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An analysis of emission lines in the spectrum of P Cygni

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Abstract. Using the coudé spectrograph of the NAO 2m telescope at the Rhodope Mountains, Bulgaria, 9 spectra in the blue and 8 spectra in the red photographic region of P Cygni were obtained during 1990. By averaging the spectra in each set a S/N-ratio of about 45 was achieved. Comparing the lists of identifications published by Beals (1950), de Groot (1969), Ozemre (1978), Stahl et al. (1993), Markova (1994) and Markova & Zamanov (1995), we conclude that the emission spectrum of P Cygni in our days is probably much richer and intensive than 60 years ago. A number of line parameters of the pure emission lines are measured. An estimate of the electron density and temperature in the region of [NII]-lines formation is obtained. Different velocity laws yielding similar density structures are discussed aiming to account for the results obtained on the basis of the [NII] lines. Possible mechanisms for the formation of the permitted pure emission-line spectrum are proposed.

Key words: stars: P Cygni-emission lines – line: formation

1. Introduction

P Cygni is the longest known galactic Luminous Blue Variable and one of the most-widely studied. It is an early B-type supergiant classified variously as B1eq, B0-B1, B1p (de Jager 1980) or B1Ia$^+$ (Lamers et al. 1983) but its spectrum differs from that of normal B-type supergiants in the appearance of so-called P Cygni-type profiles in the lines of abundant ions (de Groot 1969). In addition, the strongest lines of hydrogen and helium show wide emission wings which are due to electron scattering in the wind (Castor et al. 1970, Bernat & Lambert 1978) or to non-LTE effects in the extended atmosphere (Hubeny & Leitherer 1989).

In recent years a number of works devoted to the identification of spectral lines in the spectrum of P Cygni have been published (Stahl et al. 1991, 1993; Markova 1994; Markova & Zamanov 1995). As a result, many new lines of different ions were identified. Most prominent among these are emission lines of [FeII], [NII], FeIII, NII, SiII and AlIII.

Stahl et al. (1991) studied the forbidden emission lines in the spectrum of P Cygni. Here we present some results concerning the permitted emission lines. We shall use the term "pure emission" lines to indicate emission lines not visibly accompanied by absorption components.

2. Observations and data reduction

Using the coudé spectrograph of the NAO 2m telescope at the Rhodope Mountains, Bulgaria, 9 spectra in the blue – spectral resolution of 0.18Å/mm – and 8 spectra in the red – spectral resolution of 0.36Å/mm – photographic region of P Cygni were obtained during 1990. All spectra were converted to relative intensity and wavelength calibrated following the reduction procedure described earlier (Markova 1994). By averaging the spectra in each set we achieved a S/N-ratio of about 45. Since we intend to analize the emission spectrum of P Cygni and since the star is known to exhibit line-profile variations (Markova 1993, Stahl et al. 1994) one may ask whether the use of an average spectrum will be expedient in this case. In fact, the central velocities of the pure emission lines did not show any significant variations during our observing campaign. We also observed small variations of at most ±15 km/s in the line widths. Taking into account the quality of the photographic data, the lower intensity of some of the studied lines and the accuracy of the measuring procedure – we use a gaussian fit to the emission lines although they are not always gaussian shaped – we assume, as a first approximation, that the line parameters studied are not time variable, and that we are justified in using averaged spectra.

3. The emission line spectrum

The present spectrum of P Cygni is notable for the great number of pure emission lines. Most of them are permitted lines of FeIII, NII, SiII and probably AlIII. Further pure emission lines are the forbidden lines of [FeII], [NII], [NiII] and probably [TiII].

A simple qualitative comparison of the identification lists of Beals (1950), de Groot (1969), Ozemre (1978), Markova (1994) and Markova & Zamanov (1995) as well as an inspection

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of the spectral atlas published by Stahl et al. (1993) show that more than 70% of the pure emission lines in P Cygni's spectrum (wavelength range from 3500 to 6800 Å) appear to be new.

3.1. Permitted emission lines

Central emission velocities, V_e, averaged within the framework of each ion and multiplet, are summarized in Table 1. One can see that the first three values of V_e fall within the 3σ range while the emission radial velocity of the FeIII lines with P Cygni-type profiles is systematically higher. Also higher, i.e. more negative, are the velocities of the pure emission lines.

According to Barlow et al.(1994) and Stahl et al. (1991) P Cygni's radial velocity is -22.6±1.5 and -22±4 km/s, respectively. These values were obtained by analysing flat-topped profiles of [NiII] and [FeII] forbidden lines. Both estimates are higher than V_e derived from HI, HeI and NII lines but in excellent agreement with V_e derived from FeIII lines (see Table1). The observed differences are indeed small but appear to be real as they are above the 3σ level. A possible explanation for this result is that the central emission peak of the P Cygni profiles of the lines of abundant ions (HI, HeI and NII) are distorted by "photospheric" absorption. At the same time the FeIII lines with P Cygni – type profiles have not been affected by such absorption since they form entirely in the higher levels of the wind. Speaking about "photosphere", we mean those wind layers where a mean optical depth τ, derived from an average over all wavelengths longer than 912Å, drops to 2/3, namely $R_*=R(\tau_\lambda)$ for $\lambda > 912$Å. Irrespective of its simplicity, the above given explanation meets with some difficulties in the case of a star as extreme as P Cygni, whose wind is much denser than in normal supergiants. For example, we know from the observations that in the photographic region of P Cygni's spectrum no line of photospheric origin, i.e. centred at V_{sys}, has been observed. In the UV the situation is similar with the exception of the resonance lines of the highly ionized species, CIV and SiIV, whose absorptions are centred at their laboratory wavelength (Cassatella et al. 1979) thus pointing to a possible formation in wind layers near R_*. Therefore, the central emission peak of the observed P Cygni profiles of the HeI, HeI and NII lines would be distorted by "photospheric" absorption only if during our observations the wind was more transparent. Another possibility is the existence of large turbulent motions in the region where the expansion velocity is still small.

Adopting V_{sys} = -22km/s, we also conclude that the permitted pure emission lines in the spectrum appear to be blue shifted (see Table 1). In fact, different multiplets of the same ion can have different V_e. The observed differences can not be fully explained by inaccuracy of the position measurements since most of the studied profiles have a triangular shape with a well defined and sharp central peak. No obvious correlation between the velocity and excitation energy of the upper level of multiplets of the same ion was found.

Table 1. Mean values and standard deviations for radial velocities of emission lines of different ions

element	multiplet	n	type of profile	V_e[km/s]
HI	H22 to H$_\beta$	16	P Cygni	- 2.9±1.5
HeI	4, 5, 12, 14, 16, 18, 20, 22, 28, 34, 37, 47, 48, 50, 51, 53	16	P Cygni	- 6.3±1.6
NII	3, 5, 6, 9, 12, 15, 33	15	P Cygni	- 8.5±0.9
FeIII	4, 5, 36, 45, 68	24	P Cygni	-20.5±2.0
FeIII	113	7	emission	-32.4±2.8
FeIII	114	3	emission	-25.0±1.0
FeIII	115	3	emission	-47.0±3.8
FeIII	117	2	emission	-27.5±1.5
FeIII	118	2	emission	-46.5±1.5
FeIII	119	2	emission	-63.5±3.5
NII	1	1	emission	-34
NII	24	3	emission	-24.7±3.3
NII	28	3	emission	-31.3±5.6
NII	31	1	emission	-35
NII	36	3	emission	-58.3±5.3
NII	41	1	emission	-69
NII	45	1	emission	-28
NII	46	3	emission	-53.7±0.7
NII	57	1	emission	-45
SiII	1, 2, 4, 5	8	emission	-43.8±3.7
AlIII	3, 5	2	emission	-40±5

Various parameters of the studied pure emission lines are listed in Table 2. The full width at half maximum, FWHM, and the edge velocities, $V_{edge(b)}$ and $V_{edge(r)}$, of the lines were determined from a gaussian fit. These last two quantities were measured with respect to the position of the corresponding emission peak. Most FeIII and NII lines included in the sample, show similar values of FWHM, $V_{edge(b)}$ and $V_{edge(r)}$. The estimates range from about 65 to about 100 km/s for FWHM and from about 70 to about 100 km/s for the modulus of the edge velocities. A number of lines, however, deviate from these values of the line parameters (In Table 2 these lines are marked with an asterisk). In the majority of those cases there is a simple explanation for the aberrant behaviour: influence of blends or rather strong photographic noise interferes with both the fitting of the profiles and the determination of the continuum level. By averaging the data for the FeIII and NII lines, mean values of 84±3, -80±2 and 84±2 km/s were obtained for FWHM, $V_{edge(b)}$ and $V_{edge(r)}$, respectively.

At the same time the SiII emission lines (multiplets 2 and 4), with their mean FWHM of 194±1 km/s and mean edge velocities of- 236±5 and 231±7 km/s, are considerably broader than the FeIII and NII lines. Multiplet No.5 of SiII is a little narrower than multiplets 2 and 4 but still broader than FeIII and NII. The line parameters of SiII (multiplet No.1) were found to be quite different from those of the others SiII multiplets. But these estimates are less reliable since both profiles are affected by blends.

According to Beals (1950) and de Groot (1969) the presence of AlIII is possible but not certain. On our spectra (Markova 1994, Markova & Zamanov 1995) and those of Stahl et al.

Table 2. Permitted emission lines in P Cygni's spectrum. V_e[in km/s] is the velocity of the emission peak. $V_{edge(b)}$ and $V_{edge(r)}$[in km/s] denote the velocities of the blue and red edge of a line, measured with respect to its emission peak. "I" is the central emission intensity, measured in units of the nearby continuum; an asterisk "$*$" marks values which are uncertain

line	V_e	FWHM [Å]	$V_{edge(b)}$	$V_{edge(r)}$	I
FeIII 113					
5235.3	-36	65	-72	71	1.03
5243.3	-35	96	-99	98	1.08
5276.2	-33	68	-86	78	1.05
5282.1	-25	77	-82	82	1.06
5299.9	-44	177	-112	92	1.05*
5302.5	-28	72	-81	76	1.04
5306.6	-26	78	-81	71	1.02
FeIII 114					
5833.6	-24	67	-83	93	1.09
5929.5	-24	66	-77	87	1.10*
FeIII 115					
5920.00	-40	173	-164	165	1.05*
5953.65	-48	118	-141	131	1.17*
FeIII 117					
5999.3	-26	75	-99	90	1.14
6032.3	-29	80	-161	116	1.18*
FeIII 118					
4137.9	-48	51	-59	65	1.05
4164.8	-45	78	-83	79	1.09
FeIII 119					
4053.3	-60	94	-92	95	1.03
4081.2	-67	100	-82	77	1.02
NII 1					
4895.20	-34	92	-109	100	1.08
NII 28					
5931.79	-29	72	-79	84	1.08
5941.67	-23	84	-93	89	1.05
5960.93	-42	99	-98	90	1.07
NII 31					
6610.58	-35	72	-70	76	1.17
NII 36					
6167.82	-53	67	-79	70	1.09
6170.16	-69	66	-72	77	1.07
6173.40	-53	63	-79	80	1.06
NII 41					
6630.50	-69	90	-90	90	1.05
NII 45					
6522.30	-28	83	-88	90	1.04
NII 46					
6328.60	-52	106	-76	70	1.02*
6340.67	-55	85	-85	85	1.09
6357.00	-54	111	-93	100	1.07*
NII 57					
6242.52	-45	112	-95	99	1.06*
SiII 1					
3856.02	-35	77	-182	147	1.12
3862.59	-35	80	-105	77	1.04
SiII 2					
6347.09	-43	193	-230	235	1.33
6371.36	-41	192	-237	210	1.18
SiII 4					
5957.61	-66	196	-227	245	1.11
5978.97	-36	195	-248	230	1.30*
SiII 5					
5041.06	-46	130	-184	170	1.11*
5056.02	-49	142	-192	182	1.18

(1993), four lines of AlIII (multiplets 3, 5 and 6) appear to show emission or P Cygni-type profiles that are stronger in emission than in absorption. At the same time, the AlIII λ5696 line (multiplet No. 2) clearly shows a P Cygni-type profile with an absorption component stronger than the emission line. But a possible blend with SiIII λ5696 cannot be excluded in this case. Summarizing, we conclude that the AlIII spectrum is certainly present in emission and possibly also in absorption in P Cygni's present-day spectrum. We obtain a mean value of -40±5 km/s for the emission velocity of these lines. Unfortunately, it was not possible to derive other line parameters from our data.

Most of the permitted pure emission lines in the spectrum appear to be symmetric with a sharp maximum. In some cases (FeIIIλ5300, λ 6032, λ5833 and SiII λ6371) a weak emission shoulder can be seen on the blue or red side of the profiles (Markova & Zamanov 1995). Although no appropriate identifications have been found for all features, we believe that they are not due to emission in the corresponding lines since not all lines of the same multiplet show these features.

3.2. Forbidden emission lines

Data concerning the [FeII] spectrum are not listed in Table 2 since similar data were already published by Stahl et al. (1991, 1993). Here we shall only mention that, based on six [FeII] lines, mean values of -18±2 and 231±3 km/s were derived for the central velocity, $V_c = (V_{edge(b)} + V_{edge(r)})/2$, and the half width at zero intensity, $\mathrm{HWZI} = (|V_{edge(b)}| + V_{edge(r)})/2$, of the lines, respectively. These values are in excellent agreement with the results of Stahl et al. (1991), namely -22±4 and 230 km/s. This, then, is further evidence of the reliability of our radial-velocity data.

As Stahl et al. have noted, the [FeII] lines are flat-topped showing that they are both optically thin and formed in a region of constant expansion velocity, V_{exp}=HWZI=230 km/s. The complex structure of some [FeII] lines is probably due to blends with permitted lines of different ions (Markova 1994, Markova & Zamanov 1995; Israelian 1995). However, since the blends are weak and since the spectral resolution of our data is 20 to 40 times higher than the line widths we concluded that the HWZI for these lines could provide an almost exact measure of V_{exp}. This velocity is considerably smaller than the terminal velocity of the wind, V_{term} = 460, 400 and 311 km/s as determined from the blue edge of the UV absorption lines by Hutchings (1979), Underhill (1979) and Cassatella et al. (1979), respectively, and a little higher than the terminal velocity of 210 km/s determined by Lamers et al. (1985). Prinja et al. (1990) studied a significant sample of O and B supergiants and found that the terminal velocity is equal to the sum $\mid V_{DAC}\mid$ + HWHI$_{DAC}$ where V$_{DAC}$ is the mean velocity of the discrete components observed in unsaturated P Cygni profiles, and HWHI$_{DAC}$ is the mean value of the half-width at half-intensity of these components. In the case of P Cygni, discrete components were observed in the UV (Lamers et al. 1985) as well as in the optical part of the spectrum (Markova 1986). The corresponding values of the two quantities, V$_{DAC}$ and HWHI$_{DAC}$ are -206±2km/s and about 30 km/s (from the UV FeII lines), and -211±1.4 km/s and about 25 km/s (from the higher members of the Balmer series). This gives a value of 236 km/s for the sum $\mid V_{DAC}\mid$ + HWHI$_{DAC}$ and, consequently, for the terminal velocity of the wind. This value is a little higher than the estimate of Lamers but it is practically the same as V$_{exp}$ derived from [FeII] flat – topped profiles. Thus, we conclude that the [FeII] lines are formed in a region expanding at the terminal wind velocity. Stahl et al. (1991) came to the same conclusion but they used the estimate of Lamers (1985).

Further forbidden lines in P Cygni's spectrum are those of [NII] multiplet Nos. 1 and 3. We confirm the result of Stahl et al. (1993) that the yellow line of [NII] (λ5755) shows a rounded, blue-shifted (V$_c$=-40 km/s) and slightly narrower (HWZI=200 km/s) profile. The greater strength of the line makes the derivation of its parameters more reliable than in the case of the [FeII] lines. The presence of the two red lines of [NII] is not obvious but, in our opinion, they are present in the averaged spectrum (Markova & Zamanov 1995). Symmetrizing the Hα profile with respect to its emission centre and accounting for the existence of water vapour lines, we derive a profile of the [NII] λ6548 line that is centred a little above V$_{sys}$ and has a HWZI of about 190 km/s. The similarity in the line-parameters of the [NII] λ6548 and [NII] λ5755 is obvious. The extraction of the profile of the other red line, [NII] λ6584, is more complicated since it is influenced, not only by the H$_\alpha$ emission wing but also, by the P Cygni profiles of the two lines of CII (mult. No.2). Taking into account:

- the extent of the red emission wing of the CII λ4267 line (free of blends) and assuming the same extent for the red emission wings of the two CII lines of multiplet 2;
- the existence of absorption in CII λ6578 and the lack thereof in CII λ6583,

we come to the conclusion that the [NII] λ6584 line is also present in our spectra. Of course, in this way it is not possible to determine the shape of the profiles and their line parameters with confidence. Therefore, the above results have to be regarded as somewhat rough estimates.

3.3. Origin of the permitted emission lines

In Table 3 we list the multiplets seen in emission in P Cygni and the excitation energies of their upper and lower levels. We observe the following:

- the excitation energies of the upper levels of the listed FeIII, NII and AlIII transitions (except multiplet 1 of AlIII) fall into three groups ranging from 20.32 to 20.79 eV, from 23.14 to 23.57 eV and from 24.98 to 25.35 eV;
- the excitation energies of the upper level of the SiII transitions are grouped around 10 and 12 eV;

Table 3. Different multiplets seen in emission in P Cygni; e$_{exc(l)}$ and e$_{exc(up)}$ denote the excitation energy of lower and upper level, respectively

element	e$_{exc(l)}$[eV]	e$_{exc(up)}$[eV]
NII1	17.80	20.32
AlIII3	17.74	20.47
FeIII113	18.19	20.54
FeIII114	18.43	20.54
FeIII115	18.71	20.79
FeIII117	18.73	20.79
NII28	21.07	23.14
NII24	20.85	23.32
AlIII6	20.69	23.32
NII31	21.51	23.37
AlIII5	20.47	23.44
FeIII118	20.54	23.50
FeIII119	20.54	23.57
NII36	23.04	25.04
NII41	23.10	24.96
NII45	23.14	25.04
NII46	23.14	25.09
NII57	23.37	25.35
SiII1	6.83	10.03
SiII2	8.09	10.03
SiII4	10.02	12.09
SiII5	10.02	12.47

A preliminary result obtained on the basis of the SAC method (Friedjung & Muratorio 1987 and Baratta et al. 1995), applied to the emission lines of FeIII and NII lines with P Cygni and pure emission profiles shows that the NII levels above 23eV as well as FeIII levels above 20eV seem strongly overpopulated, suggesting that NLTE-effects have become important (Markova & Muratorio 1997).

4. Discussion and conclusions

Comparing the identifications lists of Beals (1950), de Groot (1969), Ozemre (1978), Markova (1994) and Markova and Zamanov (1995), as well as the spectral atlas published by Stahl et al. (1993) we concluded that more than 70% of the pure emission lines in P Cygni's spectrum (wavelength range from 3500 to 6800Å) appear to be of recent origin. This finding is very important and needs special attention since the appearance of so many new lines in the spectrum would be a remarkable phenomenon in the star's history as it might reflect some changes in P Cygni's atmosphere. But, are these lines really new or is their appearance a result of the more favorable signal-to-noise ratio of the present spectra? A later inspection of the spectra studied by de Groot with the benefit of hindsight showed that some of the forbidden lines (Israelian & de Groot 1992) were already present as early as 1942. One expects any change in the strength of P Cygni's emission lines to be caused or accompanied by a change in the star's T_{eff}. Lamers et al. (1983) argued convincingly that around 1980 P Cygni had T_{eff}=19300 ±700 K. On the basis of a later photographic study (Lamers & de Groot 1992) it was found that d(log T_{eff})/dt = -0.027 ±0.004 per century. This leads to the following temperatures at the following epochs: 1930 (Beals 1950), 19911 K; 1942 (de Groot 1969; Israelian & de Groot 1992), 19762 K; 1990 (this article), 19182 K. Thus, in 60 years T_{eff} has decreased by 729 K, equal to the uncertainty in the determination of T_{eff}. It is, therefore, no surprise that any indication of a change in the emission line strengths can only be marginal, in complete agreement with our finding. A very good look at the older spectra has to be taken before we can be absolutely sure that the photographic spectrum today is really much richer in emission lines than 60 years ago.

Most of the permitted pure emission lines appear to be symmetric with a sharp maximum, blue shifted with respect to V_{sys}. The similarity in the line-parameters of the FeIII and NII points to a possible formation of both in the same wind layers, where the outflow velocity $V \leq 90$ km/s. The width of the SiII pure emission lines is considerably grater than that of FeIII and NII and corresponds to an outflow velocity of about 230 km/s, that is, in fact, the terminal velocity of the wind (see Sec 3.2). Obviously, the Si II emitting region is different from that of FeIII and NII lines. A typical β-velocity law with β=4, first proposed by Barlow and Cohen (1977), with an initial velocity V_0 =4x10^{-4} V_∞ and V_∞ =240 km/s (hereafter BC-velocity law) locates the FeIII/NII and SiII emitting regions, respectively, at $R \leq 5R_*$ and $R \leq 100R_*$. All of the observed FeIII and NII transitions are from higher excited levels, which seem overpopulated. At distances $R \leq 5R_*$, where these lines probably form, the wind temperature and density are higher than 10x10^{10} cm^{-3} and 14000 K, respectively (Drew 1985). In these circumstances fluorescence is a possible excitation mechanism for energy levels between 23.14 and 23.57 eV. In fact, we propose (like Wolf and Stahl 1985) that these levels could be pumped by two UV transitions in HeI atoms at energies of 23.09 eV (λ537Å) and 23.74 eV (λ522Å). In addition, considering the coincidence of the upper levels of FeIII multiplets 113 and 114 with the lower levels of multiplets 118 and 119 one could think about possible cascade transitions between these levels. In the case of the NII levels at energies little above 25 eV dielectronic recombination seems to be more probable. But the problem is that even at the base of the wind the temperature is too low to make this mechanism effective. With respect to the excitation mechanism of the SiII pure emission lines there are two possibilities: fluorescence – pumping of electrons by Lymanβ and Lymanγ to levels 4^2D and 5^2S, respectively – or radiative recombination, both followed by cascade transitions. If these lines are really formed at a distance of about $100R_*$, where the wind temperature and density are below, respectively, 10^4 K and 5x10^6 cm^{-3} (see below), the last possibility seems more probable. In any case a detailed NLTE analysis is necessary to understand the nature of P Cygni's permitted emission-line spectrum

Mean values of -18±2 and 231±3 km/s are derived for V_c and HWZI of the [FeII] lines, respectively. The shape of the profiles – flat-topped – points to a formation of optically thin lines in a constant-velocity outflow. The excellent agreement between HWZI of the lines and V_∞, as determined in Sect. 3.2, confirms the assumption of Stahl et al. (1991) that the [FeII] lines are probably formed in a region expanding at terminal wind velocity.

On our spectra we found evidence for the existence of the red [NII] lines in addition to the yellow one. The shape as well as the width of the profiles appears to be similar and points to a formation in a region with an outflow velocity of about 200 km/s. This region is obviously different from that of [FeII]. Assuming that these three [NII] lines form in the same wind layers, an estimate of the electron density and temperature of the matter can be obtained from their flux ratio. The theoretical intensity of the λ6584 line is about 3 times that of the λ6548 line. From this we calculate a [NII] (λ6548+λ6584) / [NII] λ5755 ratio of 1.50. According to Sobolev's (1975) relation between the above line ratio, T_e and n_e, a flux ratio between 1 and 2 corresponds to n_e=5x10^6 to 5x10^7 cm^{-3} for T_e in the range 5700 to 10^{4}K, where the value of 5700 K corresponds to the high-density limit of Sobolev's formula. As Pauldrach and Puls (1990) have shown, the linear velocity law of Waters and Wesselius (1986) as well as the BC-velocity law yield the same density structure at distances larger than $3R_*$. From the mass-loss rate of P Cygni, its stellar radius and its terminal velocity of, respectively, M=1.5x10^{-5}M$_\odot$ /yr, R_* =76 R$_\odot$ (Lamers, 1989) and V_∞ = 240 km/s (present study) we derive an electron density between 5x10^6 and 5x10^7 cm^{-3} at distances from 30 to 110 stellar radii. (The matter is assumed to be fully ionized hydrogen.) At these distances the linear velocity law of Waters and Wesselius (1986) gives $V=V_\infty$ implying a flat-topped profile with HWZI= 240 km/s for an optically thin line formed there; this is contradicted by the observations. At the same distances the BC-velocity law gives a velocity of 220 to 230 km/s (for V_∞ =240 km/s). The observed width of the [NII] profiles, however, is below these values. Obviously, a velocity law flatter than one with β=4, but yielding the same density structure, would give better results. Such a velocity law was obtained by Pauldrach and Puls (1990) in the framework of their best model. Its terminal velocity, however, is quite low (195 km/s compared with our value of 240 km/s). In addition, we estimate that the adopted stellar parameters in combination with a BC-velocity law locate the region of [FeII] line-formation at $R \geq 110R_\odot$, where the density drops below 5x10^6 cm^{-3}.

Adopting for P Cygni a distance of 1.8 kpc, we obtain an angular radius smaller than 1.5 arcsec for the [NII] emitting region. This is in agreement with Stahl (1989) who determined the angular distribution of emission in the [NII] λ6584 line, corrected for the average flux from the continuum on either side of the line, and concluded that beyond an angular radius of 1.5 arcsec no evidence for excess [NII] λ6584 emission exists. But both results (ours and Stahl's) are in contradiction with Johnson et al. (1992) who did not find any [NII] emission in their on-star spectrum. Differences in the slit position angles used could possibly cause such a discrepancy. This points to a possible asymmetry in the emitting [NII] region close to the star.

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