Why does Titan have an atmosphere, and why not Ganymede?—The origin of Titan-Ganymede dichotomy

*Yasuhito Sekine[1], Yuhiko Aoyama[2], Masahiro Ikoma[2], Takayuki Tanigawa[3]

1. Earth-Life Science Insitute, Tokyo Institute of Technology, 2. Dept. of Earth and Planetary Sci., University of Tokyo, 3. Section of Liberal Arts and Sciences, National Inst. of Tech., Ichinoseki College

One of the long-standing issues in planetary science is why Saturn's moon Titan possesses a thick atmosphere and why Jupiter's moon Ganymede not. These satellites are similar in size and mass; however, only Titan has active surface environments, characterized as a thick N_2 atmosphere and liquid CH_4 cycles. Since Titan's atmospheric N_2 originates from NH_3 (Niemann et al., 2005; Sekine et al., 2011), the building materials of Titan may have contained both NH_3 and CH_4 ices in addition to H_2O ice. Previous studies hypothesized that no condensation of NH_3 and CH_4 would have occurred in the circum-Jovian disk since proto-Jupiter might have formed in a relatively warm region of the protoplanetary disk (e.g., disk temperature > 100 K) (Lunine and Stevenson, 1982). However, recent disk models show that even at a few au, the disk temperature would have become sufficiently low (i.e., < 100 K) to form NH_3 and CH_4 ices in the disk (e.g., Dodson-Robinson et al., 2009; Oka et al., 2011), thereby calling for a new explanation. Here we show that gas and solids infalling onto massive proto-Jupiter would have experienced extensive shock heating (~10^4 K) upon accretion. The shock heating is sufficient to dissociate primordial NH_3 and CH_4 to thermochemically stable N_2 and CO, which cannot condensate in the circum-Jovian disk due to their low condensation temperatures. On the other hand, dissociation of NH_3 and CH_4 proceeds only incompletely upon accretion onto less massive proto-Saturn. Accordingly, the building materials of Saturn's icy moons contain abundance of survived NH_3 and CH_4 as ices. We suggest that giant planet's mass is a critical factor to determine the chemical compositions, surface environments, and potential habitability of the icy moons.

Dodson-Robinson et al. (2009) Icarus 200, 672
Lunine and Stevenson (1982) Icarus 52, 14
Niemann et al. (2005) Nature 438, 779
Oka et al. (2011) Astrophys. J. 738, 141
Sekine et al. (2011) Nature Geosci. 4, 359

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