

# A 3D-NLTE study of the 670 nm solar lithium feature

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**Abstract.** We derive the 3D-NLTE lithium abundance in the solar photosphere from the Li I line at 670 nm as measured in several solar atlases. The Li abundance is obtained from line profile fitting with 1D/3D-LTE/3D-NLTE synthetic spectra, considering several possibilities for the atomic parameters of the lines blending the Li feature. The 670 nm spectral region shows considerable differences in the two available disc-centre solar atlases, while the two integrated disc spectra are very similar. We obtain  $A(\text{Li})_{3\text{D-NLTE}} = 1.03$ . The 1D-LTE abundance is 0.07 dex smaller. The line-lists giving the best fit for the Sun may fail for other stars, while some line-lists fail to reproduce the solar profile satisfactorily. We need a better knowledge of the atomic parameters of the lines blending the Li feature in order to be able to reproduce both the solar spectrum and the spectra of other stars. An improved line-list is also required to derive reliable estimates of the isotopic Li ratio in solar-metallicity stars.

**Keywords.** Sun: abundances – stars: abundances – hydrodynamics – line: formation

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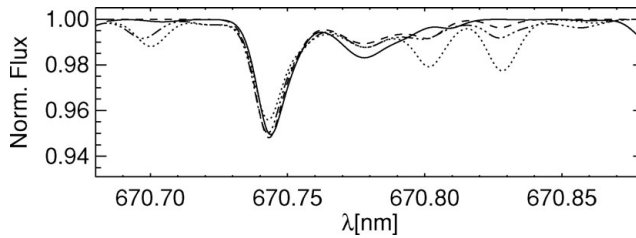
## 1. Introduction

For determining the lithium abundance in the solar photosphere one has to rely on the absorption feature of Li I at 670.7 nm. While the surrounding wavelength region is very clean in metal-poor stars making the abundance determination straightforward, this is not the case for the Sun and stars of comparable metallicity. The Li 670 nm feature is immersed in a forest of atomic and molecular lines whose atomic data are unfortunately not well known. Several line-lists for the blending components have been proposed. We applied them in 3D-NLTE spectral syntheses of the Li profile. The substantial differences among the resulting spectra indicate that for determining the Li abundance in stars of metallicity greater than 1/10 solar a major effort should be devoted to the search for data of the blending lines which are able to simultaneously reproduce the observed spectra over a wide range of effective temperatures and surface gravities.

Somewhat surprisingly, among the applied high-quality solar atlases we found noticeable differences in the Li range between the two disc-centre spectra of Neckel & Labs (1984) and Delbouille *et al.* (1973). While the lack of knowledge concerning the lines blending the Li 670 nm doublet is discussed in several papers, we could not find any information about this disagreement of the observed spectra in the literature.

## 2. Atomic and molecular data

In our analysis we assume that no <sup>6</sup>Li is present in the solar photosphere. For <sup>7</sup>Li we take into consideration ten line components. For the blending lines in the range, we



**Figure 1.** Synthetic, disc-integrated (flux) spectra for the Li I wavelength range and solar parameters: Li is modelled identically in 3D-NLTE in all syntheses while the blending components are computed in 3D-LTE, with line parameters from Hiltgen (1996) (solid), Reddy *et al.* (2002) (dash), Mandell *et al.* (2004) (dotted), and Ghezzi *et al.* (2009) (dash-dot).

used the line-lists of Hiltgen (1996), of Reddy *et al.* (2002), of Mandell *et al.* (2004), and the most recent work of Ghezzi *et al.* (2009). We computed the 3D spectral synthesis, taking into account the NLTE effects for the Li contribution. In Fig. 1, we compare the resulting synthetic profiles using the different line-lists. The disagreement between the profiles is evident, and can be explained by the fact that they have been optimised to analyse different stars.

### 3. The solar photospheric abundance of lithium

In the analysis of the solar Li abundance we only applied the line-lists for the blending components by Reddy *et al.* (2002) and Ghezzi *et al.* (2009). These authors applied and optimised their lists for the Sun, which naturally leads to a better agreement with the observed solar spectra. We further modified the line-lists slightly by changing the oscillator strength of the involved transitions to better reproduce the observations with our synthetic spectra based on 3D simulations. Performing a comprehensive fitting with synthetic 3D spectra is a computationally so demanding task that we had to restrict our approach to these small, manually introduced changes.

The abundances we obtain for the solar spectra of Neckel & Labs (1984) and of Kurucz (2005) are in close agreement. Despite that the parameters of the blending components in the two line-lists of Reddy *et al.* (2002) and Ghezzi *et al.* (2009) are different, the Li abundance does not change very much (within 0.04 dex). For the abundance determination we gave preference to the line-list of Ghezzi *et al.* (2009), and our result is  $A(\text{Li})_{3\text{D-NLTE}} = 1.03 \pm 0.03$  where the uncertainty reflects the dispersion among the results for the different observed spectra.

The 1D-LTE abundance of lithium is 0.07 dex lower than the 3D-NLTE value. However, the synthetic 1D spectrum does not reproduce the observed line profile, in part because the parameters of the blending lines have been optimised for the 3D synthesis.

### References

- Delbouille, L., Roland, G., & Neven, L. 1973, Liege: Universite de Liege, Institut d'Astrophysique, 1973
- Ghezzi, L., Cunha, K., Smith, V. V., Margheim, S., Schuler, S., de Araújo, F. X., & de la Reza, R. 2009, *ApJ*, 698, 451
- Hiltgen, D. D. 1996, Ph. D. Thesis
- Kurucz, R. L. 2005, *MemSAI* (Supplement), 8, 189
- Mandell, A. M., Ge, J., & Murray, N. 2004, *AJ*, 127, 1147
- Neckel, H. & Labs, D. 1984, *Solar Phys.*, 90, 205
- Reddy, B. E., Lambert, D. L., Laws, C., Gonzalez, G., & Covey, K. 2002, *MNRAS*, 335, 1005