RevMexAA (Serie de Conferencias), **12**, 90–91 (2002)

[WC] STELLAR WIND TURBULENT OUTFLOWS FEEDING THE ISM

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RESUMEN

Se han detectado fluctuaciones en los vientos de las estrellas centrales, con tipos [WC 8–9], de nebulosas planetarias. Estructuras en movimiento de las líneas C III λ5696 y C IV $\lambda\lambda$5801/12 son interpretadas como inhomogeneidades aceleradas por los vientos Wolf-Rayet. Sus parámetros cinemáticos son comparados con los observados en estrellas Wolf-Rayet masivas.

ABSTRACT

Wind fluctuations in [WC 8–9]-type central stars of planetary nebulae have been detected. Moving features seen on the top of the C III λ5696 and C IV $\lambda\lambda$5801/12 emission lines of HD 826 (NGC 40) and BD +30°3639 are interpreted as outflowing clumps which are radially accelerated in the Wolf-Rayet winds. Kinematic parameters of the blobs were derived and compared to those observed for massive Wolf-Rayet stars.

Key Words: **INSTABILITIES — LINE: PROFILES — PLANETARY NEBULAE — STARS: WOLF-RAYET — STARS: MASS-LOSS**

1. LINE PROFILE VARIATIONS IN [WC] STARS

In the framework of our study of wind fluctuations in [WC]-type central stars of planetary nebulae (Grosdidier et al. 2000, 2001, and references therein), we show some spectroscopic observations taken at the Observatoire de Haute-Provence (OHP; France) and the Observatoire du Mont Mégantic (OMM; Canada). Differences from the global mean profile reveal moving features on the top of the C III λ5696 and C IV $\lambda\lambda$5801/12 emission lines of HD 826 (NGC 40; see Fig. 1) and BD +30°3639 (Fig. 2). These features are interpreted as outflowing clumps which are radially accelerated outwards in the Wolf-Rayet (WR) winds (Grosdidier et al. 2000, 2001). The amplitudes of the variations range from about 5%, up to 25–30% of the adjacent continuum flux, over timescales of hours. The blue-shifted absorption component of the lines exhibiting P-Cygni profiles is significantly more variable than the emission component (see Grosdidier et al. 2000, 2001), which suggests linear sizes for the clumps of the order of the stellar radius.

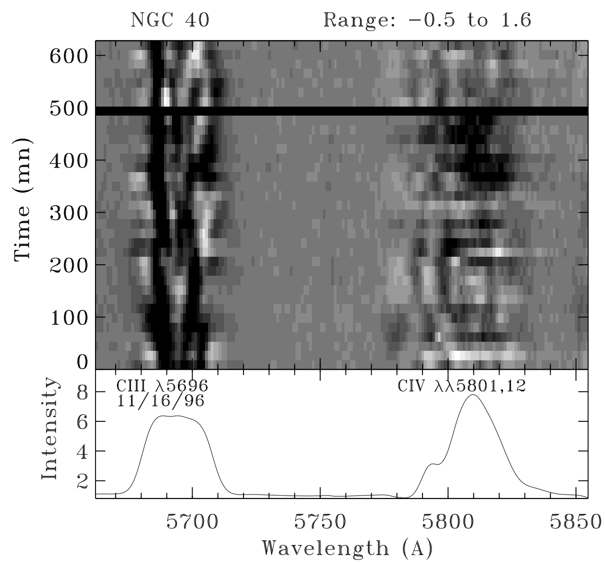

Fig. 1. Grayscale plots for HD 826 ([WC 8]) of C III λ5696 & C IV $\lambda\lambda$5801/12 residuals for one observing night at the OMM. Bottom panel shows the 22-night global mean profile. The range is in continuum units. Note the more complex nature of the multiple line C IV.

2. KINEMATICS OF THE SUBPEAKS

The features show large measurable velocity shifts during their lifetime: subpeaks (or gaps) on the top of the C III line clearly move towards the nearest line edge in a time-averaged symmetric fashion in the blue and the red (Figs. 1 and 2).

In Table 1 we give the maximum observed radial acceleration for a sample of massive WR (values from Robert 1992) and [WC] late-type stars (see Grosdidier et al. 2000, 2001), along with the number of extracted features. The values given in italics are from Lépine & Moffat (1999) and were derived through the calculation of their 'degradation function'. It turns out that this method reduces to the

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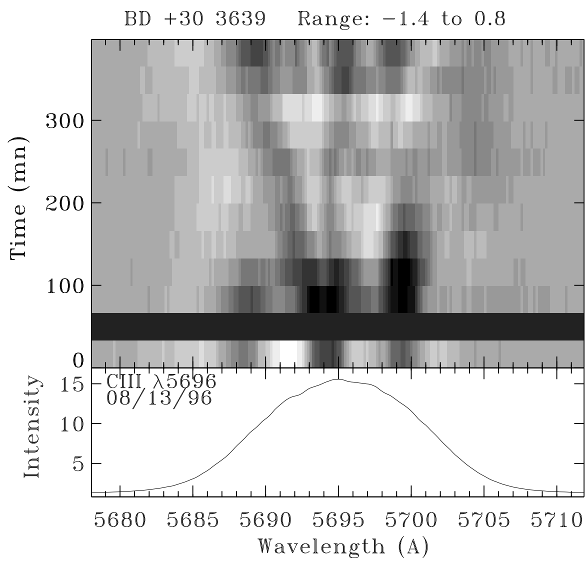

Fig. 2. Grayscale plots for BD +30° 3639 ([WC 9]) of C III λ5696 residuals for one observing night at the OHP. Bottom panel shows the 15-night global mean profile.

search of the maximum observed radial acceleration, or close to it. Therefore, although the degradation function leads to a better accuracy in the kinematic measurements, its results are comparable with the statistical approaches of Robert (1992) and Grosdidier et al. (2000, 2001). At least in the case of HD 826 (and possibly most of the [WC] stars), the maximum acceleration is significantly larger than that found for its massive spectroscopic counterpart, WR 135. This is attributed to the very small radius of HD 826 (Grosdidier et al. 2001). In the studies of Robert (1992) and Grosdidier et al. (2000, 2001), the procedure of identifying individual feature events additionally limits the loss of information inherent in the degradation function method. In particular, from the study of individual features, the β velocity field in two [WC] stars is found to possibly underestimate the true gradient within the stellar wind flow (Grosdidier et al. 2000, 2001).

TABLE 1

ACCELERATIONS IN SOME WR STARS

Star	Sp. type	N	Accel. (m s^{-2})
WR 135	WC 8	41	10.6 ± 5.0
		N/A	*11.0 ± 1.5*
HD 826	[WC 8]	120	66.3 ± 5.5
WR 103	WC 9	24	6.9 ± 0.7
		N/A	*4.5 ± 1.5*
BD +30°3639	[WC 9]	85	9.1 ± 1.4
He 2-99	[WC 9]	8	≥ 5.6

3. CONCLUSIONS

Despite the different acceleration amplitudes found in population I and II WR stars, the wind fragmentation process appears as a purely atmospheric phenomenon, independent of the strong differences between both types of hot star (Grosdidier et al. 2000, 2001). On the whole, WR population I and II winds are *similarly* highly stochastically variable on a very short time-scale, which supports a turbulent origin. Unlike the interstellar medium, we see clumps forming and dissipating in real time. The consequences of clumping in hot-star winds are many fold, including substantial constraints on the effective mass-loss rates (Moffat & Robert 1994), and their impact on the surrounding nebula itself (Dwarkadas & Balick 1998).

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Ionized Gaseous Nebulae (Mexico City, 21-24 November 2000)
Editors: William Henney, José Franco, Marco Martos, & Miriam Peña