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ICE ABSORPTION FEATURES IN NIR SPECTRA OF GALACTIC OBJECTS

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ABSTRACT

We present results of AKARI/IRC near-infrared (NIR) slit-spectroscopy (2.5–5.0 μm, $R \sim 100$) of Galactic sources, focusing on ice absorption features. We investigate the abundance of H_2O and CO_2 ices and other ice species (CO and XCN ices) along lines of sight towards Galactic H II regions, massive YSOs, and infrared diffuse sources. Even among those different kinds of astronomical objects, the abundance ratio of CO_2 to H_2O ices does not vary significantly, suggesting that the pathway to CO_2 ice formation driven by UV irradiation is not effective at least among the present targets.

Key words: astrochemistry – ISM: molecules – Milky Way – infrared: ISM

1. AKARI NIR SLIT-SPECTROSCOPY

Major solid-state molecules (ices) in the interstellar medium (ISM) are known to give rise to absorption features at near-infrared (NIR) wavelengths such as H_2O at 3.05 μm, CO_2 at 4.25 μm, XCN at 4.62 μm, and CO at 4.67 μm (Gibb et al., 2004). We investigate these ice absorption features in 2.5–5.0 μm spectra of Galactic H II regions, massive YSOs, and infrared diffuse sources, obtained with the Infrared Camera (IRC, Onaka et al., 2007) onboard AKARI (Murakami et al., 2007). The observations were performed by the use of the slit ($1' \times 3$ or $5''$) with the resolving power of R $\sim$ 100. Figure 1 shows typical spectra of the present dataset. The data were taken from 399 lines of sight for 143 pointings, which were observed in the framework of Program DTIRC (PI: AKARI IRC team), IPYSO (PI: Takashi Shimonishi), and ISMGN (PI: Hidehiro Kaneda) during the AKARI Phase 3 period. Among them, the reduced data of Galactic H II regions are released on the JAXA archive at: `http://www.ir.isas.jaxa.jp/AKARI/Archive/Catalogues/IRC_GALHII_spec/` (Mori et al., 2014). A study of part of the present dataset is also reported in Onaka et al. (2016).

2. RESULTS

From its absorption depth, we estimate each ice column density along the line of sight. In Figure 2, the variance of the CO_2 ice column density against H_2O ice column density is plotted, together with the literature values of proto-stars and field-stars from Gerakines et al. (1999). The data-points are mostly distributed in the range of $N(CO_2 \text{ ice})/N(H_2O \text{ ice}) \sim 0.10$–$0.23$ as was reported in previous studies (e.g., Gerakines et al., 1999). Even among different kinds of astronomical objects like H II regions and embedded YSOs, the ratio of the CO_2 to H_2O ice column densities does not vary significantly. This result suggests that the pathway to CO_2 formation driven by UV irradiation is not effective at least among

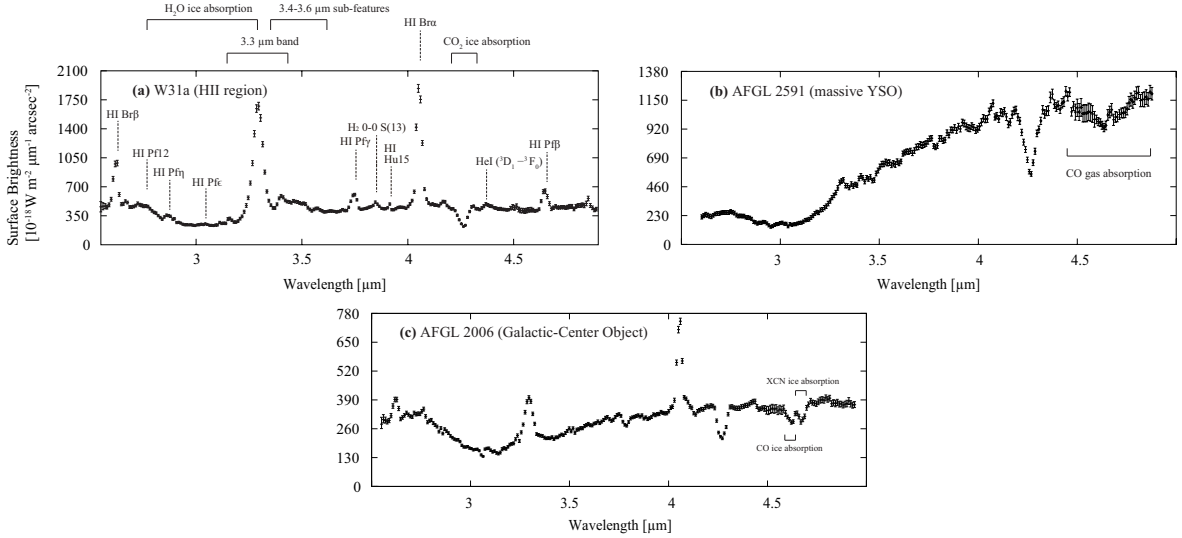

Figure 1. Typical spectra of the present dataset. Spectra of (a) a PDR+H II region complex, W31a, with a number of emission lines and strong PAH emission and ice absorption features, (b) a star-forming region with an embedded YSO, AFGL 2591, dominated by strong H_2O ice, CO_2 ice, and CO gas absorptions without significant PAH emission features, and (c) an unique object in the Galactic center, AFGL 2006, with strong CO ice and XCN ice absorptions.

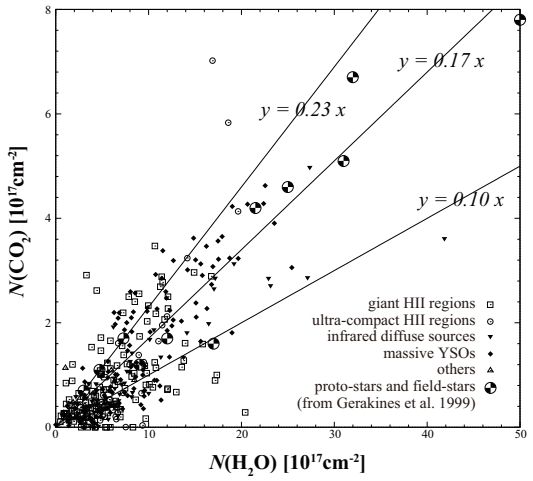

Figure 2. Plot of the column densities of CO_2 and H_2O ice. The open squares, open circles, inverse filled triangles, filled diamonds, and open triangles indicate giant H II reions, ultra-compact H II regions, infrared diffuse sources, massive YSOs, and others, taken with the AKARI/IRC, respectively. The succor balls show the results of Gerakines et al. (1999), in which the ratio of CO_2 to H_2O ice falls in the range 0.10–0.23 with the average value of 0.17.

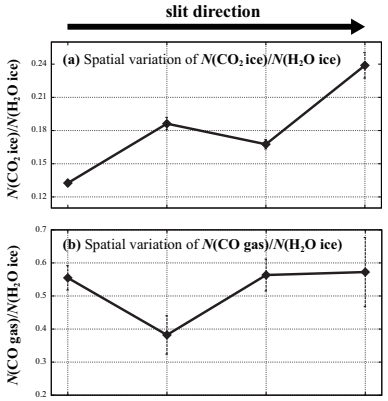

Figure 3. Spatial variation of the ratio of (a) $N(CO_2$ ice$)/N(H_2O$ ice) and (b) N(CO gas)$/N(H_2O$ ice) observed in AFGL 2591.

the present target objects. Besides, in the left-bottom corner of the plot, where the H_2O ice column density is smaller than $\sim 2\times10^{18}$cm^{-2}, the CO_2 ice column density comes to drop to zero. It possibly relates to CO_2 ice sublimation in harsh environments.

We also investigate the spatial variation of the ice abundances along the slit direction. Figure 3 shows results of a spatially-resolved object, AFGL 2591, a star-forming region at a distance of 3.33 kpc in the Cygnus X complex (Rygl et al., 2012). In addition to the strong H_2O and CO_2 ice absorption features, the spectra show CO gas absorption (Fig. 1). Away from the excitation star N3, the relative abundance of CO_2 to H_2O ices increases along the slit direction. This is also consistent with a scenario that sublimation of CO_2 ice exceeds its formation in harsh environments.

3. SUMMARY

We present observations of ice features in various Galactic sources taken with the AKARI/IRC, suggesting that UV radiation is not effective in the formation of CO_2 ice among the present targets and possible sublimation of CO_2 ice in harsh conditions.

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