SPICA As Proposed for M5

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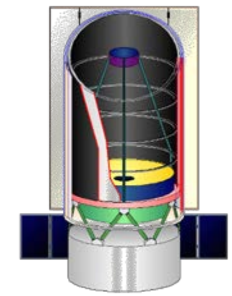
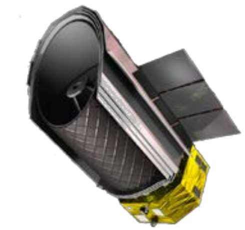
on behalf of
Peter Roelfsema and the SPICA Consortium

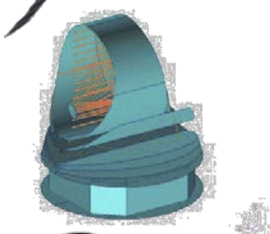
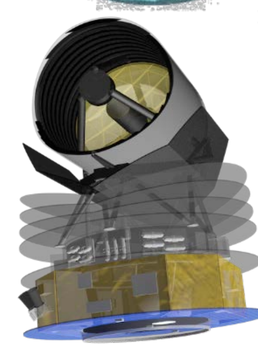
UK SPICA Meeting, RAS, London Dec. 14 2016

Some SPICA History

- **1995-2000: Japanese HII/L2 project**
  - **Cryogenic telescope as follow up to *Herschel***
- **2004: European SAFARI Consortium formed**
  - **UK-led (PI Bruce Swinyard)**
- **2007: JAXA-led; European Mission of Opportunity with ESA telescope + SAFARI**
- **2010: HII-B to HII-A launcher → smaller telescope**
- **2011-2012: JAXA “Risk Mitigation Phase”**
  - **Mission deemed too big for Japan alone**

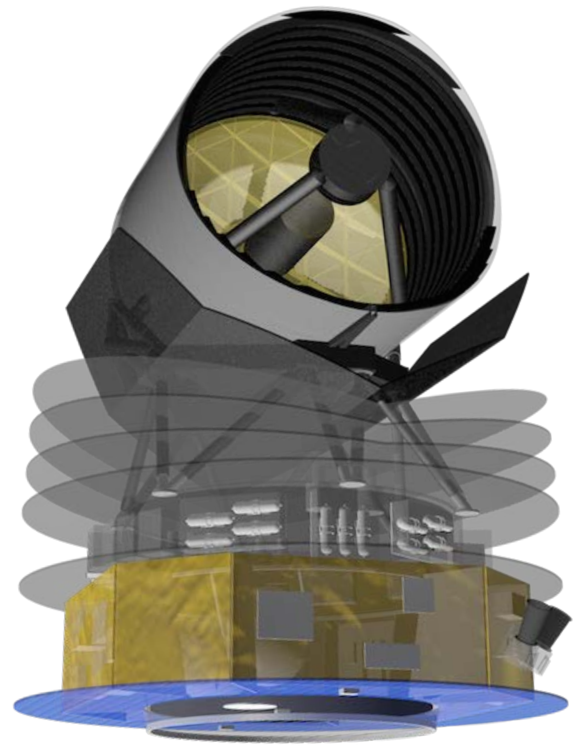
    → ESA partnership needed to increase
- **2014 – ESA/JAXA CDF mission study → M5 concept**
  - **Mission lead moves from Japan to Europe**
- **2015: Passed JAXA Mission Definition Review**
- **2016: European/Japanese proposal for ESA M5**

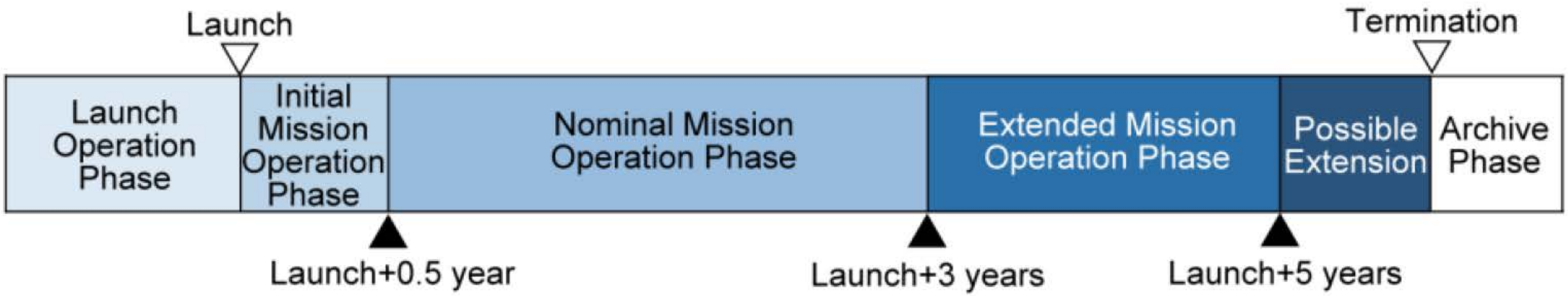



SPICA as Proposed for ESA M5

- ESA-led mission with large JAXA contribution
  - ESA M5 budget: €550M
  - JAXA contribution ~ €300M
- *Planck*-like architecture
  - Size: 4.5 m x 5.3 m
  - Mass: 3450 kg
  - V-groove radiators
  - L2 orbit
- 2.5-m telescope
  - *T* < 8 K
  - Warm launch
- Instrumentation
  - MIR imaging spectroscopy – SMI
  - FIR spectroscopy – SAFARI-SPEC
  - FIR polarimetry – SAFARI-POL
- Standard *Herschel*/*Planck* SVM
- Japanese H3 launcher
- 5 year goal lifetime



In-Orbit Mission Phases



Responsibilities

Telescope (ESA)

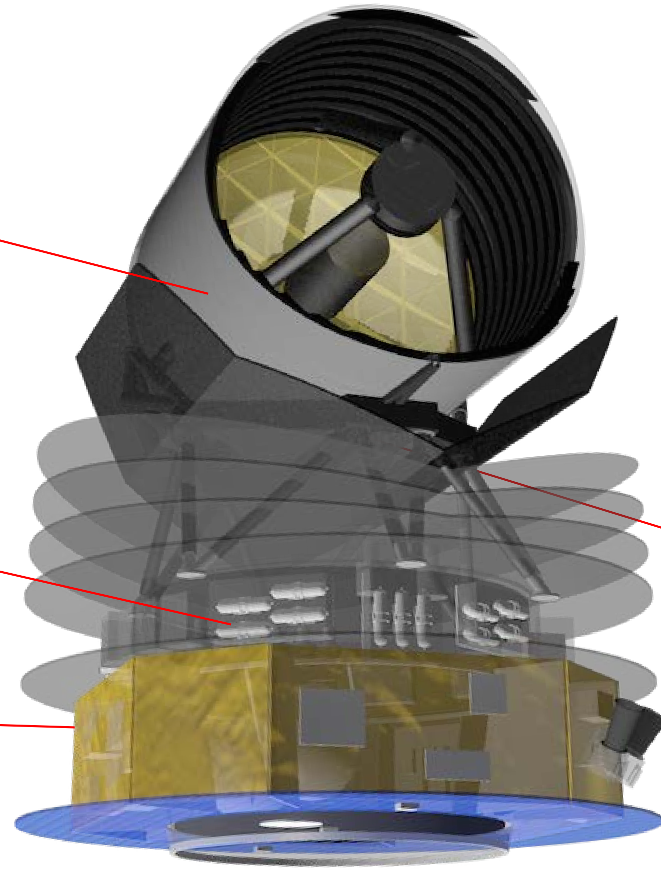
Payload Module

Cryocooler

Bus Module

Launcher

SPICA Data Center



Focal Plane Attitude Sensor

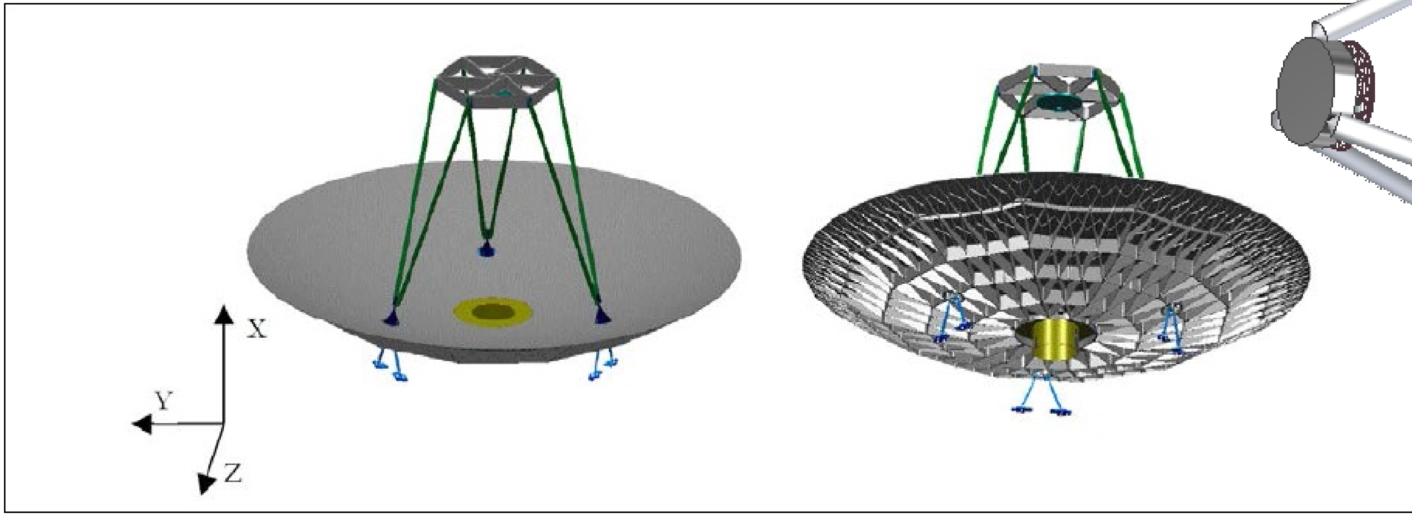
Focal Plane Instrument Assembly

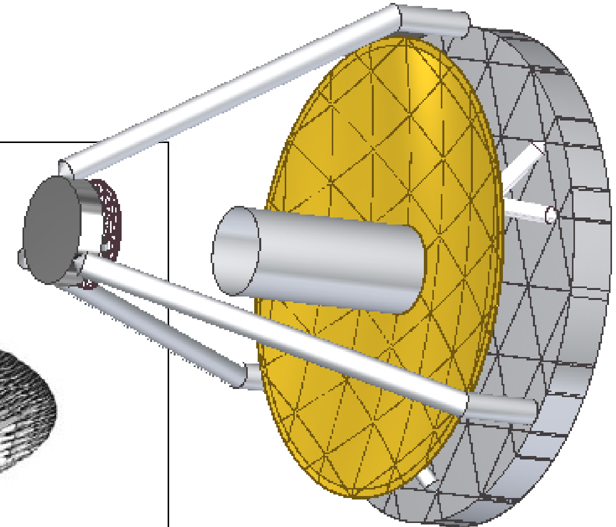
FIR Spectrometer (SAFARI)

NL + European countries + Canada & US

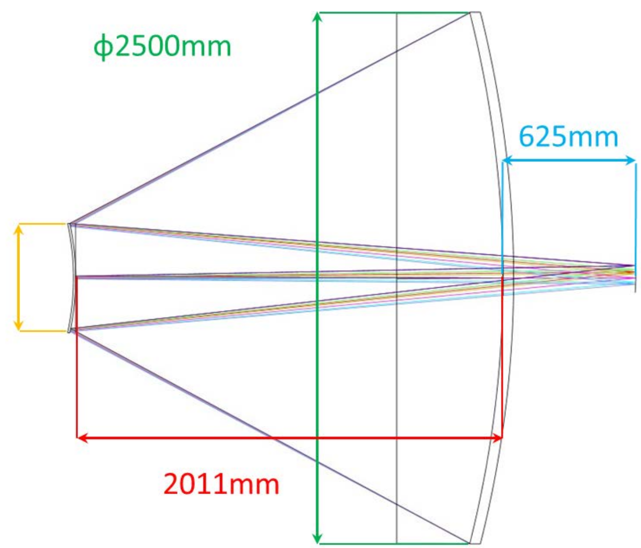
MIR Instrument (SMI)

Telescope





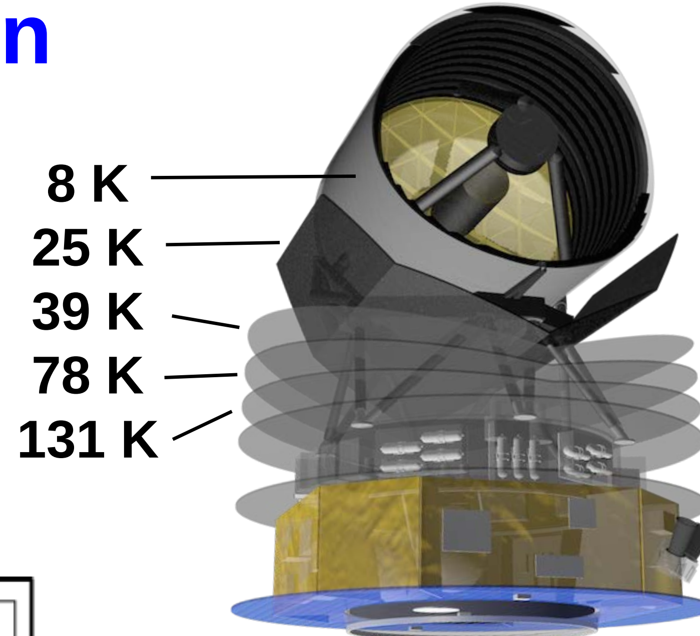
- 2.5-m Ritchey-Chretien
- SiC - *Herschel* heritage
- Three-axis secondry focusing mechanism
- Preliminary design
  - M1: 2.5 m F/1
  - M2: 0.6 m
  - M1 – M2 distance ~2 m

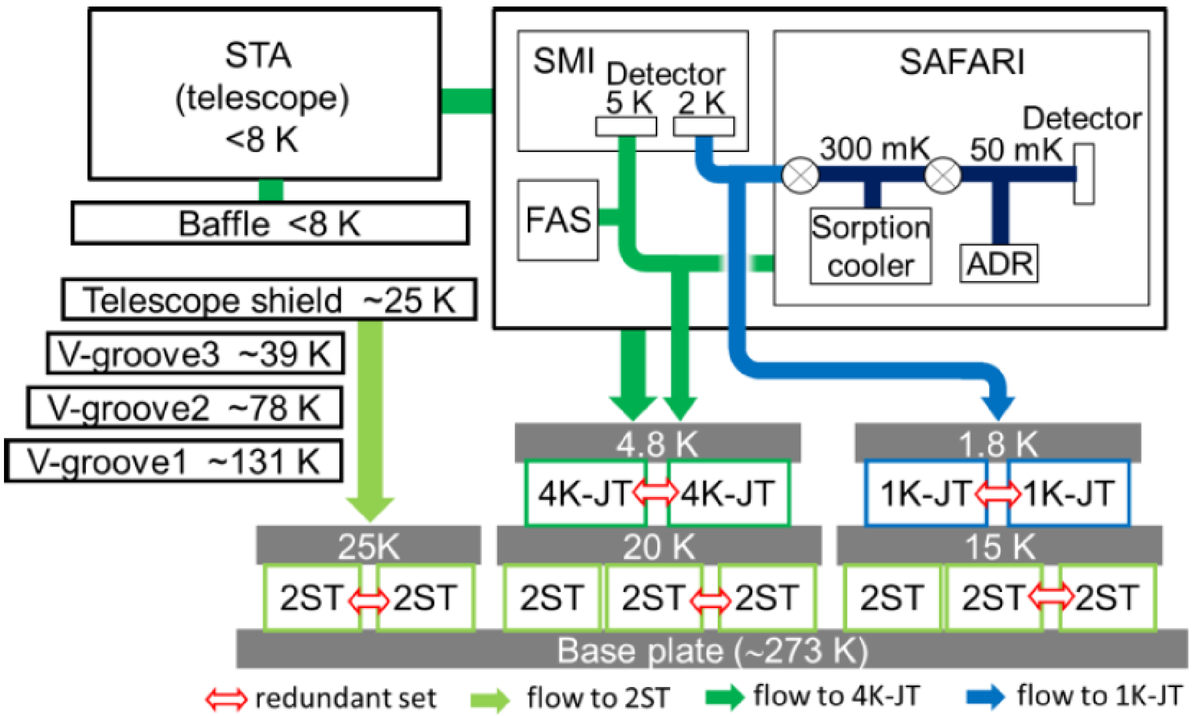


SRON

Thermal Design

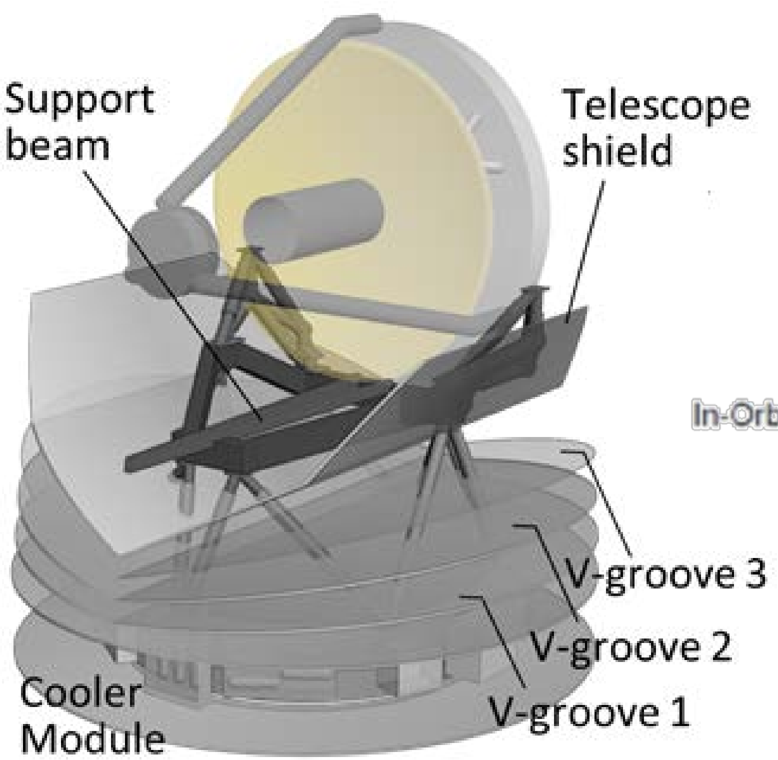
- V-grooves for passive cooling to ~ 40 K
- Active cooling to 4 K and 1.7 K
- 50-mK cooling for SAFARI detectors

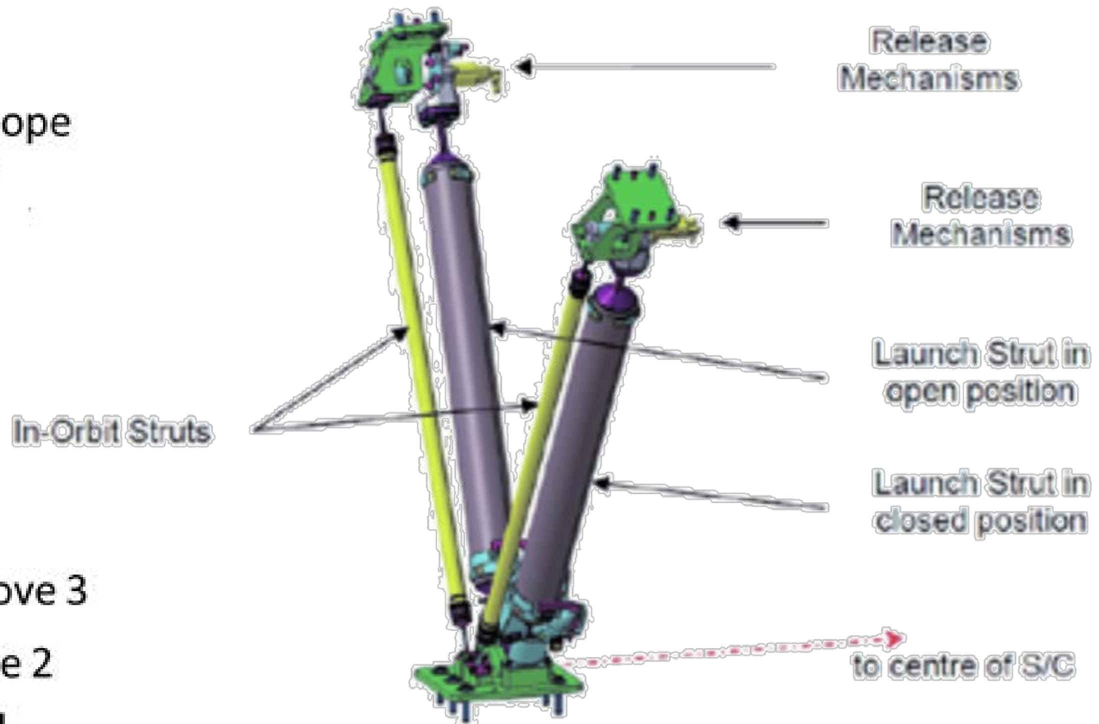




Telescope Support Structure

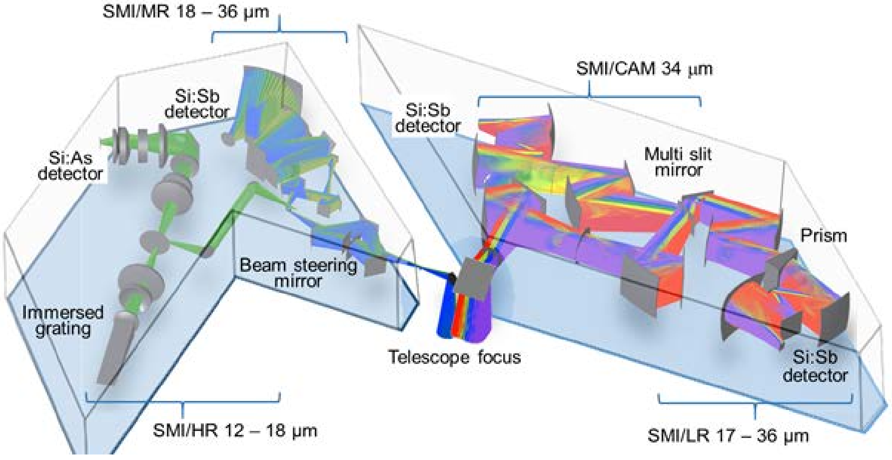
- **Support struts detached after launch**



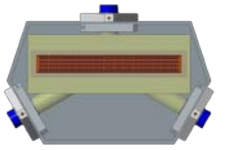


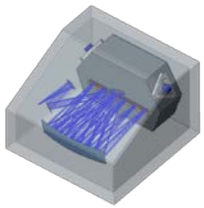
SMI - SPICA Mid-infrared Instrument

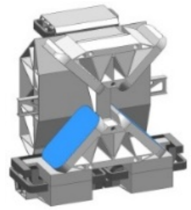
- **Low Res/Camera**
  - **Large area low resolution surveyor**
  - **17 – 36 μm, *R* = 50 – 120**
  - **4 slits (10’ long) with prism**
  - **Si:Sb detector array**
  - **Camera mode with 10’ x 12’ FoV**
- **Medium Res**
  - **Medium resolution mapper**
  - **18 – 36 μm, *R* = 1,200 – 2,300**
  - **1 slit (1’ long) with grating**
  - **Si:Sb detector array**
- **High Res**
  - **Molecular physics/kinematics**
  - **12 – 18 μm, *R* = 28,000**
  - **1 slit (4” long) with immersion grating**
  - **Si:As detector array**



SAFARI

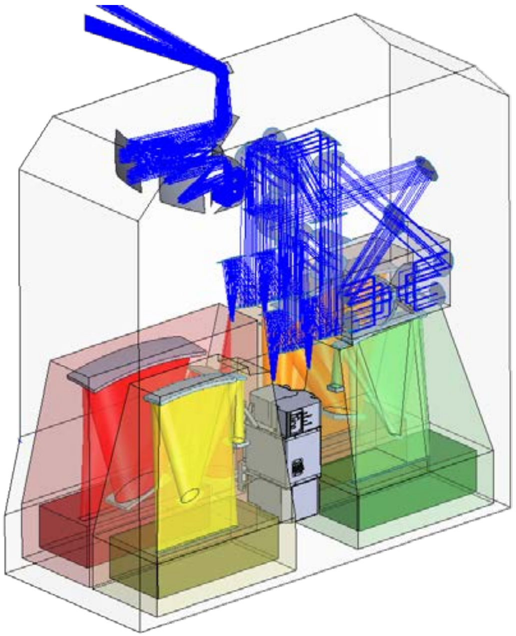






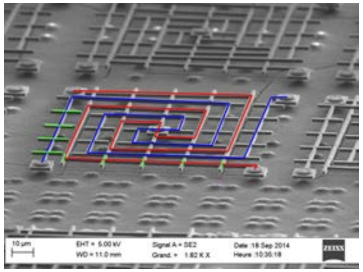
SAFARI-SPEC: high sensitivity grating spectrometer

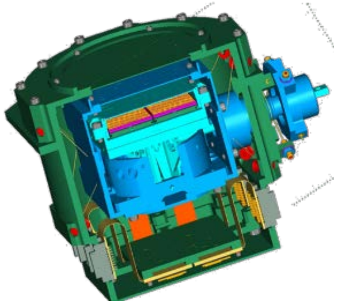
- Basic R ~ 300 mode → 1hr/5σ 5 - 7 × 10^{-20} W m^{-2}
  - Improves with better TES performance
- Martin-Puplett Interferometer for high-res mode
- 4 bands with instantaneous coverage of 35 - 230 mm
  - 34 – 56; 54 – 89; 87 – 143; 140 – 230 μm
- Limited imaging capability: 3 pixels on-sky



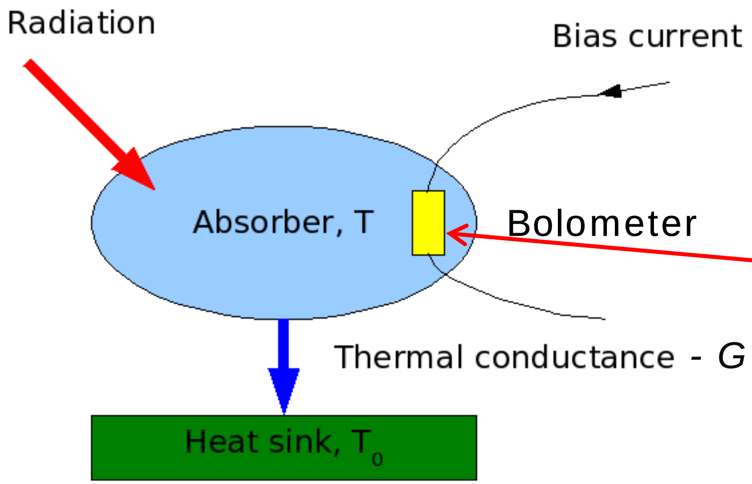
SAFARI-POL: imager/polarimeter

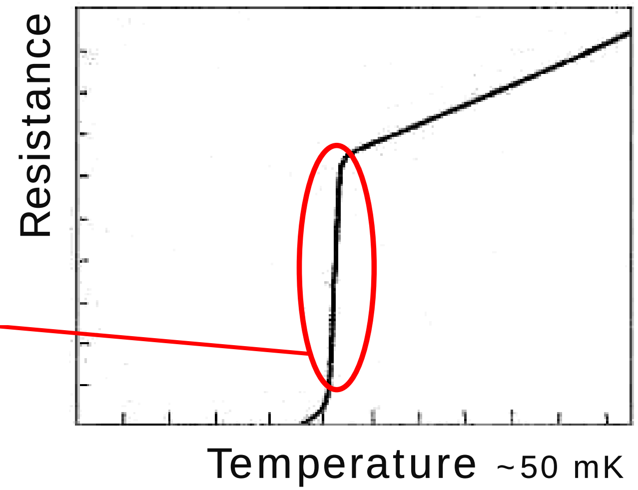
- Polarisation sensitive bolometers
  - 3 bands: 110, 220, 350 μm
- Bolometers/readout similar to *Herschel* PACS

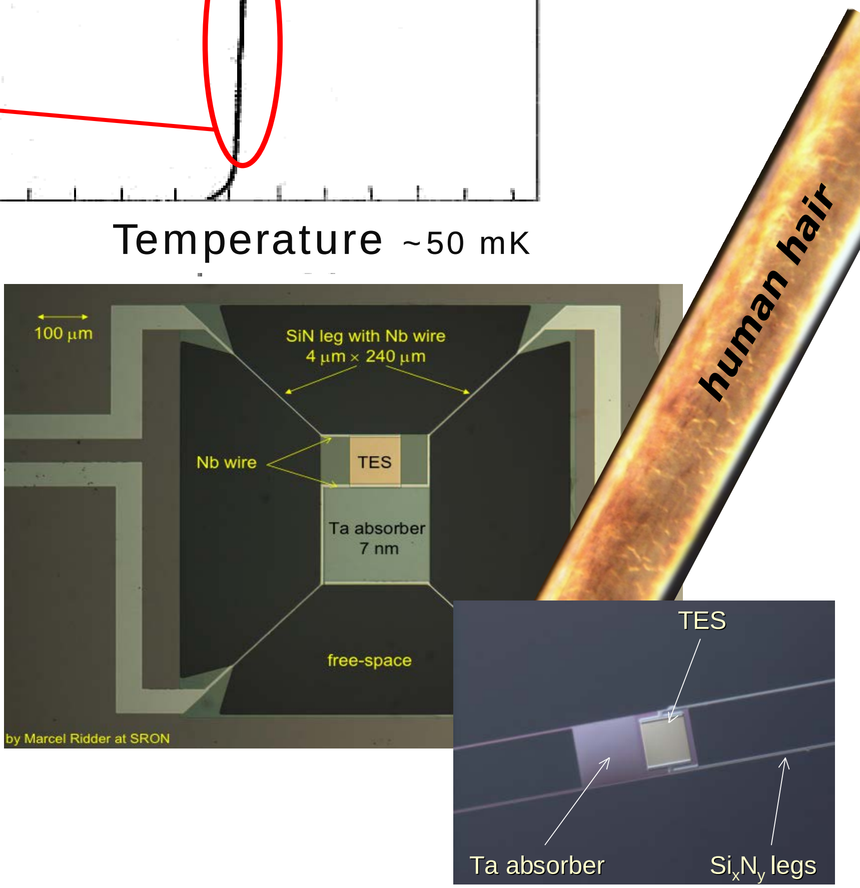




SAFARI-SPEC TES Bolometers



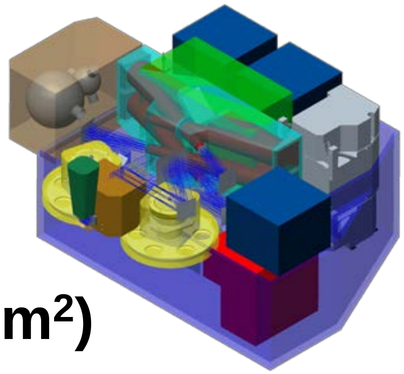




Technical challenges:

- **mK environment**
- **Very sensitive to E, B fields**
- **Small pixels (480 μm)**
- **Low thermal conductance**

Spectrometer Redesign Dictated by Science

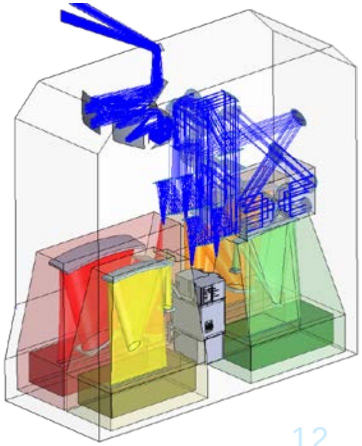


Original: imaging FTS

- Fast, efficient large area spectroscopic mapping
- Sensitivity limited by photon noise
- Best achievable 1-hr; 5-σ ~2 – 3 × 10^{-19} W m^{-2} (6 m^2)
  - Independent of TES performance

New: grating spectrometer for better sensitivity

- Basic *R* ~ 300 mode → 1hr; 5-σ = 6 – 8 × 10^{-20} Wm^{-2} (4.6 m^2)
  - Improves with better TES performance
- Martin Puplett Interferometer to provide high resolution mode (*R* ~ 2000 - 10,000)
- Four bands
- Simultaneous coverage: 35 - 230 μm
- Limited imaging capability: only 3 pixels on-sky

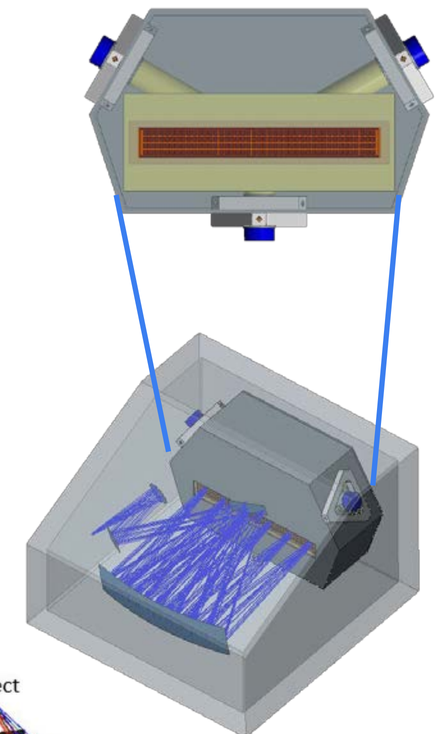


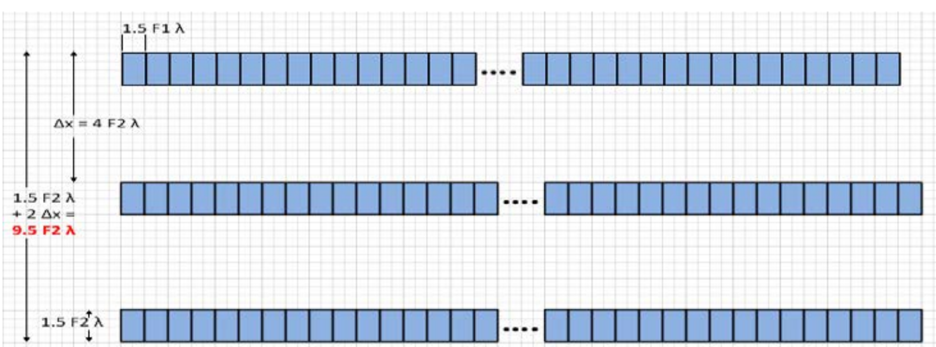
SRON

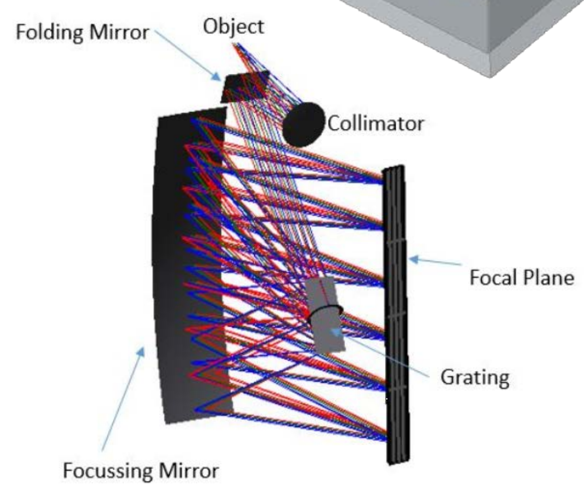
Detectors-Grating Modules

- **Linear TES arrays with FDM readout**
  - **1.5 Fλ separation in spectral direction**
  - **Three on-sky pixels**

- **Integrated FPA/Grating unit**
  - **Grating optics at 1.7 K**
  - **Shielding integrated in structure**
    - **Builds on SAFARI/FTS development**
  - **Detector modules suspended inside at 50mk**

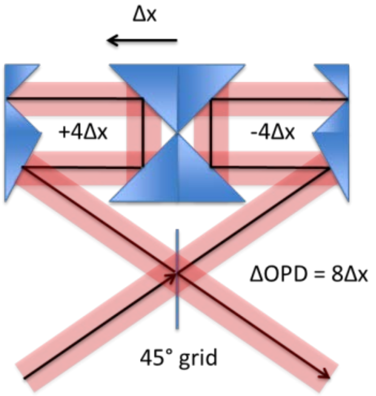


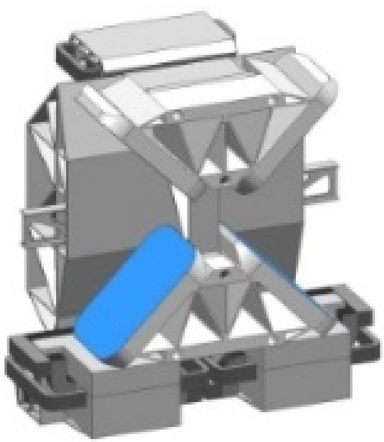




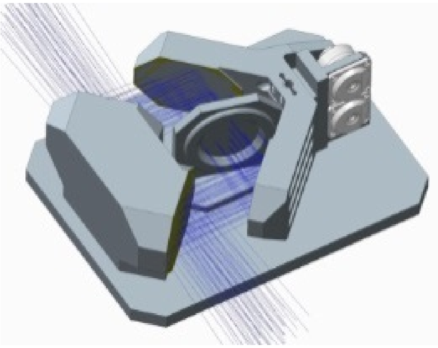
High Resolution Mode: Martin-Puplett Interferometer

- **Mechanism as in original SAFARI FTS concept**
- **Sensitivity factor of ~2 below *R* = 300 mode**
- **Compact layout achieves *R* ~ 11000-2000**





- **Backup: Fabry-Pérot Interferometer**
  - **ISO heritage**
  - **Parallel study (led by Canada)**

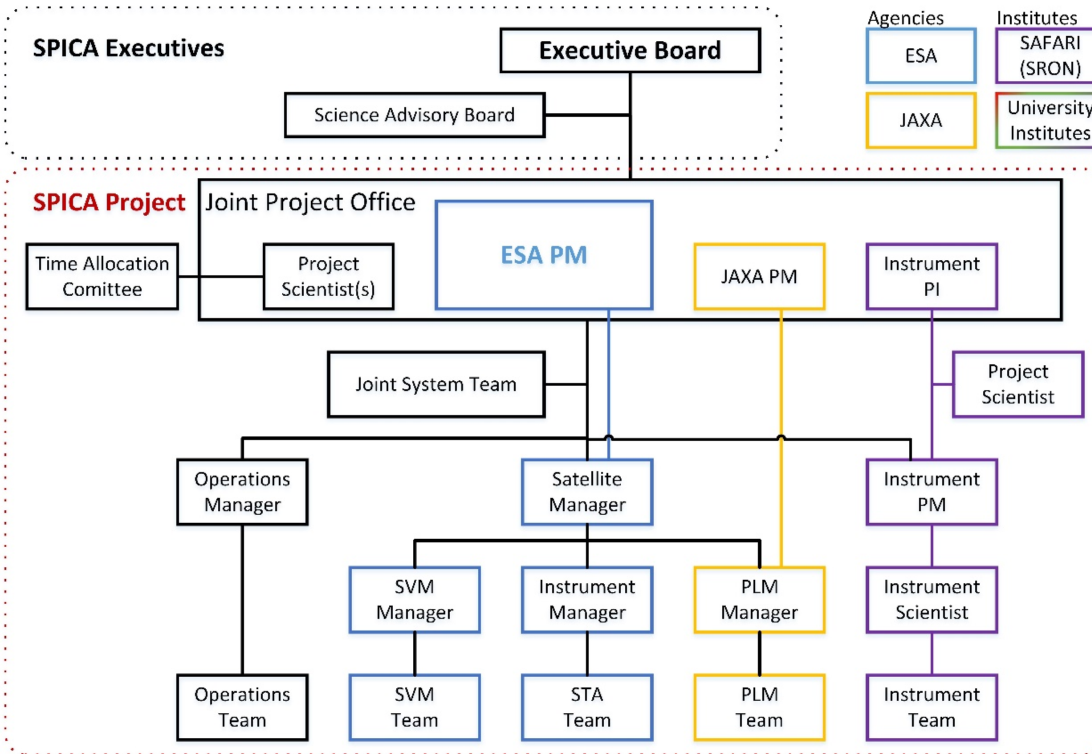


SAFARI Hardware Contributions

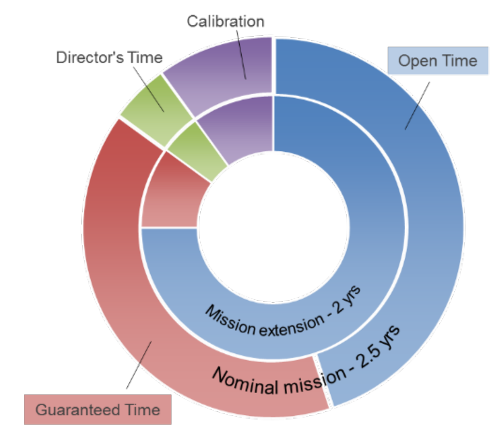
Country	Institute(s)	Prime SAFARI hardware contribution
Netherlands	SRON	Principal Investigator, Project Manager, Project Scientist, instrument system engineering, system AIV, detector system
Spain	(CAB)/INTA	Focal plane structure and optics, mechanical lead
France	LAB Bordeaux, IRAP Toulouse	Detector control unit
	CEA Grenoble and Saclay	Sub kelvin cooler system including control electronics, thermal lead
	CEA Saclay	SAFARI/POL
US	NASA/JPL	Detector system, grating modules
Canada	CSA, Univ. of Lethbridge	Martin-Puplett stage
Italy	IAPS/INAF	Instrument control unit, OBSW, warm interconnect harness
Belgium	KU Leuven/CSL	Environmental qualification, cryo-mechanisms, AIV support, calibration lead
Switzerland	Univ. of Genève	ICC lead
UK	Cardiff Univ., Univ. of Cambridge, Airbus	Detector system, FPA modules, AIV support, filters and quasi-optics: system design and analysis
Germany	MPIA	Beam steering mirror
Taiwan	ASIAA	Cold calibration source
Sweden	SSB, Univ. of Stockholm	Filters, beam splitters and dichroics
Austria	Univ. of Vienna	OBSW compression/decompression software
Ireland	NUI, Maynooth	Detector EM/optical modelling
Japan, Univ. of Tokyo; Denmark, DTU: hardware contributions TBD		

SPICA Governance and Science Organisation

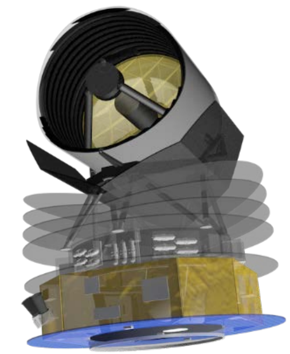
- **International mission**
  ⇒ International oversight
- **Top-level bodies**
  - **SPICA Executive Board**
  - **Science Advisory Committee**



- **Observing time**
  - **Mission will be open for *all astronomers***
  - **Guaranteed vs open time details TBD**
  - **Key projects TBD**
  - **International Time Allocation Committee**



SPICA Mission Status



- Mission well defined
  - Spacecraft elements, responsibilities
  - Instruments ready to start Phase-A
- SPICA has passed JAXA Mission Definition Review
  - SPICA officially in 'Pre-project' phase (~ Phase A)
- M5 proposal submitted
  - ESA-led mission with JAXA participation
  - JAXA committed to support at the ~ €300M level
- M5 timeline
  - Mission candidate selection (3 or 4 candidate missions): June 2017
  - Two-year Phase-A Study led by ESA
  - M5 mission selection: 2019
  - Launch: 2028/2029