ULTRAVIOLET CLASSIFICATION OF WOLF-RAYET STARS

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The ultraviolet spectra of 94 WR stars obtained from Vilspa IUE archive are used here to look for classification criteria in the UV region alone. We have tried to select as many single and SB1 type stars as possible in the Galaxy and the LMC to get the complete, flux-calibrated spectra between 1150 and 3250 Å. Altogether 56 (34 of WN and 22 of WC type) stars in the Galaxy and 38 (31 of WN and 7 of WC type) in the LMC were found, for which at least single SWP and LWR (or LWP) low resolution images are accessible – note that this is about one third of the number of known galactic and LMC WR stars. The set of stars we study is representative according to spectral subtype and brightness (it is almost complete to 12 magnitude for galactic stars). See Niedzielski & Rochowicz (1994) for the list of program stars and associated IUE images as well as for the details of reduction.

To look for classification criteria of WR stars in the ultraviolet region we will use the equivalent width (EW) and line width (FWHM) data.

WN stars. The line widths of most prominent UV emission lines in WN stars do not correlate well with spectral subtype, they can not be useful for spectral classification. Equivalent widths of NIII λ1750 line correlate relatively well with WN spectral type, but the scatter in this relation makes it useless for classification. The same concerns NV λ1241 and the UV HeII lines. Using line-line (EW) ratios, especially NIII λ1750/NV λ1241, we may obtain some kind of EW ratio vs. spectral type relation for WN stars but the scatter does not allow us to reproduce spectral types of these stars with reasonable accuracy.

WC stars. The strengths (EW) and widths (FWHM) of many UV lines correlate well with subtype of WC stars. Also some line–line relations can be used to predict the spectral type. The most promising criteria are offered by the CIV λ1551 line, the strongest in most of these stars in the UV. Using FWHM data we can obtain the spectral subtype of a galactic or LMC WC star by taking the integer part of the equation:

$$Sp^{WC} = -0.21(\pm 0.03) \times \text{FWHM (CIV 1551)}[\text{Å}] + 9.63(\pm 0.48)$$

It allows one to obtain spectral types with an accuracy of one subclass in most cases. Based on EW data for this line we obtain another criterion:

$$Sp^{WC} = -2.94(\pm 0.17) \times \log \text{EW (CIV 1551)}[\text{Å}] + 11.44(\pm 0.80)$$

K. A. van der Hucht and P. M. Williams (eds.), Wolf-Rayet Stars: Binaries, Colliding Winds, Evolution, 50–51.

which allows us to determine spectral subtypes with, at most, one subclass error. Another group of criteria comes from line ratios. Using for instance the CII λ2837 and CIV λ1551 lines we obtain:

$$Sp^{WC} = 1.95(\pm 0.01) \times \frac{\text{Log EW (CII 2837)}}{\text{Log EW (CIV 1551)}} + 7.70(\pm 0.04)$$

Thus using low resolution IUE spectra alone, we were able to reproduce spectral classification of WC stars based, in principle, on the EW and FWHM of one line - CIV λ1551. For WN stars we may obtain some kind of criterion using EW ratio for nitrogen lines of different ions; however, this is not satisfactory if we are trying to reproduce spectral types with reasonable accuracy. Let us here point out an interesting behavior of NIV λ1486, CIV λ1551 and HeII λ1640 equivalent widths in WN stars spectra. All these lines, in spite of large scatter of EW for a given subtype, show a similar tendency of increasing EW for early WN (WNE) types and decreasing EW for WNL, with a maximum around WN4-5. This is even more interesting since according to Hillier (1988) at least two of these lines, CIV λ1551 and NIV λ1486, are very electron temperature sensitive. This fact suggests that the classification scheme for WN stars is very weakly or not at all connected to temperature in WN envelopes. The observed behaviour of these lines suggests rather that within the WN sequence we deal with two opposite electron temperature sequences: one from WN 2 to WN4-5 and the second from WN4-5 to WN8.

In the case of WC stars the smooth run of equivalent widths of CIV λ1551 with spectral subtype suggests that the classification scheme of these objects reproduces the electron temperature variations in their envelopes since the CIV λ1551 line strength is mainly controlled by electron temperature according to Hillier (1989).

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References

Hillier, D.J. 1988, *ApJ* **327**, 822
Hillier, D.J. 1989, *ApJ* **347**, 392
Niedzielski, A., Rochowicz, K. 1994, *A&A Suppl.* (in press)