SPIRIT
The Space Infrared Interferometric Telescope:
a Starting Point for the Next FIRI Proposal

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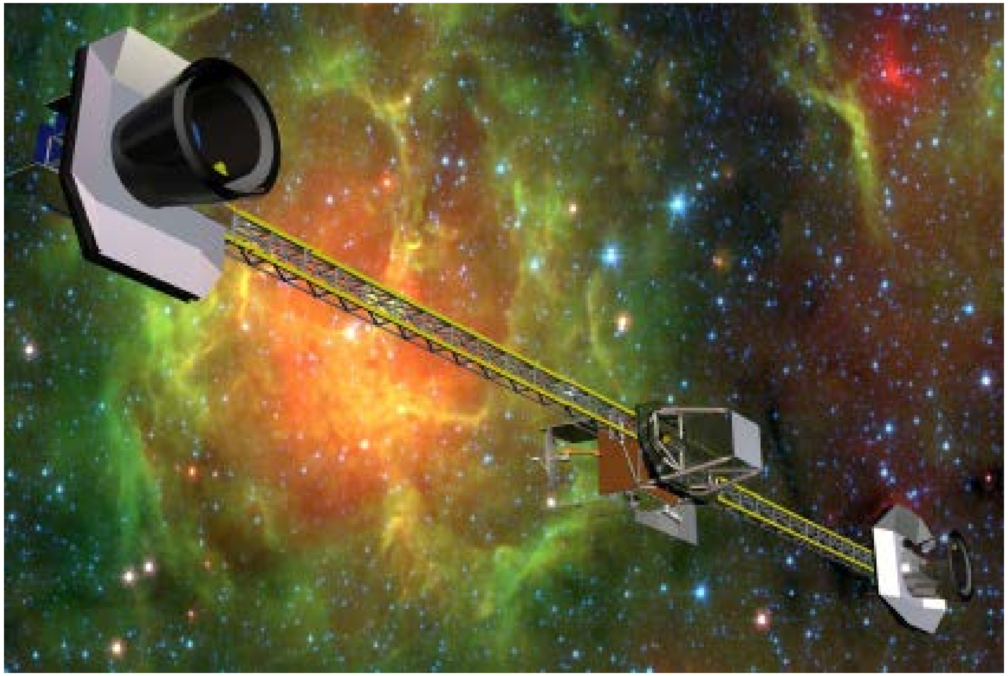
SPIRIT as a Starting Point for FIRI

- Incorporates many of the features of any double Fourier interferometer concept
  - Beam combination
  - Aperture and detector cooling
  - Detector performance
  - Data processing
  - Etc.

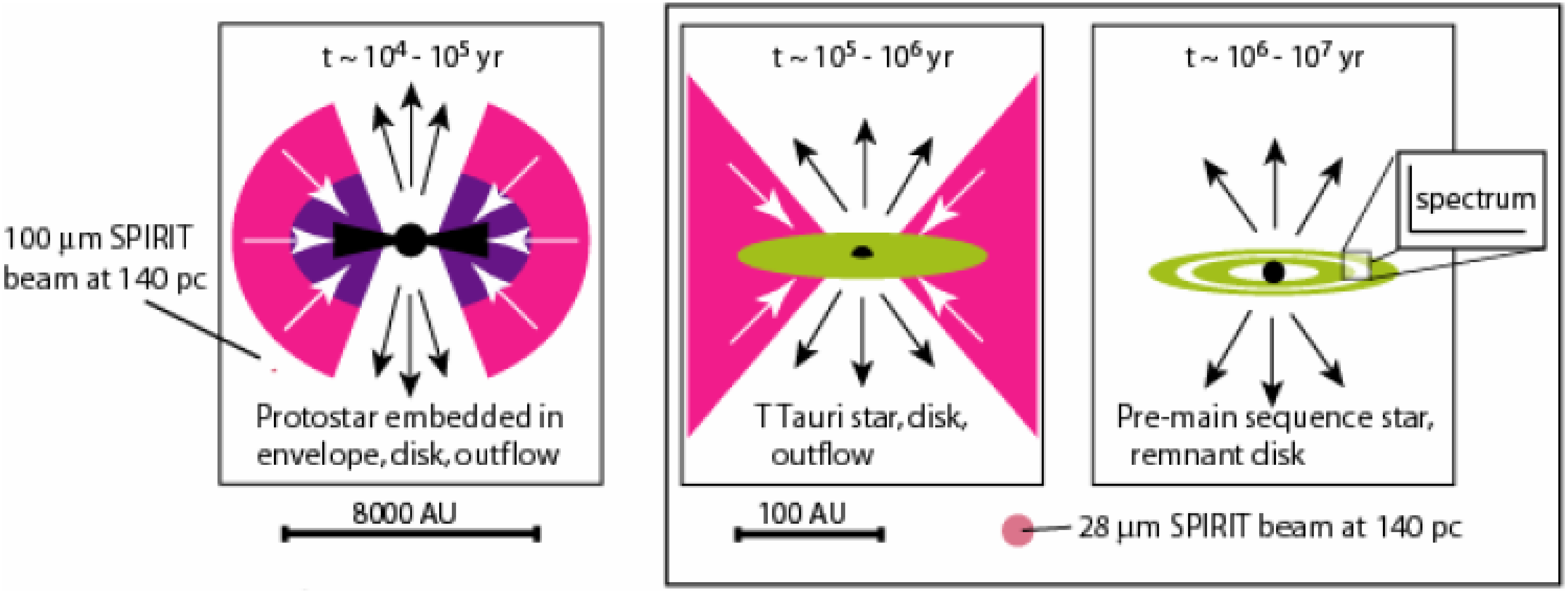


- Has been studied in detail

- Is on the affordable end of the price range

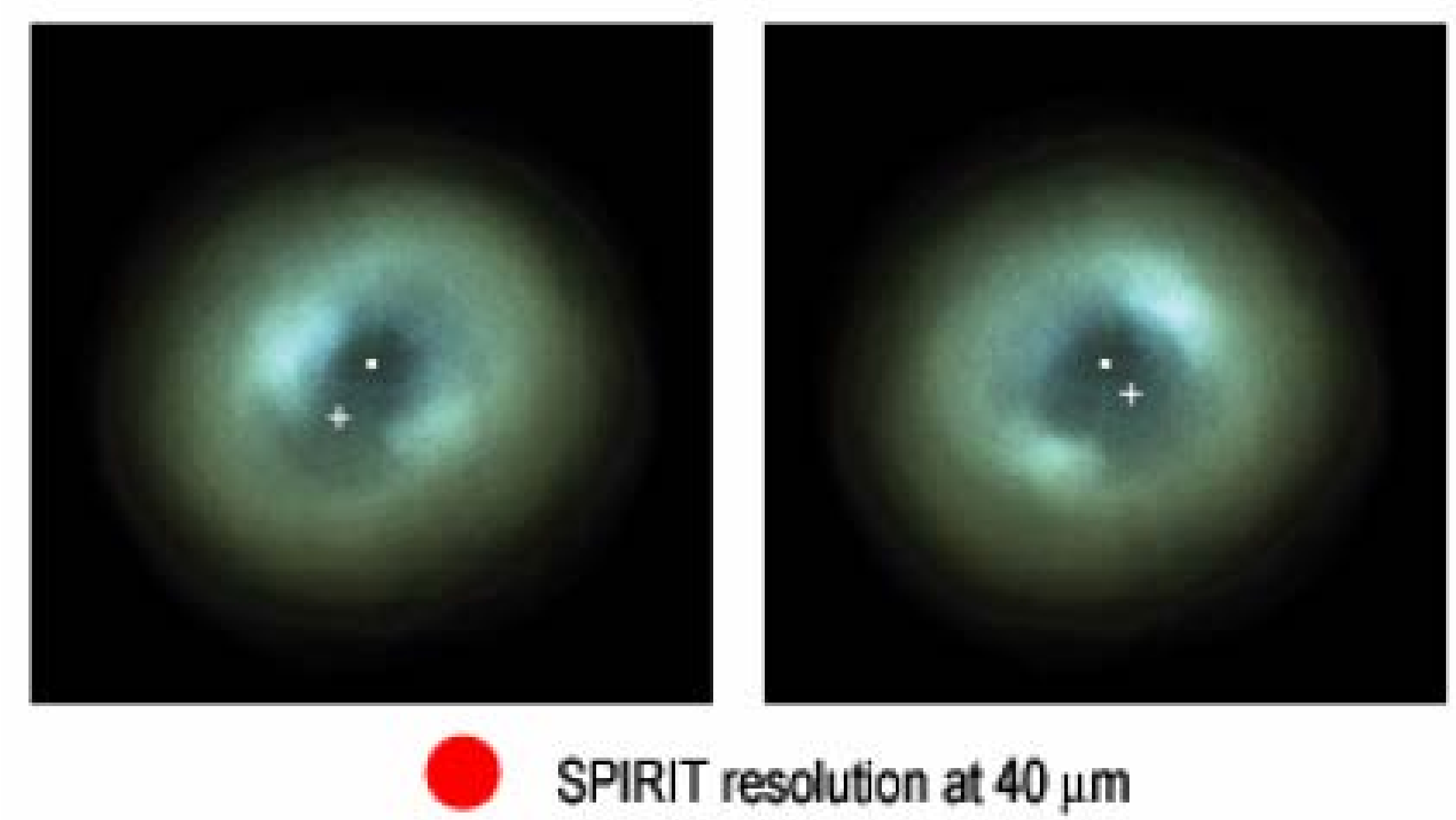
SPIRIT Science Drivers

- **Formation of planetary systems**



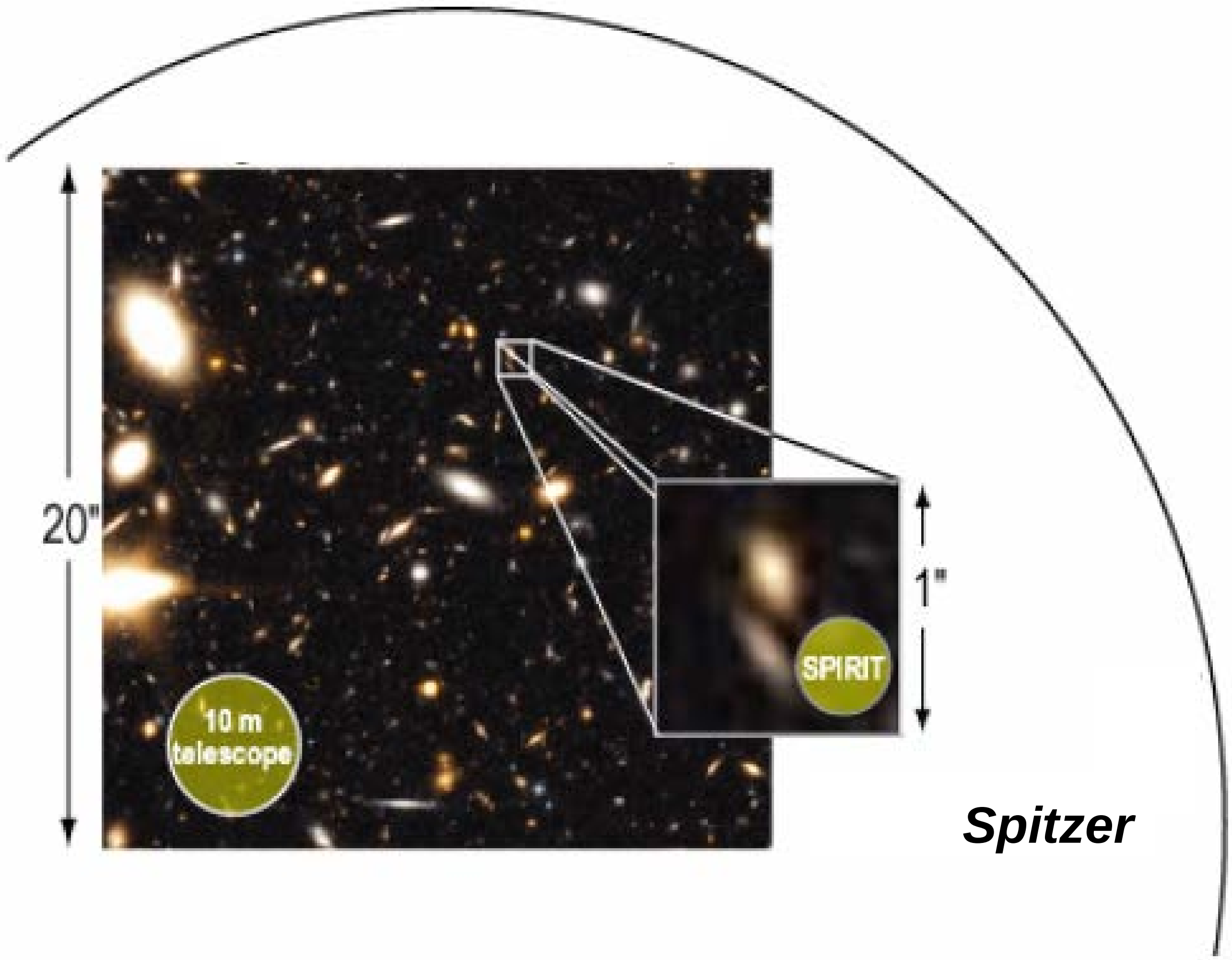
SPIRIT Science Drivers

Debris disks and exoplanet signatures



SPIRIT Science Drivers

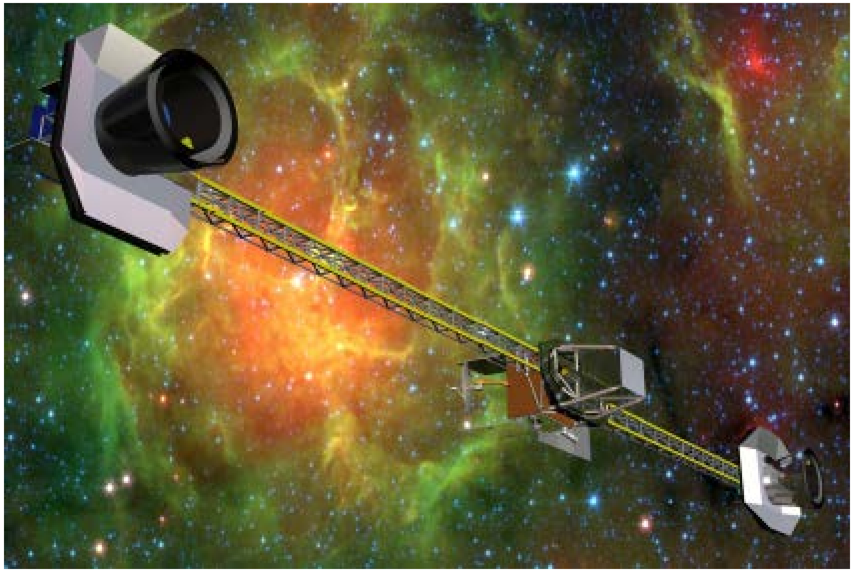
Galaxy evolution



Additional Goals

- Spectra of gas giant exoplanets
- Map nearby spiral galaxies in fine structure lines
- Thermal and density structure of pre-stellar and protostellar cores
- Spectrophotometry of KBOs
- Etc.

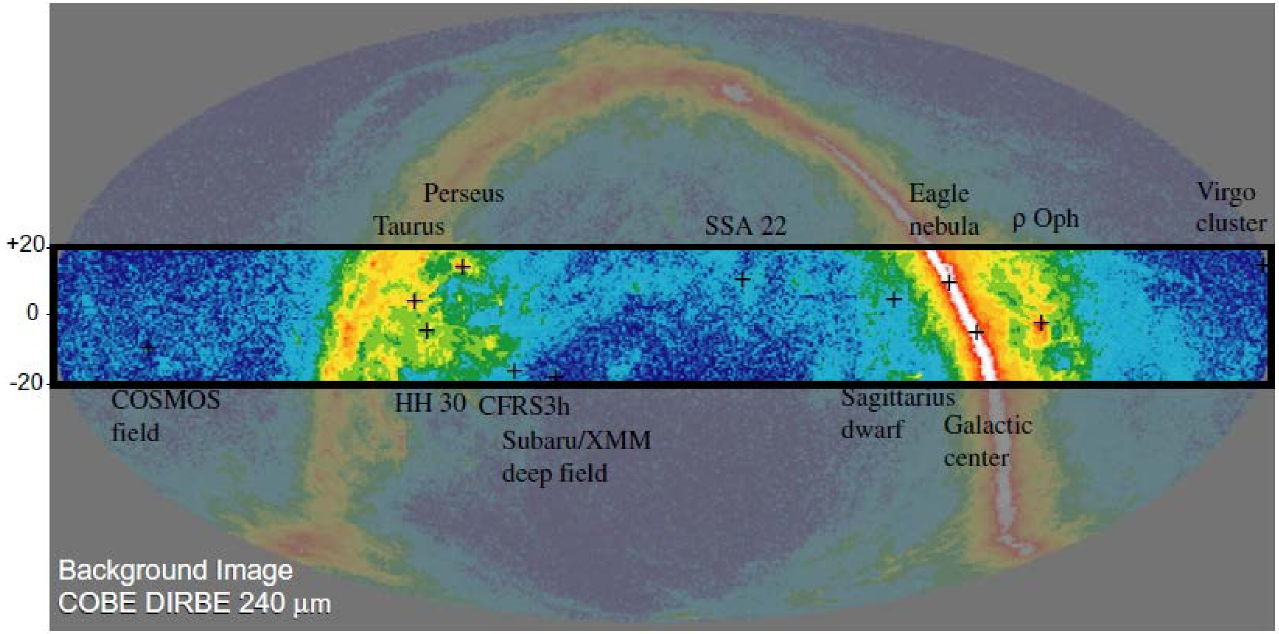
SPIRIT Summary



- Two 1-m telescopes cooled to 4 K and mounted on deployable boom
- Baseline adjustable: 6 – 36 m
- Combined with rotation, provides dense uv plane coverage
- Typ. ~ 1 day per observation
- λ = 35 – 400 μm
- Angular resolution: 0.3” at 100 μm
- One scientific instrument
- $\lambda/\Delta\lambda$ = 3000-5000 spectroscopy
- Sky photon noise limited sensitivity with ~ 50 mK detectors

Performance Summary

- Sensitivity (5 σ; 24 hrs)
  - Lines: $3 – 1.5 \times 10^{-19}$ W m^{-2} (35 – 280 μm)
  - Continuum: 15 – 50 μJy
- Lifetime 3 yrs minimum
- Instantaneous fov: 1 arcmin
- Field of regard 40^0 band centred on ecliptic



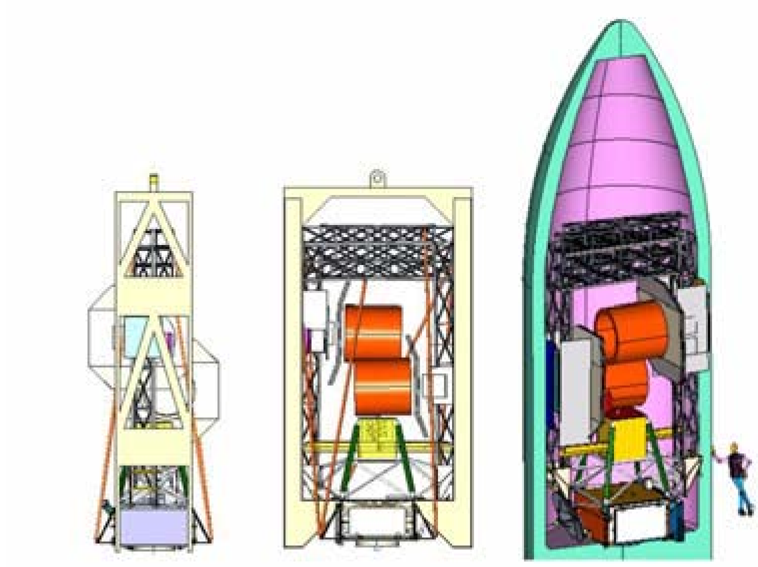
Launch and Deployment

- Launch vehicle: ATLAS V-531
  - 5.4 m fairing diameter

- Payload stowed for launch with hinged boom and jettisonable support structure

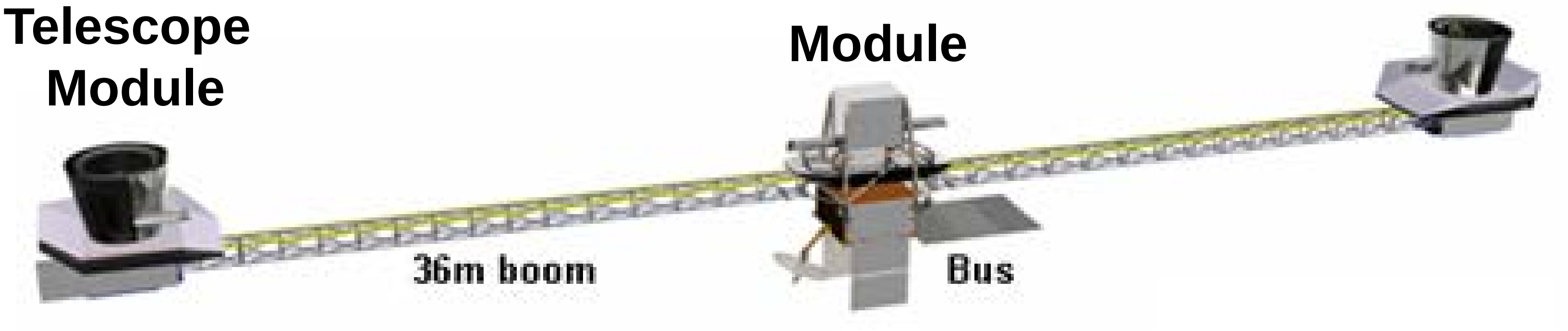
- Mass: 4.5 Tonnes

- Orbit: L2



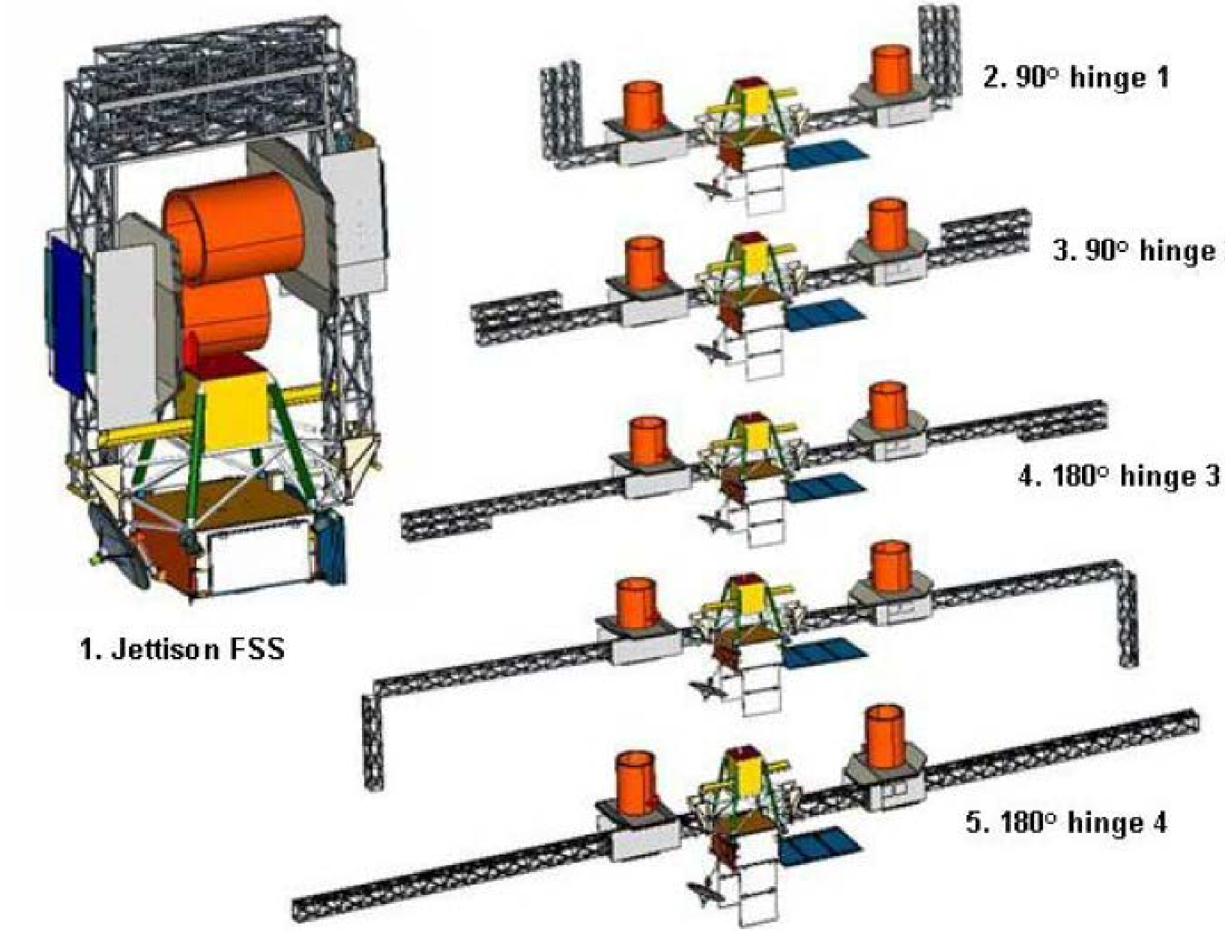
Telescope Module

Instrument Module



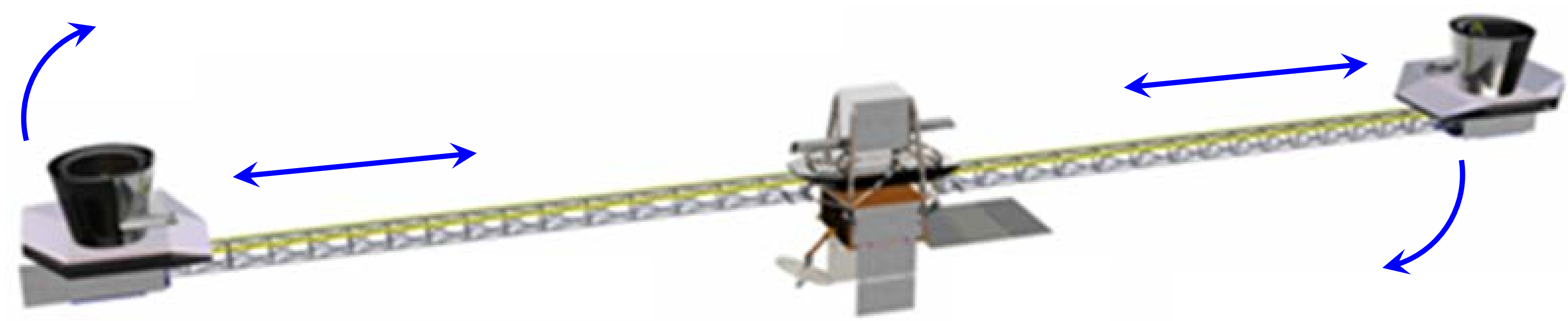
Deployment

- **Four hinges on each side of the boom**
- **Hinges latched after deployment**

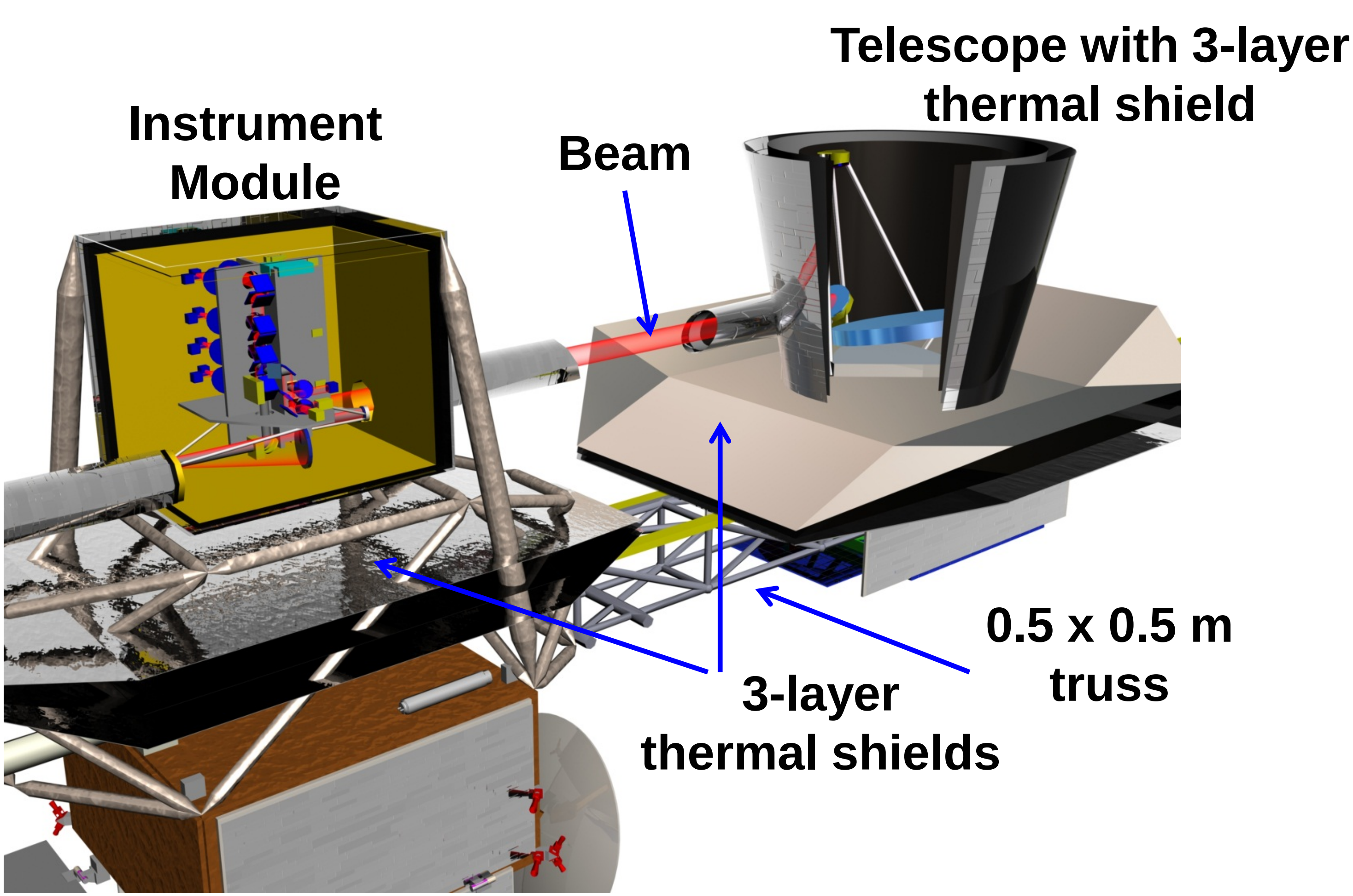


Operation and *uv* Plane Coverage

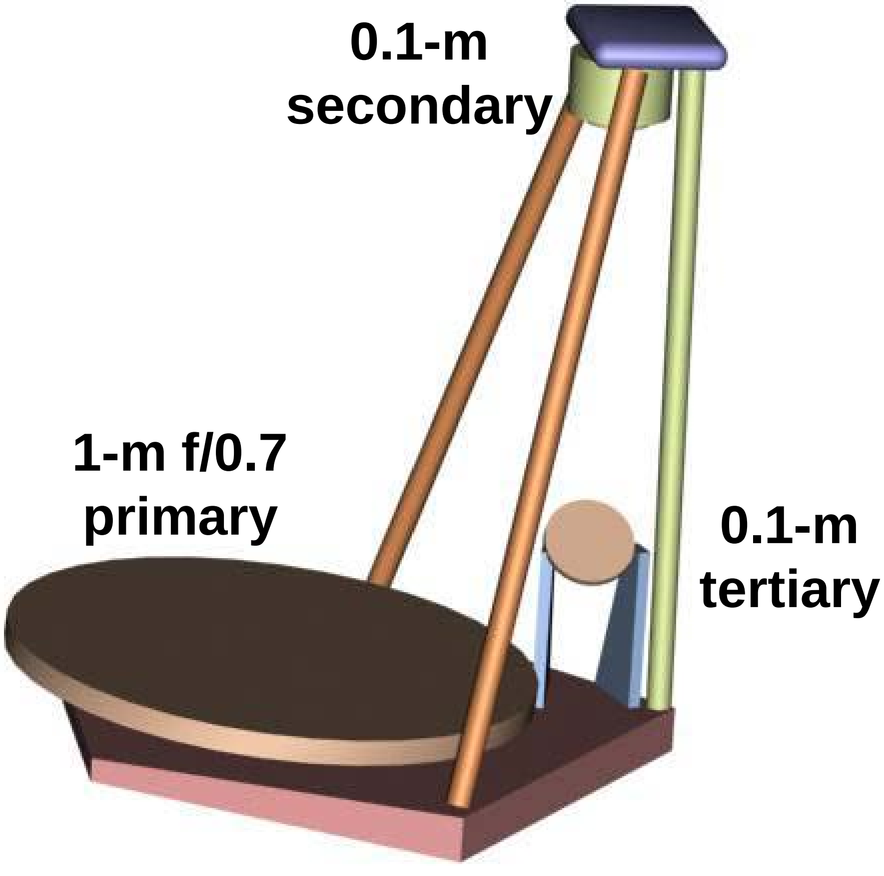
- Combination of rotation and stepping baseline provides dense *uv* plane coverage
- Typ. 30 positions from 6 – 36 m baseline
- Rotation period 0.5 – 3 rev/hr depending on baseline
- Typ. ~ 1 day per science observation
- Multiple days for deep observations

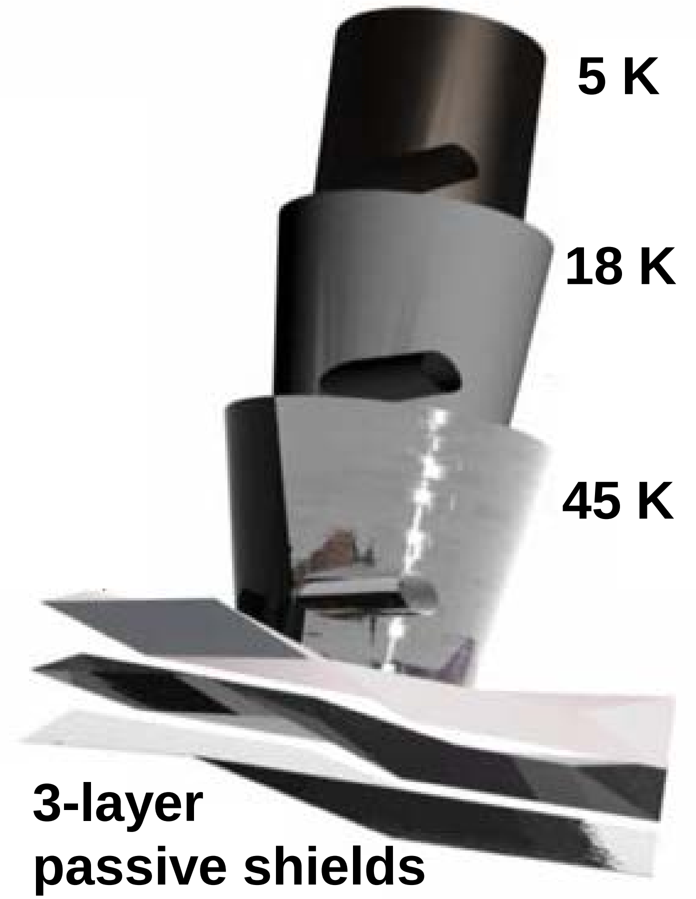


Telescope and Instrument Modules



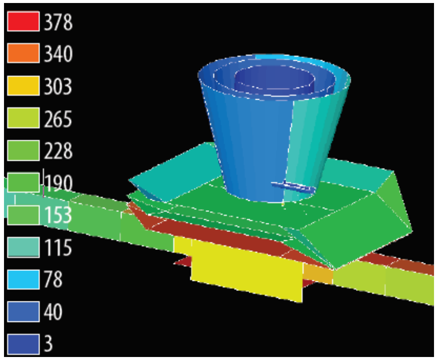
Silicon Carbide Telescopes





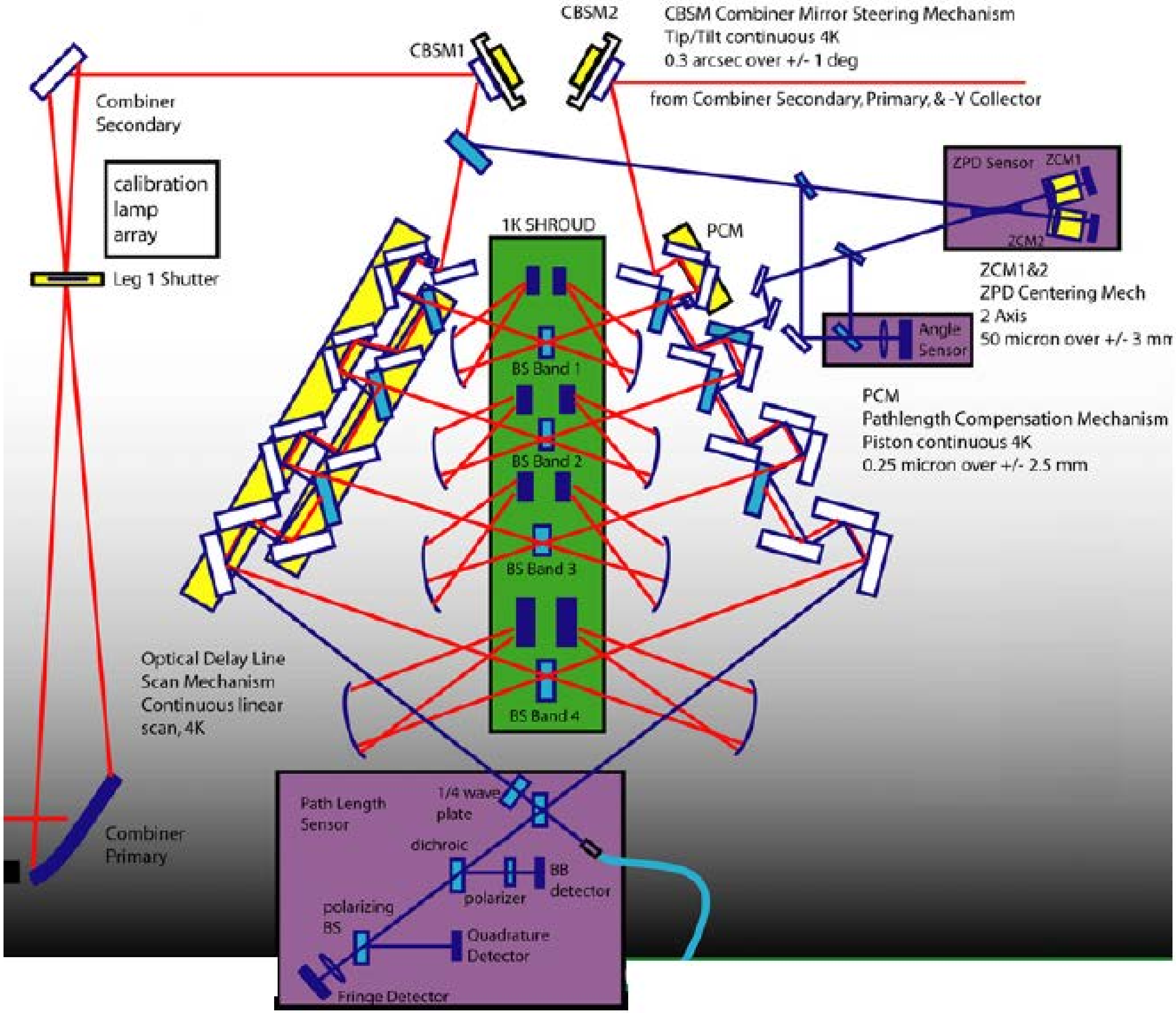
- Afocal Gregorian design
- Off-axis design to avoid diffraction effects that would complicate fringe visibility
- Telescope size limited to ~ 1 m by launch vehicle fairing size

Telescope Modules

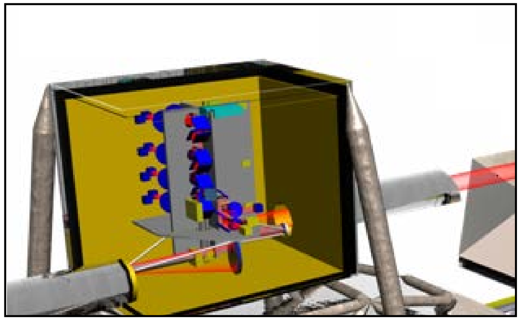


- 700 kg total mass
- Independent power, cooling, trolley drive, and communications systems
- Internal pointing mechanism allows independent telescope pointing by up to 3º
- Typical movement along the trolley of 1.5 m in ~40 sec.
- 2.5 m position precision

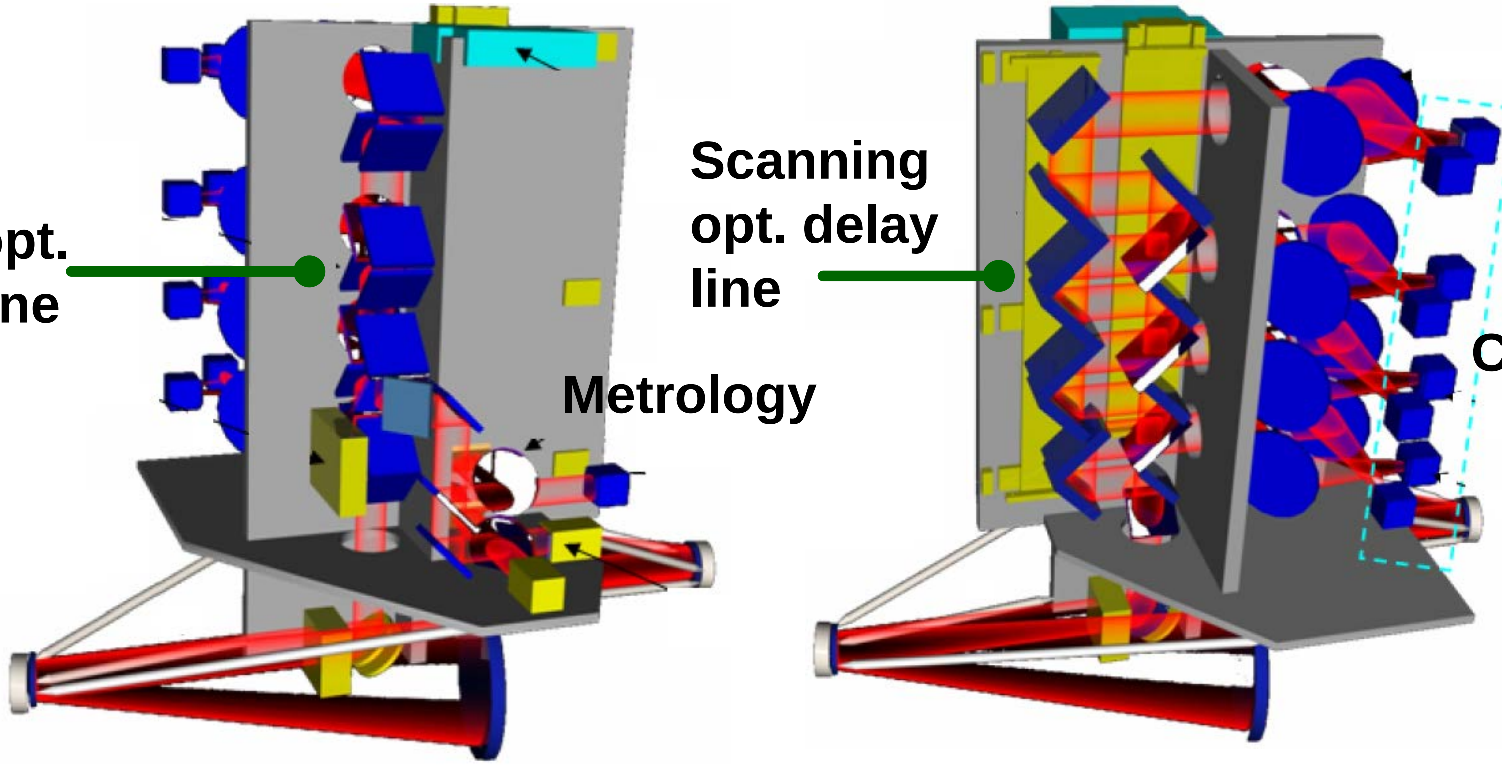
Instrument Module



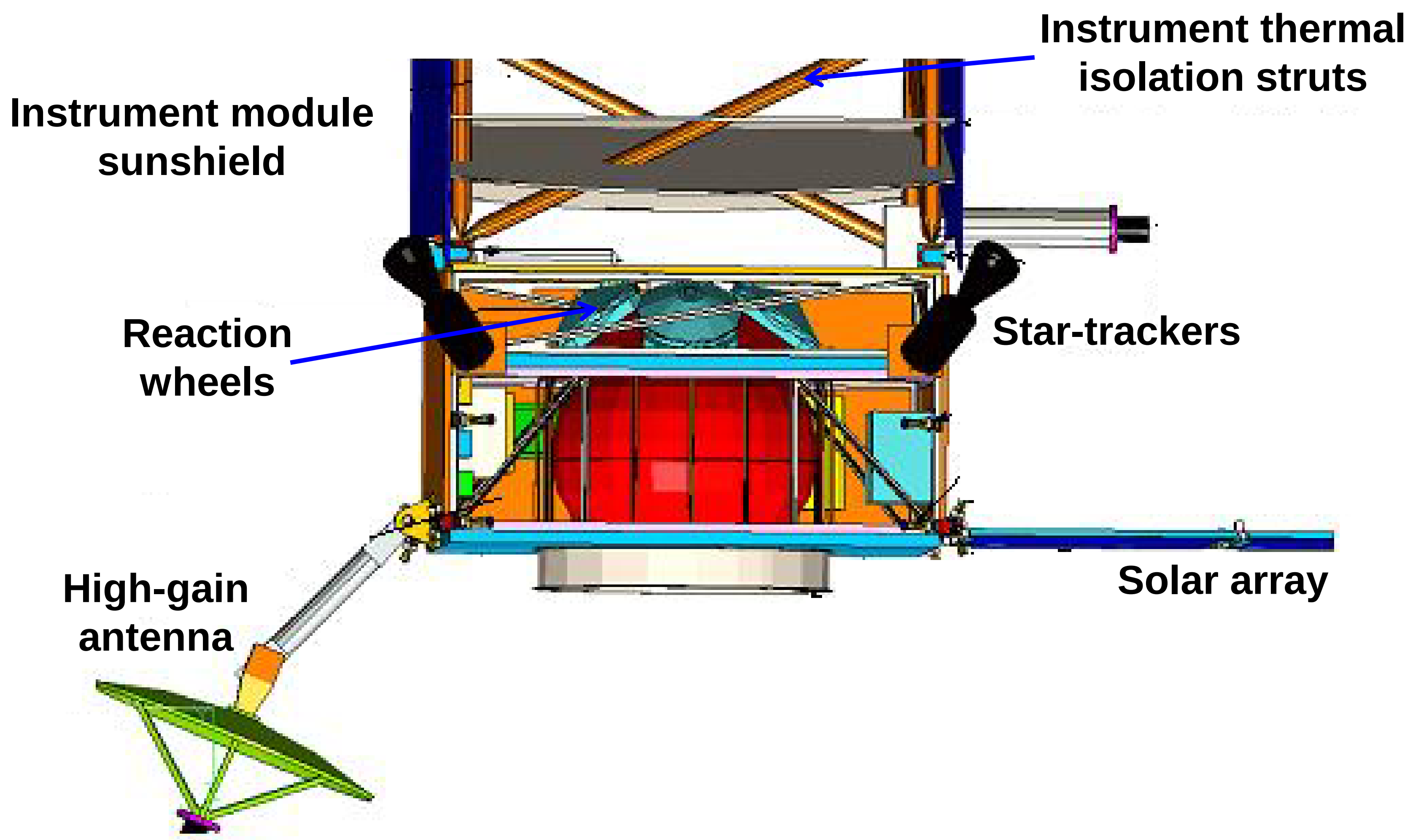
Instrument Module



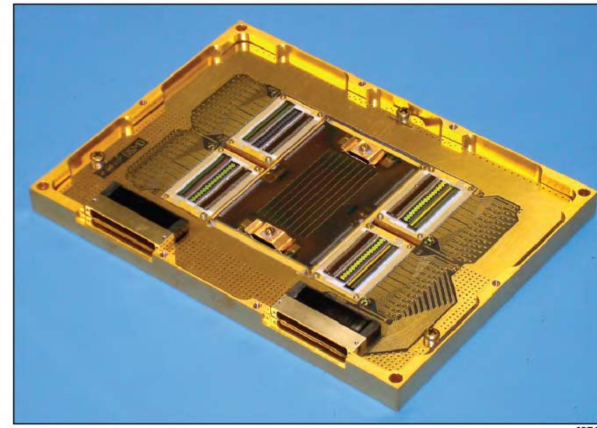
- Four quadrants
  - Metrology
  - Cameras (two per band)
  - Fixed optical delay line
  - Scanning optical delay line



Spacecraft Bus



Detectors


SPT010

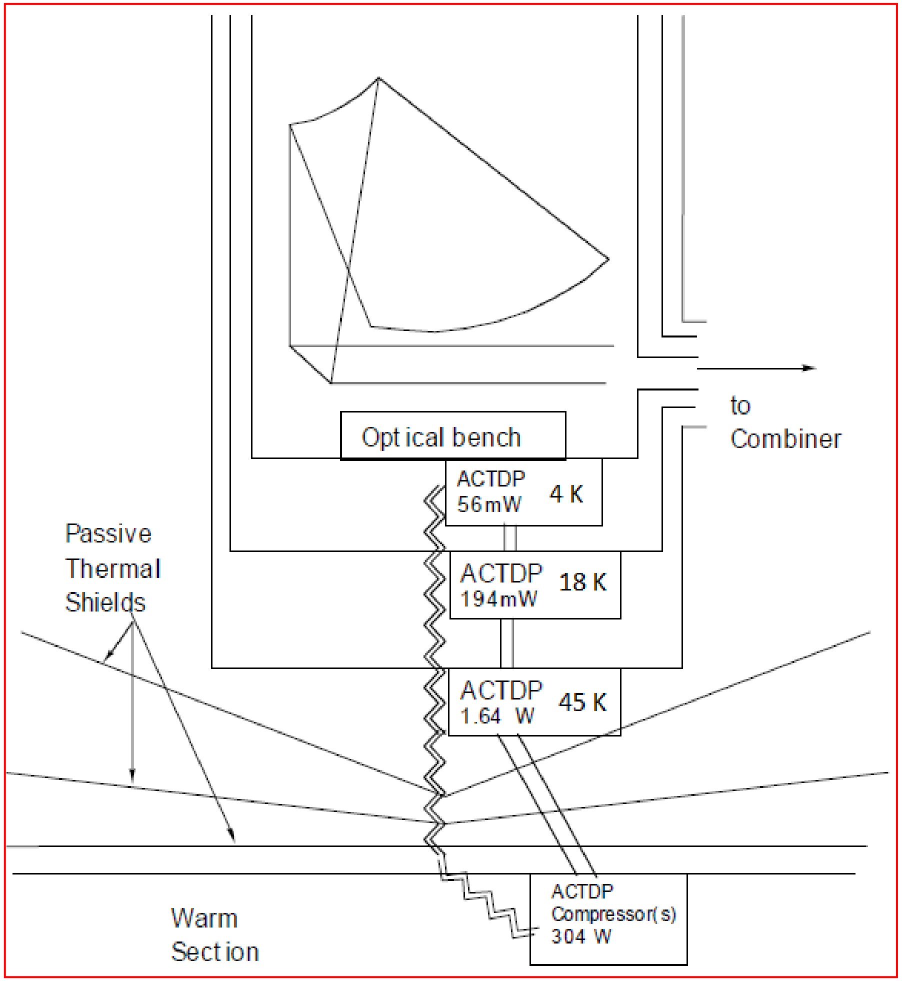
- Four $\lambda/\Delta\lambda$ = 2 bands:
  - 25-50, 50-100, 100-200, 200-400 μm
- Nyquist sampling of Airy disk at GM wavelengths (35, 70, 140, 280 μm)
  - Pixel sizes: (4.2, 8.7, 17, 35) arcsec
- 60 arcsec fov then gives required array sizes
- Sensitivity requirement: $NEP_{det} < 0.5NEP_{photon}$ so <10% contribution to total noise
- Requirements

Band	NEP (W Hz$^{-1/2}$ x 10^{-19})	No. of Pixels
25 – 50	1.9	14 x 14
50 – 100	1.1	7 x 7
100 – 200	0.7	4 x 4
200 – 400	1.8	2 x 2

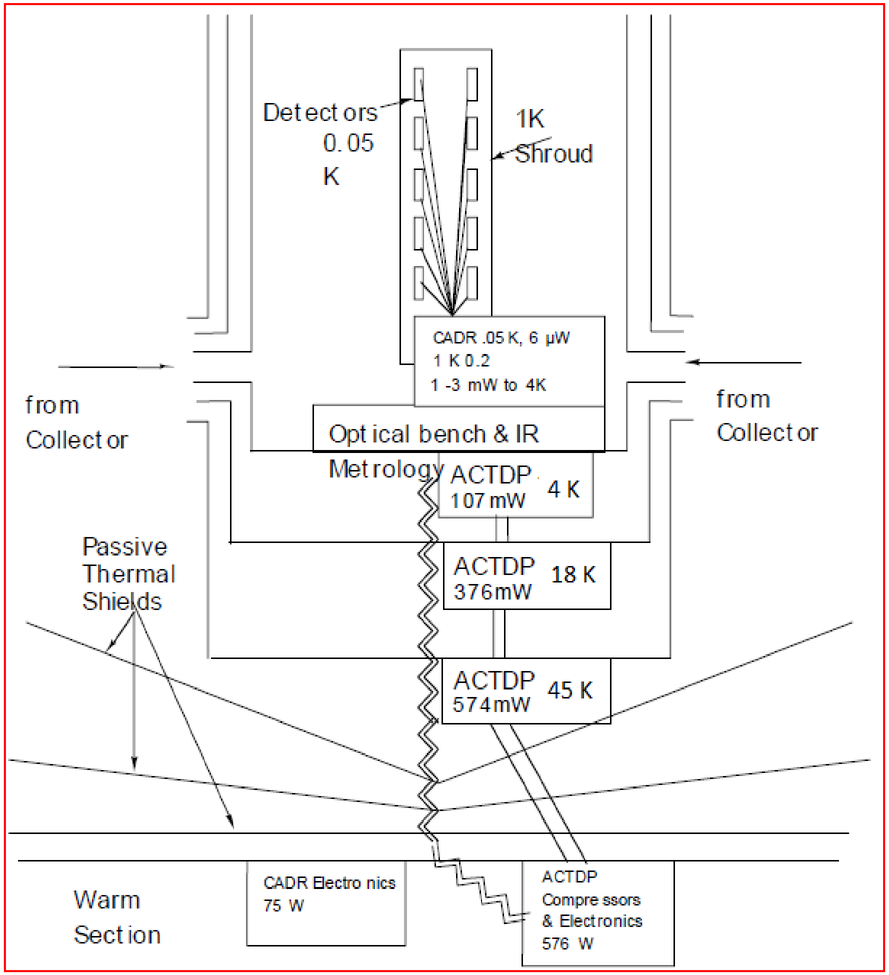
- Speed of response determined by delay line scan rate:
  - τ_{det} < 185 μs ($\approx$ 1 kHz 3-dB frequency)

Thermal Model

Telescope Module

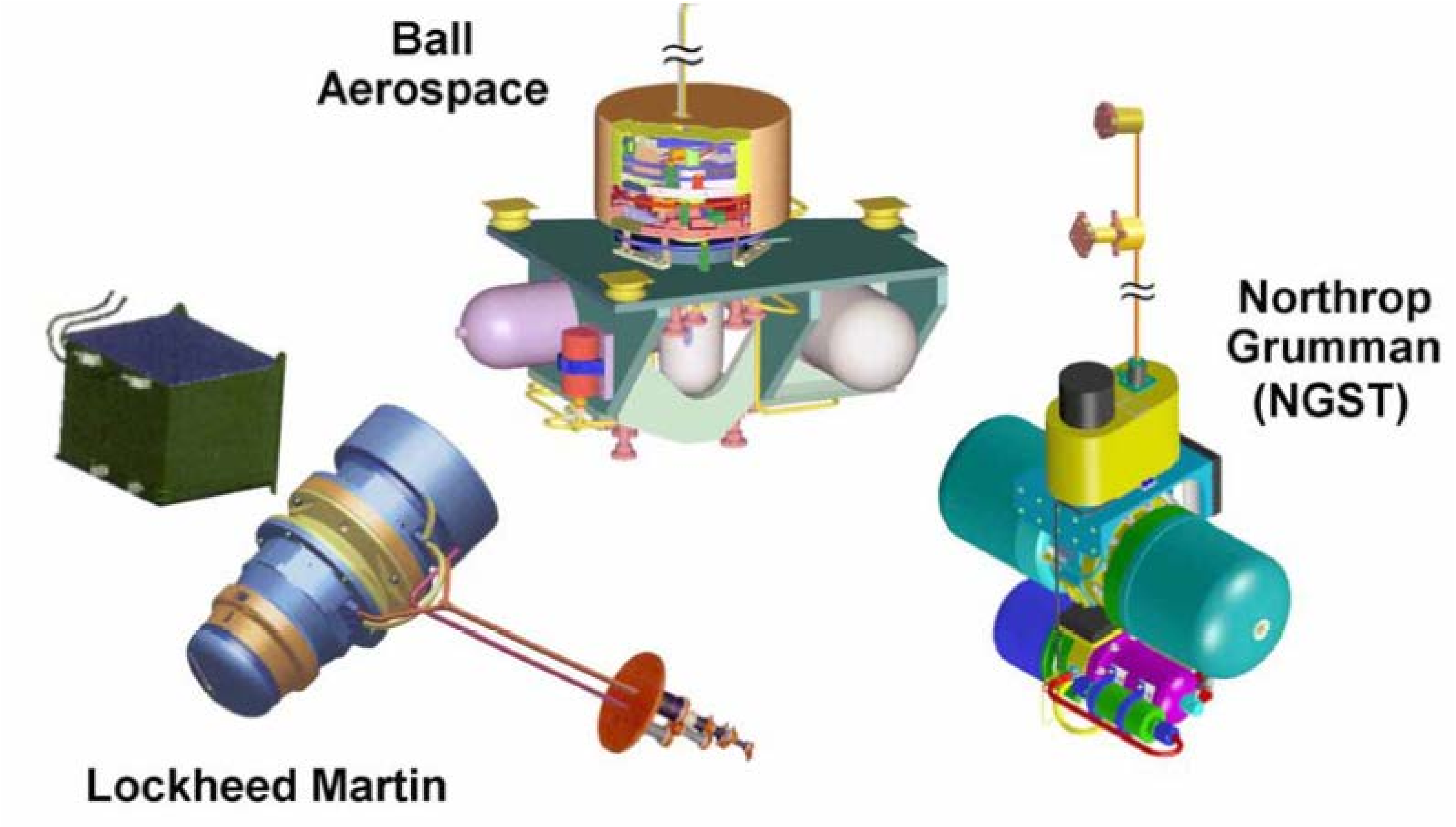


Instrument Module



US Cryocooler Development

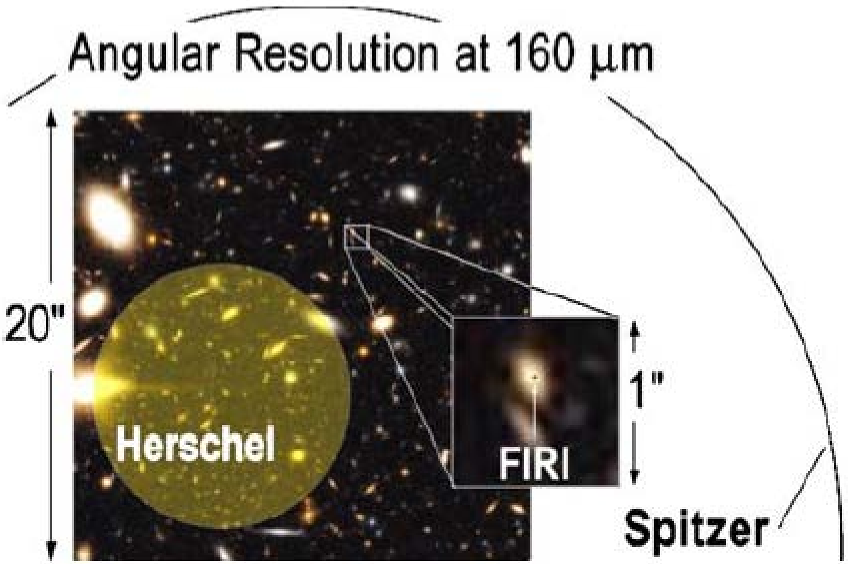
Advanced Cooler Technology Development Program

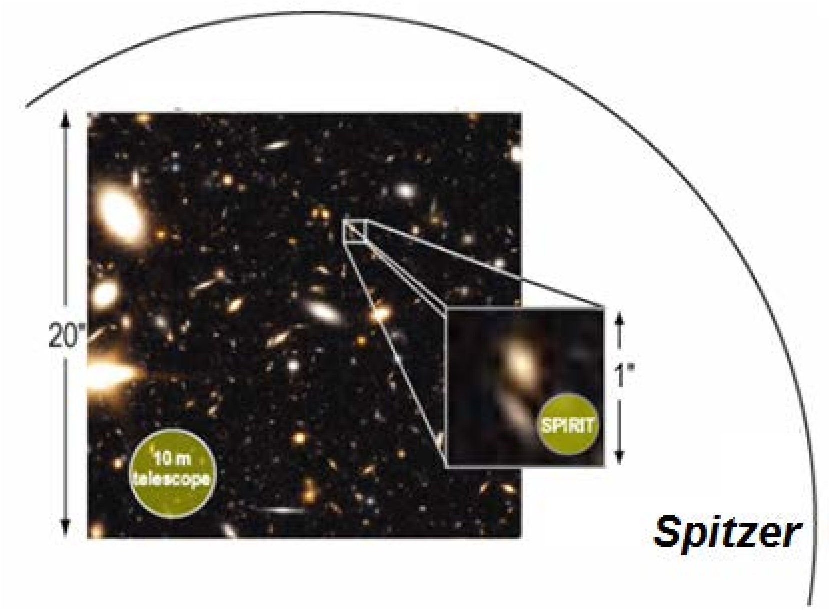


Heatloads Summary

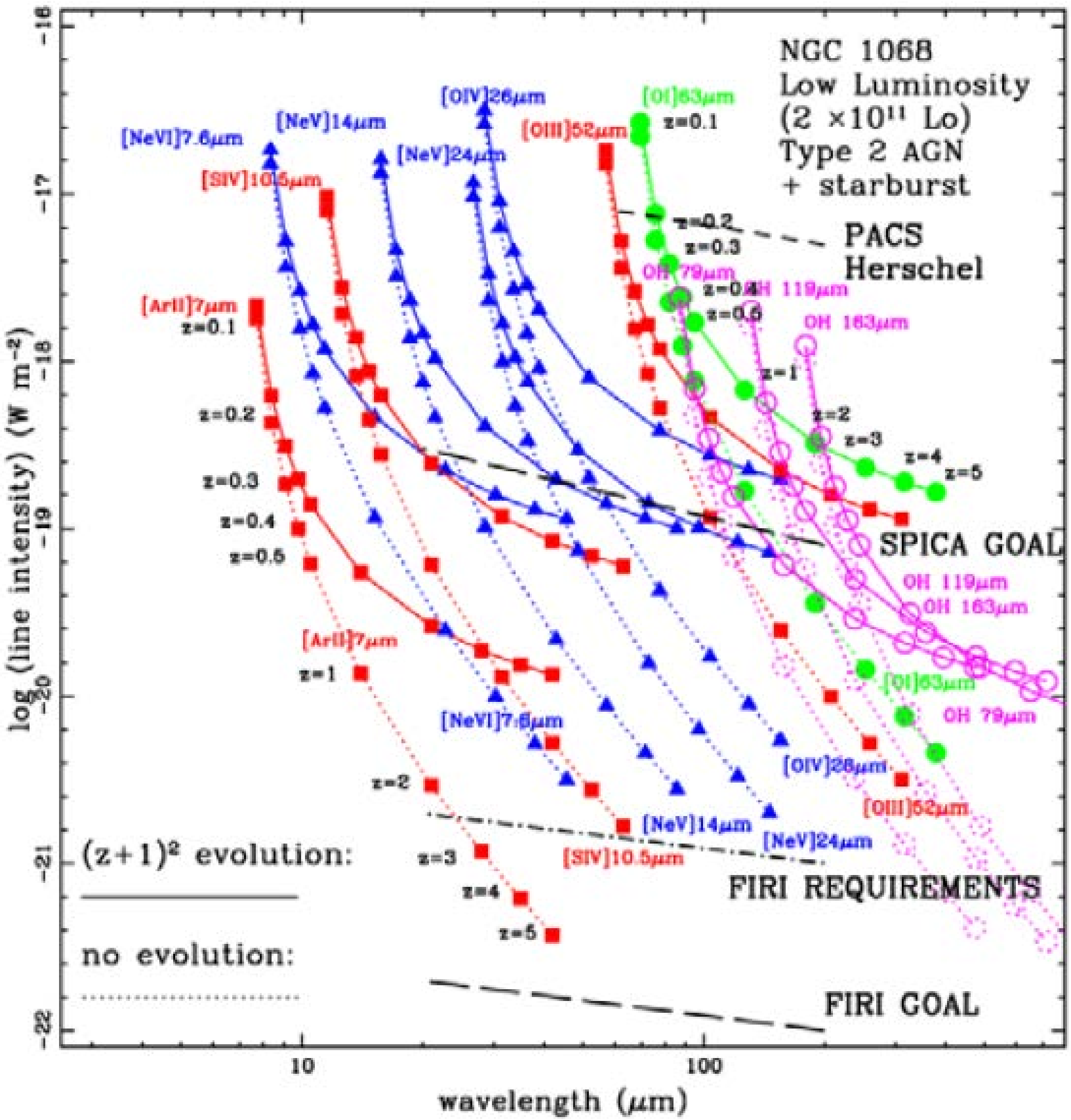
	Conductive (strut+wire)	Radiative	Mechanism Power	Cooling Needed From Cryocooler
Telescope				
4K	2mW + 15mW	11 mW	8 mW	72 mW
18K	17mW + 9mW	0 mW	N/A	52 mW
45K	0.223 W + 0.147 W	0W	N/A	0.74 W
Instrument Module				
4K	2mW + 12mW	44 mW	8 mW + 3mW from CADR	138 mW
18K	17mW + 7mW	156 mW	N/A	360 mW
45K	0.223 W + 0.773 W	0.228 W	N/A	2.448 W

SPIRIT vs FIRI as Proposed in 2007





SPIRIT vs FIRI as Proposed in 2007



SPIRIT with 1-m apertures:
Δ*F* in 24 hrs similar to SPICA In 1 hr

SPIRIT Papers and Documents

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

1. The Space Infrared Interferometric Telescope (SPIRIT): High-resolution imaging and spectroscopy in the far-infrared
2. System engineering the Space Infrared Interferometric Telescope (SPIRIT)
3. Mechanical Design of the Space Infrared Interferometric Telescope (SPIRIT)
4. The Space Infrared Interferometric Telescope (SPIRIT): Optical System Design Considerations
5. The SPIRIT Thermal System
6. Cryogenic Far-Infrared Detectors for the Space Infrared Interferometric Telescope (SPIRIT)
7. The Space Infrared Interferometric Telescope (SPIRIT): the mission design solution space and the art of the possible

Some Comments/Questions

- **SPIRIT incorporates many of the features of any double Fourier interferometer concept**
  - **Beam combination**
  - **Aperture and detector cooling**
  - **Detector performance**
  - **Data processing**
  - **Etc.**
- **A credible L-class mission proposal will probably have to be affordable as a European-dominated project**
- **Will a SPIRIT-like system meet the science requirements?**
  - **How have the science requirements evolved since 2007?**
  - **Enhanced importance of exoplanetary systems/exoplanet characterisation?**
- **Without making the concept unaffordable:**
  - **Can the aperture size be increased?**
  - **Can a free-flying version be considered, to give greater baseline?**
  - **Can a dual launch + docking version be considered?**