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The solar photospheric oxygen abundance: a new 3D-NLTE investigation of the 777 nm triplet lines

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Surprisingly, the solar photospheric oxygen abundance is still a matter of debate. The 'low' oxygen abundance, as determined over the last decade with three-dimensional (3D) hydrodynamical model atmospheres, led to a mismatch between theoretical solar models and helioseismic measurements that is so far unresolved. We present an independent redetermination of the solar oxygen abundance, exploiting the center-to-limb variation of the O I IR triplet lines at 777 nm in different sets of spectra. Among the few available oxygen abundance indicators in the Sun, the triplet lines have the advantage of being essentially unblended, but they do not form in local thermodynamic equilibrium (LTE).

Our analysis is based on a 3D hydrodynamical `CO5BOLD` model of the solar atmosphere and on 3D non-LTE line formation calculations with `NLTE3D`. The idea is to fit the observed spectra with our synthetic line profiles simultaneously at several positions across the solar disk. This allows us to empirically constrain the (experimentally and theoretically) unknown efficiency of inelastic collisions between oxygen and neutral hydrogen atoms, quantified by the scaling factor S_{H}. Since the statistical equilibrium of the O I level populations depends critically on S_{H}, knowledge of this parameter is essential for a reliable estimate of the oxygen abundance. The simultaneous best fit of the triplet lines indicates an 'intermediate' 3D non-LTE solar oxygen abundance of $A(\mathrm{O}) = 8.76 \pm 0.02$. In view of this result and recent laboratory measurements suggesting that the iron opacity in the solar interior is significantly higher than assumed so far, the conflict between surface chemical abundances and helioseismic models might be less severe than previously thought.