H_2O and CO_2 Ices around Extragalactic Young Stellar Objects

-- *AKARI* 2-5um spectroscopy --

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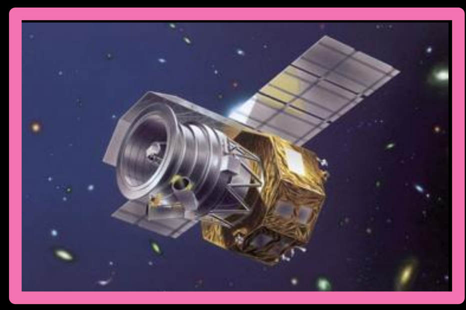
Shimonishi et al.2008, ApJ, 686, L99

Key words:
circumstellar matter — ices — extragalactic YSOs — Magellanic Clouds



1. Introduction

Ices around YSOs

- Important reservoir of heavy elements and complex molecules (Tab.1, Fig.1)
- An origin of a cometary ice and a planetary ocean (Tab.1)
- Observed by infrared absorption bands
- Formation mechanisms of ices are not understood well

Extragalactic YSOs

- The diversity of a chemical balance around YSOs in extragalactic environments
- Few spectroscopic observations of ices toward extragalactic YSOs so far

The Large Magellanic Cloud (LMC)

- The nearest (~50kpc) irregular galaxy to our Galaxy
- An ideal environments for the study of extragalactic YSOs due to its proximity and low metallicity

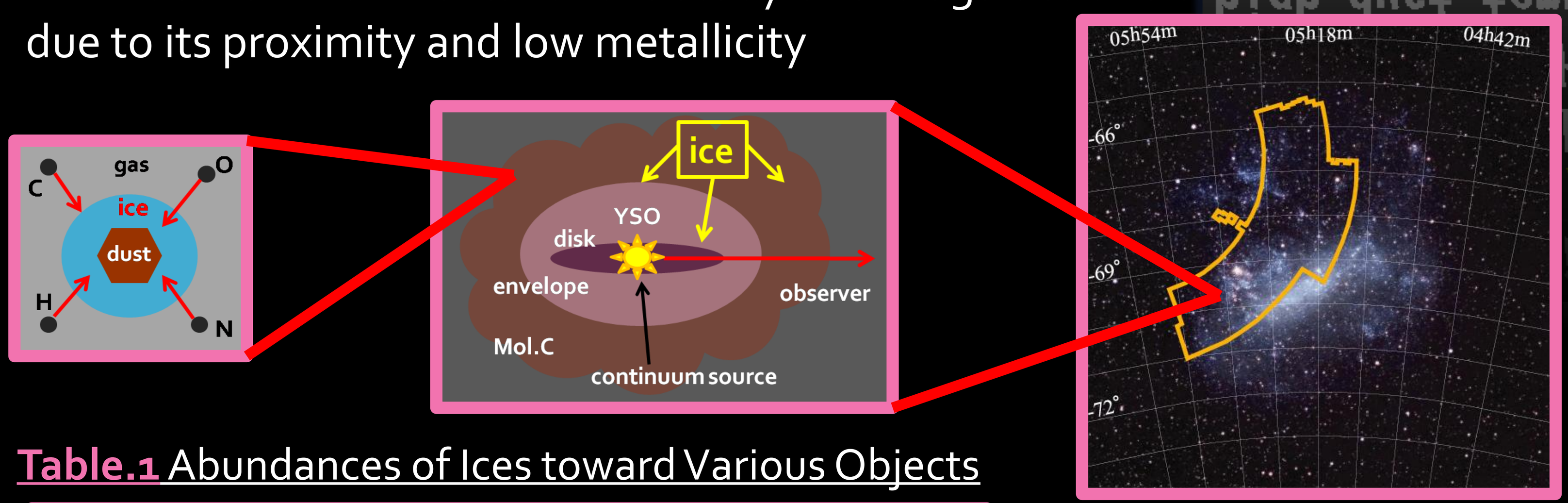


Fig.1 Ices, YSO, and the LMC

Table.1 Abundances of Ices toward Various Objects

Species	Galactic YSO [%]	Comets [%]	Extragalactic YSO (LMC) [%]
H2O (water)	100	100	100
CO2 (carbon dioxide)	17	3-6	? → 45 *
CO (carbon monoxide)	1—50	7-20	?
CH4 (methane)	1—2	0.2-1.2	?
CH3OH (methanol)	2—5	~2	?
NH3 (ammonia)	3	~1.5	?

* Result of this study

2. LMC NIR Spectroscopic Survey

- *AKARI* is the first Japanese infrared astronomical satellite
- 2–5um, R~20, slit-less prism multiobject spectroscopy
- 667 fields are observed so far (Fig.1 right), an enormous NIR spectral database is expected

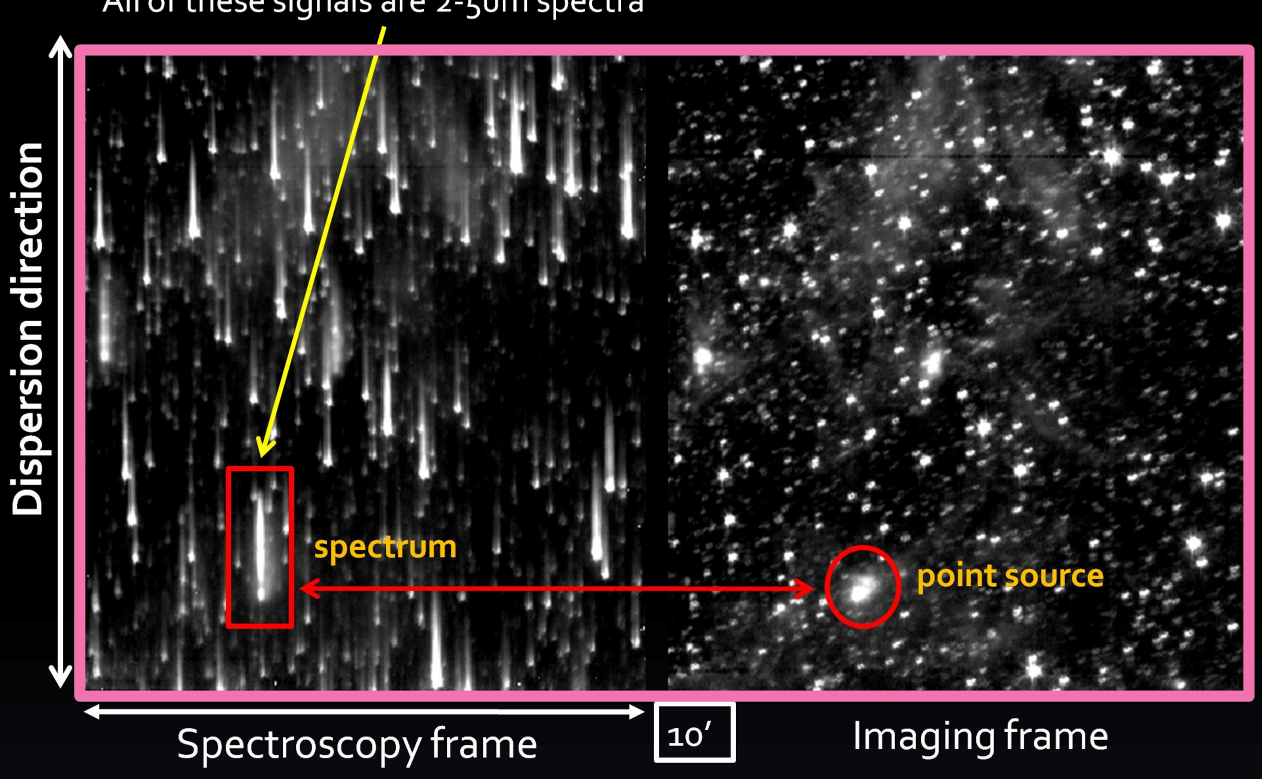


Fig.2 *AKARI* slit-less multiobject spectroscopy

3. The Selection of YSOs

2,000,000 Infrared sources (Spitzer SAGE survey) In *AKARI* survey area (Fig.1 right)

Massive YSOs are selected by this criterion

450 sources selected by the photometric selection.

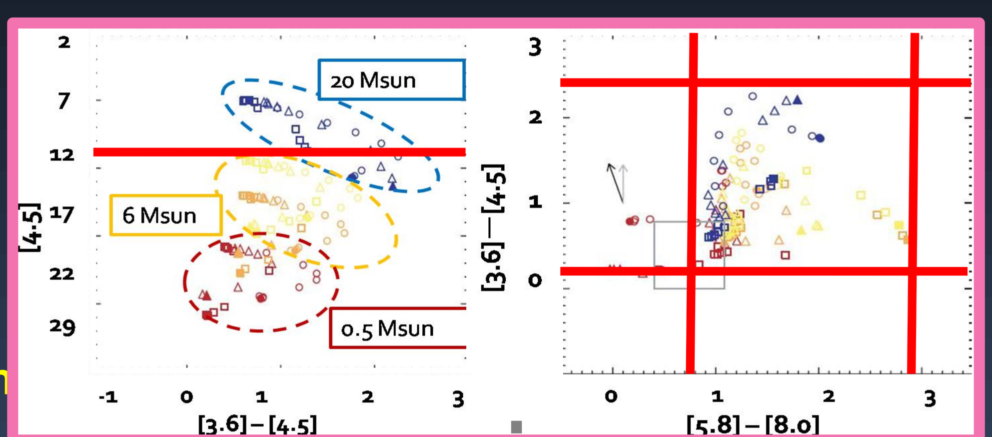


Fig.3 Color selection of YSO candidates (ref. Whitney et al.2004)

Problems of photometric selection

- Photometrically selected YSO candidates include many dusty AGBs because SEDs of these two objects are similar
- But, a presence of the CO_2 ice is able to distinguish YSOs since the CO_2 ice is not detected toward dusty AGBs.

We investigated a NIR spectrum of photometrically selected YSO candidates.
Finally, **7 massive YSOs (Fig.5) are discovered**

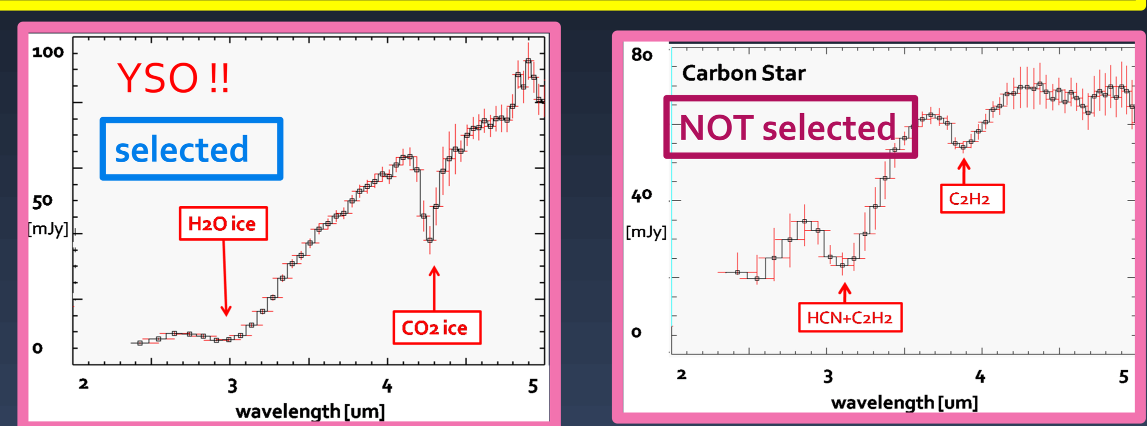


Fig.4 Spectroscopic selection of YSOs

ABSTRACT & CONCLUSION

- We have been performing the NIR spectroscopic survey of the LMC with the infrared satellite *AKARI*
- We **spectroscopically confirmed 7 massive YSOs** which show strong absorption features of H_2O (3.05um) and CO_2 (4.27um) ices
- Derived CO_2 / H_2O ice ratio is 0.45±0.17, which is higher than that of Galactic massive YSOs (0.17±0.02)
- We suggest that strong UV radiation field and/or high dust temperature in the LMC are responsible for the high CO_2 ice abundance

4. Results and Discussion

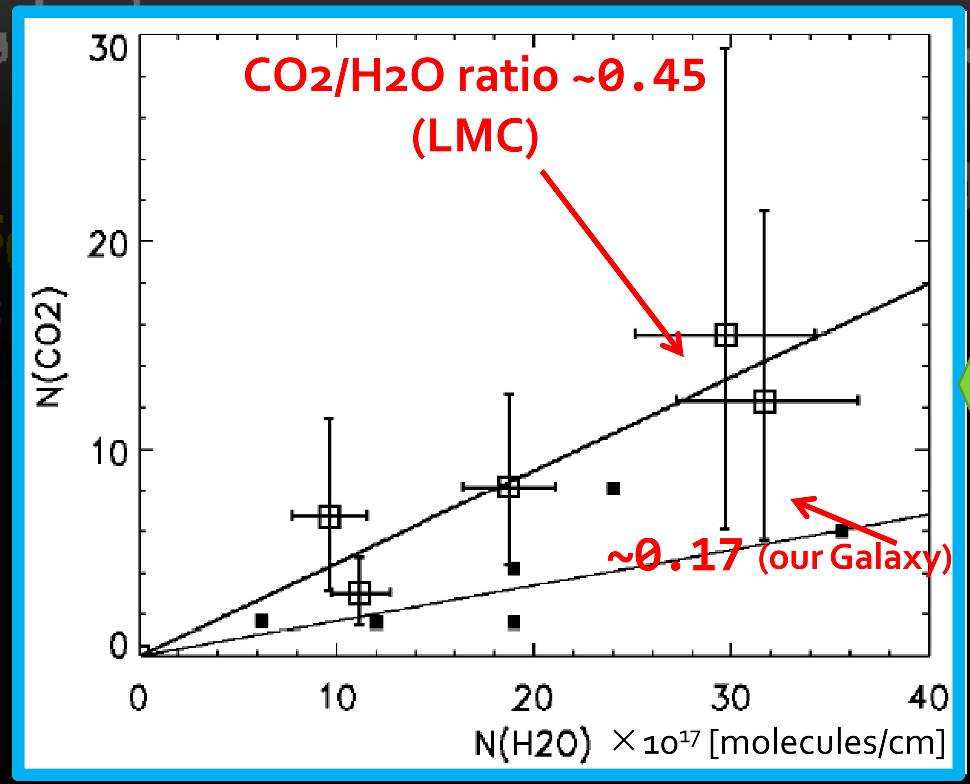


Fig.6 H2O vs. CO2 column density plot. Open and filled circles represent results of this study and that of Galactic massive YSOs.

An abundance of CO_2 ice toward massive YSOs in the LMC is higher than Galactic massive YSOs !!!

A strong UV radiation field (e.g. Israel & de Graauw, 1986) and generally high dust temperature of the LMC (e.g. Sakon et al.2006) may be responsible for the high CO_2 ice abundance around Magellanic YSOs.

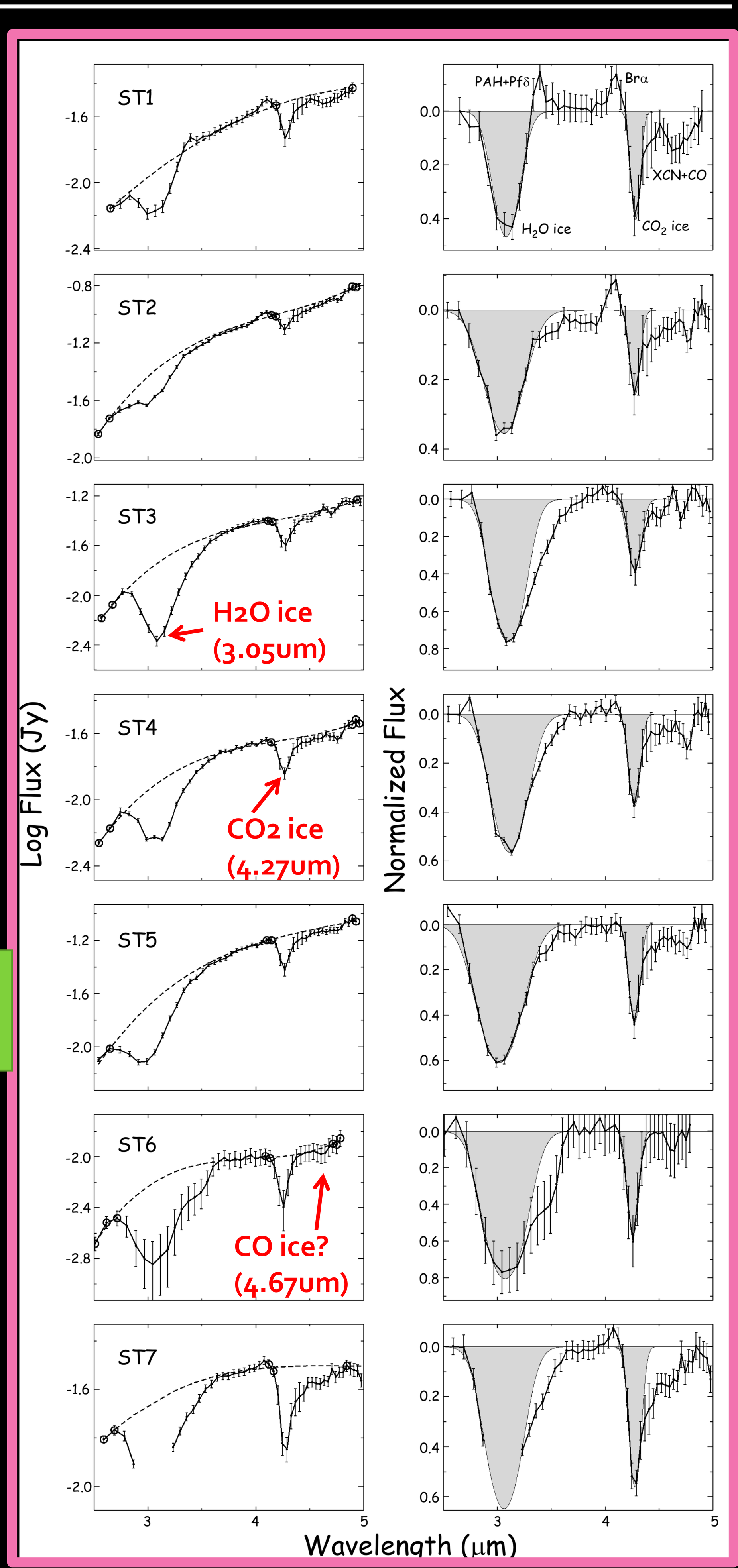


Fig.5 AKARI NIR spectra of selected 7 massive YSOs

* The formation mechanism of CO_2 ice around YSO is not understood at this time.

Table.2 Possible formation mechanisms of the CO2 production

Proccess	Explanation	Key parameter
UV photolysis	Laboratory experiments indicate that UV irradiation is necessary to produce CO2 ice	UV radiation field
Grain Surface Chemistry	Theoretical studies indicate that high dust temperature (14~18K) is necessary to produce sufficient amount of CO2 ice.	Dust temperature

5. Future Works

Follow-up Observations by *AKARI* (this winter)

- Another spectroscopy mode (R~80, 2.5-5um)
- Targets are NIR-interested objects found in our spectroscopic survey (including YSOs in Fig.5)

Partially observed

- More accurate estimation of column densities
- New species of ice in the LMC ???

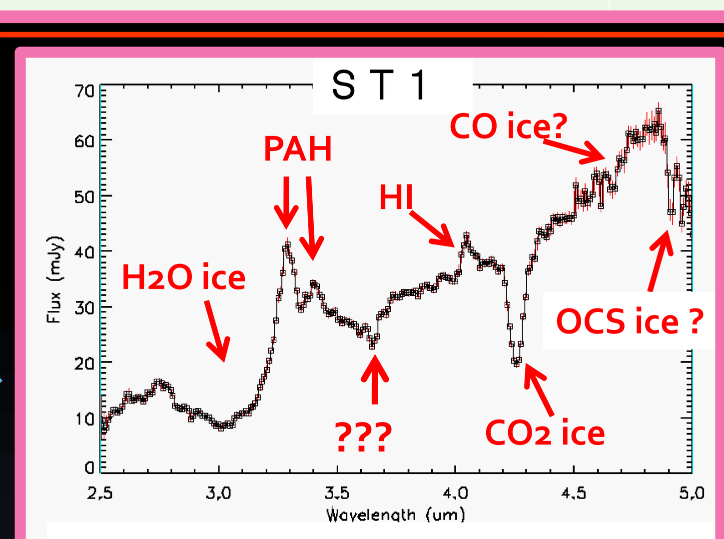


Fig. 7 Initial results of follow-up observations