SPIRE: Herschel's Submillimetre Camera and Spectrometer

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\+ the SPIRE Consortium

- SCIENTIFIC GOALS AND DESIGN DRIVERS
- INSTRUMENT DESCRIPTION
- OBSERVING MODES
- PERFORMANCE ESTIMATES

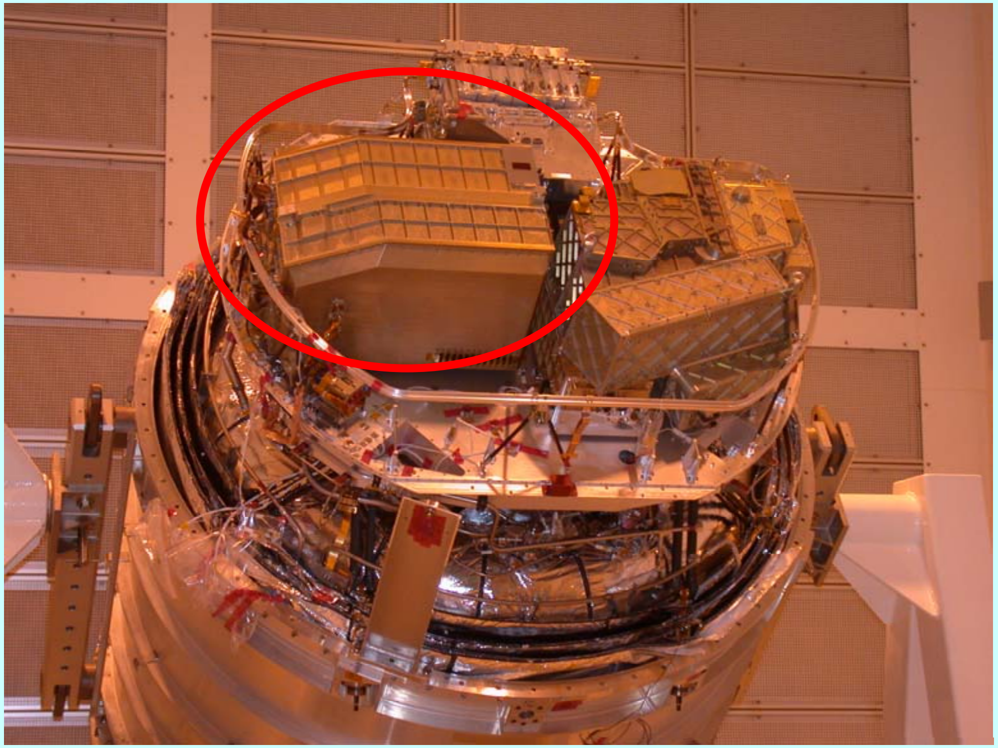
The SPIRE Consortium

Canada China France Italy Spain Sweden UK USA

- Cardiff University, UK
- CEA Service d’Astrophysique, Saclay, France
- Institut d’Astrophysique Spatiale, Orsay, France
- Imperial College, London, UK
- Instituto de Astrofisica de Canarias, Tenerife, Spain
- Istituto di Fisica dello Spazio Interplanetario, Rome, Italy
- Jet Propulsion Laboratory/Caltech, Pasadena, USA
- Laboratoire d’Astronomie Spatiale, Marseille, France
- Mullard Space Science Laboratory, Surrey, UK
- NAOC, Beijing, China
- Observatoire de Paris, Meudon, France
- Rutherford Appleton Laboratory, Oxfordshire, UK
- Stockholm Observatory, Sweden
- UK Astronomy Technology Centre, Edinburgh, UK
- Università di Padova, Italy
- University of Lethbridge, Canada

Spectral and Photometric Imaging Receiver

- **3-band imaging photometer**
  - 250, 360, 520 μm (simultaneous)
  - $\lambda/\Delta\lambda \sim 3$
  - 4 x 8 arcminute field of view
  - Diffraction limited beams (17, 24, 35”)



- **Imaging Fourier Transform Spectrometer**
  - 200 - 670 μm (complete range covered simultaneously)
  - 2.6 arcminute field of view
  - $\Delta\sigma$ = 0.04 cm^{-1} ($\lambda/\Delta\lambda \sim 20 - 1000$ at 250 μm)

Instrument Design Drivers

- **Photometer**
  - Efficient multi-band mapping with largest possible field of view
  - Point and compact source observation with high efficiency

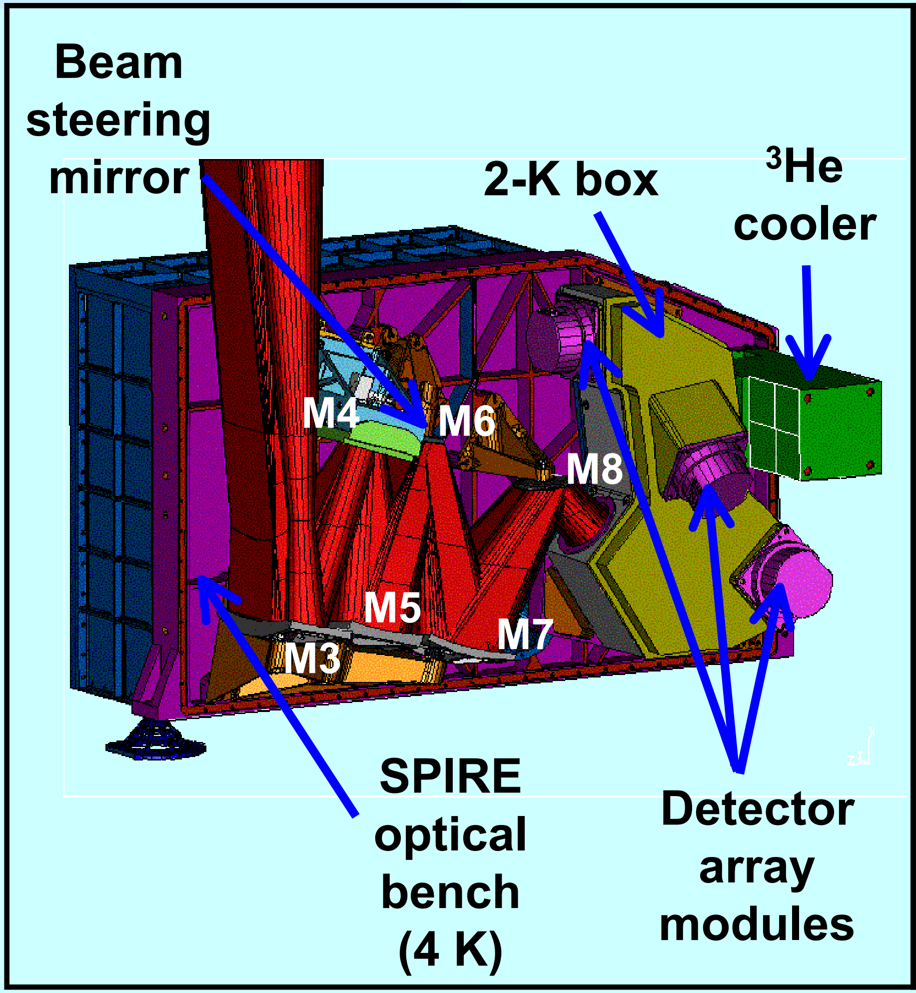
- **Spectrometer**
  - Point source survey spectroscopy with broad wavelength range
  - Imaging spectroscopy with maximum available field of view
  - Variable spectral resolving power (few x 10 to ~ 1000)

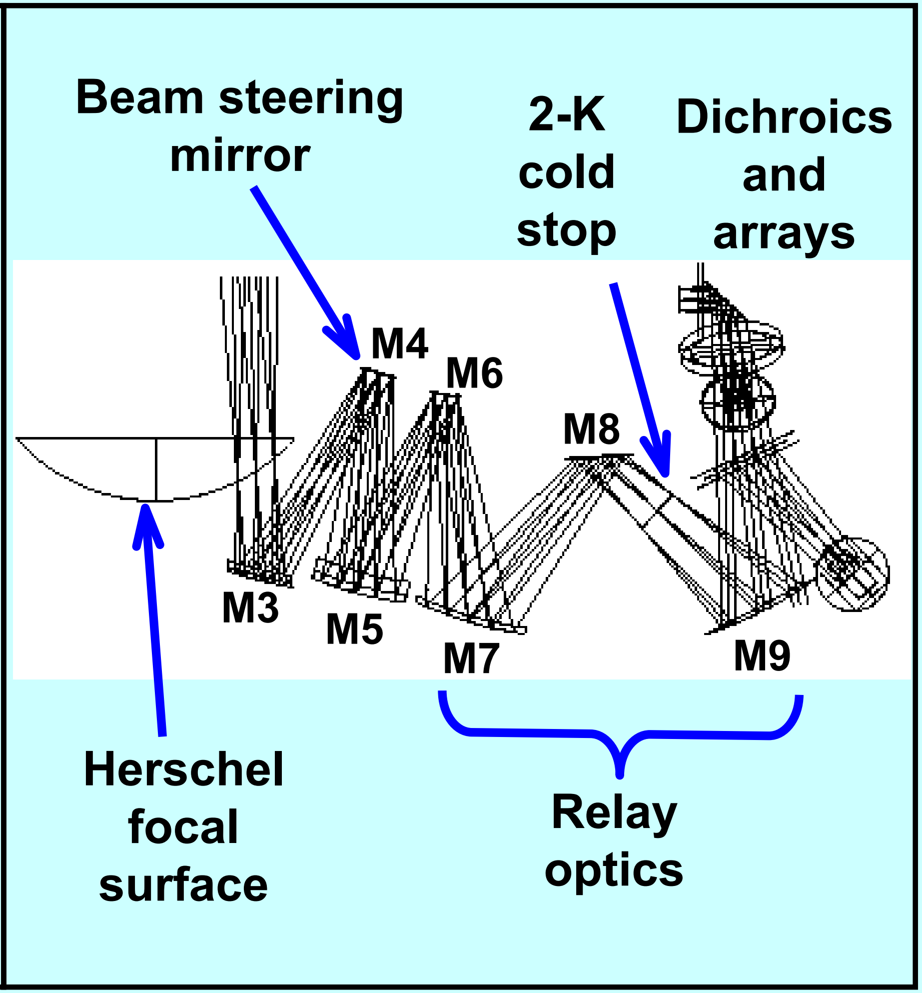
- **Both**
  - Simplicity, affordability, reliability, ease of operation
  - Complementary to other Herschel instruments and other facilities

SPIRE Scientific Goals:
GT programmes as examples

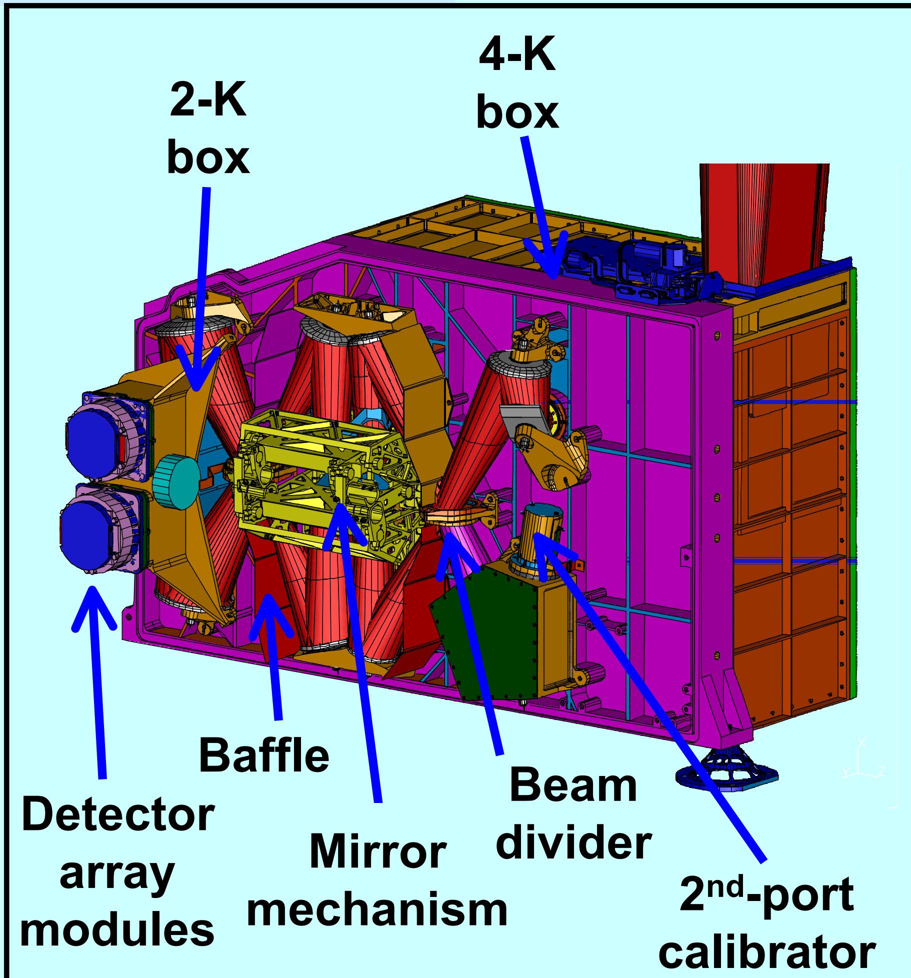
- High-redshift galaxies
- Local galaxies
- Star formation
- Interstellar medium
- Circumstellar matter
- Solar system

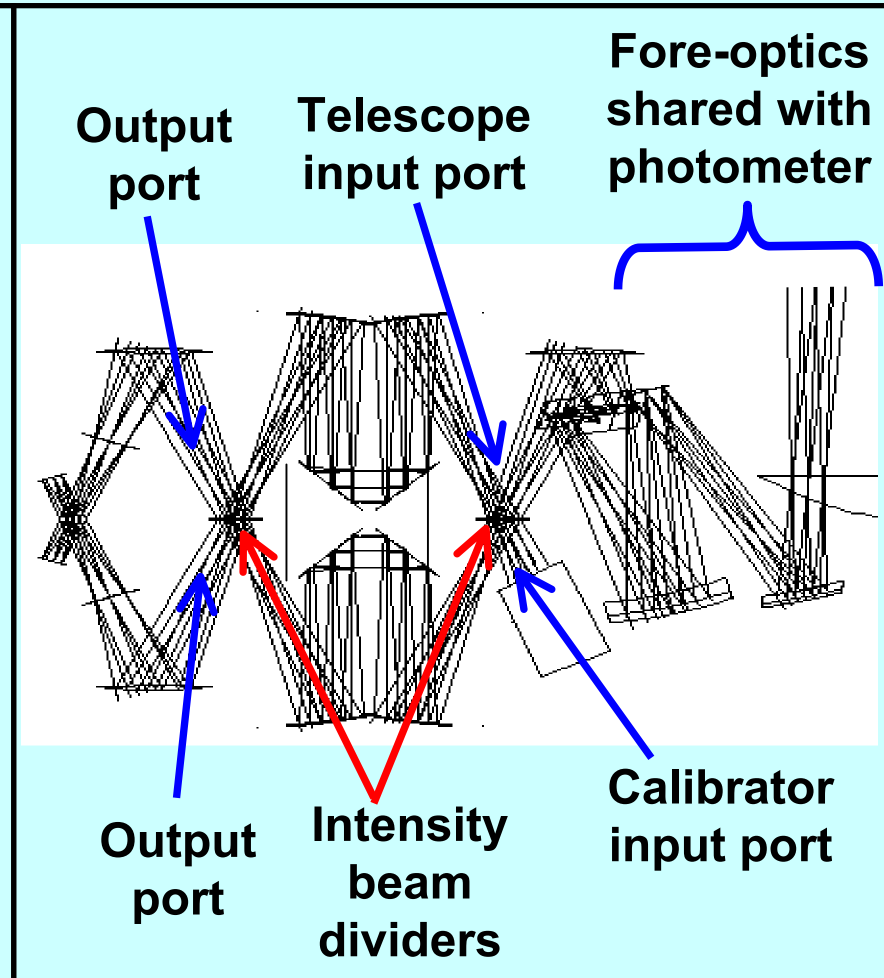
Photometer Layout and Optics





FTS Layout and Optics





Detector Arrays (2$F\lambda$ Feedhorns)

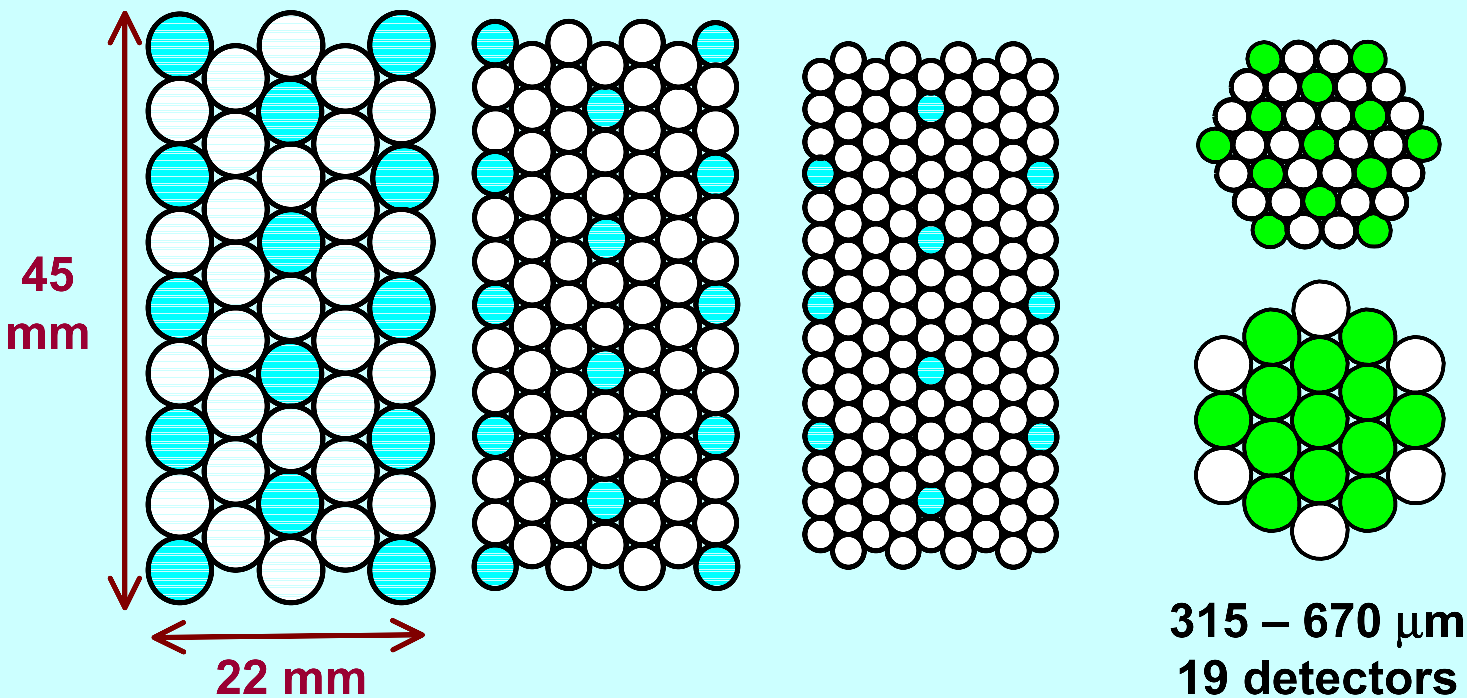
Photometer	Spectrometer

250 μm
43 detectors

360 μm
88 detectors

520 μm
139 detectors

200 – 325 μm
37 detectors

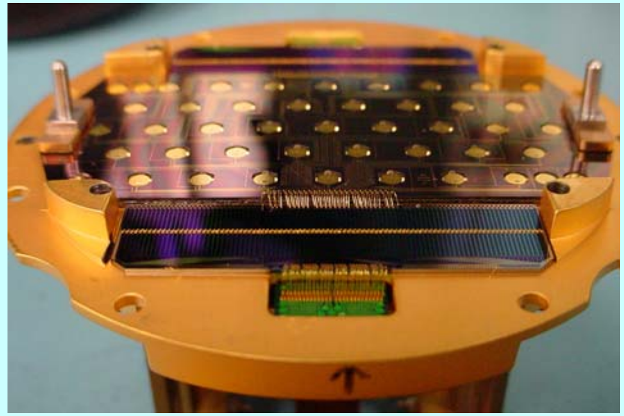


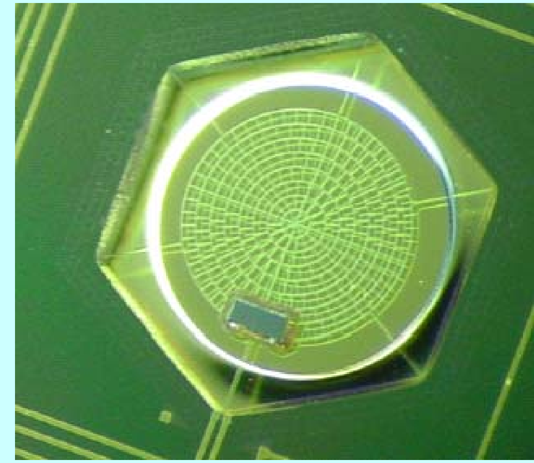
315 – 670 μm
19 detectors

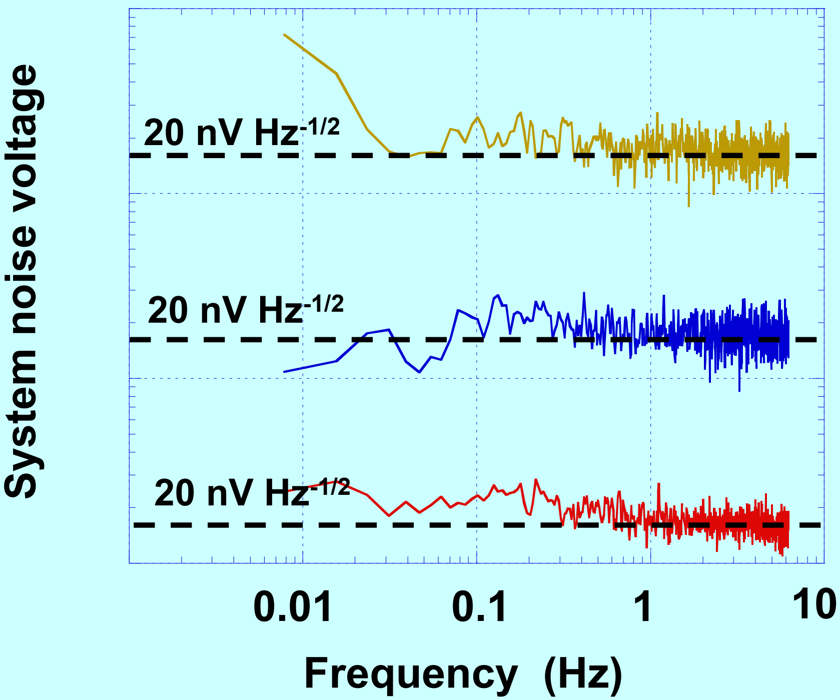
⇒ **Coincident beam centres**

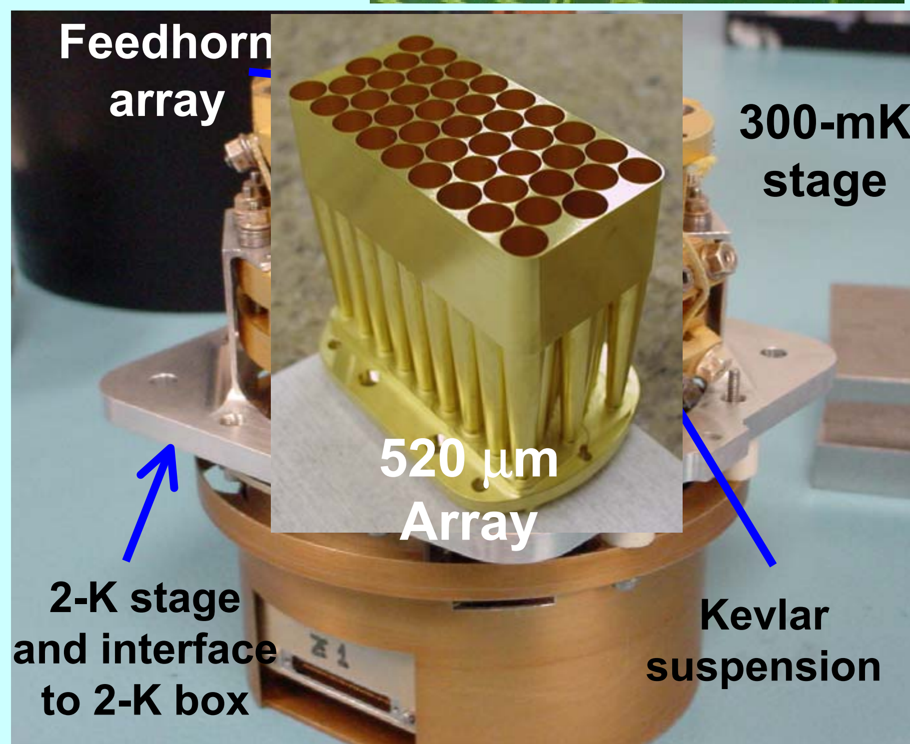
0.3-K Germanium Bolometer Arrays

- NEP ~ 3 x 10^{-17} W $Hz^{-1/2}$
- 100-K Si JFET readout
- 1/*f* noise knee < 100 mHz





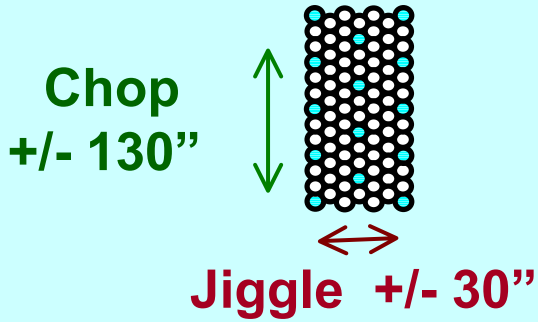


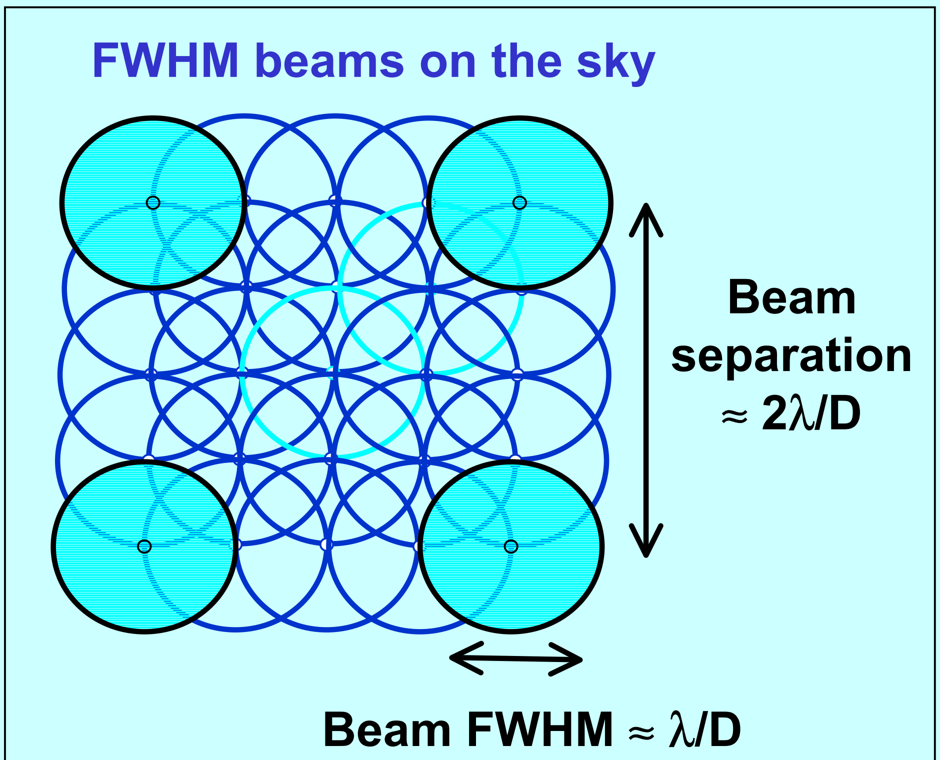


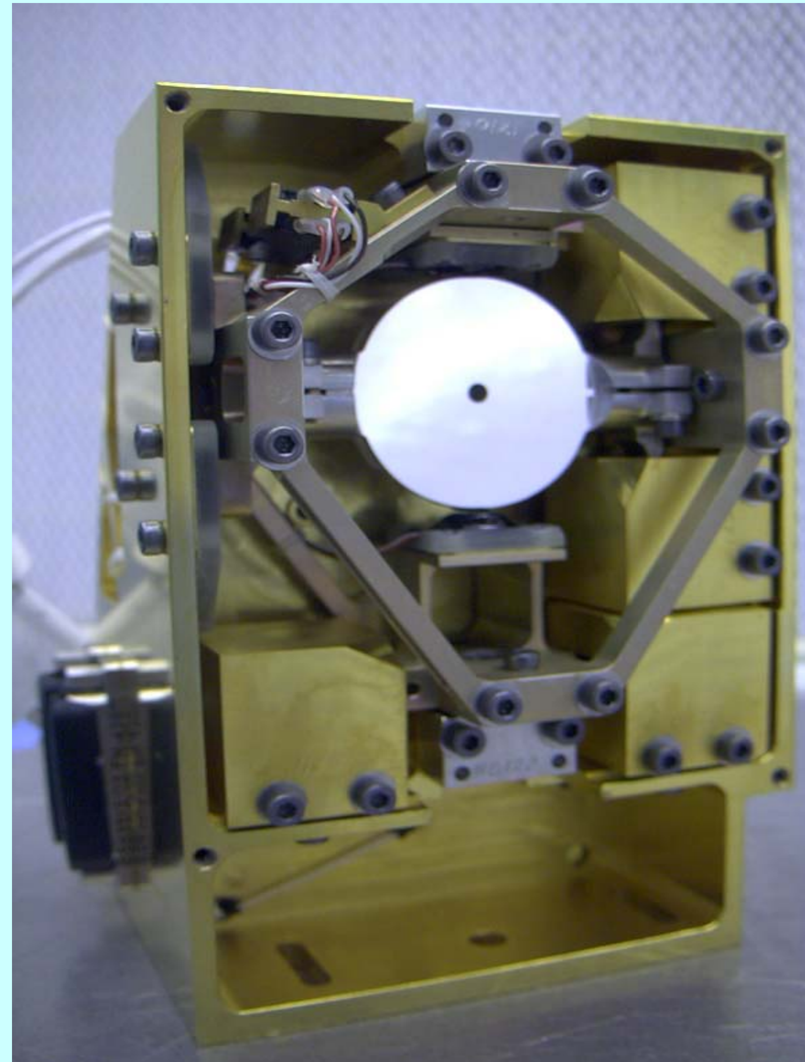
^{3}He Cooler

- **Cold stage temp. < 290 mK**
- **Hold time > 46 hrs**
- **Cycle time < 2 hrs**
- **Gas-gap heat switches (no moving parts)**
- **Heat lift provided to detector arrays > 10 μW**

Beam Steering Mechanism

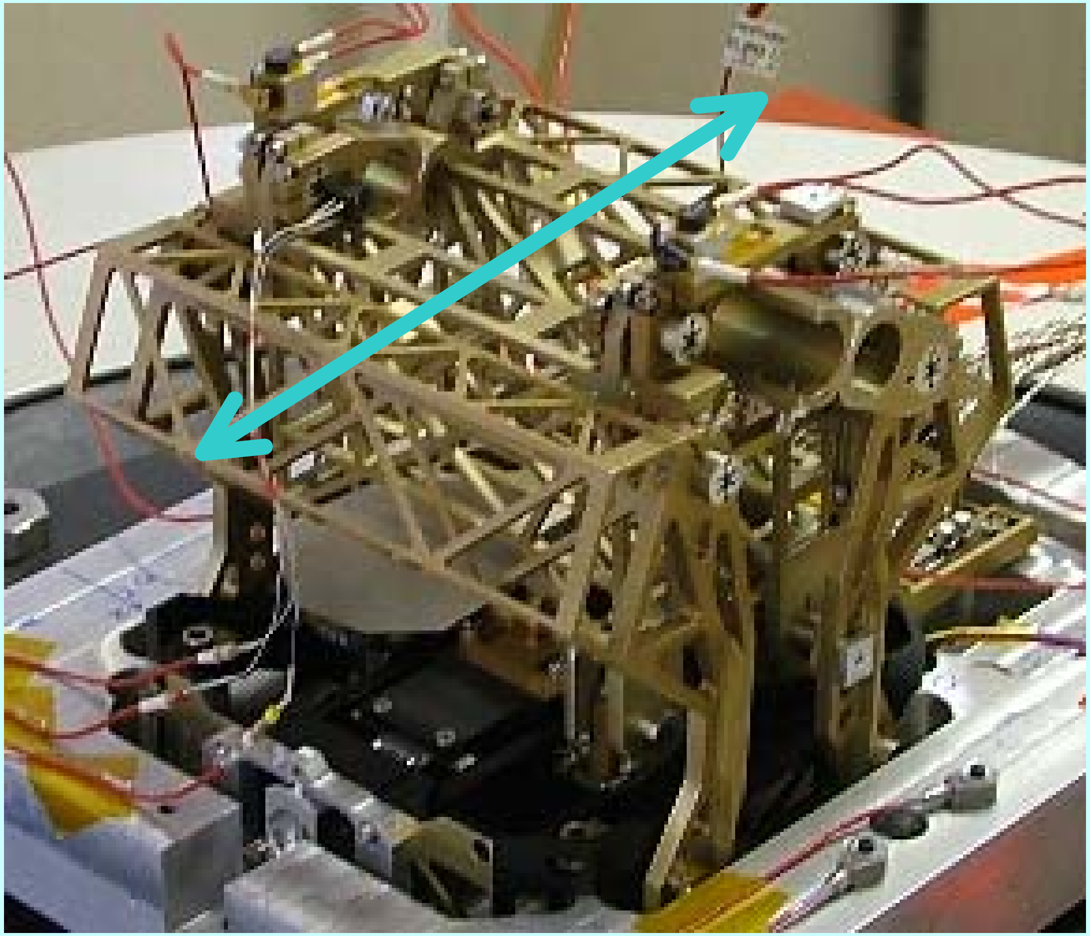






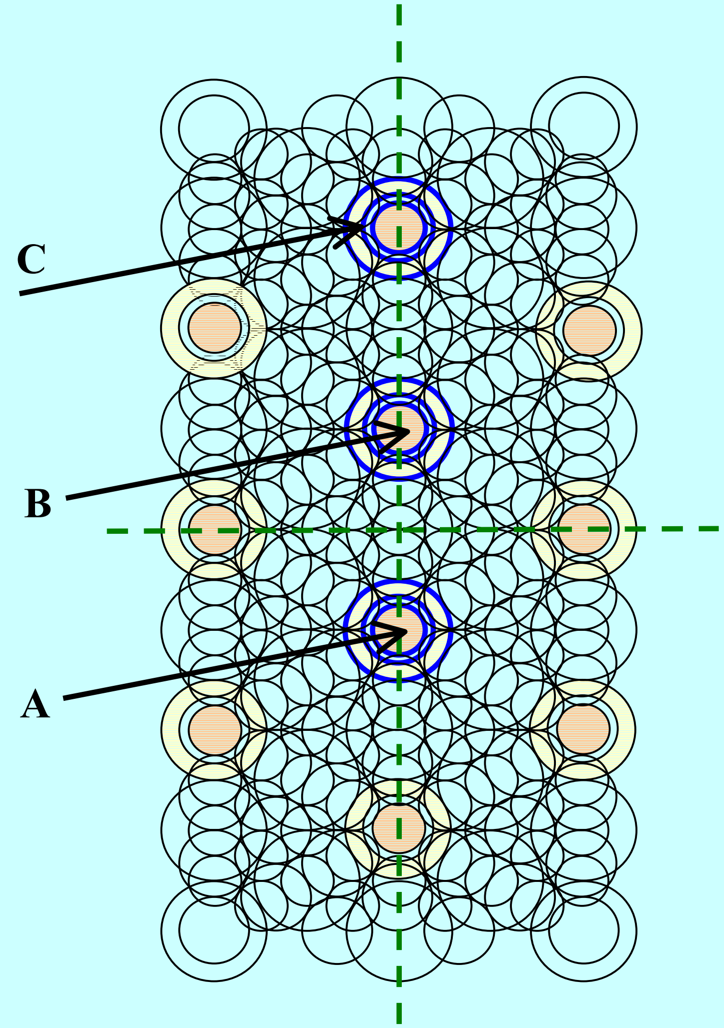
FTS Scan Mechanism

- **Double parallelogram carriage with toothless gear**
- **Moiré fringe position measurement system (0.1 μm accuracy)**
- **Continuous scan or step-and-integrate operation**
- **Nominal speed: 0.5 mm s^{-1}**
  - **Signal frequency range 3 - 10 Hz**
- **3.8-cm travel**



Photometer Observing Modes: Point Source Photometry

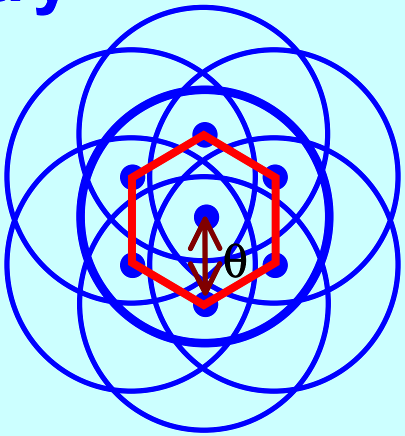
- Simultaneous observation in the three bands with sets of co-aligned detectors
- Chopping 126” and nodding, using detector sets A, B, C
- OK if the pointing is accurate enough (~ 1.5”)

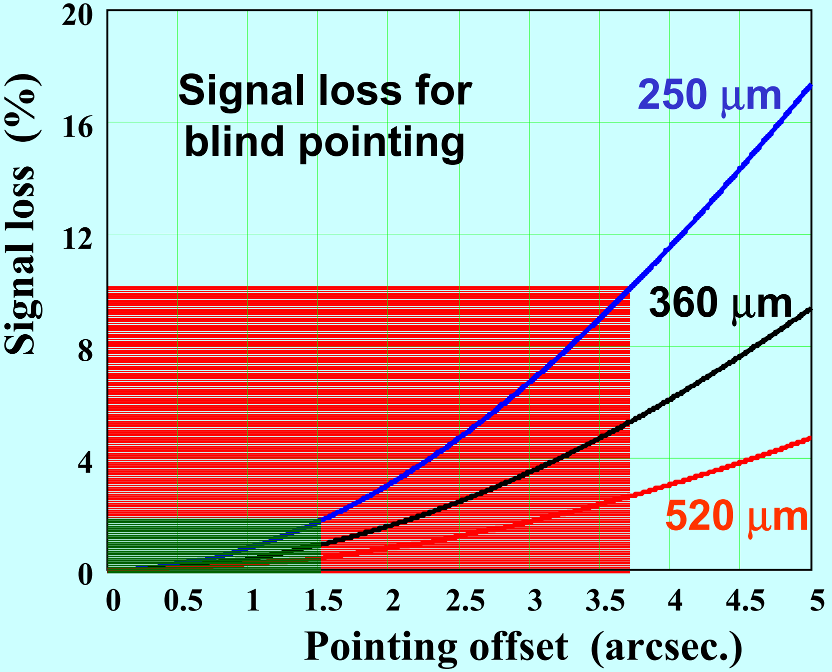


Photometer Observing Modes: Seven-point Jiggle Photometry

- Chopping 126”
- 7-point map
- Angular step θ ~ 5 arcseconds (> pointing or positional error)
- Total flux and position fitted
- Compared to single accurately pointed observation, S/N for same total integration time is only degraded by

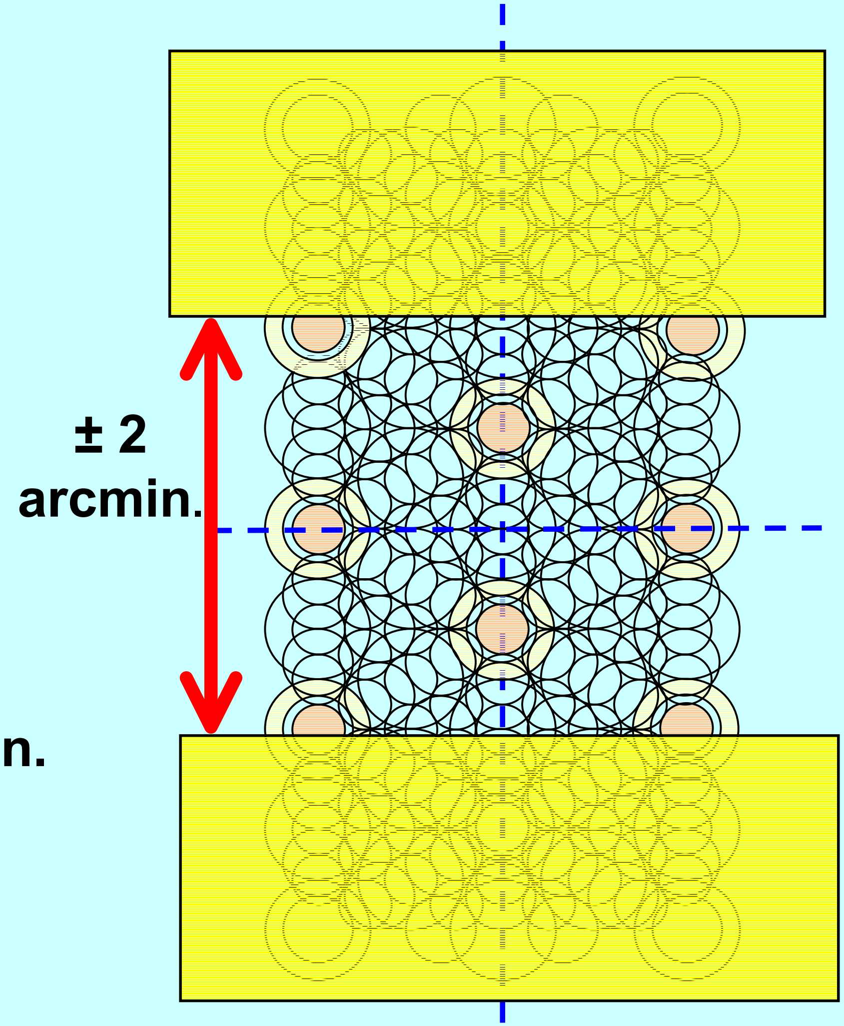
~ 20%	at	250 μm
~ 13%	at	360 μm
~ 6%	at	520 μm





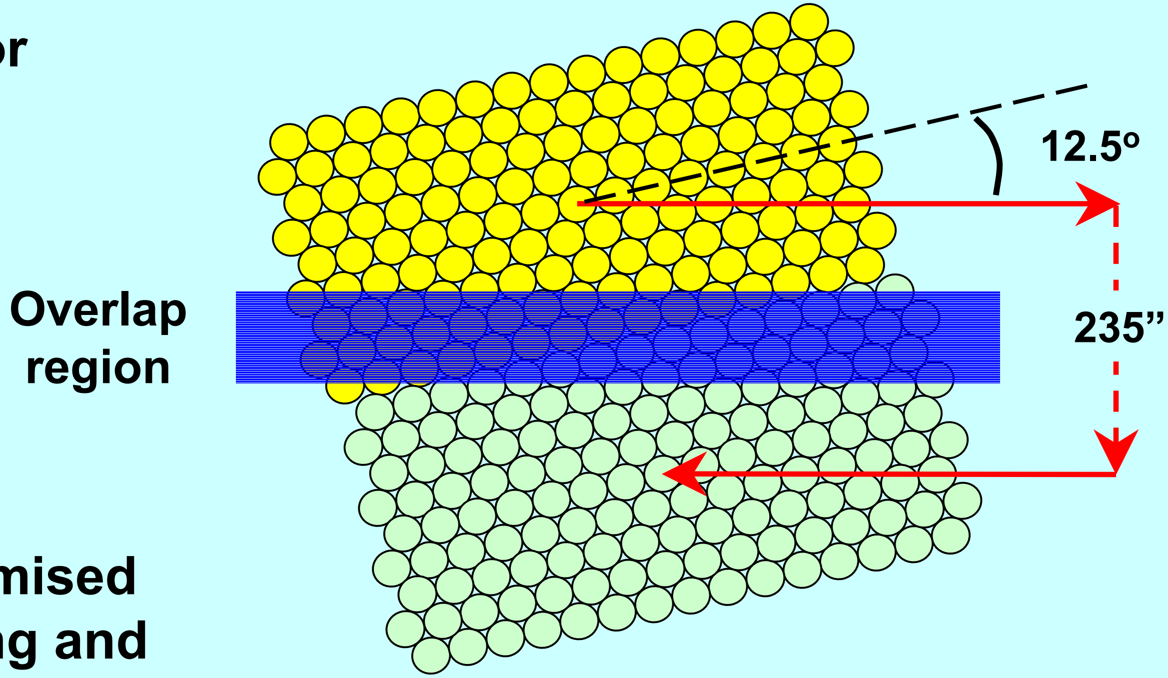
Field (Jiggle) Map

- Telescope pointing fixed or in raster mode
- Chopping ± 2 arcmin
- 64-point "jiggle" pattern for full spatial sampling
- Available FoV = 4 x 4 arcmin.



Photometer Observing Modes: Scan Map

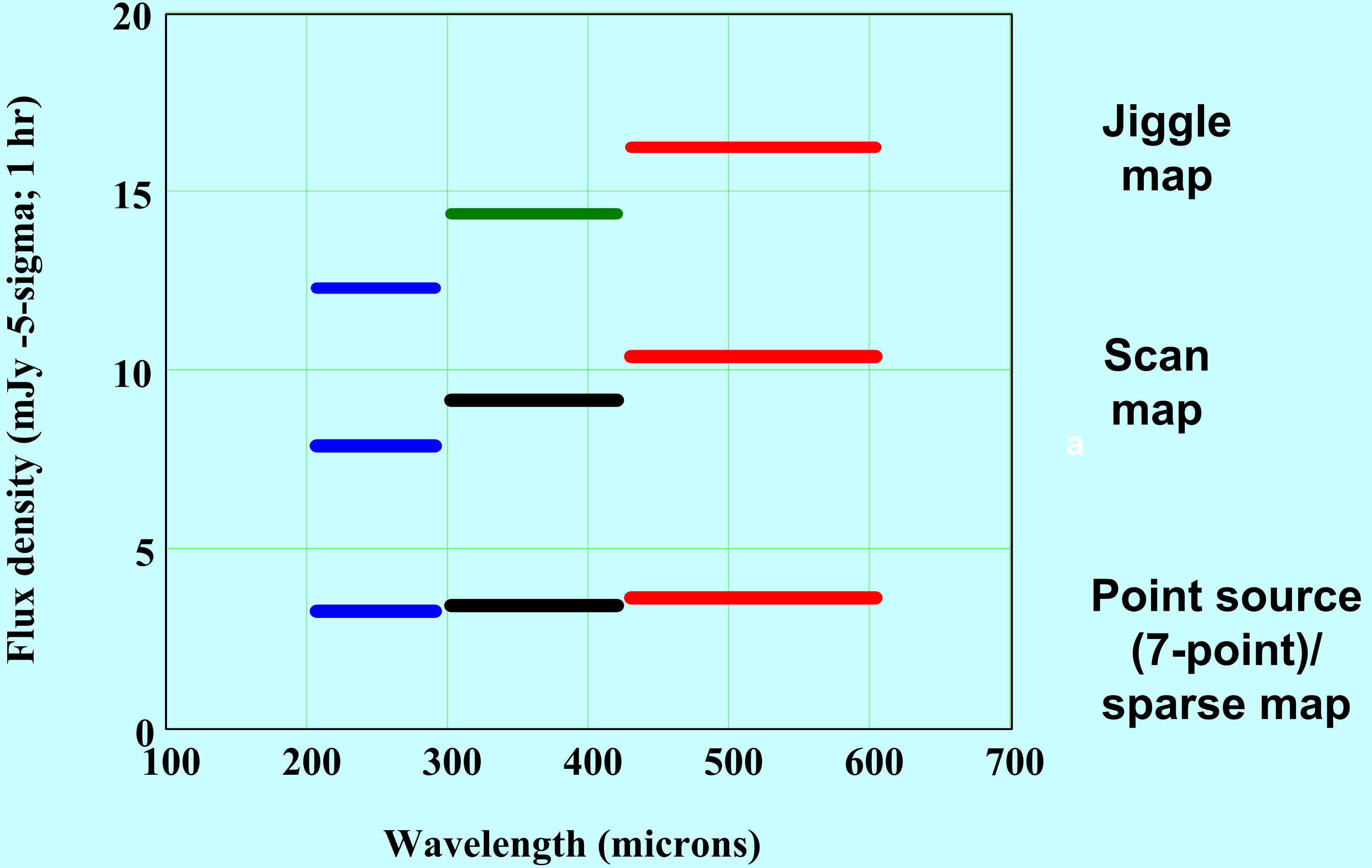
- Most efficient mode for large-area surveys
- Telescope scans continuously at up to 60”/sec.
- Scan parameters optimised for full spatial sampling and uniform distribution of integration time
- Map of large area is built up from overlapping parallel scans



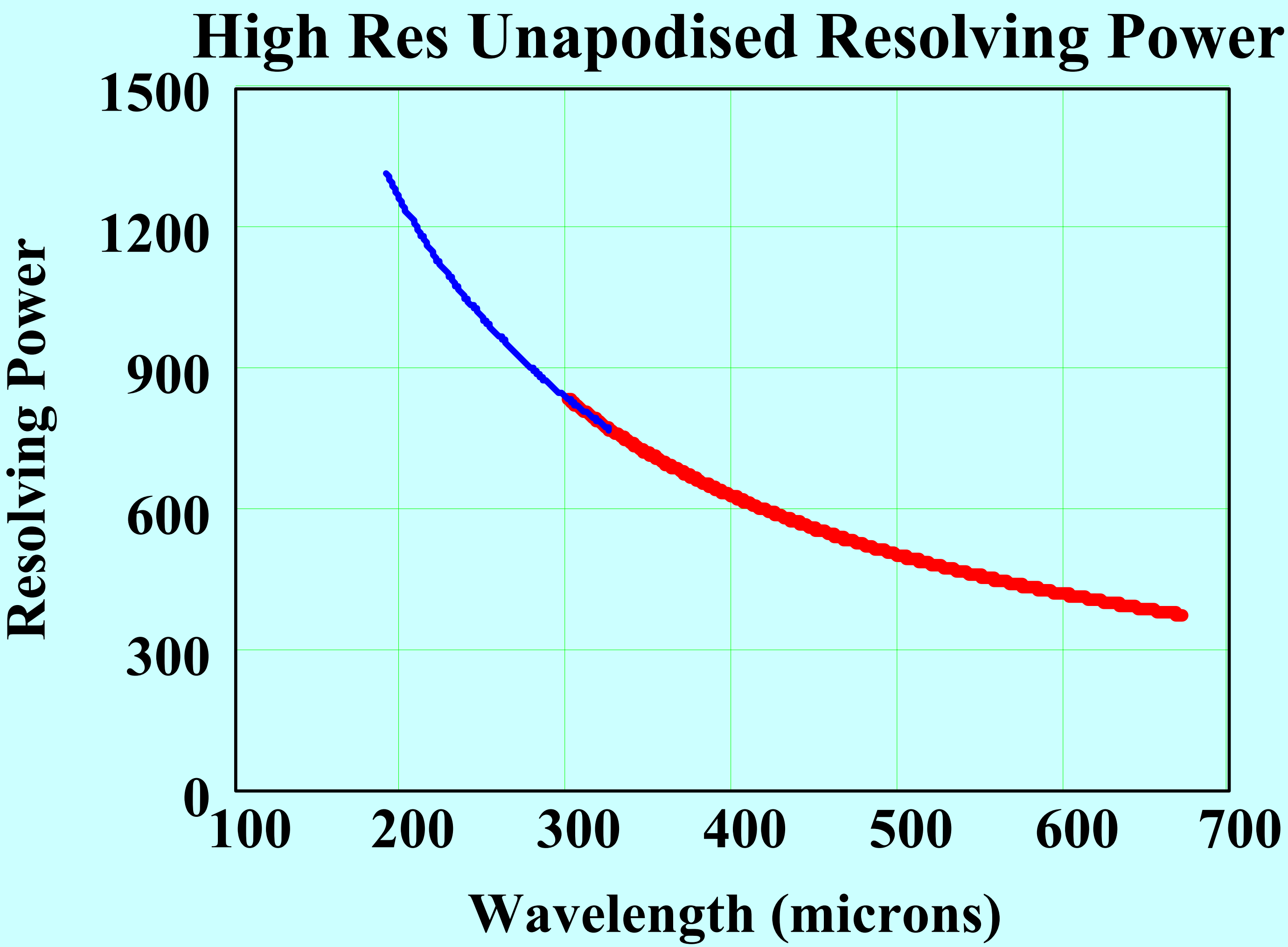
FTS Observing Modes

- $\Delta\sigma = 0.04 - 2\ cm^{-1}$ by adjusting scan length
- Continuous scan (nominal mode):
  - Calibrator in 2nd port nulls telescope background
- Step-and-integrate:
  - 2nd port calibrator is off
  - Mirror stepped with integration at each position
  - Beam Steering Mechanism chops on the sky
- Point source or sparse map spectroscopy/spectrophotometry
  - Produces 2.6- arcmin sparse map – background is characterised by adjacent pixels
- Imaging spectroscopy (fully-sampled)
  - Beam steering mirror adjusts pointing between scans to acquire fully-sampled spectral image

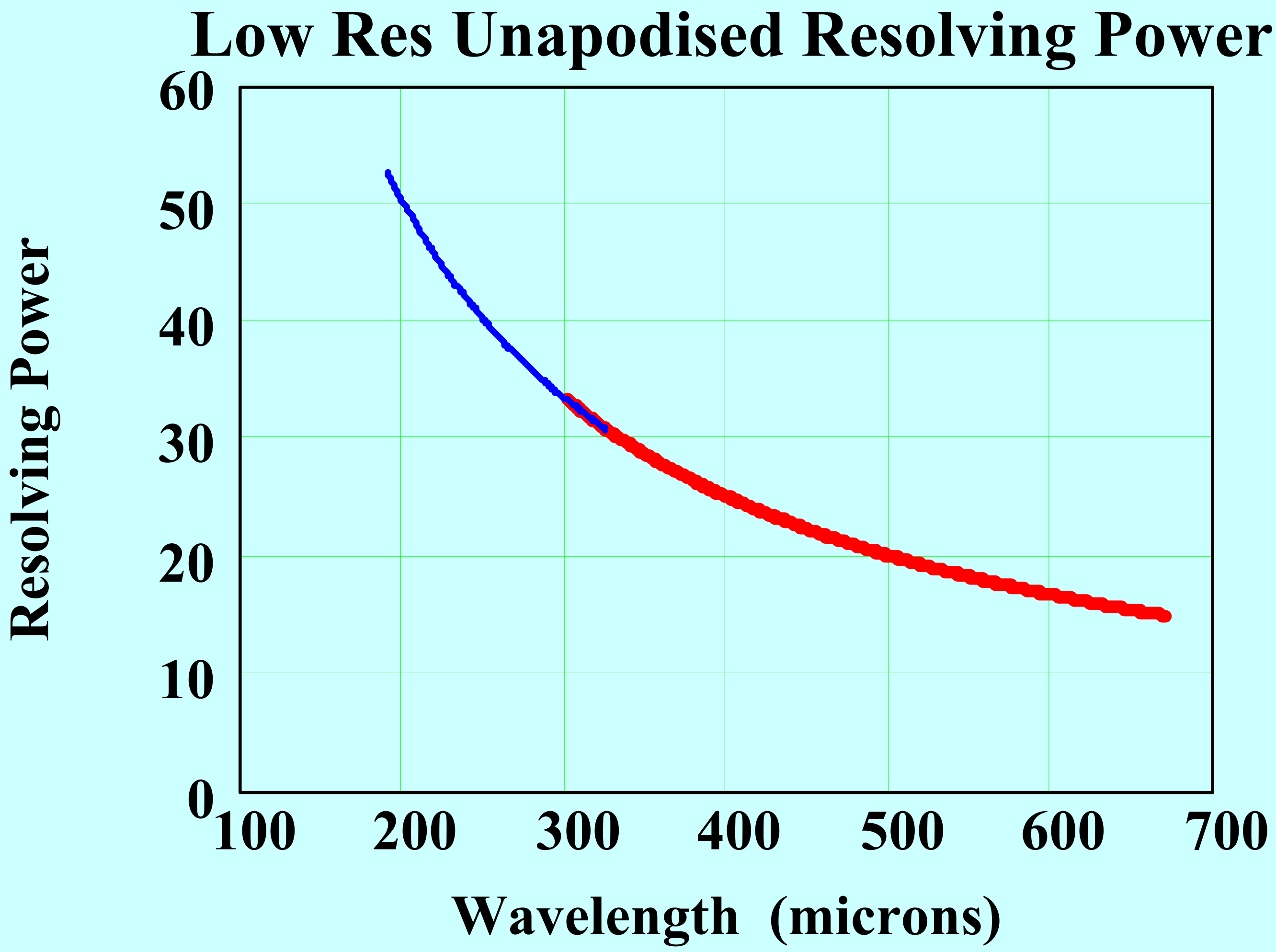
Sensitivity: Photometry
(5 σ ; 1 hr)



FTS Spectral Line Resolving Power ($\Delta\sigma = 0.04\ cm^{-1}$)



FTS Spectrophotometry Resolving Power ($\Delta\sigma = 1\ cm^{-1}$)



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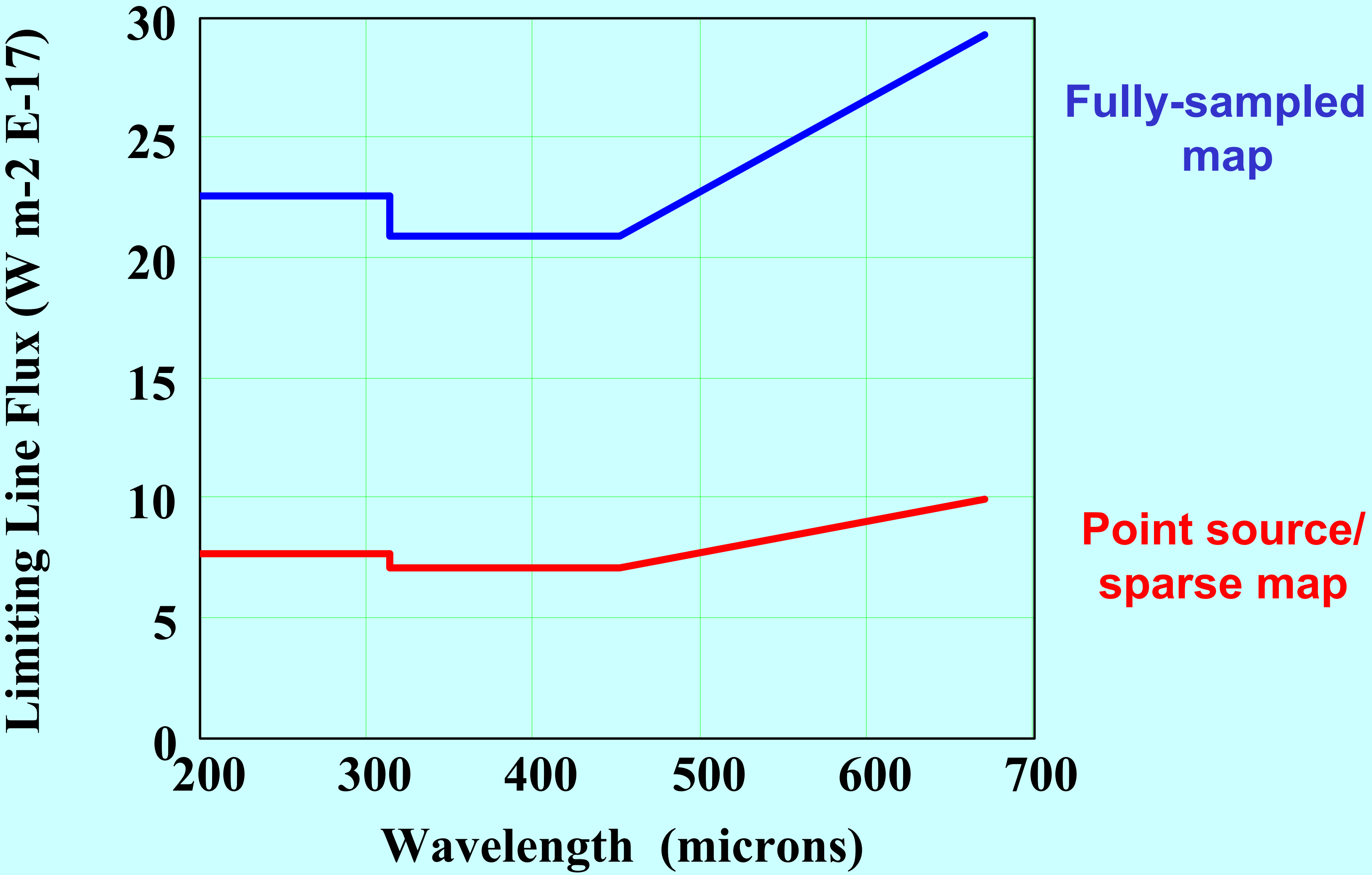
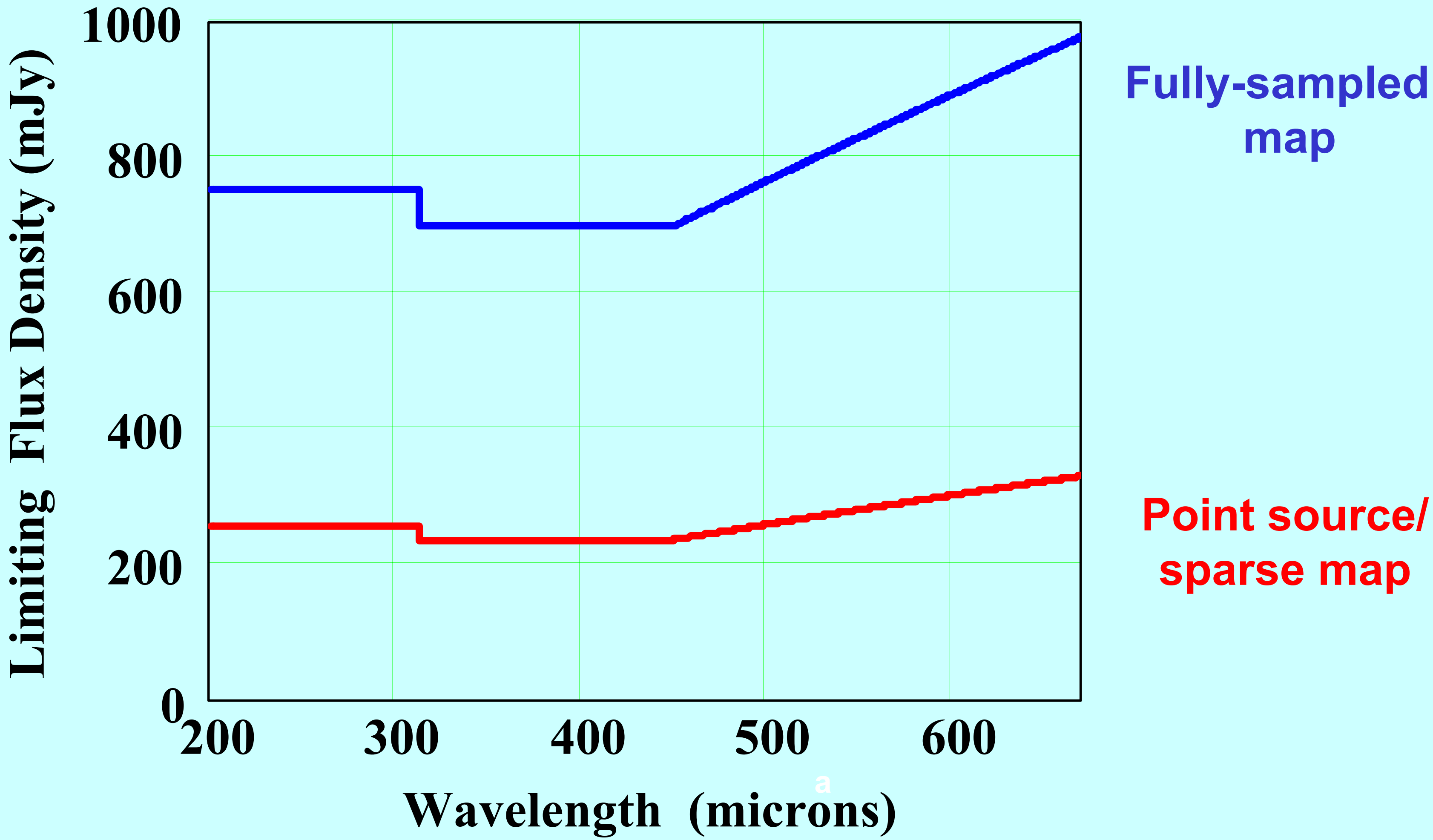
Sensitivity: Line Spectroscopy

(5 σ ; 1 hr)

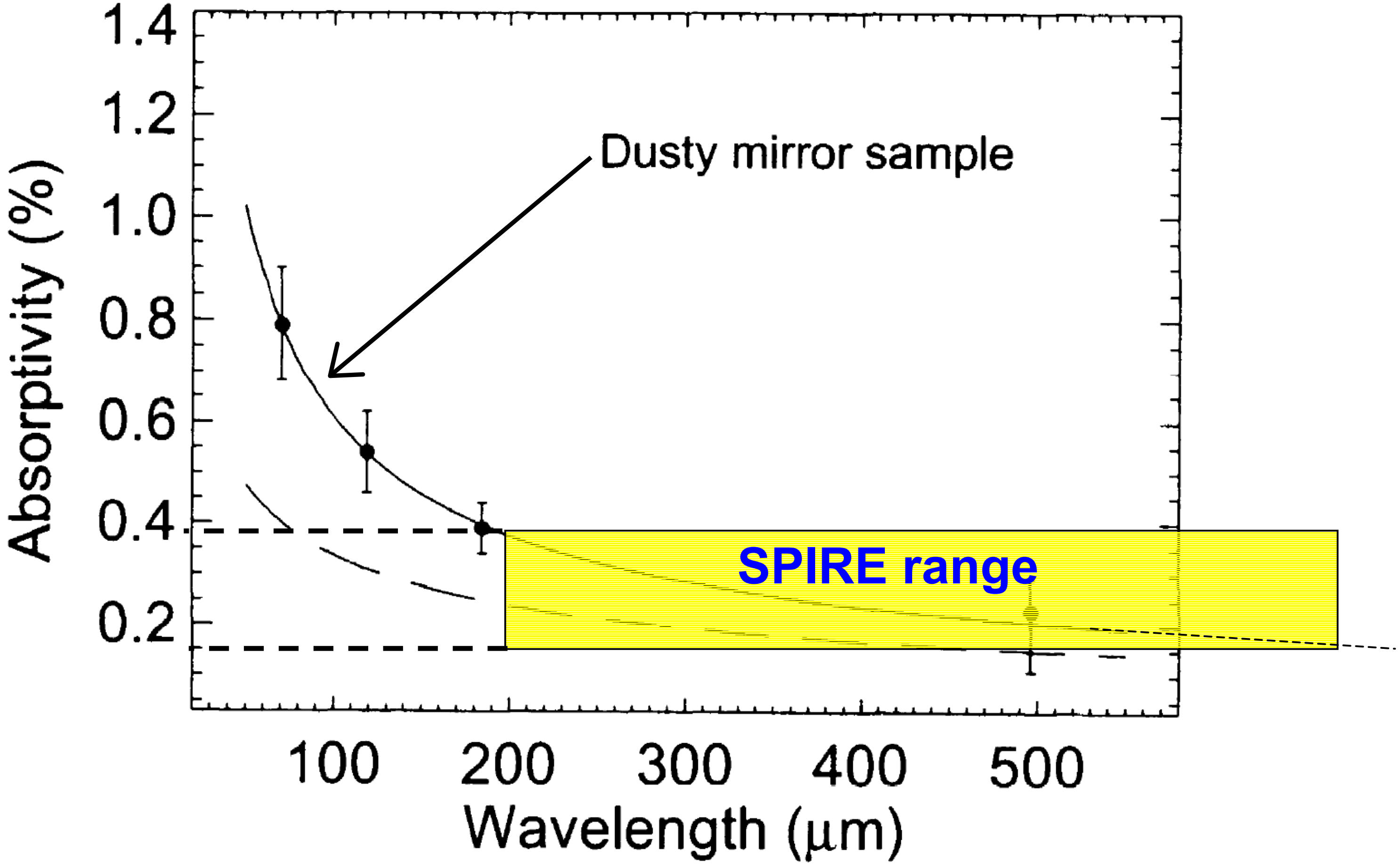


Sensitivity: Spectrophotometry

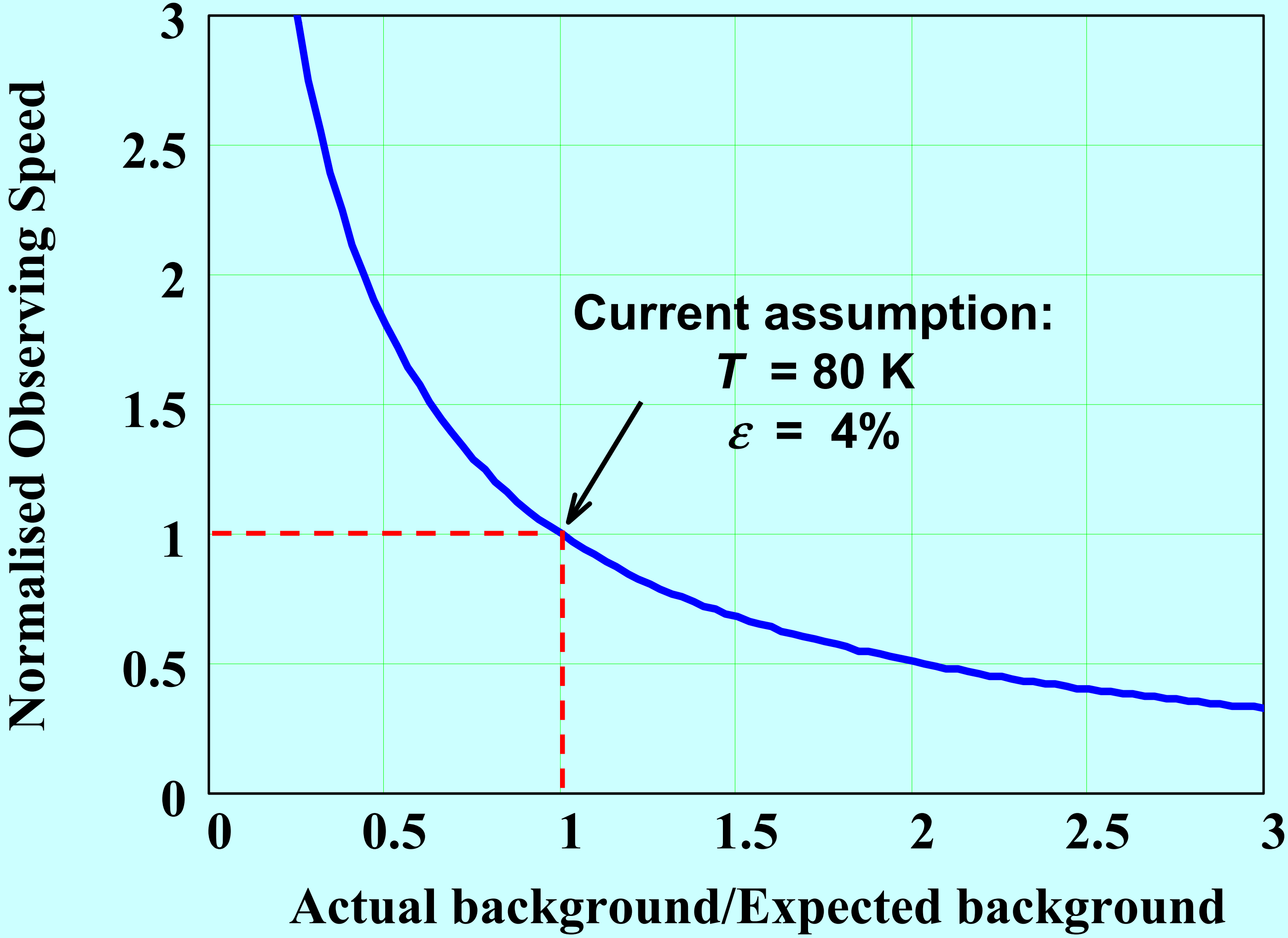
($\Delta\sigma$ = 1 cm^{-1})   (5 σ ; 1 hr)



Herschel Reflector Emissivity
(Fischer *et al.*, Applied Optics, 43, 3765, 2004)

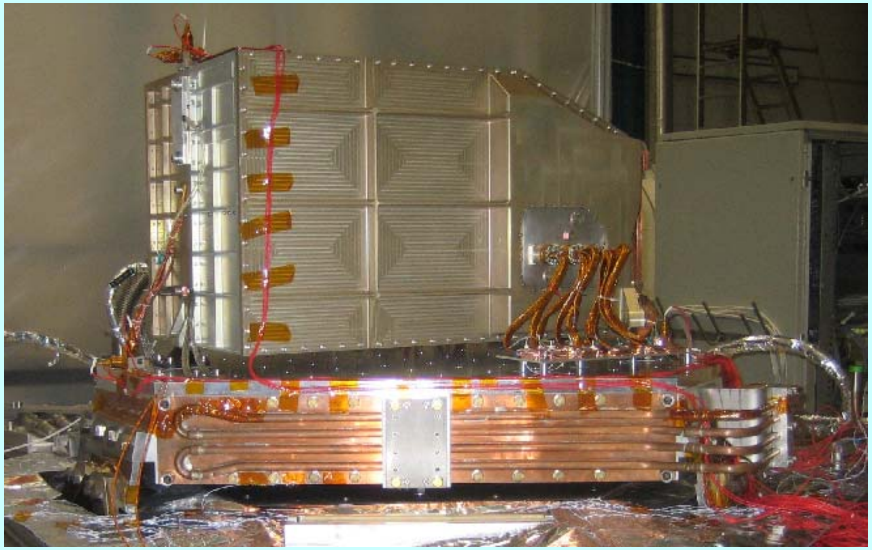


Observing Speed vs. Telescope Background Power (360 μm)



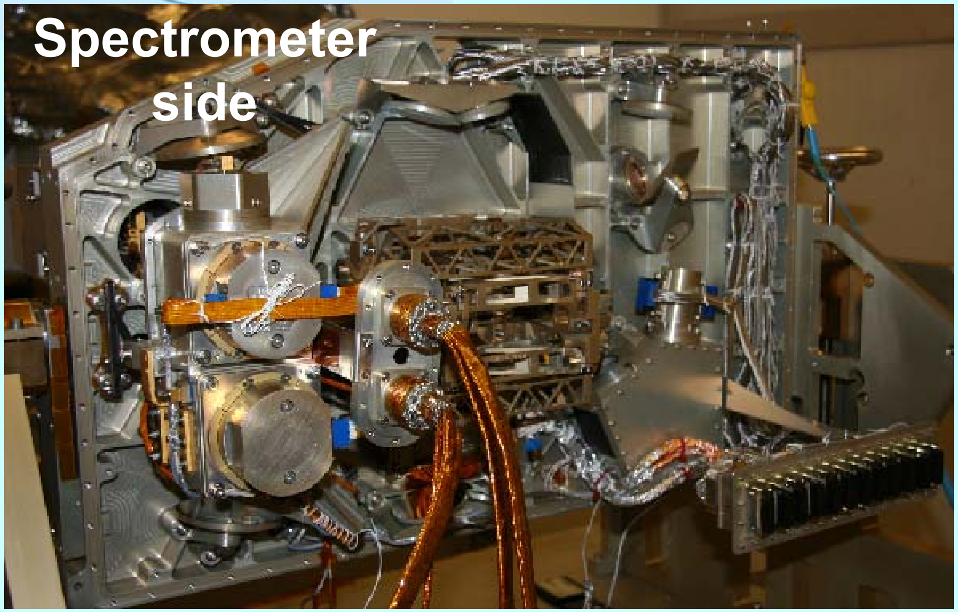
Current Status

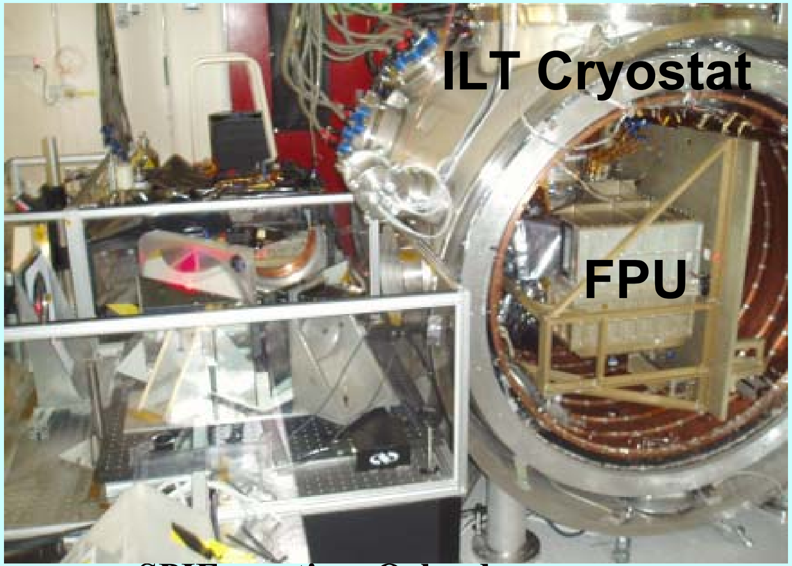
- Flight instrument is being built and tested in stages at Rutherford Appleton Laboratory, UK

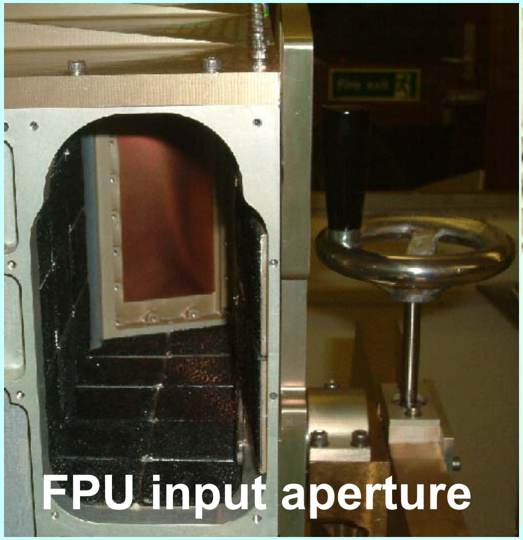


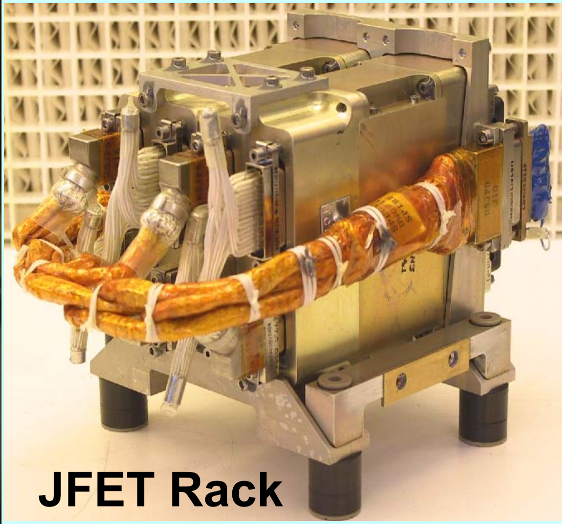
- Test campaigns so far
  - 1. Spectrometer side (early 2005)
  - 2. Full instrument (Autumn 2005)
  - Qualification vibration (end 2005)
  - 3. Post-vibration cooldown (currently in progress)
- Future steps
  - Installation of flight spectrometer mechanism
  - Final cold vibration
  - Extended instrument evaluation, calibration, observing mode testing
- Integration and test of flight spare
  - Use as a test-bed and for training after flight instrument delivery

SPIRE Flight Instrument









Other SPIRE-Related Talks and Posters at this Meeting

Swinyard et al.	6265-12	Optical performance
Lim et al.	6265-13	Flight instrument testing overview
Lindner et al.	6265-106	FTS simulator
Spencer et al.	6265-107	
Naylor et al.	6265-108	FTS system performance
Sibthorpe et al.	6270-47	Photometer observing modes
Hargrave et al.	6275-40	300-mK thermal system
Hargrave et al.	6275-41	Internal calibrators
Nguyen	6275-45	Bolometer array performance