

SPICA搭載 中間赤外線観測装置SMI: プロジェクト再定義への対応



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SMI: SPICA Mid-infrared Instrument、日本主導観測装置

構成: 3つの分光チャンネル

SMI-LRS

Multi-long-slit prism + Si:Sb w/ slit viewer
17 – 36 μm 、R = 50 – 120、slit長: 10分角、4本

SMI-MRS

Grating + Si:Sb w/ beam-steering mirror
17 – 36 μm 、R = 1300 – 2300、slit長: 1分角

SMI-HRS

Immersion grating + Si:As
12 – 17 μm 、R = 25000、slit長: 4秒角

変更点: 1) HRS追加 (MRS機能を若干、縮小)
2) slit viewer追加 34 μm -band imager (10'x10')

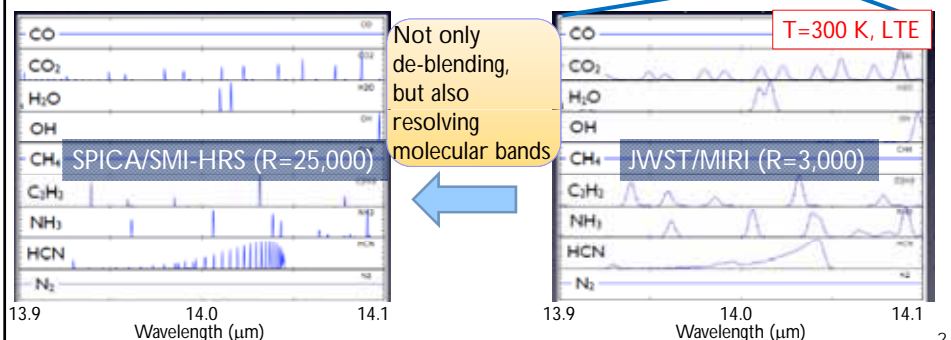
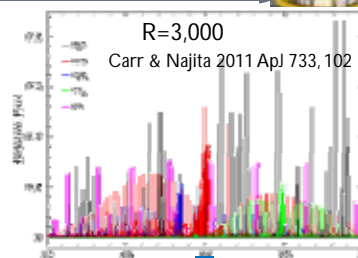
変更点1: 高分散分光チャンネルの追加



「原始惑星系円盤ガスの運動、ケミストリー」

★ 波長12–17 μm 帯には水素分子、水分子をはじめ、OH、HCN、 C_2H_2 、 CO_2 、など多くの分子輝線が存在。

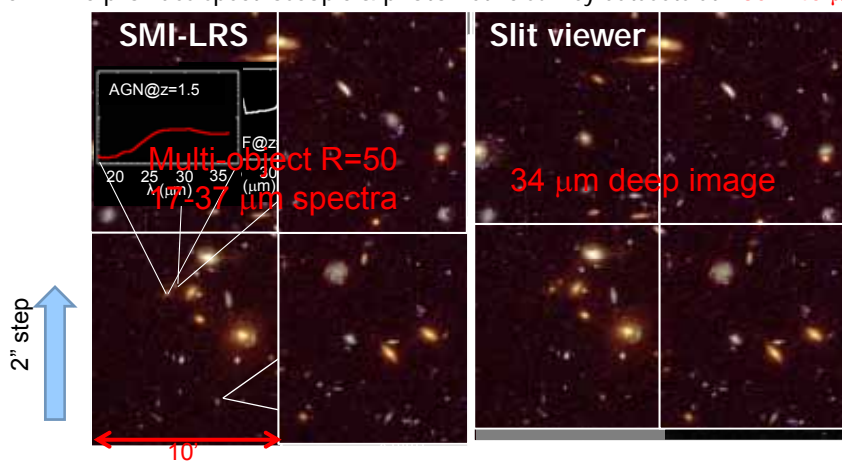
速度分解して、 $< \sim 1 - 2 \text{ AU}$ の場所を
同定。



変更点 2 : 34 μm 帯撮像機能の追加

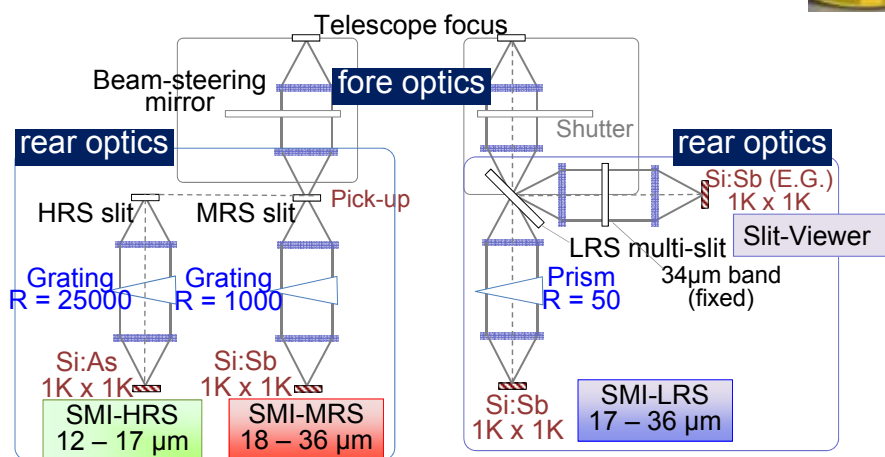
Spatial scan with 90 steps (1 step length $\sim 2'' \sim 0.5 \times$ slit width) produces a spectral map and a broad-band image of $10' \times 12'$ area, simultaneously.

- * 30 – 40 μm : **unexplored** region between Spitzer 24 μm and Herschel 70 μm surveys. SMI-LRS provides spectroscopic & photometric survey datasets at $\sim 30 - 40 \mu\text{m}$.



Slit viewer ($10' \times 10'$ FoV) provides broad-band ($R = 5$) images at $\lambda_c = 34 \mu\text{m}$.

Block diagram



No moving parts except for a beam-steering mirror (and shutter)

SMI-LRS design, characteristics

R=50 multi-slit format (4 long slits)

10' 12' 1024 pix

Detector: **Si:Sb**, 1K x 1K

rear-optics

Prism
Material: CsI

Multi slit Detector

$\lambda/\Delta\lambda$ as a function of wavelength

Color: difference from slit to slit
Solid or dotted: difference within a slit

Spectral Resolving Power

λ (μm)

- Wide FoV (4 slits, slit length 600")
- high continuum sensitivity
~30 μJy (1hr, 5 σ)
- 0.7"/pixel
- R=50–120 spectral mapping
- 10'x10' slit viewer (34 μm band)

High-speed dust-band mapping

5

Cosmological survey with SMI-LRS

Spitzer / IRS-LL

R = 60 – 120
slit size: 168"x11"

3.3'x3.3'

SPICA/SMI-LRS

R = 50 – 120
Multi slit
slit size: 10'x3.7"

3.2° x 3.2°

SMI-LRS R=50 blind survey
wide (10 square deg)
&
deep (1 square deg)

↓

Follow-up by SAFARI (& SMI)

For the same observational time & limiting flux at 25 μm

JWST / MIRI-MRS

R = 2000
slit size: 7.7"x7.7"

2'x2'

R=1000@z=3

R=50@z=3

SMI-MRS design, characteristics

Echelle format

λ_{min} λ_{max}

m = 6
m = 7
m = 8
m = 9
m = 10
m = 11

60" 36 μm

18 μm

Top
Center
Bottom

$\lambda/\Delta\lambda$

1K x 1K

Spectral resolving power

Point Source
Diffuse Source

λ (μm)

Detector: 1 **Si:Sb**, 1K x 1K

Fore Focus Rear

Telescope focus

Beam steering mirror Detector

- wide FoV (slit length 60" + beam steering mirror)
- high line sensitivity
~5 x 10⁻²⁰ W/m² (1 hr, 5 σ)
- good spectral resolution
R = 1000 – 2000
- spectral mapping

High-sensitivity spectral mapping

Spectral mapping of galaxies with SMI-MRS

Spitzer / IRS-LL

slit size : 168" x 11", R = 60 – 120
spatial resolution: 11" @35 μm

20 25 30 35
 λ (μm)

168" 11" slit size

SPICA / SMI-MRS

slit size: 60" x 3.7", R = 1000 – 2000
spatial resolution: 3.5" @35 μm

20 25 30 35
 λ (μm)

60" 3.7" slit size

Spitzer / IRS-LH

slit size : 22" x 11", R = 600
spatial resolution: 11" @35 μm

20 25 30 35
 λ (μm)

22" 11" slit size

60" 3.7" slit size

For the same observational time & limiting line flux at 35 μm

SMI-HRS design, characteristics

Echelle format

$m = 76$
 $m = 80$
 $m = 118$

12.1 μm 17.3 μm

Top
Center
Bottom

$\lambda/\Delta\lambda$ 1K x 1K

Spectral resolving power

λ (μm)

Detector: 1 **Si:As** 1K x 1K

Cross disperser CdZnTe immersion Grating

Fore-optics Focus

Detector

rear-optics

- slit length ~4"
- very high line sensitivity
~ 2×10^{-20} W/m² (1 hr, 5 σ)
- high spectral resolution
R > 25,000
- Continuous coverage from 12.1 to 17.3 μm , plus partial coverage up to 18.9 μm for H₂O 17.77 & 18.66 μm .

High-resolution spectroscopy

SMI Fact sheet (ISAS SPICAホームページに掲載)

SPICA / SMI Fact Sheet

SPICA Mid-infrared Instrument (SMI) covers the wavelength range of 12–36 μm with three spectroscopic channels: LRS, MRS, and HRS.

Parameter	Function		
	LRS (multi-disp with all slits)	MRS	HRS
Wavelength range	17 – 36 μm	16 – 36 μm	12 – 17 μm *
Spectral resolution	50 – 120 ^b (point source) 20 – 110 (diffuse)	1300 – 2300 (point source) 1100 – 1400 (diffuse)	25000 – 26000 ^c
Field of View	600" x 3.7" x 4 slits	80" x 3.7" (slit)	4" x 1.4" (slit)
FWHM	1.2 (12 μm) – 3.7 (37 μm)		
Pixel scale	0.7" x 0.7"	0.7"	0.5"
Detector	Si:As 1K x 1K	Si:As 1K x 1K	Si:As 1K x 1K
Point source	Cont. sensitivity (1 hr, 5 sigma)	20 – 140 μJy	200 – 4000 μJy
	Line sensitivity (1 hr, 5 sigma)	$(8 - 23) \times 10^{-20}$ W/m ²	$(3 - 40) \times 10^{-20}$ W/m ²
	Survey speed ^d	~ 36 arcmin ² /hr	~ 1.5 arcmin ² /hr
	Saturation limit	~ 2 Jy	~ 140 Jy
Diffuse	Continuum		
	Sensitivity ^e (1 hr, 5 sigma)	0.1 – 0.5 MJy/yr	$(0.5 - 2) \times 10^{-9}$ W/m ² /yr

a: continuous coverage up to 17.1 μm + partial coverage for H₂O 17.77 and 18.66 μm
b: $\lambda/\Delta\lambda = 120$ (LRS) and 1300 (MRS) at $\lambda = 36 \mu\text{m}$.
c: designed for $\lambda/20 \mu\text{m}$ diffraction limited PSF.
d: survey speed for the 5 sigma detection of a point source with the continuum flux of 100 μJy and the line flux of 3×10^{-19} W/m² for LRS and MRS, respectively.
e: sensitivity for a diffuse source in a 4" x 4" area.

Spectroscopy with SMI-HRS

PHS/sulfate-band mapping with SMI LRS

Spectral mapping with SMI-MRS

Sensitivity for a point source (1 hour, 5 sigma)

Continuous sensitivity of SMI-LRS (1 hr)

Line sensitivity of SMI-MRS-HRS (1 hr)

High background
Low background

Wavelength (μm)

SMI Factsheet v5 – 25 Aug 2015

まとめ



- **日本観測装置: SMI (SPICA Mid-infrared Instrument) 3分光チャンネル(LRS w/ slit viewer, MRS, HRS)**
- **変更点: (1)高分散分光チャンネルの追加、(2)34 μm 帯撮像機能の追加。とくに、「原始惑星系円盤ガス分光」と、「遠方銀河サーベイ」に重要。**
- **3分光チャンネルに対して光学設計を実施、科学要求をほぼ満足する設計解を得た。**