Advantage of a cryogenically-cooled IR telescope

- 10^5 reduction!
- SPICA (8K)
Science Goals

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

Metal and dust enrichment through galaxy evolution

- Star/Galaxy formation
  - First mineral, aromatics

- Star formation in distant galaxies

Planetary formation to habitable systems

- Gas dissipation in planet-forming disks
  - Gas dissipation in proto-planetary disks

- Dust evolution in planet-forming disks to solar system analogues
  - Changes of mineral and ice properties in debris disks

Dust-obscured AGNs and AGN outflow

- Over the peak of the cosmic star-formation history

- Star formation in nearby galaxies
  - Spatially-resolved, high-z analogs or relics
Baseline Specifications

- **Outer size:**
  - Φ4500 mm x 5285 mm
  - Fit in the H3 rocket fairing

- **Weight:**
  - 2614 kg (dry, nominal)
  - 3450 kg (wet, with margin)
  - Compliant with launching capacity of the H3 rocket. (3700 kg to L₂ transfer orbit)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telescope</td>
<td>2.5 m aperture, cooled below 8 K</td>
</tr>
<tr>
<td>Core Wavelength</td>
<td>17 – 230 µm</td>
</tr>
<tr>
<td>Orbit</td>
<td>Halo around S-E L2</td>
</tr>
<tr>
<td>Launcher</td>
<td>JAXA H3</td>
</tr>
<tr>
<td>Launch Year</td>
<td>2027-2028</td>
</tr>
</tbody>
</table>
## Basic Specification of SMI/LRS, MRS, and HRS

<table>
<thead>
<tr>
<th></th>
<th>LRS</th>
<th>MRS</th>
<th>HRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector</td>
<td>Si:Sb (1kx1k)</td>
<td>Si:Sb (1kx1k)</td>
<td>Si:As (1kx1k)</td>
</tr>
<tr>
<td>(Array Size)</td>
<td>18µm/pix</td>
<td>18µm/pix</td>
<td>25µm/pix</td>
</tr>
<tr>
<td>Pixel Pitch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wavelength range</td>
<td>17µm – 37µm</td>
<td>18µm – 36µm</td>
<td>12.14µm – 17.08µm</td>
</tr>
<tr>
<td>(µm)</td>
<td></td>
<td>(m = 6&lt;sup&gt;th&lt;/sup&gt; – 11&lt;sup&gt;th&lt;/sup&gt;)</td>
<td>(m = 84&lt;sup&gt;th&lt;/sup&gt; – 118&lt;sup&gt;th&lt;/sup&gt;) [fully covered]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>17.08µm – 18.7µm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(m=77&lt;sup&gt;th&lt;/sup&gt; –84&lt;sup&gt;th&lt;/sup&gt; ) [intermittently]</td>
</tr>
<tr>
<td>spectral resolution</td>
<td>50—100 (prism)</td>
<td>~1000 (echelle grating)</td>
<td>~28000 (imergion grating)</td>
</tr>
<tr>
<td>(R=λ/Δλ)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>plate scale</td>
<td>0.&quot;70</td>
<td>0.&quot;725</td>
<td>0.&quot;67</td>
</tr>
<tr>
<td>(arcsec/pix)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slit configuration</td>
<td>Multi (n=4) Long Slits</td>
<td>Long Slit</td>
<td>Short Slit</td>
</tr>
<tr>
<td></td>
<td>slit length: 600”</td>
<td>length: 60.&quot;0</td>
<td>slit length: 4”</td>
</tr>
<tr>
<td></td>
<td>slit width: 3.&quot;7 (5.3pix)</td>
<td>width: 3.&quot;7 (5.1pix)</td>
<td>width: 1.&quot;7 (2.5pix)</td>
</tr>
</tbody>
</table>

LRS; excellent continuum sensitivity ~30µJy (1h5σ @30µm), high spectral mapping efficiency (R=50--100)  
MRS; excellent line sensitivity ~4x10<sup>-20</sup>W/m2 (1h5σ @30µm), high spectral mapping efficiency (R~1000)  
HRS; excellent line sensitivity ~1x10<sup>-20</sup>W/m2 (1h5σ @15µm), high resolution spectroscopy (R~28000)
(1) Low-resolution spectrometer and camera

multi-slit format (4 long slits)

Detector: Si:Sb, 1K x 1K

Detector (camera)

Prism (KRS-5)

Telescope focus

- Wide FoV (4 slits, slit length 10’)
- high continuum sensitivity
  ~30 μJy (1hr, 5σ)
- 0.7”/pixel
- R = 50–120 spectral mapping
- 10’x10’ slit viewer (34 μm, R = 5)
  sensitivity: ~10 μJy (1hr, 5σ)
Detector: 1 Si:Sb, 1K x 1K

Echelle format

MRS

\[ \frac{\lambda}{\Delta \lambda} \]

1K x 1K

<table>
<thead>
<tr>
<th>m = 6</th>
<th>m = 7</th>
<th>m = 8</th>
<th>m = 9</th>
<th>m = 10</th>
<th>m = 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>60''</td>
<td>36 \mu m</td>
<td>18 \mu m</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- wide FoV (slit length 60’’ + beam steering mirror)
- high line sensitivity
  \( \sim 4 \times 10^{-20} \text{ W/m}^2 \) (1 hr, 5\( \sigma \))
- good spectral resolution
  \( R = 1200 - 2300 \)
- spectral mapping
(3) High-resolution spectrometer

- **Echelle format**
- **Slit length ~4”**
- **Very high line sensitivity**
  - $\sim 1 \times 10^{-20}$ W/m² (1 hr, 5σ)
- **High spectral resolution**
  - $R = 28,000$
- **Continuous coverage from 12.1 to 17.3 µm**
- **Plus partial coverage up to 18.9 µm for H₂O 17.77 & 18.66 µm.**

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

**Cross disperser**

**CdZnTe immersion Grating**

**Fore-optics**

**Focus**

**Ikeda et al. 2015**

Applied Optics 54, 5193
Roles of SMI in the Science Goals

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

- **Metal and dust enrichment through galaxy evolution**
  - Star/Galaxy formation
    - First mineral, aromatics
  - Star formation in distant galaxies
  - AGN Outflows with HRS
  - Cosmological surveys with LRS
  - + follow-up with MRS

- **Planetary formation to habitable systems**
  - Gas dissipation in planet-forming disks
  - Gas dissipation in proto-planetary disks
  - Resolving gas Kepler motion with HRS
  - Dust evolution in planet-forming disks to solar system analogues
    - Changes of mineral and ice properties in debris disks
  - Spectral mapping with MRS
  - Mineralogy with LRS
  - + follow-up with MRS

**Spatially-resolved, high-z analogs or relics**
- Over the peak of the cosmic star-formation history
- Star formation in nearby galaxies
- Dust-obscured AGNs and AGN outflow
SPICA/SAFARI Fact Sheet

SAFARI Overview
- Four band grating spectrometer
- Continuous spectroscopic capability from 34–230 µm

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SW</th>
<th>MW</th>
<th>LW</th>
<th>LLW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band centre / µm</td>
<td>45</td>
<td>72</td>
<td>115</td>
<td>185</td>
</tr>
<tr>
<td>Wavelength range / µm</td>
<td>34-56</td>
<td>54-89</td>
<td>87-143</td>
<td>140-230</td>
</tr>
<tr>
<td>Band centre beam FWHM</td>
<td>4.5&quot;</td>
<td>7.2&quot;</td>
<td>12&quot;</td>
<td>19&quot;</td>
</tr>
</tbody>
</table>

Point source spectroscopy (5σ-1hr)
- Limiting flux / x10^-20 Wm^-2
  - R≈300
    - Limiting flux / x10^-20 Wm^-2: 7.2 6.6 6.6 8.2
    - Limiting flux density / mJy: 0.31 0.45 0.72 1.44
  - High R
    - Limiting flux / x10^-20 Wm^-2: 13 13 13 15
    - Limiting flux density / mJy: 18 17 17 19

Mapping spectroscopy* (5σ-1hr)
- Limiting flux / x10^-20 Wm^-2
  - R≈300
    - Limiting flux / x10^-20 Wm^-2: 84 49 30 23
    - Limiting flux density / mJy: 3.6 3.3 3.3 4.1
  - High R
    - Limiting flux / x10^-20 Wm^-2: 189 113 73 51
    - Limiting flux density / mJy: 253 151 97 67

Photometric mapping* (5σ-1hr)
- Limiting flux density / µJy: 209 192 194 239
- Confusion limit (5σ): 15 µJy 200 µJy 2 mJy 10 mJy

SAFARI Mission
- ESA/JAXA collaboration
- Telescope effective area 4.6 m^2
- Primary mirror temperature 8K
- Goal mission lifetime – 5 years

System performance v.s. target flux density, relative to the background limited case
- The sensitivity decrease is due to the increased photon noise from the target source
- Data given up to the instrument saturation limits for each band (31, 51, and 87 Jy) for the SW, MW and LW bands respectively.
Sensitivity of SMI and SAFARI

![Graph showing sensitivity of SMI and SAFARI across different wavelengths and line fluxes.](image)
**SPICA Mission**

Telescope Aperture is **2.5m, cooled below 8K**

JAXA plans to launch **in 2027-2028**

*Three years* for Nominal Operation, *Five years* for Goal

Current Status;
- Japan: **Project Preparation** Phase in JAXA
- Europe: Writing a Proposal for **ESA Cosmic Vision M5**

**SPICA Mid-Infrared Instrument**

1. **LRS** (17–36 µm, R~100) w/ slit-viewer camera (34 µm)
   - 10’-length multi (4) slits. Spitzer/IRS-LL-like with higher mapping speed

2. **MRS** (18–36 µm, R~2000)
   - 1’-length slit with beam-steering mirror. IRS-LH-like with better mapping

3. **HRS** (12–18 µm, R~30000).
   - 4”-length with beam-steering mirror. Unique (↔ JWST/MIRI R~2000)

**SAFARI Grating Spectrometer**

Wavelength Coverage 34µm – 230µm

Simultaneous observation of the whole waveband (SW, MW, LW, LLW)
- High-sensitivity R = 300 Spectral Resolution mode
- High-resolution R = 1500 – 11000 mode

- 2’ × 2’ mapping capability with BSM

larger area mapping through combination of BSM and satellite pointing