An interior structure model of Pluto resolving its mysteries

*Shunichi Kamata[1], Francis Nimmo[2], Yasuhito Sekine[3], Kiyoshi Kuramoto[1], Naoki Noguchi[4], Jun Kimura[5], Atsushi Tani[6]

1. Hokkaido University, 2. University of California, Santa Cruz, 3. Tokyo Institute of Technology, 4. Tokushima University, 5. Osaka University, 6. Kobe University

Investigating the mechanism maintaining a subsurface ocean is necessary to understand the condition under which aqua planets can form. Recent planetary exploration missions suggest the presence of subsurface oceans in several outer Solar System bodies. Most of them are icy satellites of giant planets, and tidal heating is considered to play a major role in maintaining their subsurface oceans. The presence of a subsurface ocean is also suggested for Pluto, though tidal heating is negligible. In order for heat-depleted Pluto to possess a subsurface ocean, thermal convection should not occur in the ice shell above the ocean, suggesting its high viscosity. This suggestion is consistent with studies of viscous relaxation of the ice shell. This may be due to a high concentration of contaminants, such as ammonia, in the ocean, resulting in an extremely low temperature ocean; however, ammonia is not observed on Pluto’ s surface, and comets, whose bulk chemistry should be similar to that of Pluto, contains ammonia only little. Thus, the reason why Pluto possesses a subsurface ocean is a mystery.

Here we propose a thin gas hydrate layer exists between the ice shell and a subsurface ocean, and it prevents freezing of a subsurface ocean. Gas hydrates act as a thermal insulator because of its low thermal conductivity. We perform numerical calculations of long-term thermal evolution and show that a warm ocean and a cold ice shell can be maintained for a long time and that the freezing of the ocean is ineffective. We also perform numerical calculations of long-term viscoelastic deformation and show that the significant viscous relaxation requires billions of years. Our proposal does not require large amounts of contaminants. Comets contain a few % of methane with respect to water, for example, and this concentration is sufficient for creating a thin gas hydrate layer prohibiting the ocean freezing. Some gas species are easily trapped in gas hydrates while others are not, and this selective trapping may explain a large difference in volatile compositions of comets and Pluto’ s surface. The subsurface ocean maintenance mechanism we propose here would also be applicable to larger icy bodies other than Pluto. In addition, our proposal may explain the diversity of surface chemistry of Kuiper Belt Objects.

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