Revista Mexicana de Astronomía y Astrofísica, **27**, 157-160 (1993)

ABUNDANCES FOR A SAMPLE OF SOUTHERN GALACTIC PLANETARY NEBULAE

Robin L. Kingsburgh[1] and M.J. Barlow
Department of Physics & Astronomy, University College London

RESUMEN

Se presantan abundancias elementales para una muestra de 70 nebulosas planetarias (NP) galacticas del sur, basadas en observaciones opticas y ultrovioleta. En esta muestra, se clasifican solidamente 6 objetos Tipo I. Para las NP Tipo I, no se encuentran de agotamentio de oxygen comparando con NP que no son de Tipo I, por tanto el ciclo ON que operar durante la 2a fase de dragado no afecta significativamente las abundancias superficiales de la estrella progenitora. Para las NP que no son Tipo I, se encuentra que la conversion de carbon a nitrogeno durante la 1a fase de dragado es suficiente por explicar el aumento en abundancia de nitrogeno en regiones HII. Una comparison entre abundancias de nitrogeno en NP y abundancias de carbon+nitrogeno en regiones HII galacticas indica que aproximadamente 30% del carbon inicial es convirtido en nitrogeno por las NP que no son Tipo I. Sin embargo, explicar las altas abundancias de nitrogeno en las NP Tipo I, el quemado de la envolvente convectiva durante la 3a fase de dragado es necesario. Abundancias totales C+N+O se correlacionan con C/H para la muestra combinanda de Tipo I y no-Tipo I; la abundancia de carbon se incrementa via quemado de helio y subsecuentemente los productos son traidos a la superficie en el 3a fase de dragado.

ABSTRACT

We present elemental abundances for a sample of 70 southern Galactic planetary nebulae (PN), based on observations at both UV and optical wavelengths. In this sample, 6 definite Type I objects are identified. For the Type I PN, no evidence for oxygen depletion compared to non-Type I PN is found, hence the ON cycle which operates in the 2nd dredge up does not significantly affect the surface abundances of the progenitor star. For the non-Type I PN, we find that the conversion of carbon into nitrogen during the first dredge-up phase is sufficient to account for the increase in nitrogen abundances over HII regions. A comparison between nitrogen abundances in PN and carbon+nitrogen abundances in Galactic HII regions indicates that roughly 30% of the initial carbon is converted into nitrogen for the non-Type I PN. However, in order to explain the high nitrogen abundances derived for Type I PN, convective envelope burning during the 3rd dredge-up phase is required. Total C+N+O abundances are found to be correlated with C/H for the combined non-Type I and Type I sample; the carbon abundance is increased via He-burning, the products of which are subsequently brought to the surface by the 3rd dredge-up.

Key words: **PLANETARY NEBULAE: GENERAL**

[1]present address: Instituto de Astronomía, Universidad Nacional Autónoma de México

1. INTRODUCTION

This abundance study combines extensive optical observations of 70 Galactic planetary nebulae (PN) covering 3150–7400 Å, with ultraviolet observations obtained with the IUE for approximately half this sample. The derivation of abundances includes the use of a new ionization correction factor (ICF) scheme, which is based on detailed photoionization models of 10 PN (Walton, Barlow, Monk, & Clegg, in preparation). This scheme allows more accurately for unobserved high ionization stages, which can be particularly important in the case of Type I PN. It also approximates for effects like the efficiency of charge exchange reactions, which the more simplified ICF schemes cannot take into account.

2. OBSERVATIONS

Low and medium resolution optical spectra were obtained at the AAT with the RGO Spectrograph and IPCS as detector, and with the B&C Spectrograph and IDS as detector. Low resolution UV spectra obtained with the IUE satellite were accessed via the IUE Uniform Low-Dispersion Archive. Additionally, new low resolution observations of Fg 1, M 3-1 and M 3-3 were obtained with the IUE SWP camera.

3. ANALYSIS

The abundance analysis included a derivation of He/H, O/H, N/H, C/H, Ne/H, Ar/H and S/H ratios (by number). Helium abundances were derived following Clegg (1987), where collisional contributions from the 2^3S state to the populations of the upper He I states were estimated and removed. Carbon abundances were derived using collisionally excited lines only.

Final average abundances are presented in Table 1 for non-Type I PN, Type I PN, H II regions and the Sun.

Table 1: Average PN Abundances

ratio	non-Type I	Type I	HII Regions[a]	Solar[b]
He/H	0.111±0.016 (43)	0.151±0.034 (6)	0.100±0.010	0.098±0.008
O/H	8.70±0.15 (48)	8.61±0.15 (6)	8.70±0.25	8.93±0.035
N/H	8.13±0.20 (36)	8.75±0.15 (6)	7.57±0.33	8.00±0.05[c]
C/H	8.8 ±0.30 (18)	8.21±0.15 (2)	8.46±0.2	8.60±0.05[d]
Ne/H	8.03±0.20 (47)	8.02±0.10 (6)	7.90±0.17	8.09±0.10
(C+N)/H	8.88	8.86	8.51	8.70
(C+N+O)/H	9.10	9.05	8.92	9.13

Notes to Table 1: Abundances for He are by number. Abundances for O, N, C and Ne are on a logarithmic scale, where H=12. The number of PN included in each average is enclosed in parentheses following each average. Three non-Type I PN with values of N/O>1 were not included in the nitrogen or helium abundance averages. [a] – HII region abundances from Dufour (1984). [b] – solar abundances from Grevesse & Anders (1989), except for [c] – nitrogen (Grevesse et al. 1990) and [d] – carbon (Grevesse et al. 1991).

4. DISCUSSION

4.1. Type I PN

Galactic Type I PN are defined as having (N/O) ≥ -0.3 and He/H ≥ 0.125 (Peimbert & Torres-Peimbert 1983). Type I PN are often bipolar, and show a wide range of ionization stages. Figure 1 plots log(N/O) vs. log(He/H). Inspection of Figure 1 reveals a predominantly continuous sequence of N/O vs. He/H, with only 6 objects clearly separated from the bulk of the sample (all are bipolar in morphology); objects with log(N/O) ≥ -0.3 do not seem to be distinct from those with log(N/O) < -0.3; the He/H criterion is needed as well. This continuous distribution presumably points to a continuous range of progenitor mass. The 6 objects which we definitely classify as Type I are: He 2-111, He 2-112, He 2-15, NGC 2440, NGC 2899 and NGC 5189, using both N/O and He/H criteria. In all Figures, Type I PN are represented by filled circles.

Inspection of Figure 1 reveals there to be no correlation between N/O and He/H for the non-Type I PN. A clear trend of increasing N/O with increasing He/H is seen for the Type I PN only.

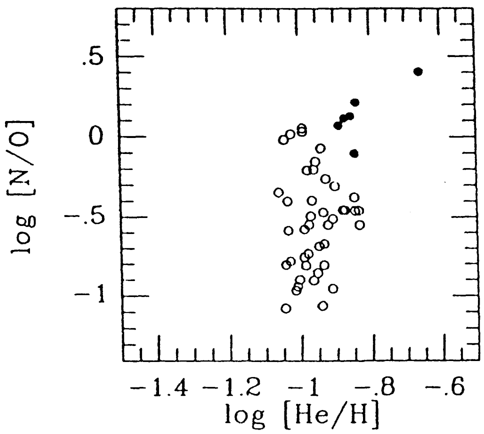

Fig. 1. — Log(N/O) vs. log(He/H). Type I PN are filled circles, non-Type I PN are open circles in all plots. A trend of increasing N/O ratio with increasing He/H ratio is found for only the Type I PN.

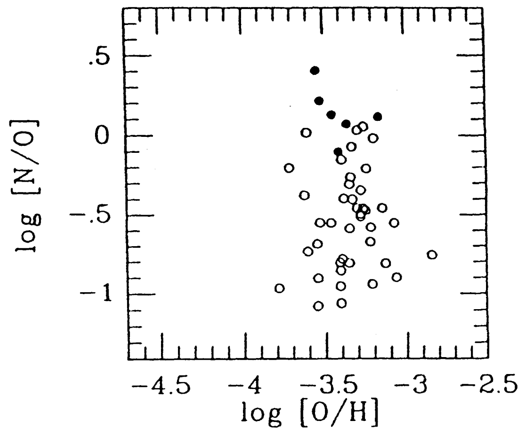

Fig. 2. — Log(N/O) vs. log(O/H). No inverse correlation is seen, hence no destruction of oxygen via the ON cycle is found, as predicted by Becker & Iben (1980) for the 2nd dredge-up phase, even for the Type I PN.

4.2. Helium

For a sample of 51 non-Type I PN, the average He/H = 0.111±0.016 by number, or by mass Y=0.307±0.035. For Galactic H II regions, the mean He/H = 0.100±0.010 by number or 0.286±0.029 by mass. The nominal excess of helium found in non-Type I PN over H II regions (which is indicative of the amount of stellar processing of H→He which occurred in the progenitor star) is ΔY=0.021. However, due to the sensitivity of helium abundances to collisional corrections, this number must be considered somewhat provisional at present.

The mean He/H abundance found for the 6 Type I PN is 0.151±0.034 by number or Y=0.377 by mass. The excess of helium found in Type I PN over H II regions is ΔY=0.091.

4.3. Oxygen

The ON cycle produces nitrogen at the expense of oxygen. Products of the ON cycle are believed to enhance the surface abundances of the PN progenitor star during the 2nd dredge–up phase, while it is on the AGB. If this process occurs significantly, one would expect an inverse trend between the N/O ratio and the O/H ratio. Figure 2 plots log(N/O) vs. log(O/H). Inspection of Figure 2 reveals that no decrease in O/H is seen with higher N/O. The oxygen abundances for the Type I PN lie in the same range as the oxygen abundances found for non-Type I PN. For 43 non-Type I PN, the average O/H = $(5.06\pm2.31)\times10^{-4}$ by number. For the 6 Type I PN, the mean O/H=$(4.07\pm1.47)\times10^{-4}$, equivalent to the non-Type I average within the errors.

Another way to look for ON processing is via a negative correlation between O/H and He/H, because if the temperature is high enough for the ON cycle to occur, H burning to He will also occur. For this sample, no trend of increased helium abundance with decreased oxygen abundance is found. Thus we find that the products of the 2nd dredge-up do not significantly alter the surface abundances of the progenitor star while it is on the AGB.

4.4. Nitrogen

Nitrogen can be produced in 2 ways: via the ON cycle, where N is created at the expense of O; or via the CN cycle, where N is created at the expense of C. Fig. 2 ruled out the production of nitrogen via the ON cycle as being significant. Products of the CN cycle may be brought to the surface during the 1st dredge–up, or during the 3rd dredge–up, when CN burning of dredged-up carbon at the bottom of the hydrogen convective envelope can occur for sufficiently massive stars. In order to ascertain the relative importance of these two processes, let us compare the nitrogen abundance of non-Type I PN and Type I PN with the total carbon+nitrogen abundances found for HII regions (Table 1). In order to obtain the mean N/H ratio of $(1.36\pm0.85)\times10^{-4}$ by number for non-Type I PN, 32% of the carbon originally present has to be converted to nitrogen. This value

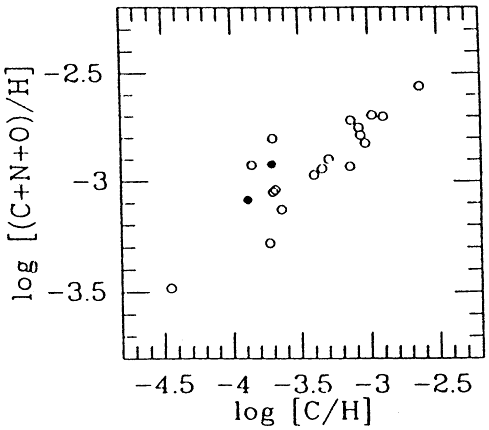

Fig. 3. — Log[(C+N+O)/H] vs. log(C/H). A positive correlation between (C+N+O)/H versus C/H is seen. This is consistent with the prediction that carbon is produced via triple-α burning and is subsequently brought to the surface of the AGB star during the 3rd dredge-up phase.

is consistent with that predicted for the 1st dredge-up phase in the solar metallicity models of Becker & Iben (1980), where 30% of the initial carbon present is converted to nitrogen. Thus for non-Type I PN, the nitrogen abundances are consistent with those predicted from the 1st dredge-up. For the Type I PN however, even if all the initial carbon is converted to nitrogen, the maximum possible N/H ratio is 3.25×10^{-4} by number, which is roughly a factor of 2 less than that found for the average Type I PN, where N/H=$(5.65\pm2.06)\times10^{-4}$. Since we find no evidence for oxygen depletion due to the 2nd dredge-up, this implies that convective envelope burning, where primary carbon produced by the 3α process is converted to N, is required to produce the high nitrogen abundances found for the Type I PN.

4.5. Carbon

Figure 3 plots log[(C+N+O)/H] vs. log(C/H). A strong correlation is seen, consistent with the scenario of carbon produced via the 3α process being brought to the surface by the 3rd dredge-up.

In this sample, we find that 9 of the 20 objects have C/O > 1. This ratio of ~45% C-rich to O-rich PN is somewhat lower than the ratio of 62% found by Zuckerman & Aller (1986; ZA) for a sample of 68 Galactic PN. If we re-examine the sample of ZA, and exclude objects where the C II 4267 Å line was used to derive the C abundance, and also exclude proto-PN, halo objects and objects with C/O=1, the percentage ratio of C-rich to O-rich objects drops to 51%, for a sample size of 36, which is consistent with the ratio found in our sample.

REFERENCES

Becker, S.A. & Iben, I. 1980, ApJ, 237, 111

Clegg, R.E.S. 1987, MNRAS, 221, 31p

Dufour, R.J. 1984, in: IAU Symp. No. 108, eds. S, van der Bergh & K.S. de Boer, Dordrecht, Holland, p. 353

Grevesse, N. & Anders, E. 1989, in Cosmic Abund. of Matter, AIP Conf. Proc. 183, ed. C.J. Waddington, American Institute of Physics, N.Y., p. 1

Grevesse, N., Lambert, D.L., Sauval, A.J., van Dishoeck, E.F., Farmer, C.B. & Norton, R.H. 1990, A&A, 232, 225

Grevesse, N., Lambert, D.L., Sauval, A.J., van Dishoeck, E.F., Farmer, C.B. & Norton, R.H. 1991, A&A, 242 488

Zuckerman, B. & Aller, L.H. 1986, ApJ, 301,772

Peimbert, M. & Torres-Peimbert, S. 1983, in: IAU Symp. No. 103, ed. D.R. Flower, Reidel, Holland, p. 233

M.J. Barlow: University College London, Dept. of Physics & Astronomy, Gower Street, London WC1E 6BT, U.K.

Robin L. Kingsburgh: Instituto de Astronomía, UNAM, Apartado Postal 70-264, 04510 México, D.F., México.