# Study suggests the existence of ferroelectric ice layer on a cold planet

Hiroshi Fukazawa, Hiroki Yamauchi, Akinori Hoshikawa
*JAEA and Ibaraki Univ.*

Whether ice in the outer solar system exists as hydrogen-ordered ices, is a question that has attracted scientific interest. Some ordered ices have ferroelectricity, and long range electrostatic forces caused by the ferroelectricity might be an important factor for planet formation. Features of the infrared spectrum of proton-ordered structures are unknown because of the difficulty in creating ordered ice in the laboratory. The aligned water ices are obtained only by doping of water samples with some catalysts, such as KOH or HCl, and the influence of the dopant on long-range ordering was not well resolved.

We produced KOD-doped D2O powder with a homogeneous concentration of KOD by rapid solidification of a mist of 0.001 - 0.1 M KOD solutions. Diffraction patterns were saved every 0.5 hours of collection time. These time-resolved measurements were performed at the HERMES in 04 ' and 05 ' [1, 2]. We have succeeded in making large quantities of ferroelectric ice, named ice XI, with the small amount of KOD, and then maintaining the samples in a 50 to 75 K temperature range over several days. From profile refinements with better values of reliability factors, which is the best way of investigating deuteron ordering, we found the temperature condition for the transformation of the largest fraction of ice Ih into ice XI. The finding confirms that ice XI is in a thermodynamically stable phase at low temperatures. We did longer experiments of same ice samples using a powder diffractometer, named the WAND, at the Oak Ridge National Laboratory, Based on the results, we propose that ice XI exists in the Universe [3]. It was picked out by US and Japanese press [4].

In spring and summer of 07 ' we used the HERMES again and first measured in-situ time-resolved neutron diffraction of ice with 0.01 M KOD, which compressed at about 0.02 GPa using a sapphire cell of a large single crystal. We observed a transformation to the ferroelectric ice XI in a 60 to 75 K temperature range over tens hours. The results show that the ferroelectric ice is stable below 0.02 GPa. It suggests that a thick layer of ferroelectric ice exists on the surface of Pluto (Figure). Future telescope or planetary probe will be able to detecte the huge ferroelectric-ice mass.

We plan to do in-situ experiments on ice under much higher pressure conditions up to 10 GPa in 08 '. We try to observe the phase transition from disordered phases to the ferroelectric ice or other ordered phases around 40-130 K (The value is the same as the temperature of Pluto's surface and inner). The experiment will reveal the whole picture of low-temperature ice structures. It will show that myriad big icy-bodies in outer solar system, which exist as dwarf planets and KBO, consist of thick ferroelectric-ice surface and several inner layers of hydrogen ordered ices.

References

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