Astron. Astrophys. 250, 159–164 (1991)

ASTRONOMY
AND
ASTROPHYSICS

Abundances of southern Type I planetary nebulae *

J. A. de Freitas Pacheco, W. J. Maciel, R. D. D. Costa, and B. Barbuy

Instituto Astronômico e Geofísico da USP, Av. Miguel Stefano 4200, CEP 04301 São Paulo SP, Brazil

Received January 17, accepted March 15, 1991

Abstract. New spectroscopic data are used to determine the chemical composition of southern planetary nebulae (PN). On the basis of He/H and N/O abundance ratios, 8 objects are classified as probable Type I nebulae, according to the classification scheme originally proposed by Peimbert.

Key words: planetary nebulae – abundances

1. Introduction

It is now well known that the subsystem of galactic planetary nebulae (PN) includes different kinds of objects, depending basically on the masses of the progenitor stars (see for example Maciel 1989, 1991; Peimbert 1978). As a consequence, galactic PN have often different chemical, spatial and kinematical properties, which led to the proposition of several classification schemes (Kaler 1970; Greig 1971; Peimbert 1978; Faúndez-Abans & Maciel 1987).

According to the system originally proposed by Preimbert (1978; see also Peimbert & Serrano 1980; Peimbert & Torres-Peimbert 1983; Peimbert 1985), Type I nebulae are objects whose progenitor stars lie on the high mass bracket of PN producing main sequence stars ($2-8\,M_\odot$). These objects have probably undergone three dredge-up episodes and, as a consequence, they present He and N enhancements, $\mathrm{He/H} > 0.125$ and/or $\log(\mathrm{N/O}) > -0.30$ (Iben & Renzini 1983; Renzini & Voli 1981). Therefore, Type I nebulae are an important source of heavy element enrichment in the interstellar medium (Peimbert 1978, 1987; Peimbert & Serrano 1980).

The number of Type I PN with known abundances in the Galaxy is about 50 (Peimbert & Torres-Peimbert 1983; Peimbert 1985; Faúndez-Abans & Maciel 1988; Maciel 1991), less than 5% of all observed galactic PN. Since the fraction of main sequence stars producing Type I nebulae is very probably higher than this value, many of the known PN are expected to be of Type I. In fact, Peimbert (1978) estimates that 10 to 30% of the PN belong to this type. Therefore, accurate spectroscopic analyses are desirable in order to determine the chemical composition of new Type I nebulae and to improve available abundance data.

In this paper, spectroscopic data on 10 southern PN are reported, based on observations taken at the National Astrophysical Observatory (LNA) in Brazil, and at the European Southern Observatory (ESO) at La Silla, Chile. This work is part of a long standing project on the determination of chemical abundances of southern nebulae (Freitas Pacheco & Veliz 1987; Freitas Pacheco et al. 1989; Maciel et al. 1990).

2. The observations

The La Silla observations were carried out using the 1.5 m ESO telescope with the Image Dissector Scanner (IDS; Robinson & Wampler 1972) as detector. The red tube was generally used, but in a few cases a blue tube (which was in test at the time) was employed. For the red tube a resolution of about 5 A was obtained at a dispersion of 118 A/mm, whereas for the blue tube a lower resolution of 12 A at a dispersion of 86.5 A mm^{-1} was attained. The reductions were done with the aid of batch sequences available at the IHAP reduction system at ESO.

The LNA observations were secured using a Boller & Chivens cassegrain spectrograph attached to the 1.6 m reflector. The detector used was a 1024 pxl intensified Reticon, allowing a reciprocal dispersion of 1.2 A pxl^{-1} or 4.3 A pxl^{-1} following the grating chosen. The data were reduced through a standard procedure, including wavelength calibration, flatfielding and atmospheric extinction corrections. Flux calibration was obtained by observing standard stars on the same nights. The log of the observations is given in Table 1.

The La Silla line intensity data were obtained with respect to Hα since most useful observations were made with the red tube. The conversion to the usual Hβ scale ($I_{\mathrm{H}\beta} = 100$) was performed through the derived Hα/Hβ ratio from the LNA measurements. We have averaged line fluxes when they showed internal consistency, since both sets of data were obtained with similar slit widths. Otherwise, they were independently analysed. The adopted relative line intensities I and the corrected intensities I_0 are given in Table 2. The colour excesses $E(B-V)$ are based on the Balmer ratios, under the assumption that they follow case B, and are given in Table 3.

3. Abundance determination

The electron temperatures and densities were derived using the line ratios

$R([\mathrm{O\,III}]) = I(\lambda 4363)/I(\lambda 5007)$,
$R([\mathrm{N\,II}]) = I(\lambda 5754)/I(\lambda 6584)$ and
$R([\mathrm{S\,II}]) = I(\lambda 6717)/I(\lambda 6730)$.

Send offprint requests to: W. J. Maciel

* Based on observations collected at the National Astrophysical Observatory (LNA), Brazil, and at the European Southern Observatory (ESO), La Silla, Chile

Table 1. Log-book of the observations

Object	α_{1950}	δ_{1950}	Date	$\Delta\lambda$	Observatory
NGC 5189	13 30 12	−65 44.0	1985 Jun. 22	4300–6650	ESO
			1989 May 4	3900–8400	LNA
			1989 May 5	3900–8400	LNA
			1989 May 10	3900–8400	LNA
NGC 5315	13 50 54	−66 18.0	1988 Jun. 23	3800–7700	LNA
			1989 May 8	3900–8400	LNA
			1989 May 10	3900–8400	LNA
NGC 6153	16 28 00	−40 08.0	1989 May 9	3900–8400	LNA
			1989 May 10	3900–8400	LNA
NGC 6302	16 57 08	−34 45.0	1987 Apr. 16	3900–8400	LNA
NGC 6751	19 03 12	−06 04.0	1985 Jun. 22	4300–6650	ESO
			1985 Jun. 23	4600–6000	ESO
			1989 May 10	3900–8400	LNA
			1989 May 12	3900–8400	LNA
NGC 6818	19 41 06	−14 16.0	1983 Sept. 1	4200–7000	LNA
Hb-5	17 44 42	−29 59.0	1984 Aug. 3	4900–6800	ESO
			1985 Jun. 22	4300–6650	ESO
			1989 May 9	3900–8400	LNA
He 2–111	14 29 30	−60 37.0	1985 Jun. 22	4300–6650	ESO
			1989 May 9	3900–8400	LNA
M 1–13	07 19 00	−18 02.5	1986 Jan. 7	5800–8000	ESO
			1986 Jan. 8	4600–6800	ESO
			1989 May 11	3900–8400	LNA
M 1–17	07 38 01	−11 24.8	1986 Jan. 8	4600–6800	ESO
			1989 May 12	3900–8400	LNA

Table 2. Relative line fluxes. I_0 are the corrected intensities

	NGC 5189		NGC 5315		NGC 6153		NGC 6302		NGC 6751	
Ion	I	I_0	I	I_0	I	I_0	I	I_0	I	I_0
[Ne III] λ3869	–	–	28.2	45.5	59.3	154.0	–	–	118.0	159.0
[Ne III] λ3968, Hε	–	–	26.9	41.0	49.8	116.0	–	–	98.0	127.0
Hγ λ4340	44.0	55.4	37.0	46.6	33.0	52.0	45.6	78.3	55.0	63.5
[O III] λ4363	9.7	12.1	3.5	4.4	7.0	10.9	–	–	–	–
He I λ4471	–	–	5.0	5.9	4.0	5.6	–	–	–	–
He II λ4686	82.7	89.0	–	–	13.9	16.1	69.2	83.5	–	–
Hβ λ4861	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
[O III] λ4959	465.0	447.0	331.5	319.0	396.0	366.0	591.0	536.0	410.0	400.0
[O III] λ5007	1339.0	1263.0	1101.0	1039.0	1241.0	1105.0	1727.0	1496.0	1250.0	1206.0
[He II] λ5411	–	–	–	–	–	–	7.7	4.6	–	–
[N II] λ5754	–	–	4.6	3.4	1.4	0.7	44.3	20.4	–	–
[He I] λ5875	10.9	7.7	17.8	12.5	31.9	15.7	32.5	13.7	27.3	21.9
[O I] λ6300	17.2	10.7	4.4	2.7	1.1	0.4	62.0	19.9	7.7	5.7
[S III] λ6312	3.6	2.2	3.4	2.1	2.2	0.9	7.3	2.3	2.9	2.1
Hα λ6563	503.0	292.0	490.0	285.0	903.0	290.0	1114.0	305.0	406.0	290.0
[N II] λ6584	360.0	208.0	291.0	168.3	125.0	41.9	1798.0	487.0	330.0	235.0
[He I] λ6678	–	–	5.7	3.2	10.8	3.4	–	–	7.5	5.3
[S II] λ6724	78.8	44.1	14.4	8.1	15.6	4.9	140.4	35.3	46.5	32.4
[Ar V] λ7005	–	–	–	–	–		33.8	7.4	–	–
[Ar III] λ7135	46.0	23.4	48.7	24.8	68.1	17.6	111.0	22.7	49.8	32.8
[O II] λ7324	11.6	5.7	20.3	9.9	10.7	2.6	70.2	13.1	4.5	2.9

1991A&A...250..159D

Table 2 (continued)

	NGC 6818		Hb-5		He 2–111		M 1–13		M 1–17	
Ion	I	I_0	I	I_0	I	I_0	I	I_0	I	I_0
[Ne III] λ3869	55.9	64.7	59.1	227.0	–	–	–	–	–	–
[Ne III] λ3968, Hε	–	–	–	–	–	–	–	–	–	–
Hγ λ4340	41.6	45.3	31.6	60.6	–	–	35.9	47.0	–	–
[O III] λ4363	11.2	12.2	18.9	35.1	–	–	8.3	10.7	–	–
He λ4471	–	–	–	–	–	–	–	–	–	–
He II λ4686	47.5	49.0	55.7	68.4	57.4	62.0	18.0	19.6	–	–
Hβ λ4861	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
[O III] λ4959	488.0	480.8	808.0	723.0	359.0	344.0	407.0	389.0	436.0	418.0
[O III] λ5007	1544.0	1510.0	2565.0	2178.0	1018.0	958.0	1255.0	1172.0	1321.0	1241.0
[He II] λ5411	3.2	2.9	7.0	3.9	8.8	7.1	–	–	–	–
[N II] λ5754	1.9	1.7	23.2	9.5	34.8	24.9	7.5	5.2	5.4	3.9
[He I] λ5875	13.5	11.8	27.2	10.0	16.3	11.1	19.2	12.7	26.3	18.3
[O I] λ6300	3.9	3.2	70.0	18.4	35.9	21.8	41.0	23.5	–	–
[S III] λ6312	4.1	3.4	5.6	1.4	19.7	12.0	1.5	0.9	–	–
Hα λ6563	347.0	280.0	1428.0	295.0	504.0	285.0	545.0	288.0	512.0	285.0
[N II] λ6584	60.2	48.5	2039.0	435.0	3022.0	1702.0	921.0	484.0	437.0	243.0
[He I] λ6678	4.3	3.4	11.5	2.3	18.8	10.3	2.7	1.4	–	–
[S II] λ6724	18.1	14.4	73.4	14.2	324.4	176.3	45.4	22.9	102.0	54.8
[Ar V] λ7005	–	–	41.7	6.7	15.2	7.7	–	–	–	–
[Ar III] λ7135	–	–	279.0	41.6	94.1	46.4	39.9	18.0	35.6	17.3
[O II] λ7324	–	–	144.0	19.2	21.4	10.1	23.8	10.3	59.4	27.7

Table 3. Derived nebular data

Object	$E(B-V)$	T_e(O III)	T_e(N II)	n_e (cm^{-3})
NGC 5189	0.50	10850	–	10^4 [a]
NGC 5315	0.50	8600	10060	1.2 10^4
NGC 6153	1.00	11200	10400	2400
NGC 6302	1.20	–	16000	7300
NGC 6751	0.31	10^4 [b]	10^4 [b]	400 [b]
NGC 6818	0.18	11400	–	10^4 [a]
Hb-5	1.41	13240	10880	8900
He 2–111	0.50	–	9100	10^4 [a]
M 1–13	0.56	10900	8720	2200
M 1–17	0.51	–	9600	9800

[a] Adopted value.

[b] Adopted from Pottasch (1984).

In a few cases where the electron density could not be determined, an average value of 10^4 cm^{-3} was adopted (see for example Pottasch 1984). The resulting effect of this assumption on the derived abundances is very small, provided $n_e \leqq 10^5$ cm^{-3}. For NGC 6751, both T_e and n_e are from Pottasch (1984), as the lines [N II] λ5754 and [O III] λ4363 are too weak in our spectrum to allow a reliable estimate of the electron temperature. When both T_e(O III) and T_e(N II) are available and different, the ionic abundances of Ne^{2+}, Ar^{2+}, Ar^{3+}, S^{2+} are calculated using the O^{2+} temperature, while those of N^+, O^+, and S^+ are estimated using the N^+ temperature. The derived electron temperature and density for our objects are given in Table 3.

The ionic concentrations have been calculated using a three-level atom model, which includes collisional excitation and de-excitation as well as radiative transitions. We have used in our computations the atomic data compiled by Mendoza (1983). The ionization correction factors (icf) are those used by Freitas Pacheco et al. (1989). The helium abundance was estimated assuming that the lines are formed by pure recombination. The concentration of He^+ was estimated using the transitions at λ5876 and λ6678. The transition at λ7065 was discarded, since this line has its strength affected by radiative transfer effects. PN with $O^+/O > 0.4$ seem to have substantial neutral helium inside the ionized zone (Torres-Peimbert & Peimbert 1977). In this case, we have used the recipe by Peimbert & Torres-Peimbert (1977) to estimate the total helium concentration. The resulting abundances are given in Table 4.

4. Discussion

On the basis of the results shown in Table 4, three groups of objects can be distinguished: (i) The first group contains five nebulae that can be classified as of Type I (NGC 5189, NGC 6302, NGC 6751, Hb-5, and He2-111). (ii) The second group includes the nebulae NGC 6153, NGC 6818 and M1-17, which are more uncertain, as He/H is enhanced, but N/O is essentially "normal". The third group includes the remaining 2 objects, NGC 5315 and M1-13, which are probably of Type II.

The nebulae NGC 5189, NGC 6302, and NGC 6751 of the first group have already been considered as of Type I (Peimbert & Torres-Peimbert 1983), and M1-13 and M1-17 have been included in a list of Type I PN candidates by Peimbert & Torres-Peimbert (1987). The object M1-17 has been classified as such by Faúndez-Abans & Maciel (1988) on account of abundance determinations by Kaler (1980). The nebulae Hb-5 and He2-111 have been suggested as Type I by Peimbert & Torres-Peimbert (1983), based on their filamentary and bipolar structure apparent on photographic plates. The Type I nature of He2-111 has also been pointed out by Dopita et al. (1985), on the basis of its bipolar structure and

Table 4. Abundances[a]

Object	He/H	log (N/O)	N	O	Ne	S	Ar
Sun[b]	0.098	−0.93	8.00	8.93	8.09	7.21	6.56
NGC 5189	0.135	−0.01	8.97	8.98	–	7.30	6.38
NGC 5315	0.106	−0.44	8.44	8.88	8.03	7.28	6.70
NGC 6153	0.127	−0.59	8.03	8.61	8.12	6.65	6.30
NGC 6302	0.170	+0.34	8.76	8.41	–	6.69	6.18
NGC 6751	0.158	−0.12	8.57	8.69	8.24	7.05	6.66
NGC 6818	0.126	−0.68	8.05	8.72	–	7.10	–
Hb−5	0.134	−0.16	8.88	9.04	8.36	6.74	6.83
He 2−111	0.150	+0.39	9.46	9.08	–	7.94	7.22
M 1−13	0.112	−0.46	8.46	8.92	–	6.44:	6.65
M 1−17	0.137:	−0.80	8.15	8.94	–	>6.65	6.36

[a] Abundances given are $\log(X/H)+12$ except for He/H and $\log(N/O)$.
[b] Solar abundances from Anders & Grévesse (1989) and Grévesse (1991).

intense N lines. Most of these objects have also been included in a recent study of abundance variations in galactic PN (Maciel 1991).

For most of these nebulae, some abundance data are available in the literature, which can be compared with our results. NGC 6302 has been the subject of a detailed study by Aller et al. (1981). From both optical and UV data, they have obtained physical conditions and element abundances similar to the values given here. Our O and N abundances are slightly lower, but still within the expected observational errors. For NGC 6751, our heavy element abundances (N, O, S, Ne, Ar) are similar to those given by Pottasch (1984), Peimbert & Torres-Peimbert (1983) and Aller & Czyzak (1983). Helium seems to be overabundant in comparison with these sources, although the value quoted by Pottasch (1984) includes He^+ only. In this nebula, nitrogen is clearly enhanced, so that it is of Type I. The physical conditions and element abundances of Hb 5 are in good agreement with those derived by Aller & Keyes (1987).

The objects in the second and third groups have abundances close to the limit between Types I and II. NGC 5315 has been reported as of Type I (Peimbert & Serrano 1980; Peimbert & Torres-Peimbert 1983; Faúndez-Abans & Maciel 1988), but our derived He/H abundance is well under 0.125, as required by the classification criteria. On the other hand, the N/O abundance is also rather low, so that the nebula is probably of Type II. Our derived physical conditions and abundances (N, O, S) are similar to those given by Pottasch (1984) and Peimbert & Torres-Peimbert (1983), except for the helium abundance, where Peimbert & Torres-Peimbert quote an older (and higher) value by Torres-Peimbert & Peimbert (1977). Our value seems to be more compatible with the relatively weak helium lines observed. In the framework of the subdivision of Type II nebulae proposed by Faúndez-Abans & Maciel (1987). NGC 5315 is of Type IIa, that is, $\log(N/H)+12>8.00$ (our derived value is 8.44). A similar conclusion can be drawn for M1-13. Here, electron density and temperature agree well with previously determined values by Peimbert & Torres-Peimbert (1987), the same being true for the N and O abundances.

For NGC 6153, NGC 6818, and M1-17, our He/H abundances (Table 4) are close to the limit between Types I and IIa, within an estimated uncertainty of 0.01. Also, N abundances are compatible with Type IIa PN, as $\log(N/H)+12=8.03$, 8.05, and 8.15 for these nebulae. The He abundance of NGC 6153 is the same as that derived in a detailed study by Pottasch et al. (1986). However, our abundances of some of the heavy elements (N, S, Ar) are lower, which is probably due to the higher electron temperature derived by us, although other sources of errors cannot be ruled out. For NGC 6818 the electron density has been adopted from Pottasch (1984). Our abundances (N, O, S) are similar to those given by Pottasch (1984) and Aller & Czyzak (1983), with the exception of helium, where we found a somewhat higher value. Since N does not seem to be enhanced in this object, we feel it is probably a Type II PN. Finally, our data on M1-17 is generally in agreement with the values given by Peimbert & Torres-Peimbert (1987), again except for helium, which may be partially due to the high uncertainty ascribed to our result and to the presence of neutral helium within the nebula.

Recent detailed abundance analyses are given in the literature (see for example Henry 1990; Maciel 1991). It seems established that a general correlation exists between N/O and He/H, at least for PN of Types I and II, that is, disk nebulae. This is expected from theoretical models for intermediate mass stars (Renzini & Voli 1981; Iben & Renzini 1983). Figure 1 shows the 10 objects studied in the present paper, along with some results from Maciel (1991), corresponding to 113 PN of Types I and II. It can be seen that the five nebulae in the first group are located at the middle or to the right of the diagram, as expected for Type I PN. The objects of the second group have similar location on the diagram, except M1-17, which lies below the main group of PN of Types I–II. The two nebulae in the third group are clearly to the left, where most Type II PN are located. Therefore, the positions of the PN studied here on a N/O vs. He/H plane are in good agreement with the proposed classification, with the possible exception of M1-17. This is consistent with the relationship between the N/O ratio and the central star mass recently proposed by Stasinska & Tylenda (1991).

The elements O, Ne, S, and Ar are essentially not affected by the nucleosynthesis in intermediate mass stars, which are the progenitors of planetary nebulae. Some O may be converted into N by the ON cycle (see for exemple Renzini & Voli 1981; Henry 1990; Maciel 1991), but the general abundances of these heavy elements closely follow the interstellar abundances. An interesting result found in the present sample is related to the absolute value of the oxygen abundance. The values of O/H given in Table 4 are generally close to the solar value of $\log(O/H)+12=8.93$ or $O/H=8.5\ 10^{-4}$ (Anders & Grévesse 1989). In particular, the nebulae NGC 5189, Hb-5, and He 2-112 show an oxygen over-

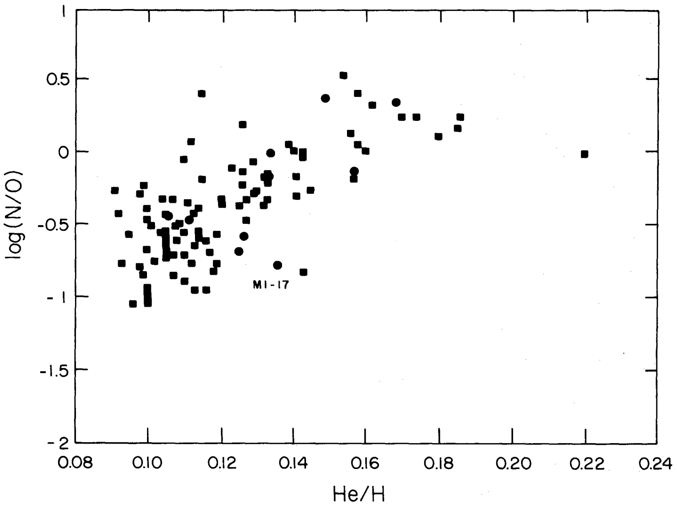

Fig. 1. N/O vs. He/H for the planetary nebulae listed in Table 4 (circles) superimposed on data for disk PN from Maciel (1991) (squares)

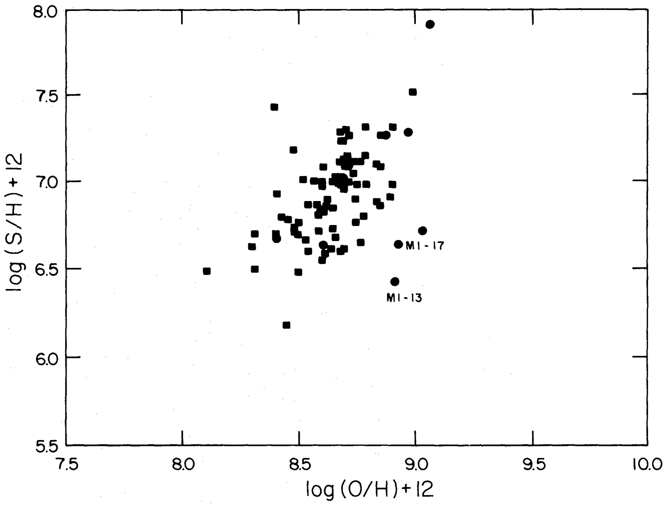

Fig. 2. The same as Fig. 1 for S/H vs. O/H

abundance relative to the solar value, suggesting that their central stars were massive enough to have formed out of a richer interstellar medium. On the other hand, the objects NGC 6153 and NGC 6302 have relatively low oxygen abundances, which may be an evidence of ON processing in their central stars. A mean value for disk PN (as well as H II regions) is $\log(\mathrm{O/H}) + 12 = 8.60-8.70$ (Maciel 1991). This is about 0.3 dex lower than the solar oxygen abundance. This puzzling question was discussed by Luck & Lambert (1985) and Barbuy (1990). The PN in the present sample have an average of $\log(\mathrm{O/H}) + 12 = 8.83$, which is essentially solar, given the observational uncertainties.

Regarding the remaining heavy elements, the average abundances for our objects are $\log(\mathrm{N/O}) = -0.62$, $\log(\mathrm{S/O}) = -1.84$, and $\log(\mathrm{Ar/O}) = -2.25$, in good agreement with the averages for PN of Types I and II estimated by Maciel (1991). The behaviour of the elements S, Ar, and Ne as tracers of interstellar abundances, as is oxygen, can be seen in Figs. 2–4. Figure 2 shows S/H against O/H for PN of Types I and II from Maciel (1991), where again the 10 PN studied here are indicated. Most follow closely the observed trend, except Hb-5, M1-13 and again M1-17, whose sulphur abundances are probably underestimated, although some scatter is certainly to be expected. Figure 3 shows Ar/H vs. O/H, which presents a better agreement between the new data and the sample studied by Maciel (1991). Here, NGC 5189 shows some Ar underabundance, and M1-17 again lies below the main group of PN. In Fig. 4, Ne/H vs. O/H is plotted for the 4 PN in the present sample with measured Ne abundances. They all can be considered as normal Type I–II objects. In all diagrams of Figs. 2–4, the separation of Type I and II is not as clear as in Fig. 1, so that it can only be said that the heavy element abundances given in Table 4 are consistent with the proposed classification.

As secondary criteria, most Type I PN show filamentary and bipolar structure on sufficiently exposed plates, generally attributed to a consequence of the higher angular momentum associated with the higher mass progenitors (see for example Peimbert & Torres-Peimbert 1983; Calvet & Peimbert 1983). The five nebulae of the first group do present such structures, as can be seen on plates in Perek & Kohoutek (1967), Westerlund & Henize (1967), and Acker et al. (1982). The remaining PN are compact

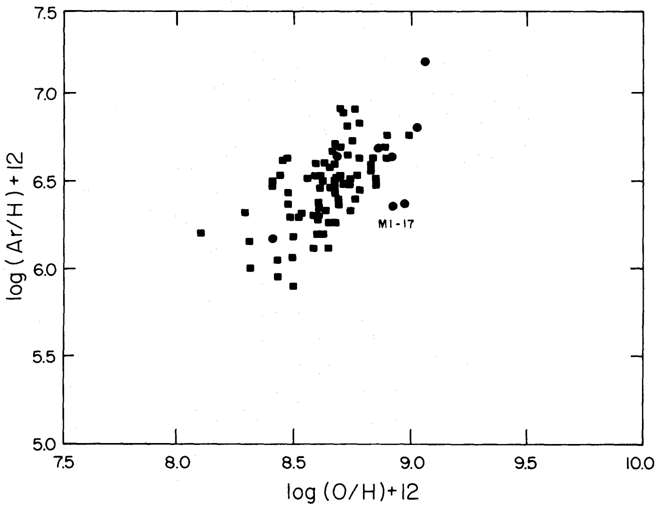

Fig. 3. The same as Fig. 1 for Ar/H vs. o/H

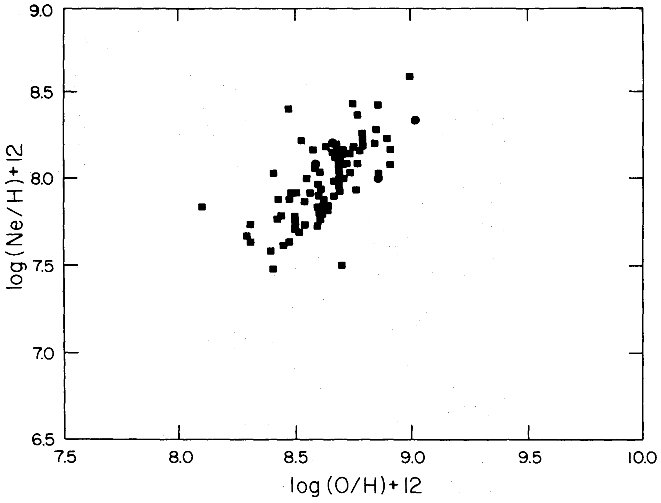

Fig. 4. The same as Fig. 1 for Ne/H vs. O/H

objects, so that no resolved structures can be observed (see references above).

Further information on the present sample of PN can be supplied by their spatial and kinematical properties. Adopting distances by Maciel (1984), and radial velocities by Schneider et al. (1983), average heights $|z|$ from the galactic plane and peculiar radial velocities $|\Delta v|$ can be obtained. As an illustration, we have taken the rotation curve from Burton & Gordon (1978) for $R < R_0$, and from Blitz et al. (1980) for $R > R_0$ (for details see Oliveira & Maciel 1986). It turns out that all objects in Table 4 have $|z| \leqq 0.5$ kpc. In fact, only two of them (NGC 6818 and M1-17) have $|z| \geqq 0.3$ kpc. The peculiar radial velocity of all nebulae are $|\Delta v| \leqq 60\,\mathrm{km\,s^{-1}}$, and only NGC 6751 and NGC 6153 have $|\Delta v| \geqq 30\,\mathrm{km\,s^{-1}}$. The peculiar radial velocity of NGC 6751 is near the limit for PN of Type I ($|\Delta v| = 60\,\mathrm{km\,s^{-1}}$), but it should be recalled that uncertainties in the distance and on the rotation curve could probably play a role. Therefore, both the spatial distribution and kinematical data on the PN in Table 4 support our conclusion that most of them are Type I nebulae.

Acknowledgements. We thank Dr. F. Sabbadin for some comments on an earlier version of this paper. This work was partly supported by CNPq and FAPESP (Brazil).

References

Acker A., Gleizes F., Chopinet M., Marcout J., Oschenbein F., Roques J. M., 1982, Catalogue of the central stars of true and possible planetary nebulae, CDS Strasbourg

Aller L. H., Czyzak S. J., 1983, ApJS 51, 211

Aller L. H., Keyes C. D., 1987, ApJS 65, 405

Aller L.H., Ross J.E., O'Mara B.J., Keyes C.D., 1981, MNRAS 197, 95

Anders E., Grévesse N., 1989, Geochim. Cosmochim. Acta 53, 197

Barbuy B., 1990, in: Sixth Cambridge Workshop on Cool Stars, Stellar Systems and the Sun, ed. G. Wallerstein, ASP Conf. Ser., Vol. 9, p. 328

Blitz L., Fich M., Stark A. A., 1980, IAU Symp. 87, ed. B. H. Andrew, Reidel, Dordrecht

Burton W. B., Gordon M. A., 1978, A&A 63, 7

Calvet N., Peimbert M., 1983, Rev. Mex. Astron. Astrofis. 5, 319

Dopita M.A., Ford H.C., Webster B.L., 1985, ApJ 297, 593

Faúndez-Abans M., Maciel W.J., 1987, A&A 183, 324

Faúndez-Abans M., Maciel W. J., 1988, Rev. Mex. Astron. Astrofis. 16, 105

Freitas Pacheco J. A., Veliz J. G., 1987, MNRAS 220, 107

Freitas Pacheco J. A., Costa R. D. D., Maciel W. J., Codina-Landaberry S. J., 1989, An. Acad. Bras. Cienc. 61, 389

Greig W. E., 1971, A&A 10, 161

Grévesse N., 1991, in: Elements and the Cosmos, ed. R. Terlevich, Cambridge University, Cambridge (in press)

Henry R. B. C., 1990, ApJ 356, 299

Iben I., Renzini A., 1983, ARA&A 21, 271

Kaler J. B., 1970, ApJ 160, 887

Kaler J. B., 1980, ApJ 239, 78

Luck R. E., Lambert D. L., 1985, ApJ 298, 782

Maciel W. J., 1984, A&AS 55, 253

Maciel W. J., 1989, IAU Symp. 131, ed. S. Torres-Peimbert, Kluwer, Dordrecht

Maciel W. J., 1991, in: Elements and the Cosmos, ed. R. Terlevich, Cambridge University, Cambridge (in press)

Maciel W. J., Freitas Pacheco J. A., Codina-Landaberry S. J., 1990, A&A 239, 301

Mendoza C., 1983, IAU Symp. 103, ed. D. R. Flower, Reidel, Dordrecht

Oliveira S., Maciel W.J., 1986, Ap&SS 128, 421

Peimbert M., 1978, IAU Symp. 76, ed. Y. Terzian, Reidel, Dordrecht

Peimbert M., 1985, Rev. Mex. Astron. Astrofis. 10, 125

Peimbert M., 1987, in: Planetary and protoplanetary nebulae: from IRAS to ISO, ed. A. Preite Martinez, Reidel, Dordrecht

Peimbert M., Serrano A., 1980, Rev. Mex. Astron. Astrofis. 5, 9

Peimbert M., Torres-Peimbert S., 1977, MNRAS 169, 217

Peimbert M., Torres-Peimbert S., 1983, IAU Symp. 103, ed. D. R. Flower, Reidel, Dordrecht

Peimbert M., Torres-Peimbert S., 1987, Rev. Mex. Astron. Astrofis. 14, 540

Perek L., Kohoutek L., 1967, Catalogue of galactic planetary nebulae, Academia, Prague

Pottasch S. R., 1984, Planetary Nebulae, Reidel, Dordrecht

Pottasch S. R., Dennefeld M., Jing-er M., 1986, A&A 155, 397

Renzini A., Voli M., 1981, A&A 94, 175

Robinson L.B., Wampler E.J., 1972, PASP 84, 161

Schneider S. E., Terzian Y., Purgathofer A., Perinotto M., 1983, ApJS 52, 399

Stasinska G., Tylenda R., 1991, A&A (in press)

Torres-Peimbert S., Peimbert M., 1977, Rev. Mex. Astron. Astrofis. 2, 181

Westerlund B. E., Henize K. G., 1967, ApJS 14, 154