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ON THE CLASSIFICATION OF EMISSION-LINE SPECTRA OF PLANETARY NUCLEI

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ABSTRACT

Emission-line spectra of nuclei of planetary nebulae are ordered into five classes according to whether they closely resemble spectra of Population I Of and Wolf-Rayet stars or show marked differences from the latter. Spectra that are closely similar to those of Population I stars are in the minority. One of the classes—which we call the O VI sequence—includes spectra which correspond to extremely high excitation; the nucleus of NGC 5189, which has been tentatively identified as an X-ray source, has a spectrum that falls in this class.

I. INTRODUCTION

The nuclei of planetary nebulae frequently show spectra that are similar to those of Population I stars of spectral type B or earlier, and they are traditionally classified in the same way. When emission lines are present, the spectra are usually classified Wolf-Rayet (W-R) or Of, according to whether the emission lines are broad or narrow. (There are a few cases where the spectra resemble other peculiar classes, such as P Cyg. Spectra of this type are rare among planetary nuclei and are not considered in this paper.) There is considerable confusion in the literature; the spectra in the two classes W-R and Of are often lumped together with inadequate distinction. Further, we have found that within each of the two classes only some of the spectra are truly similar to those of Population I stars; the majority display features which are found almost exclusively in spectra of planetary nuclei.

Similarity between the spectra of nuclei of planetary nebulae and those of Population I stars is remarkable. The planetary nebulae are believed to belong to the intermediate-disk population (Minkowski and Abell 1963; Perek 1964), to have masses of the order of 1 $M_\odot$ (O'Dell 1963; Seaton 1966), and to have absolute visual magnitudes fainter than -3 (O'Dell 1962, 1963; Henize and Westerlund 1963). The W-R and Of stars belong to extreme Population I and are believed to have masses of the order of 10 $M_\odot$ and absolute visual magnitudes brighter than -4 (L. F. Smith 1968*b*, *c*). Hence, the objects must be quite different in structure and evolutionary history. On the other hand, there was intensive discussion at the recent W-R Symposium (Gebbie and Thomas 1968) as to whether W-R stars form a distinct class of objects or whether they represent an atmospheric phenomenon that can occur at widely different stages of stellar evolution. It therefore appears to us that a careful evaluation of the similarities and dissimilarities between the spectra of planetary nuclei and those of Population I stars will prove relevant to our attempts to derive models for both types of objects.

In the present paper, we present a division of the emission-line spectra of planetary nuclei into five classes—W-R, O VI sequence, Of, Of peculiar, and W-R–Of—based on similarities to and differences from the spectra of Population I W-R and Of stars. More detailed and quantitative studies of spectra in each of these classes are currently in progress by the authors and by Miss S. R. Heap, and will be published separately. Preliminary discussion of the proposed classification divisions can be found in the proceedings of the W-R Symposium (Gebbie and Thomas 1968, pp. 141, 145–152); here we present in more detail the basis for these divisions, together wtih classifications of the spectra of many nuclei.

II. CRITERIA FOR THE PROPOSED CLASSIFICATION

a) Wolf-Rayet Spectra

A Wolf-Rayet (W-R) spectrum was originally defined by Beals (1938) to consist of "a continuous spectrum on which are superposed numerous strong emission bands due to atoms of high ionization potential," in particular, neutral and ionized helium, and ionized carbon, nitrogen, and oxygen. The Of stars also show emission lines of such atoms, but the lines are not so broad as in W-R spectra; in the blue region of the spectrum, 4 Å (corresponding to about 300 km sec^{-1}) is found to be a convenient dividing line between the width of emission lines found in W-R spectra and the width of those in Of spectra. Beals's definition implies the absence of absorption lines; it is worth noting explicitly that, in W-R spectra, absorption lines occur only as violet absorption edges to emission lines. When undisplaced absorption lines are observed in association with W-R emission lines, the spectrum is interpreted in terms of a binary system; confirmation in the form of variations in radial velocity is available in all cases where sufficiently detailed observations have been made. By contrast, Of stars display a well-developed absorption spectrum.

At the recent W-R Symposium (Gebbie and Thomas 1968, p. 247) Thomas proposed that we acknowledge, as an important additional criterion of a W-R spectrum, that the temperature implied by the high excitation potential of the emission lines is greater than the temperature implied by matching the continuous energy distribution to that of model atmospheres. It has also been suggested (H. J. Smith 1955; Underhill 1966; Sahade 1968) that the absence of significant variability of the spectral features is an important characteristic; in this context "significant" means "sufficient to change the assigned spectral classification." In short, a W-R spectrum is currently defined by the presence of broad ($\geq$ 4 Å) emission lines of He, C, N, O; by the absence of undisplaced absorption lines; by the high temperature implied by the emission lines compared with that implied by the continuous energy distribution; and, secondarily, by the absence of significant spectral variation. Most of the stars included by this definition are Population I stars, which are generally referred to as "classical" W-R stars, or simply "W-R stars" without qualification. The spectra are divided into two sequences, WN and WC. Subclassification of the spectra in each sequence has been discussed in detail (Beals 1938; H. J. Smith 1955; Hiltner and Schild 1966; L. F. Smith 1968*a*) and need not be discussed again here.

It has long been realized that the spectra of the nuclei of some planetary nebulae are extremely similar to those of the classical W-R stars. The star BD $+30°3639$ (Campbell's hydrogen-envelope star) was included by Beals (1938) as an example of the subclass WC 9. We now know six objects among the nuclei of planetary nebulae whose spectra closely resemble those of the classical W-R stars. The spectra of many other planetary nuclei have been called "W-R" by other authors, but these spectra really belong in the other four classes defined in the following sections. The six planetary nebulae whose nuclei show true W-R spectra are listed in Table 1A; the subclassifications given are according to the system of Smith (1968*a*). Of the six spectra in this group, five are classified WC and one is classified WN. The WC spectra include examples of both high-and low-excitation subclasses. The WN spectrum is in the lowest excitation subclass currently recognized. The table contains:

Col. (1), NGC number, I = first index catalog, II = second index catalog, He 2 = Henize (1966), M1 = Minkowski (1946), A = Abell (1966), VV = Vorontsov-Velyaminov (1962), and BD or HD number of the object.

Col. (2), Number in the Perek-Kohoutek catalog (1967).

Cols. (3) and (4), Right ascension and declination for equinox 1950.

Col. (5), Spectral type.

Cols. (6) and (7), Magnitude of the nebula and of the central star. In general, these numbers are the photographic magnitudes given by Berman (1937). However, when quoted to 0.01 mag, they are B magnitudes (Johnson-Morgan system) from one of the sources given in the reference column, and when marked by an asterisk (*), they are the photographic magnitude (for m_n) and photovisual magnitude (for m_*) given by Liller (1955).

Col. (8), An "x" in this column indicates that spectrograms of this star have been obtained in the current program. Most spectra were obtained with either the coudé or the prime-focus spectrograph on the 120-inch reflector at Lick Observatory. Southern objects were observed with the 60-inch telescope at Cerro Tololo. In each such case, the classification given has been made from the new spectrograms.

Col. (9), Reference to previous work on the object. The list is not intended to be complete. References are given only to papers that give an illustration, the best published description, and/or measurements of the line strengths of the spectrum of the star.

b) O VI *Sequence*

One of the more controversial points in discussions of classical W-R spectra has been the presence and general prevalence of lines due to O VI. It is our opinion that the O VI doublet λλ3811, 3834 is present in emission in all WC spectra of subclass WC 7 and earlier; however, Underhill (Gebbie and Thomas 1968, p. 208) considers that other ions may be responsible for these lines. It is clear, however, that, among classical W-R spectra, the O VI lines are weak.

At the W-R Symposium (Gebbie and Thomas 1968, p. 145) and the Planetary Nebula Symposium (Aller 1967), we presented preliminary reports on a number of objects among the planetary nuclei in whose spectra the emission lines due to the O VI doublet λλ3811, 3834 are among the strongest lines in the spectrum. This feature is the defining characteristic of a class which we call the "O VI sequence." Emission lines of C IV λ4658 and He II λ4686 are also present and are usually of comparable intensity to the O VI lines. (The O IV λ4658 line has been incorrectly identified in previous discussions [Greenstein and Minkowski 1964; Aller 1967; Gebbie and Thomas 1968, p. 150] as C III λ4650.) Other lines in the photographic region (principally due to these same ions) are sometimes present but are much weaker than the above-mentioned lines. The widths of the emission lines range from about 40 Å (e.g., NGC 7026 and NGC 1589) to about 1 Å (NGC 246); when the lines are broad, the two components of the O VI doublet are blended together, as are the He II λ4686 and C IV λ4658 lines. When the lines are broad, the spectra fall within the definition of the W-R spectra and have frequently been so classified in the literature; however, we emphasize again that such overwhelming strength of the O VI lines is not found among the spectra of Population I W-R stars. When the emission lines are narrow, the spectra somewhat resemble those of Of stars, but O VI lines are not found in the spectra of Population I Of stars or in the spectra of the planetary nuclei discussed in the following sections.

The energy required to ionize oxygen five times is 114 eV, more than required for the production of any other ion contributing to the spectrum in the visual region. The great

TABLE 1

PLANETARY NUCLEI WITH EMISSION-LINE SPECTRA

NGC No., etc. (1)	Perek-Kohoutek No. (2)	R.A. (1950) (3)	Decl. (1950) (4)	Spectral Type (5)	m_n (6)	m_* (7)	Spectrograms Held (8)	References (9)
				1A. Wolf-Rayet Spectra				
NGC 40	120+9°1	00^{h}10^{m}3	+72°15′	WC 8	10.7*	11.0*	x	Aller (1943); (Hiltner and Schild (1966)
He 2-99	309−4°1	13 48.7	−66 08	WC 9	...	...	...	Webster (1967)
NGC 5315	309−4°2	13 50.9	−66 18	WC 6	13 0	14.8	x	
NGC 6751	29−5°1	19 03.2	−06 04	WC 6	12.9	13.3	x	Aller (1951)
M1-67	50+3°1	19 09.3	+16 47	WN 8	...	10.24	x	Bertola (1964)
BD +30°3639	64+5°1	19 32.8	+30 24	WC 9	9 6	10.1*	x	Beals (1938); Aller (1943, 1956); Andrillat (1957); Hiltner and Schild (1966); Underhill (1962)
				1B. O VI Sequence				
NGC 246	118−74°1	00^{h}44^{m}5	−12°09′	...	9.4	11.2	x	Aller (1948)
A78	81−14°1	21 33 4	+31 28	...	16.0	13.04	...	Abell (1966); Greenstein and Minkowski (1964)
A30	208+33°1	08 44.0	+18 04	...	15.6	14.23	...	Abell (1966); Greenstein and Minkowski (1964)
II 2003	161−14°1	03 53.2	+33 43	...	12.6	17.8	x	
II 1747	130+1°1	01 54.0	+63 05	...	13.9	14.9	x	Chopinet (1963)
NGC 1501	144+6°1	04 02.7	+60 47	...	12.6	13.3	x	Swings and Swenson (1952)
NGC 2371-2	189+19°1	07 22.4	+29 35	...	12.6	13.2	x	
NGC 2452	243−1°1	07 45.4	−27 13	...	13.3	19 1	x	
NGC 2867	278−5°1	09 20.1	−58 06	...	9.7	14.9	x	
NGC 6905	61−9°1	20 20.2	+19 57	...	12.1	13.9	x	Aller (1951); Swings and Swenson (1952)
NGC 7026	89+0°1	21 04.6	+47 39	...	12.5	14.8	x	Swings and Swenson (1952)
NGC 5189	307−3°1	13 30.2	−65 44	...	11:	14.11	x	Blanco *et al.* (1968*b*)
				1C. Of Spectra				
NGC 2392	197+17°1	07^{h}26^{m}2	+21°01′	O7f	10.4*	10.4*	x	Aller and Wilson (1954)

TABLE 1—*Continued*

NGC No., etc. (1)	Perek-Kohoutek No. (2)	R.A. (1950) (3)	Decl. (1950) (4)	Spectral Type (5)	m_n (6)	m_* (7)	Spectrograms Held (8)	References (9)
				1D. Ofp Spectra				
I 418	215−24°1	05h25m5	−12°44′	O7fp	9 4*	10.8	x	Aller and Wilson (1954); Andrillat (1957); Aller and Kaler (1964*b*)
II 2149	166+10°1	05 52.6	+46 07	O7.5fp	11.2*	13.3	x	Aller and Wilson (1954); Heap and Aller (1968)
II 4593	25+40°1	16 09.9	+12 12	O7fp	11.4*	10.2	x	Aller (1948); Aller and Wilson (1954)
NGC 6164-5	336−0°1	16 30.2	−48 00	Ofp	...	6.81	x	Westerlund (1960); Heap and Aller (1968)
NGC 6826	83+12°1	19 43.5	+50 24	O6fp	9.8*	9.9*	...	Aller (1948, 1956); Swings and Swenson (1952); Swings (1942)
				1E. W-R–Of Spectra				
I351	159−15°1	03h44m3	+34°54′	...	12.4	15.0	...	Swings and Swenson (1952)
NGC 6543	96+29°1	17 58.6	+66 38	...	8.8*	10.3*	x	Aller (1943, 1956, 1967)
NGC 6572	34+11°1	18 09 7	+06 50	...	9.0*	11.0*	x	Swings (1942)
HD 167362	1−6°2	18 13.0	−30 53	...	11.1	...	...	Swings and Struve (1940); Swings (1942)
II 4997	58−10°1	20 17.9	+16 35	...	11.4	11.5	...	Swings (1942); Aller (1956); Aller and Kaler (1964*a*)
				1F. Unclassified Emission Spectra				
VV 29	190−17°1	05h02m8	+10°38′	...	12.9	13.5	...	Vorontsov-Velyaminov (1962)
VV 57	...	07 16.3	−13 06	...	...	...	...	Vorontsov-Velyaminov (1962)
VV 391	38+12°1	18 15.2	+10 08	...	12.9	13:	...	Vorontsov-Velyaminov (1962)
II 4776	2−13°1	18 42.6	−33 24	...	12.6	15	...	Beals (1930); (Payne (1930); Vorontsov-Velyaminov (1931)
VV 458	51+9°1	18 47 6	+20 47	...	12.2	13	...	Vorontsov-Velyaminov (1962)
VV 510	52−4°1	19 40.0	+15 02	...	...	...	...	Vorontsov-Velyaminov (1962)
NGC 6879	57−8°1	20 08.2	+16 46	...	13.6	15	...	Chopinet (1963)
VV 564	104−1°1	22 30.4	+55 55	...	...	...	...	Vorontsov-Velyaminov (1962)
VV 576	111−2°1	23 24.0	+57 54	...	14:	15:	...	Vorontsov-Velyaminov (1962)

strength of the O VI lines in the spectra of these stars implies that they may represent a higher-excitation version of the W-R and Of phenomena, as has been suggested by Freeman, Rodgers, and Lyngå (1968) for one such spectrum. If so, it follows that the energy source that excites the emission spectrum is greater in some planetary nuclei than in *any* of the classical W-R stars. In this regard it should be noted that the temperatures derived by Capriotti and Kovach (1967) and Seaton (1966) for some of these planetary nuclei are in the range 90000°–120000° K. This is significantly higher than the continuum temperatures (of the order of 50000° K) currently believed for W-R stars (Gebbie and Thomas 1968, p. 215).

In all spectra known (in this class) in which all emission lines are narrower than about 10 Å (NGC 246, NGC 2371–2, A30, A78), an O-type absorption spectrum is observed. In two cases, A78 (Greenstein and Minkowski 1964) and NGC 246 (Heap and Aller 1968), considerable variability of the absorption spectrum and of the emission lines He II λ4686 and C IV λ4658 has been observed. These properties are shared with Of spectra (e.g., Oke 1954). It is not yet known whether the presence of absorption lines and the spectral variability are restricted to the sharp-line objects. No absorption lines have been detected by visual inspection of spectra characterized by stronger and broader emission, and no variability has been noticed. However, overlying nebular emission lines can make stellar absorption lines hard to detect at the dispersion employed (100 Å mm^{-1}), and the objects are so faint that few spectra of each star are available. Should significant variability or an absorption spectrum be detected in the broad-line O VI spectra, they would no longer "fall within the definition of the W-R spectra" as stated earlier in this section.

One member of the O VI sequence, NGC 5189, has been tentatively identified with the X-ray source Cen XR-2 (Blanco *et al.* 1968*b*). Another object (which has a similar spectrum) has been tentatively identified with the X-ray source GX 3 + 1 (Blanco *et al.* 1968*a*) and is situated within a planetary-like nebula (Blanco *et al.* 1968*c*). While this object has not been called a planetary nebula, its similarity to NGC 5189 and the other objects considered in this section is obvious.

The spectra of the nucleus of NGC 5189 and of the object identified with GX 3 + 1 have extremely broad emission lines. If such a spectrum, with strong, broad O VI emission, is an indication of X-ray emission, we may expect NGC 7026, NGC 2867, NGC 2452, and NGC 6905 to be X-ray sources also. NGC 7026 lies 5°.5 from the position given for Cyg XR-4 (Friedman *et al.* 1967); this is a little greater than the estimated position errors (±4°). None of the other nebulae mentioned lie near known X-ray sources. However, the association of these objects with X-ray sources warrants further attention when more X-ray sources are observed and their positions become more accurately known.

Planetary nebulae whose nuclei are known to belong to the O VI sequence are listed in Table 1B, and the spectra of some are shown in Figure 1 (Plate 5). Most of the spectra in the plate were obtained with the prime-focus spectrograph of the 120-inch reflector at Lick Observatory at a dispersion of 100 Å mm^{-1}. The spectrogram of the nucleus of NGC 5189 was taken by Wares and Aller with the 60-inch reflector at Cerro Tololo Observatory at a dispersion of 125 Å mm^{-1}. A spectrum of the nucleus of NGC 6751, classified WC 6 (Table 1A), and of θ Crt, a B9 star, are given for comparison. In both Table 1B and Figure 1 the objects are arranged in order of increasing strength and width of the O VI lines. It seems likely that this represents a sequence of increasing excitation.

c) Of Spectra

An Of spectrum is generally defined by the presence of He II λ4686 and N III λλ4634, 4641–2 in emission together with an O-type absorption spectrum. Line widths are of the order of 2 Å, and the strengths of both absorption lines and emission lines are often variable (Oke 1954; Mannino and Humblet 1955). In the present classification scheme we add the stipulation that C III λλ4647, 4650–1 should not be present in emission.

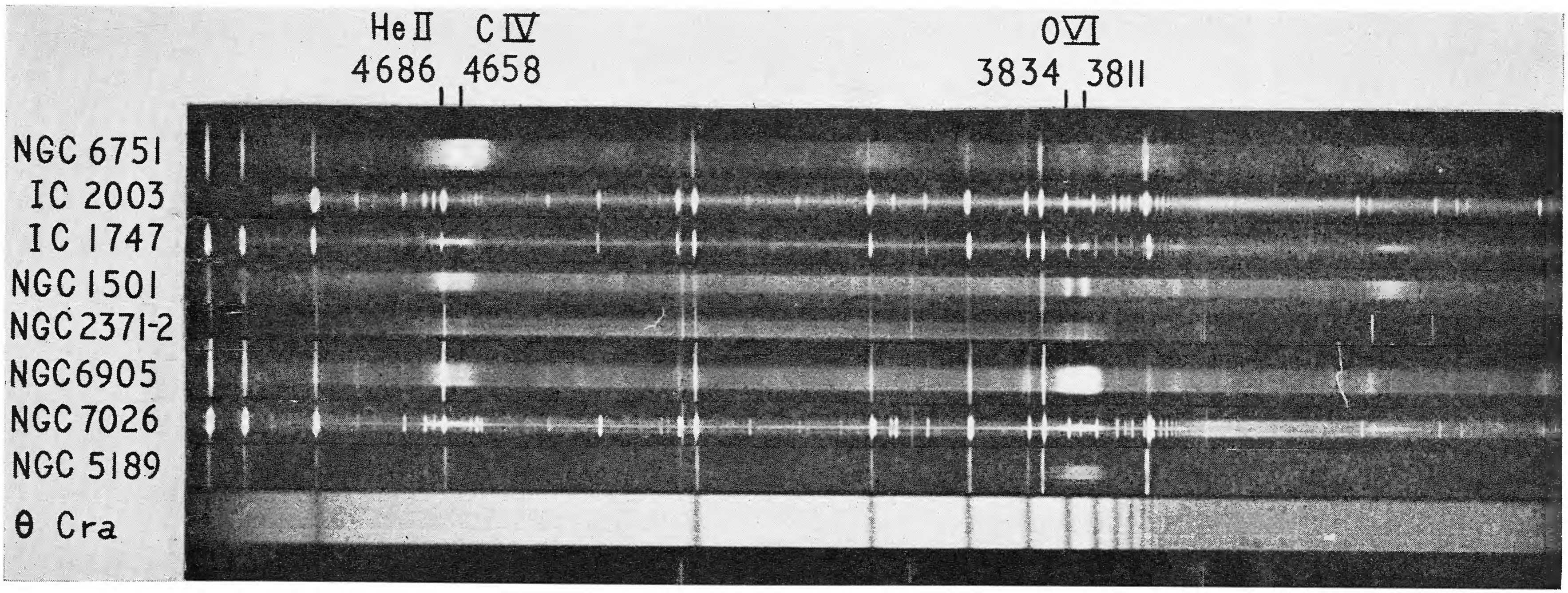

FIG. 1.—Spectra of planetary nuclei in the O VI sequence. Spectra of the nucleus of NGC 6751 (WC 7) and θ Crt (B9) are included for comparison

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Among the Population I stars, this form of spectrum is common. However, among the planetary nuclei it is uncommon; the only star known to the authors which falls in this class is the nucleus of NGC 2392, which is, therefore, the sole occupant of Table 1C.

d) *Of Peculiar Spectra*

Spectra in this class differs from "normal" Of spectra described in the previous section by the presence of emission lines of C III λλ4647, 4650–1 with intensities that are comparable to those of the N III λλ4634, 4641–2 lines. That is, we define this class by the presence of emission lines of C III λλ4647, 4650–1, of N III λλ4634, 4641–2, and of He II λ4686 together with an O-type absorption spectrum.

This form of spectrum is almost entirely unknown among Population I stars; the authors know of only two such stars, HD 108 and HD 152408, and in both stars the C III lines are quite weak and may be variable. (Swings [1942] does not note the presence of the C III lines in either spectrum.) These two stars are also unusual in that line profiles of the P Cyg type are present (Gebbie and Thomas 1968, p. 91; Heap and Aller 1968).

By contrast with the Population I stars, nuclei of planetary nebulae whose spectra display C III λλ4647, 4650–1 as well as N III λλ4634, 4641–2 and thereby fall in the class Ofp are quite common; stars in this class comprise five out of twenty-nine of the planetary nuclei classified in this paper. The great frequency of this form of spectrum among the planetary nuclei (by contrast with Population I W-R and Of stars) was first noted by Swings (1958) and is completely confirmed by the present survey. The planetary nebulae whose nuclei fall in this class are listed in Table 1D.

It should be noted that there is one carbon line (C III λ5696) which appears moderately often in spectra of Population I Of stars, and Swings (1942) has noted a range of types, from spectra in which the line does not appear to spectra in which it is stronger than N III λ4641. Unfortunately, we do not have data from which to determine the relationship between the strength of C III λ5696 and the strength of C III λλ4647, 4650–1 in the Ofp spectra. The line of C III λ5696 arises from transitions between the lowest *singlet* states that contribute to the visual C III spectrum. Underhill (1957) has suggested that it may be excited by a fluorescent mechanism involving the ionization of C II by a He II 303 quantum. The lines of C III λλ4647, 4650–1 arise from transitions between the lowest *triplet* states that contribute to the visual C III spectrum. Thus, it may well be that there is no direct relationship between the strengths of C III λ5696 and of C III λλ4647, 4650–1.

There is an interesting parallel between the spectra of WN stars, which are dominated by helium and nitrogen lines but apparently always show the lines C IV λλ5801, 5812 in emission, and the spectra of Of stars, which are also dominated by helium and nitrogen lines but which occasionally show the C III λ5696 line in emission. (The origin of the C III λ5696 line is given above. The lines of C IV λλ5801, 5812 arise from transitions between the lowest [doublet] states that contribute to the C IV visual spectrum.) The higher ionization of the carbon evidenced in the WN spectrum is in keeping with the generally higher excitation of the entire spectrum. It is also true of WN spectra, as for Population I Of spectra, that a more extensive mixture of carbon and nitrogen lines (in particular, the presence of C III λλ4647, 4650–1 and N III λλ4634, 4641–2) in the spectrum is extremely rare; only four such cases are known (HD 62910, HD 90657, HD 117688, and MR 76; see L. F. Smith 1968*a*).

Within the group of spectra that are characterized by O-type absorption lines plus emission lines, it is almost tempting to name classes that are analogous to the W-R classes WN, WC, and intermediate types WN-C. We might call the "normal" Of stars "ON" and the Ofp stars "ON-C." However, analogues to the WC stars, the "OC" stars, appear to be rare or entirely unknown; HD 167362, discussed in the following section, may qualify for this class.

e) Of-W-R Spectra

Population I Of and W-R spectra have been described in previous sections. Intermediate-type spectra are not known among Population I stars. However, among planetary nuclei there are objects that appear to be of genuinely intermediate spectral type. Spectra in this group are characterized by narrow emission lines and the absence of an O-type absorption spectrum. The spectra are often variable (e.g., NGC 6543; see Aller 1967). Frequently a mixture of line widths occurs; e.g., in NGC 6543 and NGC 6572, He II λ4686 is fairly broad ($\sim$10 Å) while all other lines are narrow ($\leq$ 4Å). Excitation is often higher than in Of spectra; the C III and N III lines are occasionally replaced by N V $\lambda\lambda$4603, 4619 and C IV $\lambda\lambda$4646, 4658 (e.g., NGC 6543). Nitrogen lines may be missing altogether; e.g., HD 167362 shows, according to Swings and Struve (1940), emission lines of He I, He II, C III, C IV, and O III; nitrogen is not observed, and no absorption lines are reported. Spectra of NGC 6572 obtained by one of us (L. H. A.) at Mount Wilson Observatory at 12.5 Å mm^{-1} indicate that only the emission lines of He II λ4686 and C IV $\lambda\lambda$4658, 4646 can be definitely attributed to the nucleus. Swings (1942) reports both carbon and nitrogen in the nuclear spectrum. Possibly the star is variable, or possibly Swings mistook nebular lines for stellar lines. This spectrum is difficult to work with because the surface brightness of the nebula is high compared with the brightness of the nucleus.

Stars assigned to this class are listed in Table 1E. It should be noted that the last two objects in Table 1E are classified only on the basis of verbal descriptions in the literature. For all other objects in Table 1A–E, classifications have been made from spectrograms held by the authors or from prints, line profiles, or line-intensity measurements published in the papers quoted.

f) Unclassified Emission Objects

Table 1F contains planetary nebulae whose nuclei are reported to have emission spectra, but for which the descriptions in the literature are inadequate to place them into one of the classes defined here. Table 2 contains planetary nebulae whose nuclei have at some time been claimed to show emission-line spectra, but for which the evidence now indicates that no emission lines are present. This situation usually results from confusion between nebular and stellar emission lines, particularly the high-excitation lines characteristic of Of spectra which are formed only in the innermost parts of the nebula. Aller (1958) has shown in two such cases that the emission lines almost certainly originate in the nebula.

III. CONCLUSIONS

We have found six planetary nuclei that have spectra similar to those of Population I W-R stars and one planetary nucleus that has a spectrum similar to those of Population I Of stars. The remainder of the emission-line spectra of planetary nuclei studied (twenty-two objects) fall into three classes, which have no equivalent among spectra of Population I stars. The distinctive features of spectra in the latter classes are, respectively, (1) strong emission of O VI $\lambda\lambda$3811, 3834, (2) simultaneous presence of emission lines of C III $\lambda\lambda$4647, 4650–1 and N III $\lambda\lambda$4634, 4641–2 with comparable intensity, and (3) presence of narrow emission lines without the presence of an O-type absorption spectrum.

We wish to thank Miss S. R. Heap and R. N. Thomas, who read the manuscript and offered suggestions. Miss Heap also provided classification data for a number of Of stars prior to publication. The majority of the work was completed while one of us (L. F. S.) was at the University of California, Los Angeles, and was supported by National Science Foundation grant GP 5182.

TABLE 2

PLANETARY NUCLEI WHICH PROBABLY DO NOT HAVE EMISSION SPECTRA

NGC No , ETC (1)	PEREK-KOHOUTEK No. (2)	R A (1950) (3)	DECL (1950) (4)	m_n (4)	m_* (5)	REFERENCES: Emission (6)	REFERENCES: No Emission (7)
II 3568	123+34°1	$12^{h}31^{m}6$	+82° 50′	10 8	12 0	Vorontsov-Velyaminov (1962)	Present program
NGC 6210	43+37°1	16 42 4	+23 54	9 7*	11 3*	Chopinet (1963)	Heap and Aller (1968)
NGC 6790	37−6°1	19 20 7	+01 25	11 4	17 3	Chopinet (1963)	Aller (1951)
NGC 6803	46−4°1	19 28 9	+09 57	12 4*	14 1	Vorontsov-Velyaminov (1962); Chopinet (1963)	Aller (1951)
NGC 6884	82+7°1	20 08 8	+46 19	12 0	19:	Vorontsov-Velyaminov (1962)	Aller (1951)
NGC 6891	54−12°1	20 12 8	+12 33	12 1	11 6	Chopinet (1963); Swings and Swenson (1952)	Present program Heap and Aller (1968)
NGC 7009	37−34°1	21 01 5	−11 34	8 9*	10 9*	Swings and Swenson (1952)	Aller (1958)
II 5219. ..	100−5°1	22 21 9	+50 43	12 6	14 6	Beals (1930); Vorontsov-Velyaminov (1931, 1962)	Aller (1951)
NGC 7662	106−17°1	23 23 5	+42 16	9 2*	11 1*	Swings and Swenson (1952)	Aller (1958)

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