SPICA coronagraph for the detection and characterization of exo-planets

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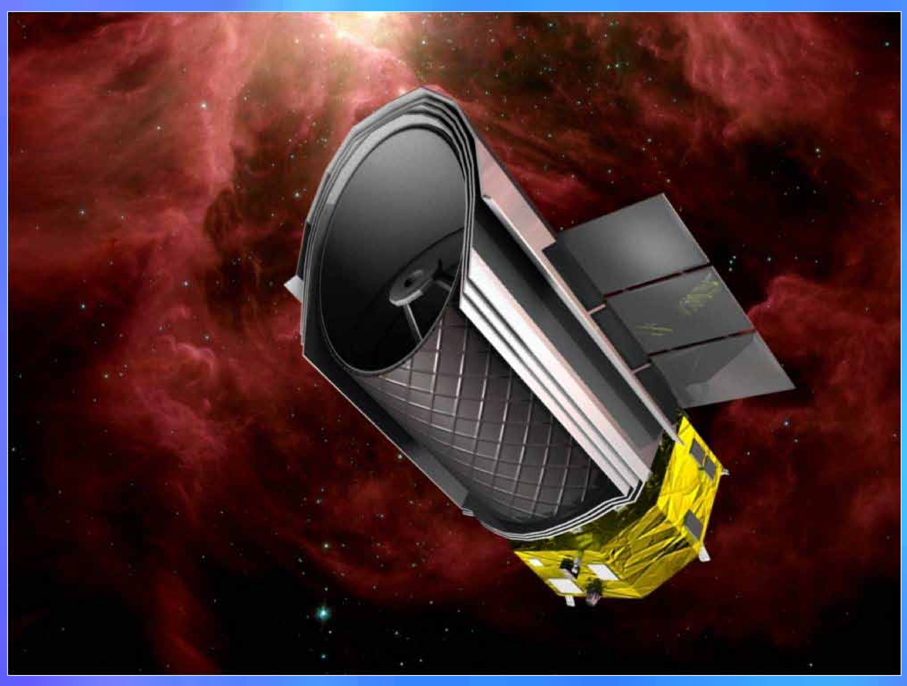
SPace Infrared telescope for Cosmology and Astrophysics (SPICA) is a infrared space-borne telescope mission of the next generation by JAXA, ESA, and international collaborators. SPICA will carry a telescope with a 3m class diameter monolithic primary mirror and the whole telescope will be cooled to 6 K. SPICA is planned to be launched in 2018, into the sun-earth L2 libration halo orbit and execute infrared observations at wavelengths mainly between 5 and 210 micron. The large telescope aperture, the simple pupil shape, the capability of infrared observations from space, and the early launch gives us with the SPICA mission a unique opportunity for coronagraphic observation. Design and development of the SPICA coronagraph instrument (SCI) is ongoing. Systematic detection and characterization of exo-Jovian planets are the primary target of SCI. In an experiment with a binary shaped pupil coronagraph with a He-Ne laser (λ=632.8nm), the achieved raw contrast was 6.7×10^{-8}, derived from the average measured in the dark region. Development of a cryogenic MIR chanber, free standing masks, deformable mirror are in progress to realize MIR coronagraph system for SPICA.

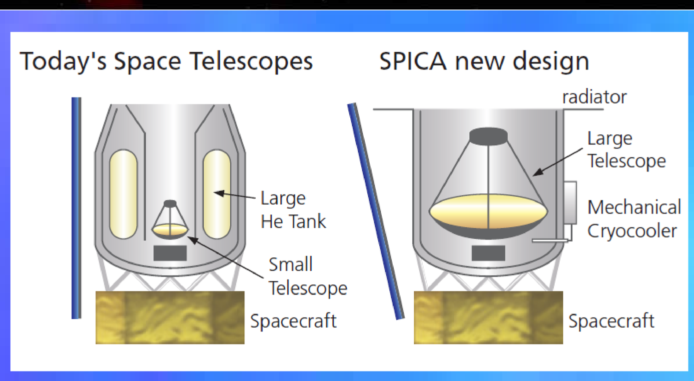
1. Overview of SPICA mission

- SPICA is an infrared space-borne telescope observatory of the next generation by JAXA, ESA, and international collaborators.

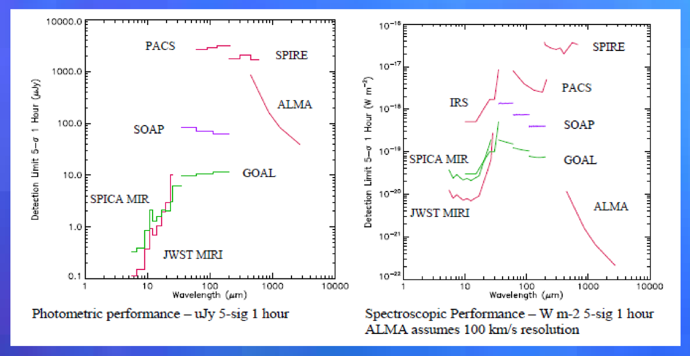


Specifications

Telescope aperture: 3.2m
Telescope temperature 6 K
Core wavelength: 5-210 μm
MIR Instrument
Including Coronagrap
Far-Infrared Instrument (SAFARI)
US Instrument (Optional)
Orbit: Sun-Earth L2 Halo
Mission Life: 3 years (nominal),5 years (goal)
Weight: 3.7 t
Launch: FY2018

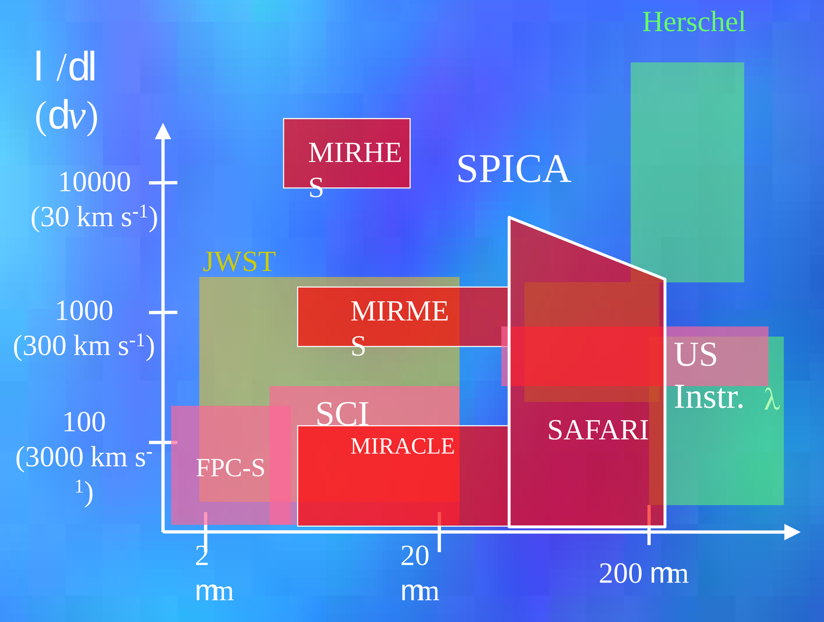


Concept of cryogenics: Why SPICA can be large?



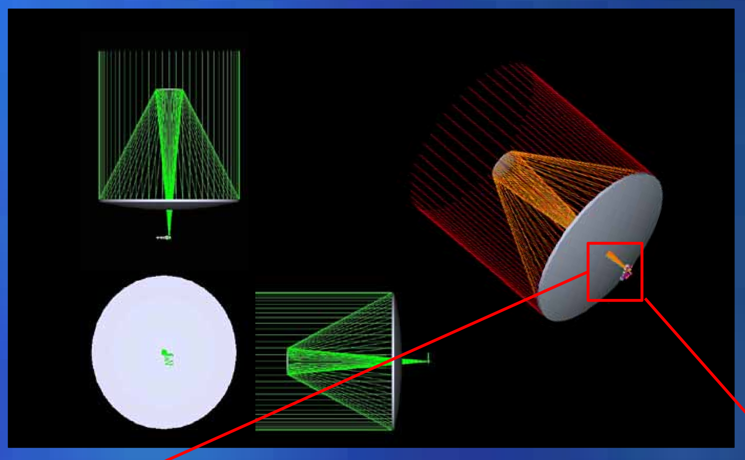
Cool telescope: huge gain of cryogenics insensitivity

Proposed focal plane instruments



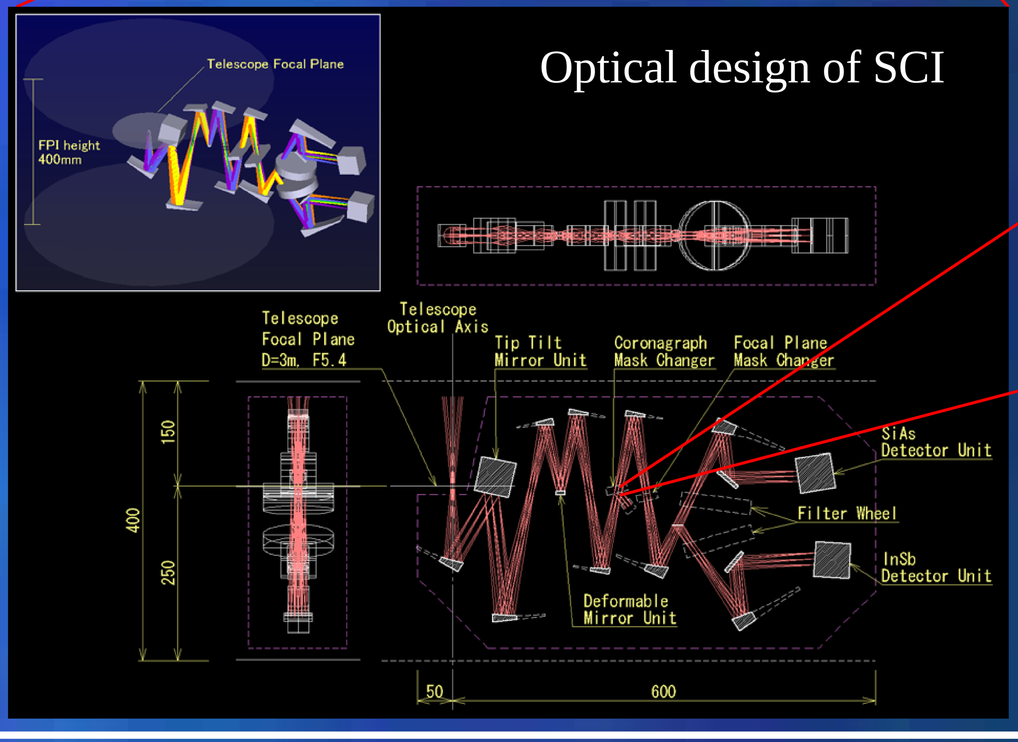
2. SPICA coronagraph Instrument (SCI)

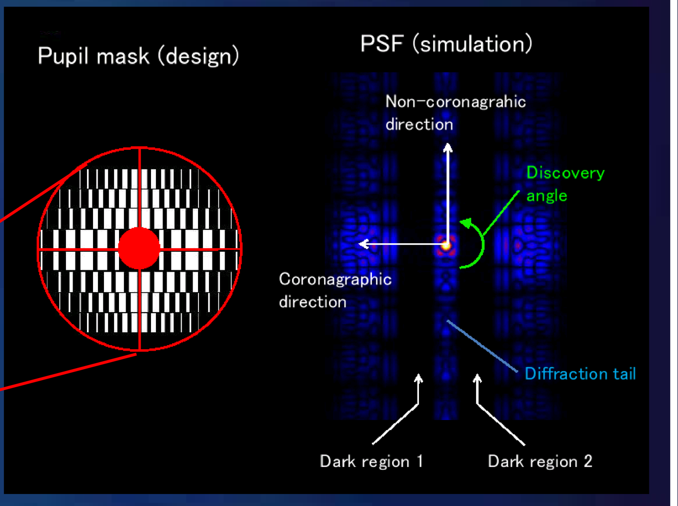
- We have proposed SCI as one of the focal plane instruments of SPCIA.
- Design and development of key technology for SCI is ongoing.
- Unique opportunity for high-dynamicrange observation of exo-planets:
  - Large telescope aperture.
  - Advantage of contrast between planets and the central star in MIR.
  - Free from air turbulance



Specifications

Wavelength (λ)	Core wavelength lambda = 3.5-27 μm Short wavelength channel: λ = 3.5~5 μm Long wavelength channel: $\lambda \gtrsim 5$ μm (At λ < 3.5μm, high contrast imaging is not guaranteed, but the instrument has sensitivity by InSb detector)
Coronagraph method	Binary shaped pupil mask
Observation mode	Coronagraphic imaging Coronagraphic spectroscopy Non-coronagraphic imaging Non-coronagraphic spectroscopy
contrast	10^{-6} @ PSF
Inner working angle	3.3 λ/D (D is telescope aperture diameter)
Outer working angle	16 λ/D
Filter	Band-pass filters for each channels
Detector	a 1K × 1K Si:As array for the long wavelengths a 1K × 1K InSb array for the short wavelengths
FoV	High-contrast coronagraphic FoV: 16λ/D (FOV of 1' × 1' is available but high-contrast is not guaranteed out of 16 λ/D)
Spectral resolution	~20 and ~200 (to be realized by transmissive dispersion devices, e.g. grism)

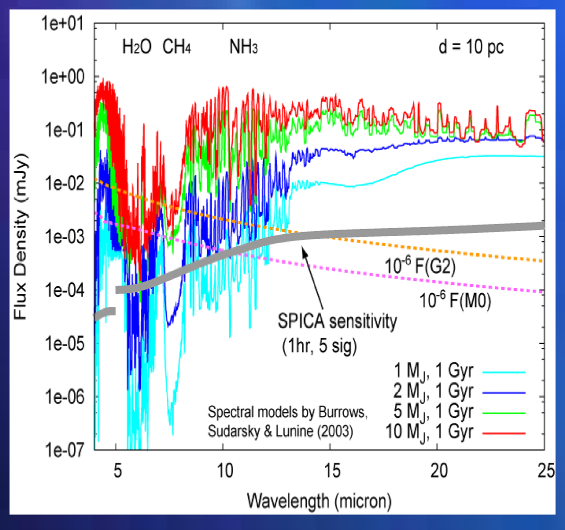


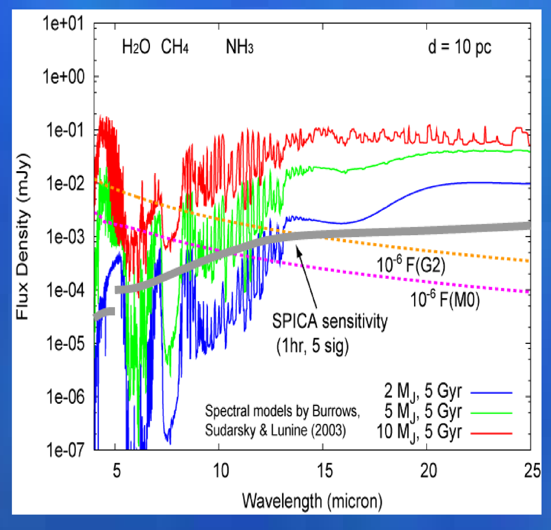


Design of a binary shaped pupil mask and expected PSF.

3. Science case

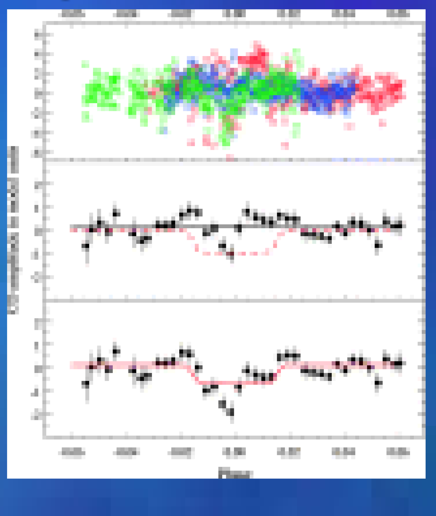
- Detection and characterization of exo-planets and planetary system by high-dynamicrange imaging and spectroscopy.



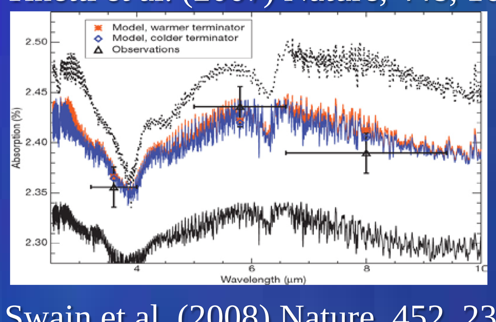


Critical science case 1: Coronagraphic imaging and spectroscopy of Jovian exo-planets
=> poster by Matsuo et al.

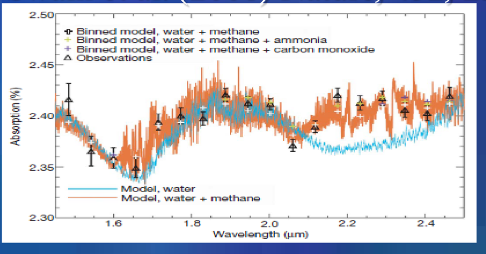
Deming et al. (2005) ApJ , 622, 1149



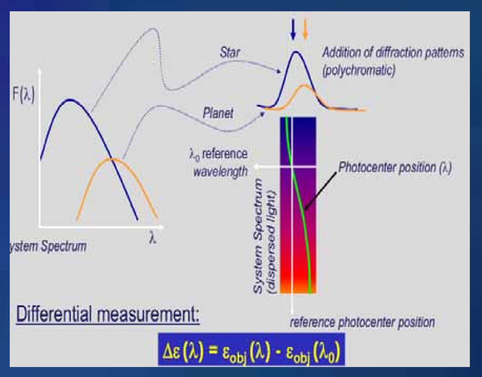
Tinetti et al. (2007) Nature, 448, 169



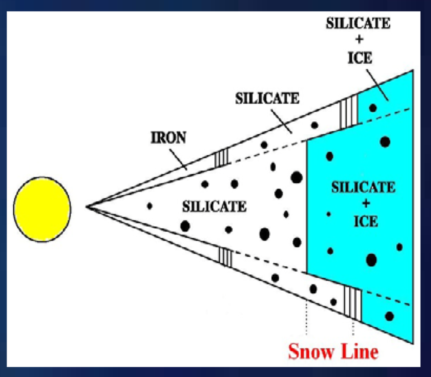
Swain et al. (2008) Nature, 452, 239



Critical science case 2: Spectroscopic monitor of transiting exo-planet *=> Poster by Narita et al.*



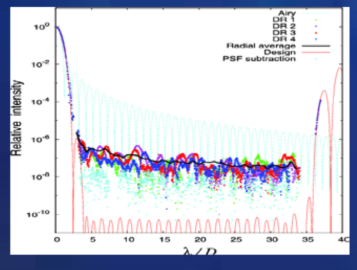
Concept of Color Differential Astrometory (CDA) of exo-planet observation.
=> Poster by Abe et al

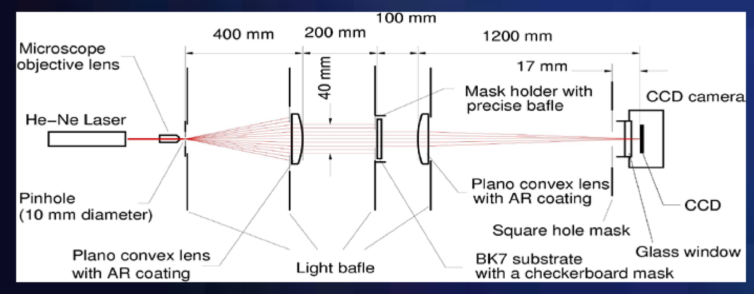


Snow-line search in disk.

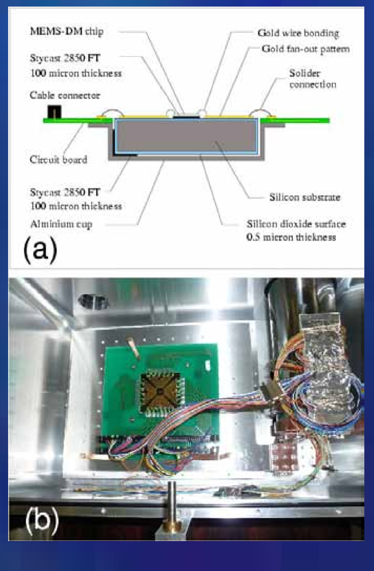
Other important science case

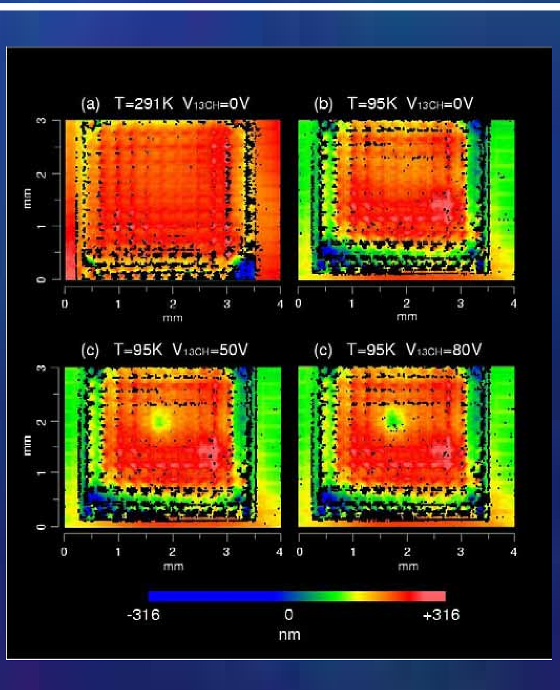
6. Toward the MIR-coronagraph for SPICA





Top-left: Designed and manufactured checherboard masks of Al thin film on BK7 substrate, using electron beam nano-fabrication. Right: Observed coronagraphic PSF. Contrast of $7x10^{-8}$ is achieved by an experiment with He-Ne laser(6328nm) w/o AO.





Top left: schematic view of the prototype DM unit. Bottom left: The DM unit installed in a cryostat. The radiation shield and temperature sensor are not shown in this photograph. Right: 3D data of surface deformation by interferometer.

Top: Vacum chamber. The primary goal with the chamber is demonstration of cryo-MIR coronagraph, while the chamber can be useful to improve our optical *experiment => Poster by Haze et al.*
Bottom: Test fabrication of masks for MIR coronagraph is on-going.