OVERABUNDANCE OF SODIUM IN THE ATMOSPHERES OF MASSIVE SUPERGIANTS AS A POSSIBLE MANIFESTATION OF NeNa CYCLE

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Studies of chemical composition of the atmospheres of F-K supergiants have revealed the existence of two specific peculiarities, deficit of carbon and excess of nitrogen. Anomalous abundances of C and N in yellow supergiants is explained by mixing of surface material with CNO-processed material of stellar interiors (the first dredge-up). Somewhat unexpectedly, F-K supergiants were found to show one more general chemical peculiarity: overabundance of sodium. Fig.1 shows the available values of $[Na/H] = \log[N(Na)/N(H)]_{*} - \log[N(Na)/N(H)]_{\odot}$ as summarized by Boyarchuk and Lyubimkov(1983). Different symbols refer to data of various authors. Fig.1 shows that sodium overabundance increases with the decrease of surface gravity. For small log g it reaches $[Na/H] \sim \sim 1$. Recently Sasselov(1986) has suggested that this correlation is essentially a consequence of a relation between [Na/H] and a mass of supergiant.

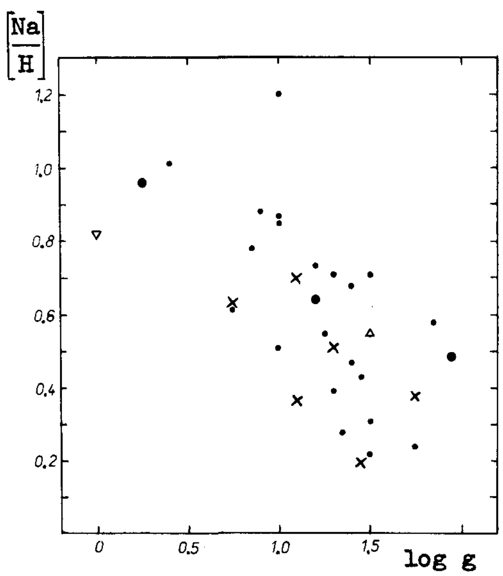

Figure 1. Sodium overabundance versus surface gravity of F-, G- and early K-supergiants

All the estimates of [Na/H] presented in Fig.1 are found from the LTE analysis of subordinate and not resonance lines of NaI. To estimate the role of non-LTE effects on inferred values of [Na/H] for several F-

https://doi.org/10.1017/S0252921100093532 Published online by Cambridge University Press

supergiants we have calculated the non-LTE level populations of NaI and the equivalent widths W_λ of the most important NaI lines. Nineteen levels of NaI and the ground state of NaII were taken into account in calculations. Two different computer codes were used. They were independently developed in the Astronomical Institute of the Czechoslovac Academy of Sciences and in Kazan' University. The results obtained using these two codes are in excellent agreement. See Boyarchuk et al. (1987) for details. The calculations showed that the differences between LTE and non-LTE W_λ values of NaI subordinate lines do not exceed 10%. The corresponding differences in Na abundances are less than 0.1 dex. Only for the most massive supergiants (log g$\sim$0) the LTE sodium abundance may be overestimated up to 0.2 dex.

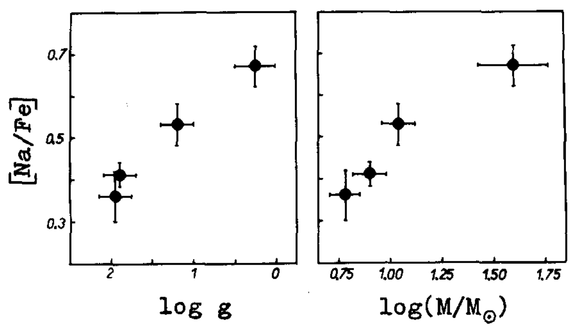

Figure 2. Non-LTE sodium overabundance for F-type supergiants αUMi, α Car, γCyg and ρCas plotted against surface gravity and mass.

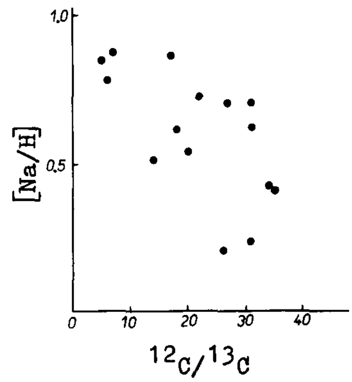

Figure 3. Sodium overabundance versus $^{12}C/^{13}C$.

Among those stars for which we have performed non-LTE calculations are αUMi, γCyg, ρCas and αCar. For these four F-supergiants detailed and accurate measurements of W_λ values of sodium lines were known. For αCar the observed values of W_λ were taken from literature, while for the three other stars the spectra were obtained at the Crimean Astrophysical Observatory (with dispersion 4, 6 and 8 Å/mm). In Fig.2 non-LTE [Na/Fe] values for these four stars are plotted versus g and M. One may conclude that non-LTE analysis also shows overabundance of Na correlated with g and M.

Earlier two of us (Boyarchuk and Lyubimkov, 1983) have suggested that the observed overabundance of Na in F-K supergiants is a manifestation of NeNa cycle

$$^{20}Ne(p,\gamma)^{21}Na(\beta^+\nu)^{21}Ne(p,\gamma)^{22}Na(\beta^+\nu)^{22}Ne(p,\gamma)^{23}Na(p,\alpha)^{20}Ne \ .$$

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This cycle operates in the interiors of main sequence stars parallel to the CNO cycle. It produces nuclei of ^{23}Na which together with the products of CNO cycle at a later phase of evolution are dredged up.

Detailed analysis of the kinetics of this cycle has shown (Denisenkov and Ivanov, 1987) that the reaction $^{22}Ne(p,\gamma)^{23}Na$, due to the presence of recently discovered resonance at E_r=30 KeV, is fast enough to provide a mechanism of (5-6)-fold sodium enrichment of central regions of core hydrogen burning (MS) stars with $M \gtrsim 1.5\ M_\odot$ due to ^{22}Ne burning (assuming Cameron's (1982) isotopic abundance of Ne). Lifetime of ^{22}Ne is markedly longer than the time needed for $^{12}C/^{13}C$ to reach its equilibrium value. Hence, if surface layers of supergiants (and red giants) are enriched in material processed deeply enough in core regions on MS phase, one should expect a correlation between [Na/H] and $^{12}C/^{13}C$. Such correlation does exist (Fig.3: $^{12}C/^{13}C$ and [Na/H] values by Luck, 1977). Low abundance of C in Na-rich atmospheres shown in Fig.3 is a manifestation of Na production on hydrogen rather than helium burning phase. The data given in Fig.2 and 3 indicate that mixing is more effective with the increase of mass.

To summarise: <u>sodium is to be added to those few elements, whose atmospheric abundance is a probe of stellar interiors</u>.

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https://doi.org/10.1017/S0252921100093532 Published online by Cambridge University Press