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Abundance determinations in the dIrr galaxy Leo A

Francisco Ruiz-Escobedo[1], Miriam Peña[1], Liliana Hernández-Martínez[2] and Jorge García-Rojas[3]

[1]Instituto de Astronomía, Universidad Nacional Autónoma de México Apdo. Postal 70264, Ciudad de México, 04510, México
email: fdruiz,miriam@astro.unam.mx

[2]Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, Apdo. Postal 70543, Ciudad de México, 04510, México
email: lilihe.mtz@gmail.com

[3]Instituto de Astrofísica de Canarias (IAC), E-38200; Universidad de La Laguna, Dept. Astrofísica. E-38206, La Laguna, Tenerife, Spain
email: jogarcia@iac.es

Abstract. Physical conditions and chemical abundances of two H II regions and a planetary nebula in the dIrr galaxy Leo A are presented. These determinations were performed using the direct method (T_e measured) and the ONS method. We also constructed photoionization models for the three nebulae to determine the abundances and to analyse the ionizing stars. The O abundance was determined to be 12+log(O/H) $= 7.4 \pm 0.2$ in all cases.

Keywords. galaxies: irregulars, galaxies : individual (Leo A), galaxies: ISM, ISM: abundances, planetary nebulae: general

1. Introduction

Dwarf Irregular galaxies (dIrr) are low-mass, gas-rich, low-metallicity systems and seem to be dominated by dark matter. These galaxies are considered the building blocks of large-scale galaxies. The study of the ISM abundances of these galaxies, derived from H II regions and planetary nebulae, allow us to infer their chemical evolution (Hernández-Martínez *et al.* 2009).

Leo A is an isolated dIrr galaxy of the Local Group located at 803 kpc from the MW (McConnachie 2012). Only a small number of H II regions and one PN have been found in Leo A. van Zee *et al.* (2006) determine the abundances of four H II regions in this galaxy, from strong-line and semi-empirical methods; they also determine abundances for the PN by using the direct method. They found that Leo A is a very low metallicity galaxy, with an average value of 12+log(O/H) $= 7.30 \pm 0.05$.

In this work, our main goal was to obtain accurate determinations of chemical abundances (in particular of O) of two H II regions in Leo A: from deep spectra measure the [O III] $\lambda4363$ line to determine T_e and, with it, the abundances using the direct method. Also, we re-analyse the data for the PN published by van Zee *et al.* (2006) to calculate its physical conditions and abundances using the same methodology as for H II regions. In this proceeding, we present some of the results recently published by Ruiz-Escobedo *et al.* (2018).

Table 1. Physical conditions

	H II West		H II East		PN	
	Direct Method	Best Model	Direct Method	Best Model	Direct Method	Best Model
n_e (cm^{-3})	113 ± 120	100	<100	100	1000*	1000
T [O III] (K)	17046 ± 2925	14790	—	13994	20897 ± 931	18725
T [O II] (K)	14932 ± 2048	13889	—	12402	17628 ± 651	17528

*Assumed density.

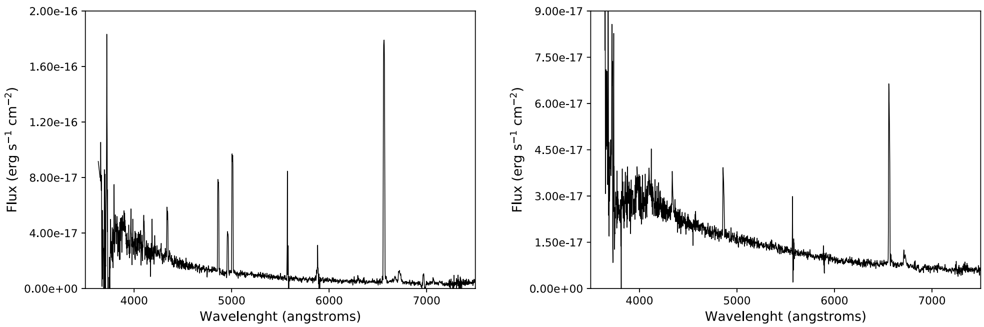

Figure 1. Calibrated spectra of H II region West (left) and H II region East (right).

2. Observations

The spectra of the two H II regions in Leo A were obtained with the OSIRIS spectrograph in long slit mode, attached to GTC 10-m telescope, and the R1000B grism. Coordinates for H II regions are: α=09:59:17.2; δ=+30:44:07 (J2000) for H II region West (H II W), and α=09:59:24.5; δ=+30:44:59 (J2000) for H II region East (H II E). The total exposure time was of 3.75 hrs. The data reduction was performed with IRAF standard procedures. **Reduced spectra of both H II regions are presented in Figure 1**. The [O III] auroral line λ4363 was only detected in H II W.

3. Physical conditions and abundances

PyNeb v1.1.1 (Luridiana *et al.* 2015) was used to derive the physical conditions, ionic and total abundances of the H II regions and the PN: electronic density n_e was derived from the [S II] $\lambda\lambda$6731/6716 lines ratio and T_e was derived from the [O III] $\lambda\lambda$(5007+4959)/4363 lines ratio (T[O III]). The [O III] line λ4363 was not detected in H II E, thus it was not possible to determine its T_e and its abundances from the direct method. Physical conditions of the three nebulae are presented in Table 1.

Ionic abundances of O^+, N^+, S^+, O^{+2}, Ne^{+2} and Ar^{+2} were derived assuming a two-temperature zones model, where T[O III] is the temperature of the high-ionization zone, while the low ionization zone temperature, T[O II], was derived from Campbell *et al.* (1986) relation. Total abundances of O, N, S, Ne and Ar were obtained by adding the ionic abundances and the respective ICFs from literature for each element. O and N total abundances were also calculated using the ONS method (Pilyugin *et al.* 2010). Results are presented in Table 2.

4. Photoionization models

For the three nebulae, we constructed simple photoionization models using CLOUDY v.17 (Ferland *et al.* 2017) aiming to reproduce the observed parameters and estimate the

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Table 2. Total abundances and input parameters for the photoionization models.

	H II West			H II East	PN	
	Direct method	ONS Method	Best Model	Best Model	Direct method	Best Model
12+log(He/H)	10.98 ± 0.06	—	11.00	11.00	10.97 ± 0.04	11.00
12+log(O/H)	7.39 ± 0.10	7.40 ± 0.15	7.55	7.40	7.34 ± 0.02	7.45
12+log(N/H)	5.74 ± 0.09	5.58 ± 0.21	5.80	5.80	—	7.00
log(S/O)	-1.19 ± 0.04	—	-1.40	-1.70	—	-1.70
log(Ne/O)	—	—	-0.80	-0.80	-0.77 ± 0.01	-0.70
log(Ar/O)	—	—	-2.10	-2.10	-2.65 ± 0.12	-2.60
T_{eff} (K)	—	—	35600	28000	—	125000
log(g)	—	—	3.9	4.0	—	7.0
log(Q(H^0))	—	—	48.8	48.0	—	48.0

objects abundances. Stellar atmosphere grids were used to simulate the ionizing source (central star) of each object: the Tlusty OB stars Atlas by Lanz & Hubeny (2003, 2007) for the H II regions and the Rauch (2003) grid for the PN. Input parameters for the models were:

- For the gas: n_e, inner radius (r_{in}) and abundances of He, C, N, O, Ne and Ar.
- For the central star: effective temperature (T_{eff}), surface gravity (g) and ionizing photons rate (Q(H^0)).

Input parameters and results of photoionization models are presented in Table 2.

5. Conclusions

In this work, we were able to determine O, N and S total abundances in the highest excited H II region of Leo A (H II W) and O, Ne, Ar in the PN using the direct method; we also estimated the abundances of the three regions by constructing photoionization models. Observational results and models show that the three regions have similar metallicities 12+log(O/H) $\sim 7.4 \pm 0.2$ (Table 2). This results confirm that Leo A is a very low metallicity galaxy in the Local Group. The models also show that the ionizing stars of the H II regions have effective temperatures $T_{eff} \sim$ 35 600 K (O8V star) and 28 000 K (B0V star), for H II W and H II E respectively; for the PN its central star has a $T_{eff} \sim$ 125 000 K and log(g) = 7.0. Leo A is a very low-mass galaxy producing high-mass stars of about 25 $M_{\odot}$.

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