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OPTICAL AND NEAR-IR SPECTROSCOPY OF LOW EXCITATION H II REGIONS WITH THE GTC

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RESUMEN

La determinación de abundancias químicas en regiones de gas ionizado se basa en la detección de las líneas de emisión de tipo auroral, a partir de las cuales se pueden deducir las temperaturas de línea de distintos iones. Dichas líneas son débiles en objetos de baja excitación, por lo que su medición en muchos de ellos es sólo posible en telescopios de gran abertura. El GTC permitiría llevar a cabo un estudio exhaustivo de abundancias químicas en dichos objetos a partir de espectros de media–alta resolución, lo que acotaría aún más las restricciones observacionales a los modelos de evolución química en distintos tipos de galaxias.

ABSTRACT

The determination of chemical abundances in ionized-gas nebulae is based on the detection of auroral emission lines, from which it is possible to deduce the line temperatures of several ions. These lines are weak in low excitation objects, so their measurement is only possible in large aperture telescopes. The GTC would allow us to plan a comprehensive study of chemical abundances in such objects from mid to high resolution spectra, which would give place accurate observational constraints on models of chemical evolution.

Key Words: **GALAXIES: ABUNDANCES — H II REGIONS**

The introduction and use of both a new generation of ground-based telescopes of 8–10 m diameter and more sensitive detectors is going to allow the observation and subsequent analysis of a wide range of astrophysical objects with low surface brightness and/or at large distances that have not hitherto been accessible. These new instruments will also enhance the quality of the spectra and images of other objects that, although observed, have not been completely studied owing to the lack of data of high enough signal to noise.

The determination of chemical abundances in ionized-gas nebulae is an example of what these instruments could improve. In the so-called direct method, the chemical composition of H II regions is deduced from the value of the electron temperature, which can be calculated from the measured intensity line ratio of certain ions (e.g., [O III] (4959 Å+ 5007 Å)/4363 Å, [S III] (9069 Å+ 9532 Å)/6312 Å). Nevertheless, as faint auroral lines are intrinsically weak they are measurable only in objects of high excitation and/or at not very large distances.

This can be seen in Figure 1, where the spectra of both high (the upper panel) and low excitation (lower) H II regions are shown (Castellanos et al. 2002).

On the upper panel, H13 is classified as a giant extragalactic H II region (GEHR), on the outer part of the disk of NGC 628, a late-type normal spiral galaxy. The derived line temperatures for this region are nearly identical around 10 000 K. This diagnostic yields an oxygen abundance of $12+\log(\mathrm{O/H}) = 8.24 \pm 0.08$ for the gas (0.2 solar metallicity, if $12+\log(\mathrm{O/H})_\odot = 8.92$). CDT1, in the lower panel, is another GEHR in the inner part of the Sc spiral galaxy NGC 1232 and seems to be one of the most metallic H II regions for which a line temperature has been directly measured. In fact, the derived values for log O_{23} and log S_{23} are 0.25 and 0.11 respectively, which, according to Díaz & Pérez-Montero (2000) implies solar or greater than solar abundances. The derived values for the $t(S^{2+})$ and $t(N^+)$ ion-weighted temperatures in this region are 5400 and 6700 K. Hence, the value for the oxygen temperature is $12+\log(\mathrm{O/H}) = 8.95 \pm 0.20$ (1.1 solar metallicity)

The derived oxygen abundances for both regions explain the observed differences in the spectra. At high metallicity, the forbidden oxygen lines are far less intense than at low metallicity (as the gas cools down, the oxygen lines dominate in the mid infrared). It is clearly seen that this is not the case for the near-infrared (NIR) sulfur lines owing to their lower dependence on the line temperature. Hence,

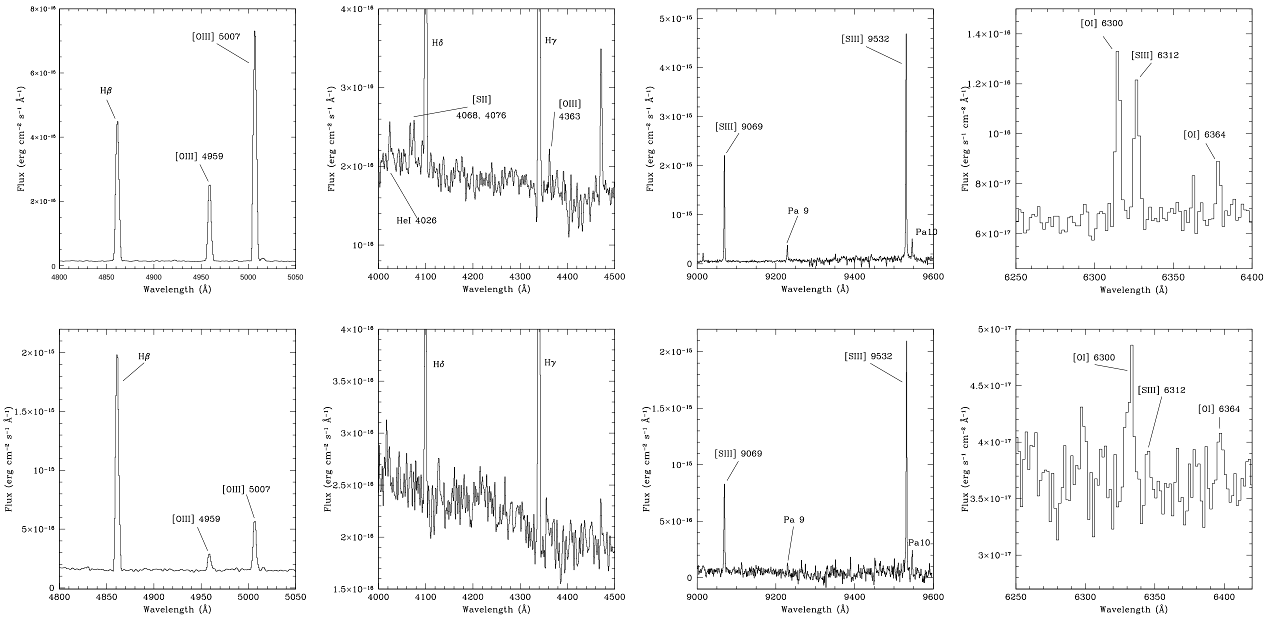

Fig. 1. The spectra of H13 (upper panel) and CDT1 (lower panel), showing the emission lines used for the determination of electron temperatures.

the observation of the NIR sulfur lines seems to be expendable at high metallicities.

In the case of low excitation regions, it is necessary to rely on different grids of photoionization models in order to infer the value of the unmeasured line temperatures. For this purpose, the relations deduced by Pérez-Montero et al. (in preparation) have been adopted. In these relations the new sets of atomic coefficients for S^{2+} (Tayal & Gupta 1999) and both the latest versions of stellar atmosphere and photoionization models are taken into account. Hence, the derived relations are compared with those objects for which more than one line temperature has been measured. The relation between $t(O^{2+})$ and $t(S^{2+})$ holds as follows:

$$t(S^{2+}) = (0.90 \pm 0.03)t(O^{2+}) + (0.06 \pm 0.02).$$

This approach works out rather well at the low excitation regime, where it could be especially useful because, although the [O III] $\lambda 4363 \mathring{A}$ line cannot be observed, the [S III] $\lambda 6312 \mathring{A}$ can be detected with the aid of both good signal-to-noise ratio and low–intermediate resolution spectra. However, the validity of this trend in the high excitation regime ($T_e > 13\,000$ K) needs to be discussed in further detail. Regarding $t(O^+$, $t(N^+$ and $t(S^+$, the former ones can be taken to be equal to a good aproximation, while the relation with $t(S^+$ can be written as follows:

$$t(S^+) = (0.85 \pm 0.01)t(O^+) + (0.07 \pm 0.01).$$

In summary, we have shown that the observation of the NIR sulfur lines ([S III] 9069 Å, 9532 Å) can be attained in both low and high excitation H II regions. A moderate spectral resolution (at least 2 Å/pix) is required in order to subtract correctly the OH rotational–vibrational transitions of the night-sky spectrum.

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