RevMexAA (Serie de Conferencias), **44**, 22–22 (2014)

XIV Latin American Regional IAU Meeting (Florianópolis/SC, Brazil, 25-30 November 2013)
Editors: A. Mateus, J. Gregorio-Hetem & R. Cid Fernandes

ABUNDANCE DETERMINATIONS IN IONIZED NEBULAE AND THEIR SENSITIVITY TO TEMPERATURE

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Our main source of uncertainty in the determination of chemical abundances in H II regions and planetary nebulae arises from a discrepancy: the abundances implied by recombination lines are larger than those implied by collisionally excited lines. The discrepancy amounts to a factor of 2 in most objects, but reaches much higher values in some planetary nebulae. There are several possible explanations for this effect. Here we explore a recent proposal and determine what kind of deviations from a Maxwellian electron energy distribution are needed in order to reproduce the measured abundance discrepancies. We note the parallelisms between this explanation and other explanations that are based on the sensitivity to temperature of collisionally excited lines: the presence of metal-rich inclusions within the ionized gas or temperature fluctuations in a chemically homogeneous gas.

We have compiled a sample of 21 H II regions and 71 planetary nebulae (PNe) with available spectra of enough quality to measure O II lines of the brightest multiplet, V1. We used these lines to derive in a homogeneous way for all the sample objects the values of O^{++}_{RLs}, the oxygen abundances implied by recombination lines (RLs). We also derived O^{++}_{CELs}, the oxygen abundances implied by the collisionally excited lines (CELs) [O III] $\lambda\lambda 4959, 5007$. We used the recombination coefficients of Storey (1994), the collision strengths of Aggarwal & Keenan (1999), and the transition probabilities of Wiese et al. (1996) and Storey & Zeippen (2000). The calculations were performed for the average electron density implied by different diagnostics and T_e([O III]), the electron temperature implied by the intensity ratio of [O III] lines $(\lambda 4959 + \lambda 5007)/\lambda 4363$.

We compared the resulting abundance discrepancy factors, $ADF(O^{++}) = O^{++}_{RLs}/O^{++}_{CELs}$, with the ones that would be obtained if the electrons did not follow a Maxwell-Boltzmann distribution but a κ-distribution, as proposed by Nicholls et al. (2012). We find that the values of $ADF(O^{++})$ in some PNe and in H II regions of near-solar metallicity can be reproduced by moderate deviations from a Maxwellian, with $\kappa = 20$–50, but most PNe and low metallicity H II regions require larger deviations, even reaching $\kappa \lesssim 5$.

Moreover, the values of $ADF(O^{++})$ in H II regions of near-solar metallicity, with $T_e([O\,III]) < 10^4$ K, decrease with increasing T_e([O III]). This trend goes in the opposite direction to the one that we would get from errors in the temperature determinations. If the trend is not introduced by errors in the recombination coefficients, we find that it could arise from any of the three effects related to the sensitivity to temperature of CELs: (1) deviations of the Maxwell-Boltzmann distribution characterized by a small range of values of the κ parameter, (2) temperature fluctuations of comparable amounts in all the involved objects, and, probably, (3) metal-rich inclusions with roughly consistent properties.

Finally, we also find that most of the PNe that deviate from the trend defined by the H II regions towards larger values of $ADF(O^{++})$ show a high degree of excitation.

Further details will be found in Rodríguez & Manso Sainz (in preparation).

MR acknowledges support from the IAU and from Mexican CONACYT grant CB-2009-01/131610; RMS acknowledges support from the Spanish MINECO under grants AYA2010-18029 and CONSOLIDER INGENIO CSD2009-00038.

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