SAFIR

The Single Aperture Far Infrared Observatory

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Genesis of SAFIR

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.
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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
<th>Science Targets</th>
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<tbody>
<tr>
<td>Aperture</td>
<td>~10m</td>
<td>distant galaxies, circumstellar disks</td>
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<tr>
<td>Temperature</td>
<td>4K</td>
<td>Galaxy @ z=5</td>
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<tr>
<td>Wavelength</td>
<td>&lt;20-500+µm</td>
<td>coolant line emission (JWST, ALMA overlap)</td>
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<tr>
<td>Diffraction limit</td>
<td>λ≥40µm (1&quot;)</td>
<td>circumstellar disks, distant galaxies</td>
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<tr>
<td>Lifetime</td>
<td>&gt;5 years</td>
<td>Productivity, time variability!</td>
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• 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?
- 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 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

H₂  C, N, O  MgH
H₂O  CHₙ  SiH
CO  OH  SH
HD  LiH  AlH etc. etc.
large pre-biotic molecules

Birth of a Planetary System

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SAFIR will offer orders of magnitude improvement in
- spectroscopic sensitivity
- point source detectivity

**no confusion limits for spectroscopy!**
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

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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

SOA suggests that thermal requirements are achievable!
SAFIR Cryogenic Technology

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

SAFIR strawman targets

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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
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