Giant Impacts in the Saturnian System: Origin of Variety in Mid-Sized Satellites

Y. SEKINE[1*] and H. GENDA[2]

[1]*Dept. of Complexity Sci. & Engr., University of Tokyo, JAPAN*
*(*5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8561, Japan: sekine@k.u-tokyo.ac.jp)*
[2]*Dept. Earth & Planet. Sci., University of Tokyo, JAPAN*

The last stage of the formation of gas planets involves an inflow of gas and solids from the solar nebula and the formation of circumplanetary disks. In the disk, regular icy satellites are likely to have been assembled by collisions of rock-ice planetesimals [1]. In this respect, the satellite systems of gas planets are often viewed as miniature solar systems. Unlike the Jovian and Uranian systems, however, the Saturnian system seems to be enigmatic from the viewpoint of a miniature solar system. This is because (1) Titan is the only large satellite in the Saturnian system and (2) mid-sized Saturnian satellites have various bulk densities; for example, Tethys has a surprisingly low density close to that of pure ice; whereas, the high densities of Enceladus and Dione suggest their rock-rich compositions [3]. These facts are difficult to be explained by the simple minimum mass model of the satellite systems [1, 2] based on that of the solar system. These aspects on the Saturnian system perhaps reflect a greater importance of stochastic events during satellite assembly than those in the Jovian and Uranian systems.

Recently, a gas-starved model [4] proposes satellites growth in an actively supplied circumplanetary disk, sustained by an inflow from the solar nebula. In this model, satellites growth continuously occurs in the disk until the inflow ends. Large satellites formed in the disk migrate inward by interaction with the gas and are eventually lost to the gas planet, implying cycles of formation and loss of large satellites in the disk. This model can explain why Titan is the only large satellite in the Saturnian system, but the mechanism responsible for the variety in the mid-sized satellite densities remains mystery. Based on the gas-starved model, “giant impacts” between icy satellites (between large satellites and/or between large and mid-sized satellites) are expected to occur during the satellites migration. Such a dynamic process might have formed a rock-rich and/or ice-rich satellite by blowing off ice mantle of impactor and/or target satellites, as proposed for the mechanisms for the formation of Mercury and Moon [5, 6].

Here, we discuss the impact conditions of the giant impacts that result in dramatic changes in the satellites density using a 3-D SPH simulation. Our calculations show that rock-rich satellites are formed at wide impact conditions; impact angles of ~30–60° and impact velocities > 1.5 times the escape velocity. In contrast, the formation of ice-rich satellites requires much higher impact velocities (> twice the escape velocity). Our findings suggest that the giant impacts have played a key role for determining the fundamental physical properties of the Saturnian icy satellites as well as those of the terrestrial planets in the inner solar system.

References

[1] Lunine & Stevenson, *Icarus* **52**, 14 (1982). [2] Mosqueira & Estrada, *Icarus* **163**, 198 (2003). [3] Jacobson et al., *Astron. J*. **18**, 492 (2004). [4] Canup & Ward, *Nature* **441**, 834 (2006). [5] Benz et al., Icarus 74, 516 (1988). [6] Cameron, *Icarus*, **126**, 126 (1997).