Ice lines and the formation of Uranus and Neptune

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We aim at investigating whether the chemical composition of the outer region of the protosolar nebula can be consistent with current estimates of the elemental abundances in the ice giants. To do so, we use a self-consistent evolutionary disc and transport model to investigate the time and radial distributions of $\text{H}_2\text{O}$, CO, $\text{N}_2$, and $\text{H}_2\text{S}$, i.e., the main O-, C-, N, and S-bearing volatiles in the outer disc. We show that it is impossible to accrete a mixture composed of gas and solids from the disc with a C/H ratio presenting enrichments comparable to the measurements (70 times protosolar). We also find that the C/N and C/S ratios measured in Uranus and Neptune are compatible with those acquired by building blocks agglomerated from grains and pebbles condensed in the vicinities of $\text{N}_2$ and CO ice lines in the nebula. In contrast, the presence of protosolar C/N and C/S ratios in Uranus and Neptune would imply that their building blocks agglomerated from particles condensed at higher heliocentric distances. Our study demonstrates the importance of measuring the elemental abundances in the ice giant atmospheres, as they can be used to trace the planetary formation location and/or the chemical and physical conditions of the protosolar nebula.