

ALMA 望遠鏡によるエンセラダス・プルーム内の HCN 観測可能性とその科学的意義

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

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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 planetesimals in the outer solar system, and because it readily hydrolyzes in warm water (>50 °C), 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 present 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 H₂O gas density based on results from Cassini's observations and plume eruption modeling. Then, we calculate radiative 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 present 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.