Tracing Uranus and Neptune Formation with Disequilibrium Species

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Uranus and Neptune are the most distant and least explored planets within our solar system. To this day, the formation history of these ice giants remains uncertain. A better understanding of their deep atmospheric composition helps constrain where and how both planets formed. Remote sensing techniques can only probe the atmosphere down to a few bars. Similarly, an entry probe as part of the Uranus Flagship mission may only measure the atmospheric composition down to ~10 bars. Several disequilibrium species in the deeper troposphere are quenched to the pressure levels these measurements are made. Atmospheric models are thereby needed to interpret how the measured abundances reflect the deeper atmospheric composition.

Using a pseudo-2D thermochemical & diffusion model to account for the meridional variation of several parameters of interest, we aim to take advantage of such disequilibrium species to further constrain Uranus and Neptune deep atmospheric composition. We namely investigate the impact of accounting for convection inhibition due to planetary rotation. We present a range of plausible deep oxygen abundances and carbon-to-oxygen ratio, as well as assess the impact of chemical uncertainties on such ratio. When compared against the results of a protoplanetary disk model (Mousis et al. 2024), this work provides constraints on the formation history of Uranus and Neptune and support support the need for in-situ measurements, namely with the Uranus Orbiter and Probe mission.