THE HELIUM-TO-HYDROGEN RATIO OF STARS IN YOUNG CLUSTERS AND ASSOCIATIONS

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Abstract. A photoelectric narrow-band index, I(4026), of the He I λ 4026 line has been observed with an echelle spectrometer for B-type stars in young clusters and associations.

Model-atmosphere computations of the Strömgren $[c_1]$ index, the Hβ index, and I(4026) as functions of T_{eff}, g and the helium-to-hydrogen ratio have been used to derive these atmospheric parameters from the observed indices for each star.

For the OriOBI$_b$, LacOBI and Sco-Cen associations 11 out of 48 stars in the temperature range from 14 000 to 20 000 K are found to be helium poor in the sense that the derived helium-to-hydrogen ratios lie in the range from 0.05 down to very low values. In the temperature range from 20 000 to 30 000 K no helium poor stars are found, but two stars in OriOBI$_b$ are helium rich. Both of these stars show rather strong variations of the I(4026) index.

All stars in $h + \chi$ Per and CepOBIII are apparently helium deficient compared to nearby field stars.

In a review paper on photoelectric narrow-band photometry B. Strömgren (1966) proposed to observe an index of one of the helium lines in the spectra of B-type stars in order to determine the helium abundances of a large sample of stars in the Galaxy. Following this proposal I have observed an index, $I(4026)$, of the strength of the He I λ 4026 absorption line for several hundred B-type stars.

The $I(4026)$ index is defined as:

$$I(4026) = 2.5 \log \frac{F_{14}(4026)}{F_6(4016) + F_6(4036)} \quad ,$$

where $F_{14}(4026)$ is the flux of the star in a 14 Å wide spectral band centred on He I λ 4026, and $F_6(4016) + F_6(4036)$ is the total flux of two 6 Å wide 'continuum' bands at 4016 Å and 4036 Å respectively. The bands are defined by exit slots in the spectrum formed by an echelle spectrometer with a linear dispersion of 1.3 Å mm^{-1} at 4026 Å. The intensity of the light passing the slots is measured with pulse-counting technique.

In an earlier publication (Nissen, 1974) it was described how model-atmosphere computations of the Strömgren $[c_1]$ index, the Hβ index, and $I(4026)$ as functions of T_{eff}, g and the helium-to-hydrogen ratio, $\epsilon(\mathrm{He}) = N_{\mathrm{He}}/N_{\mathrm{H}}$, could be used to derive these stellar atmospheric parameters for each observed star. It was found that the mean helium abundance of field stars, that lie within 500pc from the sun, was about ϵ (He) = 0.10. The rms scatter of ϵ(He) was found to be smaller than 0.01. Furthermore stars in the rather distant cluster, NGC 6231, were found to have about the same mean helium abundance as the field stars.

In the present paper I want to describe some new results, that are based on observations of $I(4026)$ recently obtained with the ESO 100 cm telescope at La Silla, Chile, and the 193 cm telescope at Observatoire de Haute Provence, France. The observations

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include the Sco-Cen, OriOBI$_b$ and LacOBI associations, for which the whole range of B spectral types was covered, and $h + \chi$ Per and CepOBIII, for which the observations were confined to the spectral range B0-B3.

For Sco-Cen, OriOBI$_b$ and LacOBI 11 out of 48 stars in the effective temperature range from 14 000 to 20 000 K are found to be helium poor in the sense that the derived helium abundances lie in the range from $\epsilon(\text{He}) = 0.05$ down to very low values. In Sco-Cen these stars are HD 142884, 144334, 151346, 142990, 143699, and 146001, of which the first three have been classified as weak helium-line stars by Garrison (1967). In OriOBI$_b$ the helium-poor stars are HD 36046, 36526, 37525, 37642, and finally one star in LacOBI, HD 213918, was found to be helium poor. For all these stars there is a rather large inconsistency between the $[c_1]$ index and the spectral type, but I remark that for the stars in OriOBI$_b$ and LacOBI I have been able to find HD types only.

In the effective temperature range from 20 000 to 30 000 K no helium-poor stars were found, but two stars in OriOBI_b are helium rich. These stars are σOriE and HD 37776. Both are found to be variable in $I(4026)$, and for σOriE Thomsen (1974) has found the variations to be periodic.

The spectral range B0-B2 is particularly suitable in deriving the helium abundances, because the model-atmosphere computations have revealed that a linear combination of $I(4026)$ and the Hβ index, that is observed by D. Crawford and collaborators, is nearly independent of effective temperature and surface gravity, but a sensitive function of the helium-to-hydrogen ratio. This means that differential helium abundances can be directly determined from the observed values of $I(4026)$ and Hβ, both of which indices are independent of interstellar reddening.

The mean helium abundances for different groups of stars as derived from stars in the spectral range B0-B2 are given in Table I. N is the number of stars in each group, and $\langle y \rangle$ is the mean logarithmic helium-to-hydrogen ratio. The $\langle y \rangle$ value for the field stars is normalized to -1.00, and the quoted errors, that are derived from the rms scatter of the individual y values, refer to differential helium abundances. From Table I I conclude that two groups of stars, namely $h + \chi$ Per and CepOBIII, have an apparently lower helium abundance than the rest of the stars observed.
Details of this work will be given elsewhere.

TABLE I

Group	N	$\langle\epsilon(\text{He})\rangle$	$\langle y \rangle \pm \sigma(\langle y \rangle)$
Field stars	33	0.100	−1.00
Sco-Cen	12	0.101	−0.99 ± 0.02
NGC 6231	10	0.087	−1.06 ± 0.03
$h + \chi$ Per	12	0.059	−1.23 ± 0.03
CepOBIII	10	0.060	−1.22 ± 0.03
LacOBI	6	0.085	−1.07 ± 0.03
OriOBI$_b$	8	0.091	−1.04 ± 0.03

References

Garrison, R. F.: 1967, *Astrophys. J.* **147**, 1003.
Nissen, P. E.: 1974, *Astron. Astrophys.* **36**, 57.
Strömgren, B.: 1966, *Ann. Rev. Astron. Astrophys.* 4, 433.
Thomsen, B.: 1974, *Astron. Astrophys.* **35**, 479.

DISCUSSION

Spinrad: Please elaborate on the galactocentric distances of the clusters with various He abundances, which you have just described.

Nissen: The associations with a helium-to-hydrogen ratio of $N_{He}/N_H = 0.10$, namely Sco-Cen, Ori OBI$_b$, Lac OBI$_b$, all lie within a distance of 600 pc from the Sun. The NGC 6231 cluster, for which $N_{He}/N_H \cong 0.10$, lies in the Sagittarius spiral arm, 2000 pc away from the Sun. The $h + \chi$ Per cluster with the low helium abundance of $N_{He}/N_H = 0.06$ lies in the outer spiral arm at a distance of 2000pc. Finally CepOBIII, for which $N_{He}/N_H = 0.06$ lies at a distance of 800 pc in nearly the same direction as $h + \chi$ Per.

Stephenson: Did you say anything about the non-influence of stellar rotation on your 4026 index, and if so would you please repeat what it was you said?

Nissen: No, I did not say anything about the influence of stellar rotation on $I(4026)$. However, in an earlier publication (*Astron. Astrophys.* **36** (1974), 57) I investigated if there was any dependence of the derived helium-to-hydrogen ratios of field stars on rotational velocity and I did not find any effect for projected rotational velocities below 300 km s^{-1}.

Morgan: There is a large systematic error in the Henry Draper Catalogue for faint B stars in the Orion region. Stars having HD types of B8 and B9 have MK types of around B3 to B5.

Nissen: This means that one needs MK types in order to see if there is a discrepancy between colours and spectral types for the stars in Orion, which I find to be apparently helium poor.

Walborn: (1) Can you say anything about periodicities in σ Ori E in your own λ 4026 data?

(2) How large a telescope would be needed to reach stars in the Magellanic Clouds ($\sim 16^m$) with your system?

Nissen: (1) No, I can only refer to B. Thomsen's observations.

(2) With a 4-m telescope it should be possible to determine the $I(4026)$ index for the early B-type stars with an accuracy of $0.^m005$ if several hours of integration time per star is applied.

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