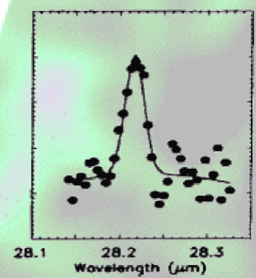
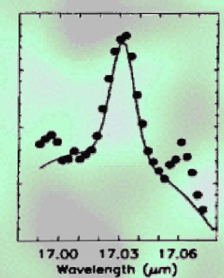
SAFIR

The Single Aperture Far Infrared Mission



Progress Report from the SAFIR study group



to the Origins and Structure & Evolution of the Universe Subcommittees of the NASA Space Science Advisory Committee

Dan Lester, University of Texas

27 February 2003

SAFIR in the OSS Roadmaps and Decade Survey

"… the Single Aperture Far Infrared mission consisting of a single 8-10-meter telescope operating in the far IR could serve as a building block for the Life Finder, while carrying out a broad range of scientific programs beyond JWST and SIRTF."

2003 Origins Theme Roadmap

"A cryogenic, large aperture infrared telescope would be able to see these molecular lines, and offer a unique window into early star formation. Such a single aperture far-infrared (SAFIR) mission could build upon James Webb (next generation) Space Telescope technology."

2003 SEU Theme Roadmap

"To take the next step in exploring this important part of the spectrum, the committee recommends the Single Aperture Far Infrared (SAFIR) Observatory…"

2000 NRC Decade Report

Goal of Presentation to A&P Subcommittees

- In view of value of SAFIR to SEUS *and* OS communities, we offer a briefing on its *developing scientific vision* and *program status*.

- SAFIR has $100K from A&P in FY03, and some substantial investments from both JPL and GSFC. *$$ well spent.*

- SAFIR is poised to benefit dramatically from technology investment. Look forward to *continued subcommittee support for such investment*.

- While no funding line for SAFIR at this time, NASA needs a mix of well studied science missions. *It's time to pick up the pace on SAFIR.*

It's always important to identify opportunities. SAFIR presents us with a rich set.

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 form the path for future IR missions.

- Recognized that large aperture, low temperature FIR telescope is now achievable, especially with technology advances from JWST.

- Recognized SAFIR as a scientific successor to SIRTF and Herschel, and as a powerful scientific partner to JWST and ALMA.

- SAFIR embraces what was known as FAIR, and the concept known as DART.

Facility-Specific Study Team Activities

- 3/7-8/02 2nd Workshop New Concepts FIR/Submm Astronomy
  - "Charting the Winds that Change the Universe: SAFIR" (G. Reike)
- 5/7/02 SEUS meeting
  - SAFIR technology briefing to SEUS (D. Benford)
- 7/31-8/1/02 SAFIR Science Team meeting
- 8/22-28/02 SPIE
  - "A Single Aperture Far Infrared Observatory" (P. Harvey et al.)
  - "Engineering Concept and Enabling Technologies for SAFIR" (M. Amato et al.)
  - "DART Technology Development" (M. Dragovan & J. Dooley)
- 10/10-11/02 COSPAR
  - "NASA's Far-IR Roadmap Missions SAFIR and SPECS (D. Leisawitz)
- 1/5-9/03 AAS Seattle
  - "The Single Aperture Far-InfraRed Observatory (SAFIR)" (H. Yorke et al.)
- 2/5-6/03 New Millenium ST9 Workshop
  - contributions to "System Technology for Large, Space Telescopes" splinter groups
- 2/25/03 SAFIR Science Team meeting

What SAFIR is …

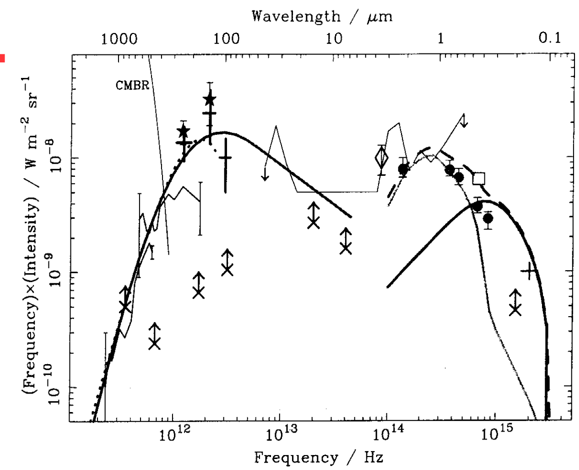
SAFIR is defined as a set of science objectives that answer key astrophysics questions in the far-infrared.

Several concepts are being developed. Commonality in technology needs.

Implementation will flow from *science requirements* and *technology capabilities*.

Parameter	Requirement	Science Targets
Aperture	~10m	high z galaxies, debris disks
Temperature	4K (@L2?)	L* galaxy @ z=5 (zodi lim)
Wavelength	<20-500+μm	coolant lines (JWST, ALMA overlap)
Diffraction limit	$\lambda \geq 40\mu$m (1")	debris disks, distant galaxies
Lifetime	>5 years	productivity!

The stage on which SAFIR plays …



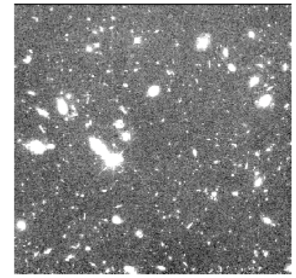
- Half the luminosity in the Universe is in far-IR! The young universe is redshifted there.
- Of the far-IR background, <1/3 is accounted for by discrete galaxies.
- Star formation -- near and far, now and long ago is an IR problem.
- The youngest primordial gas clouds will be visible only in the far-IR.
- Dust is everywhere (eventually) -- be not fooled …

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

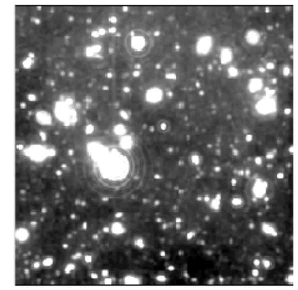
Era of JWST and ALMA.
SIRTF, SPICA, Herschel are done.

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

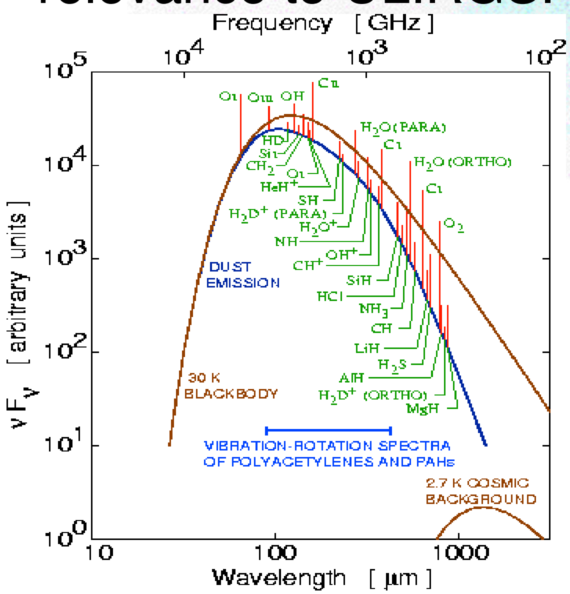
- Resolve the FIR background -- trace star formation to z>5 in an unbiased way, measuring redshifts directly.
- Understand <u>how</u> primordial material forms stars. Proto - bulges and -disk formation in pristine gas. H_2 @ z=20?
- Understand role of AGN in galaxy formation, and relevance to ULIRGS.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



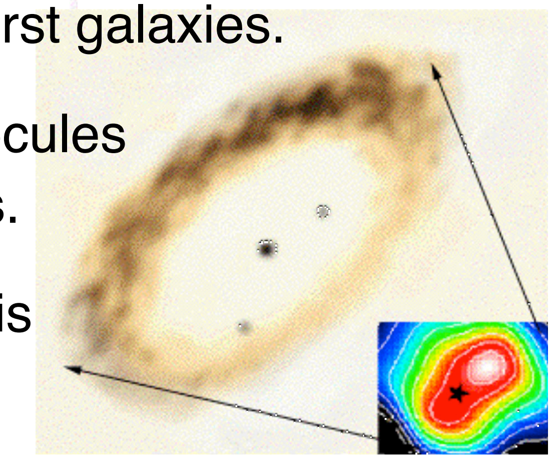
HDF



HDF at 1" res



- 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.

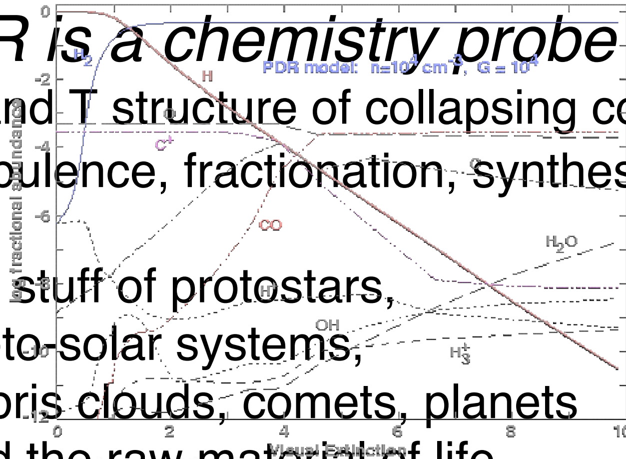


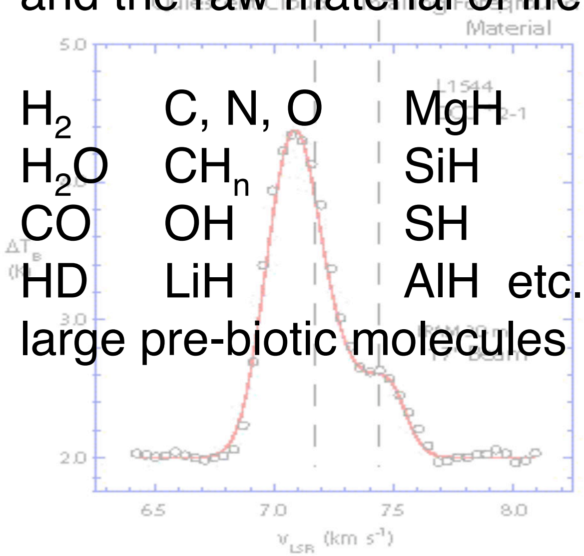
SAFIR: molecules to stars to planets to ??

SAFIR is a chemistry probe of the warm cosmos

ρ and T structure of collapsing cores, chemical composition, ionization, turbulence, fractionation, synthesis, condensation, disk energetics, B fields

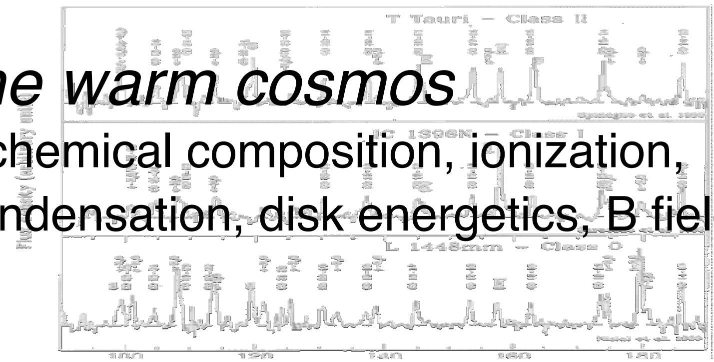
the stuff of protostars,
proto-solar systems,
debris clouds, comets, planets
and the raw material of life

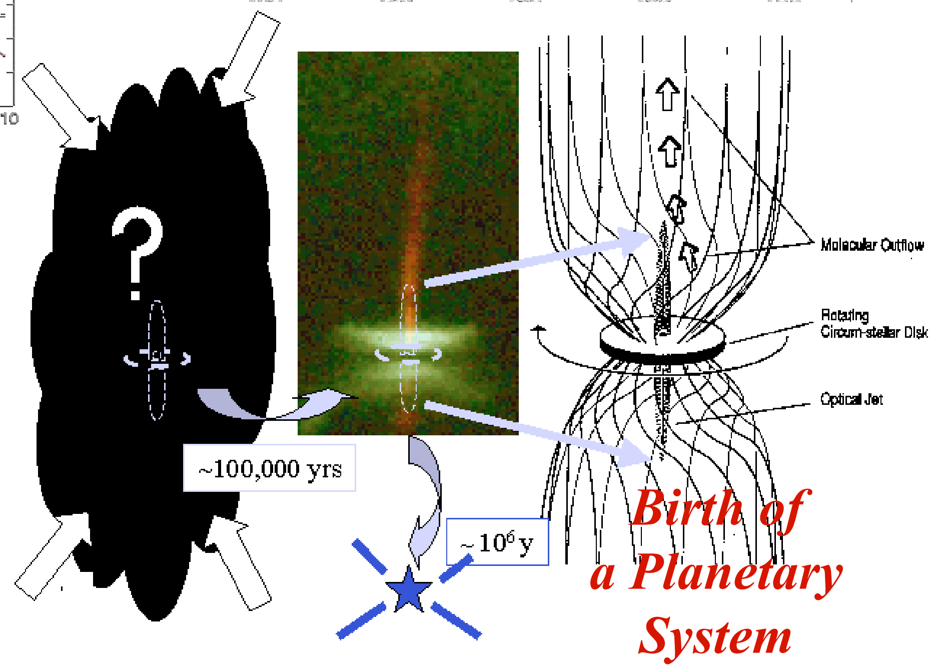




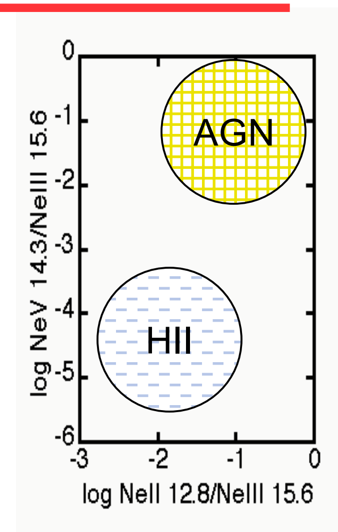
H_2	C, N, O	MgH
H_2O	CH_n	SiH
CO	OH	SH
HD	LiH	AlH etc. etc.

large pre-biotic molecules





SAFIR: relationship of AGNs and ULIRGs



10^{12} L_{sun} galaxies are numerous in early universe; huge A_v
super starbursts? buried AGNs? intermediate stage?

powerful extinction-free mid-IR radiation diagnostics:

Soft HII: [FeII] 26, 35 …, [NeII] 12.8, [FeIII] 23, 33 …, [SIII] 18 & 33μm

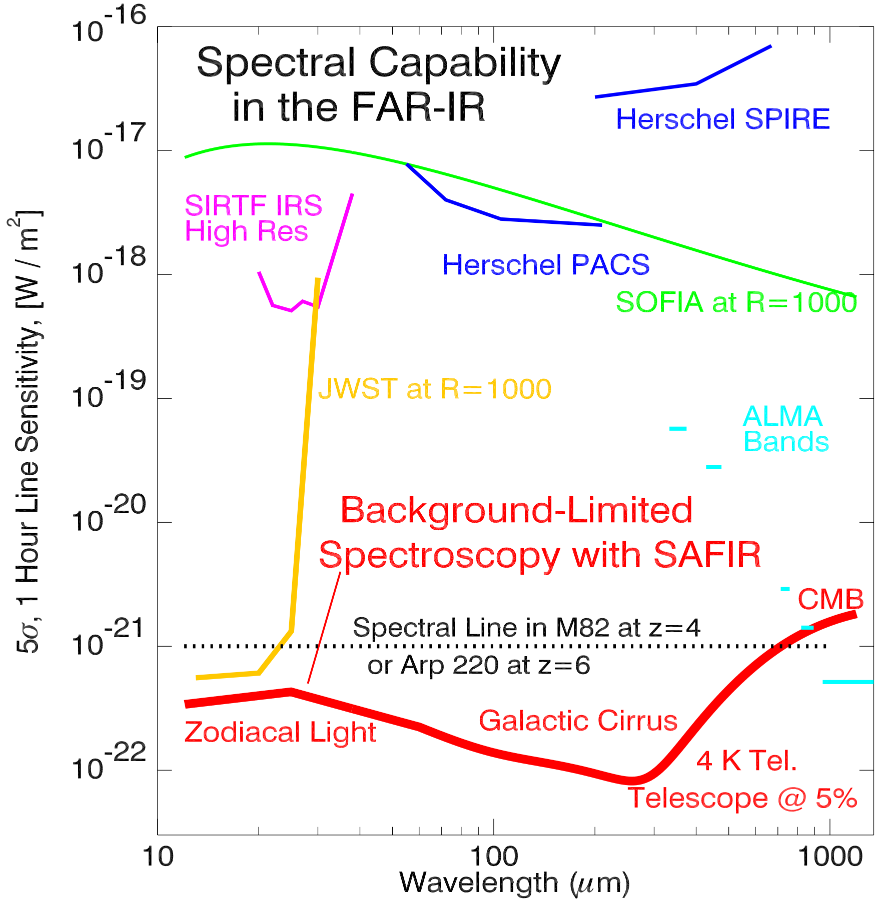
Hard HII: [SIV] 10.5, [NeIII] 16 & 36 , [OIII] 52 and 88μm

AGN: [MgV] 13.5 , [OIV] 26 , [ArV] 13, and [NeV] 14 and 24μm

search for broad lines; dynamics of nuclear toroids
accretion history of universe (with X-ray missions)

see Arp220-class galaxies with SAFIR out to z=7 !

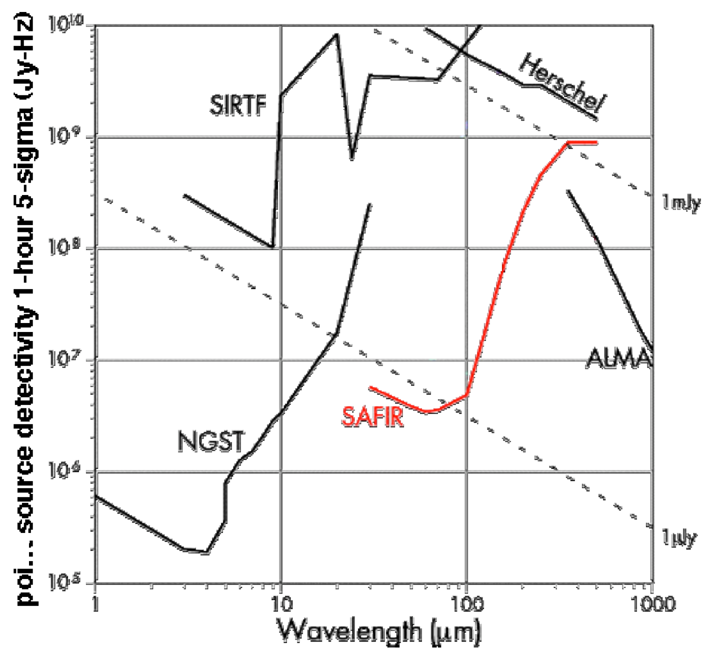
A Huge Discovery Space



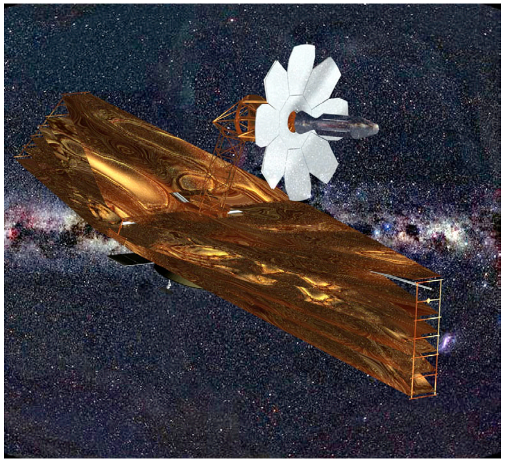
no confusion limits for spectroscopy!

SAFIR will offer orders of magnitude improvement in

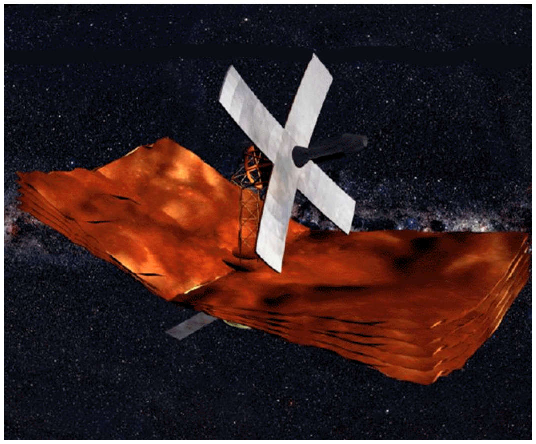
- spectroscopic sensitivity
- point source detectivity



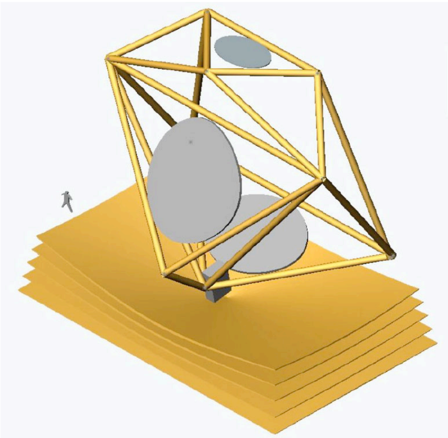
Flavors of SAFIR



- 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
✈ large format, low noise detectors
✈ cryocoolers, thermal management
✈ large, lightweight optical structures

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 desireable)

- 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

- focal plane cooling technologies for <100mK
  - multistage ADR
  - dilution refrigerators

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

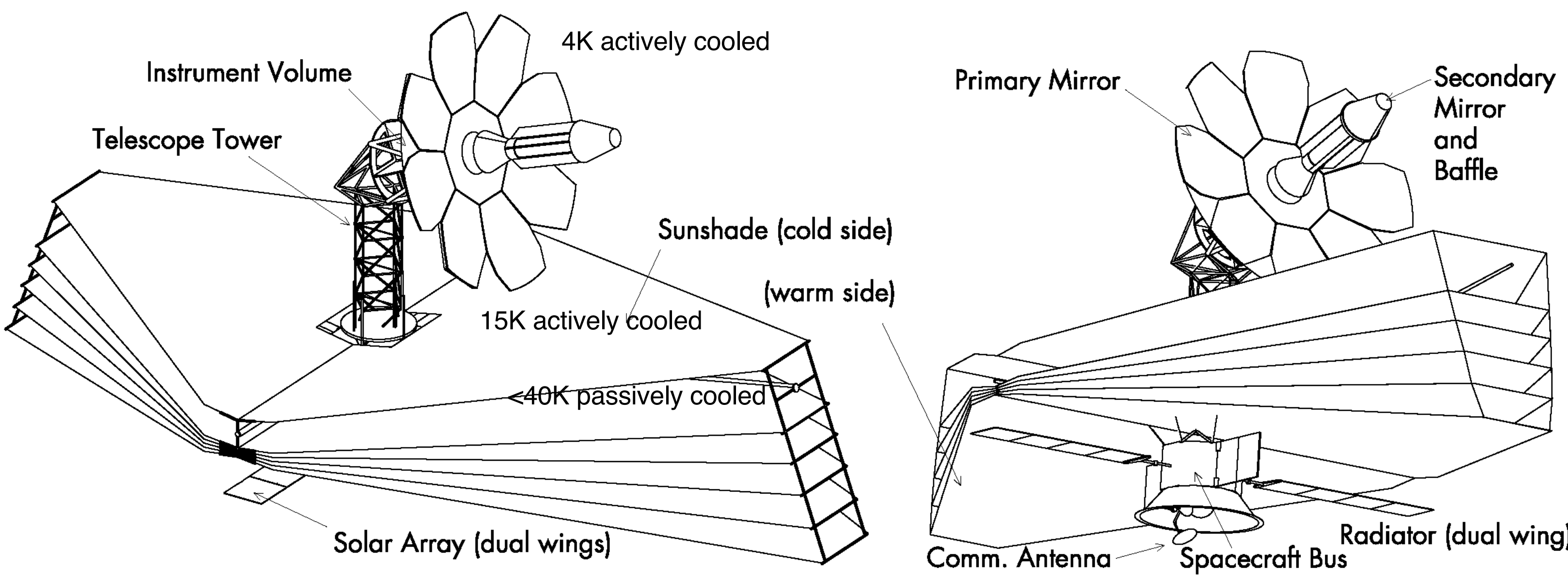
- quantum noise-limited heterodyne spectrometers

Thermal Model Targets for SAFIR

(cooling is the biggest challenge …)

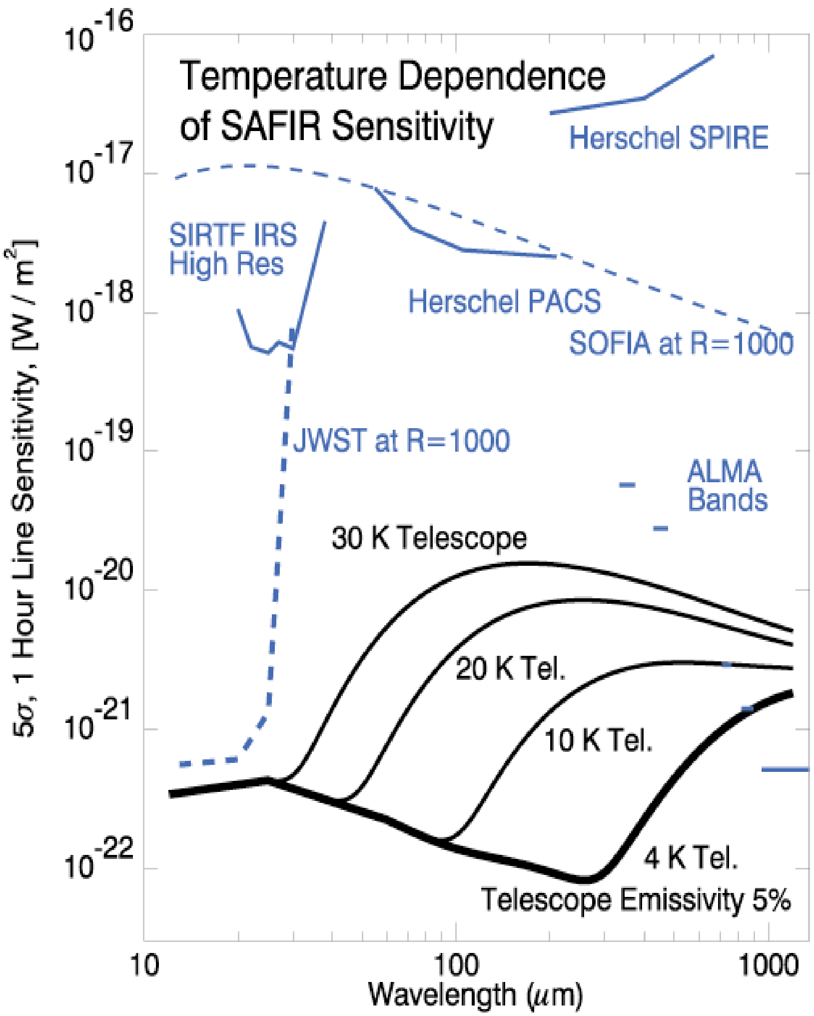
- <40K “JWST plus” sunshade
- 15K actively cooled shield blocks sunshade; 1W lift
- 4K actively cooled telescope under shield; 85mW lift
- 50 mK actively cooled focal plane; 10μW lift

(1W lift + 85mW lift: ~200W)



SOA suggests that thermal requirements are achievable!

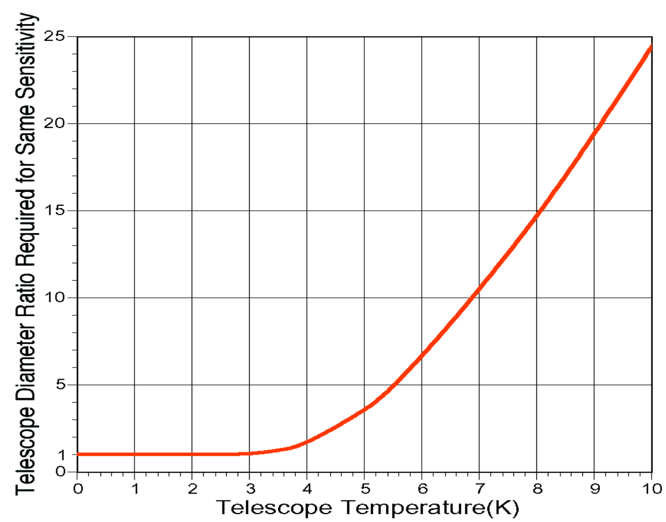
But Why 4K for SAFIR?



Because it makes a big difference!

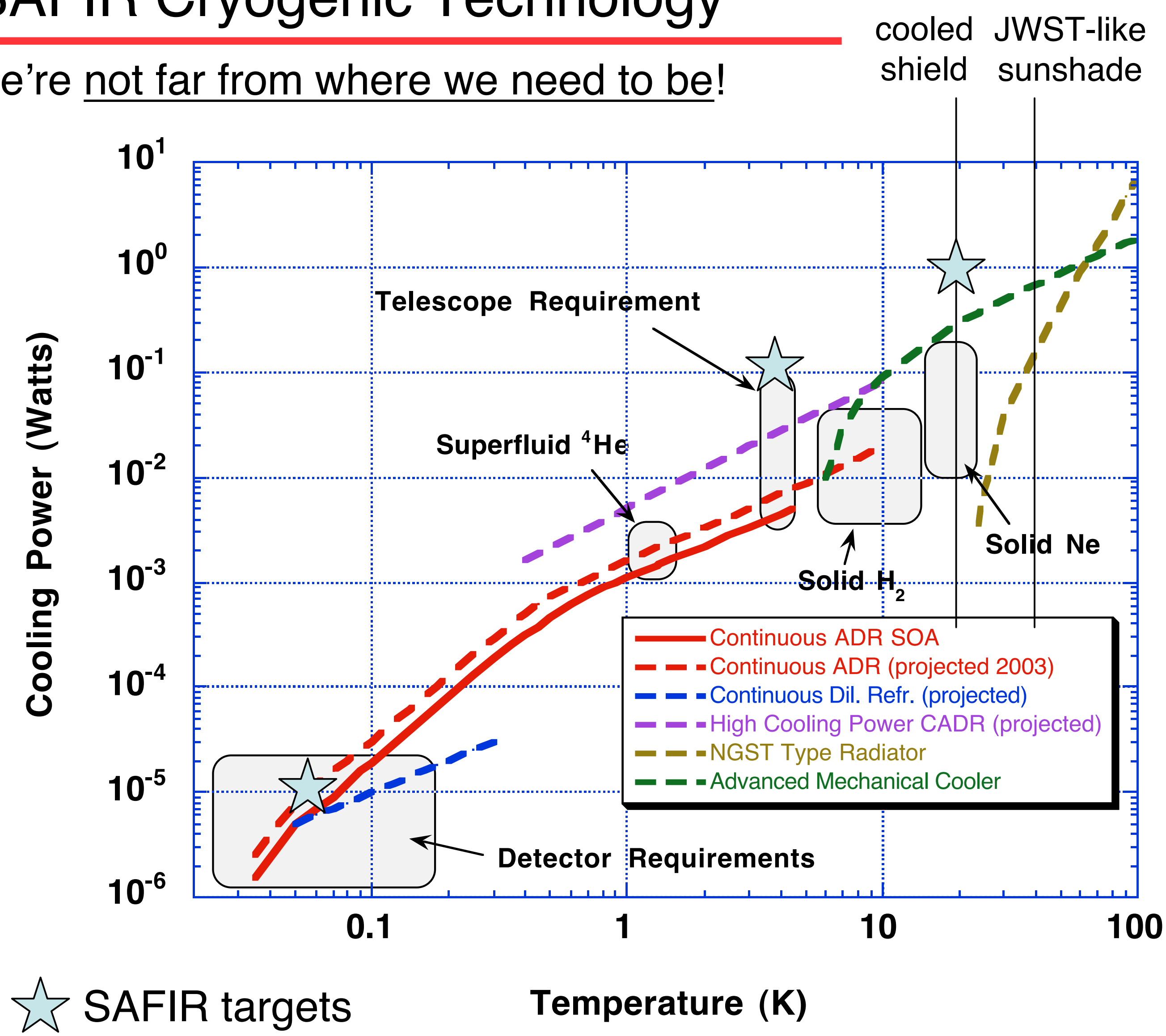
A 4K scope is background-limited (zodi @ <200μm, CMB @ >200μm)

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



SAFIR Cryogenic Technology

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



Summary

- SAFIR has seen a lot of thought and effort over the year.
  Convergence of science opportunity and tech feasilbility.

- we ask OS and SEUS to *support technology development* for SAFIR
  – support work with Code R for science-driven technology funding
  – insist that SAFIR needs be mapped into A&P technology initiative
  – ensure awareness of SAFIR needs in JWST and Con-X efforts
  – support SOFIA and ground based proof-of-concepts for new detector and spectrometer architectures

- we ask OS and SEUS to recommend continued funding to ensure further progress on pre-Phase A feasibility studies.

- we ask OS and SEUS to *recognize FIR/submm community white paper* which presents a programmatic case for a new mission line!

SAFIR Study Team

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