Synergistic Probe-Orbiter Science and Measurements for Understanding the Formation and Evolution of the Icy Giant Planets

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The Galileo Probe was designed to measure the abundances of the heavy elements (mass > helium) and helium in Jupiter since they are key to understanding the planet’s formation and heat balance. Broadly speaking, the same formation scenarios presumably apply also to the Icy Giant Planets (IGP), Uranus and Neptune, so the determination of their heavy elements and He is equally important. We will show that the bulk of C, N, S, and O are sequestered in condensible volatiles whose well-mixed regions in the atmospheres of the IGP’s are extremely deep compared to Jupiter. That poses formidable challenges to their direct in situ measurements. On the other hand, being non-condensible and chemically inert, the noble gases − He, Ne, Ar, Kr and Xe − are expected to be uniformly mixed all over the planet, unlike the condensibles whose distribution is governed by dynamics, convection and purported deep oceans. Thus the noble gases would provide the most critical set of data for constraining the IGP formation models. Although the noble gases should be well-mixed everywhere below the homopause, measurements at and below the 1-bar level are needed considering their low mixing ratios, except for He. That depth also gets around any potential cold trapping of the heavy noble gases at the tropopause or adsorption on methane ice aerosols. Entry probes deployed to relatively shallow pressure levels of 5-10 bars would allow a robust determination of the abundances and isotopic ratios of the noble gases, amongst other things. A measurement of CO from orbit, along with other disequilibrium species has the potential of estimating the O/H ratio. Microwave radiometry from orbiter and the Earth have the potential of measuring the depth profiles of NH₃ and H₂O, which would be important for understanding the atmospheric dynamics and weather in the deep atmosphere. Combined with the above data and the data on the interior and the magnetic field, the probe results on the noble gases would provide essential constraints to the formation, migration and evolution models of the Icy Giant Planets.