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New abundances of southern planetary nebulae*

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Abstract. — As a continuation of a long-term observational program with the purpose of deriving the chemical abundances of southern planetary nebulae (PN), we present here the line fluxes, colour excesses, electron temperatures and densities, and abundances of He, O, N, S, Ar and Ne for 15 PN. These objects were classified according to the Peimbert classification scheme, taking into account the chemical and kinematical properties as well as distance-independent correlations.

Key words: planetary nebulae: general — ISM: abundances

1. Introduction

In view of the fact that only a small number of the known galactic planetary nebulae (PN) have their abundances already determined, a long-term observational program with the purpose of deriving physical parameters and chemical composition of southern PN has been developed at the University of São Paulo in the past few years. Earlier results can be found in Freitas Pacheco et al. (1991, 1992, 1993a, b, Costa et al. 1993; Maciel et al. 1990) and references therein.

Properties of these objects, such as chemical abundances, electron temperatures and densities, space distribution and kinematic parameters vary over a wide range. The understanding of these properties contributes not only to the study of the late evolutionary stages of intermediate mass stars, but also to the study of the chemical evolution of the galactic disk.

In this paper, we present abundances and kinematic parameters for a sample of 15 southern planetary nebulae. Observed and extinction-corrected fluxes for the emission lines used to derive our results are also presented.

2. Observations

All the observations were carried out at the National Observatory for Astrophysics (LNA, Brasópolis, Brazil), using a Boller & Chivens Cassegrain spectrograph attached to the 1.60 m telescope. A long, east-west aligned slit with 300 μm (4 arcsecs) width was used in all observations. The detector was a UV-coated GEC CCD with 1152 $\times$ 770 pixels, with a grating allowing a dispersion of 4.3 Å/pixel. The nebulae were observed during an observational run in April, 1992. Table 1 shows the logbook of the observations, including common names, coordinates and dates.

Table 1. Log of the observations

Object	α_{2000}	δ_{2000}	Date
NGC 3132	10 07 02	-40 26 10	Apr. 06, 1992
NGC 3699	11 27 59	-59 57 32	Apr. 09, 1992
IC 4406	14 22 26	-44 09 06	Apr. 07, 1992
IC 4593	16 11 44	+12 04 27	Apr. 09, 1992
H 4-1	12 59 28	+27 38 14	Apr. 09, 1992
He 2-15	08 53 31	-40 03 34	Apr. 08, 1992
He 2-21	09 13 52	-55 28 31	Apr. 08, 1992
He 2-117	15 05 59	-55 59 21	Apr. 09, 1992
He 2-141	15 59 09	-58 23 21	Apr. 07, 1992
He 2-143	16 01 00	-55 05 39	Apr. 07, 1992
M1-14	07 27 56	-20 13 23	Apr. 07, 1992
M1-20	17 28 58	-19 15 53	Apr. 09, 1992
M2-4	17 01 06	-34 49 39	Apr. 08, 1992
M3-8	17 24 52	-28 05 55	Apr. 08, 1992
PB 3	08 57 18	-50 32 19	Apr. 08, 1992

Data reduction was performed using the IRAF package and followed the standard procedures including dark, bias and flatfield corrections, extraction of the spectra, wavelength calibration, atmospheric extinction correction and flux calibration. Atmospheric extinction was corrected through mean coefficients derived for the observatory, and flux calibration was secured observing standard stars in each night.

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*Based on observations made at the National Laboratory for Astrophysics - Brasópolis - Brazil

Table 2. Observed and extinction-corrected fluxes

Ion	NGC 3132		NGC 3699		IC 4406		IC 4593		H4-1
	I	I_0	I	I_0	I	I_0	I	I_0	$I = I_0$
[Ne III] λ3869	204.6	212.3	186.5	241.3	149.9	159.5	65.8	66.0	-
[Ne III] λ3967+Hϵ	71.3	73.8	59.1	74.8	33.8	35.8	34.4	34.5	-
Hδ λ4101	-	-	17.9	21.9	17.3	18.2	25.4	25.5 7	33.1
Hγ λ4340	52.6	53.7	46.3	53.8	49	50.8	48.5	48.6	62.9
[O III] λ4363	2.9	3.0	-	-	3.2	3.3	-	-	14.5
He I λ4471	3.3	3.4	-	-	5.4	5.6	10.6	10.6	9.8
He II λ4686	9.1	9.2	64	67.5	21.5	21.8	-	-	8.9
Hβ λ4861	100	100.0	100	100.0	100	100.0	100	100.0	100
[O III] λ4959	298.0	296.8	501.1	487.0	368.1	365.6	184.5	184.4	214.6
[O III] λ5007	883.4	879.8	1492.0	1450.2	1101.9	1094.4	552.4	552.3	649.1
[N II] λ5754	6.9	6.7	8.6	7.0	4.8	4.6	-	-	5.24
He I λ5875	15.6	15.1	11.4	9.1	14.1	13.4	13.7	13.7	13.5
[O I] λ6300	29.5	28.3	30	22.5	25.5	23.8	-	-	10
[S III] λ6312	1.8	1.7	-	-	-	-	0.6:	0.6:	-
Hα λ6563	304.2	290.0	404.5	290.0	314.1	290.0	291.1	290.1	233.7
[N II] λ6548+6584	722.7	688.4	749.2	534.3	452.9	417.6	12.7	12.7	126.6
He I λ6678	4.8	4.6	4.1	2.9	4.3	4.0	3.9	3.9	3.6
[S II] λ6716+6730	97.4	92.6	23	16.1	11.7	10.7	1.5:	1.5:	-
[Ar V] λ7005	-	-	2.6	1.8	-	-	-	-	-
He I λ7065	4.3	4.1	3.7	2.5	3.9	3.5	3.9	3.9	4.2
[Ar III] λ7135	29.1	27.4	47	31.3	26.9	24.4	9.5	9.5	0.98
[O II] λ7320+7330	10.7	10.1	21.7	14.1	11.6	10.4	2.3	2.3	6.1

Ion	He2-15		He2-21		He2-117		He2-141		He2-143	
	I	I_0	I	I_0	I	I_0	I	I_0	I	I_0
[Ne III] λ3869	-	-	80	123.9	-	-	139	185.0	-	-
[Ne III] λ3967+Hϵ	-	-	34.9	52.1	-	-	54.9	71.3	-	-
Hδ λ4101	-	-	-	-	-	-	31.4	39.4	-	-
Hγ λ4340	42.2	70.8	46	59.4	28	70.8	58.5	69.1	21.6	64.0
[O III] λ4363	14.2	23.8	8.6	11.1	6.5	16.4	5.0 :	-	-	-
He I λ4471	-	-	-	-	-	-	-	-	-	-
He II λ4686	54.7	65.8	33.8	37.0	-	-	78.1	82.9	28.1	41.4
Hβ λ4861	100	100.0	100	100.0	100	100.0	100	100.0	100	100.0
[O III] λ4959	324.6	294.3	381.7	363.7	260.9	218.9	431.5	418.1	601.6	489.9
[O III] λ5007	1014.5	914.9	1153.9	1099.5	831.1	697.2	1299.6	1258.7	2038.8	1660.2
[N II] λ5754	49.4	24.5	-	-	11	3.1	2.3	1.8	27.2	6.2
He I λ5875	31.4	14.5	15.6	10.6	82.8	20.6	8.9	6.9	82.3	16.1
[O I] λ6300	97.2	35.8	2.8	1.7	25.9	4.3	9.4	6.8	102	12.6
[S III] λ6312	9.0	3.2	0.5:	0.3:	9.7	1.5	3.4	2.4	35.6	4.1
Hα λ6563	912.1	290.1	510	290.0	2263.5	289.9	419.5	290.0	3210.7	290.1
[N II] λ6548+6584	5885.1	1837.3	11.7	6.6	1511.3	187.3	165.7	113.9	2991.2	260.0
He I λ6678	16.3	4.9	5.9	3.2	42.1	4.8	3.4	2.3	47.3	3.7
[S II] λ6716+6730	410.6	121.3	2.7:	1.5:	85.2	9.6	14.3	9.7	223.8	17.3
[Ar V] λ7005	10.6	2.7	-	-	-	-	2.7	1.7	39.9	2.3
He I λ7065	17.3	4.3	6.3	3.2	105.9	8.8	3.3	2.1	125	6.8
[Ar III] λ7135	126.9	31.2	11.1	5.6	323.9	26.1	34.1	21.7	586.2	30.8
[O II] λ7320+7330	66.1	14.8	2.6	1.2	93.8	6.4	9.2	5.7	332	14.4

Line intensities were calculated also using IRAF, by adopting gaussian profiles to the emission lines. A gaussian de-blending routine was also used when necessary. Intensities are given in Table 2, in the scale in which $I(\mathrm{H}\beta)=100$. Typical errors in line intensities are of about 10% for the lines stronger than 10 and 20% for weaker lines. These last range of uncertainties leads to typical errors of 10% in electron temperature estimates, mainly due to the weak auroral lines [NII]λ5754 and [OIII]λ4363. Those lines marked with colons have uncertainties of about 40%.

Table 2 contains both the observed and extinction-corrected intensities for each line. Interstellar extinction was estimated on the basis of the Balmer ratio Hα/Hβ, assuming case B (Osterbrock 1989), and using the interstellar extinction law by Nandy et al. (1975). For H4-1, no correction was made. $E(B-V)$ values derived for

Table 2. continued

Ion	M1-14		M1-20		M2-4		M3-8		PB 3	
	I	I_0	I	I_0	I	I_0	I	I_0	I	I_0
[Ne III] λ3869	-	-	-	-	-	-	-	-	116	267.7
[Ne III] λ3967+Hϵ	12.7	22.0	-	-	-	-	-	-	38.8	83.5
Hδ λ4101	19.9	31.9	-	-	14.1	25.2	-	-	21.8	42.3
Hγ λ4340	35.2	49.9	37.2	54.6	26.2	40.2	-	-	39.4	64.2
[O III] λ4363	-	-	9.4	13.8	5	7.7	-	-	7.3	11.9
He I λ4471	5.9	7.8	-	-	6.2	8.7	-	-	-	-
He II λ4686	-	-	-	-	-	-	-	-	28.5	33.9
Hβ λ4861	100	100.0	100	100.0	100	100.0	100	100.0	100	100.0
[O III] λ4959	99.0	92.7	326.4	303.5	262.0	241.6	199.6	175.7	495.3	451.6
[O III] λ5007	305.2	285.7	1014.6	943.6	824.0	759.9	650.9	573.0	1537.0	1401.5
[N II] λ5754	2.7	1.7	1.9:	1.1:	3.7	2.1	6.9	2.8	11.7	6.0
He I λ5875	22.7	13.5	27.1	15.2	31.4	16.5	51.4	18.7	26.6	12.8
[O I] λ6300	1.7	0.9	10	4.8	10.3	4.5	9.7	2.6	50.5	19.7
[S III] λ6312	1.0:	0.5:	1.9:	0.9:	3.5	1.5	-	-	6.4	2.4
Hα λ6563	627.8	290.0	678.1	290.0	747.6	289.9	1288.1	290.0	853.8	290.0
[N II] λ6548+6584	244.7	111.6	107.1	45.2	282.6	107.9	614.6	135.1	1228.7	410.1
He I λ6678	8.1	3.6	9.7	3.9	-	-	23.1	4.8	10.5	3.3
[S II] λ6716+6730	10	4.4	9	3.6	30.7	11.2	44.9	9.2	153.6	48.7
[Ar V] λ7005	-	-	-	-	-	-	-	-	2.2	0.6:
HeI λ7065	14.1	5.5	26.5	9.5	22.8	7.2	29.4	4.8	15.1	4.1
[Ar III] λ7135	18.9	7.3	25.5	9.0	62.1	19.4	119.5	19.2	93.2	24.8
[O II] λ7320+7330	42.8	15.6	43	14.2	35.2	10.2	50.4	7.2	78.2	19.1

each nebula can be found in Table 3; these values can be converted to the logarithmic extinction parameter $c(\mathrm{H}\beta)$ through the relation computed by Kaler & Lutz (1985). Results are also in Table 3.

3. Physical parameters and chemical abundances

Electron densities and temperatures necessary to derive the chemical composition were estimated from the intensity ratios:

$$R(\mathrm{OIII}) = \frac{\lambda 4363}{\lambda 5007}; R(\mathrm{NII}) = \frac{\lambda 5754}{\lambda 6584}; R(\mathrm{SII}) = \frac{\lambda 6716}{\lambda 6730}$$

Densities were estimated from the [SII] ratio, except for H4-1, where the de-blending routine procedure was not possible due to low signal-to-noise ratio, so that a mean density of 10^4 cm^{-3} was adopted. Electron temperatures were estimated both from [OIII] and [NII] ratios; when these temperatures showed differences smaller than 20%, a mean value was adopted; otherwise, the [OIII] temperature was adopted to estimate abundances of higher ionization potential ions like O^{+2}, S^{+2}, Ar^{+2}, Ne^{+2}, and the [NII] temperature was adopted for ions of lower potential like O^{+}, N^{+}, S^{+}. Atomic data used were taken from Osterbrock (1989). Table 3 shows the physical parameters derived for the nebulae.

Ionic abundances are listed in Table 4 and were calculated by solving the statistical equilibrium equations for a three-level atom model, including radiative and collisional transitions. Atomic parameters were obtained from the compilation of Mendoza (1983). Elemental abundances were calculated using ionization correction factors (icf) to account for unobserved ions. The following icf's were used:

$$\frac{\mathrm{O}}{\mathrm{H}} = \frac{\mathrm{O}^{+} + \mathrm{O}^{+2}}{\mathrm{H}^{+}} \left(\frac{\mathrm{He}}{\mathrm{He}^{+}} \right)$$

(Torres-Peimbert & Peimbert 1977)

$$\frac{\mathrm{N}}{\mathrm{H}} = \frac{\mathrm{N}^{+}}{\mathrm{H}^{+}} \left(\frac{\mathrm{O}}{\mathrm{O}^{+}} \right)$$

(Peimbert & Torres-Peimbert 1977)

$$\frac{\mathrm{S}}{\mathrm{H}} = \frac{\mathrm{S}^{+} + \mathrm{S}^{+2}}{\mathrm{H}^{+}} \left[1.43 + 0.196 \left(\frac{\mathrm{O}^{+2}}{\mathrm{O}^{+}} \right)^{1.29} \right]$$

(Köppen et al. 1991)

$$\frac{\mathrm{Ar}}{\mathrm{H}} = \frac{\mathrm{Ar}^{+2}}{\mathrm{H}^{+}} \left[1.34 \left(\frac{\mathrm{O}}{\mathrm{O}^{+2}} \right) \right]$$

(Freitas Pacheco et al. 1993b)

$$\frac{\mathrm{Ne}}{\mathrm{H}} = \left(\frac{\mathrm{Ne}^{+2}}{\mathrm{H}^{+}} \right) \frac{\mathrm{O}^{+} + \mathrm{O}^{+2}}{\mathrm{O}^{+2}}$$

(Peimbert 1990)

Table 3. Extinction and physical parameters

Object	$R(6716/6730)$	$E(B-V)$	$c(\mathrm{H}\beta)$	T_e[OIII](K)	T_e [NII] (K)	N_e (cm^{-3})
NGC 3132	0.89	0.48	0.75	8400	9590	710
NGC 3699	0.95	0.33	0.50	-	10900	560
IC 4406	0.84	0.08	0.10	8150	11700	930
IC 4593	0.59:	0.01	0.01	12600**	-	3160
H 4-1	-	-	-	15100	18300	10000*
He 2-15	0.83	1.14	1.90	17500	10900	890
He 2-21	0.53:	0.56	0.88	11600	-	5010
He 2-117	0.45	2.04	3.63	16000	9880	25120
He 2-141	0.69	0.37	0.57	-	11700	1780
He 2-143	0.49	2.39	4.35	-	13300	8910
M1-14	0.49	0.77	1.24	-	10800	8910
M1-20	0.46	0.84	1.37	13100	12500	17780
M2-4	0.55	0.94	1.54	11600	12500	4470
M3-8	0.50	1.48	2.53	-	12300	9330
PB 3	0.60	1.07	1.78	11000	11100	2820

* adopted; ** Costa (1993)

Table 4. Ionic abundances

Object	He^0	He^+	O^+	O^{+2}	N^+	S^+	S^{+2}	Ar^{+2}	Ne^{+2}
NGC 3132	0.113	0.008	3.77×10^{-4}	4.54×10^{-4}	1.31×10^{-4}	3.12×10^{-6}	6.01×10^{-6}	2.57×10^{-6}	1.64×10^{-4}
NGC 3699	0.071	0.059	1.65×10^{-4}	3.95×10^{-4}	6.13×10^{-5}	3.21×10^{-7}	-	1.86×10^{-6}	1.72×10^{-4}
IC 4406	0.097	0.019	7.48×10^{-4}	2.42×10^{-4}	1.07×10^{-4}	4.97×10^{-7}	-	1.24×10^{-6}	8.20×10^{-5}
IC 4593	0.108	-	9.09×10^{-6}	9.96×10^{-5}	1.08×10^{-6}	3.03×10^{-8}	5.44×10^{-7}	4.17×10^{-7}	3.27×10^{-5}
H4-1	0.111	0.008	5.71×10^{-6}	5.98×10^{-5}	6.64×10^{-6}	-	-	2.62×10^{-8}	-
He2-15	0.118	0.058	1.63×10^{-4}	7.54×10^{-4}	2.12×10^{-4}	2.54×10^{-6}	1.09×10^{-6}	7.73×10^{-7}	
He2-21	0.083	0.033	6.35×10^{-6}	2.50×10^{-4}	6.88×10^{-7}	4.38×10^{-8}	3.64×10^{-7}	2.91×10^{-7}	7.62×10^{-5}
He2-117	0.148	-	5.93×10^{-5}	7.10×10^{-5}	3.58×10^{-5}	1.17×10^{-6}	6.22×10^{-7}	7.49×10^{-7}	-
He2-141	0.055	0.073	3.74×10^{-5}	2.78×10^{-4}	1.12×10^{-5}	1.95×10^{-7}	2.84×10^{-6}	1.11×10^{-6}	1.08×10^{-4}
He2-143	0.123	0.037	3.42×10^{-5}	2.54×10^{-4}	2.09×10^{-5}	5.14×10^{-7}	3.06×10^{-6}	1.22×10^{-6}	-
M1-14	0.101	-	1.05×10^{-4}	8.03×10^{-5}	1.44×10^{-5}	2.05×10^{-7}	7.89×10^{-7}	4.43×10^{-7}	-
M1-20	0.118	-	3.49×10^{-5}	1.65×10^{-4}	4.30×10^{-6}	1.85×10^{-7}	7.49×10^{-7}	3.84×10^{-8}	-
M2-4	0.128	-	4.58×10^{-5}	1.53×10^{-4}	1.02×10^{-5}	2.86×10^{-7}	1.58×10^{-6}	9.31×10^{-7}	-
M3-8	0.143	-	2.43×10^{-5}	1.09×10^{-4}	1.29×10^{-5}	3.30×10^{-7}	-	8.84×10^{-7}	-
PB 3	0.096	0.030	1.52×10^{-4}	3.64×10^{-4}	4.68×10^{-5}	1.27×10^{-6}	3.51×10^{-6}	1.43×10^{-6}	1.81×10^{-4}

Table 5. Abundances and classification

Object	Type	He/H	ϵ(O/H)	ϵ(N/H)	ϵ(S/H)	ϵ(Ar/H)	ϵ(Ne/H)	$\log(N/O)$
NGC 3132	I	0.121	8.95	8.49	7.19	6.93	8.48	-0.46
NGC 3699	I	0.130	9.01	8.58	-	6.91	8.39	-0.43
IC 4406	IIa	0.116	9.07	8.23	-	7.01	8.53	-0.85
IC 4593	III	0.108	8.04	7.11	6.52	5.89	7.55	-0.93
H4-1	IV	0.119	7.85	7.91	-	4.72	-	0.07
He2-15	I	0.176	8.56	8.67	6.74	6.80	-	0.11
He2-21	IIb	0.116	8.55	7.59	7.28:	5.85	7.89	-0.97
He2-117	I	0.148	8.11	7.90	6.48	6.37	-	-0.22
He2-141	IIa	0.128	8.87	8.34	7.09	6.69	8.09	-0.52
He2-143	I	0.160	8.57	8.36	7.16	6.48	-	-0.21
M1-14	III	0.101	8.27	7.41	6.19	6.24	-	-0.86
M1-20	V	0.118	8.30	7.39	6.43:	$>$ 4.90	-	-0.91
M2-4	III	0.128	8.30	7.65	6.64	6.31	-	-0.65
M3-8	V	0.143	8.12	7.85	-	6.26	-	-0.27
PB 3	IIa	0.126	8.83	8.32	6.99	6.65	8.41	-0.51

The derived abundances are listed in Table 5, where $\epsilon(X/H) = \log(X/H) + 12$ is given, except for He/H and $\log(N/O)$. After the derivation of the chemical abundances, the nebulae were classified according to the Peimbert scheme, as discussed in the following section.

Table 6. Average properties of the PN types

	I	IIa	IIb	III	IV
He/H	0.138	0.106	0.104	0.099	0.104
ϵ(O/H)	8.68	8.78	8.58	8.42	8.08
ϵ(N/H)	8.57	8.29	7.78	7.74	7.41
ϵ(S/H)	7.04	7.02	6.83	6.74	5.64
ϵ(C/H)	8.67	8.78	8.73	8.48	8.54
ϵ(Ne/H)	8.03	8.06	7.87	7.71	7.27
ϵ(Ar/H)	6.61	6.47	6.26	6.07	5.22
ϵ(Cl/H)	5.43	5.32	5.00	4.99	-
$< z >$ (pc)	150	280	420	660	7200
$< \Delta V >$ (km/s)	20.5	21.3	22.1	64.0	172.8

4. Discussion

The planetary nebula phase is one of the fundamental evolutionary stages for intermediate-mass stars ($0.8 \leq M/M_{\odot} \leq 8$). As this group of objects spans a large range in mass, it constitutes a mixed population in the Galaxy, going from population I to population II extreme. Such populations reflect a wide range of properties, not only with respect to the progenitor mass, but also regarding the kinematics, spatial distribution and chemical composition (Maciel & Dutra 1992; Peimbert 1990; Maciel 1992; Maciel & Chiappini 1992).

Given the wide range of properties of planetary nebulae, it is of crucial importance that they should be adequately classified. Several classification schemes have been proposed in the literature. In particular, Peimbert (1978) suggested that PN can be divided into four main types, according to their chemical composition and kinematical properties. This classification scheme has been updated and revised (cf. Faúndez-Abans & Maciel 1986; Peimbert & Torres-Peimbert 1983; Maciel 1989), and can be shown to directly relate to the PN progenitor masses. As a result, average abundances can be derived for the different PN types, as shown by Maciel (1992), Freitas Pacheco (1993), Chiappini (1993), and Maciel & Chiappini (1994). Table 6 presents the averages as given by Chiappini (1993), and can be used in order to classify the PN in the present sample.

The average space and kinematical properties of galactic PN have been studied in detail by Maciel & Dutra (1992), who derived average values for the distance $< z >$ to the galactic plane and peculiar velocity $< \Delta V >$. These averages are also included in Table 6. As discussed by Maciel & Dutra (1992), the standard deviations of the peculiar velocities are of the order of 15 km/s for types I–II, 45 km/s for type III, and 82 km/s for type IV PN. In order to apply the space and kinematical properties to the PN in the present sample, we adopted distances from Maciel (1984) and velocities given by Schneider et al. (1983), as shown in Table 7. Exceptions are M1-14 and M1-20, for which we used distances by Cahn et al. (1992), and M2-4, for which we used a distance by Amnuel et al. (1984). We have determined the heights z from the galactic plane and peculiar velocities ΔV using the PN rotation curve as given by Maciel & Dutra (1992), however correcting for $R_0 = 7.6$ kpc at the sun's position (see for example Maciel 1993). The results are also included in Table 7.

Taking into account the average abundances and kinematical properties of each PN type, we have classified the objects of the present sample, as shown in Table 5. The PN classification was also investigated on the basis of distant-independent correlations. This can be seen in Fig. 1, where we have plotted $\log(N/O)$ vs. He/H for the present sample (triangles) along with planetary nebulae reported by Costa (1993), Freitas-Pacheco et al. (1991, 1992) and Maciel et al. (1990). Here we distinguish type I PN (squares), type IIa (empty circles), type IIb (filled circles), and type III (crosses). The existing trend reflects the enrichment in He and N due to the dredge-up episodes in the PN progenitors. The separation of the different types is clear and it can be seen that the positions of the PN studied here on the plot are in good agreement with the proposed classification. The same conclusion applies when we check the behaviour of the present PN sample regarding the observed galactic gradients for the different PN types (Maciel & Köppen 1994; Maciel & Chiappini 1994).

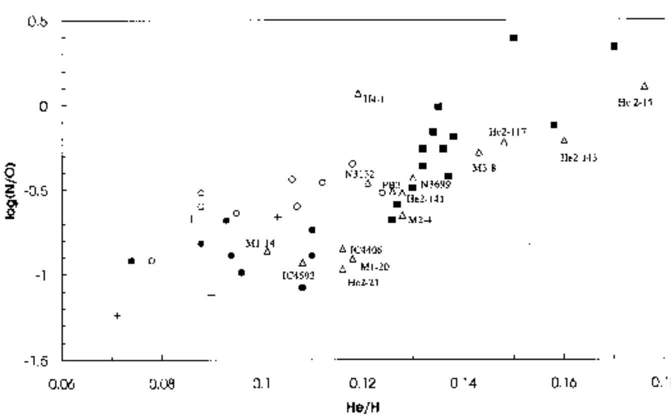

Fig. 1. N/O vs. He/H for the PN listed in Table 5 (triangles), superimposed on PN from Costa (1993). Type I: squares; type IIa: empty circles; type IIb: filled circles; type III: crosses

As already observed by Freitas-Pacheco et al. (1992), such separation is not as clear in Figs. 2-4, where S/H, Ar/H and Ne/H are plotted against O/H, respectively. The differences between the average abundances of these

Table 7. Space distribution and kinematics

Object	D(kpc)	$V_{\rm LSR}$(km/s)	$\mid z \mid$ (kpc)	R(kpc)	ΔV(km/s)
NGC3132	1.1	−28.5	0.2	7.6	−29.6
NGC3699	2.0	−15.6	0.0	7.1	1.7
IC4406	1.7	−40.2	0.5	6.4	−11.3
IC4593	2.4	38.7	1.6	6.0	16.3
H4-1	12.7	−133.1	12.7	7.3	−133.3
He2-15	2.1	-	0.1	8.2	-
He2-21	7.2	-	0.6	9.9	-
He2-117	1.7	−30.0	0.1	6.4	1.3
He2-141	2.8	−46.3	0.2	5.5	9.6
He2-143	2.7	−34.3	0.1	5.5	19.2
M1-14	4.0	112.7	0.1	10.4	62.3
M1-20	3.4	104.6	0.5	4.3	-
M2-4	2.9	−175.8	0.2	4.8	-
M3-8	4.9	105.5	0.4	2.7	-
PB3	3.2	-	0.2	8.3	-

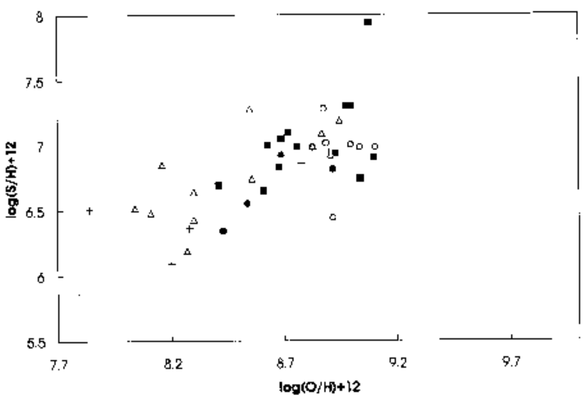

Fig. 2. The same as Fig. 1 for S/H vs. O/H

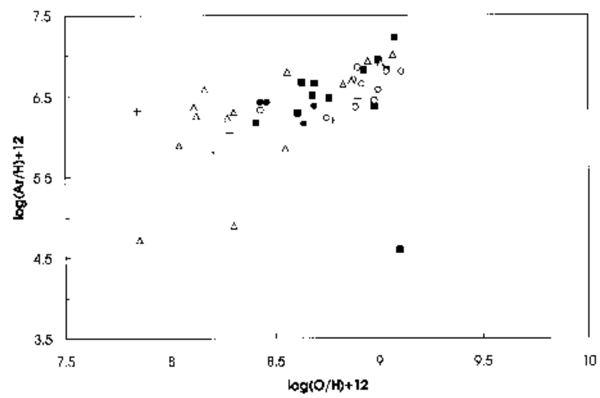

Fig. 3. The same as Fig. 1 for Ar/H vs. O/H

elements for the various PN types are small and reflect the galactic chemical enrichment, as the intermediate-mass stars do not produce significant quantities of these elements. As expected, there is a lockstep relation between Ne, Ar and S with oxygen, so that all these elements can be considered as tracers of the interstellar medium metallicity.

Among the objects studied in this sample, six were already reported by the IAG group (Freitas Pacheco et al. 1992; Maciel et al. 1990), namely IC 4406, He 2-15, He 2-21, He 2-117, He 2-141 and IC 4593). The new abundances reported here are in general agreement with previous estimates in the literature. Here we have some remarks:

IC 4406: This object has been classified in the past as a type I PN in consequence of the high He abundance found by Kaler (1980) and Peimbert & Torres-Peimbert (1983). The lower helium abundance derived in the present work is consistent with our previous result (Freitas Pacheco et al. 1992). Considering the other criteria discussed above and the new value for the He abundance, the classification as a type IIa seems more correct.

He 2-15: For this object we have the $T_{\rm e}$[OIII], which was not available in our previous result. The results agree with those reported by Kingsburgh & Barlow (1994).

He 2-21: Our S/H value is higher than previous estimates, which could be a consequence of the very low intensities of the [SII] lines, so that the result is uncertain.

He 2-117: The abundances are systematically lower than those reported by Freitas Pacheco et al. (1992). However, in that work $T_{\rm e}$[OIII] was not available and $T_{\rm e}$[NII] was used to estimate all ionic abundances.

He 2-141: The Ar and Ne values presented here are higher than those reported by Kingsburgh & Barlow (1994). However, as the authors observe, their reddening correction is uncertain and they could have underestimated the abundances. For this object, despite its high helium abundance, we maintain its classification as a type

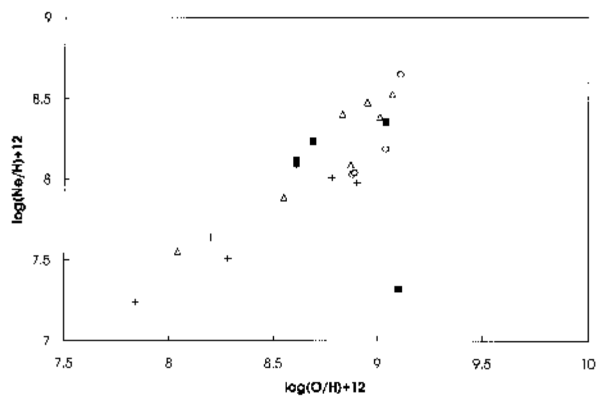

Fig. 4. The same as Fig. 1 for Ne/H vs. O/H

IIa PN in view of its N/O value, kinematical properties and location in Fig. 1.

The two objects classified as bulge or type V PN (cf. Maciel 1989), namely M1-20 and M3-8 (Acker et al. 1991), have large radial velocities as expected. For these nebulae, the rotation curve given by Maciel & Dutra (1992) cannot be applied, since it requires $R > 5$ kpc. The object H4-1 is a type IV PN, as shown by its relatively high helium abundance, low metallicity and extremely large distance to the galactic plane. Other recent distance determinations in the literature are consistent with the results presented here (cf. Cahn et al. 1992). For NGC 3132 the abundances of He, O and N reported here are in good agreement with previous estimates (Pottasch 1984; Peimbert & Torres-Peimbert 1983). Abundances of Ne, Ar and S are reported for the first time.

For the planetary nebulae NGC 3699, He 2-143, M 1-14, M 2-4 and PB 3 few abundance data are found in the literature, and for most of the elements, we are reporting the abundance values for the first time.

NGC 3699 and He 2-143: These PN have chemical and kinematical properties which are characteristic of type I PN, which is also confirmed by their location in Fig. 1.

M 1-14: This is a type III PN as suggested by its high peculiar velocity and by the low metallicity.

M2-4: This object was classified as a type III PN as suggested by its position on the radial abundance gradients plots, the low nitrogen abundance and the location in Fig. 1. However, the helium abundance is typical of a younger PN, and its space location and velocity suggest that it may be a bulge nebula.

PB3: The classification as a type IIa PN was based on the abundances (except for helium that is very high), its distance to the galactic plane and its position on distance-independent diagrams.

Finally, we observe that, despite our reduced sample, the average oxygen abundance for type I PN is about 0.2 dex lower than that of the sun, in agreement with the conclusions of Freitas Pacheco (1993) This oxygen depletion in type I PN could be an evidence of ON processing in their central stars or even a result of the dilution by the infalling halo material (Freitas Pacheco 1993). Recently, Kingsburgh & Barlow (1994) have seen no evidence for such depletion. However, their average oxygen abundance for non-type I objects could include the type III PN and therefore resulting in a lower value similar to that found for type I PN. We emphasize also that recent observations of unevolved Orion stars by Cunha & Lambert (1994) indicate that both stars and nebula are oxygen deficient by a factor 0.2 dex with respect to the solar value. These findings give further support to the planetary nebula data and suggest that oxygen was diluted after the birth of the sun.

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