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Plasma diagnostics for planetary nebulae and H II regions using N II and O II optical recombination lines

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Abstract. We carry out plasma diagnostic analysis for a number of planetary nebulae (PNe) and H II regions. We use N II and O II optical recombination lines (ORLs) with new effective recombination coefficients calculated under the intermediate coupling scheme, for a range of electron temperatures (T_e) and densities (N_e), and fitted against the most reliable measurements. Comparing T_e derived from ORLs, collisionally excited lines (CELs), the hydrogen Balmer Jump, and/or He I if available, we find the relation T_e(ORLs) < T_e(He I) < T_e(H I BJ) < T_e(CELs), confirming the physical conditions in the bi-abundance model postulated by Liu *et al.*, i.e. the nebula contains another cold, metal-rich and probably H-deficient component.

Keywords. planetary nebulae: general, HII regions, atomic data, atomic processes

1. Methodology

For N II ORLs, the effective recombination coefficients cover a log T_e [K] range from 2.1 to 4.3, with an increment of 0.1, and a log N_e [cm^{-3}] range from 2 to 6 , also with an increment of 0.1. For O II ORLs, the effective recombination coefficients cover a log T_e [K] range from 2.6 to 4.2, with an increment of 0.2, and a log N_e [cm^{-3}] range from 2 to 5, also with an increment of 0.2, and later bilinearly interpolated to a resolution of 0.05 by 0.05. The location of the minimum χ^2 value corresponds to the optimal T_e and N_e for each wavelength combination of the observed intensities. Figure 1 of the poster† shows the log χ^2-distributions for 8 PNe and one H II region (Hf 2-2, M 1-42, NGC 6153, and M 2-36, NGC 7009, NGC 6543, IC 4191, M 3-32, and M 42), matching the archived data for each nebula against the theoretical predictions from each wavelength.

Once the optimal T_e and N_e were located for each PN, the comparison is also calculated for each combination of simulated intensities within a 1-σ Gaussian distribution confined to the errors of the observed intensities. Figure 2 of the poster† shows the Gaussian-distributions for N II and O II wavelengths within 1-σ of the observed intensities. The optimal T_e and N_e locations for each simulation would provide the error estimates of the optimal T_e and N_e from the observed intensities. The randomly generated intensities were combined for each simulation and compared with the theoretical predictions based on the effective recombination coefficients for each wavelength covering a range of temperatures and densities. Figure 3 of the poster† shows the frequencies of the optimal T_e and N_e locations derived from the simulated intensities.

†available at http://astroatom.wordpress.com/2011/08/15/
plasma-diagnostics-for-planetary-nebulae-and-h-ii-regions-using-n-ii-and-o-ii/

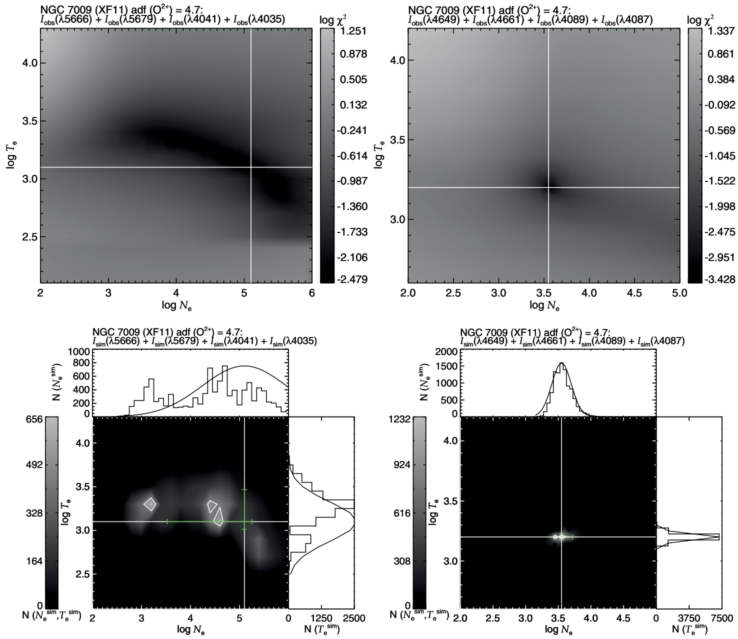

Figure 1. The top-left panel shows the χ^2 distribution for a combination of 4 major N II lines from Multiplets V3 & V39 over the T_e N_e grid for NGC 7009. The top-right panel shows the same for a combination of 4 major O II lines from Multiplets V1 & V48. The bottom-left shows the distribution of optimal T_e and N_e minima from randomly generated intensities within a 1-σ Gaussian distribution of the observed intensity for N II. The bottom-right shows the same for O II.

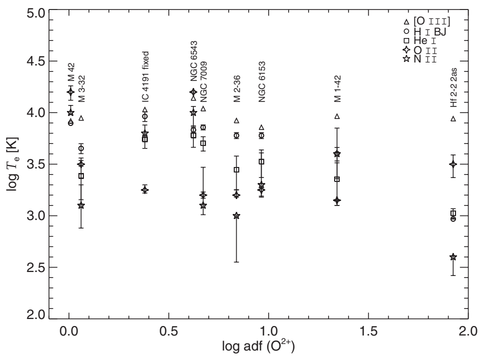

Figure 2. T_e results from our ORL diagnostics and from literature for 8 PNe and 1 H II region.

2. Results

For all nebulae analyzed here, the mean values of the electron temperatures and densities are listed as follows: log T_e ([O III]) $\sim$ 4.02, log T_e (H I BJ) $\sim$ 3.95, log T_e (He I) $\sim$ 3.75, log T_e (O II ORLs) $\sim$ 3.32, log T_e (N II ORLs) $\sim$ 3.29, log N_e (O II ORLs) $\sim$ 4.07, and log N_e (N II ORLs) $\sim$ 3.14. The T_e's for He I are derived from the λ7281/λ6678 ratio. Fig. 2 shows the results for the 8 PNe and 1 H II region discussed. Therefore the relationship among these electron temperatures is T_e (ORLs) < T_e (He I) < T_e (H I BJ) < T_e (CELs), which confirms the physical conditions predicted by the bi-abundance model, i.e. the PNe and H II regions contain a previously unknown cold, metal-rich and probably H-deficient component.

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