AN EMPIRICAL STUDY OF WOLF-RAYET STELLAR WIND IONIZATION STRATIFICATION

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Abstract. We present an analysis of high resolution UV (*IUE*) and optical (*INT*, *AAT* and *ESO*) spectroscopy of eight galactic WN and WC stars. We examine the correlation between ionization potential (IP) and the velocity structure of the stellar winds and find important correlations between line-width, IP and excitation potential (EP). These results provide potential constraints on the velocity law used in models of WR atmospheres.

Key words: stars: Wolf-Rayet – atmospheres – stratification – winds

1. Introduction

Beals (1929) first demonstrated the now familiar correlation between ionization potential (IP) and line-width for WR stars (Kuhi 1973). This view was questioned by Willis (1982), who argued that the correlation existed between excitation potential (EP) and line-width. Hillier (1989) reconciled the two opposing views, showing that the principal correlation is between IP and line-width, whilst a weaker but significant relationship exists between the IP and EP. Recently the line-width *vs.* EP correlation has been re–examined by Niedzielski (1994).

2. Analysis and results

We use high resolution (~0.1 to 2 Å) UV and optical observations to examine the velocity structure of eight galactic WR stars. For each star, a large sample of emission lines were identified in the rectified spectra, and measurements made of the FWHM by fitting Gaussian profiles. Where appropriate we corrected for the multiplet nature of individual line profiles. Quantitative comparisons of FWHM *vs.* IP were made for each star, and correlations assessed by determining linear least squares fits in each case, and Pearsons r coefficient. Similar comparisons were made with FWHM *vs.* EP for the program WN 5–7 stars.

Our results show correlations between the FWHM and IP for each star, which are summarised in Table I. There does not appear to be a trend connecting the gradient (g) or FWHM at zero IP (k), with either spectral subtype, $v_{\rm black}$ or $v_{\rm max}$. This lack of distinct correlation of FWHM with IP

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is not surprising when the variety of line formation mechanisms and range of optical depths of the lines measured in our sample are considered. This is supported by the relatively large errors on g and k which are due to the intrinsic scatter of the data resulting from stratification effects within each ionization stage. We find that the lower EP transitions are formed at higher velocities in three of the four WN 5–7 stars (WR6, WR136 and WR78), and may also be the case in the fourth, WR134. These findings support the results of Niedzielski (1994).

TABLE I
Summary of ionization stratification study

star HD	WR	subtype	g (km s^{-1}eV^{-1})	k (km s^{-1})	$-r$	v_{max} (km s^{-1})	v_{black} (km s^{-1})
50896	6	WN 5	-11.2 ± 3.03	2359.5 ± 214.50	0.605	2650	1700
191765	134	WN 6	-20.2 ± 3.96	3495.8 ± 235.13	0.816	2300	1905
192163	136	WN 6	-19.1 ± 3.96	2932.4 ± 239.94	0.790	2000	1605
151932	78	WN 7	-6.6 ± 2.00	760.1 ± 115.91	0.613	2150	1365
96548	40	WN 8	-5.5 ± 1.49	970.1 ± 55.39	0.742	1800	930
165763	111	WC 5	-9.9 ± 2.23	2717.3 ± 184.85	0.686	3550	2145
192103	135	WC 8	-18.7 ± 4.12	2381.5 ± 242.17	0.687	1900	1405
164270	103	WC 9	-14.6 ± 3.02	1597.9 ± 137.14	0.667	1400	1190

Notes: v_{max} from Abbott *et al.* (1986); v_{black} from Prinja *et al.* (1990).

The predictions of ionization and excitation stratification made by the standard model, (*e.g.,* Hillier 1989), have been confirmed observationally once more by our analysis. Our dataset provides a potential method of constraining the velocity laws of WR stars. We hope to provide such constraints in future work. The information available from stratification effects, are certain to play a crucial role in the development of our knowledge of wind dynamics and variability of the WR stars.

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