The Space Infrared Interferometric Telescope (SPIRIT)

Concept for a sub-arcsecond far-IR space observatory in your lifetime

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SPIRIT Origins Probe Mission Concept Study Team

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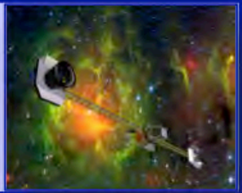
Outline



- Science – design drivers
- Concept overview
- Measurement capabilities
- Mission capture success criteria
- Technical feasibility
- Affordability and partnership

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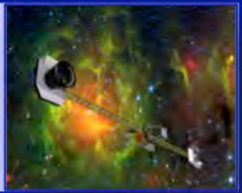
Science goals drive the design

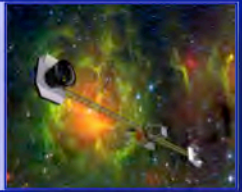


- Image protoplanetary disks and measure the distributions of water vapor and ice to learn how the conditions for habitability arise during the planet formation process;
- Image structures in a large number of debris disks to find and characterize unseen exoplanets; and
- Make profound contributions to our understanding of the formation, merger history, and star formation history of galaxies.

Also:

- Probe the atmospheres of extrasolar giant planets; and
- A vast, untapped discovery space

Derived requirements



- Sub-arcsecond angular resolution over the wavelength range 25 – 400 μm (between JWST and ALMA)
  - Image protostellar and debris disks
  - Beat extragalactic source confusion
- Spectral resolution, R ~ 3000 (integral field spectroscopy)
- ~10 μJy continuum, 10^{-19} W/m^2 line sensitivity
  - Detect low surface brightness debris disks
  - Measure SEDs and spectral lines of high-z galaxies
- >1 arcmin instantaneous FOV

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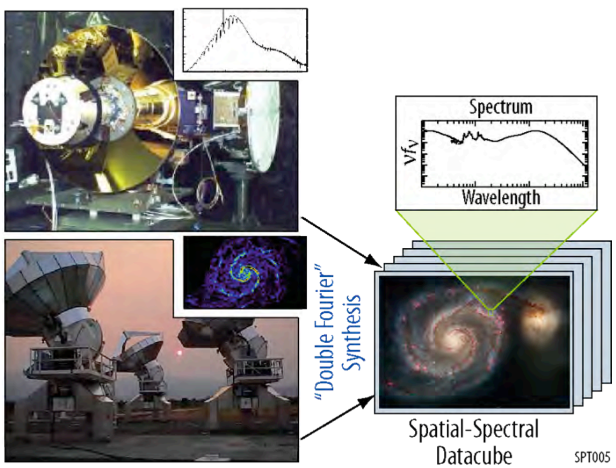
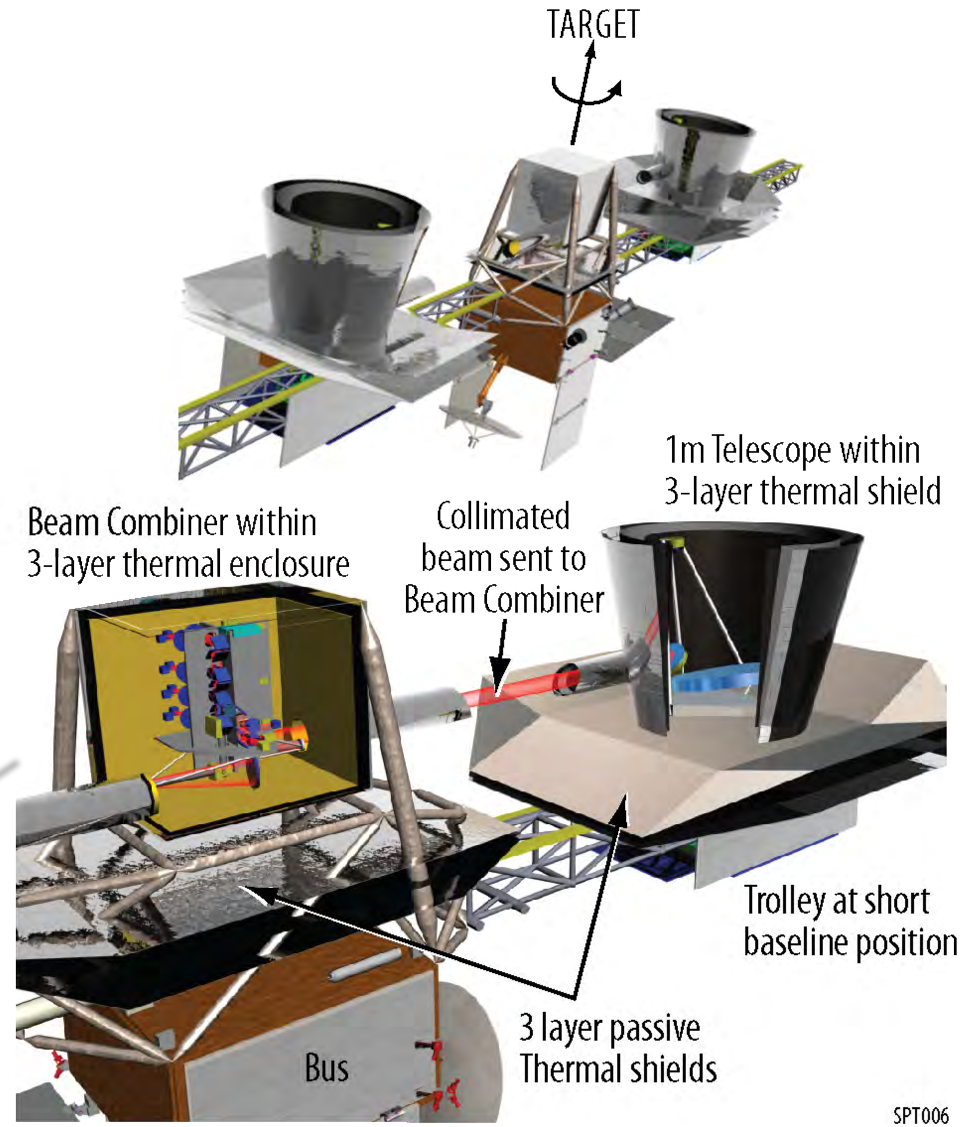
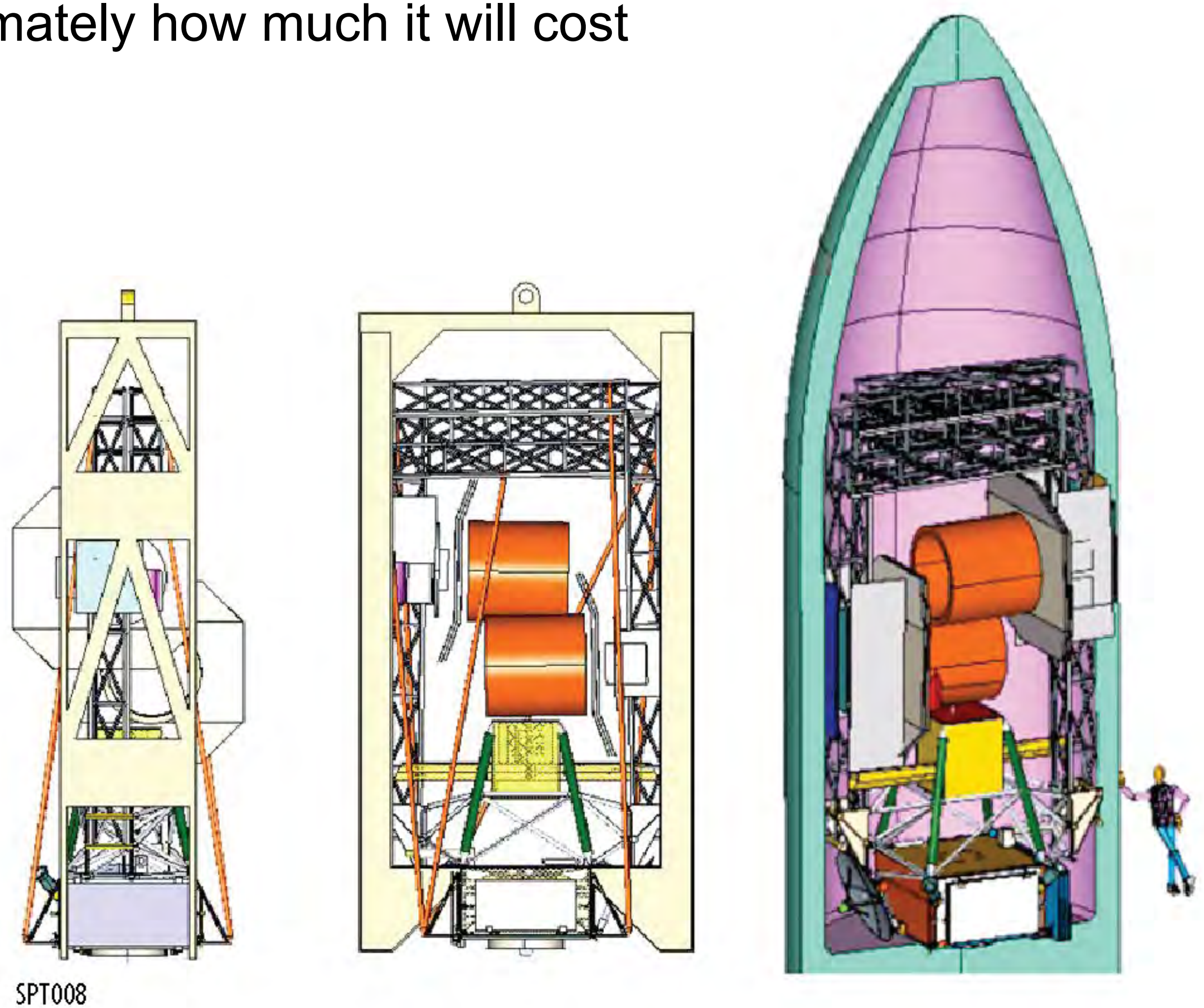
- SPIRIT is a spatio-spectral (“double Fourier”) interferometer
- The mission concept was developed to Phase A level





A single instrument

We know how to build, test, launch, and operate SPIRIT, and we know approximately how much it will cost ($1.3B).



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- **Measurement capabilities**
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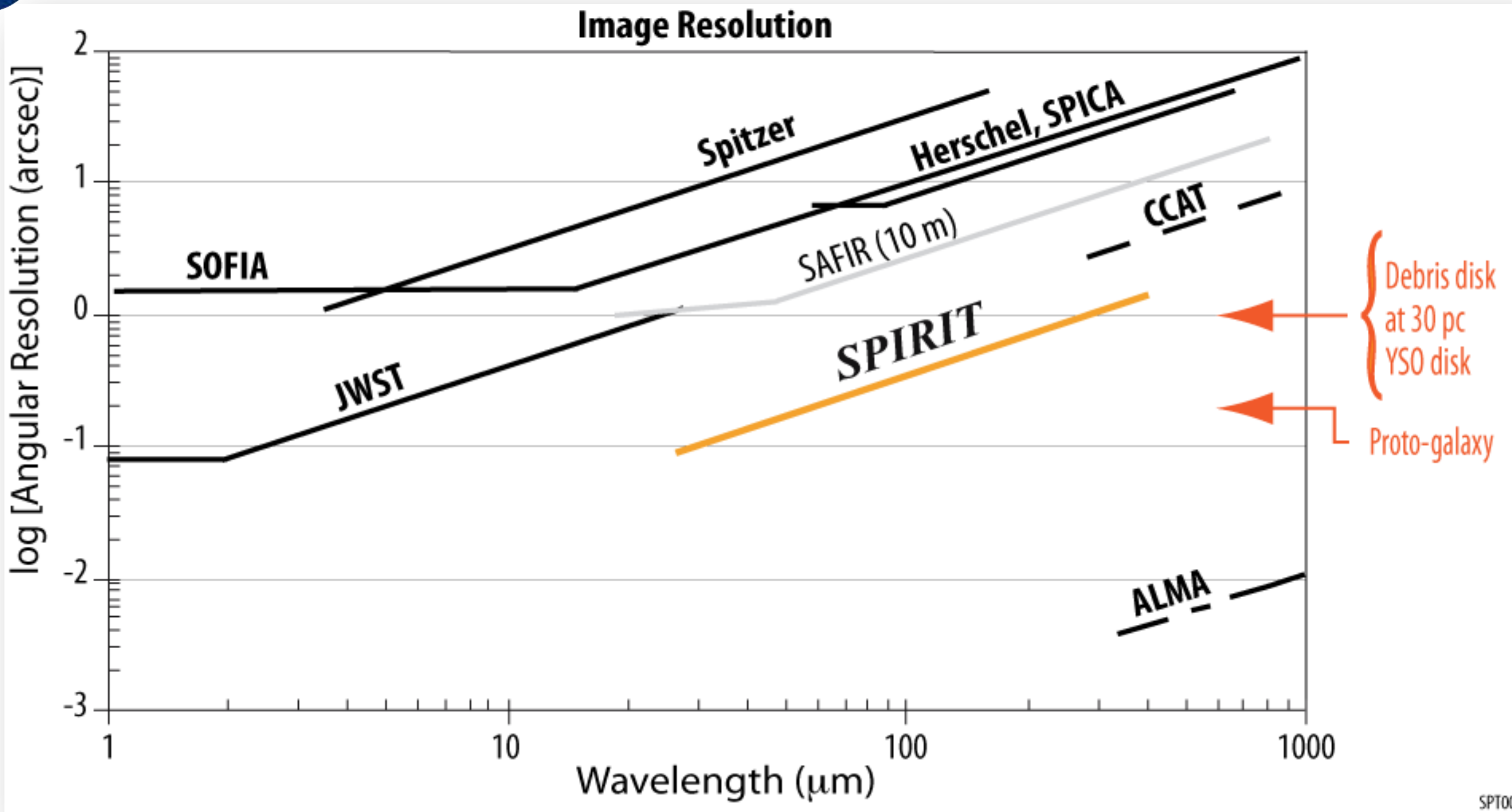
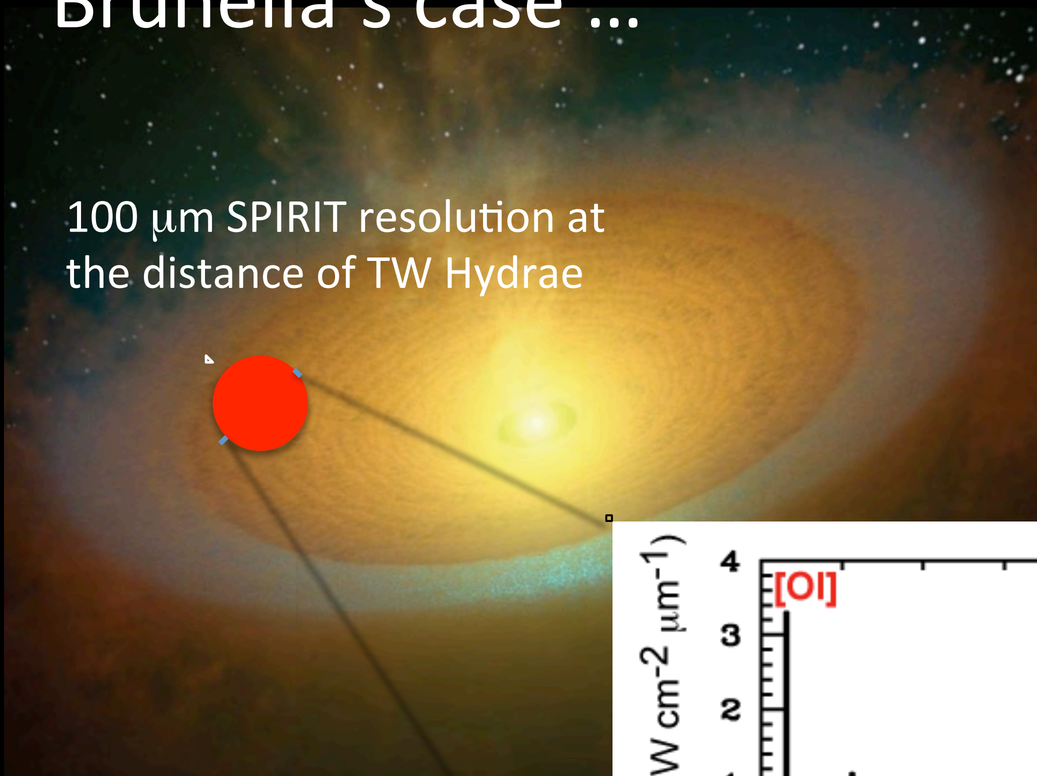


Sub-arcsecond angular resolution is sorely lacking in the far-IR, where protoplanetary and debris disks, and even high-z galaxies, are bright and their information content is great.

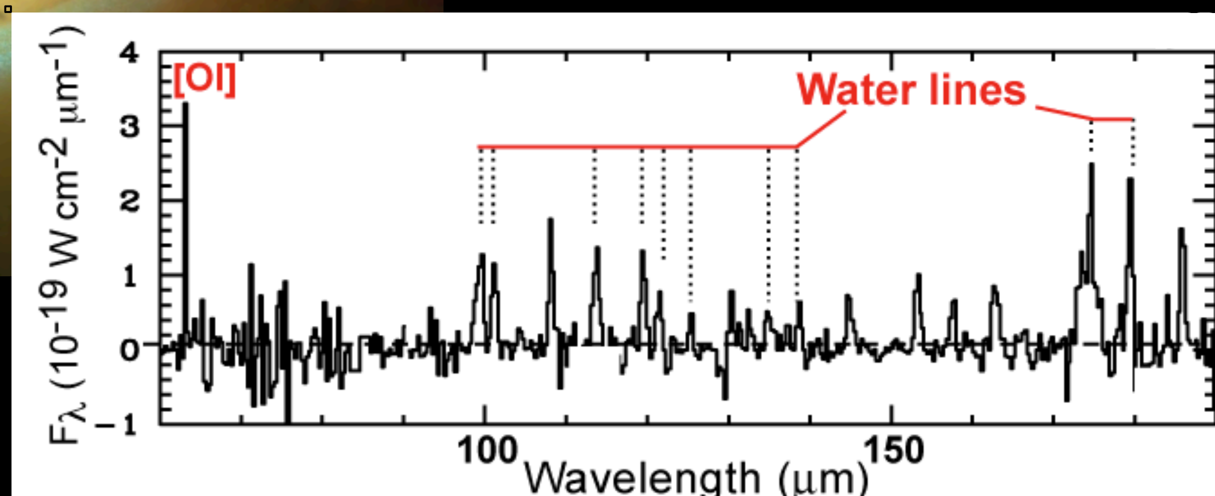
Forming habitable planets

Brunella’s case …



How did the Earth acquire its water? How do habitable planets form?

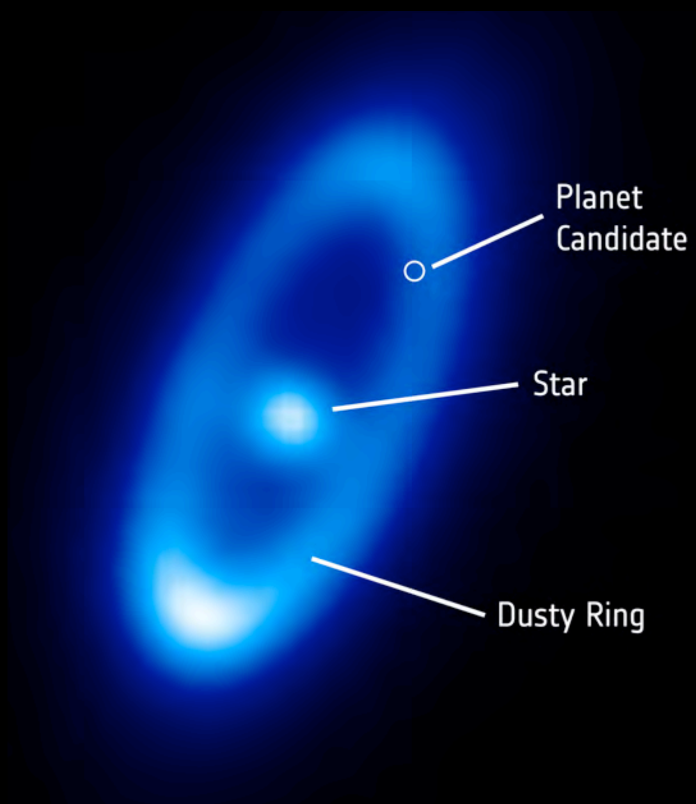
SPIRIT will provide the missing information.



Debris disks, planetary systems

Wayne's case …

Fomalhaut analog at 100 pc

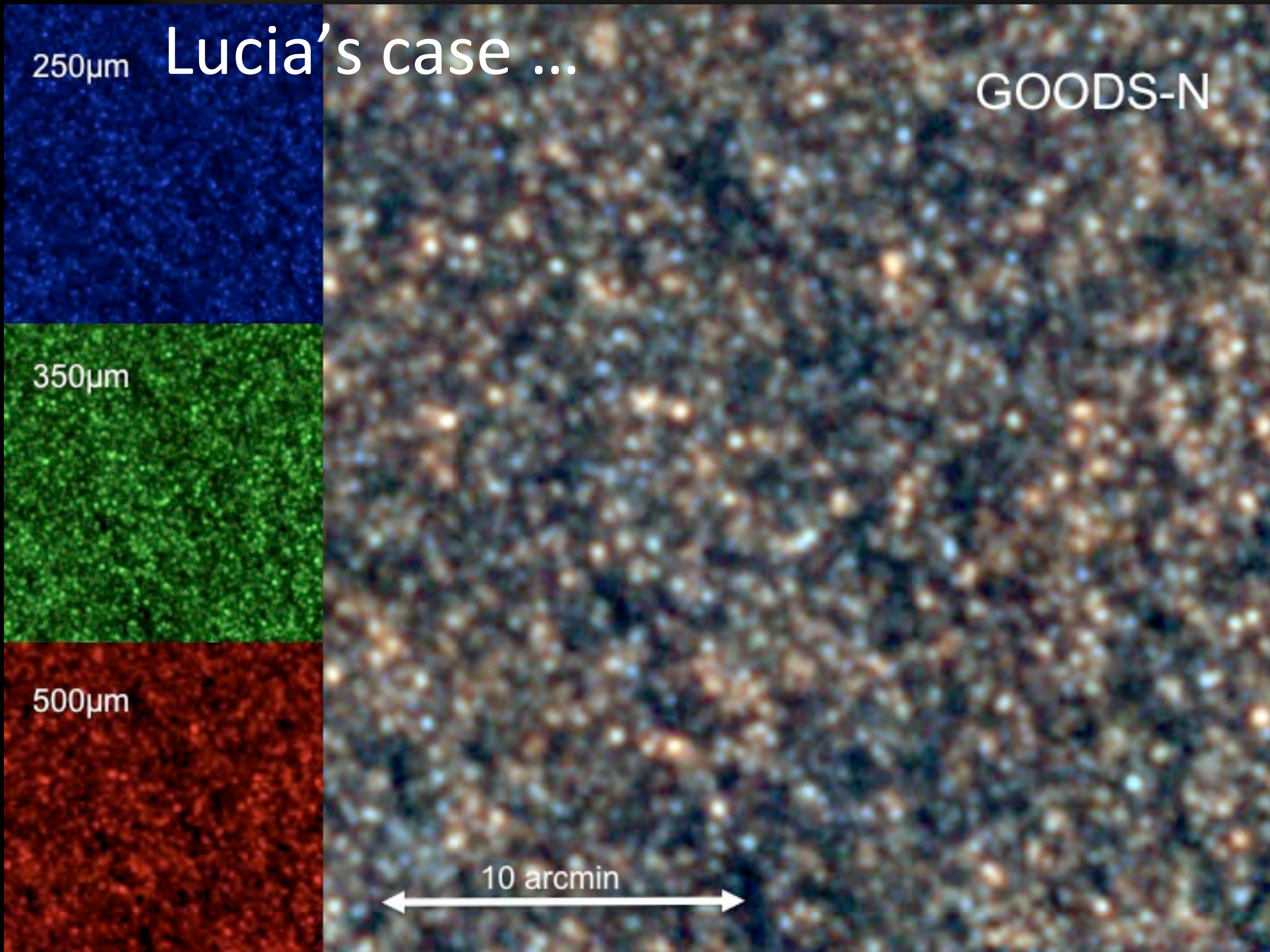


SPIRIT will image hundreds of debris disks

- SPIRIT resolution at 70 μm

Probing the universe deeply

Lucia’s case …



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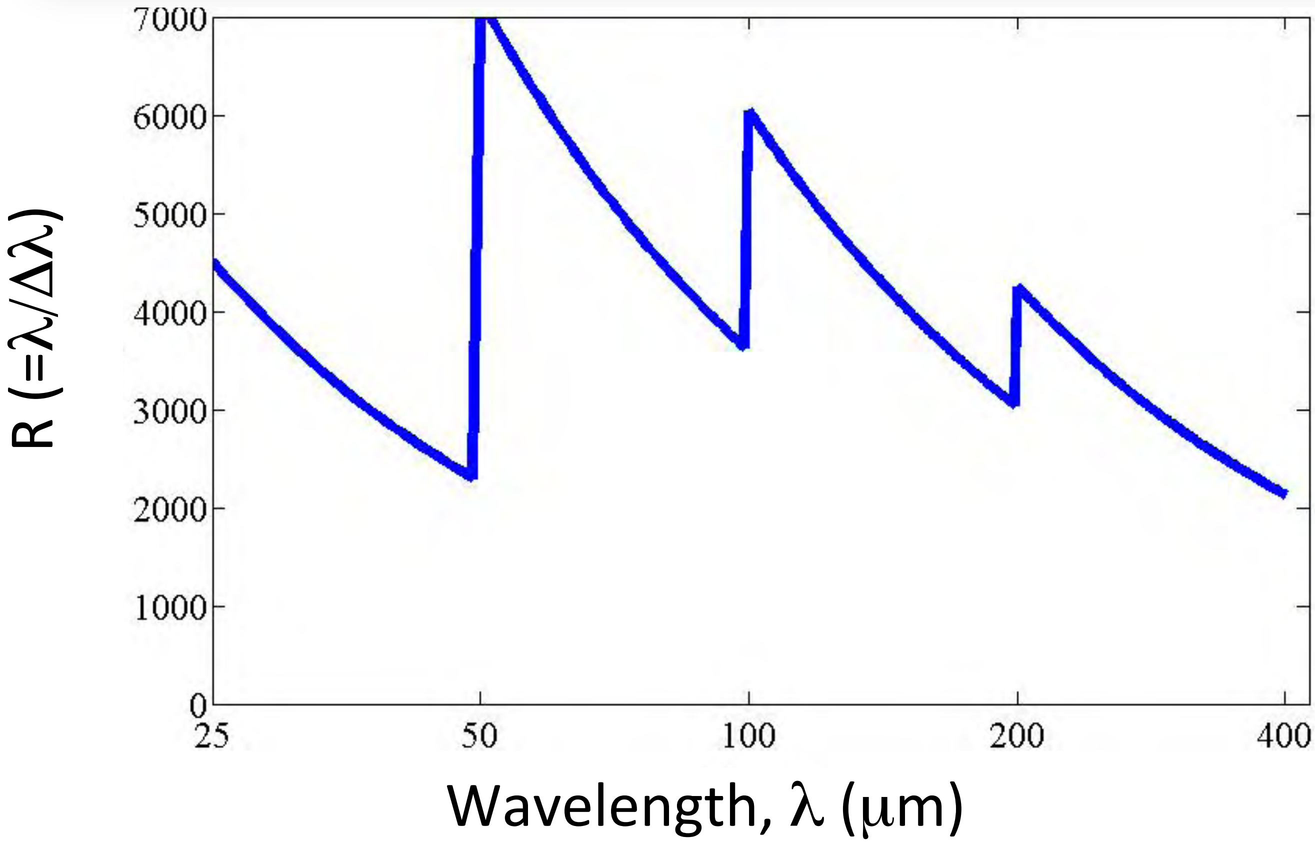
Deep field with a 3.5m telescope *(Herschel)*

Spectral resolution



Hyde et al. (2007), in Proc. SPIE 6687

SPIRIT spectral resolution, R (=λ/Δλ), as a function of wavelength. A cryogenic optical delay line scans physical distance 6.15 cm to satisfy the requirement R = 3000 at the center (geometric mean) of the 200-400 μm band.

Sensitivity

Point Source Sensitivity (5σ, 24 hrs – standard time on target)	Band-center wavelength (μm)			
	35	70	140	280
Spectral line (10^{-19} W m^{-2})	2.9	1.7	1.4	1.3
Continuum (μJy)	14	20	31	48

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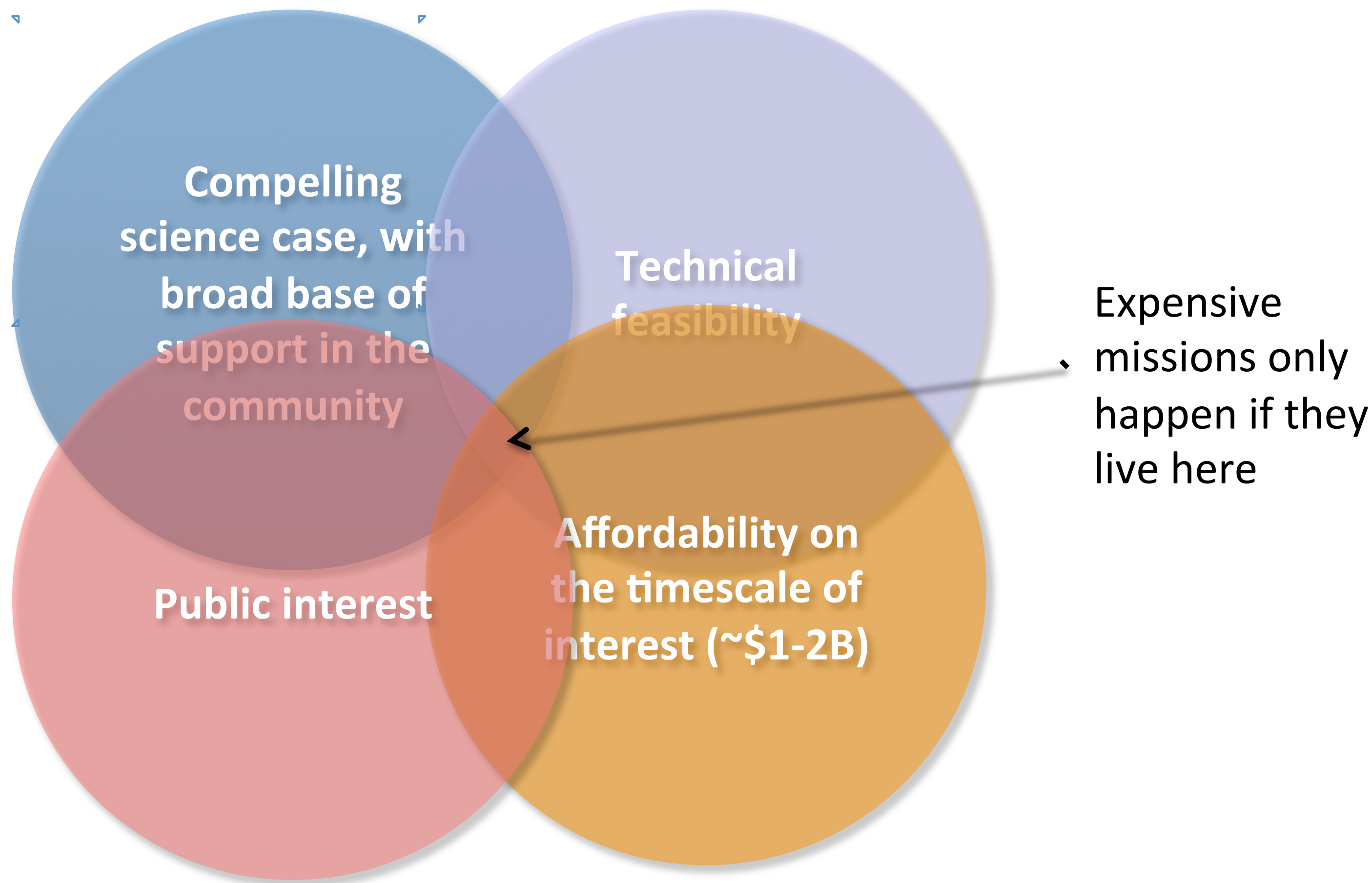
Prerequisites for success



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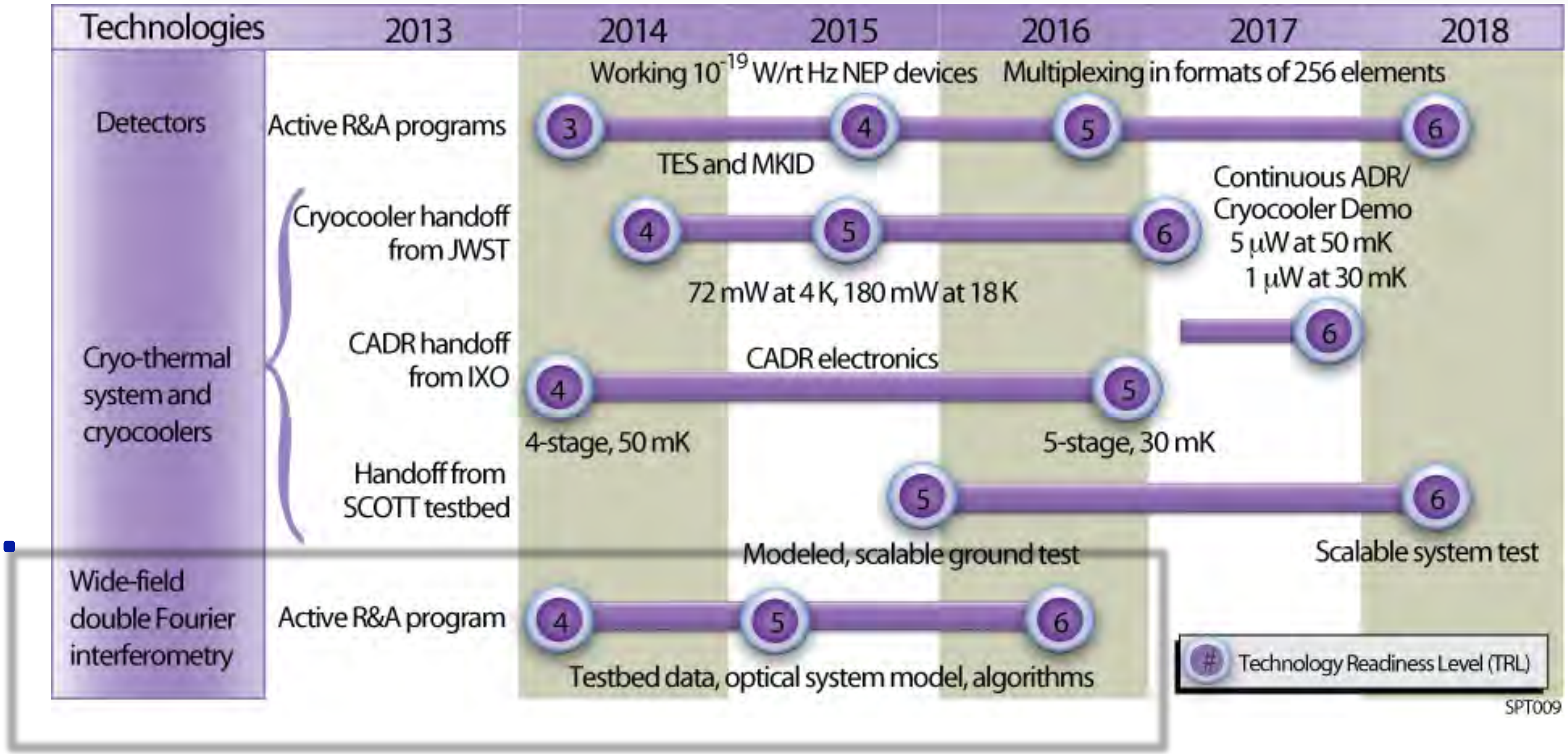
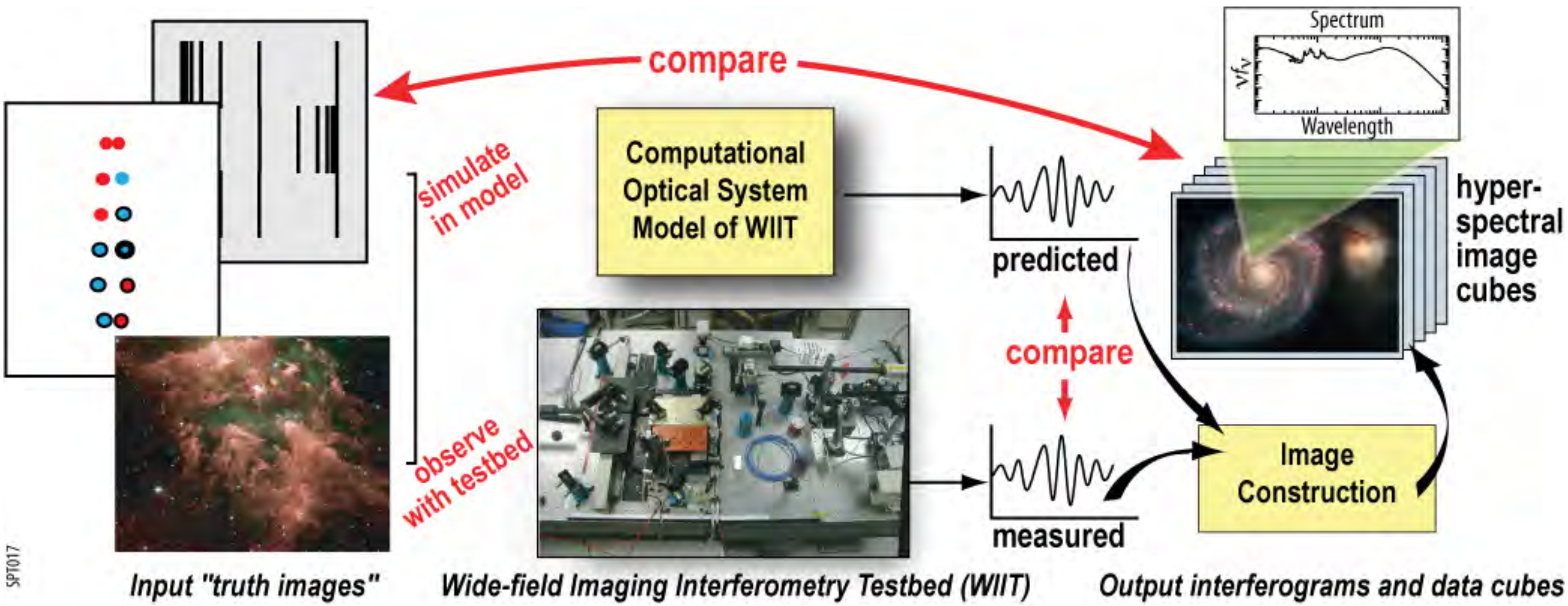
SPIRIT technology roadmap



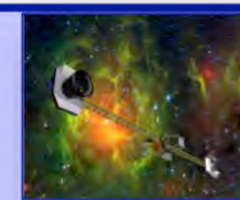
In the far-IR, wavefront control and mirror surface accuracy requirements are readily attainable. The technical challenges are those to which IR astronomers are accustomed: detectors and cryogenic temperatures.

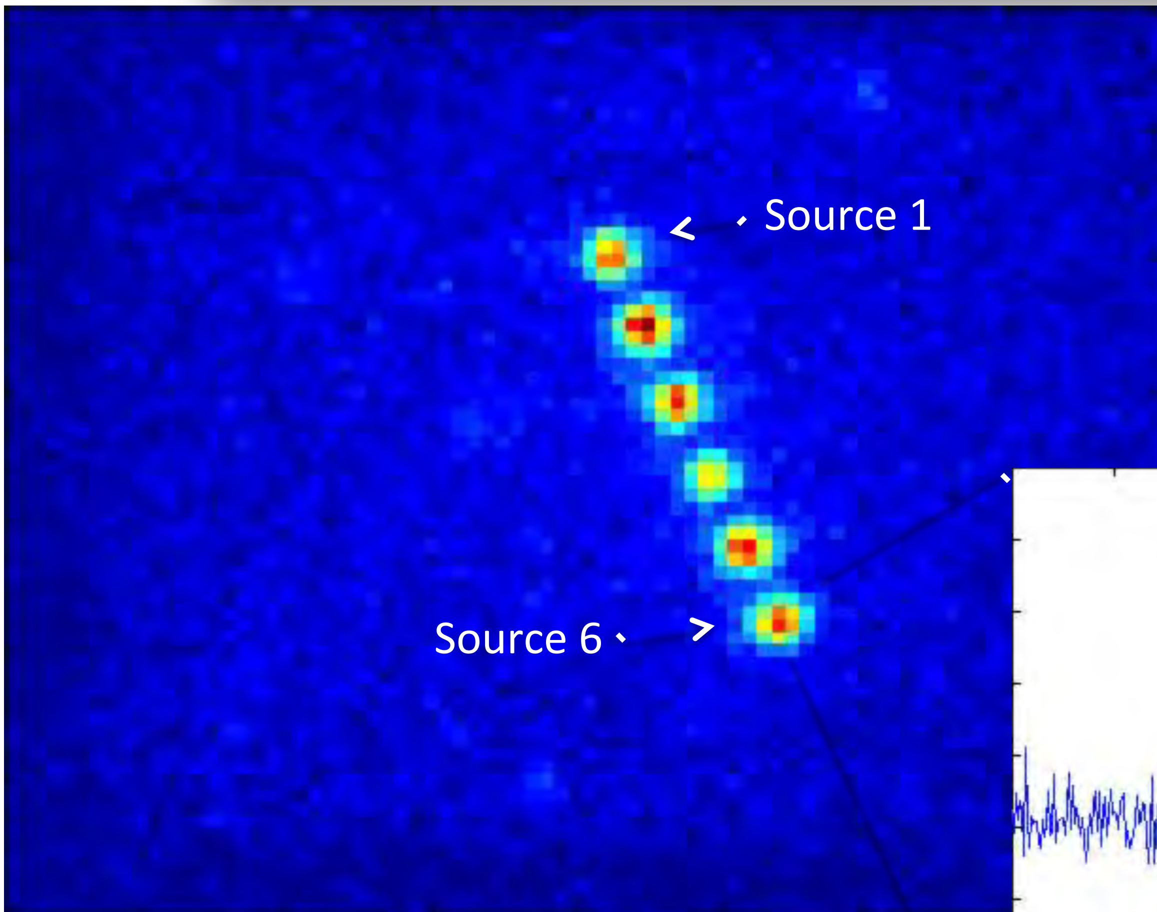
Developing spatio-spectral interferometry



Goal: Demonstrate the viability of spatio-spectral interferometry in realistic circumstances, recognizing that far-IR astronomical sources are spatially and spectrally complex.

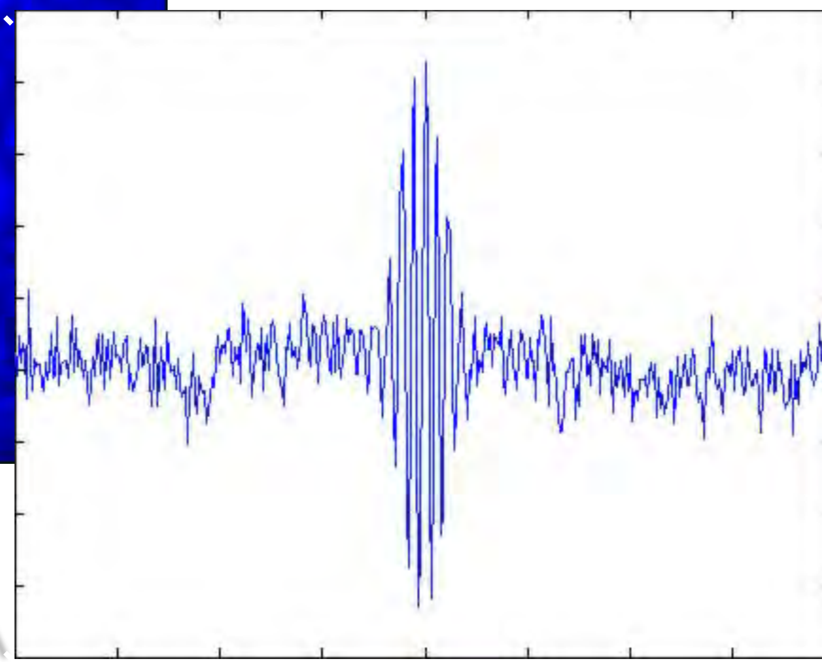
Representative testbed data





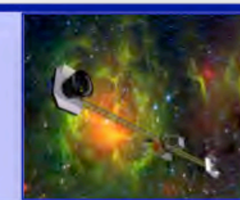
WIIT data from 2013-05-02:

- Baseline: 56 mm
- PA = -67.5 deg

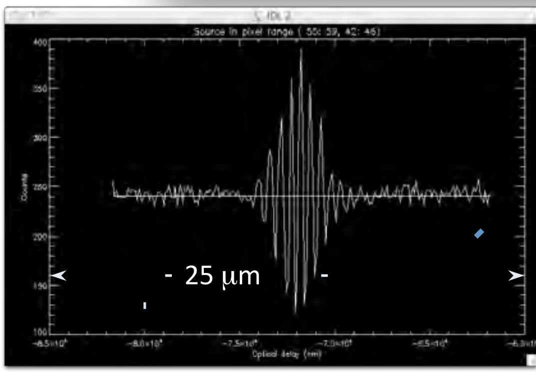


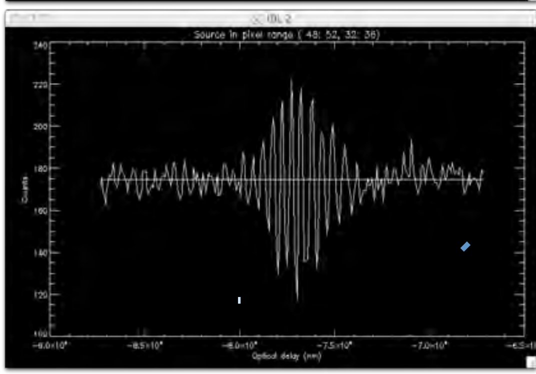
421 baselines like this; dense *u*-*v* plane coverage.

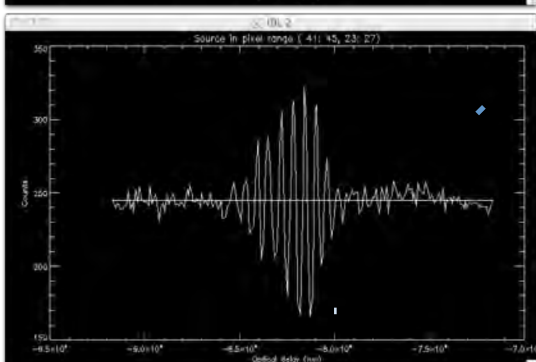
Representative testbed data

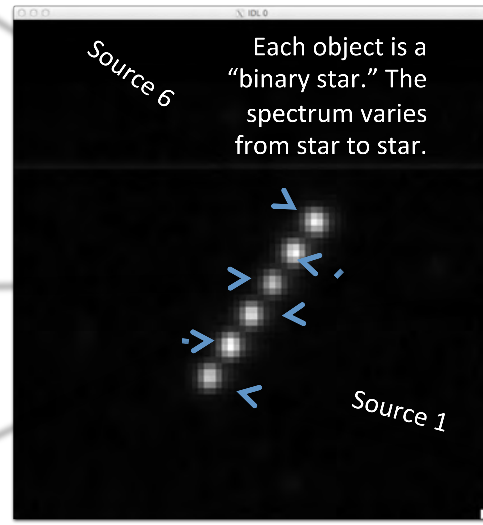


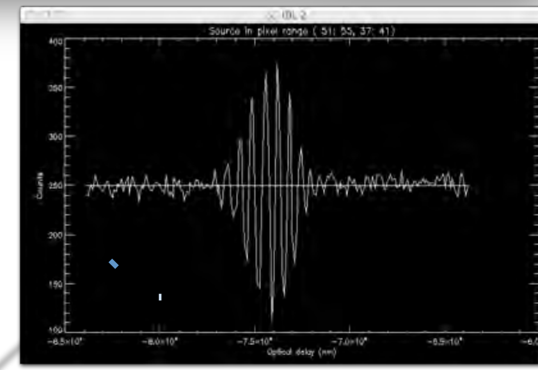
Spatial and spectral information is encoded in the interferograms.

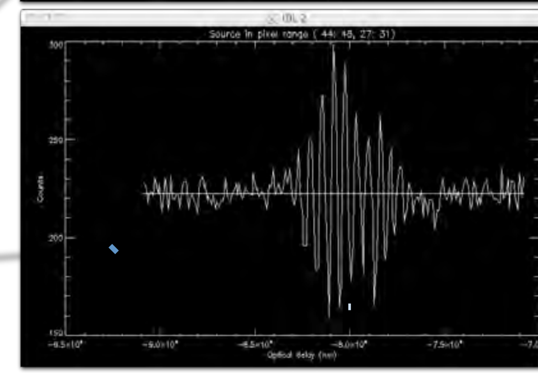


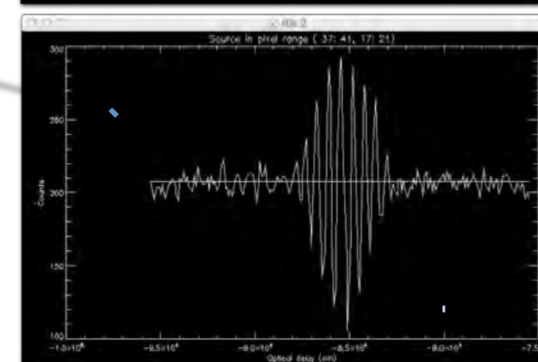








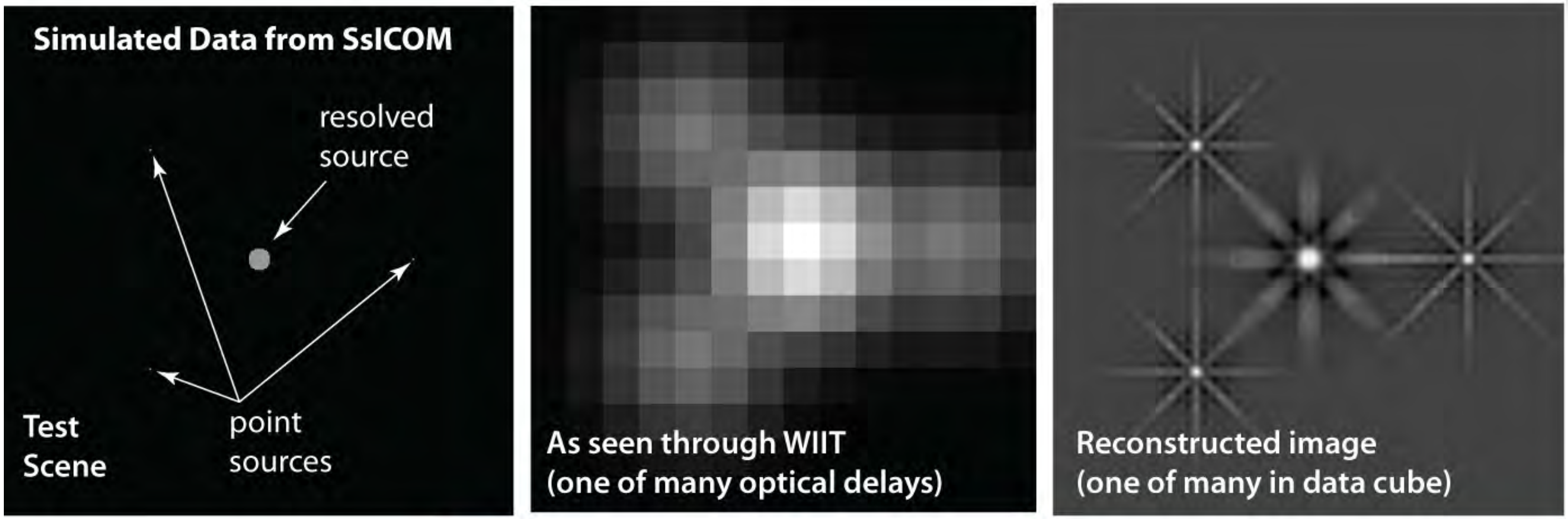




WIIT data from 2013-05-02:

- Baseline: 66 mm
- PA = -54.0 deg

“Double Fourier” synthesis



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NASA Astrophysics Roadmap

A recent community-generated multi-decade Roadmap – “Enduring Quests – Daring Visions” – foresees interferometry at the heart of nearly all of NASA’s astrophysics missions in the 2030+ “Visionary Era.”

The Roadmap Committee envisages a far-infrared interferometer as the first such mission, on a 15 to 30 year timescale.

Maybe next decade, SPIRIT …

A Probe-class far-infrared mission to:

- image protoplanetary disks and measure the distributions of water vapor and ice to learn how the conditions for habitability arise during the planet formation process;
- image structures in a large number of debris disks to find and characterize unseen exoplanets;
- probe the atmospheres of extrasolar giant planets; and
- make profound contributions to our understanding of the formation, merger history, and star formation history of galaxies.

http://astrophysics.gsfc.nasa.gov/cosmology/spirit/

Questions? David.T.Leisawitz@nasa.gov

- Wavelength range 25 – 400 μm
- Angular resolution 0.3 (λ/100 μm) arcsec
- Dense u-v plane coverage for high quality imaging
- Integral field spectroscopy over a 1 arcmin FOV
- Spectral resolution λ/Δλ > 3000 in each spatial resolution element
- Sensitivity 10 μJy continuum; 10^{-19} W m^{-2} spectral lines
- Single scientific instrument ("double Fourier" beam combiner)
- Mature technology in time for 2020 Decadal Survey
- Could develop and launch in the next decade with international collaboration