CYCLICAL SPECTRAL AND PHOTOMETRIC VARIATIONS OF THE APPARENTLY SINGLE WOLF-RAYET STAR WR 134

T. MOREL AND S. V. MARCHENKO
Département de Physique, Université de Montréal, Canada.

P. R. J. EENENS
Departamento de Astronomía, Universidad de Guanajuato, México.

A. F. J. MOFFAT
Département de Physique, Université de Montréal, Canada.

G. KOENIGSBERGER
Instituto de Astronomía, UNAM, México.

I. I. ANTOKHIN
Sternberg Astronomical Institute, Moscow, Russia.

T. EVERSBERG
Département de Physique, Université de Montréal, Canada.

G. H. TOVMASSIAN
Instituto de Astronomía, Ensenada, México.

G. M. HILL
McDonald Observatory, Fort Davis, Texas, USA.

O. CARDONA
Instituto Nacional de Astrofísica, Optica y Electronica, Puebla, México.

AND

N. ST-LOUIS
Département de Physique, Université de Montréal, Canada.

Abstract. Evidence is presented for the existence of a 2.3 day periodicity in the line-profile changes of the *apparently single* Wolf-Rayet star WR 134. This cyclical variability may be induced either by the presence of an orbiting collapsed companion, or by the rotational modulation of a largely inhomogeneous outflow.

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1. Introduction

The strongly variable, apparently single Wolf-Rayet star WR 134 (WN 6; HD 191765) has received much attention over the last few years, not only because of its high level of spectral and photometric variability, but also because of the suspected (multi)periodic nature of the variations. If the currently favored period of $\approx$ 2.3 d (McCandliss *et al.* 1994) is confirmed, it might rejuvenate the idea of the association of WR 134 with an orbiting collapsed companion (neutron star or black hole; Antokhin & Cherepashchuk 1984). As an intriguing alternative, it might point to the persitence of large-scale wind structures, as is likely in the peculiar WN 5 star EZ CMa (St-Louis *et al.* 1995; Morel *et al.* 1997, 1998).

2. Observations

In an effort to reveal the nature of this object, an intensive monitoring campaign of WR 134 (both in spectroscopy and photometry) was carried out from 1989 to 1997. This large dataset originates from several sources:

CCD spectroscopy:
- 1992 Jul.-Aug. San Pedro Martír (0.4 Å pix^{-1}, S/N $\approx$ 160, 65 spectra) — hereafter Epoch I.
- 1993 Oct. San Pedro Martír (0.8 Å pix^{-1}, S/N $\approx$ 115, 38 spectra) — hereafter Epoch II.
- 1995 May-Oct. Mont Mégantic (1.6 Å pix^{-1}, S/N $\approx$ 170, 69 spectra) — hereafter Epoch III.

Photoelectric photometry:
- 1989-1993 Hipparcos ($Hp \sim B + V$).
- 1990-1997 APT (UBV).
- 1992 — Maidanak (λ_c = 6012 Å; FWHM = 87 Å) + San Pedro Martír (λ_c = 5185 Å; FWHM = 250 Å, UBV).
- 1995 — San Pedro Martír (V) + Crimea (V).

3. Results

3.1. SPECTROSCOPY

- A significant signal at $\nu \approx 0.444 \pm 0.010$ d^{-1} ($\mathcal{P} = 2.25 \pm 0.05$ day), is found in the power spectra of the skewness ($\sim$ degree of asymmetry) and centroid variations (note that these variations do *not* reflect a global shift of the profile) of the He II λ4686 emission line during Epoch I; other epochs are less appropriate for a period search, either because of the smaller time

span of the observations (Epoch II), or because of large time gaps (Epoch III). This period is similar, within the uncertainties, to the period found in the line-profile changes by McCandliss *et al.* (1994): 2.27 ± 0.04 day.

• A significant signal at the same frequency, $\nu \approx 0.444$ d^{-1}, is also present in the line-profile changes within the observed spectral range during Epoch I (Fig.1).

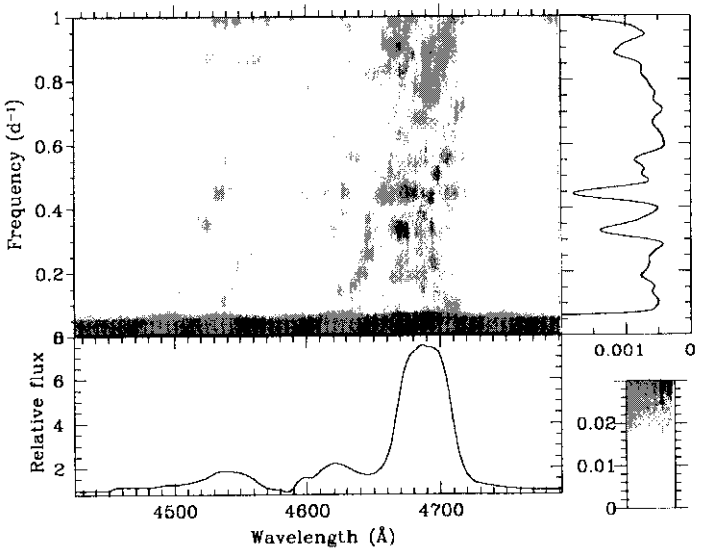

Figure 1. The 2-D periodogram of the 65 rectified spectra of Epoch I. The lower and right-hand panels show the mean spectrum and the normalized summed power over all wavelengths, respectively. The highest peak corresponds to a frequency: $\nu \approx 0.444$ d^{-1}.

• He II λ4686 – whose variations are representative of those of the other He II transitions – demonstrates a fairly coherent pattern of variability during Epochs I and II (which cover 13 and 4 cycles, respectively). However, the pattern of variability partially loses its coherency when the time span of the observations is longer, as for Epoch III (63 cycles). There are no apparent similarities in the variability pattern of different epochs (Fig.2).

3.2. PHOTOMETRY

We observe an intricate interplay between the long-term (from months to years; see Marchenko *et al.* 1996), and relatively short-term (∼ days) variations. The photometric data secured during Epoch I reveal also – although marginally – the 2.3 day period seen in the simultaneous optical spectroscopy.

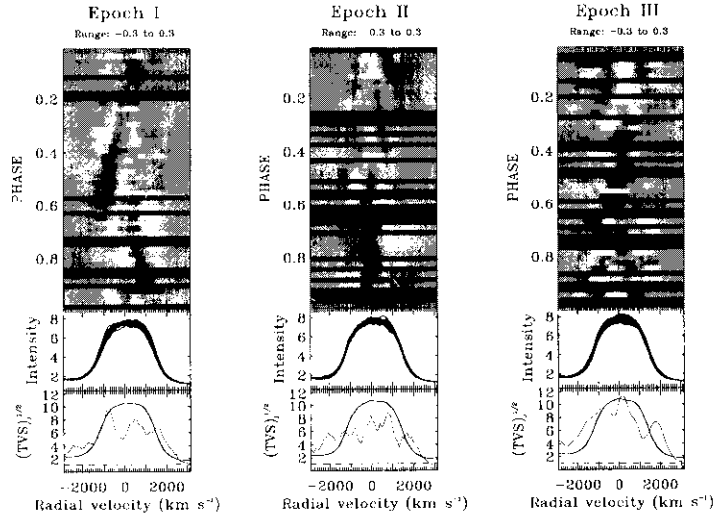

Figure 2. Gray-scale plots of the time series of the residuals (the individual spectra minus the mean spectrum of the epoch; binned to 0.02-phase resolution) of He II λ4686, phased with the ephemeris of McCandliss *et al.* (1994). Excess-emission components appear brighter. The middle panels show a superposition of the rectified profiles. The values of $TVS^{1/2}$ (Fullerton, Gies & Bolton 1996) and the mean profiles are plotted in the lower panels. The horizontal dashed line indicates the 99.0 % confidence level for significant variability.

4. Preliminary Conclusion

Although the pattern of variability resembles in some aspects that of the probably single Wolf-Rayet star EZ CMa — for which the existence of a largely inhomogeneous outflow has been inferred — the presence of an orbiting compact companion in WR 134 cannot be ruled out at this stage of the analysis.

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