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NGC 456 AND THE UNIVERSE'S UNDERESTIMATED METALLICITY

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RESUMEN

Queremos recalibrar el diagrama log(O_{23}) vs. 12+log(O/H) para objetos de baja metalicidad, en la presencia de inhomogeneidades térmicas, t^2. Encontramos que el punto correspondiente a NGC 456 en dicho diagrama, se mueve hacia arriba 0.24 dex en el eje 12+log(O/H). Este aumento, junto con el mismo comportamiento de otros objetos, implica que las abundancias en el Universo necesitan ser corregidas por un factor de aproximadamente 2.

ABSTRACT

We want to recalibrate the log(O_{23}) vs. 12+log(O/H) diagram for low metallicity objects in the presence of temperature inhomogeneities, t^2. The first object of our study is NGC 456; we find that the point corresponding to NGC 456 in such diagram shifts up by 0.24 dex in the 12+log(O/H) axis. This shift along with the same behavior in other objects, implies that abundances in the Universe need to be corrected by a factor of approximately 2.

Key Words: galaxies: abundances — galaxies: individual (NGC 456) — H II regions

In the traditional study of H II regions it is assumed that the electronic temperature, T_e, is homogeneous throughout the whole volume of the object. This temperature is generally determined through auroral to nebular line ratos such as [O III] 4363/4959+5007 Å and then it is used to calculate abundances for all available ions. Nonetheless, there are important problems with this traditional assuption: (1) abundances determined using collisionally excited lines (CELs) are always lower than abundances calculated with recombination lines (RLs) only (this is also known as the abundance discrepancy factor, ADF, which can be easily explained with the assumption of non homogeneous temperature), (2) the temperature in the O^+ zone always differs from that of the O^{++} zone, and (3) the auroral [O III] 4363 Å line is not always observed with good S/N, which implies errors in the determination of T_e([O III]) and therefore in the resultant abundances.

This paper is part of a study on the correction of the O/H value due to the presence of temperature inhomogeneities, t^2, as presented by Peimbert (1967). The study consists on performing a careful analysis (determining temperatures, densities, and abundances with and without the assumption of thermal homogeneities) of a small set of objects, of which NGC 456 is the first.

One way to obtain the O/H value, particularly for objects with low intrinsecal brightness, high redshift, or low metallicity, is the strong-line method introduced by Pagel et al. (1979). This consists on measuring log(O_{23}) = log([O II] 3727 Å + [O III] 4959+5007 Å)/Hβ and finding the corresponding value of O/H on the 12+log(O/H) axis (see Figure 1). However, this method works well if we know which branch the object belongs to and if the calibration of the curve is good.

Calibrations of the O_{23}−O/H diagram are done using measurements of well known objects and with photoionization models but all these assume homogeneous temperature throughout the object. There has been some progress on calibrating the upper branch of the diagram without the assumption of homogeneous temperature, using RLs (see Figure 1). However, no progress has been done on the lower branch considering the presence of temperature inhomogeneities. Another important goal of this project is to recalibrate the O_{23}−O/H diagram considering thermal inhomogeneities, focusing on low metallicity H II regions (Peña-Guerrero PhD Thesis, in preparation).

For NCG 456, which is the seccond brightest H II region in the Small Magellanic Cloud, we find that there is an important discrepancy between the temperature determined through RLs of He I and the temperature obtained from the CELs of O. In fact, many studies using deep spectra of the brightest Galactic and extragalactic H II regions obtained in the last years (Luridiana et al. 2002; Esteban et al. 2002; Peimbert et al. 2002; García-Rojas et

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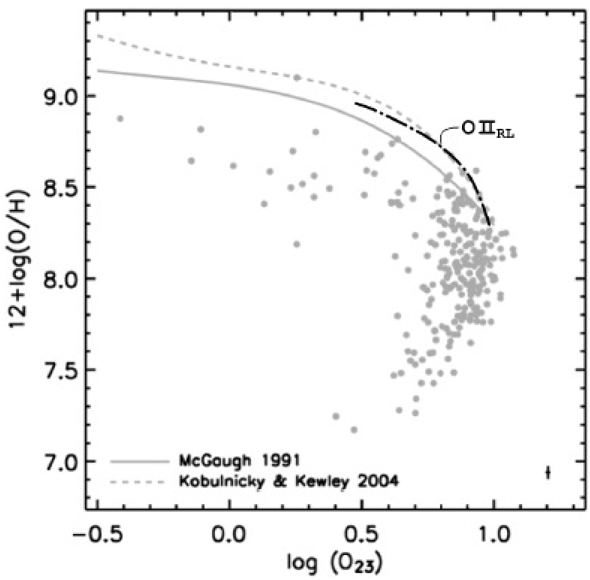

Fig. 1. Calibration from the work of Peimbert et al. (2007) for a parameter P =[O III] 4959+5007 Å ([O II] 3726+3729 Å + [O III] 4959+5007 Å)=0.8. The figure also shows the calibrations made by McGaugh (1991) and Kobulnicky & Kewley (2004), both based on photoionization models.

al. 2004, 2005; Peimbert et al. 2007; Esteban et al. 2009) show that the O^{++}/H^{+} ratio obtained from RLs and from the correction on the CELs' abundance due to the temperature inhomogeneities measured from faint He I lines, is from 0.10 to 0.35 dex higher than the values obtained from CELs under the usual assumption of thermal homogeneity.

To avoid the problem of the exponential temperature dependence of CELs, RLs can be used to measure abundances. However, RLs of heavy elements are extremelly faint, limiting their usefulness to high metallicity objects. For low metallicity objects, one alternative is to determine the ADF from the value of t^2 obtained from the thermal discrepancies between temperatures determined through RLs and temperatures obtained with CELs.

When correcting abundances from CELs for the effect of t^2, we find that for NGC 456 abundances are 1.75 times higher than with the traditional assumption of thermal homogeneity (see Table 1). This means that the point corresponding to NGC 456 in the $O_{23}-O/H$ diagram shifts up by 0.24 dex on the value of 12+log(O/H), which is slightly smaller than values determined from RLs in the upper branch of the diagram.

We have recalculated abundances considering thermal inhomogeneities for other 4 low metallicity objects and we find that their abundances are higher by a factor of about 2 than abundances traditionally determined. This implies that their corresponding points in the $O_{23}-O/H$ diagram will also shift up. The systematic shifting upwards in the 12+log(O/H) axis in both branches of the diagram implies that abundances of heavy elements in the Universe are underestimted by approxmately a factor 2.

TABLE 1

CHEMICAL ABUNDANCES OF NGC 456

	$t^2 = 0.000$	$t^2 = 0.067 \pm 0.013$
Element	12+log(X/H)±error	12+log(X/H)±error
Helium	10.923±0.008	10.918±0.008
Nitrogen	6.67±0.01	6.90±0.03
Oxygen	7.99±0.02	8.23±0.05
Neon	7.25±0.01	7.51±0.05
Sulfur	6.45±0.04	6.42±0.14
Chlorine	4.45±0.02	4.70±0.08
Argon	5.76±0.04	5.97±0.13

The implications of this study are of great importance in many fields of astronomy. Our results imply that: (1) there are 2 times more stars forming in H II regions, (2) determinations of *yields* have to be recalculated, (3) the IMF would also have to be reevaluated, (4) some modifications have to be made to chemical evolution models of the Universe, and (5) there are 2 times more places in the Universe where heavy elements provide the necessary ingredients for life to begin.

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