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AN ABUNDANCE COMPARISON BETWEEN B STARS AND NEBULA IN THE ORION ASSOCIATION

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RESUMEN

Se presentan abundancias en ETL del Carbon, Nitrógeno y Oxígeno para 12 estrellas de tipo B pertenecientes a los sub-grupos mas jóvenes de la associación de Orion. Estos analisis estelares confirmam otros yá publicados sobre la nebulosa de Orion la cual aparece subabundante respecto al Sol.

ABSTRACT

LTE Carbon, Nitrogen and Oxygen abundances are presented for 12 B stars belonging to the youngest subgroups of the Orion association. These stellar analyses confirm published abundances analyses of the Orion Nebula that show Orion to be underabundant relative to the Sun.

Key words: **ISM: ABUNDANCES — ISM: INDIVIDUAL OBJECTS (M42) — STARS: ABUNDANCES — STARS: EARLY TYPE**

1. INTRODUCTION

The Orion Complex: the Orion OB association, the Orion Nebula and the associated molecular clouds have been the subject of numerous observational and theoretical studies over the years, providing us with important clues to the understanding of the physical processes involved in the formation of stars and their interaction with HII regions and molecular clouds (cf. Goudis 1982). Its HII region, the Orion Nebula - M42, has certainly been the most observed nebular region in the sky with several studies attempting to characterize the ionized gas within the Nebula in order to derive its fundamental properties such as: density, temperature and ultimately its chemical composition. Virtually all the studies that address the topic of chemical composition of the Orion Nebula have come to the unanimous conclusion that its Carbon, Nitrogen and Oxygen abundances are lower than the Solar values (cf. Peimbert 1987 and references in Walter, Dufour & Hester 1992). This is a puzzling result as the Sun, in a simple-minded chemical evolutionary model, should be less enriched in heavy elements when compared to Orion. This result, however, is still subject to some controversy as Walter, Dufour & Hester (1992) propose that the lower abundances found for Orion could be an artifact caused by significant temperature fluctuations across the Nebula. Therefore the study of the chemical composition of the stars in the Orion association can also provide us with an important independent confirmation of the results obtained in Nebular studies.

The Orion association stars have been the objects of a spectroscopic study by Cunha & Lambert (1992) in which they derive the Oxygen abundances for a sample of 18 B main-sequence stars belonging to the four distinctive subgroups of different ages: Ia, Ib, Ic and Id in Orion (Blaauw 1964). They present evidence pointing to a modest degree of self-enrichment within the Orion association in the gas that formed the succesive stellar generations. In this work, we present a continuation of that study with the LTE abundance results for C,N and O for 12 stars belonging to the two youngest subgroups (Ic and Id) in the Orion association and we compare our abundance values for the B stars with those obtained for the Orion HII region.

2. OBSERVATIONS

The targets for this study were early B-type stars belonging to the subgroups Ic and Id of the Orion OB1 association. 12 main-sequence B stars were observed at the 82" and 107" telescopes at the McDonald Observatory of the University of Texas, at Coudé, with a CCD detector, at a resolution of 0.33 Å and with an approximate wavelength coverage of 65 Å per observed spectral region. The approximate central wavelengths of the observed regions were the following: 4100 Å, 4164 Å, 4579 Å, 4649 Å, 5100 Å, 5143 Å, 5676 Å, 5721 Å and 6387 Å and they included a number of OII, CII, and NII absorption lines which were then used in the abundance analysis.

The data reduction of the spectra was done with the IRAF data reduction package in a standard manner. The equivalent widths of up to 7 CII lines, 9 NII lines, and 22 OII lines were measured in the spectra assuming Gaussian line profiles.

A list of the observed stars together with their respective spectral types, membership classifications, and derived stellar parameters, which will be discussed in the next section, is presented in Table 1.

3. DERIVATION OF STELLAR PARAMETERS

In order to derive effective temperatures and gravities for the studied stars we adopted the method presented in Gies & Lambert (1992) which is based upon photometric calibrations coupled with the comparison of observed and computed Hγ line profiles, in an iterative scheme.

Various calibrations of luminosity and temperature based on the Strömgren photometric system are available in the literature and these can provide us with fairly good, first estimates of the stellar parameters. For B stars, in particular, the magnitude of the Balmer discontinuity, the C_0 index, is a good temperature indicator, while the β index is more sensitive to gravity variations. We made use of the calibrations presented in Lester, Gray & Kurucz (1986) and Balona (1984) for C_0 and β photometric indices, both based on synthetic colors calculated with Kurucz model atmospheres (Kurucz 1979) and we computed an average temperature based on these two calibrations as our initial guess of the T_{eff} for the stars. Then we constructed a grid of theoretical Hγ line profiles (Kurucz 1979) for the given temperature covering a range in log g and obtained the best fit (best log g) between the observed and theoretical profiles. We repeated this procedure with the new T_{eff} estimate until we reached convergence. The theoretical profiles were previously broadened in order to take into account rotational velocity, macroturbulence and instrumental resolution. In Table 1, we list our adopted values of effective temperatures and gravities.

Table 1- Program Stars, Stellar Parameters and Abundances

STAR	Subg	Sp Type	T_{eff}	Log g	C	N	O
HD36285	Ic	B2 V	21930	4.40	8.41	7.89	8.79
HD36430	Ic	B2 V	19640	4.36	8.43	7.81	8.82
HD36512	Ic	B0 V	31560	4.42	-	-	8.56
HD36629	Ic	B2 V	22300	4.35	8.33	7.70	8.50
HD36959	Ic	B1 V	24890	4.41	8.34	7.77	8.73
HD36960	Ic	B0.5V	28920	4.33	8.35	7.66	8.75
HD37209	Ic	B1 V	24050	4.13	8.30	7.69	8.74
HD37356	Ic	B2 V	22370	4.13	8.39	7.83	8.61
HD37481	Ic	B1.5IV	23300	4.17	8.33	7.75	8.99
HD37020	Id	B0.5V	29970	3.92	8.34	7.65	8.87
HD37023	Id	B0.5V	32600	4.70	-	-	8.69
HD37042	Id	B1 V	31600	4.70	8.45	8.05	8.80

4. ABUNDANCE ANALYSIS

LTE line-blanketed model atmospheres were computed for each derived pair of stellar parameters using the ATLAS6 code (Kurucz 1979) for solar composition and a constant microturbulent velocity of 2 km/s. These model atmospheres were used as input to the program WIDTH6 (R. L. Kurucz - private communication) which calculated the abundances for each CII, NII, and OII transition. LTE abundances were then computed for a range of microturbulent velocities for the individual lines. Our derivation of the microturbulent velocity representative of each star was based upon our sample of OII and NII lines.

The gf-values for the studied CII, NII, and OII transitions were obtained from Pradhan (1990), Becker & Butler (1988) and Becker & Butler (1989), respectively.

In Table 1, we present the mean stellar abundance results (in a scale where Hydrogen abundance is 12) of Carbon, Nitrogen, and Oxygen. These values correspond to average abundance values calculated from all considered lines of each species. The combined errors of these abundance results are expected to be smaller than, or of the order of, 0.1 dex.

5. DISCUSSION

An interesting discussion of the stellar results can be done on the basis of the comparison of the chemical composition of the stars that formed out of the interstellar gas in the Orion association with the nebular gas. Rather than compare the Nebular abundances in the literature to the derived abundances for the individual B stars in Orion, we will consider the mean abundance values for the 12 program stars in subgroups Ic and Id as representative of the chemical composition of the B stars in the subgroups. This mean abundance, would supposedly represent a good point of comparison with the composition of the Orion Nebula, which is actually associated with the youngest stars in the Orion association.

In order to sumarize the information, we have assembled in Table 2, mean Carbon, Nitrogen, and Oxygen abundances calculated from the abundances of the individual program stars in the Orion association, followed by the standard deviation of the mean, together with the results of 5 extensive nebular studies of the Orion Nebula in the literature. These studies, referred in the table as B91, R91, O92, P87 and W92 (see table caption) are all based on nebular models with no temperature fluctuations accross the nebula, except for the abundance values listed in the second column of the pair of values calculated by W92 which assumes significant temperature fluctuations (with an assumed rms temperature fluctuation of 0.055) accross the Nebula. We also include the solar abundances from Anders & Grevesse (1989), referred as AG89, for comparison. From inspection of this table, one can see that the mean stellar abundance, as well as the nebular abundances from the literature except for the (C and N) abundances derived assuming temperature fluctuations in W92, show the Carbon, Nitrogen and Oxygen abundances to be below solar.

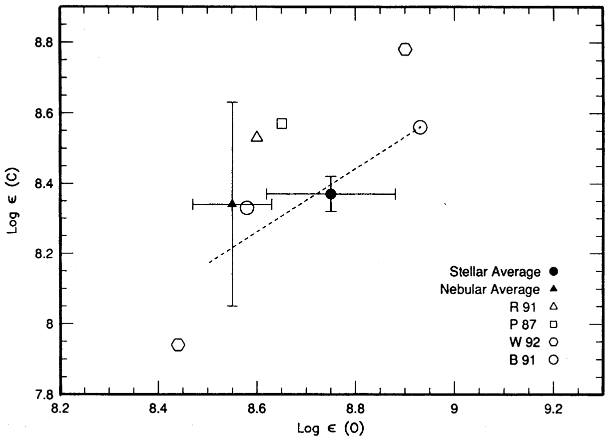
Table 2 - Abundance Comparison

	BSTARS	NEBULA					SUN
Element	C 93	B 91	R 91	O 92	P87	W 92	AG 89
C	8.37 ± 0.05	8.33	8.53	—	8.57	7.94/8.78	8.56
N	7.78 ± 0.12	7.94	7.83	7.57	7.68	7.50/7.73	8.05
O	8.74 ± 0.14	8.58	8.60	8.49	8.65	8.44/8.90	8.93

C 93 = Cunha (this paper); B 91 = Baldwin et al 1991; R 91 = Rubin et al 1991; O 92 = Osterbrock, Tran & Veilleux 1992; P 87 = Peimbert 1987; W 92 = Walter, Dufour & Hester 1992; AG 89 = Anders & Grevesse 1989

A comparison of the mean stellar abundance result with the results of the various nebular studies presented in Table 2 indicates that they roughly agree within the uncertainties expected in the analyses and confirm the underabundance relative to the Solar values. In this simple comparison of the stellar and nebular abundances we have disregarded any considerations concerning the depletion of the elements onto grains, although we know that small amounts of light elements can be trapped on grains and a correction for the nebular gaseous abundance should be included.

The rough agreement of the abundances can be pictured in Figures 1 and 2, where we show a comparison of the mean stellar C, N, and O abundances for Orion against the average abundance value calculated from the results of nebular abundances listed in Table 2. We have excluded from the nebular average abundances the results by Walter et al. (1992) which are derived with temperature fluctuations in the Nebula although their



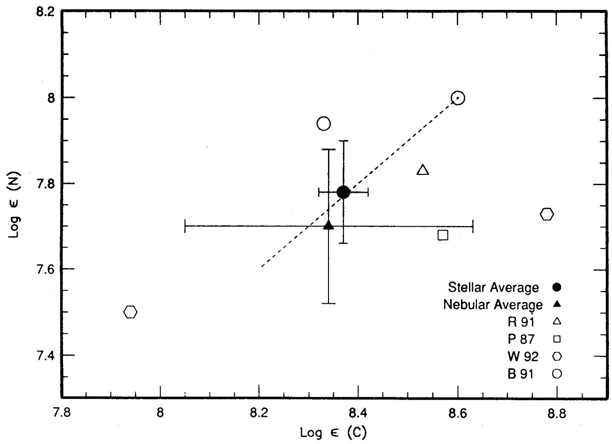


Figure 1 - (left) Comparative diagram of C/O ratios for Orion. The stellar average from B stars and the nebular average are shown with thier respective error bars. The other symbols represent individual nebular ratios obtained in the literature (see table 2). The solar value is indicated with a solar C/O ratio for decreasing abundances, indicated by the dashed line.

Figure 2 - (right) Same as Figure 1 for N/C ratios.

inclusion would not change the average abundance significantly but would increase the dispersion. The error bars of the nebular average represent the standard deviation of the mean corresponding to the different nebular studies and may give an indication of the uncertainties involved in the nebular abundances. We present as well, the nebular abundances from the individual studies by Baldwin et al. (1991), Rubin et al. (1991), Walter et al. (1992) as well as the value quoted in Peimbert's review (1987).

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