なぜタイタンには大気があり、ガニメデにはないのか？ータイタンとガニメデの二分性の起源

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

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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.

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