Rev. Mexicana Astron. Astrof., **21**, 197-201 (1990)

NEW RESULTS ON THE DETERMINATION OF THE PREGALACTIC HELIUM ABUNDANCE

Walter J. Maciel
Cristina C. M. Leite

Departamento de Astronomia
Instituto Astronômico e Geofísico da USP

ABSTRACT: A sample containing 58 objects comprising blue compact galaxies, galactic H II regions, and planetary nebulae is considered in order to determine the pregalactic helium abundance Yp and the enrichment ratio of helium relative to heavy elements $\Delta Y/\Delta Z$.

RESUMO: Neste trabalho, é considerada uma amostra contendo 58 objetos, incluindo galáxias compactas azuis, regiões H II galáticas e nebulosas planetárias, com o objetivo de determinar a abundância pregalática de hélio Yp e a razão de enriquecimento entre hélio e elementos pesados, $\Delta Y/\Delta Z$.

Key words: INTERSTELLAR-ABUNDANCES

. INTRODUCTION

According to standard Big Bang nucleosynthesis, predictions can be made for the rimordial abundances of the light elements, which in principle can be checked by the bservations. In particular, determinations of the pregalactic helium abundance are usually ade either by taking the average of a sample of very metal poor objects, such as blue compact alaxies (BCG, see for example Kunth and Sargent, 1983), or by assuming a simple model for the hemical evolution of the Galaxy, which implies a relationship between the He abundance by ass Y and the heavy element abundance Z (or oxygen abundance relative to H). The second pproach was introduced by Peimbert and Torres-Peimbert (1974; 1976), and followed for example y Lequeux et al. (1979), French (1980), Pagel et al. (1986), and Pagel (1988).

Recently, this method has been modified by Maciel (1988), who considered a sample f He- and N-poor planetary nebulae (the so-called "type IIb" objects, cf. Faúndez-Abans and aciel, 1987a) along with metal poor blue compact galaxies and galactic H II regions. Assuming hat these different kinds of objects evolve in a similar way, this method has the obvious dvantage of extending the range of metallicities used to derive the pregalactic abundance, hich tends to decrease the uncertainties in this determination. In that work, an average has een obtained for the pregalactic helium abundance by mass, Yp = 0.234 ± 0.004, and the slope $Y/\Delta Z$ = 3.5 ± 0.3, which are comparable to most recent estimates of these quantities (see for xample Pagel and Simonson, 1989).

In the present work, a careful estimate is obtained for the errors involved in the bundance determinations both for galactic/extragalactic H II regions and planetary nebulae, hich led to new determinations of the quantities Yp and $\Delta Y/\Delta Z$.

I. ABUNDANCE UNCERTAINTIES FOR PLANETARY NEBULAE

The heavy element abundances adopted in this work have been taken from the ompilation of Faúndez-Abans and Maciel (1986; 1987b). The adopted Z values and the helium bundances are given in Maciel (1988). It can be shown that the average uncertainties in the elium abundances are higher than of the main heavy elements (see for example Kunth and argent, 1983), so that for practical purposes we will assume that in the Y vs. Z correlations our uncertainties are concentrated on the helium abundance only. The main uncertainties can be divided into three classes:

(a) Helium contamination from the central stars

Most theoretical models for central stars predict some helium production (see for example Becker and Iben, 1980; Renzini and Voli, 1981; Chiosi, 1986; for recent reviews see Peimbert, 1983; Pottasch, 1984). For type IIb planetary nebulae, the progenitor masses are expected to be small (about one solar mass), so that the main contribution comes from the firs dredge-up, and is probably less than or close to $\Delta Y = 0.010$, or about 3% in the abundance by mass.

(b) Helium collisional excitation

Recent work on atomic collision theory has modified the adopted collision parameters, so that previously determined abundances are probably overestimated (see for example Pagel, 1988; Pagel and Simonson, 1989). Although the amount by which a given abundance will change depends on the lines considered, it can be assumed that the average contribution of this effect is smaller than the previous one, that is, $\Delta Y < 0.010$, so that they can be treated together (see for example Peimbert, 1989).

(c) Observational uncertainties

Several effects may alter the derived abundances, such as abundance variations inside the nebulae, non linearity of detectors, presence of temperature fluctuations, weak lines, etc. Most planetary nebulae in this study are classified as of quality "A" (Aller and Czyzak, 1983; Aller and Keyes, 1987), with a few objects of quality "B". We have adopted the following scheme:

Case 1

$\sigma(Y) = 0.014$	Quality A
$\sigma(Y) = 0.047$	Quality B

Case 2

$\sigma(Y) = 0.024$	Quality A
$\sigma(Y) = 0.071$	Quality B

Given the average helium abundance in our sample, $\langle Y \rangle = 0.293$, this corresponds to errors of 5 - 16% (Case 1) and 8 - 24% (Case 2).

III. ABUNDANCE UNCERTAINTIES FOR H II REGIONS AND BCG

The average uncertainties in the helium abundance by number of H II regions are in the range 10 - 20% (Shaver et al., 1983; Shaver, 1983), reaching a few percent in the best cases. We have adopted an uncertainty $\sigma(Y) = 0.019$, which corresponds to about 7% in the He abundance by mass.

For blue compact galaxies, we have adopted the individual errors estimated by Pagel (1988), which lie in the range $0.006 < \sigma(Y) < 0.020$, with an average of about 5% by mass

IV. RESULTS AND DISCUSSION

The main results of this paper are shown in Figures 1 and 2 and in Table 1. Figure 1a shows the obtained variation of the helium abundance with Z for case 1 and $\Delta Y = 0$, that is, no He contamination from the central star. Assuming that the helium contamination is about $\Delta Y = 0.010$, we have the results shown in Figure 1b, also for Case 1. As expected, the slope is somewhat decreased and the Yp value is increased, as the correction introduced affects the

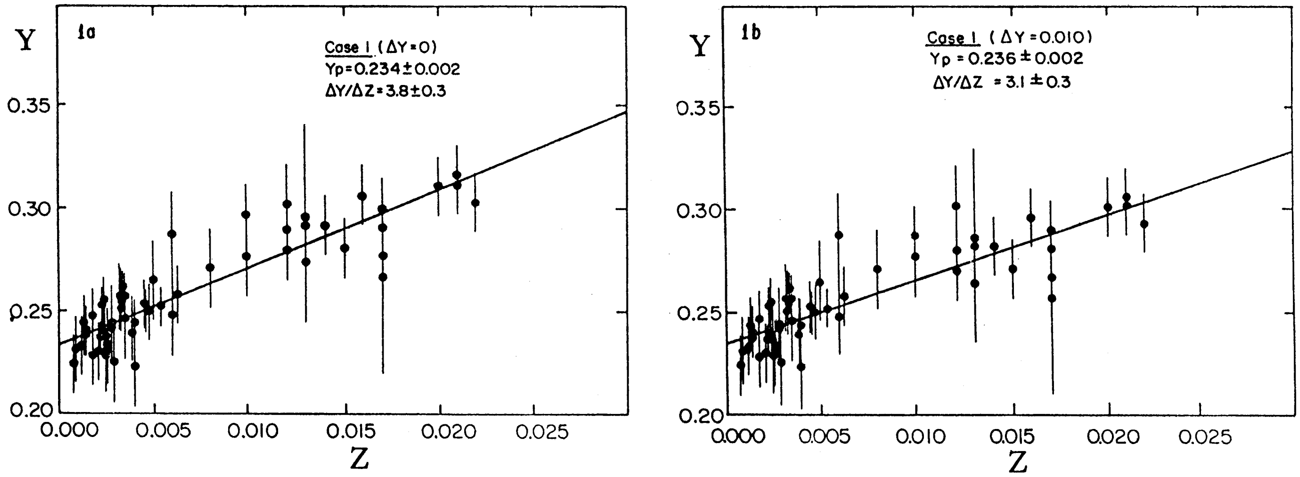

Figure 1

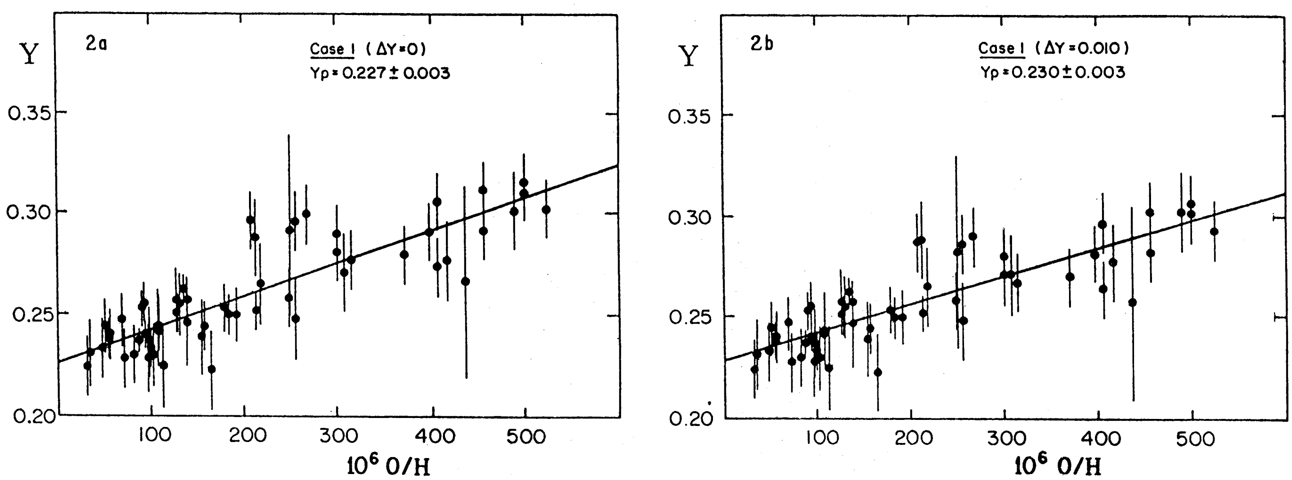

Figure 2

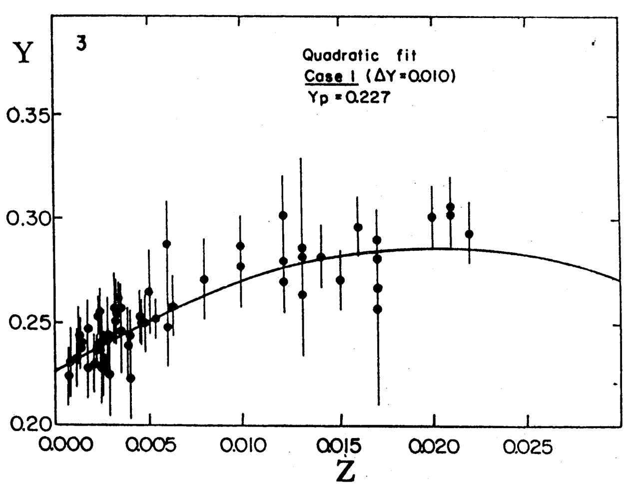

Figure 3

Table 1

Case	Figure	ΔY	Yp	$\Delta Y/\Delta Z$	r
1	1a	0.000	0.234 ± 0.002	3.8 ± 0.3	0.91
2	--	0.000	0.233 ± 0.003	4.0 ± 0.4	0.86
1	1b	0.010	0.236 ± 0.002	3.1 ± 0.3	0.87
2	--	0.010	0.235 ± 0.003	3.4 ± 0.4	0.82
1	2a	0.000	0.227 ± 0.003	-	0.88
2	--	0.000	0.227 ± 0.003	-	0.84
1	2b	0.010	0.230 ± 0.003	-	0.86
2	--	0.010	0.229 ± 0.003	-	0.82

planetary nebulae only. It is seen that, for reasonable amounts of helium production, the derived values of Yp and $\Delta Y/\Delta Z$ are essentially unchanged. In fact, a correction factor $\Delta Y = 0.03$ or higher is necessary in order to obtain a pregalactic abundance Yp = 0.240 or higher. From the results given in Table 1, it can be seen that even in the pessimistic case 2 the derived values do not change significantly, showing that they are reasonably well determined.

Figures 2a and 2b show the corresponding correlations using O/H instead of Z. As discussed by Maciel (1988), planetary nebulae and H II regions have different Z vs. O/H correlations, so that adoption of the oxygen abundances without taking into account the Z values produce generally lower values of the pregalactic abundance. Similar results are obtained using the oxygen abundance by mass Z(16) instead of the ratio O/H.

A similar value of the pregalactic helium abundance (that is, Yp = 0.227) is obtained adopting $\Delta Y = 0.010$ and Case 1 if a *quadratic* fit is assumed, instead of a *linear* one (Figure 3). As the correlation Y vs. Z is expected to flatten out to large Z, this is an important confirmation of the results given in Table 1. It is difficult to decide which set of values is more appropriate. For BCG and H II regions the ratio O/H is simpler to work, as it does not need any assumption on the relative importance of oxygen. For planetary nebulae, several important elements have relatively well determined abundances, so that their Z values are probably correct. It should be noted that the lower Yp values derived from the O/H ratio are closer to recent determinations based on a large sample of very metal poor BCG (Terlevich, R., private communication). Apart from the use of N (see for example Pagel, 1988; Pagel and Simonson, 1989), this question may be solved by the possibility suggested by Steigman (1987), in the sense that carbon should be used instead of oxygen. Since C and He may be produced by stars of similar masses, a clear correlation can be anticipated. Obviously, carbon abundances are difficult to obtain and, for PN, a correction due to C production in the central star is probably necessary.

It is interesting to note that the results obtained in this work are remarkably similar to those reached about 15 years ago by Peimbert and Torres-Peimbert (1976), based on a limited set of data. The main difference lies in the derived uncertainties, which have been reduced by at least a factor 2. Another important result of the present work is that the enrichment ratio seems to be limited to values in the range $3 < \Delta Y/\Delta Z < 4$, if the pregalactic abundance Yp lies within the limits given and the ratio $Z/(O/H) > 15$, which is supported by empirical determinations (see for example Peimbert and Torres-Peimbert, 1974; 1976; Maciel, 1988).

Acknowledgements. This work was partially supported by CNPq, FAPESP and Figueiredo Ferraz Engenharia e Consultoria de Projeto.

EFERENCES

.ller, L. H., Czyzak, S. J. 1983, Ap. J. Suppl. 51, 211
.ller, L. H., Keyes, C. D. 1987, Ap. J. 65, 405
ecker, S. A., Iben, I. 1980, Ap. J. 237, 111
hiosi, C. 1986, Nucleosynthesis and chemical evolution, ed. B. Hauck, A. Maeder, G. Meynet, Saas-Fee, p. 197
aũndez-Abans, M., Maciel, W. J. 1986, Astr. Ap. 158, 228
aũndez-Abans, M., Maciel, W. J. 1987a, Astr. Ap. 183, 324
aũndez-Abans, M., Maciel, W. J. 1987b, Astr. Sp. Sci. 129, 353
rench, H. B. 1980, Ap. J. 240, 41
unth, D., Sargent, W. L. W. 1983, Ap. J. 272, 81
equeux, J., Peimbert, M., Rayo, J. F., Serrano, A., Torres-Peimbert, S. 1979, Astr. Ap. 80, 155
aciel, W. J. 1988, Astr. Ap. 200, 178
agel, B. E. J. 1988, Lectures to ESO/CERN School on Astroparticle Physics, ed. A. de Rujula, D. Nanopoulos, P. A. Shaver, World Scientific
agel, B. E. J., Simonson, E. A., 1989, R. Mex. Astr. Ap. (in press)
agel, B. E. J., Terlevich, R. J., Melnick, J. 1986, P. A. S. P. 98, 1005
eimbert, M. 1983, Primordial Helium, ed. P. A. Shaver, D. Kunth, K. Kjar, ESO, p. 267
eimbert, M. 1989, IAU Symp. 131, ed. S. Torres-Peimbert, Kluwer, p. 577
eimbert, M., Torres-Peimbert, S. 1974, Ap. J. 193, 327
eimbert, M., Torres-Peimbert, S. 1976, Ap. J. 203, 581
ottasch, S. R. 1984, Planetary nebulae, Reidel
enzini, A., Voli, M. 1981, Astr. Ap. 94, 175
haver, P. A. 1983, Primordial Helium, ed. P. A. Shaver, D. Kunth, K. Kjar, ESO, p. 299
haver, P. A., McGee, R. X., Newton, L. M., Danks, A. C., Pottasch, S. R. 1983, M.N.R.A.S. 204, 53
teigman, G. 1987, 13th Texas Symposium on Relativistic Astrophysics, ed. M. P. Ulmer, World Scientific

ristina C.M. Leite and Walter J. Maciel: Departamento de Astronomía, Instituto Astronômico e Geofísico da USP, Caixa Postal 30.627, CEP 01051 São Paulo SP, Brazil.