MASS LOSS FROM CENTRAL STARS OF PLANETARY NEBULAE*

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ABSTRACT

From a high resolution spectrum taken with IUE, the central star of the planetary nebula IC 2149 is found to exibit a wind with edge velocity of 1440 ± 100 km s^{-1} . Our preliminary evaluation of the associated mass loss rate gives $10^{-8} M_{\odot} yr^{-1}$. Other planetary nebulae nuclei are studied with low resolution IUE spectra and indications are found of mass loss rates consistent with the above value.

1. INTRODUCTION

In a previous note (Benvenuti and Perinotto, 1980), evidence has been presented, from low resolution IUE spectra, that stellar winds are often present in central stars of planetary nebulae with velocities of 1000-3000 km s^{-1} . The lines showing more clearly the P Cygni profile are resonance lines (λ 1240 N V, 1549 C IV) and subordinate lines (λ 1340 O IV, 1371 O V, 1719 N IV) of abundant elements. First attempts in estimating the associated mass loss rates were also made.

In the present paper we report about high resolution IUE observations of the nucleus of IC 2149 and try to evaluate its mass loss rate. We make also new estimates of the mass loss rate in the PN nuclei studied by Benvenuti and Perinotto (1980).

*) Based on observations by the International Ultraviolet Explorer collected at the Villafranca Satellite Tracking Station of the European Space Agency.

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2. OBSERVATIONS

IC 2149 is classified as an optically thick planetary nebula of small linear radius (Cahn and Kaler, 1971; Acker, 1978). The object may therefore be considered to be in its early phases of the planetary nebula stage. According to the HR diagram and radii of nuclei of planetary nebulae by Pottasch et al. (1978), we can then assign to the IC 2149 nucleus a radius similar to the solar one and a luminosity $L \lesssim 3\ 10^3\ L_\odot$. The nucleus of the planetary nebula IC 2149 (spectral type O4 (f)) has been observed at high resolution with the short wavelength camera (λ 1150-1950 A) under the VILSPA IUE Observatory programme.

3. RESULTS AND DISCUSSION

The spectrum shows narrow low ionization absorption lines of interstellar origin and wide lines of stellar origin. From comparison with low resolution IUE spectra of the same object, we can exclude any contribution from the nebula to the high resolution spectrum.

All the strongest stellar lines show evidence of the P Cygni phenomenon. In Fig. 1 we present the region of the C IV λ 1550 doublet. It is seen that the C IV lines are saturated so that they will allow to determine only a lower limit to the mass loss rate. On the other hand they permit a rather accurate measurement of the edge velocity of 1440 ± 100 km s^{-1}, that in the following is assumed as terminal velocity even for the other ions.

The observed line profiles have been matched with the theoretical P Cygni profiles computed by Castor and Lamers (1979). The parameters describing the theoretical profiles are β (exponent in the velocity law), γ or α (exponents in opacity laws), T the total optical depth or T', the optical depth between $v/v_\infty = 0.20$ and $v/v_\infty = 1.00$. The best fit values of these parameters are given in Table 1. Regarding the ionization structure, we have used for Si IV and N V the results of Gathier et al. (1980). The ionization fraction of C IV was assumed to be intermediate between those of Si IV and N V.

For the excited lines of O IV, O V and N IV we have assumed physical conditions similar to those of ζ Puppis (Lamers and Morton, 1976) with an adopted radiation temperature of 35 000 °K. This is consistent with the properties of the nucleus of IC 2149 given in Section 2.

We so obtain the mass loss rates given in Table 1. Excluding the lower limit value from C IV, we have $< \log \dot{M} > = -7.85 \pm 0.51$, corresponding to $\dot{M} = 10^{-8}\ M_\odot\ yr^{-1}$ with an uncertainty of a factor of three.

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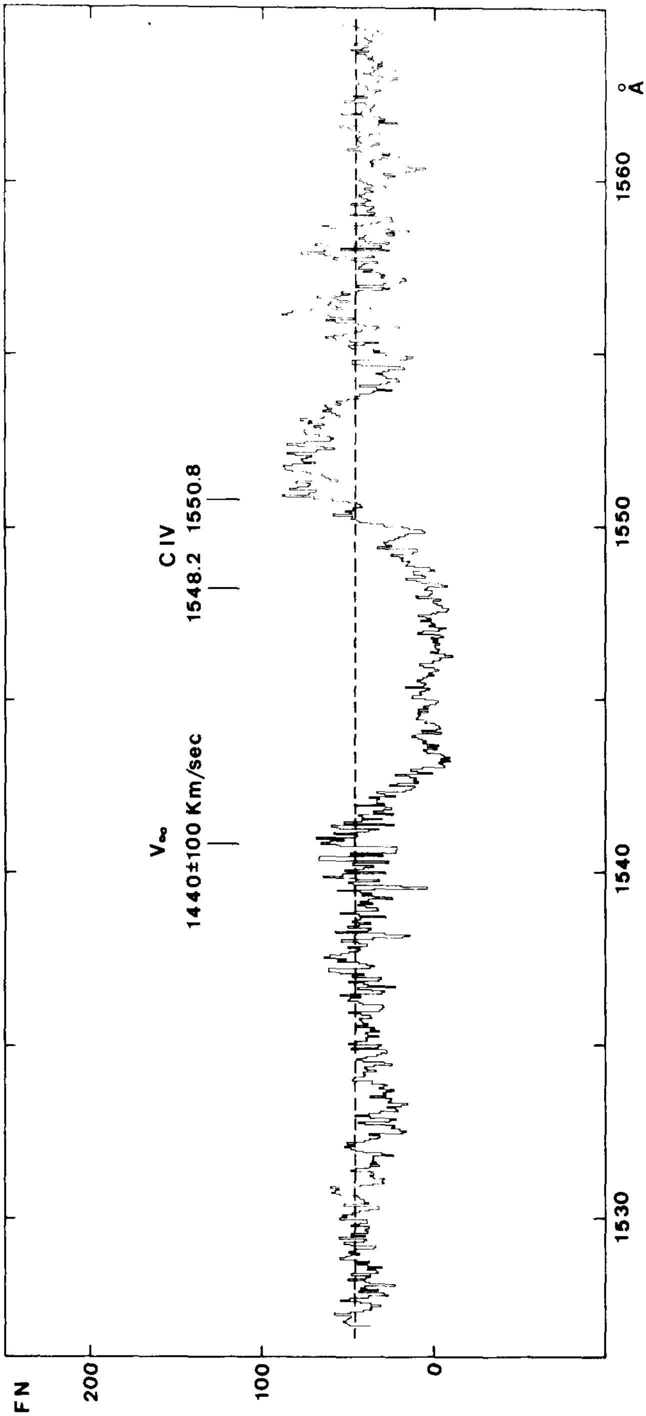

Fig. 1. IUE spectrum of nucleus of IC 2149 showing the P Cyg profile of the C IV 1550 lines.

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The latter clearly represents only the scatter among the different values. We underline that in deriving the above mass loss rates, solar chemical abundances have been used. The theory instead predicts (Renzini and Voli, 1980) that the material at the surface of the PN nuclei has been substantially affected from the nuclear evolution of the star.

Table 1. Mass loss from nucleus of IC 2149

Ion	λ	Parameters*	T	T'	$\dot{M}(M_{o}\ yr^{-1})$
C IV	1548.19 1550.77	$\gamma \simeq\ 2$	-	$\gtrsim 5$	$\gtrsim 5\ 10^{-9}$
Si IV	1393.76	$\alpha \simeq -2$	-	~ 0.4	$4\ 10^{-9}$
N V	1238.81	$\gamma \simeq\ 2$	-	0.5	$6\ 10^{-9}$
N IV	1718.55	$\alpha \simeq -2$	1.	-	$6\ 10^{-8}$
O V	1371.29	$\alpha \simeq -2$	0.3	-	$4\ 10^{-8}$
O IV	1338.60	$\alpha \simeq -2$	0.2	-	$1\ 10^{-8}$

*β = 0.5 or 1.

Oxygen should be little influenced, while carbon and nitrogen should increase by factors up to an order of magnitude or more depending on the initial mass. If the chemical abundance of a given element is increased, the mass loss rates of corresponding ions decrease linearly. If we, however, lower the mass loss rates from carbon and nitrogen lines in Table 1 (say by a factor of 5) we do not get less dispersion in the resulting values from all the lines, because in Table 1 values from oxygen are not smaller than those from nitrogen. We than prefer to leave our evaluation as it is, keeping in mind that for the mentioned reason, it may be an upper limit to the correct value.

The consequences of such mass loss on the dynamics of the nebula are important on a nebular lifetime scale, as it is evident from a comparison of the momentum transferred from the stellar wind to the nebula $< Mv > \sim \dot{M}\ v\ t_{yr} = 3\ 10^{33}\ t_{yr}$ with the nebular momentum $\sim 0.2\ M_{o} \times 20$ km $s^{-1} = 8\ 10^{38}$ gr cm s^{-1}.

If we accept $3\ 10^{3}\ L_{o}$ as the luminosity of the central star of

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IC 2149, the quantity $\dot{M}/L = 3.3\ 10^{-12}\ M_{\odot}\ yr^{-1}\ L_{\odot}^{-1}$ compares well with corresponding values from population I star. In fact log $\dot{M}/L$ for IC 2149 is -11.5 while analogous values for population I supergiants, giants and dwarfs are -11.41, -11.67 and -11.97 respectively (Tanzi et al., 1981).

4. ESTIMATES OF MASS LOSS RATES FROM OTHER PN NUCLEI

We have used the above procedure for new estimates of mass loss rates of the planetary nebulae nuclei investigated by Benvenuti and Perinotto (1980).

Table 2. Mass loss from central stars of PN

Object (NGC, IC)	λ (A)	Ion	v_{∞}(km s^{-1})	T	T'	$\dot{M}$ ($M_{\odot}$ yr^{-1})
40	1549	C IV	2800	-	1.2	$7\ 10^{-9}$
3242	1240	N V	2300	-	1.0	$1\ 10^{-8}$
6826[a)]	1240	N V	2050	-	$\gtrsim$ 6	$\gtrsim 1\ 10^{-8}$
	1341	O IV	1550	-	-	-
	1371	O V	900	0.5	-	$7\ 10^{-8}$
	1549	C IV	1850	-	$\gtrsim$ 6	$\gtrsim 6\ 10^{-9}$
	1719	N IV	950	0.2	-	$1\ 10^{-8}$
7009[b)]	1240	N V	2900	-	$\gtrsim$ 6	$\gtrsim 3\ 10^{-8}$
	1371	O V	2600	0.5	-	$2\ 10^{-7}$
2149	1549	C IV	1350	-	$\gtrsim$ 6	$\gtrsim 5\ 10^{-9}$

a) Adopted $< v_{\infty} > = 1450$ km s^{-1} ; b) Adopted $< v_{\infty} > = 2750$ km s^{-1}.

Since we have low resolution IUE spectra of these objects, we need, in addition to the other assumptions, hypotheses on the parameters β and γ that are taken equal to 1. The results are presented in Table 2. The mass loss rates are not far from the value $10^{-8}\ M_{\odot}\ yr^{-1}$ found for the central star of IC 2149 and again may be regarded as upper limits to the true values in so far as solar solar chemical abundances have been used (see Section 3).

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