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Effects of the Temperature Structure on the Derivation of Abundances in HII Galaxies

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Abstract. We propose a methodology to perform a self-consistent analysis of the physical properties of the nebular material of HII galaxies adequate to the data that can be obtained with the XXI century technology. This methodology requires the production and calibration of empirical relations between the different line temperatures that should supersede the currently used ones based on very simple, and poorly tested, photo-ionisation model sequences.

The analysis of spectroscopic data covering from 3500 to 10500 Å, allowing a careful and realistic treatment of the observational errors yields total oxygen abundances with accuracies between 5 and 9%. These accuracies are expected to improve as better calibrations based on more precise measurements, both on electron temperatures and densities, are produced.

1. Observations

The blue and far red spectra were simultaneously obtained using double beam spectrographs, ISIS mounted on the WHT (for three objects, Hägele et al. 2006) and TWIN mounted on the 3.5m telescope of CAHA (for another seven). In the blue arm of ISIS the spectral range was 3200-5500 Å and in the red arm, 5500-10550 Å, with a spectral resolution of 0.86 and 1.64 Å/pix, respectively. The spectral ranges of the CAHA data were 3400-5700 Å and 5800-10400 Å in the blue and red arm respectively, with corresponding resolutions of 1.09 and 2.42 Å/pix. The instrumental configuration was planned in order to cover the whole spectrum from 3200 to 10550 Å, to guaranteeing the simultaneous measurement of the nebular lines of [O II] $\lambda\lambda$ 3727,29 and [S III] $\lambda\lambda$ 9069,9532 Å at both ends of the spectrum, in the very same region of the galaxy. A good signal-to-noise ratio was also required to allow the detection and measurement of weak lines such as [O III] λ 4363, [S II] λ 4068, and [S III] λ 6312.

2. Results and Conclusions

Four different electron temperatures (T([O III]), T([O II]), T([S III]) and T([S II]), and in three cases T([N II])) and electron density (n([S II])) have been computed from the emission line data using the five-level statistical equilibrium model in the task TEMDEN of IRAF. Ionic and total abundances of He, O, S, N, Ne, Ar and Fe are obtained using the stronger available emission lines detected in the spectra (see details in Hägele et al. 2006). The logarithmic N/O ratios found for the three galaxies with T([OII]) and T([NII]) determinations are -1.06±0.10, -1.26±0.12 and -1.20±0.13. For the other objects we estimate the log(N/O) ratio assuming T([OII]) $\simeq$ T([NII]). It is worth noting that an analysis of the data using photo-ionisation model sequences, i. e. T([OII]) derivation from T([OIII]) according to Stasińska (1990) models, would provide for one of the objects, SDSS J002101.03+005248.1, an N/O ratio larger by a factor of 3 (log N/O= -0.64). Therefore it is plausible that part of the scatter found in the N/O vs. O/H diagram may be due to the methodology employed in the derivation of the N/O ratios. The log(S/O) ratios found are barely consistent with solar (S/O=-1.39) except for J002101.03+005248.1 which it is lower by a factor of about 2.7.

The measurement of the [SIII] IR lines allows the calculation of the sulphur abundance parameter S_{23} (=([SII]+[SIII])/Hβ; Vílchez & Esteban 1996) probably the best empirical abundance indicator for HII galaxies, since the calibration is linear up to solar abundances, solving the ambiguity problem usually presented by this kind of objects. Our observations are in very good agreement with the calibration derived by Pérez-Montero & Díaz (2005).

The ionisation structure found for the observed objects from the O^+/O^{2+} and S^+/S^{2+} ratios points to high values of the ionising radiation as traced by the values of the "softness parameter" η (Vílchez & Pagel 1988) which is less than $\sim$1 for all objects.

The measurements of several different line temperatures and a careful and realistic treatment of the observational errors yield total oxygen abundances with accuracies between 5 and 10%. The fractional error is as low as 2% for the ionic O^{2+}/H^+ ratio and increases to 15% for the O^+/H^+ ratio. The accuracies are lower in the case of the abundances of sulphur (of the order of 20% for S^+ and 12% for S^{2+}), the error increases further (up to 30%) for the total abundance of sulphur due to the uncertainties in the ICF.

This is in contrast with the small errors quoted for line temperatures other than T([OIII]) in the literature, in part due to the commonly assumed methodology of deriving them from the measured T([OIII]) through theoretical relations. These relations are obtained from patronisation models and no uncertainty is attached to them. If this methodology were to be adopted, the theoretical relations should be adequately tested and empirical relations between the relevant line temperatures should be obtained in order to quantify the corresponding model uncertainties.

References

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