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Spectroscopic Monitoring in the Optical Wavelength Region of Nine WC9 Stars

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Abstract: We present a preliminary report of a spectroscopic monitoring campaign in the optical wavelength region of nine WC9 stars that we have carried out at the El Leoncito Observatory in Argentina in May-June 2009. The stars in our sample are not known binaries but have been shown from previous studies to present short-term spectroscopic variability. We confirm that large-scale, line-profile variability is indeed present for several stars in our sample with timescales shorter than $\sim$1 day. A simple visual inspection of the shape of the line-profiles as a function of time does not allow us to conclude if the variations are periodic or not. A more thorough analysis of the data (measurements of the radial velocity, equivalent width, skewness, etc) will be required. Our ultimate goal is to determine the origin of the spectroscopic variability which could lead to new insight into the origin of the dust in presumably single WC9 stars.

1 Introduction

Near-infrared photometry of WC-type Wolf-Rayet (WR) stars has shown that most WC9 stars (14 out of a total of 17) and a large fraction of WC8 stars produce dust (Williams, van der Hucht & Thé 1987). Only 3 WC9 stars (WR81, WR88, WR92) have not yet shown evidence of dust. Cherchneff et al. (2000) have investigated the formation of carbon chains and molecular precursors to dust in WC winds. They find that large density enhancements are a pre-requisite for the formation of dust grains in the harsh UV radiation field.

For WC9 stars that are members of a WR+O binary system, such as WR140 (Williams et al. 2009) or WR137 (Williams et al. 2001), the origin of the required gas compression is relatively well understood. Indeed, in such a case, when the two stellar winds collide, a region of shocked gas forms between the two stars. In this shock zone, that roughly has the form of a cone, the gas density is naturally increased. However in the region immediately between the two stars it is also heated to X-ray emitting temperatures. The X-rays are seen to vary as a function of orbital phase as they are absorbed by varying amounts of gas column (e.g. Willis, Schild & Stevens 1995). As the gas flows along the shock cone, it cools and gradually recombines. Line emission is then produced and in the case in which the transition is normally known to occur in the WR wind, the cone emission can be observed superposed on the broad wind emissions. By studying its behavior as a function of phase

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Table 1: Spectral type, v magnitude and number of spectra obtained for the stars in our sample.

Star	Spectral Type	v	Nb. of spectra
WR 53	WC8d	10.88	24
WR 69	WC9d	9.43	25
WR81	WC9	12.71	22
WR88	WC9	13.25	21
WR 92	WC9	10.43	23
WR 103	WC9d	8.86	24
WR 106	WC9d	12.33	17
WR 119	WC9d	12.41	17
WR 121	WC9d	12.41	20

(Doppler shift and width), one can gather information on the shock cone structure such as its opening angle or flow velocity along the shock (Luehrs 1997). As the gas reaches high distances from the star where it has sufficiently cooled and the UV radiation field has decreased significantly, dust is able to form.

But not all WC9 stars are known binaries. For single WC9 dust makers, the origin of the regions of compressed gas required to form dust is less clear. WR winds are known to be highly clumped (e.g. Lépine & Moffat 1999) and the inhomogeneities are possible regions in which the dust could form. Another possibility are Corotating Interaction Regions (CIRs). Hydrodynamical simulations by Cranmer & Owocki (1996) have shown that if a perturbation occurred at the base of the wind of a rotating star, either a dark or bright spot, an excess or deficit of radiative force would cause fast material to collide with slow material causing a compression or even a shock. As this compressed gas makes its way through the wind, it is wrapped around by stellar rotation forming a spiral-like structure.

From a systematic survey of optical spectroscopic variability of WR stars in the northern and southern hemispheres, St-Louis et al. (2009) and Chené & St-Louis (2010) have found evidence for short-scale (days) optical spectroscopic variability of WC9 stars thought to be single. Actually, *all* WC9 stars in their sample showed profile variability at a level of $\sim$10% of line flux. It is thought that clumping leads to lower amplitude variations ($\leq$ 5%) and that these changes with higher amplitudes have a different origin. Such a large fraction of stars showing large-amplitude spectral variability is not found for other WR spectral subtypes. Is it possible that some of these presumably single WC9 stars are in fact yet undetected binaries? Alternatively, some might have CIRs in their wind. The goal of this project is to search for binary or CIR-related spectroscopic variability of the WC9 line profiles in order to shed some light on the physical origin of the changes and to search for other clues as to the absence or presence of dust in such an inhospitable environment as a WR wind.

2 Observations

Our dataset was secured at the El Leoncito Observatory (CASLEO) in Argentina between the 15 May – 15 June 2009 using the 60-cm Helen Sawyer Hogg telescope and a grating giving a dispersion of 0.97 Å/pix. The typical S/N of the spectra we obtained is $\sim$100. The stars we observed with their spectral type, v magnitude and number of spectra obtained are listed in Table 1.

3 Preliminary Results

In Figures 1, 2 and 3, we show examples of line profiles from the spectroscopic dataset we secured. We present timeseries of the C IIIλ5696 transition for WR81, WR88 and WR103 respectively. The profiles have been shifted vertically for clarity and the separation between them reflects the time difference between exposures. The Julian Dates are indicated on the y-axis.

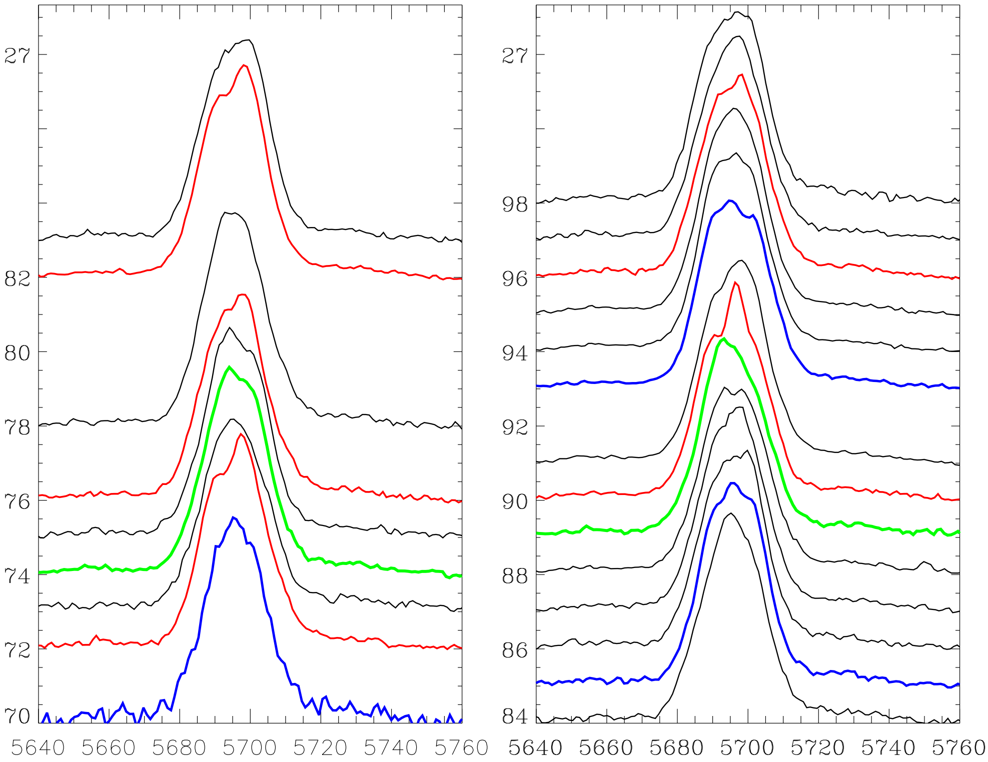

Figure 1: Series of C IIIλ5696 line profiles for WR 81.

Clear large-scale variability is present in the form of relatively large emission excesses superposed at various positions on the broad wind emissions. The changes can occur on relatively short timescales. For WR81 for example, the C III profile obtained on Julian Day 2 454 972 presents a large excess emission on the red side of the line while the spectrum obtained on day 2 454 973 shows a much more symmetric profile. The next day, an excess emission is developping on the blue side of the line. A similar pattern of variability is also seen ∼10 days later.

Note that the variability is found for well-known dust makers such as WR103 (Figure 3) but also for stars such as WR81 (Figure 1) and WR88 (Figure 2) for which no evidence for dust has been found in two decades of IR monitoring (van der Hucht 2001). For each plot, we have drawn in different colours, spectra showing similar line shapes. No clear period or timescale can of course be identified by simple visual inspection of the line profiles, but it is clear that lines with similar shapes do re-occur at various times in all three cases. The detailed nature of the changes remains to be determined. We will be able to characterize them by carrying out various measurements such as radial velocity, equivalent width, skewness and kurtosis of the profiles and studying their behavior as a function of time. Several questions remain to be answered. Is this variability related to binarity or to the presence of CIRs in the wind of the WR star? If so, is the fact that they occur even for dustless WC9 stars telling us something about the dust formation mechanism? Are some binaries too tight to harbor physical conditions favourable for dust production? We are confident that the present dataset will help us address at least some of the above questions.

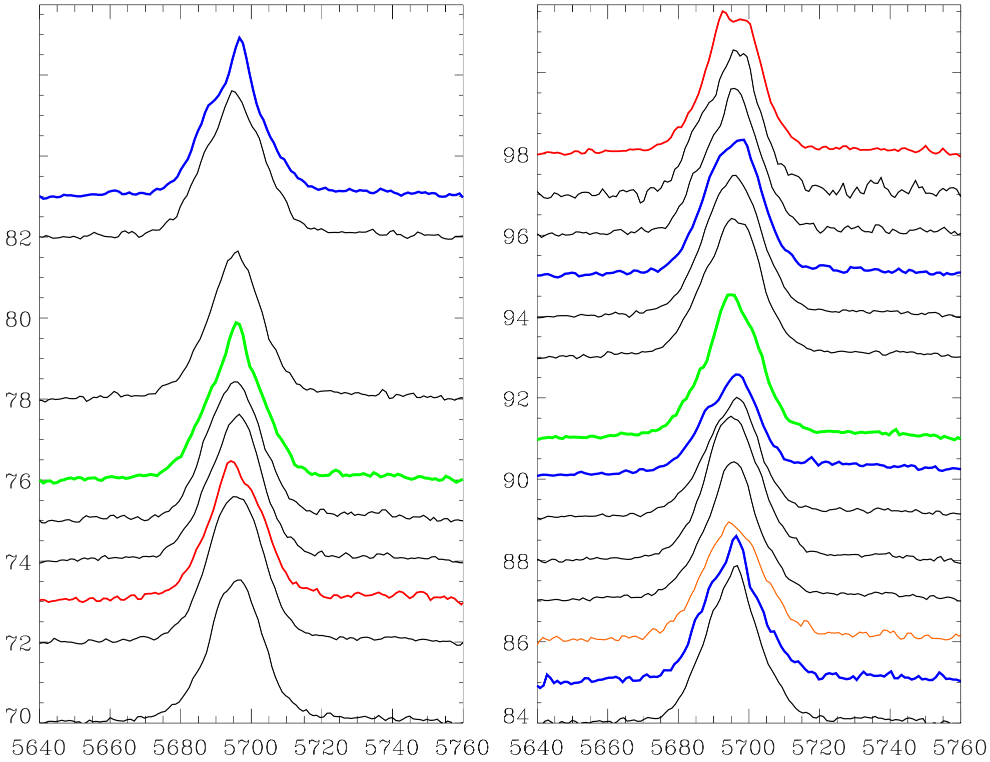

Figure 2: Series of C III λ5696 line profiles for WR 88.

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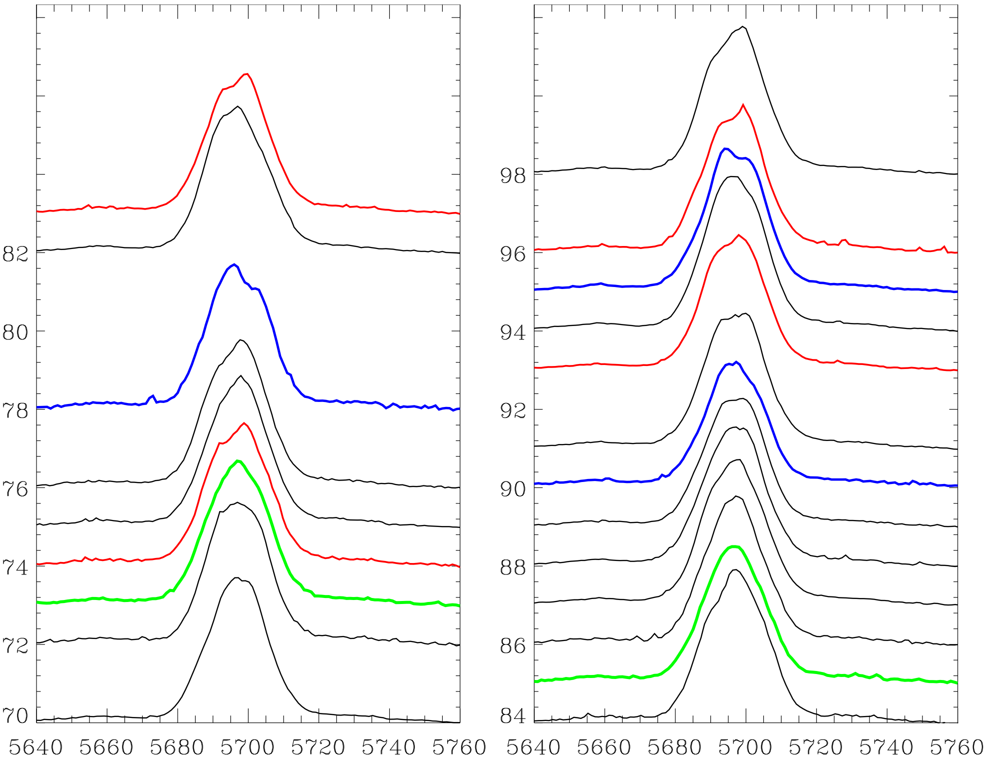

Figure 3: Series of C III λ5696 line profiles for WR 103.