Herschel-SPIRE: Design, Ground Test Results, and Predicted Performance

Matt Griffin
for the SPIRE Consortium

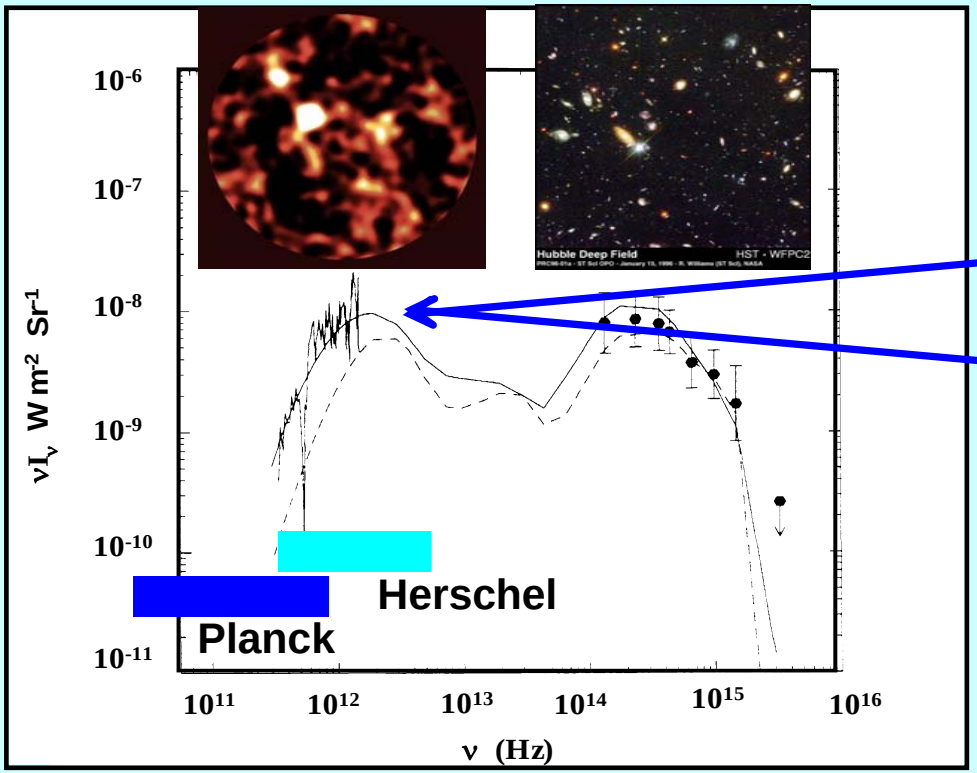
- Scientific goals
- Instrument overview
- Current status
- Performance estimates

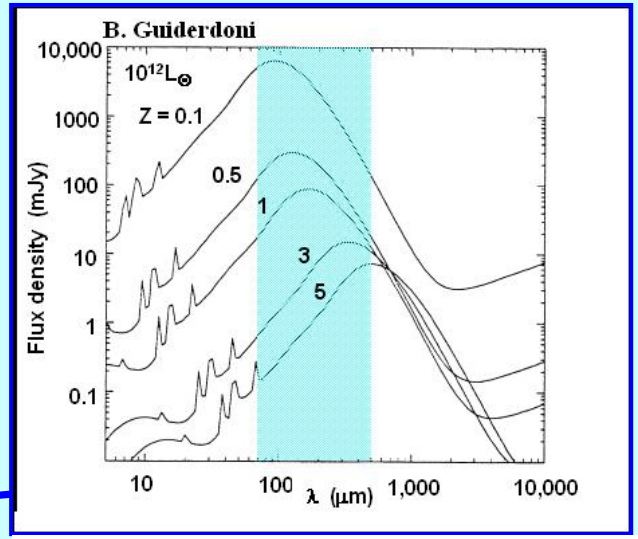
The SPIRE Consortium

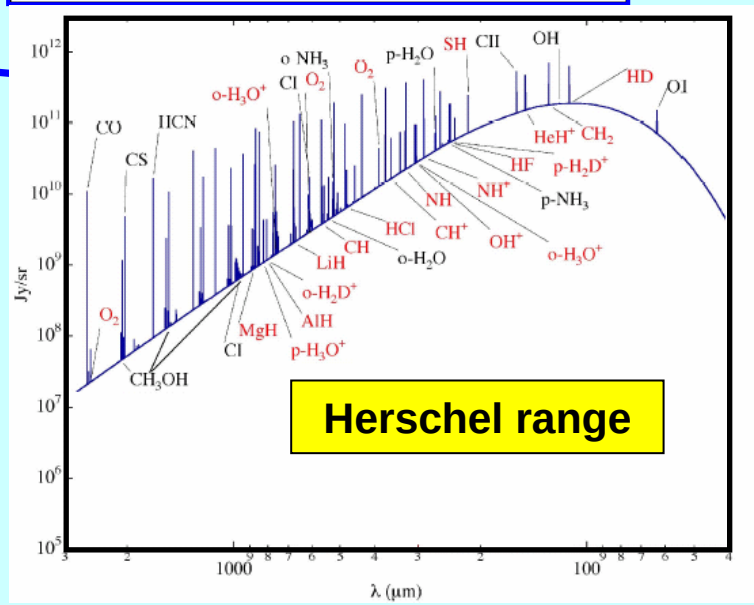
Canada China France Italy Spain Sweden UK USA

- 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
- University of Colorado, USA
- University of Lethbridge, Canada
- Università di Padova, Italy

Herschel/SPIRE Science Goals

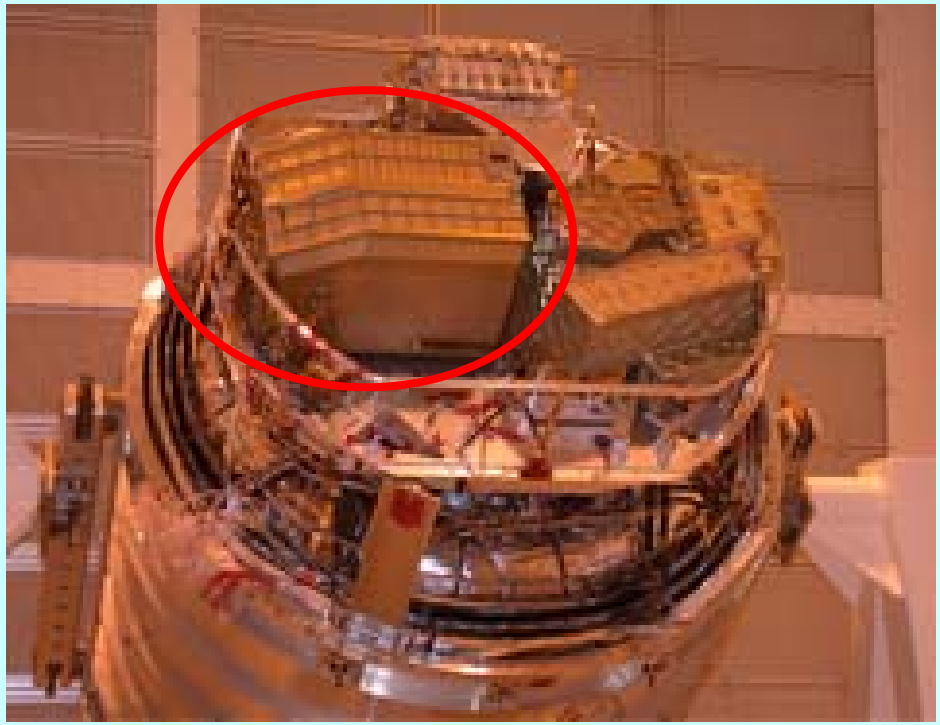






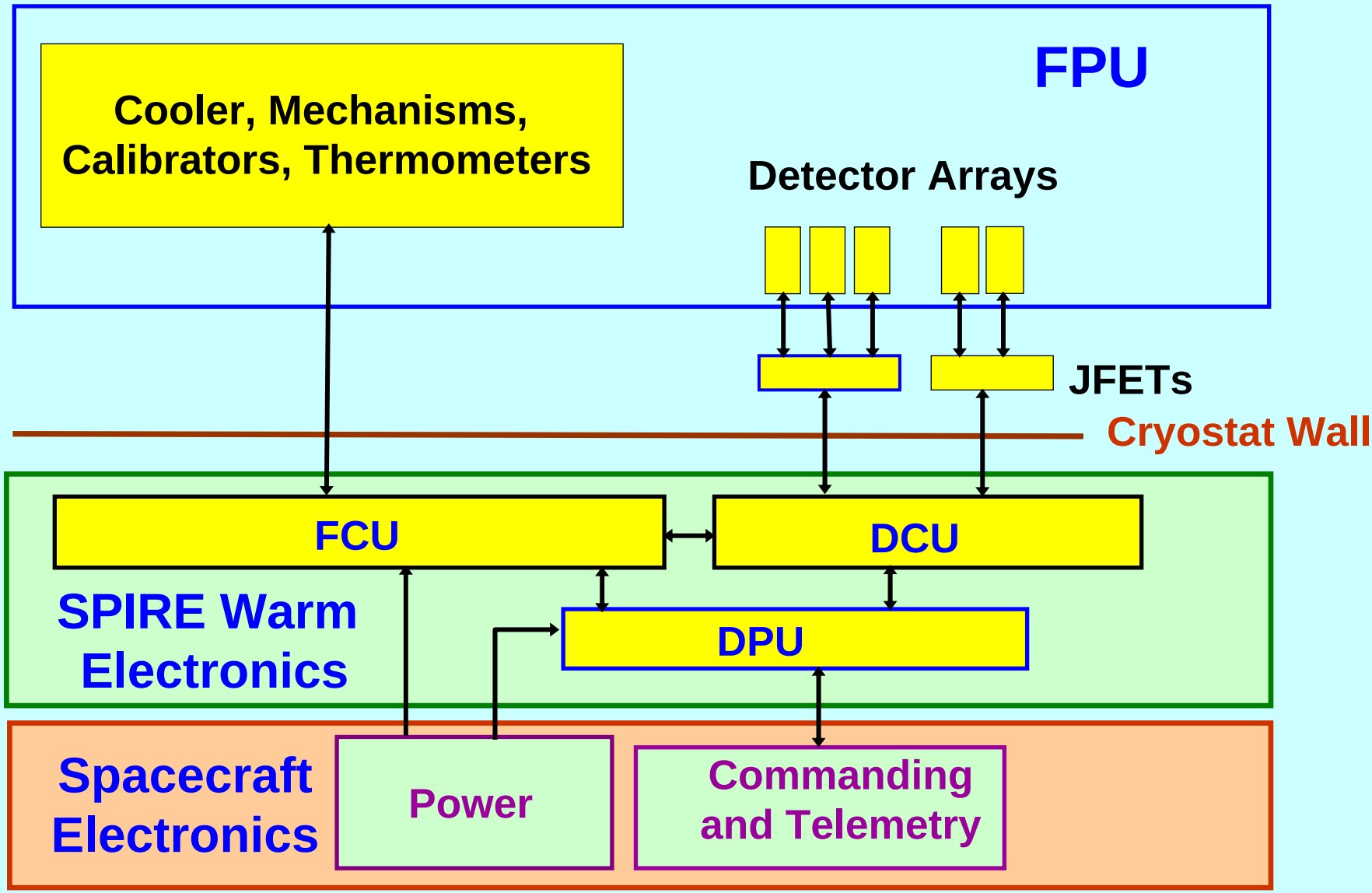
Spectral and Photometric Imaging Receiver

- **3-band imaging photometer**
  - **250, 350, 500 μm (simultaneous)**
  - **λ/Δλ ~ 3**
  - **4 x 8 arcminute field of view**
  - **Diffraction limited beams (19, 24, 35")**

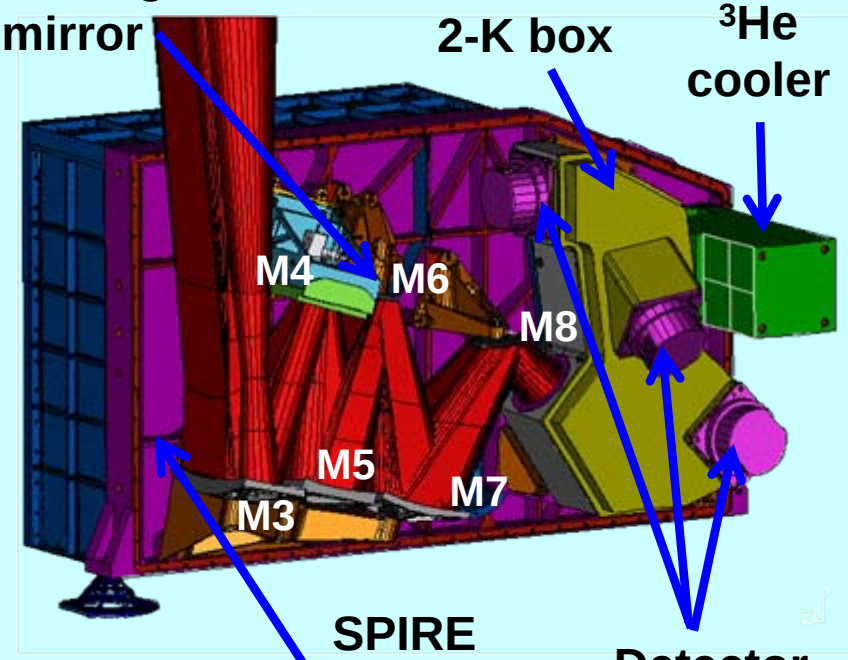


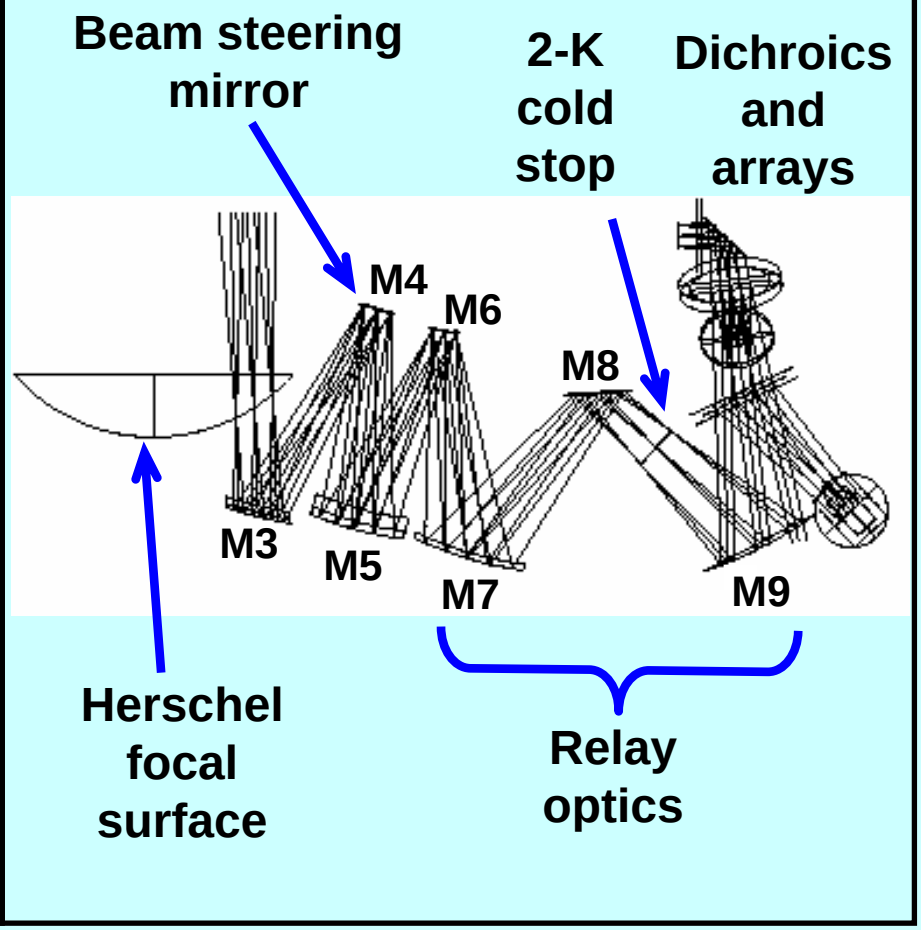
- **Imaging Fourier Transform Spectrometer**
  - **194 - 672 μm (complete range covered simultaneously)**
  - **2.6 arcminute field of view**
  - **Spectral resolution up to $\Delta\sigma$ = 0.04 cm^{-1} (λ/Δλ ~ 1000 at 250 μm)**

SPIRE Block Diagram

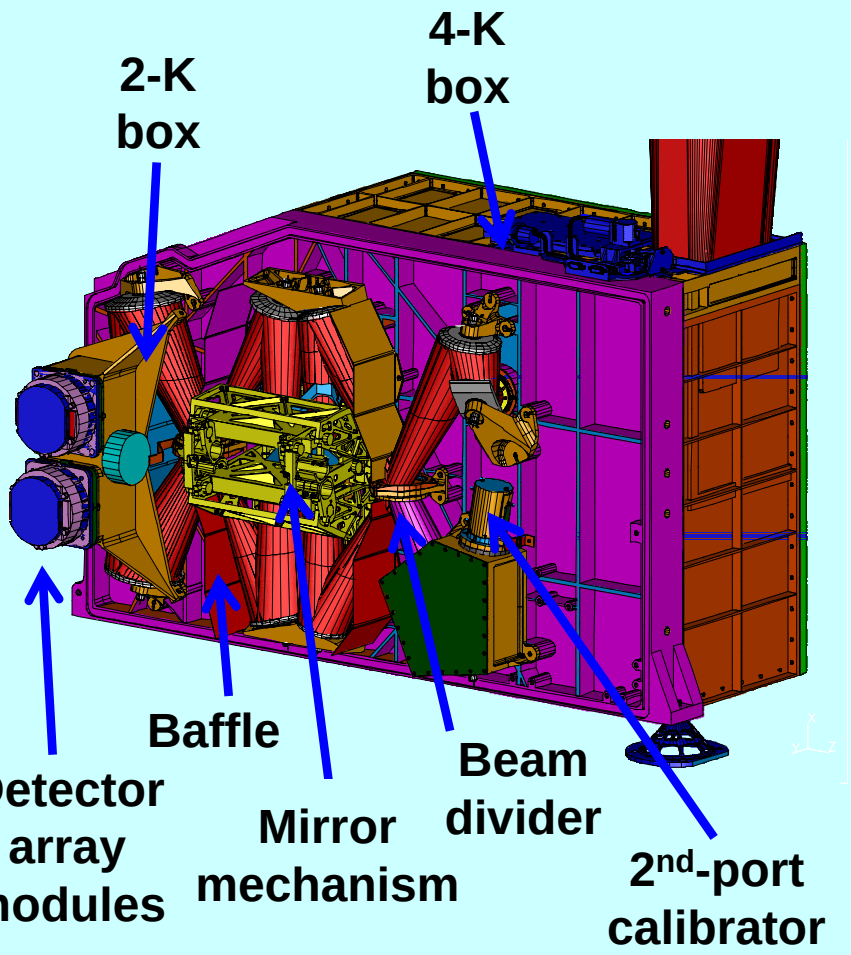


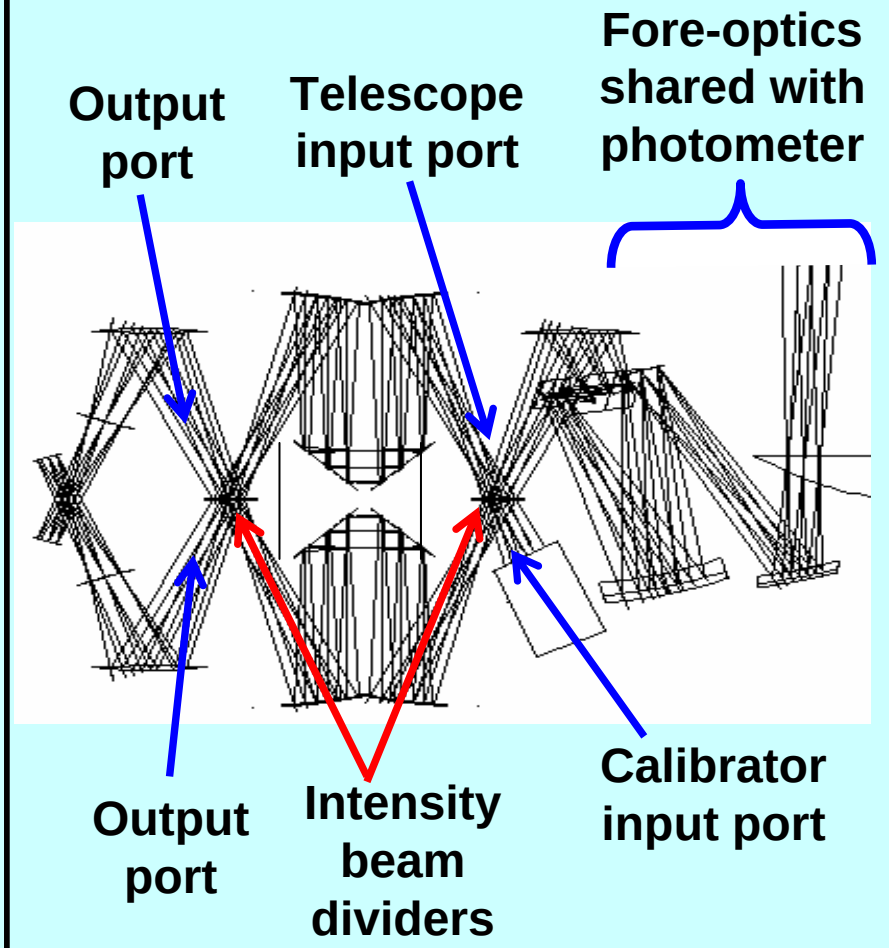
Photometer Layout and Optics



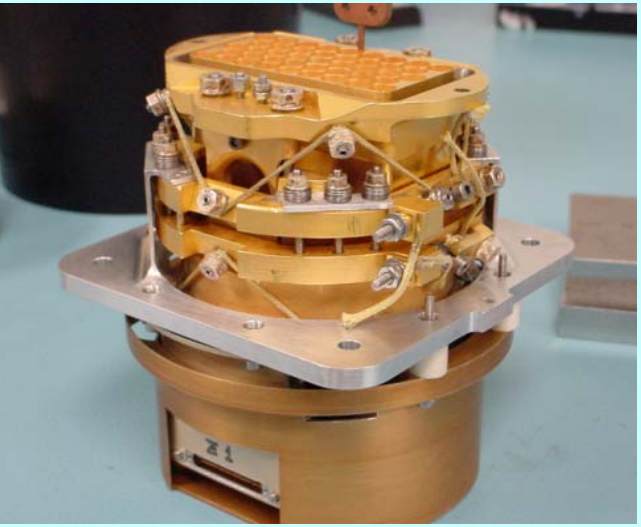


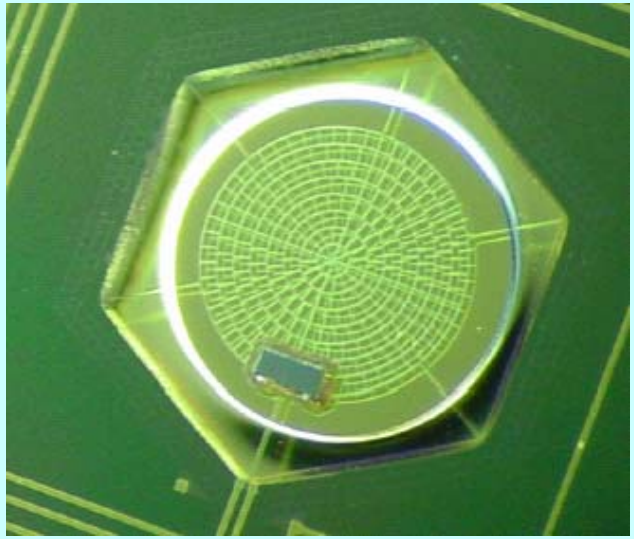
FTS Layout and Optics

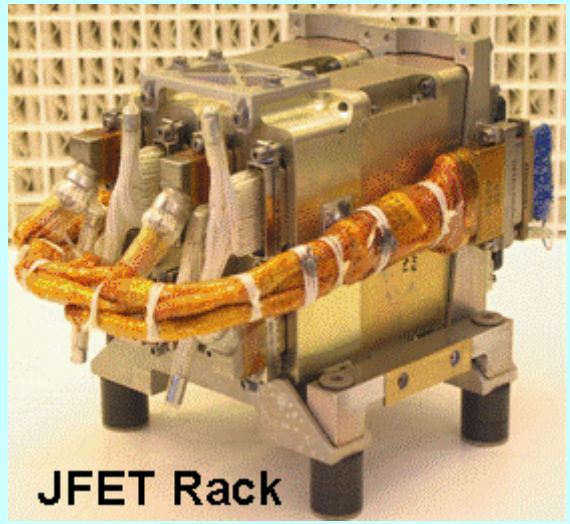


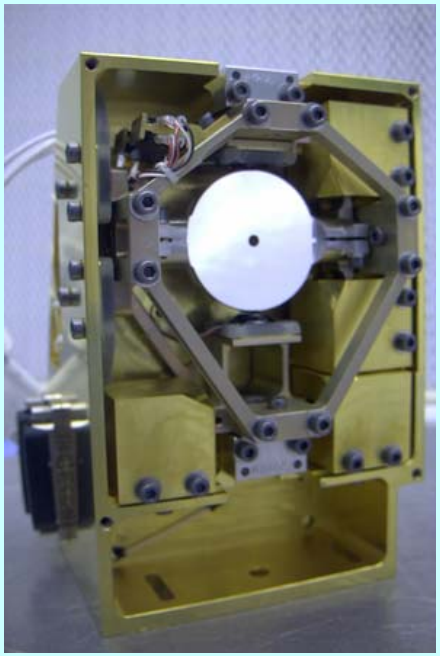


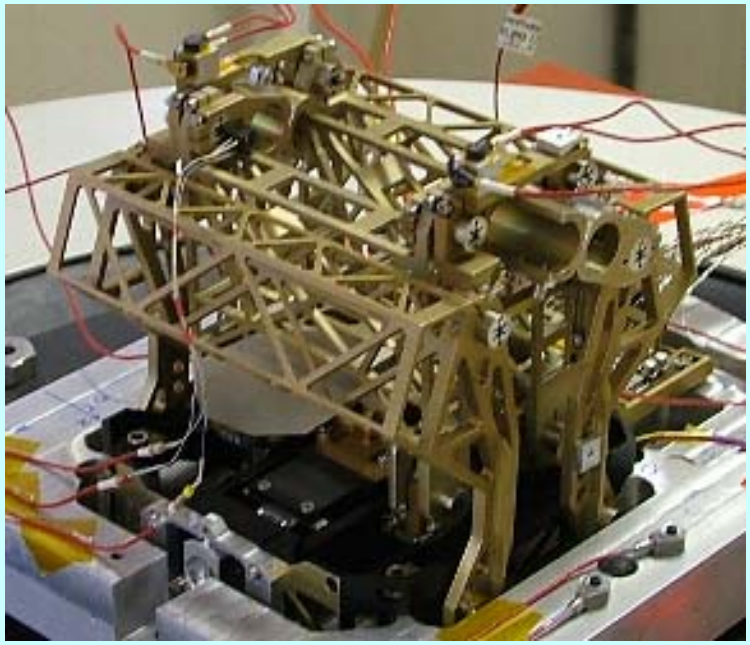
SPIRE Subsystems

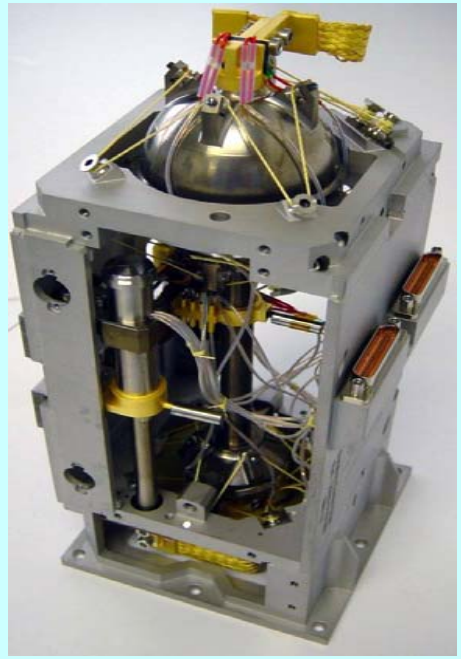






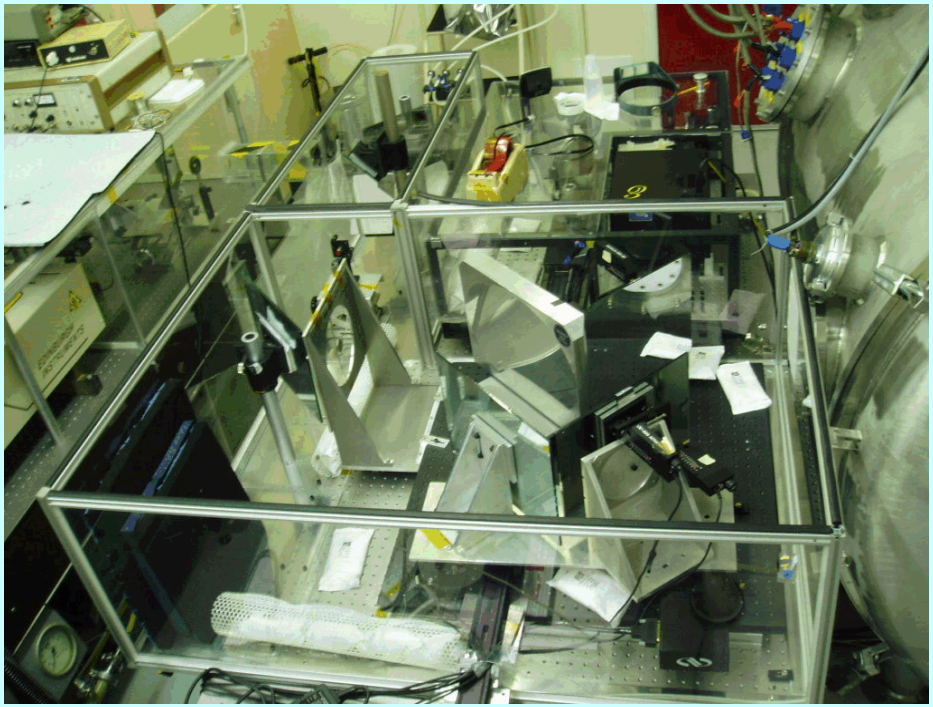


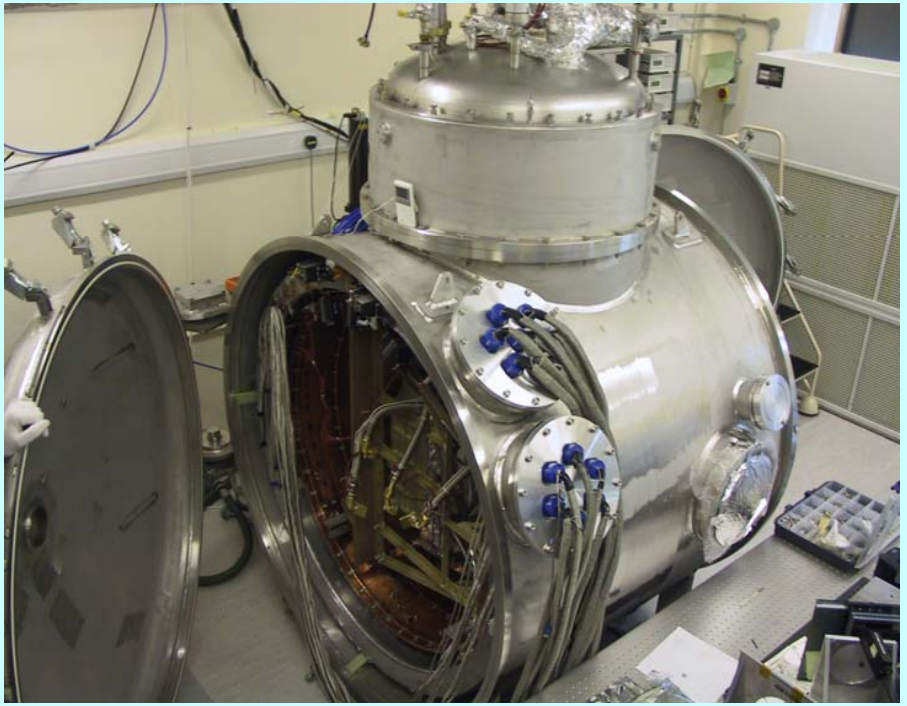




Instrument Assembly and Testing

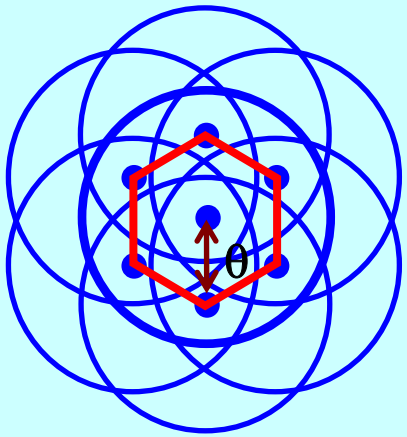
- Instrument assembled in stages and tested in dedicated facility at RAL, UK
- Started February 2005
- Finished March 2007 - instrument delivered April 2007
- Five cooldowns
- Two cold vibrations
- All major requirements and most goals are met



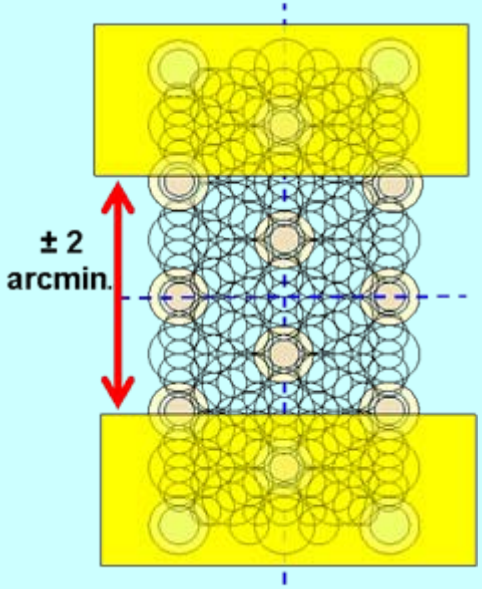


Photometer Observing Modes

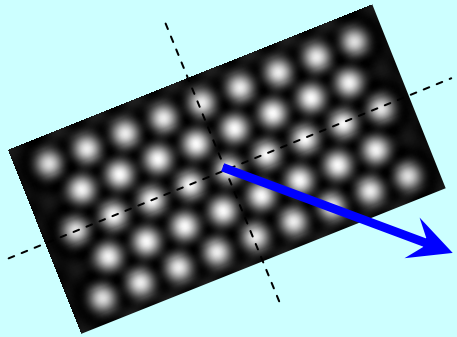
Point source:
7-point

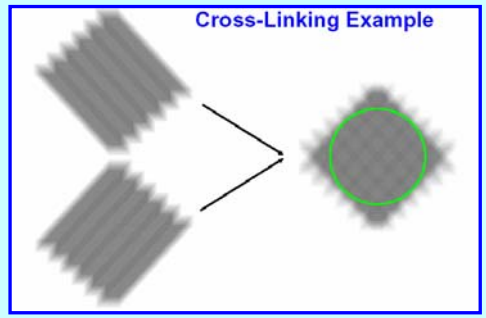


Small map:
4 x 4 arcmin
jiggle-map



Large map:
Scan-map



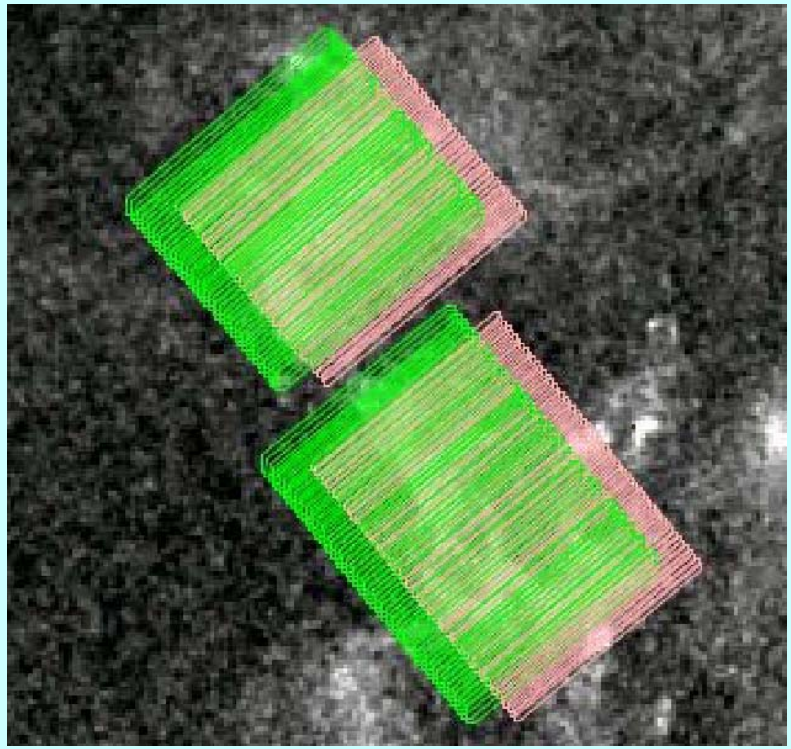


SPIRE-PACS Parallel Mode

- **Scan map with SPIRE and PACS simultaneously**

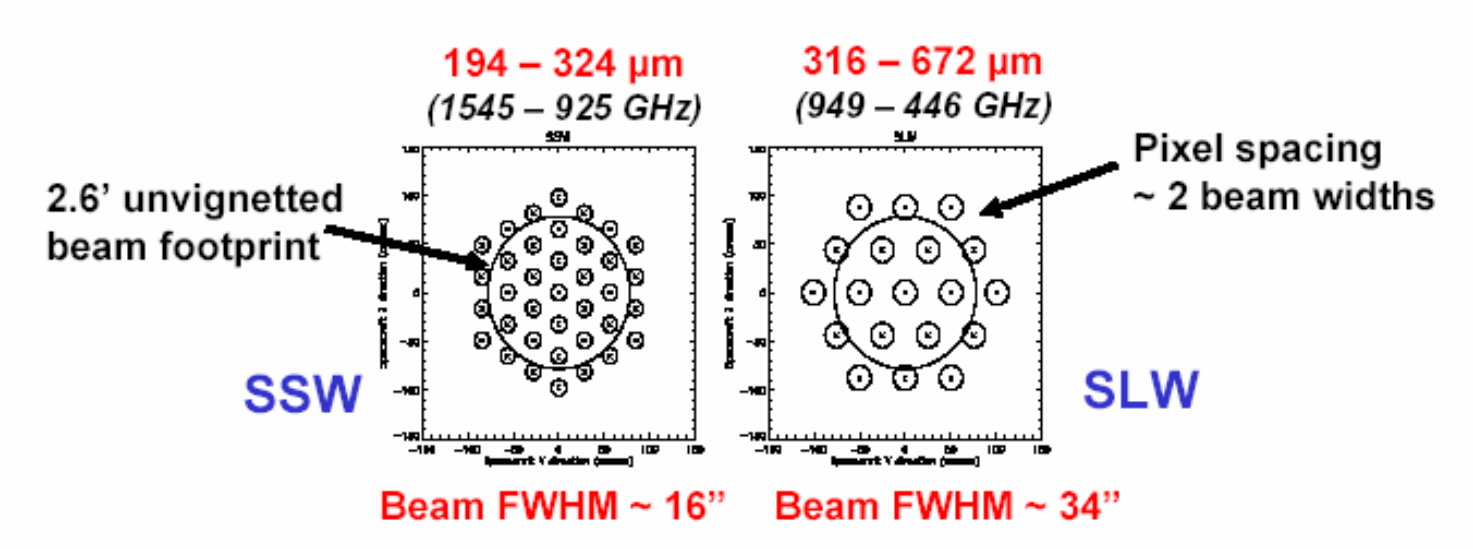
- **Suitable for large area shallow surveys (~ 20 mJy rms)**
- **SPIRE**
  - **Three bands; no loss of data**

- **PACS**
  - **Two bands**
  - **Enhanced data compression**
  - **Some beam smearing at high scan speed**

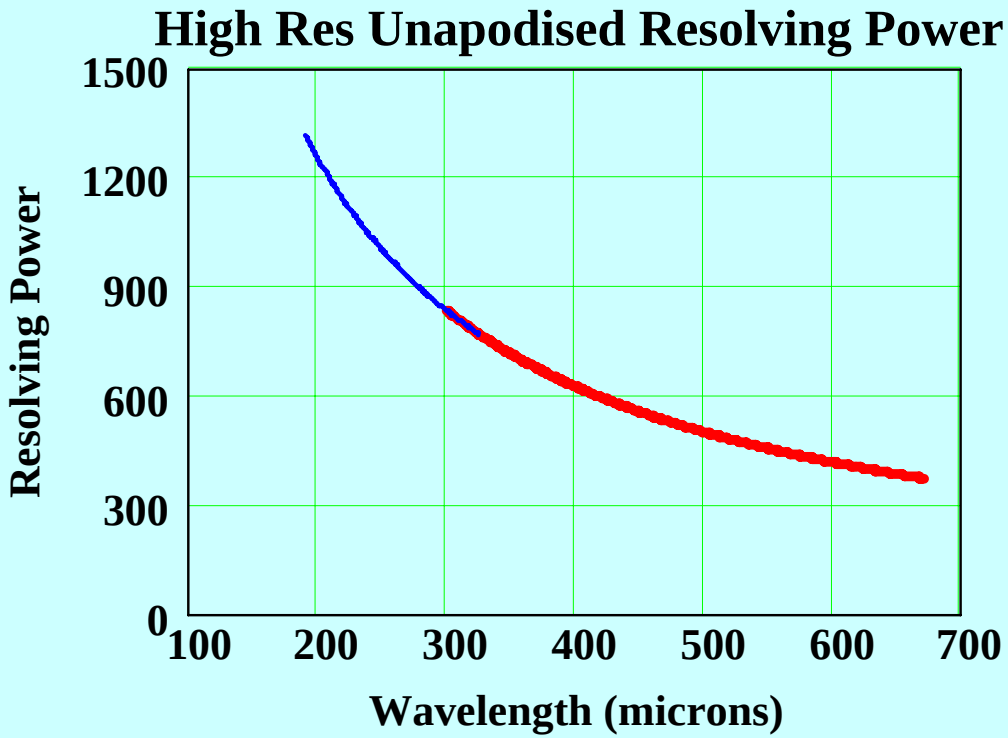


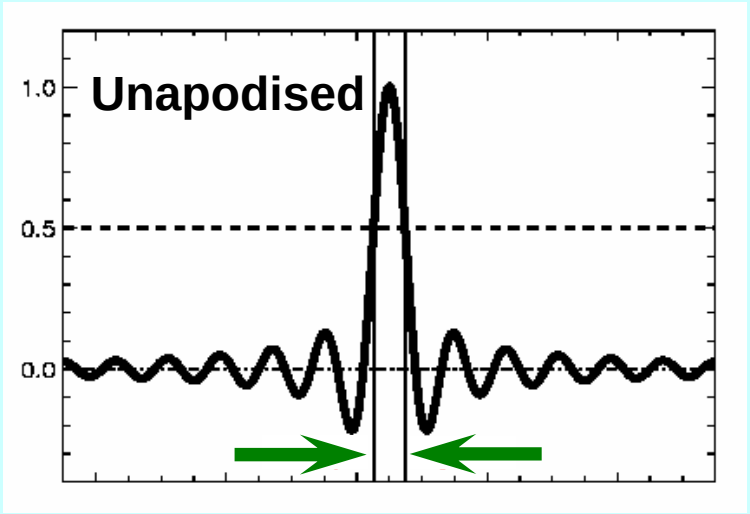
FTS Observing Modes

- $\Delta\sigma$ = 0.04 - 2 cm^{-1} by adjusting scan length
- **Continuous scan (nominal mode):**
  - Calibrator in 2nd port nulls telescope background
- **Point source or sparse map spectroscopy/spectrophotometry**
  - Also produces sparse map – background characterised by adjacent pixels
- **Imaging spectroscopy (full spatial sampling)**
  - Beam steering mirror adjusts pointing between scans to acquire fully-sampled spectral image

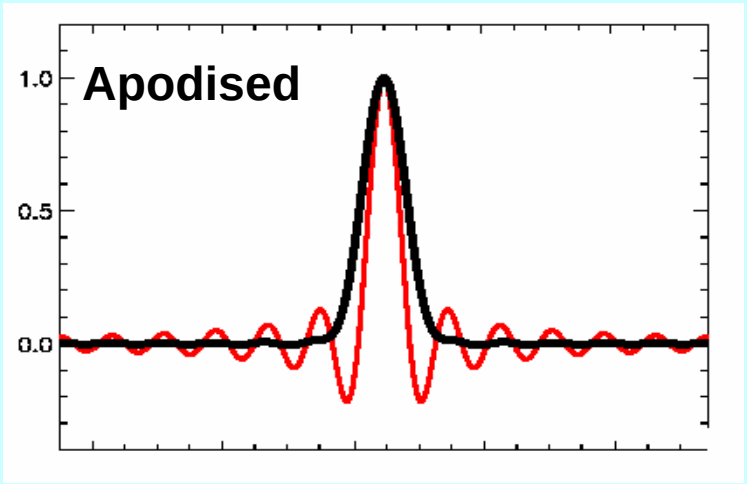


FTS Spectral Line Resolving Power ($\Delta\sigma$ = 0.04 cm^{-1})

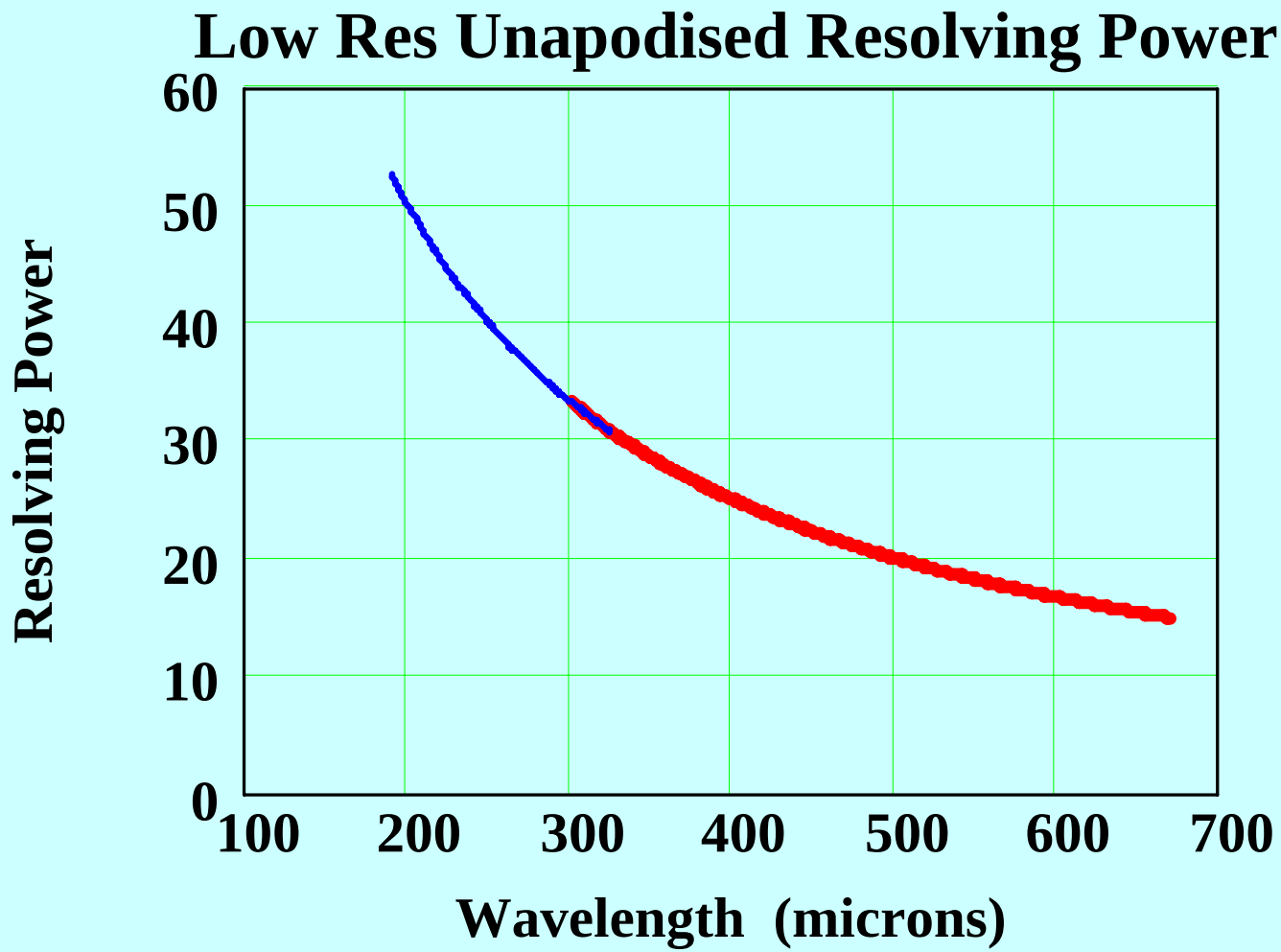




FWHM = 0.048 cm^{-1}
= 1.4 GHz



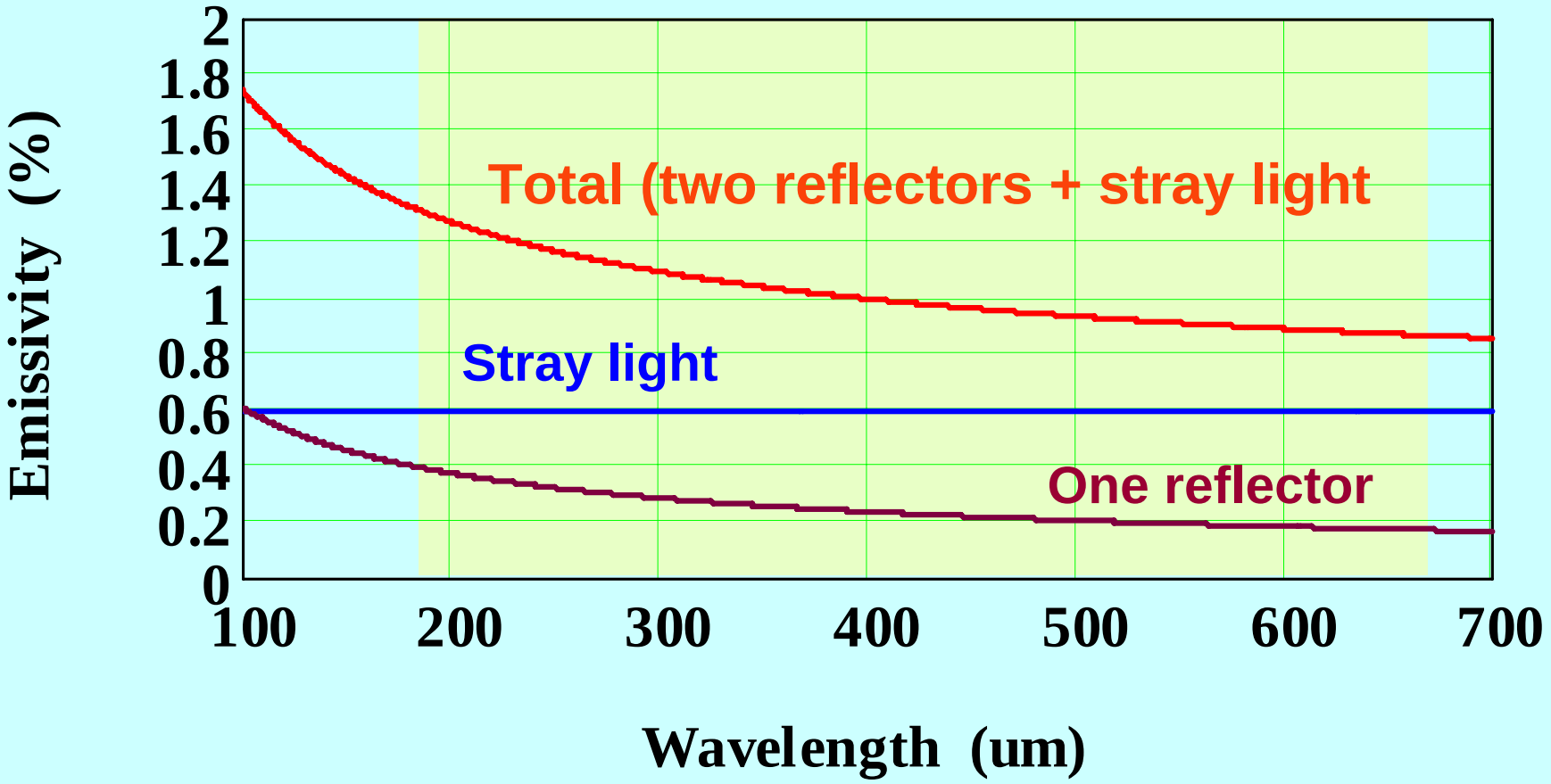
FTS Spectrophotometry Resolving Power ($\Delta\sigma$ = 1 cm^{-1})



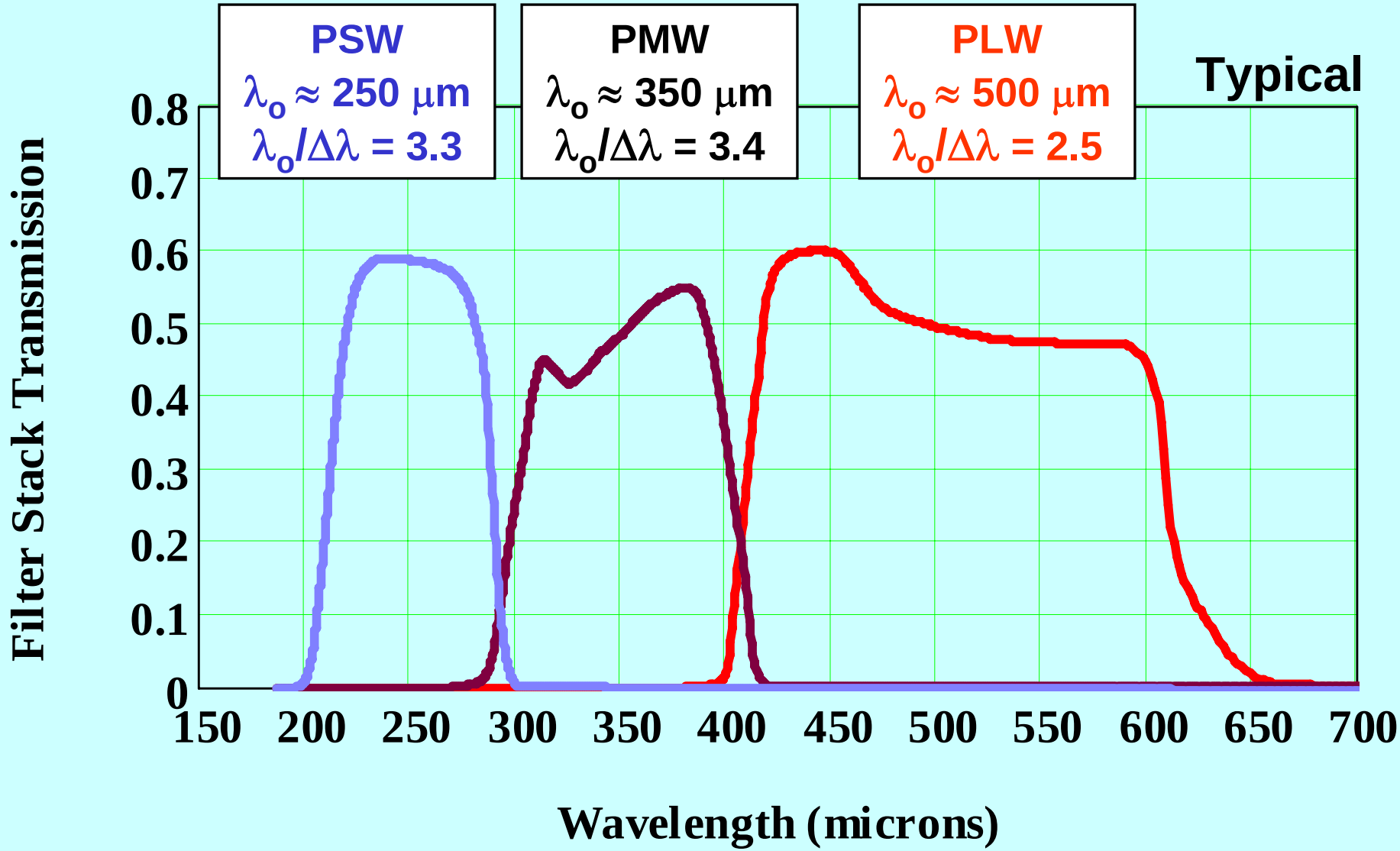
Instrument Performance Estimates

Telescope Emissivity and Stray Light Model

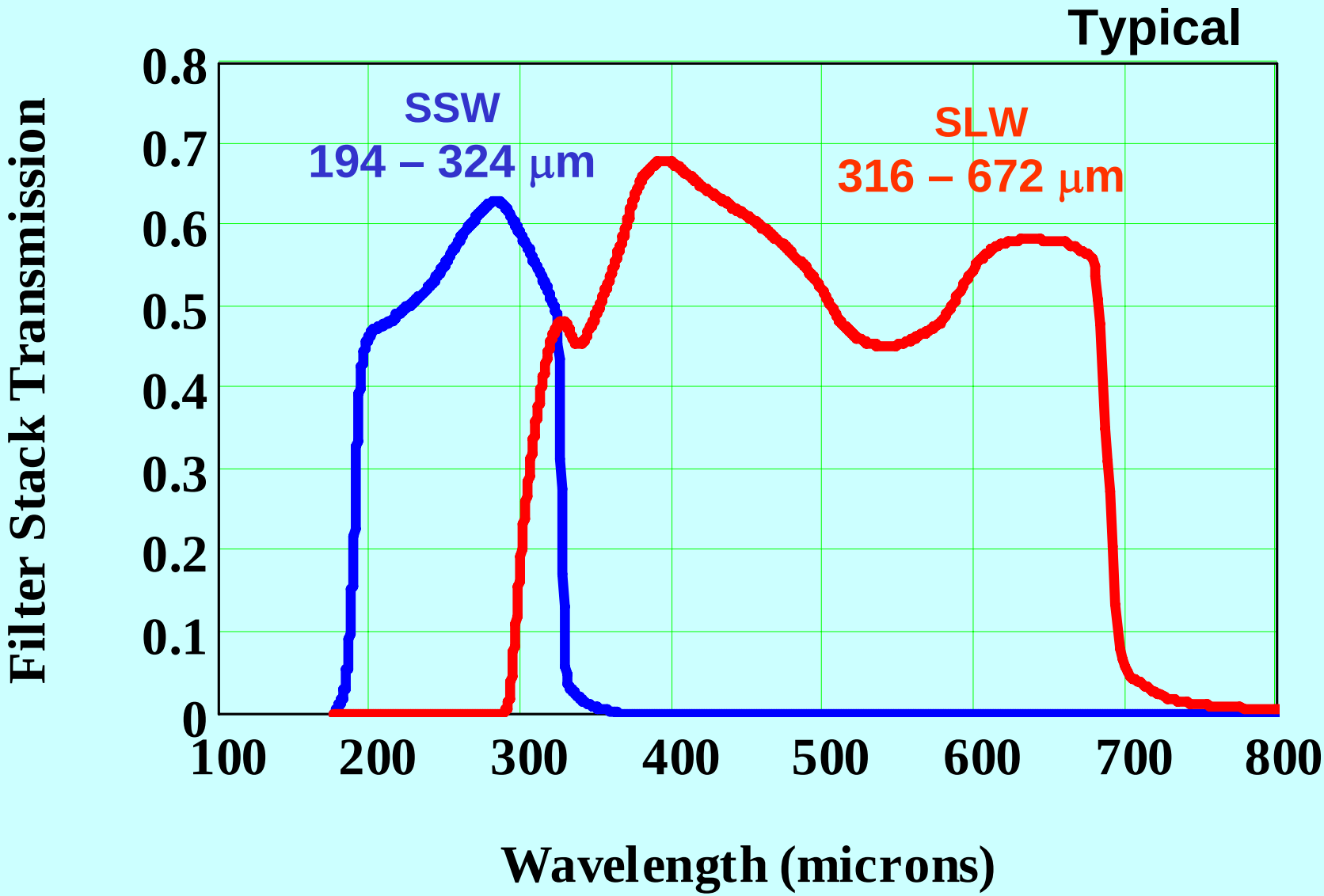
- Two reflectors
- Stray light component equivalent to10% of a 70-K; 3% emissive telescope



Photometer Filter Bands



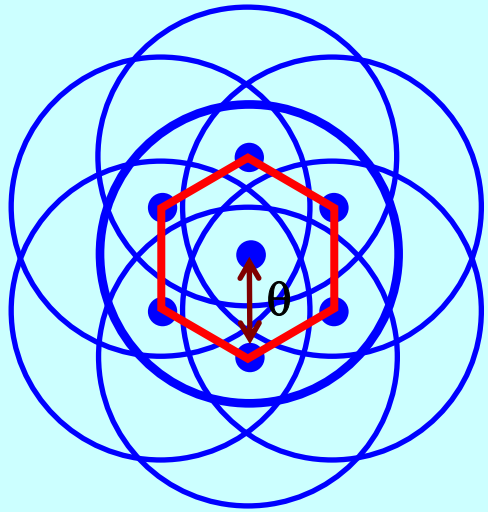
FTS Bands


Typical
SSW
194 – 324 μm
SLW
316 – 672 μm
Filter Stack Transmission
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
200
300
400
500
600
700
800
Wavelength (microns)

Photometer Sensitivity

Point Source 7-Point Observation

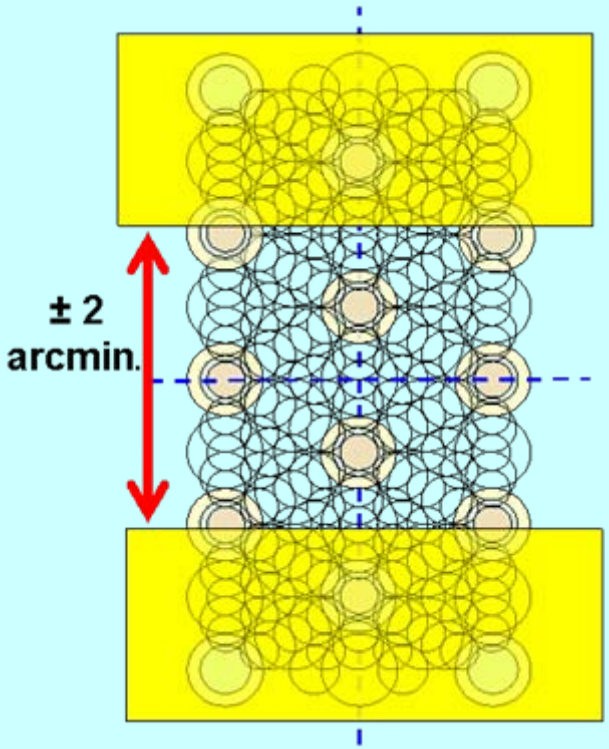
- **Typical observation**
  - **Nod sequence A-B-B-A with 64 s each on source = 256 s**
  - **8 BSM positions per nod position (centre observed twice) with 8 sec. each**
  - **Chop freq = 2 Hz → 16 chop cycles per position**
  - **Instrument overheads = 143 s**
  - **Slewing overhead = 180 s**
  - **Total time = 579 s (44% efficient)**
- **Predicted 1-σ sensitivities:**
  - **(1.4, 1.6, 1.3) mJy at (250, 350, 500) μm**
  - **Anticipated 1-σ extragalactic confusion level ~ 7 mJy**



Photometer Sensitivity

Small (4x4 arcmin) Jiggle Map

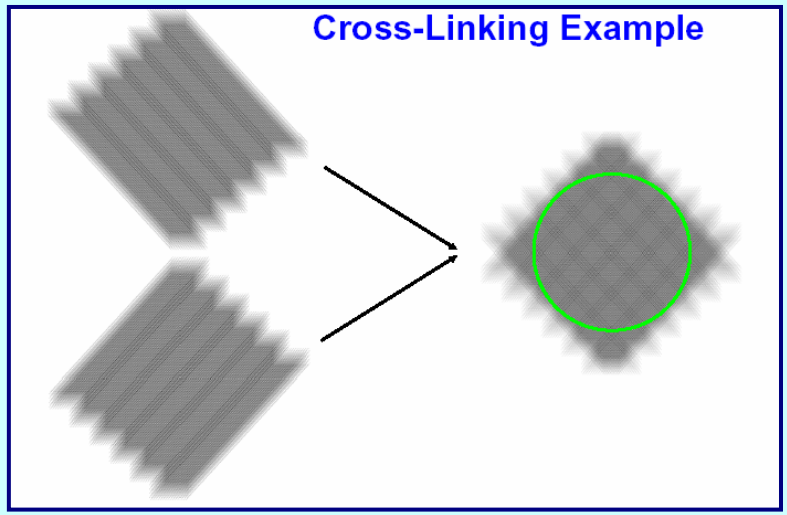
- Typical observation
  - 64-point jiggle map with 9” spacing
    - Over-sampled at 350, 500 μm
    - Half-beam sampling at 250 μm
  - Nod cycle A-B-B-A-A-B-B-A
  - 64 s per nod position
    → 512 s integration time
  - 16 BSM positions per A-B pair
    → 4 sec. per BSM position
    → 8 chop cycles per BSM position



- Instrument overheads = 433 s
- Slewing overhead = 180 s
- Total time = 1135 s (45% efficiency)
- Predicted 1-σ sensitivities:
  - (3.3, 4.5, 3.8) mJy at (250, 350, 500) μm
- Can do it quicker (687 s; 37% efficiency)
  - (4.7, 6.3, 5.3) mJy at (250, 350, 500) μm

Photometer Sensitivity

Large Scan Map

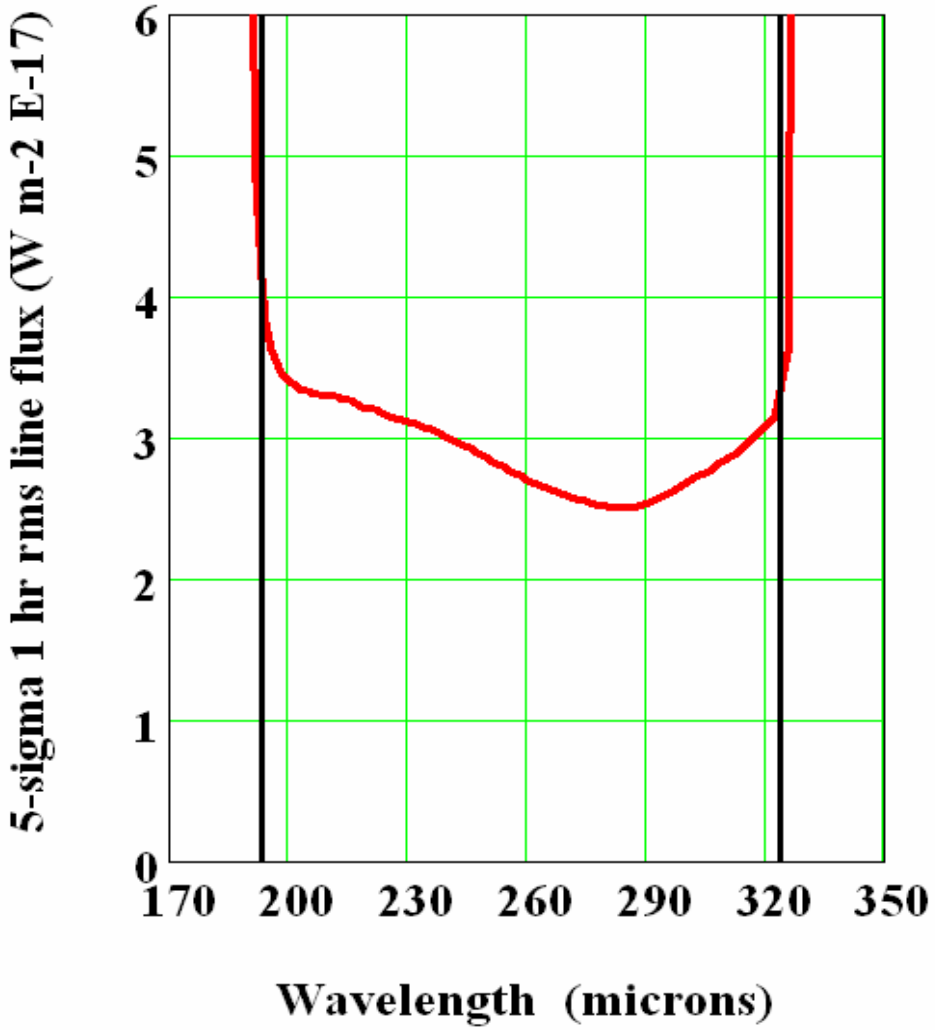


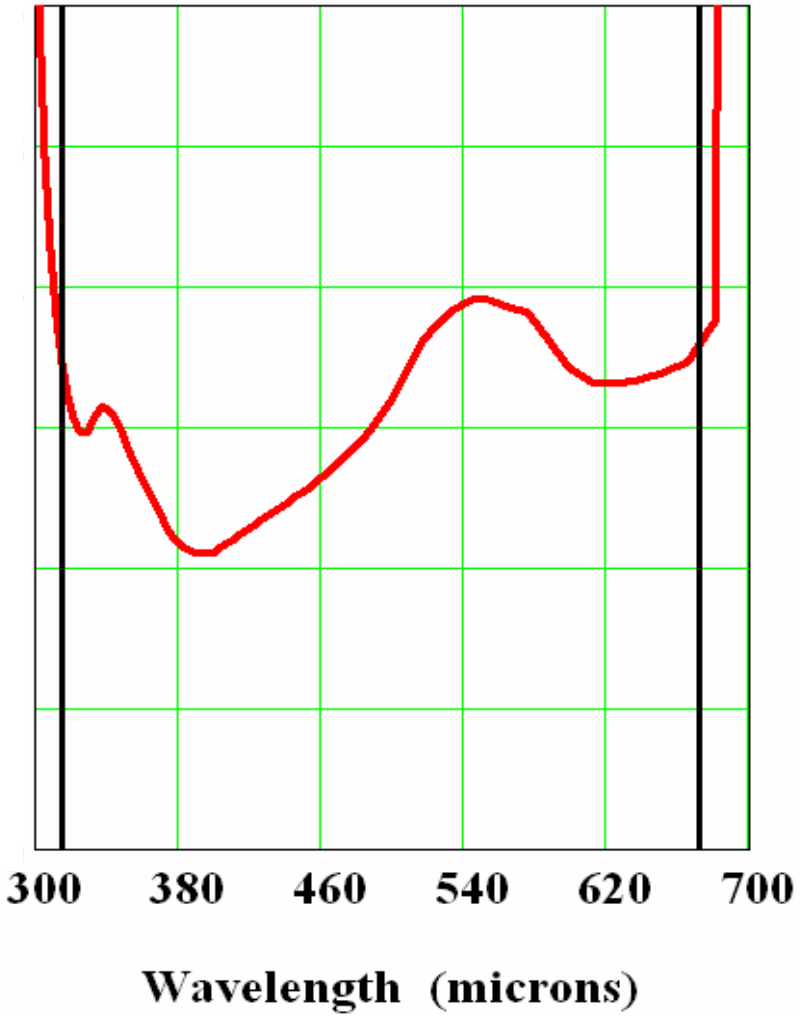
- Typical observation
  - 30”/s scan speed
  - 30 x 30 arcmin
  - Cross-linked with 1 repeat
- 944 s on-source
- Instrument overheads = 651 s
- Slewing overhead = 180 s
- Total time = 1775 s (53% efficiency)
- Predicted 1-σ sensitivities:
  - (10, 13, 11) mJy at (250, 350, 500) μm
- Larger maps are more efficient

FTS Sensitivity

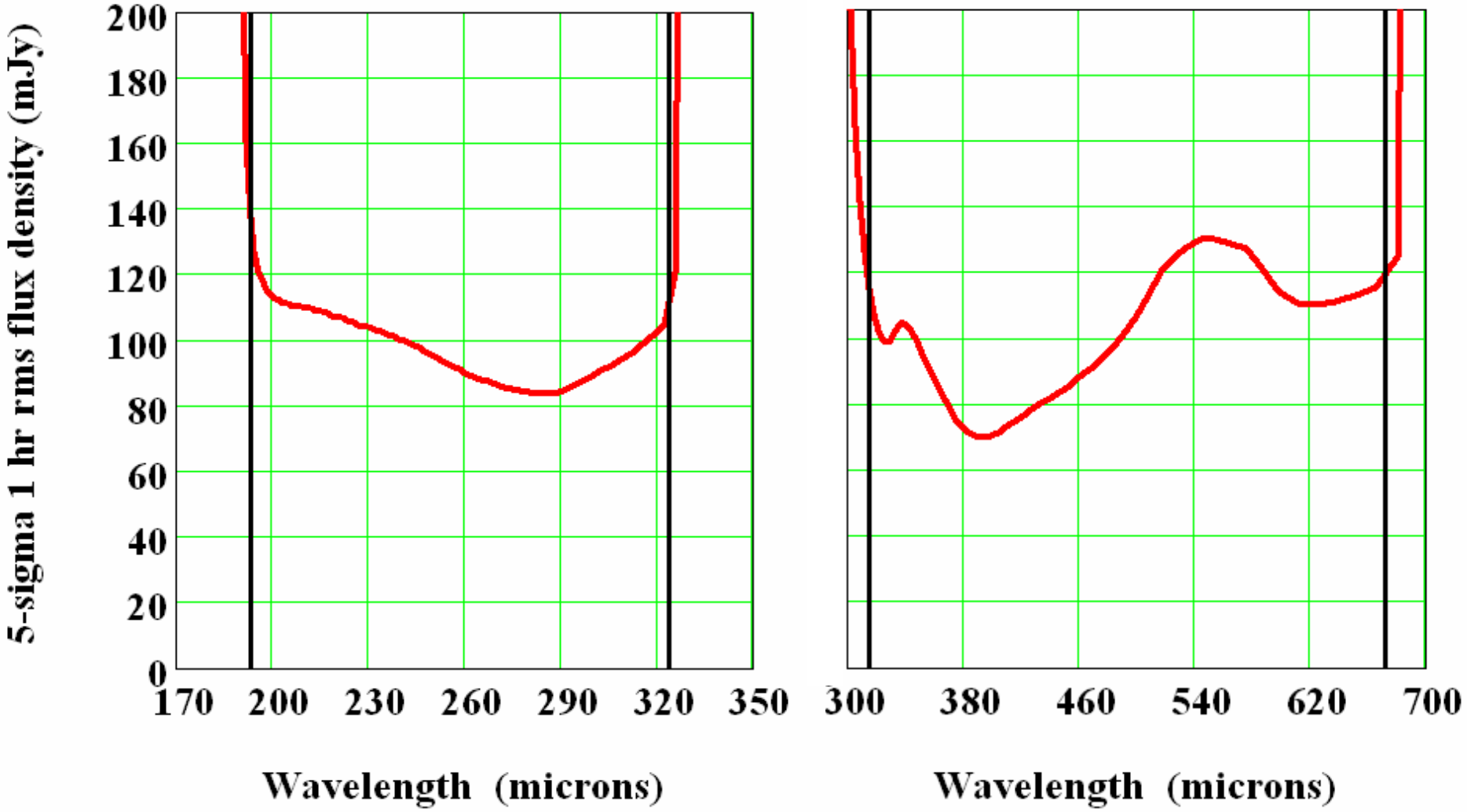
Point Source; Line Spectroscopy ($\Delta\sigma$ = 0.04 cm^{-1})

($W\ m^{-2} \times 10^{-17}$ 5-σ 1 hr)





FTS Sensitivity
Point source; Spectrophotometery
($\Delta\sigma$ = 1 cm^{-1}: mJy 5-σ 1 hr)



Current Status

- System-level testing of Herschel is in progress
- Spacecraft mechanical qualification tests done
- First operation in Herschel at 0.3 K in July
  - Verification of performance
- Some technical concerns to be evaluated:
  - Detector temperatures
  - Microphonic and EMI susceptibility
  - SMEC friction and microvibration sensitivity
- Planning for operations in progress