Infrared coronagraph for SPICA

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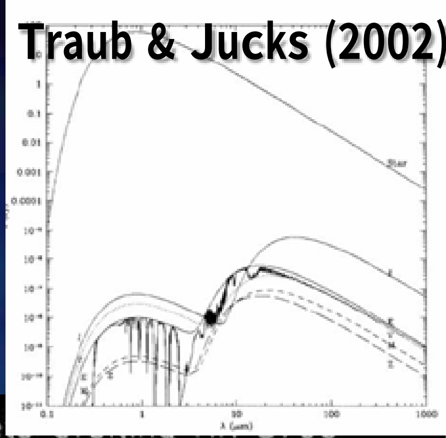
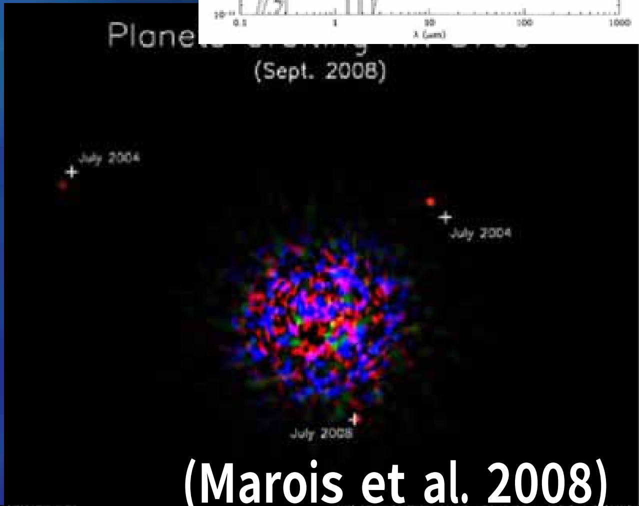
Direct observation of exo-planets

- Improtance
  - 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.

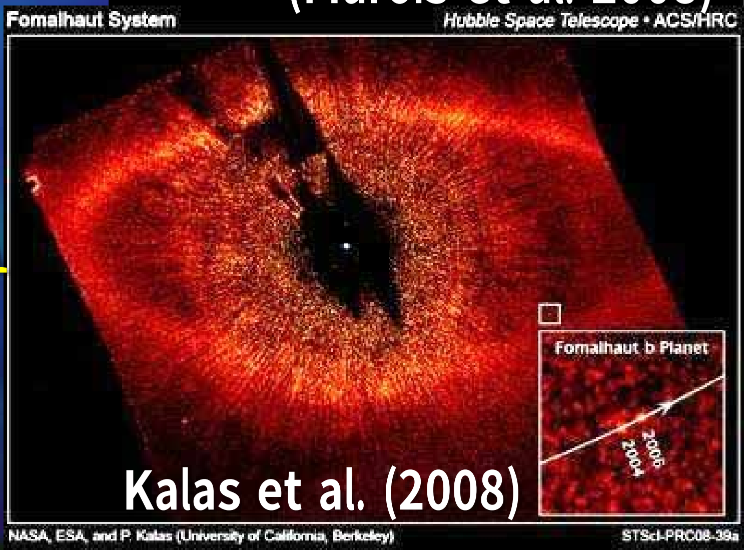
We are performing R&D for SPICA coronagraph instrument (SCI)



Traub & Jucks (2002)



(Marois et al. 2008)



Kalas et al. (2008)

- Relating presentation: Thanks to big effort by SCI sicence 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 coronagrpah

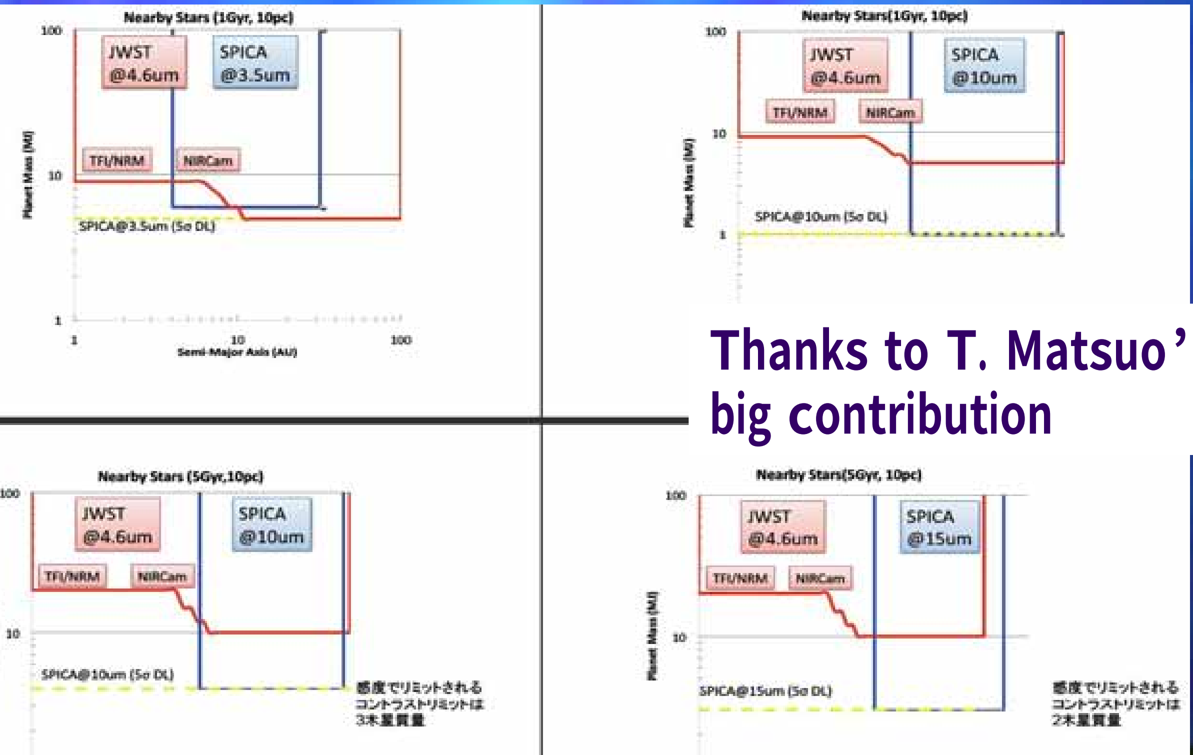
- Vs. ground based telescope (Large aperture, quick realization)
  - Free from air turbulence
  - Infrared advantage in contrast
  - Continuous wavelength coverage in infrared
- Vs. TPF, DARWIN, ... (Ultimate performance)
  - SPICA will be launched ealier
- Vs. JWST (6.5m space telescope, 2013 launch: the most powerful rival)
  - ~x10 higher contrast by monolithic mirrors and active optics
  - Capability of coro.+spectroscopy (JWST does'nt have)

SCI has significant advantage over JWST

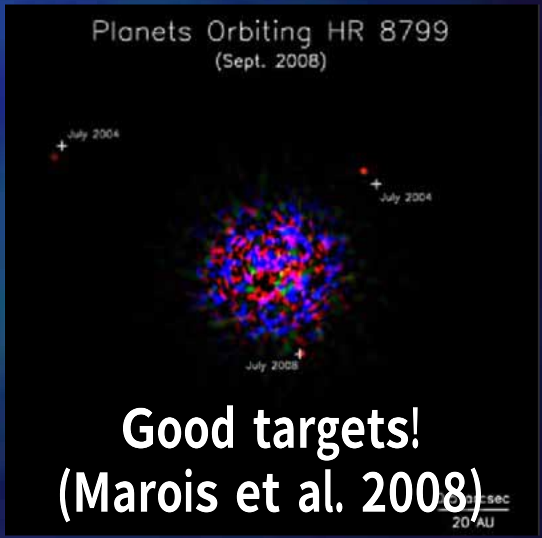
What can SCI reveal?

- 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.



Thanks to T. Matsuo' big contribution



Good targets!
(Marois et al. 2008)

Specifications

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

* D = 3.5m

- Baseline specification is presented.
- Further improvement is ongoing toward the best, final solution.

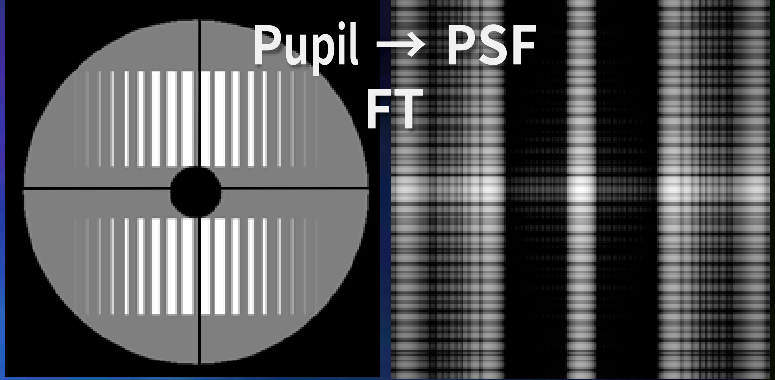
Optical layout

- Compact solutions are obtained.

  (~13kg for housing@100Hz stiffness, ~12kg for optics, mechanics, electronics)

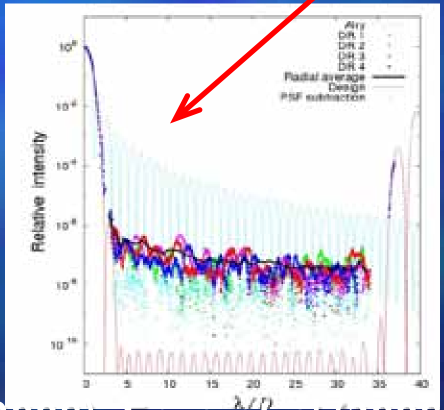
- Further improvement is ongoing toward the best, final solution.

Coronagraph method



Example of mask design
(Enya et al. 2009)

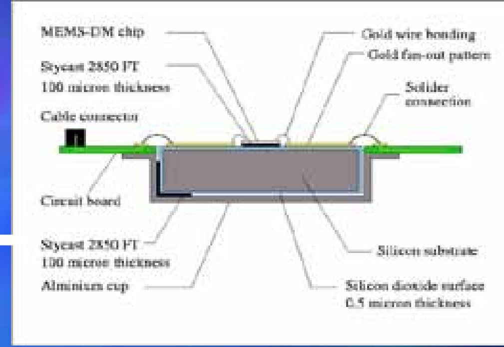
- Binary shaped pupil mask coronagraph
  - Advantage1: Very robust against pointing error.
  - Advantage2: Achromatic work (except PSF size effect)
    → continuous spectrum
  - Challenge: High precision fabrication is needed
- Laboratory experiments succeeded
  - Demo. of principle with masks on substrate → 6×10^{-8}
  - Demo. of free standing mask for MIR coroangraph → 7×10^{-7}



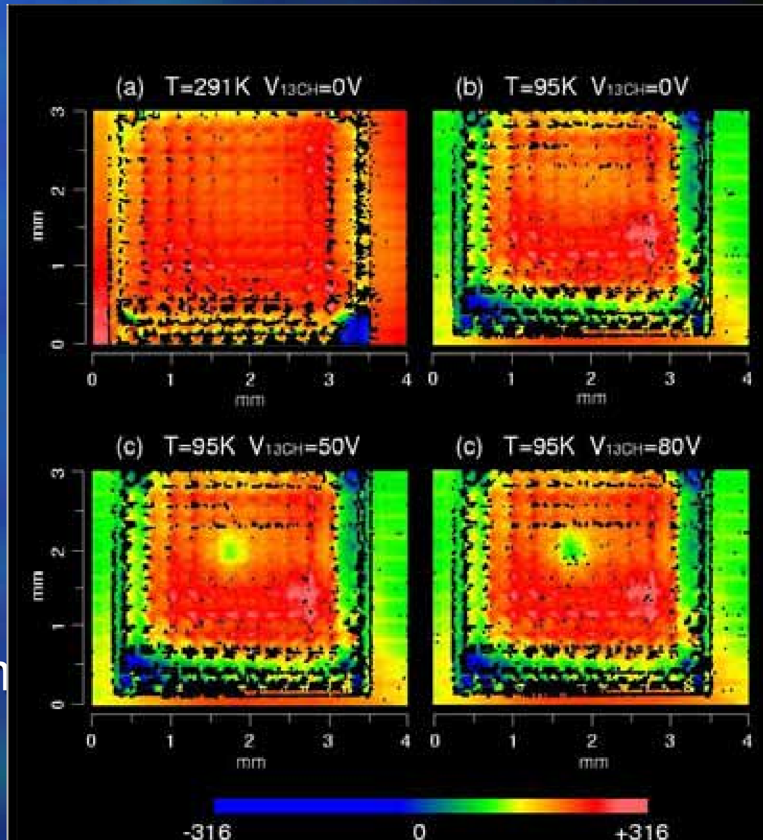
e.g., Enya et al. (2007), Haze et al.(2008), Enya et al.(2008)

- Improvement of mask design is ongoing.

Cryogenic active optics



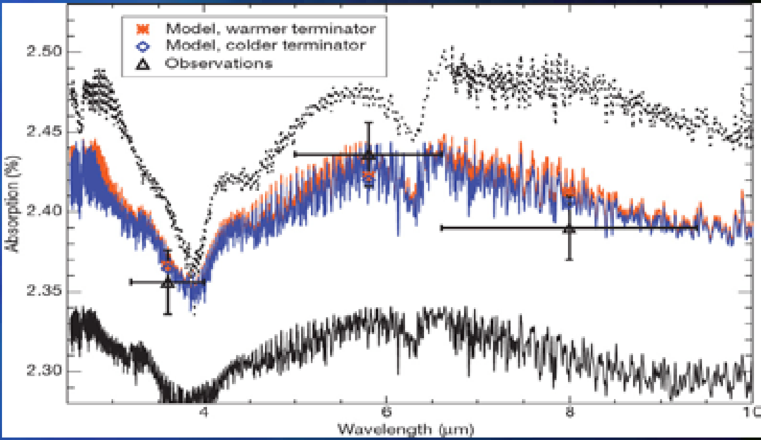
- Cryogenic deformable mirror(DM)
  - MEMS DM: compact, large format (many channels)
  - Demo. with a prototype device succeeded.
  - Big issue: Wire harness
- Cryogenic tip-tilt mirror
  - Baseline design uses piezo actuators.
  - Collaboration with IoA (Miyata, Sako, Nakamura)
  - Should be considered in total atitude control system
  - Current the most challenging issue for SCI.



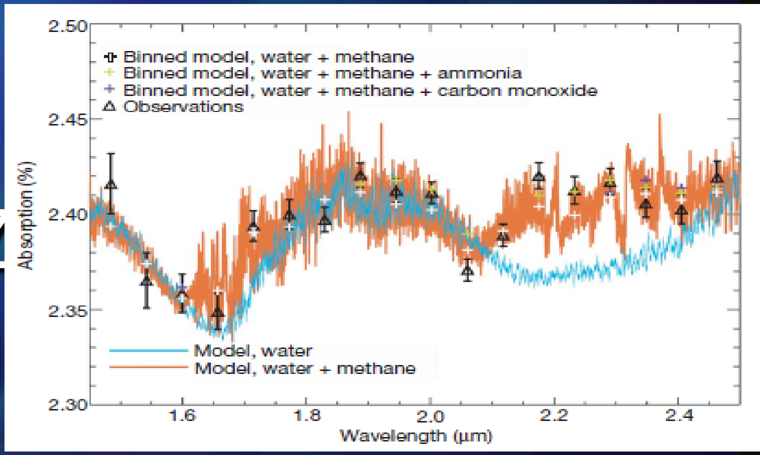
Enya et al. (2008)

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



Tinetti et al. (2008)



Swein et al. (2008)

Summary

- We are performing R&D for SCI
- Some big progress
  - Scientific study
  - Techinical 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