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TIME VARIATIONS OF THE Hα LINE PROFILE FROM THE CORE OF ETA CARINAE[1]

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ABSTRACT

Observations with high spectral resolution of the Hα line profile from the core of η Carinae show variations of the shape of the profile in time scales less than a year. A Gaussian analysis of the observed line profiles suggests the presence of several knots of material with high velocities with respect to a central object. The time variation of the profile can be interpreted as due to physical changes in the central object of η Carinae.

Subject headings: stars: individual — stars: massive

I. INTRODUCTION

Perhaps the most luminous star in our galaxy, η Carinae has been considered an astronomical rarity by several generations of astronomers who have studied it intensively since it became the second brightest star in the sky in 1843 (see, for example, Innes 1903; Gaviola 1950; Thackeray 1953; Rodgers and Searle 1967; Walborn 1976; and Davidson, Walborn, and Gull 1982). Only recently, however, has some progress been made in understanding theoretically the nature of this remarkable star. Accordingly, the "η Carina phenomenon" would correspond to the late stages of the evolution of very massive stars, before they become Wolf-Rayet stars to eventually end as supernovae (Maeder 1983; Davidson, Walborn and Gull 1982). Maeder (1983) argues that η Car belongs to the general class of stars called Hubble-Sandage variables, which are the brightest stars observed in other galaxies (Humphreys and Davidson 1979).

Although the theoretical picture of Hubble-Sandage variables is still substantially incomplete, it is sufficiently clear to show that these objects play a crucial role in the evolution of massive stars; thus, observations of η Car are of interest no longer as an astronomical rarity, but as a much needed contribution to improve our understanding of stellar evolution.

Excellent descriptions of the optical appearance of η Car have been presented by Walborn (1976) and Davidson, Walborn, and Gull (1982) who also discuss the spectral characteristics of some of the components. These observations show that before, during, and after the great maximum of 1843, η Car ejected several shells of material that are now seen as knots and filaments expanding from the core of the star at large velocities (Walborn and Liller 1977).

Motivated by the intrinsic interest of η Car as a laboratory to study astrophysics of massive stars, and by the activity shown by the star during the past 150 years, we started a systematic program to monitor variations in the emission-line profiles from the "core" of η Car. In this *Letter* we report the results of the first 1.5 yr of monitoring where we have observed dramatic changes in the Hα profile.

II. OBSERVATIONS

The observations were performed with the coudé echelle spectrograph (CES) of the ESO 3.6 m telescope, fed by the 1.4 m coudé auxiliary telescope (CAT). The CES was used in its single-pass mode with a cooled 1872 element reticon detector. The data reported here were obtained in 1982 March, 1983 March, and 1983 June. The Hα profile of 1983 June was kindly obtained for us by Drs. Roger Ferlet and Eric Maurice.

The slit was 1″ by 5″ corresponding to a resolution of 0.05 Å (FWHM) centered at the core of η Car. During the observing run in 1983 March, we obtained the Hα profile with different slit lengths and position angles in order to check for the possible influence of the surrounding structure (homunculus) on the form of the line profile. The profiles reproduced in Figures 1 and 2 were taken with integration times between 5 and 7 minutes depending on sky conditions. The intensity scale is in arbitrary units. Wavelength calibration was performed using a thorium comparison spectrum, and the accuracy in wavelength is estimated to be ± 0.01 Å.

III. RESULTS AND DISCUSSION

The profile obtained in 1982 March has the same general appearance as that previously obtained in 1981 by Melnick, Ruiz, and Maza (1982), by Viotti in 1966 (1970), and described by Thackeray (1956). These observations have different resolutions, thus preventing a more detailed comparison of the profiles obtained by the various authors.

Much to our surprise the Hα profile obtained in 1983 March had changed its appearance from what it had been at least in the last 30 years (see Figs. 1 and 2). The narrow component blueshifted with respect to the main peak disappeared, while this last one became somewhat more important compared with the broad wings (in 1983 June the profile was similar to the one in 1983 March). This variation is not due to changes in the position angle of the slit between the two observations since we found no profile variations when we

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[1] Based on observations collected at the European Southern Observatory, La Silla, Chile.

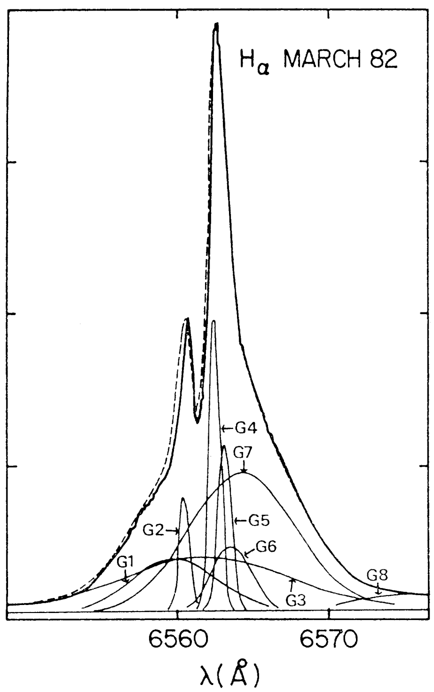

FIG. 1

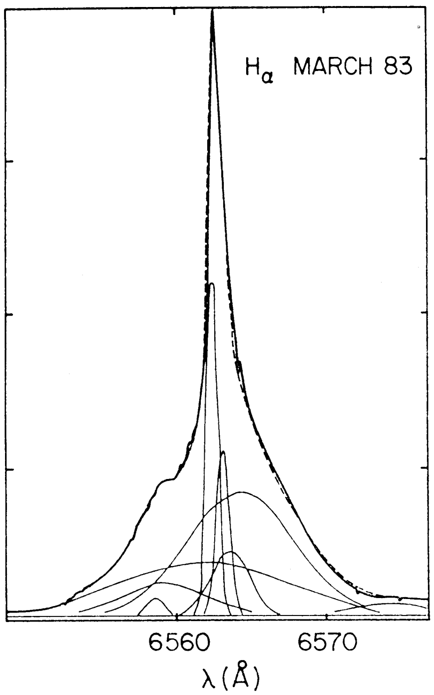

FIG. 2

FIGS. 1 and 2.—Observed Hα profiles obtained in 1982 March and 1983 March. The solid line curve represent the observations, and the dotted one, the Gaussian fit. Individual Gaussian components used for the fitting of the observations are also drawn.

observed η Car in 1983 March centered at the core with the slit at several position angles covering a full 360° range.

In an attempt to quantify this variation we have decomposed the observed Hα profiles using individual Gaussian components. In principle, one should use both emission and absorption components. However, the relevant features (i.e., those that changed) are much too sharp to be produced by stellar or circumstellar gas, while clearly the broad wings may be strongly affected by absorption troughs (Thackeray 1953; Melnick, Ruiz, and Maza 1982). Thus, as a first attempt to quantify the line profile variations, we will consider only emission-line components, while bearing in mind that broad absorptions must be considered if one is to understand the overall profile structure.

The results of the Gaussian fit can be seen in Figures 1 and 2; the parameters of the Gaussians are given in Table 1. Since, given a large enough number of Gaussian components, it is possible to fit almost any curve, we adopted the criterion of the minimum amount of components that will reasonably reproduce the observed profiles. In addition we tried to reproduce the observed variations in the profile in terms of the same Gaussians with the minimum necessary changes in the parameters.

As it is obvious by just looking at the profiles in Figures 1 and 2, the main change is due to the dimming of the G2 component that also got blueshifted and widened. Unfortunately, we do not have a calibrated intensity scale, so we do not know whether the observed change in the profile repre-

TABLE 1

GAUSSIAN ANALYSIS OF THE Hα LINE PROFILES

	I[a]		λ_0(Å)[c]		σ(Å)		FWHM[d] (km s^{-1})		$\Delta\lambda$[e] (km s^{-1})	
COMPONENT	P1[b]	P2[b]	P1[b]	P2[b]	P1[b]	P2[b]	P1[b]	P2[b]	P1[b]	P2[b]
G1	17	9.6	6559.98	6559.32	2.78	2.78	298.4	298.4	−115.2	−145.4
G2	38	5.4	6560.62	6558.77	0.34	0.58	36.4	62.6	−85.9	−170.5
G3	18	15.8	6562.15	6562.15	5.56	5.56	596.8	596.8	−16.0	−16.0
G4	100	100	6562.50	6562.50	0.34	0.34	36.4	36.4	0	0
G5	56	49	6563.34	6563.34	0.42	0.42	44.8	44.8	+38.4	+38.4
G6	22	19.3	6563.71	6563.71	1.25	1.25	134.3	134.3	+55.3	+55.3
G7	46	36.8	6564.56	6564.56	3.47	3.47	372.8	372.8	+94.2	+94.2
G8	4	3.5	6574.86	6574.86	2.78	2.78	297.9	297.9	+565.0	+565.0

[a] Normalized to I(G4) = 100.
[b] P1, P2: Hα profiles obtained in 1982 March and 1983 March, respectively.
[c] Reduced to the Sun.
[d] FWHM ≈ 2.35 σ.
[e] With respect to λ_0(G4) = 6562.50.

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sents a net energy loss in the line or just a redistribution of energy in the profile itself.

The physical meaning of the different components is still to be established but it seems possible that the broad components (FWHM ≈ 400 km s^{-1}) could represent individual clouds expanding from the central object (at a scale smaller than 2″), while the narrow components (FWHM ≈ 40 km s^{-1}) probably represent the true central emission.

The dimming of the narrow blueshifted component could be interpreted in terms of a central source of UV photons surrounded by a recombination shell and a scattering shell, both in expansion. The blueshifted component disappears when the random velocities in the shell (thermal, turbulent) increase compared to the expansion velocity of the shell to a critical value of $V_{\rm exp}/V_{\rm rand} \approx 3$; see Rottenberg (1952). Alternatively, the component that disappeared could be the He II λ6560.1 line that faded due to a decrease in the excitation of the emission-line region. This in turn could be due to the ejection of a shell by the central star.

IV. FINAL REMARKS

The onset of variability in massive stars that gives rise to the Hubble-Sandage phase seems to be related to sudden massive outflows of matter presumably via the so-called de Jager instability (de Jager 1980). Thus, if the variations in the Hα line reported in this paper are related to this phenomenon, we would also expect variations in the stellar luminosity due to pulsation. Whitelock (reported by Feast 1981) has observed a 0.4 mag increase of the 1–4 μm flux of η Car, which could be related to the line profile change we found. It would therefore be of great importance to monitor the flux of η Car at several wavelengths. It would also be of interest to search for profile variations in other lines and in particular the He II λ4686 Å and other high-excitation lines. New observations of the UV lines observed by Cassatella, Giangrande, and Viotti (1979) would be useful to assess the possible contribution of absorption components.

At least two groups have obtained speckle interferometry of the core of η Car; Weigelt (1983) and Perrier (1982) have privately communicated to us preliminary aspects of their work, but we have no quantitative results as yet. These observations could clearly resolve the question of the presence of discrete, high-velocity clouds, within the core of η Car.

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We are also grateful to the referee for suggesting the possibility that component G2 could be due to He II and for several other useful comments.

Note added in manuscript.—In 1984 February, Drs. Roger Ferlet and Eric Maurice kindly obtained for us Hα profiles at the core of η Car with the same equipment we used, and the shape is almost the same as in 1983 March shown in Figure 2 of this paper.

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