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Filling factor and temperature variations in planetary nebulae

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Abstract. We have found a strong correlation between small filling factors and large t^2 values in planetary nebulae. We have also found that in general the filling factor for Type I PNe is smaller than for Type II PNe. These results imply that the abundance correction due to temperature inhomogeneities in general is larger for Type I PNe than for Type II PNe. This difference permits to reproduce the expected abundance difference between PNe of Type I and II predicted by Galactic chemical evolution models.

Keywords. ISM: abundances, planetary nebulae: general; Galaxy: abundances

1. Discussion

To test the abundance determinations of PNe we will compare the Galactic chemical evolution model by Carigi & Peimbert (2011) with the abundances derived from collisionally excited lines for PNe of Type I and Type II. To make this comparison we have to address several problems. We need to estimate: a) the correction of the O/H value due to the temperature structure of the nebulae, b) the fraction of H that is converted into He during the central star evolution, c) the fraction of O trapped by dust grains in the nebulae and d) the average ages of the two types of PNe.

We present a preliminary discussion of the relationships for a set of PNe between: a) the abundance discrepancy factor, ADF, versus the radius of the nebulae, b) the filling factor, defined by $\epsilon = N_e(\mathrm{rms})^2/\mathrm{N_e(FL)}^2$, versus the ADF values, and c) ϵ versus radius.

We are in the process of increasing the number of data points with accurate ϵ, t^2 (Peimbert 1967), and abundance values. The sources of error, that in some cases are not independent, include the following: the angular radius θ (e. g. Mallik & Peimbert 1988), the distance to the object, the average root mean square density $\langle N_e(\mathrm{rms})\rangle$, the average forbidden line density $\langle N_e(\mathrm{FL})\rangle$, the reddening correction $C(\mathrm{H}\beta)$, the ADF that includes the errors in the line intensities, and the average t^2 value.

In Table 1 we compare the Galactic chemical evolution model by Carigi & Peimbert (2011) with: a) the H II region abundances of the solar vicinity derived form RLs by Esteban and collaborators corrected by the amount of O embedded in dust grains according to Peimbert & Peimbert (2010), b) the metal richest F and G stars of the solar vicinity studied by Bensby & Feltzing (2006), c) the protosolar abundances presented by Asplund *et al.* (2009), and d) the abundances for PNe of Types I and II presented in the literature and in this poster.

2. Conclusions

1) We find a strong correlation between the ADF value and the filling factor, or t^2 and ϵ. The smaller values of ϵ imply larger density variations, and in the presence of larger density variations we expect larger temperature variations.

Table 1. 12 + log O/H values.

Age (Gyr)	G.C.E.[a]	Type I PNe (CELs)	Type I PNe (RLs)	Type II PNe (CELs)	Type II PNe (RLs)	Other
0	8.88	...	...	...	...	8.87[b]
1	8.84	8.57[c]	9.14[d]	...	...	8.84[e]
4.5	8.68	...	...	...	...	8.73[f]
6	8.58	...	...	8.58[c]	8.87[d]	...

[a] Galactic chemical evolution model, solar vicinity, Carigi & Peimbert (2011).
[b] Solar vicinity H II regions, Carigi & Peimbert (2011).
[c] Solar vicinity PNe, Stanghellini & Haywood (2010) and Henry *et al.* (2010).
[d] This work.
[e] Young F and G stars of the solar vicinity, Bensby & Feltzing (2006).
[f] Protosolar value, Asplund *et al.* (2009).

2) From Galactic chemical evolution models it is found that $\langle z \rangle$ is about 100 pc for Type I PNe (about one Gyr old) and about 280 pc for Type II PNe (3–9 Gyr old), see Allen *et al.* (1998) and García-Segura *et al.* (2002). Furthermore it is also found that the O/H value of the ISM when Type I PNe were formed was about 0.25 dex higher than when Type II PNe were formed.

3) We find that the ADF for Type I PNe is about 0.25 dex higher than for Type II PNe. In other words that from recombination lines it is found that the O/H value for Type I PNe is about 0.25 dex higher than for Type II PNe.

4) Stanghellini & Haywood (2010) and Henry *et al.* (2010) find that for the solar neighborhood the 12 + log O/H values for Type I and Type II PNe derived from CELs are practically the same and amount to about 8.58. Rodríguez & Delgado-Inglada (2011) find that for 8 well observed PNe of Type II of the solar vicinity the 12 + log O/H average value for CELs amounts to 8.68 and for RLs amounts to 8.98.

5) We find that the O/H values for Type I and Type II PNe derived from RLs are about 0.3 dex higher than those predicted by Galactic chemical evolution models. This discrepancy should be studied further.

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