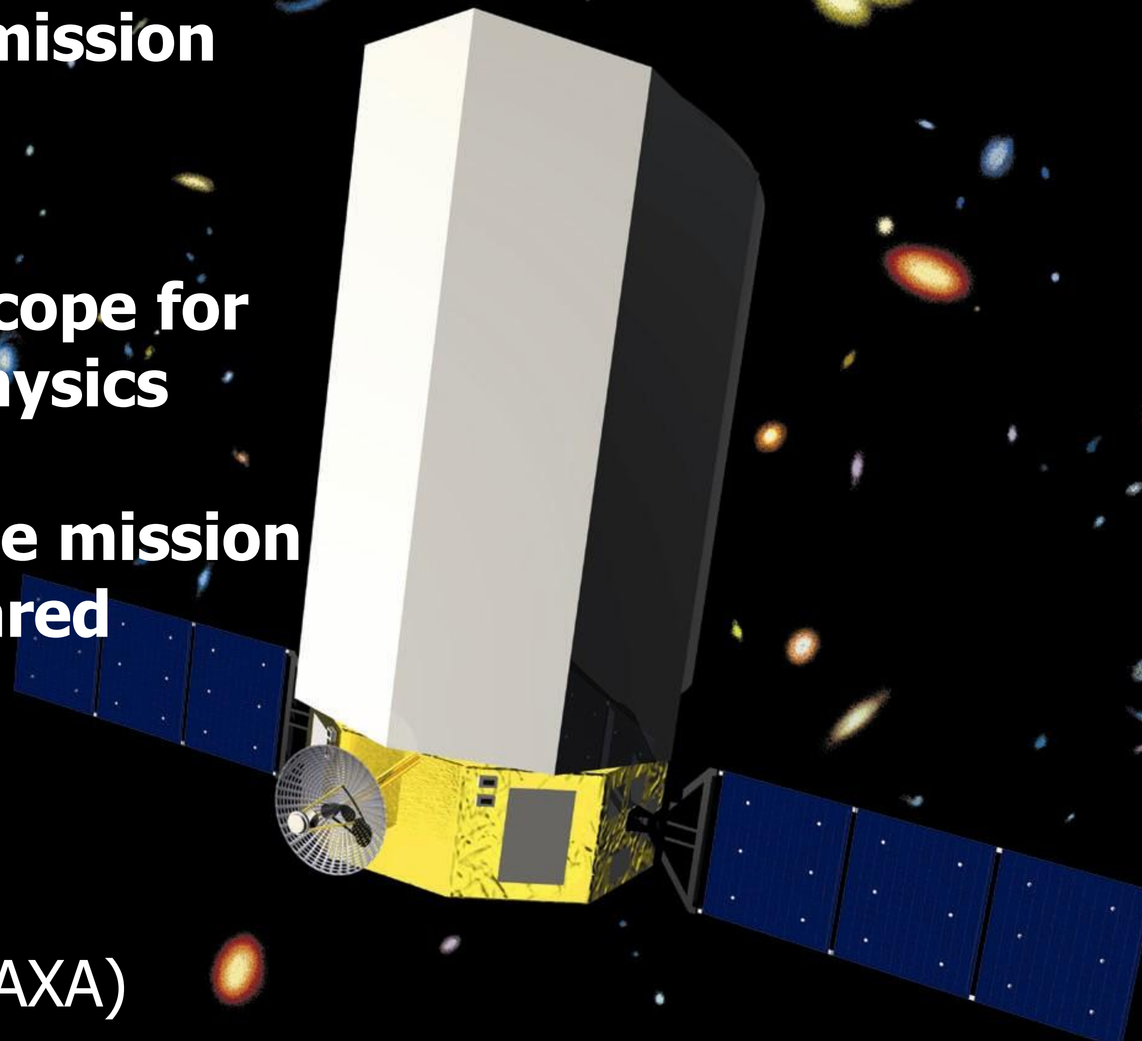
The next-generation Infrared astronomy mission

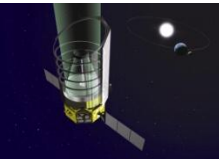
SPICA

Space Infrared Telescope for Cosmology & Astrophysics

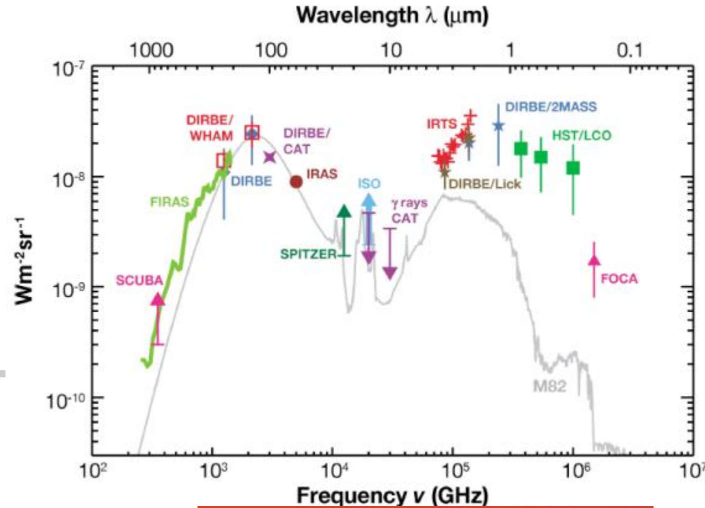
3.5m cooled telescope mission for mid- and far-infrared astronomy



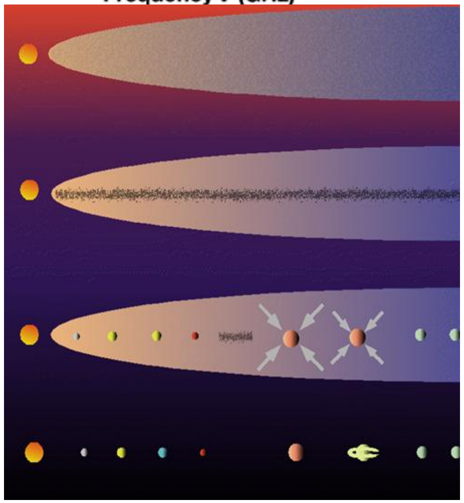
Takao Nakagawa (ISAS/JAXA)
for SPICA team

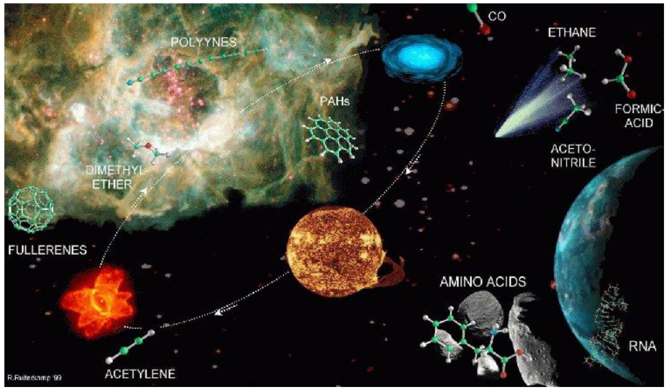


Scientific Goals

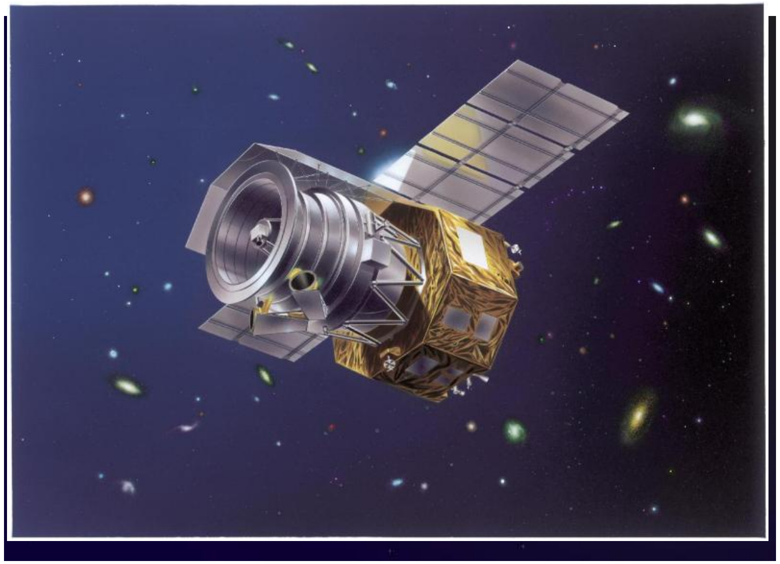


- How did the Universe originate and what is it made of ?
- What are the conditions for stellar and planetary formation ?
- How did the universe evolve chemically ? The emergence of life ?



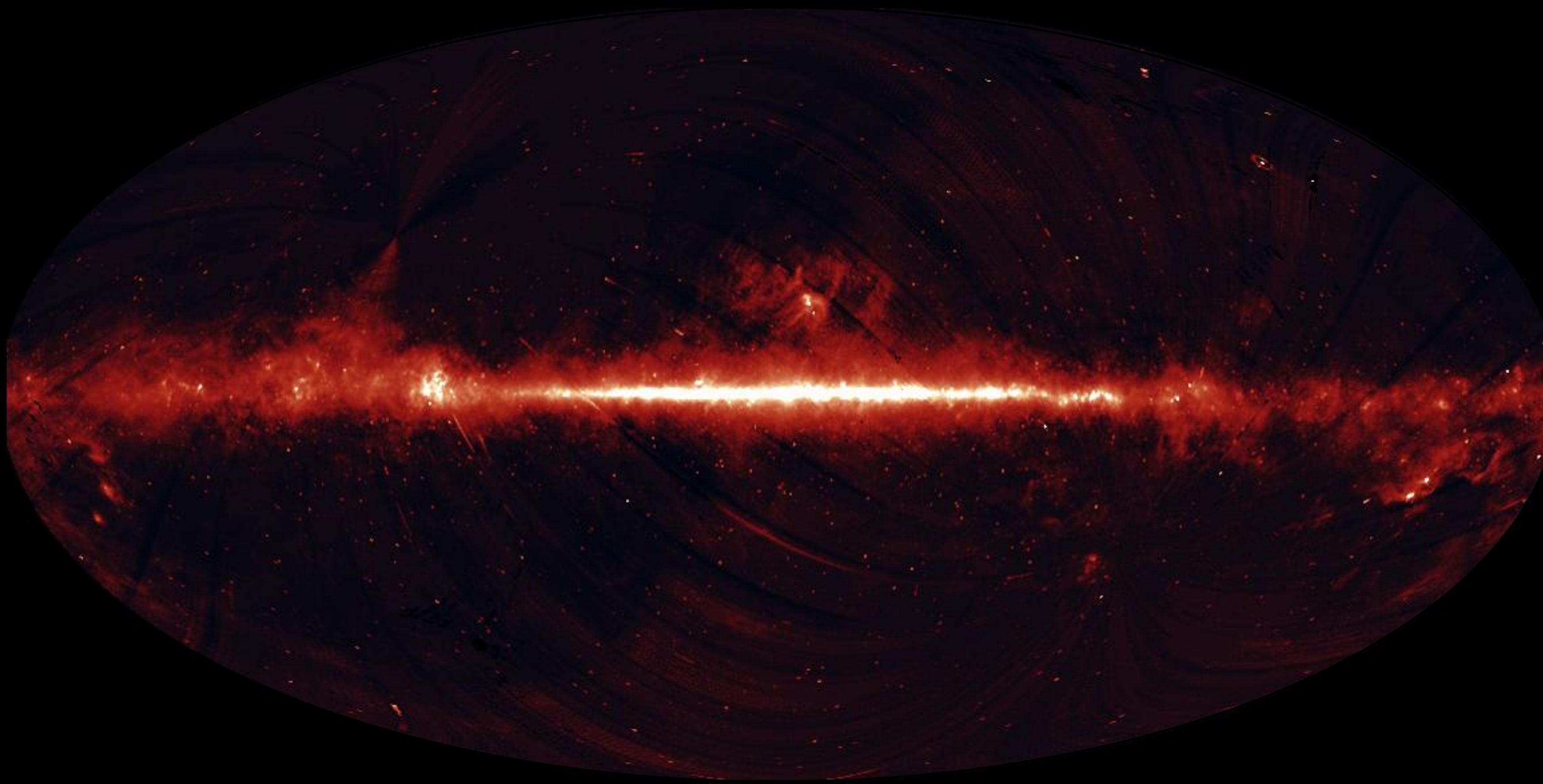


From AKARI to SPICA
(from Survey to observatory)

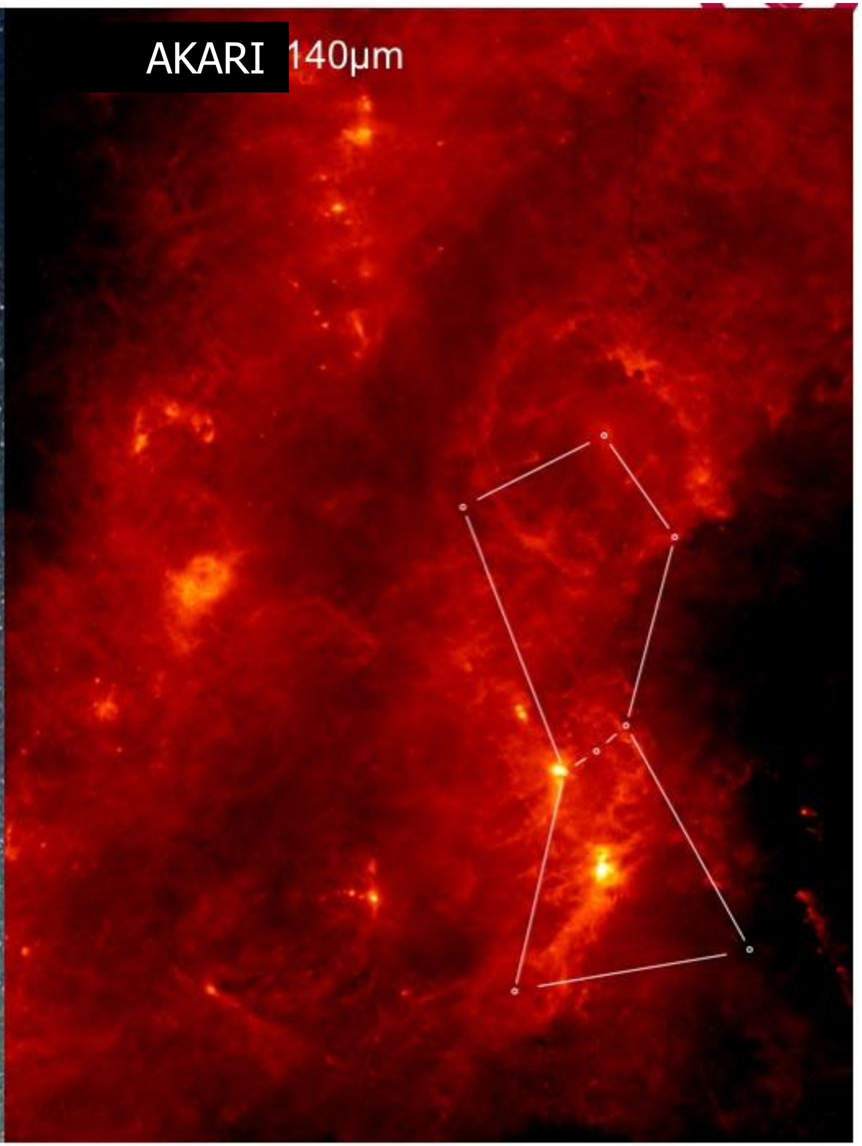


- AKARI
  - JAXA Infrared Astronomy project with the participation of ESA.
  - Launched 2006

All Sky Image at 9μ m by AKARI

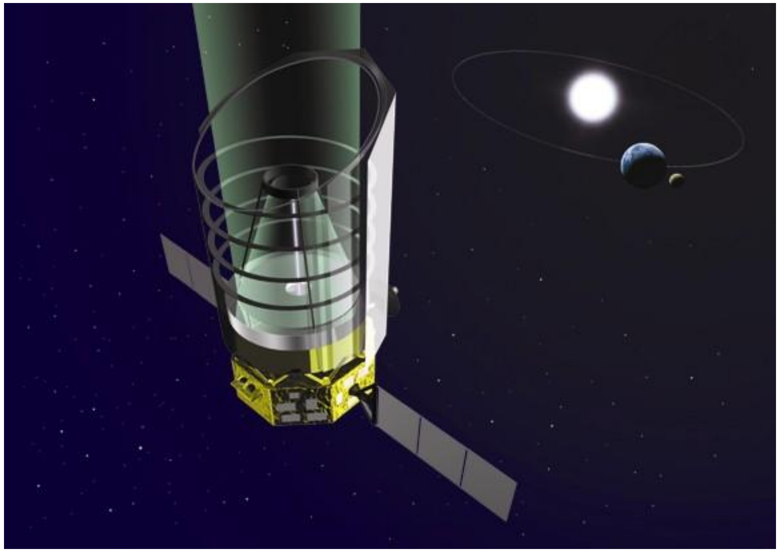


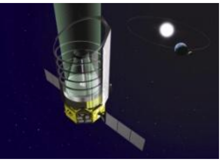
Star-formation in Orion



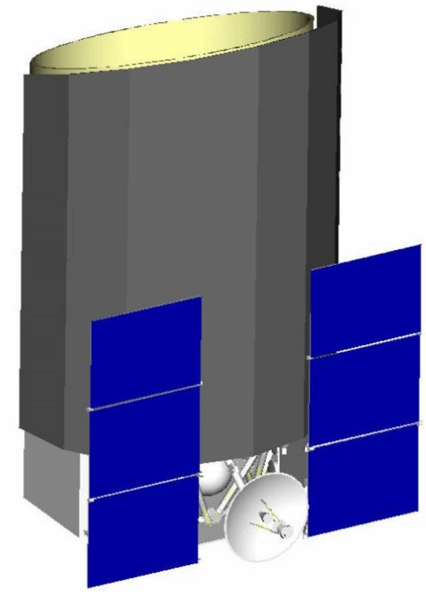
The Next Step: from Survey to Observatory

SPICA

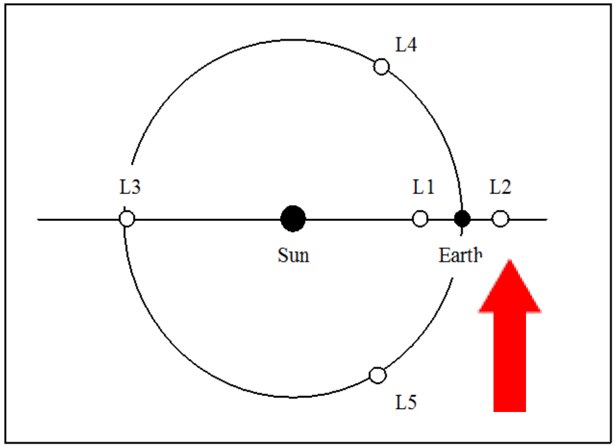


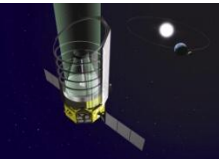


Mission Overview



- Scientic Objectives
  - Revealing the history of cosmic evolution
  - Heritage of previous mission
    - AKARI, SPITZER, ISO, Herschel
- Specficiations
  - Telescope: 3.5m, 5 K
    - Revolving CIB at its energy peak
    - Direct detection of exoplanets
  - Core wavelength: 5-200 μm
    - MIR Instrument
      - Including Coronagraph (Option)
    - Far-Infrared Instrument (SAFARI)
      - BLISS/BASS (Option)
  - Orbit: Sun-Earth L2 Halo
  - Weight: 3 t
  - Launch: mid 2017 (H-IIA)





Cooled Telescopes

D < 1m

↓

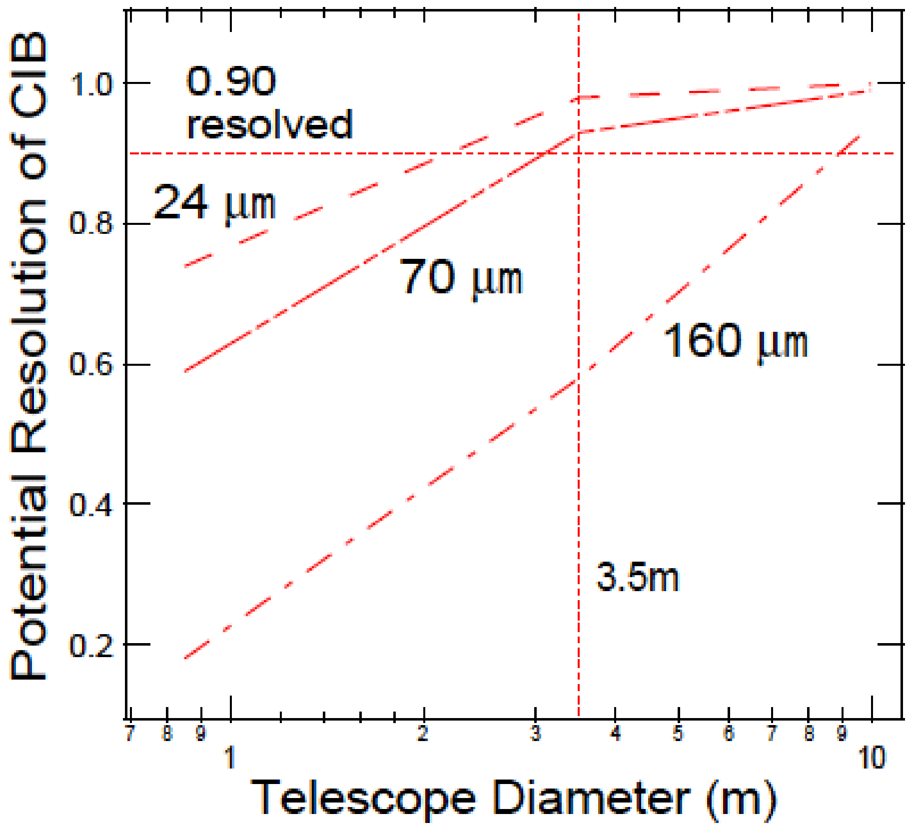
Wanted !
Larger Telescope

ISO
Nov, 1995 Launched
60 cm cooled Tel.
Observatory

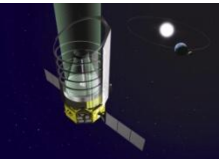
SPITZER
Aug 25, 2003 Launched
85 cm cooled Telescope
Observatory

AKARI
Feb 21, 2006 Launched
70 cm cooled Telescope
All Sky Survey

Scientific Requirements: Large! Telescope

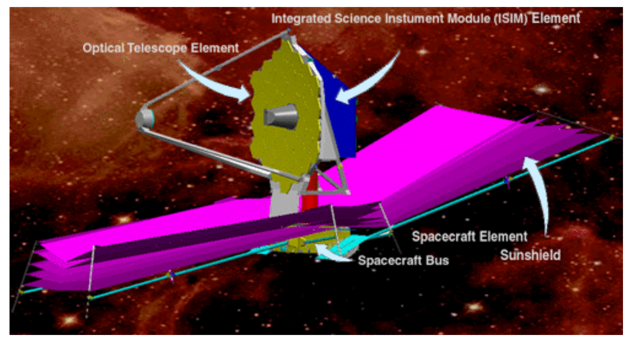


- 3.5m class telescope is required
  - Resolve CIB into individual sources
  - Direct detection of exoplanets



Herschel & JWST

Herschel
2009 Launch
3.5 m, 80 K
FIR-Submm

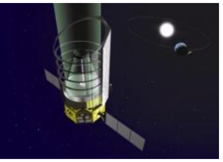


JWST
2013 Launch
6.5 m, < 50 K
NIR-MIR

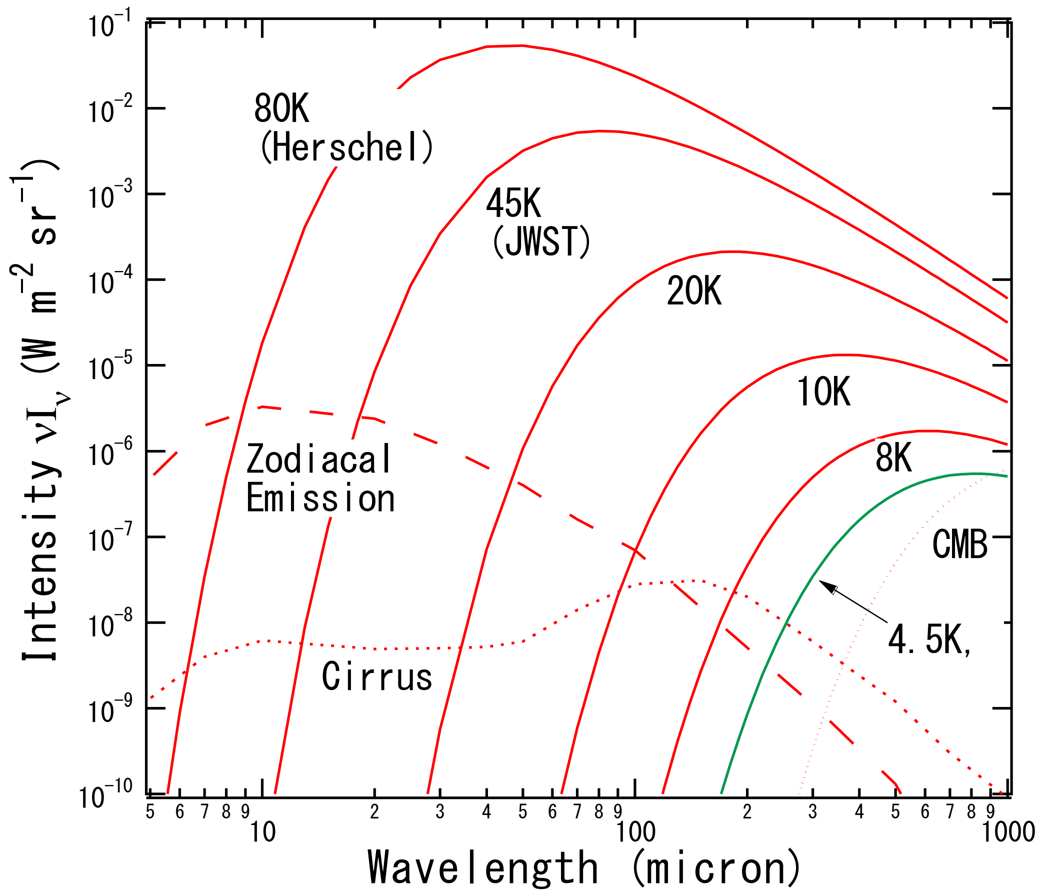
T > 20K

↓

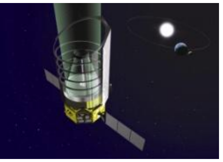
Wanted !
Cooled Telescope



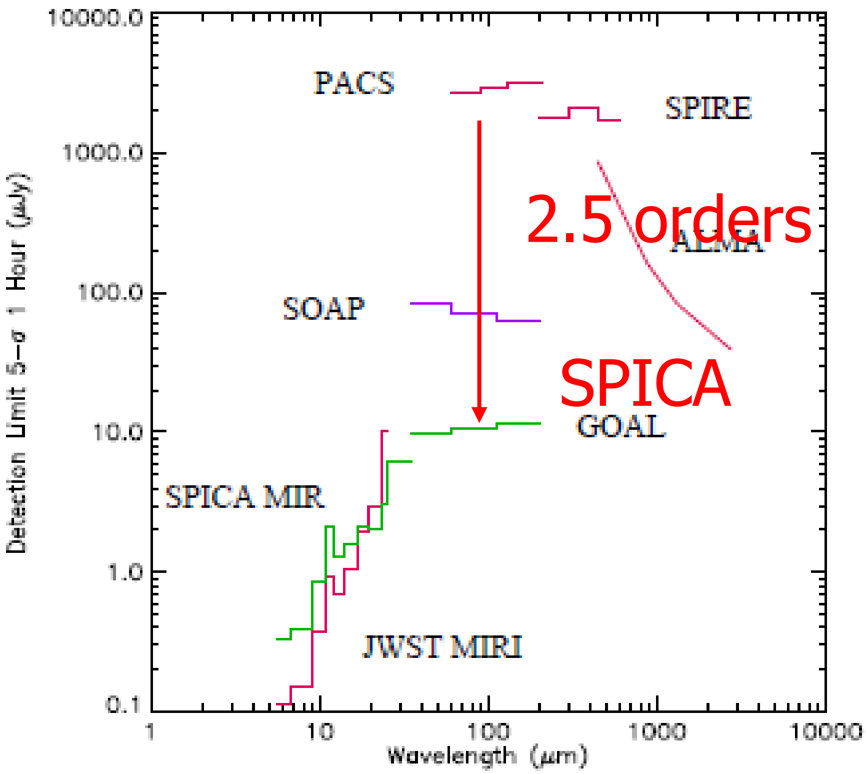
Cool ! Telescope



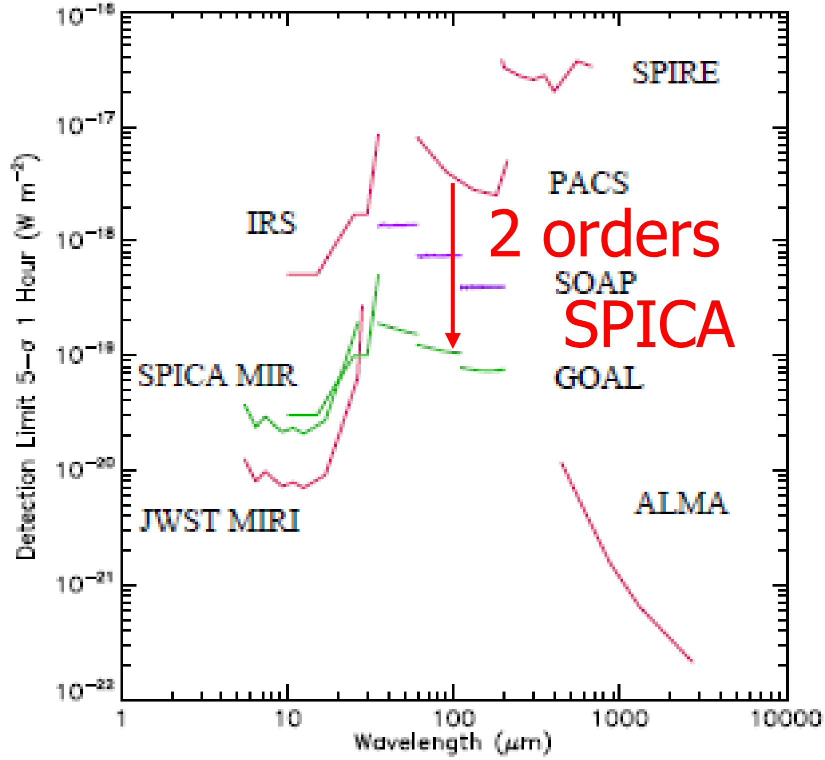
- Telescope Temperature: <5 K required



Huge Gain of Sensitivity !

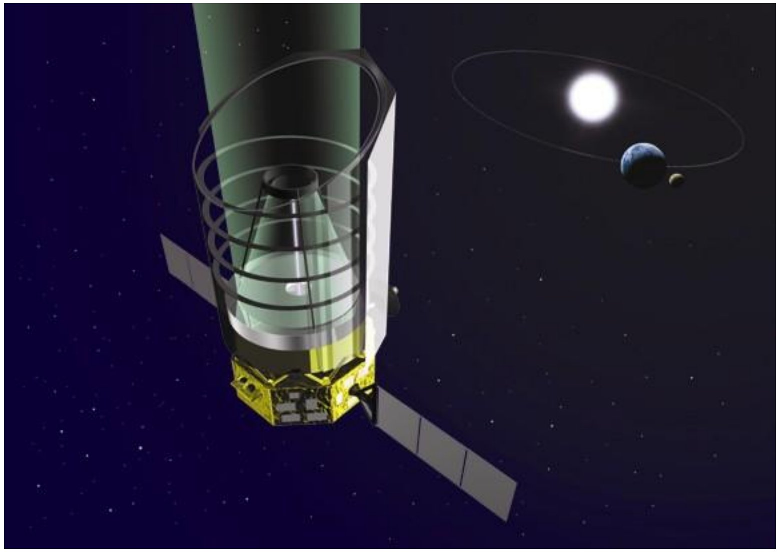


Photometric performance – uJy 5-sig 1 hour

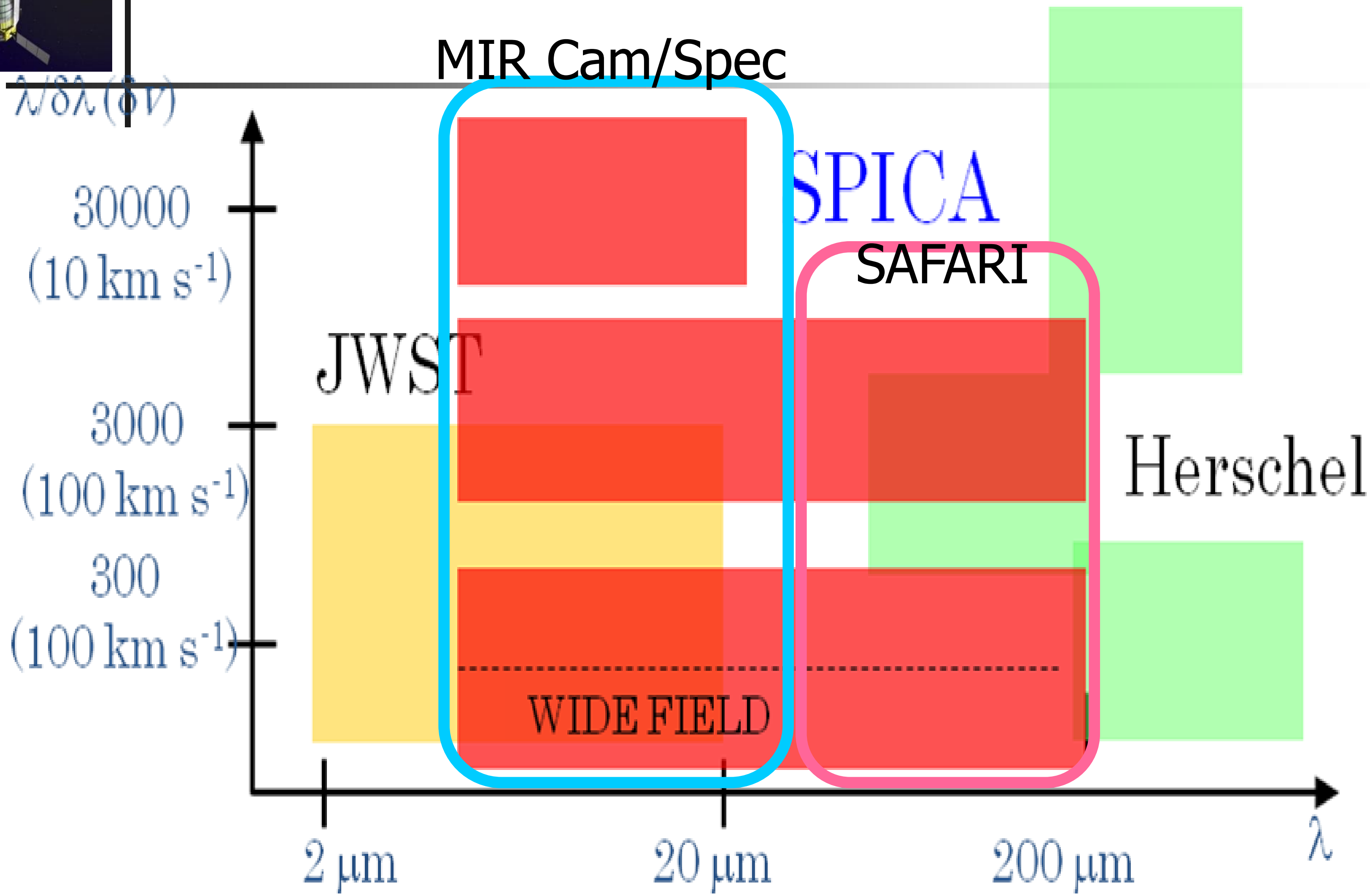


Spectroscopic Performance – W m-2 5-sig 1 hour
ALMA assumes 100 km/s resolution

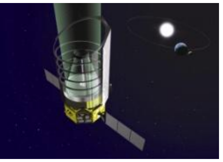
Focal Plane Instruments



SPICA FPI coverage



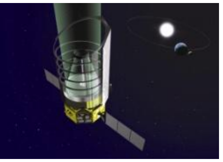
Unique / complementary to other projects



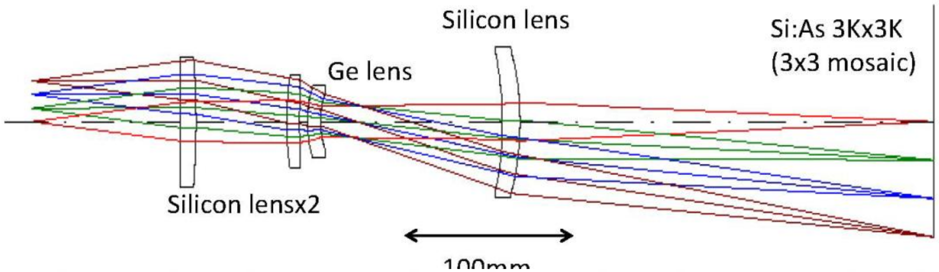
Mid-infrared Camera and Spectrometer

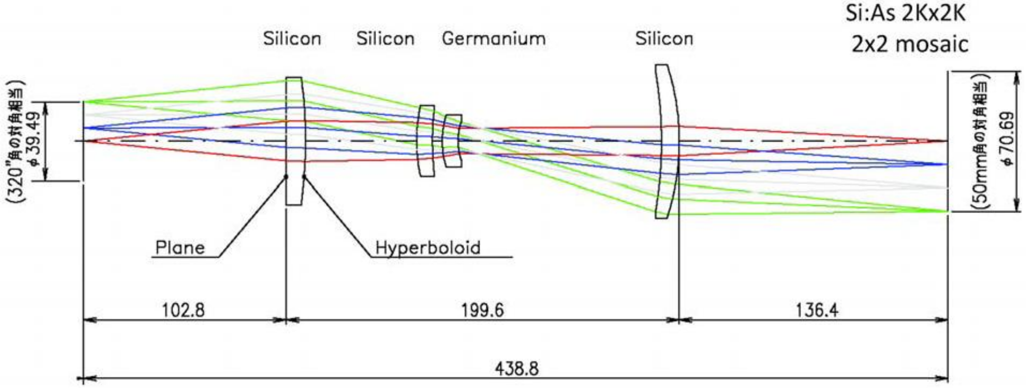
Goal Nominal

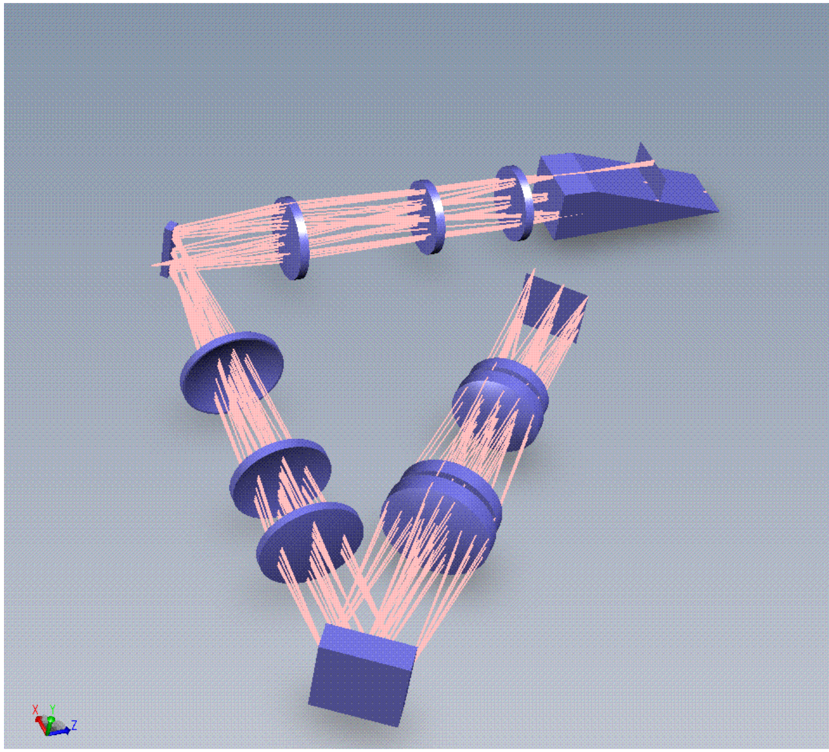
		Wavelength coverage (um)	FOV (arcsec)	Detector	Thermal dissipation
Tip-tilt					4mW
Focal Plane star sensor				InSb	
Wide Field Camera	ch1	5〜9	300x300 (Nominal: 200x200)	Si:As x 9 (Nominal: x4)	15mW (Nominal: 7mW)
	ch3	14〜27	(Nominal: 280x280)	Si:As x 1	
	ch2	8〜15	400x400 (Nominal: 160x160)	Si:As x 4 (Nominal: x1)	
	ch4	20〜38	(Nominal: 200x200)	Si:Sb x 1	
High dispersion spectrometer	Short	4〜8	10x5	Si:As x 1	2mW
	Long	12〜18	10x5	Si:As x 1	
Long wavelength spectrometer	Short	16〜25	20x10	Si:As x 1	2mW
	Long	24〜38	20x10	Si:Sb x 1	
Coronagraph	Short	3〜5	25x25	InSb x 1	2mW
	Long	5〜20		Si:As x 1	



MIR Instrument (Japan/Korea)

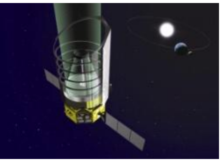




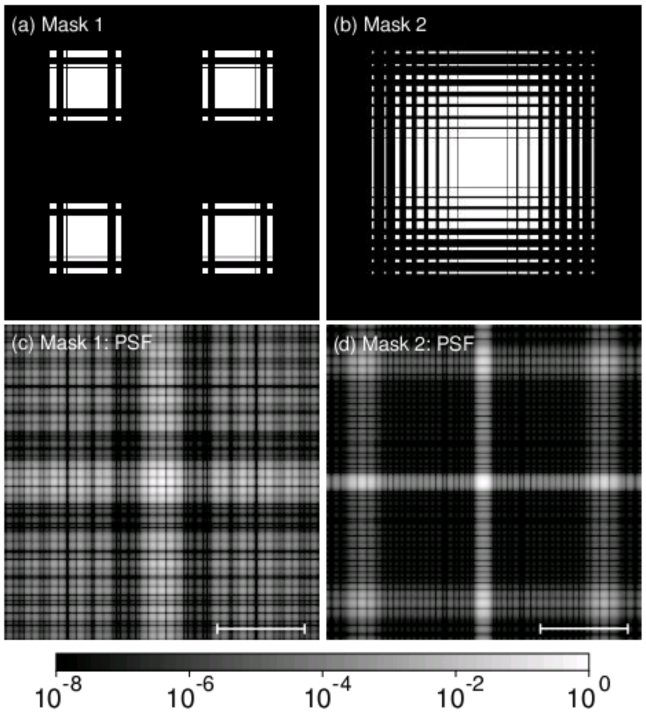


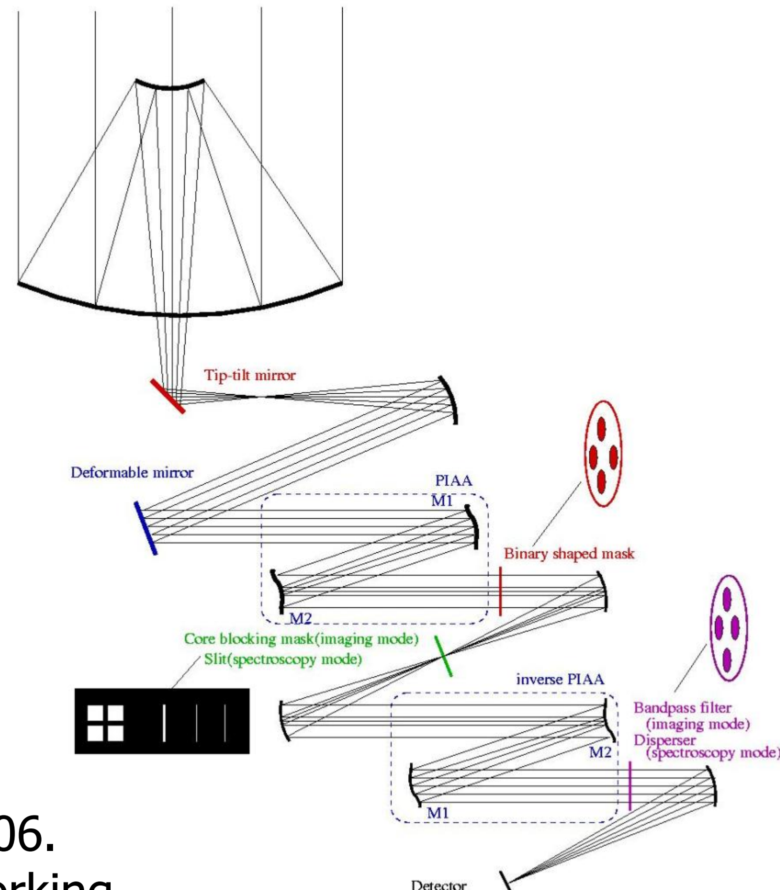
- Imaging and R~200 grism spectroscopy w/ 180-280 arc second field of view.
- Long-slit R=1000-3000 spectroscopy at 16-38 μm
- R=30,000 spectroscopy at 4-18 μm.

- MIR High-Resolution Spectrometer
  - Immersion Grating



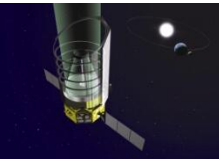
MIR Coronagraph





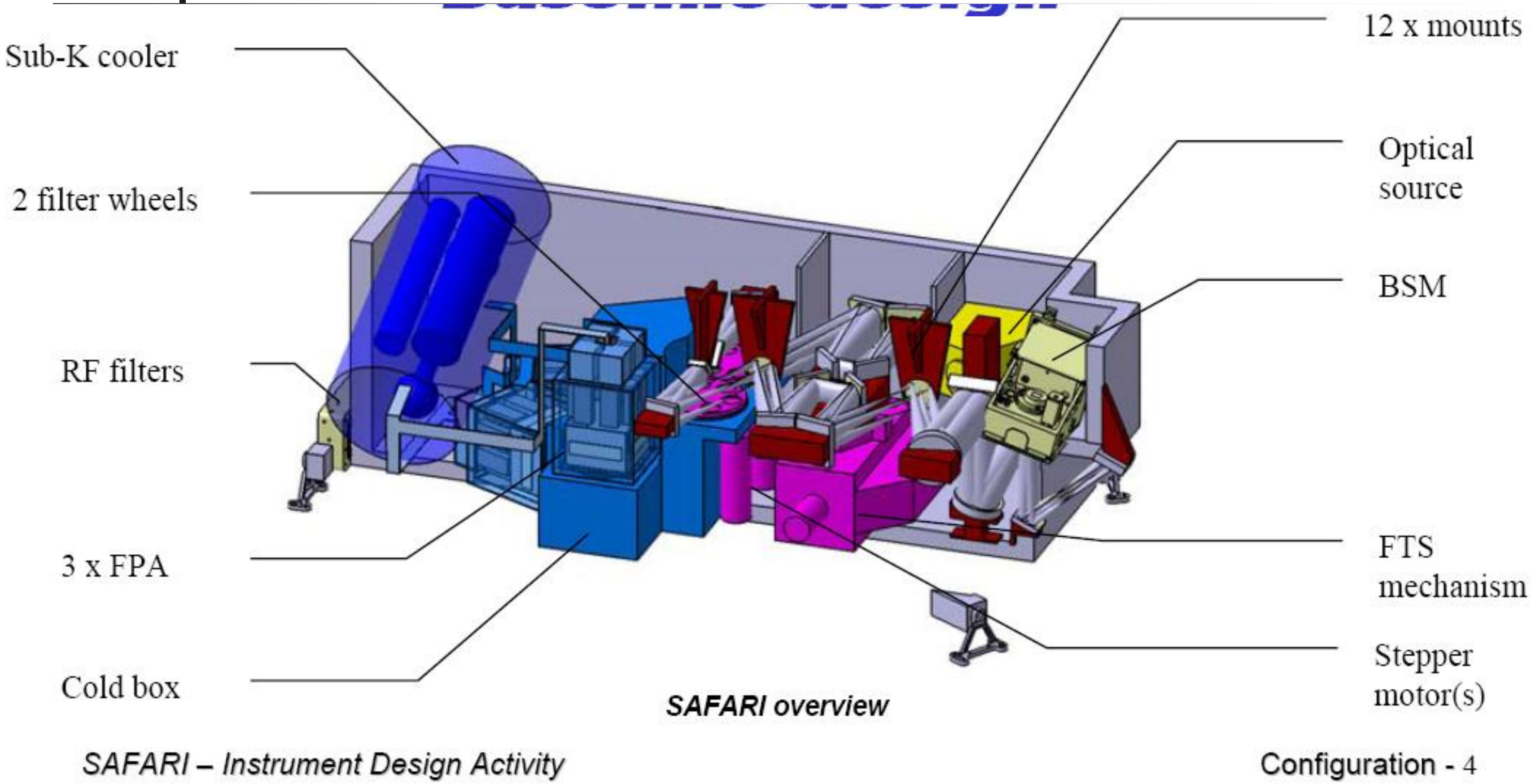
Mid-IR Coronagraph (Japan)

- 5-27 μm core range with contrast > 106.
- Inner working angle 2-5 λ/D, outer working angle 10-30 λ/D.



SAFARI

(SPICA Far-Infrared Instrument)



- baselined as 30-210 μm imaging Fouriertransform spectrometer (IFTS), 2 x 2 arcmin FOV with R variable from 10 to a few 1000.
- Detectors TBD; Ge photoconductors or (NTD or TES) bolometers.

Possible US Contributions

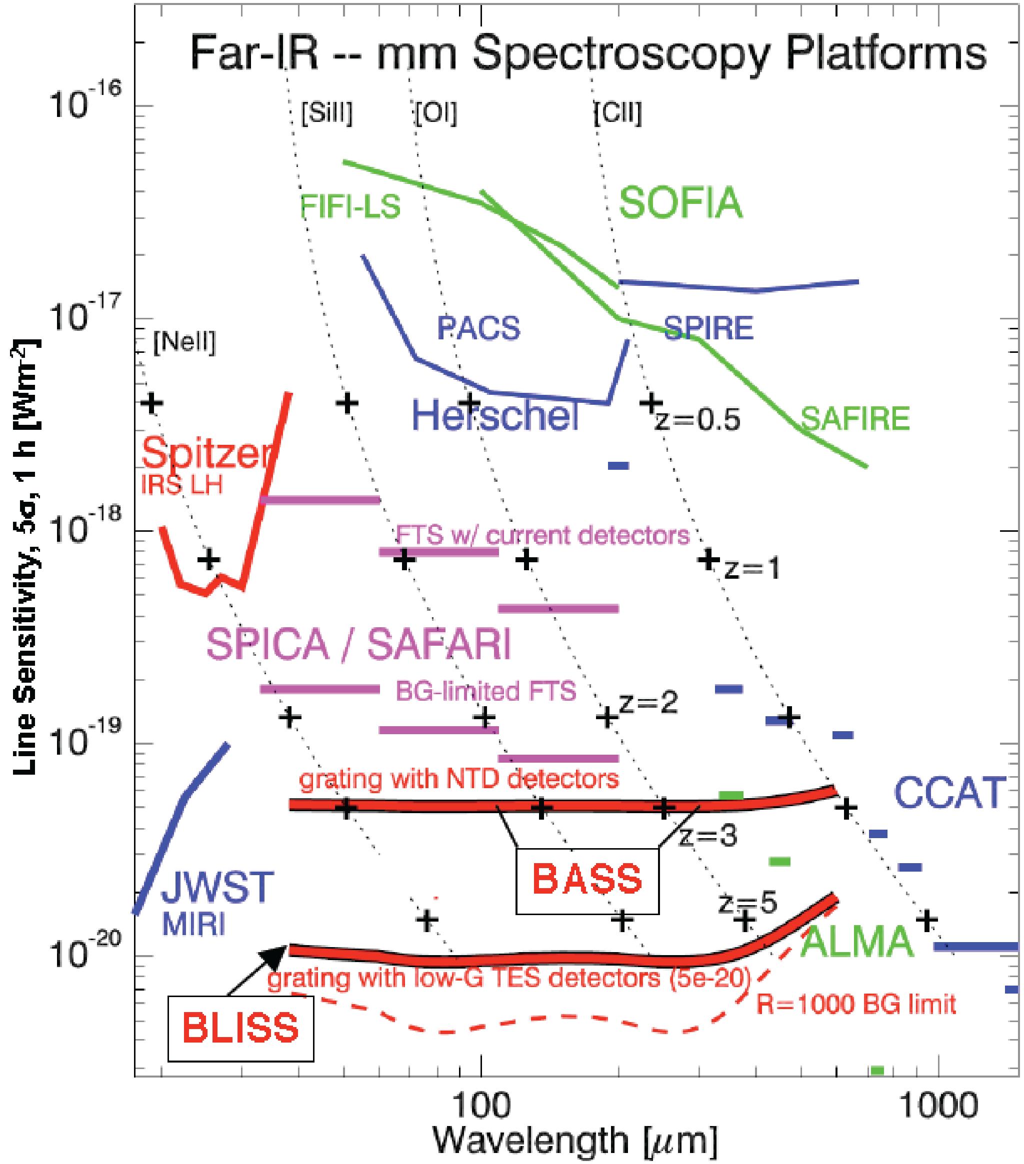
Huge advances are possible in the far-infrared with a cold telescope

- Ultimate sensitivity limitation is the astrophysical backgrounds with ~1000-10,000 times lower noise.
- **Spectroscopy of sources in the early universe (z~1-5) is possible with a cryogenic space telescope and sensitive instrumentation.**
- But reaching the background limit requires new detectors with NEP approaching 4×10^{-20} W Hz$^{-1/2}$ for a R~1000 grating.

Cryogenic Bolometers in the US

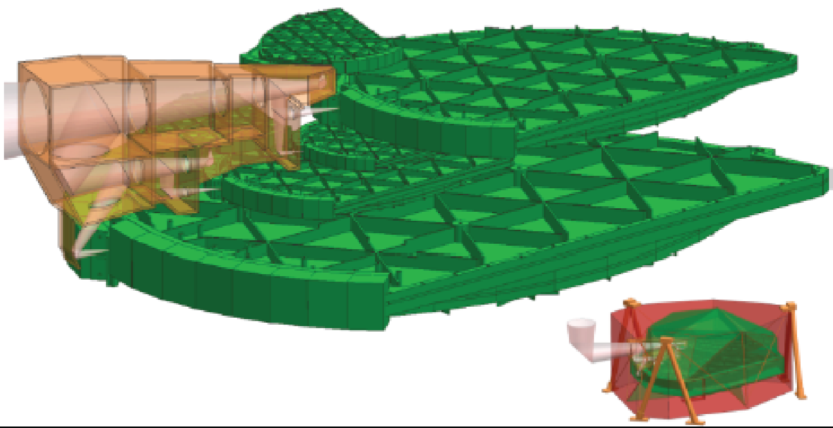
Semi-conducting neutron-transmutation-doped (NTD) bolometers with JFET readouts developed for SPIRE, Planck (Bock et al.)
- Very well-behaved, excellent quantum efficiency, built for flight,
- But individually read-out -> formats limited to 1-2 x 1000 detectors
- And NTD bolometer sensitivity is limited to ~3e-19 W Hz$^{-1/2}$ due to heat capacity

- **Superconducting bolometers (TES) can overcome format and sensitivity limitations**: have superconducting MUX, and greater response speed allows sensitivity in low 10^{-20} W Hz$^{-1/2}$ range (still requires some demonstration).

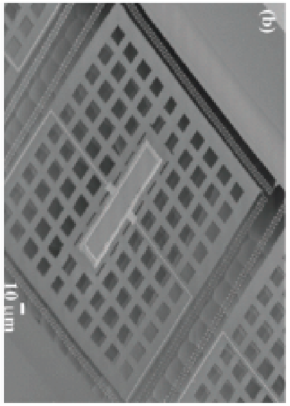


A Broad-band Spectrograph: Two approaches

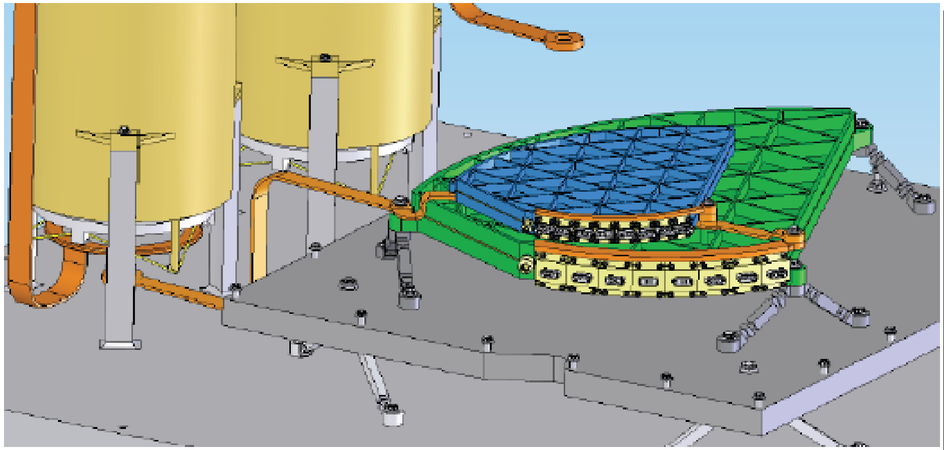
BLISS Background-Limited Infrared-Submillimeter Spectrograph -> *goal instrument*



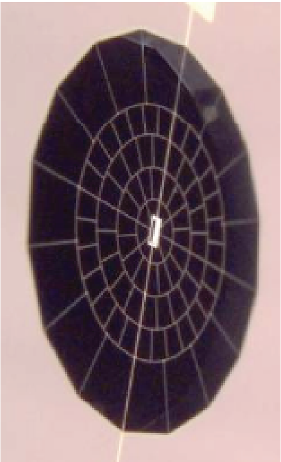
- full 38-430 μm coverage in 5 bands at R=700
- 4200 superconducting bolometers with sensitivity approaching the background limit.
- cooled to 50 mK with magnetic refrigerator
- two beam on the sky, modulated by cold chopper

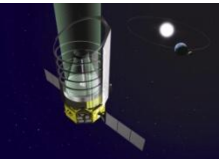


BASS Bolometer Array Survey Spectrograph -> *very low risk, proposed to SMEX MoO call*



- full 132-320 μm coverage in 2 bands at R=300
- 320 semiconducting bolometers based on technology developed for Herschel and Planck, ready to build now.
- cooled to 50 mK with magnetic refrigerator
- two beam on the sky, modulated by cold chopper

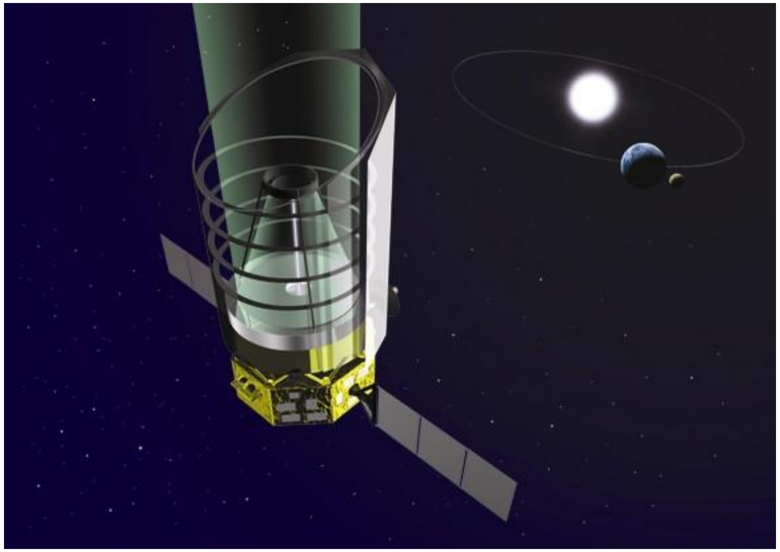


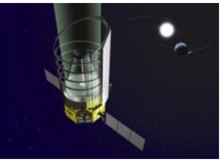


Resources for Focal Plane Instruments

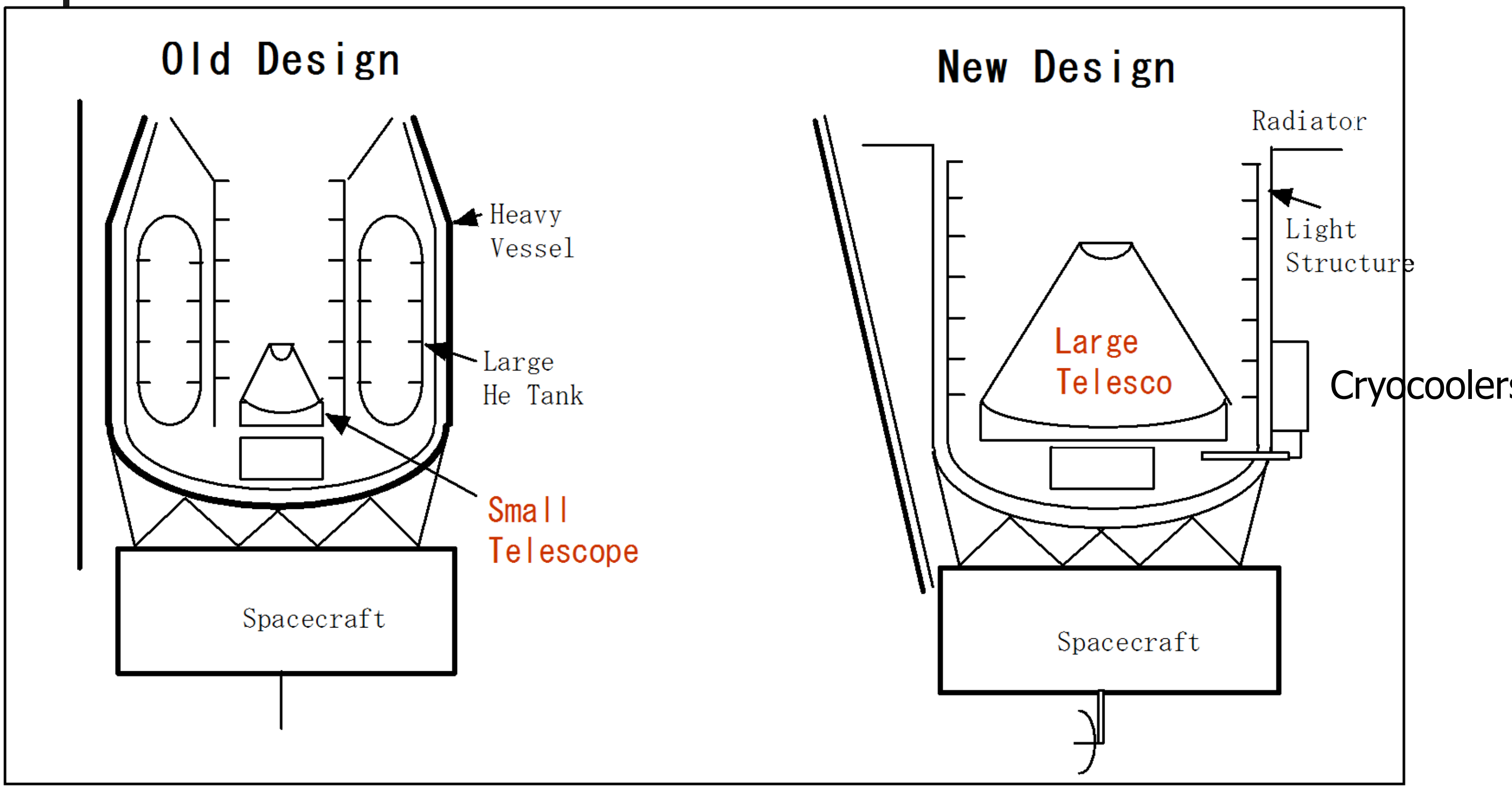
- Volume : Cylindrical, 2.5m diameter x 0.5m height
- Weight : 200 kg (cold mass : 100kg including 20% margin)
- Thermal :
  - 15mW @ 4.5K stage
  - 5mW @ 1.7K stage
- Electrical Power : 200W
- Data : Generation < 4Mbps / Recorder < 60GB/day
- Attitude Control
  - Absolute pointing accuracy : 30 arcsec (3σ)
  - Pointing Stability : 0.5 arcsec/minute

Make it Feasible !





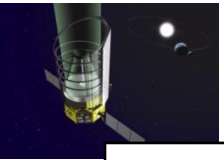
Revolution of Design Philosophy



No Cryogen → Large Telescope

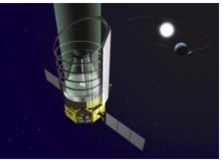
ISO: 2.6t for 60cm → SPICA 3t for 3.5m

Cryocoolers for SPICA

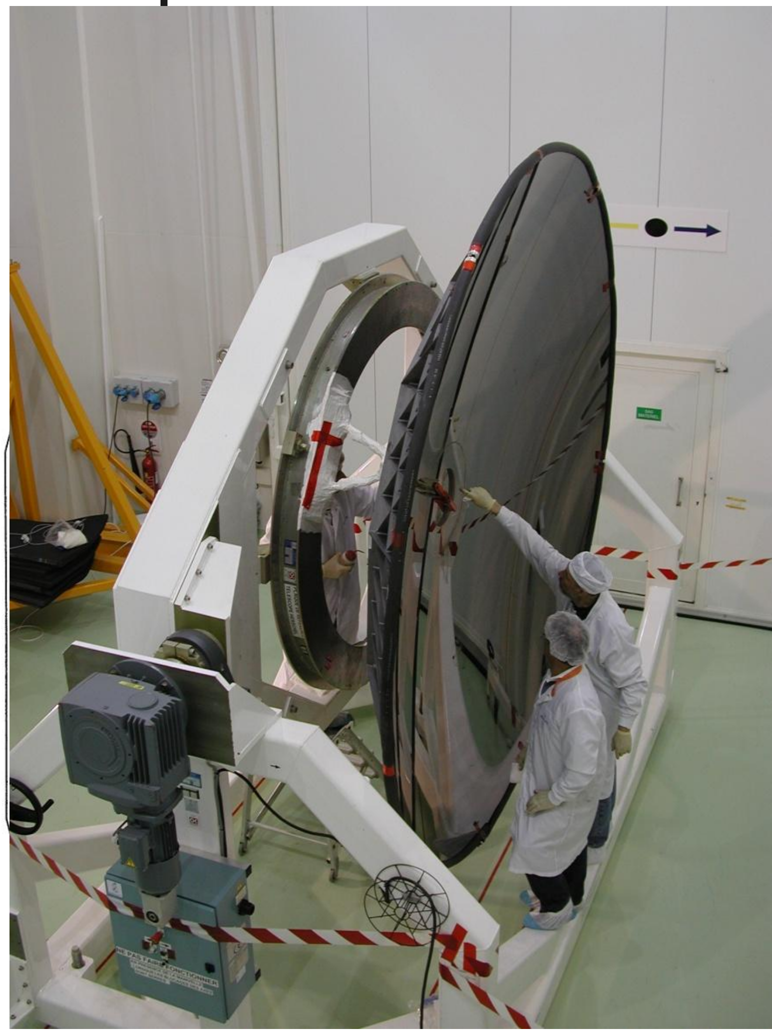


Cooler type	20 K class	4 K class	1 K class
Cooling object	Precooling for JT	Primary mirror & Optical bench	Far-IR detector
Configuration	**2-stage Stirling**	**2ST + ^{4}He-JT**	**2ST + ^{3}He-JT**
Minimum cooling requirement	200mW@20K	30mW@4.5K (x 2 sets)	10mW@1.7K
Demonstrated Cooling Power	325mW@20K	50mW@4.5K	16mW@1.7K
Driving power	< 90 W	< 160 W (x 2 sets)	< 180W
Service life	> 5 years	> 5 years	> 5 years
R&D level	**AKARI** (2006) Under improvement	**ISS/SMILES** (2009) Under Improvement	**SRG**(2012), **NeXT**(2013) Under development

- Most of the coolers will be flight-proven very soon.

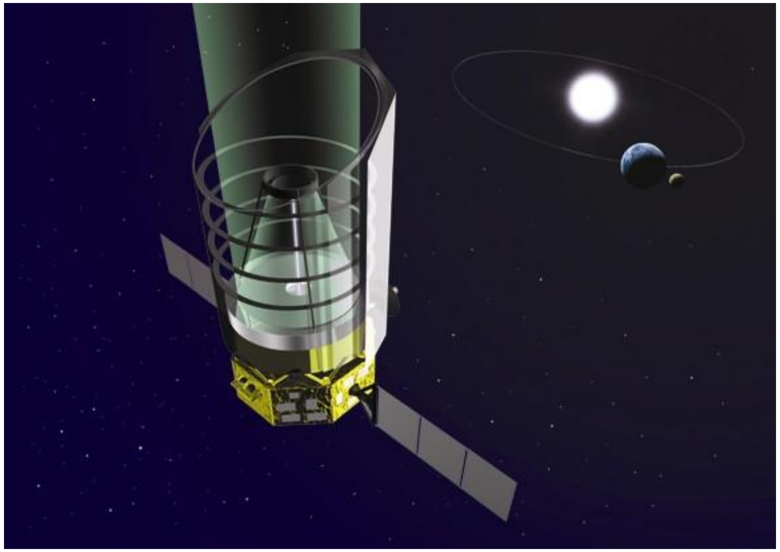


Monolithic mirror

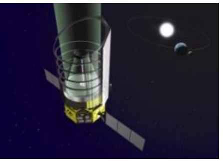


- 3.5m is technically a good choice
  - Monolithic Mirror
  - No deployable mechanism
    - Simple, Feasible, Reliable
  - Smooth PSF
    - Essential for Coronagraph
  - Herschel Heritage
    - WFE 6μm → 0.35μm
    - 80K → 5K

Roadmap to SPICA



Roadmap for Space Astronomy

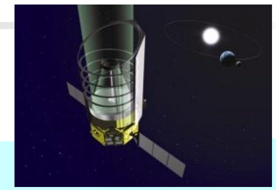


2005 2010 2015

IR

IRTS/SFU (1995)

Akari (2006-)



SPICA

JTPF

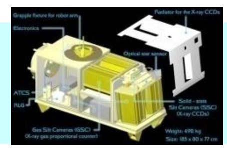
JASMINE

Evolution of the Universe

X-ray

Asca (-2000)

Suzaku, (2005-)



M A X I

NeXT

XEUS

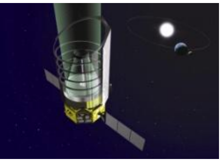
Physics in Extreme Environments

Radio

Halca (1996 -2005)
Space VLBI

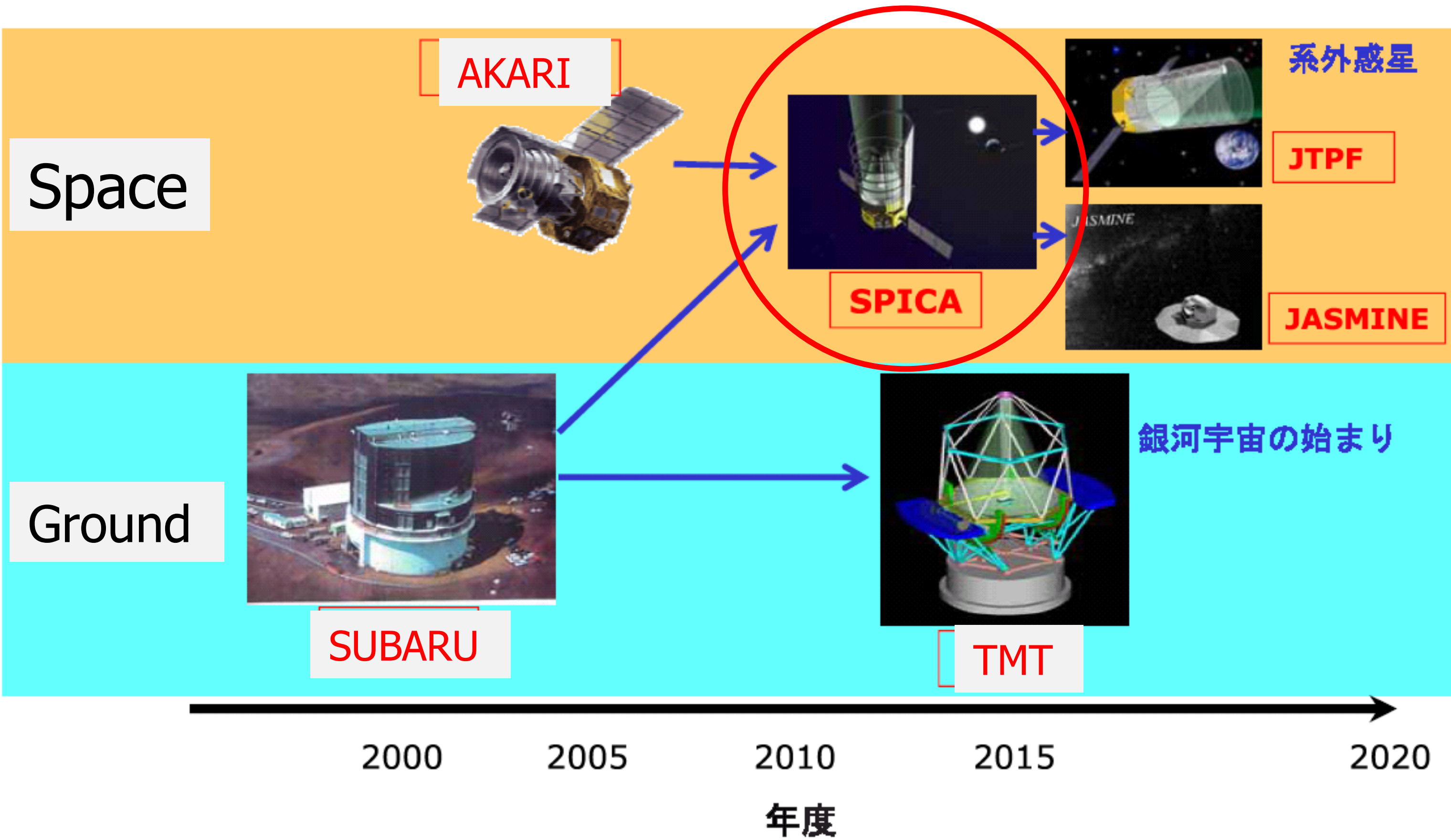
Astro-G

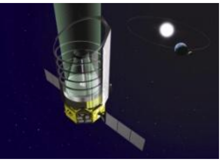
(white box)	**Launched**	(green box)	**Approved**	(red box)	**Pre-Project**	(yellow box)	**WG**



Roadmap of Opt/IR Astronomy in Japan

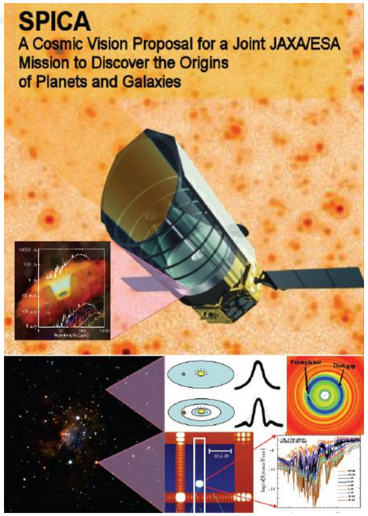
- SPICA is regarded as a key mission



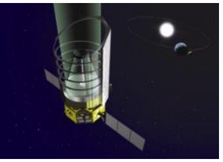


SPICA as an International Mission

- JAXA
  - Integration & Test
  - Spacecraft
  - Launch
  - Mission Cryogenics
  - MIR Instrument
- ESA
  - Telescope (Herschel Heritage)
  - (Part of) Ground Segments
  - (Part of) User Support
- European Consortium
  - Far-Infrared Instrument (SAFARI)
- USA (sub-mm instrument) under discussion
- Korea (MIR instrument) under discussion



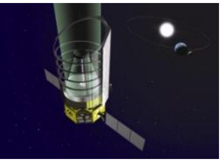
ESA Cosmic Vision Proposal
(P.I. Swinyard, RAL, UK)
accepted



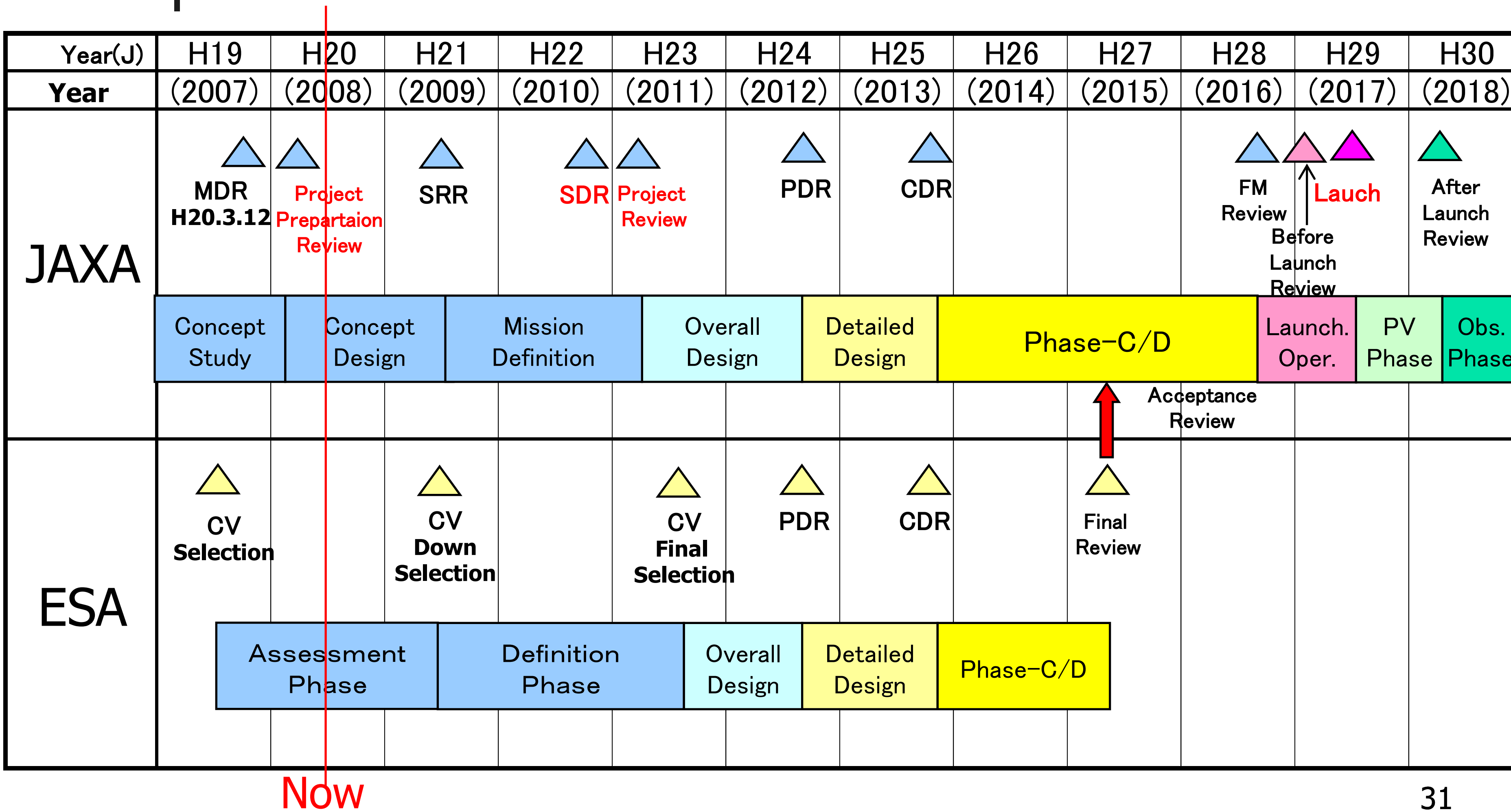
Current Status of SPICA

- Japan
  - Mission Definition Review passed (Mar 08)
  - Project Preparation Review passed (May 08)
  - JAXA pre-project (Phase-A) team started in July 08
- Europe
  - ESA Cosmic Vision proposal accepted (Oct 07)
  - ESA Internal Study (Nov 07- May 08)
  - ESA Industrial Study (- Sep 09)
- USA
  - Consortium Meeting (May 08)
- Korea
  - Korea-Japan meeting (July 08)

Phase-A work started officially both in Japan and Europe.



Schedule



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Overall
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SPICA
Space Odyssey in 2017