1995RMxAC...2...41D

RevMexAA (Serie de Conferencias), **2**, 41-45 (1995)

ONE CENTURY OF SPECTROSCOPIC OBSERVATIONS OF η CAR

A. Damineli Neto
Instituto Astronômico e Geofísico da USP, 04301 São Paulo, Brazil
A. Cassatella and R. Viotti
Istituto di Astrofisica Spaziale, CNR, 00044 Frascati, Italy
G.B. Baratta
Osservatorio Astronomico, 00136 Roma, Italy
and
G.J. Carranza and M. Villada
Observatorio de la Universidad de Córdoba, 5400 Córdoba, Argentina

RESUMEN

η Car fue observada durante su espectacular evolución tipo-nova de 1893–1912. En tiempos más recientes, se han observado eventos transientes *episodios de shell*, los que se caracterizaron por un debilitamiento de las líneas de emisión de energías más altas. Observaciones *IUE* del episodio de 1981–82 mostraron un gran decaimiento de la línea de N III] λ1750 y de las líneas de alta excitación de Fe II $\lambda\lambda$1785–88 y 2507–8. Un nuevo episodio de *shell* se registró en 1992 con el telescopio Brasileño LNA de 1.6-m. Un monitoreo continuo demostró que, desde 1990, la línea metaestable de He I λ10829 A se estaba debilitando gradualmente, hasta casi desaparecer en junio de 1992. Una disminución similar se encontró en otras líneas de emisión de He I, mientras las líneas de H no cambiaron mayormente, indicando que el episodio estaba localizado en las líneas de más alta energía. Observaciones ópticas e *IUE* obtenidas en diciembre de 1992, indicaron que el episodio había finalizado. Un nuevo análisis de las observaciones disponibles nos lleva a sugerir que la excitación de líneas en el viento de η Car está oscilando continuamente, con un cuasi-período de alrededor de 5 años, en antifase con la curva de luz del infrarrojo cercano. Esto podría ser el resultado de la propagación a la superficie de inestabilidades estructurales en estrellas supermasivas.

ABSTRACT

η Car was observed one century ago during its spectacular nova-like evolution of 1893–1912. In more recent times, transient events, or *shell episodes*, which were characterized by a fading of the higher energy emission lines. *IUE* observations of the 1981–82 episode have shown a large decrease of the N III] λ1750, and of the high excitation Fe II $\lambda\lambda$1785–88 and 2507–8 lines. A new shell episode was recorded in 1992 with the 1.6-m LNA Brazilian telescope. From continouos monitoring we found that, since 1990, the metastable He I λ10829 A line was gradually fading, down to nearly disappearance in June 1992. A similar weakening was found in other He I emission lines, while the H lines did not strongly change, indicating that the episode was focused on the higher energy lines. Optical and *IUE* observations in December 1992 showed that the episode was ended. A reanalysis of all the available observations leads us to suggest that the line excitation of the η Car wind is continuously oscillating, with a quasi-period of about 5 years, in antiphase with the near-IR light curve. This might be the result of the propagation to the surface of structure instabilities in supermassive stars.

Key words: **INSTABILITIES — LINE: PROFILES — STARS: INDIVIDUAL: (η CAR) — STARS: MASS-LOSS**

© Universidad Nacional Autónoma de México • Provided by the NASA Astrophysics Data System

1995RMxAC...2...41D

1. INTRODUCTION

η Car is since long known for its very rich emission line spectrum, which is reflecting the presence of a very extended expanding envelope surrounding the star. The study of the time variability of its spectrum in the broadest wavelength range might provide important information on the dynamical structure of massive stars' winds. The spectrum of η Car was first observed visually during the fading phase by Le Seuer (1869) who noted the presence of bright lines. Since 1892 the Harvard Observatory telescope made a continued monitoring of the η Car's spectrum. The results described by Hoffleit (1933) and Whitney (1952) indicate a nova-like evolution following the 1889 maximum, which should be associated with the formation of a dense expanding envelope, followed by its gradual dissipation. In 1893 the star displayed a spectrum similar to that of an F-type supergiant (cF5) with absorption lines shifted by about -180 km s^{-1}, and the Balmer series in emission. In the following years the spectrum was dominated by strong emission lines, with a gradual increase of [Fe II] with respect to Fe II. Since then, the η Car spectrum has remained up to present substantially constant with strong H and Fe^+ emission lines.

2. THE SHELL EPISODES

In more recent times a number of transient events, or *shell episodes*, have been observed which were characterized by marked spectral variations. The first episode was recorded in 1948–49 by Gaviola (1953) and described in detail by Viotti (1968), who found a general fading of the emission line equivalent widths, from a factor two for the Fe II lines up to a factor $\sim$ 7–10 for the higher temperature lines of He I, [Fe III] and [N II], while [Ne III] completely disappeared (Figure 1a).

Other episodes were discovered by Rodgers & Searle (1967) in 1964–1965, and by Zanella, Wolf, & Stahl (1984) in December 1981. Zanella et al. also noted a similar effect in the ultraviolet spectrum of the star

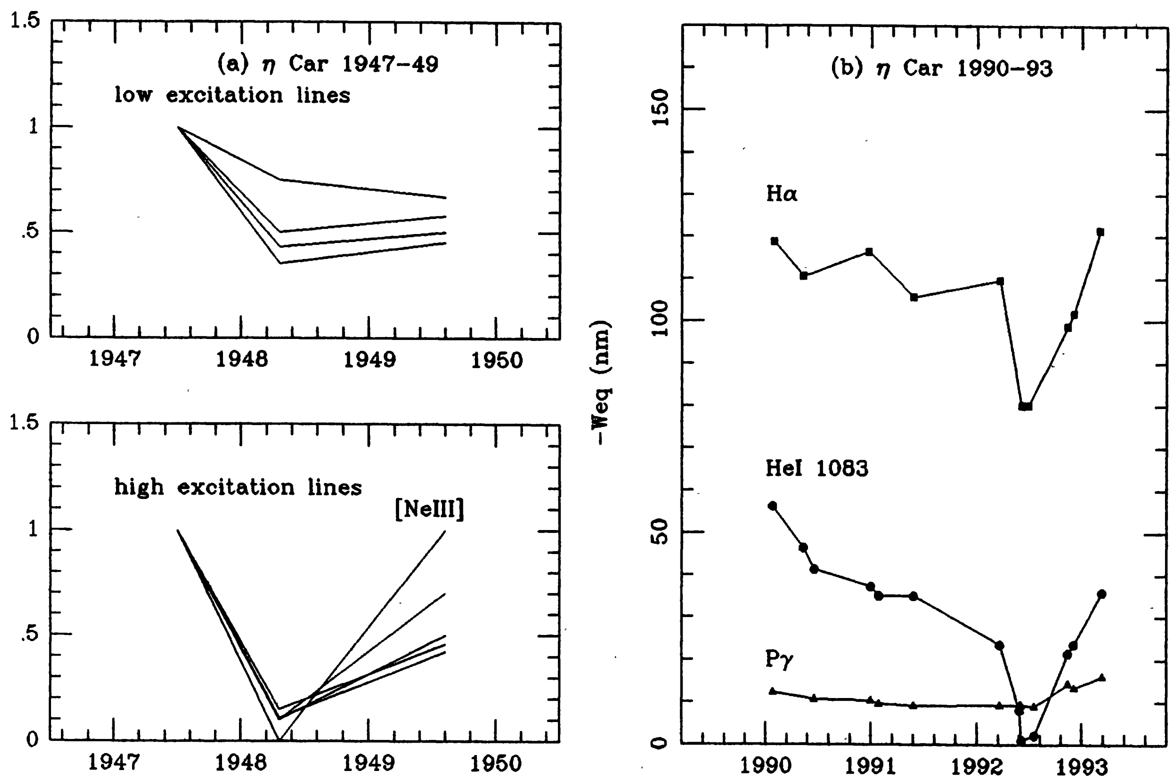

Fig. 1. Spectral variation of η Car during 1947–49 (Viotti 1968), and 1990–1993.

© Universidad Nacional Autónoma de México • Provided by the NASA Astrophysics Data System

1995RMxAC...2...41D

observed with *IUE* a few months later, as discussed below. It is clear from the above that all these episodes were discovered by chance, for no systematic monitoring of the spectrum of η Car was performed in the past years. It is therefore conceivable that many other unobserved episodes should have occurred. We have in fact found in the near-IR spectra of 1981 and 1987 discussed by Allen, Jones, & Hyland (1985) and Maillard et al. (1992) a large fading of the He I λ10829 A line, not noted by the authors.

A new shell episode in 1992 was recorded with the 1.6-m telescope of the Brazilian National Astronomical Laboratory (LNA). From a continuous spectroscopic monitoring in the optical and near-IR we found that in June 1992 the metastable He I λ10829 A line, which normally displays a very strong emission peak and high velocity P Cygni absorptions (Damineli et al. 1993), has largely decreased down to nearly disappearance (Figure 1b). A similar weakening was found in the other He I emission lines, and in the [A III] λ7155 line. In the meantime the hydrogen lines have not strongly changed, indicating that the episode was mostly focused on the higher energy lines. A careful analysis of all the previous observations has shown that the episode started long ago, probably around 1990, with a gradual fading of the He I λ10829 A intensity and a more rapid decrease in March–May 1992. We also note that in the FTS spectrum of η Car of January 1987 described by Maillard et al. (1992) the He I lines were much weaker than in 1990.

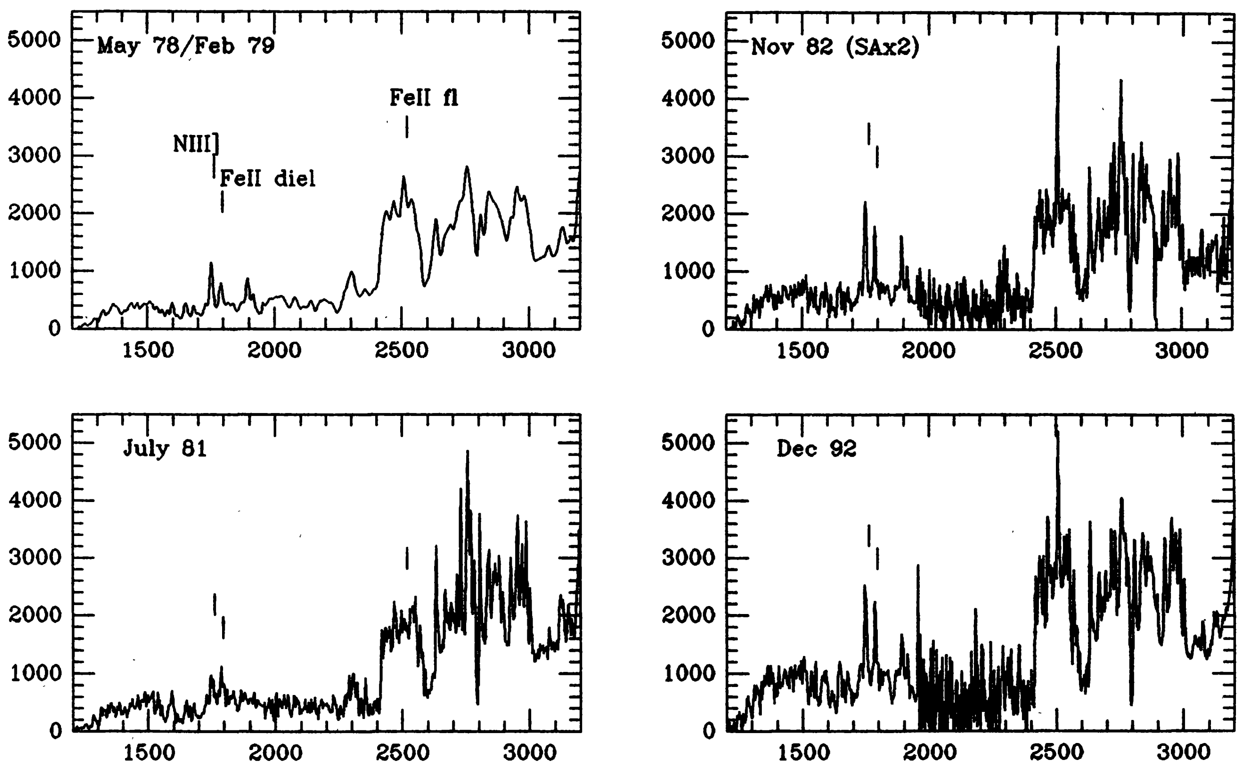

Fig. 2. Spectral variation of the ultraviolet (*IUE*) spectrum of η Car during 1978–1992. The Fe II high excitation lines at 1785–88 A and 2507–8 A, and the N III] multiplet are indicated. Ordinates are fluxes in 10^{-14} erg cm^{-2} s^{-1}.

η Car has been frequently, though not regularly, observed in the UV with the *IUE* satellite. Figure 2 shows the UV spectrum of η Car in four different epochs. Of particular interest is the large variation of the intensity of the N III] λ1750 intercombination multiplet, and of the Fe II high excitation lines at $\lambda\lambda$1785–8 and $\lambda\lambda$2507–8 at the time of the 1981 shell episode discussed by Zanella et al. (1984). The November 1982 *IUE* spectrum indicates that this shell episode was ended. Also the December 1992 *IUE* spectrum, obtained when the star was in a phase of gradual recovering of the intensity of He I λ10829 A, is that characteristic of the higher temperature phases. In Figure 3 we present the blue spectrum of η Car obtained at CASLEO in March 1993, compared with the spectrum of the same region observed in August 1991 with the FOS of the *Hubble Space*

© Universidad Nacional Autónoma de México • Provided by the NASA Astrophysics Data System

1995RMxAC...2...41D

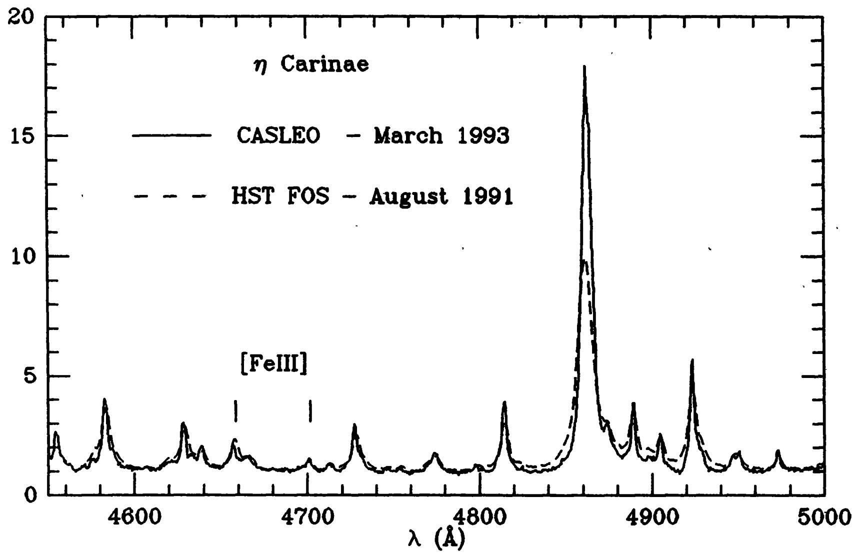

Fig. 3. Comparison of the optical spectrum of η Car in August 1991 observed with the FOS onboard of the *Hubble Space Telescope*, and in March 1993 obtained at CASLEO. The high temperature [Fe III] emission lines at 4658 and 4701 A are indicated.

Telescope. The two spectra are strikingly similar, in spite of the very different observing techniques, and show that 10 months before and after the June 1992 episode the star was at the same higher excitation stage, as for instance indicated by the presence of the [Fe III] lines.

3. A PULSATION MODEL OF η CAR

The above discussed shell episodes should be important probes of the structure of the η Car wind, but, in the absence of a consistent model of the η Car atmosphere, we can only make a qualitative intepretation of the phenomenon. We suggest that the observed events are the result of propagation in the envelope of dynamical instabilities which produce a change in the wind opacity to the higher energy photons, and, consequently, a decrease of the mean wind ionization. In this framework we should also expect a variation of the emerging energy spectrum, with a shift to longer wavelengths, as for instance observed in AG Car during its 1981–85 event (Rossi et al. 1995). An increase of the near-IR flux was in fact observed by Whitelock et al. (1983) and Whitelock (1992) at the time of the last three recorded shell episodes. In addition, Viotti (1968) noted a cooling of the blue continuum during the 1948 episode. Although the spectral coverage is poor, the available information leads us to conclude that the shell episodes do not represent accidental phenomena of the present stage of η Car. On the contrary, the structure of the star's wind is probably continuously varying with "deep minima" of the line excitation at the time of the shell episodes. The analysis of the published data seems to suggest a period of about 5 years, as indicated by the time of occurrence of the few reported episodes, and of those discovered from a search of published data as well. These oscillations of the wind structure are fairly similar in time scale and amplitude to those observed in in the OH/IR red giants (Wood 1979), and could have a similar nature. Glatzel & Kiriakidis (1993) and Kiriakidis, Fricke, & Glatzel (1993) have recently studied the propagation of instabilities caused by pulsations of the stellar structure in very massive stars, but the time scale should be much shorter than that observed in η Car. At this moment however, the available information is still too poor to unveil the nature of these variations. Therefore the continued study of the variability of η Car is needed in order to provide crucial information on the structure of very massive stars.

We are grateful to M. Friedjung for comments. A. Damineli Neto acknowledges a contribution from FAPESP. This paper is partially based on a FOS-*HST* spectrum obtained from the Space Telescope - European Coordinating Facility *HST* Archive.

© Universidad Nacional Autónoma de México • Provided by the NASA Astrophysics Data System

1995RMxAC...2...41D

REFERENCES

Allen, D.A., Jones, T.J., & Hyland, A.R. 1985, MNRAS, 291, 280
Andriesse, C.D., Donn, B.D., & Viotti, R. 1978, MNRAS, 185, 771
Damineli Neto, A., Viotti, R., Baratta, G.B., & de Araujo, F.X. 1993, A&A, 268, 283
Gaviola, E. 1953, ApJ, 118, 233
Glatzel, W., & Kiriakidis, M. 1993, MNRAS, 263, 375
Hoffleit, D. 1933, Harvard Bull. No. 893, 111
Kiriakidis, M., Fricke, K.J., & Glatzel, W. 1993, MNRAS, 264, 50
Le Seuer, A. 1869, Proc. Royal Soc., 18, 245
Rodgers, A.W., & Searle, L. 1967, MNRAS, 135, 99
Rossi, C., Barylak, M., Cassatella, A., Damineli Neto, A., Polcaro, V.F., Villada, M., & Viotti, R. 1995, RevMexAASC, 2, 123
Viotti, R. 1968, Mem. Soc. Astron. Ital., 39, 105
Viotti, R., Rossi, L., Cassatella, A., Altamore, A., & Baratta, G.B. 1989, ApJS, 71, 983
Whitelock, P.A. 1992, SAAO Report for the year 1991
Whitelock, P.A., Feast, N.W., Carter, B.S., Roberts, G., & Glass, I.S. 1983, MNRAS, 203, 385
Whitney, C.A. 1952, Harvard Bull. No. 921, 8
Wood, P.R. 1979, ApJ, 227, 220
Zanella, R., Wolf, B., & Stahl, O. 1984, A&A, 137, 79

© Universidad Nacional Autónoma de México • Provided by the NASA Astrophysics Data System