SPICA in Japan

SPICA mid-IR instrument (SMI) and its unique capabilities with particular science cases in SPICA science goal

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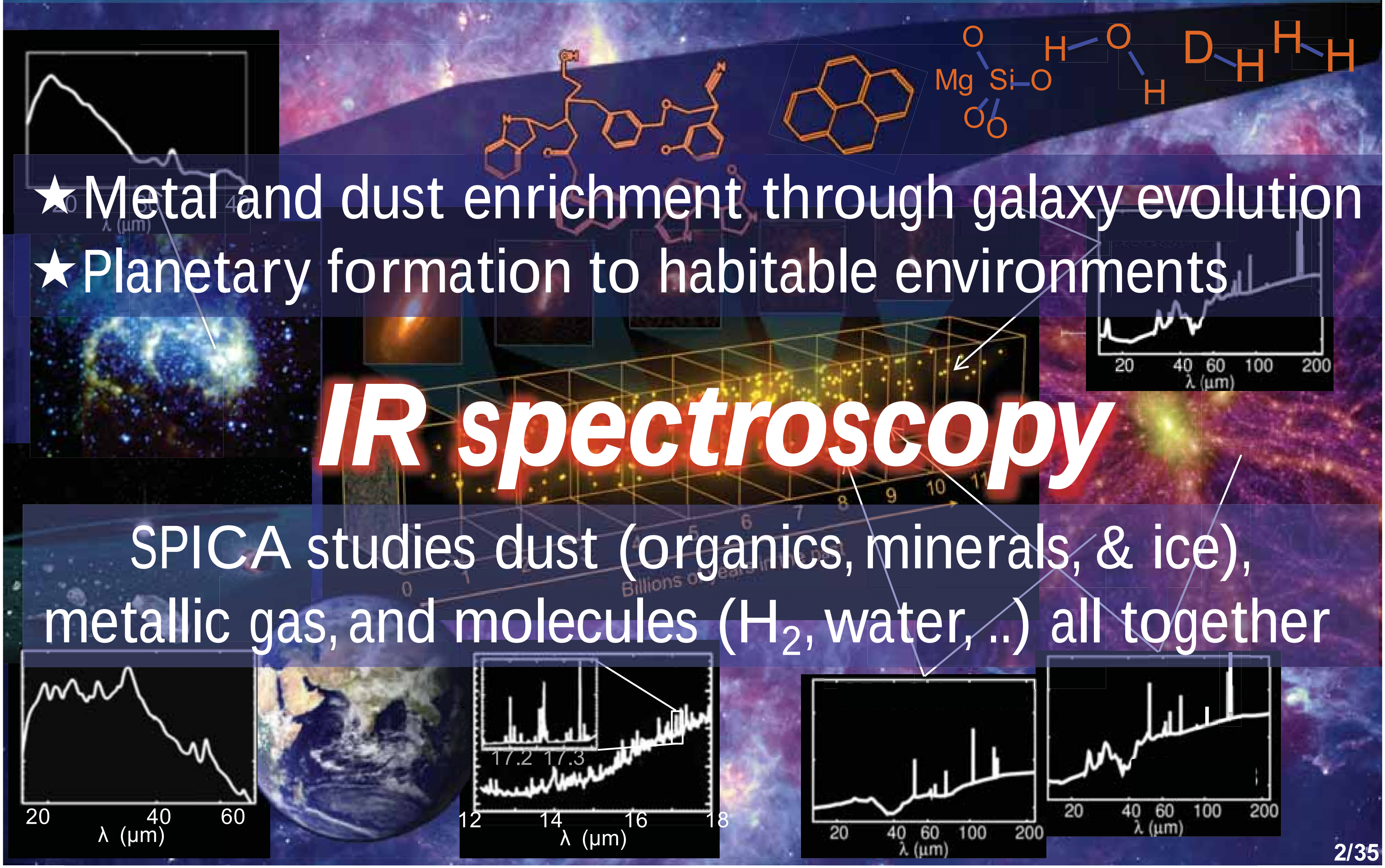
On behalf of Japanese SPICA team

Enrichment of the Universe with metal and dust leading to the formation of habitable worlds

★Metal and dust enrichment through galaxy evolution

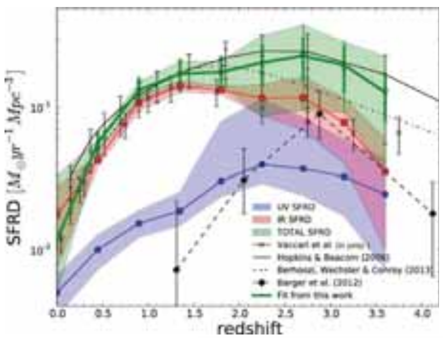
★Planetary formation to habitable environments



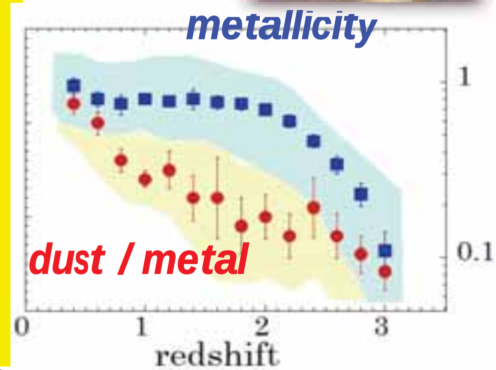
IR spectroscopy

SPICA studies dust (organics, minerals, & ice), metallic gas, and molecules (H_2, water, ..) all together

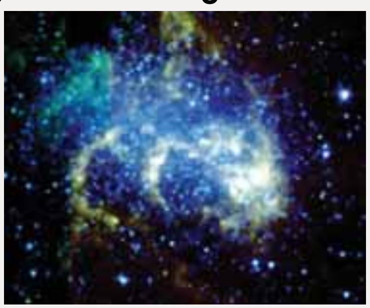
Metal and dust enrichment through galaxy evolution



Spectroscopy of metal and dust enrichment processes and the star formation and AGN interplay in galaxy evolution



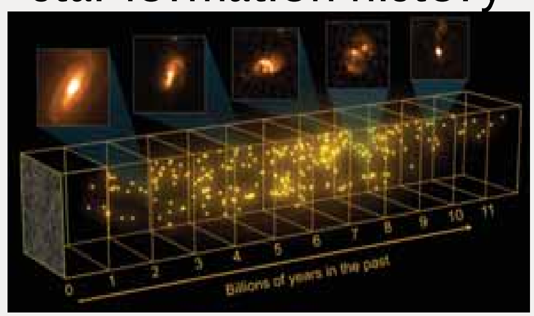
Spatially-resolved, high-z analogs or relics



~4,000 nearby galaxies at <100 Mpc

→ Spectral mapping

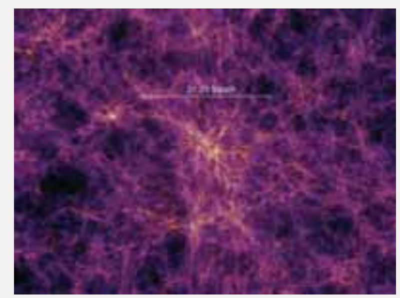
Over the peak of the cosmic star-formation history



~60,000 galaxies at z = 0.5 – 4
1,000 SF galaxies & 1,000 AGNs for detailed study

→ Unbiased spectroscopic survey

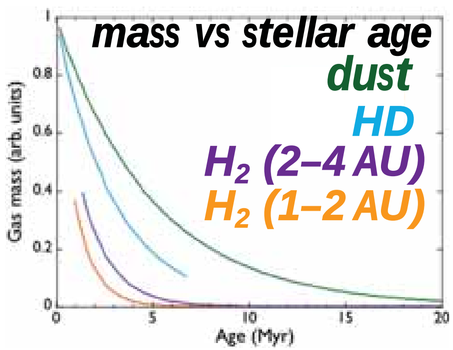
Beyond the peak, first mineral, aromatics



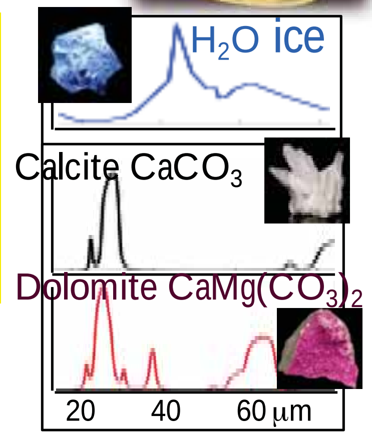
>100 galaxies at z = 4 – 10

→ Targeted spectroscopy

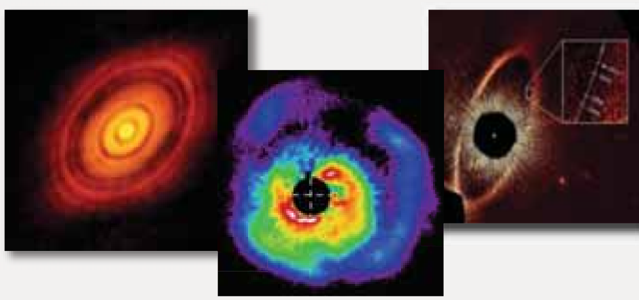
Planetary formation to habitable environments



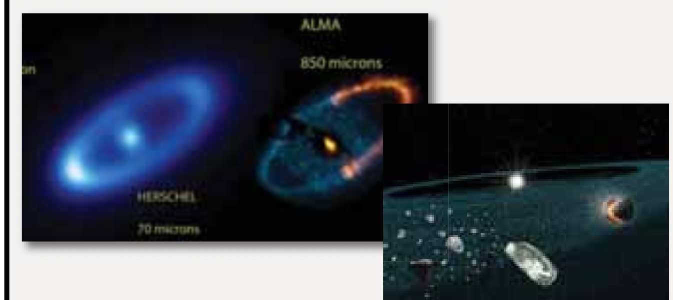
Spectroscopy of gas dissipation and dust evolution processes along planetary system formation



Gas dissipation in proto-planetary discs (PPDs)



Changes of mineral and ice properties in debris discs

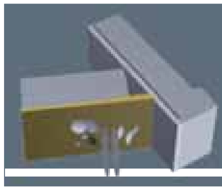


>200 PPDs

>1,000 debris discs with mid-IR excess down to the solar system level

Targeted spectroscopy

Unbiased spectroscopic survey



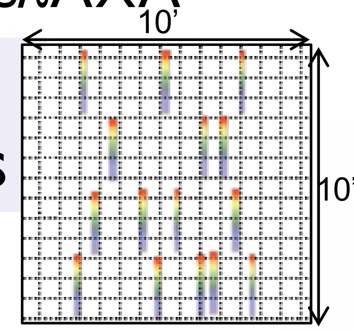
Focal-plane instruments: SAFARI + SMI
SMI: SPICA Mid-infrared Instrument

SMI Consortium: Nagoya Univ., Univ. of Tokyo, Osaka Univ., Tohoku Univ., Kyoto Univ., & ISAS/JAXA

LRS

Multi-long-slit prism + Si:Sb w/ slit viewer
17 – 36 µm, R = 50 – 120, slit: 10' long, 4 slits

High-efficiency dust-band mapping
(high-z and debris disc survey)

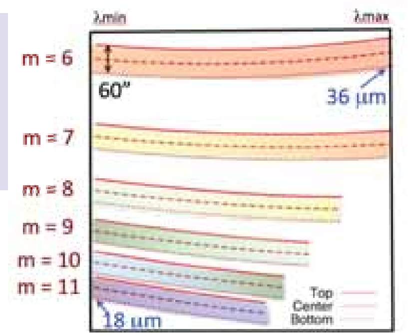


1024x1024 pix

MRS

Grating + Si:Sb w/ beam-steering mirror
18 – 36 µm, R = 1200 – 2300, slit: 1' long

High-sensitivity spectral mapping
(follow-ups and nearby galaxy mapping)

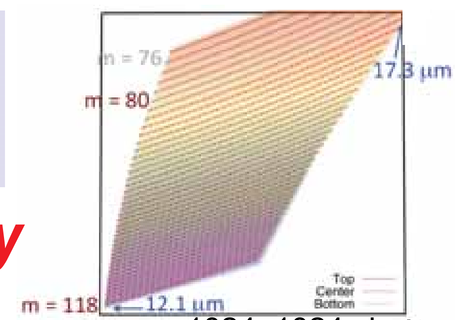


1024x1024 pix

HRS

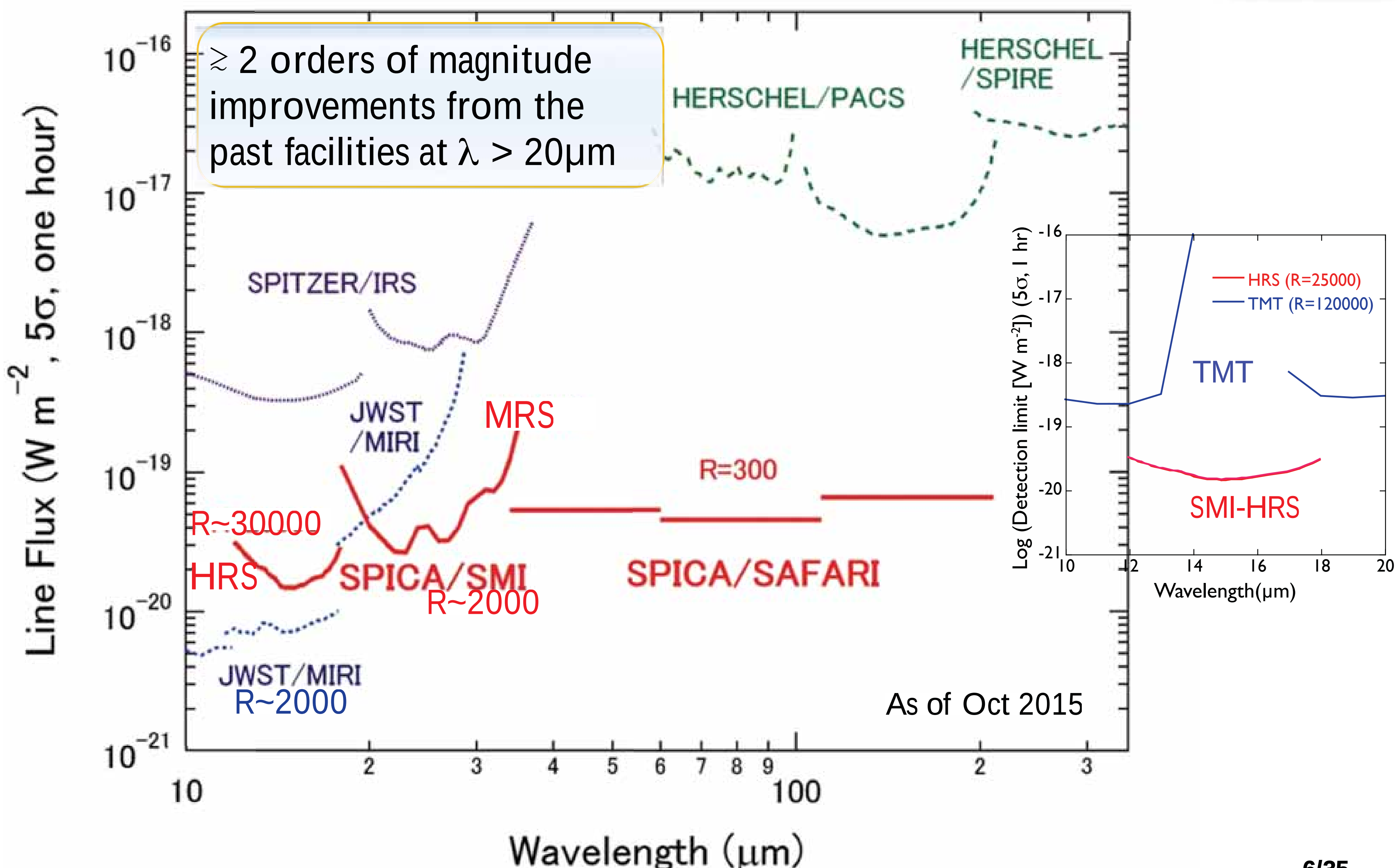
Immersion grating + Si:As w/ BS mirror
12 – 18 µm, R = 28,000, slit: 4" long

High-resolution (molecular-)gas spectroscopy
(AGN outflow and kinematics of gas in discs)



1024x1024 pix

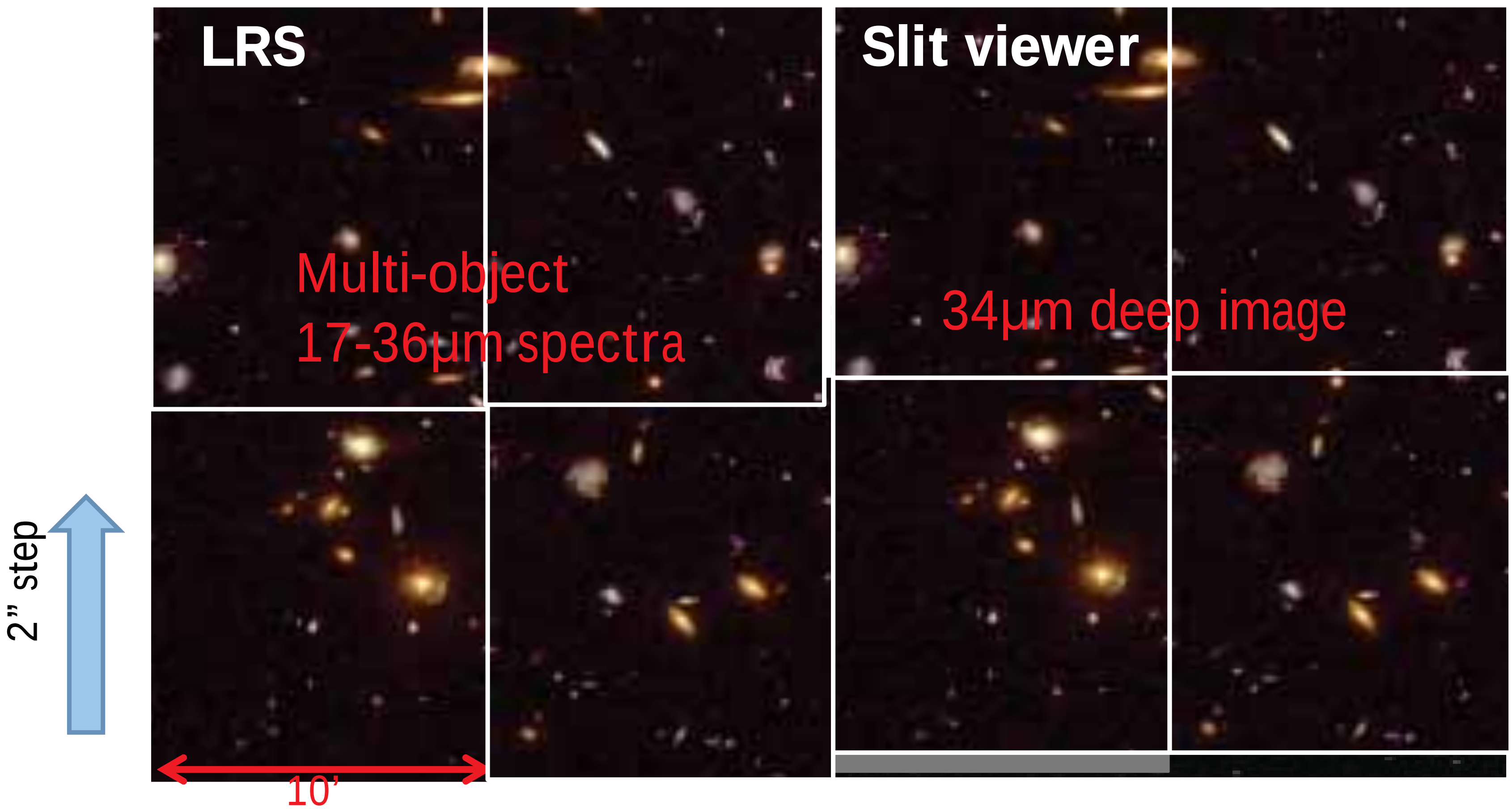
Comparison of spectroscopic sensitivities



17-36μm spectroscopy & 34μm wide-band imaging

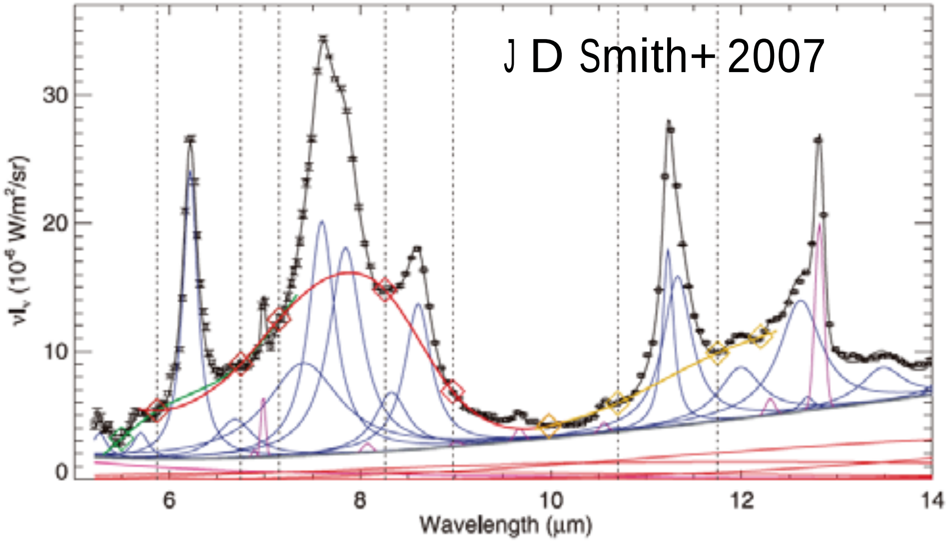
30–40μm: unexplored region between Spitzer and Herschel surveys
SMI-LRS survey provides spectroscopic & photometric datasets at ~30–40μm

Spatial scan with 90 steps (1 step length ~ 2” ~ 0.5 x slit width) produces a spectral map and a broad-band image of 10’ x 12’ area simultaneously



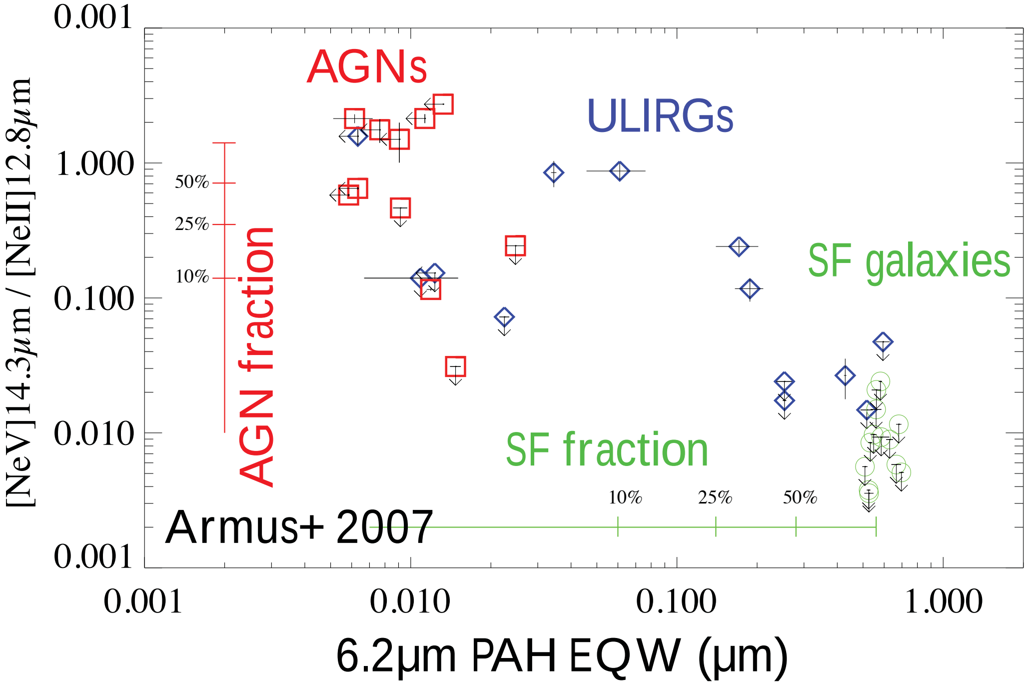
Slit viewer (10’ x 10’ FoV) provides broad-band (R = 5) images at λ_c = 34μm

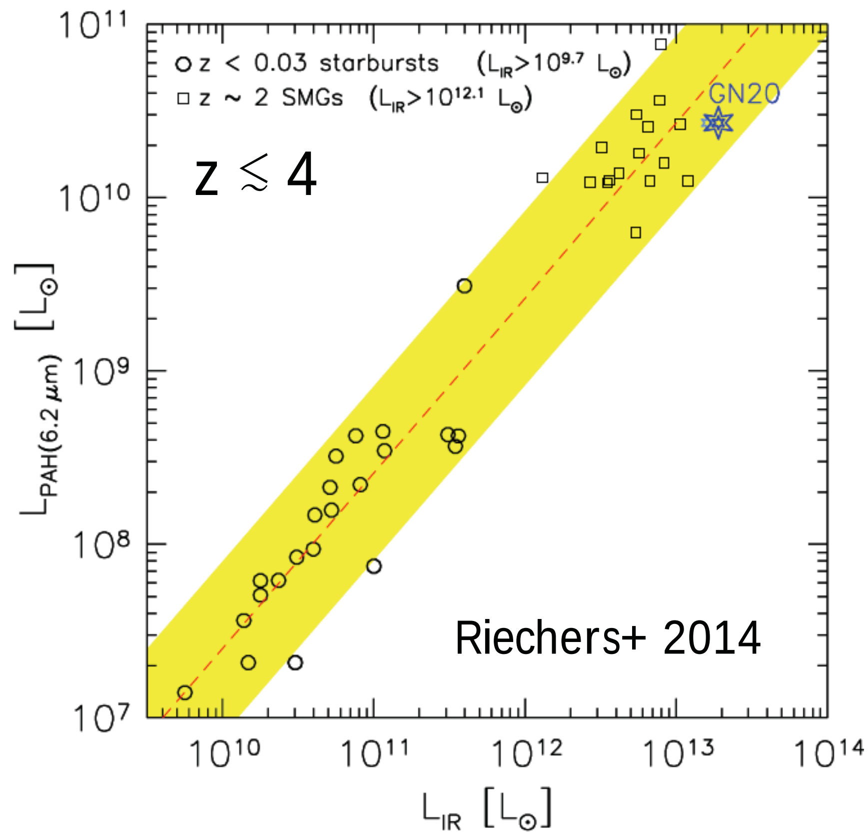
PAH bands: Useful tracer for star-formation & AGNs



PAH bands dominates in MIR

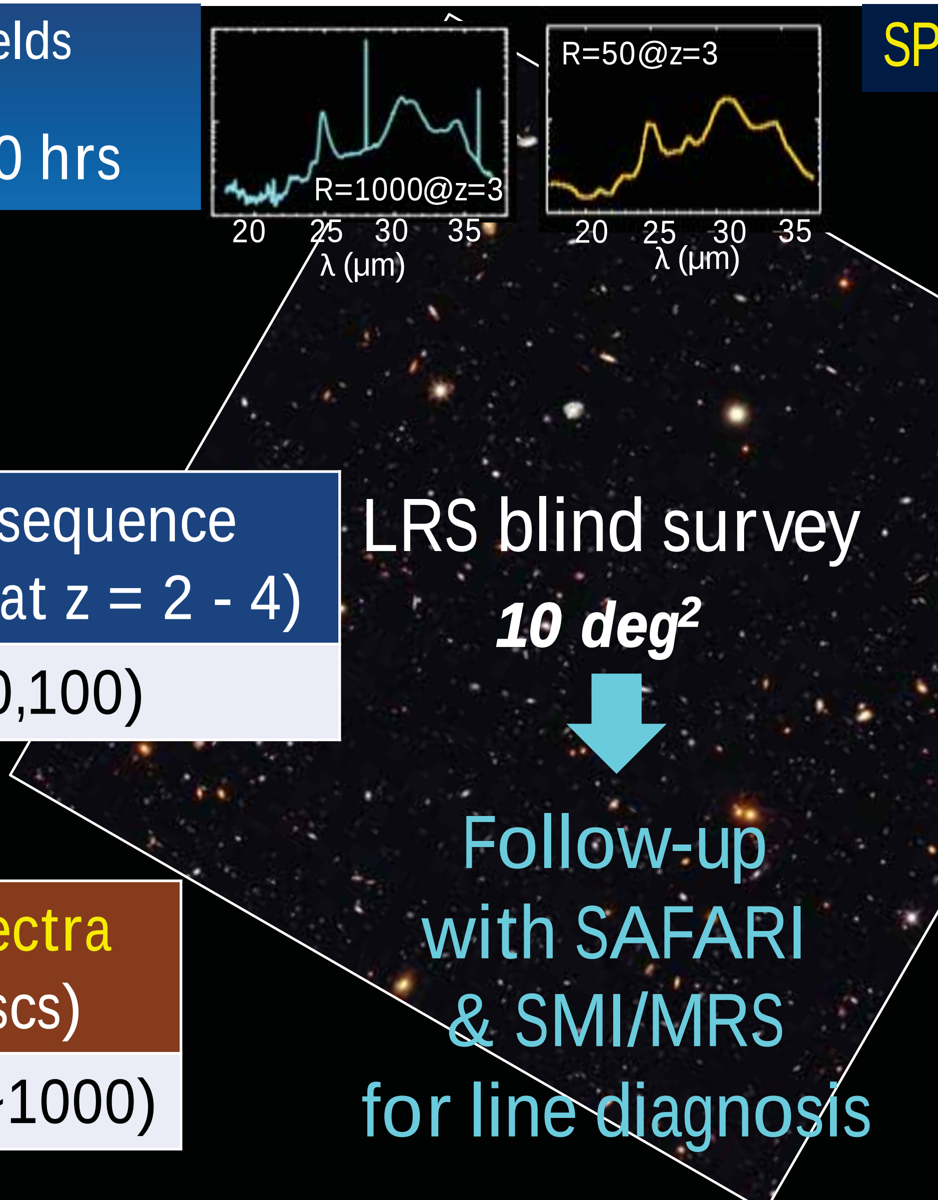
PAH bands are useful tracer to estimate redshift, SFR, and AGN fraction





Cosmological survey with LRS

~2 hrs / field x 300 fields
1 field = 10’x12’
→ 10 deg^2 in ~600 hrs



SPICA/SMI-LRS

R = 50 – 120

Multi slit
slit size: 10’x3.7”

PAHs in main-sequence galaxies at z > 1(at z = 2 - 4)
31,500 (10,100)

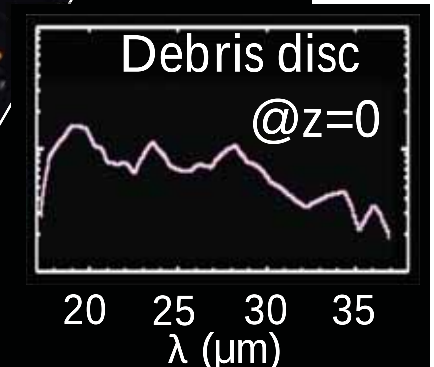
LRS blind survey

10 deg^2

⬇

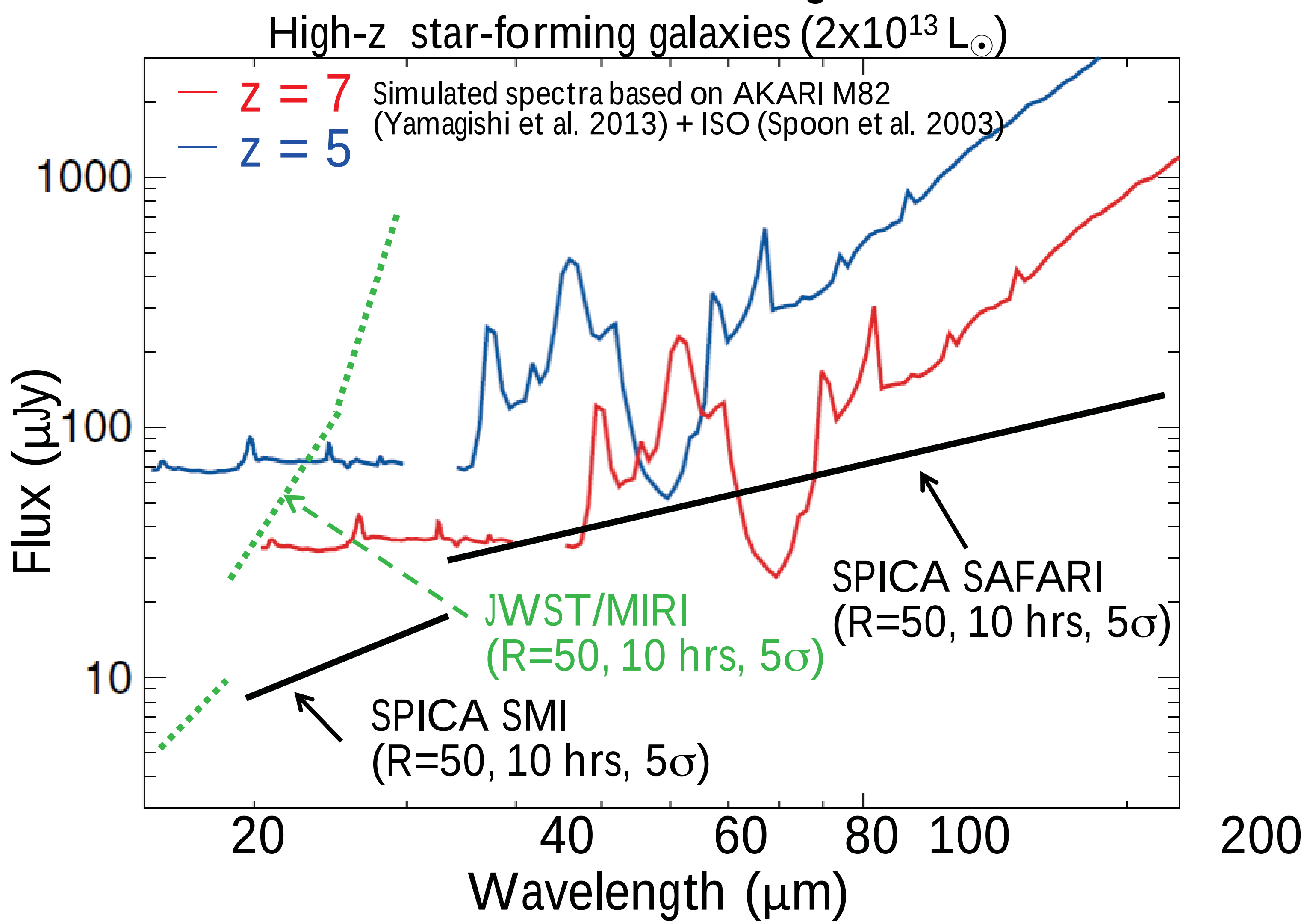
Follow-up
with SAFARI
& SMI/MRS
for line diagnosis

MS star spectra (debris discs)
9,900 (>~1000)



High-z PAHs and ices with SPICA

SPICA Mid & far-IR spectroscopy offers the opportunity to detect PAHs and ices at most distant galaxies ever observed



Hot dust in high-z quasars with SPICA

Hot dust continuum: dust of ~50 $M_\odot$ in quasars at z = 10 is detectable

Absorption by cold dust in a host galaxy:

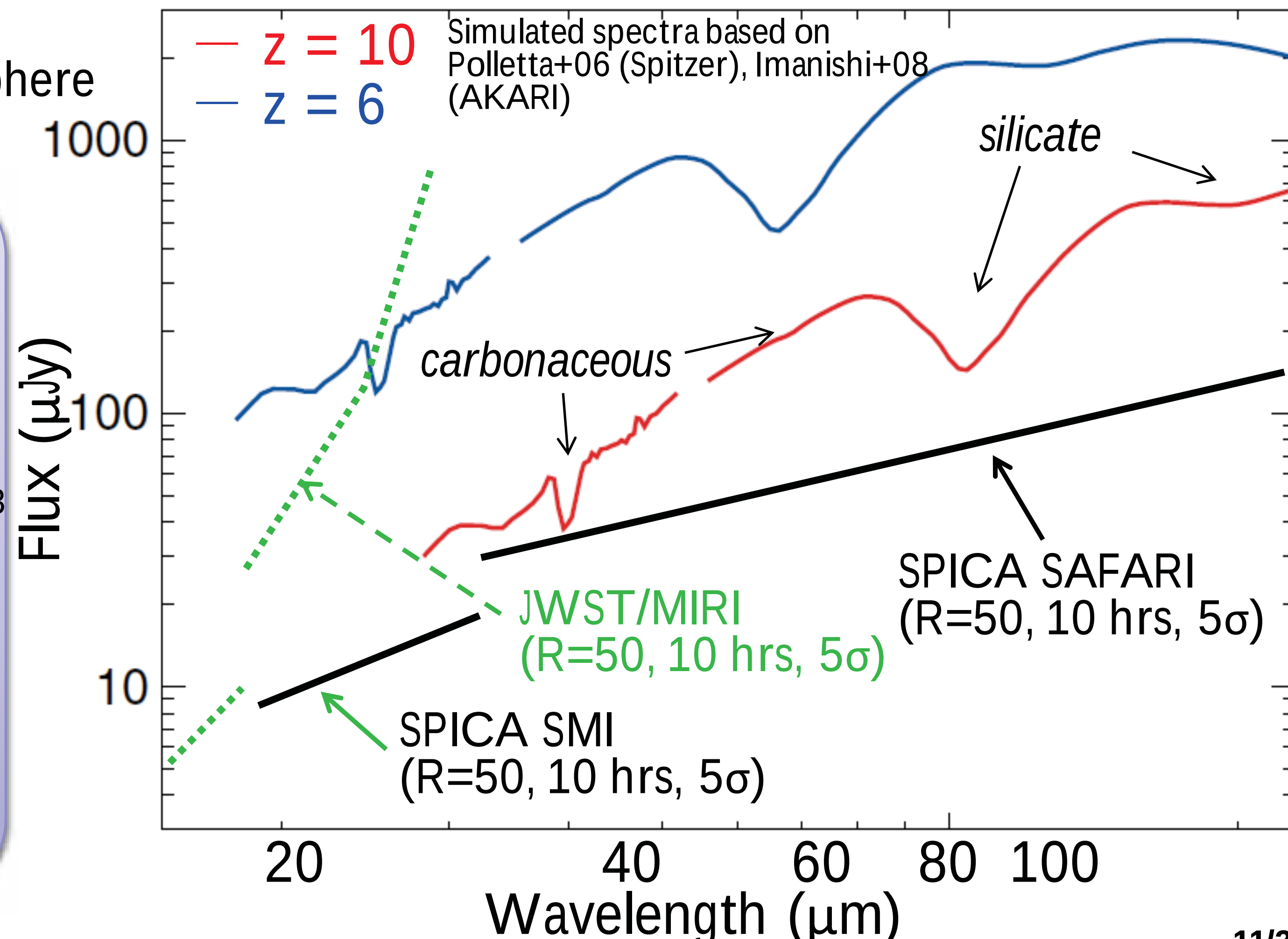
assuming silicate of 2×10^6 $M_\odot$
uniformly distributed
in a 1-kpc-diameter sphere

Pop III stars
with initial masses
10 – 40 $M_\odot$:
silicate ~ carbonaceous
Todini&Ferrara01, Nozawa+13

above ~100 $M_\odot$:
silicate-rich
Nozawa+13, Schneider+04

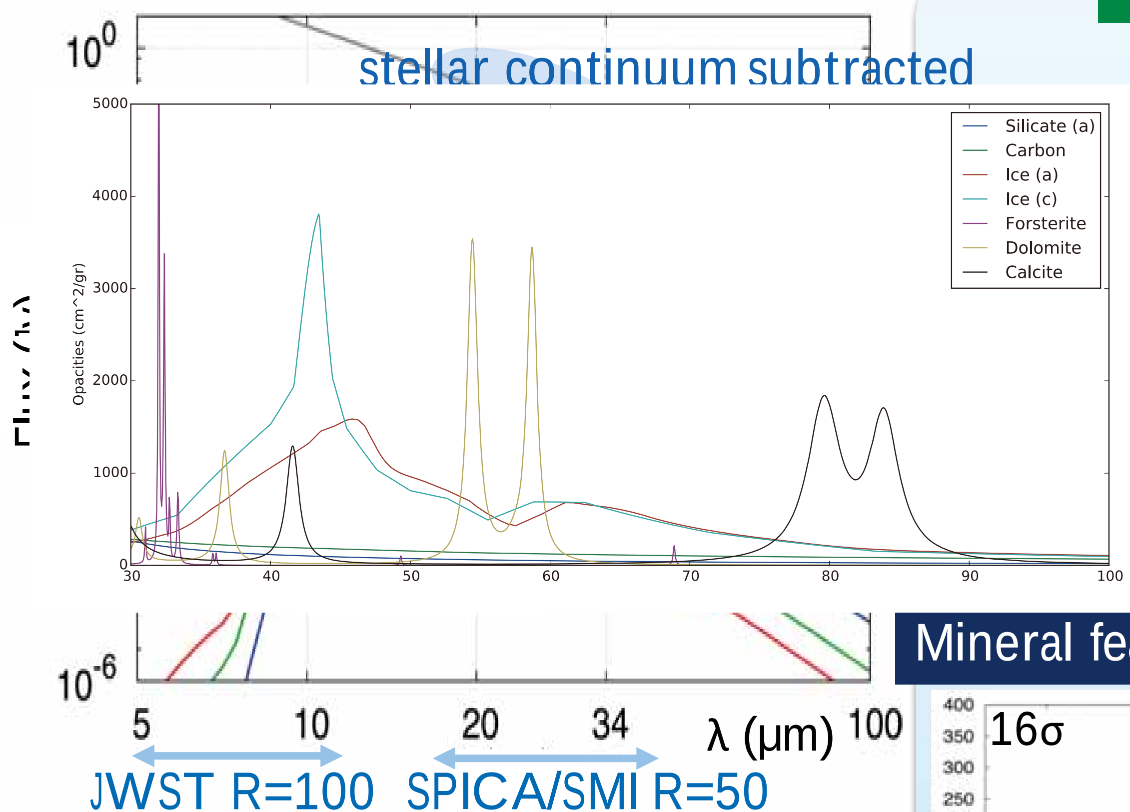
above ~250 $M_\odot$:
carbonaceous-rich
Nozawa+14

High-z quasars (1×10^{13} $L_\odot$)



Faint debris disc detection with SMI-LRS

G2V at 10 pc; 6,000 K → 400 mJy at 20μm

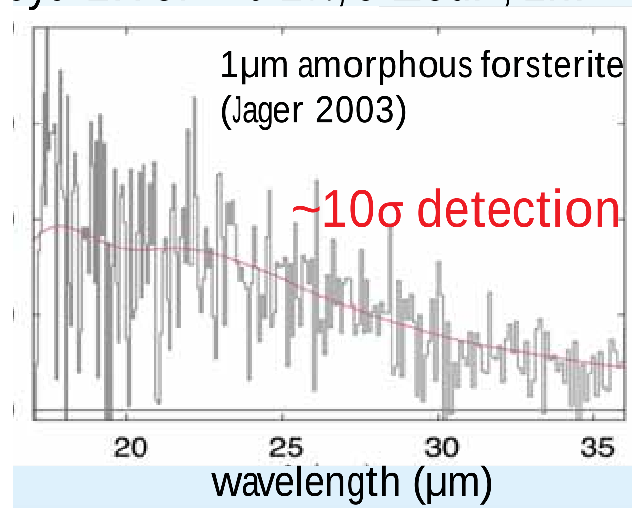


x6 better contrast at 20μm than 10μm

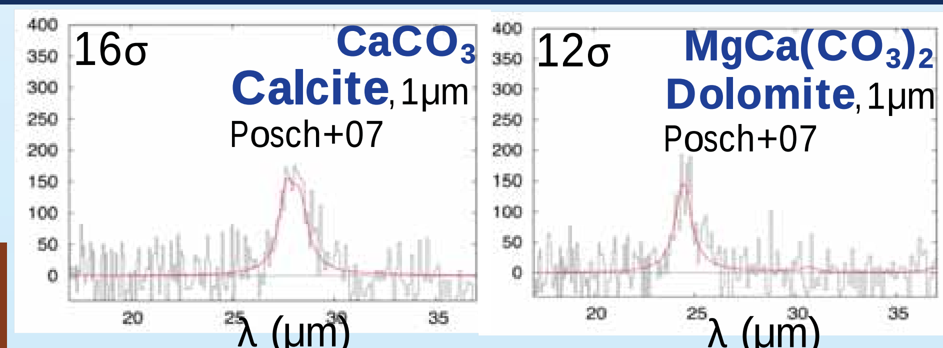
LRS spectra and SAFARI follow-up spectroscopy provides full MIR-FIR spectra for mineralogy of debris discs

Detection our zodi analogs

Sys. Error = 0.1%, 5 Zodi. , 1hr.



Mineral feature search with SMI and SAFARI

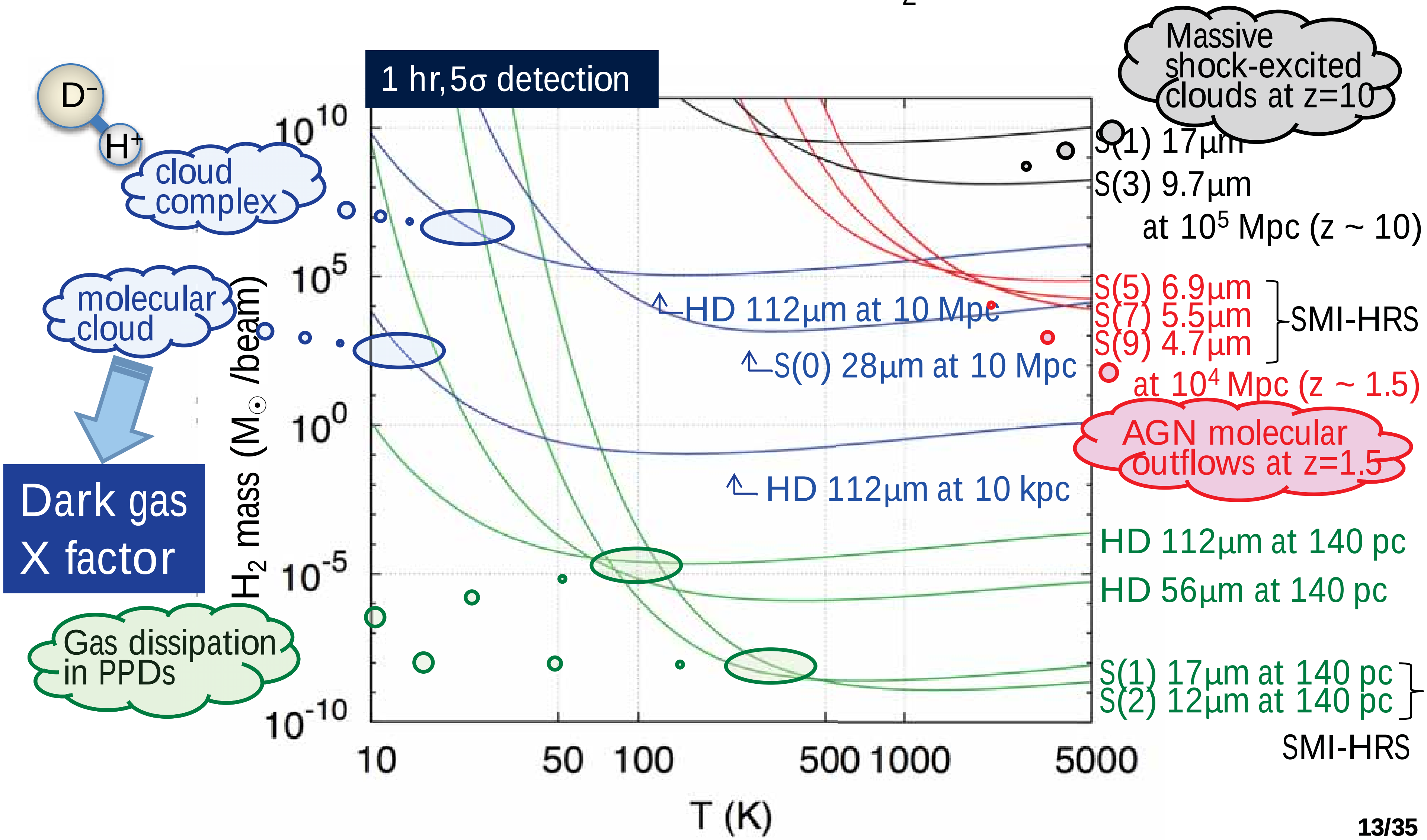


Low-T, link to water, atmosphere and ***life***

e.g., Halevy et al. 2011

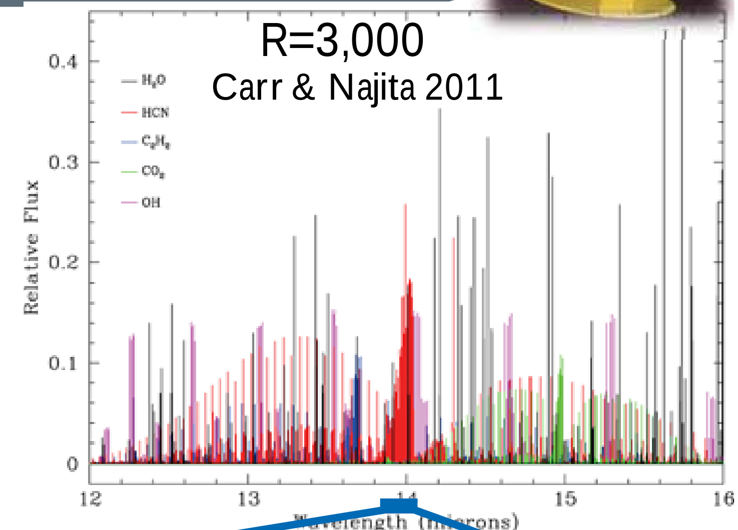
Observations of H_2 and HD with SPICA

D/H isotope ratio is ~ $2x10^{-5}$ ±20%. SPICA obtains the first robust estimate on the molecular mass of cool H_2 with the HD lines



Chemistry in the innermost region (1-2AU) of discs

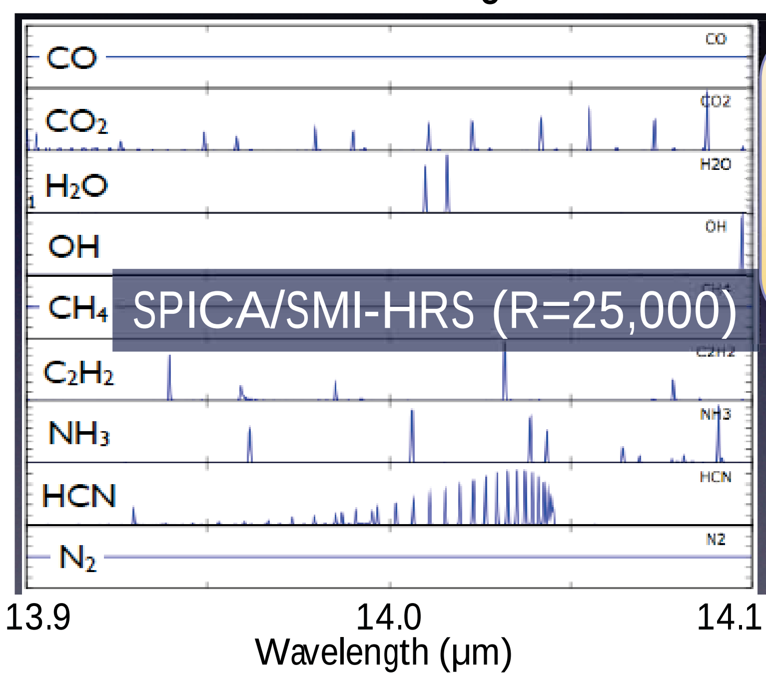
- With R=28000, Keplerian motion at 1 AU around $1M_\odot$ star can be resolved
- Spectral range of 12–18μm contains numerous bands of major C-bearing molecules, such as HCN, C_2H_2, and CO_2, as well as lines of H_2O, OH, and H_2



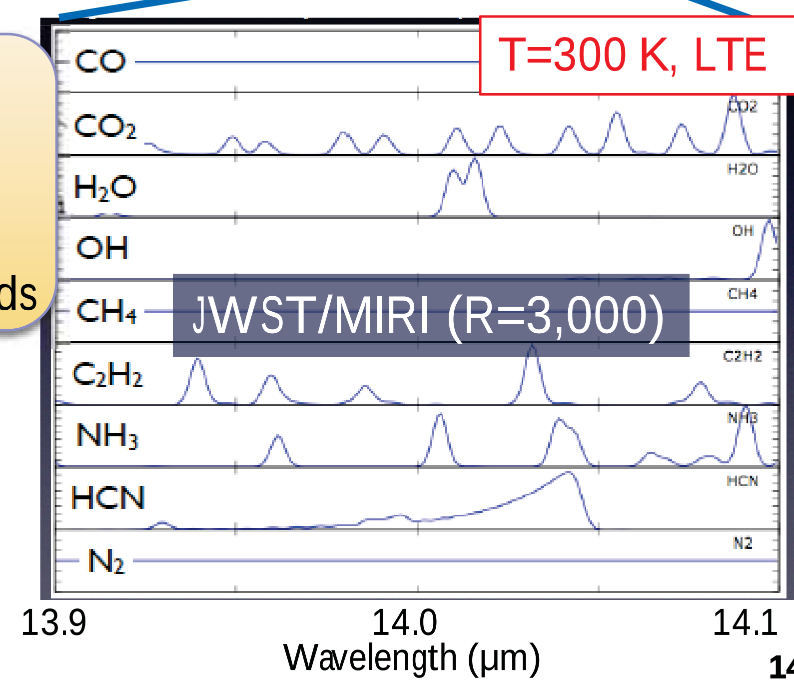
Velocity-resolved H_2O, OH, HCN, CO_2, C_2H_2 lines

→ C/O ratio distribution at <~1–2 AU in discs

Characteristics of planetary atmosphere depend on the C/O ratio of the gas at a formation site.



Not only de-blending, but also resolving molecular bands



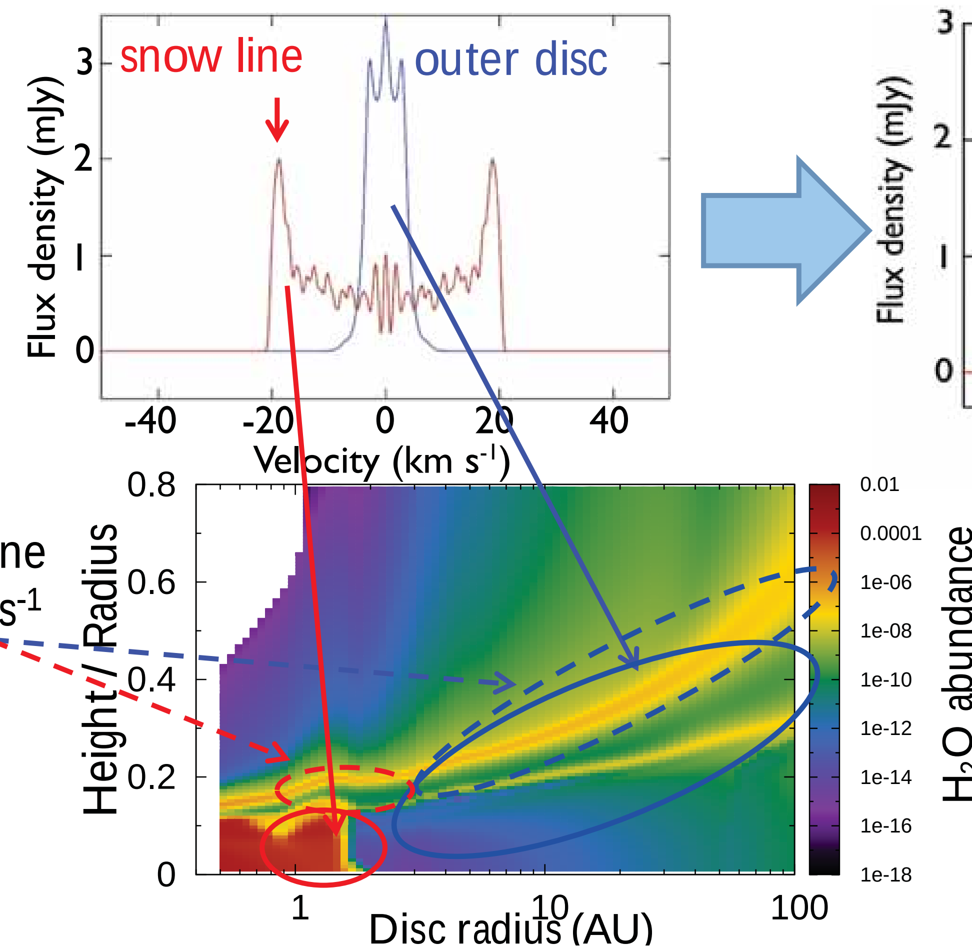
3(2)-D geometry of snow line/surface

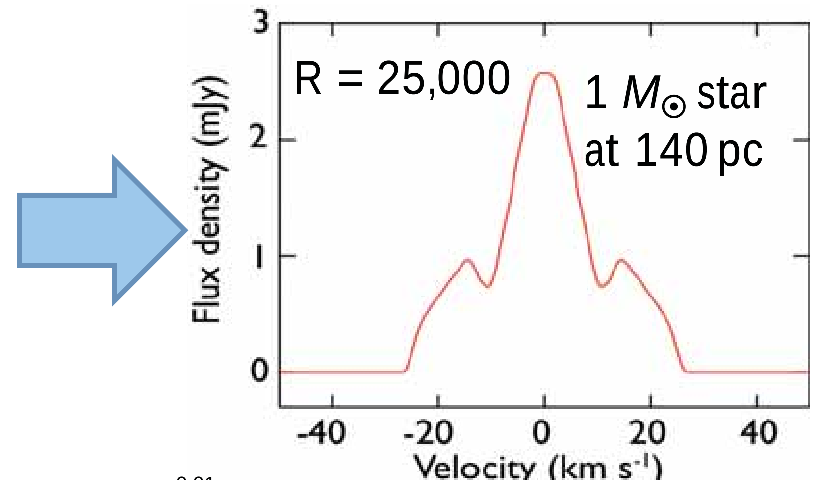
Snow line directly links to giant planet formation and chemistry

SMI dissects 3(2)-D geometry of snow line/surface by velocity-resolved spectroscopy of multiple H_2O lines with different Einstein A-coefficients
Complementary to SAFARI spectroscopy (Zhang+ 2013)

17.8µm H_2O line, A = 2.91×10^{-3} s^{-1}, E_u = 1,279 K

18.7µm H_2O line
A = 1.69×10^{-2} s^{-1}
E_u = 1,504 K





(Notsu & Nomura in prep)

HRS can separate the snow line (red) from the contribution of the outer disc surface (blue)

Current status and summary

Revised SPICA science cases and design have passed a series of reviews by JAXA/ISAS (international science review at Paris and Mission Definition Review)

SPICA is now in the preproject phase (≃ phase A)

SMI has three unique spectroscopic channels:

LRS (17-26μm, R~100) multi-slit w/ slit viewer (34μm)

MRS (18-36μm, R~2000) long-slit (~1’) w/ beam-steering mirror

HRS (12-18μm, R~28000) w/ beam-steering mirror

SMI-SAFARI unique sciences

PAHs and dust science in the distant Universe

Dust and gas in nearby galaxies (mapping and low-Z environments)

Gas and dust dissipation and chemistry (incl. snow lines) in PPDs

Detection of faint debris discs and their mineralogy


Thank you for your attention