Light element abundances in He-rich stars

M. Zboril[1] **and P. North**[2]

[1] *Armagh Observatory, Armagh, College Hill, BT61 9DG, N. Ireland*

[2] *Institut d'Astronomie de l'Université de Lausanne, CH-1290 Chavannes-des-Bois,Switzerland*

Abstract. We present an abundance analysis of light elements in He-rich stars. The analysis is based on both low and high resolution observations collected at ESO, La Silla, Chile in the optical region and includes 6 standards and 21 He-rich stars. Light-element abundances display a diverse pattern: they range from under-solar up to above-solar values.

Key words: Stars: abundances – Stars: chemically peculiar – Stars: early type

1. Introduction

The He-rich stars are the most massive CP stars. Their helium abundance ranges from nearly solar up to larger than unity with respect to hydrogen ($n(He)$=1.). Spectroscopic and photometric variability is explained by an abundance distribution across the stellar surface. Given standard atmospheric conditions in B type stars (assuming no wind), diffusion is unable to support helium in the stellar atmosphere and helium sinks. However, Vauclair (1975) showed that diffusion could lead to He overabundance in the presence of mass-loss. Models of abundance anomalies with selective mass loss for He-rich stars suggest normal CNO abundances as a test (Michaud et al. 1987). So in this contribution, we analyse both low and high resolution ESO spectra to obtain light element abundances for He-rich stars and to put constraints on the theoretical model. He and preliminary CNO abundances have already been examined by Zboril et al. (1994, 1997).

2. Observations

High resolution spectra (resolving power R = 30000) were obtained using the CAT telescope and the CES spectrograph at ESO, La Silla, Chile, in April 20-24, 1992 and in June 25-29, 1993. The low resolution spectra (resolving power $R \sim 4150$) were obtained using the 1.5m spectrographic telescope and the Boller & Chivens spectrograph at ESO in January 4-11, 1993. The total sample consists of 6 standard stars and 21 He-rich stars.

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3. Abundance analysis and results

Given the instrumentation set up the abundance analysis from high resolution spectra is based on the range 4235-4270Å while low resolution spectra cover the 3952-4938Å interval. Thus the optical region is fairly well covered; however, photospheric abundances are in general difficult to determine due to the weakness of the majority of photospheric lines. The UV resonance lines are much more pronounced but require exhaustive NLTE treatment. To start with, we derived carbon abundance and $v \sin i$ values from the 4268Å transition. The following analysis is based on the best atmosphere models for early type stars, i.e. Kurucz (1992) models. New atmosphere models for He-rich stars reflecting helium abundance, proper line blanketing and NLTE treatment are being built up.

It turned out that it was better to put aside the constant for Stark broadening for the C II 4268 transition and to apply instead the classical formula, $\Gamma_S \sim n_e.n_{eff}^5$, where n_e stands for electron plasma density and n_{eff} for the effective quantum number of the upper level; otherwise, the line wings did not fit any of the observed line profiles, especially for sharp-lined stars. Other damping constants (e.g. natural radiative) associated with broadening mechanisms matched the observations very well. Other line parameters, oscillator strengths etc., have been maintained from the original line list. The abundance analysis has been performed by a standard synthetic spectrum method. The number of well pronounced transitions for light elements in the spectrum is not large enough to estimate reliably microturbulent velocity and therefore we adopted a depth-independent microturbulent velocity value of 2 $\mathrm{km\,s^{-1}}$. The abundances (defined relative to hydrogen) for light elements can be found in Table 1. The column entitled "method" stands for effective temperature determination method. Note that non-solar magnesium abundance often coincides with helium overabundance; the magnesium line is in the wing of a helium spectral line and consequently is formed in higher atmospheric layers. In the error analysis, the errors on the continuum location and total equivalent width determination have been considered as the maximal error contribution for low resolution spectra, and amount to 28% of the derived abundance. In the case of high-resolution spectra, error bars were computed using standard analysis, assuming error propagation from several sources. In this case the total abundance error does not exceed 11%.

4. Conclusion

The observed CNO abundances do not entirely fulfill the predictions of the model proposed by Michaud et al. (1987). In particular, C appears underabundant in most He-rich stars (in agreement with Hunger & Groote 1993), especially the hotter ones. More detailed models including the magnetic and wind geometry would be welcome.

Table 1. Elemental abundances $n(X)/n(H)$ in He-r stars (upper part of the table) and in normal, reference stars (lower part). The solar abundances are listed at the very bottom. The DM numbers obey the HD rule.

HD/DM	T_{eff}	method	C	N	O	Mg	$v \sin i$
169467	16600	phot.	4.2e-4	2.2e-4	6.7e-4	—	30. ±3.
168785	23400	phot.	2.4e-5	4.0e-5	2.7e-4	—	14. ±2.
-69 2698	25300	phot.	7.0e-5	1.1e-4	9.7e-5	—	30. ±3
149257	24900	phot.	7.2e-5	7.7e-5	1.5e-4	—	40. ±4
133518	18600	spectr.	2.3e-4	2.2e-4	3.3e-3	8.0e-6	0. ±1.
96446	22000	spectr.	4.5e-5	1.1e-4	1.1e-3	8.0e-6	0. ±1.
92938	15000	spectr.	9.2e-4	1.1e-4	—	3.4e-5	125. ±4.
-46 4639	22000	spectr.	1.2e-4	1.1e-4	4.4e-3	3.4e-5	80. ±4.
66522	18800	spectr.	3.7e-4	3.3e-4	5.5e-3	8.2e-6	0. ±1.
108483	19100	spectr.	2.2e-4	1.1e-4	6.7e-4	3.4e-5	130±12.
-62 2124	26000	spectr.	1.1e-4	1.1e-4	6.7e-4	3.4e-5	75±8.
60344	21700	spectr.	7.0e-5	3.3e-4	2.1e-3	3.4e-5	55±6.
64740	22700	spectr.	8.0e-5	3.3e-4	2.8e-3	3.4e-5	130±9.
58260	19000	spectr.	9.0e-5	2.2e-4	1.4e-3	3.4e-5	45±6.
-27 3748	22700	spectr.	3.0e-5	1.1e-4	6.7e-4	7.0e-6	45±4.
264111	23200	spectr.	2.0e-5	1.9e-4	1.0e-3	3.4e-5	75±8.
260858	19200	spectr.	8.0e-5	2.2e-4	1.4e-3	1.5e-5	47±3.
37776	21800	spectr.	8.0e-5	2.2e-4	1.4e-3	3.4e-5	75±7.
37479	22200	spectr.	1.7e-5	1.1e-4	6.7e-4	3.4e-5	~100±15.
37017	19200	spectr.	2.7e-5	9.0e-5	6.0e-4	1.8e-5	~80.±9.
36485	18400	spectr.	5.0e-4	1.1e-4	6.7e-4	3.4e-5	54±3.
144218	20300	phot.	2.4e-4	3.3e-4	1.3e-3	—	60. ±4.
122980	19400	phot.	4.4e-4	4.4e-4	4.3e-3	3.4e-5	20. ±2.
110879	19700	phot.	6.2e-4	2.2e-4	—	3.4e-5	130. ±4.
56139	18000	phot.	1.2e-4	~1.1e-4	~6.7e-4	3.4e-5	80.±7.
105435	26000	phot.	2.2e-4	~1.1e-4	~6.7e-4	—	~240.±11.
121790	19600	spectr.	2.2e-4	2.2e-4	1.4e-3	3.4e-5	90.±8.
solar	—	—	3.7e-4	1.1e-4	6.7e-4	3.4e-5	—

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