Planetary Nebulae: Multi-Wavelength Probes of Stellar and Galactic Evolution
Proceedings IAU Symposium No. 323, 2016
X. Liu, L. Stanghellini & A. Karakas, eds.
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doi:10.1017/S1743921317001624

The systematic uncertainties introduced by atomic data in nebular abundance determinations

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Abstract. Atomic data selection is one important source of systematic uncertainty since there are important variations between the values provided by different authors. We explore the effect of using different atomic data in the determination of physical conditions and chemical abundances in a sample of Galactic planetary nebulae and H II regions. We find that the available datasets introduce significant differences in the results, especially at densities above 10^4 cm^{-3}, where O/H and N/O reach uncertainties higher than a factor of 4.

Keywords. planetary nebulae: general, ISM: abundances, atomic data, H II regions

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The derivation of chemical abundances in ionized nebulae requires the values of transition probabilities and collision strengths for transitions involving the lower energy levels of several ions. These atomic data are calculated using different approaches that lead to variations among the existing determinations, and the uncertainties are very difficult to estimate (Aggarwal & Keenan 2013). We explore these uncertainties by calculating the impact of different combinations of atomic data in the derived electron densities, n_e, electron temperatures, T_e, and ionic an total abundances for all the posible combinations of atomic data. Note that a single set of atomic data, can affect all the calculations, and different combinations of atomic data will affect the results in complex ways.

To explore the effect that atomic data have in the computations of physical conditions and chemical composition in nebular objects we have selected from the literature a sample of 36 Galactic planetary nebulae (PNe) and 8 H II regions with deep observed spectra and good spectral resolution. The sample objects cover a wide range in characteristics such as density and degree of ionization so they can be considered representative of the population of ionized nebulae. We use the atomic datasets available in the software for nebular analysis PYNEB (Luridiana *et al.* 2015), for the ions O^+, O^{++}, N^+, Cl^{++}, Ar^{++}, Ar^{+3}, Ne^{++}, S^+, and S^{++} (52 atomic datasets in total). For each object we obtain the distributions of results for the values of T_e[N II], T_e[O III], n_e[S II], n_e[O II], n_e[Cl III], n_e[Ar IV], and the ionic and total abundances of O, N, Cl, Ar, Ne, and S, implied by the different combinations. We calculate the average density obtained from the four density diagnostics, and use T_e[N II] to determine the abundances of the single ionized ions, with the exception of He^+, and T_e[O III] for the remaining ions. The total abundances of O, Cl, S, Ar, and Ne are obtained using the ionization correction factors proposed by Delgado-Inglada *et al.* (2014). For N we use the traditional ICF, $N/O = N^+/O^+$.

We measure the total widths of the final distributions for the different parameters, which give an indication of the uncertainties introduced by atomic data, and plot them as a function of the median of the average density. The uncertainties in the average density are higher than a factor of 4 at $n_e \geqslant 10^4$ cm^{-3}. The uncertainties in temperature

https://doi.org/10.1017/S1743921317001624 Published online by Cambridge University Press

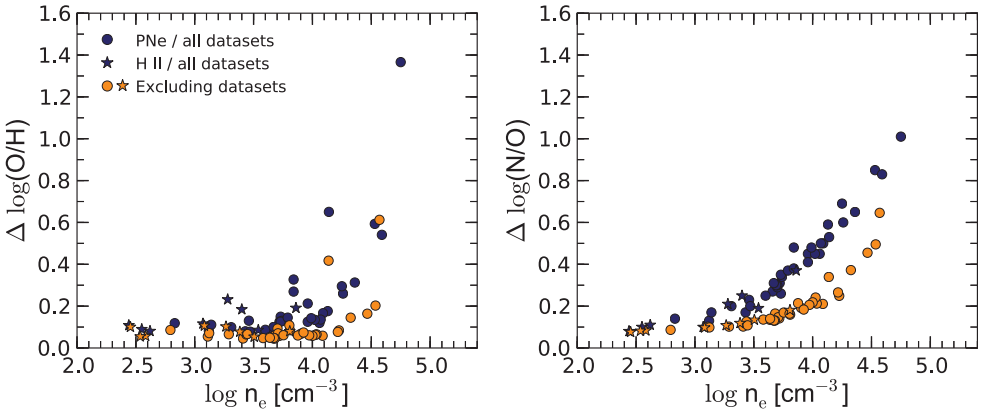

Figure 1. Total widths of the O/H and N/O abundance ratios for all the objects in the sample. The blue symbols show the results implied by all the available 52 datasets; the orange symbols show the results when we exclude the 4 datasets that lead to discordant values of density or temperature.

are below 0.05 dex at $n_e \geqslant 10^4$ cm^{-3} but reach a factor of 2 for T_e[N II] at higher densities. The spreads in the ionic abundances reach factors higher than 30 at $n_e \geqslant 10^4$ cm^{-3} for ions whose transitions have upper levels with low critical densities, like O^+, N^+, S^+. The spreads in total abundances are ~ 0.2 dex at low densities, but increase to factors of 4–6 or higher at $n_e \geqslant 10^4$ cm^{-3}. The total uncertainties in the abundances of O/H and N/O are shown in Figure 1, where the dark symbols represent the results implied by all the available 52 datasets. For O/H we obtain variations of a factor of 2 at $n_e \sim 10^4$ cm^{-3} that increase to factors of 6–25 at the highest densities. Uncertainties are especially important for N/O where the differences reach a spread of one order of magnitude at $n_e \geqslant 10^4$ cm^{-3}.

We identify four datasets that lead to discordant values of density or temperature: the transition probabilities of Wiese, Fuhr, & Deters (1996) and Tayal & Zatsarinny (2010) for O^+ and S^+, respectively, and the collision strengths of Palay *et al.* (2012) and Mendoza (1983) for O^{++} and Ar^{+3}, respectively. By excluding these datasets the differences are significantly reduced, as can be seen in Figure 1, where the orange symbols show the total widths obtained excluding these atomic data. The whole analysis will be presented in Juan de Dios & Rodríguez (in prep.).

Acknowledgements. We acknowledge support from an IAU travel grant and the Mexican CONACYT grant CB-2014-240562.

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