,km\,s^{-1}$ while for the broad component it is $V_{bro} = -9.5 \pm 23.0\,km\,s^{-1}$, leading to a clear radial velocity variation in this line component. The fact that both the red and the blue branches of the broad line profiles move together (Fig. 1) indicates that radial velocity variations represent the bulk motion of a star. If changes in the line baricenter were produced by variability in the P Cygni absorption component, when this feature was stronger the line baricenter would be redshifted, contrary to what is observed. As can be seen in the Pa-12 line (Fig. 1a, Fig. 1b), when the P Cygni blue absorption is deeper the baricenter of the broad line component also is displaced to the blue.

Table 1
Radial velocities of broad line components

JD 24+	Phase	Paγ km s^{-1}	Paδ km s^{-1}	HeI 6678 km s^{-1}
47 614.6	0.411	−2.9	−0.6	–
47 916.6	0.562	−26.3	−18.0	–
48 059.4	0.632	−22.2	–	–
48 256.7	0.730	−43.0	–	–
48 286.7	0.745	−42.3	–	–
48 402.6	0.802	−41.3	–	–
48 702.5	0.952	−45.9	–	–
48 776.5	0.988	−59.3	−60.0	–
48 797.7	0.998		–	−53.2
48 798.7	0.999		–	−48.2
48 820.7	0.010	−38.4	–	–
48 824.8	0.012		–	38.5
48 829.8	0.015		–	34.7
48 837.8	0.019		–	27.7
48 938.8	0.069	47.8	44.0	–
48 960.7	0.080	36.8	–	–
49 057.7	0.128	36.8	–	–
49 105.5	0.152	34.1	–	–
49 136.5	0.167	42.3	–	–
49 190.4	0.194	17.6	–	–
49 344.7	0.270	−7.1	–	–
49 387.6	0.292	−9.8	–	–
49 433.5	0.315	−9.8	–	–
49 561.5	0.378	−15.3	–	–
49 646.8	0.420	−7.1	–	–
49 761.6	0.477	−23.5	–	–
49 849.5	0.521	−15.3	−11.0	–
50 052.5	0.622	−4.0	–	–
50 110.5	0.651	−20.8	–	–
50 210.5	0.700	−18.1	−47.0	–

HeI lines, such as λλ 7065, 5876 and 4471 showed a variable pattern similar to the Paschen series lines. During the low excitation phase, when only the broad component was present, the HeI lines showed the same radial velocity of Paγ. However, outside the phase of low excitation, the HeI lines displayed complex line profiles which were difficult to deblend. The subtraction of only the narrowest and more intense component resulted in a systematic shift of $-77\,km\,s^{-1}$ for HeI 6678 Å relative to Paγ. Different velocities for different lines are commonly found also in WR stars in binary systems. As we had only a few observations on Paδ and HeI 6678 Å, and in order to use a more homogeneous set of data, we restricted our analysis to the Paγ line. The others were used to check for the consistency of Paγ measures.

3. A predictable star

The 5.52 year period proposed by Damineli (1996) was based on the epochs of the two best-observed low excitation events of June 1992 and April 1948 (Gaviola, 1953) and indications of reoccurrence from the events of 1981.49, 1987.04 and 1992.42. The predictions using this period recovered the low excitation event observed by Rodgers & Searle (1967) with a phase difference of only 0.05. The low excitation events are in coincidence with peaks in the near-infrared light-curve. Four peaks in 1976.1, 1981.62, 1987.09 and 1992.30, in the data of Whitelock et al. (1994) were recovered close to the predictions. The minima observed in radio flux in 1992.68 (Duncan et al., 1995) and in X-rays in 1992.46 (Corcoran et al., 1995) were also near the epoch of the spectroscopic low excitation event. Light peaks in the optical light curve observed in 1976.3 and 1981.89 by Van Genderen et al. (1994) and three bursts visually observed in 1827.1, 1838.0

and 1843.2 (Innes, 1903) also can be associated with low excitation events. Other maxima in the historical light-curve fit the 5.52 year cycle. The question of which optical light curve maxima are due to a low excitation event can raise some controversy when no spectroscopy data close in time are available. We selected only the sharp peaks in homogeneous sets of data, but, in any case, the exclusion of the optical light curve would not change our results, as the period is determined mainly by spectroscopic data. In order to better date the 1992 event, previously based only on the HeI 10830 Å line, we measured several other lines. Each line reached minimum intensity at different times, from the beginning of June to the end of July, resulting in a mean epoch of 27 June 1992 (JD = 2 448 800) with an uncertainty of 33 days. By using $T(\mathrm{JD}) = 2\,448\,800$ and $P = 2014$ we fit all the low excitation events, with an average deviation $O - C = 0.025$ (50 days) and a maximum deviation of $O - C = 0.078$ (157 days), as shown in Fig. 2. In the linear regression of Fig. 2, we assigned double weight to the event of 1948.30 and forced the passage through the origin (1992.49) that appears as filled squares in Fig. 2. The double weight to 1948.30 is due to the fact that HeI, [FeIII] and [NeIII] lines faded completely at that time and several observations were made in the preceding and following years, constraining very well the central epoch of the low excitation event. The assignment of T to the 1992.49 event is due to the fact that it is by far the best observed.

The scatter in $O - C$ is surprisingly low, taking into account the bad time sampling of the observations. This is easily explained by the fact that the large variations that characterize the low excitation events are restricted to a short time interval of ~5–8 months, outside of which the spectroscopic and photometric variability of the star are small. The 5.52 year cycle is very coherent and cannot be explained by S Dor or other kind of stellar oscillations. Is it strictly periodic? Indications of strict periodicity are supported by the phase diagram of the observations. In Fig. 3a we show the magnitude variations in the H-band, measured by Whitelock et al. (1994), spanning 4 cycles. In this figure we subtracted the component of secular increasing brightness repre-

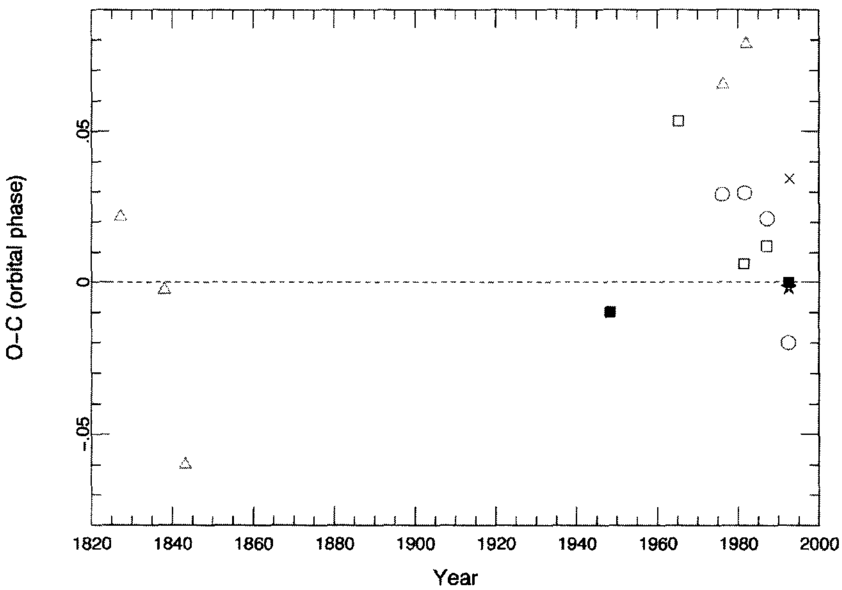

Fig. 2. O − C residuals from the fitting of the low excitation events; squares refer to spectroscopic events of line fading, circles to NIR peaks, triangles to optical light peaks, crosses to radio minimum and star to X-ray minimum.

sented by a 2nd order polynomial fit through the minima in the light-curve. In Fig. 3b we show a phase diagram of the HeI 10830 Å equivalent widths, measured in the last 16 years, covering 3 cycles. In this plot we normalized the equivalent widths by the secular decrease represented by a first order polynomial fit through the peaks of the curve of line variations.

Additional support for periodicity in η Car can be seen in a plot of line luminosity variations. In Fig. 4 we plotted the luminosity of the HeI 10830 Å line obtained from equivalent widths published in Damineli (1996) and augmented by some data collected in 1996. Equivalent widths of HeI 10830 Å were transformed to flux, after extrapolation of the stellar continuum measured in the J and H in epochs close to the spectroscopic observations (Whitelock et al., 1994). The absolute flux in the line was derived for a distance of 2.6 kpc and then divided by the bolometric luminosity of the sun. The V-band (5441 Å) and W-band (3235 Å) luminosities was obtained in the same way of HeI 10830 Å, using data from Van Genderen et al. (1994) and applying the flux calibration constants of De Ruiter & Lub (1986) for the Walraven system. Fig. 4 shows that the luminosity and color of the star is practically constant when the HeI 10830 Å line varies by thousands of solar luminosities, indicating that this line cannot be radiatively excited by the star. The best explanation is collisional excitation which could be produced by

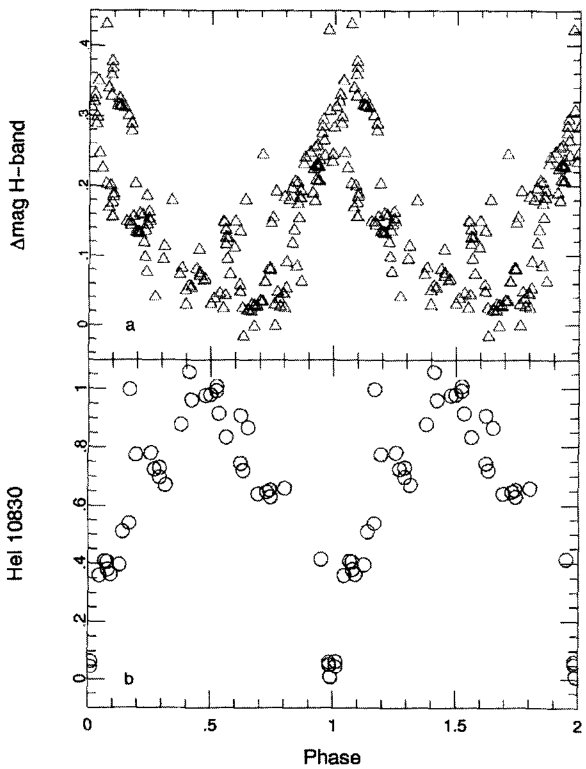

Fig. 3. Phase diagrams; a)[upper] magnitudes in the H-band (4 cycles); b)[lower] equivalent width of HeI 10830 Å line (3 cycles).

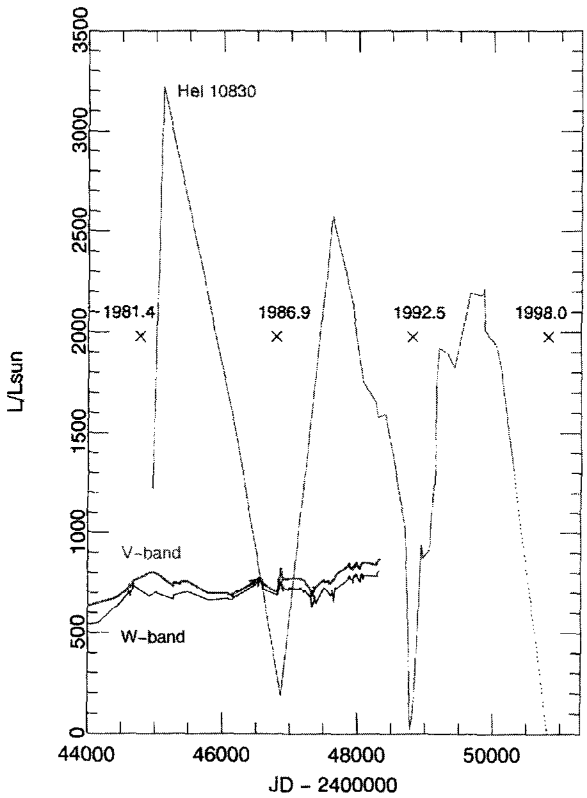

Fig. 4. Luminosities normalized to $L_\odot$ (Lsun) ($d = 2.6$ kpc); solid line represents HeI 10830 Å line, heavy line the continuum flux in the V-band (5441 Å), light line the continuum in the W-band (3235 Å) and crosses the predicted epochs of low excitation events. The dotted line connects the last observation (1996.92) to the next predicted low excitation event (1998.0) – see text.

variable wind-wind collision in a highly elliptical binary system. In Fig. 4, the dashed line connects the observation of HeI 10830 Å in 25 November 1996 with the next predicted low excitation event (1998.0), indicating that the 5.52 year cycle is really at work. The suggestion of binarity at this point is irresistible and encouraged us to search for an orbital solution of the Paγ radial velocity curve.

4. The orbital elements

We adopt the working hypothesis that the radial velocities for the Paγ broad line represent the orbital motion of the primary component of a single-lined binary system. Fig. 5 was constructed with data of Table 1. We acknowledge that, except for phases 0.4 to 0.7, radial velocities were covered only for one cycle. As stated before, only the Paγ line was considered in the radial velocity curve solution, Paδ and HeI 6678 measures were plotted as an additional check. The orbital elements were derived by a least squares procedure, keeping P and T fixed, and are presented in Table 2.

The radial velocity fit is quite good. The eccentricity 0.63 is high and the large mass function implies a high mass secondary, irrespective of the inclination. The inclination angle is smaller than 90°, as the system is non-eclipsing. The γ velocity of the system ($-15\,\mathrm{km\,s^{-1}}$) is compatible with results of Conti et al. (1977), who measured the radial velocity of seven O-type stars in and near the Carina Nebula, obtaining $V_{rad} = -7\pm9\,\mathrm{km\,s^{-1}}$. The line-of-sight of the observer points 16° seen from the major axis (phase 0.008). We derived an orbit with $a\sin(i) = 7.6$ A.U. and assuming $i = 60°$ display a schematic view in Fig. 6. The orbital inclination is such that the points of the ellipse at the right side of the line of nodes are above the plane of the sky. The major axis of the orbit is tilted by 10–25° from the line-of-sight (see Section 5), much less than the Homunculus main axis ±40–50°. The orbital motion of the primary is counterclockwise, with zero phase coincident with the periastron passage. The last periastron passage was in 27 June 1992 and the next is

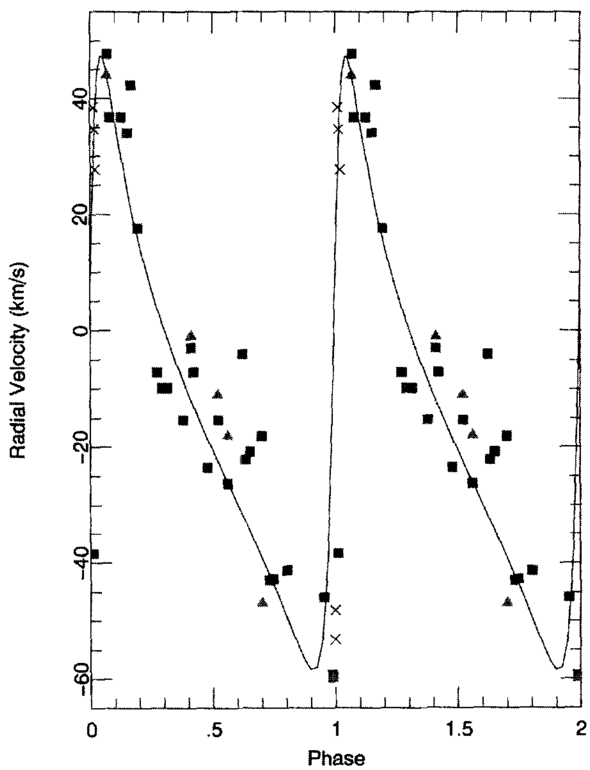

Fig. 5. Radial velocities of the baricenter of the line broad component; squares are from Paγ, triangles from Paδ, crosses from HeI 6678 and the solid line represents the best fit to the orbital parameters.

predicted for the first days of January 1998 (±3 months). The primary component reached inferior conjunction (in front of the less luminous) at phase 0.008 (13 July 1992) and superior conjunction at

Table 2
Orbital elements

Parameter	Value ± error
Period	2014±50 days
T	2 448 800±33 (JD)
γ	$-15\pm3\,\mathrm{km\,s^{-1}}$
K	$53\pm6\,\mathrm{km\,s^{-1}}$
e	0.63±0.08
ω	286°±6°
$a\sin(i)$	7.6±1.7 A.U.
mass function	$14.6\pm7.2\,M_{\odot}$

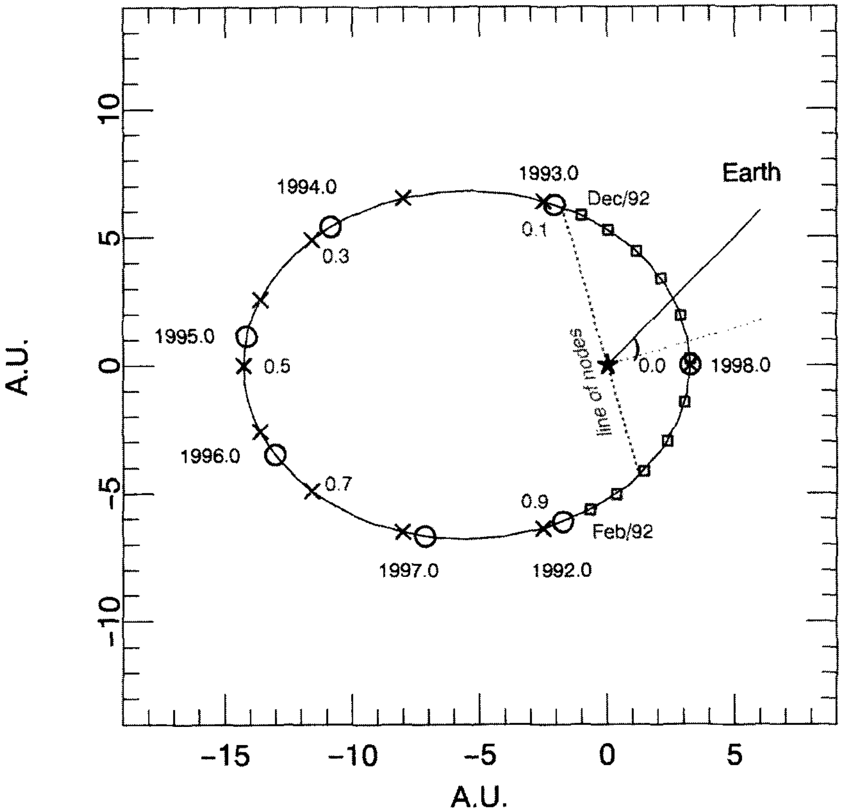

Fig. 6. Orbit of the m_1 component relative to m_2 in scale of A.U. for $i = 60°$; circles mark beginning of each year, squares the beginning of month in 1992 (February through December) and crosses the orbital phases.

phase 0.645 (17 January 1996). The semi-major axis is $a = 8.78$ A.U., the periastron distance is $d_{per} = 3.25$ A.U. and apastron distance is $d_{apa} = 14.31$ A.U. The maximum angular separation between the stars is about 0″.004 (adopting a distance of 2.6 kpc). This is not spatially resolvable by current techniques, but may be feasible in the near future.

5. Masses and evolutionary stage

In order to estimate the masses of the binary components, we adopted the following additional constraints: a) the total luminosity – $4 \times 10^6 L_\odot$ (the average found in the literature) – is produced by the combined luminosity of the stars, b) the primary (single lined system) is more luminous than the secondary, c) the system is not eclipsing, d) neither massive star is near the ZAMS (as they would provide too hot an ionization balance in the nebula), and e) the primary is "evolved" but has not yet reached the He-burning phase (taking into account its "Of/WN"-like spectral type and the anomalous abundances found in the Homunculus (Davidson et al., 1986)). We adopted the models of Schaller et al. (1992) with solar abundances ($Z = 0.02$), with standard mass-loss rates (which have a large impact on the current masses). A very narrow range of masses and ages can satisfy the constraints listed above. On one hand, the primary star must have passed the stage of core hydrogen burning (in the models), with a current mass $m > 50\,M_\odot$, in order to account for the major part of the luminosity of the system. On the other hand, for $i \sim 90°$, the masses of the components need to be similar, as a few percent difference in their masses result in a large mass-function, and the mass of the secondary component increases rapidly with decreasing inclination angle. This implies that the secondary star cannot yet have finished the core H-burning phase, otherwise it would be as luminous as the primary and the system would not be single-lined. The crossing of the HR diagram from the end of the core H-burning to the beginning of the He-burning is very fast; we thus adopted an age of 2.56 Myr for the system (after some experimentation). The derived (current) masses are then: Primary – $64\,M_\odot \leq m_1 \leq 68\,M_\odot$; Secondary – $71 M_\odot \geq m_2 \geq 65\,M_\odot$; $65° \leq i \leq 80°$; $1.6 \leq L_1/L_2 \leq 2.2$.

The age is in good agreement with the upper limit of 3 Myr found by Massey et al. (1995). The main sequence progenitors would have been around 110–$117 M_\odot$ for the primary and 85–$90 M_\odot$ for the secondary, making η Car an impressively massive binary which has already lost considerable mass from the system, consistent with the substantial surrounding nebulosity. The range of derived parameters is relatively narrow and as the mass of the secondary increases rapidly for increasing orbital inclination it is not well determined. Temperatures can be found from the ages, current masses and luminosities. The primary, however, changes from about 33 000 K to 18 000 K (O9 to B3 spectral type) in only seven thousand years, when the star evolves since the end of core H-burning to the beginning of the core He-burning phase. The mass also changes very little during this phase. We will assume this range as the uncertainty in the effective temperature of the primary. As η Car shows lower excitation lines than P Cygni at optical wavelengths the temperature of the primary is more likely to be at the cooler end of the range. This indicates that the primary component is close to entering the phase of core He-burning. The secondary star is in the phase of core H-burning and evolves more slowly. Its present mass and luminosity lead to a temperature of 27 500 K (B1 spectral type). However, we must consider that spectral types are very difficult to be derived from massive star evolutionary models. Corrections for wind blanketing may lower the stellar temperatures, especially for the primary. This could explain why the spectral types implied by models, O9 – B3 + B1 are substantially hotter than B8 + B2, suggested by Ebbets et al. (1997) on the basis of UV spectra. In Fig. 7 we show the error boxes of the proposed binary components in the HR diagram, as derived from the models. In the near future the system will be losing large amounts of

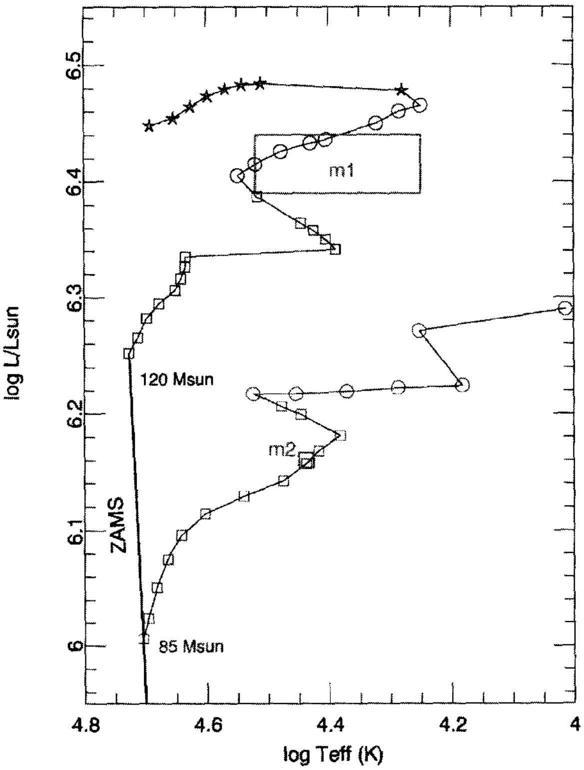

Fig. 7. Position of the η Car m_1 and m_2 components in the HR diagram; squares represent the phase of core H-burning, circles the exhaustion of H in the core and stars the core He-burning.

matter and evolve through a WR + WR binary as derived from models.

6. Discussion

The orbital characteristics of the system indicate that a strong phase dependent wind–wind interaction is taking place. Massive binaries with colliding winds show enhanced X-ray emission, as shown by Chlebowski & Garmany (1991) from analysis of *Einstein* data. Moreover, recent ASCA X-ray spectra of η Car show an 83 million K component of thermal origin with a strongly absorbed component (Corcoran et al. (1997), see also Chlebowski et al. (1984)), typical of colliding wind binaries. η Car shows many other features in common with the WC + O type binary HD 193793 (Williams et al., 1990), a prototype of a colliding wind system, such as a rapid decline of X-ray (Corcoran, 1995; Corcoran et al., 1995) and radio flux (Cox et al., 1995; Duncan et al., 1995) near the periastron, peaks in the near-infrared light-curve (Whitelock et al., 1994) around periastron and almost constant fluxes and color indices at optical and UV ranges. Cyclic variations in the HeI 10830 Å feature seems to originate in the zone of a wind–wind collision, as this line needs X-ray radiation in a dense medium to be excited. In the case of nebular lines, cycles could be due to mutual eclipses of the winds, as seen from the line-of-sight of the emitting nebula. This is consistent with the fact that nebular lines reached their minima about one month after that of HeI 10830 Å.

We suggest that the *low excitation* events are associated with wind–wind interactions which are accentuated during periastron passage. This massive binary is enveloped in a substantial wind, illuminated and excited by two very luminous stars, with highly varying distances from one another. Previously perplexing observations over many wavelengths may now be better understood within this wind interaction framework (e.g., the complicated helium emission line profiles).

Observations of more lines in the next cycle would be desirable to derive the orbital elements with a higher degree of confidence. Unfortunately, this is not an easy task for η Car, taking into account the long period involved and the difficulty in finding lines free of blends. The derived masses are large, in accord with the mass-function and the luminosity of the system. The predicted positions of the components in the HR diagram are compatible with normal massive stars, which are relatively comfortable compared to the Eddington limit. The evolutionary stages of the components are in accord with the spectral characteristics of the primary and chemical composition of the ejecta. However, the exact masses of the components must be regarded as very uncertain, as the adopted models of extremely massive stars are not completely well established. The spectral type may differ substantially from the models, due to the correction of the effective temperature by wind blanketing. Direct information about the spectrum of the secondary star would be very helpful. Our calculations favor a small luminosity ratio between the components, indicating that the spectrum of the secondary could be detected under favorable conditions. Observations with STIS on HST, scanning the spectrum with high spatial and spectral resolution might bring new insights to this question. Spectroscopy with a small entrance aperture (minimizing the contamination by surrounding ejecta) in epochs near periastron when the line velocities of the components differ considerably provide the best chance of detection of the secondary star.

The spectral types and masses derived in this work are consistent with the existence of an LBV phenomenon in the η Car primary. This is not in contradiction with the fact that the photometric and spectroscopic behavior of the star in the last 50 years is better explained by a binary system than by S Dor variability. The light peaks separated by 5.52 years during the giant outburst of the last century do not seem to be the cause of the eruption but only a modulation superimposed on the broad maximum. The binary orbit may not have played any significant role in the eruption in the 1830s, other than tidal deformation and wind–wind interaction. That event seems to have been originated by a "major" LBV outburst in one of the components, which we assign to the primary, similar to that which has occurred recently in HD 5980 (Barbá et al., 1995).

A critical confirmation for the proposed scenario depends on the predicted occurrence of a low excitation event by 1998.0. Taking into account the uncertainties of the period and T, this event may occur at any time between early October 1997 and late March 1998. The intensity of HeI 10830 Å and other lines is declining as predicted, leading to high confidence that a new event of this kind is under way. The question now is whether the central epoch of the new event will confirm or rule out the proposed strict periodicity.

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