ON THE DISTRIBUTION OF THE LITHIUM ABUNDANCE IN NORMAL LATE-TYPE GIANTS

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The abundance of lithium in stellar atmospheres presents an important observational constraint to the hydrodynamical models of the outer layers of stars. It can be considered as a cumulative measure of the extent of matter exchange between surface and deeper layers during the stellar evolution.

From the observed large scatter of lithium abundances in evolved stars it follows that the efficiency of mixing has been highly variable from one object to another. At present, it seems to be difficult to find any satisfactory explanation to the lithium abundances of individual stars. We suppose that at this stage the statistics of lithium abundances in different types of stars can give some insight into the character of mixing processes operating in stars. In this report some observational results about the distribution of the lithium abundances in normal late-type giants are presented.

The observations of the lithium resonance line at λ6708.8 Å were carried out with a SIT vidicon detector attached to the coudè spectrometer of the 1.5 m telescope of the Tartu Astrophysical Observatory. The sample of stars observed consists of 70 K0 - K5 and 75 M0 - M4 giants. A set of spectra of K giants with different strengths of lithium resonance doublet is shown in Fig. 1.

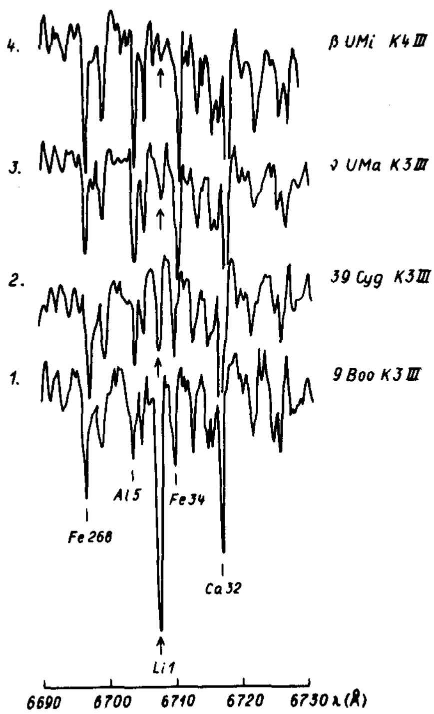

Fig. 1. A set of the spectra of K giants with different strength of the lithium resonance line.

Comparatively low spectral resolution (Δλ ∿ 0.6 Å) and difficulties with the intensity calibration did not warrant any detailed abundance analysis of our spectral material. Instead, the stars with similar spectral types were divided into four groups according to the strength of the lithium line. The groups may be described as follows (see Fig. 1): 1 - the lithium line is extraordinarily strong, its intensity exceeds that of the nearby CaI line λ6717.7 Å; 2 - the lithium line is strong; 3 - the lithium line is weak, but its contribution to the blend is still noticeable; 4 - the line is undetectable in our spectra.

In Fig. 2 the frequency distribution of lithium line strengths is shown for three intervals of spectral classes. Our sample of K0 - K1 giants mainly consists of the objects with undetectable or weak lines of lithium. Due to the high degree of the ionization of lithium in these stars, the line can be detected only when the lithium abundance exceeds $\log N_{Li} \sim 1.0$ (in the scale of $\log N_H = 12.0$). This estimate is based on the common stars of this study and the work by Lambert et al. (1980), where the abundance of lithium has been derived by the method of spectrum synthesis using high-quality spectra. Only one star out of 20 early K giants surveyed by us was found to possess a relatively strong line of lithium - BS 5361 (K0III). Certainly, our sample of K0 - K1 giants is too small to guarantee the detection of extreme cases of lithium line strengths.

In the case of K2 - K5 giants as well as M0 - M4 giants again more than 60% of the stars have no detectable lithium resonance line, although the detection limit lies at much lower abundance values. The constancy of the relative number of the stars with an undetectable lithium line despite different detection limits seems to be noteworthy. It may imply that about 63 - 65% of field late-type giants independently of their position on the red giant branch, really have a very low abundance of lithium. Lithium deficiency of these stars, most probably, originates from the period of main sequence evolution.

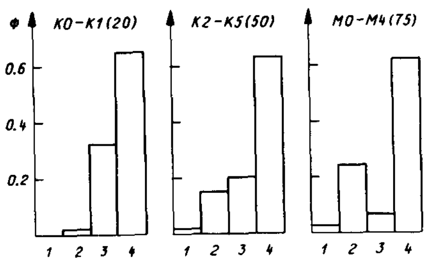

Fig. 2. Frequency distribution of the lithium resonance line strengths in red giants. The number of observed stars is indicated in the brackets.

The next feature that deserves attention in Fig. 2, is bimodal frequency distribution of lithium line strengths for M0 - M4 giants. Here we get some hint at the existence of a gap in the distribution of the lithium abundances of the evolved stars. The results of a more precise abundance analysis of 25 M giants by Luck and Lambert (1982) and 10 M giants by Hänni (1983) also tend to show a discontinuity in the lithium abundances within the sample of stars with similar effective temperature.

About 25% of M giants - the stars of group 2 - show a definite lithium line in their spectra. As indicated by common objects of the present survey and of the two above-mentioned studies, the lithium abundances of these stars are clustering around the abundance value of log $N_{Li} \sim 0.0$. They form an extension to the sequence of G - K giants of declining surface lithium abundance with advancing spectral type defined by the stars with a detectable and strong line of lithium. The decrease of the surface lithium content may be attributed to the increasing convective dilution as a star evolves upwards along the red giant branch. The starting value of the lithium abundance of the evolved stars with a still measurable lithium content would have been high. Most probably, these stars have left the main sequence with the initial atmospheric abundance of lithium which, according to abundant observational data, is close to the cosmic abundance of log $N_{Li} \sim 3.0$. As evidenced by the theory of stellar evolution, the early M-type giants should have been experienced the maximum amount of mixing caused by the growth of the convective envelope in the stage of the first red giant branch. Therefore, the abundance of log $N_{Li} \sim 0.0$ probably represents the final value of the lithium abundance after the first dredge-up phase for stars, which have become red giants with undepleted surface lithium content. It gives us an estimate of the reduction factor of the lithium abundance equal to 1000, whereas theoretical calculations by Iben (1967a, b) predict the factor no more than 60. Some doubt may be expressed about the validity of standard models of the stellar interior structure.

Finally, I would like to stress that the bulk and quality of the lithium abundance data for red giants need to be considerably raised for an adequate statistical analysis. The main task of the present report was to provoke some interest in the problem concerning the distribution of lithium abundances in evolved stars.

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