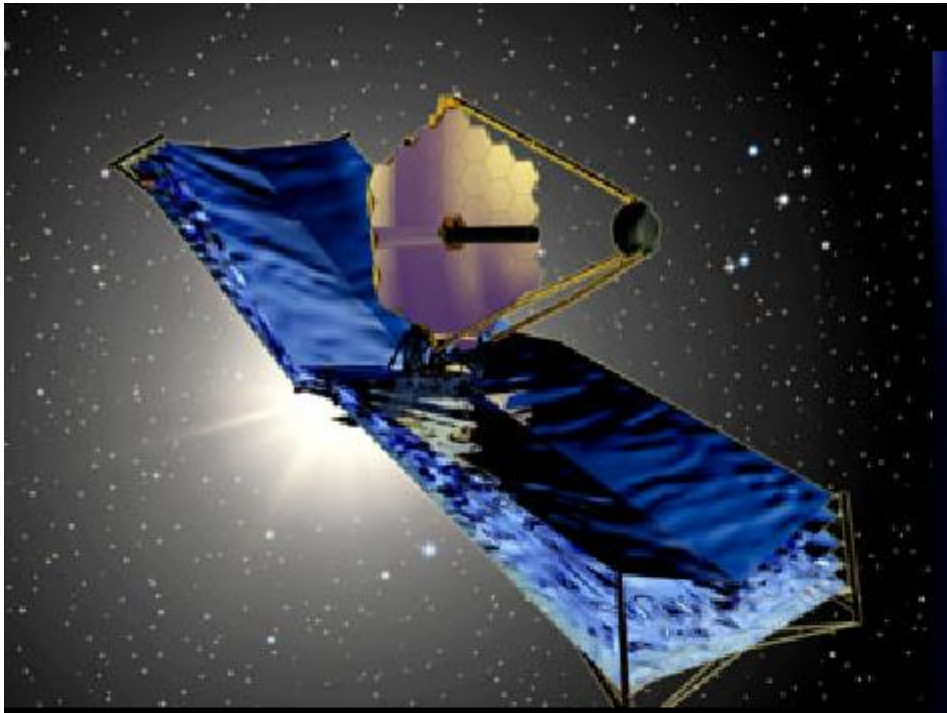
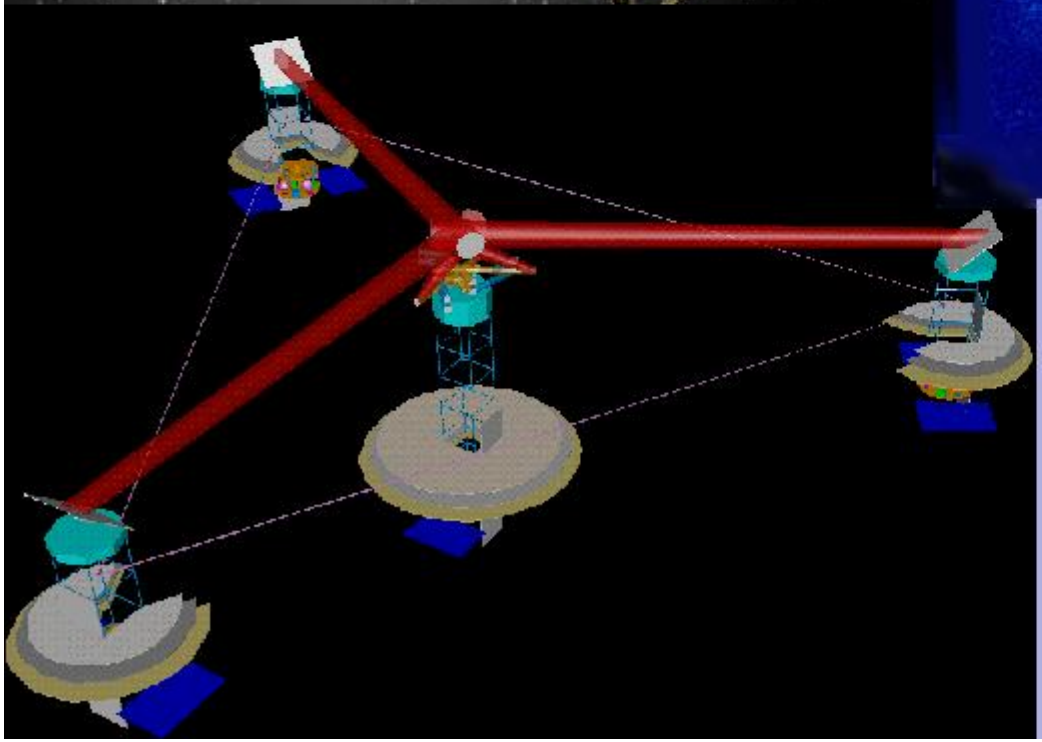


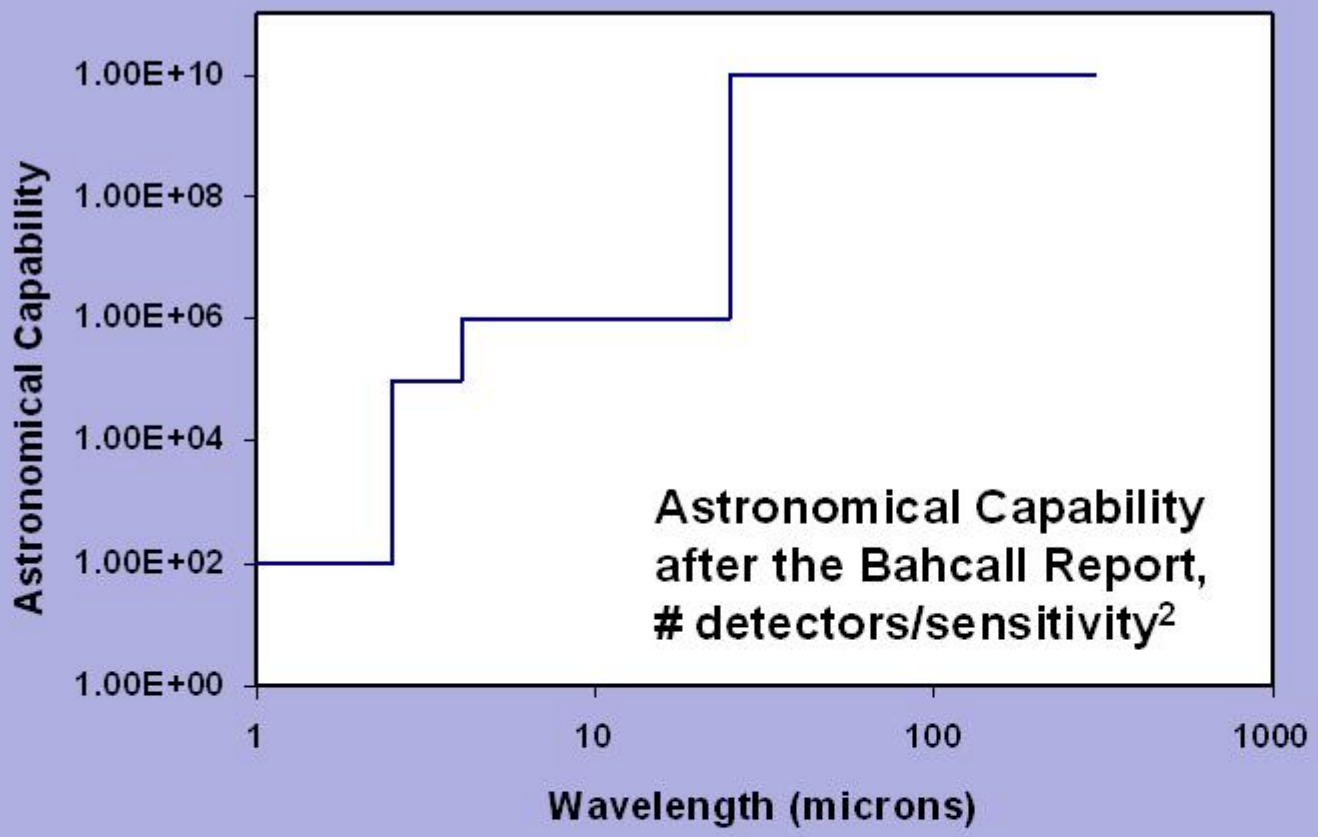


Far Infrared Science Opportunities

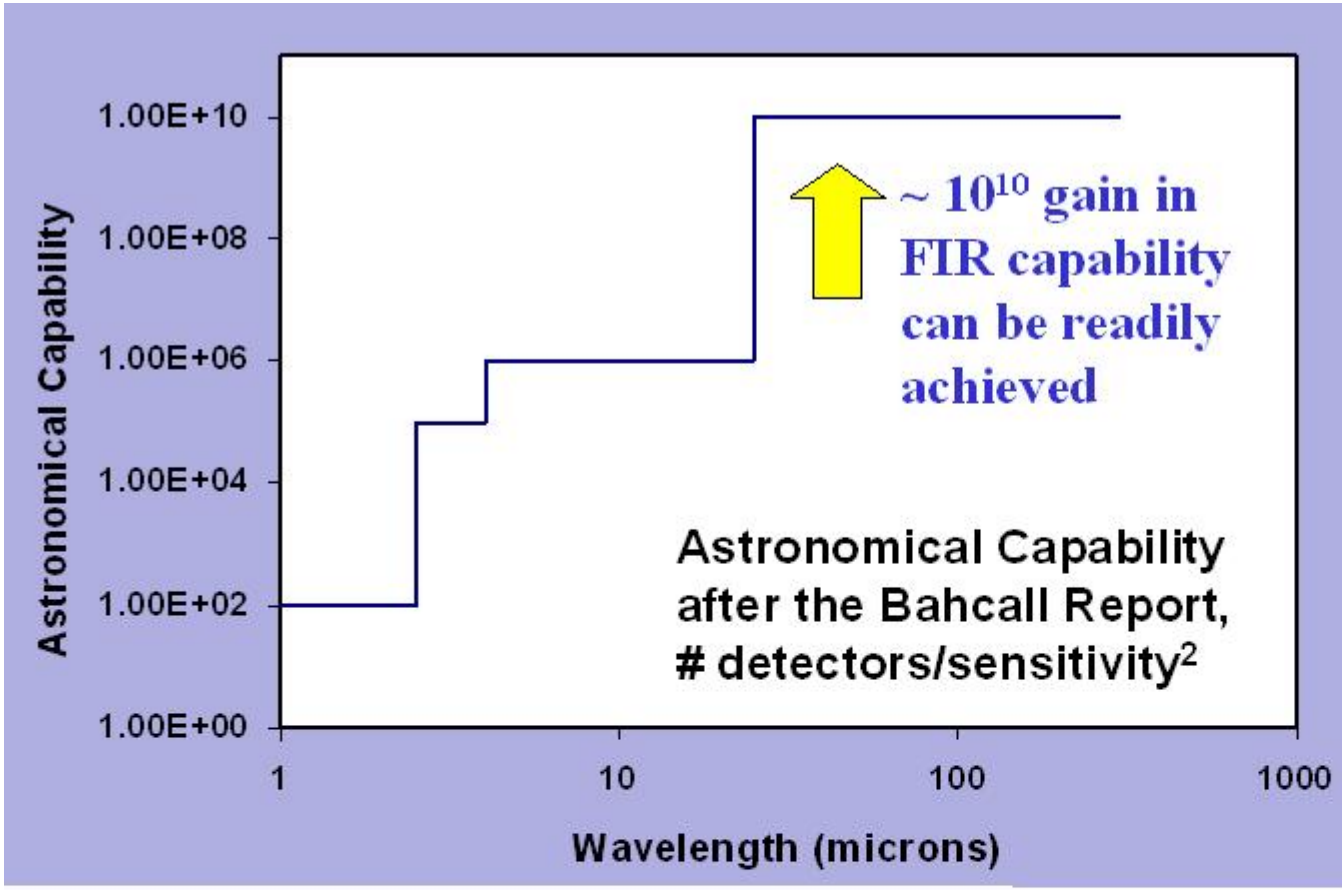
G. H. Rieke

Clockwise from upper left: NGST, SAFIR/FAIR, SPECS

The FIR/submm has Huge Discovery Potential



"Astronomical Capability" is a simple figure of merit proportional to the time required to obtain a given number of image elements to a given sensitivity limit. It is therefore a measure of the discovery potential.



The FIR/submm has Huge Discovery Potential

The largest telescopes used routinely in the far infrared are < 1 meter in aperture. No true imaging array has been used with them.

STUDIES BASED ON THE COLORS AND MAGNITUDES IN STELLAR CLUSTERS

TWELFTH PAPER: REMARKS ON THE ARRANGE SIDEREAL UNIVERSE'

By HARLOW SHAPLEY

I. THE GENERAL GALACTIC SYSTE

1. *Introduction.*—A fairly definite conception of t of the sidereal system evolves naturally from the observational work discussed in the preceding *Contributions*. We find, in that globular clusters, though extensive and massive structures,

~ 10^7 gain in optical astronomical capability

The Hubble Deep Field and the Early Evolution of Galaxies

o Madau

ce Telescope Science Institute, 3700 San Martin Drive, Baltimore, 21218

stract. I review some recent progress made in our understanding of xy evolution and the cosmic history of star formation. The *Hubble Deep Field* (HDF) imaging survey has achieved the sensitivity to capture the bulk of the extragalactic background light from discrete sources. No evidence is found in the optical number-magnitude relation down to $AB = 29$ mag for a large amount of star formation at high redshifts. A census

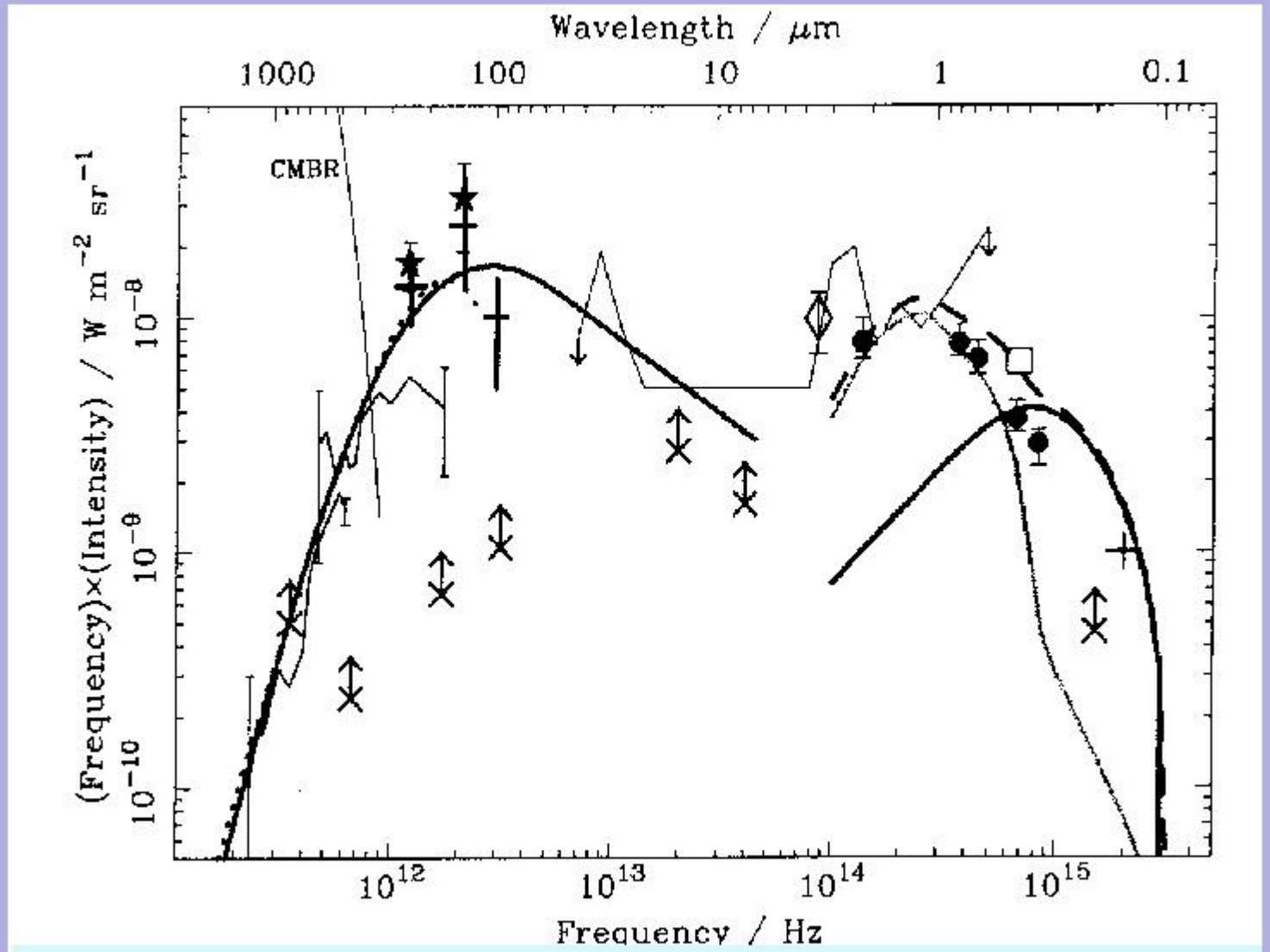
Examples of Science Potential of SAFIR, a 10-m FIR Telescope

Cosmology

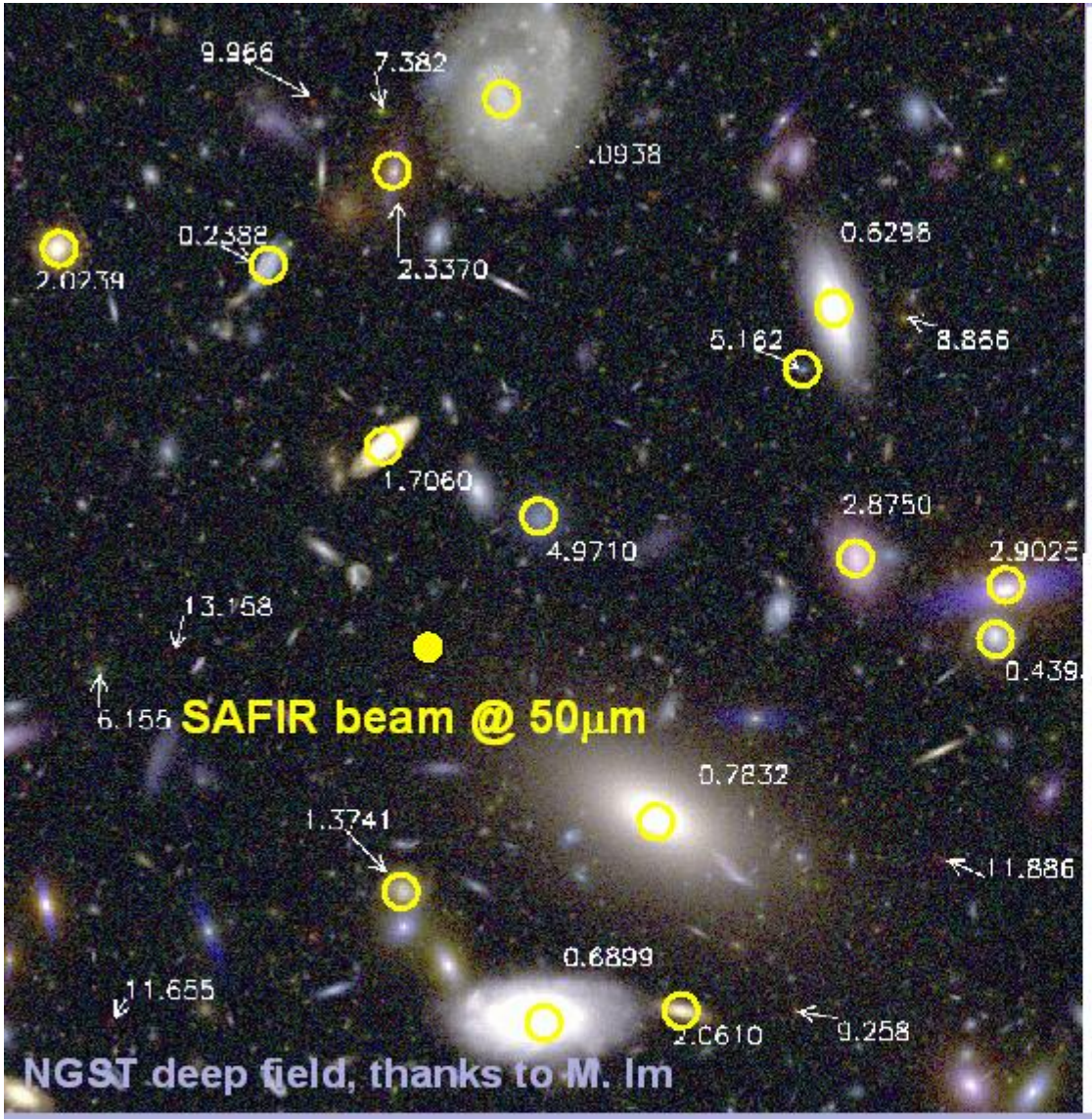
Formation of stars and planetary systems

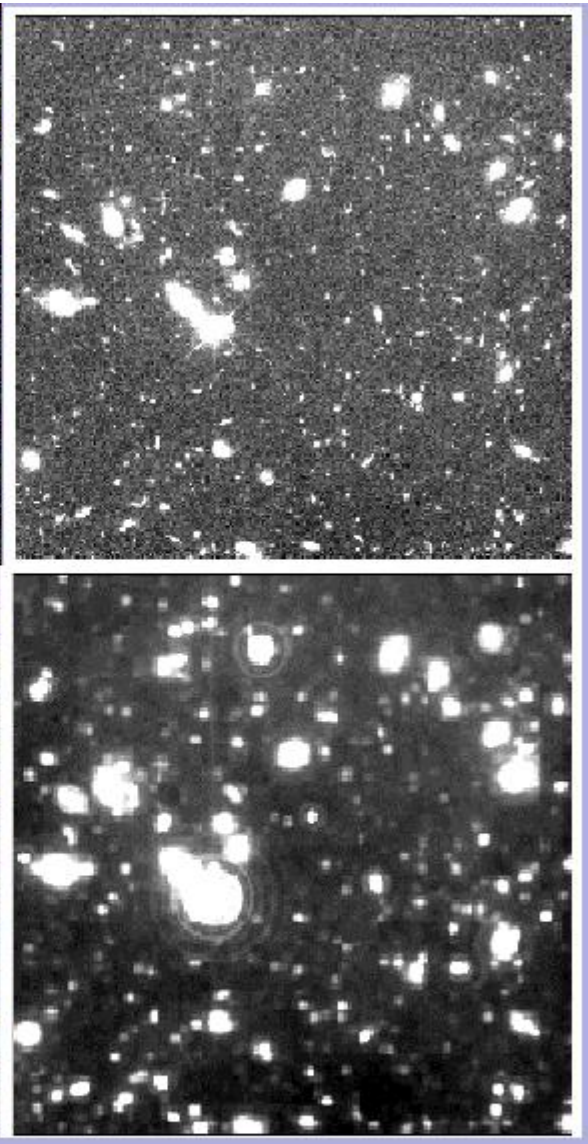
Planetary system evolution

More than Half the Cosmic Background from Galaxies must be Studied in the FIR/Submm



Comparison of COBE background measurements and various limits for integrated light of individually detected galaxies



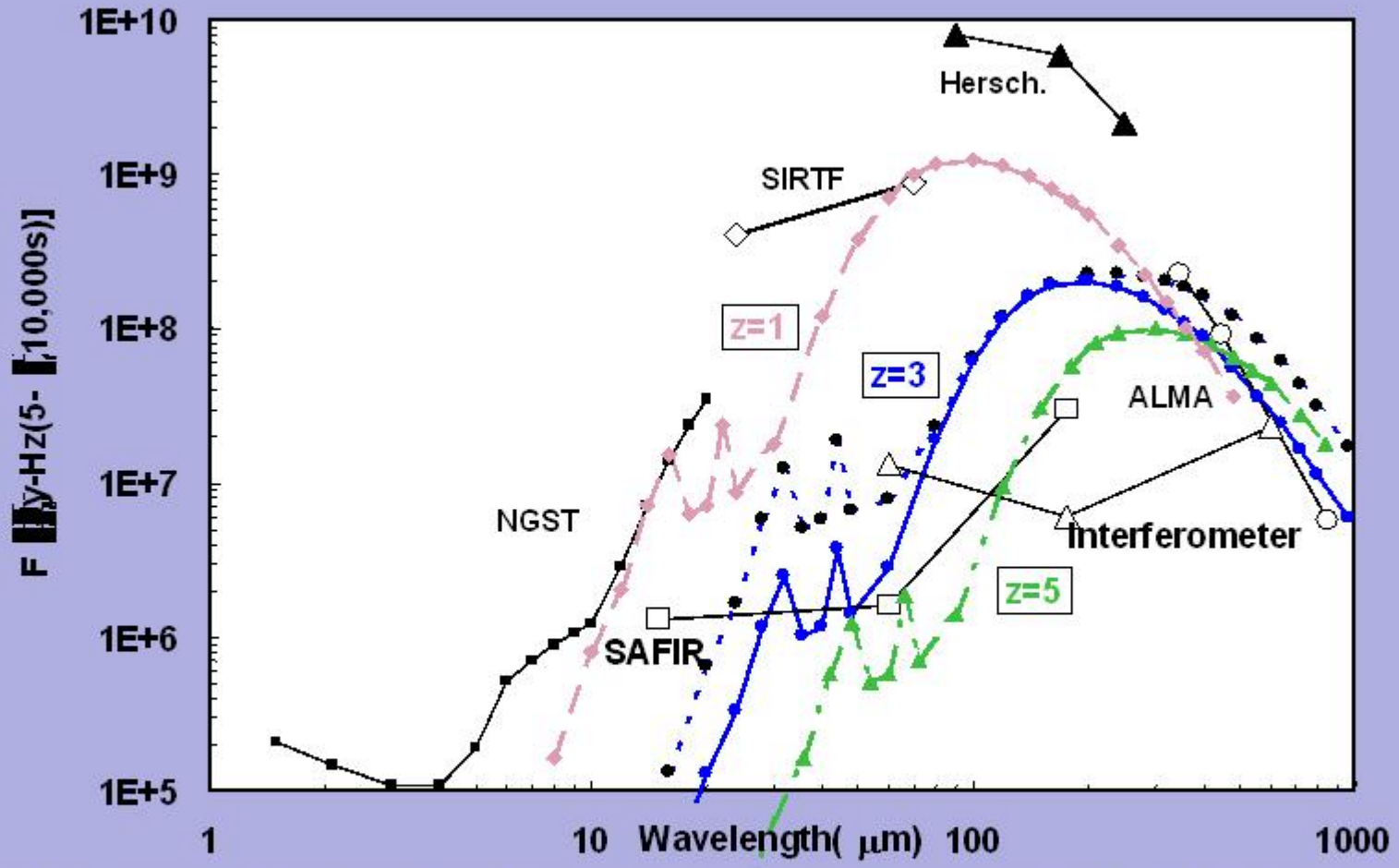


A section of the HDFN at original resolution (upper panel) and at resolution of SAFIR @ 50μm (lower panel) (thanks to J. Bechtold).

Because of difficulties in determining extinction in the rest frame UV, there are significant uncertainties in the star forming rate for $z > 1$.

SAFIR can measure luminosities of starburst galaxies out to $z = 5$ (ALMA is effective at luminosity measurement for $z \geq 4$). To illustrate, we have projected the SAFIR beam @ 50μm onto the NGST simulated galaxies at $z \leq 5$.

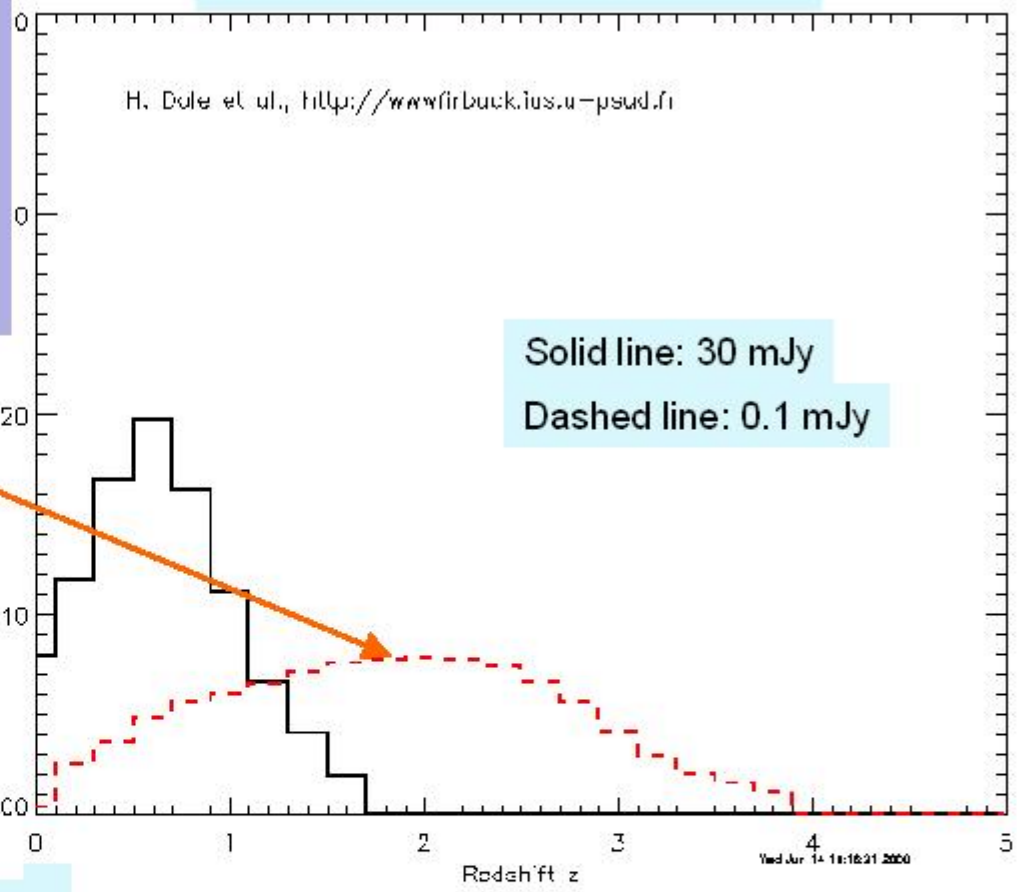
The FIR/Submm missions have unique capability for investigating normal galaxies over their period of formation.



Starburst powered far infrared output of an L*(IR) galaxy. We also indicate the performance of NGST, SIRTF, FIRST, ALMA. SAFIR, and a 30m cold interferometer. For the z=3 case, we have shown the total (starburst plus IR cirrus) spectrum as a dashed line with black dots.

At the sensitivites of SAFIR and a longer wavelength interferometer, the detected galaxies will be distributed out to z = 5

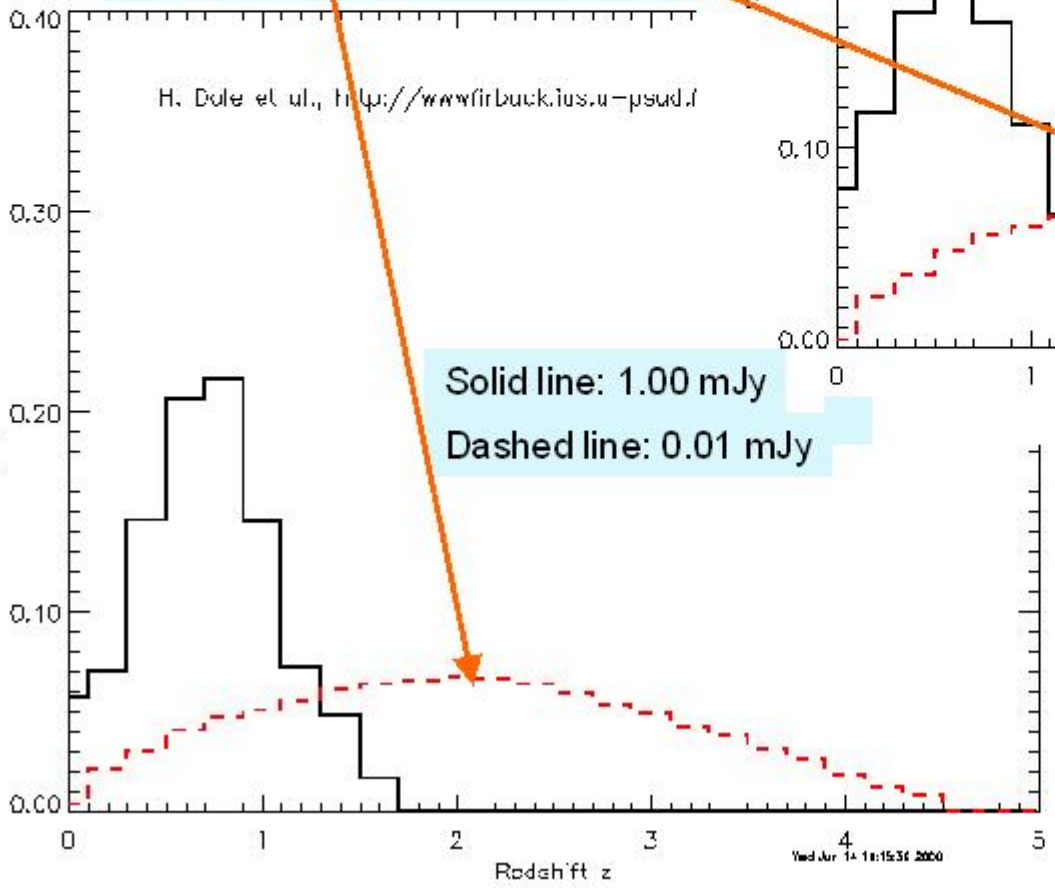
Redshift Distribution at 160 microns



Solid line: 30 mJy

Dashed line: 0.1 mJy

Redshift Distribution at 70 microns



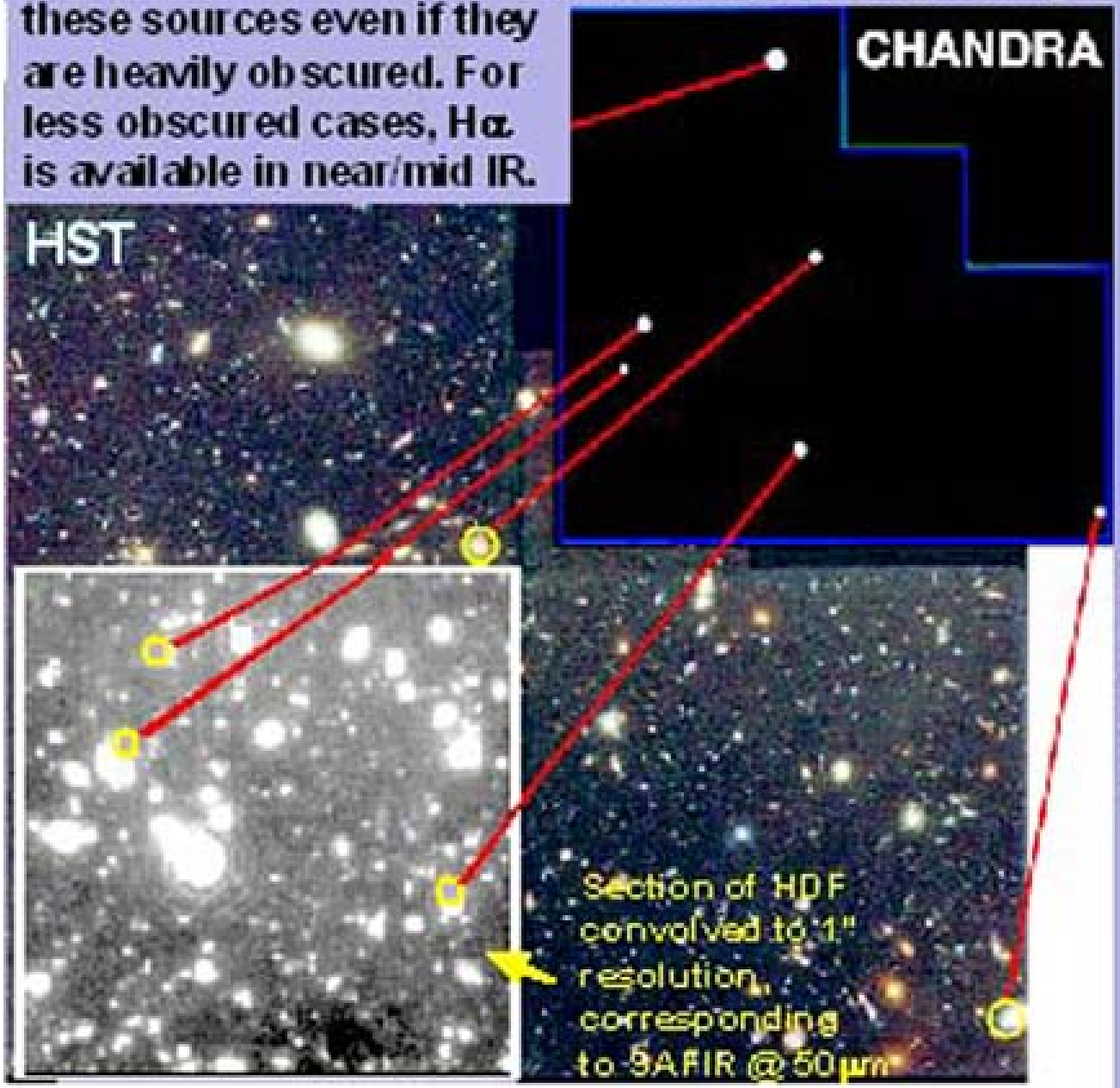
Solid line: 1.00 mJy

Dashed line: 0.01 mJy

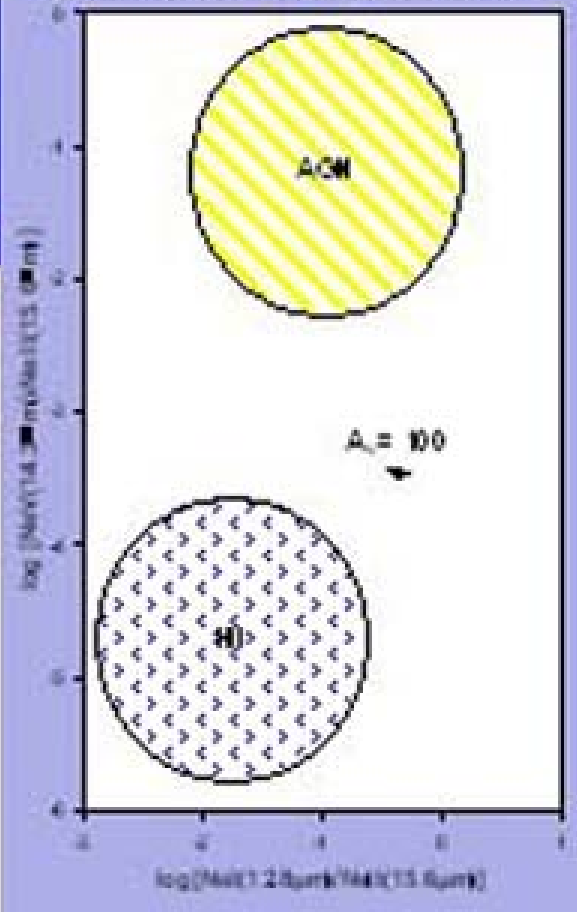
z distribution based on a model fitted to COBE background and deep ISO counts, by H. Dole.

Probing Distant X-Ray Sources/ULIRGs

Mid-IR fine structure lines (shifted to far IR) can study these sources even if they are heavily obscured. For less obscured cases, Hα is available in near/mid IR.

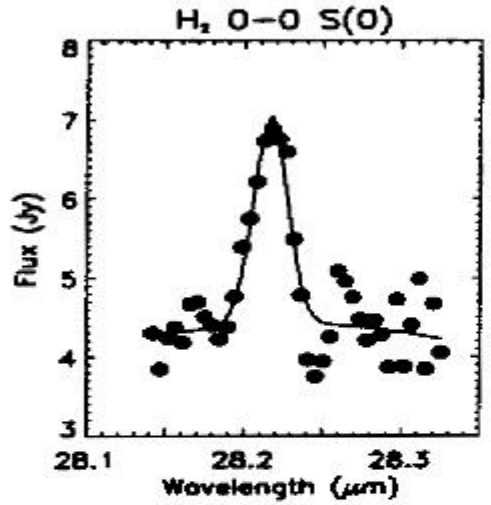


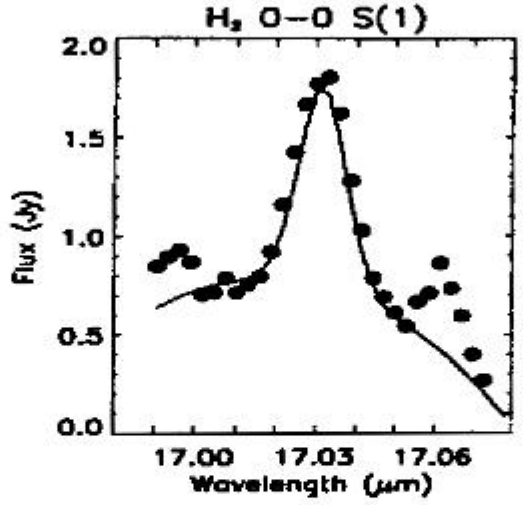
Ne V is not excited by hot stellar spectra, but is by the hard UV spectra of AGNs. Hence, NeV(14.3μm)/NeIII(15.6μm) vs. NeII(12.8μm)/NeIII(15.6) distinguishes the two types and gives the slope of the UV continuum. The ratios are virtually extinction independent.



What Happened Before Galaxies Formed??

Far infrared and submm spectra are one of the few conceivable ways to find out.





ISO detections of low Lying H_2 emission lines from diffuse interstellar gas at T ~ 100K and n ~ 3000cm^{-3}, from Thi et al.

How do the first gas clouds form? How do their characteristics change as the first traces of metals are injected into them by stellar processing? The low lying H_2 lines at 17 and 28.2μm are one of the few conceivable ways to study molecular gas prior to the formation of metals. These lines are undetectable together from the ground until z > 20. Once even traces of metals have formed, the C^+ line at 157μm becomes very bright; it will be routinely observed from the ground only at $z \geq 4$.

Formation of stars and planetary systems

Star and planet formation occurs hidden from view in cold cloud cores that can be penetrated in the FIR/Submm

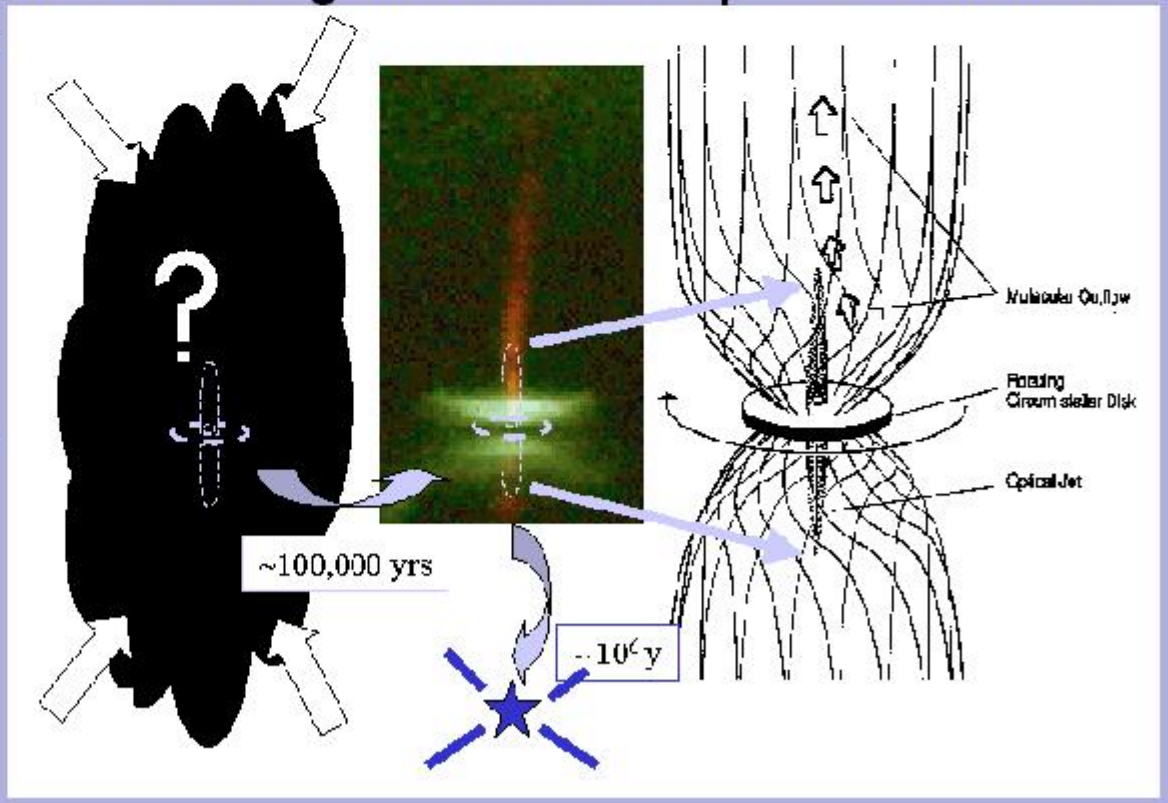
A large FIR/Submm telescope can reveal:

- Density and temperature structure of collapsing cold cores
- Chemical composition, ionization state, turbulence
- Formation of binary stars, circumstellar disks
- Magnetic field structure (through polarimetry)

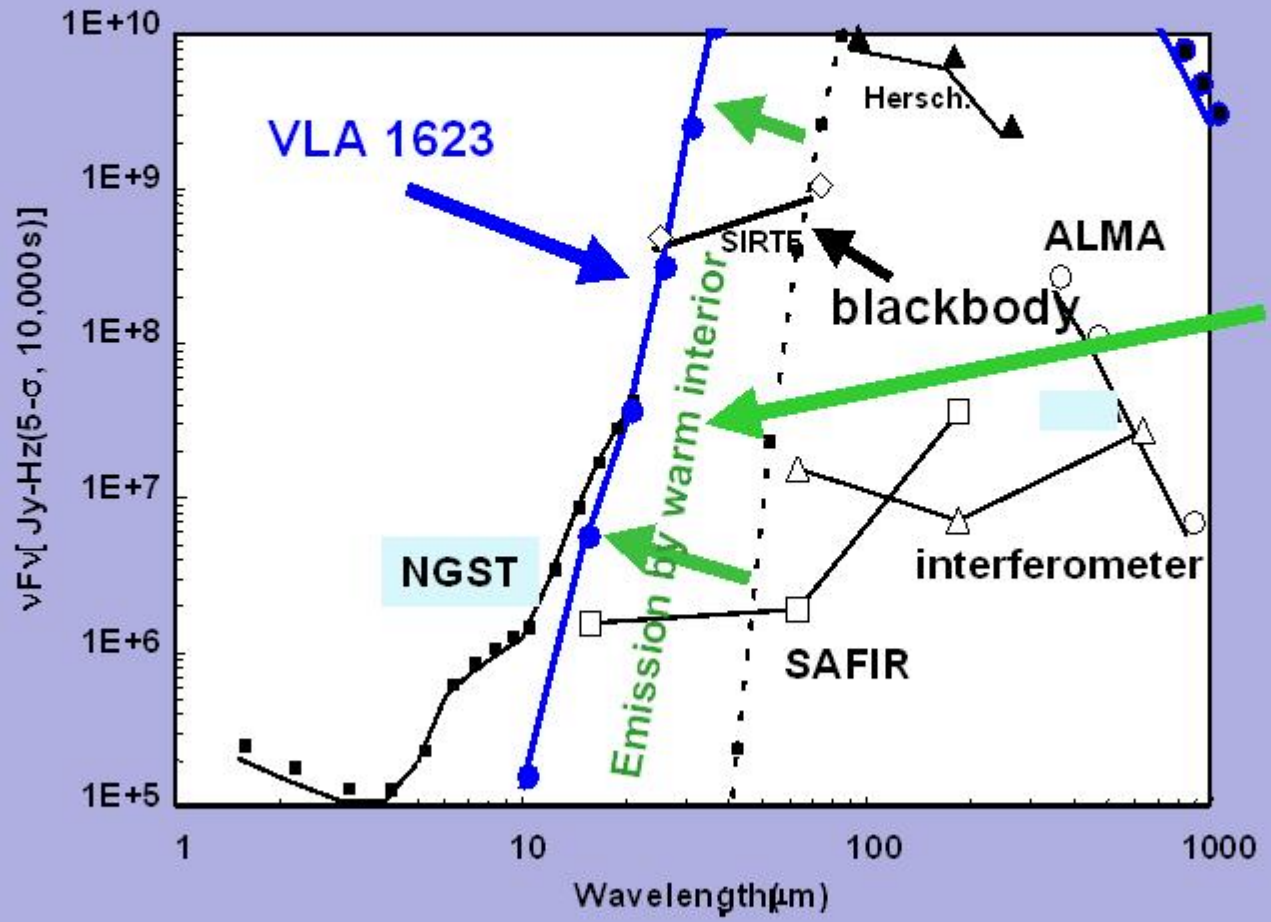
An interferometer could probe:

- Circumstellar disk structure in the region of terrestrial planet formation
- Role of magnetic fields in accelerating and collimating jets

Birth of a Planetary System

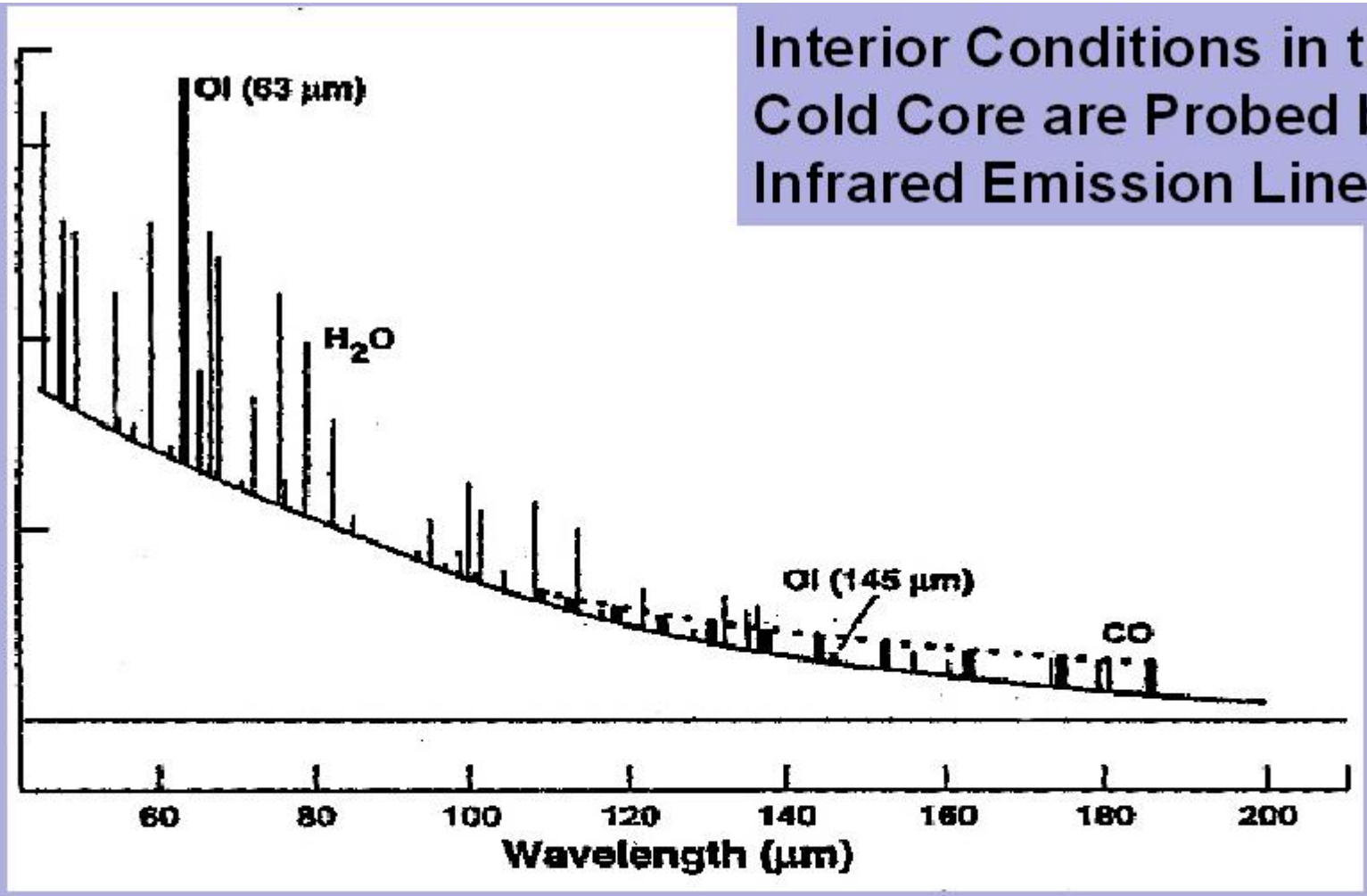


The Output of a Cold Cloud Core is Peaked in the FIR/Submm, and its Structure and Interior Conditions are Best Observed in Those Spectral Regions.



SAFIR is well suited to studying the structure and radiative transfer from the interior of the cloud.

Interior Conditions in the Cold Core are Probed by Far Infrared Emission Lines.



Predicted far infrared spectrum of a collapsing cold cloud core, from Ceccarelli, Hollenbach, and Tielens. The spectrum is dominated by OI with narrow components from the infalling envelope and broad ones from outflow shocks; complexes of CO, which are the main coolant for the outer cloud; and H_2O, the dominant coolant in the inner cloud, where a broad component is expected from the accretion shock and a narrow one from the disk.

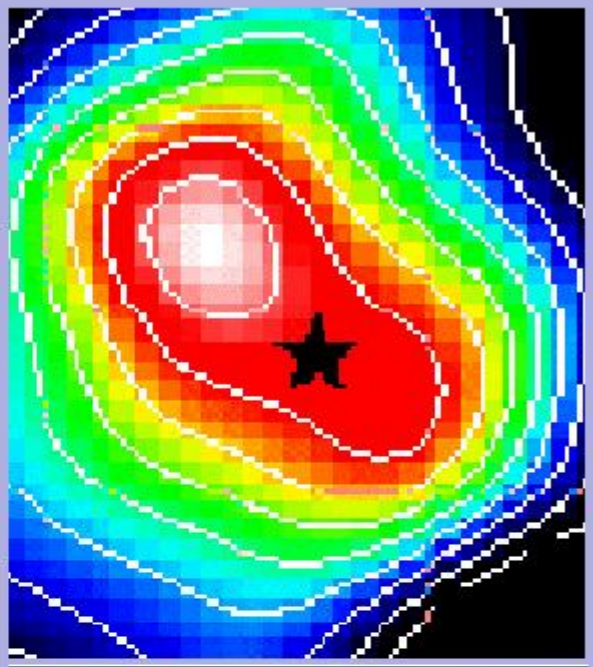
Planetary system evolution

Planetary debris disks can reveal

- Voids due to planets (and other causes)
- Bright and warm zones from planetesimal collisions
- Mineralogy at different distances from star; e.g., features at 15-35μm can distinguish crystalline and amorphous silicates
- Water ice @ 63μm

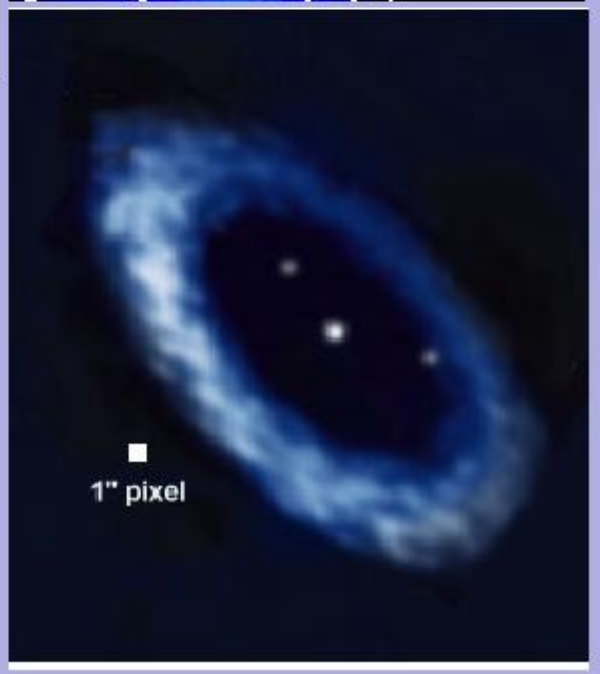
A large FIR/Submm telescope can image nearby debris disks in the regions of terrestrial and giant planet formation

An interferometer could obtain similar images of young disks in the nearest star forming regions



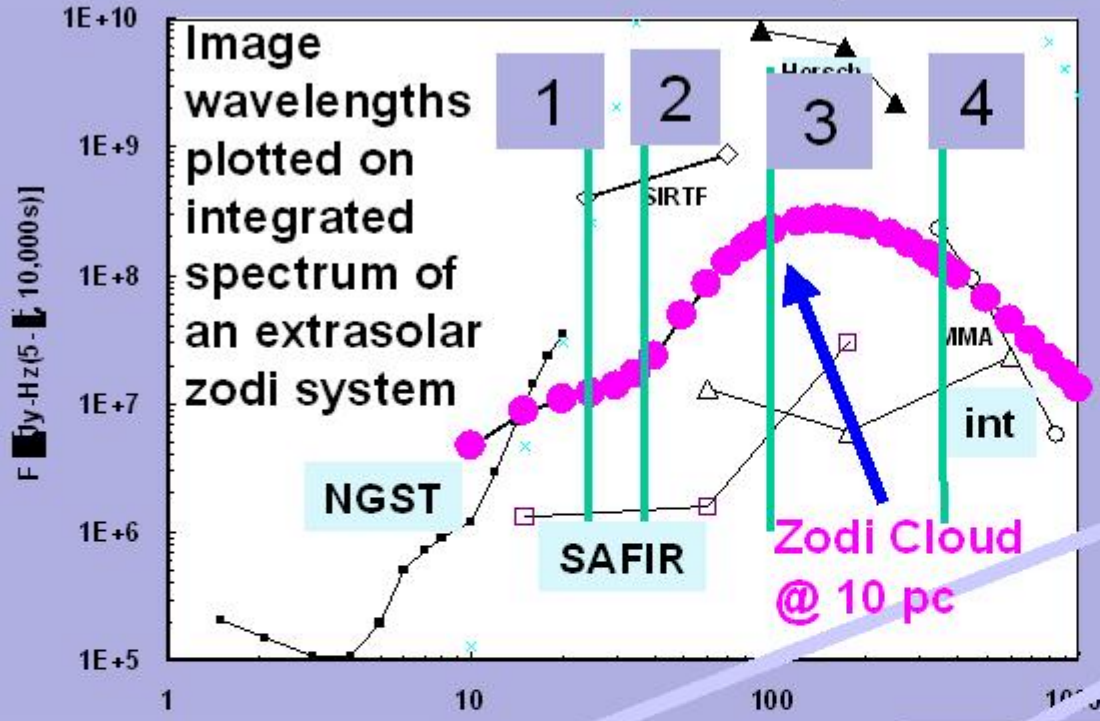
SCUBA image of Vega

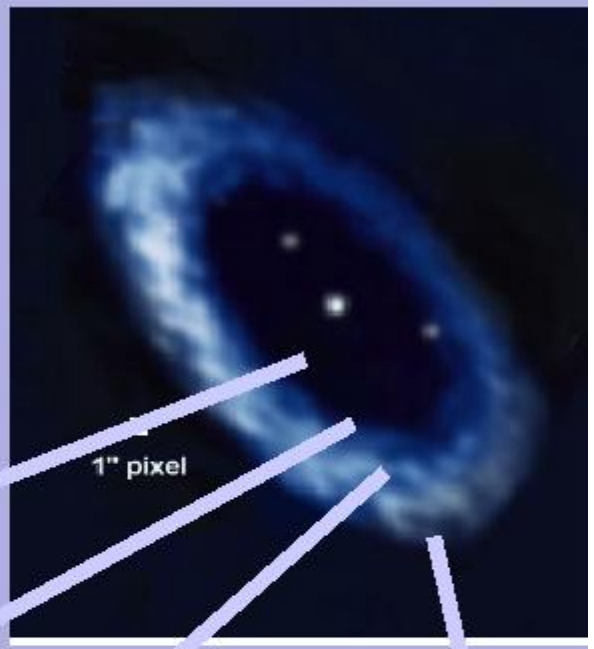
10-m telescope @ 50μm

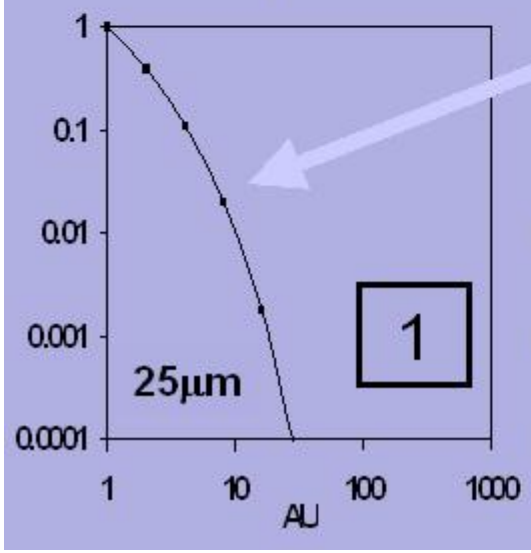


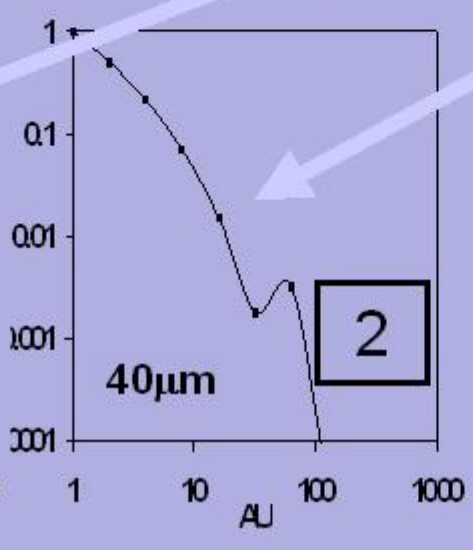
Planet Systems Evolve

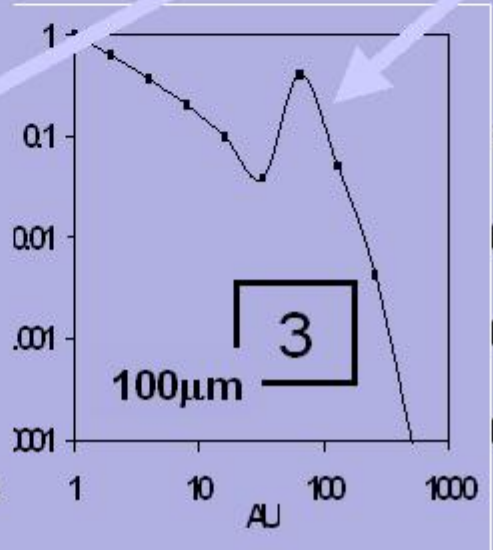
Images of a Debris Disk at Different FIR Wavelengths Reveal Different Aspects of its Structure.

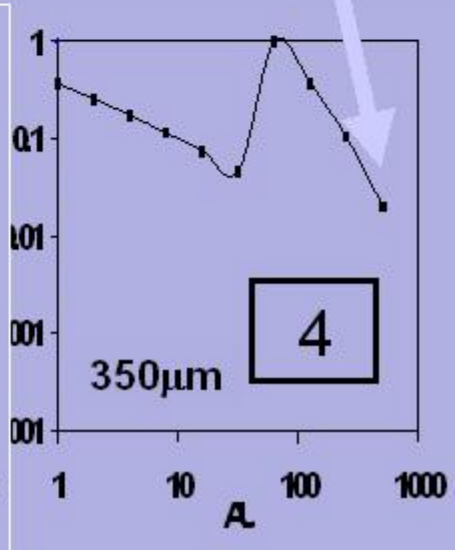


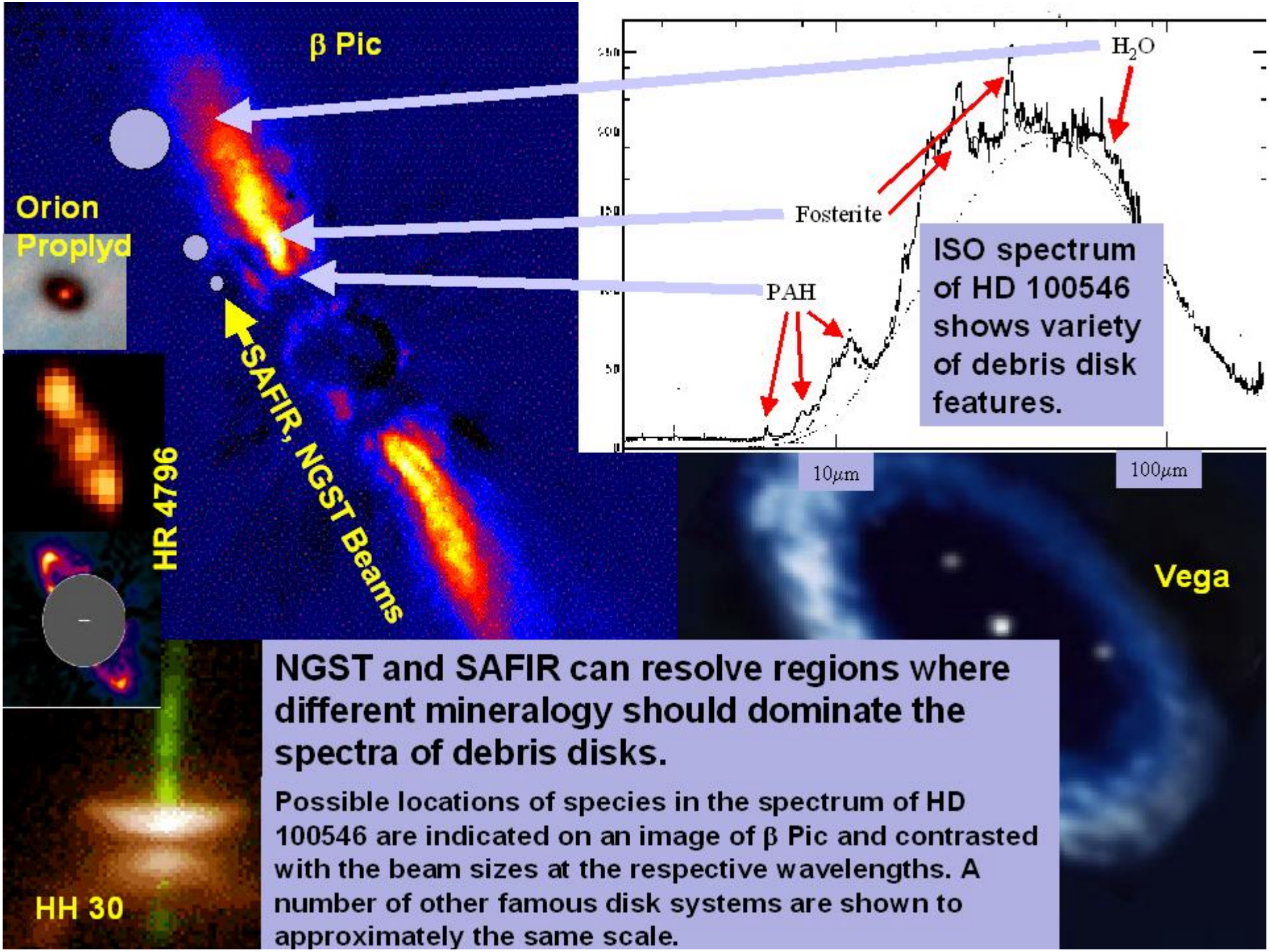






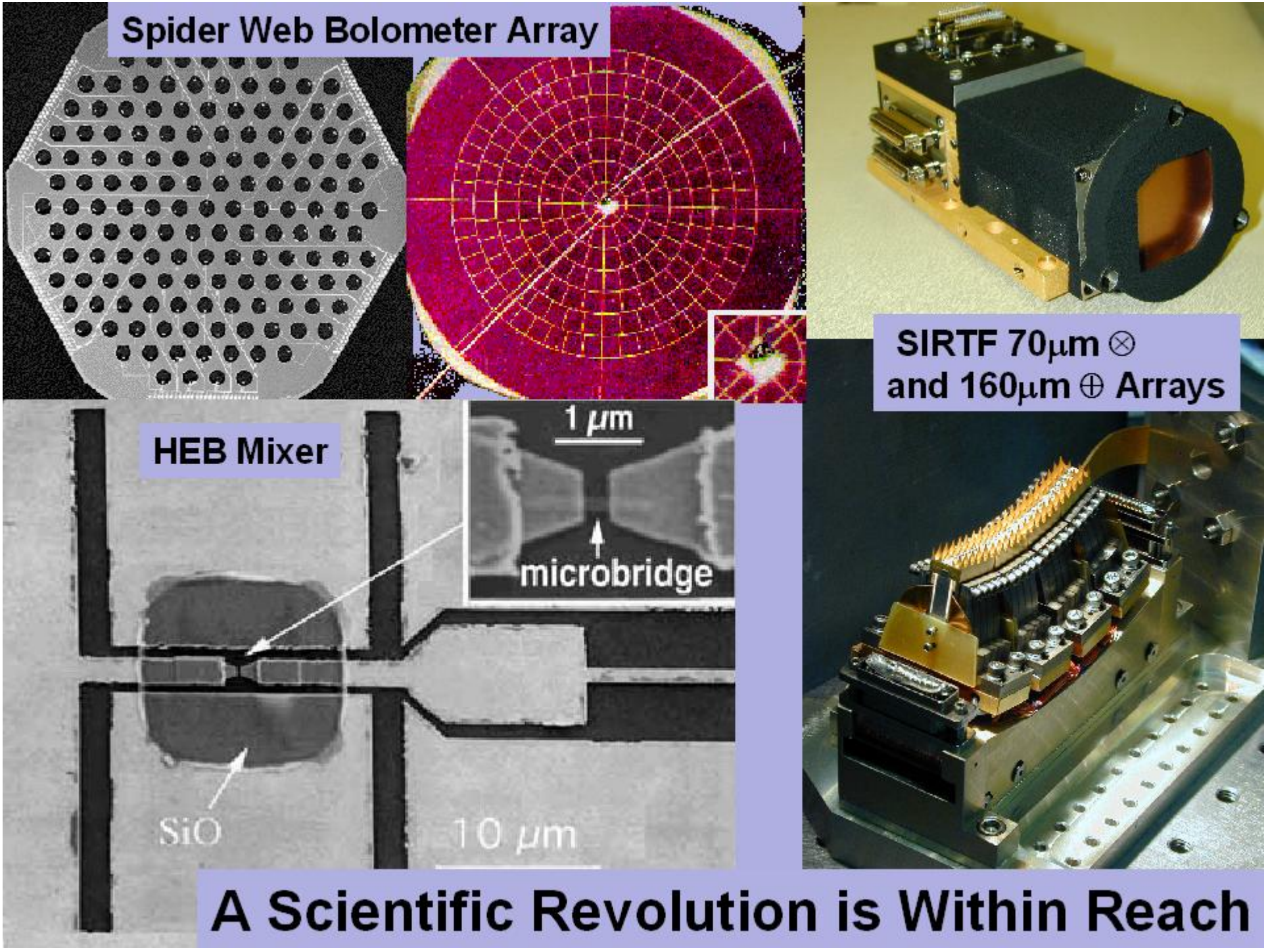






NGST and SAFIR can resolve regions where different mineralogy should dominate the spectra of debris disks.

Possible locations of species in the spectrum of HD 100546 are indicated on an image of β Pic and contrasted with the beam sizes at the respective wavelengths. A number of other famous disk systems are shown to approximately the same scale.


Spider Web Bolometer Array
SIRTF 70μm ⊗
and 160μm ⊕ Arrays
HEB Mixer
1 μm
microbridge
SiO
10 μm
A Scientific Revolution is Within Reach

What might we learn in the FIR? Similar gains have revolutionized our understanding in the radio and X-ray!!

…. an exciting new chapter in the history of astronomy is beginning to unfold. At this early stage, many of the most promising theories may be completely incorrect. …….

It may turn out that none of the X-ray sources are neutron stars, for the simple reason that such a star may not exist.

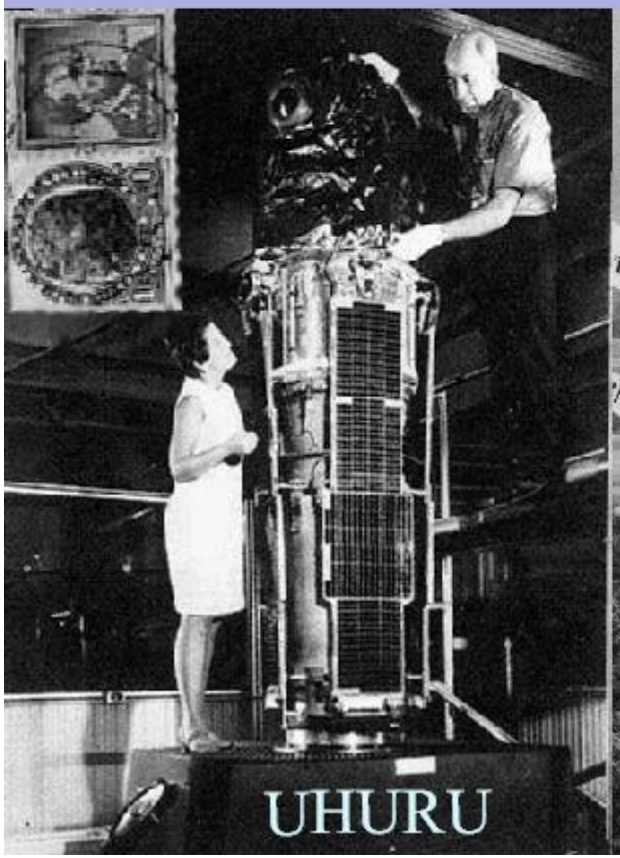
Until the sources of X-ray emission in the night sky are understood, they will intrigue us especially. Bowyer, S&T, 30, 264, 1964

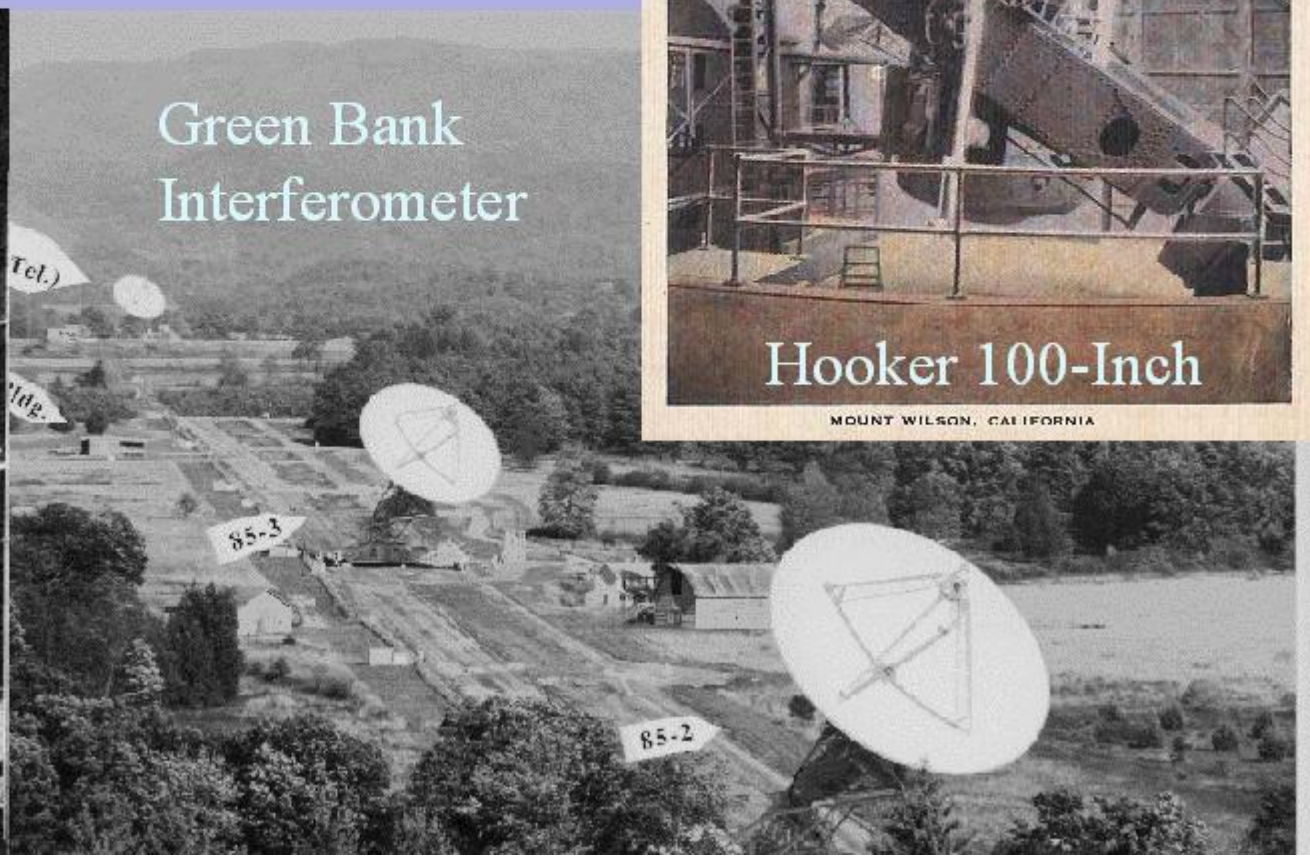
……we should like to state that the *Astronomical Journal* heartily welcomes authors to submit papers on radio astronomy and assures them that their papers will be given every consideration….

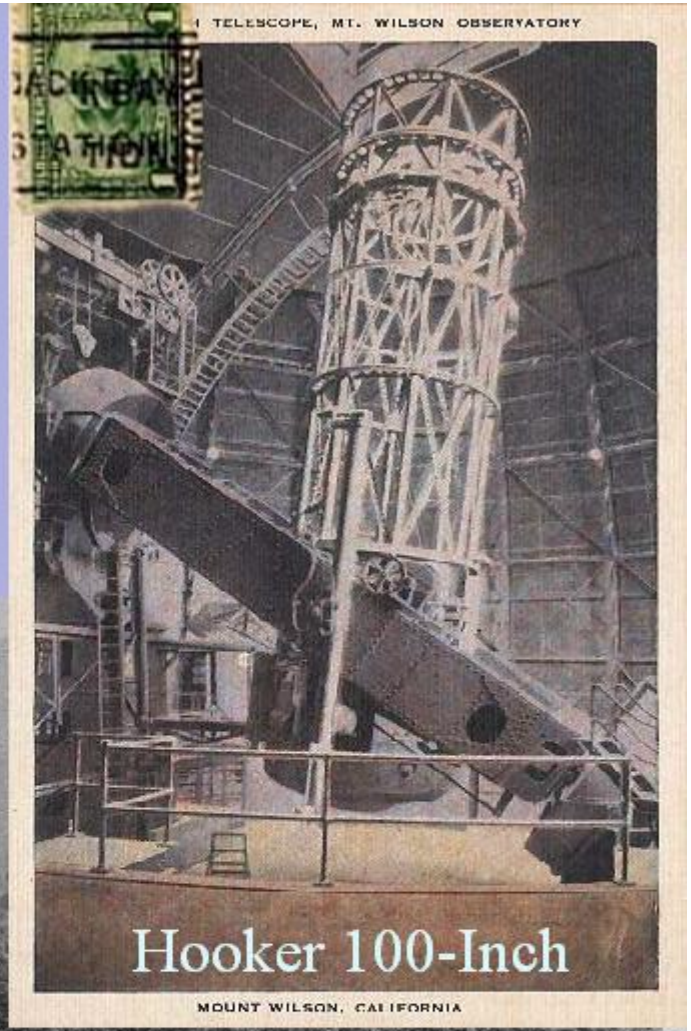
Radio astronomy is a rapidly developing branch of astronomy; and any schism between this newer branch and the older branch of optical astronomy is to be greatly regretted. Brouwer and Smith, AJ editorial, 1959.

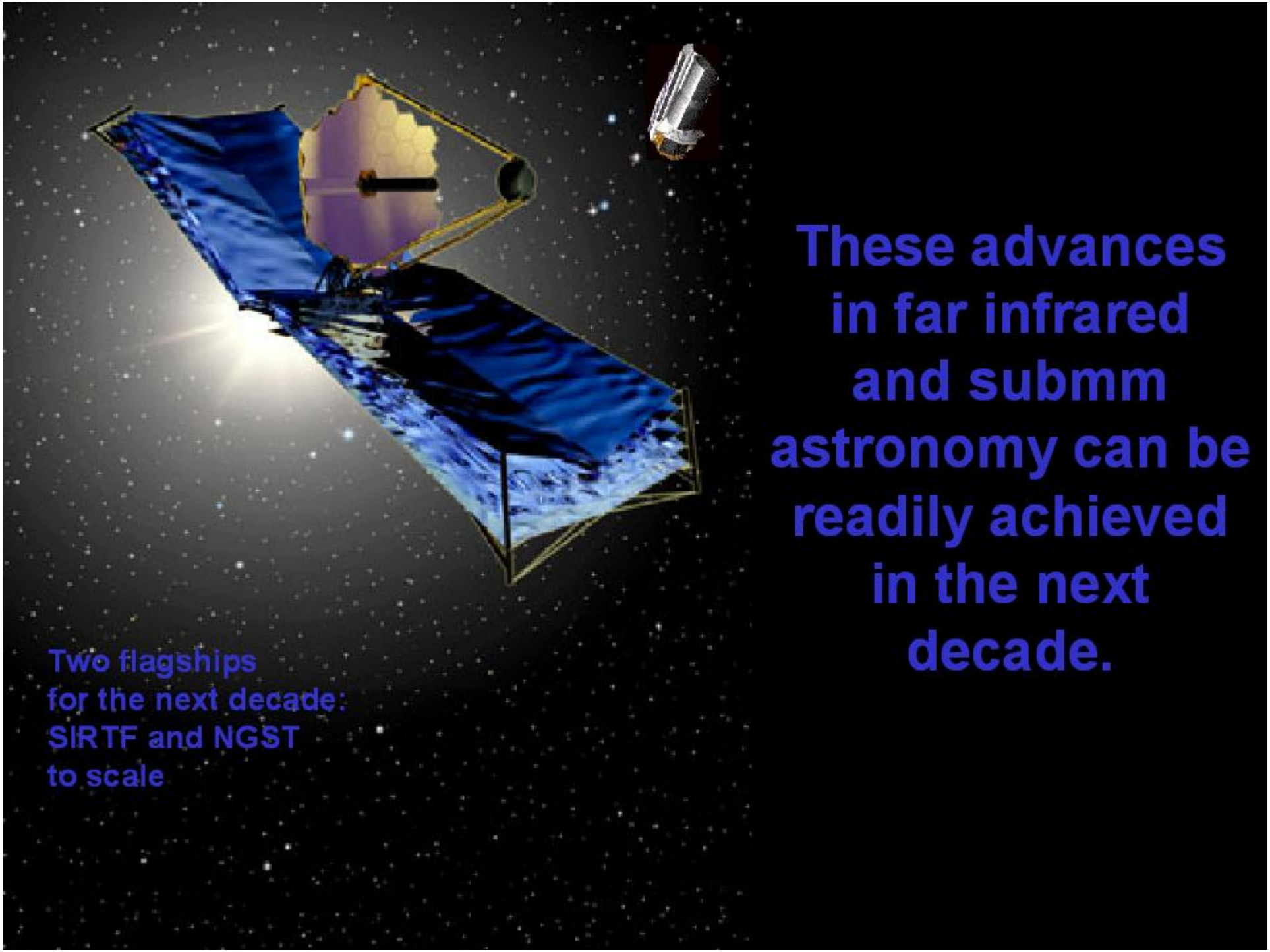
Both articles from the eras when the fields were ~ 10^{10} behind current capability

Postcards from the past: when X-ray, optical, and radio astronomy came well within a factor of 10^{10} of their current astronomical capability








These advances
in far infrared
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Two flagships
for the next decade:
SIRTF and NGST
to scale