Wolf-Rayet Phenomena in Massive Stars and Starburst Galaxies
Proceedings IAU Symposium No. 193, ©1999 IAU
K.A. van der Hucht, G. Koenigsberger & P.R.J. Eenens, eds.

On the so-called WO stars

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The Wolf-Rayet WO spectral sequence was introduced by Barlow & Hummer (1982) for four Pop I WR stars with very strong O VI 381 nm doublet emission. At the time, the evolution of very massive stars was poorly known, and their classification was based on phenomenological grounds. Recently, efforts to improve the WO spectral subtype classification are increasing (Kingsburgh *et al.* 1995; Crowther *et al.* 1998).

A spectral category makes sense when it groups a large number of stars showing similar spectral features, so that one can obtain meaningful information of the physical state of their atmospheres from detailed studies of a few of them and then draw conclusions on the class as a whole, on statistical grounds (*e.g.*, Jaschek & Jaschek 1987). To date, six stars are considered Pop I WO stars of which four of the five stars described by Sanduleak (1971): Sand 4 and Sand 5 in our Galaxy; Sand 2 in the LMC; Sand 1 in the SMC; the galactic WR 30a; and DR 1 in the irregular galaxy IC 1613. These stars were further arranged by various authors into four WO subclasses, taking into account the spread in the mean ionization level among them.

One could wonder if it is possible to add to this handful of stars the few Central Stars of Planetary Nebulae (CSPN) formerly considered members of the O VI sequence. However, the Pop I WR and the [WR] CSPN are well-separated evolutionary stages and different mass sequences, where different physical processes are active (*e.g.*, Stanghellini 1996). Their spectra can show similar features, since the WR phenomenon is strictly atmospheric, due to particular effective temperature and mass-loss conditions. On the other hand, WR stars go through carbon burning, while [WR] stars end their evolution as white dwarfs. Due to this fact, the hottest stars of the two classes are the most different ones and, actually, it is impossible to find Pop I stars that have spectra similar to the so-called PG1159-type CSPN. Furthermore, the spectra of these stars appear easy to discriminate from each other, even at a simple visual inspection, due to the wind velocities which in WR stars are more than twice larger than in the CSPN. We are thus dealing with a group of only six WO stars: we need to see if they can be considered a spectral class in their own.

Polcaro *et al.* (1996) used the Torres & Massey (1986) atlas to analyse the relationship between WC and WO spectra, and concluded that in many respects the WO stars behave like extreme WC stars, with wind velocities systematically faster than the earlier WC stars. Recently, Crowther *et al.* (1998) confirmed that *the dominance of the oxygen lines in WO spectra is primarily a result of higher ionization rather than higher oxygen abundance* and *therefore favour the* *adoption of WO sublass numbers that reflect a smooth ionization sequence from WC to WO.* We thus tentatively attribute to WO stars the subtype WC3.

We have enlarged the sample used in the previous work with the catalogue of Smith *et al.* (1990) and our measurements in order to increase the statistics. We firstly noticed that when the same feature is measured on the same spectrum by different authors, its parameters are remarkably similar but, when it is measured (even by the same authors) on different spectra, it is not uncommon to notice significant differences, well outside the uncertainties of the measurements: this suggests that many WCE stars are spectroscopic variables.

EW(C IV 581 nm) increases up to the subtype WC5 both in Galactic and MC stars, then it bends in Galactic WC, while it follows to rise in the MC stars. The 465 nm blend has a similar behaviour, despite of the contribution to this feature of the He II. *EW*(C III 569 nm) monotonically decreases with the spectral type, while the *EW*(O V 559 nm) increases, apart from a decrease from WC9 to WC8, that can be due to the contribution of a different ion. The C IV 581 nm FWHM dramatically rises at the WC3 subtype. In contrast, the 465 nm blend FWHM smoothly increases with the spectral subtype.

A possible interpretation puts the WC4 and WC3 (presently named WO) stars in a very late phase of He-shell burning which seems less sharp than foreseen by current models. This transition might occur through instability stages, as suggested by the variability of the 465 nm blend with *hot* and *cold* phases, like those observed in LBV stars. No real physical discontinuity between the WC4 and WC3 stars is to date evident, as it is between WN and WC stars.

We conclude that it is not useful to retain the so-called WO classification as a spectral class different from the WCE classification. On the contrary, such a forced separation masks a number of physical facts that should be of interest in refining the late evolution of high-mass stars. The only meaningful spectral classification for the stars now named Pop I WO is that of WC3. Any new Pop I WCE should be assigned to this class when the following conditions are satified: O VI 381.1-3.4 nm and O VI 529.0 nm strong, while *EW*(C III 569.0 nm) $\leq$ 10 nm.

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