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A HISTORICAL OVERVIEW OF THE η CARINAE PROBLEM

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RESUMEN

η Car es uno de los objetos astrofísicos más peculiares cuya naturaleza aún está lejos de ser comprendida. En este trabajo se describen algunas de las características del objeto y se indican los campos que requerirían más trabajo futuro. Se hace una revisión crítica de la curva de luz histórica de η Car y se discute el cambio asociado en la nebulosa de la Cerradura (controversia de Herschel). El rico espectro de líneas de emisión en todas las regiones de longitud de onda es una clave para investigar la estructura atmosférica de una estrella muy luminosa. Pero también es un laboratorio celeste ideal para física atómica y para desarrollar nuevas técnicas de análisis de datos. También se ilustran varios aspectos conflictivos del problema de η Car, tales como la presencia simultánea de una fuente de rayos X y un proceso efectivo de formación de polvo, así como el gran rango en velocidad y temperatura en el viento. Finalmente, se estudia el problema de η Car en el escenario general de la evolución de estrellas masivas.

ABSTRACT

η Car is one of the most peculiar astrophysical objects whose nature is still far from being understood. In this paper some major characteristics of the object are reviewed, and the fields which should require more work in the future are indicated. A critical overview of the historical light curve of η Car is given, and the associated change of the Key-Hole nebula (Herschel's controversy) is discussed. The very rich emission line spectrum in all the wavelength regions is a key to investigate the atmospheric structure of a very luminous star. But it is also an ideal celestial laboratory for atomic physics and to develop new techniques of data analysis. The many conflicting aspects of the η Car problem, such as the simultaneous presence of an X-ray source and of an effective process of dust formation, and the wide velocity and temperature range in the wind, are also illustrated. Finally, the η Car problem is studied in the general scenario of the evolution of massive stars.

Key words: **ATOMIC PROCESSES — CIRCUMSTELLAR MATTER — DUST, EXTINCTION — STARS: INDIVIDUAL: (η CAR) — STARS: MASS-LOSS**

1. INTRODUCTION

η Car is one of the most disconcerting astrophysical objects for assembling many extreme peculiarities, such as the large light variation of the past century and the associated change of the Key-Hole nebula, the very rich emission line spectrum from the space ultraviolet to the infrared, the huge IR excess, the X-ray emission, and the rapidly expanding circumstellar nebula. In a few words η Car is the prototype of many different types of astrophysical phenomena, and the best astrophysical laboratory for their study. In that sense we shall, in the following, speak of the η Car phenomenon. This review is mostly concerned on a few aspects of the phenomenon, the historical light curve, the spectrum, and the nature of the central object.

2. THE HISTORY

2.1. The Historical Light Curve

The light history of η Car can be schematically divided into three main phases, the ***bright phase*** from around 1822 to 1856, the ***big fading*** from 1856 to 1870, and the ***low luminosity phase*** from 1870 up to present (Figure 1). The most important part of the η Car light curve is that of the past century. Most of our information on it comes from a paper published in 1903 by Innes who made a synthesis of the available observations during 1836 to 1902 (Innes 1903). Earlier observations back to 1500 were reviewed by Gratton (1963). Innes' work was essentially a critical review of a great deal of individual observations of many different persons. There must have been a large scatter of the individual observations; some observers, for instance, might have quoted the luminosity reported by previous observers, rather than their own data. In order to produce an acceptable light curve Innes must have discarded some largely deviating data. The final plot shown in Figure 1 is in fact a rather smooth curve which might possibly hide small real fluctuations. In particular, a curious case is the nearly exponential light decrease during 1857 to 1869 with an e-folding time scale of 1.9 years. In this regard, very recently Polcaro & Viotti (1993) have brushed up an old, nearly forgotten article by a professional astronomer, Kulczycky (1865), who described a large brightening of η Car during 1860-62. According to his observations the star at that time was about 2 magnitudes brighter with respect to the Innes' smooth curve (Fig. 1), although a kind of upward pointing arrow is present in the original plot of Innes at around 1861 (see also van Genderen & Thé 1984). Taking into consideration from one side the very weak chance of an observational error by Kulczycky, Polcaro, & Viotti (1993) suggest that η Car should have suffered at that epoch large luminosity fluctuations. These might have been noted by other observers, but they probably were later "revised" by Innes or by the observers themselves who could have considered the large deviations to be wrong. A memory of this could be the 1862 halt, half-a-way of the fading phase as reported in the Innes' curve.

Very recently, Feast, Whitelock, & Warner (1994) have questioned the validity of Kulczycky's reports on the basis alone of their marked discrepancy with the observations of Tebbutt used for the Innes' light curve.

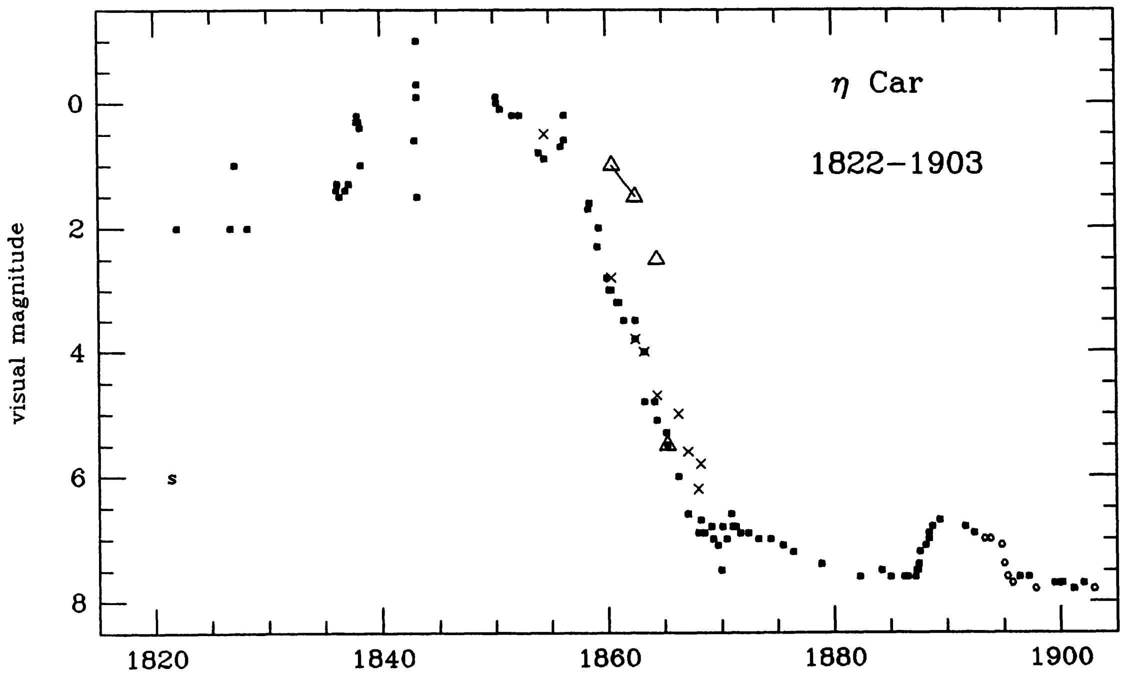

Fig. 1. The historical light curve of η Car (1822–1903). *Dots*: Innes' (1903) data. *Triangles*: Kulczycky's data (Polcaro & Viotti 1993). *Crosses*: revised Tebbutt's data (Feast et al. 1994). *Circles*: Hoffleit's (1933) photographic data normalized to Innes' data. *s*: Scully's observation of February 1822 (Innes 1903).

Feast et al. however have reanalyzed the original Tebbutt's magnitudes, and found significant differences (up to about 1^m in 1865–67; see Fig. 1) between the revised Tebbutt's magnitudes and those reported by Innes. The presence of a gap should also be noted in the Innes curve for the period 1892–96 which corresponds to the end of the 1887 light maximum. Hoffleit (1933) in her study of the spectral variation of η Car has also given the photographic light curve of the star during 1893–1926. These data are of special interest since they show the final part of the 1887 maximum, while Innes (1903) only gives the earlier phases of it. In the figure, Hoffleit's photographic data have been corrected by -0.6^m in order to put them on the same scale of Innes' visual magnitudes. These data show the peculiar shape of this event, with a five year of permanence at maximum luminosity which is unique in the light history of η Car.

It is clear from the above considerations that the historical light curve is still far from being well known, and that, following the works of Polcaro & Viotti (1993) and of Feast et al. (1994), a careful search of archival data must be done in view of the fundamental importance of the behaviour of the star during this epoch, as discussed below. As far as the star's "prehistory" is concerned, according to Gratton (1963) η Car was recorded as a fourth magnitude star in 1603 and 1677, around 2^m to 4^m in 1685–89, 2^m in 1752, and 4^m at the beginning of 1800. A single observation of Scully on February 20, 1822 provides the star with a sixth magnitude, while the following observation of Fallows of March 15th reports η Car as a second magnitude star. These latter observations, if confirmed by future detailed archive studies, would imply large luminosity fluctuations of η Car on a very short time scale of a few weeks during its bright phase. We must also consider that the apparent luminosity increase or jump of at least two magnitudes before 1800, if real, should have an important impact on the possible models of η Car, but at present it cannot yet be the subject of profound theoretical speculations.

The main feature of the "bright phase" is a number of luminosity peaks, with 1–1.5 magnitudes of amplitude and a duration of many months to one year (Fig. 1). These maxima are frequently referred to as "outbursts", although this term already belongs to an interpretation of the phenomenon, rather than to a mere description of it, and could mislead the scholar. Light maxima were recorded in 1827 (Gratton 1963), 1838, 1843, and 1856 (Innes 1903). The star was also very bright around 1850–52. The luminosity "Guiness record" was that of -1.0 in 1843, when the star was the second brightest star in the sky after Sirius. The published light curve of η Car during its bright phase has so many gaps that it is impossible to state whether they were a kind of semiregular large amplitude oscillations, or the star was at a mean magnitude of about $V = 1$, with a few occasional maxima. In this regard, I would like to recall the deep minimum reported by Innes himself just at the time of the 1843 record luminosity, and the 1822 6th magnitude minimum reported by Scully, discussed above. As discussed above, a maximum occurred during the big fading phase in 1860–62, and another one in 1887–1895 (Innes 1903; Hoffleit 1933), when the star was already at minimum luminosity. Another small maximum occurred in 1870 at the end of the fading phase. Thus the apparently "paroxystic" phase of the star continued long after the end of the bright phase.

Studies of the proper motions of the η Car nebula have shown that some regions of the nebula (also called "condensations") should have been ejected from the central star close to the time of the maxima, including that of 1887 (Gaviola 1950; Ringuelet 1958; Walborn, Blanco, & Thackeray 1978), which confirms that they were associated with massive ejections of matter with velocities of 600 to 1000 km s^{-1}. Walborn et al. also found that the condensations of the outer nebular shell should have been ejected by η Car a few to many hundreds years ago, which supports the idea of a violent stellar activity spanning a long period of time. It would be important to find more ancient records of the star's luminosity to confirm this point.

Another important historical information on η Car might be derived from the visual records of its apparent color. Indeed the star has been in a few times reported as 'reddish', 'yellowish', or so. For instance in 1843.3 ($V = -0.1$) η Car was reported to have the same color of Arcturus (B–$V = +1.23$), and in 1850.2 ($V = -0.1$) it has a 'yellowish red light more marked than Mars', while a few months later in 1850.6 ($V = +0.1$) it was 'not as red as Arcturus' (Innes 1903). Since the red color of η Car is partly due to the strong Hα emission, and partly to the interstellar extinction, it is not possible at the moment to relate any visual color estimate to the stellar energy distribution. We might only suspect that its color has indeed varied during the light variations with the same trend as observed in other luminous blue variables, the color being redder near the visual maxima. This is a crucial point for the constant luminosity model which will be discussed later.

2.2. Herschel's Controversy

One astonishing effect of the large brightness variation was the change of the shape of the nebulosity near η Car. In this regard, this is one of the few well documented cases of variability of a diffuse nebula. This fact however was not immediately accepted by the astronomical community. In 1830–40 Herschel spent almost three years in observing the whole region near η Car and the large nebula (NGC 3372). The results of his very detailed measurements and drawings are described in his report (Hershel 1847). Of special interest was the peculiar shape of the nebula near η Car, displaying in the central parts of the nebula a dark region in the form of a "lemniscata". This feature looks like an (old fashion) key hole, and this actually was the origin of the name given to NGC 3372, the Key Hole nebula. A couple of decades later the nebula was studied again, but the central part appeared very different from that shown in the Herschel's drawings. In particular the lemniscata appeared open in its southern part. This fact rised a very hot discussion among astronomers, whether the "hole" was closed or open, and doubts were put about the earlier Herschel's observations. For instance Gould wrote: 'But such observations of the nebula around η Argus as I have been able to make, compared with Sir John Herschel's drawings, have tended strongly to impress me with the conviction that the allerged change is altogether imaginary' (Gould 1871; see also Gaviola 1950). And Bok accepted 'this verdict as final' (Bok 1932). But, as discussed by Gratton (1961, 1963), Herschel's observations were very accurate, as for instance indicated by the precise positions of the faint stars immersed in the nebula which matches very well those derived from the present photographic measurements (Gratton 1961). His measurements are so precise and his statements on the Key Hole shape so explicit, that it is hard to admit such a large error in his drawings, as said by his detractors. Gratton concludes that the variations of the nebula were certainly real, and that they have to be associated with the large luminosity fading of η Car. This is in particular one proof of the association of η Car with the Key Hole nebula.

3. SPECTROSCOPIC INVESTIGATIONS

3.1. The Emission Line Spectrum

In 1870 Le Seuer reported the first visual observation of the spectrum of η Car. He noted the presence of a number of bright lines, i.e., in emission, most probably of hydrogen and helium (Le Seuer 1870; Walborn & Liller 1977). Thanks to the 13-in telescope of the Harvard Observatory in Peru, a series of objective prism and slit spectrograms were obtained of the star since May 1892. The 40 plates taken between 1892 and 1903 were analyzed by Hoffleit (1933), who described the marked spectral evolution following the 1887 light maximum. The most interesting spectrum is that of June 1893 showing a rich absorption spectrum with a few emission lines. The absorption spectrum was typical of that of an F supergiant, with many Fe I lines, and with a radial velocity shift with respect to the emissions of -180 km s^{-1} (Cannon 1916; Whitney 1952; Gratton 1963; Walborn & Liller 1977). Quite curiously, at that time the spectrum of η Car resembled, both in the spectrum and in the radial velocity shift, those of the symbiotic nova RR Tel in 1949 during its longstanding light maximum (Viotti 1990), and of the classical symbiotic star Z And during its 1939 outburst (cf., Swings & Struve 1941). This similarity is suggestive of a similar physical evolution of the matter ejected from the hot component of the symbiotic systems and from the stellar core of η Car. A remarkable point is the fact that the previous plate of η Car taken on 20 May 1892 displayed a rich emission line spectrum with strong [Fe II] lines which disappeared one year later, at the time of the F-supergiant spectrum, and reappeared in May 1895 (Hoffleit 1933). Walborn & Liller (1977) however have reexamined the 1892 plate and questioned Hoffleit's identification. After the end of the 1887–1895 light maximum, the spectrum of η Car evolved very slowly with an increase of the [Fe II]/Fe II intensity ratio between May 1895 and June 1902 (Hoffleit 1933), similar to the spectral evolution observed during the earlier phase of classical novae, also known as the *η Car stage*, but with a much longer time scale, and without the following nova phase characterized by the appearance of lines with higher and higher ionization energy. In this regard we must note that η Car was included by Payne-Gaposchkin (1957) in her list of novae, although, as shown below, the energy budget of the star during its light maxima is by far much larger.

Besides the few ***shell episodes*** described elsewhere in these Proceedings by Damineli et al. (1995), the spectrum of η Car remained the same up to present times with a very rich emission line spectrum in all the wavelength ranges. Many hundreds emission lines have been identified in the optical spectrum among others by Gaviola (1952), whose identification was later revised by Viotti (1968), Thackeray (1953), and Aller & Dunham (1966). The longwave red-near IR region was examined by Thackeray (1967, 1969), Allen, Jones, & Hyland (1985), Maillard, Viotti, & Altamore (1992), and Hamann et al. (1994). In the shortwave side the high resolution ultraviolet (*IUE*) spectrum was discussed in detail by Viotti et al. (1989). The low resolution UV spectrum is shown in Fig. 2. The most remarkable features in this spectrum are the N V resonance doublet with a broad absorption, the strong emissions of the N III] and Si III] intercombination lines, and the Fe III emission line at λ1895. It should be noted that at low resolution the latter could be easily misidentified with C III], which on the contrary is absent. In the longwave spectral region, the blend of many Fe II P Cygni absorptions largely depress the spectrum shortwards of 2400 A. This *Fe II jump* is a signature of the presence of a dense cool wind

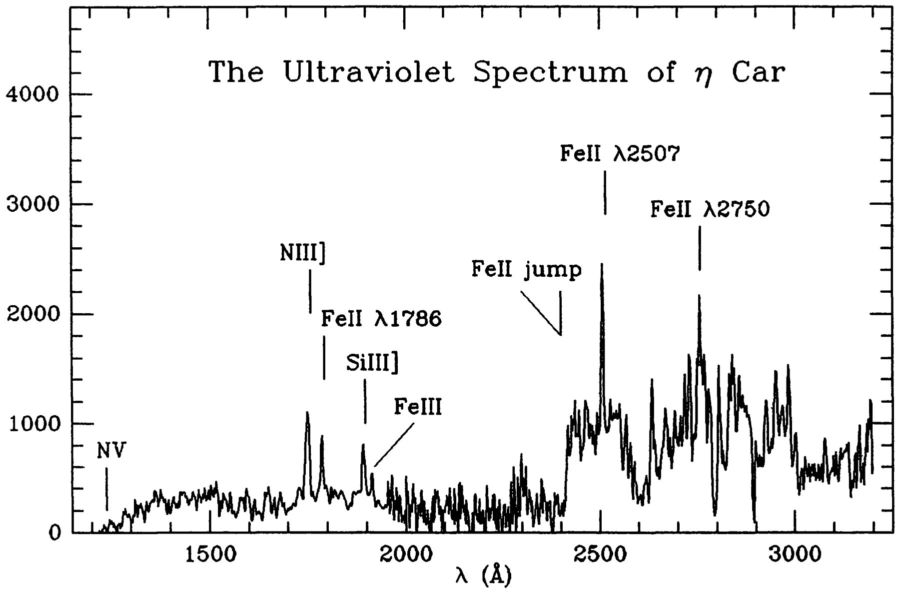

Fig. 2. The low resolution ultraviolet spectrum of η Car. The main spectral features are indicated: the marked flux depression shortward 2400 A due to the large Fe II line absorption, the high temperature N v λ1240 resonance doublet with a P Cygni profile, the Fe III emission near Si III] λ1892, and the high excitation Fe II lines at 1786 and 2507 A. Ordinates are fluxes in 10^{-14} erg cm^{-2} s^{-1}.

in this star, which could be detectable also at lower resolutions. Observation of this spectral feature in the UV spectra of distant luminous stars, such as LBVs in external galaxies, should provide important information on their winds.

In general the main characteristics of the present spectrum of η Car is the great deal of Fe^+ lines in all the wavelength regions, and the wide variety of atomic species, ranging from lines of neutral species (Na I, O I, Fe I), to high ionization energy, such as [Fe III], [Ne III] in the optical, and N III], C IV, He II, and N v in the UV. The line profile generally displays a narrow peak over a broad, asymmetric emission, and a violet-shifted broad absorption line extending to $-600/-800$ km s^{-1}. Higher velocity components have also been observed in the resonance Si IV UV doublet (Viotti et al. 1989), and in the metastable He I λ10829 A line (Damineli et al. 1993). Another peculiarity is the presence of blue-shifted emission components in the strongest lines of Fe II, [Fe II] and [Fe III] (e.g., Aller & Dunham 1996), as well as of [S III] and [A III] (Hamann et al. 1994).

3.2. η Car as a Laboratory for Atomic Physics

In astrophysical objects spectral lines are formed under extreme physical conditions which cannot be reproduced in terrestrial laboratories. Thus the observation of their spectra has in most cases given an important contribution to Atomic Physics. In this regard η Car, for the richness of its emission line spectrum in the widest wavelength range, has been and is one of the most promising astrophysical laboratories. Going back 65 years ago we recall the first identification of [Fe II] in an astrophysical and laboratory plasma which was made by Merrill (1928) in the Harvard spectra of η Car. In more recent times, Garstang (1962) illustrated the agreement of the intensity of the [Fe II] emission lines in the star with his computed transition probabilities. We should also remind that, more recently, Johansson (1977) was able to identify the highly excited lines of Fe II, not included in the most commonly used Moore's RMT tables (Moore 1945). Indeed, in the near–IR the non-listed Fe II λ9997 line is very strong, with an intensity comparable to that of the nearby Pδ line (Viotti et al. 1992, Johansson & Hamann 1993), in spite of the fact that the Fe II line belongs to a transition from a highly excited term. In the space ultraviolet Viotti et al. (1989) have remarked the peculiar fact that in the low resolution *IUE* spectrum of η Car the most prominent emission feature is that of Fe II λ2508 (Fig. 2), which actually belongs to a transition from a highly excited term not listed in the Moore's (1952) Ultraviolet Multiplet Tables.

The anomalous strength of these high excitation lines can be explained as the result of the combination of a low line autoabsorption and of selective excitation mechanisms, such as fluorescence (for the λ2507 and λ9997 lines), or dielectronic recombination (for the $\lambda\lambda$1785–88 system).

3.3. The Fe II Problem and the Interstellar Extinction

There are a couple questions which immediately arise from looking at such a rich Fe II emission line spectrum. They are: which information can be derived from their strength, and why are there so many forbidden lines with an intensity comparable to that of the permitted ones. Actually, these are problems which concern a large variety of astrophysical objects throughout the whole H–R diagrams (and beyond it), from *Be* stars to symbiotic and Mira variables, from novae, supernovae, and SNRs to the Seyfert galaxies, all showing a rich Fe II and [Fe II] emission line spectrum (Viotti, Vittone, & Friedjung 1988). Within this *Fe II problem*, η Car is the most representative and most studied object. The Grotrian diagram of Fe^{+} is quite complex, and provides a large number of electric dipole permitted and forbidden transitions in a wide spectral range. This fact, on the other hand, may allow a statistical treatment of the problem, even in the case of fairly low quality laboratory (atomic) and observational data, as it was the case of the earlier studies of the Fe II spectrum of η Car. If the emission lines are formed in an optically thin region, their intensity can be used to derive the relative level population. The first attempt was done by Thackeray (1967) who used his visually estimated Fe II line intensities, and derived a level excitation temperature of about $8500°K$. Later, Viotti (1969) from a statistical analysis of the equivalent widths of 300 lines of Fe II and [Fe II] obtained $T_{ex} \simeq 8000°K$. Since Viotti included lines from a wide spectral range, from 3300 A to 6800 A, he had to include in the fit a wavelength dependent term, which turns out to be the relative energy distribution of the stellar continuum below the emission lines. This actually is the intrinsic (not reddened) continuum, and its comparison with the observed one led Viotti to determine an estimate of the interstellar extinction of $E_{B-V} \simeq 1.1$. A similar value of 1.2 was previously derived by Pagel (1969) who used the observed emission line intensities of the Fe II lines measured by Aller & Dunham (1966), while Lambert (1969) obtained 1.8 from the [Fe II] line intensities from the same source. Later, Ade, & Pagel (1970) derived $E_{B-V} = 1.26 \pm 0.17$ from the equivalent widths of many sets of Fe II lines having common upper levels. As discussed by Andriesse, Donn, & Viotti (1978), this color excess is partly *interstellar*, and partly *circumstellar*. The latter, with $E_{B-V} = 0.6$–0.8, is due to the circumstellar dust envelope, and most probably does not follow the standard galactic extinction law, but should have a larger A_V/E_{B-V} ratio of about 5 (see also van Genderen & Thé 1984).

The problem of the different mechanisms of Fe II line excitation in emission line objects was first faced by Viotti (1976) who concluded that in η Car the Fe II and [Fe II] lines should be formed in a region with an electron density of about 5×10^{10} cm^{-3}, if the radiation field is neglected. The study of Fe II emission lines is however hampered by the large line opacity and by the complex atomic structure. Thus statistical techniques such as the curve–of–growth analysis should be more appropriate for this study. Since we are dealing with emission lines, a most powerful technique is the Self–Absorption–Curve method (SAC) which allows the determination of the level population even for optically thick lines. This technique has been used in the study of luminous variables (Muratorio & Friedjung 1988; Muratorio et al. 1992), while its application to the η Car spectrum, which is not so trivial for the complex line profiles, is under way.

3.4. Diagnostics

It is difficult to reconcile the very wide range of ionization energy and of line strength observed in the spectrum of η Car with any standard stellar wind model. From the side of the evolution models, a crucial point would be the peculiar chemical abundance of η Car's wind, as suggested by the absence of some important lines of carbon and oxygen in the optical and UV spectrum. A first attempt to make a diagnostics of the η Car spectrum was performed by Rodgers & Searle (1966) who, from the intensity of the hydrogen, [N II], [S II] and [Ne III] lines, and the upper limits for the [O II] and [O III] lines, concluded that the lower ionization lines are formed in an extended region with $T_e = 20000°K$ and $n_e = 3 \times 10^6$ cm^{-3}, while the doubly ionized lines are formed in a smaller volume with with a T_e near $50000°K$. They also concluded that oxygen is underabundant with respect to nitrogen and sulfur. A CO/N anomaly was also suggested by Davidson et al. (1986) from their analysis of the UV spectrum of the η Car's ejecta. Viotti et al. (1989) however, have shown that the absence of the C III] λ1909 line in the stellar core spectrum would imply either a carbon underabundance, and/or an electron density $\geq 3 \times 10^{10}$ cm^{-3}, in the Si^{+2}, C^{+2} region of the η Car's wind.

Another constraint is the line profile. Both the low and high ionization resonance lines display a P Cygni absorption component extending to nearly the same terminal velocity, which implies a wide ionization range throughout the whole stellar wind (Viotti et al. 1989). On the other hand, both in the stellar spectrum and in that of the expanding circumstellar nebula narrow emission lines have been observed (e.g., Baratta, Cassatella, & Viotti 1995), which is suggestive of the presence of a low projected velocity region, possibly a circumstellar disk. Therefore, the η Car's wind is neither spherical symmetric, nor homogeneous (Viotti et al. 1986).

4. η CAR AS A VERY LUMINOUS, DUSTY STELLAR OBJECT

4.1. The Dust Envelope

Condensation and growth of dust grains from cosmic gas clouds is a fundamental process in Astrophysics, as it pertains the earlier phases of formation of the solar system. η Car is one of the few astrophysical objects in which there is a clear evidence that this process is taking place since the middle of last century. The first direct evidence of the presence of a dust envelope was given by the infrared observations of Neugebauer & Westphal (1968), and Westphal & Neugebauer (1969) who found that the infrared radiation from η Car is so intense as to make the star the brightest celestial source in the mid-IR outside the Solar System. More than 90% of the radiation from η Car is emitted in the IR, which actually is the stellar core flux absorbed by the circumstellar dust envelope, and reemitted at longer wavelengths. A second fact is the polarization of the radiation from the Homunculus, discovered by Thackeray in 1961, which originates from the scattering of the stellar core radiation by dust particles in the nebula.

As discussed above, the circumstellar nebula was formed following the massive matter ejection during the bright phase of the past century. At some distance from the star dust began to form, thus causing the (apparent) luminosity fading of the star (Davidson 1971). Andriesse et al. (1978) suggested that the dust condensation process started in 1856, probably as the result of an increase of the stellar mass loss rate. The analysis of the light curve led them to conclude that dust is still condensing from the stellar wind, at a distance in excess of 3.7×10^{16} cm, at a rate of $\dot{M}_d \sim 10^{-4}\ M_\odot\ y^{-1}$. The corresponding *continuous* outflow of gaseous matter from η Car is $\geq 10^{-2}\ M_\odot\ y^{-1}$, which turns out to be the highest continuous mass loss rate measured in a stellar source. A similar study of the light curve of η Car was made by Men'shchikov, Tutukov, & Shustov (1989), who developed a model with a mass loss of $10^{-1}\ M_\odot\ y^{-1}$, during the first 15 y after the main outburst and slowly declining in time.

The above facts indicate that in the η Car's atmospheric outskirts there should exist the most favourable conditions, of high density and low temperature, for the condensation and growth of dust grains. Yet, according to our current (still rather poor) knowledge of these processes, even more extreme conditions are required for dust grains to be formed (cf., Andriesse et al. 1978). This would for instance imply that at some distance from the star the wind matter should start to aggregate to form small high density condensations, which are not penetrated by the UV stellar photons. This scenario is in agreement with the knotty shape of the homunculus, as for instance shown by the coronographic observations of Burgarella & Paresce (1991).

The nature of the condensate is another puzzle. Carbon, oxygen, and silicon are the most common compounds of dust grains. Andriesse et al. (1978) suggested that in η Car the first nuclei are disordered silicate clusters. In many astrophysical objects carbon compounds are considered to be fundamental ingredients of dust grains formed from the ejected stellar matter. However, the η Car's wind is thought to be underabundant in CO, which should make dust condensation more difficult, unless we take into consideration other types of condensate. Alternatively, we might consider that *carbon and oxygen are depleted in the stellar wind as the consequence of the process of dust condensation.* In order to check these hypotheses, an accurate determination of the chemical composition of the wind is needed, which, as discussed above, is far from being known at present, and would require a better knowledge of the atmospheric structure.

4.2. The Stellar Luminosity

Since η Car is emitting most of its radiation in the little absorbed infrared, its apparent bolometric magnitude can be derived by integrating the IR energy spectrum. The resulting value of $m_{bol} = 0.0$ (e.g., Andriesse et al. 1978) implies, if we assume for the star the same distance modulus of the Trumpler 16 association (V_0–M_V = 12.0, Feinstein, Marraco, & Muzzio 1973, Thé, Bakker, & Antalova 1980, Tapia et al. 1988), an absolute bolometric luminosity of $M_{bol} = -12.0$, or $5 \times 10^6\ L_\odot$ (2×10^{40} erg s^{-1}). Therefore η Car is one of the most luminous stellar objects in the sky, even more luminous than the peculiar object SS 433 (cf., Harrison 1990).

It would be important to compare the present bolometric luminosity of η Car with that of the 1800 bright phase. As discussed above, at that time the stellar radiation was not affected by the circumstellar dust envelope which was formed later. Thus, following Andriesse et al. (1978), if we assume a visual interstellar extinction of 1.2–1.5 mag, a nil bolometric correction near the light maxima, and, outside them, B.C.=–2, we derive for the bright phase a mean bolometric magnitude of about –1/–2, which is 1–2 magnitudes brighter than present. Andriesse et al. (1978) considered that the very large mechanical power associated with the huge mass outflow should be accounted for this difference, so that the total power from the star might have remained the same since at least 150 years. van Genderen & Thé (1984) on the contrary concluded for a true variation of the energy power from η Car, with a maximum bolometric luminosity of $M_{bol} \leq$–14.8 near the 1843 peak. This is another point which should deserve more study in the future. It would also be important to investigate whether the many light peaks of the past century were real increases of the stellar luminosity, implying an energy output of the order of 10^{48}–10^{50} erg, comparable to that of a supernova explosion, or they were mere transient variations of the energy distribution, with the maximum of the energy spectrum moving from the blue–UV to the yellow at the time of the outburst. Indeed, this phenomenon of visual luminosity variation at constant bolometric luminosity was recently observed in many luminous blue variables, such as AG Car. Therefore, the possibility should be taken into consideration that *η Car has not largely changed (and possibly not changed at all) its total power, radiative plus mechanical, since at least 1800.* This a basic point if we want to investigate the structure instabilities of the star.

4.3. Wind's Structure and Binarity

η Car is an object of the upper H–R diagram which has been as bright as $\sim 10^7\ L_\odot$ during at least the last few centuries, and should therefore be a very massive star ($M \simeq$ 140–150 $M_\odot$, Davidson 1971, Andriesse et al. 1978, van Genderen & Thé 1984, Kiriadikis, Fricke, & Glatzel 1993, etc.). Alternatively, it could be a close binary system, possibly in the common envelope phase, as it has been suggested by Tutukov & Yungelson (1979). No direct evidence of binariety has been so far found, but the asymmetric structure of its wind (as derived from the line profiles) and of the circumstellar nebula might be the result of tidal interactions in a close binary system.

However, theoretical models of the evolution of massive stars have shown that the stars are in an unstable state and that strong pulsations with different modes can be originated (Tsiopa 1990). Matter is not ejected through a uniform wind, but it is thrown away as a system of dense shells, which breaks out at some distance from the star. The angular momentum of the wind due to a rotation of the stellar core might produce a dense, low velocity disk in the equatorial plane, where dust condensation is likely more effective. High velocity wind matter is ejected in the polar directions, which should produce elongated circumstellar nebulae, as observed in η Car. It is however difficult to explain the presence of a jet at right angles with respect to the homunculus axis (Hester et al. 1991).

Andriesse et al. (1978) have shown that in η Car a strong magnetic field could be present and play a fundamental role both in shrinking the wind matter and in stabilizing the density fluctuations against turbulent perturbations, so favouring dust to condense. A magnetic field collimation might also explain the high asymmetry of the star's wind and circumstellar nebula. Therefore, the presence of a stellar rotation and/or of a strong, inhomogeneous magnetic field can in principle explain the η Car features, without invoking the presence of a binary system.

4.4. Some Considerations on the Work to Be Done

Future studies of the η Car problem should span a wide range of topics. We shall here underline a few ones which do not require large funds and expensive high quality instrumentations or satellites.

- Careful search of archival data for a better knowledge of the historical (and pre–historical) light curve, and of the amplitude and time–scale of the spectral variations.

- Development of appropriate models of the η Car's wind in order to determine its mass loss and chemical composition.

- Organization of campaigns of multiwavelength monitoring of η Car to give a quantitative ground for investigating the star's structure instabilities, and/or binarity.

- Study of the nature, binarity, and kinematics of the nearby stars of Trumpler 16.

5. FINALE

For its many peculiarities η Car has been frequently considered a very exotic animal in the Astrophysical Zoo, a kind of monster too peculiar to be included in any current theoretical scenario. From the above discussion it turns out that η Car is on the contrary like a siren, which is bewitching us with her charming aspect and behavior. In fact, in spite of the many powerful means of investigation and analysis, which are at our disposal in present times, η Car still remains a most enigmatic object which, I would say, to day is even more mysterious than yesterday. Indeed it is evident that new observations instead of giving a final answer to our questions, are on the contrary posing new problems. This does not mean that we are disappointed, but rather stimulated to make more research. Finally, to complete this picture, I would like to remind that, in the old drawings of the sky constellations, η Car is placed near the bow of the Argonauts' ship, just at the right position of the front figure, and that a siren is a most common front figure in the sailing vessels. Therefore, we would like to suggest a new name for our star: η *Prorae*, the brightest star of a new constellation, the *Prora* of the Argonauts' ship.

I would take this occasion to express my thanks to the many collaborators who enthusiastically flanked me in the enterprise to unveil the mysteries of this star, and to many persons with whom I had many exchanges of ideas and discussions. I would in particular like to acknowledge M. Friedjung for 23 years of discussions on the Fe II problem, and V. Francesco Polcaro for the evolutionary considerations. But above all I would like to recall Prof. L. Gratton, to whom this talk is dedicated, for having introduced me this fascinating star 30 years ago, and for having put at my disposal many spectroscopic plates of η Car obtained half a century ago at the Bosque Alegre Observatory, which have been the starting point of my research in Astrophysics.

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