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Scientific importance and possibility of HCN detection in Enceladus plumes by ALMA

KODAMA, Kenya[1*] ; SEKINE, Yasuhito[1] ; IINO, Takahiro[2] ; SAIGO, Kazuya[6] ; KASAI, Yasuko[3] ; SAGAWA, Hideo[4] ; MAEZAWA, Hiroyuki[5]

[1]Dept. Complexity Sci. and Engr. Univ. of Tokyo, [2]Solar-Terrestrial Environment Laboratory,Graduate school of science,Nagoya University, [3]Senior Researcher Global Environment Division National Institute of Information and Communications, [4]National Institute of Information and Communications Technology, [5]Department of Physical Science Osaka Prefecture University, [6]National Astronomical Observatory of Japan

Saturn's icy moon, Enceladus, exhibits ongoing geological activities, including eruption of water-rich plumes from warm fractures near the south-pole region. These geological activities together with the findings of Na-rich salts in the plumes suggest the presence of an interior liquid ocean beneath the icy crust. This demonstrates that Enceladus' plumes provide a unique opportunity to investigate the chemical composition of oceanic water, possible geochemical reactions, and habitability of the icy moon. However, due to limitations of in-situ measurements of the plumes by the Cassini spacecraft, it is not able to identify or quantify some key molecules, which could probe physical and chemical conditions of the ocean.

Here we discuss scientific importance and possibility of detection of HCN in the plumes by large ground-based, sub-millimeter telescope, ALMA. Because HCN is one of the fundamental materials contained in icy planetasimals in the outer solar system, and because it readily hydrolyzes in warm water($>$50 ℃), a lack of HCN suggests that Enceladus' interior would have experienced relatively high temperatures, i.e., a presence of hydrothermal activity. On the other hand, if HCN were presence in the plumes, this in turn means that Enceladus would have been cold throughout its history. Given the results of thermal evolution model, the latter case suggests late formation of the Saturnian system($>$5Myr) after CAI formation, which would result in a depletion of short-lived radiogenic heat source in Enceladus.

To evaluate the possibility to detect HCN in the plumes by ALMA, we first estimate a special distribution of H_2O gas density based on results from Cassini's observations and plume eruption modeling. Then, we calculate radiactive temperatures of HCN in the field of view of ALMA as a function of HCN concentration. Finally, the upper limit of HCN as a function of observation time will be obtained. For instance, if HCN were not detected within 4-6 hours of observation time, an upper limit of the HCN concentration in the plumes becomes 0.2% relative to water, which is comparable to a typical concentration of HCN in comets. Thus, the ALMA telescope is capable of detecting HCN in Enceladus' plumes within a reasonable observation time, if it were present in an amount comparable to that of comets. In either case whether HCN were presence or not, we would be able to constrain geochemical reactions and thermal history of Enceladus as well as the timing of formation of Saturnian system.