MASS LOSS FROM CENTRAL STARS OF PLANETARY NEBULAE

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Abstract. Stellar winds have been revealed in a large fraction of central stars of planetary nebulae from P Cygni profiles observed with the IUE satellite. The relevant lines are essentially the resonance lines NV λ 1240, Si IV λ 1397, CIV λ 1549 and the subordinate lines OIV* λ 1342, OV* λ 1371, NIV* λ 1579. Edge velocities are of the order of 1000-3000 km s^{-1}, similar to the case of population I O stars. Detailed determinations of the mass loss rate have been performed for NGC 6543, NGC 2371, IC 2149 and IC 3568 with values between 4.10^{-9} to 7.10^{-7} $M_{\odot}$ yr^{-1}. The accuracy of these determinations is not well known. It is however clear from the variety of observed profiles in these and in several other objects that properties of the winds (ionization structure, etc.) varies considerably from object to object and that very likely the mass loss rate will span over a large interval. Some possible consequences of these winds are discussed.

1. INTRODUCTION

Our concern is with relatively fast winds originating in stars known to be already in the phase of planetary nebula.

Such a wind can make itself evident through radiation in the continuum or in the line spectrum. In practice we may have:

a) Free-free emission of the ionized expanding envelope in the radio domain.

b) Similar emission in the infrared (IR) spectral range.

c) P Cygni profiles in the subordinate lines of hydrogen and helium, in particular at Hα and λ 4686 He II in the visible region of the spectrum.

d) P Cygni profiles in resonance lines or in subordinate lines of

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abundant heavy ions in the space UV ($\lambda < 3000$ A).

2. EVIDENCE OF WINDS IN CENTRAL STARS OF PN

Methods involving the radio or IR continuum did not provide so far, to my knowledge, evidence of winds originating in central stars of planetary nebulae. The reason is soon recognized in the fact that, at present state of technology, methods 1a and 1b are not sensitive enough to the mass loss rate $\dot{M}$, while on the other hand planetary nebulae are relatively distant objects.

Actually an ionized envelope with $T_e = 10^4$ K expanding at a velocity v_∞ is predicted to produce at Earth a radio flux (cf. Panagia and Felli, 1975; Wright and Barlow, 1975),

$$S_\nu = 2.4\ 10^4 \left(\frac{\dot{M}}{M_\odot yr^{-1}}\right)^{4/3} \left(\frac{v_\infty}{1000\ km\ s^{-1}}\right)^{-4/3} \left(\frac{\nu}{10\ GHz}\right)^{0.6} \left(\frac{D}{Kpc}\right)^{-2}\ Jy. \quad (1)$$

Favorable values of $\dot{M} = 10^{-7}\ M_\odot\ yr^{-1}$ (we will see this corresponds to $\sim$ the maximum $\dot{M}$ so far quoted for central stars of PN), $v_\infty = 2000$ km s^{-1}, $\nu = 5$ GHz (6 cm), D = 500 pc implies $S_\nu = 0.01$ mJy which is rather below the sensitivity limit of present radiotelescopes. A much higher sensitivity, coupled with high spatial resolution (~0".1) to exclude radiation contributed by the nebula, is then needed to detect weaker winds in more distant objects.

Similar arguments apply to the IR range where in addition one has to detect a faint free-free source over a possibly strong stellar source and must avoid a generally important contribution from heated dust.

Evidence of an expanding atmosphere from the optical spectrum (method 1c) is clear from the blue-shifted absorption components observed in nuclei of WR-type (see Aller, 1976). Evidence in the optical range was also noted in other nuclei of planetaries, as in He 2-131 from P Cygni profiles of various lines (Koelbloed, 1962; Heap, 1977) and in NGC 6891 and 6826 from broad emission lines (Heap, 1977).

The existence of "brisk stellar winds" was also suggested to explain high excitation lines appearing in the optical spectrum (λ 3811, 3834 O VI) (Aller, 1976).

However a definitive evidence of mass loss by stellar winds in central stars of planetary nebulae was obtained with method 1d during the commissioning period of the IUE satellite with the detection of P Cygni profiles of NV λ 1240, CIV λ 1549 and NIV* λ 1719 in the nucleus of NGC 6826 (Heap et al. 1978).

Some detections of P Cygni profiles from IUE spectra and first estimates of properties of associated winds have followed (cf. Heap, 1979; Seaton, 1980; Benvenuti and Perinotto, 1980; Koppen and Werhse, 1980; Perinotto, Benvenuti and Cacciari, 1981). A few detailed analysis of stellar winds from IUE spectra have appeared, on which we will report later on. Clearly much more studies are expected in the near future.

3. NEW INFORMATION FROM A SAMPLE OF LOW RESOLUTION IUE SPECTRA

We have searched a number of released low resolution (~ 7 A) IUE spectra of planetary nebulae and their central stars for the presence of P Cygni - like profiles in order to assess the general properties of the phenomenon. The detection of a stellar P Cygni like profile requires: 1) To reveal the stellar continuum, 2) to identify the profile and 3) to correct it for nebular contamination. Item 1) is achieved for a relatively large number of planetaries so far observed with IUE. Concerning item 2), since P Cygni like profiles vary considerably in the relative importance of the emission and absorption components, limiting cases may require the high IUE resolution (~ 0.15 A) to a proper wavelength setting. The high IUE resolution is also decisive for item 3) since nebular lines are much narrower than stellar or circumstellar features. To exploit 3), with low resolution IUE spectra only, one takes advantage from considering the properties of spectrum of the central star in the optical, the general level of excitation of the nebular spectrum and particularly the comparison of large aperture (~ 220 arcsec square) spectra with small aperture (~ 7 arcsec square) spectra.

We report in Table 1 preliminary results of the inspection of a number of IUE low resolution spectra. The objects in Table 1 have all a stellar continuum visible in the spectra. Ions with lines displaying a relatively clear P Cygni profile are indicated approximately in order of decreasing importance of the phenomenon.

We see from Table 1 that the phenomenon of stellar winds

1) is quite common in nuclei of planetary nebulae;

2) appears fairly ubiquitous among nuclei of PN with different spectral type with the exception of stars having a "continuum" spectrum in the optical;

3) is presumably present in objects of quite different luminosity and gravity, so strongly increasing the range of these parameters in hot stars known to display mass loss.

These facts are evidently quite important not only for the study of these objects, but to investigate the causes of hot star winds in general. Point 1) and 2) are better illustrated in Table 2 showing stars with detected P Cygni profiles versus spectral type.

In WR and Of nuclei the phenomenon appears always present in the

Table 1. P Cygni phenomenon in central stars of planetary nebulae from low resolution IUE spectra.

Object	mag 1)	Sp Type 2)	P Cygni 3)	
NGC 40	11.6 V	WC8	CIV,SiIV	
246	11.9 V	OVI	-	
1360	11.2 V	-	-	
1514	9.4 V	A0+O	NV,OV	
1535	11.6 V	O7,(Sd)O3:	NV,OV	
2022	14.9 V	cont.	-	
2371	14.8 V	OVI	CIV	
2392	10.5 V	O7f, O6f	-	
2867	14.9 P	OVI	-	(d)
3132	8.8 P	A+sdO	-	
3211	-	-	-	(d)
3242	>11.3 -	cont.	-	
4361	12.9 V	O6	-	
5189	14.1 V	OVI	CIV,NV	
6210	11.3 pV	O7f,(sd)O3	NV,OV	
6572	>11.0 V	Of+WR	NV,CIV,SiIV	
6720	14.7 V	cont.	-	
6826	10.2 V	O6fp,O3f	CIV,NV,SiIV,OIV,OV,NIV	
6891	11.1 P	O7f,O3:f	CIV,NV,SiIV,OV,NIV	
6905	13.9 P	OVI	-	
7009	11.5 P	cont.	NV,OV	
7293	∿13 p	cont.	-	
7662	(12.5)P	cont.	-	
IC 351	15 P	cont.	-	(d)
418	9.6 V	O7fp	CIV,SiIV,NIV	
1297	-	-	-	(d)
2149	10.5 pV	O7.5fp,O4:(f)	CIV,NV,SiIV	
2448	-	-	-	
3568	11.4 V	O5f	CIV,NV,OV	
4593	10.8	O7fp	CIV,NV,SiIV,OIV,NIV	
A 30	14.3	O5fep	CIV,NV,OV	
A 36	11.5 V	SdO7	-	
A 78	13.3 V	O5fek	CIV,NV,OV	
J 320	13.5 P	em uncl	NV,OV	
BD+30 3639	10.1 V	WC9	CIV,SiIV	
CD-23 12238 = Me 2-1	-	-	-	(d)
HD 167362	11 -	Of+WR	CIV,SiIV,NIV	
HD 138403 = He 2-131	10.3 V	-,O7(f)eq	CIV,SiIV,NV	
Hu 2-1	-	-	CIV,NV,SiIV,OIV,NIV	

1) From Aller (1976) except NGC 7293 from PK Catalogue and He 2-131 from Heap (1977).
2) From Aller (1976) and Heap (1977).

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3) From present work: ions with lines showing P Cyg profile, ordered approximately with decreasing strength of the phenomenon. "d" means that the presence of a stellar continuum is doubtful.

Table 2. Detected P Cygni profiles versus spectral type.

	Sp. Type		No. of positive detection / No. of considered nuclei	
	-WR	....	2/2	
	-Of+WR	....	2/2	
	-Of	....	3/4	
	-Ofp,e	....	7/7	
	-OVI	....	2/5	
	-cont.	....	1/7	
				Total 17/27 = 63%
Others:				
	06,07	....	1/2	
	A+O	....	1/1	
	A+sdO	....	0/1	
	sdO	....	0/1	
	unclassified	....	2/6	Total 4/11 = 36%
				Gross Total 21/38 = 55%

UV, about in half cases in OVI stars and never (as reasonably expected) in the "continuum" stars, with the only exception of NGC 7009 that likely is not a bona fide "pure continuum" star. The percentage of positive detection is of 63% for the mentioned nuclei and of 36% for the other 11 objects with miscellanea spectra shown on Table 2. The gross total of detections amounts to 55%. These numbers are subject to revision when more accurate analysis of these and of other objects will be made; likely they may result underestimated.

As for T_{eff} the phenomenon is present in objects as cold as IC 2149 ($T_{eff} \sim 30\,000$ K) and as hot as NGC 2371 ($T_{eff} \sim 100\,000$ K). The two nuclei have $L/L_o \sim 3.5$ and 3.2 respectively. As for the luminosity the phenomenon is present in NGC 6210 ($\log L/L_o \sim 2.2$, $\log T_{eff} \sim 4.70$) and NGC 6891 ($\log L/L_o \sim 3.8$, $\log T_{eff} \sim 4.72$). These numbers come from the Zanstra method following Harman and Seaton (1966) after allowing for distances by Acker (1978), except for IC 2149, taken from Perinotto et al. (1981).

The behaviour of the phenomenon varies greatly from object to object in Table 1, as shown by the variety of profiles of the various lines. The edge velocities are of the order of 1000-3000 km s^{-1}, similar to the case of population I O stars. It is clear that a lot of

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information on the properties of the winds in central stars of planetary nebulae, including insight on the causes of the phenomenon of stellar wind in hot stars and on the reasons why the phenomenon is not present in various cases is shortly expected from the accurate study of the large quantity of material obtained and to be obtained with the IUE satellite.

4. DETAILED ANALYSIS

To my knowledge the following nuclei of planetary nebulae have received relatively accurate studies of wind's properties and associated mass loss: NGC 6543 by Castor, Lutz and Seaton (1981) (CLS), NGC 2371 by Pottasch, Gathier, Gilra and Wesselius (1981) (PGGW), IC 2149 by Perinotto, Benvenuti and Cerruti-Sola (1982) (PBC) and IC 3568 by Harrington (1982) (H). To these works, a value of $\dot{M} \simeq 7\ 10^{-7}\ M_o\ yr^{-1}$ for the nucleus of NGC 6543 by high resolution IUE spectra (Heap, 1981) (given without further details) is to be added.

The observed P Cygni profiles have been interpreted in all these works basically in terms of the Sobolev approximation (wind velocity large compared with the local thermal velocity) of the theory of line formation for a two-level atom in an expanding atmosphere (Lucy and Solomon, 1970; Castor, 1970; Lucy, 1971; Castor, Abbott and Klein, 1975). Based on it, Castor and Lamers (1979) (CL) have produced an atlas of theoretical P Cygni-type line profiles valid for resonance lines and a similar work has been made by Olson (1981) for excited lines.

Recently, calculations have been made in which the Sobolev approximation has been released (Weber, 1981; Leroy and Lafon, 1982a,b). The role of multiple scattering of photons has also been investigated (Panagia and Macchetto, 1982). These progresses in the theory do not seem, at their present stage, very important for a better determination of the mass loss rate in the above objects, relative to the use of the mentioned theory, also because of uncertainties in the relevant stellar parameters (see later on).

In the recalled approximate theory, the optical depth for scattering can be expressed as

$$\tau(v) = \frac{\pi e^2}{mc} f \lambda_o n_i(r) \left(\frac{dv}{dr} \right)^{-1} \tag{2}$$

where m is the mass of the electron, λ_o is the laboratory wavelength of the line, f its oscillator strength, dv/dr is the velocity gradient in the envelope and $n_i(cm^{-3})$ is the number density of absorbers. The velocity law and the opacity law can be parametrized (CL)

$$w(x) = w_o + (1-w_o)(1-\frac{1}{x})^{\beta} \tag{3}$$

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$$\tau(w) = T(\gamma+1)(1-w_o)^{-1-\gamma}(1-w)^{\gamma} \tag{4}$$

$$x = r/R_{\star} \quad , \quad w = v/v_{\infty} \tag{5}$$

where $R_{\star}$ is the photospheric radius coincident with the base of the wind where its velocity has a low value w_o (generally assumed $\simeq 0.01$), β is positive to ensure an outward increasing velocity (in agreement with various observational tests) up to a terminal velocity v_{∞} , $\gamma \geq 0$ and

$$T = \int_{w_o}^{1} \tau(w)\, dw = \frac{\pi e^2}{mc}\, f\, \lambda_o\, v_{\infty}^{-1}\, N_i \tag{6}$$

is the total optical depth in the wind due to ions with column density $N_i (cm^{-2})$.

The quantities β, γ , T can be obtained by matching observed profiles with computed ones using e.g. the atlas of CL.

The mass loss rate, under hypothesis of spherical symmetry and homogeneity, can be written

$$\dot{M} = 4\pi r^2\, \rho(r)\, v(r) \quad . \tag{7}$$

Thus one obtains

$$q_i\, \dot{M} = (4\pi\mu m_H)\, \frac{mc}{\pi e^2}\, \frac{R_{\star}\, v_{\infty}}{\lambda_o f A_i}\, T(\gamma+1)(1-w_o)^{-1-\gamma}(1-w)^{\gamma}[x^2 w\, \frac{dw}{dx}] \;, \tag{8}$$

where A_i is the abundance of the element relative to hydrogen and q_i is the fractional ionic abundance. The right side of (8) can be evaluated at any point x . The value of x corresponding to $w = 0.5$ is generally chosen since with this choice the quantity in square bracket depends little on a accurate determination of β .

The above two-level atom theory has been shown to be valid even for the subordinate lines of OIV* λ 1342, OV* λ 1371, NIV* λ 1719, by CLS. In this case one must evaluate the population of the lower level of the transition, that now do not coincide with the total abundance of the ion, via an appropriate radiation temperature.

Although with some formal differences, the authors of the mentioned detailed studies have used this theory to obtain the values of $q\, \dot{M}$ reported in Table 3. A proper determination of the parameters T, β , γ requires high resolution IUE spectra. Such spectra have been used by PBC and H, while CLS and PGGW use low resolution IUE spectra. Actually CLS develop a method which permits the best use of low resolution IUE spectra. The method however assumes $\beta = 1$, $\gamma = 1$ in equations (3) and (4). H, on the other hand, uses expressions (calculated for $\beta = 1$)

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that allow to obtain $q\dot{M}$ at the point of the wind where q is maximum, while q in the previous formulation is essentially an average value across the wind.

Despite these differences the values of $q\dot{M}$ in Table 3 should be comparable, as illustrated from the similarity of the $q\dot{M}$ by CLS in NGC 6543 to the $q_m\dot{M}$ deduced for the same object using the data of CLS and the expressions of H. (See Columns 3 and 6 of Table 3). It is to be noted that CLS did prefer to relay on the subordinate lines to deduce $\dot{M}$. This is due in part to problems with profiles of CIV and NV lines in NGC 6543, and mostly to advantages offered from the OIV*, OV* lines in the determination of q_i, since most of the oxygen is believed to be in this object in these two ionization stages. PBC have preferred instead to relay on the resonance lines because: 1) profiles of subordinate lines in IC 2149 show winds developed to a much lower velocity than resonance lines and theoretical profiles appropriate to match these lines were not available, nor the CLS method ($\beta = \gamma = 1$) was here applicable; 2) T_{eff} of IC 2149 is relatively lower than that of NGC 6543 or IC 3568 so that $\dot{M}$ becomes quite sensitive to the exact value of the radiation temperatures. As for the uncertainties in $q\dot{M}$, a factor of 2-3 comes from the photospheric radius which depends on T_{eff} and the adopted distance or luminosity and another factor of 2 from chemical abundances.

The next step to deduce $\dot{M}$ is to determine q. CLS argue that $q(OV) + q(OIV) \simeq 1$ in the wind of NGC 6543 and thus deduce $\dot{M}$ and then the q_i's of the other ions. However the comparison of these "observed" ionizations with the ones calculated using present theories for ionization in the winds raises problems discussed by CLS. Another procedure (used by PBC) is to accept the mean ionization structure adopted by Lamers, Gathier and Snow (1980) who have determined empirical mean ionizations from a group of O4 to B1 population I stars. We underline that whatever will result the most correct way to determine the ionization structure, the last appears quite different in IC 3568 and NGC 6543, the wind being more ionized in the first object than in the second one (much larger values of $q(NV)/q(NIV)$ and $q(OV)/q(OIV)$). Also it must be realized that particularly in nuclei with small radius ($< 0.1\ R_o$) the characteristic time of expansion in the wind becomes smaller than recombination time for the relevant C,N,O ions. Therefore classical computations of the ionization structure in the wind will be inadequate. If we accept errors in q in NGC 6543, IC 2149 and IC 3568 again of a factor of 2, we arrive to a total uncertainty in $\dot{M}$ of an order of magnitude. This would mean that the discussed determinations of $\dot{M}$ might be not really different to each other. However the numbers of Table 3 taken at their face value, the determination by Heap (1981) of $7 \cdot 10^{-7}$ in NGC 6543 and the variety of profiles and strengths of the P Cygni phenomenon observed in many central stars of planetary nebulae, show that it is very likely $\dot{M}$ will vary over a large range, possibly $10^{-6} \div 10^{-9}\ M_o$ yr^{-1}. We mention finally that $\dot{M}$ in NGC 6543 is not likely to be much larger than $10^{-6}\ M_o\ yr^{-1}$, because of an upper limit of 5 10^{-6} obtained for it with VLA at 6 cm wavelength (Thompson and Sinha, 1980).

Table 3. Mass loss rates in central stars of PN ($\dot{M}$ in $M_o\ yr^{-1}$).

λ	Ion	NGC 6543 (CLS) $q\dot{M}$	q	$\dot{M}_8$	$q_m\dot{M}$	NGC 2371 (PGG W) $q\dot{M}$	q	$\dot{M}_8$	IC 2149 (PBC adapted) $q\dot{M}$	q	$\dot{M}_8$	IC 3568 (H) $q_m\dot{M}$	q	$\dot{M}_8$
1240	NV	-	-	-	3.3-10	-	-	-	1.4-10	1.2-2	1.2	1.4-9	∿0.35	-
1342	OIV*	7.9-8	0.92	9	8.4-8	-	-	-	-	-	-	-	-	-
1371	OV*	0.7-8	0.09		0.7-8	-	-	-	-	-	-	3.9-9	∿1.	>0.4
1397	SiIV	6.8-11	8.-4	-	7.2-11	-	-	-	∿2.4-11	3.7-3	∿0.6	-	-	-
1549	CIV	-	-	-	3.6-11	2.8-11	>3.-3	<10	>2.4-10	1.5-2	>1.6	3.5-10	∿0.09	-
1719	NIV*	1.2-8	0.14	-	1.2-8	-	-	-	-	-	-	5.4-10	∿0.13	-
	Adopted $\dot{M}$	$\sim 10^{-7}$				$< 10^{-7}$			10^{-8}			$\sim 4\ 10^{-9}$		

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5. DISCUSSION

One wishes to know: a) how the derived mass loss rates for nuclei of planetary nebulae compare with observations in population I stars and with predictions of theories of stellar winds, b) which are the consequences for the evolution of the star and c) for the behaviour of the nebula. To this aims we use the numbers of Table 3 at their face values.

a) Observed mass loss rates in population I stars have been found to fit a single dependence on L of the type $\dot{M} \propto L^{a}$ with $a = 1.73$ (Garmany et al., 1981 from UV study of 30 O stars). Other works, based on larger variety of population I objects found a dependence even on radius and mass (Chiosi, 1981; Lamers, 1981). The last study obtains $\dot{M} \propto L^{1.42} R^{0.61} M^{-0.99}$. We adopt 0.6 M_o for the PN's nuclei of Table 3, from their position in the HR diagram. The Garmany et al. law predicts values of $\dot{M}$ unacceptably smaller (2 order of magnitude) than the observed ones. The last are instead consistent with the Lamers law, which on the other hand is considered compatible with the radiation driven wind theory. This theory also predicts (Castor, Abbott and Klein, 1975) v/v_{esc} equal to $2 \div 3$. The present values are somewhat larger than that in NGC 6543 (4.0) and IC 2149 (4.2) and smaller in IC 2371 (1.4). Moreover the momentum of the wind exceeds the one of the radiation field by a factor of 5 (using $\dot{M} = 10^{-7}\ M_o\ yr^{-1}$) in NGC 6543, against the prediction of the single scattering radiation driven wind theory. Therefore improvements in the theory seem required by the presently available data on stellar winds in central stars of PN. The fluctuations theory by Andriesse (1979), based on perturbations caused by non thermal processes in the photosphere, predicts values of $\dot{M}$ an order of magnitude smaller than observed in NGC 6543 (accepting $10^{-7} M_o\ yr^{-1}$) and in IC 3568 and therefore is little supported by present data in nuclei of PN.

b) The consequences of the fast stellar winds are expected to be important for the evolution of the central star since the nuclear burning rate along the upper part of the evolutionary track for a 0.6 M_o star by Paczynsky (1971) is $\sim 3\ 10^{-8}\ M_o\ yr^{-1}$ and less in the lower part.

c) The momentum available in the wind during the lifetime of the nebulae is easily seen to be comparable with the one of the nebulae. Therefore the winds are important for the nebular dynamics and they may also produce observable effects in the radiation from the nebula in optically thin cases, i.e. if the kinetic energy transferred from the wind into nebular radiation is comparable with the absorbed UV radiation from the central star (Harrington, 1982). Finally the properties of the observed winds might be used to test the interacting stellar winds theory (Kwok et al., 1978; Kwok, 1982), according to which the presently seen nebula would be build up at the interface of the slow wind of the red giant precursor phase and of the fast wind produced by the exposed hot core. It is unfortunate that properties of the slow wind have at present been detected only in NGC 7027 and IC 418 through observations of the molecular CO cloud (cf. Knapp et al., 1982), because the theory could be simply tested from the measured expansion velocity of the optical nebula and $\dot{M}$, v_∞ of the two winds.

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MENDEZ: I would like to comment on the spectral types you used. There are two kinds of O VI objects, one with WC characteristics and the other with predominantly absorption lines (e.g. NGC 246). We have recently reclassified the WC "O VI" objects (Méndez and Niemela, IAU Symposium no. 99). I would suggest that WC "O VI" objects ought to be grouped with the other WC's.

COHEN: You showed a viewgraph of the locations in the HR diagram of nuclei with and without winds. Does this plot imply that stars with winds have the lower masses? If so, it would seem to contradict Heap's finding that low mass nuclei do not show winds in IUE low dispersion spectra.

PERINOTTO: No - the diagram shows the wide range in both luminosity and temperature of nuclei showing the P Cyg phenomenon.

HEAP: The reason that I derived a higher rate of mass loss from the nucleus of NGC 6543 than Castor, Lutz and Seaton (CLS) is that I used a much softer velocity law for the wind. CLS assumed a velocity law typical of young O-stars (β = 1). High resolution spectra of the central star of NGC 6543 show wind profiles that can be reconciled with the theoretical profiles of Castor and Lamers only for a more slowly accelerating wind (β = 4).

PERINOTTO: The analysis of CLS is also based on the assumption of γ = 1 in the opacity law.

KALER: Feibelman and I have observed some stars with high gravities and find a P Cyg profile with $v_\infty \approx 10^4$ km s^{-1}. We are still uncertain of the identification, and confirmation is important. If correct, we have $v_\infty / v_{escape} \approx 3$ or 4, up to log g $\approx$ 8.

PERINOTTO: It would be interesting to confirm your finding; the maximum value of v_∞ in the group of objects I discussed is approximately 4000 km s^{-1}.

CLEGG: Do there exist means of determining the kinetic temperature in the central star winds?

PERINOTTO: The electron temperature in the wind is not yet well determined. Calculations of the ionization equilibrium in the wind suggest rather high temperatures, to match the "observed" fractional abundances. However, such high temperatures would imply much stronger emission in the C IV lines than is observed. The C IV emission is consistent with a temperature close to the effective temperature of the central star.

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