AKARI NEAR-INFRARED SPECTROSCOPIC SURVEY FOR CARBON DIOXIED IN COMETS.

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Introduction: Comets consist of primordial icy materials and refractory dust grains. It is considered that comets are the most pristine objects and they provide us precious clues to the solar system formation. Especially, chemical abundances of the icy materials in comets have been used to infer the conditions in the early solar nebula. Most abundant molecular species in cometary ices are water (H_2O), carbon dioxide (CO_2), and carbon monoxide (CO).

Carbon dioxide in comets: To date, however, there are only several direct measurements of CO_2 in comets. Although CO_2 has the fundamental ν_3 band at 4.26 μm in the near-infrared wavelength region, cometary CO_2 cannot be observed from ground-based observatories due to the severe absorption by the telluric atmosphere. Space observatories or spacecraft are required for observations of CO_2 in comets. Parent CO_2 from the comet nucleus was detected in the coma of comet 1P/Halley by the Russian *Vega* space probe for the first time [1]. Since then, it has been directly observed in only three other comets: Hale-Bopp, 103P/Hartley and 9P/Tempel with *Infrared Space Observatory* (*ISO*) and *Deep Impact* flyby spacecraft (see references in [2], [3]).

***AKARI* observations:** We present the observational results of H_2O, CO_2, and CO for 18 comets observed with the Infrared Camera (IRC) onboard the Japanese infrared satellite AKARI. The IRC has the capability to take spectra from 2.5 to 5 μm, and simultaneous observations of these three major molecules (H_2O, CO_2, and CO at 2.7, 4.3, and 4.7 μm, respectively) could be performed with AKARI/IRC. We detect CO_2 in 17 out of 18 comets except for comet 29P/Schwassmann-Wachmann 1 around 6 AU from the Sun, while we detected a reliable CO emission band only in 3 comets, including comet 29P. Our dataset provides the largest homogeneous database of CO_2/H_2O production rate ratios in comets obtained so far.

Mixing Ratios: The CO_2/H_2O production rate ratios (mixing ratios) are considered to reflect the composition of cometary ice when a comet was observed at the heliocentric distance within ~ 2.5 AU since water ice fully sublimates there. Our results show that the CO_2 mixing ratios in comets are in the range from several to ~30% among the comets observed within 2.5 AU from the Sun (13 out of the 17 comets).

The range of CO_2/H_2O ratio represented by upper and lower quartile values is 11%-24% (the median value is 17%), and is comparable to that of high-mass protostellar ices (12%-22%), while the mixing ratio of CO_2 in low-mass protostar envelopes is 22%-35% [4]. CO_2 in cometary ice is more depleted with respect to water and more diverse than low-mass protostellar ices. The ices incorporated into comets should have been altered in the early solar nebula if the cometary ice composition has not been altered significantly after the formation of cometary nuclei.

We obtain only upper limits for CO in most comets with the *AKARI* observations. Although it is difficult to investigate in detail based on our data, we can discuss the diversity of the ratio between CO and CO_2. Significantly small upper limits of CO/CO_2 (<~ 0.1) in some comets indicate highly oxidized environments for the molecular formation. Alternatively, small upper limits of CO/CO_2 in some comets could be explained by the scenario that CO was exhausted in cometary nuclei, especially from the near surface, after multiple approaches to the Sun since CO is more volatile than CO_2.

References: [1] Combes M. et al. (1988) *Icarus* 76, 404. [2] Ootsubo T. et al. (2010) *ApJ*, 717, L66. [3] A'Hearn M. F. et al. (2011) *Science* 332, 1396. [5] Öberg K. I. et al. (2011) *ApJ* 740, 109.