ALMA and AKARI Observations of Mysterious Interstellar Icy Objects:
A New Site for Organic Molecule Formation?

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Interstellar icy objects with unknown nature

- Two peculiar icy objects were serendipitously found in the data of the infrared satellite *AKARI* (Onaka+ 2021, [1]).
- Both objects show deep ice/dust absorption bands (H_2O, CO_2, CO, CH_3OH, XCN) that are often seen in embedded YSOs or background stars behind dense clouds
- However, they are located neither in known star-forming regions nor in known dense clouds.
- Their infrared SEDs show a peak around 5 micron (Fig.1), which are incompatible with those of other known interstellar embedded objects with ice absorption bands
- They are located in the Galactic plane direction (Fig.2)

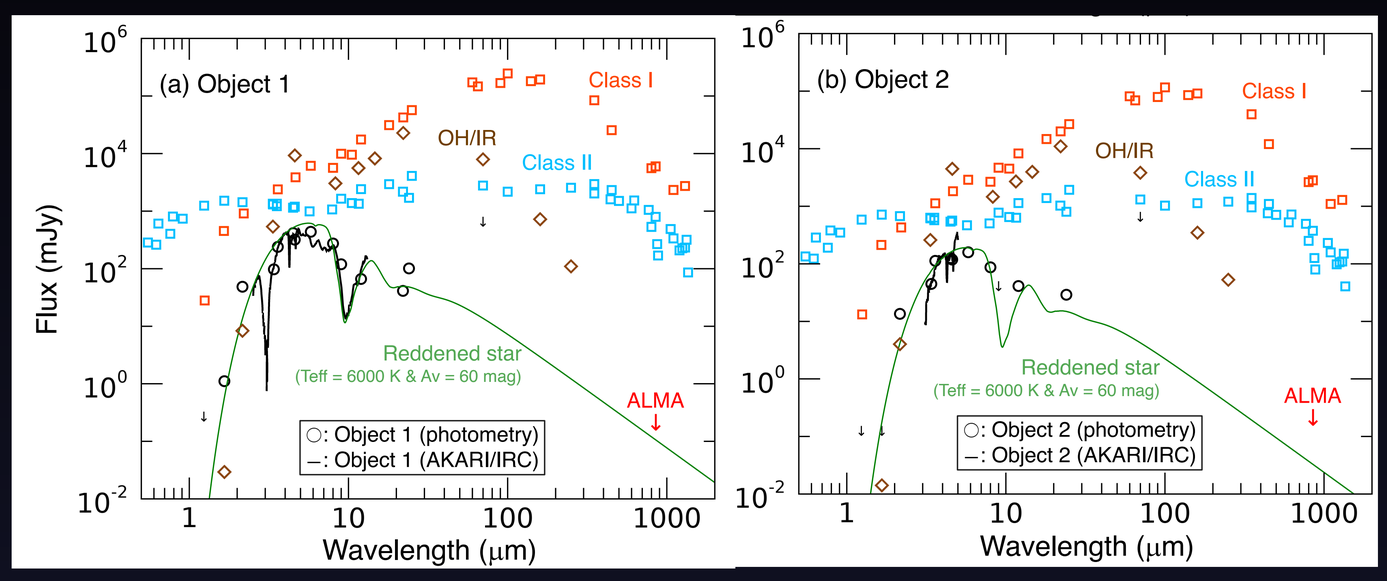


Fig.1 Observed infrared spectra of two peculiar icy objects. Typical spectra of known interstellar icy sources are also plotted (Class I YSO: red, Class II YSO: blue, OH/IR star: brown).

What is their nature?

- YSOs? ... then similar objects should have eluded past photometric surveys, lack of mid-/far-infrared excess is puzzling.
- Background stars? ... then there must be very compact, dense, and isolated cores, or ice growth in diffuse clouds.
- AGB stars? ... then there must be unknown grain surface chemistry to form organic molecules in stellar ejecta.

To investigate the nature of these enigmatic icy objects, we conducted observations with ALMA.

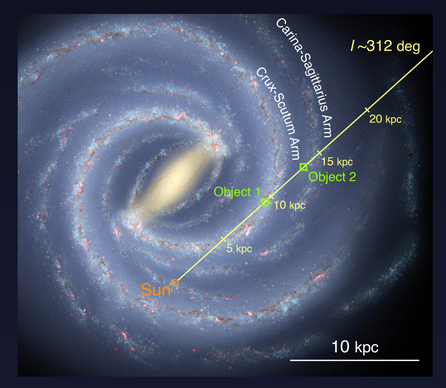


Fig.2 Source's direction. Their distances are estimated based on the kinematic distance.

ALMA 12m+ACA observations in 350 GHz (Shimonishi et al. 2025 [2]) —another mystery emerges

- Very compact emission of CO(3-2) and SiO(8-7) are detected at the positions of two icy objects (Fig.3); other lines are not detected
- Line widths are broad (10-15 km/s) in both sources
- SiO/CO ratio is *very* high
  N(SiO)/N(CO) ~1e-3 assuming LTE and T=20-50 K (see Table. 1)
  => Suggesting shock chemistry.
- Large dust extinction (Av ~80-120 mag) is implied from their deep dust/ice absorption bands, but no dust continuum is detected.
  => Suggesting large beam dilution. They must be very compact.
- The two objects show clearly different systemic velocities, although they are located in the same direction
  => Suggesting isolated nature. Two objects are independent.

✓ Their characteristic SEDs (no MIR/sub-mm excess), the deep ice/dust absorptions, compact source size, and SiO-dominated broad molecular lines cannot easily be accounted for by any of known interstellar ice-absorption sources (Table. 2).

A new type of interstellar embedded objects that provide an environment conducive to the formation of organic ices?

Table 1. SiO/CO ratios

	N(SiO)/N(CO)
Object 1,2	~1e-3
Shock regions	~1e-4–1e-2
Protostellar envelopes	~1e-6
Dark clouds	~1e-8
AGB stars	~1e-3–1e-1

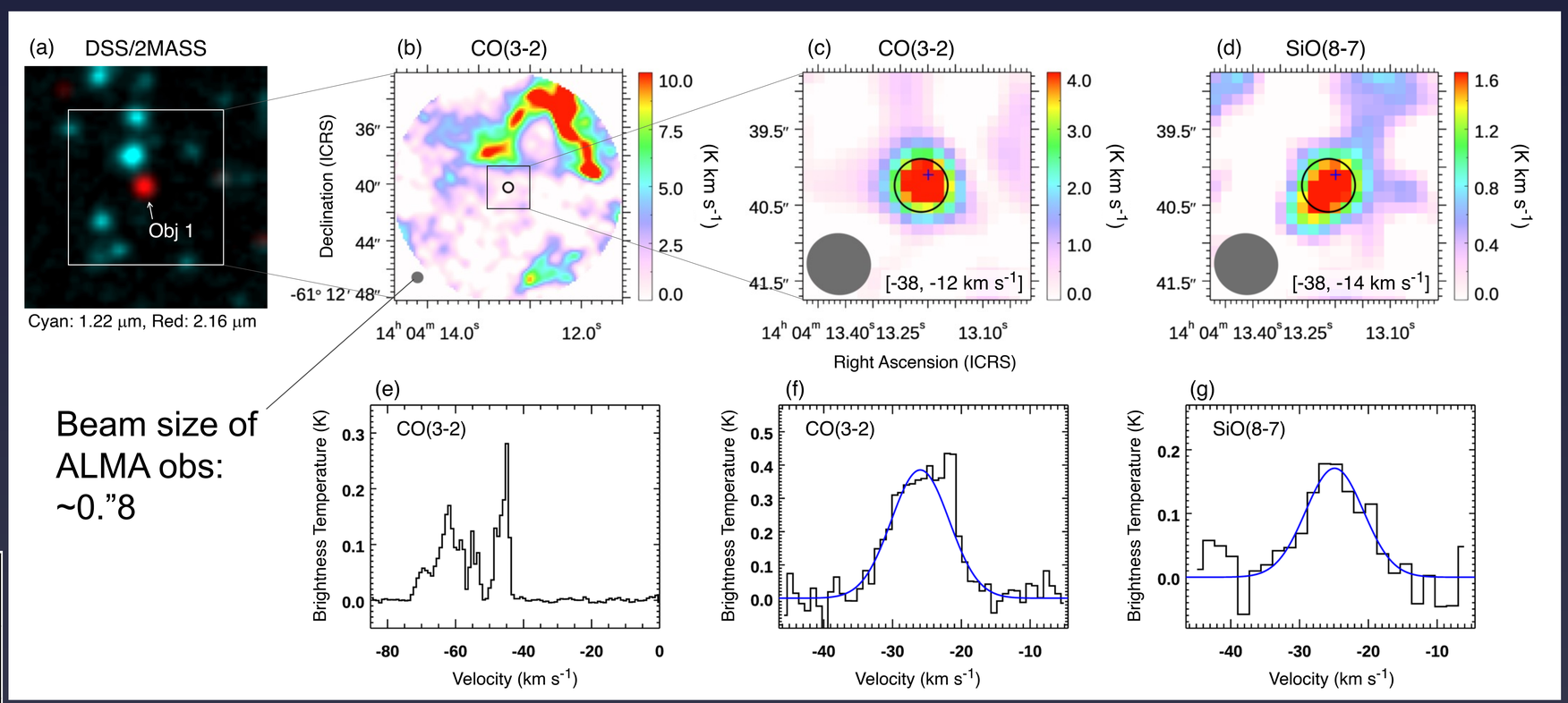


Fig.3 ALMA results (up: Object 1, bottom: Object 2)

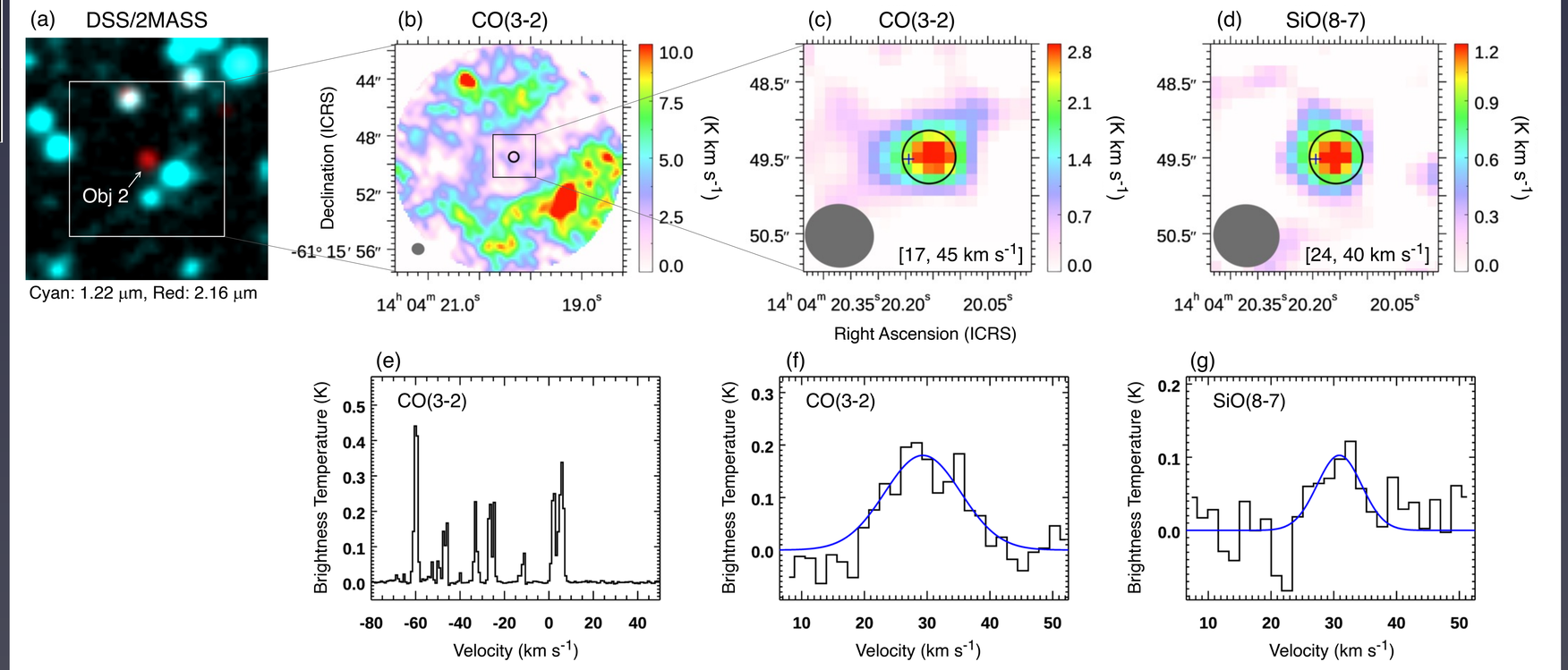


Table.2 Correspondence table of the characteristics of the two peculiar icy sources

Type	SED	Size	SiO/CO	Line width	2μm flux	Organic ice
Dense core + BG star	◎	×	×	×	×	○
Protostar (Class I)	×	△	△	○	○	◎
Edge-on disk (Class II)	×	○	×	△	○	○
Evolved star (OH/IR)	×	○	○	○	○	×

◎ = strongly consistent, ○ = moderately consistent,
△ = conditionally consistent, × = inconsistent.

References
[1] T. Onaka et al. 2021, ApJ, 916, 75
[2] T. Shimonishi et al. 2025, ApJ, 981, 49