AKARI NIR spectroscopy of interstellar ices

Takashi Onaka1, Tamami I. Mori1, Itsuki Sakon1, Fumihiko Usui1, Ronin Wu1 and Takashi Shimonishi2

1Department of Astronomy, Graduate School of Science, The University of Tokyo
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
email: onaka@astron.s.u-tokyo.ac.jp

2Frontier Research Institute for Interdisciplinary Sciences, Tohoku University
6-3 Aramaki-aza aoba, Aoba-ku, Sendai, Miyagi, 980-8578, Japan

Abstract. The Infrared Camera (IRC) onboard AKARI has a near-infrared (2–5 μm) spectroscopic capability with high sensitivity that allows us to study the major ice components in various objects. In particular, H2O and CO2 ice absorption features have been detected towards nearby galaxies, including several young stellar objects (YSOs) in the Large Magellanic Cloud (LMC), as well as a number of HII-region-PDR complexes for the first time by IRC spectroscopy. While observations in the LMC show a high ratio (~0.34) of the CO2 to H2O ice column densities, the ratios in Galactic HII-region-PDR complexes are in the range of 0.1–0.2, being compatible with those found in Galactic massive YSOs in previous studies. The good correlation supports concurrent formation of the two ice species on the grain surface and the higher ratio in the low-metallicity LMC suggests possible environmental effects in the formation process.

Keywords. (ISM:) dust, extinction, ISM: lines and bands, infrared: ISM, astrochemistry

Ices of various species play important roles in interstellar chemistry (e.g., van Dishoeck 2014). Characteristic bands of ice species reside in the near- to mid-infrared (2–20 μm) and thus infrared observations are the most efficient means for the study of ices in the interstellar medium (ISM). ISO and Spitzer studied ice features towards deeply embedded young stellar objects (YSOs) and stars behind molecular clouds, making significant progress in our understanding of interstellar ices (e.g., Gibb et al. 2004; Pontoppidan et al. 2008). They indicate good correlations between the column densities of H2O and CO2 ices, suggesting concurrent formation of the two ice species on the grain surface (Ippolo et al. 2011; Oba et al. 2012).

The Infrared Camera (IRC) onboard AKARI offered high-sensitivity spectroscopy in 2.5–5 μm (Onaka et al. 2007), where major ice species have strong absorption bands, such as H2O at 3.05 μm, CO2 at 4.27 μm, XCN at 4.62 μm, and CO at 4.67 μm. The IRC allows us to study ice absorption features in faint objects, including nearby galaxies and relatively evolved diffuse objects. A recent study of ices in nearby galaxies with the IRC suggests no clear correlation between H2O and CO2 ices, which may be attributed to the relatively large beam (~5") that contains various components on the line-of-sight (Yamagishi et al. 2015). Studies of ice absorption towards YSOs in the Large Magellanic Cloud (LMC) with the IRC, on the other hand, show by a factor of 2 larger column densities of CO2 ice relative to H2O ice than towards Galactic massive YSOs, which must be related to the low-metallicity condition of the LMC and give important implication on the ice formation process (Shimonishi et al. 2008, 2010). A study of Galactic molecular clouds with the IRC further suggests multi-stage ice formation (Noble et al. 2013).

In this report, we present latest results of NIR spectroscopy of ice species in Galactic HII-photodissociation region (PDR) complexes made with the IRC. Those targets are extended and relatively evolved compared to YSOs in previous studies and thus may
indicate evidence for interstellar processing of ice species. Previous studies of the emission bands related to polycyclic aromatic hydrocarbons (PAHs) indicate that IRC spectra of those objects indeed show ice absorption features (Mori et al. 2014; Onaka et al. 2014). Figure 1a shows the correlation of the column densities between CO2 and H2O ices for the present samples, which is in agreement with previous results for Galactic massive YSOs except for several data located below the correlation line(s), suggesting possible interstellar processing. Figure 1b plots the ice column densities against the HI line intensity ratio, which suggests a threshold for the presence of these ices. The suggested threshold is $A_v \sim 5 \pm 1$, being compatible with those found in the Taurus cloud (Whittet et al. 2001, 2007). The new IRC results support concurrent formation of CO2 and H2O ices and suggest common physical conditions present for ice formation in the ISM.

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References

van Dishoeck, E. F. 2014, Faraday Discuss., 168, 9