SPICA mission

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On Behalf of the SPICA Team

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AKARI Far-IR all-sky map

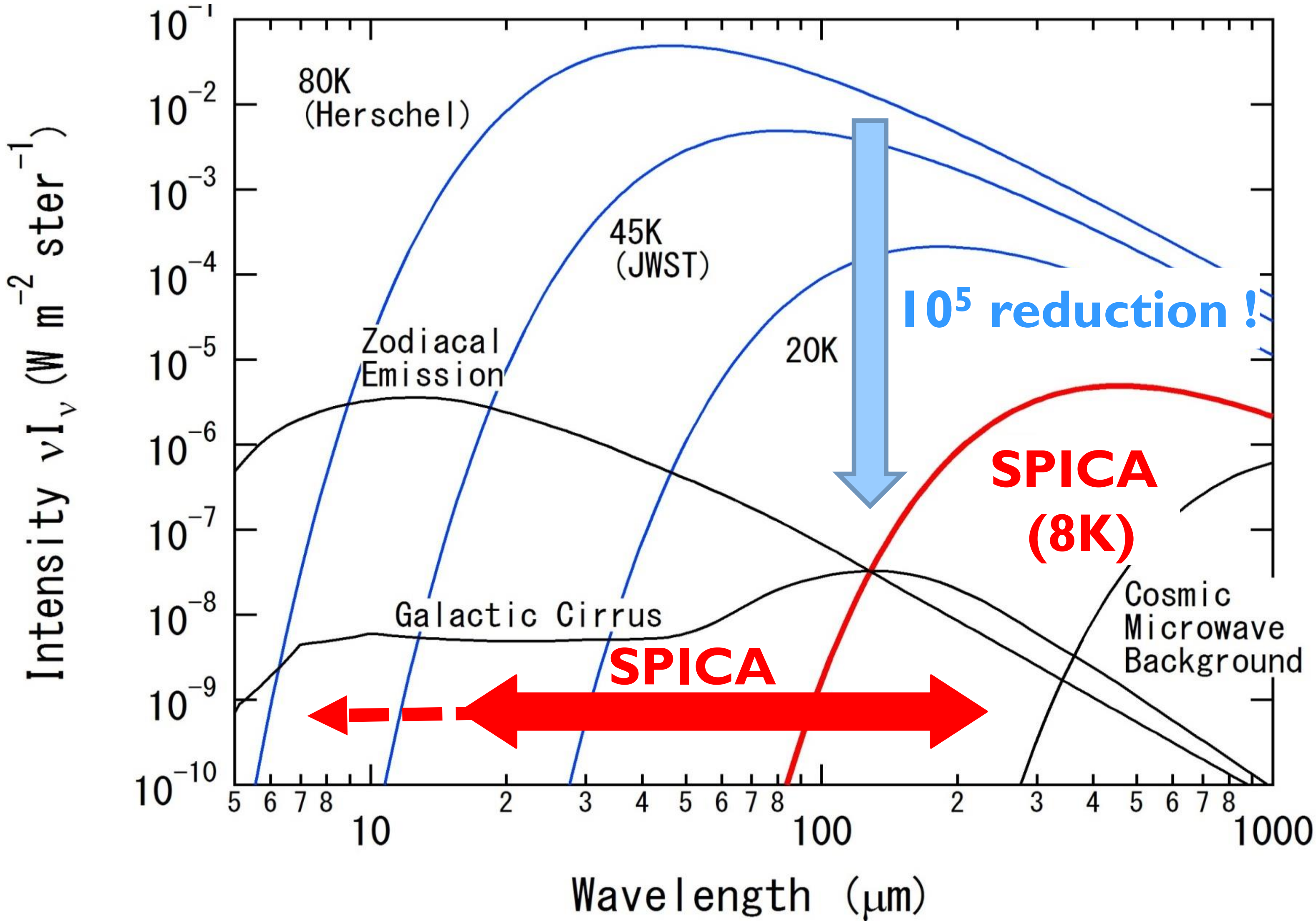
SPICA – Space Infrared Telescope for Cosmology and Astrophysics

- SPICA is a space mission optimized for mid- and far-IR astronomy.
- SPICA unveils the "dusty era" in the Universe (evolution of galaxies), and finds a route to habitable planets (formation of planetary systems).
- SPICA is launched at ambient temperature, and cooled down in space. (The cryo-cooler system is a key heritage of JAXA from IRTS and AKARI.)
- Japanese SMI is a mid-IR spectrometer covering 17–37 μm.
- European SAFARI is a far-IR spectrometer covering 34–230 μm.
- SPICA is a joint mission of JAXA and ESA with other international partners.
- SPICA is now in its re-definition phase in JAXA, and will go to the open competition as an M-class mission of the ESA Cosmic Vision program.

- Baseline specifications
  - Telescope : 2.5 m aperture, cooled below 8 K
  - Core wavelength : 17–230 μm
    (+ High-resolution spectrometer at 12–18 μm, Exoplanet instrument at 5–20 μm)
  - Orbit : S-E L2 Halo Orbit
  - Launcher : JAXA H3 Vehicle
  - Launch Year : 2027–2028

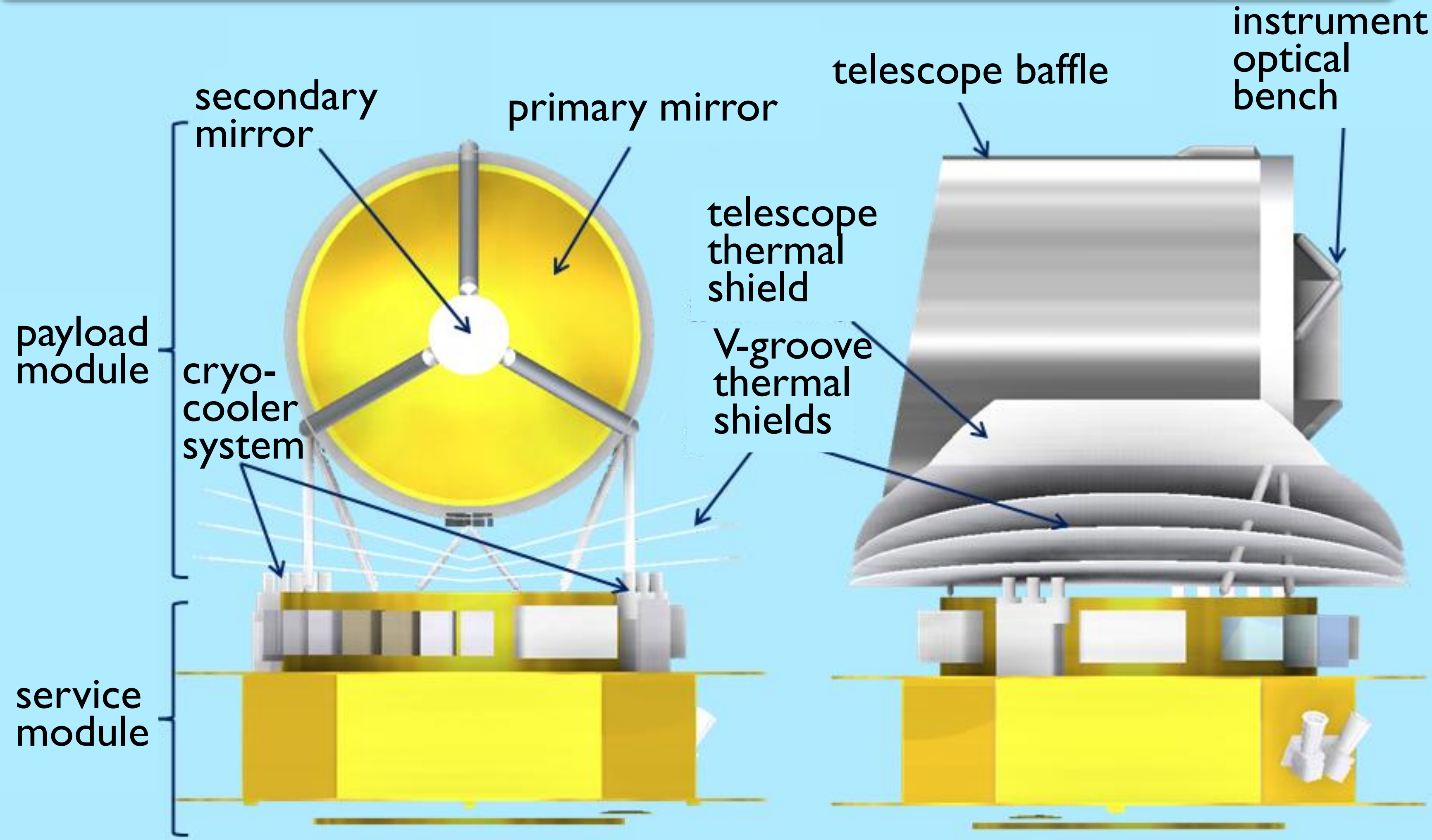
Importance of a cryogenically-cooled IR telescope

A cryogenically-cooled telescope significantly reduces the thermal emission from the telescope.



Baseline Design

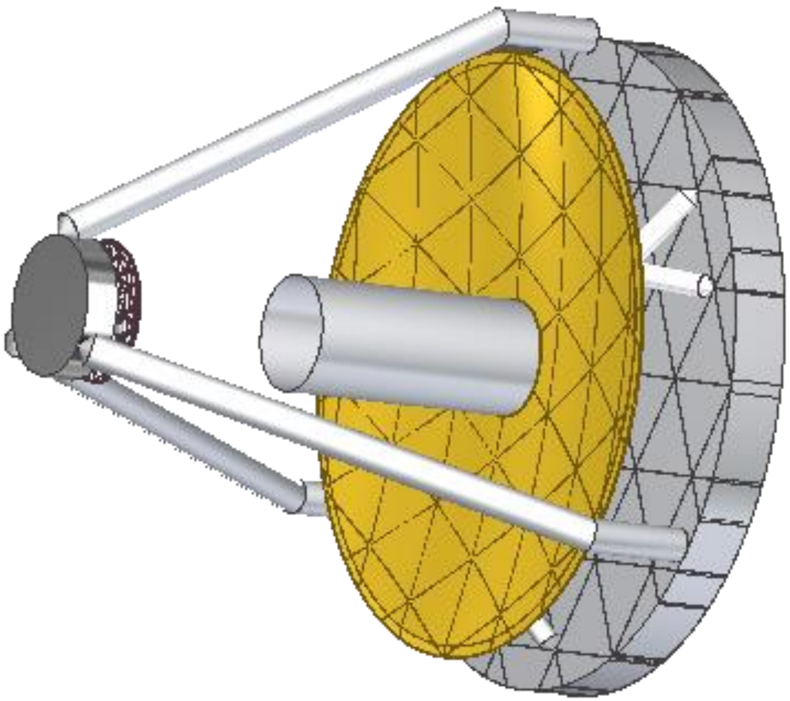
Planck-type PLM with a 2.5 m, 8 K telescope (JAXA follow-up study)



Front view   Side view

Telescope

- Optical design
  - The 2.5 mϕ optical design is scaled from the 2.0 mϕ CDF study.
- Optical specifications
  - Telescope type : Ritchey–Chrétien
  - Entrance Pupil Diameter : 2.5 m
  - Field of View : 30 arcmin
  - Wave Front Error : <1.4 μm rms
  - Diffraction limited at 20 μm
- Temperature
  - Launch: Room temperature
  - Operation: < 8 K
- Fabrication
  - ESA is in charge of the procurement of the telescope.
- Technical Heritage
  - The mirrors are based on the AKARI and Herschel heritage (SiC mirrors).



Work-sharing plan

Telescope

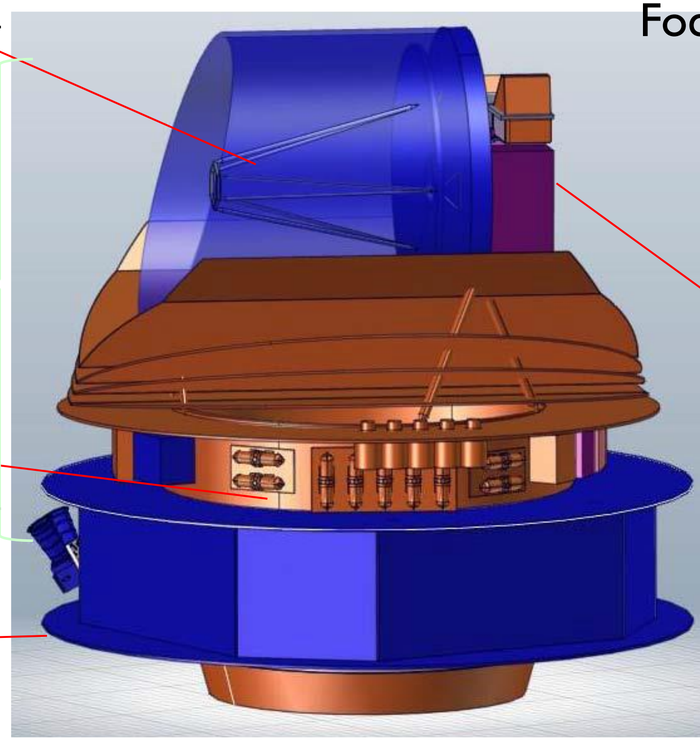
Payload Module

Cryocooler

Bus Module

Launcher

SPICA Data Center
(NAOJ)



Focal Plane Attitude Sensor

Focal Plane Instrument Assembly

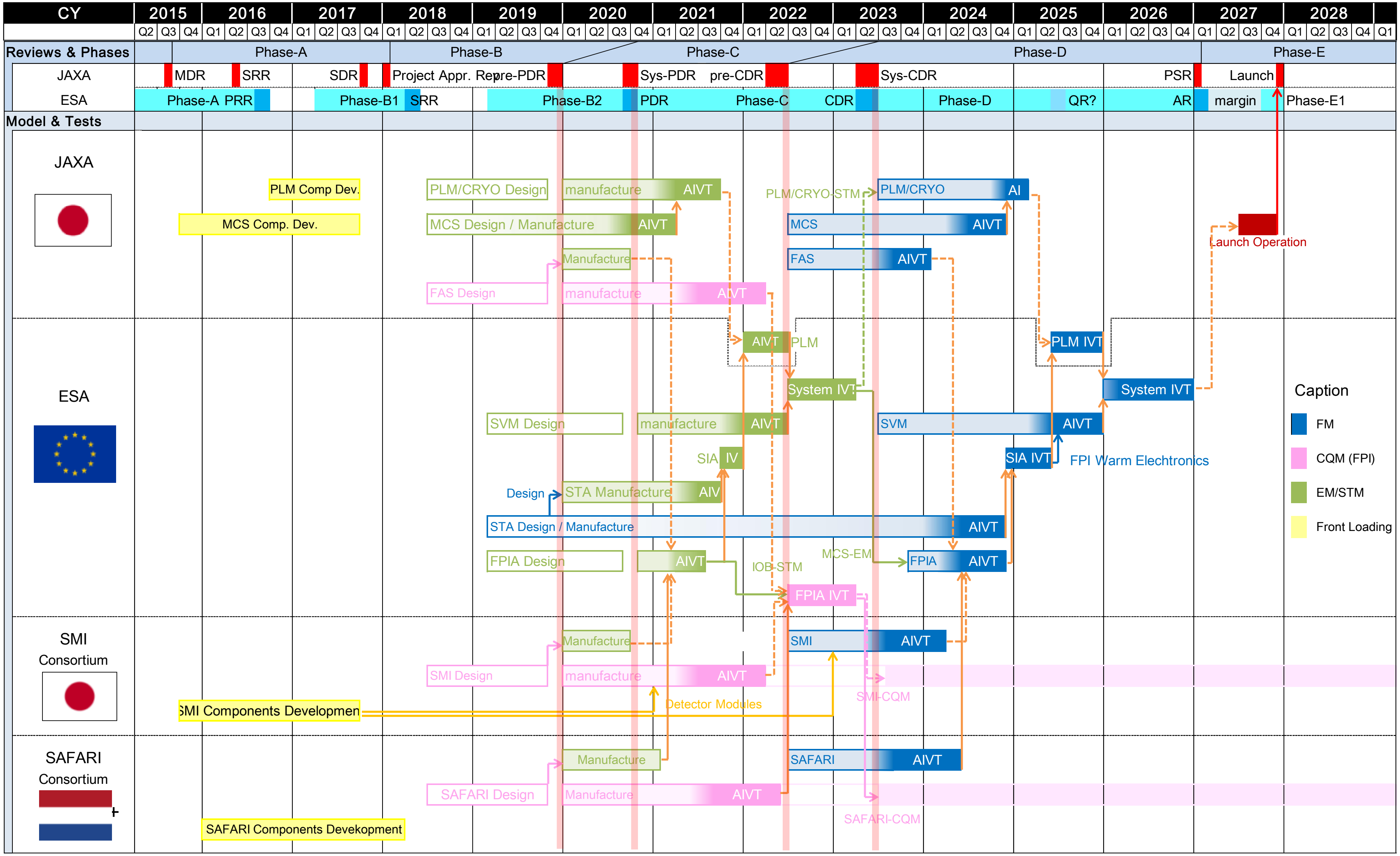
FIR Spectrometer
(SAFARI)
NL + European countries
+ Canada & US

MIR Instrument (SMI)

Exoplanet Spectroscopy
(SPEChO)
European countries

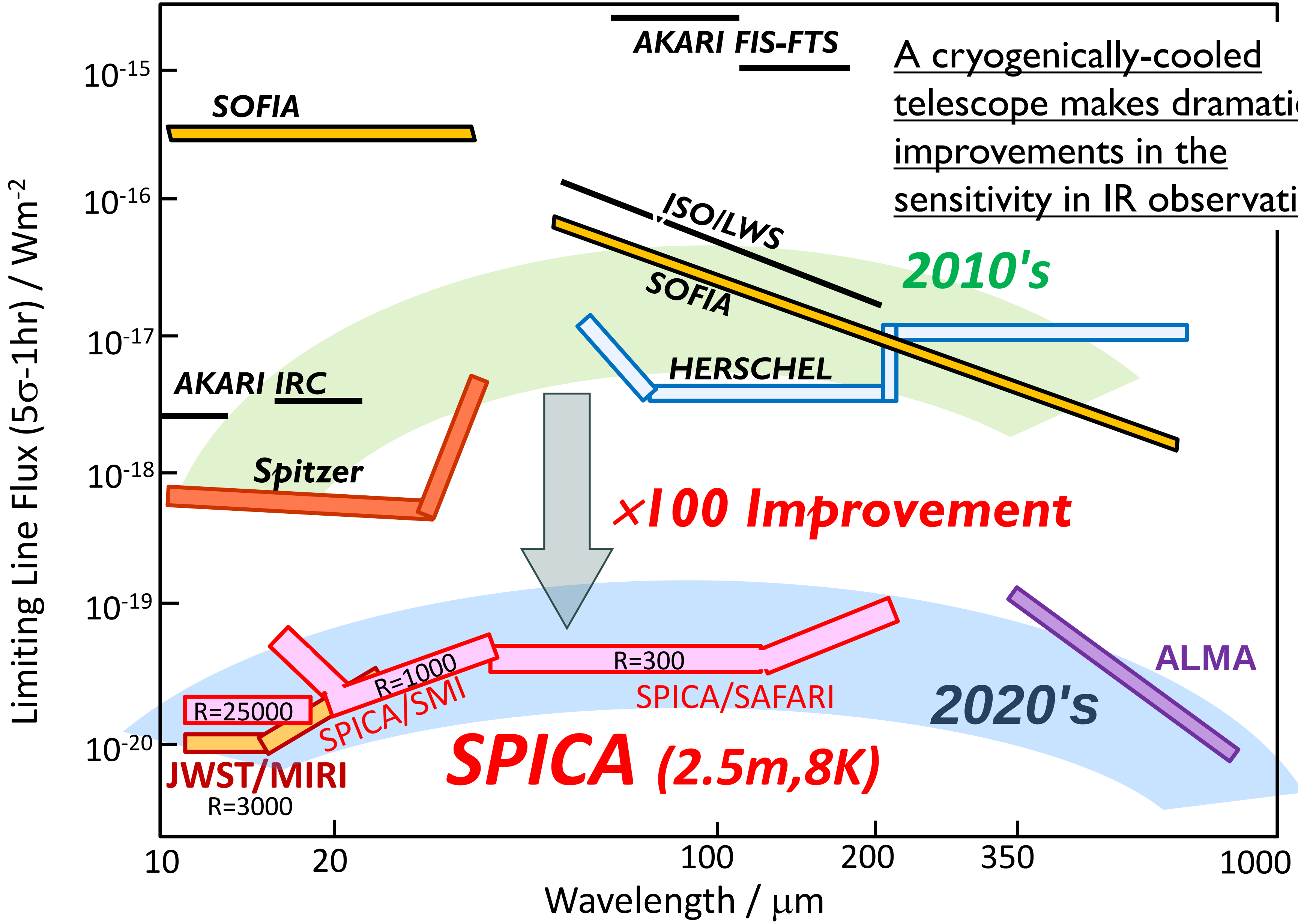
Science Community
JP, Europe, US, KR, TW,,,

Project schedule



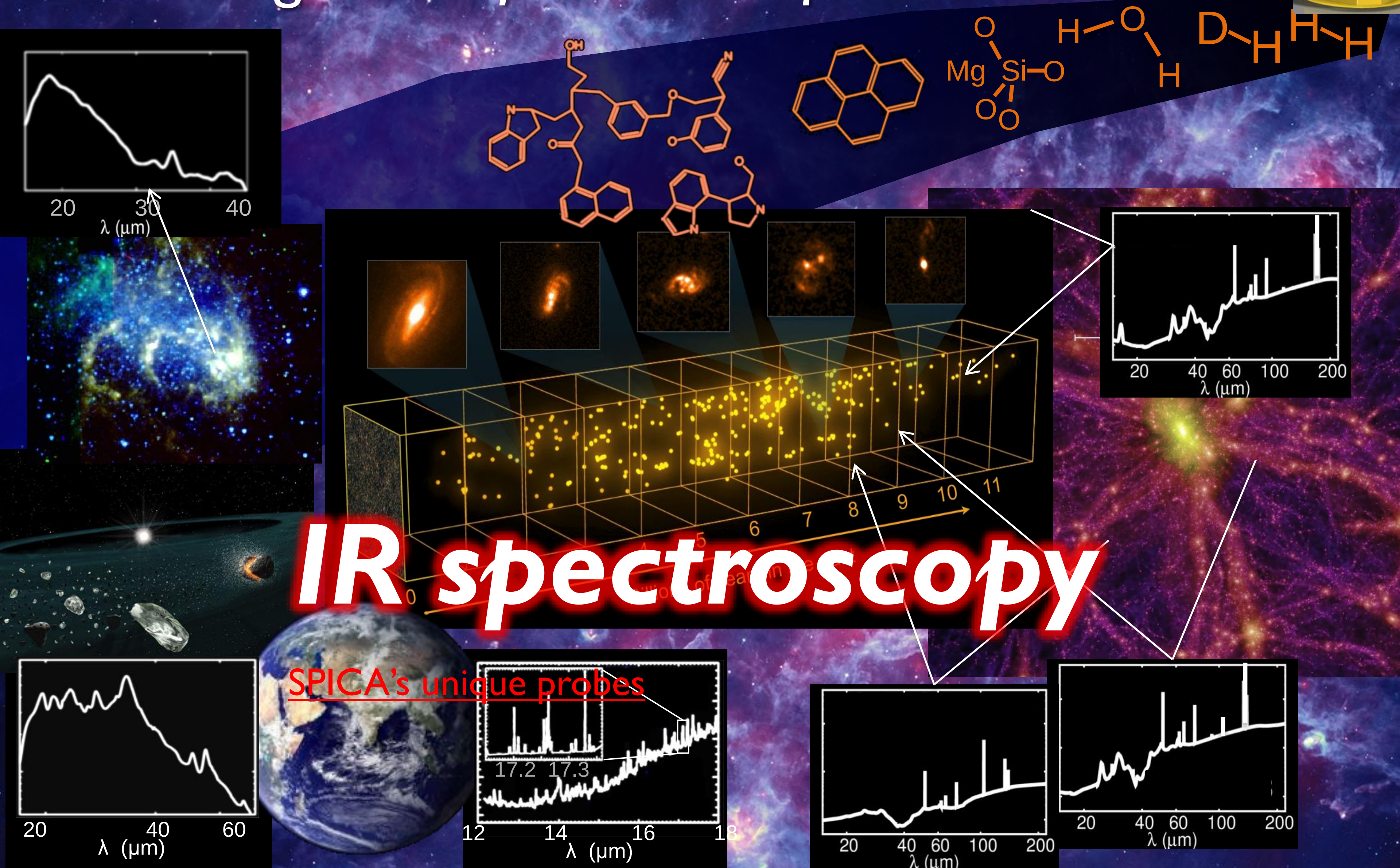
Operation: 3 Years (Nominal), 5 Years (Goal)

Dramatic improvement in the sensitivity



A cryogenically-cooled telescope makes dramatic improvements in the sensitivity in IR observations.

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



AKARI Mid-IR all-sky map

Science goals and objectives

Top-level goal
Enrichment of the Universe with metal and dust, leading to the formation of habitable worlds

SCIENCE GOALS

[SG1] Evolution of galaxies

Science objectives

- **[SO1]** Star formation of distant galaxies
- **[SO2]** AGN outflow
- **[SO3]** Star formation in nearby galaxies

[SG2] Formation of planetary systems

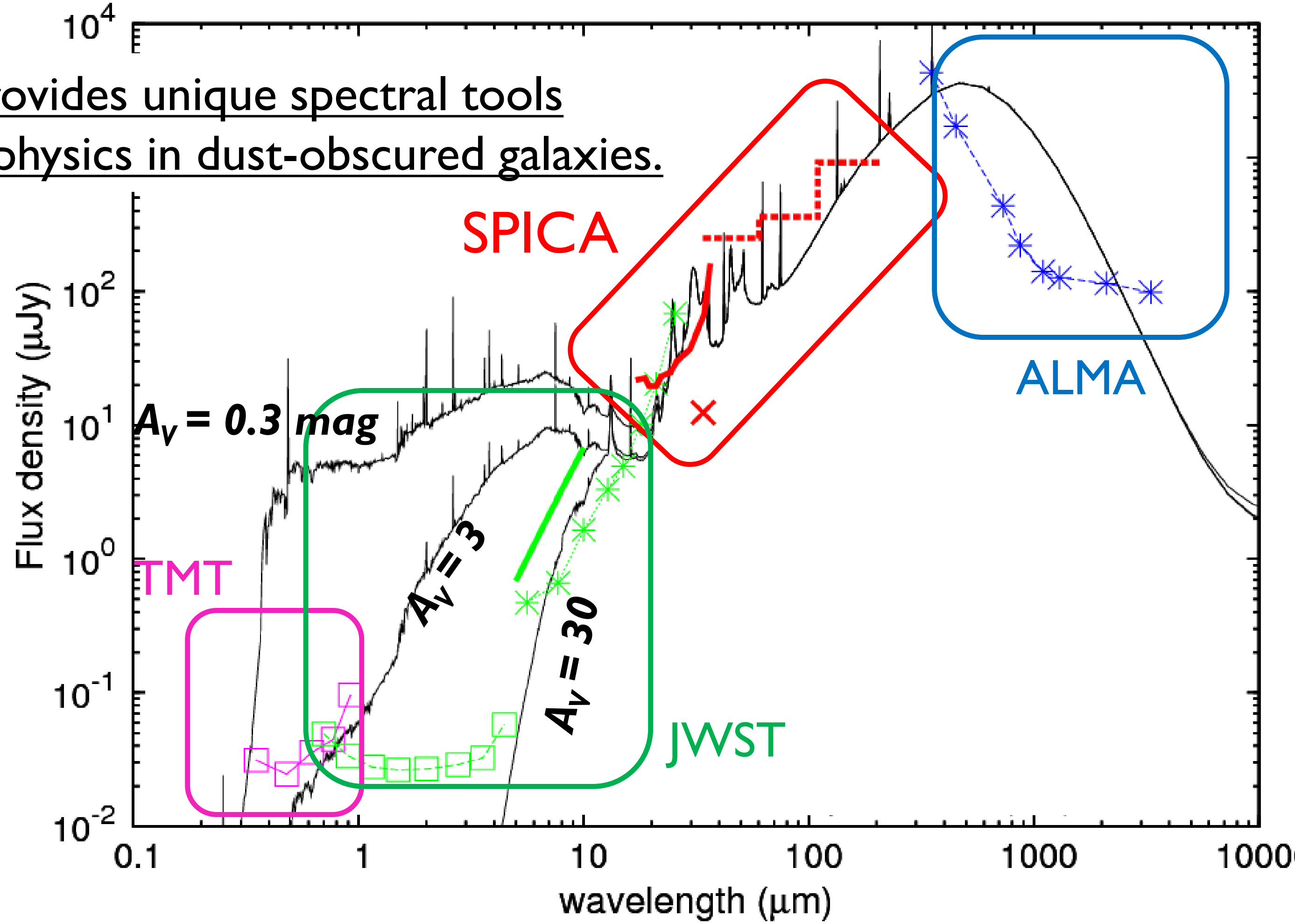
Science objectives

- **[SO4]** Gas dissipation in PPDs
- **[SO5]** Debris disks to solar system
- **[SO6]** Exoplanet atmosphere

SPICA's uniqueness in extra-galactic astronomy

Sensitivity (5σ, 1 hour) of ALMA, SPICA, JWST and TMT, plotted on spectra of typical star-forming galaxies at z = 3 with different dust extinction values (A_V = 0.3, 3, 30 mag).

SPICA provides unique spectral tools to study physics in dust-obscured galaxies.

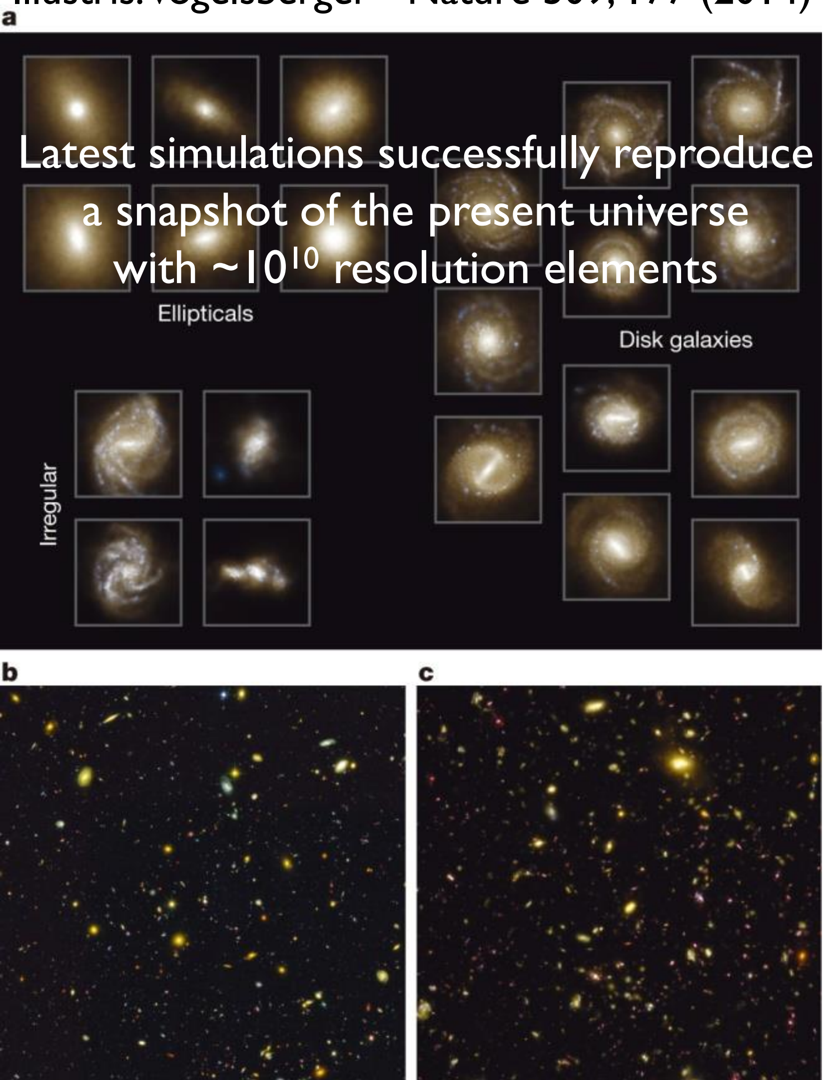


How well do models simulate our Universe ?

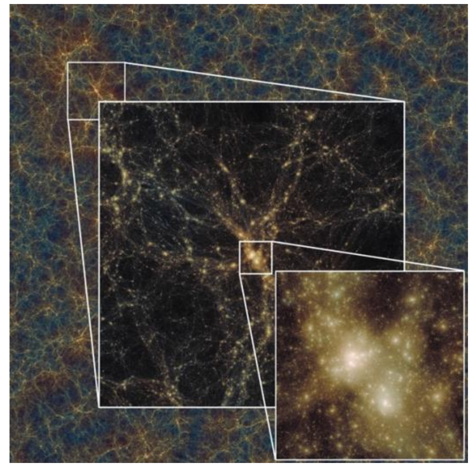
Cosmological hydro-dynamical simulations are performed based on the first principle.

Illustris: Vogelsberger+ Nature 509, 177 (2014)

Latest simulations successfully reproduce a snapshot of the present universe with ~10^{10} resolution elements

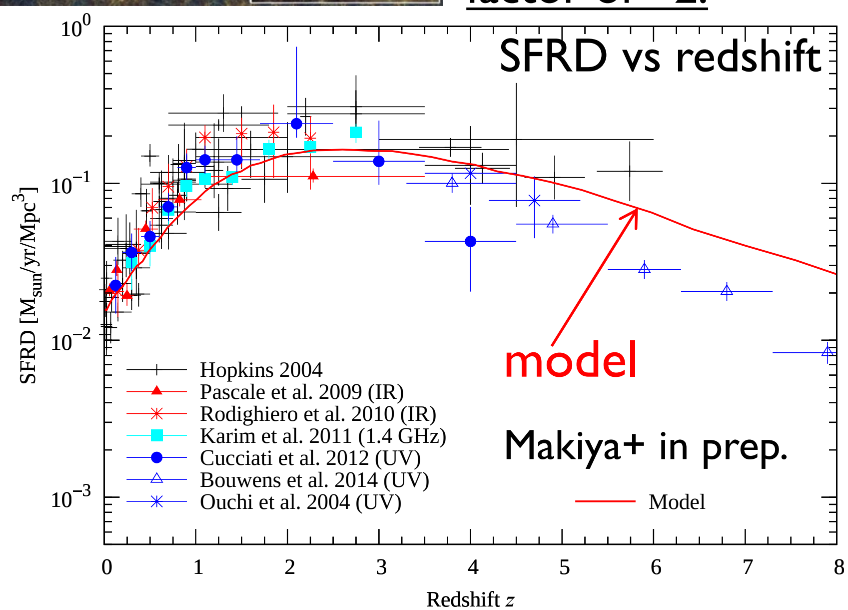


Semi-analytical models can explore a large parameter space.



ν²GC (Mitaka model) calculates 5.5×10^{11} dark matter particles.
(Ishiyama+2015 PASJ in press)

<u>Simulations reproduce the evolution of star-formation rate density (SFRD) within a factor of ~2.</u>

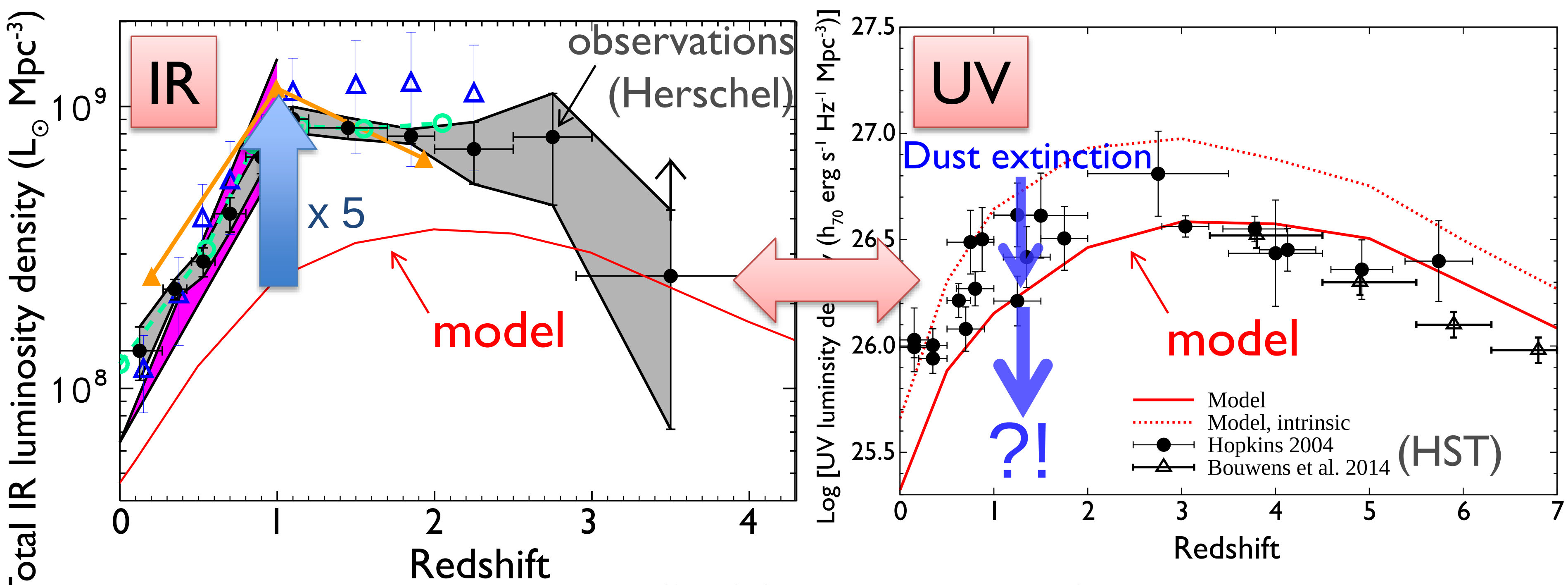


Discrepancy in IR luminosity density

- Discrepancy by a factor of 2–5 exists in L_{IR} density at z = 0.5–3.
- Simulations cannot account for rapid decrease in L_{IR} density at z < 1.

Difficulty in reproducing L_{IR} density is a general consequence of simulations.

SPICA investigates the following possibilities to solve this problem:
(1) a large contribution to L_{IR} from hidden, obscured AGNs
(2) rapid growth of metallicity and dust grains in obscured regions at z = 0.5–3
(3) top-heavy initial mass function (IMF) in IR-bright galaxies

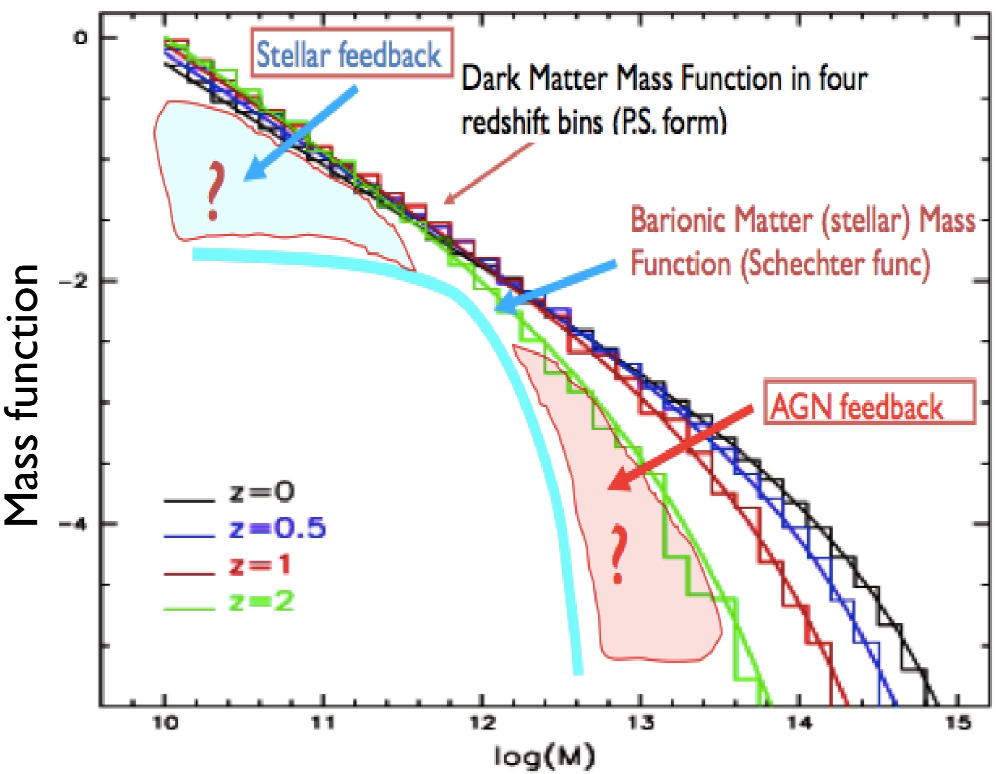


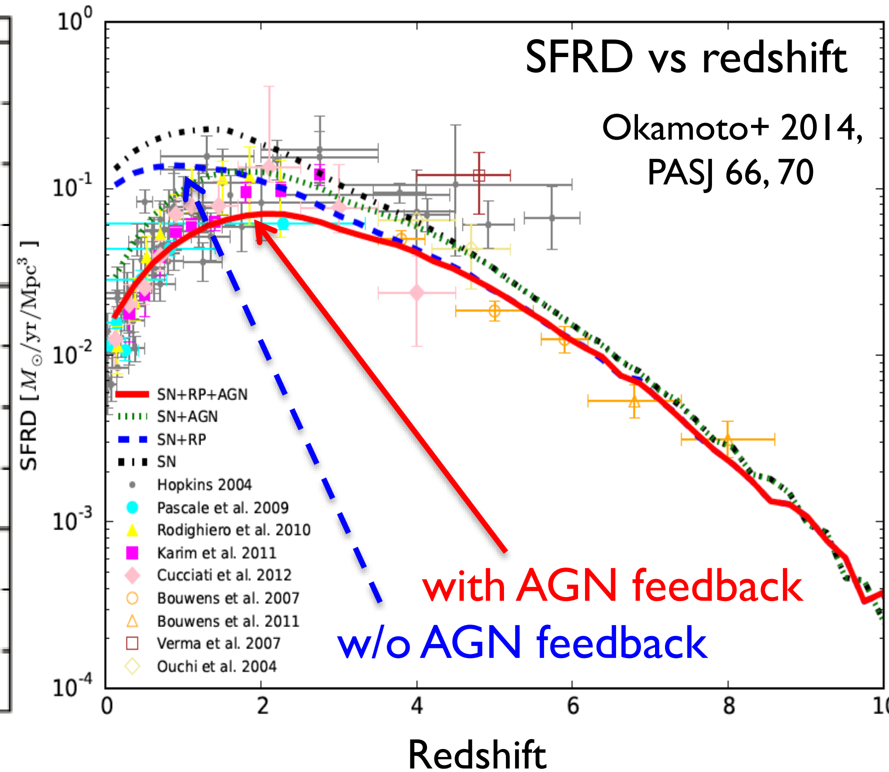
Mitaka model (SAM) (Makiya et al. priv com)

Feedback processes in galaxy evolution

- Difference between the dark matter mass function and the galaxy stellar mass function (GSMF) calls for AGN outflow and stellar feedbacks that quench star formation at both ends of the GSMF.

- <u>AGN outflow is the key to reproducing the SFRD with cosmic time.</u>

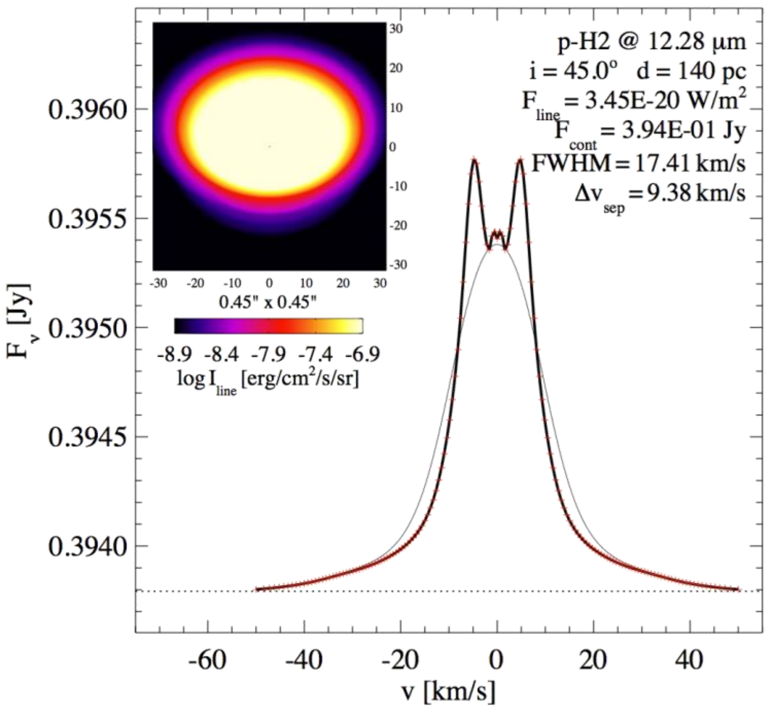




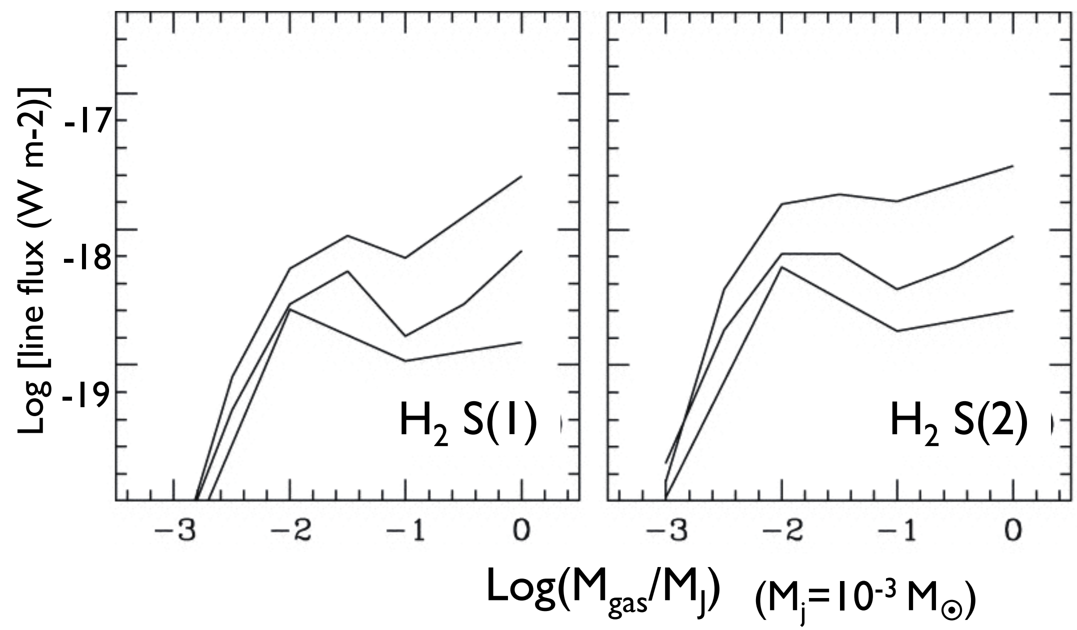
Revealing gas dissipation by H_2

High spectral-resolution (R>20000) spectroscopy with SPICA detects the line emission arising from the innermost region (1–2AU) of the disk by their line width using the Keplerian motion.

H_2 S(1) & S(2) spectroscopy is sensitive to H_2 gas at planet-forming regions (T~300K). $M_{gas} > 10^{-5} M_\odot$ can affect dust growth.



H_2 S(2) emission from a PPD model of a 1 $M_\odot$ star with i = 45 deg with R = 25000.

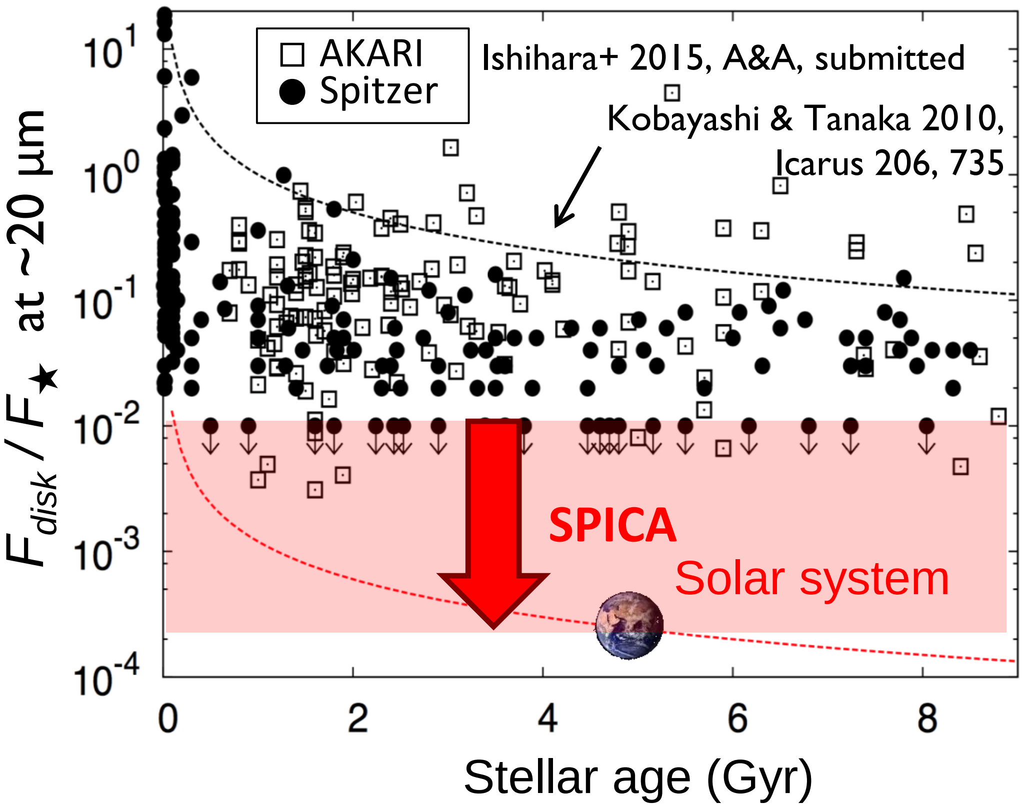


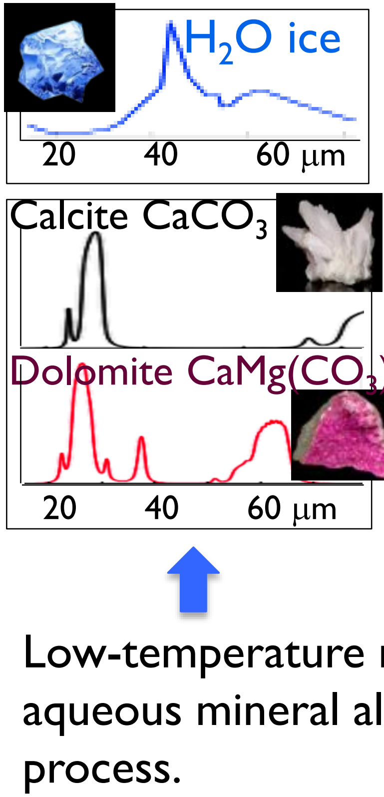
Model estimate of H_2 flux from a 1 $M_\odot$ star at 140 pc (Gorti & Hollenbach 2004 ApJ 613, 424).

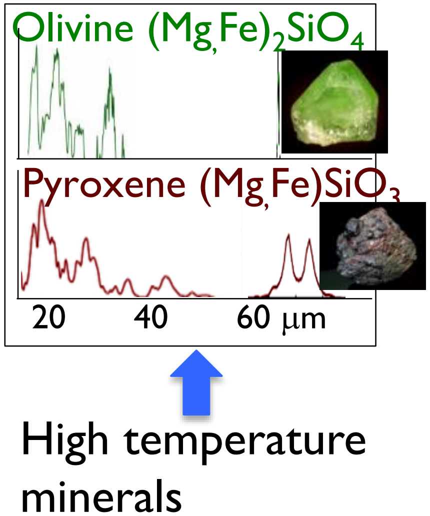
Evolution of debris disks to our solar system

Spectroscopy of various mineral features in 17–100 μm in different environments (e.g., metallicity, radiation field, and stellar age) enables the characterization of debris disks along their evolution and the study of the history of our solar system.

SPICA offers the first opportunity to search for true zodiacal disk analogues and study our solar system in the framework of evolution of debris disks.





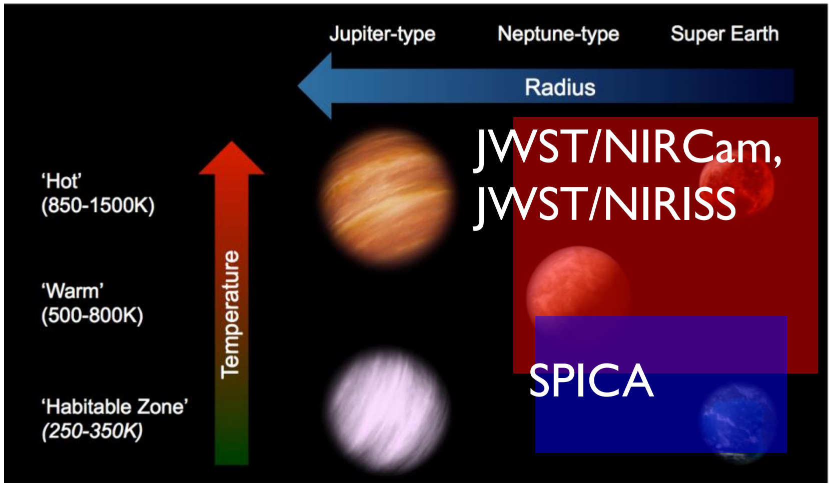


Characterization of Atmosphere of sub-Neptune and super-Earth by Transit Spectroscopy

Targets will be provided by TESS & PLATO.

- SPICA can have a dedicated small instrument for exoplanet science. SPICA has a potential capability for cooler exoplanets (300K or cooler)

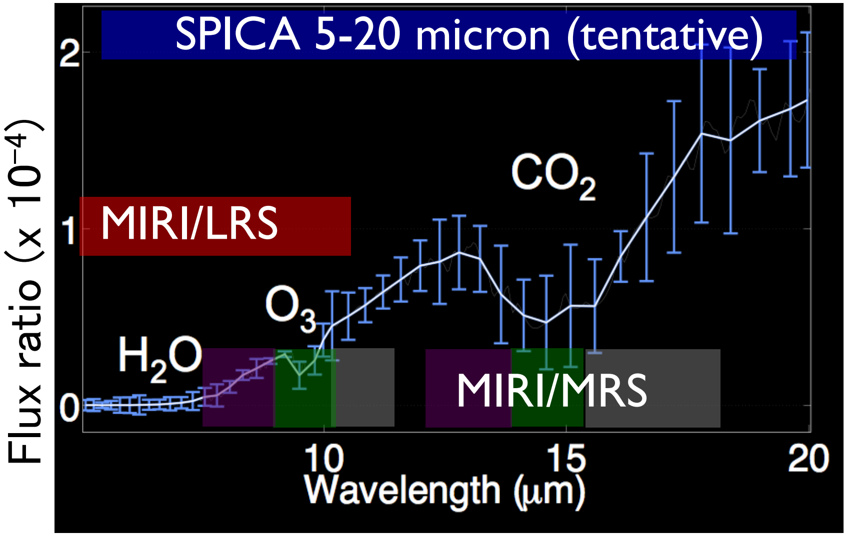
JWST-SPICA can cover wide temperature range of exoplanet's atmosphere.



JWST/NIRCam, NIRISS covers hot (> 600 K) planets.

Survey

Characterization by spectroscopy



Flux ratio of Super-Earth around M-type stars

Summary

After the re-definition,

- ***SPICA has 2.5 m, 8 K telescope with cryo-cooler.***
- ***SPICA is a collaborative mission between JAXA and ESA with other international consortiums.***
- ***The expected launch year is 2027-8.***

- ***SPICA will soon go into its next project phase in Japan.***
- ***SPICA will be proposed as a next M-class mission to ESA jointly by the European and Japanese team.***
- ***SPICA has a capability for a small exoplanet instrument, but not decided yet.***