Key Atmospheric Signatures for Identifying the Source Reservoirs of Volatiles in Uranus and Neptune

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We investigate the enrichment patterns of several delivery scenarios of the volatiles to the atmospheres of ice giants, having in mind that the only well constrained determination made remotely, i.e. the carbon abundance measurement, suggests that their envelopes possess highly supersolar metallicities, i.e. close to two orders of magnitude above that of the PSN. In the framework of the core accretion model, only the delivery of volatiles in solid forms (amorphous ice, clathrates, pure condensates) to these planets can account for the apparent supersolar metallicity of their envelopes. In contrast, because of the inward drift of icy particles through various snowlines, all mechanisms invoking the delivery of volatiles in vapor forms predict subsolar abundances in the envelopes of Uranus and Neptune. Alternatively, even if the gravitational instability mechanism remains questionable in our solar system, it might be consistent with the supersolar metallicities observed in Uranus and Neptune, assuming the two planets suffered subsequent erosion of their H-He envelopes. Because current technologies do not enable entry probes to reach levels deeper than a few dozens of bars in the atmospheres of giant planets, subsequent probe measurements should focus on the determination of the abundances of the noble gases since these latter never condense in the envelopes of Uranus and Neptune and are expected to be well mixed, even in the top layers at the ~1-bar level. Because these species are highly sensitive to the considered mechanism of volatiles delivery, they should be considered in the top priority of the measurements to be made by an ice giant entry probe.