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Survey of CO_2 in 18 comets with the Japanese Infrared Satellite *AKARI*

T. Ootsubo (1), H. Kawakita (2), S. Hamada (2), **H. Kobayashi** (2), M. Yamaguchi (2), F. Usui (3), AKARI MP-SOSOS tram and AKARI/IRC team
(1) Tohoku University, Japan, (2) Kyoto Sangyo University, Japan (h_kobayashi@cc.kyoto-su.ac.jp / Fax:+81-75-705-1612), (3) JAXA/ISAS, Japan

Abstract

We performed the survey of cometary volatiles by the Japanese Infrared satellite *AKARI* with the Infrared Camera (IRC) in the wavelength range from 2.5 – 5 μm from 2008 to 2009. In our survey, both Oort-cloud comets and Jupiter-family comets were observed, and observations were carried out twice or more in some cases. Most prominent emission bands were the fundamental vibrational bands of water (H_2O) at 2.7 μm and carbon dioxide (CO_2) at 4.3 μm in our spectra. The fundamental vibrational band of carbon monoxide (CO) at 4.7 μm was also recognized in some comets as well as broad emission features probably related to C-H bearing molecules around 3.4 – 3.5 μm region. Especially, CO_2 in comets can be observed from the space only. Our dataset provides the largest and homogeneously analyzed database of CO_2/H_2O ratios in comets at present. The mixing ratios of CO_2 span from a few to ~30 % among the comets.

1. Introduction

Comets are the most primordial objects in the solar system. One of the important characters of comet is the mixing ratio, especially for organic volatiles relative to H_2O. Mixing ratios are thought as clues to the chemical evolution in the proto-planetary disk of the Sun. CO_2 is the most abundant volatile in the cometary coma except water. However, because of the severe absorption of telluric CO_2 in the atmosphere, we cannot access the cometary CO_2 by ground-based observations. To date, the daughter species of CO_2 has been used to determine the mixing ratio of CO_2, or direct measurements by satellites or spacecrafts were available only in some cases. In this paper, we will present the results of our survey of CO_2 mixing ratio in 18 comets by using Japanese Infrared satellite *AKARI*.

2. Observations

Japanese Infrared satellite *AKARI* [5] is equipped with a 68.5 cm telescope and two scientific instruments. We used Infrared Camera (IRC) [4] for our survey. *AKARI* was launched on 2006 February 21 UT, and its liquid helium cryogen boiled off on 2007 August. Our survey started in the post-liquid helium phase (called as "phase 3") as the "SOSOS Mission Program". We observed 18 comets by the *AKARI*. The effective spectral resolution is R < 100 at 3.6 μm. Data was analyzed with the toolkit customized for diffused object [6]. An example of calibrated spectrum is shown in Figure 1. Since the "dust continuum" has to be subtracted from the calibrated spectra to measure the flux of molecular emissions, we fit the continuum component by polynomial functions.

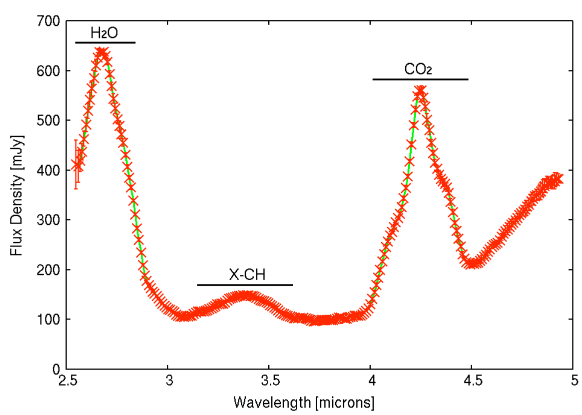

Figure 1: Calibrated spectrum of comet C/2007 N3 (Lulin). No CO was detected in this comet.

3. Results

Mixing ratios of CO_2 and CO relative to H_2O are defined as the ratios of production rates of those molecules ($Q(X)/Q(H_2O)$, $X=CO_2$ or CO).

Production rates were calculated by comparing observed molecular band flux with the g-factor multiplied by the total number of the molecules within the aperture, calculated based on the following formula;

$$n_X = \frac{Q_X}{4\pi v_{\exp}\rho^2}\exp\left[-\frac{\rho}{v_{\exp}\tau_X}\right] \qquad (1)$$

Here Q_x is the production rate of molecule "X", ρ denoted nucleocentric distance, τ_x denotes the lifetime of "X", v_{exp} denotes the expansion velocity. The band g-factors are taken from [1]. Obtained mixing ratios of CO_2 are summarized in Figure 2.

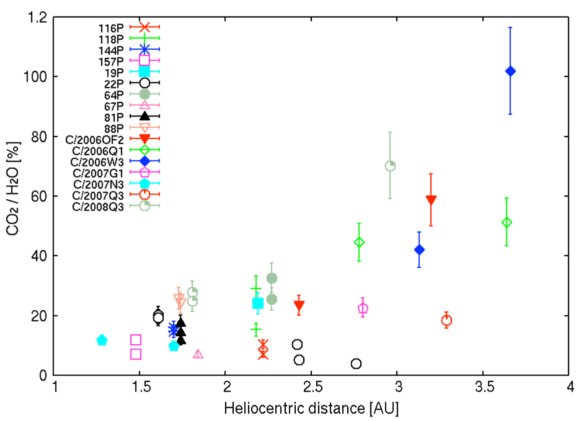

Figure 2: Mixing ratios of CO_2 in 18 comets versus heliocentric distances at the observations.

4. Discussion and Conclusions

In figure 2, the mixing ratios of CO_2 are systematically higher for the comets observed at further distances from the Sun (> ~3 AU). This could be explained by that water could not sublimate efficiently at such further distances from the Sun. The surface temperature of the nucleus could be comparable or lower than that for the sublimation of H_2O (~150 K) while hyper volatiles such as CO_2 and CO could sublimate sufficiently even at such further distances. Therefore, the gas production rate ratios of CO_2 and CO with respect to H_2O observed at further than 3 AU should be considered as upper limits of the mixing ratios of the cometary ice. On the other hand, around 1 AU from the Sun, H_2O can evaporate efficiently and the gas production rate ratios are considered as good indicators for the composition of the cometary ice. Our results show that the CO_2 mixing ratios in the 18 comets are in the range from several to ~30 % and this ratios are consistent with the previous measurements of CO_2, including indirect observations, as illustrated in Figure 12 of [2]. The wide variety can be found in the CO mixing ratios (only upper limits could be obtained in most cases) as already investigated by radio and near-infrared observations in the past [2]. Obtained CO/CO_2 ratios are summarized in Figure 3. Although most of them were determined as upper limit. CO/CO_2 ratios are smaller than unity. Our results did not agree with the CO/CO_2 ratio measured in interstellar ice (CO/CO_2 > 1). This fact implies that the nebula processing (e.g., gas phase formation mechanism of CO_2) occurred in the proto-planetary disk.

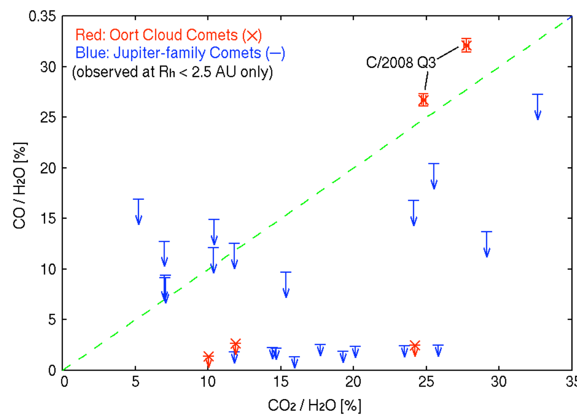

Figure 3: Mixing ratios of CO_2 versus mixing ratios of CO in 18 comets.

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