A RECLASSIFICATION OF WC AND "O VI" CENTRAL STARS OF PLANETARY NEBULAE, AND COMPARISON WITH POPULATION I WC STARS

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We have started a study of WC central stars of planetary nebulae, including "O VI" objects which show WC characteristics. One of our purposes was to check, all along the WC spectral sequence, if the emission lines of planetary nuclei are narrower than for Population I objects, as they are in the case of the WC9 central star BD+30°3639 (Smith and Aller 1971).

We have obtained image-tube spectrograms of the central stars of NGC 2867, NGC 5189, NGC 5315, He 2-99 and HD 167362 with the 4-m and 1-m telescopes at Cerro Tololo, covering the spectral region from 3600 to 6700 Å on baked IIIa-J plates, with a dispersion of 45 Å mm-1. Similar spectrograms of several Pop. I WC stars were taken for comparison. A detailed description of this material is in preparation.

The previous spectral classification of the earlier WC and "O VI" central stars of PN (Smith and Aller 1969, Aller 1976) is based mainly on the width of the emission feature at λ4658. Therefore, a meaningful comparison of the line widths of PN nuclei with those of Pop. I WC stars required a reclassification of PN nuclei using criteria which are independent of line widths. We adopted the classification criteria listed in Table VII of the Sixth Catalogue of Galactic Wolf-Rayet stars (van der Hucht et al. 1981), which depend only on line intensity ratios.

Figure 1 shows intensity tracings corresponding to the central stars of NGC 2867 and NGC 5189. According to the previous classification (WC7-8, O VI) we expected to find a rather strong C III stellar emission at λ5695. However, as seen in Fig. 1, C III is essentially absent in these spectra. An inspection of the published descriptions of other "O VI" objects (Aller 1976, 1977) indicates that none of them shows strong C III together with strong O VI.

Hence, the previous classification of these PN nuclei

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is not consistent with the observed high excitation of C. We note that the excitation of C is quite compatible with the excitation of O; at least as compatible as in "normal" (non-OVI, Pop.I) WC stars, which are known to show weak O VI emissions at spectral types as late as WC7 or 8, with increasingly strong O VI emission towards earlier WC subtypes.

In summary, we find that the WC - O VI PN nuclei appear all together, in the WC spectral sequence, at the earliest (highest excitation) subtype. Therefore, it seems convenient to suggest an extension of the WC spectral sequence towards earlier subtypes; we propose the classification criteria listed in Table 1. These criteria provide a smooth connection with the spectral types of van der Hucht et al. (1981), and, furthermore, make it unnecessary to use the "O VI" label for the WC central stars of PN. The "O VI" central stars which do

TABLE 1 - PROPOSED CRITERIA FOR CLASSIFICATION

SP.TYPE	CRITERIA
WC6	C IV >> C III > O V
WC5	C IV >> C III, O V > C III > O VI
WC4	C IV strong, O V > O VI > C III
WC3	C III absent, C IV strong, O VI ≳ O V > O VII
WC2	C III absent, C IV strong, O VI > O VII > O V

FEATURES USED:

C III	5695
C IV	5805
O V	5595
O VI	5290
O VII	5670

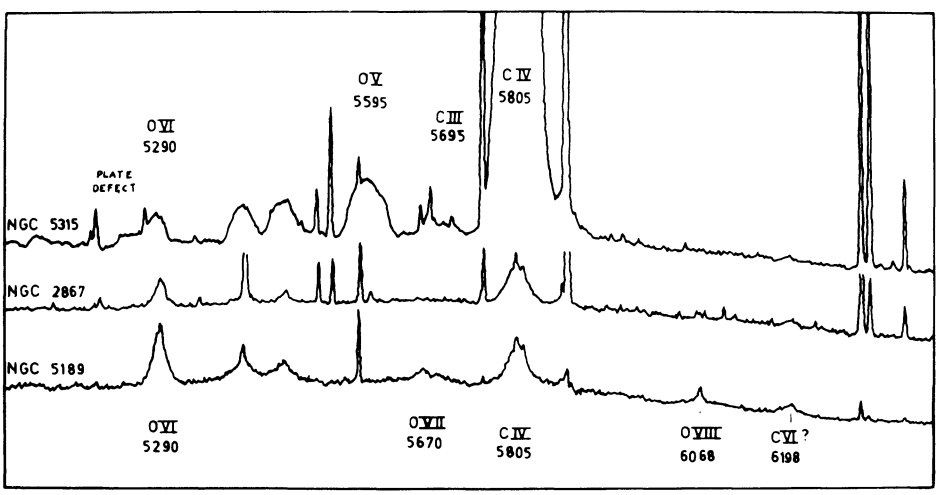

Figure 1.- Intensity tracings obtained with the PDS microphotometer of the Kitt Peak National Observatory, U.S.A.

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not have a WC spectrum (NGC 246, Abell 30, Abell 78) deserve a separate discussion. Let us add here that Barlow and Hummer (this Symposium) have suggested that the star Sanduleak 3 (Barlow, Blades and Hummer 1980) is more probably related to PN nuclei than to massive Pop.I objects. Using Table 1, the spectral type of Sanduleak 3 becomes WC3.

Table 2 gives, for each PN nucleus, the old and new classification, and the nebular excitation class. For NGC 1501, NGC 2371, NGC 6751 and IC 2003, the spectral descriptions available in the literature do not permit to attempt a reclassification. We also note here that NGC 5189, NGC 6905 and NGC 7026 show the λ5670 emission feature, identified by Barlow, Blades and Hummer (1980) as due to O VII. Our spectral type WC2 is defined as having this feature stronger than O V 5595; at present, the only candidate for such a spectral type is the nucleus of NGC 5189, which also shows very clearly emissions at 3890, 4945 and 6068 Å, attributed to O VII, C V and O VIII, respectively, by Barlow, Blades and Hummer (1980). We would add that an emission feature shown by most of the WC2 and WC3 objects at λ6198 might be attributed to a blend of the 11-9 and 13-10 transitions of C VI (García and Mack 1965).

TABLE 2 - SPECTRAL TYPES AND NEBULAR EXCITATIONS

OBJECT	PREVIOUS CLASSIF.	NEW CLASSIF.	NEB.EXC.CLASS
NGC 5189	WC 7-8, O VI	WC2	7
NGC 6905	WC 7, O VI	WC3	7
NGC 7026	WC 7, O VI	WC3	6
NGC 2867	WC 7-8, O VI	WC3	7
NGC 2452	WC 7-8, O VI	WC3	7
IC 1747	WC 6, O VI	WC4	6
NGC 5315	WC6	WC4	5
NGC 40	WC8	WC8	2
BD+30°3639	WC9	WC9	1
He 2-99	WC9	WC9	1
HD 167362	WC9	WC9	2
CPD-56°8032	WC10		1
M4-18	WC10		1
He 2-113	WC10		1

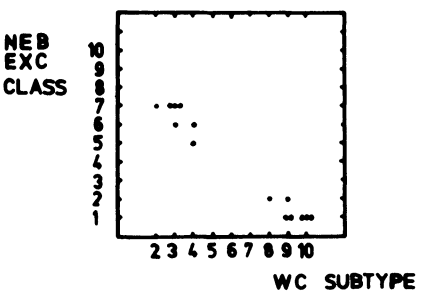

Figure 2.- The correlation between nebular excitation and the new spectral types for WC central stars of planetary nebulae.

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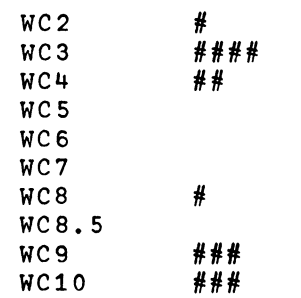

Figure 3.- The distribution of WC subtypes for planetary nuclei and Pop. I WC stars. The spectral types of Pop. I WC stars were taken from van der Hucht et al. (1981).

Aller (1977) has already noted that "O VI" central stars are associated with nebulae of high excitation. Fig. 2 shows that the new spectral types are well correlated with the nebular excitation class. It seems reasonable to infer that there is a significant difference in Teff between the extremes of the WC spectral sequence.

An interesting detail in Table 2 and Fig. 2 is the absence of subtypes WC5, 6 and 7 among PN nuclei. Such a marked discontinuity between "late" and "early" WC PN nuclei does not exist for Pop.I WC stars. In Fig.3 we have compared the distributions of WC subtypes. The difference is striking. Its existence may be useful to put constraints on possible interpretations of the WC phenomenon.

Concerning the widths of stellar emission lines, the comparison of PN nuclei with Pop.I stars must be preceded by a reclassification of the earliest Pop.I WC stars. At the present time, we can say the following:

(a) The nucleus of NGC 5315 (WC4) has narrower lines than the massive Pop.I star HD 63099 (WC5).
(b) The nuclei of NGC 5189 (WC2) and NGC 2867 (WC3) have narrower lines than the nucleus of NGC 5315.

It would be interesting to check, among Pop.I objects, if the widths go through a maximum at WC5, decreasing again for the earlier subtypes.

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DISCUSSION FOLLOWING MENDEZ AND NIEMELA

Underhill: The blend of C IV at 5801 and 5812 Å is a poor choice for determining the width of C IV lines in a spectrum because the shortward side may be eroded by C IV displaced absorption components, and the longward side may be eroded by aborption due to a displaced component of He I 5876. It is better to use the relatively unblended C IV line at 4441 Å.

Méndez: Our results do not depend on C IV (5801,11) only. Concerning the 4441 line, it may also be affected by absorption features: the interstellar absorption at 4430 Å and the violet displaced He I 4471.

Garmany: I wanted to ask if there is any special selection effect between the planetary nuclei and Pop I WC?

Méndez: No, I don't think so.

Leep: Among the WC stars line width increases in step with the increase in C IV equivalent width, and hence with earlier WC type. While there is some scatter in line width in any subtype we do not find any drop in width as you see in the early WC type planetary nebula. It will be interesting to try and reclassify our spectra with your new classification scheme.

van der Hucht: I would like to suggest to discriminate between Pop I WR stars and planetary nuclei WR stars by putting the subclasses of the latter between brackets.

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