An overview of the AKARI results

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& AKARI ISM Nearby Galaxy team

AKARI Mission
JAXA, Nagoya-U, U. of Tokyo, NAOJ, ..
International collaboration with ESA, IKSGO, & SNU

Menu

Overview of the AKARI mission
Ice chemistry in the LMC
Debris disk search in the AKARI all-sky survey
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Current status of AKARI & perspectives

AKARI satellite

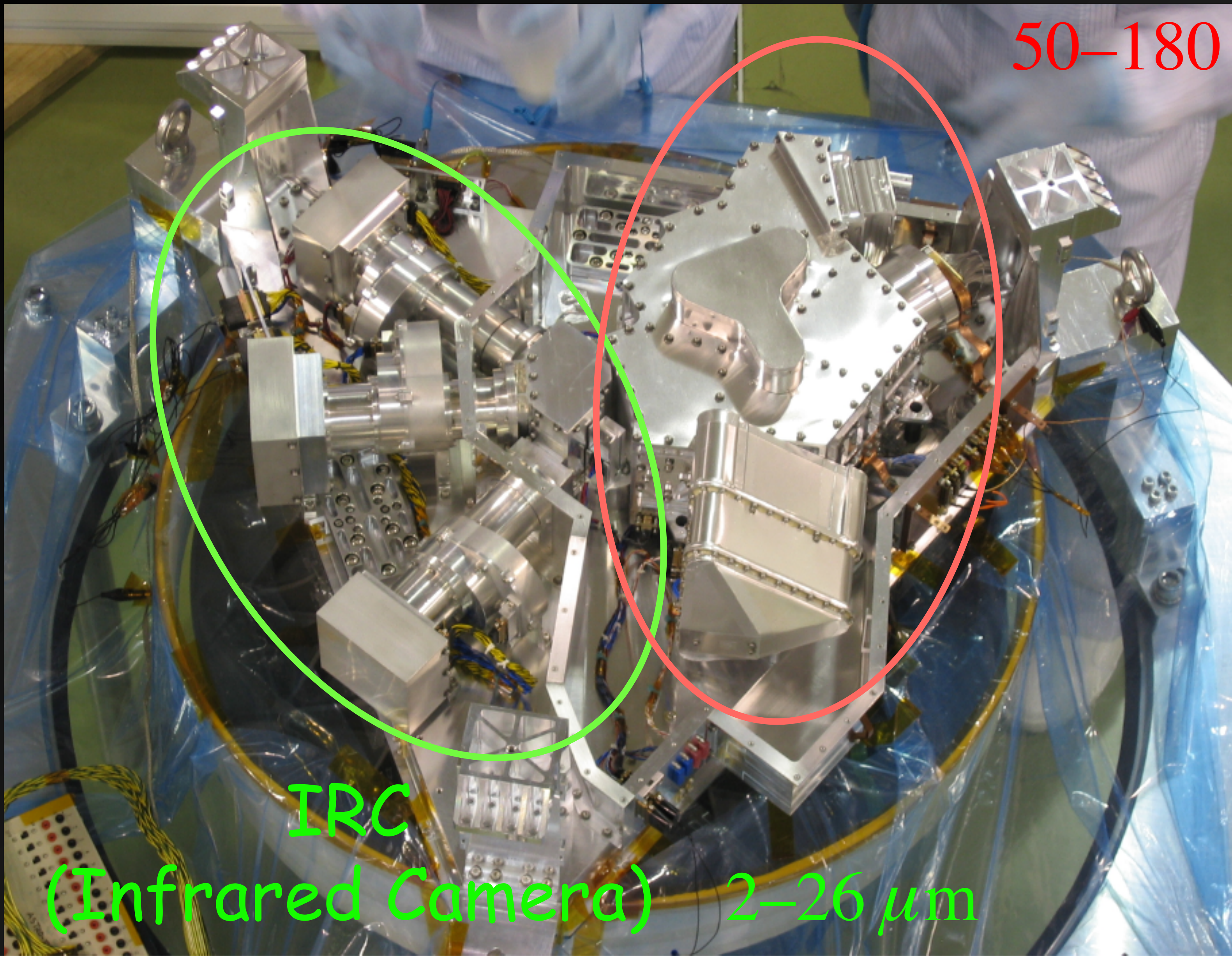
70cm SiC mirror
180L LHe + cryocoolers
on a 700km sun-synchronous polar orbit
18 month cold mission
(2006.2-2007.8)

All-sky survey at 9, 18, 65, 90, 140, & 160 μm to surpass IRA
+
Pointing observations of imaging and spectroscopy in 2-180μm

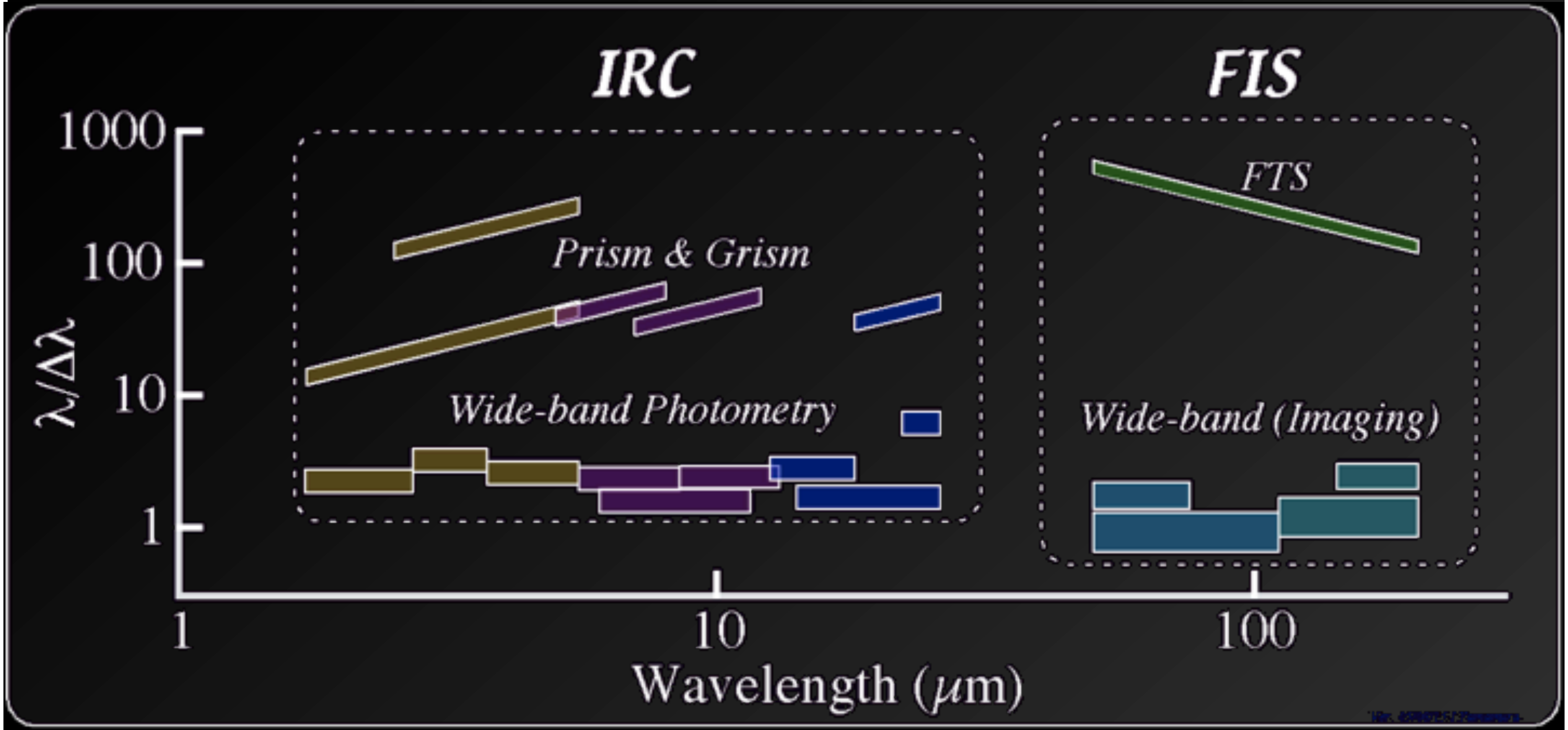
Warm mission
(NIR observations) continued

On-board Instruments

(Far-Infrared Surveyor) FIS



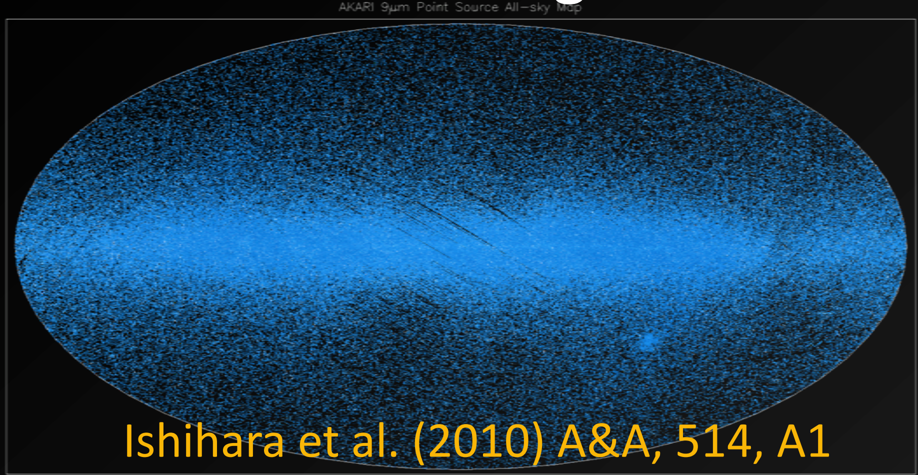
Instrument capability

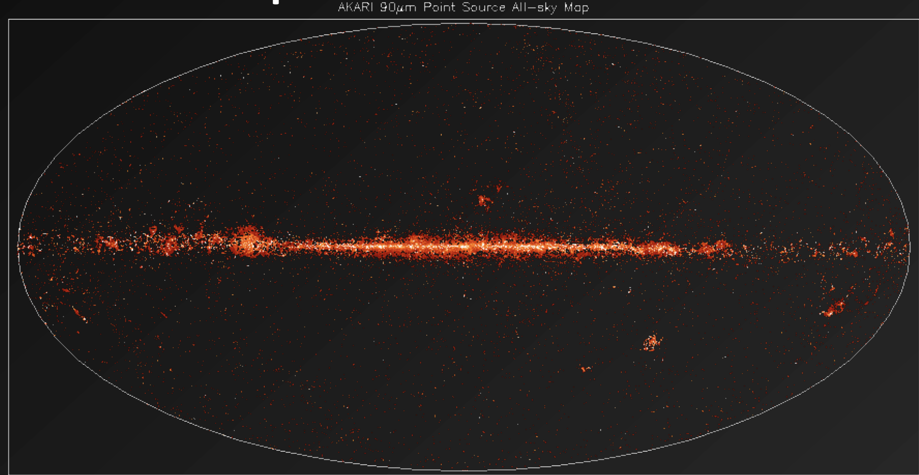


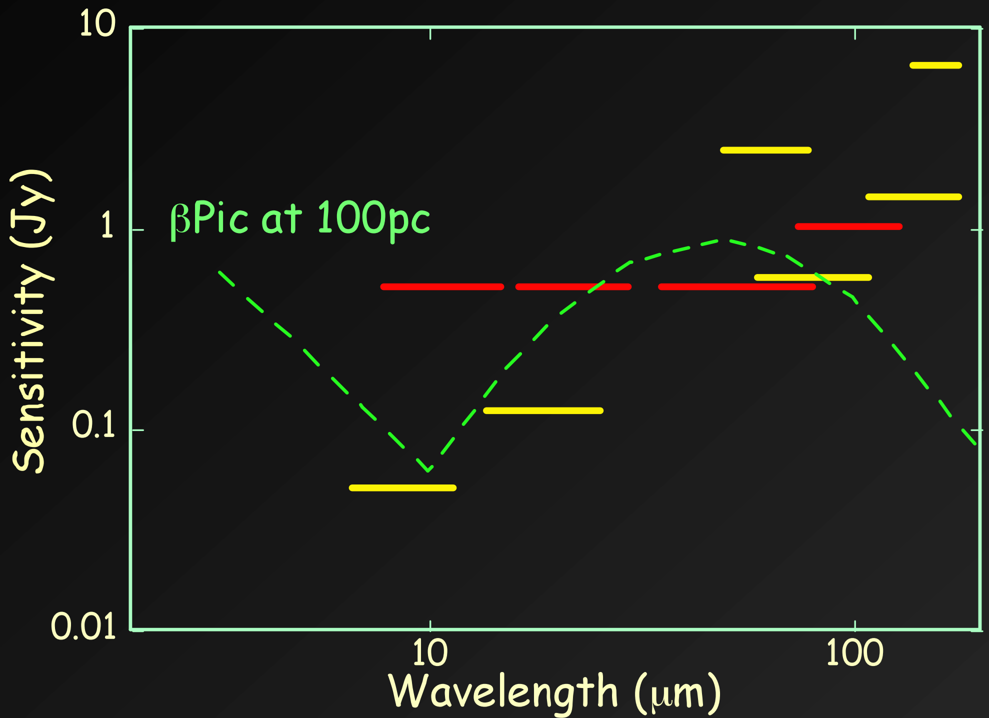
AKARI all-sky survey

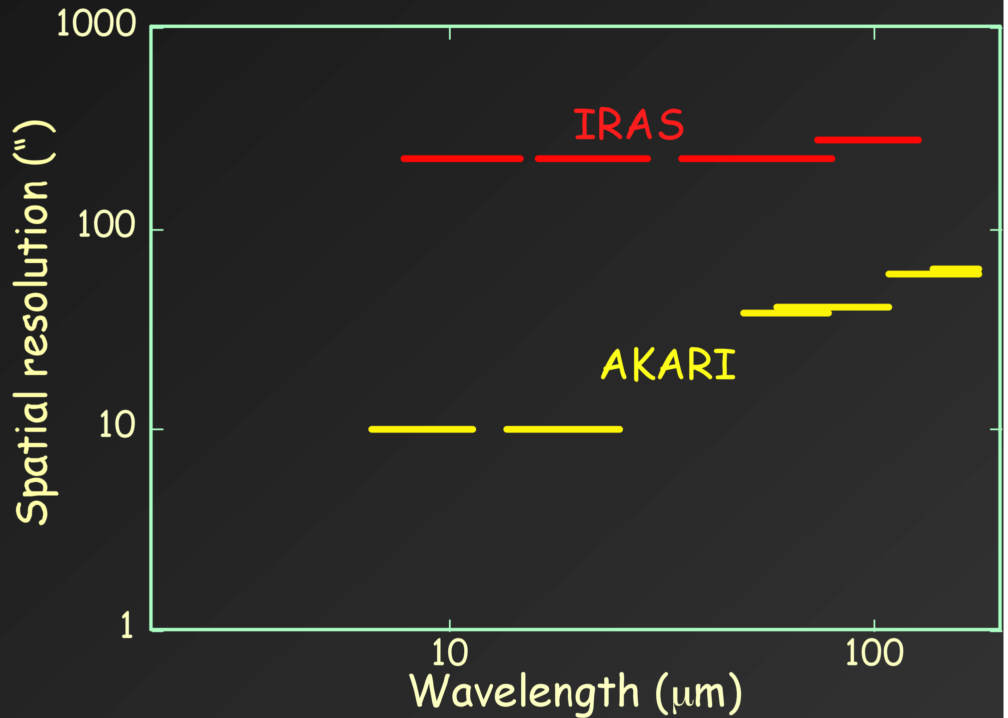
9μm source (~870,000) 90μm source (~37,000)

Point source catalogs were released to the public in March 2010







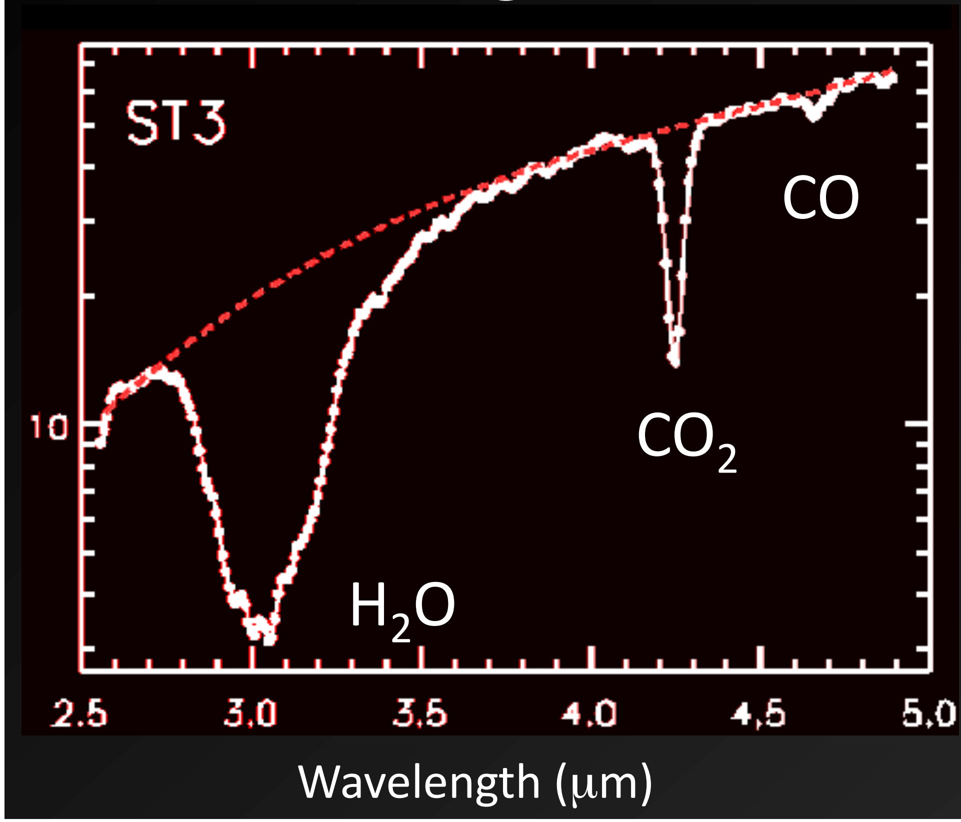


Ices in LMC YSOs

[Takashi Shimonishi et al. (2008) ApJL 686, L99, (2010) A&A, 514, A12]

Ices (H_2O, CO_2, CO, ..) are key ingredients to form large bodies
But ice chemistry is still not fully understood.

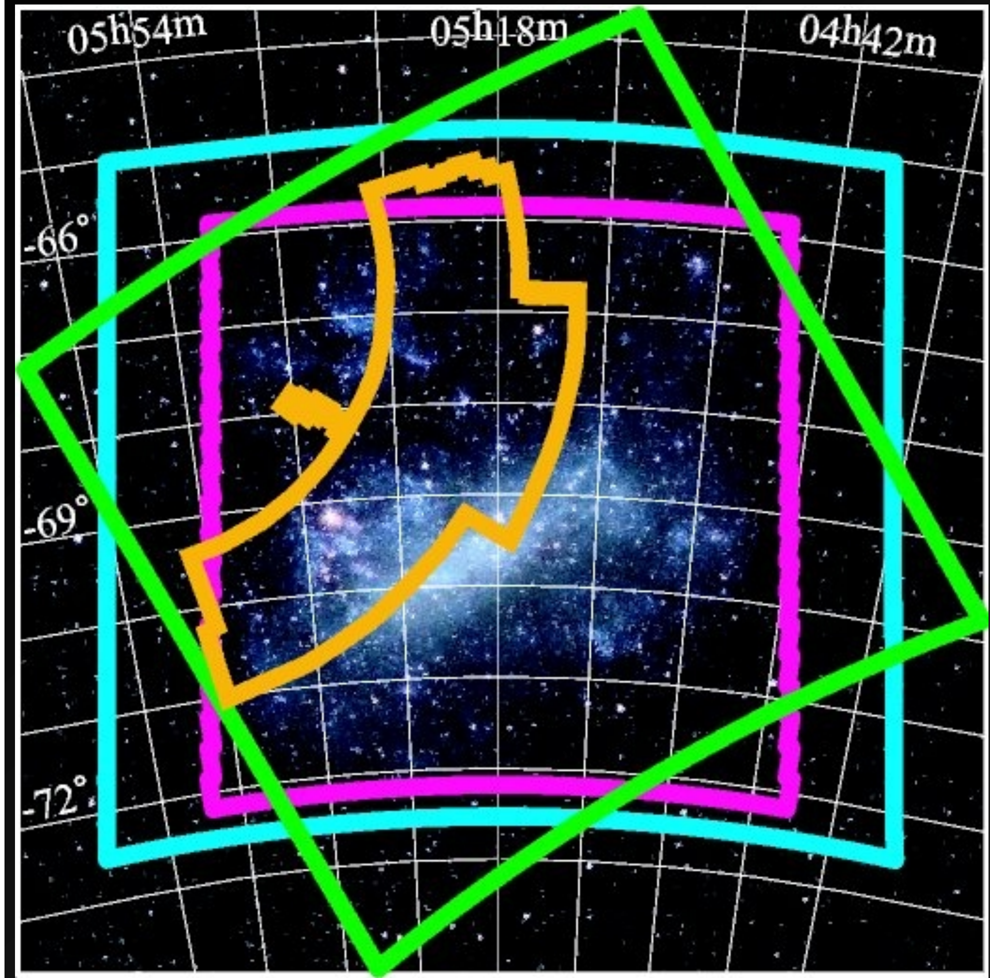
Ices in YSOs in different environments (metallicity, radiation,..) will give us a new insight into ice chemistry



The low-metallicity Magellanic Clouds (LMC & SMC) provide an interesting place to investigate ice chemistry

Major ice features (particularly H_2O) are in 2-5μm NIR spectroscopy is important

AKARI Large Magellanic Cloud Survey



AKARI IRC survey ~10 deg^2

3, 7, 11, 15, & 24μm

+ slit-less spectroscopy

(2-5μm, R~20)

(Ita et al. 2008 PASJ, 60, S435)

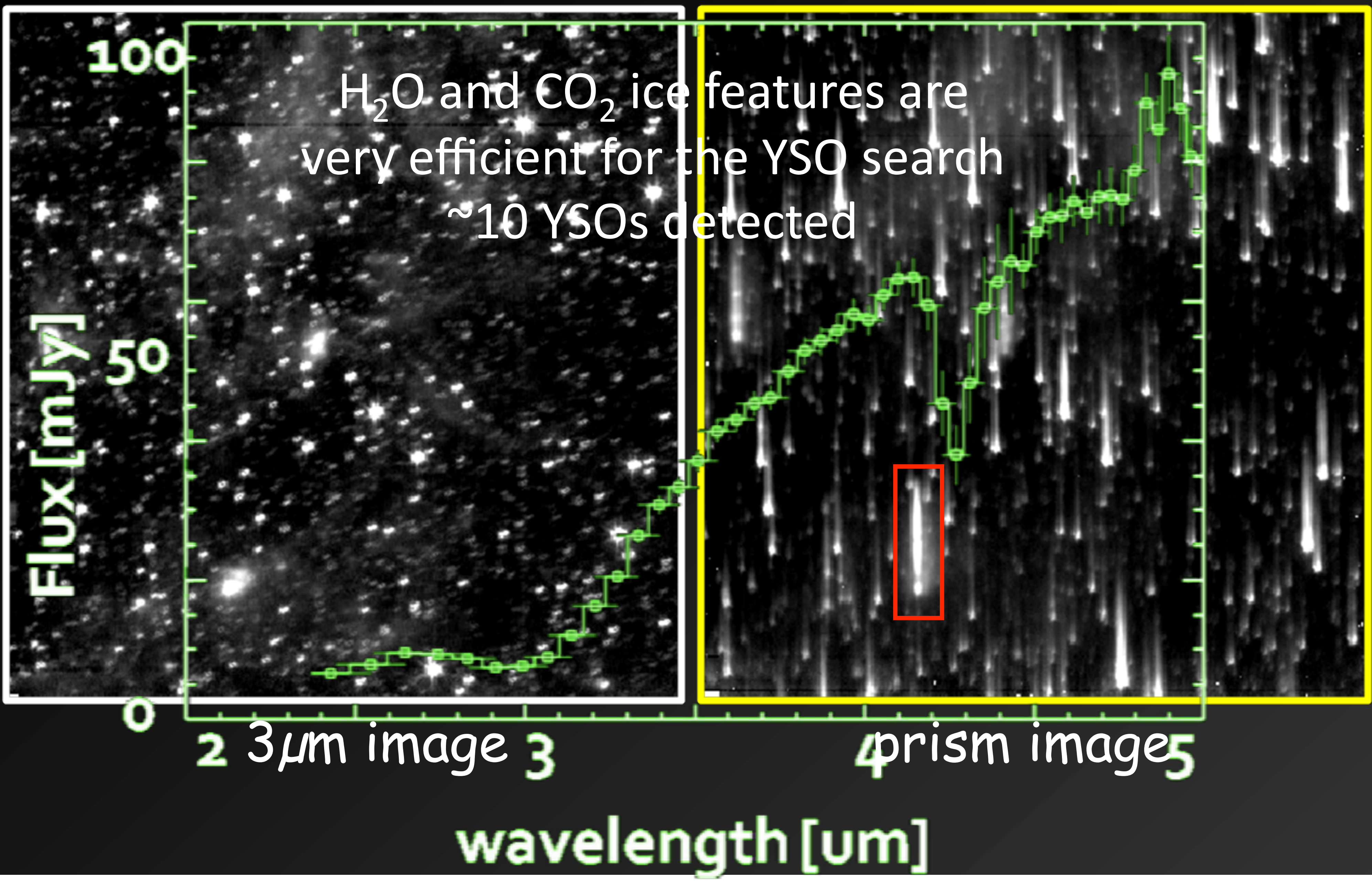
PSC to be released

IRSF/SIRIUS JHK survey

Spitzer SAGE survey

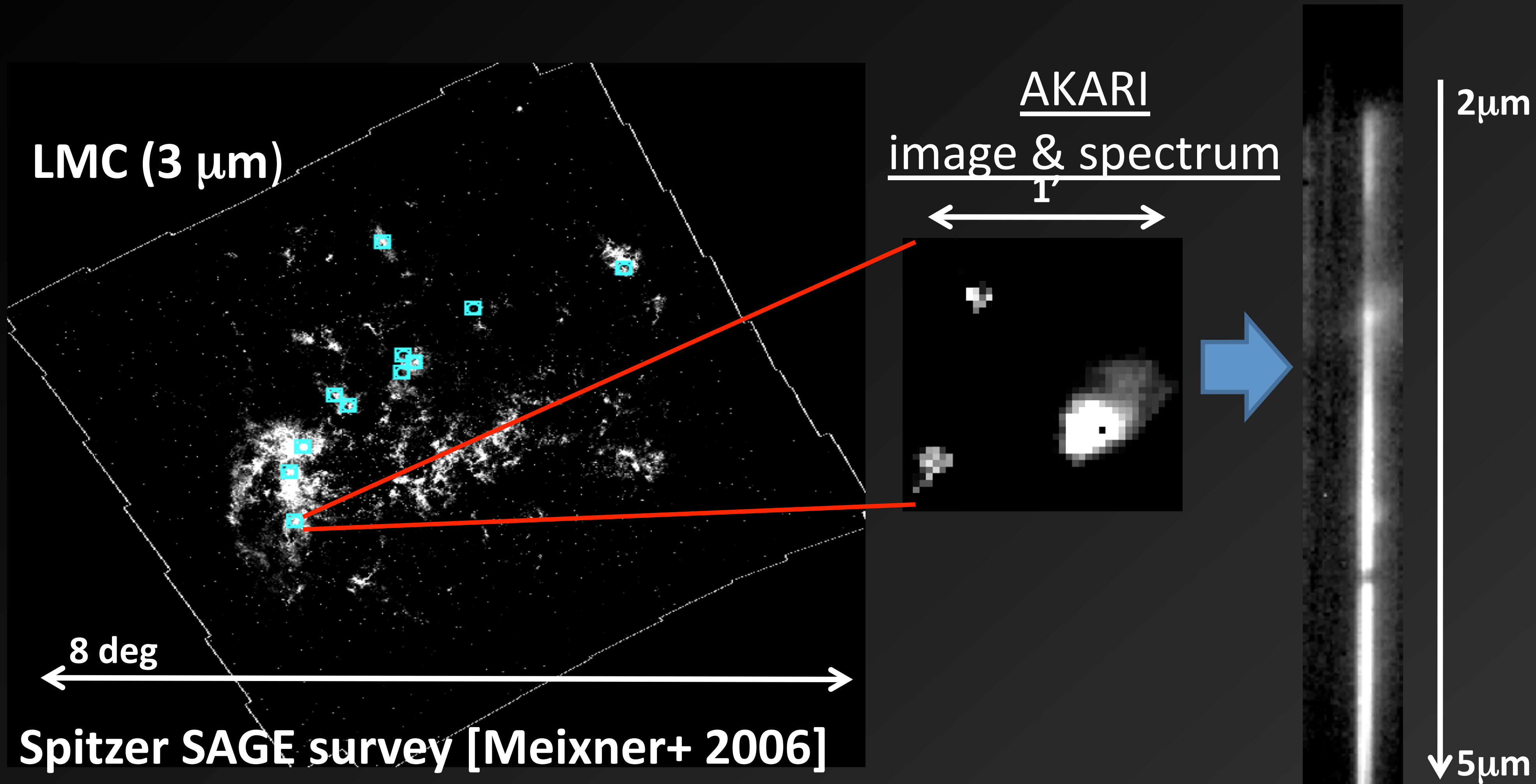
Zaritsky Optical survey

AKARI/IRC prism slit-less spectroscopic survey



Follow-up Observations with grism

56 YSO candidates (10~36 $M_\odot$) in LMC and 10 in SMC selected from photometry + YSO models of Robbitaile et al. (2006) were observed with IRC grism mode (R~80)



Hunting frozen YSO is not easy

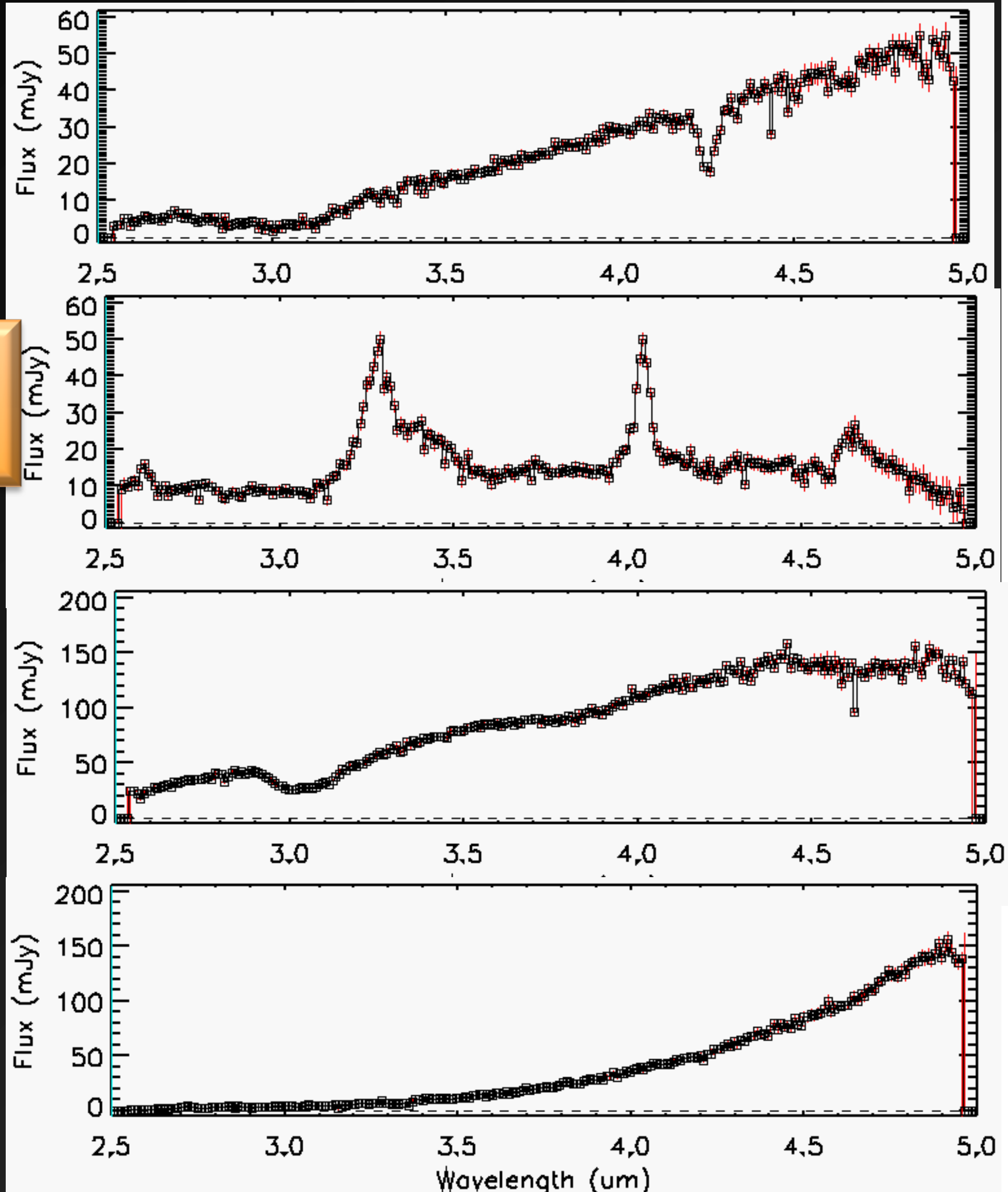
Total
56 objects

Icy YSO
11

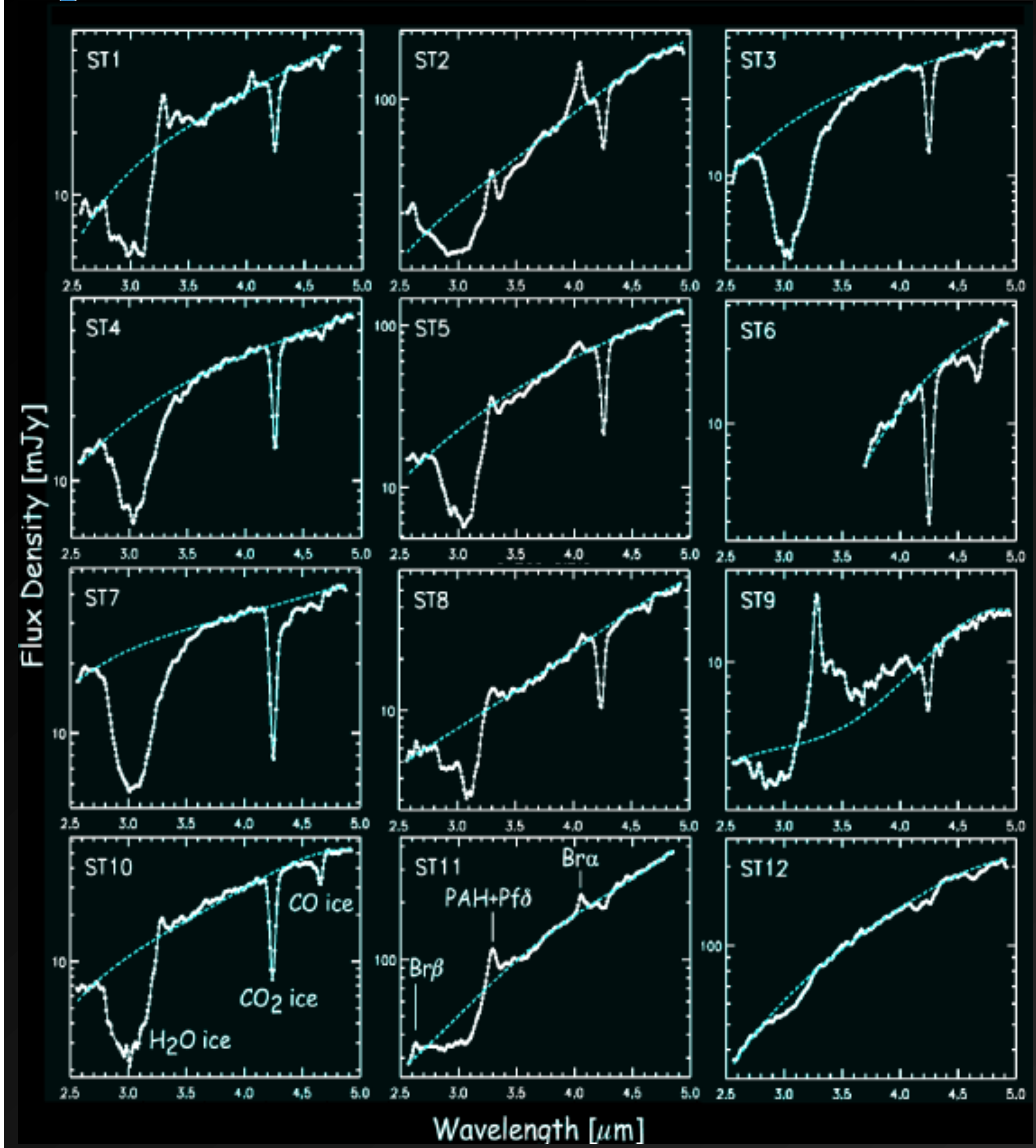
Emission Obj.
14

AGB star
11

Unknown
20



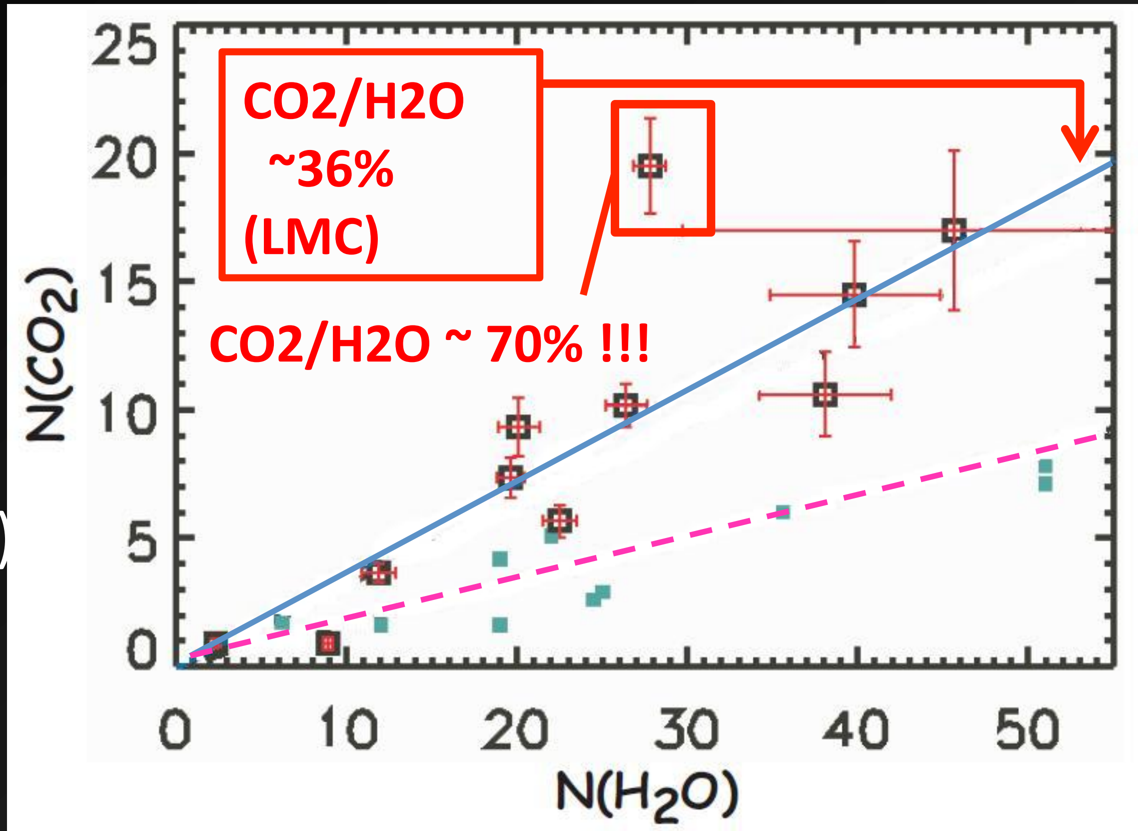
Spectra of LMC YSOs



Shimonishi et al. (2010)
A&A, 514, A12

High CO_2 ice Abundance in the LMC

Column densities are derived by the curve-of-growth method



□: LMC (Shimonishi et al. 2010)

■: Galactic (Gibb et al. 2004)
CO_2/H_2O ~ 17%

*10^{17} [molecule * cm^{-2}]

CO_2 ice is more abundant in LMC than in our Galaxy

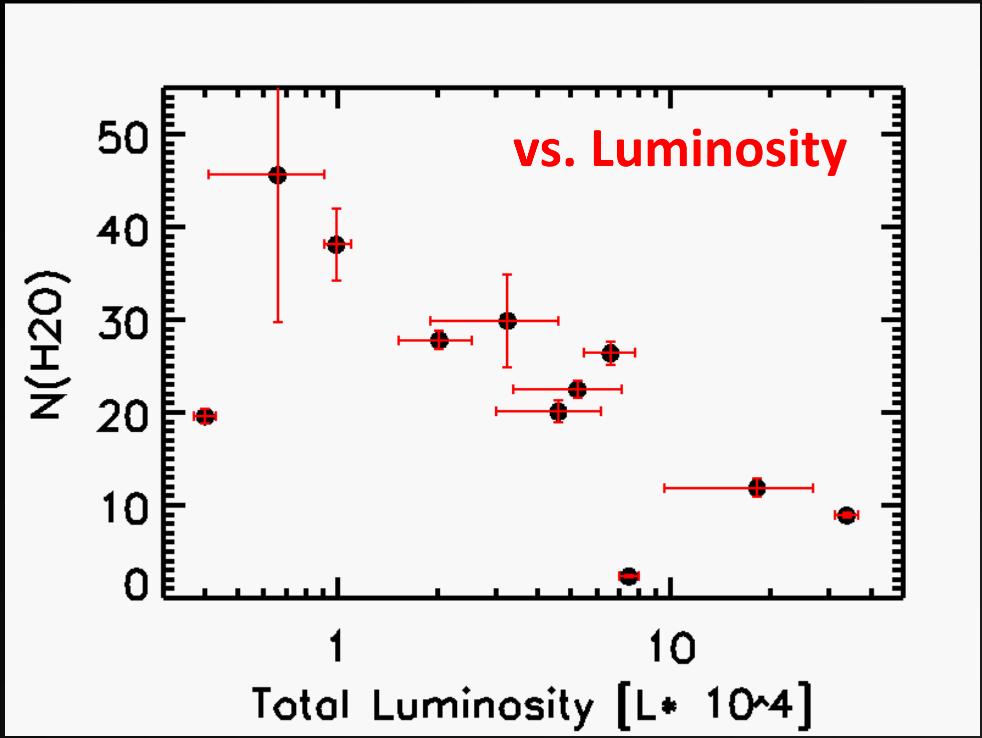
$H_2O + CO + h\nu \rightarrow CO_2 + 2H$ (enhanced by UV radiation)

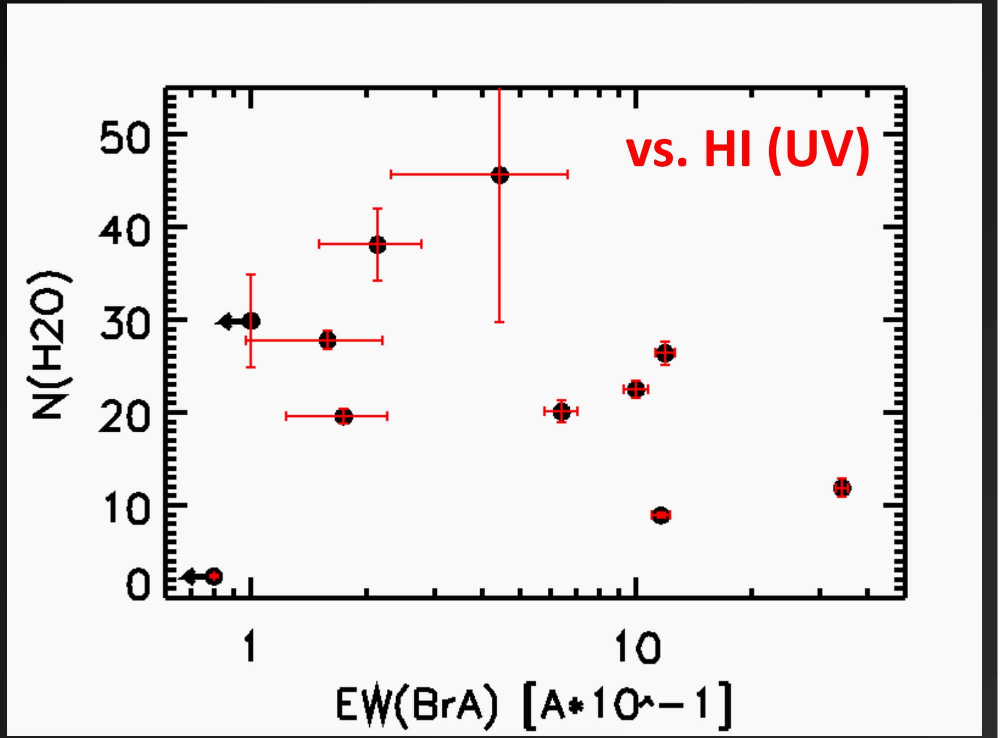
(Watanabe et al. 2002, ApJ, 567, 651)

Surface reaction enhanced at high dust temperatures

(Ruffle & Herbst 2001, MNRAS 324, 105)

Correlation between H2O ice column density and YSO properties





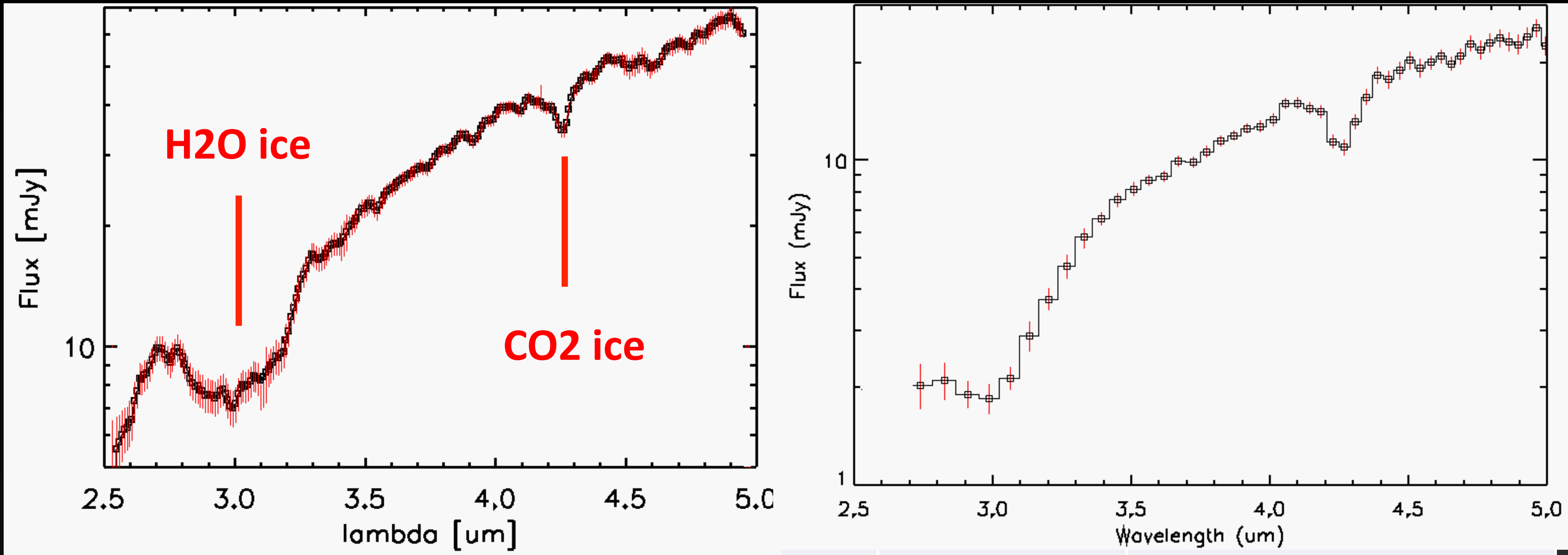
Negative correlation between total luminosities

and column densities of H_2O ice

Ices evaporate at higher luminosities?

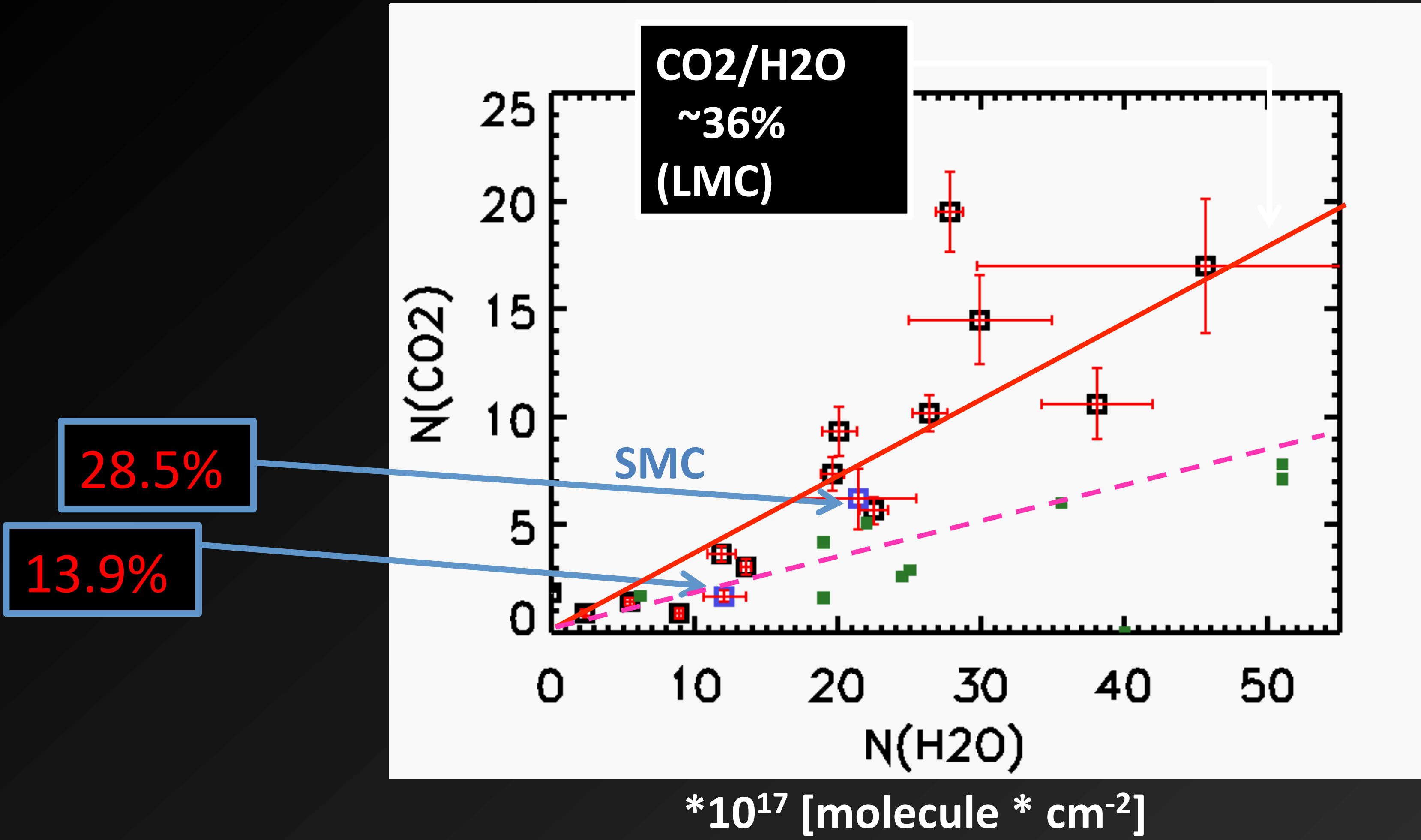
Galactic Environments in MW, LMC and SMC

AKARI NIR spectra of SMC's YSOs (Shimonishi+ in prep.)



	Milky Way	LMC	SMC	ref.
field				
C/O	0.60	0.33	0.16	Dufour+1982

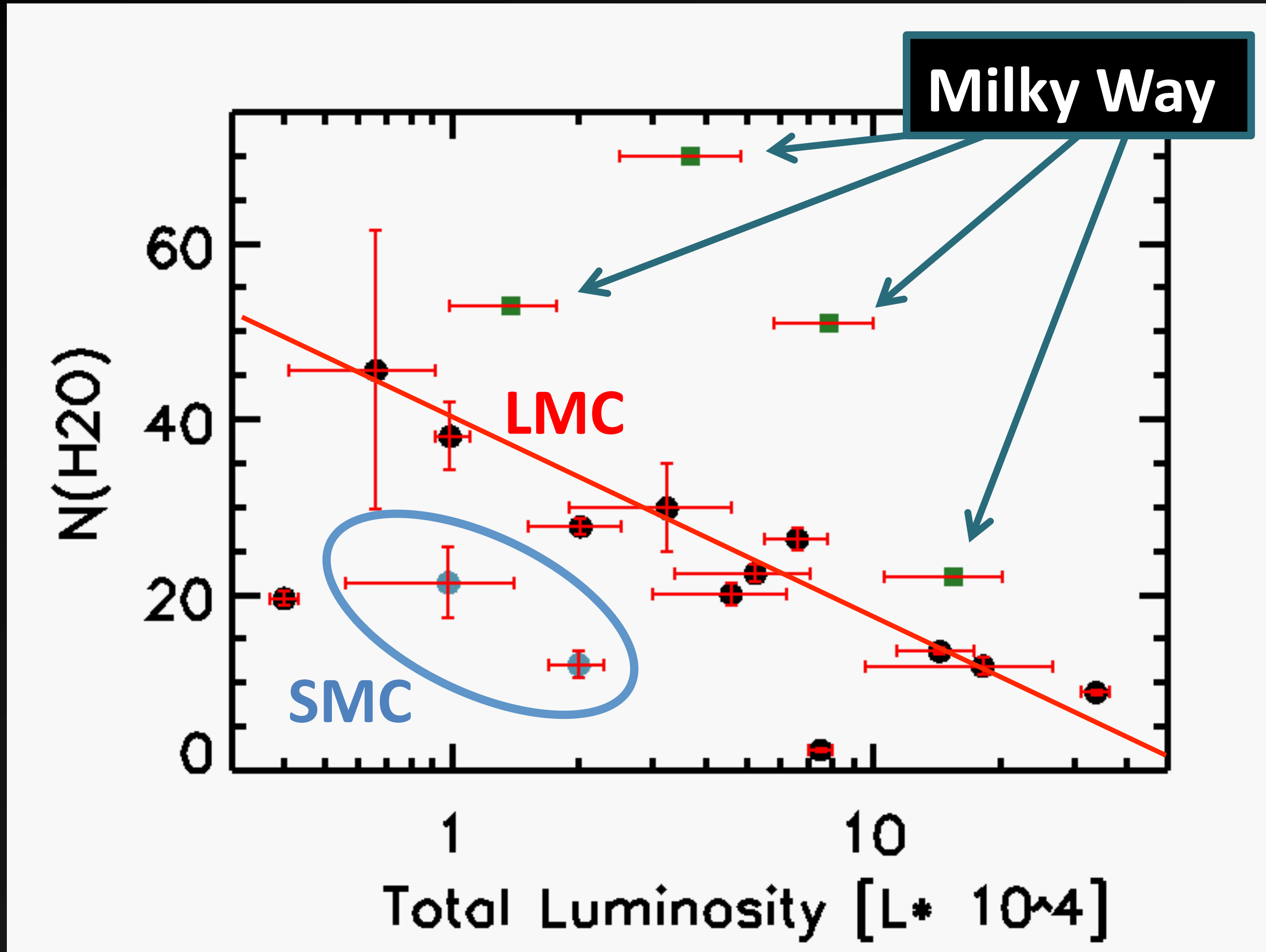
CO_2 ice abundance in the SMC



CO_2/H_2O is neither a simple function of metallicity nor of dust temperature

N(H_2O) vs. Luminosity for SMC YSOs

●: LMC
●: SMC
■: MW



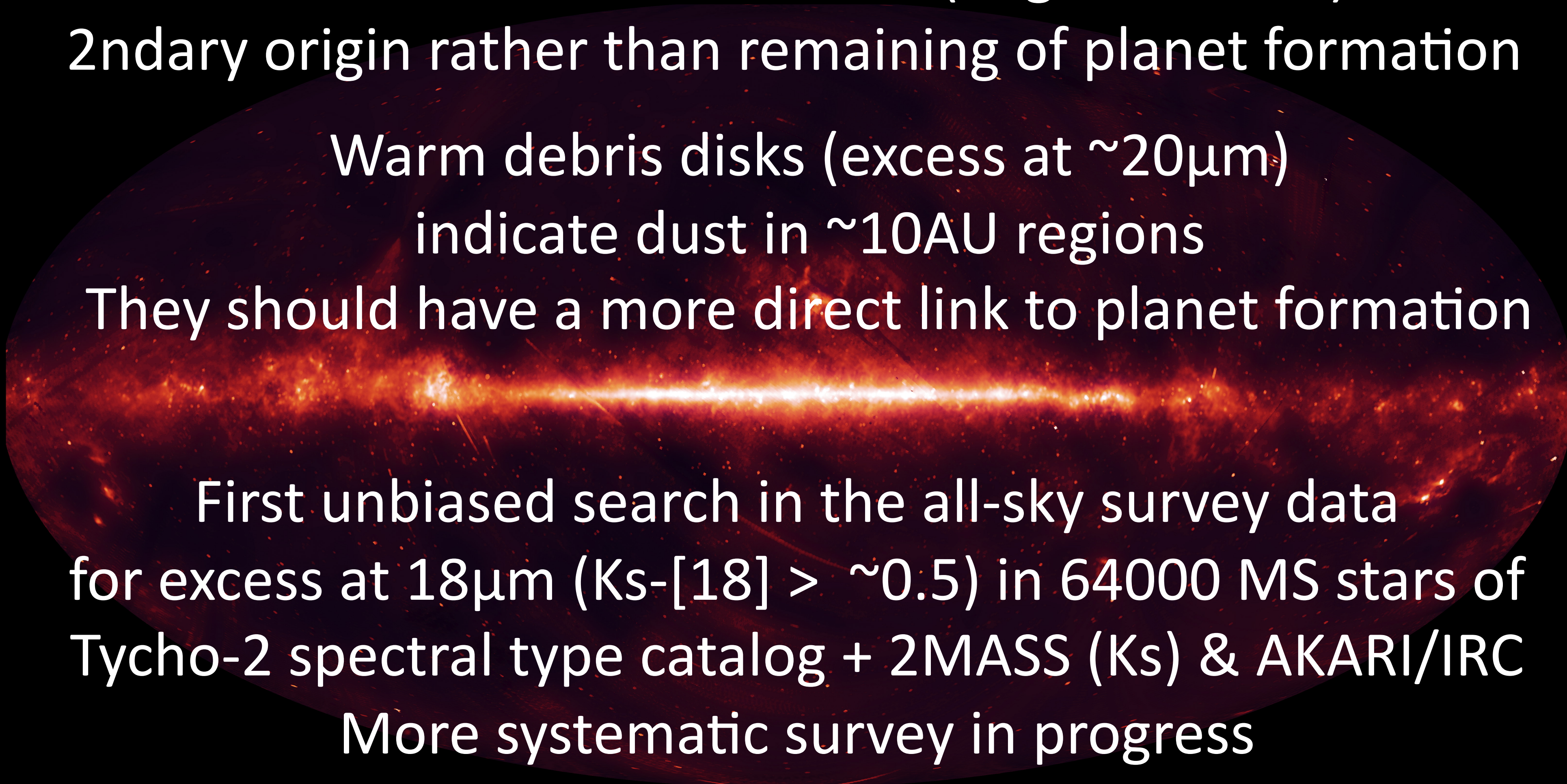
Ice formation is reduced at low-metallicity

Less shielding to UV?

Search for warm debris disks at 18μm in the all-sky survey data

Hideaki Fujiwara et al. (2010) ApJL, 714, L152; (2010) submitted to A&A

Short life time of dust in debris disks (Vega-like stars) indicates 2ndary origin rather than remaining of planet formation



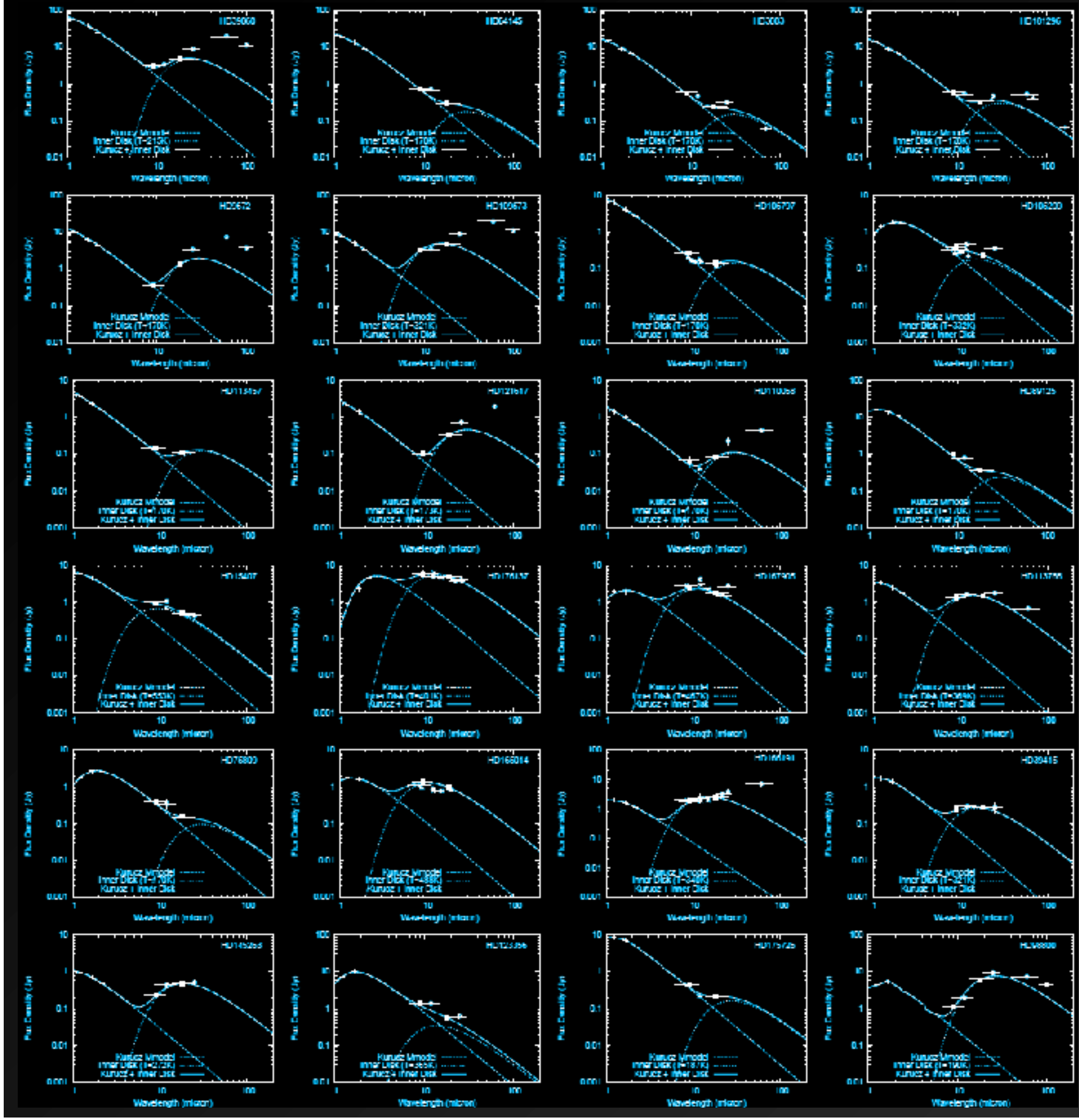
Warm debris disks (excess at ~20μm) indicate dust in ~10AU regions

They should have a more direct link to planet formation

First unbiased search in the all-sky survey data for excess at 18μm (Ks-[18] > ~0.5) in 64000 MS stars of Tycho-2 spectral type catalog + 2MASS (Ks) & AKARI/IRC

More systematic survey in progress

Debris candidates



24 debris disk candidates are detected

12 known debris disks
4 detected by IRAS, but not confirmed
8 new candidates discovered by AKARI

Frequency of debris disk

Detection of 18μm excess: 24/856 ~ 2.8%

Smaller than Spitzer's results

30% for A (Su et al. 2006); 6% for FGK (Beichman et al. 2006)

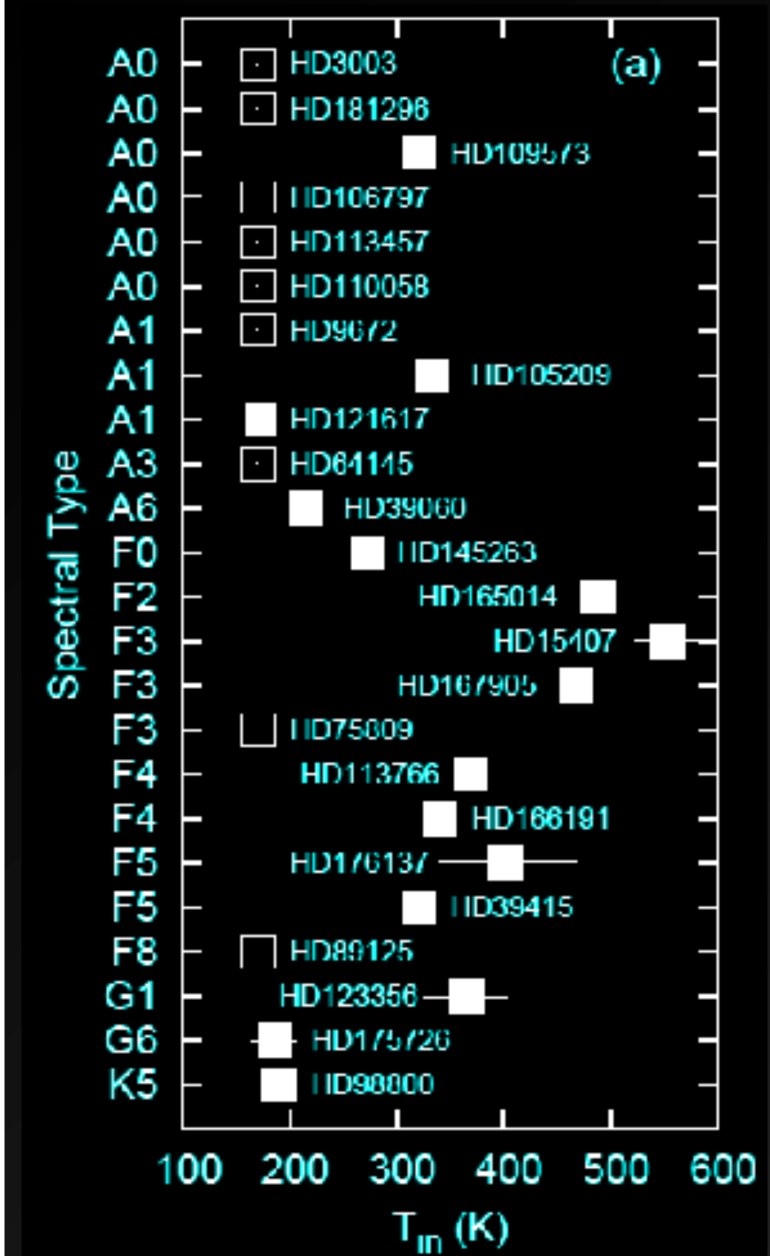
Spec. Type	Input	Detection at 18 um	Debris	Freq.(%)
A	18232	196	11	5.6
F	29766	324	10	3.1
G	14013	173	2	1.2
K	2122	144	1	0.7
M	76	19	0	0.0
Total	64209	856	24	2.8

Difference in criteria

Spitzer: ~10% of photosphere at 24μm

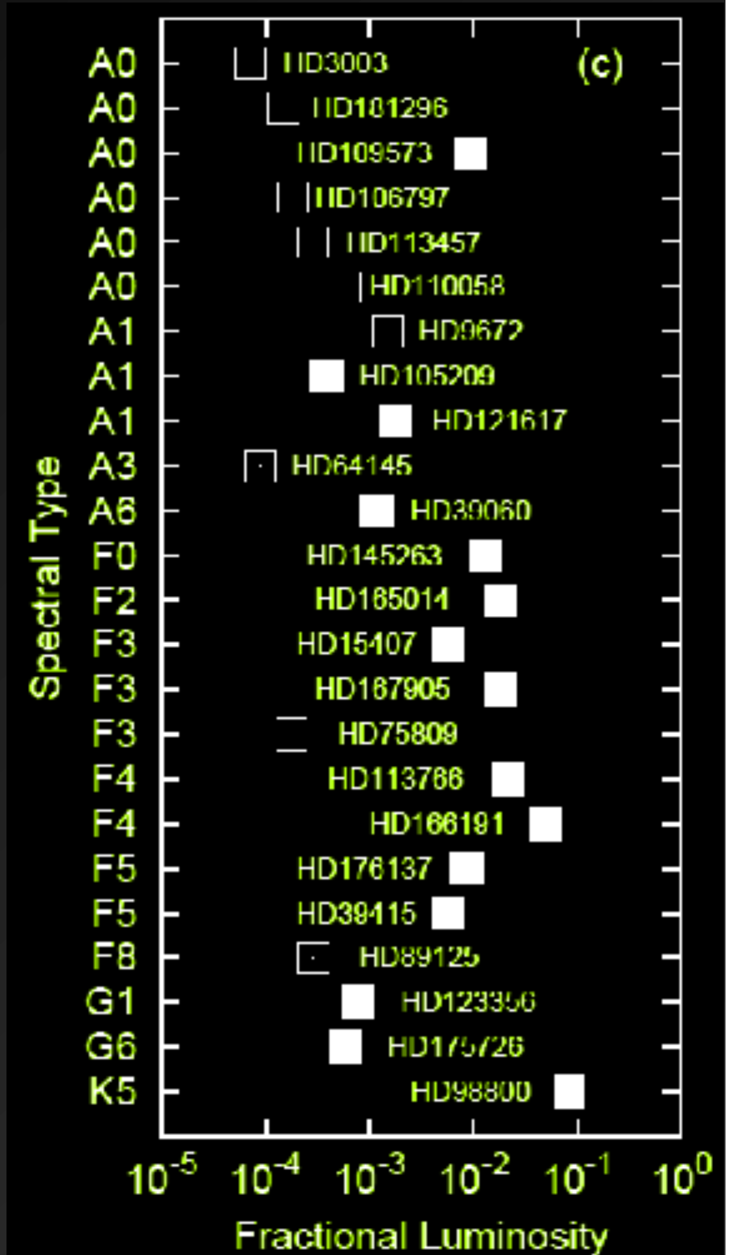
AKARI: ~50% of photosphere at 18μm

Spectral-type dependence



FKG-type stars tend to have higher T

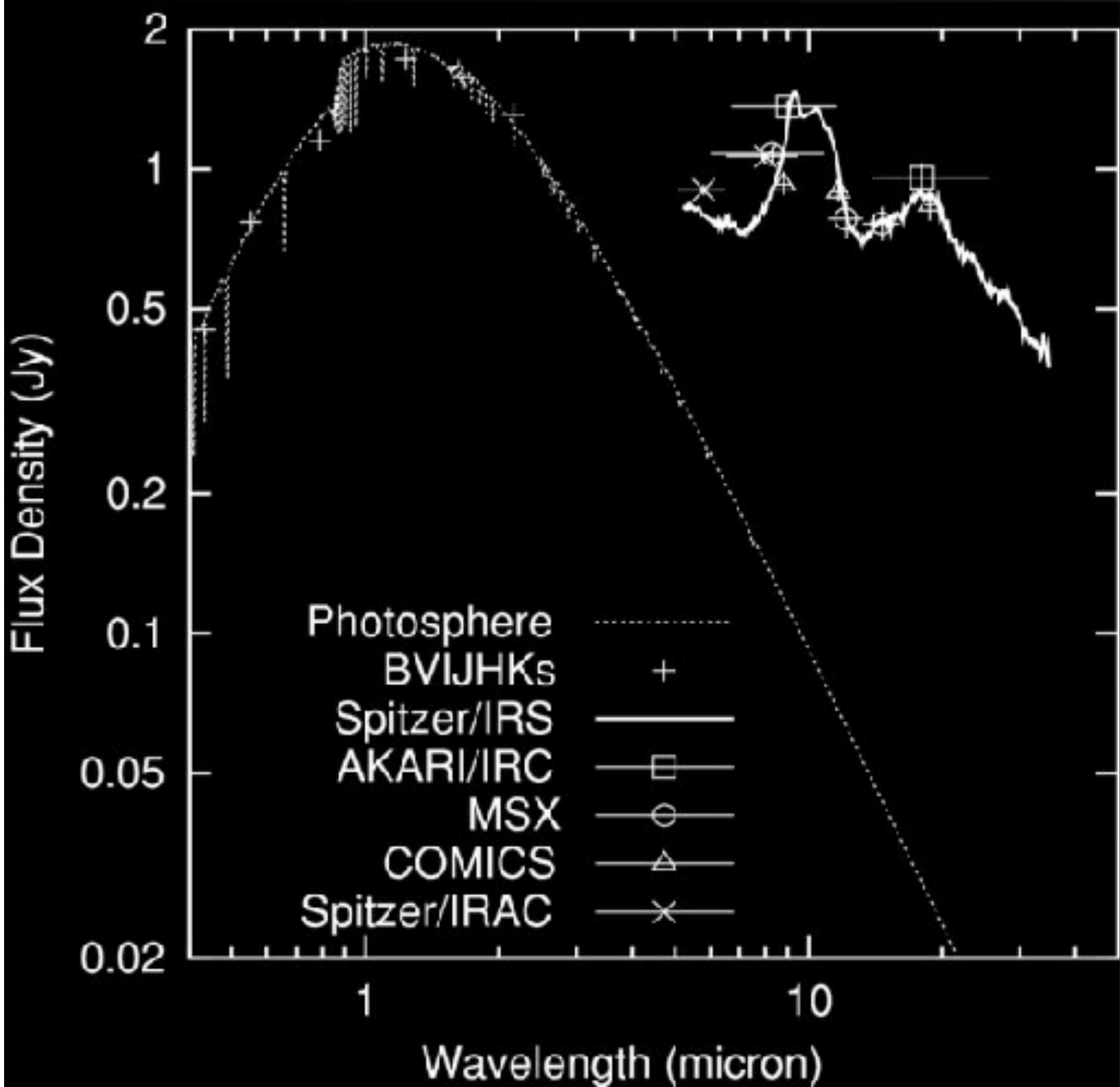
Strong radiation in early-type stars may push dust outward



□ w/o 9μm excess

■ with 9μm excess

Follow-up Observations: HD165014



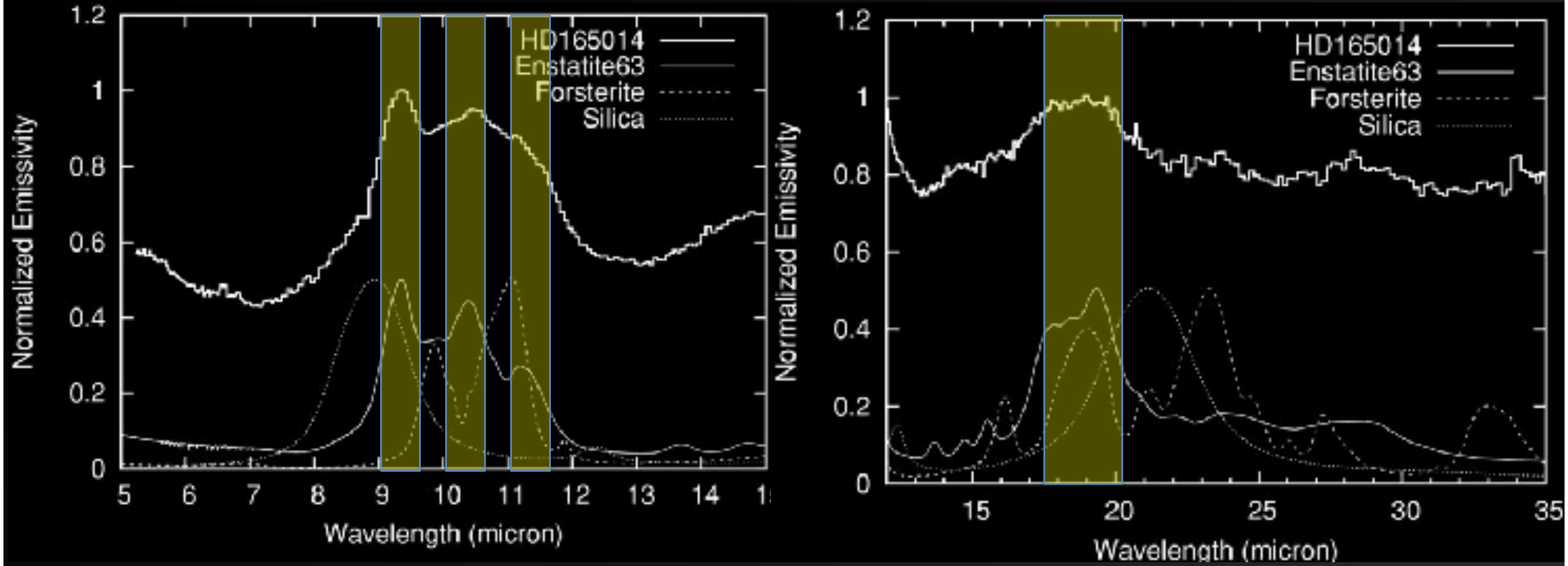
A0V star at ~ 140pc

Spitzer IRS observations obtain 5 – 37μm spectrum

Fractional luminosity $F_{disk}/F^* \sim 5 \times 10^{-3}$ similar to β Pic

Fujiwara et al. (2010) ApJL 714, L152

HD165014: Enstatite-rich debris disk



T ~ 300 – 750K; r ~ 0.4 – 4.4 AU (~ asteroid belt)

Fine structures in 10 – 20μm can be accounted for by enstatite better than foresterite; Fo/En ~ 20

Enstatite-rich debris may have been formed from differentiated rocky bodies analogous to E-type asteroids

Warm debris disks

AKARI found several debris disk objects at 18μm

They show fine structures in the 10μm feature more frequently than those detected at 60μm

Detected fine structures may suggest the presence of large bodies in these system

They may be a different class of debris disks,
"warm debris disks"
and may have a more direct link to planet formation

More systematic survey is in progress

AKARI Warm Mission

NIR imaging & spectroscopy are continuued
2--5μm spectroscopy is a unique capability of AKARI/IRC

Observations of the ice features (Shimonishi et al)
Study of Ultra Luminous IR Galaxies
(Imanishi et al. ApJ in press)

Study of the Unidentified IR (PAH) bands
Search for deuterated PAH (PAD) features
(Onaka, Boulanger, et al.)

3.3, 3.4, & 3.5μm features arise from the smallest particles
They carry information on CH_3 and CH_2
but have barely been explored

Search for Deuterated PAH (PAD) features

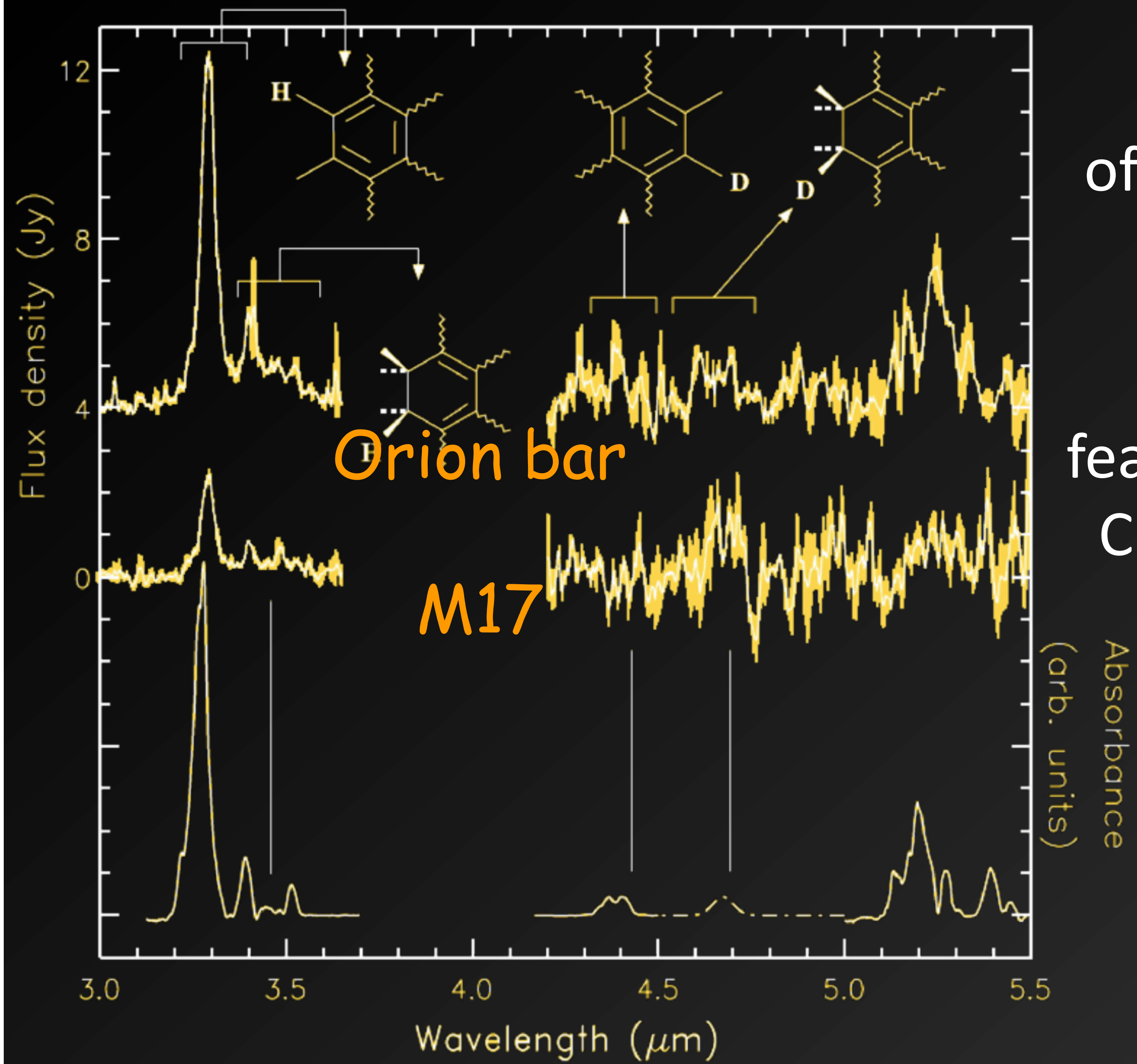
FUV observations suggest
interstellar deuterium is depleted onto dust grains
(Linsky et al.2006 ApJ 647, 1106)

PAHs may be a reservoir of interstellar deuterium
Expected ratio would be PAD/PAH ~0.3
(Draine 2004 ASP 348, 58)

PAH 3.3 & 3.4 μm bands shift to 4.3 – 4.7μm in PAD
Possible detection (4.4σ) of 4.4 & 4.65μm features
with ISO/SWS at Orion bar and M17
(Peeters et al. 2004, ApJ 604, 252)

ISO Observations of PAD features

Peeters et al. (2004) ApJ 604, 252

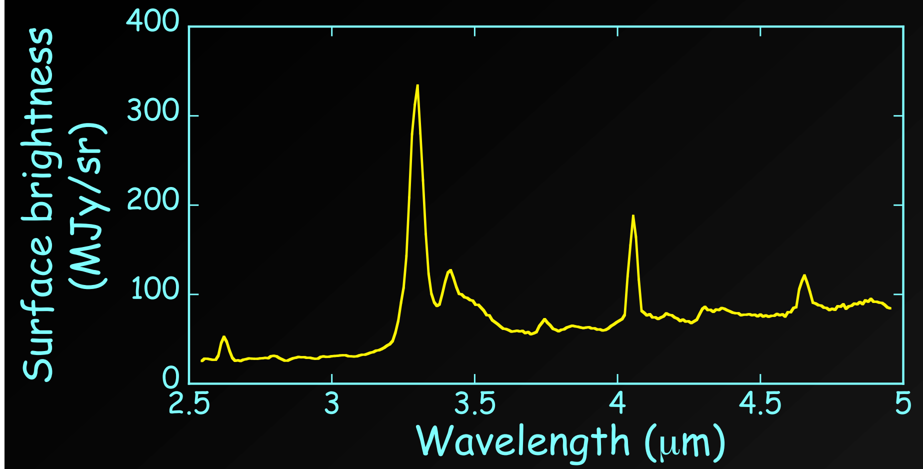


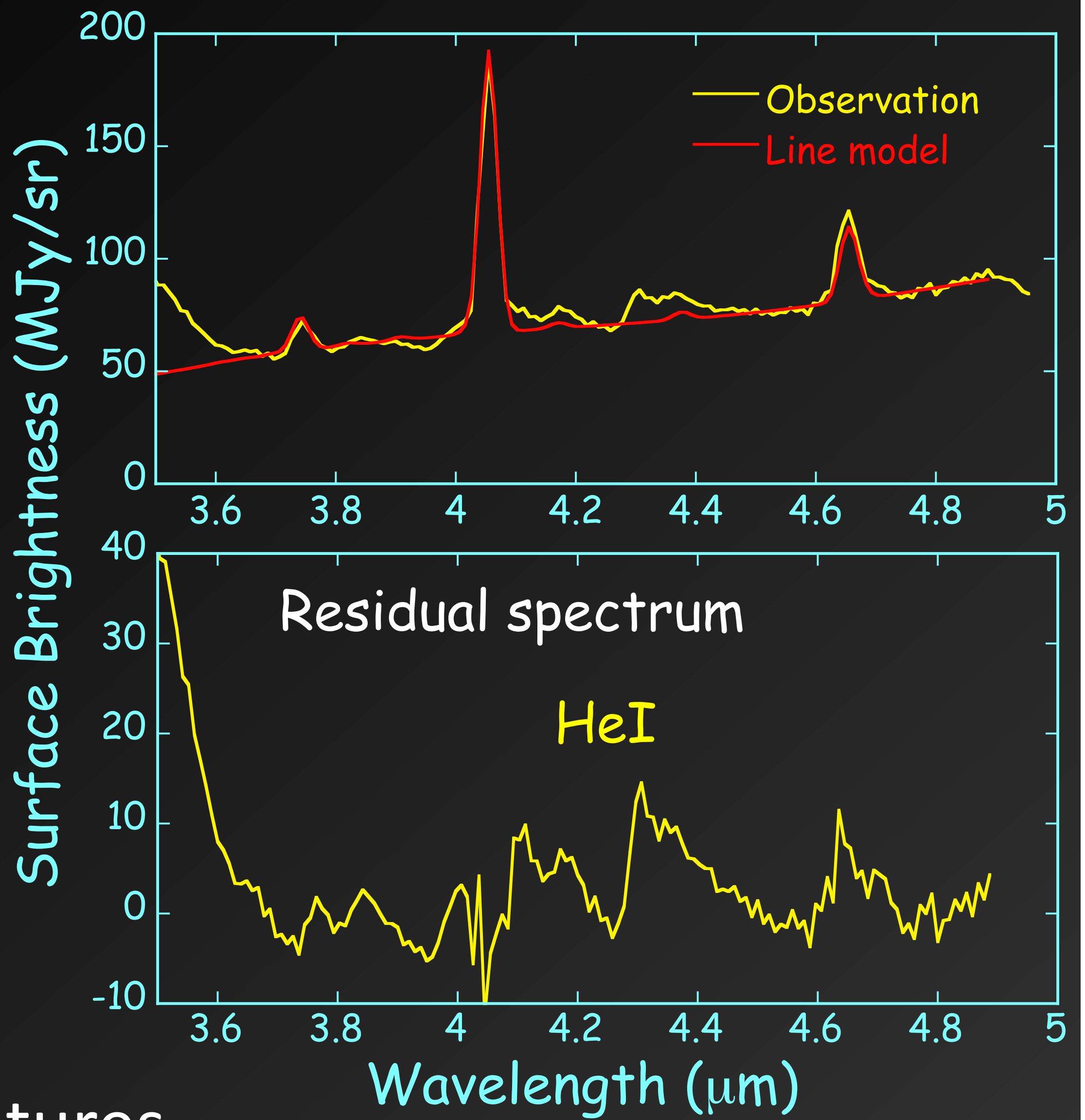
ISO observations of M17 and Orion bar

Detection of PAD features with S/N ~ 4.4

CD/CH ~ 0.17 & 0.36

AKARI Observations: M17



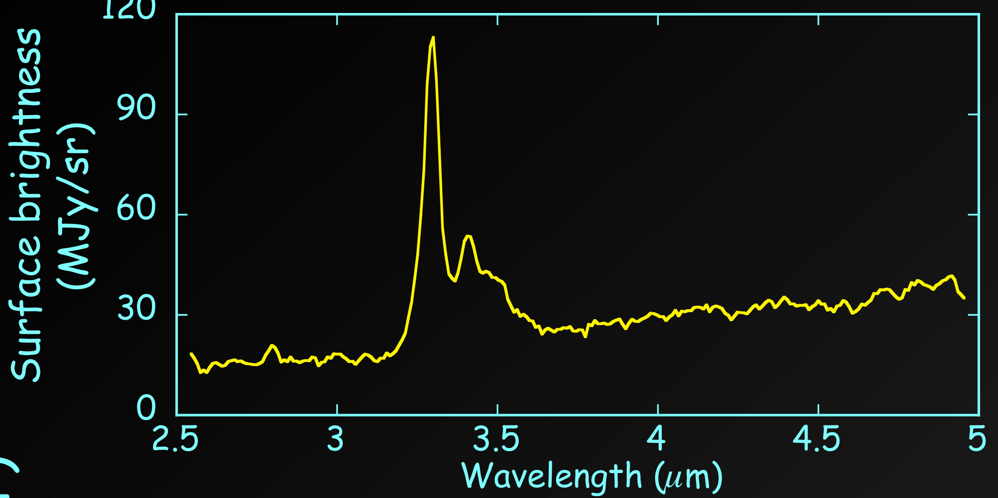


Residual emission may remain around 4.65μm after removal of Pfδ

Total intensity
-> CD/CH < 0.03

Better to search for features at regions without ionized gas

Spectrum of the Galactic Plane (l ~ 10)



No apparent lines from ionized gas

No obvious features in 4 - 5μm

Total intensity

->

CD/CH < 0.02

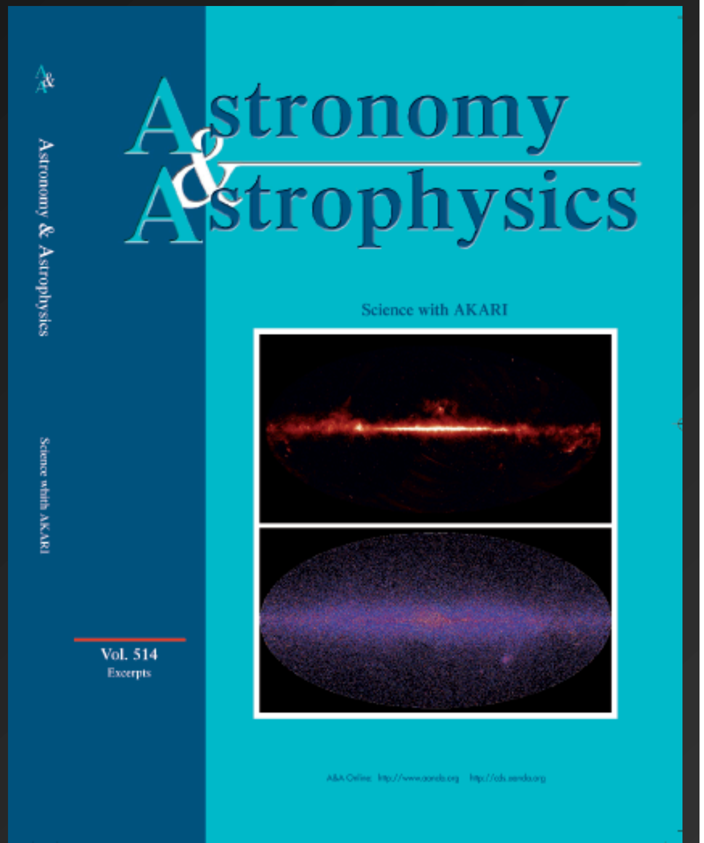
Current Status of AKARI

AKARI continues NIR observations in the warm mission owing to the onboard cryocooler

Until 2010 February
~10000 scientific observations have been carried out
Most of them are spectroscopy

Degradation in the cooling power of the cooler becomes significant

Refurbishment operation of the cooler will be made in November



SPICA

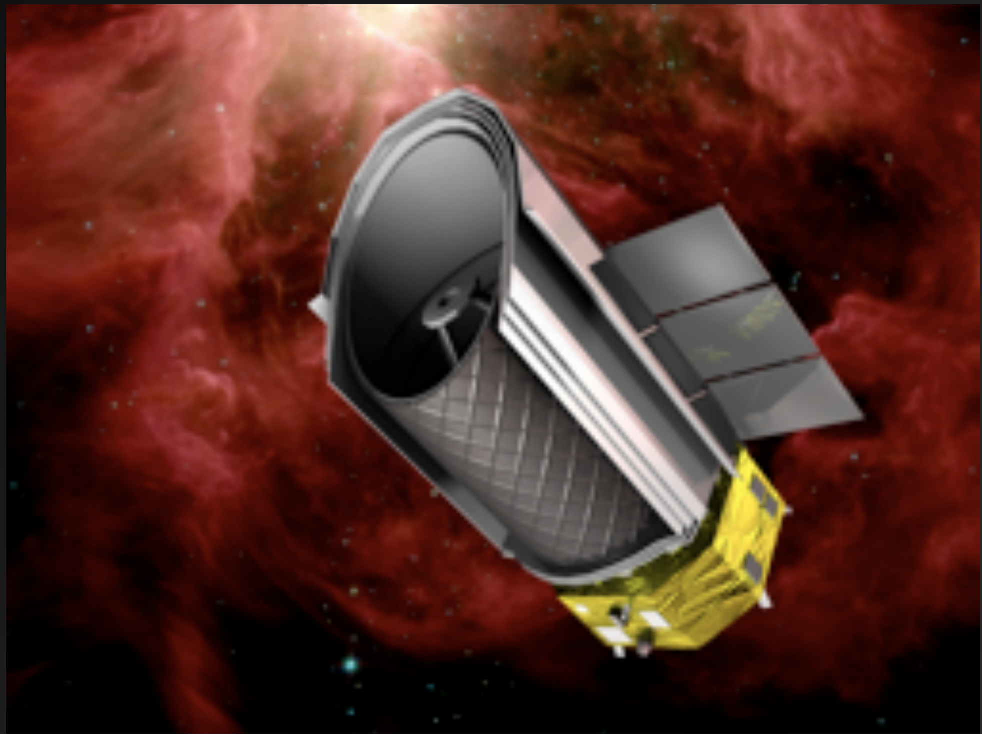
Space Infrared Telescope for Cosmology and Astrophysics

3m-class telescope cooled by mechanical coolers

for observations of 5 – 210μm

Target launch: 2018

JAXA + ESA (CV) + (NASA) international project



Thank you for your attention