The future of instrumentation for dust observations

introduction to the discussion

Laure Ciesla & Denis Burgarella

Journées de la SF2A — Besançon 2022

After SPICA's death: a new hope for IR astronomy

October 2020: ESA put an end to SPICA

October 2021: US Decadal Survey on Astronomy and Astrophysics 2020

Novembre 2021: Survey of the community needs in terms of IR observations

December 2021: ESA M7 call

January 2022: Workshop "Next generation mid/far-IR space missions, a European perspective"

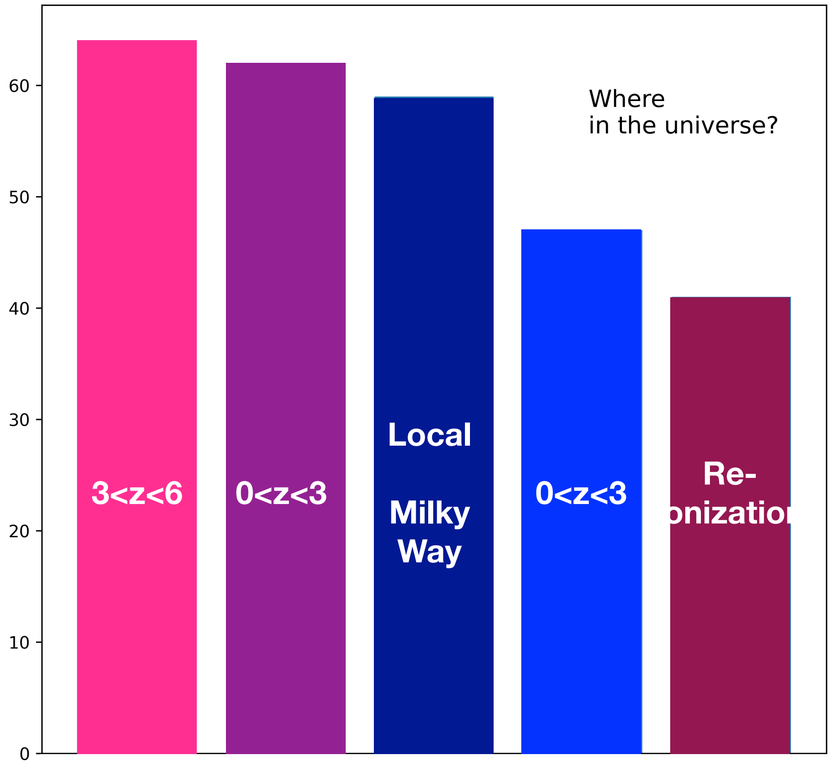
Spring 2022: Organisation and preparation of the different US IR probe candidates

May 2022: Results of ESA M7 first selection

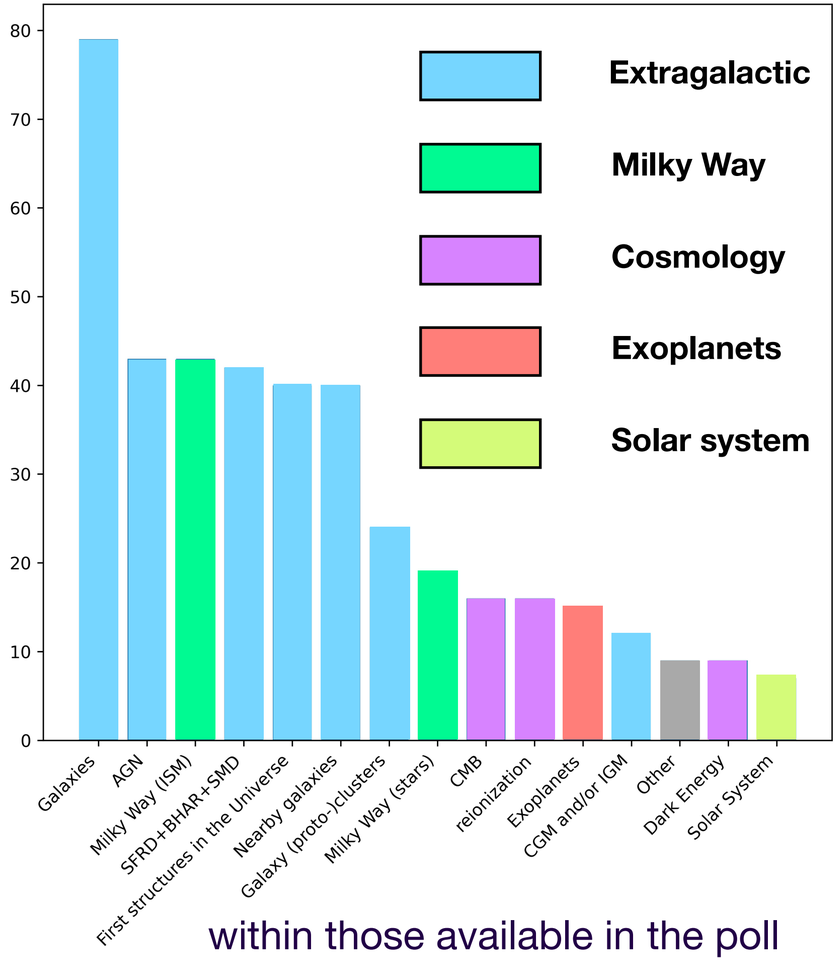
Infrared community survey

140 persons provided answers (as of December 13th 2022)

Redshift range of interest



Topic of interest



within those available in the poll

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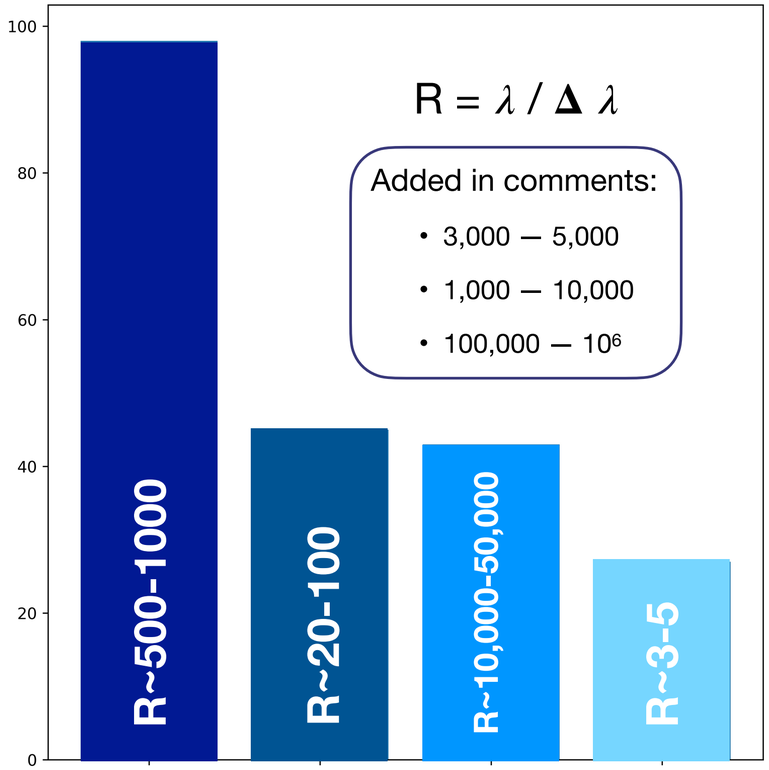
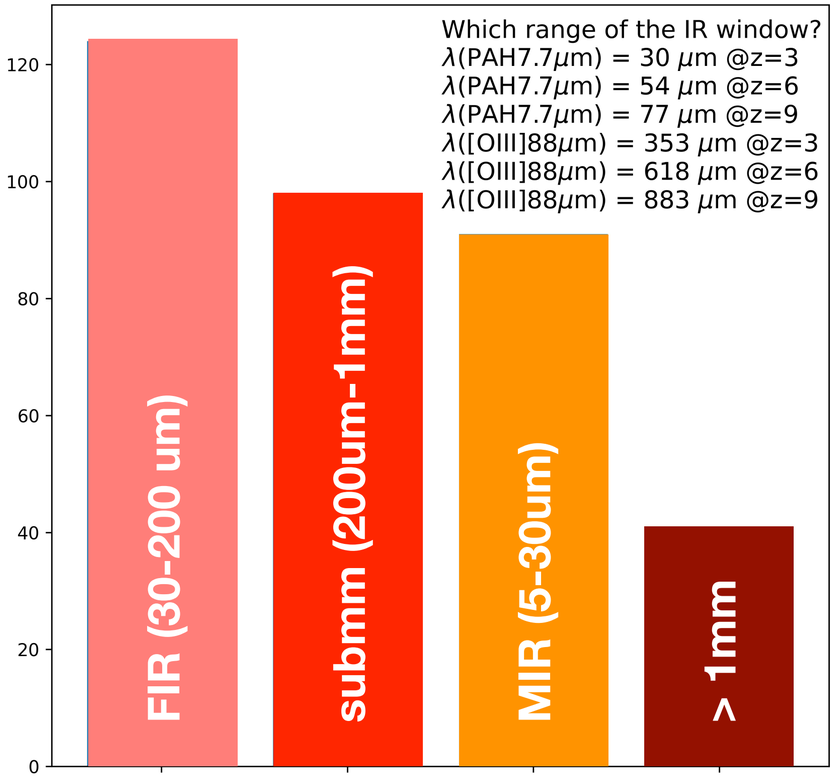
Spectral resolution



within those available in the poll

Wavelength range of interest



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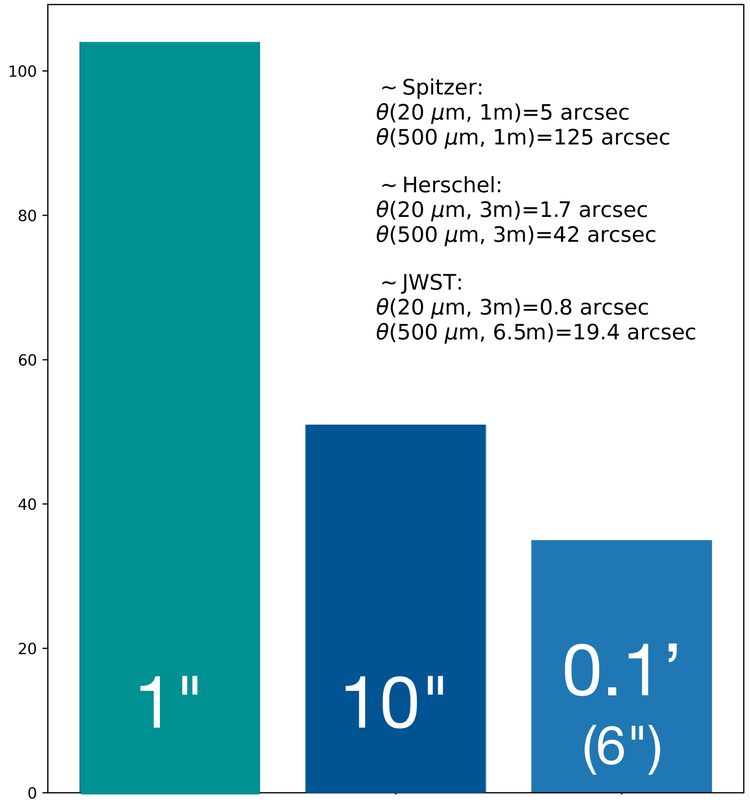
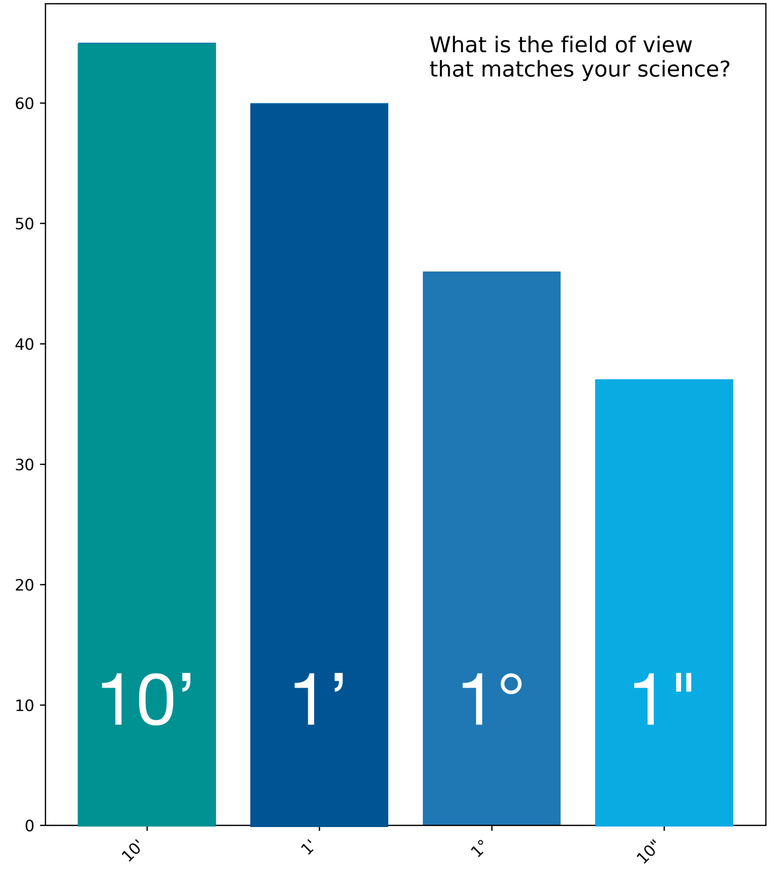
Spatial resolution

within those available in the poll



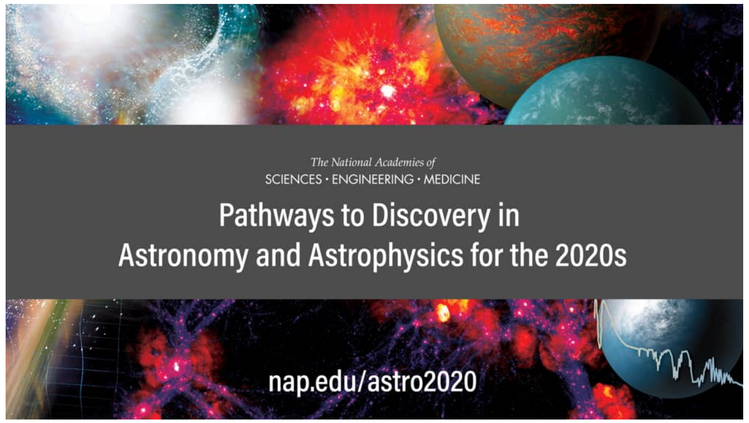
Field of view



Conclusions of the survey

- “**Galaxies**” (extragalactic in general) seems to be the principal interest, followed by **local star formation** and **planet formation** (**exoplanets**)
- Almost equal number of votes for **0<z<3**, **3<z<6** and **Milky way**
- Preferred wavelength range: Far-IR = **30-200 μm**
- Required spectral resolution: **R = 500 - 1000**
- Required spatial resolution: **1”**
- Sensitivity: faint-to-medium depth objects (**M_{AB}~24-28**)
- Preferred instrument: **Integral Field** (& **MOS**)
- Field of view: Medium size **1’-to-10’**

NASA call for X-ray / IR probe



Astro2020 called out the science areas enabled by a FarIR Probe:

- Measure the **building up of galaxies**, h**eavy elements**, and **interstellar dust** from the **first galaxies to today**
- Probe the **co-evolution** of **galaxies** and their **supermassive black holes** across cosmic time
- Trace the **astrochemical signatures** of **planet formation** (**within and outside** our own Solar System)

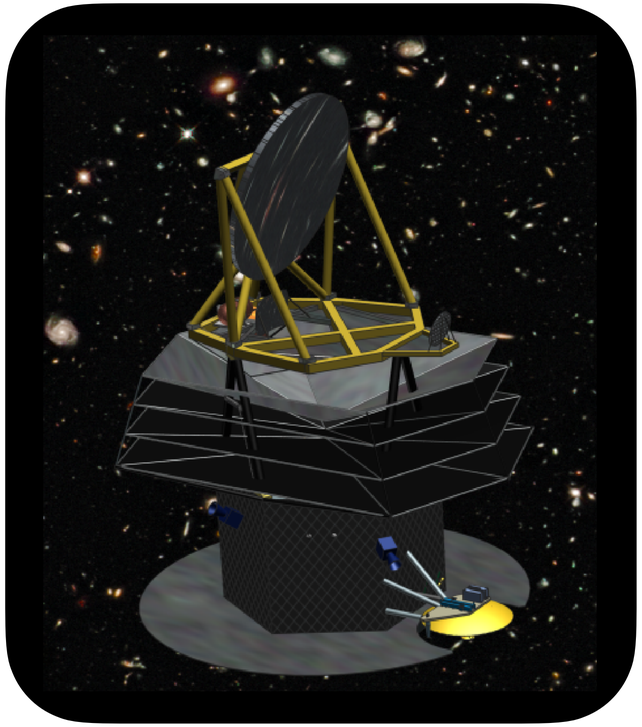
Release of this second notice:	May 2022
Release of draft AO:	July 2022 (target)
Release of final AO:	July 2023 (target)
Preproposal conference:	~ 3 weeks after final AO release
Proposals due:	**90 days after AO release (~October 2023)**
Selection for competitive Phase A:	**Mid 2024 (target)**
Concept study reports due:	Early 2025 (target)
Down-selection:	**Mid/Late 2025 (target)**

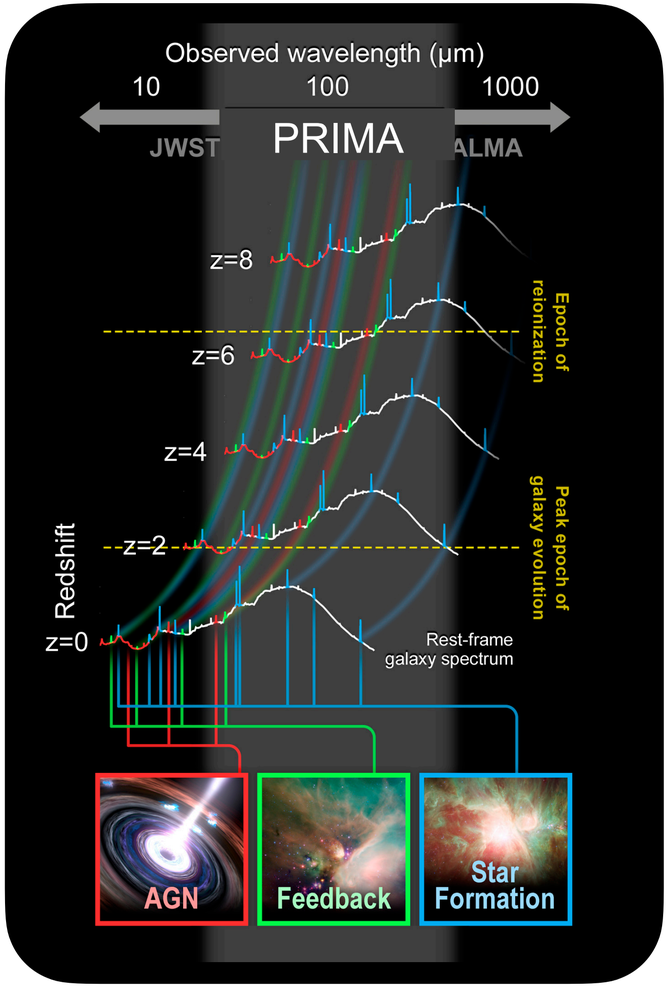
Goddard SPACE FLIGHT CENTER NASA JPL cnes LAM LABORATOIRE D'ASTROPHYSIQUE DE MARSEILLE SRON Netherlands Institute for Space Research

PRIMA

PRobe **I**nfrared **M**ission for **A**strophysics

Exoplanets — Solar System — Local galaxies — AGN — ISM — Star and planet formation — Dust and metals — Galaxies evolution





PI: Jason Glenn

Deputy PI, Caltech contact: Matt Bradford

Science lead: Alex Pope

European contact: Denis Burgarella

PRIMA

The PRobe far-Infrared Mission for Astrophysics

Goddard SPACE FLIGHT CENTER · NASA · JPL · cnes · LAM LABORATOIRE D'ASTROPHYSIQUE DE MARSEILLE · SRON Netherlands Institute for Space Research

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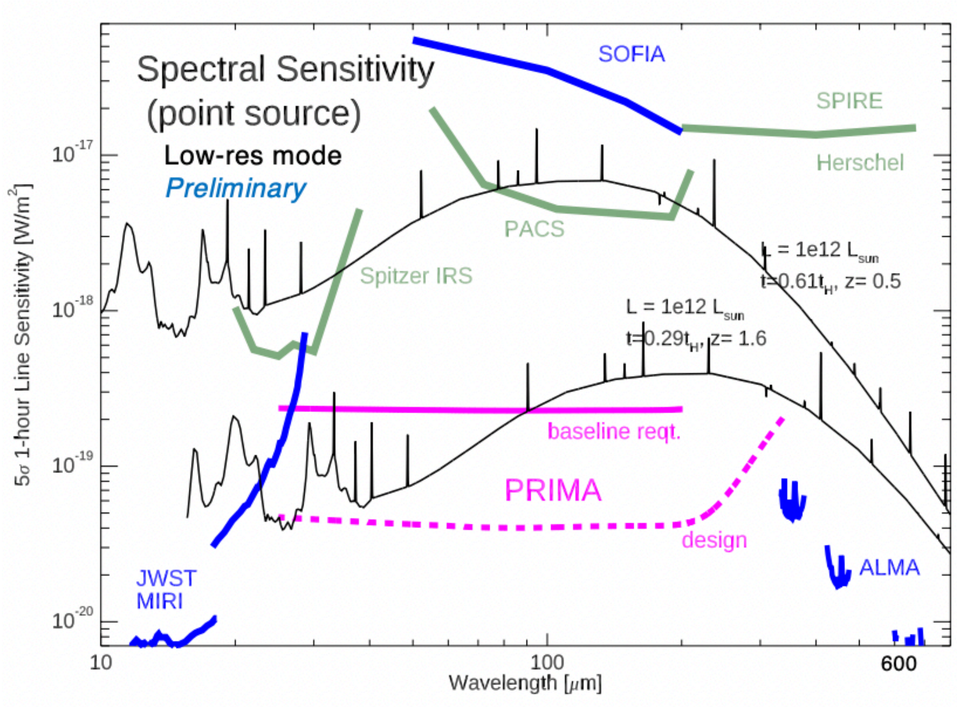
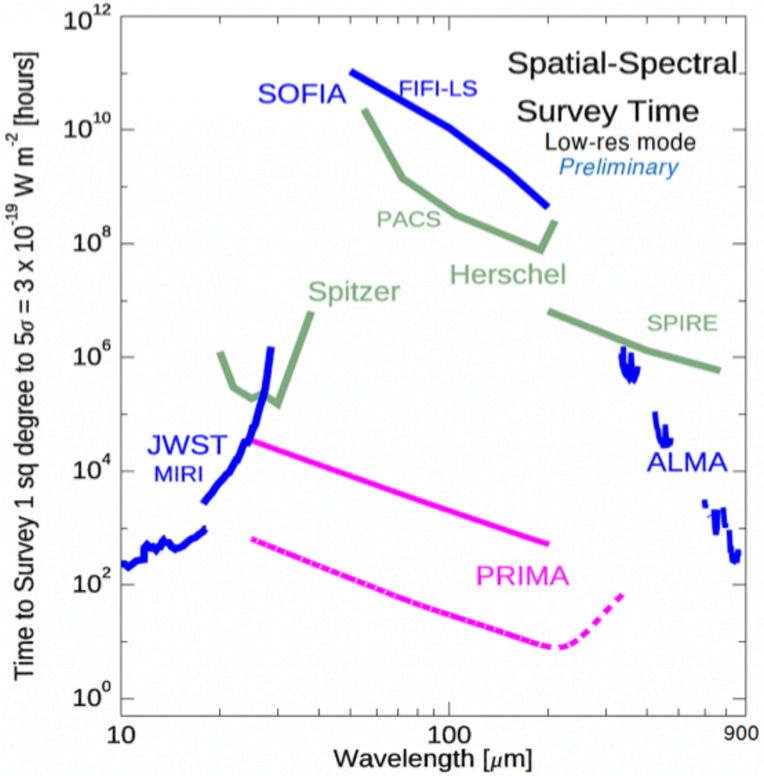
PRobe **I**nfrared **M**ission for **A**strophysics





PRIMA: very first design of the Imager

Contacts:

LAM:

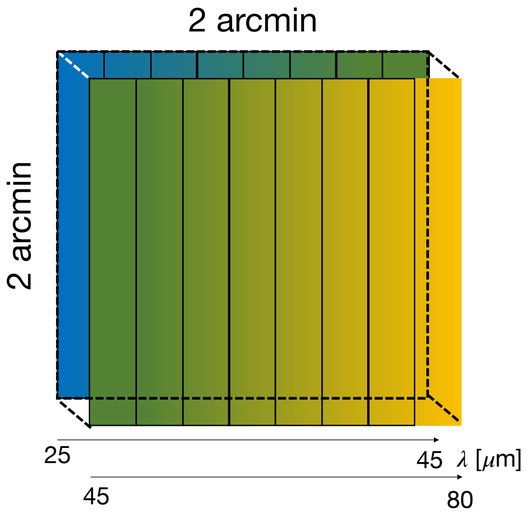
Denis Burgarella

Laure Ciesla

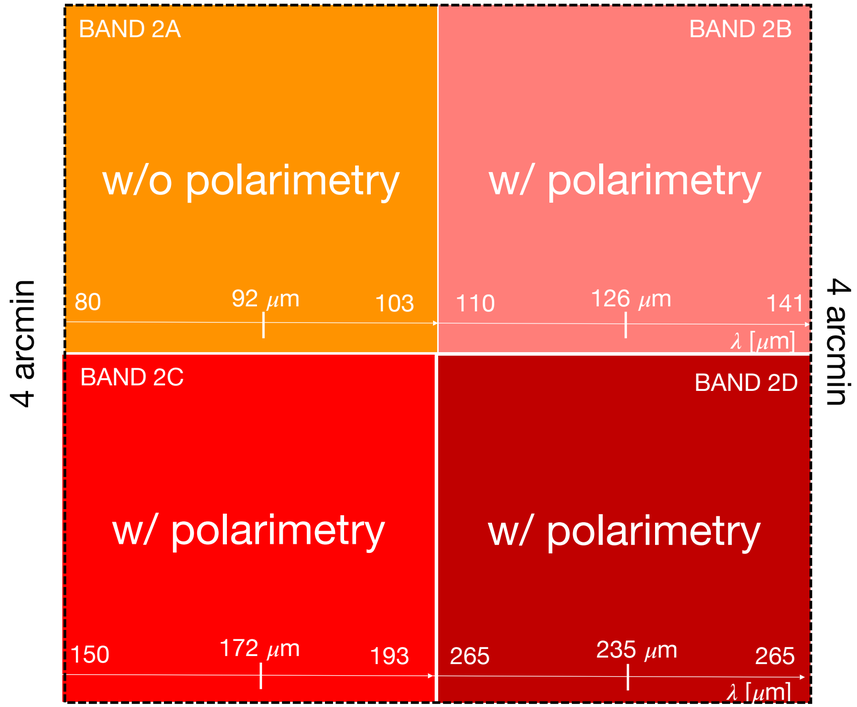
Eric Prieto

SRON:

Willem Jellema



R = λ / Δ λ = 10



R = λ / Δ λ = 4

Post LAM – SRON
Meeting Field Geometry
2 June 2022

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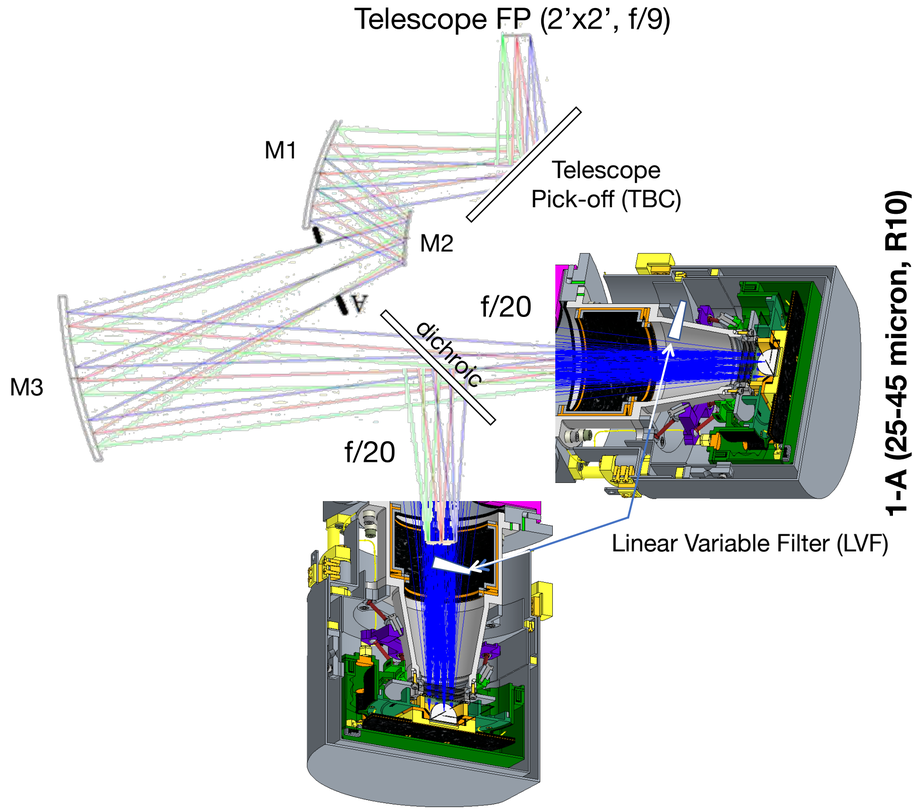
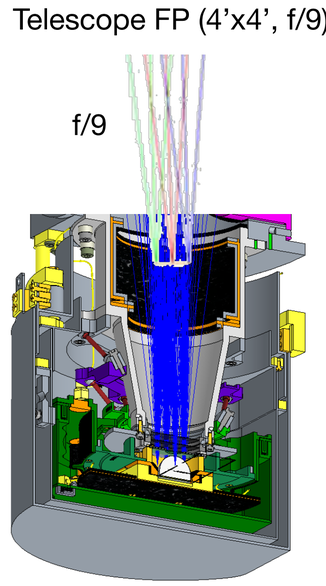
Hyperspectral imager unit



Polarimetric imager unit



2 imager units (instruments)
3 FPA's
1 set of reimager optics (relay)

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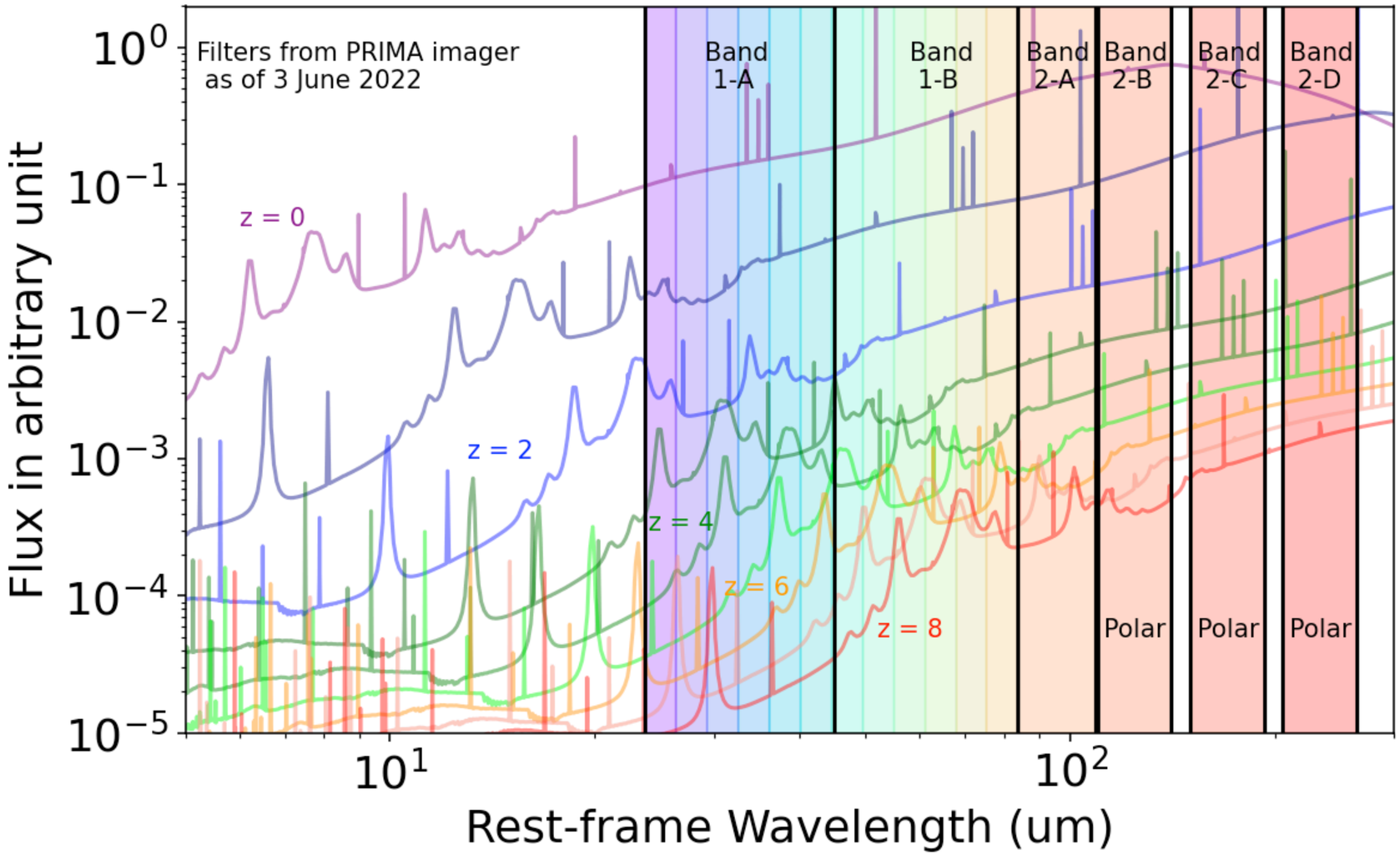
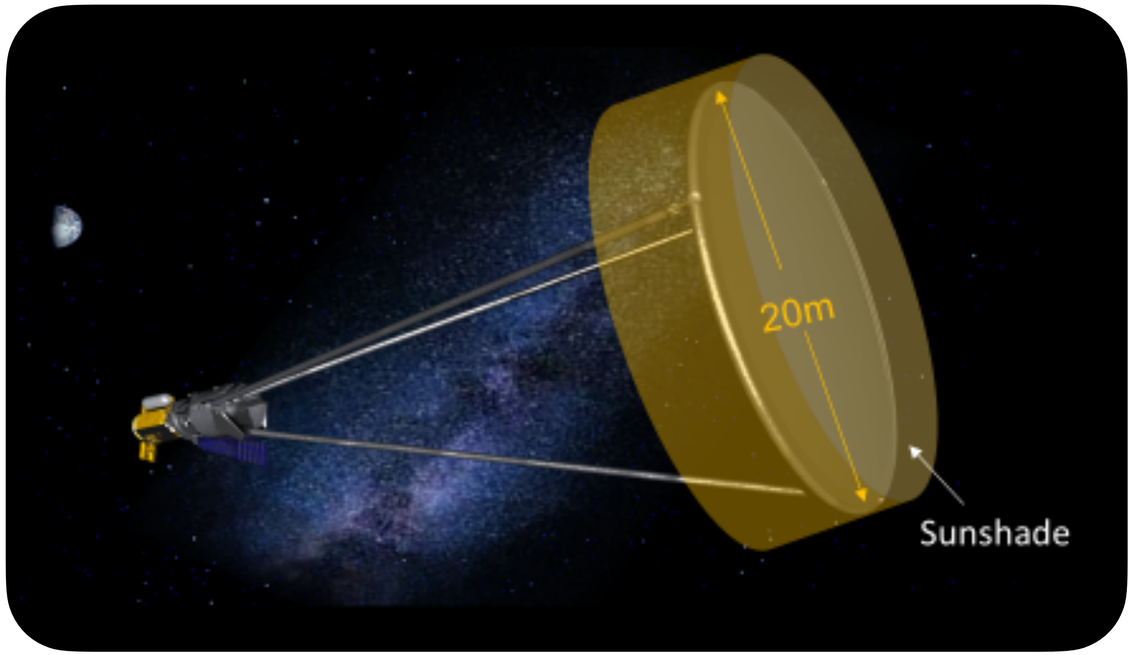


SALTUS

Single **A**perture **L**arge **T**elescope for **U**niverse **S**tudies

PI: Chris Walker (Goddard)

European contact: Peter Roelfsema

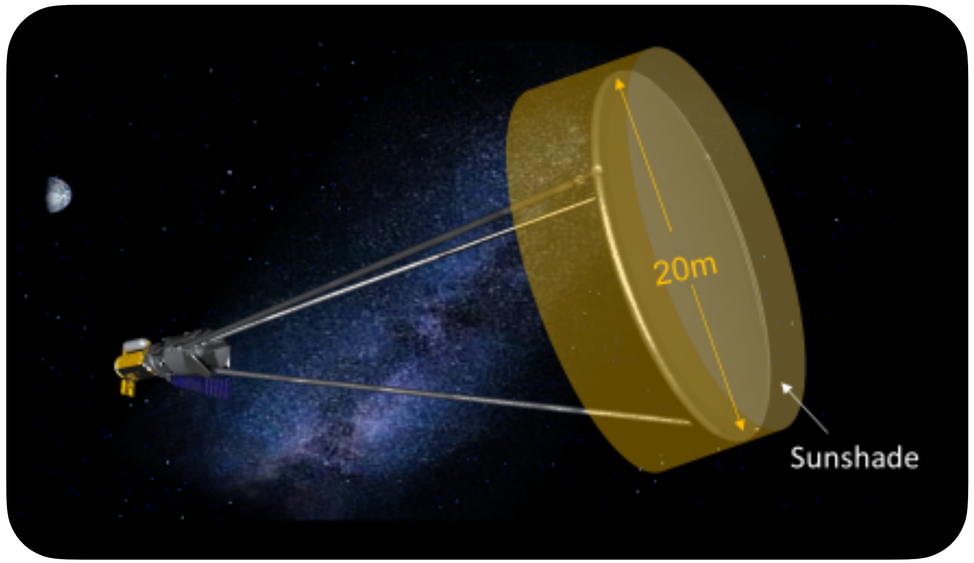


SALTUS concept

Contact in Europe:

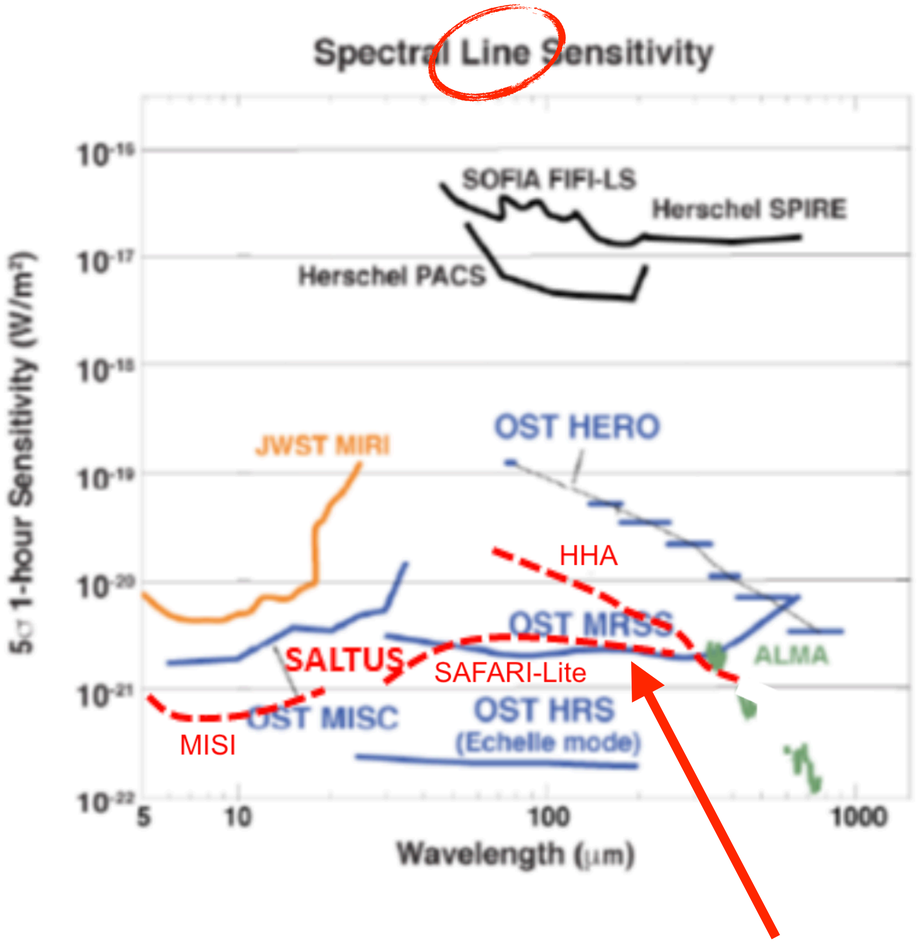
Peter Roelfsema

- 20m
- 45K Optics
- Coherent & Incoherent Spectroscopy/Imaging
- Adaptive Optics
- 1mm — ~3um
- EHT Space node
- 5 years Baseline Mission



Exoplanets — Solar System — Habitability during planet formation — Protoplanetary disks — Galactic feedback from black holes & stars — Formation and transport of dust and metals — Dust, metals and the first stars at cosmic dawn

SALTUS instruments



Mid-IR Spectroscopic Imager (MISI)

- ~3 — 13um
- R = 64 — 600

SAFARI-Lite

- 30 — 300um (4 bands)
- R = 300

HEB Heterodyne Array (HHA)

- 60 — 300um (4 bands)
- R = 10^5—10^6

SIS Heterodyne Array (SHA)

- 520 — 650um (ISM Spectroscopy; Polarization)
- 870 — 1300um (EHT)
- R = 10^5—10^6

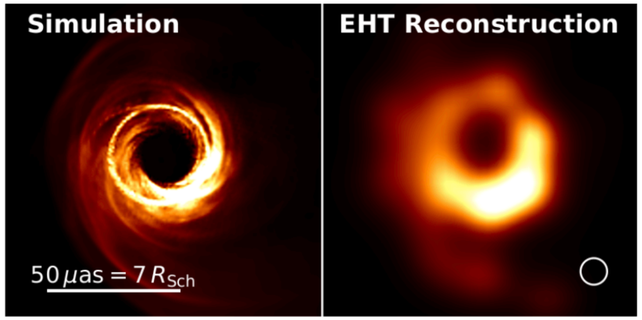
SALTUS microarcsecond VLBI

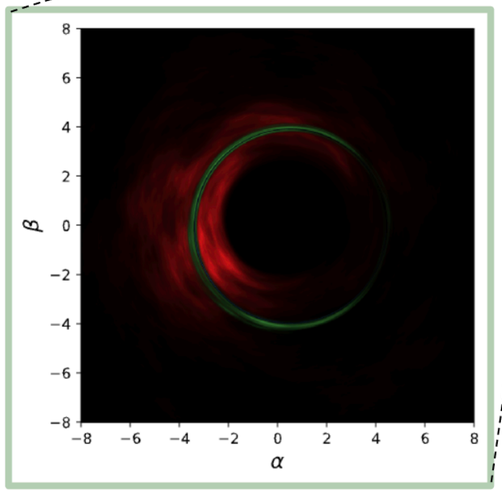
Dan Marrone: dmarrone@arizona.edu

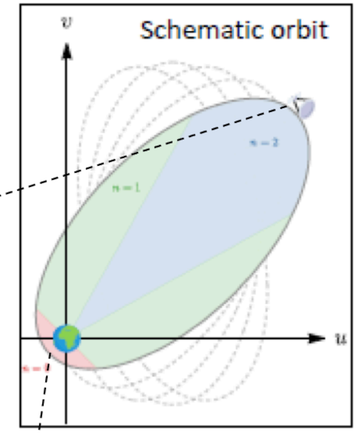
SALTUS Microarcsecond VLBI

Extending mmVLBI to space enables science far beyond EHT

- Near apogee: BH mass census
  Using angular diameters (~M/D) to weigh black holes across the universe







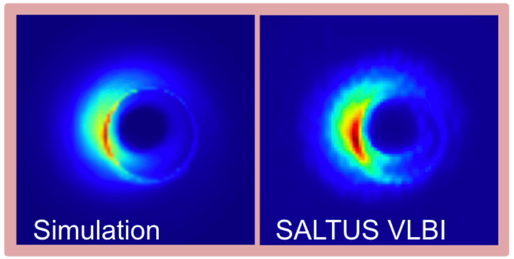
LO Timing?
- USO
- Maser

Data Back?
- Laser Comms
- Big Antenna

- Inbound/outbound: Precision GR test via lensed photon ring

Gralla, Lupsasca, and Marrone 2020
https://doi.org/10.1103/PhysRevD.102.124004

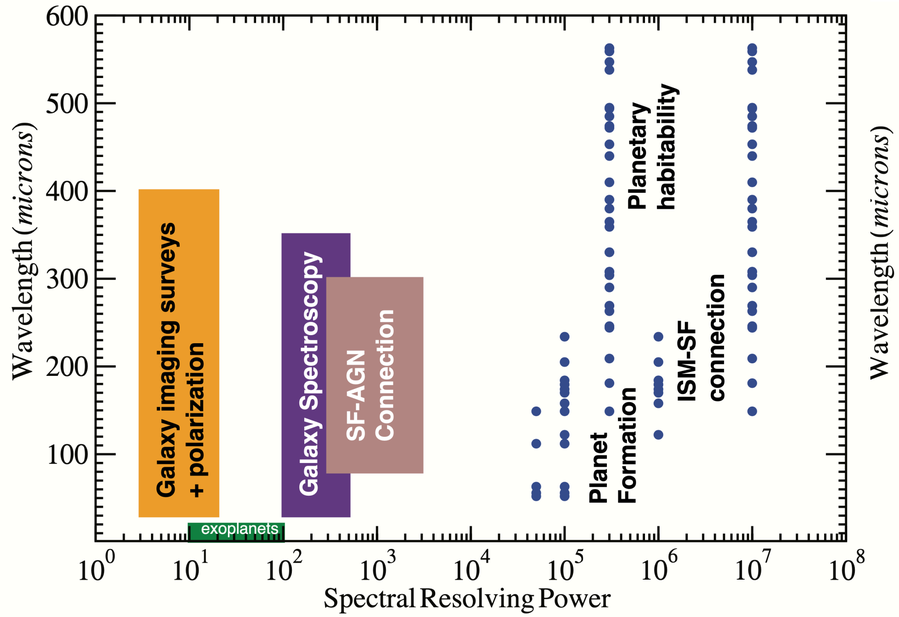
- Perigee: Exploring accretion and jets with BH movies at 5x EHT resolution

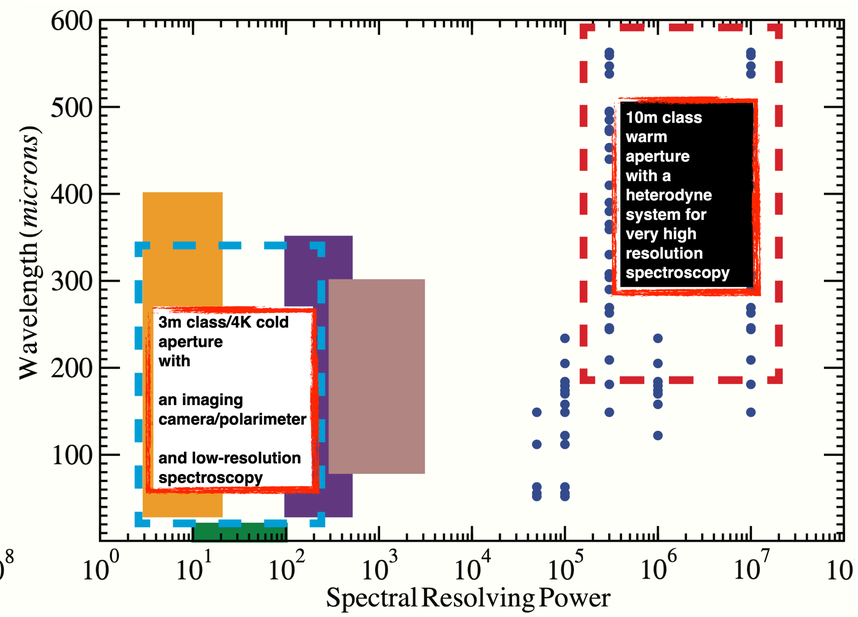


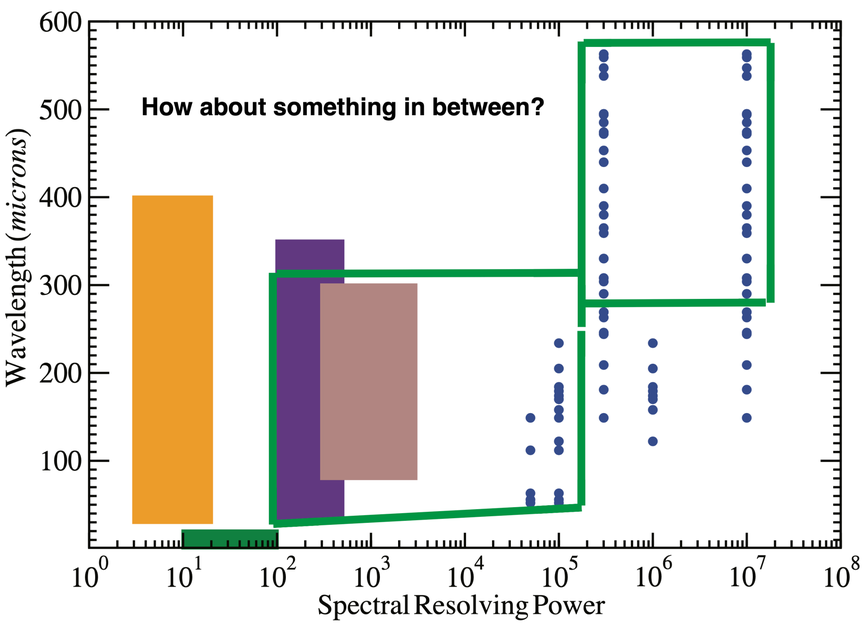
JOHNS HOPKINS APPLIED PHYSICS LABORATORY

FIRSST

Far-IR Spectroscopy Space Telescope





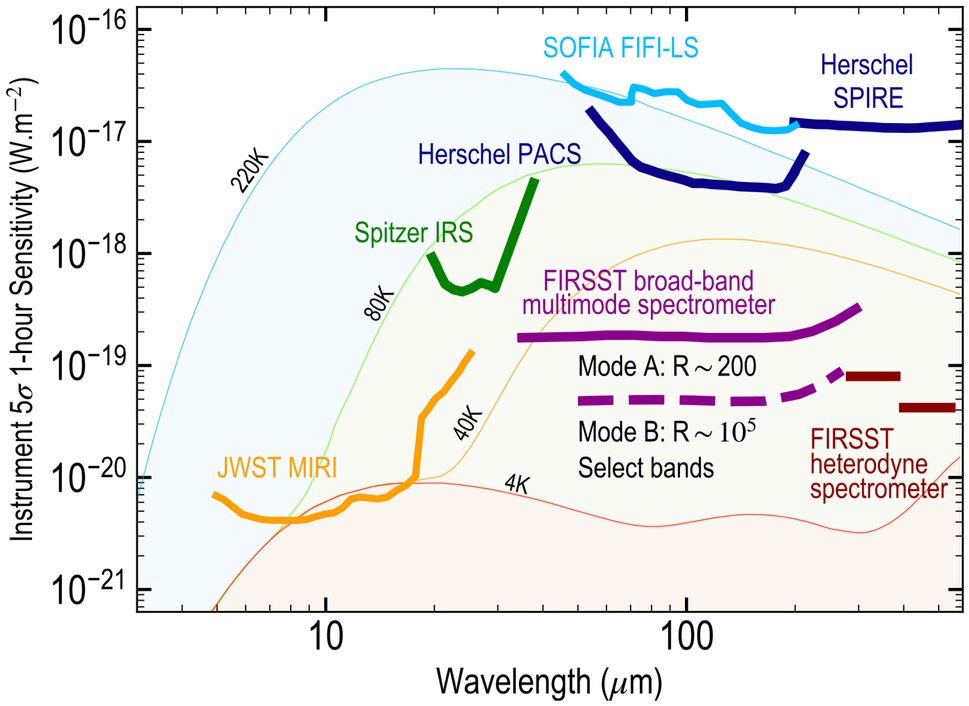


PI: Asantha Cooray

French contact: Martina Wiedner

FIRSST at a glance

- Low-risk Spitzer-like architecture
- 1.5m class aperture, actively cooled
- >98% community-led science + GTO to science/instrument teams
- 5 year science mission operations



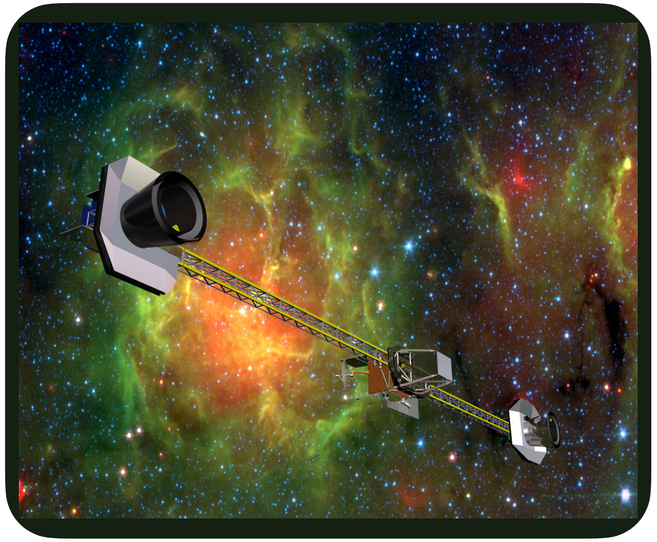
- 30 — 270um, R=200 spectroscopic mapping
- 50 — 250um, R=10^5 (3 km/s) spectroscopic mapping on selected bands (optimized for planet formation, habitability, galaxy outflows)
- 270 — 560um simultaneous point source R=10^6—10^7 (<1km/s) spectroscopy

Origin and evolution of planet-forming disks — trail of water from molecular clouds to oceans — Mass assembly of galaxies

~~SPIRIT~~ SPICE

SPace **I**nfra**R**ed **I**nterferometric **T**elescope

- 25 – 400um, R > 3000 in each spatial resolution element
- Angular resolution 0.3 (λ/100um) arcsec
- Dense *u-v* plane coverage for high quality imagingIntegral field spectroscopy over a 1 arcmin FOV
- Sensitivity 10 μJy continuum; 10^{-19} W m^{-2} spectral lines
- Single scientific instrument (“double Fourier” beam combiner)

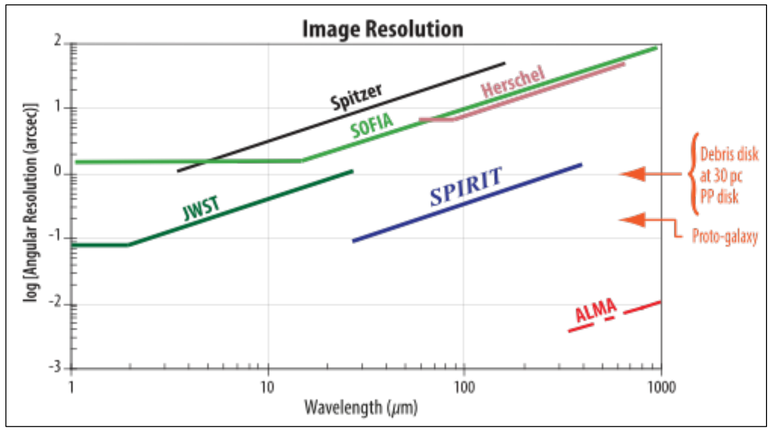


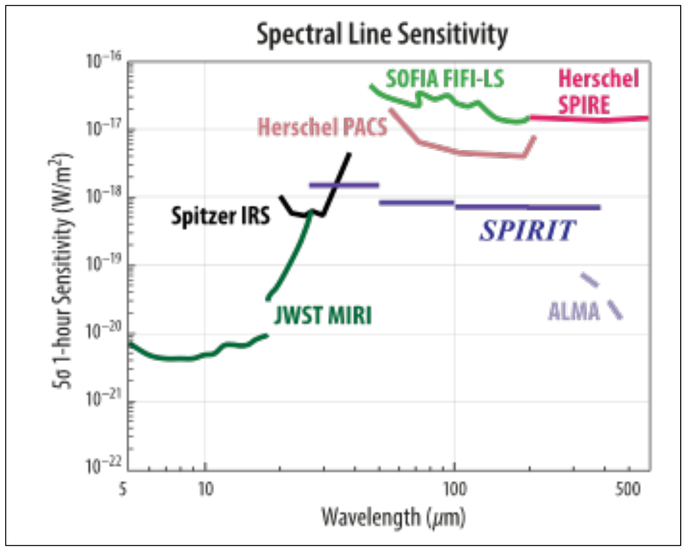
PI: Dave Leisawitz

French/European contact: ?

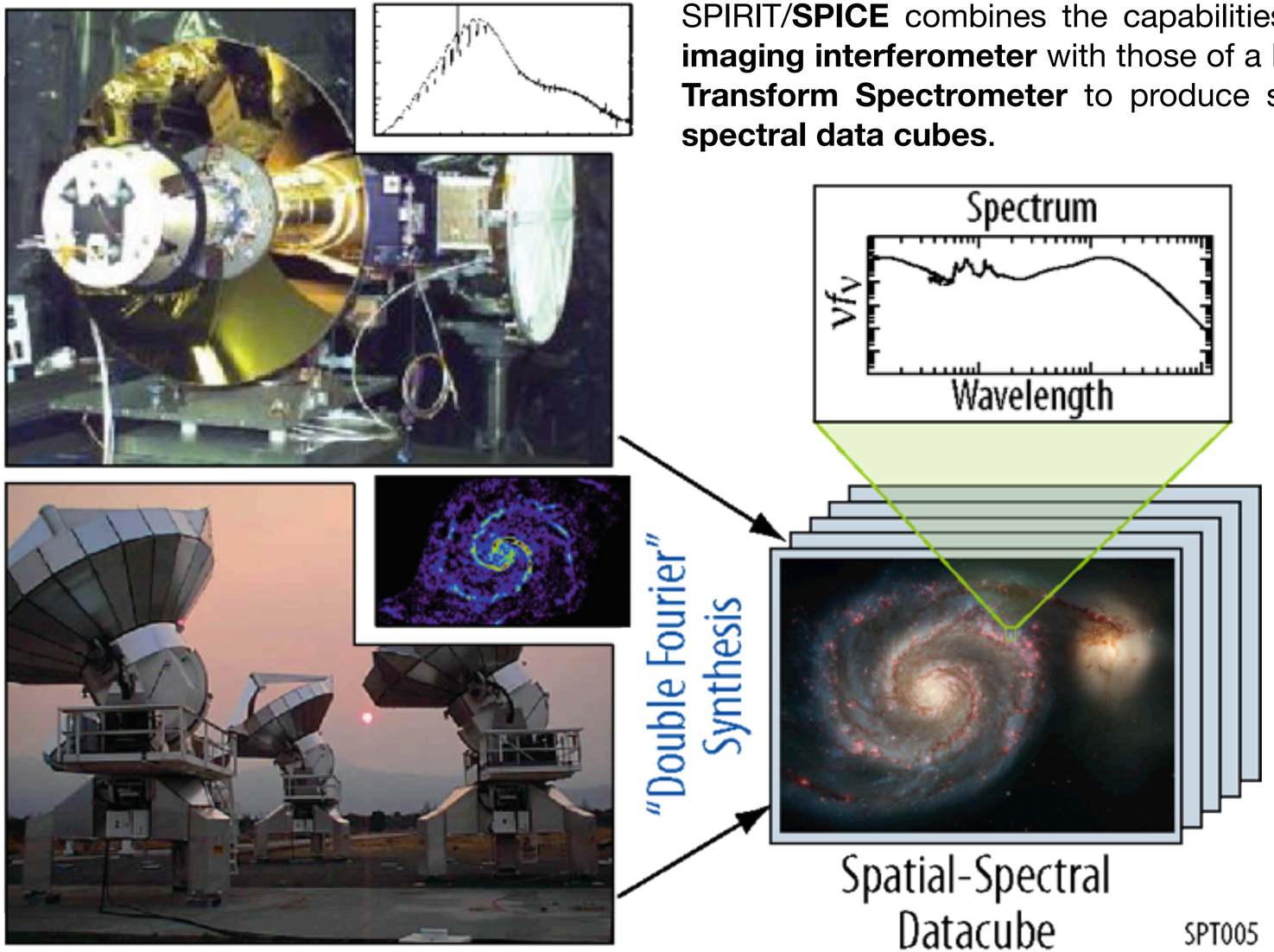
Galaxy formation and evolution — Protoplanetary disks and planet formation — Debris disks and planetary system architecture

SPICE at a glance





SPIRIT/**SPICE** combines the capabilities of an **imaging interferometer** with those of a F**ourier Transform Spectrometer** to produce s**patial-spectral data cubes.**



More information on IR NASA probes

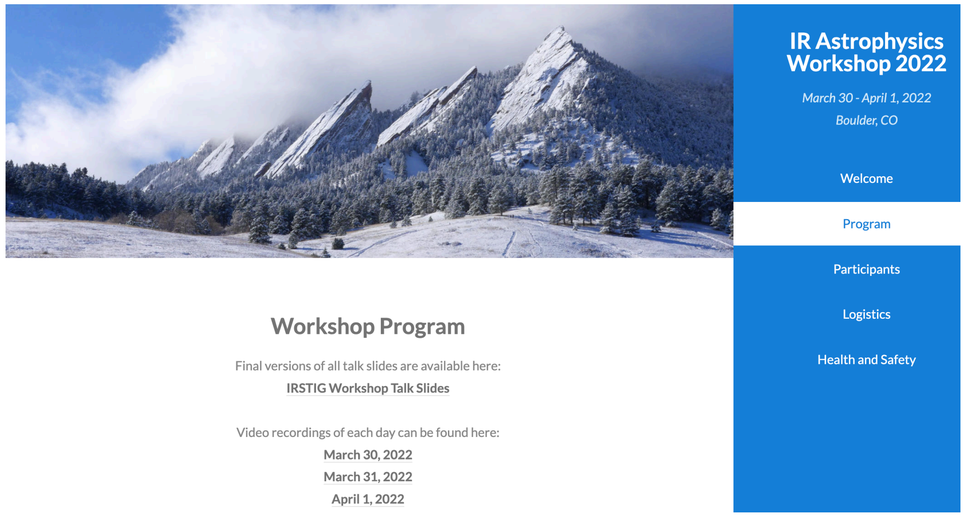
PRIMA: Denis Burgarella, Laure CIESLA

FIRSST: Martina Wiedner

SALTUS: Peter Roelfsema

SPIRIT/SPICE: …

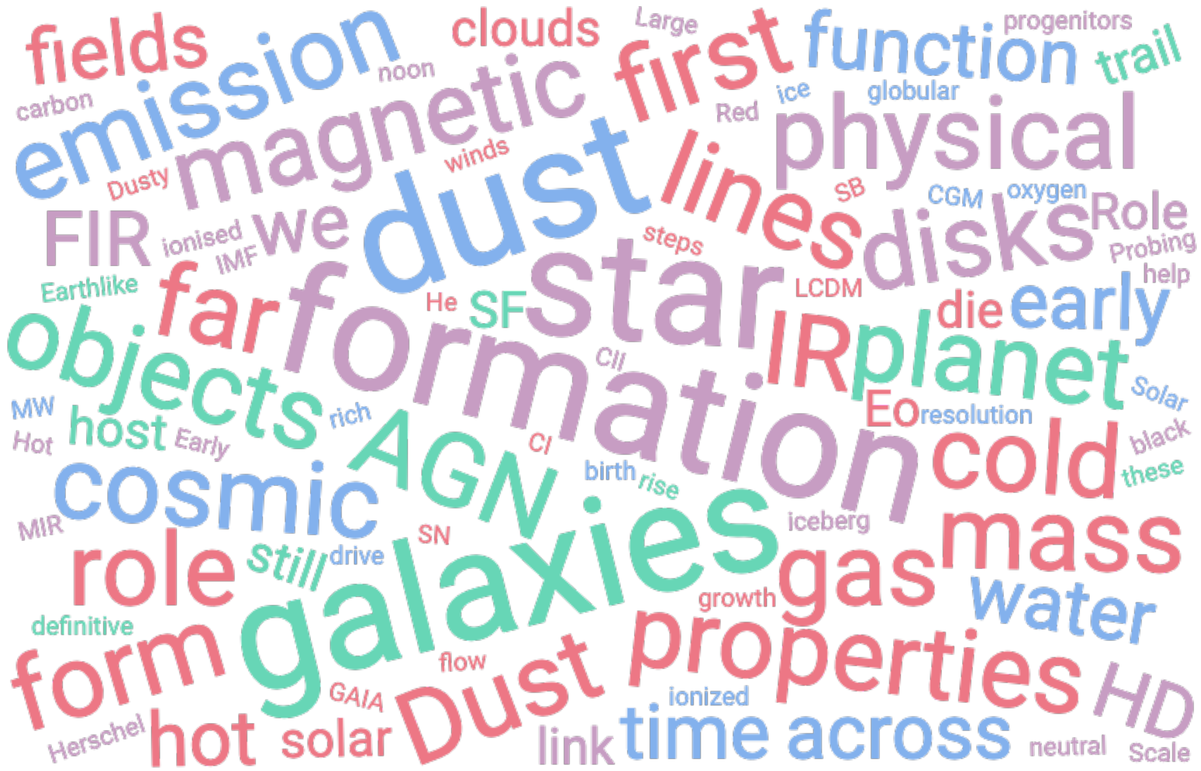
https://casa.colorado.edu/~mema5817/irworkshop_program.html



What about ESA?

As a result of the M7 first selection: no IR mission, only LiteBird (CMB experiment in mm)

ESA contribution to a NASA IR probe: very unlikely



Informations provided in this talk on the probes mostly date from April 1st 2022

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Where do the answers come from?

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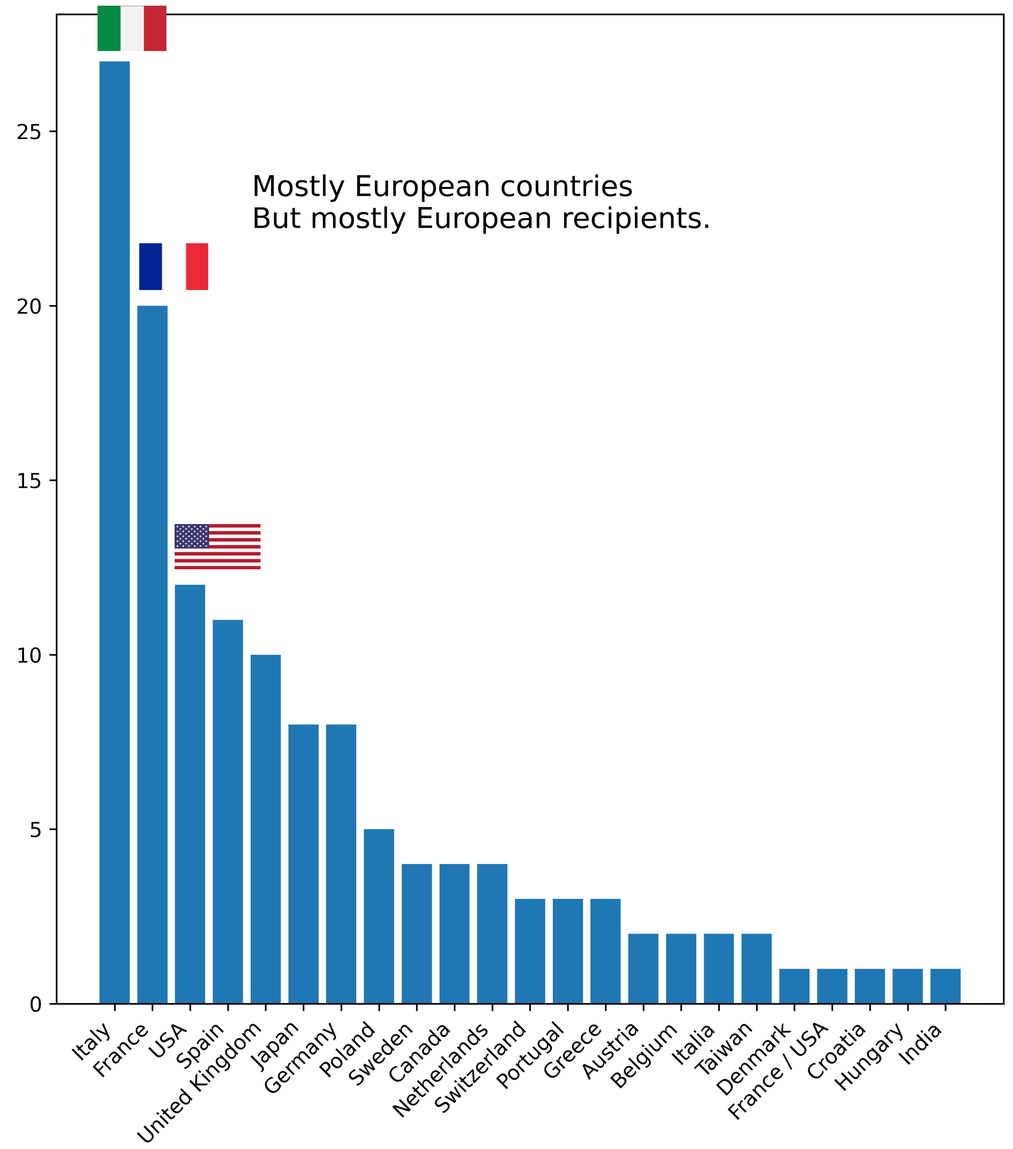
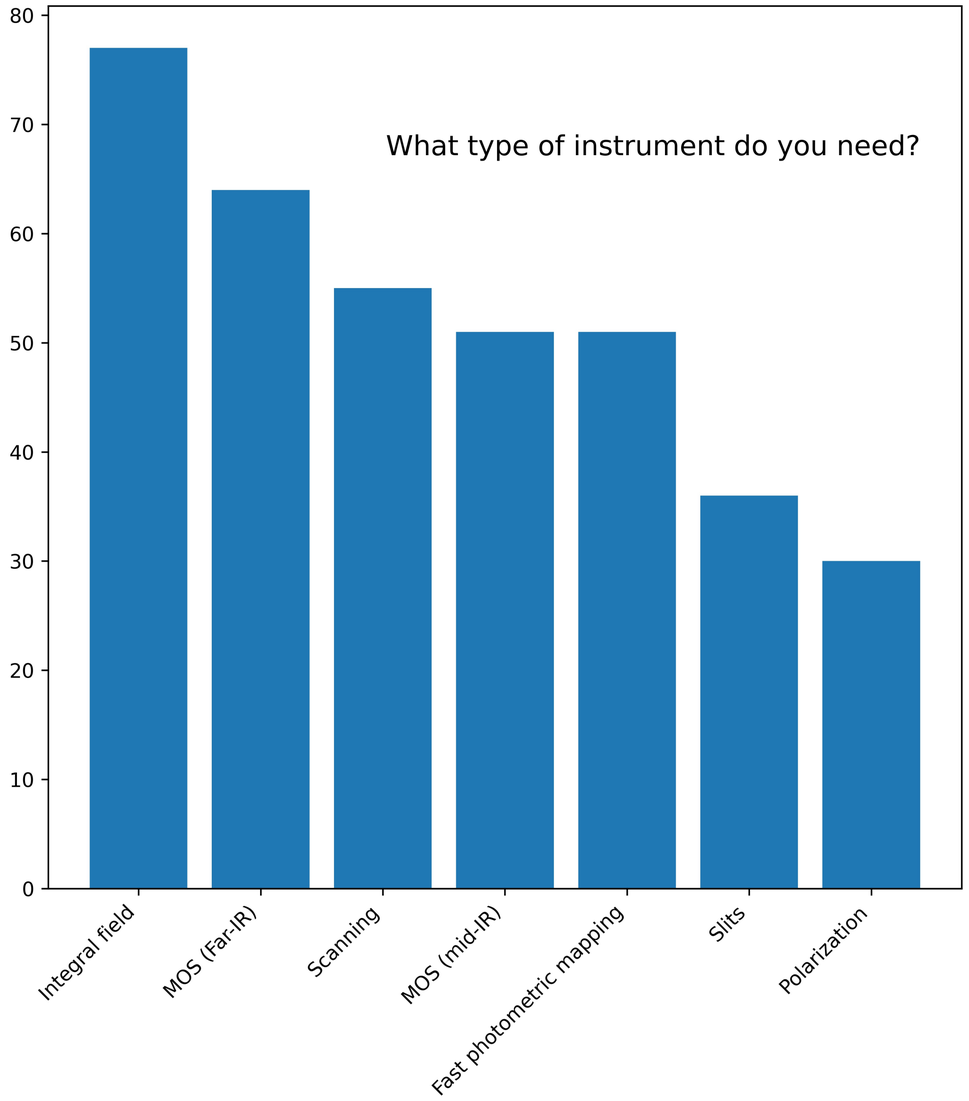


Infrared community survey

Type of data

within those available in the poll

Heterodyne spectroscopy was mentioned in the comments



SALTUS instruments: SAFARI-Lite

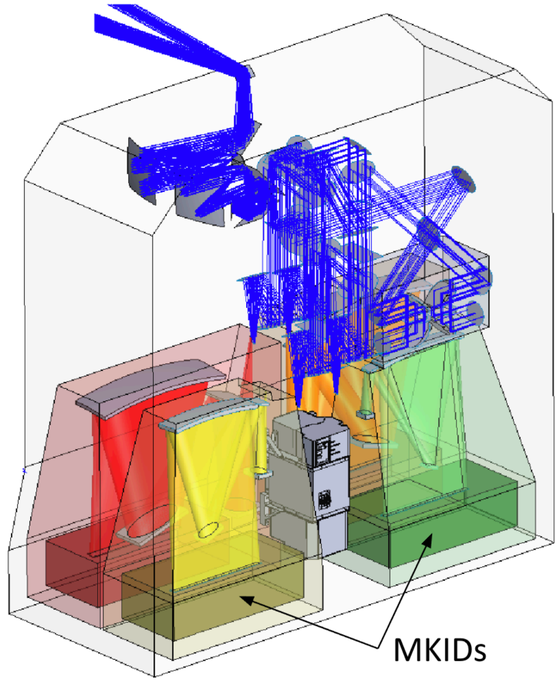
SAFARI-Lite

Roelfsema+18

Table 2 SAFARI performance summary.

Band	SW	MW	LW	VLW
λ range	34-56μm	54-89μm	87-143μm	140-230μm
high R	11700-7150	7400-4500	4600-2800	2850-1740
nom. R	300	300	300	300
FWHM	4.5"(0.6“)	7.2"(1.1“)	12"(1.8“)	19"(3“)
Point source spectr. 5σ-1hr flux limit (10^{-20} Wm^{-2})				(3“)
high R	13	13	13	15
nom. R	7.2	6.6	6.6	8.2
Mapping spectr. 1'×1' 5σ-1hr flux limit (10^{-20} Wm^{-2})				
high R	189	113	73	51
nom. R	84	49	30	23
Mapping phot. 1′ × 1′ 5σ-1hr flux density limit (μJy)				
	209	192	194	239
5σ conf.	15	200	2000	10000

high R - high resolving power mode; μm
$R \sim 11000$ at 34 to $R \sim 1500$ at 230 μm
nom. R - nominal resolving power; $R \sim 300$
5σ conf. - 5σ confonfusion limit



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SRON
Netherlands Institute for Space Research