LITHIUM LINES IN SPECTRA OF C-GIANTS

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The resonance λ 670.8 nm and subordinate $\lambda\lambda$ 812.6, 610.4, 497.2, and 460.3 nm lithium lines are investigated as the lithium abundance indicators in spectra of cool C-giants.

INTRODUCTION

The lithium abundance in stellar atmospheres provides information on various details of the stellar evolution and physical processes in stars. Among lithium-rich stars AGB, Li-rich ($\log N(\mathrm{Li}) \geq 1$ in scale $\log N(\mathrm{H}) = 12.0$) and super Li-rich giants (SLR, $\log N(\mathrm{Li}) \geq 4$) are of great cosmological interest, because they belong to the main suppliers of lithium into the interstellar medium.

The resonance Li I line λ 670.8 nm is usually strong and sometimes very strong in spectra of cool C-stars. Besides, there are some subordinate Li I lines in optical and near IR regions that can also be strong in spectra of lithium-rich C-giants. Four lines formed by transitions from a level 2p are in the range $\lambda\lambda$ 450–820 nm, namely, $\lambda\lambda$ 812.6, 610.4, 497.2, and 460.3 nm. From the computations [5, 7] follows that only the Li I lines $\lambda\lambda$ 812.6, 670.8, 610.4, and 497.2 nm can be used as the lithium abundance indicators in spectra of C-giants. The line λ 460.3 nm is severely blended by the Fe I line at the same wavelength [6].

Different lithium lines are quite strong and sensitive to the lithium abundance for different values $\log N(\mathrm{Li})$. So, the Li I lines $\lambda\lambda$ 812.6 and 610.4 nm are saturated in spectra of SLR C-stars and, therefore, they are rather non sensitive to the lithium abundance. But the Li I line λ 497.2 nm is quite strong and sensitive to the lithium abundance for $\log N(\mathrm{Li}) = 3$–5 [5, 7].

We use for the calculations a model atmosphere and parameters of the spectra of the J-type star WZ Cas (C9.2J).

PROCEDURE

The profiles of the lithium lines were computed using the LTE approach realized in the program WITA6 [4]. Continuum opacities for a case of carbon-rich atmospheres were used. Then, we implemented an additional continuum absorption to account of unidentified yet sources by increasing of a continuum opacity by factor κ. Parameters of the used for WZ Cas model atmosphere (see [2]) are as follows: $T_{\mathrm{eff}}/\log g/[\mu] = 3000/0/0$, $\mathrm{C/O} = 1.007$. We adopted oxygen and nitrogen abundances from the model atmosphere and used carbon abundances obtained in our previous work [7] from the fits to an observed spectrum. The microturbulence velocity $V_t = 2.5$ km/s and isotopic ratio $^{12}\mathrm{C}/^{13}\mathrm{C} = 5$ were used (see [1]). Parameters of Li lines were taken from VALD [3]. We calculated the profiles of the Li I lines $\lambda\lambda$ 812.6, 670.8, 610.4, and 497.2 nm for $\log N(\mathrm{Li}) = -2 \div +5$ and analyzed this lines as possible lithium abundance indicators. We used in our calculations κ, $\log N(\mathrm{C})$, and a half width of the smoothing gaussian δ, which were chosen for WZ Cas in [7].

RESULTS

The calculated profiles of the four Li I lines for various lithium abundances are showed in Fig. 1. It is worth noting:

- The core of the resonance Li I line λ 670.8 nm is very sensitive to the lithium abundance for $\log N(\mathrm{Li}) = -2 \div 0$. For $\log N(\mathrm{Li}) > 0$ the core of resonance Li I line becomes saturated and shows a low sensitivity to the lithium abundance. But for $\log N(\mathrm{Li}) \geq 3$ the wings of the resonance line become strong. Their intensities are highly sensitive to the lithium abundances and we can derive $\log N(\mathrm{Li})$ from this wings.
- The subordinate Li I line λ 812.6 nm is very sensitive to the lithium abundance for $\log N(\mathrm{Li}) = 1.5$–3.5.

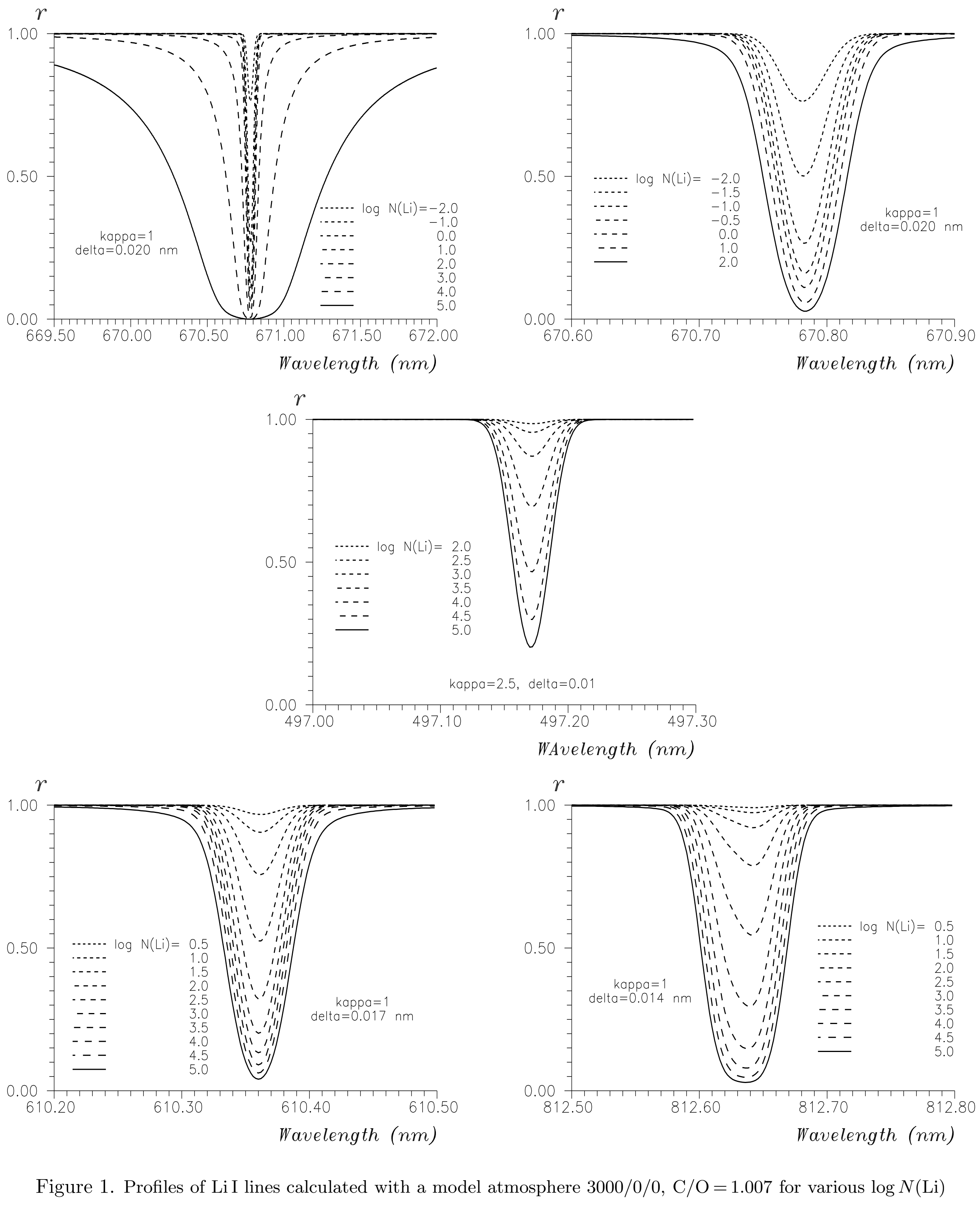

Figure 1. Profiles of Li I lines calculated with a model atmosphere 3000/0/0, C/O = 1.007 for various log N(Li)

- The subordinate Li I line λ 610.4 nm is very sensitive to the lithium abundance for $\log N(\mathrm{Li}) = 1.0$–$3.0$.
- The subordinate Li I line λ 497.2 nm is very sensitive to the lithium abundance for $\log N(\mathrm{Li}) = 3.0$–$5.0$.

As result, we see that in spectra of cool C-giants for $\log N(\mathrm{Li}) < 1$ only the resonance lithium line at λ 670.8 nm can be a lithium abundance indicator. For $0 < \log N(\mathrm{Li}) < 3$ this line is not a very good indicator due to a weak sensitivity on $\log N(\mathrm{Li})$. For $\log N(\mathrm{Li}) \approx 1$–$3.5$, the subordinate Li I lines at $\lambda\lambda$ 610.4 nm and 812.6 nm must be the best lithium abundance indicators. Then, in SLR C-stars the resonance Li I line and the line Li I λ 497.2 nm should be the best lithium abundance indicators.

The real situation with lithium abundance indicators is more complicate due to the blending of all lithium lines by atomic and molecular lines. The blending reduces the sensitivity of the lithium lines on $\log N(\mathrm{Li})$. In optical spectra of C-giants the bulk of molecular lines belong to molecules C_2 and CN. The strong telluric absorption exists in region of the Li I line at λ 812.6 nm. We should use the most complete and exact line lists to take into account the blending near lithium lines. We note that the line lists used in [1] and [7] are not quite perfect. The situation is more simple for SLR stars due to very strong lithium lines, but for normal lithium abundances the situation with the line lists is crucial.

Now we can present some conclusions on lithium abundances in SLR C-giants which we obtained by studying the four lines [1, 7]:

- Both the LTE and NLTE $\log N(\mathrm{Li})$ values derived for the λ 497.2 nm line are equal to or a bit lower than estimations for the λ 670.8 nm line ($\Delta \log N(\mathrm{Li}) \leq 0.4$).
- Lithium abundances for the λ 610.4 nm line are essentially (by ≈ 1 dex) lower a those for the resonance line.
- The estimations for the line λ 812.6 nm are equal to or higher then those for the λ 670.8 nm line. NLTE corrections improve the agreement in $\log N(\mathrm{Li})$ for these lines.

DISCUSSION

Our results show that the subordinate lithium lines can be good lithium abundance indicators for Li-rich ($\log N(\mathrm{Li}) > 1$) stars. This conclusion was tested for SLR C-giants [1, 7]. The last research confirms that the resonance λ 670.8 nm and subordinate λ 497.2 nm Li I lines are the best lithium abundance indicators in spectra of SLR C-giants.

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