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DIAGNOSTIC DIAGRAMS OF H II REGIONS IN THE LOCAL GROUP

G. Delgado,[1,3] K. Viironen,[2,3] A. Mampaso,[3] and R. L. M. Corradi[4]

We have studied here for the first time the use of the log(H α/[N II]), log (H α/[S II]) diagnostic diagram for determining the metallicities and ionization parameters of the H II regions in the Local Group. An important advantage of using these lines is their proximity in wavelength, which both simplifies the observations and makes the de-reddening corrections much safer or even unnecessary. In order to study the behaviour of extragalactic H II regions in this diagram, we carried out a thorough bibliographical search comprising all H II regions in all those galaxies of the Local Group for which adequate information about the relative intensities of the four lines is available, and compared this observational data to theoretical grids based on MAPPINGS III (Sutherland and Dopita 1993) and CLOUDY 96b5 (Ferland 2002) photoionization codes. We found out that both the MAPPINGS and the CLOUDY models fit the observations well and our main result is that the studied diagram is a powerful tool for estimating metallicities in extragalactic H II regions.

Introduction

The diagnostic diagram representing log(H α6563/[N II]6583) vs. log(H α6563/ [S II]6717+6731) was first introduced by Sabbadin and D'Odorico (1976) to attain an optimal separation of galactic planetary nebulae, H II regions and supernova remnants. Denicoló et al. (2002) have studied the use of these line ratios separately to estimate metallicities of H II galaxies. We study here the use of this diagram for determining the metallicities and ionization parameters of the H II regions in the Local Group.

Estimating the metallicity

In order to study the behavior of extra-galactic H II regions in the log(H α/[N II]), log (H α/[S II]) diagram, we carried out a bibliographical search comprising all H II regions in all those galaxies of the Local Group for which adequate information about the relative intensities of the four lines was available. The metallicities [O]=12+log(O/H) of the parent galaxies (see Van den Bergh 2000 and references therein) vary between 7.57 and 9.0, and hence cover almost the whole range of known H II region metallicities: from 7.17 for 1 ZW 18 (Skillman and Kenicutt 1993) to 9.40 for CCM19 in M51 (Díaz et al. 1991). All in all, our sample consists of 115 H II regions.

Plotting these regions on the diagram reveals an ordered distribution, so that the H II regions belonging to galaxies with high metallicity are located

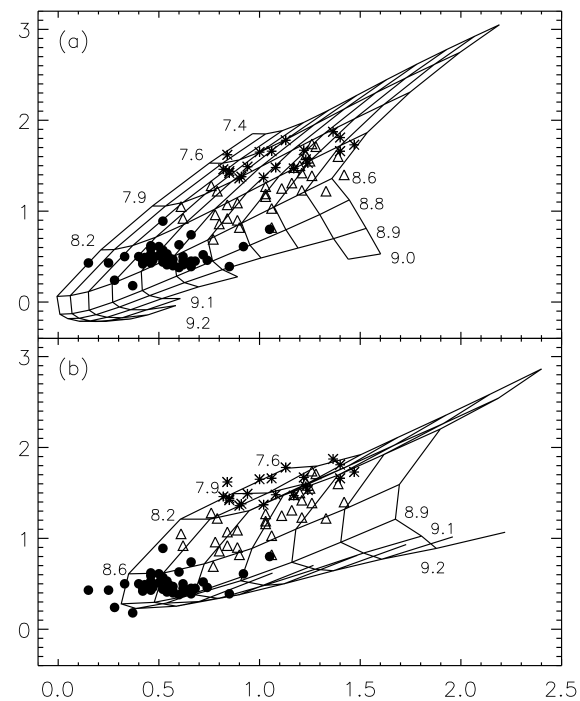

Fig. 1. (a) The sample of H II regions in the Local Group (stars: [O]=7.5–8.0; triangles: [O]=8.1–8.6; dots: [O]>8.6) and a theoretical grid of models calculated using CLOUDY96b (with [O] from 7.4 to 9.2 and ionization parameter increasing from left to right: q=3e6, 5.3e6, 9.5e6, 1.7e7, 3e7, 5.3e7, 9.5e7, 1.7e8, 3e8, 5.3e8, 9.5e8). (b) The same sample as in (a) and the grid of models calculated using MAPPINGS III (Kewley and Dopita 2002) ([O]=7.6–9.2; q=5e6, 1e7, 2e7, 4e7, 8e7, 1.5e8, 3e8).

[1]Departamento de Astrofísica, Universidad de La Laguna, Tenerife, Spain.
[2]Astronomy Division, Department of Physical Sciences, University of Oulu, Finland.
[3]Instituto de Astrofísica de Canarias, La Laguna, Spain.
[4]Isaac Newton Group of Telescopes, Spain.

at the left and bottom, whereas they are displaced toward the top and right when the metallicity decreases (Figure 1).

Next we constructed two theoretical grids using, first the results from Kewley and Dopita (2002) calculated with the MAPPINGS III photoionization code (Figure 1 (b)). Later, we calculated our own grid of models using CLOUDY 96b5 photoionization code (Figure 1 (a)).

It is clear that both the MAPPINGS and the CLOUDY models fit the observations well. However, at high metallicities the metallicity values predicted by both models are somewhat lower than the observed values for corresponding H II regions. This discrepancy requires further study. Other small differences between the individual models may be due to differences in the input parameters (for example, we used for CLOUDY a single ionizing star model instead of a cluster, as used in MAPPINGS) or to differences in the codes themselves. However, in general the agreement with the observations is very good.

In addition to the previously mentioned advantage concerning reddening, there is not much folding in our grid of models, which makes the metallicity estimates more accurate. This accuracy is highest at intermediate metallicities (7.9-8.9), where most of the studied H II regions are located.

Dopita et al. (2000) have studied the use of different diagnostic diagrams for estimating metallicities of H II regions. They suggest that the [N II]6548+6583/[O II]3727+3729 vs. [O III]5007/[O II]3727+3729 diagram is optimal in the sense that the folding is minimal. However, the lines used are rather separated in wavelength, and hence, the uncertainties due to interstellar reddening corrections are not avoided, as in the case of our diagram.

We estimate that GTC+OSIRIS can measure the faint [S II] lines of a typical giant H II region (H α luminosity of 10^{39} erg s^{-1}) with S/N=5 in 1 hr integration in galaxies out to 80 Mpc, allowing metallicity measurements to be made for galaxies even at the distance of the Coma cluster. The H α luminosities of bright H II galaxies reach 10^{42} erg s^{-1} and hence their metallicities could be measured with the GTC even at a distance of 2500 Mpc.

Conclusions

We have studied the log(H α/[N II]), log (H α/[S II]) diagnostic diagram for estimating the metallicities of extra-galactic H II regions. We have shown that the diagram is indeed a powerful tool for this purpose. The advantage of using these lines is their proximity in wavelength, which simplifies the observations and reddening corrections.

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