ABUNDANCES IN LOCAL GROUP PLANETARY NEBULAE

JAMES B. KALER

Department of Astronomy, University of Illinois
103 Astronomy Bldg., 1002 West Green, Urbana, IL 61801, USA

I. Why?

We are able to measure the chemical compositions of hundreds of planetary nebulae in our own Galaxy and in the Magellanic Clouds. Why, therefore, do we need to expend the effort to observe much more difficult targets in other Local Group galaxies? A severe lack of distances does not allow us to place Galactic planetary nuclei on the log L-log T plane with any degree of accuracy, so we cannot properly examine composition differences relative to core mass and state of evolution. We can perform such tasks for Magellanic Cloud objects, but do not know how the Clouds' low-metallicities affect the results, and thus do not know how this sample of planetaries relates to the nebulae in our own system. We know, for example, that in the Clouds, nitrogen enrichment begins above a core mass of about 0.68 $M_\odot$ (Kaler and Jacoby 1990), but other than a clear link between core mass and chemical enrichment in the Galaxy, do not know at what point it becomes important. To study such relationships, we therefore have to go to other galaxies with a variety of initial conditions for which distances are secure, namely those of the Local Group.

2. Published Results

Results to date on planetaries in the Local Group (minus the Galaxy, LMC, and SMC) are characterized by extreme paucity. Ford's (1983) definitive summary included abundances for single nebulae in Fornax (Danziger et al. 1978), NGC 185 (Jenner and Ford 1978), NGC 6822 (Dufour and Talent 1980), and M 32 (Jenner, Ford, and Jacoby 1979) and for a trio of objects in M 31, two of which are in the halo. These were later assigned improved abundances by Jacoby and Ford (1986), who also reviewed the literature. The NGC 185 and NGC 6822 nebulae are highly enriched in nitrogen and that in M 32 probably is, but less so. The M 31 objects exhibit normal nitrogen and indicate O/H variations in the halo. Maran et al. (1984) subsequently determined a very high C/O ratio (nearly 4) in the Fornax object.

3. Some New Results

To help ameliorate the lack of data, Jacoby, Kaler, and Ciardullo (1995) observed 90 planetaries in the bulge of M 31 with the Kitt Peak 4-meter's multiple object spectrograph, and Jacoby et al. (1995) similarly observed another 15 in NGC 205. Of these, 29 of the M 31 set have been reduced and analyzed, enough to provide some good statistical information, as have two of the NGC 205 set (those with

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upper limits to [O II] λ3727 intensities). Preliminary results are presented in Table 1, which gives abundances derived from Kaler's (1985) updated code (see Kaler and Jacoby 1990). The table also gives a summary of the compositions of the other nebulae discussed above as calculated with the same code. Nebular conditions present a severe problem. Of the M 31 nebulae, only a handful allow measurement of electron temperature or density, and these are subject to considerable error. All but one are low excitation, so the electron temperatures should be of the order of 10,000 K (Kaler 1986). That and a density

Table 1. Local Group Abundances

	He/H	10^4O/H	N/O	Ne^{+2}/O
M 31 (JK)[a]	0.15±0.02	6.0±2.0	0.19±0.10	0.18±0.04
M 31 (JF)	0.15	2.8	0.36	0.16
M 32	0.08	3.25	1.7	...
NGC 185	0.16	0.8	>2.1	0.07
NGC 205	...	>4	>0.2	0.14
NGC 6822	0.16	1.5	4.6	0.02
Fornax	0.11	2.2	0.14	0.13
LMC[b]	0.085	3.7	0.18	...
SMC[b]	0.10	1.6	0.17	...
Galaxy	0.10	5.3	0.14	0.18[c]

[a] T_e = 10,000 K, N_e = 10^3 cm^{-3}; [b] M_c < 0.65; [c] Actual Ne/O

of 10^3 cm^{-3} are adopted to give the mean M 31 bulge abundances in the first row. Raising the temperature to 15,000 K approximately reduces O/H by a factor of 3 and doubles N/O. Increasing the density to 10^4 increases O/H by about 30% and decreases N/O by roughly 10%. The objects' spectra are remarkably similar, and are obviously the result of a homogeneous, low-mass population. The variations among abundances are treated as random errors, and the errors are the mean errors of the mean.

The abundances recomputed for the next six rows are based on the actual calculated T_e[O III], T_e[N II] from Kaler's (1986) relationships and a density of 10^3 cm^{-3}. For comparison, the last three rows present abundances from the literature. Those for the Magellanic Clouds are from Kaler and Jacoby (1990) for core masses below 0.65 $M_\odot$, which are probably most appropriate for the M 31 bulge planetaries and for those in elliptical galaxies. Mean He/H and Ne/O for Galactic nebulae are taken from Henry (1990), and O/H is presented for disk objects from Kaler (1980).

4. Some Discussion

He/H for the previously published results on Local Group nebulae has been reduced some by the application of Clegg's (1987) collisional formula. He/H still seems high in M 31. In the bulge objects, however, the intensity of He I λ5876 is probably overestimated, as [N II] λ6548 is too strong relative to [N II] λ6584 (the latter alone is used for N/O ratios). O/H for the M 31 bulge is high relative to the other values, and may be appropriate to the metal-enrichment seen in the Galactic bulge (Price 1981). It is very close to that found in the galactic disk, assuming the adopted electron temperature and density are correct. O/H for smaller galaxies seems clearly lower. The mean N/O for M 31, the Galaxy, and the low-mass populations of the Magellanic Clouds are remarkably similar. Only in three small galaxies do we find highly enriched nitrogen. The high C/O and low N/O in the Fornax planetary is consistent with the an anticorrelation between the C and N enrichment suggested for the Magellanic Clouds (Kaler and Jacoby 1990, 1991). The accuracy of N/O is checked by the mean Ne^{+2}/O ratios. We might expect Ne/O to be constant among objects, as it is in the Galaxy, and therefore the calculated Ne^{+2}/O must be less than the mean Galactic Ne/O, which it is, strongly suggesting that the [O II] λ3727 intensities (which are hard to derive, given significant atmospheric dispersion and small spectrograph apertures) are relatively free of systematic error.

The results are intriguing. We see the expected similarity between M 31 and the Galaxy and possible differences between the planetaries in the large spirals and those in the smaller systems. This review demonstrates the importance of probing into them, to gain another dimension in the study of how advanced giants enrich their atmospheres and eject their mass back into their respective galaxies as the planetary nebulae.

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