Infrared coronagraph for SPICA

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Direct observation of exo-planets

**Importance**
- Approach to a fundamental question:
  - How were the planets born?
  - How did they evolve?? How about life???

**Difficulty**
- High contrast and small angular separation between a planet and the parent star.

**No longer dream**
- Next step is systematic characterization.

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(Images and text related to exoplanet observations and characterizations, including references to Marois et al. 2008, Kalas et al. 2008, and Traub & Jucks 2002.)
Relating presentation: Thanks to big effort by SCI science team

- Takami et al:
  A review of galactic science

- Itoh, Fukagawa et al.:
  Direct observation of exo-planets

- Narita, Yamashita et al:
  Monitor observation of planetary transit

- Honda et al:
  Snow line
SPICA as a platform of coronagraph

Vs. ground based telescope (Large aperture, quick realization)
- Free from air turbulence
- Infrared advantage in contrast
- Continuous wavelength coverage in infrared

Vs. TPF, DARWIN, ... (Ultimate performance)
- SPICA will be launched earlier

Vs. JWST (6.5m space telescope, 2013 launch: the most powerful rival)
- ~x10 higher contrast by monolithic mirrors and active optics
- Capability of coro.+spectroscopy (JWST doesn’t have)
What can SCI reveal?

On going work
- Quantitative estimation and comparison of performance
- Trial selection of concrete target (talk by Itoh, Fukagawa)

Next step: combining them, imaginary legacy survey
- More detail estimation of observation time, improvement of observation strategy, feedback to instrumentation, stronger justification for SCI.

Good targets!
(Marois et al. 2008)

Thanks to T. Matsuo's big contribution
# Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core wavelength ($\lambda$)</td>
<td>3.5–27 micron (shorter wavelength is optional)</td>
</tr>
<tr>
<td>Observation mode</td>
<td>w/woCoronagraph, Imaging/Spectroscopy</td>
</tr>
<tr>
<td>Coronagraphic mode</td>
<td>binary shaped pupil mask</td>
</tr>
<tr>
<td>Inner working angle (IWA)</td>
<td>~3.3$\lambda$/D *</td>
</tr>
<tr>
<td>Throughput</td>
<td>~20%</td>
</tr>
<tr>
<td>Outer working angle (OWA)</td>
<td>16$\lambda$/D</td>
</tr>
<tr>
<td>Contrast</td>
<td>10$^{-6}$ @PSF  ( ~10$^{-7}$ after subtraction)</td>
</tr>
<tr>
<td>Detector</td>
<td>1k x 1k Si:Asarray (InSb detector is optional)</td>
</tr>
<tr>
<td>Field of View</td>
<td>1$\times$1$\times$</td>
</tr>
<tr>
<td>Spectral resolution</td>
<td>~20 and ~200</td>
</tr>
<tr>
<td>Filter</td>
<td>Band pass filters</td>
</tr>
<tr>
<td>Disperser for spectroscopy</td>
<td>transmissive devices (e.g. grism) in filter wheel</td>
</tr>
</tbody>
</table>

Baseline specification is presented. Further improvement is ongoing toward the best, final solution.
Compact solutions are obtained.

(\(\sim13\text{kg for housing@100Hz stiffness, } \sim12\text{kg for optics, mechanics, electronics}\))

Further improvement is ongoing toward the best, final solution.
Coronagraph method

- Binary shaped pupil mask coronagraph
  - Advantage 1: Very robust against pointing error.
  - Advantage 2: Achromatic work (except PSF size effect)
    - continuous spectrum
  - Challenge: High precision fabrication is needed

- Laboratory experiments succeeded
  - Demo. of principle with masks on substrate → $6 \times 10^{-8}$
  - Demo. of free standing mask for MIR coronagraph → $7 \times 10^{-7}$

- Improvement of mask design is ongoing.
Cryogenic active optics

- **Cryogenic deformable mirror (DM)**
  - MEMS DM: compact, large format (many channels)
  - Demo. with a prototype device succeeded.
  - Big issue: Wire harness

- **Cryogenic tip-tilt mirror**
  - Baseline design uses piezo actuators.
  - Collaboration with IoA (Miyata, Sako, Nakamura)
  - Should be considered in total attitude control system
  - Current the most challenging issue for SCI.
Observation of planetary transit

- Important by-product
  (→ talk by Narita, Yamashita)
  - non-coronagraph mode as a fine camera & spectrometer is useful.

- SPITZER pioneered
  - Characterization of Infrared spectral features of exo-planets
  - Stability is essential.

- SPICA can be better than SPITZER

- JWST is the most powerful rival
  - Internal calibrator is considered
Summary

- We are performing R&D for SCI

- Some big progress
  - Scientific study
  - Technical challenge
  - Constraints of resource
  - Concrete design of the instrument

  Still more progress is needed.

- Teaming
  - Why we have to hurry?
  - Participation for Scientific study, instrumentation
  - Please feel free to contact to enya@ir.isas.jaxa