SAFIR

The Single Aperture Far Infrared Observatory

Harold Yorke
Jet Propulsion Laboratory
Harold.Yorke@jpl.nasa.gov

March 13, 2003
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.
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. Protobulges and -disk formation in pristine gas. \( \text{H}_2 \) @ \( z = 20 \)?

- 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.

13 March 2003 • SAFIR: IEEE Origins Panel Discussion

Harold Yorke 5
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

\[
\begin{align*}
H_2 &\quad C, N, O &\quad MgH \\
H_2O &\quad CH_n &\quad SiH \\
CO &\quad OH &\quad SH \\
HD &\quad LiH &\quad AlH, etc. etc. \\
\end{align*}
\]

large pre-biotic molecules

Birth of a Planetary System

~100,000 yrs

~10^6 yrs
SAFIR capabilities in comparison

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

Background-Limited Spectroscopy with SAFIR

Spectral Line in M82 at z=4
or Arp 220 at z=6

Zodiacal Light
Galactic Cirrus
4 K Tel.
Telescope @ 5%

no confusion limits for spectroscopy!

13 March 2003 • SAFIR: IEEE Origins Panel Discussion Harold Yorke 7
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
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!

13 March 2003 • SAFIR: IEEE Origins Panel Discussion  Harold Yorke
SAFIR Cryogenic Technology
we're not far from where we need to be!

SAFIR strawman targets

Temperature (K)

13 March 2003 • SAFIR: IEEE Origins Panel Discussion Harold Yorke 10
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

- 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

13 March 2003 • SAFIR: IEEE Origins Panel Discussion  Harold Yorke 12
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