ACTA ASTRONOMICA
Vol. **45** (1995) pp. 307–318

Terminal Velocities of Wolf-Rayet Star Winds from Low Resolution IUE Spectra[1]

by

K. Rochowicz and A. Niedzielski[2]

Institute of Astronomy N. Copernicus University, ul. Chopina 12/18, 87-100 Toruń, Poland
e-mail: (kroch,aniedzi)@astri.uni.torun.pl

Received Jan 9, 1995

ABSTRACT

Attracted by the simplicity of the recently published by Prinja (1994) method of determination of terminal wind velocities in hot stars from low resolution IUE spectra we investigate its application to WR stars. With a large sample of low resolution IUE spectra of WR stars we found even simpler, that is linear instead of square, empirical relation between $\Delta\lambda$ as defined by Prinja (1994) and terminal wind velocity – v_∞. Using this new empirical relation we present v_∞ for a sample of 85 galactic and LMC stars, 19 of them determined for the first time. We almost tripled the number of terminal velocity determinations for LMC WR stars. The comparison with other determinations shows that this simple method is accurate to within 10–20%.

We confirm the correlation between terminal velocity and WC subtype. We also show that terminal velocities of WN stars are lower than that of WCE. A comparison between galactic and LMC stars shows that the LMC WN stars have slower winds in most of WN subtypes.

Key words: *Stars: early-type – Stars: Wolf-Rayet – Stars: mass-loss*

1. Introduction

The Wolf-Rayet stars (WR) are most probably the end points of massive stars evolution. They undergo substantial mass-loss during their evolution from the main sequence which not only decreases their masses but also affects substantially the interstellar environment. The knowledge of precise terminal velocities is therefore important for evolutionary track of these stars and estimates of their contribution into interstellar environment. Because of complexity of their spectra, composed mainly of strong and broad emission lines originating in dense and fast moving envelopes, physical parameters of WR stars are still very uncertain (see van der Hucht 1992 for a recent review). Actually the situation is even worse since many

---

[1] Based on IUE Archive data from Vilspa.

[2] Visiting Professor, Padova University and Padova and Asiago Astrophysical Observatories

parameters easily determinable for other types of stars, like temperatures and luminosities, are impossible to obtain from observations only (*cf.* Hillier 1991, Schmutz 1991, Hamann 1991).

Sophisticated models have been developed to obtain temperatures, radii and luminosities of WR stars (see Hillier 1991 for a review and references therein). One of fundamental results of these modeling studies is that the spectra of WR stars can be reproduced with high accuracy using as many as four observational parameters, which are: equivalent widths of one HeII and one HeI line, continuum flux at some wavelength and final velocity of the wind, v_∞ (Hamann and Schmutz 1987, Wessolowski *et al.* 1988, Schmutz *et al.* 1989, Koesterke *et al.* 1992). That is the conclusion of the so-called Standard Model which although a bit idealized accounts for most of features seen in WR spectra.

Equivalent widths of many HeII and HeI lines, with accuracy of 10–20%, are easily available from many published spectra (*e.g.,* Massey 1984, Torres-Dodgen and Massey 1988). Photometric and spectrophotometric investigations give continuum fluxes for most, if not all, WR stars accurate to several hundreds of magnitude. The most uncertain parameter remains the final velocity of the wind v_∞ closely related to the mass-loss.

The ultraviolet spectra of WR stars, where many emission lines of P Cygni type are located, were used for many years as the most reliable way to obtain v_∞. These studies, however, were based mainly on high resolution (0.1–0.2 Å) spectra since they allow for detailed profile measurements. Even such determinations are not free from observational uncertainties. First of all the P Cygni profiles of the resonance UV lines are superimposed on other lines and the assignment of the bluest part of absorption component is a risky task. Moreover, the assumption that the bluemost part (where absorption reaches continuum) of P Cygni absorption is a good estimate of terminal velocity, failed. Determination based on such assumption led to significant overestimate of v_∞ because for the strong resonance UV lines the intrinsic line profile results in shifting the absorption component to the blue.

More recently terminal velocities are measured as the "bluemost point of the steepest part of the absorption" (Howarth and Schmutz 1992). Much improvement of the v_∞ data comes also from detailed analysis of NIR or IR spectra of WR stars, mainly from HeI λ10830 (Howart and Schmutz 1992) or HeI λ2.058 μ (Eenens and Williams 1994) profiles.

Recently Prinja (1994) presented an empirical relation between easily measured in low resolution IUE spectra quantities ($\lambda^{\mathrm{Abs}}_{\mathrm{min}}$ and $\lambda^{\mathrm{Emis}}_{\mathrm{peak}}$) to v_∞ of NV λ1240 and CIV λ1550 lines as measured in high resolution IUE spectra. Using the material at hand (Niedzielski and Rochowicz 1994, Paper 1) we decided to investigate reality of this method in a large sample of WR stars.

2. Observational Material and Reduction

The observational material used here is described in detail in Paper 1. Let us, therefore, remind only its basic characteristics.

The low resolution IUE spectra of WR stars used here were obtained from the IUE Archive in Vilspa. We tried to gather spectra for as many single and SB1 WR stars as possible in both Galaxy and Large Magellanic Cloud. The resulting sample is composed of 55 galactic (33 WN, 22 WC) and 38 LMC (31 WN, 7 WC) stars. Our sample contains 30% known WR stars in the Galaxy. It is also representative with respect to spectral subtype of WR stars, and almost complete to 12 magnitude.

For all stars we requested at least two images for each wavelength range to obtain mean spectrum. This procedure allowed us to minimize the number of saturated points in the resulting spectra. In some cases the SAP spectra were used in addition to LAP. In every such case an empirical calibration was done to obtain correct absolute fluxes. All our spectra as gathered from different observing runs and from different epochs were absolutely recalibrated according to Bohlin and Holm (1980).

The spectra were analyzed using ReWiA 2.0 PC-based system (Borkowski 1992). The wavelengths of emission and absorption components of the resonance line of CIV $\lambda 1550$ were measured through profile fitting procedure FIT of ReWiA.

3. The Correlation of v_∞ with $\Delta\lambda = \lambda^{\rm Emis}_{\rm peak} - \lambda^{\rm Abs}_{\rm min}$

A careful reader of Prinja (1994) may notice that the empirical relation between $\Delta\lambda$ (low resolution IUE) and v_∞ (high resolution IUE) given there, although based on a total sample of 68 O stars, B supergiants, WR stars and PN spectral stars is based actually on 13 WR stars for the CIV $\lambda 1550$ relation and 6 WR stars for NV $\lambda 1420$. Since we have at hand a much larger sample of uniformly reduced low resolution IUE spectra of WR stars (94 galactic and LMC stars) we decided to check the validity of the empirical correlations of Prinja (1994) for WR stars alone.

The empirical relation of Prinja (1994) is based on high resolution v_∞ determinations from Prinja *et al.* (1990), therefore we decided to use the same data for calibration.

With our low resolution IUE data for galactic and LMC WR stars we were able to study all empirical correlations given in Prinja (1994). We found that the empirical relation between $\Delta\lambda$ for NIV $\lambda 1241$ and terminal wind velocity for WR stars alone is very weak – $r = 0.50$. Such a relation, studied for 14 galactic WN stars in common with Prinja *et al.* (1990), gives no chance for reliable v_∞ estimation. Also the $\Delta\lambda$ *vs.* v_∞ relation for CII $\lambda 1335$, studied by us for 10 galactic WC stars can hardly be called a correlation ($r = 0.66$).

Of empirical relations given in Prinja (1994) that one for CIV $\lambda 1550$ line is the most universal (this line is present in both WC and WN stars). For 24

WR stars in common (14 WN and 10 WC) we found that a correlation between $\Delta\lambda = \lambda_{\rm peak}^{\rm Emis} - \lambda_{\rm min}^{\rm Abs}$ for CIV λ1550 as measured in low resolution IUE spectra and v_∞ from Prinja *et al.* (1990) indeed exists. However, for WR stars we found it to be linear rather than square. A comparison between Prinja (1994) and our empirical relations is given in Fig. 1. The linear empirical relation is characterized by the correlation coefficient $r = 0.93$ and it is really good. In this situation, instead of using the relation by Prinja (1994) we will further proceed with our linear empirical relation:

$$v_\infty = -198.4(\pm 145.3) + 146.6(\pm 10.6) \times \Delta\lambda\,.$$

This relation is valid for $v_\infty \sim 700 - 3200$ km/s. The estimated accuracy (assuming v_∞ from Prinja *et al.* (1990) as accurate) is 200 km/s (rms). For v_∞ lower than 2000 km/s it is accurate to 170 km/s (rms).

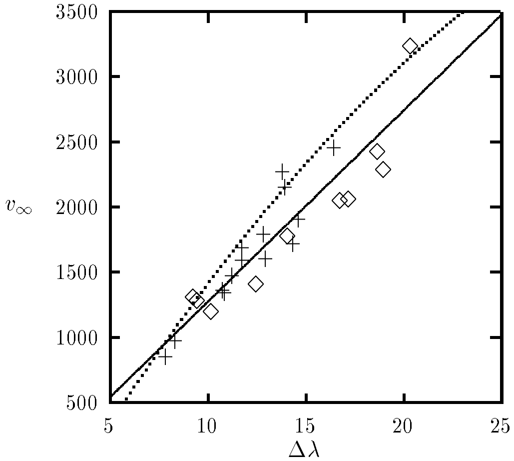

Fig. 1. The $\Delta\lambda = \lambda_{\rm peak}^{\rm Emis} - \lambda_{\rm min}^{\rm Abs}$ in angstroms measured in low resolution IUE spectra for CIV λ1550 line plotted as a function of the violet edge v_∞ (in km/s) from Prinja *et al.* (1990) for 24 WR stars in common with Paper 1. Crosses represent WN stars and diamonds – WC. The empirical relation by Prinja (1994) is shown by the dotted line, while our – by the continuous one.

These uncertainties are intrinsic to the empirical correlation itself rather than absolute errors of v_∞ determined from low resolution IUE data. The absolute, difficult to estimate, errors may be much larger than predicted from the relation given above. The most important source of uncertainties is, of course, the low resolution of IUE data which influence $\Delta\lambda$.

Also the determination of wavelength of both emission and absorption components of the resonance line CIV λ1550 through FIT (fitting Gaussian profile) introduces uncertainties. To estimate them we also measured λ using MIPOS procedure which finds lines extrema from their shape. We found that errors related to wavelength determinations through FIT procedure are not greater than 2 Å, far below the spectra resolution. These uncertainties may produce a 300 km/s error in terminal velocities.

Another important uncertainties arise due to possible, and difficult to overcome shifts in IUE low resolution wavelength calibration. Finally, additional uncertainties, in the absolute sense, come from errors of v_∞ determinations from high resolution IUE data in Prinja *et al.* (1990).

Summing up, the intrinsic accuracy of the empirical relation given above should be of the order of 10–20%, which is very good. The absolute errors connected with terminal velocities may be much larger due to low resolution of the spectra. The overall quality of the empirical relation will be tested by comparison with results from other studies in Section 5.

We may conclude, however, that although precise determinations of v_∞ should be obtained from better quality data, the empirical relation can be successfully used as a first approximation, where more detailed studies are not available, *e.g.,* for highly reddened or faint objects.

4. The Final Wind Velocities v_∞ for our Program Stars

With the empirical relation given above we are able to obtain terminal velocities for 85 galactic and LMC stars (31 galactic WN, 20 galactic WC, 28 LMC WN, 6 LMC WC). To obtain maximum possible uniformity we excluded from our sample (Paper 1) WR 2, WR 3, 104, 106, 157, Br 43, 56, 58 and 98 for which CIV λ1550 line is not seen.

In Tables 1 and 2 terminal velocities are listed for galactic and LMC stars, respectively. For every star its catalog name (WR or Br), detailed identification, spectral type, and v_∞ in km/s as determined from our correlation for CIV λ1550 are given. The results of other extensive studies of terminal wind velocities are shown as well.

Our results are also plotted *vs.* spectral type for WN and WC stars separately in Fig. 2 and Fig. 3.

For galactic WN stars we find that the terminal velocity ranges from 695 to 2615 km/s with the mean value of 1520 $\pm$430 km/s. We also note, that most of the galactic WN stars, $\sim$ 80%, have terminal velocities between 1000 and 2000 km/s.

In the case of LMC WN stars v_∞ ranges from 665 to 2765 (exceptionally high terminal velocity in the case of Br 6 = HD 32109, WN 3p). The mean value is 1510 $\pm$ 410 km/s, and $\sim$ 80% of LMC WN stars have terminal velocities between 1000 and 2000 km/s. In all subclasses except for WN 3, the LMC WN stars have slower winds than their galactic counterparts, however the mean terminal velocity of LMC WN stars is equal to that of the galactic ones.

For LMC WC stars such "statistics" makes no sense, since we only have 6 stars in our sample. For the galactic WC stars we note, however, that the terminal velocity ranges from 1165 to 3480 km/s and is substantially higher than for WN stars. The mean value of v_∞ gives no further information since clear relation between WC spectral subtype and terminal velocity exists (see Section 6).

Table 1

Terminal velocities of galactic WR stars (in km/s).

WR	Ident.	Sp Type	Torres *et al.* (1986)	Schmutz *et al.* (1989)*	Howarth Schmutz (1992)	Eenens Williams (1994)	Prinja *et al.* (1990)	This work CIV λ1550
1	4004	WN 5		2000	2100			2135
4	16523	WC 5	3200					3040
5	17638	WC 6	2800					2365
6	50896	WN 5(SB1)		1700	1820	1800	1720	1915
7	56925	WN 4		1600				1545
10	65865	WN 4.5		1500			1475	1460
12	CD-45 4482	WN 7(SB1)		(1100)				1165
14	76536	WC 6	2900	2500		1900	2055	2325
15	79573	WC 6	3600					2325
16	86161	WN 8		900		700	855	960
17	88500	WC 5	2200					2340
18	89358	WN 5		2100				2000
22	92740	WN 7+a(SB1)		1000		1300	1790	1695
23	92809	WC 6	2900	2700		2250	2280	2585
24	93131	WN 7+a		1200			2155	1855
25	93162	WN 7+a		1200			2455	2220
33	95435	WC 5	4500					3480
40	96548	WN 8		1000		900	975	1035
44	LSS 2289	WN 4		(1400)				1620
50	LSS 3013	WC 6+a	3200					1970
52	115473	WC 5	3800				3225	2790
53	117297	WC 8	1700					1240
55	117688	WN 7		(1100)				1195
56	LS 8	WC 7	1750					2205
57	119078	WC 7	2100				1770	1870
61	LSS 3208	WN 4.5		(1400)				1430
69	136488	WC 9	1500	1400		1340	1275	1195
71	143414	WN 6(SB1)					1590	1530
75	147419	WN 6		2300				1280
78	151932	WN 7		1200		1200	1365	1385
85	LSS 3982	WN 6						1430
86	156327	WC 7	2400	2000		1855		1650
90	156385	WC 7	1800				2045	2265
92	157451	WC 9	1300			1100	1300	1165
103	164270	WC 9(SB1?)	1350			1100	1190	1295
108	E313846	WN 9	900	1220	1100			1255
110	165688	WN 6		2300	3190	2250		2615
111	165763	WC 5	3000	2900	2300	2150	2415	2545
123	177230	WN 8(SB1)		(1020)				1310
128	187282	WN 4(SB1)		1500			2270	1840
134	191765	WN 6(SB1)		1900	1960	1800	1905	1955
135	192103	WC 8	2100	2000	1500	1525	1405	1635
136	192163	WN 6(SB1)		1600	1760	1660	1605	1705
138	193077	WN 6+a(SB1)		1500	1400		1345	1400
141	193928	WN 6(SB1)		(1720)	1650	1550		1560
148	197406	WN 7(SB1)		(1000)				1545
152	211564	WN 3		(1800)	1800			1840
154	213049	WC 6	3100		2700			1900
155	214419	WN 7(SB1)		(1300)	1330	1400	1690	1530
156	AC+60 38562	WN 8		(700)				695:
158	AS 513	WN 7		(900)				885

* – the values of v_∞ from Hamann *et al.* (1995) are given in parenthesis.

Table 2

Terminal velocities of LMC WR stars (in km/s).

Br	Ident.	Sp Type	Torres *et al.* (1986)	Koesterke *et al.* (1991)	This work CIV λ1550
1	L-10, FD1	WN 3		2000	1255
3	WS 1, FD2	WN 3			1735
6	32109	WN 3p		2900	2765
7	32125	WC 5	3500		2570
8	32257	WC 5-6	3750		2600
10	32402	WC 5	5300		2675
12	268847	WN 3		2175	1855
13	33133	WN 8		1000	1060
14	269015	WN 4			1650
15	L-115,FD14	WN 4			1445
18	269227	WN 9-10			915
19	34783	WN 3			2105
23	AL-140,FD22	WN 3			1590
24	AL-150,FD23	WN 7		1200	1325
25	AB-16	WN 3			1445
26	36063	WN 7		1600	1490
27	WS20, FD25	WN 3		2000	1575
29	269485	WN 3/WCE		2000	2160
35	269549	WN 4			1430
38	AB-2	WN 3			1135
40	269624	WN 3		1950	1735
46	269692	WN 3			1445
50	37680	WC 5	3500		2970
59	AL-348,FD52	WN 3			1460
62	269818	WC 5			2470
64	W27/23,FD56	WN 9-10		500	665
71	269883	WN 7			1195
80	R135, FD64	WN 7			1295
89	38282	WN 7			1475
90	269928	WN 7			1515
92	38344	WN 6			1515
93	FD73	WC 6-7			3160
99	AL-414,FD79	WN 4			1105
100	270149	WN 3-4			1870

5. Comparison with other Determinations

As it was already stated in Section 3 the final test of our terminal velocities accuracy will be done through comparison with results by other authors, and with different (more precise) methods. However, one may notice that we have here the same number of stars in common with Torres *et al.* (1986) – 24, Schmutz *et al.* (1989) – 24, or with Eenens and Willis (1994) also 24, as with Prinja *et al.* (1990). A question arises, why not to use one of these papers to calibrate $\Delta\lambda$ from

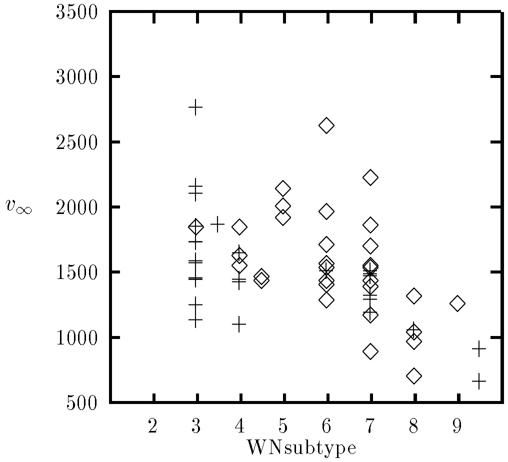

Fig. 2. Terminal velocities of WN stars plotted *vs.* WN spectral subtype. Crosses represent the LMC WN stars, diamonds – the galactic ones.

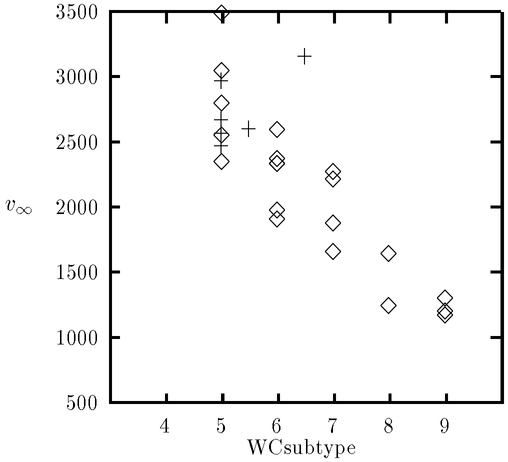

Fig. 3. Terminal velocities of WC stars plotted *vs.* WC spectral subtype. Crosses represent the LMC WC stars, diamonds – the galactic ones.

low resolution IUE data? The answer is simple: in the above-cited papers v_∞ is determined by rather nonstandard methods. Such calibrated low resolution data would be additionally affected by possible intrinsic uncertainties of these methods. Therefore all above-cited papers will be used as a comparison of our results only.

Torres *et al.* (1986) obtained v_∞ for a large sample of 71 galactic and LMC WC stars. Their results are based on the FWHM *vs.* EP relation and the terminal velocities are obtained by extrapolation of such a relation (based sometimes on 30 lines, corrected for line shape) to zero excitation potential. These terminal velocities range from 1300 to 7400 km/s. We assume this determination as a very approximate because the much more subtle effect of line FWHM dependence on optical depth in line (Hillier 1987, Niedzielski 1994) influences substantially

FWHM *vs.* EP relation. Nevertheless, we compared our results with those of Torres *et al.* (1986) for 24 galactic and LMC stars in common and found their terminal velocities, on the average, 1.27 ± 0.26 times higher than ours. The correlation is not very good, $r = 0.81$, but noticeable.

Schmutz *et al.* (1989) while analyzing spectra of 30 galactic WR stars obtained v_∞ for all of them from the maximum width of HeII $\lambda 5412$ and HeI $\lambda 10830$ lines. These range from 900 to 3100 km/s and are considerably smaller than those of Torres *et al.* (1989). Based on 24 galactic WR stars in common we find that the correlation between these values and ours is even worse than with Torres *et al.* (1986), $r = 0.71$. The values of terminal velocity agree, however, well. Their terminal velocities are equal 0.98 ± 0.25 of ours, on the average.

Hamann *et al.* (1995) enlarged the number of v_∞ determinations of Schmutz *et al.* (1989) by 10 newly measured galactic WN stars. For 29 galactic WN stars in common with that paper we have $r = 0.68$ and their values are systematically 0.92 ± 0.22 of ours, essentially very close to those of Schmutz *et al.* (1989).

Also Koesterke *et al.* (1991) used the same method of maximum width applied to optical helium lines in their analysis of 19 LMC WN stars. The terminal velocities as determined by them range from 500 to 3000 km/s. For 10 LMC WN stars in common we find that correlation is good ($r = 0.90$) and their values of terminal velocities are 1.08 ± 0.22 of presented here.

More recently Howarth and Schmutz (1992) found terminal velocities for 20 galactic WR stars from the P Cygni profiles of HeI $\lambda 10830$ line. Their v_∞ range from 1220 to 5000 km/s. For 13 WR stars in common we find that the overall agreement, including the only binary stars in our sample (WR 155) is good, $r = 0.86$ and their values are on the average 1.02 ± 0.14 times higher.

Finally, our data can also be compared to those of Eenens and Willis (1994). These authors determined terminal velocities for 41 WR stars through profile fitting with the SEI (Sobolev with exact integration) method (Lamers *et al.* 1987) of NIR and IR emission lines (HeI $\lambda 10830$ and HeII $\lambda 2.058\ \mu$). The terminal velocities as determined in that paper range from 750 to 2900 km/s. For 24 WR stars in common we found that agreement is very good ($r = 0.91$), their values are 0.91 ± 0.11 of ours, on the average.

This comparison proves that the method of v_∞ determination based on linear empirical relation described here, and low resolution IUE data is quite precise, when compared to results of other authors. Except for Torres *et al.* (1986) our terminal velocities agree within 25% with other determinations. The best agreement, *i.e.*, the lowest scatter in the ratio of "their" to "ours" values, with the data of Eenans and Willis (1994), and Howarth and Schmutz is noticeable. The accuracy of our method could be estimated, from these two most recent papers, to be of the order of about 15%.

6. Correlation of v_∞ with Spectral Subtype

Having such a large number of uniformly measured terminal velocities of WR winds we are here in position to check possible correlation between v_∞ and spectral subtype of WR stars. Such a correlation was presented by Koesterke *et al.* (1991) for LMC WN stars. Later on Howarth and Schmutz (1991) using their own determinations together with data from Prinja *et al.* (1990) and Schmutz *et al.* (1989) showed that a relation between spectral subtype and terminal velocity is easily seen (the higher the ionization stage in the envelope, earlier WR subtype, the higher the terminal velocity) but with given scatter within one subclass did not call it a correlation. This problem was studied again by Eenans and Williams (1994) who see a clear correlation (same as Howarth and Schmutz 1991) for WC stars (with some exceptions) but due to large scatter exclude similar correlation in the case of WN stars.

Plots of v_∞ as a function of spectral subclass are given in Fig. 2 and 3 for WN and WC stars, respectively.

One can easily notice that terminal velocities of WN stars seem to be lower than that of WC stars. The maximum terminal velocity of WN stars is about 2200 km/s with only 3 exceptions, while most of them (80%) have terminal velocities between 1000 and 2000 km/s. Terminal velocities of WC stars range up to 3000 km/s, with two exceptions of even higher terminal velocities.

It is clear from Fig. 2 that the terminal velocities of WN star are not related at all to the spectral subtype of these stars. The velocity range for a given subtype may be as large as 2000 – 2500 km/s. An interesting finding is that the LMC WN stars have lower terminal velocities than their galactic counterparts in all subclasses except for WN 3 where we have only one galactic star. However, the mean value of terminal wind velocities for galactic and LMC stars seems to be identical.

On the other hand the close relation between terminal velocity of the wind and the spectral subtype of WC stars is clearly seen in Fig. 3. It is not the first time when WC stars appear to be a better defined group than WN (*cf.* Torres *et al.* 1986, Paper 1). One can notice in Fig. 3 that for WC 9 stars v_∞ is as low as 1200 – 1300 km/s and grows up to 2300 – 3000 km/s for WC 5. Only two stars do not follow that trend (WR 33, WC 5 and Br 93, WC 6–7). The comparison between galactic and LMC WC stars is not possible because of lack of the latter. Only in the case of WC 5 stars we can say that galactic and LMC stars have similar terminal velocities (if we exclude WR 33 and Br 93 from these considerations).

With the two exceptions, mentioned above, we may roughly predict terminal velocity of a WC star with spectral features classified as WCx by: $v_\infty = -374(\pm 29) \times x + 4523(\pm 190)$ km/s with the correlation coefficient of $r = 0.92$.

7. Conclusions

Given the number of different methods used to estimate terminal velocities of WR winds one might expect a large scatter between different authors. However, as it can be seen from Section 5, v_∞ for WR stars appears to be a well defined parameter and different determinations agree within 10–20%.

The simple method of determining terminal wind velocities from low resolution IUE spectra in WR stars, presented in this paper, seems to be a powerful tool since it allows to study with a reasonable accuracy stars either too faint or too reddened for more precise observations.

Finally, such a simple method allows to obtain v_∞ for large samples of WR stars and study the dependence of terminal velocity on other parameters.

Based on our determination of terminal wind velocities for 85 galactic and LMC stars we show that:

1. terminal wind velocities of WR stars range from 600 – 3500 km/s;
2. most of WN stars (80%) have v_∞ between 1000 – 2000 km/s;
3. there is no correlation between WN spectral subtype and terminal wind velocity;
4. LMC WN stars have slower winds than their galactic counterparts in all subtypes except WN 3;
5. WCE stars have faster winds than WN stars;
6. WC subtypes correlate well with v_∞: the earlier the WC subtype the faster the wind.
7. The CIV λ1550 line seems to be a key one for understanding WR or at least WC stars. In Paper 1 it allowed us to reproduce the spectral classification of WC stars, now we can see that it also allows to obtain reliable v_∞ estimates for both WN and WC stars.

Acknowledgements. AN acknowledges the financial support from Padova University through the staff-exchange project and kind hospitality of Prof. Roberto Barbon in Asiago, where a part of this work was done. This work was supported by KBN grant No. 2 2112 92 03 through Nicolaus Copernicus University in Toruń.

REFERENCES

Bohlin, R.C., and Holm, A.V. 1980, *NASA IUE Newsletter*, **10**, 107.

Borkowski, J. 1992, *"ReWiA 2.0 - User's Manual"*, in Polish.

Eenens, P.R.J., and Williams, P.M. 1994, *MNRAS*, **269**, 1082.

Hamann, W.-R. 1991, in "Wolf-Rayet Stars and Interrelations with Other Massive Stars in Galaxies", IAU Symposium 143, eds. K.A. van der Hucht and B. Hidayat, Kluwer, p. 81.

Hamann, W.-R., and Schmutz, W. 1987, *Astron. Astrophys.*, **174**, 173.

Hamann, W.-R., Schmutz, W., and Wessolowski, U. 1988, *Astron. Astrophys.*, **194**, 190.

Hamann, W.-R., Koesterke, L., and Wessolowski, U. 1995, *Astron. Astrophys.*, in press.

Hillier, D.J. 1987, *Astrophys. J. Suppl. Ser.*, **63**, 965.

Hillier, D.J. 1988, *Astrophys. J.*, **327**, 822.

Hillier, D.J. 1989, *Astrophys. J.*, **347**, 392.

Hillier, D.J. 1991, in "Wolf-Rayet Stars and Interrelations with Other Massive Stars in Galaxies", IAU Symposium 143, eds. K.A. van der Hucht and B. Hidayat, Kluwer, p. 59.

Howarth, I.D., and Schmutz, W. 1992, *Astron. Astrophys.*, **261**, 503.

van der Hucht, K.A. 1992, *Astron. Astrophys. Review*, **4**, 123.

Koesterke, L., Hamann, W.-R., Schmutz, W., and Wessolowski, U. 1991, *Astron. Astrophys.*, **248**, 166.

Koesterke, L., Hamann, W.-R., and Wessolowski, U. 1992, *Astron. Astrophys.*, **261**, 535.

Lamers, H.J.G.L.M., Cerruti-Sola, M., and Perinotto, M. 1987, *Astrophys. J.*, **314**, 726.

Massey, P. 1984, *Astrophys. J.*, **282**, 789.

Niedzielski, A. 1994, *Astron. Astrophys.*, **282**, 529.

Niedzielski, A., and Rochowicz, K. 1994, *Astron. Astrophys. Suppl. Ser.*, **108**, 669.

Prinja, R.K. 1994, *Astron. Astrophys.*, **289**, 221.

Prinja, R.K., Barlow, M.J., and Howarth, I.D. 1990, *Astrophys. J.*, **361**, 607.

Schmutz, W., Hamann, W.-R., and Wessolowski, U. 1989, *Astron. Astrophys.*, **210**, 236.

Schmutz, W. 1991, in "Wolf-Rayet Stars and Interrelations with Other Massive Stars in Galaxies", IAU Symposium 143, eds. K.A. van der Hucht and B. Hidayat, Kluwer, p. 39.

Torres, A.V., Conti, P.S., and Massey, P. 1986, *Astrophys. J.*, **300**, 386.

Torres-Dodgen, A.V., and Massey, P. 1988, *Astron. J.*, **96**, 1076.