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SAFIR

The Single Aperture Far Infrared Observatory

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Genesis of SAFIR

pronounced “sapphire”!

Huge science need and opportunity coupled with feasibility!

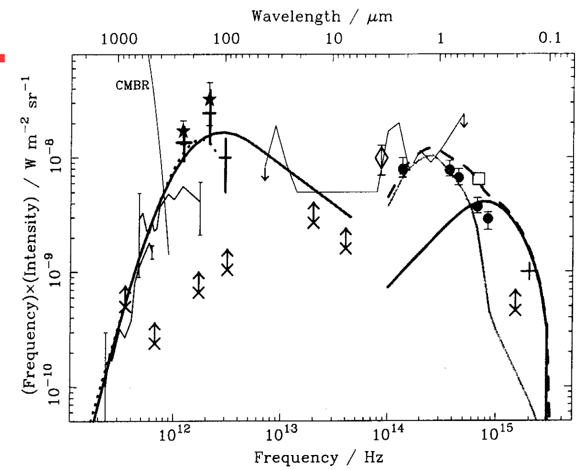
- SAFIR was recommended in the Decade Report for technology and concept development that would lead to future infrared missions.
- SAFIR was mentioned prominently in current Structure and Evolution of the Universe and Origins Theme Roadmaps.
- Recognized that large aperture, low temperature far infrared telescope is now achievable, especially with technology advances from JWST, SIRTF, and Herschel.
- Recognized SAFIR as a scientific successor to SIRTF and Herschel, and as a powerful scientific partner to TPF, JWST, and ALMA.

What SAFIR is …

SAFIR is defined as a set of science objectives that answer key astrophysics questions in the far-infrared.
Several concepts are being developed. Commonality in technology needs.
Implementation will flow from *science requirements* and *technology capabilities*.

Parameter	Requirement	Science Targets
Aperture	~10m	distant galaxies circumstellar disks
Temperature	4K	Galaxy @ z=5
Wavelength	<20-500+μm	coolant line emission (JWST, ALMA overlap)
Diffraction limit	$\lambda \geq 40\mu$m (1”)	circumstellar disks distant galaxies
Lifetime	>5 years	Productivity, time variability!

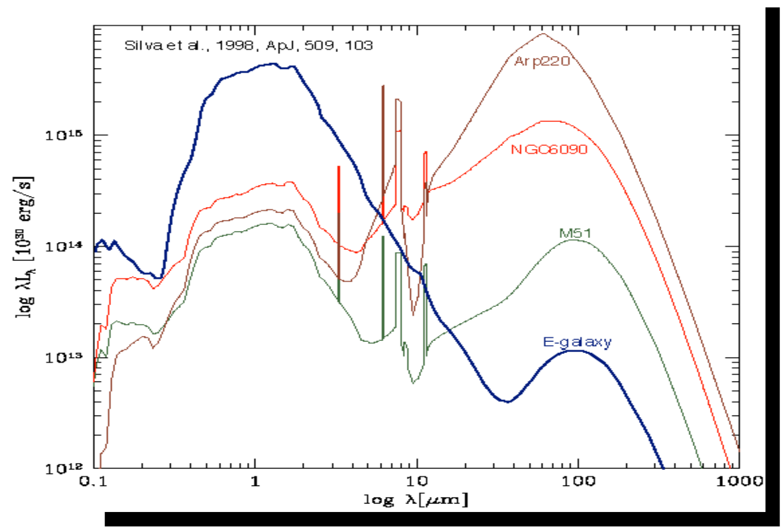
The stage on which SAFIR plays …



- Half the luminosity in the Universe is in far-IR! The young universe is redshifted there.
- Of the far-IR background, <1/3 is accounted for by discrete galaxies.
- Star formation -- near and far, now and long ago is an IR problem.
- The youngest primordial gas clouds will be visible only in the far-IR.
- Dust is nearly everywhere

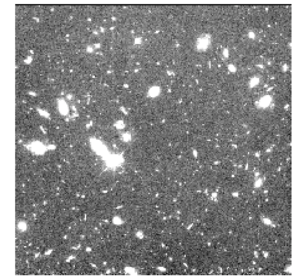
JWST will detect the first galaxies -- SAFIR will understand why they hide!

Era of JWST and ALMA. SIRTF, SPICA, Herschel are done.

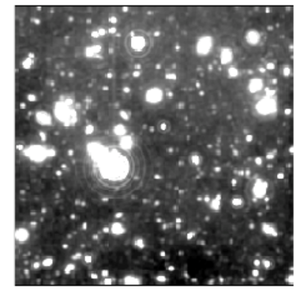


SAFIR Key Science Drivers *(pre-SIRTF!)*

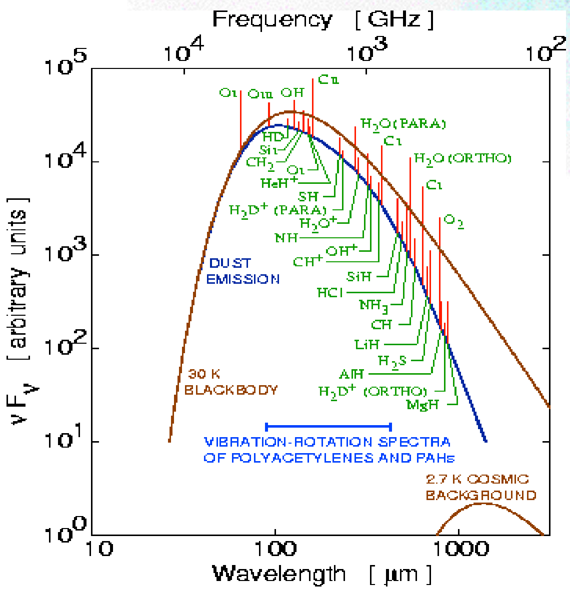
- Resolve the FIR background -- trace star formation to z>5 in an unbiased way, measuring redshifts directly.
- Understand how primordial material forms stars. Proto-bulges and -disk formation in pristine gas. H_2 @ z=20?
- Understand role of active galactic nuclei in galaxy formation, and relevance to ULIRGS. Unification?



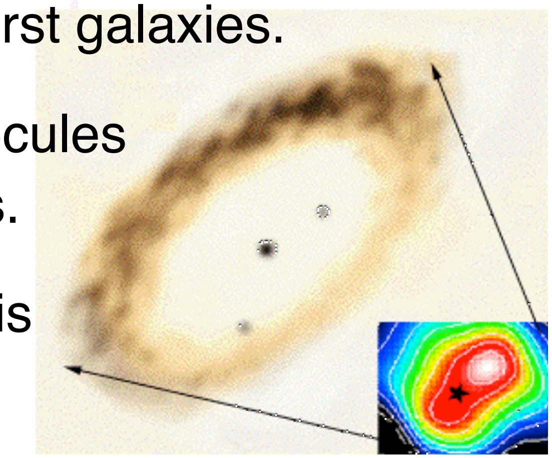
HDF



HDF at 1"



- Bridge gap between local high mass star formation and starburst galaxies.
- Track pre-biotic molecules from cores to planets.
- Identify voids in debris disks around stars.



SAFIR: Molecules to stars to planets to life?

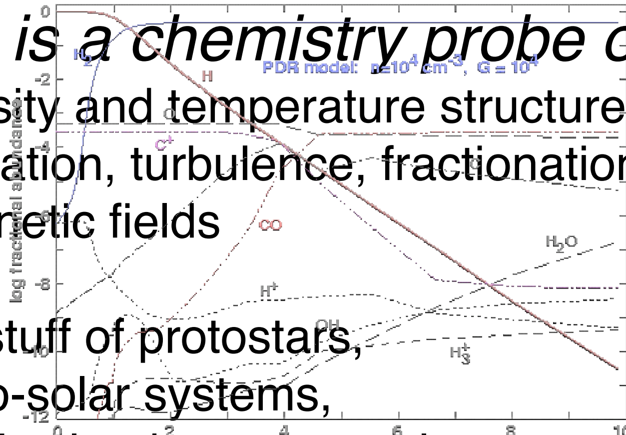
SAFIR is a chemistry probe of the warm cosmos

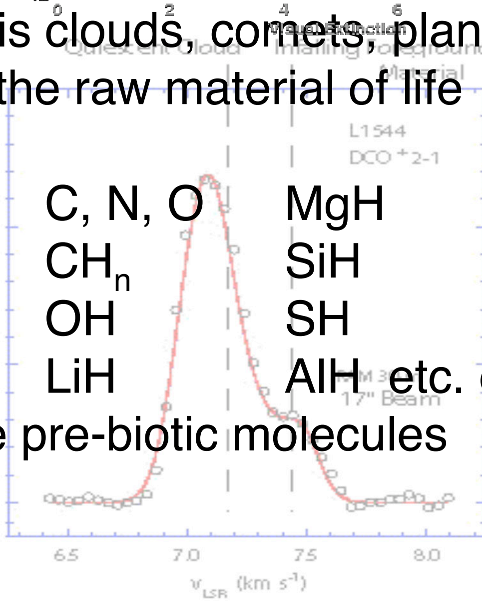
Density and temperature structure of collapsing cores, chemical composition, ionization, turbulence, fractionation, synthesis, condensation, disk energetics, magnetic fields

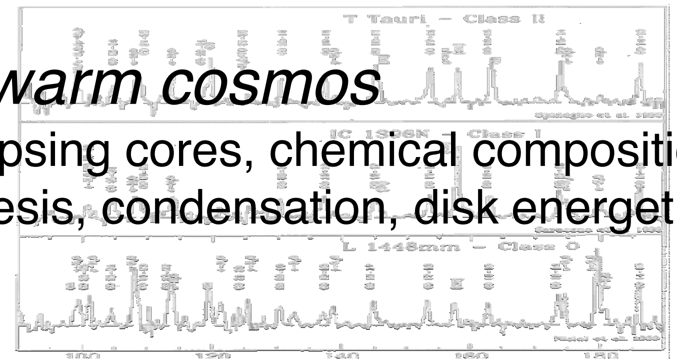
the stuff of protostars,
proto-solar systems,
debris clouds, comets, planets
and the raw material of life

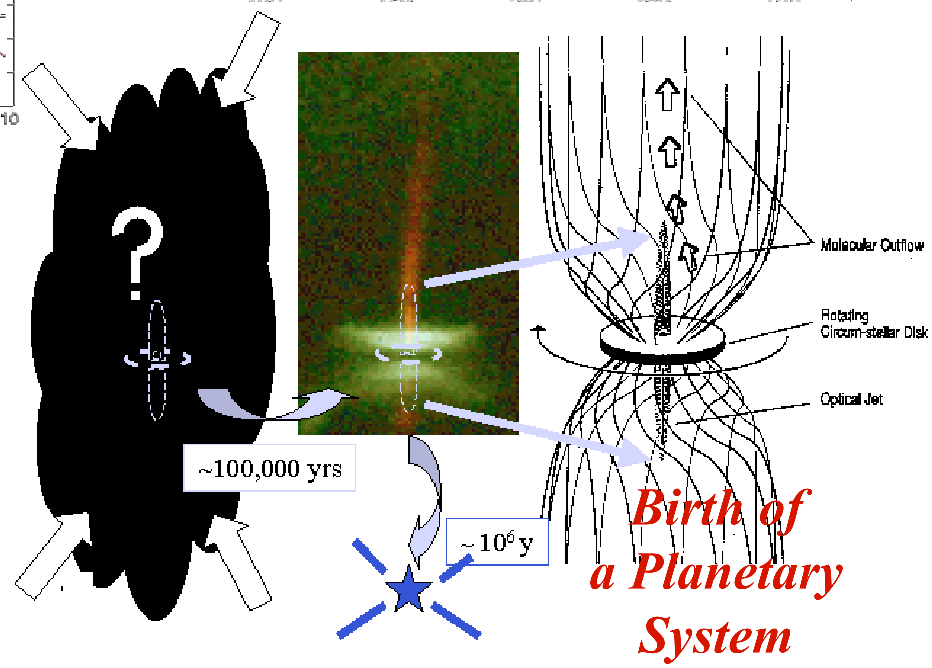
H_2	C, N, O	MgH
H_2O	CH_n	SiH
CO	OH	SH
HD	LiH	AlH etc. etc.

large pre-biotic molecules

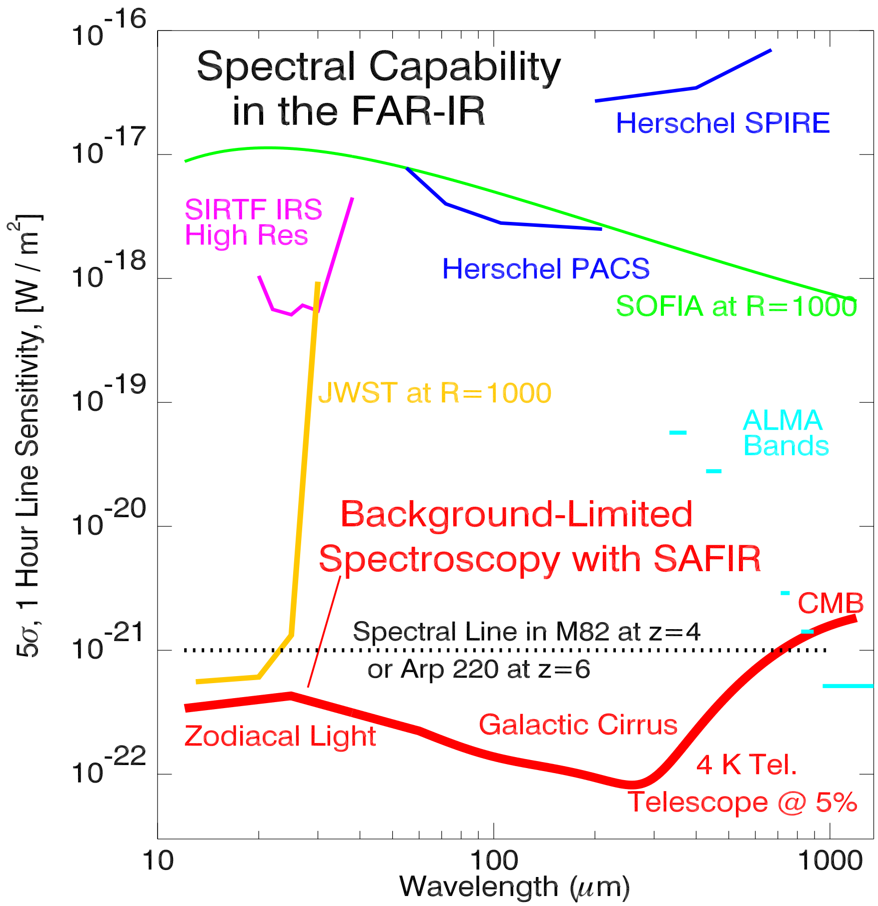








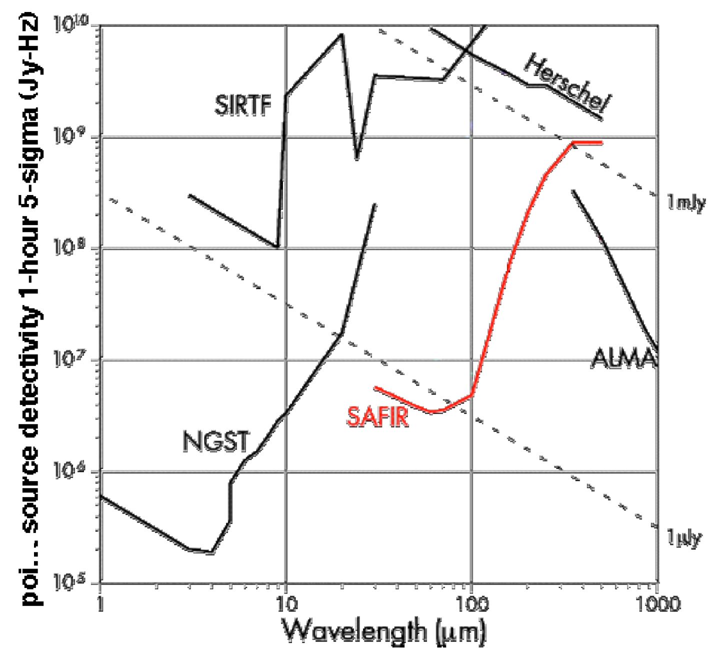
SAFIR capabilities in comparison



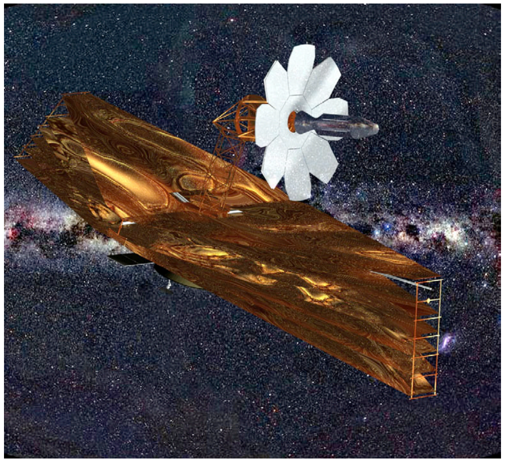
no confusion limits for spectroscopy!

SAFIR will offer orders of magnitude improvement in

- spectroscopic sensitivity
- point source detectivity

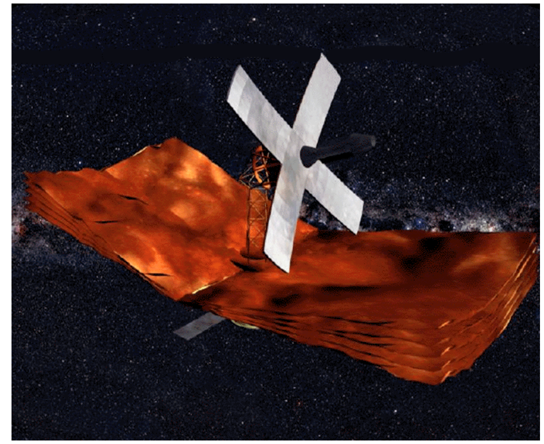


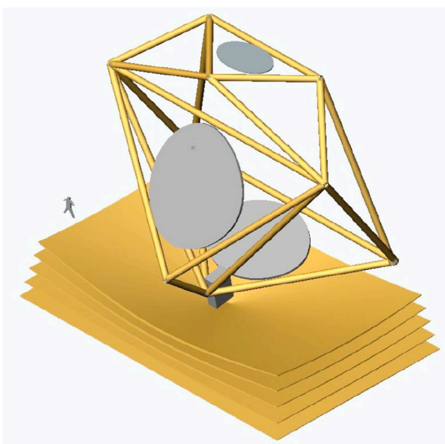
Flavors of SAFIR



- JWST-like
  max system validation

  - sparse aperture
    maximize baselines
    deployment simplicity





- "DART" w/ membrane mirrors
  large aperture/weight ratio

commonality in technology needs

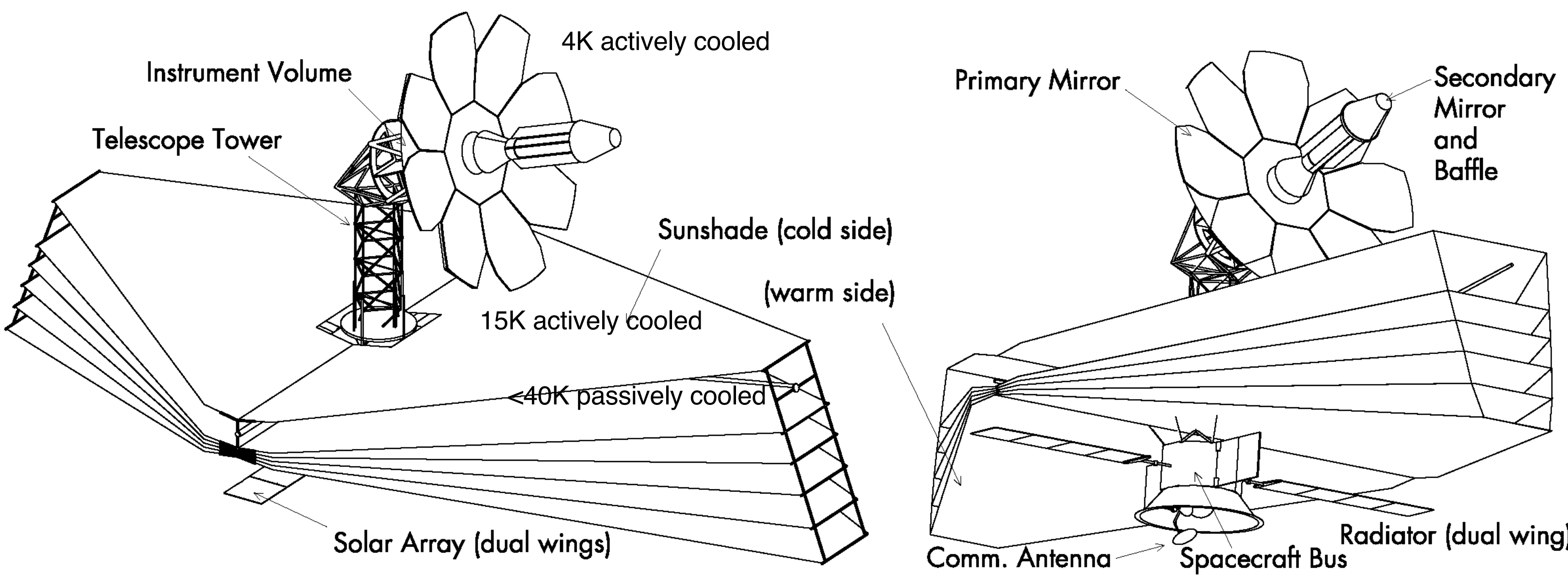
✈ deployment, active surface control ✈ cryocoolers, thermal management
✈ large format, low noise detectors ✈ large, lightweight optical structures

A Thermal Strawman Design for SAFIR

(cooling is the biggest challenge… maybe we can do better?)

- <40K "JWST plus" sunshade
- 15K actively cooled shield blocks sunshade; 1W lift
- 4K actively cooled telescope under shield; 85mW lift
- 50 mK actively cooled focal plane; 10μW lift

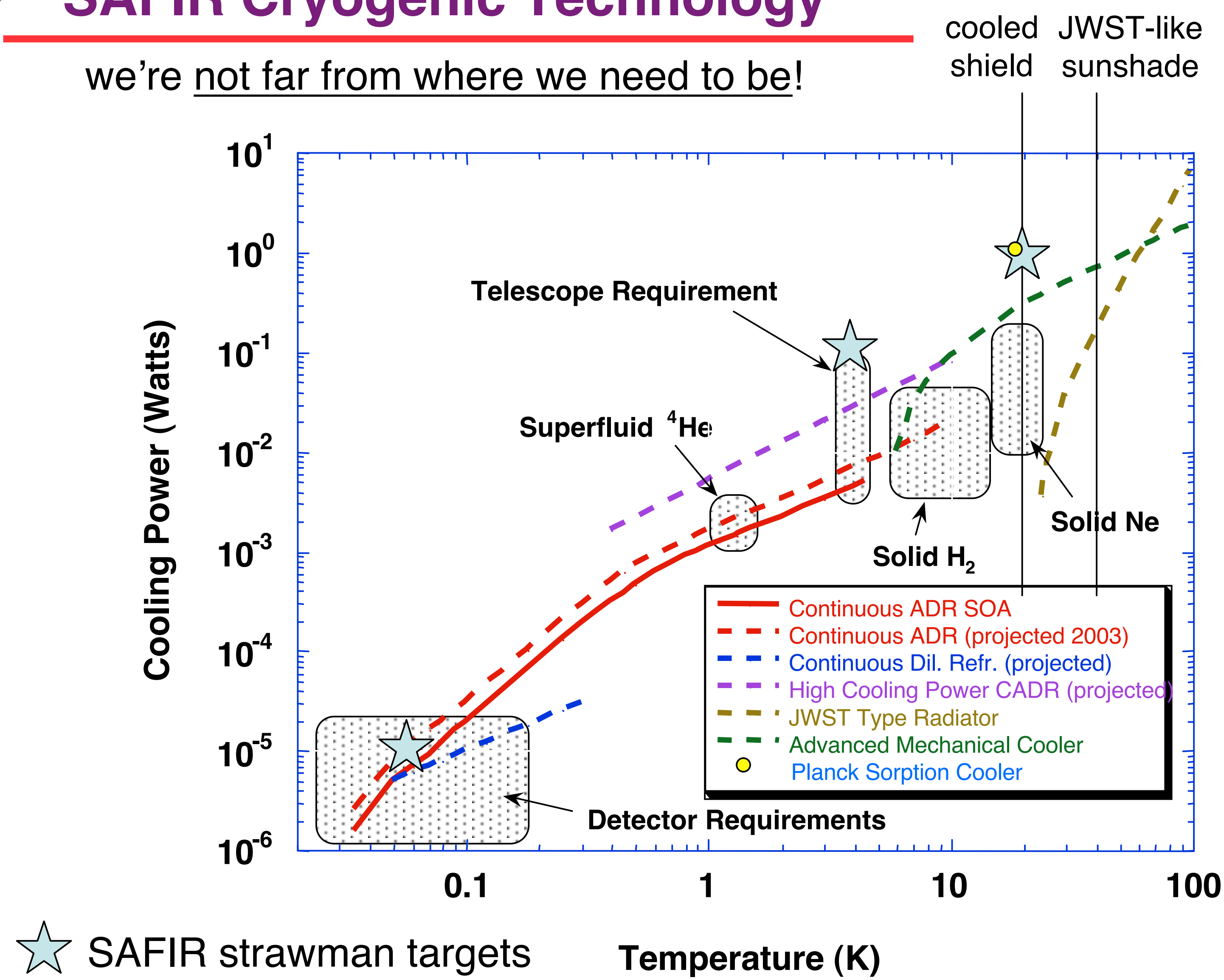
~200W



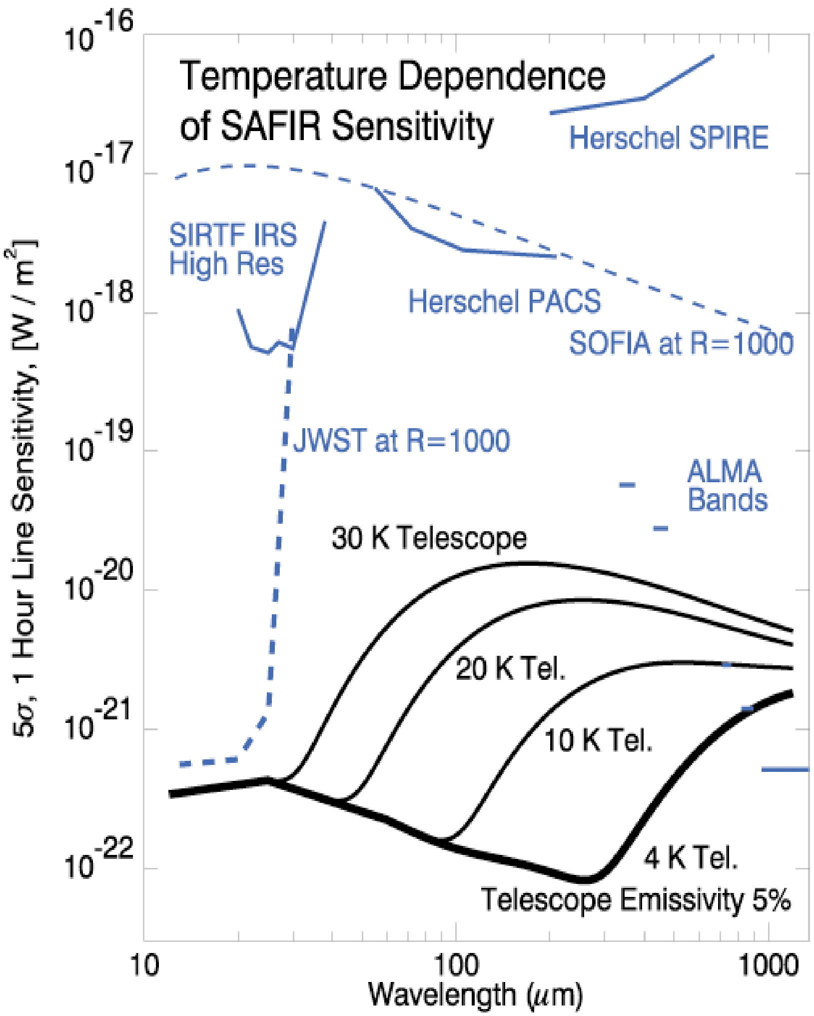
SOA suggests that thermal requirements are achievable!

SAFIR Cryogenic Technology

we're not far from where we need to be!



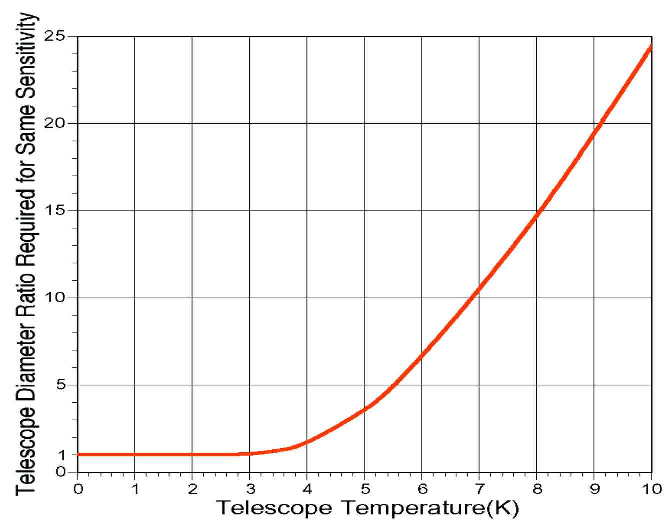
But why 4K for SAFIR?



Because it makes a big difference!

A 4K scope is background-limited (zodi @ <200μm, CMB @ >200μm)

At these wavelengths, point source sensitivity is more dependent on temperature than on aperture!



SAFIR *Observatory* Critical Technologies

incremental steps …

- cryogenic, deployable large apertures
  - actuators, latches, mirror substrates
  (zero-G proof-of-concept highly desirable)

- optimized sun shield technology
  - material properties, refine designs
  (LEO or L2 proof-of-concept highly desirable)

- thermal transport technology
  - gas flow, capillary technology
  (zero-G proof-of-concept highly desirable)

- cryocooler technology
  - extension of ACTDP at 4-20K
  - augment existing ADR capabilities at 50mK-4K

(JWST heritage)

(JWST ConX heritage)

ST9 validation candidates

Code R technology investments

SAFIR *Focal Plane* Critical Technologies

- new spectrometer architectures (scaled-up versions of IR spectrometers are huge)

- focal plane cooling technologies for <100mK

- large-format (10^3-10^4 pixel) broadband arrays
    - semiconducting and superconducting (TES) bolometer arrays
    - Ge, Si BiB photoconductor arrays
    - SQPCs

- quantum noise-limited heterodyne spectrometers

Summary

- SAFIR will enable very compelling Origins *and* SEU science

- SAFIR is technologically challenging but within our grasp