Cloud Structure, Elemental Abundances, and the Formation of Uranus and Neptune

*Sushil K Atreya[1], Joong Hyun In[1]

1. University of Michigan Ann Arbor

Migration is all but essential for the formation of Uranus and Neptune. These ice giant planets most likely began and completed much of their formation in the orbital neighborhood of the gas giants, Jupiter and Saturn. The core accretion is the preferred model for the formation of the giant planets. Abundances of the heavy elements (mass greater than helium), in particular, are key to the formation and evolution scenarios. Those abundances are derived from the bulk composition. That bulk lies in the well-mixed atmosphere well below the cloud levels for condensible constituents. In this talk, we will show that current thermochemical equilibrium models place the well-mixed region of water –the deepest condensible –at several hundreds of bars in Uranus and Neptune [1]. In fact, that is an utterly optimistic scenario, as water is expected to form a superionic phase much deeper, between 50-75 GPa (500-750 kilobars) [2,3], which would in effect remove much of the water at those levels. Removal of ammonia, and possibly hydrogen sulfide, the other condensibles, is also quite likely in the water ionic ocean. Greatly subsolar ammonia at shallow tropospheric levels [4; M. Hofstadter, personal comm., 2016] and an intrinsic magnetic field [5] may be an evidence of the purported ionic ocean in Uranus and Neptune [1]. Thus, it is crucial to determine with high precision the elemental abundances and isotope ratios of the noble gases, He, Ne, Ar, Kr and Xe, that can be measured at relatively low tropospheric pressures, but not chase after the illusive, condensible gases, water, ammonia and hydrogen sulfide (methane is also condensible, but it can be accessed in the same shallow region as the noble gases). Entry probes are the only means to carry out the measurements of the noble gases, deep methane, and the isotopes. Those data in the atmospheres of the ice giant planets and their comparison with Jupiter and Saturn will then provide robust constraints to the models of the formation and evolution of the ice giant planets. References: [1] S. K. Atreya and Joong Hyun In (2016) Role of entry probes in the exploration of the solar system giants, Proc. 67th IAC, Paper ID IAC-16-32269. [2] N. Goldman, et al. Phys. Rev. Lett. 94 (2005) 217801. [3] A. F. Goncharov, et al. (2005) Phys Rev Lett 94, 125508. [4] I. de Pater, et al. (1991) Icarus 91 (1991) 220. [5] N. Ness, et al., Science 233 (1986) 85.

Keywords: Uranus, Neptune, Giant Planets, Origin and Evolution, Entry Probes

