The SAltus FARIr spectrometer

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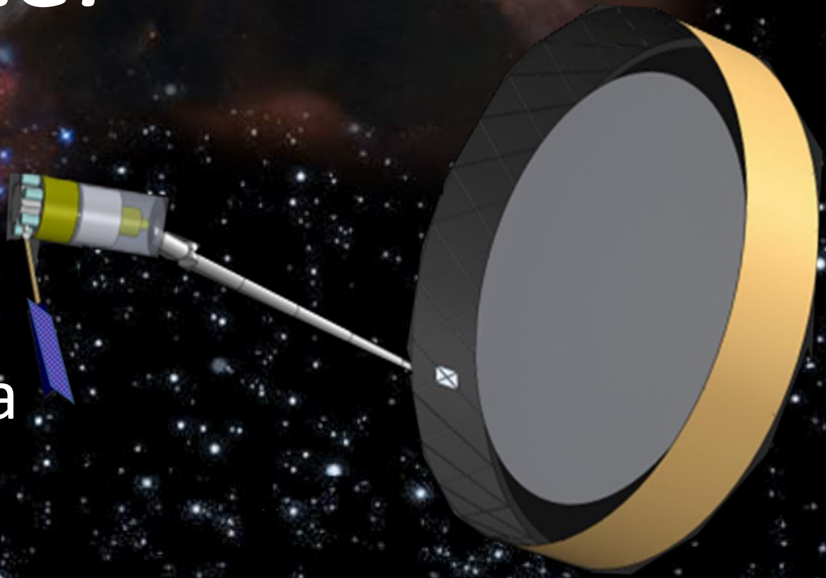

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Netherlands Institute for Space Research

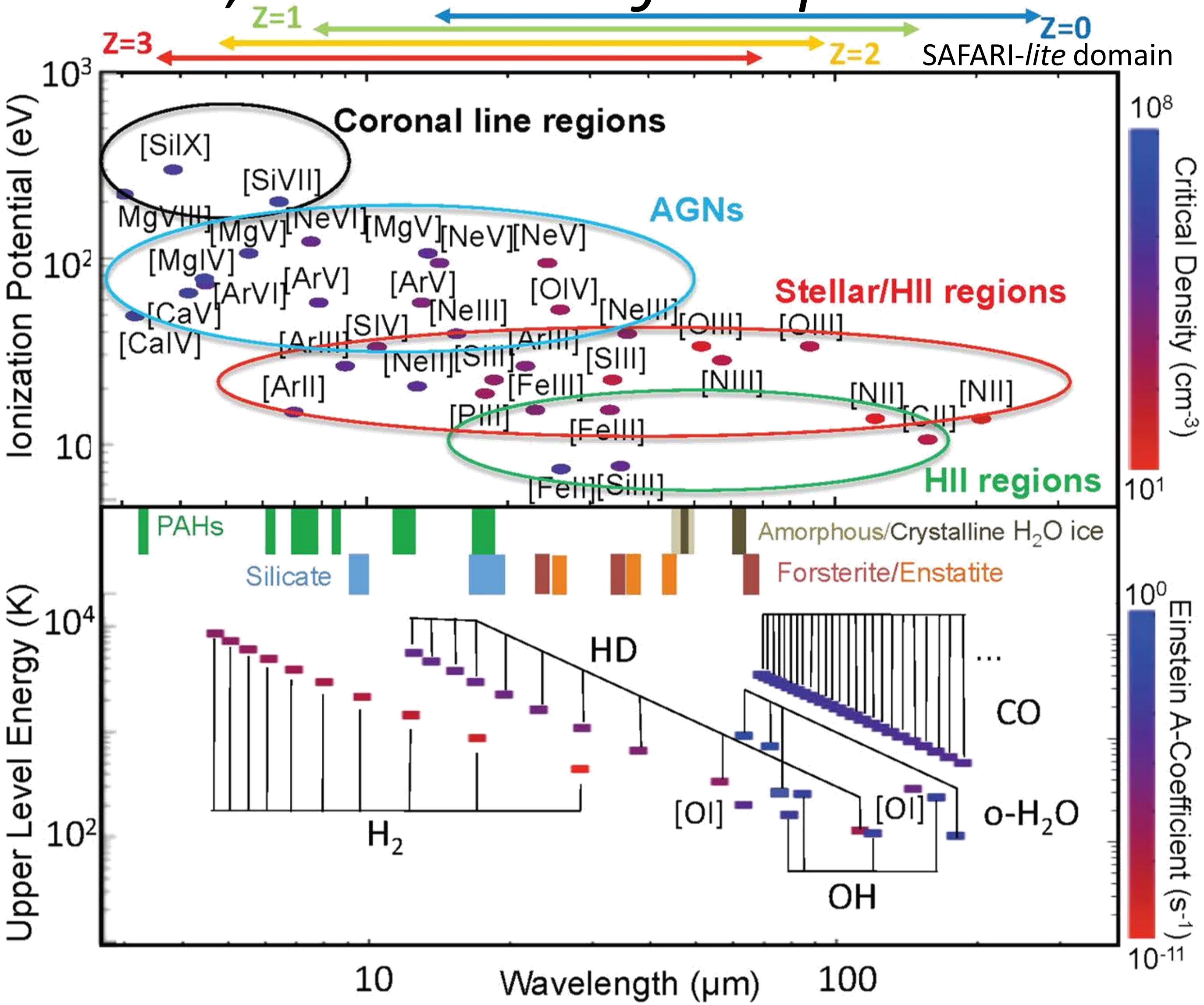
Netherlands Organisation for Scientific Research

Introduction

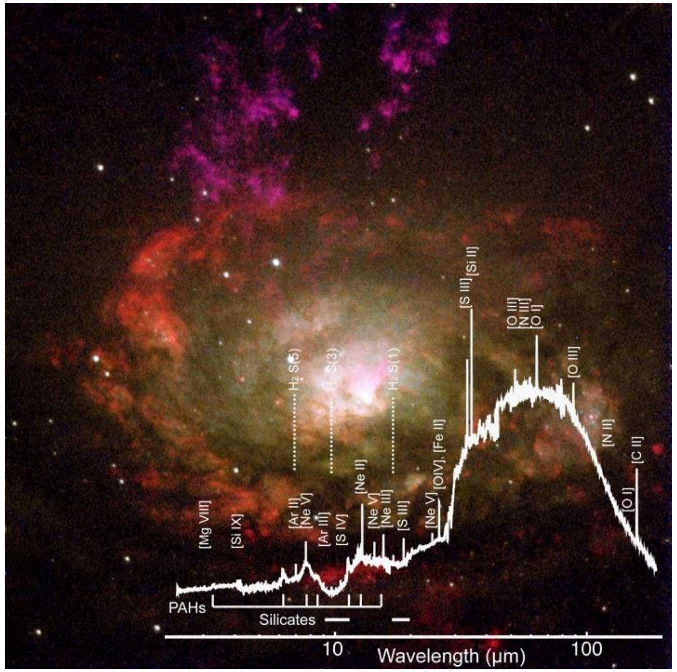
- Why again the Far-IR? – borrowing heavily from SPICA/SAFARI
  - Unveil the hidden universe
  - Spectroscopy yields physical understanding
- SAFARI-*lite* concept

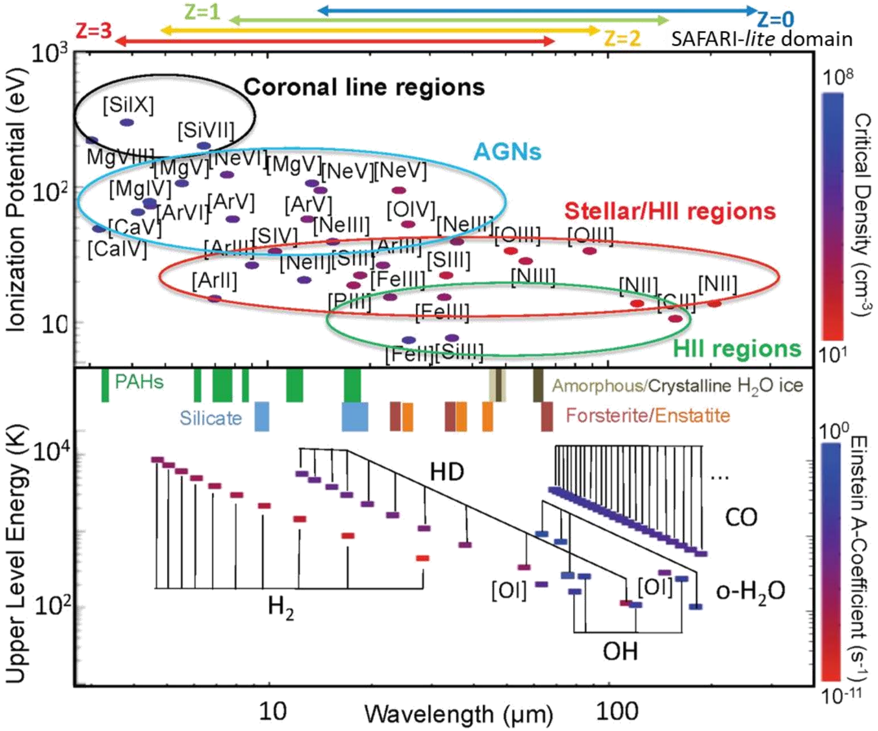
  a 'lite' version of SPICA/SAFARI; no high R mode, and KIDs i.s.o. TESs
  - 35-240 mu grating spectroscopy at R~300
- Getting it built
  - Who can do what?
- Challenges
  - Building a SAFARI-*lite* consortium
  - The timeline
  - Convincing the community

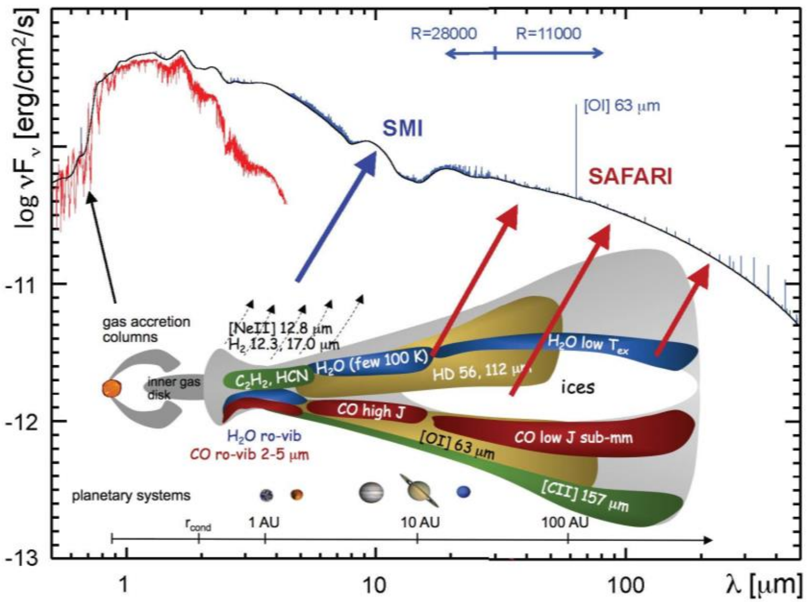
Why again IR?;... *loads of important lines!*

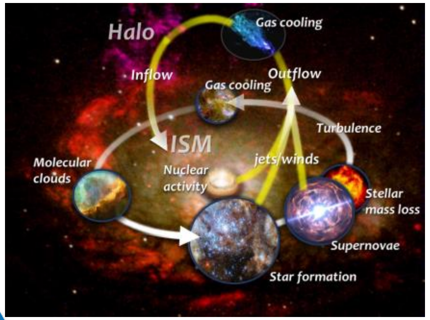


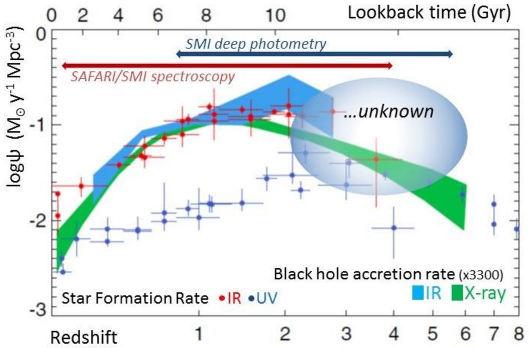
Why again IR?;... *loads of important science!*

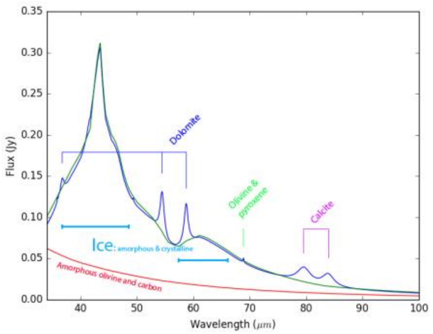


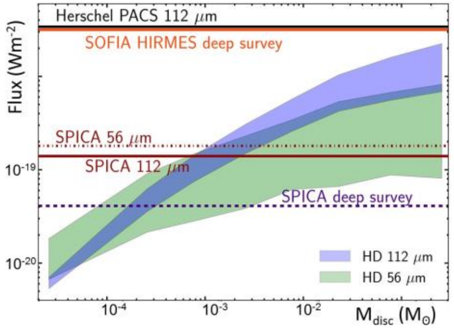












SAFARI-*lite*

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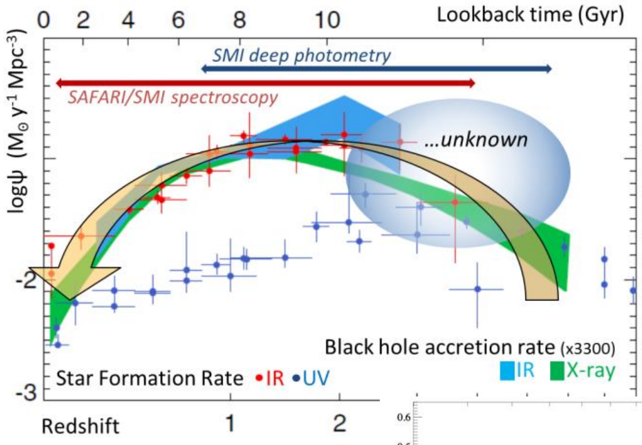
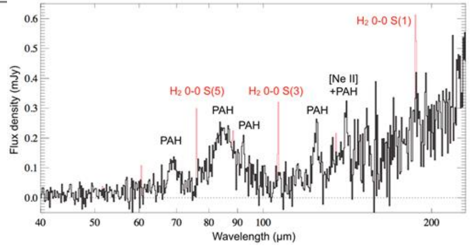
Science Objectives – design drivers

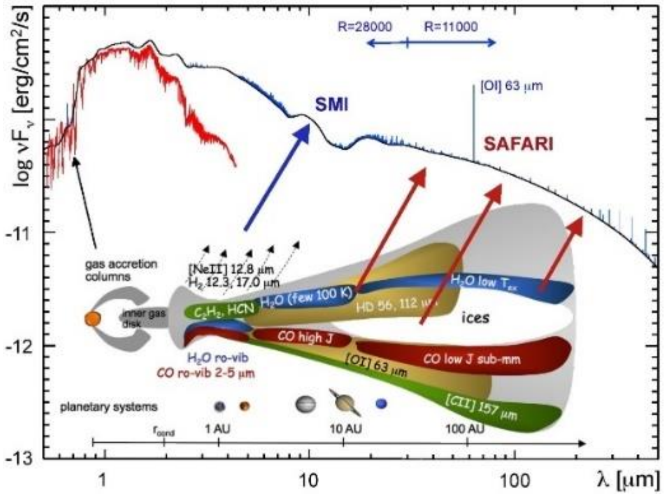


- What processes govern **star formation across cosmic time**
  - What starts it, controls it, and stops it?
  - What are the major physical processes in the most obscured regions of the universe?
  - What is the interplay between these processes and the enrichment of the universe with metals
  - Trace all these properties for **'average' (L*)** galaxies



- What is the **origin** and composition of **the first dust**, how does this relate to present day dust processing?

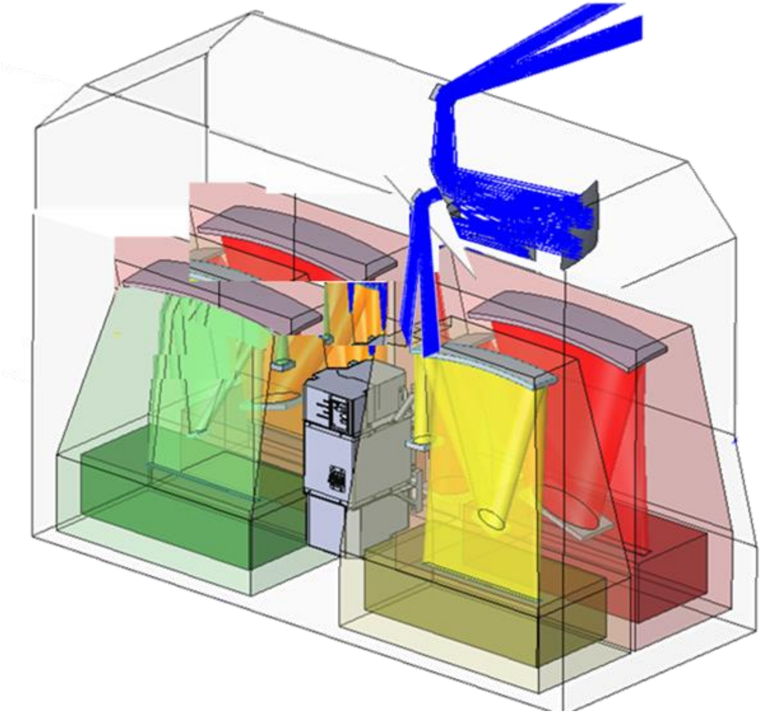
- What is the thermal and chemical **history** of the **building blocks of planets** – connecting planet forming systems with **our own solar system**
  - Establish the disk mass distribution to very low mass
  - Trace the snow lines
  - Follow the evolution of ices and minerals

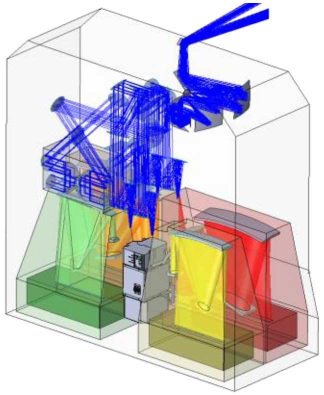


The SAFARI-*lite* instrument - overview

Far-IR grating spectrometer optimized for point source staring observations

- 4 bands in the 35-240 µm domain, co-aligned on sky
  - Lower edge limited by KID technology
  - Instantaneous contiguous coverage
- Interlaced KID arrays provide R~300 after processing
  - ~180 pixels in spectral direction
  - TBC 6-10 pixels in spatial direction
- Sensitivity 5 σ /1hr: ~ 5 $\times 10^{-20}$ W/m^2
- Warm electronics
  - Instrument power, monitoring and control
  - Detector control and read-out
- Observing modes
  - Point source staring mode
  - (small) raster maps
  - TBC on-the-fly mapping
  - ‘continuum’ measurements by averaging spectral channels





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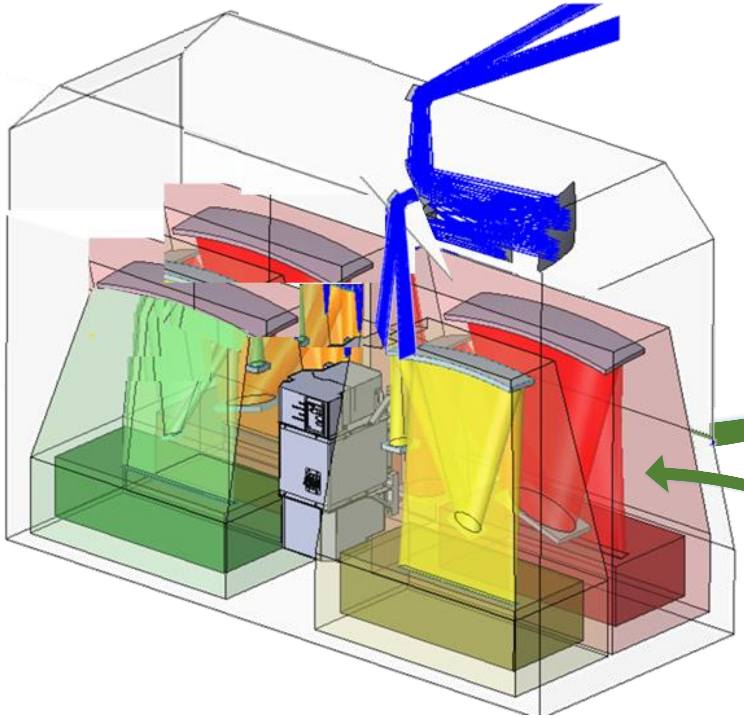
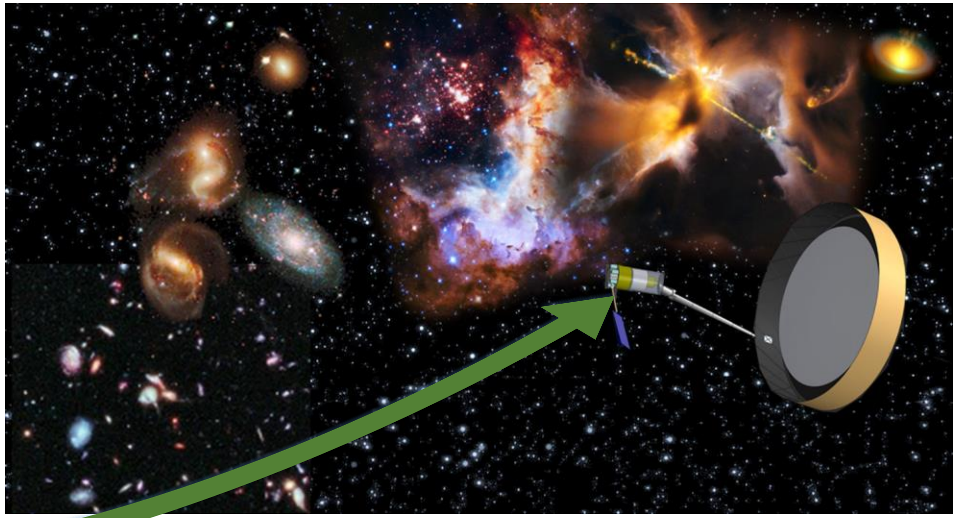
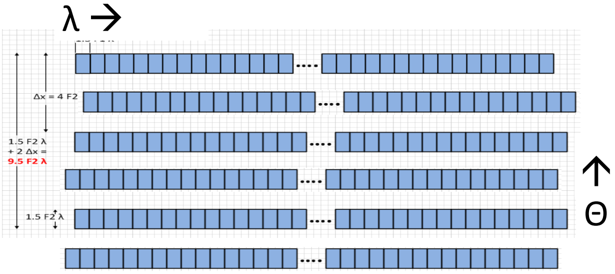
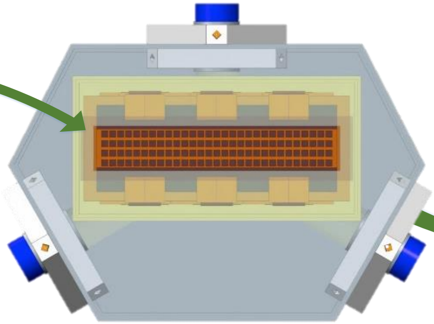
Focal Plane Unit (at ~4.5K)
all 4 bands co-aligned on-sky



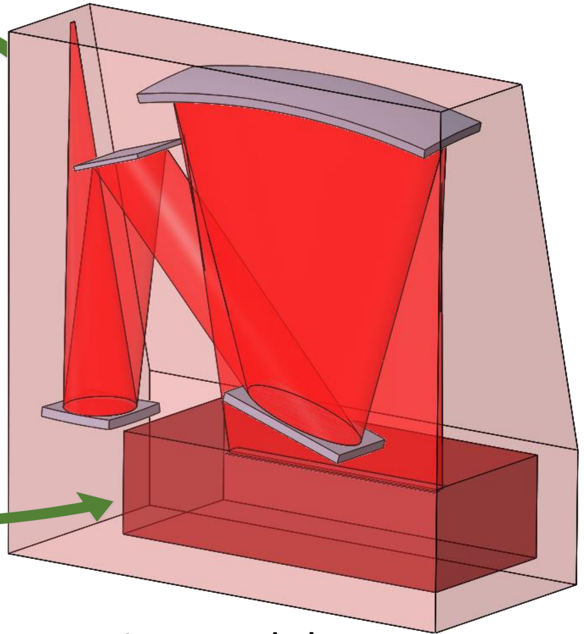




Detector arrays (100mK)



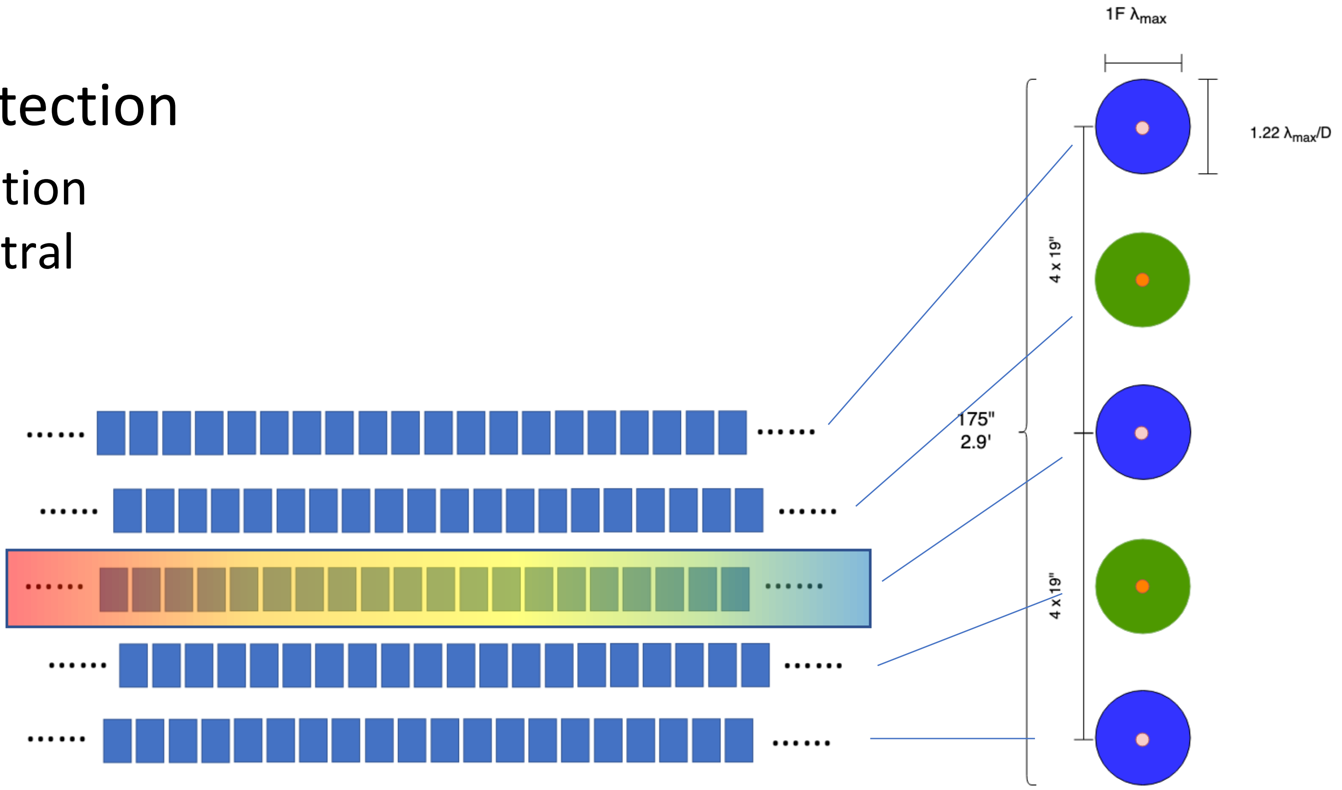
Detector assembly (50/300mK)



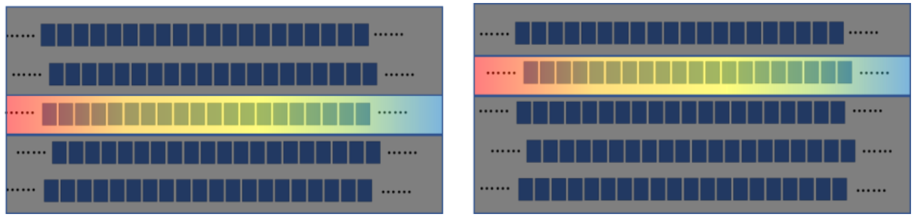
Grating module (1.8K) – one for each band

An N-pixel point source optimized spectrometer

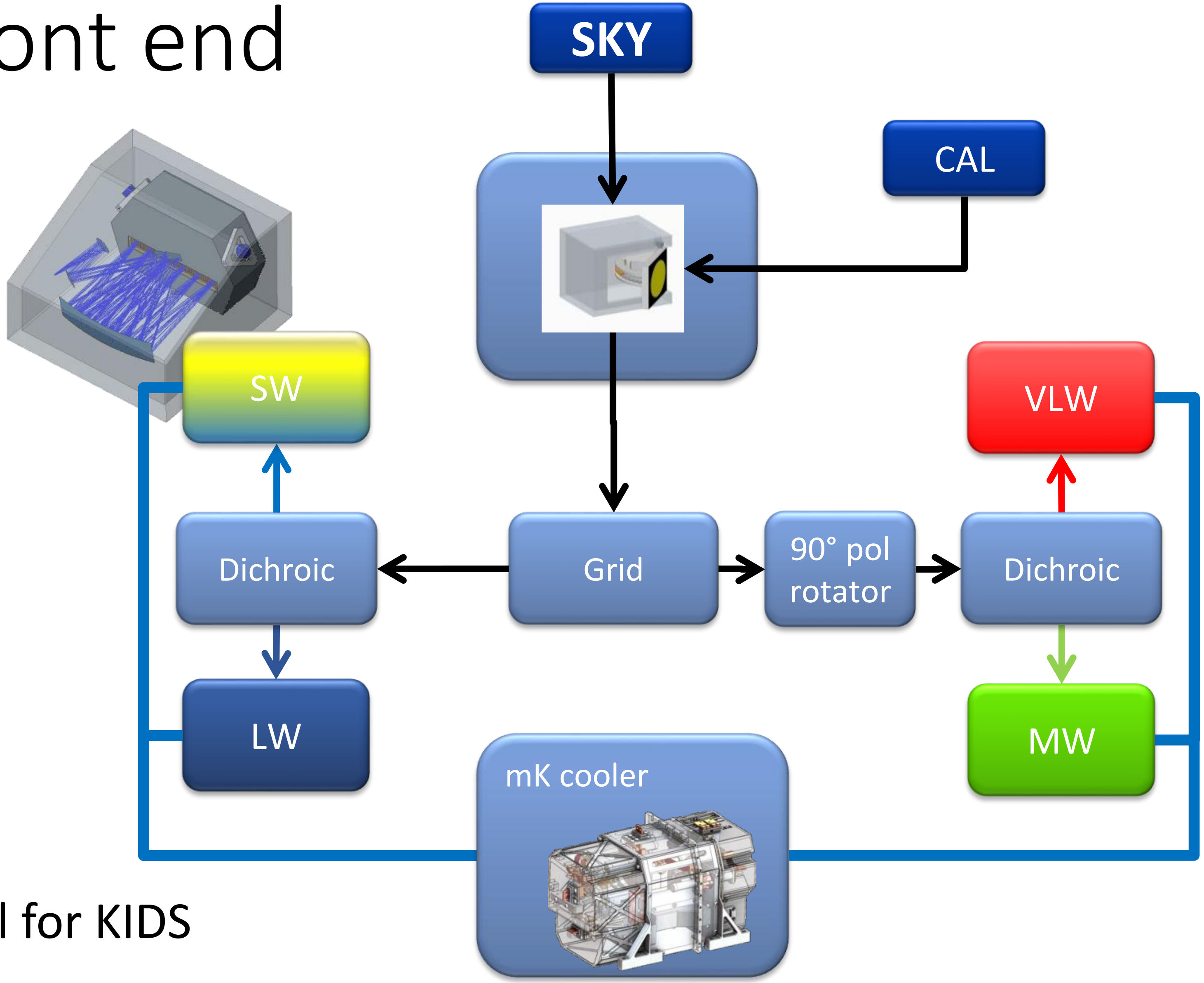
- System optimized for point source detection
  - Basic design: all pixels see the same position
  - Green/orange: arrays offset by half spectral resolution element in grating module.



- Per grating
  - N arrays → spatial
  - ~180 pixels per array → spectral
  - Odd arrays offset by ½ pixel
  - Grating disperses on one array
  - Pixels sample grating resolution @ 1 pix/R
  - R300 ~Nyquist sampling achieved by chopping and combining 2 neighbor arrays
  - Remaining pixels provide measure for background



System design – front end

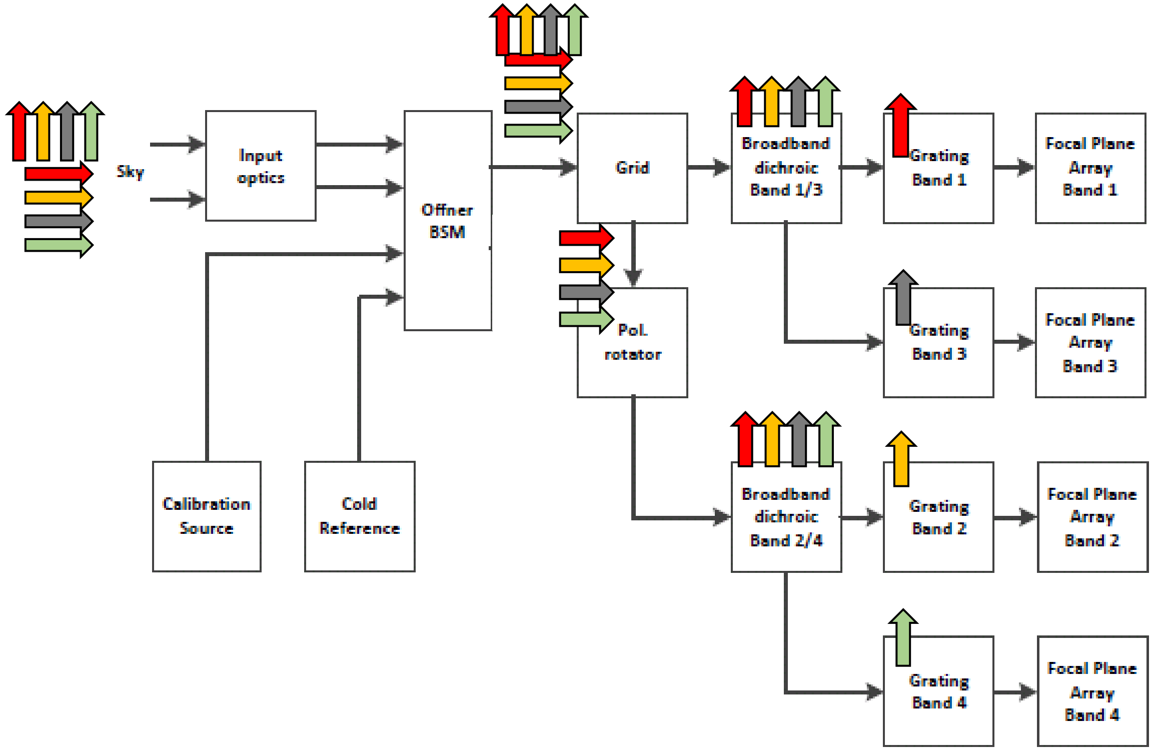


- Input selected with chopper
  - Internal calibrator
  - Sky – sky-background
- 4 grating modules
  - Grid + dichroics to crate bands
- Interlaced KID arrays
  - ~180 pixels in spectral direction
  - 6 pixels in spatial direction
- mK cooler provides 100mK level for KIDS

Optics – band selection

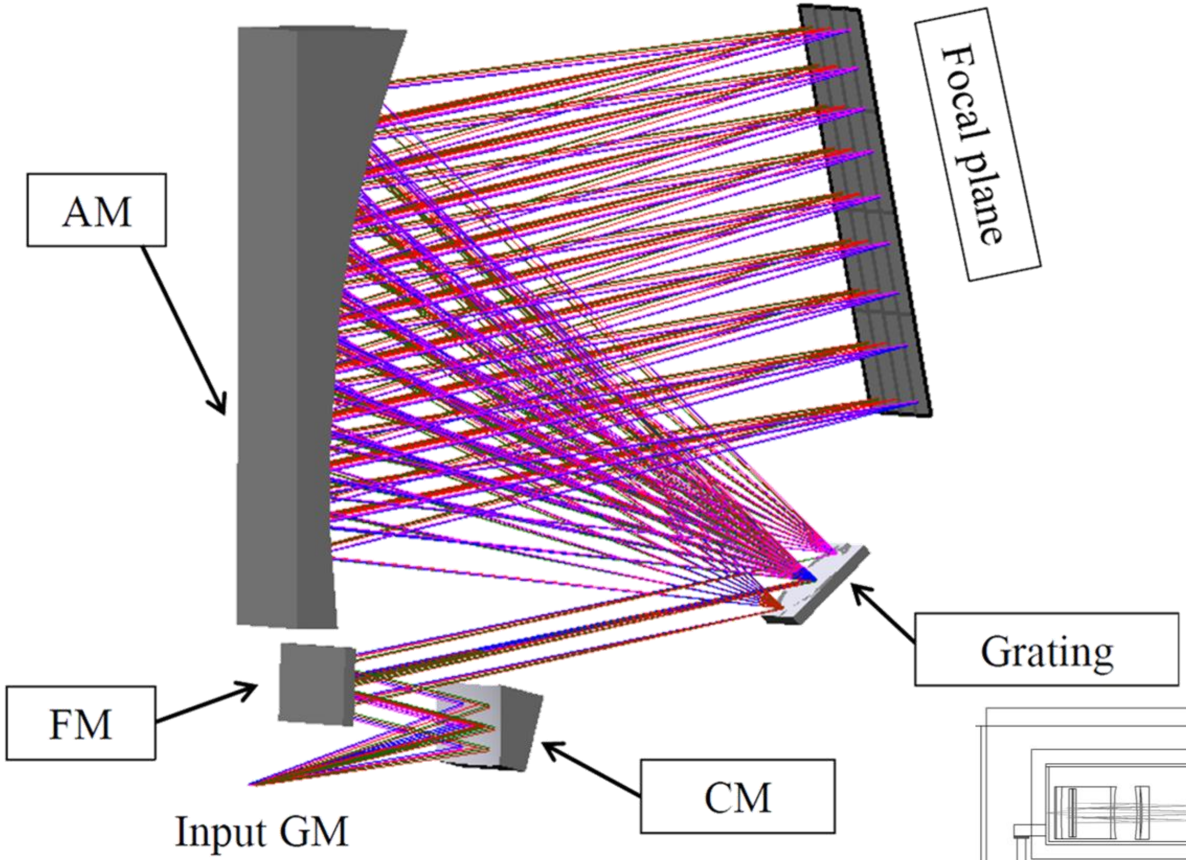
High incidence gratings → instrument is effectively single polarized

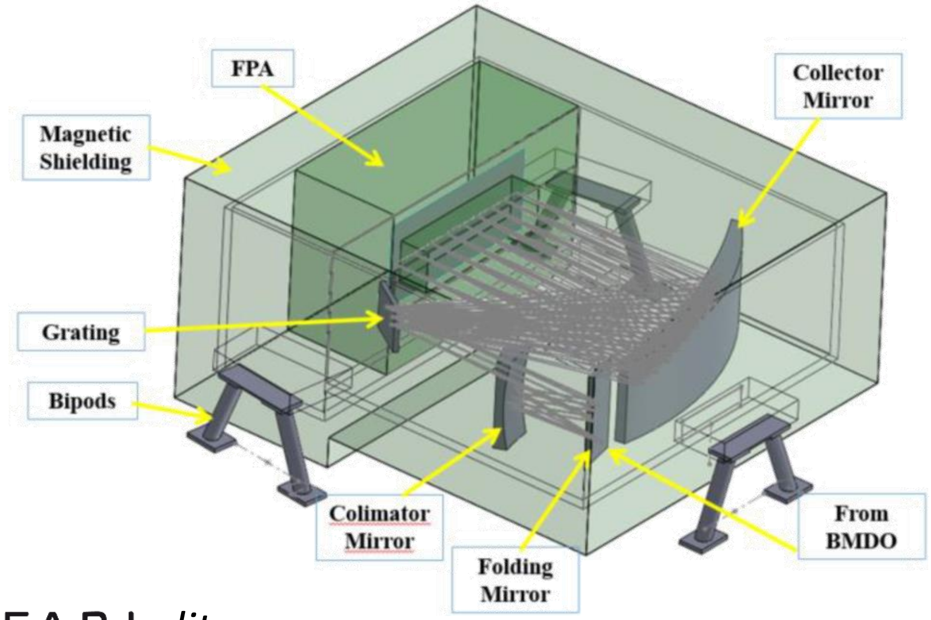
- Allows use of grid for band splitting → no gaps between bands

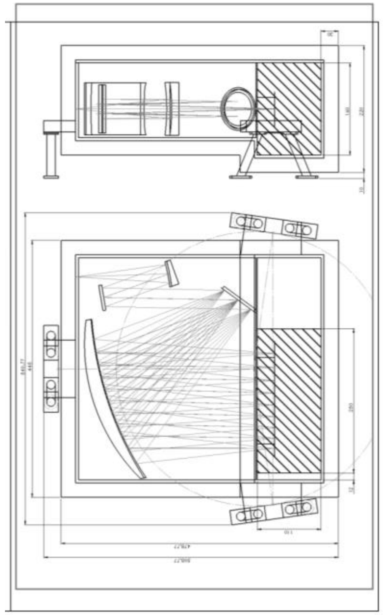


Grating module – 5K

- Dispersive optics
- Focal Plane Assembly
- Shielding
- Re-use SAFARI-design

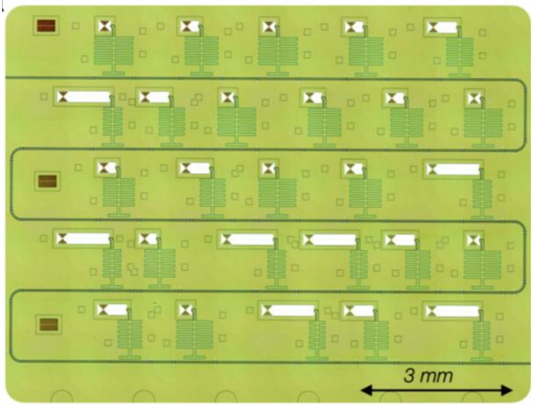


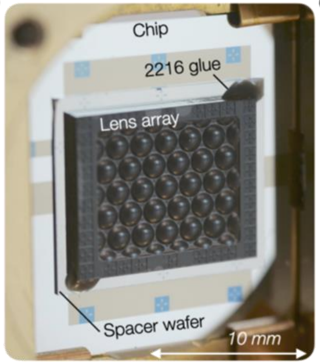


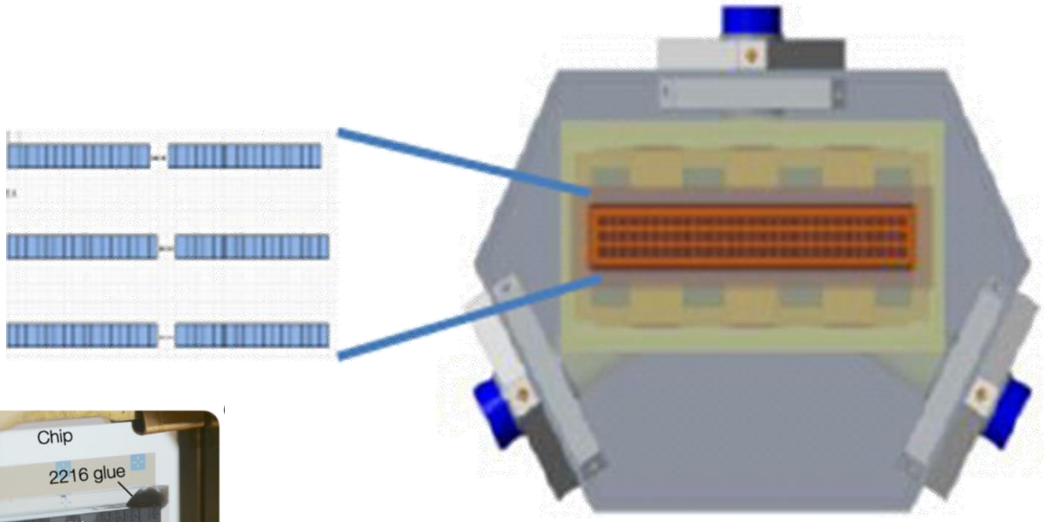


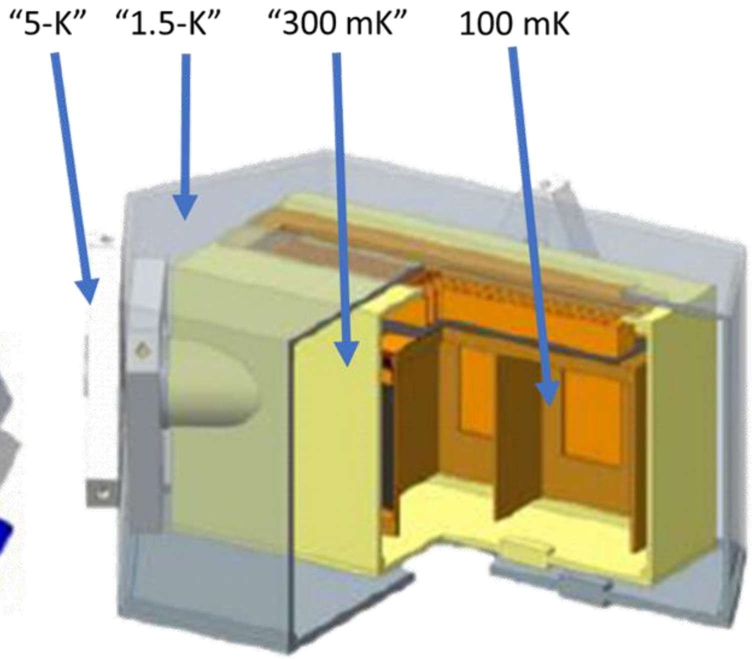
Focal Plane Assembly

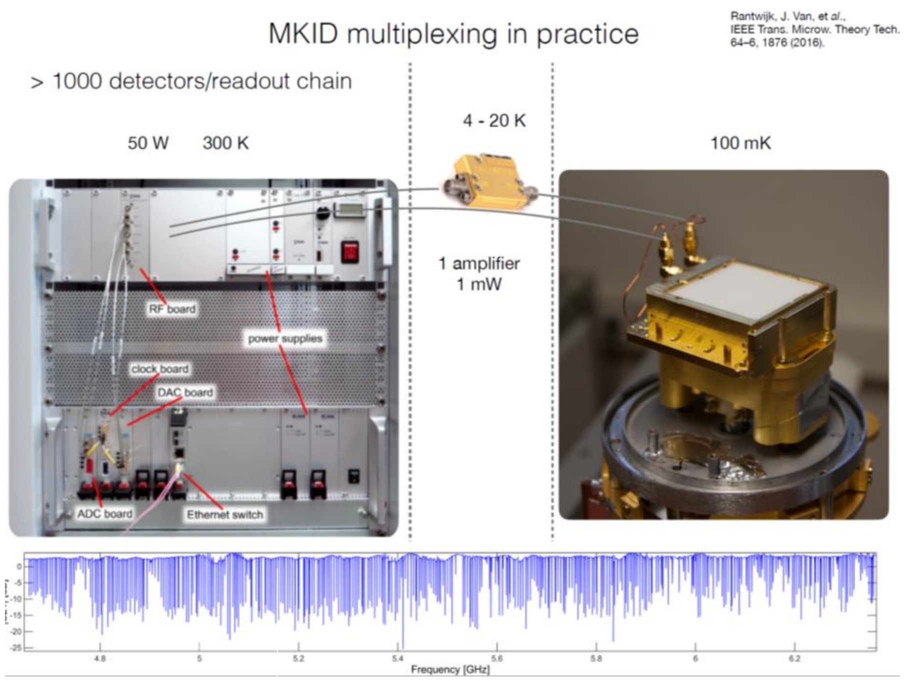
- KID arrays with lenses and readout at 100mK
- Several temperature between 5K and 100mK
  - Actual levels still TBC





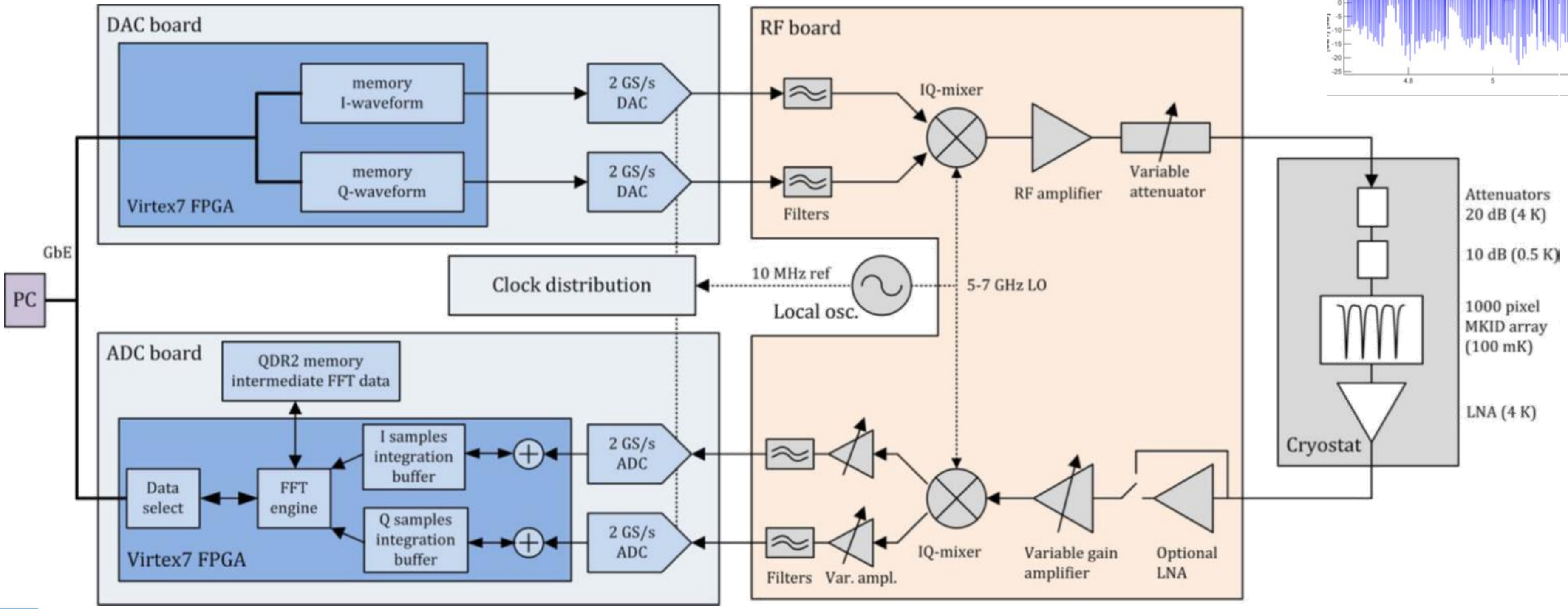






System design – back-end

- Multiplexing to reduce number of wires
  - KID multiplex ~1000 pixel/channel
  - Digital control for multiplex/demultiplex signals
  - Well established technology – implemented in FPGA



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Ballpark SAFARI-*lite* sensitivity

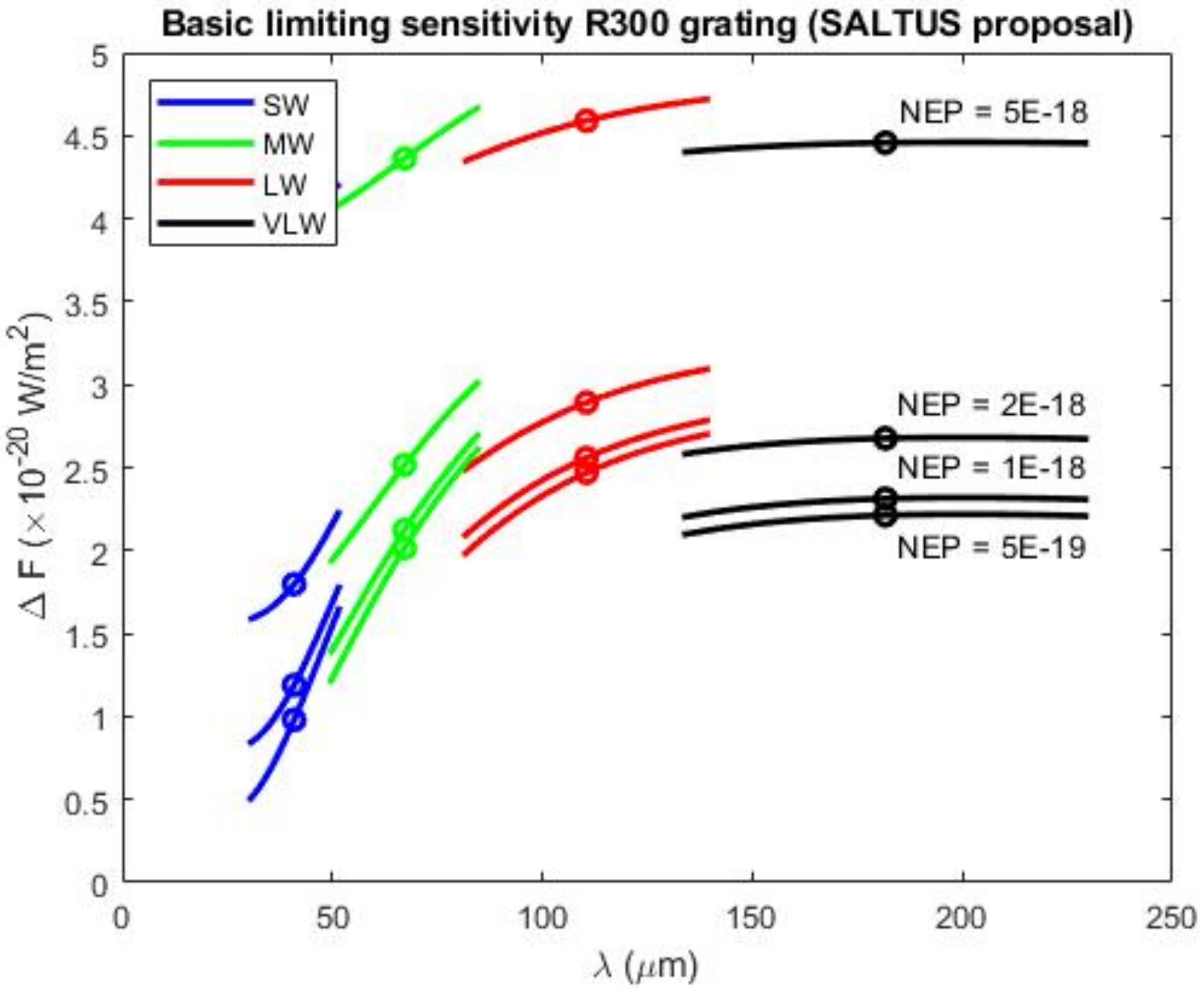
Based on SAFARI performance model

- Telescope 20 mtr, 45 K
- Realistic filters, stops, grating etc.
- Single polarization
- Detectors $5 \times 10^{-19} - 5 \times 10^{-18}$ W/√Hz
- Dithered array with ~180 pixels

  → effective R~300

→sensitivity of few × 10^{-20} W/m²

- Telescope background photon noise limited
  → better detectors don't help (anymore)



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Ballpark SAFARI-lite sensitivity – mapping

Using SPICA/SAFARI band configuration and with 8 spatial pixels:

- For 1 $arcmin^2$ mapping line flux sensitivity is a few times 10^{-18} Wm^{-2} 5σ/1hr
- Averaging over the bands allows ‘photometry’ at a 5σ/1hr broadband sensitivity level of 1.2 mJy
- In this broadband photometry mode, the Hubble Deep Field could be imaged at a 1mJy level in about 20hrs

	Waveband			
	SW	MW	LW	VLW
Band centre / µm	45	72	115	185
Range / µm	34-56	54-89	87-143	140-230
Band centre beam FWHM	0.46”	0.74”	1.2”	1.9”
Point source spectroscopy – R300 (5σ-1hr)				
Limiting flux / x10^{-20} Wm^{-2}	5	5	5	5
Limiting flux density / µJy	230	360	580	930
Mapping spectroscopy* - R300 (5σ-1hr)				
Limiting flux / x10^{-19} Wm^{-2}	46	29	18	11
Limiting flux density / mJy	21	21	21	21
‘Photometric’ mapping* - R1 (5σ-1hr)				
Limiting flux density / mJy	1.2	1.2	1.2	1.2
Confusion limit (5σ)	…	…	…	…

* Mapping performance is for a reference area of 1 $arcmin^2$

SAFARI - *lite*

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Getting SAFARI-*lite* built – a BIG job

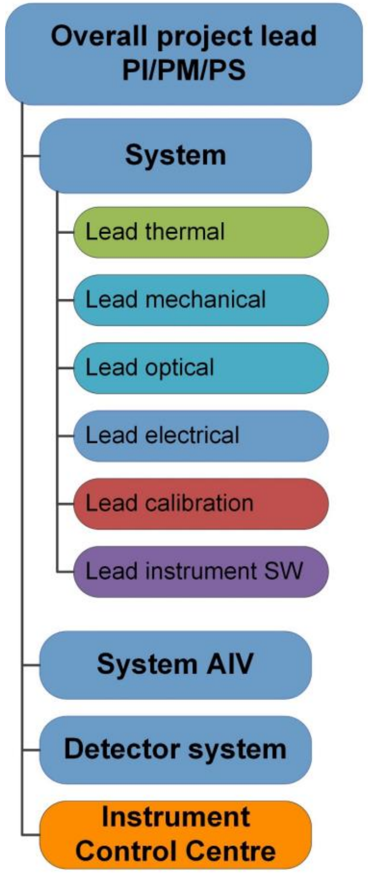
- Consortium needs to be set up
  - System lead institute; PI, PM
  - Sub unit suppliers
    - FPAs, grating modules, 5K structure, cooler, filters, dichroics, chopper, warm electronics…
  - System AIV program and test facilities
  - Organization (and financing)

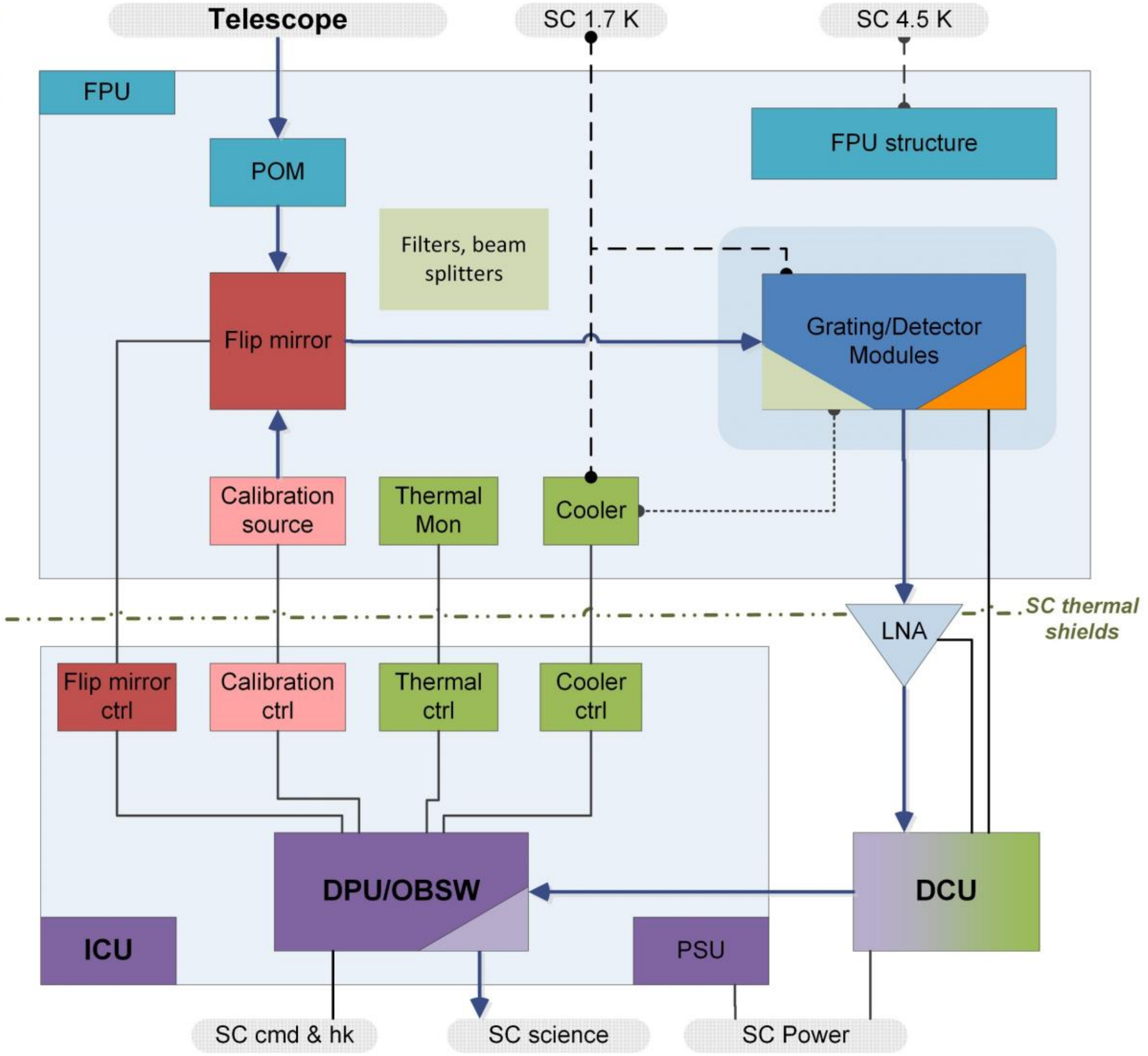
- For the proposal
  - Conceptual design
  - TRL approach, risk assessment
  - Description and supporting documentation
  - Consortium agreements

‘SAFARI-lite’ consortium partner tasks

Allocation of responsibilities

- Re-use of SPICA/SAFARI experience
- Based on specific expertise in various institutes
- Some institute leads have already indicated (strong) interest and/or commitment for these roles
    - France, Austria, Spain, Belgium, Taiwan, Switzerland
- Discussions/negotiations on-going





SAFARI-*lite* organization

Phase 0

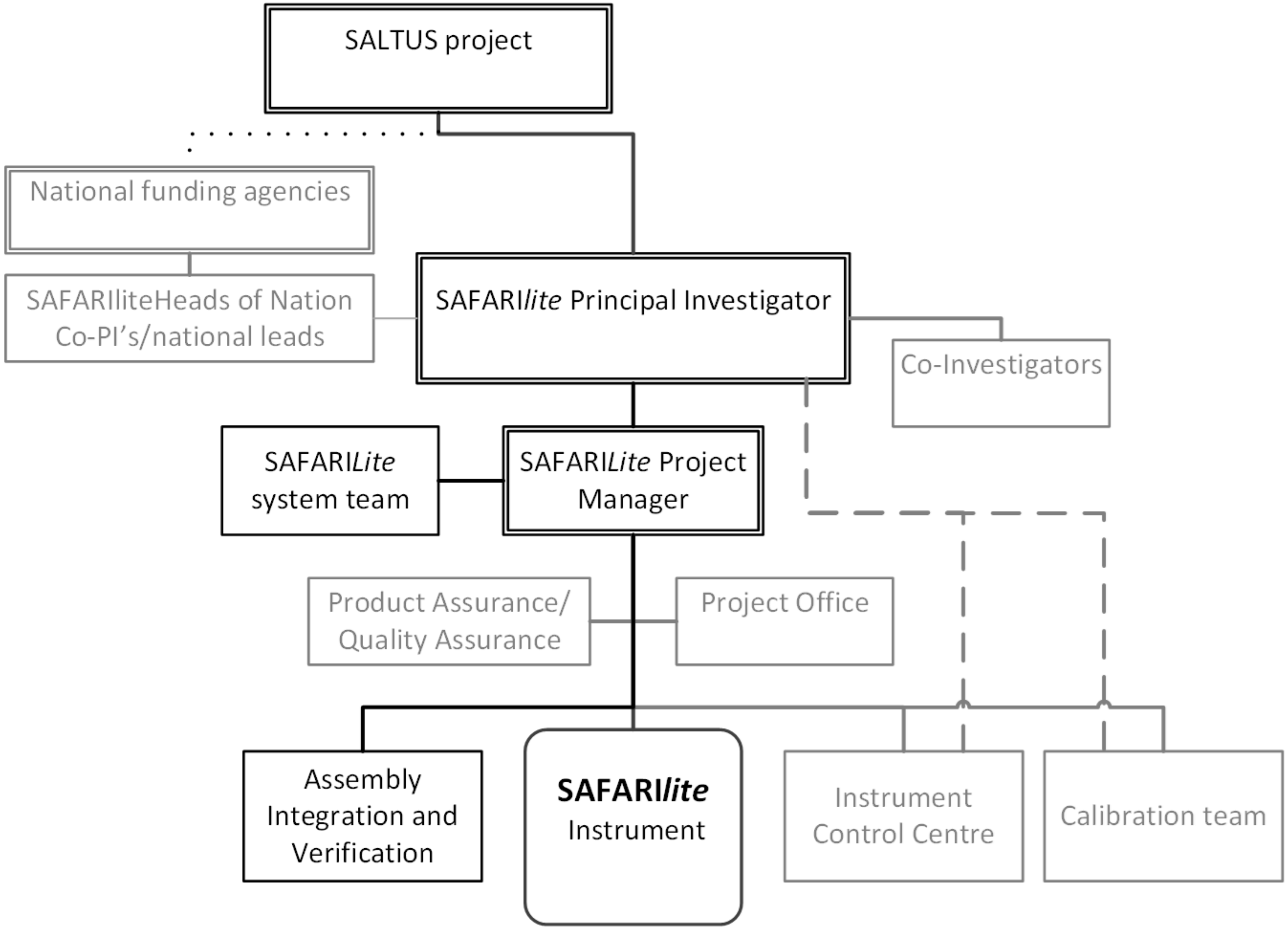
- SRON leads system design
- SRON organizes collaboration
- PI/PM is one person

Phase A

- NN co-leads with SRON
- NN provides PI, hopefully PM
- SRON leads FPA design

Phase BCD

- NN leads
- NN provides PI and PM



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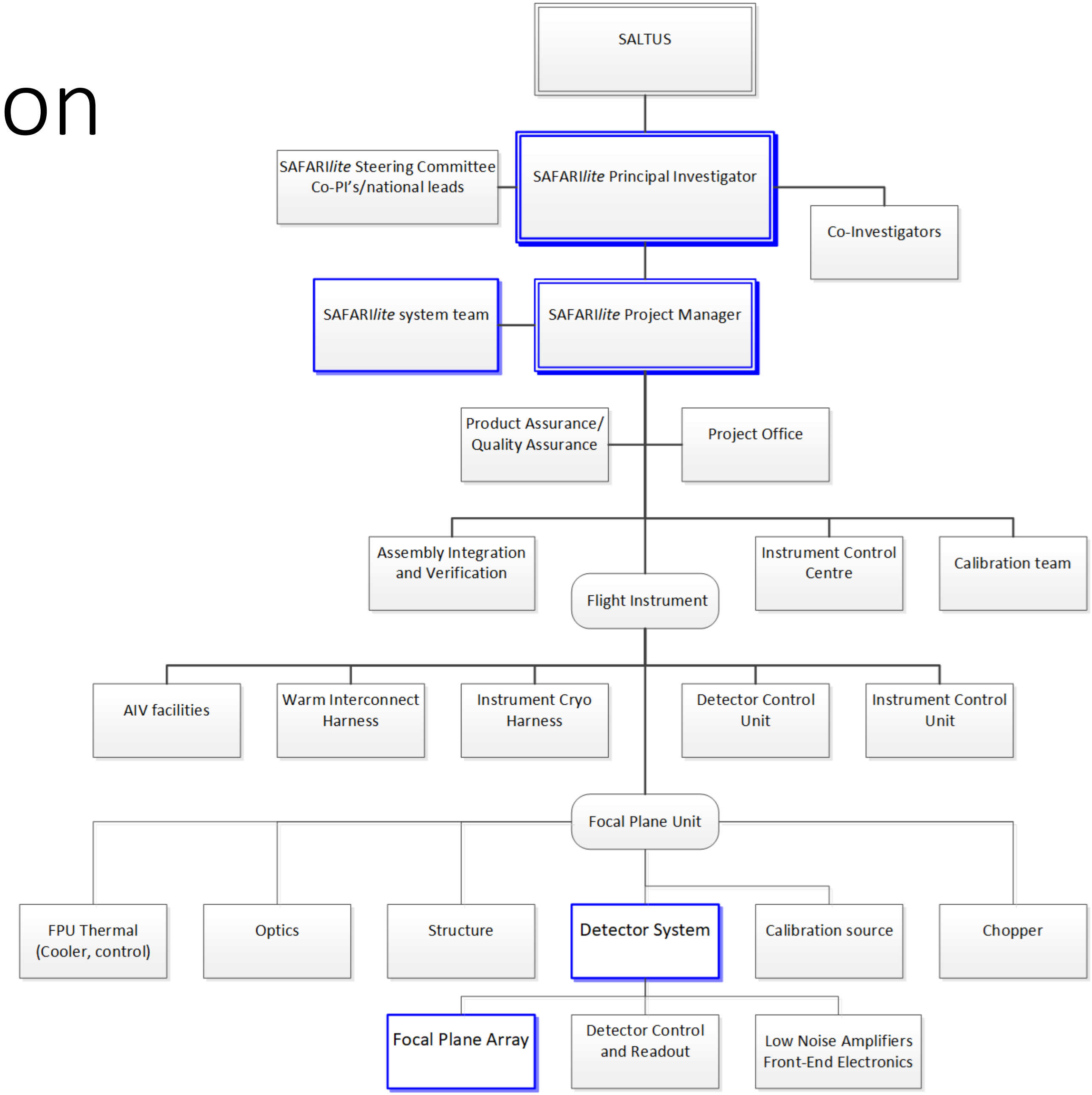
SAFARI-*lite* organization

- Full project in phases BCD



Challenges – some bigger then others

- Managerially
  - Consortium definition, especially finding a consortium lead
  - Timeline – mid 2029 is ***very*** near
- Technically
  - Satellite pointing – SAFARI-*lite* needs ~20mas! Stable pointing
  - Thermal behavior of the satellite → consequences for stray light
  - Getting high (enough) TRL for the KID configuration
- Scientifically
  - Shortest wavelength; 35 µm can be reached, shorter is conceivable but uncertain
  - Limited dynamic range – what are the brightest sources we need to observe?
  - Calibration strategy – we'll need to bootstrap to a new set of calibration sources (e.g. asteroids)
- Understanding fully what is needed
  - Getting/keeping the US and Europe expectations/approach 'aligned'
  - Processing software needs/environment

Great possibilities

- Lots of work done and to be done
  - Technically
  - Managerially

  …and in a short time

SAFARI-*lite* ~ 10 x SPICA

in sensitivity *and* spatial resolution

→ a fantastic science opportunity

…so, we* have *to make it work