SPIRE

Instrument Design
Performance Estimates
GT Programme Overview

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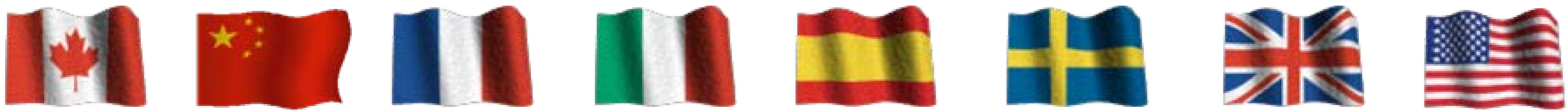
and the SPIRE Consortium

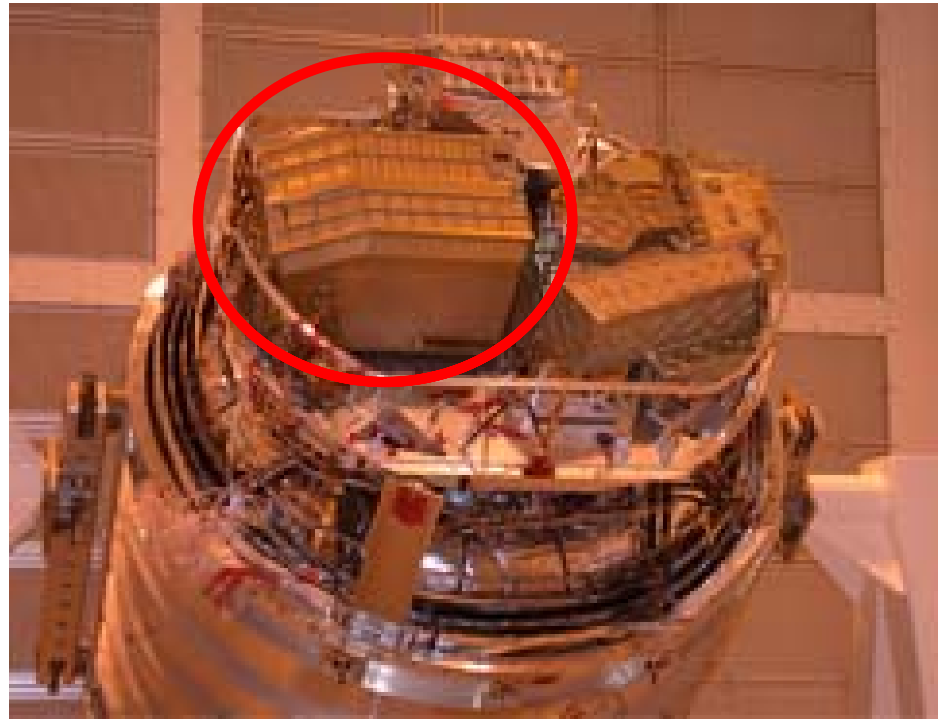
The SPIRE Consortium

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
- National Astronomical Observatories, Beijing, China
- Observatoire de Paris, Meudon, Paris
- Rutherford Appleton Laboratory, Oxfordshire, UK
- Stockholm Observatory, Sweden
- UK Astronomy Technology Centre, Edinburgh
- University of Lethbridge, Canada
- Università di Padova, Italy

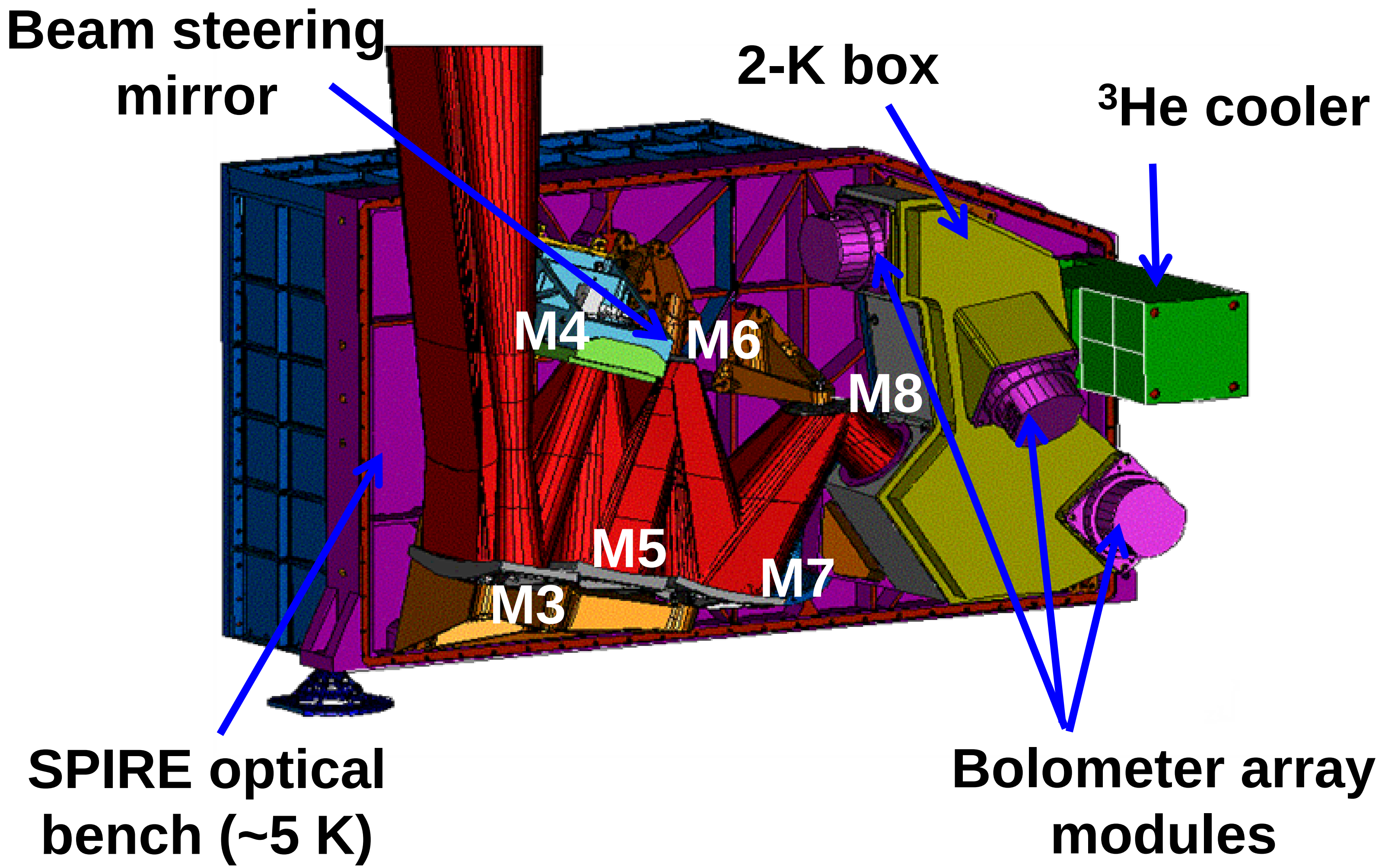
Spectral and Photometric Imaging Receiver



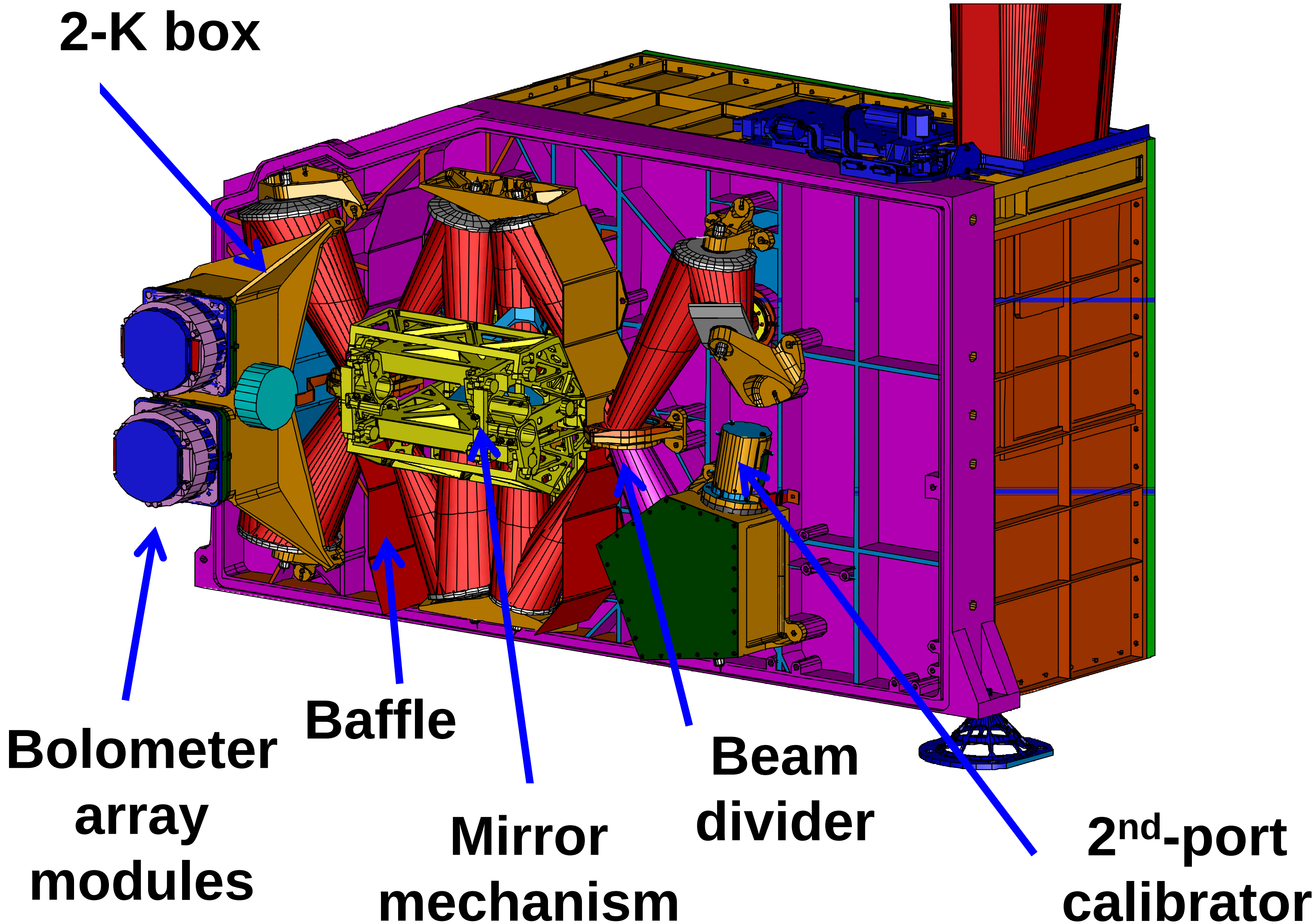
- **3-band imaging photometer**
  - 250, 350, 500 μm (simultaneous)
  - λ/Δλ ~ 3
  - 4 x 8 arcminute field of view
  - Diffraction limited beams (18, 25, 36”)

- **Imaging Fourier Transform Spectrometer**
  - 194 - 672 μm (complete range covered simultaneously)
  - 2.6 arcminute field of view
  - Two overlapping bands: 194 – 324 μm and 316 – 672 μm
  - Beam FWHM: ≈ 16” ≈ 35”
  - $\Delta\sigma$ = 0.04 cm^{-1} (λ/Δλ ~ 20 - 1000 at 250 μm)

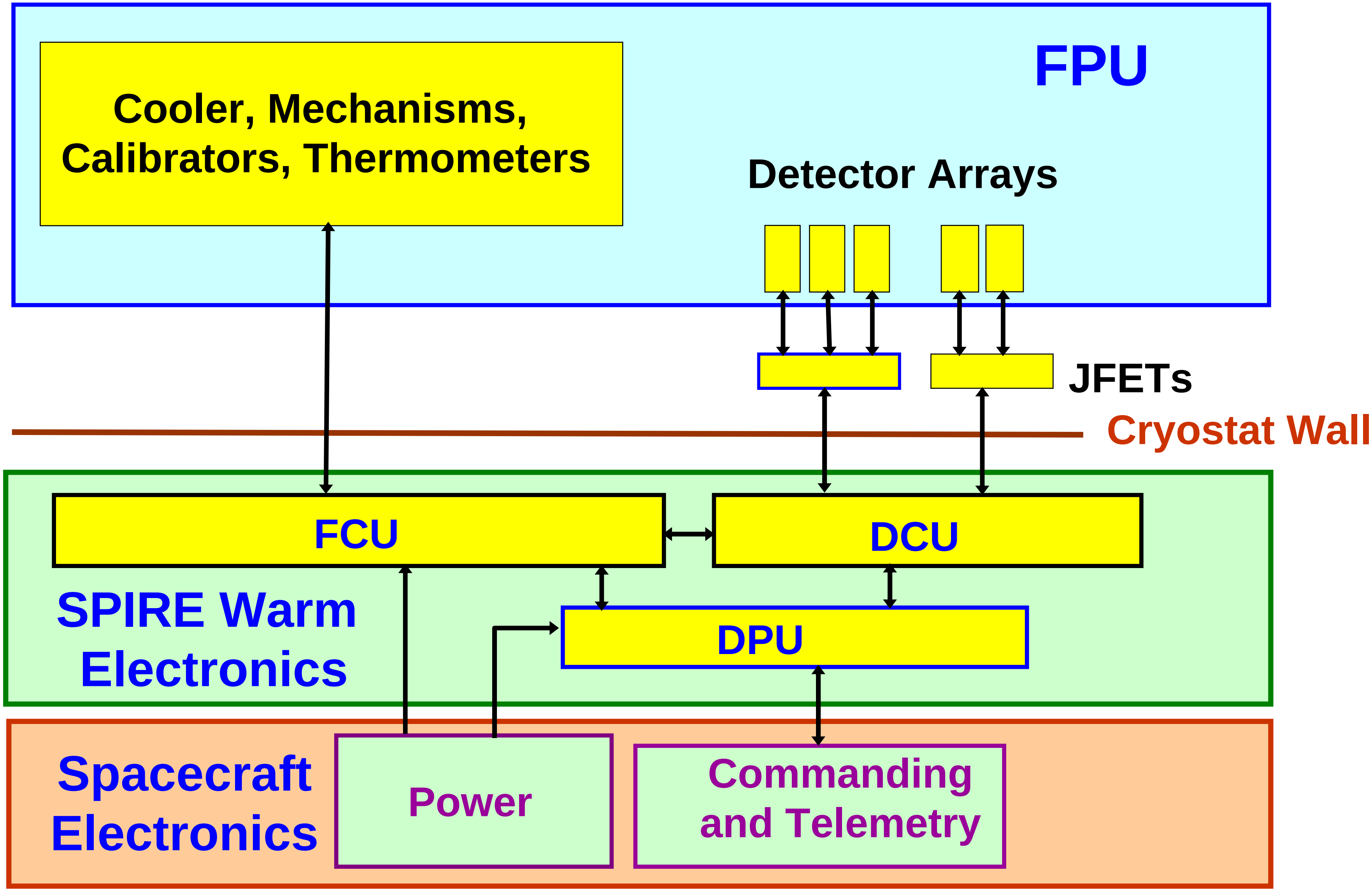
Photometer Layout and Optics



FTS Layout and Optics



SPIRE Block Diagram



^{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**

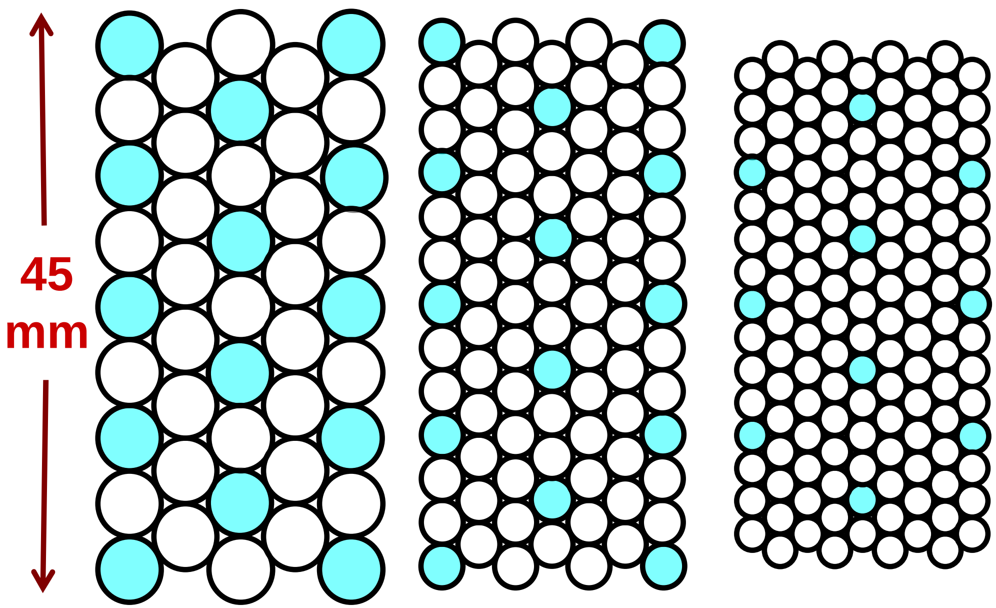
SPIRE Detector Arrays: $2F\lambda$ Feedhorns

Photometer

520 μm 43 detectors

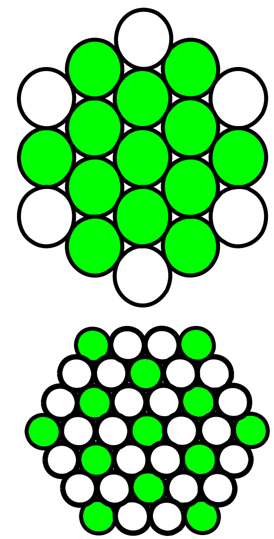
360 μm 88 detectors

250 μm 139 detectors



Spectrometer

315-670 μm 19 detectors

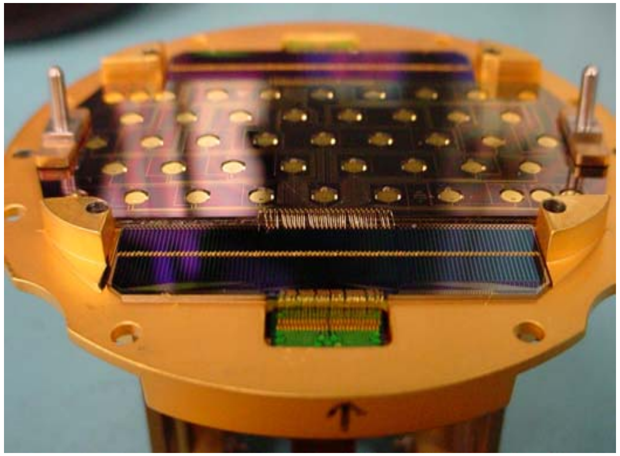


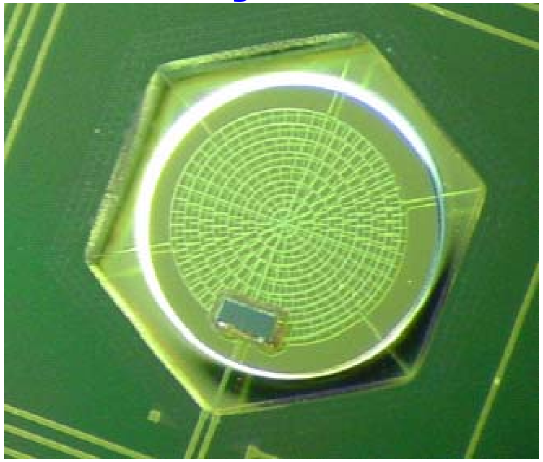
200-325 μm 37 detectors

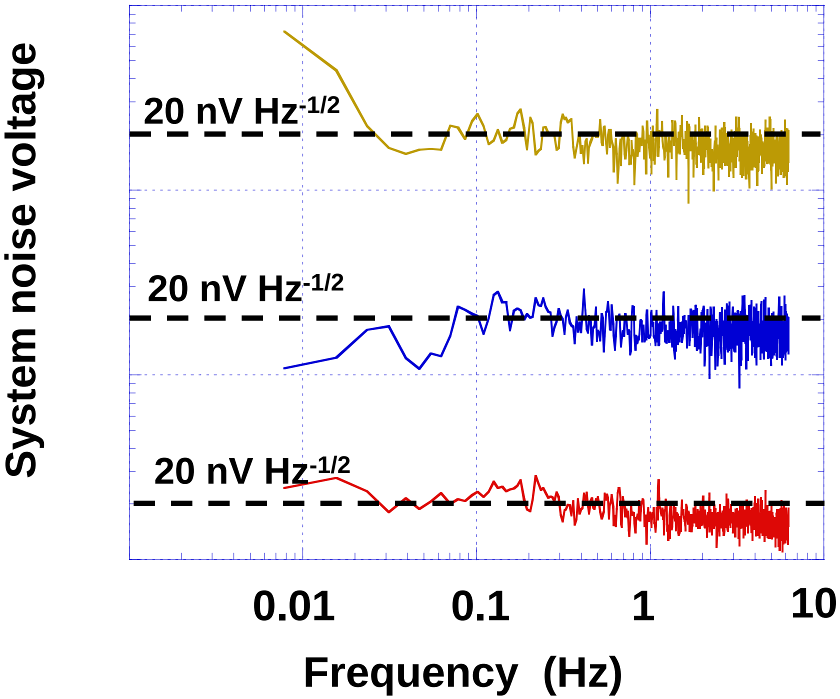
⇒ Coincident beam centres

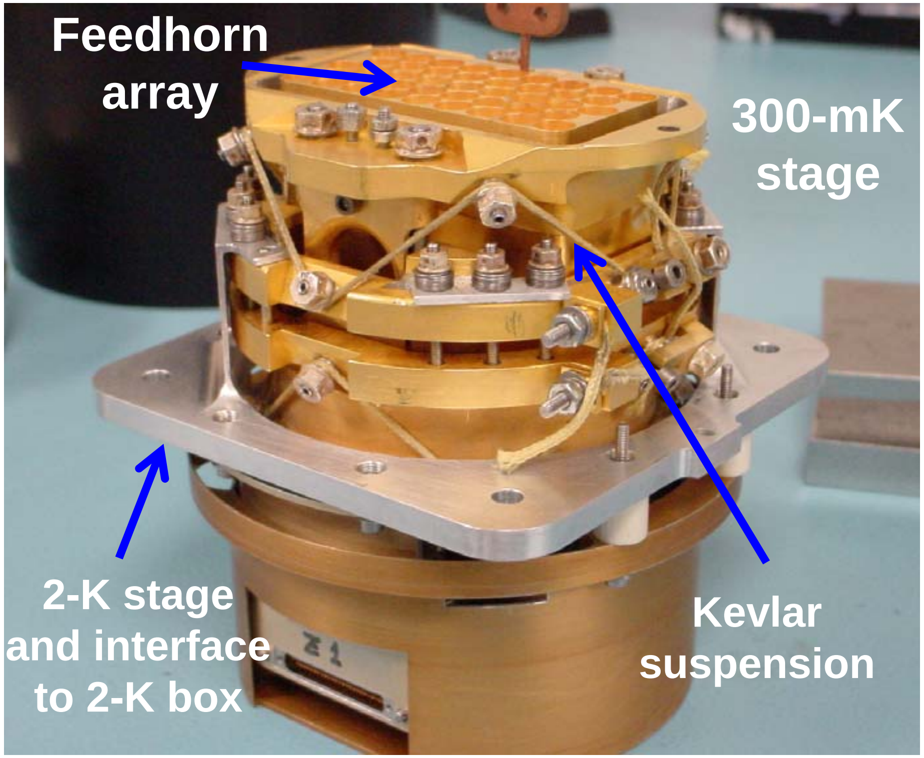
300-mK Germanium Bolometer Arrays

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





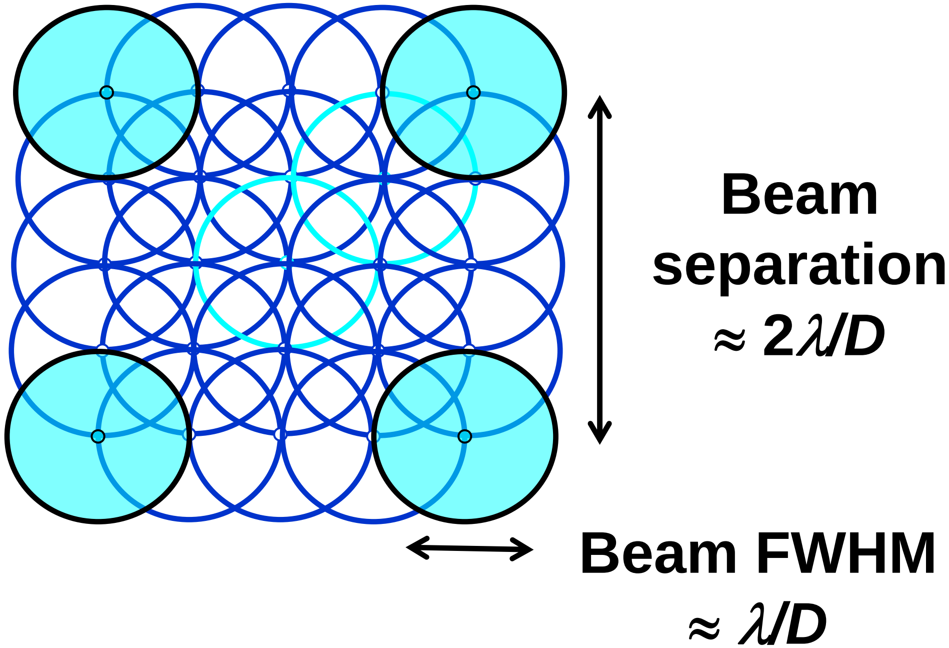


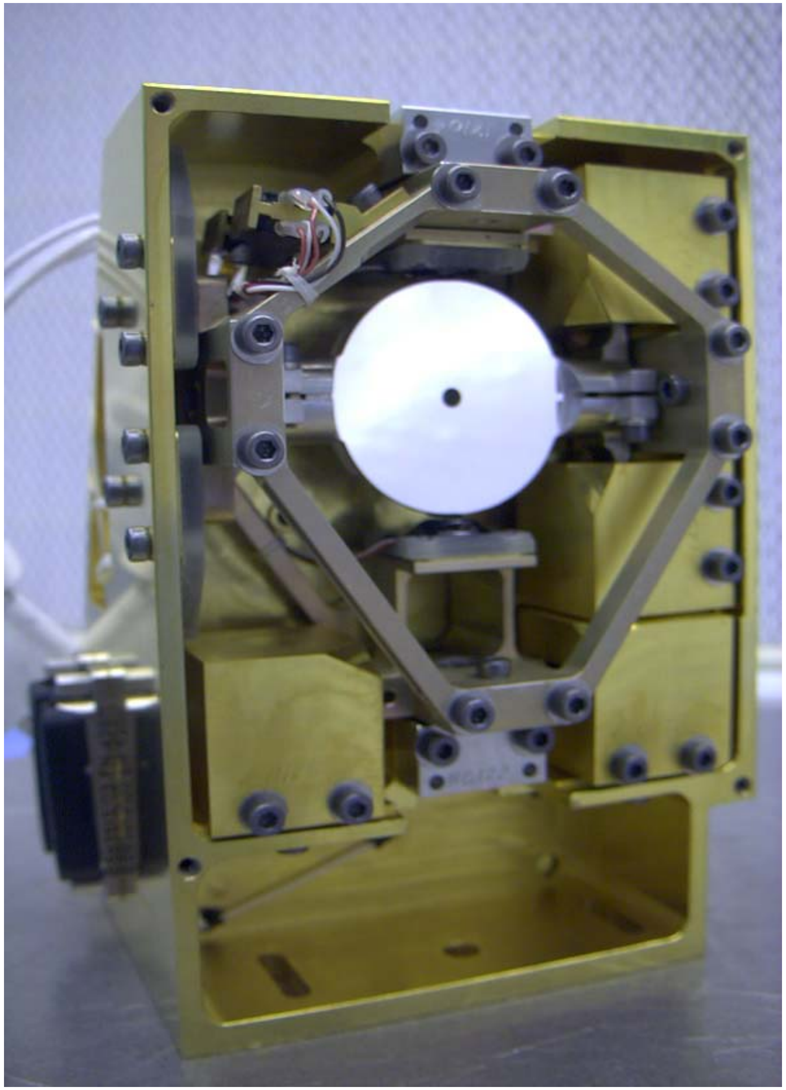


Beam Steering Mechanism

- Chop ± 130 arcsec.
- Jiggle ± 30 arcsec.

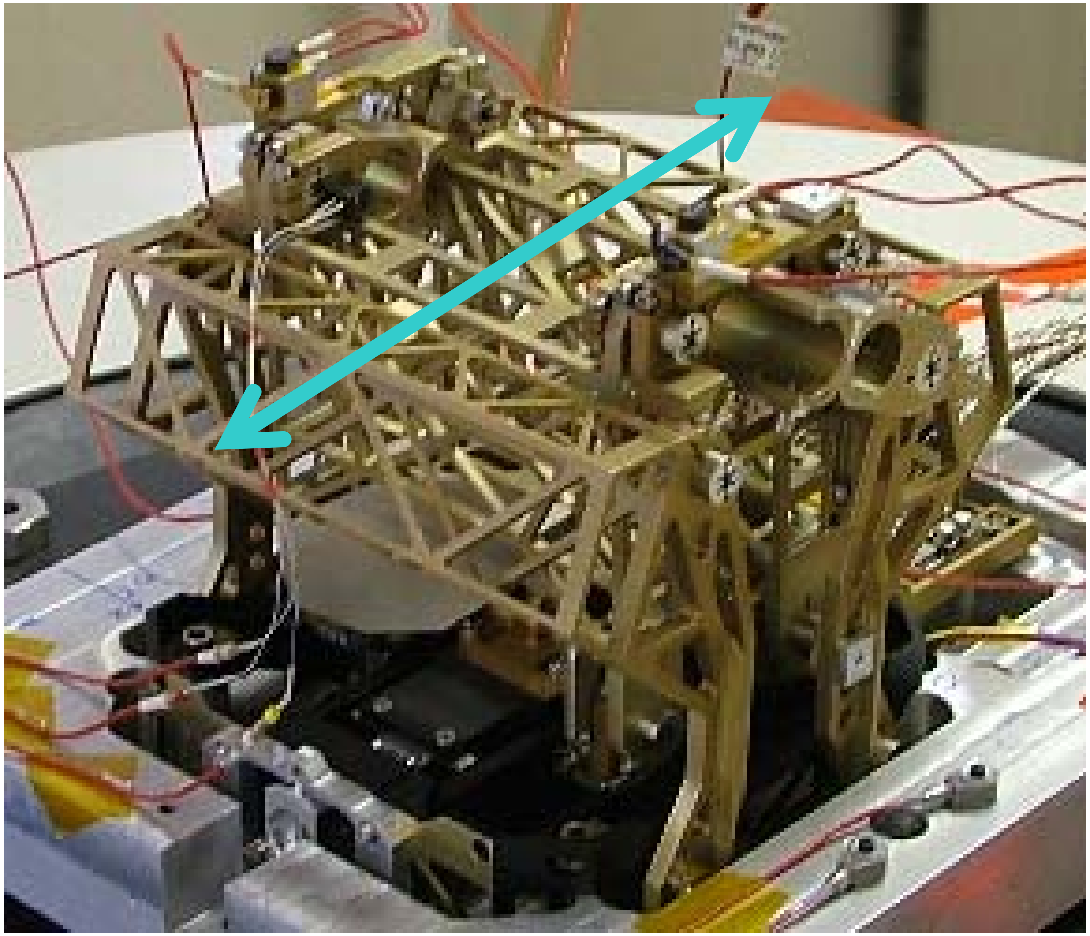
FWHM beams on the sky don't overlap





FTS Scan Mechanism

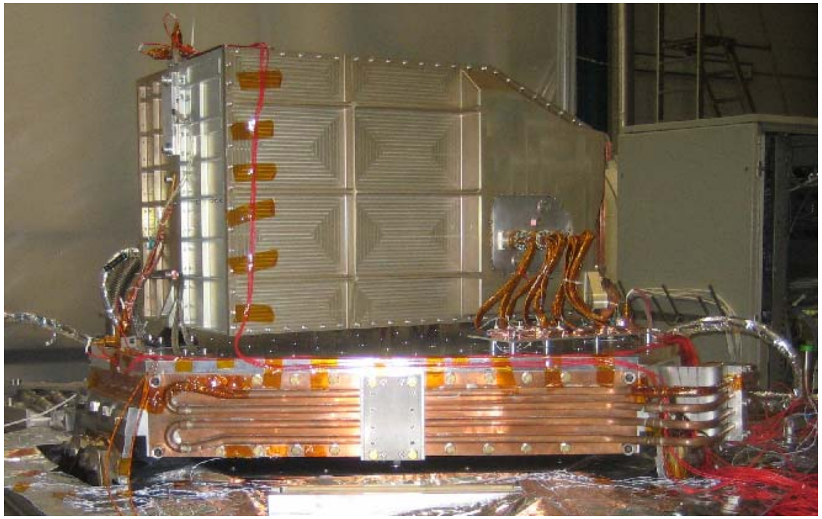
- Double parallelogram carriage with toothless gear
- Position measurement accuracy ~ 0.1 μm
- Nominal mode: continuous scan
- Scan speed: 0.5 mm s^{-1}
  - Signal frequency range 3 - 10 Hz
- 3.8-cm travel

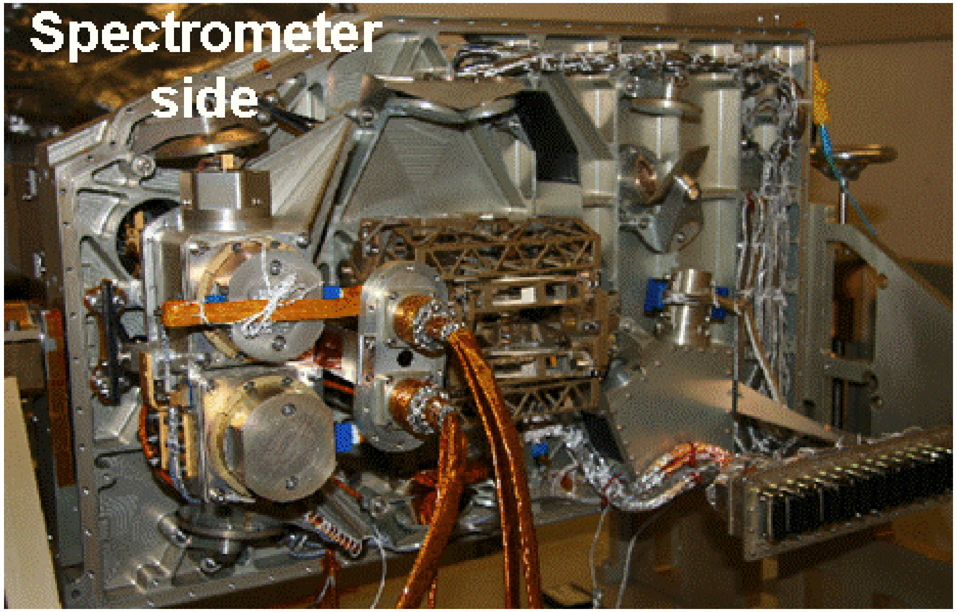


SPIRE Current Status

- Flight instrument undergoing 5th and final cold test campaign at Rutherford Appleton Laboratory, UK

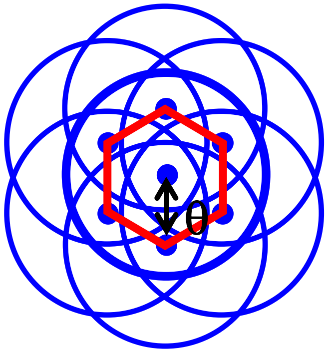
- Delivery planned for end March 2007

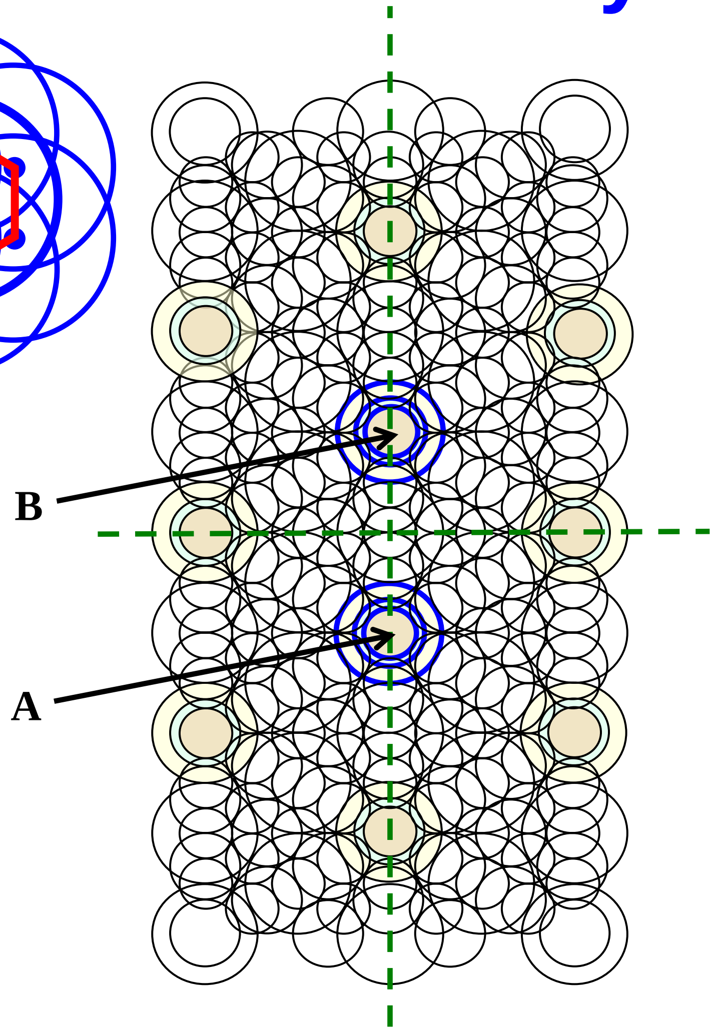




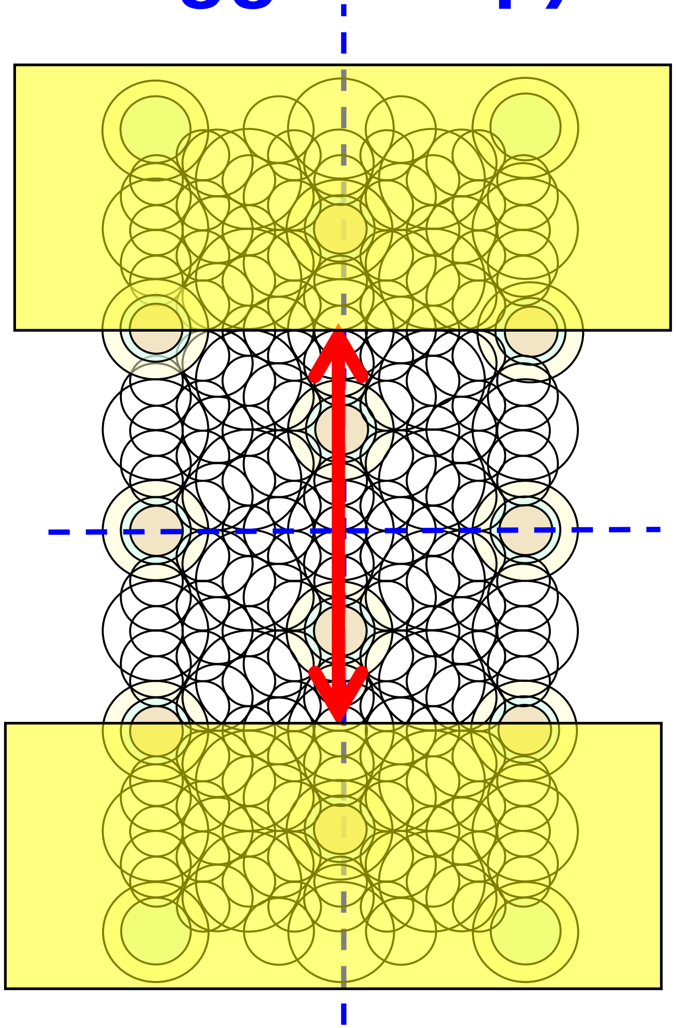
Observing Modes

Seven-Point Photometry



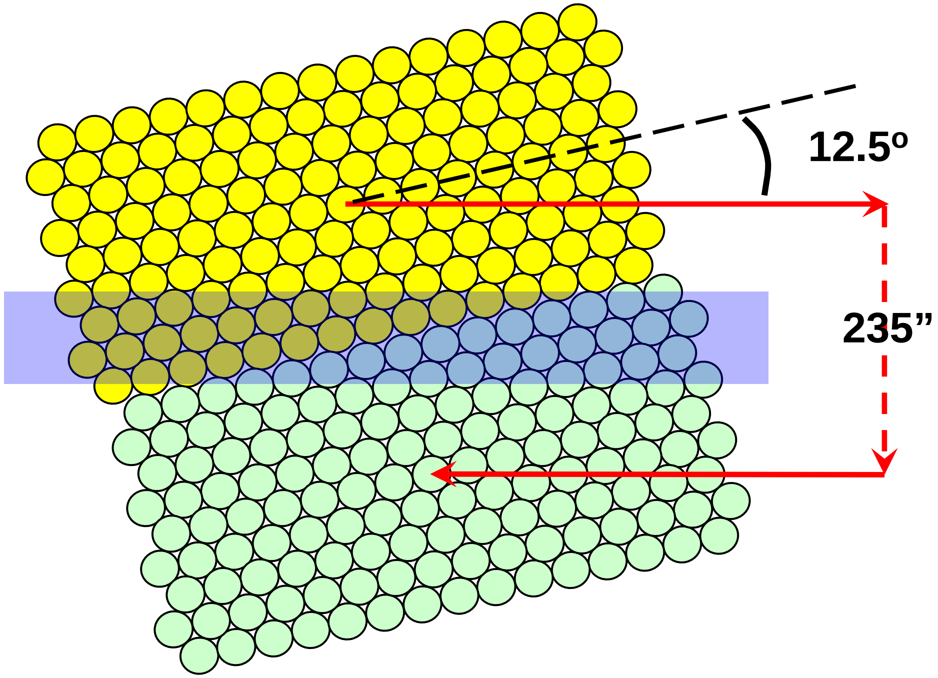


Field (64-Point Jiggle Map)



Scan Map

- **Most efficient mode for large-area surveys**



- **Scan parameters optimised for**
  - **full spatial sampling**
  - **uniform distribution of integration time**
  - **cross-linking for 1/*f* noise removal**

FTS Observing Modes

- $\Delta\sigma$ = 0.04 - 1 cm^{-1} by adjusting scan length

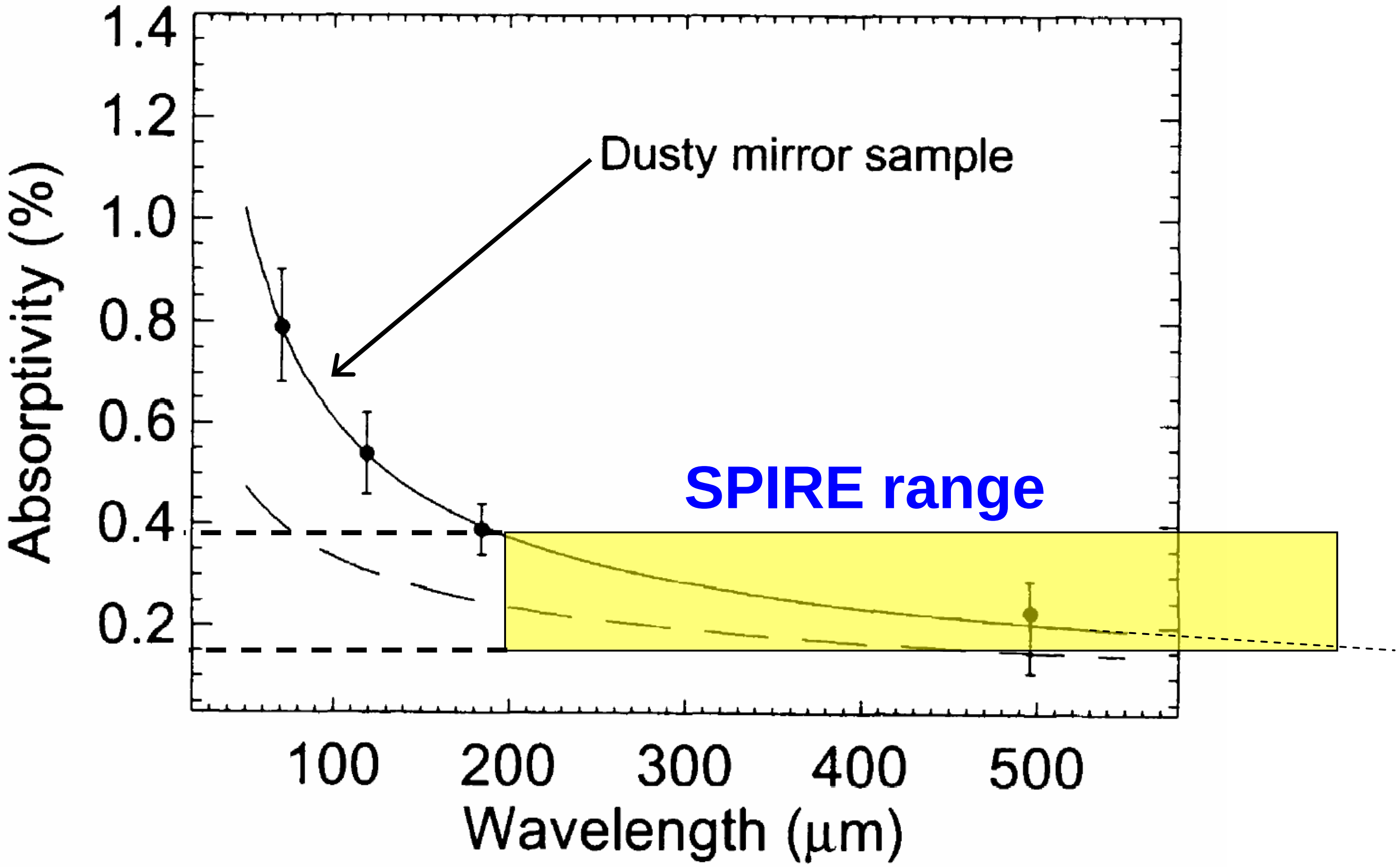
- Point source/sparse map spectroscopy or spectrophotometry
  - Telescope pointing fixed
  - Produces 2.6- arcmin sparse map – background characterised by adjacent pixels

- Imaging spectroscopy
  - Beam steering mirror adjusts pointing between scans to acquire fully-sampled spectral image

Instrument Performance

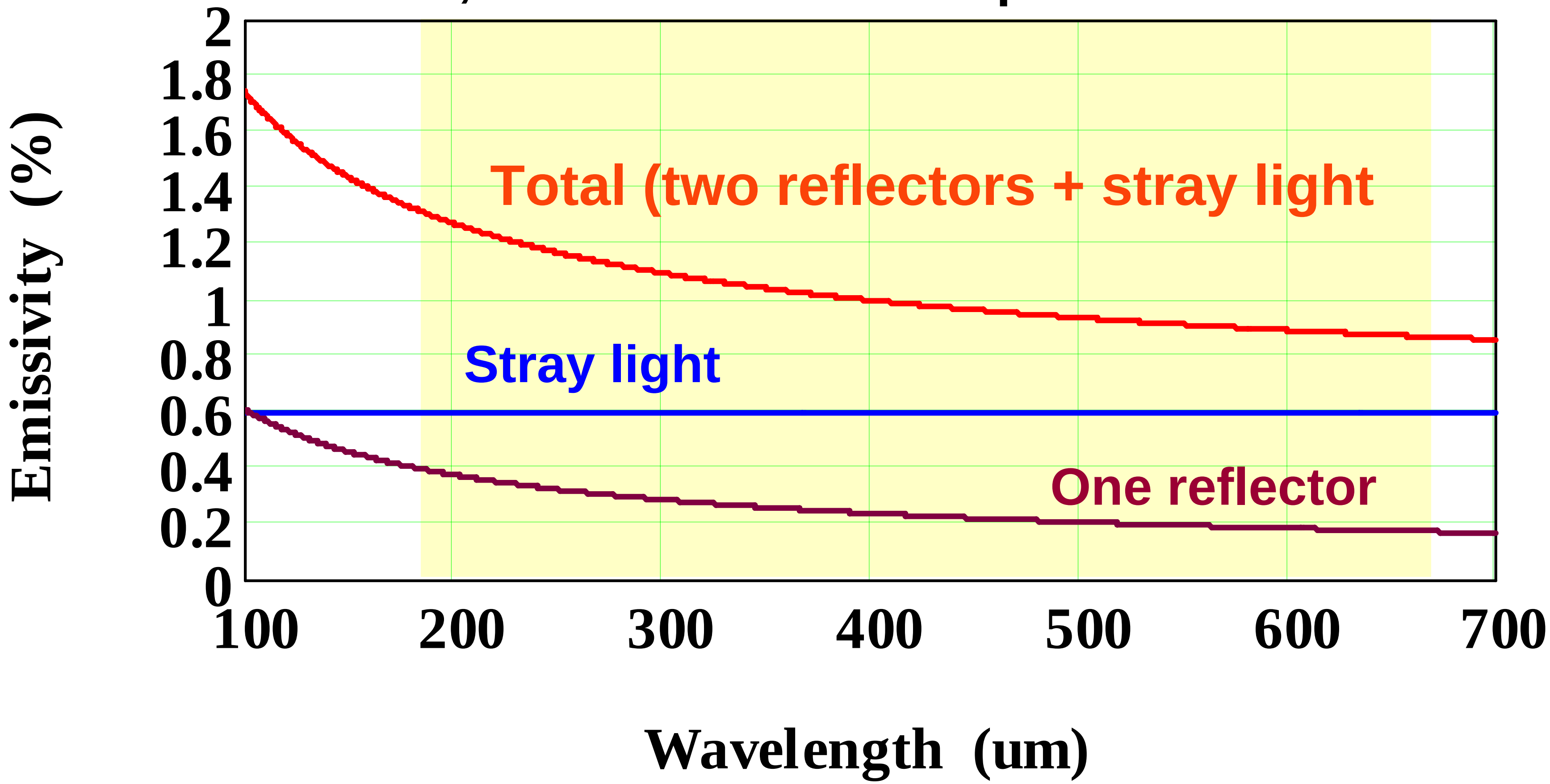
Herschel Reflector Emissivity

(Fischer et al., Applied Optics, 43, 3765, 2004)

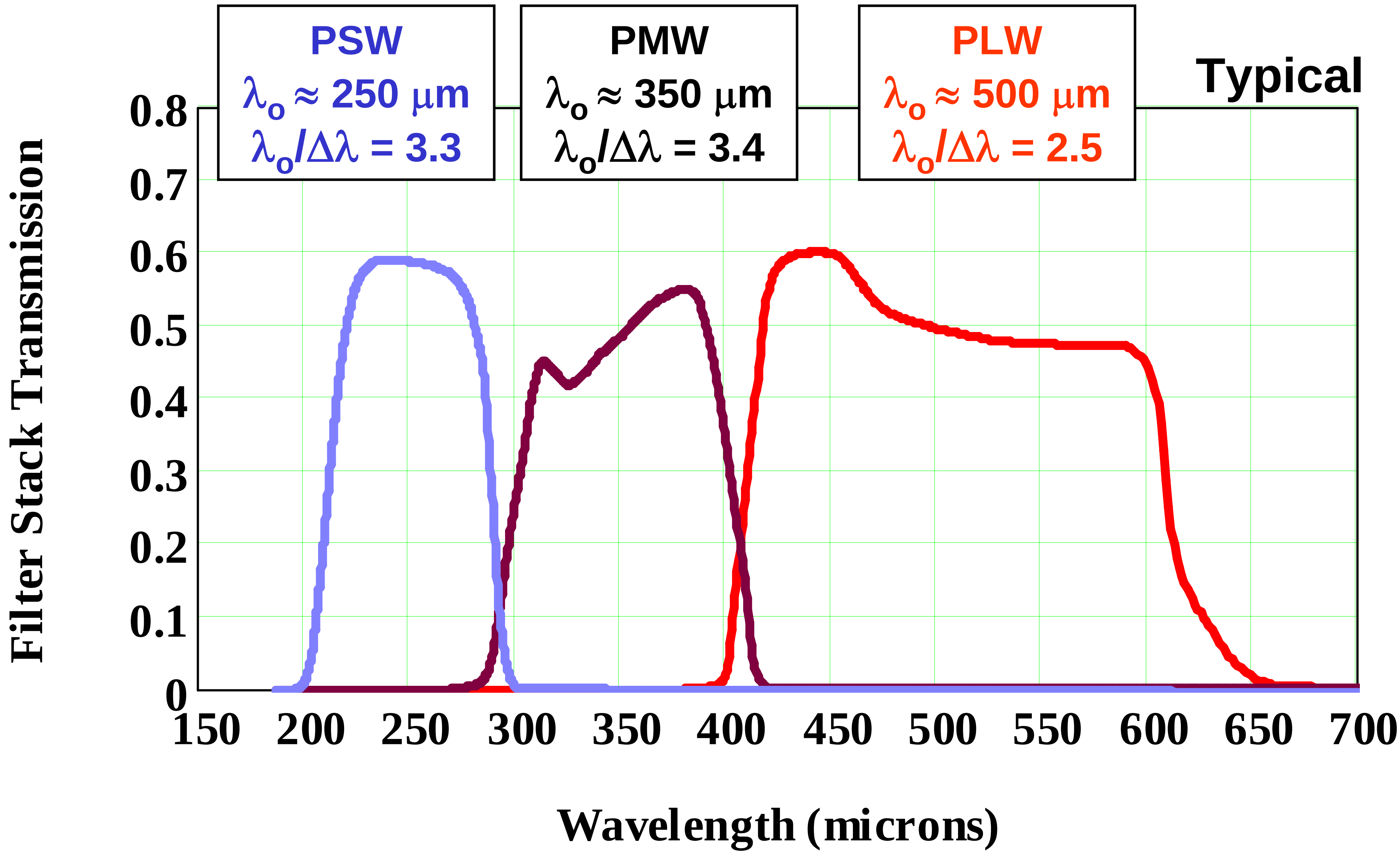


Telescope Emissivity and Stray Light Model

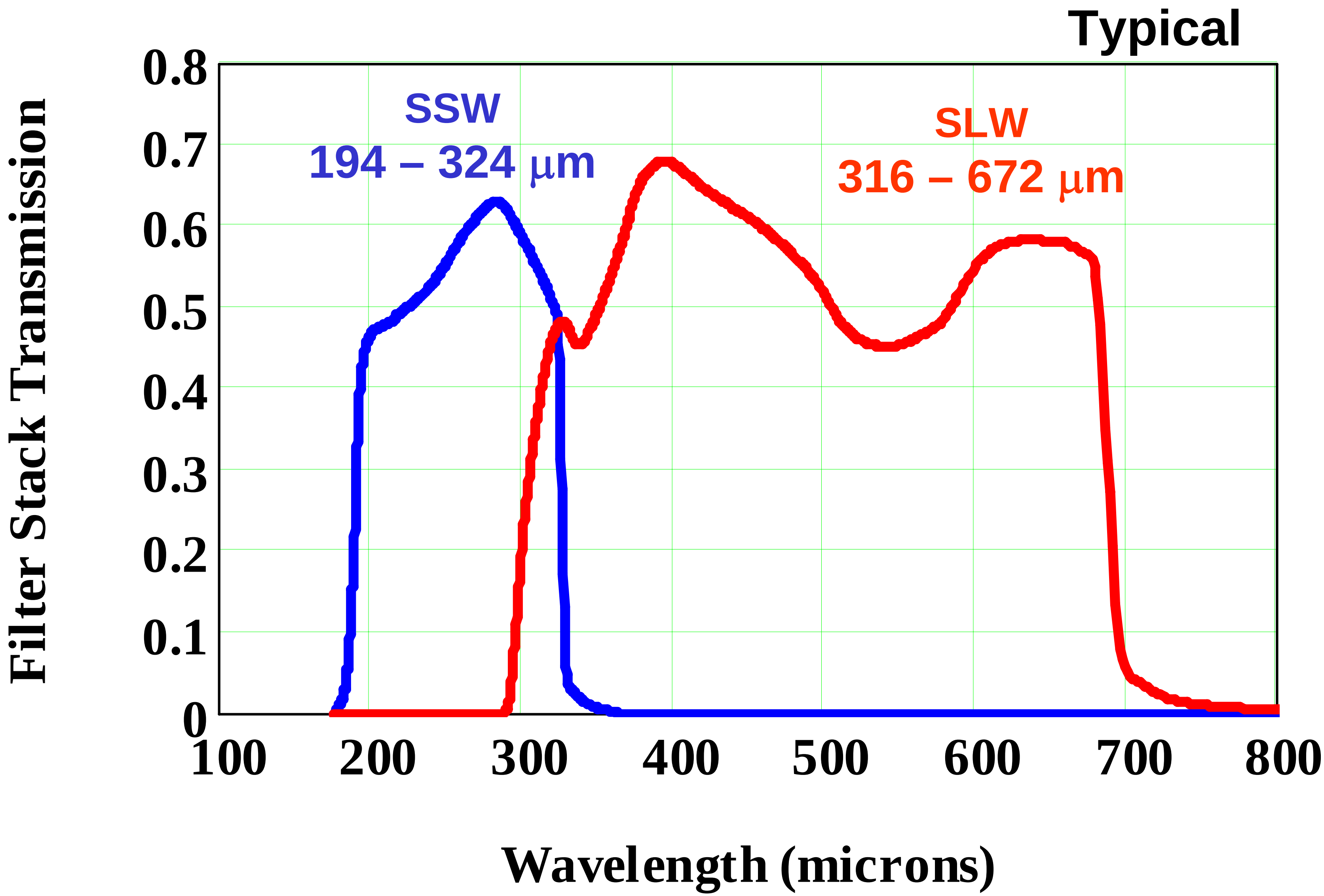
- Two reflectors with Fischer et al. emissivity
- Stray light component equivalent to10% of a 70-K; 3% emissive telescope



Photometer Filter Bands



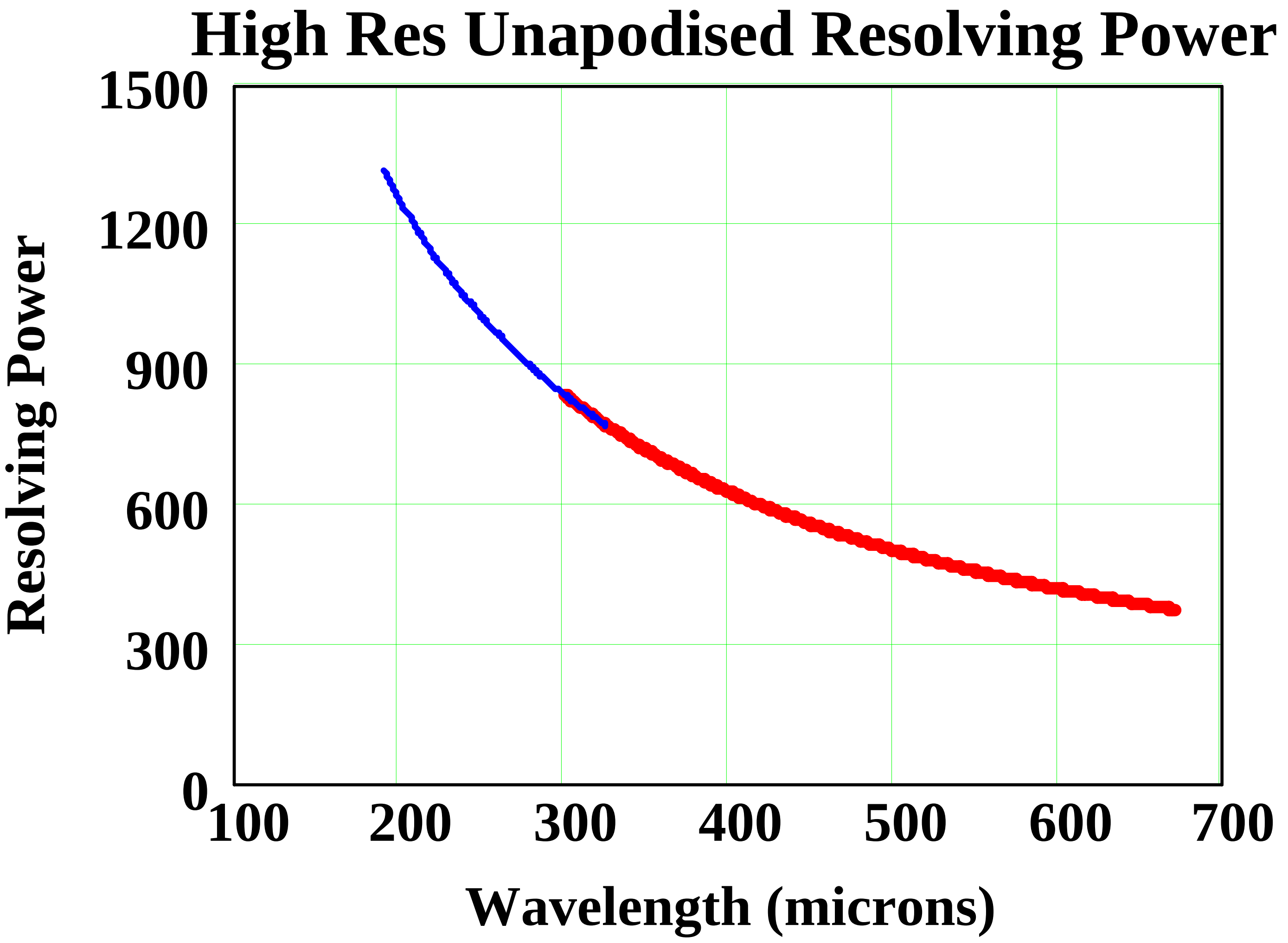
FTS Bands


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)

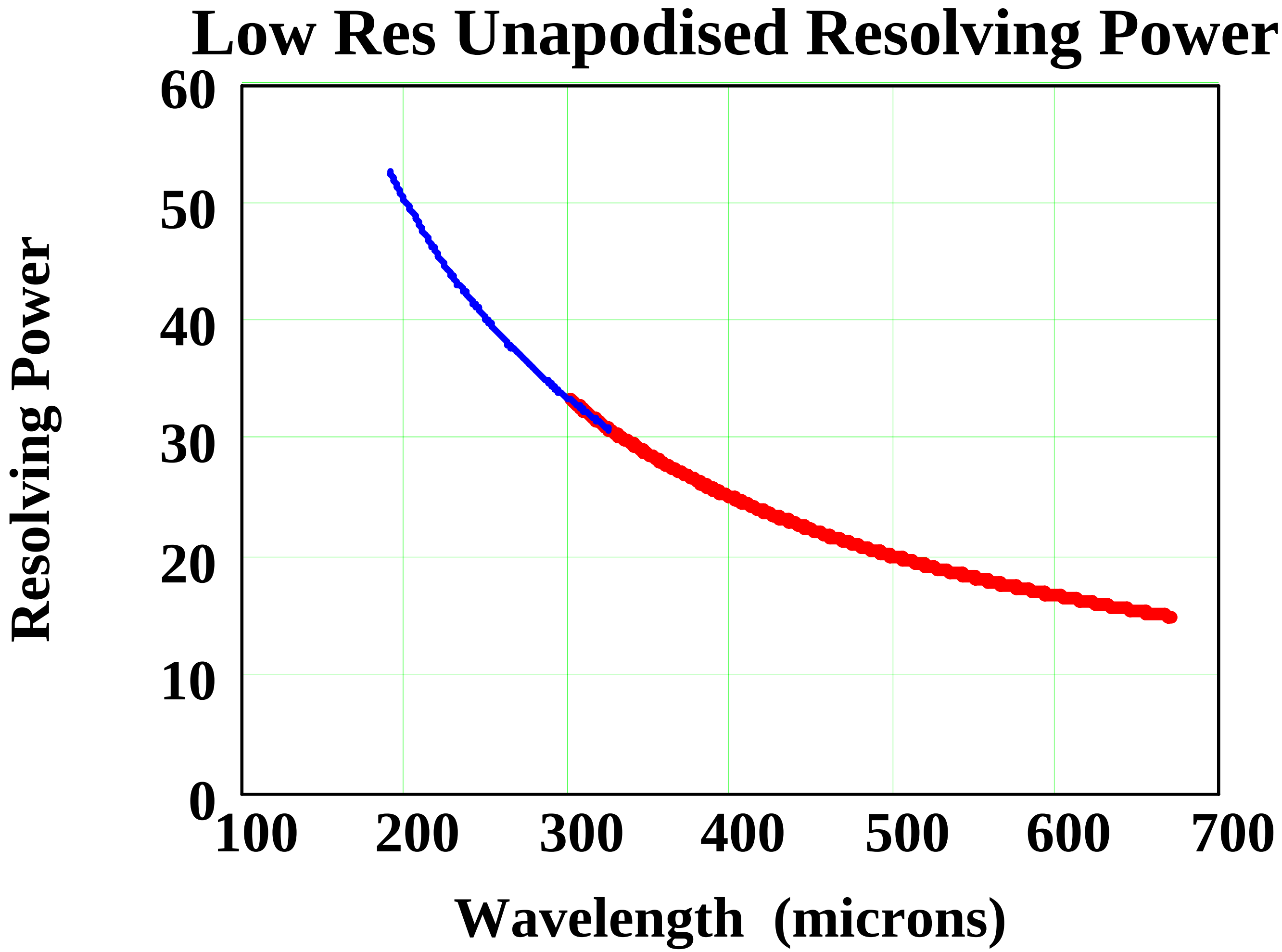
Photometer Sensitivity (Point Source Measurement)

Band (μm)	250	350	500
Point source (mJy 5-σ 1 hr)	1.8	2.2	1.7
Jiggle map (mJy 5-σ 1 hr) (4 x 4 arcmin)	6.2	8.4	7.1
Scan map (with cross-linking)			
1 scan (mJy 5-σ)	55	75	65
On-source time (hrs) to map 1 sq deg. to 3 mJy rms	7.8	16	13

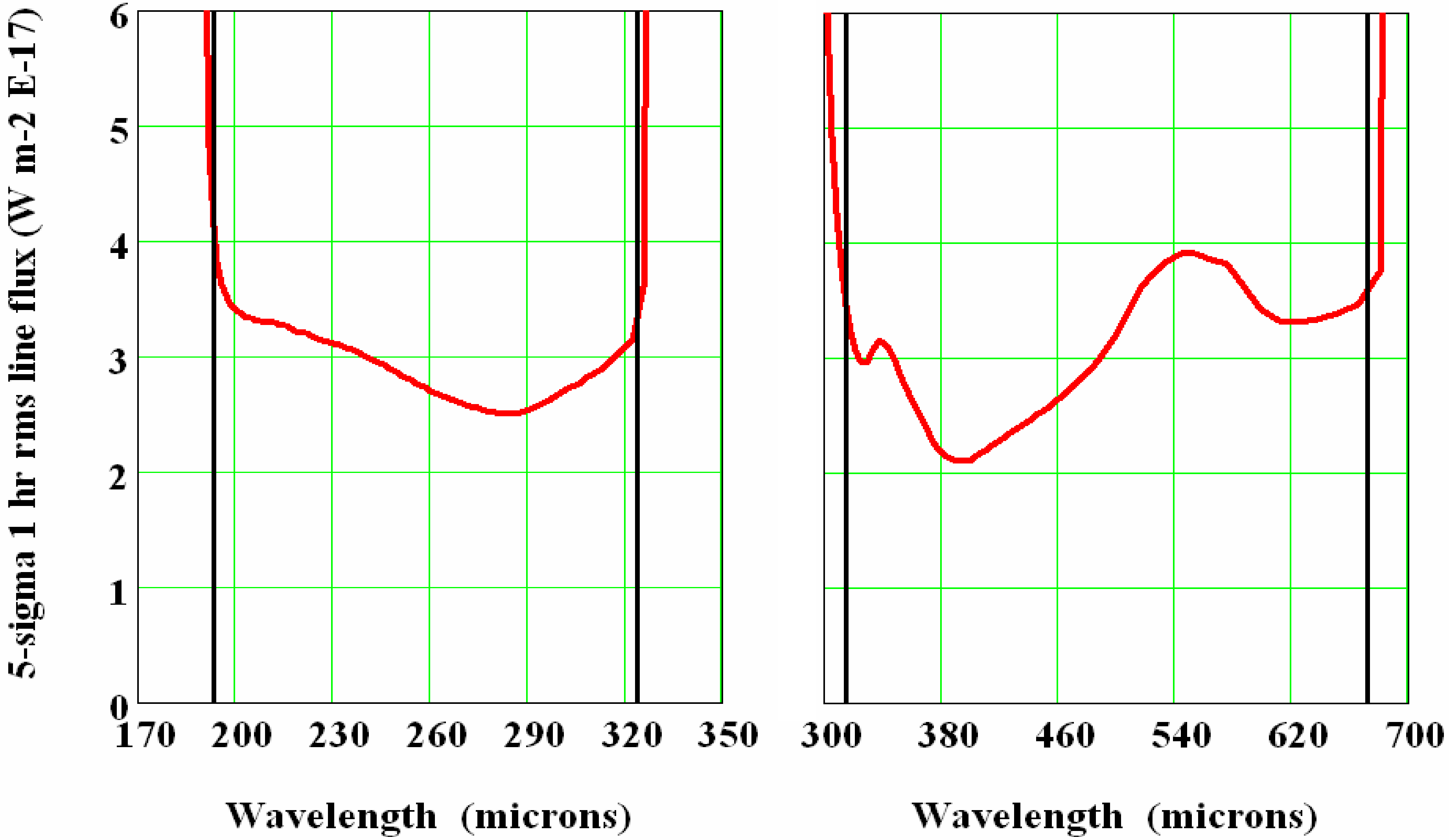
FTS Spectral Line Resolving Power ($\Delta\sigma = 0.04$ cm^{-1})



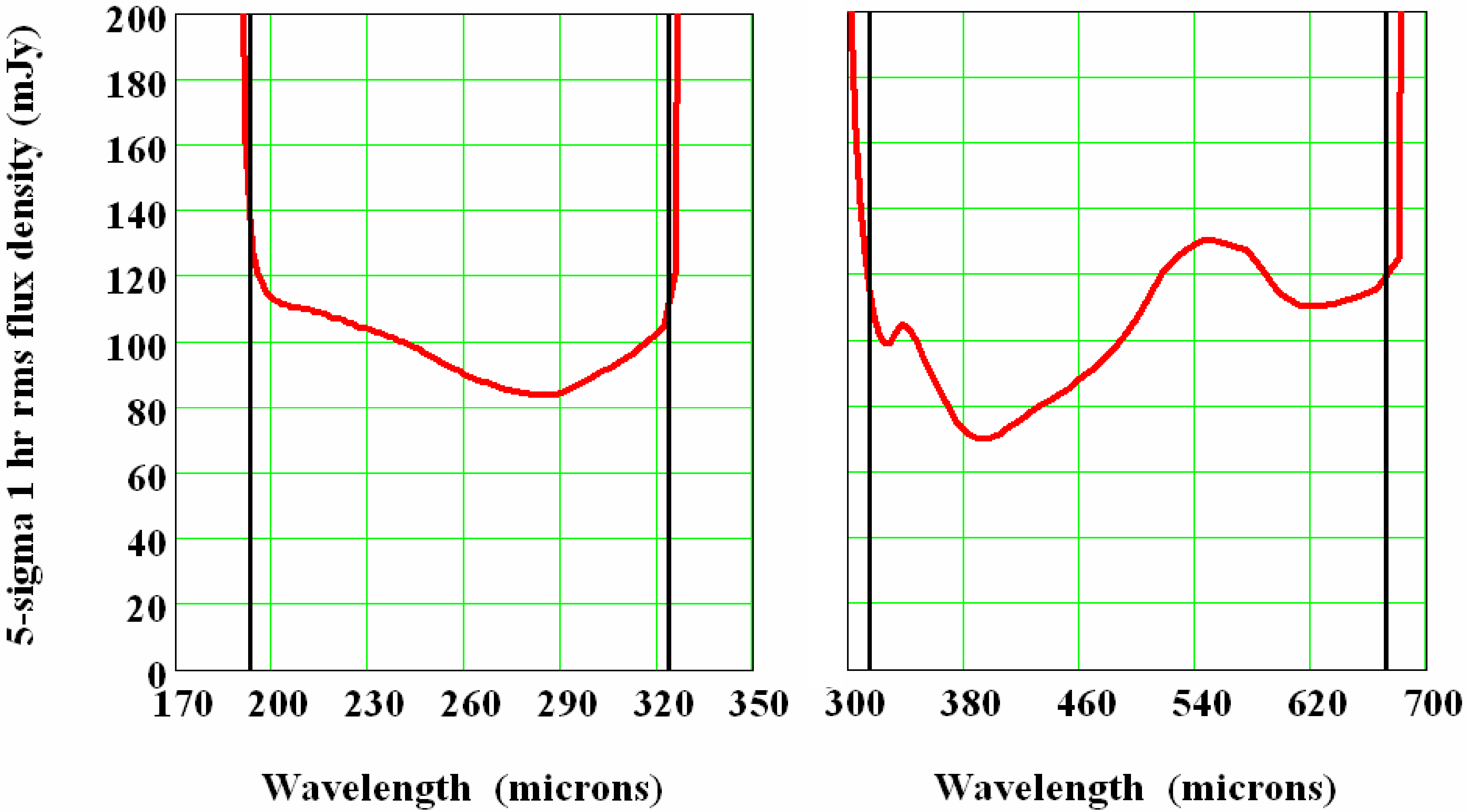
FTS Spectrophotometry Resolving Power ($\Delta\sigma = 1\ cm^{-1}$)



FTS Line Spectroscopy
(W m^{-2} x 10^{-17} 5-σ 1 hr)



FTS Low-Res. Spectrophotometery (mJy 5-σ 1 hr)



Some Comments on Sensitivities

- Sensitivity calculations incorporate many assumptions about instrument performance and telescope effective emissivity
- SPIRE sensitivity estimates are subject to large uncertainties
  - Could be better or worse by nominal factor of 2
  - Scientific merit of proposals should not rely on achieving the nominal sensitivities
- Telescope motion overheads are significant
  - Currently under review
  - Possible reduction in overheads (but no guarantee)
    - Compromise on pointing accuracy
    - Adaptation of observing modes
- Achieving scan map sensitivity requires cross-scanning
  - Baseline observing mode may be updated soon to “diagonal scanning“

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SPIRE Consortium Guaranteed Time Programmes

Division of SPIRE GT (1898 hrs)

SAG 1	High-redshift galaxies	43%
Coordinators: Jamie Bock and Seb Oliver		
SAG 2	Local galaxies	15%
Coordinators: Walter Gear and Suzanne Madden		
SAG 3	Star formation	16%
Coordinators: Philippe André and Paolo Saraceno		
SAG 4	Interstellar medium	9%
Coordinators: Alain Abergel and Jean-Paul Baluteau		
SAG 5	Solar system	2.5%
Coordinators: Regis Courtin and Bruce Swinyard		
SAG 6	Stellar & circumstellar	7.5%
Coordinators: Mike Barlow and Göran Olofsson		

Reserved for small programmes later 7%

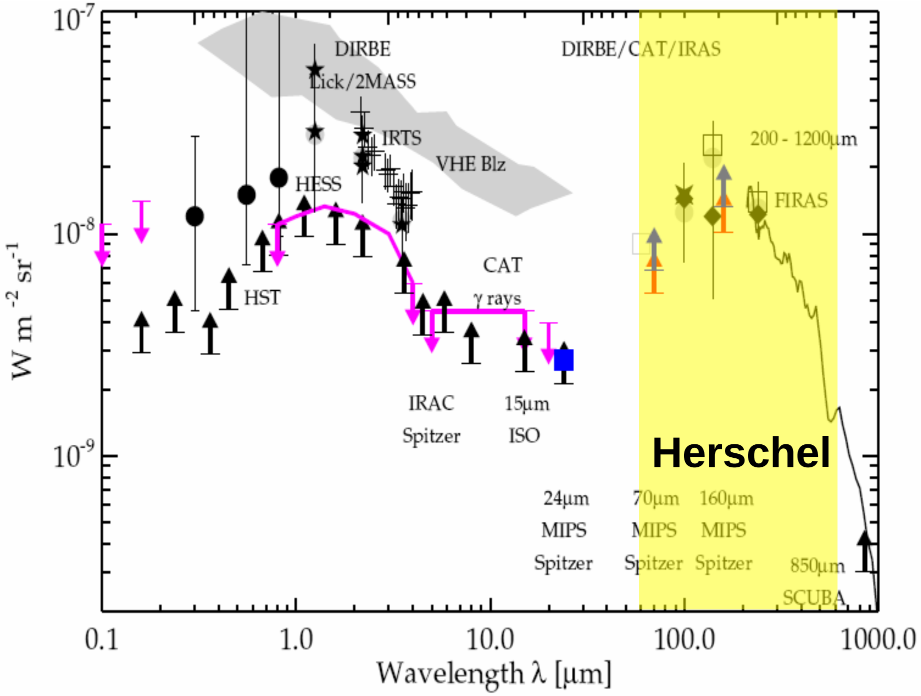
SAG 1
High-Redshift Galaxies

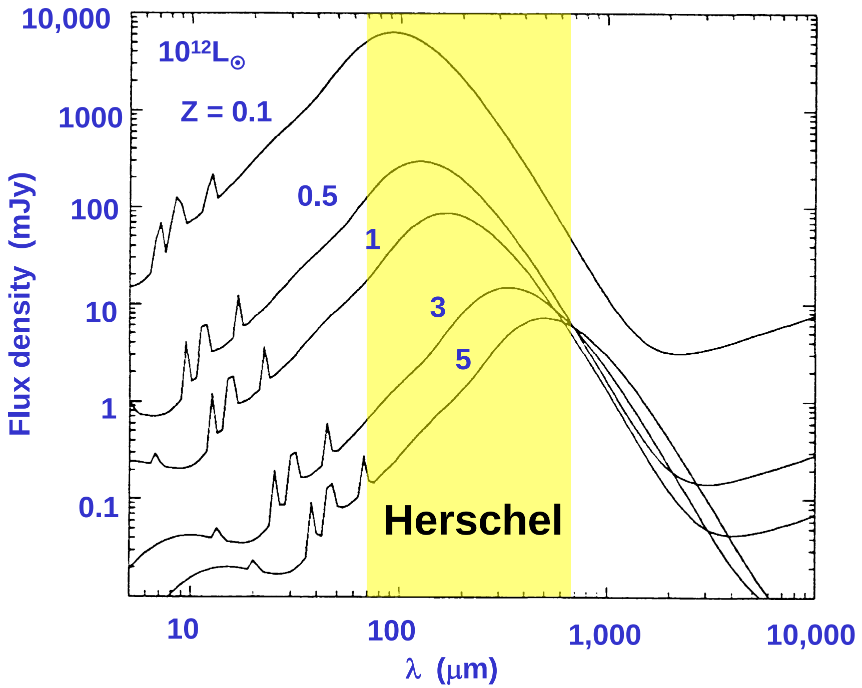
- **Multi-band surveys (multi-tiered "wedding cake") covering the peak of the FIR background**
  - **Coordinated with PACS**

- **Cluster survey**

SEDs and Luminosities

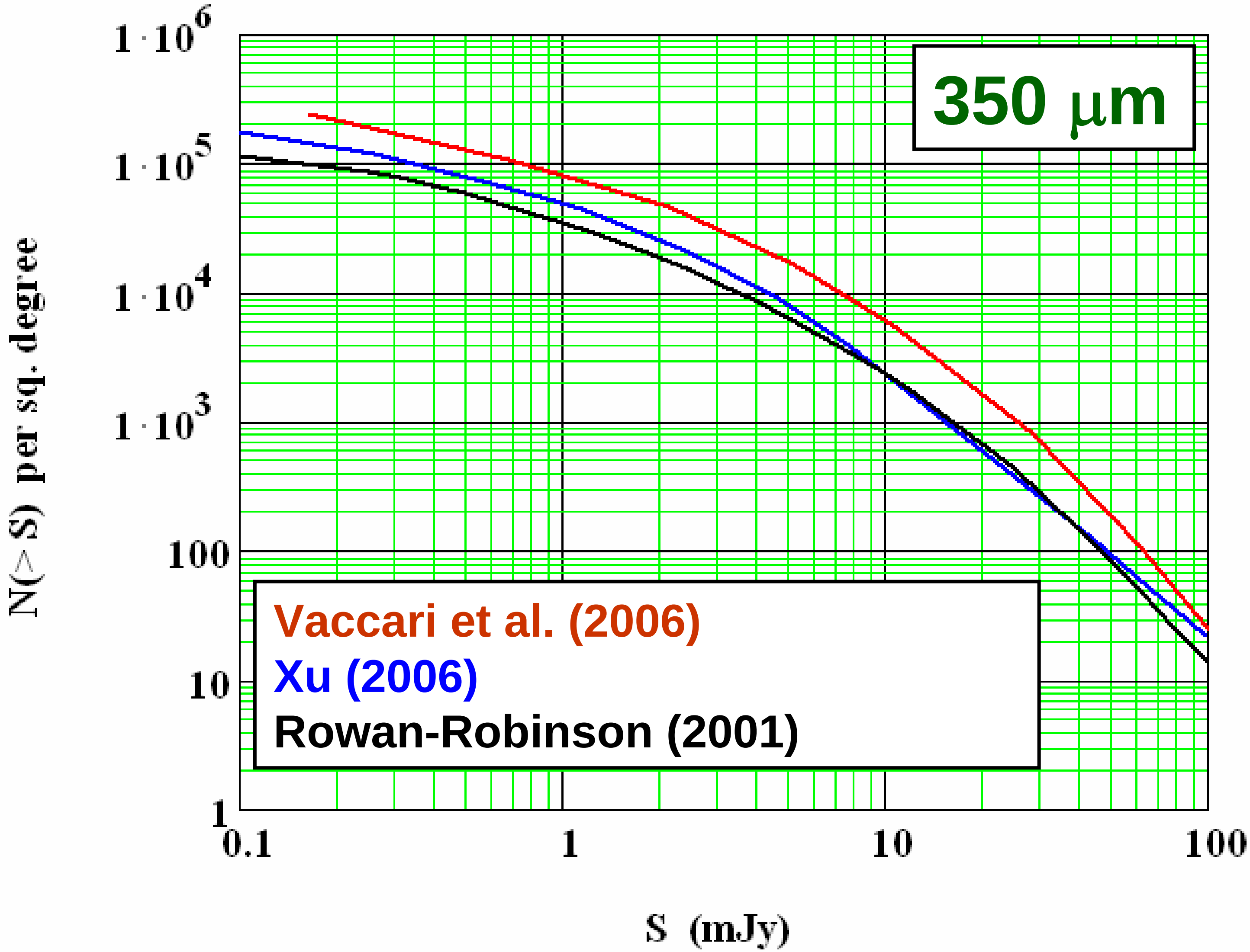
Herschel probes the rest-frame bolometric emission from galaxies as they formed most of their stars



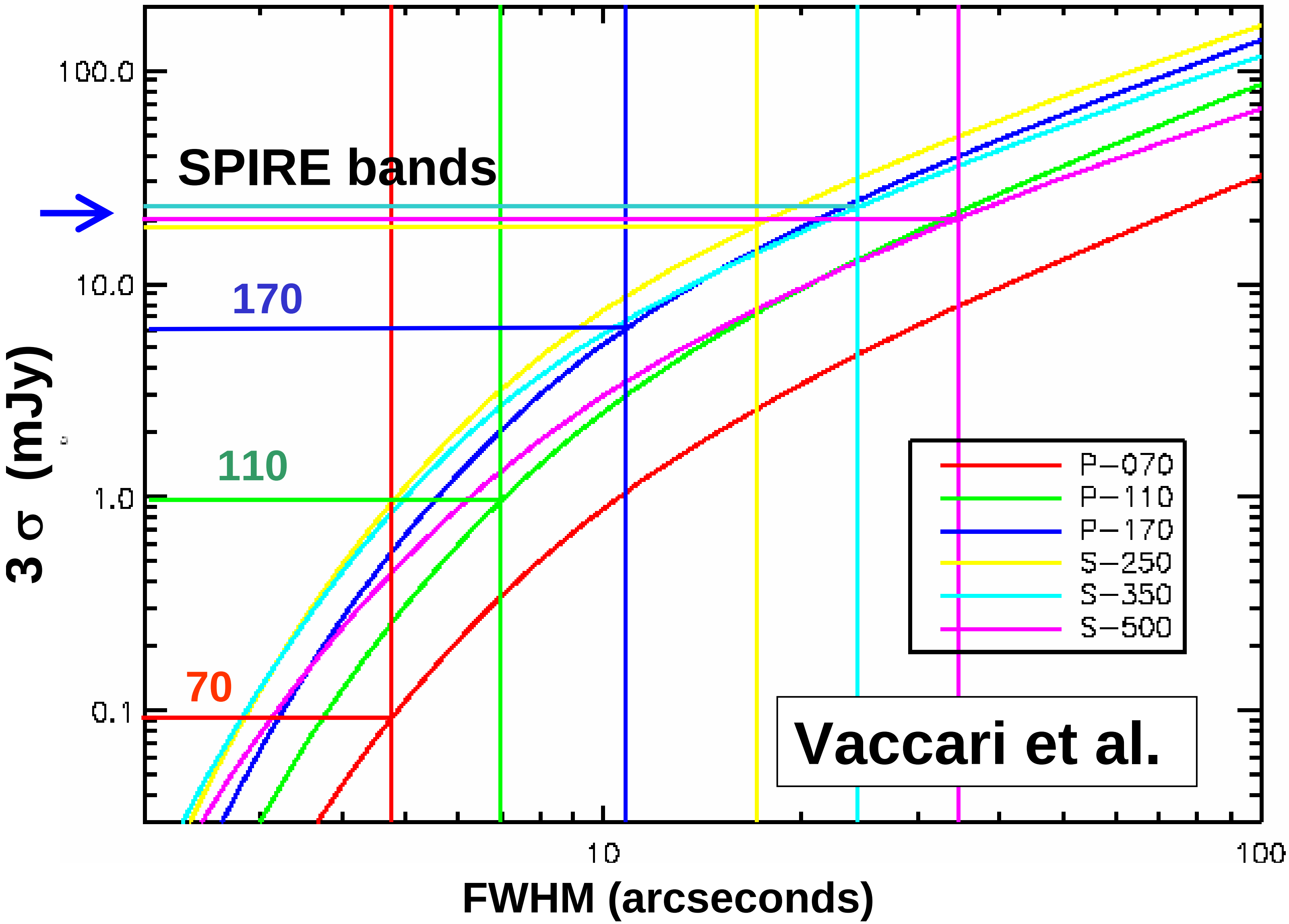


After Guiderdoni et al. MNRAS 295, 877, 1998

Source Count Models

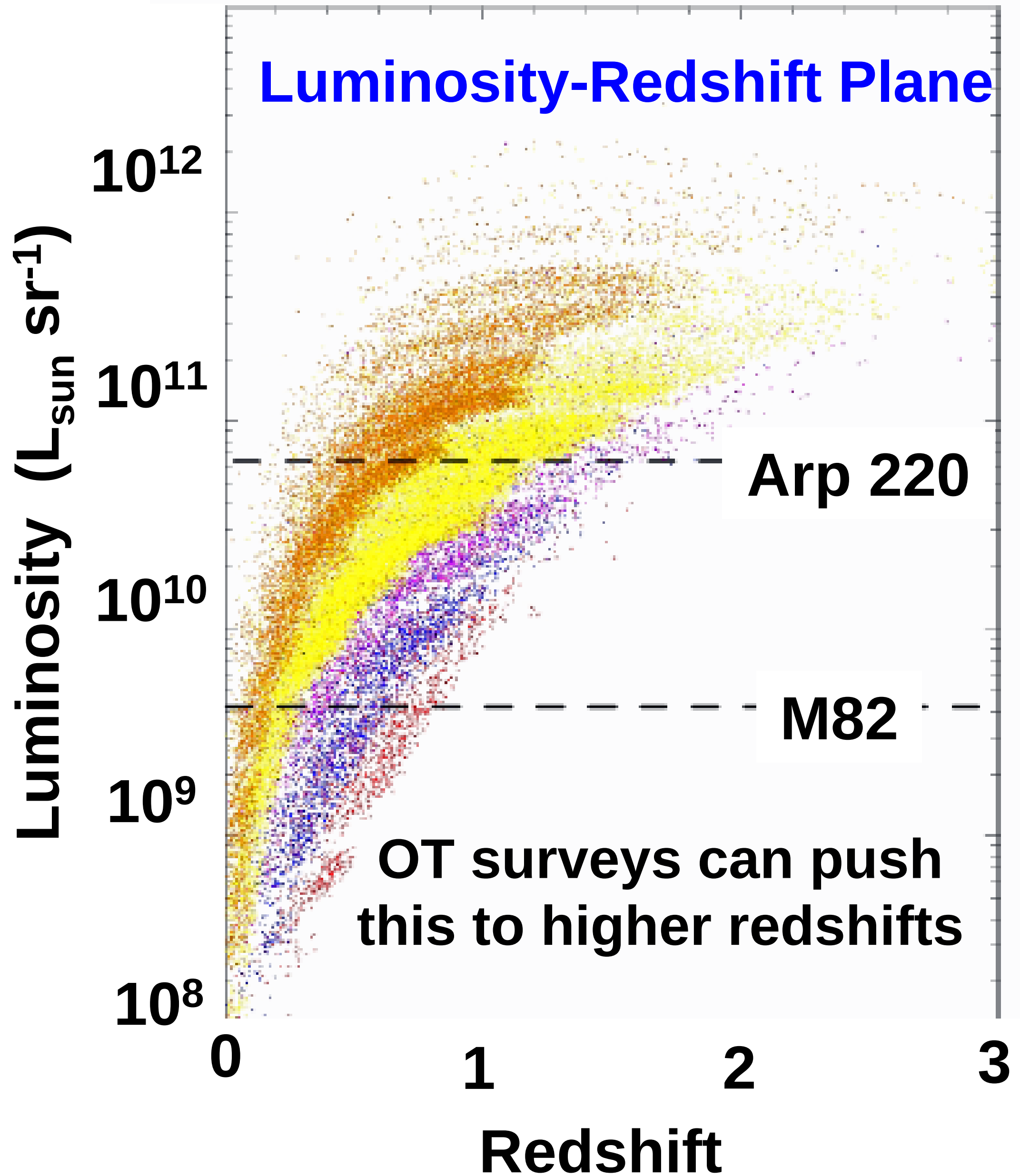


Predicted 3-σ Confusion Fluctuations

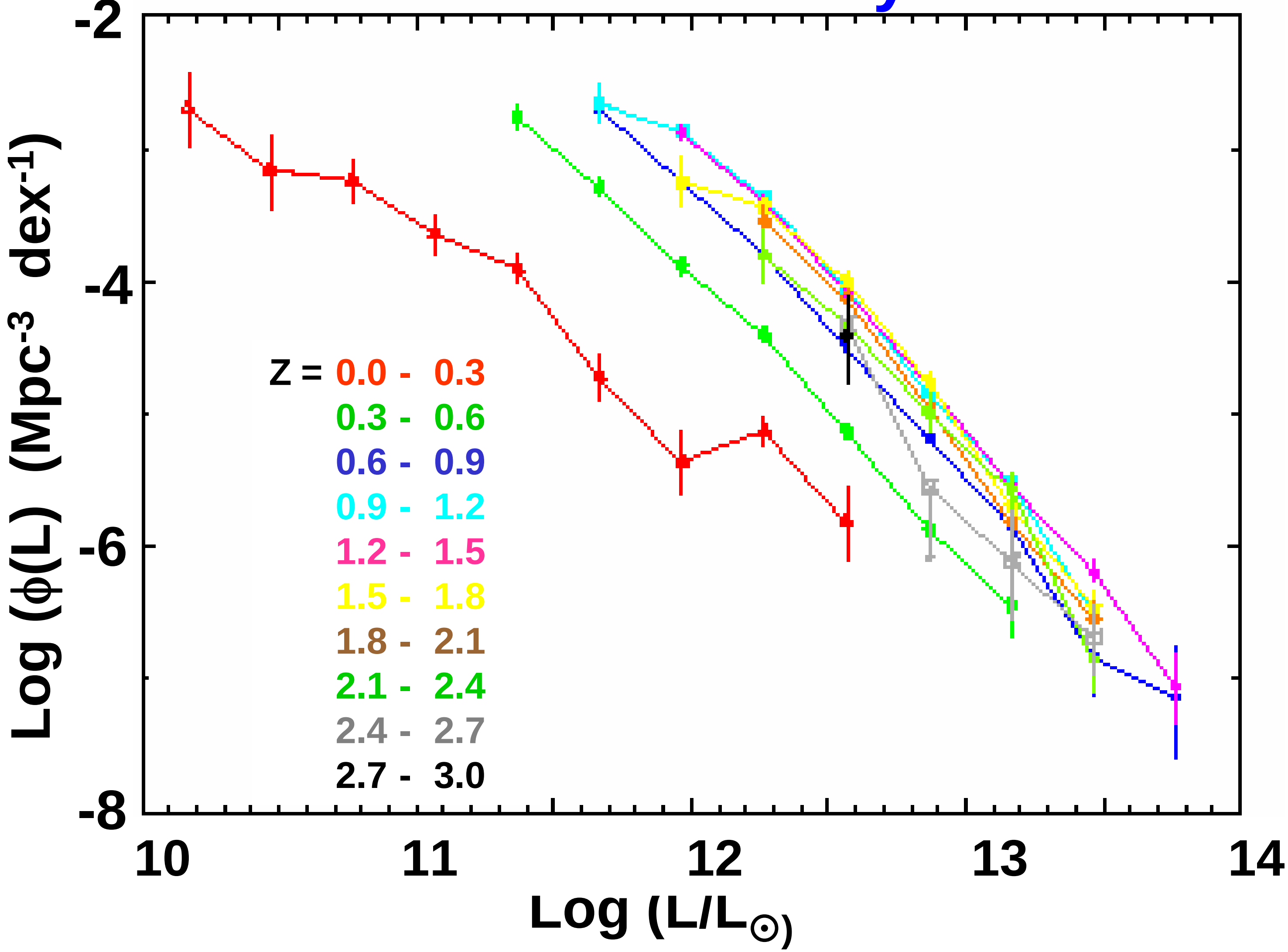


Wedding Cake Survey will probe L_{Bol} over a wide redshift range

Surveys of a selection of fields with varying depth and field size (0.04 to ~ 50 sq deg.)



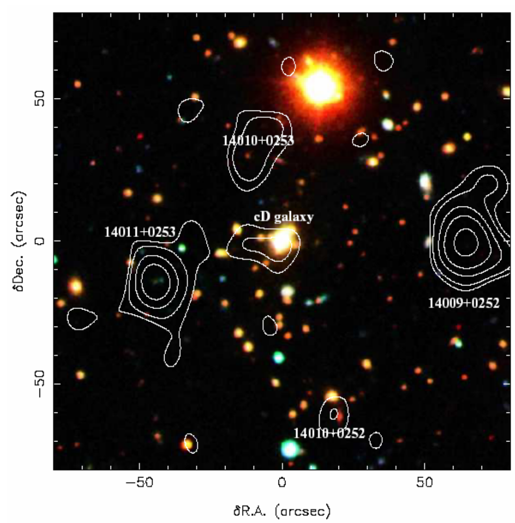
Reconstructing the Evolution of the Bolometric Luminosity Function



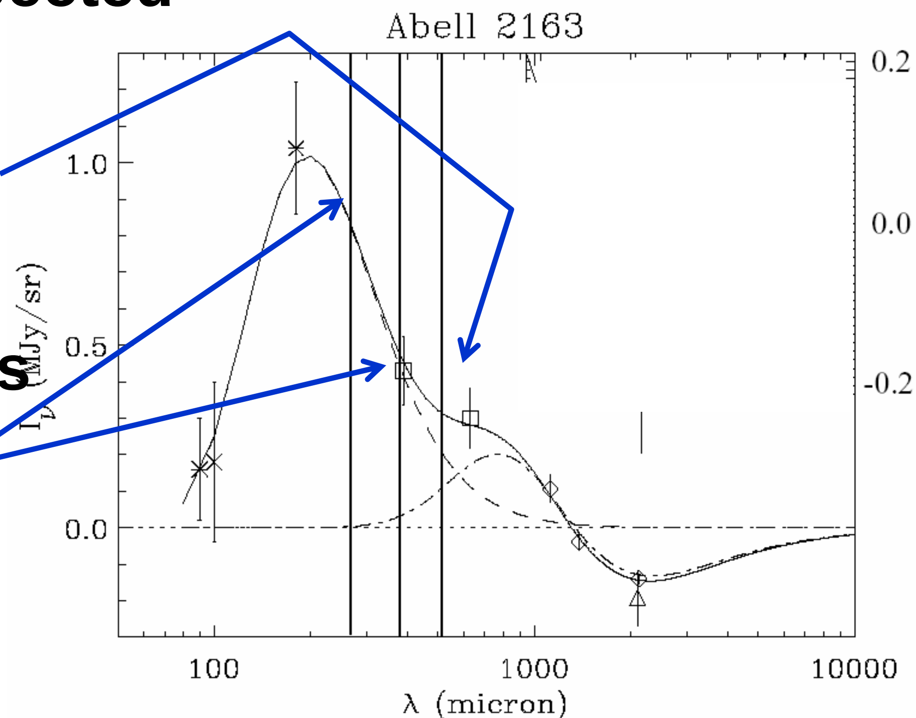
Cluster Imaging

- **Sample of rich clusters from z = 0.2 to > 1**

- **Lensing**
  - **Extend below blank field confusion limit to about 5 mJy**
  - **About 200 detections expected**

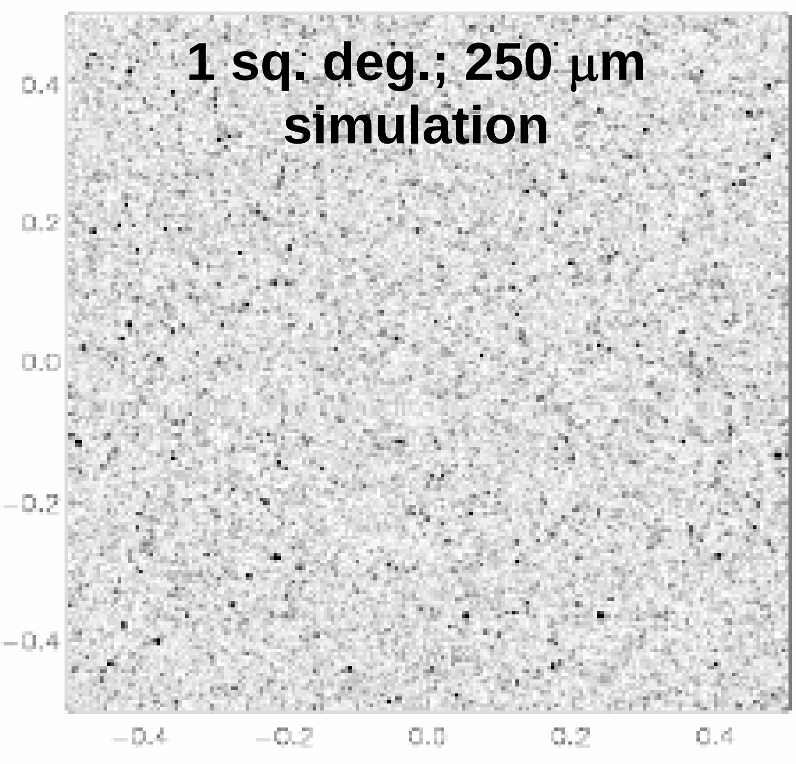


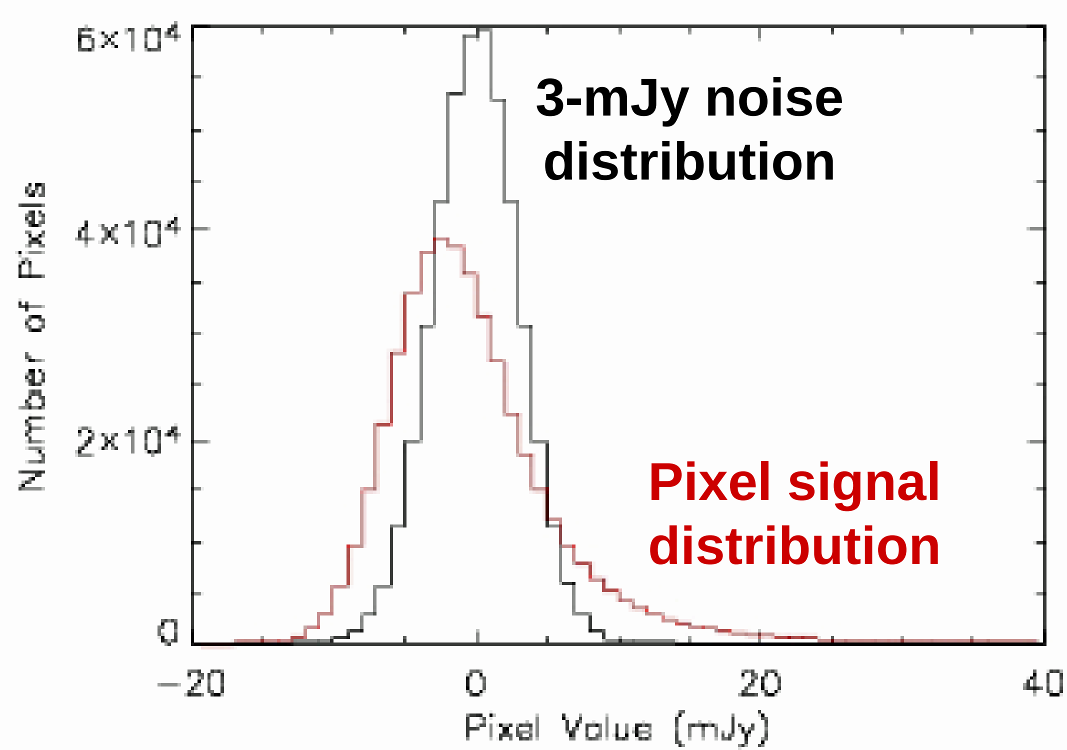
- **Sunyaev Zel'Dovich effect**
  - **Significant S-Z effect at 500 μm**
  - **Shorter wavelength bands will allow contribution from cluster galaxies to be subtracted**



P(*D*) Analysis

- Deep SPIRE observation of ~ 1 sq. deg.
- Fluctuations down to ~ 3 mJy (~ 1 source/beam)
- *P*(*D*) depends on beam profile and slope of number counts

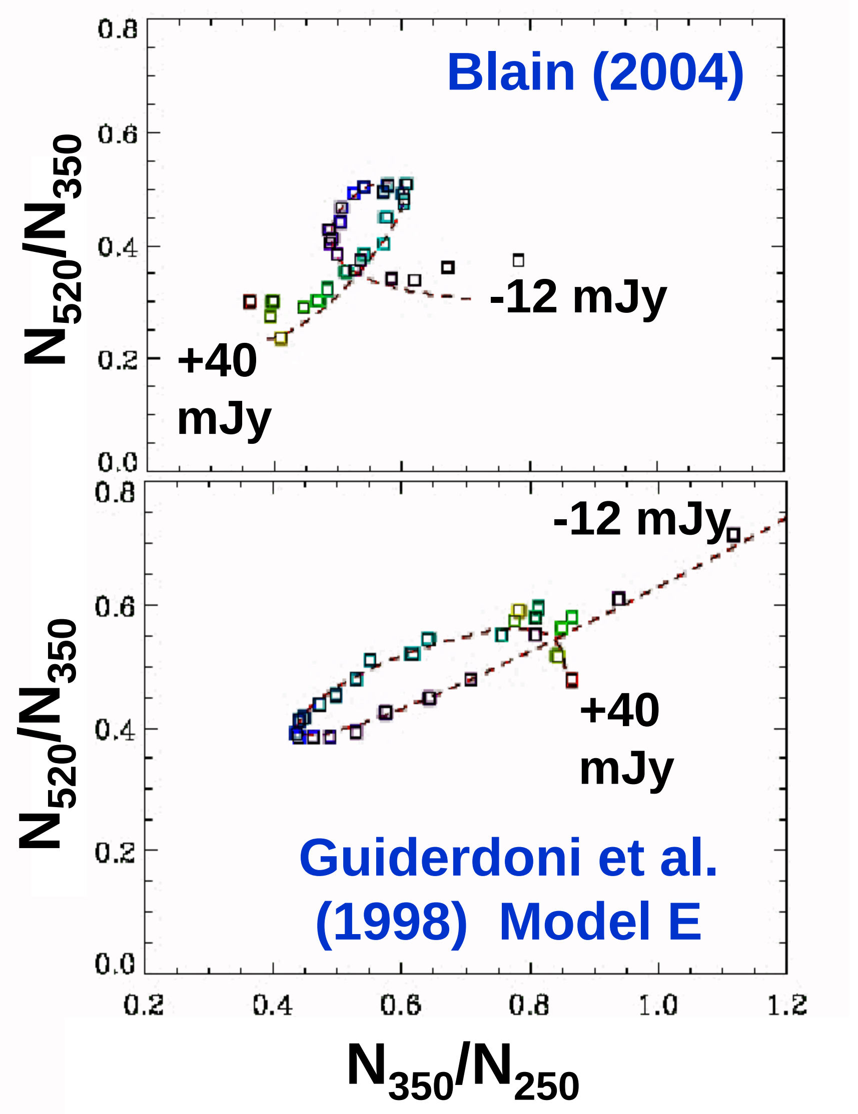




Multi-Band Pixel Analysis

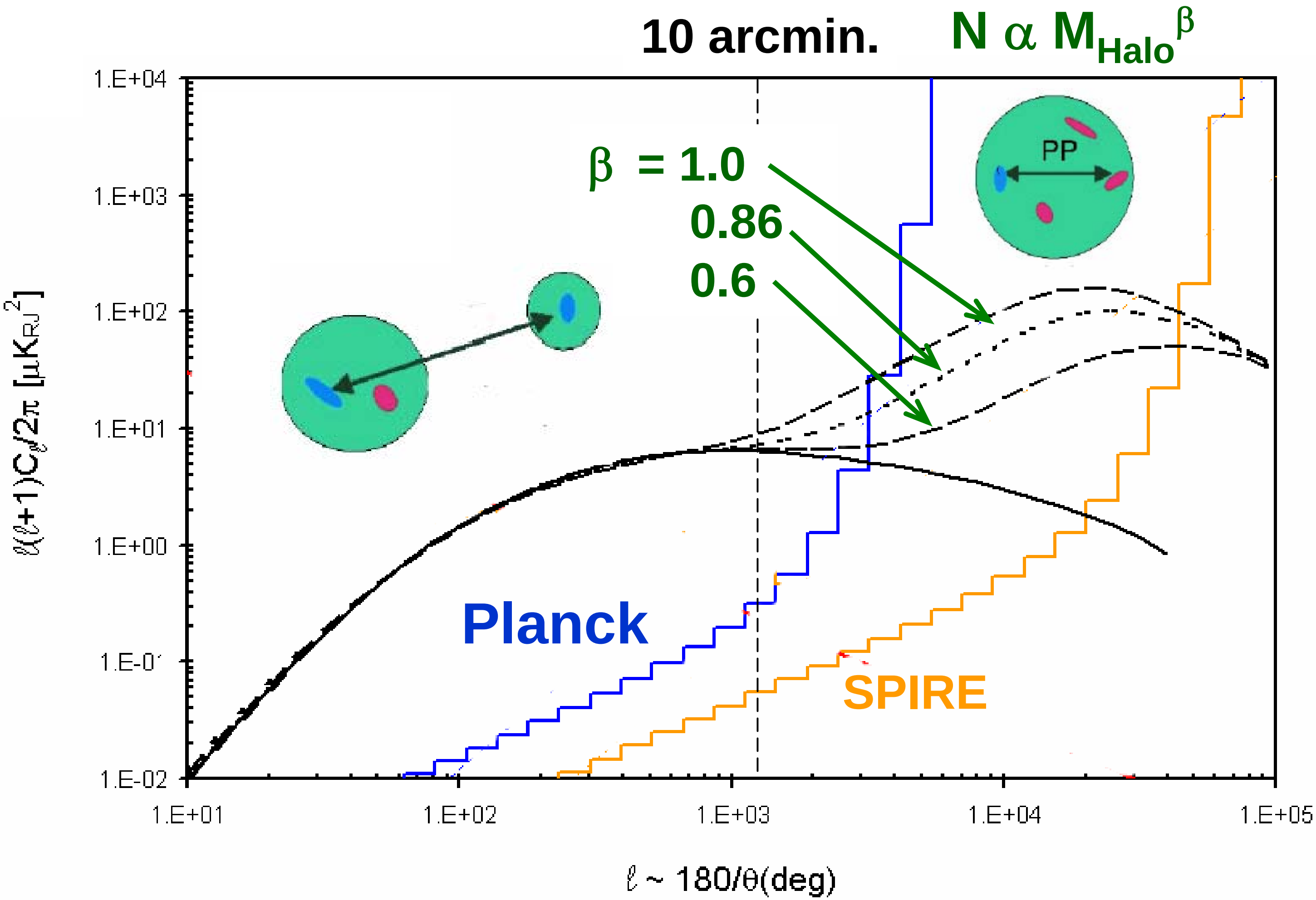
- **Three-band pixel analysis will help distinguish between number count models**

Simulated - - - - -
Recovered ◻



Background Fluctuations

- **SPIRE survey will probe galaxy clustering within dark matter halos on scales < 10 arcmin.**



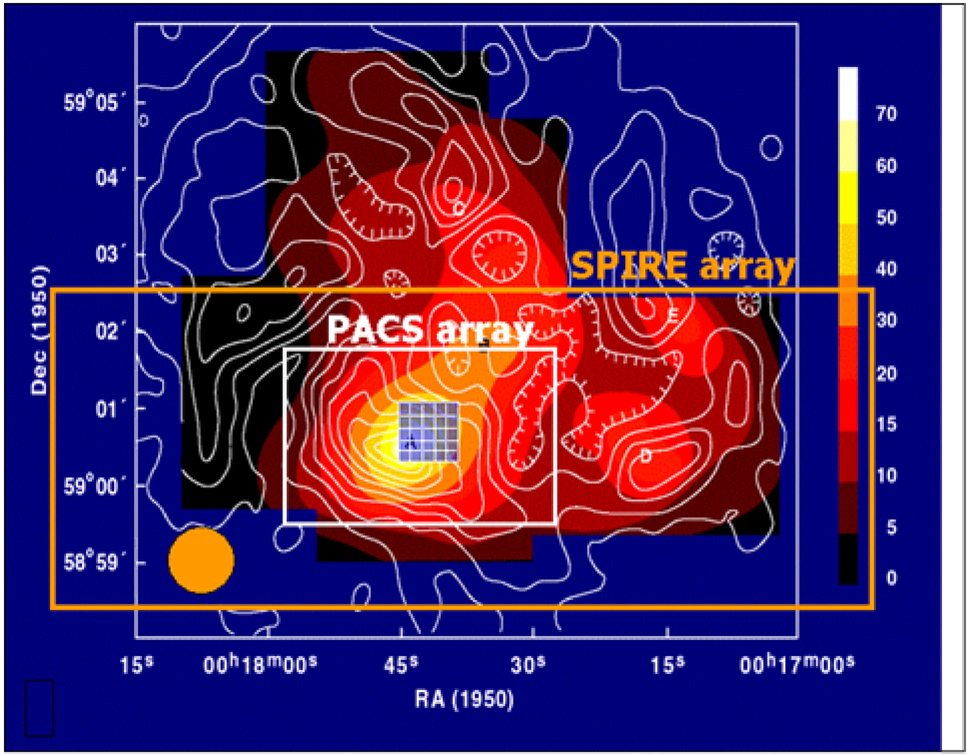
SAG 2
Local Galaxies

Three Key Projects

- **ISM in Very Nearby Galaxies**
  - PACS + SPIRE
- **ISM in Low Metallicity Environments**
  - PACS + SPIRE
- **The Herschel Galaxy Reference Survey**
  - SPIRE only

ISM in Nearby Galaxies

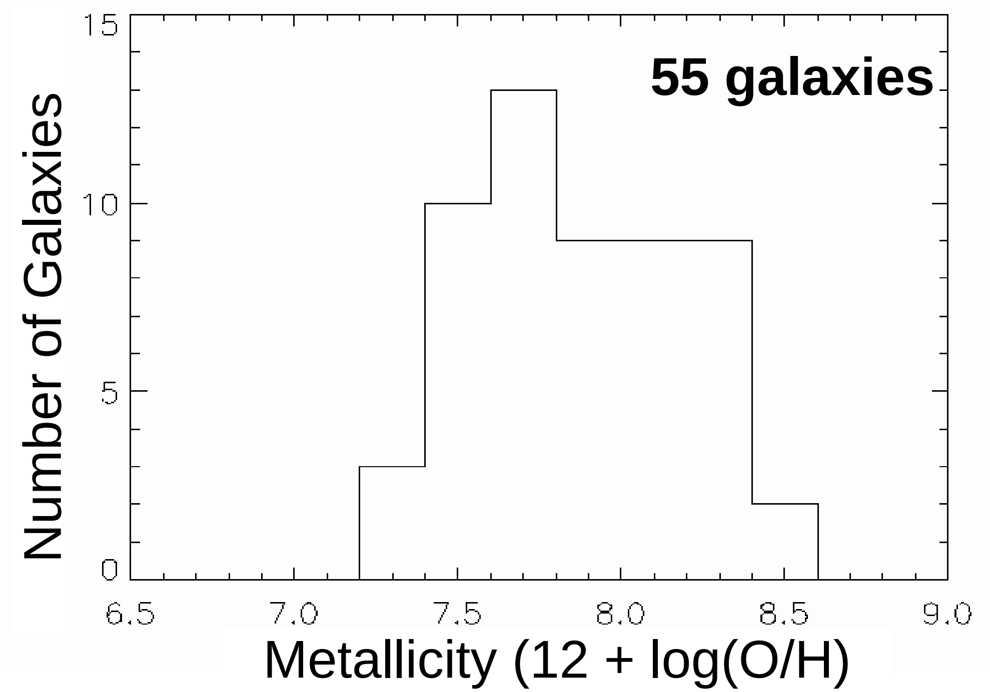
- Sample of nearby galaxies well-studied from X-ray-radio
  - Early & late type spirals
  - Low mass spiral
  - Edge-on spiral
  - Starburst spiral
  - Starburst galaxy
  - Quiescent dwarf
  - Starburst dwarf
  - Seyferts
  - Ellipticals



- Photometry, spectroscopy with PACS, SPIRE, HIFI
- Detailed SEDs and dust properties
- Chemistry/metallicity variation and evolution
- Variations inside a galaxy as well as global properties

Low Metallicity Dwarf Galaxies

- Programme of SPIRE/PACS/HIFI photometry and spectroscopy
- Analogues of high-z building blocks
  - ISM and SF in primordial galaxies
- Dust components and properties in metal-poor galaxies
- Influence of metallicity on ISM structure, radiation field, star formation activity

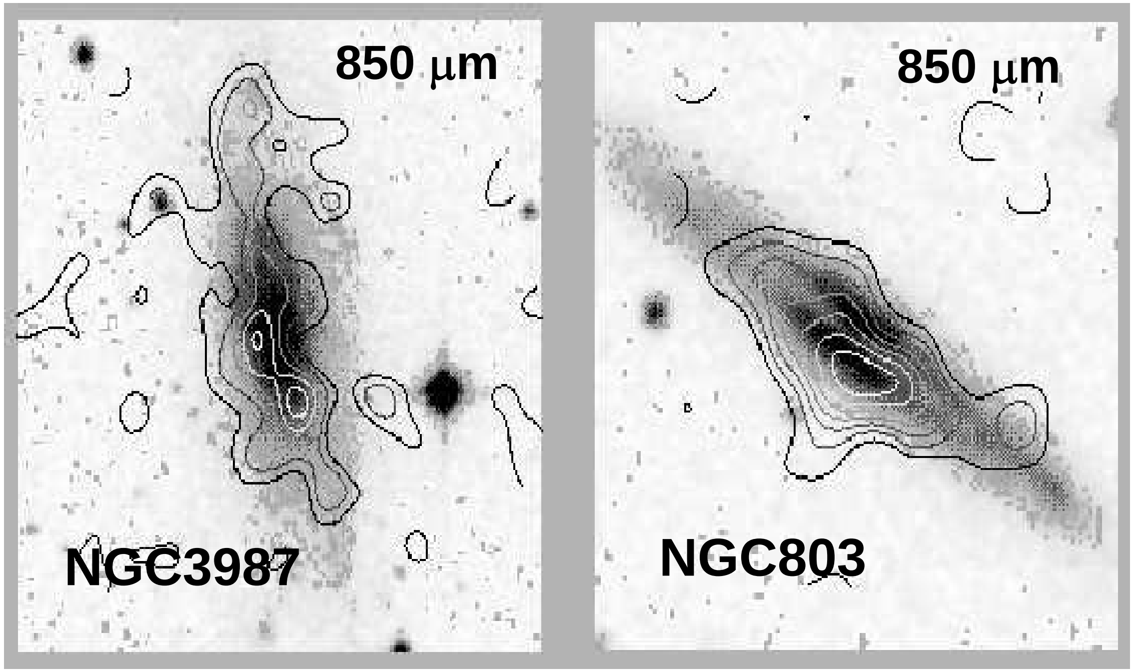


1/3 – 1/50 solar metallicity

- Impact of super star clusters on surrounding gas and dust

Herschel Reference Survey of Dust in Galaxies

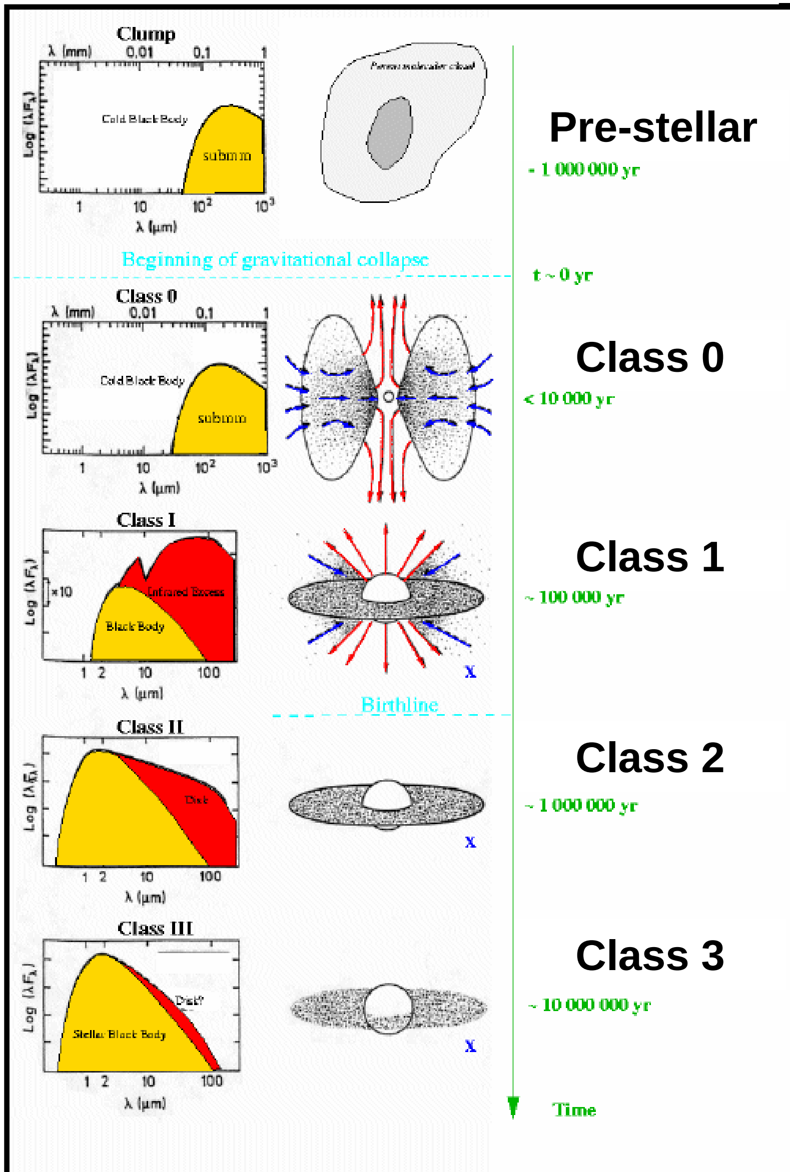
- Statistical survey of dust in the nearby universe
- SPIRE photometry of sample of > 300 galaxies
- Relate present-day galaxies to high-z ancestors
- How do dust mass and distribution depend on
  - Galaxy type?
  - Environment?
  - Luminosity?

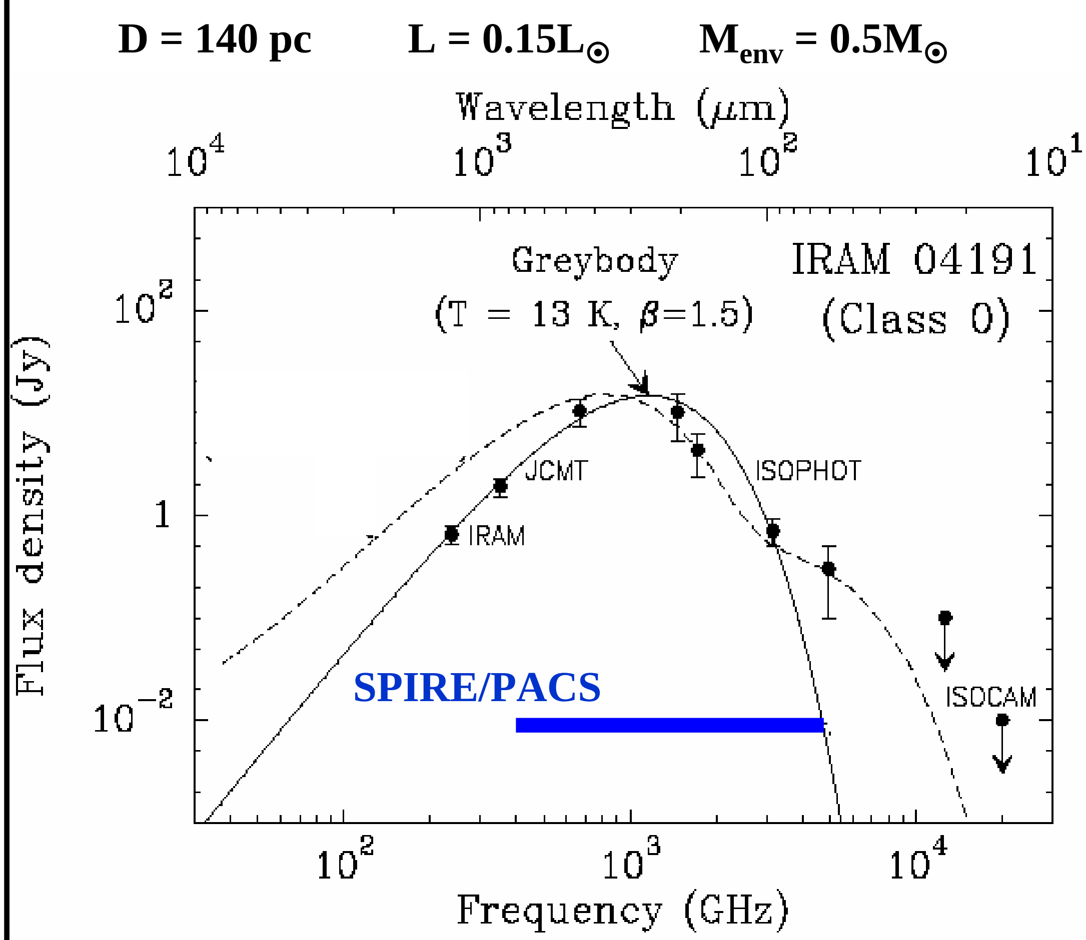


SAGs 3, 4, 6
Galactic Key Projects

- SAG 3
  - Low-mass SF and the IMF
  - High mass SF
- SAG 4
  - Evolution of dust
- SAG 6
  - Debris disk evolution
  - Dust production by stars and supernovae

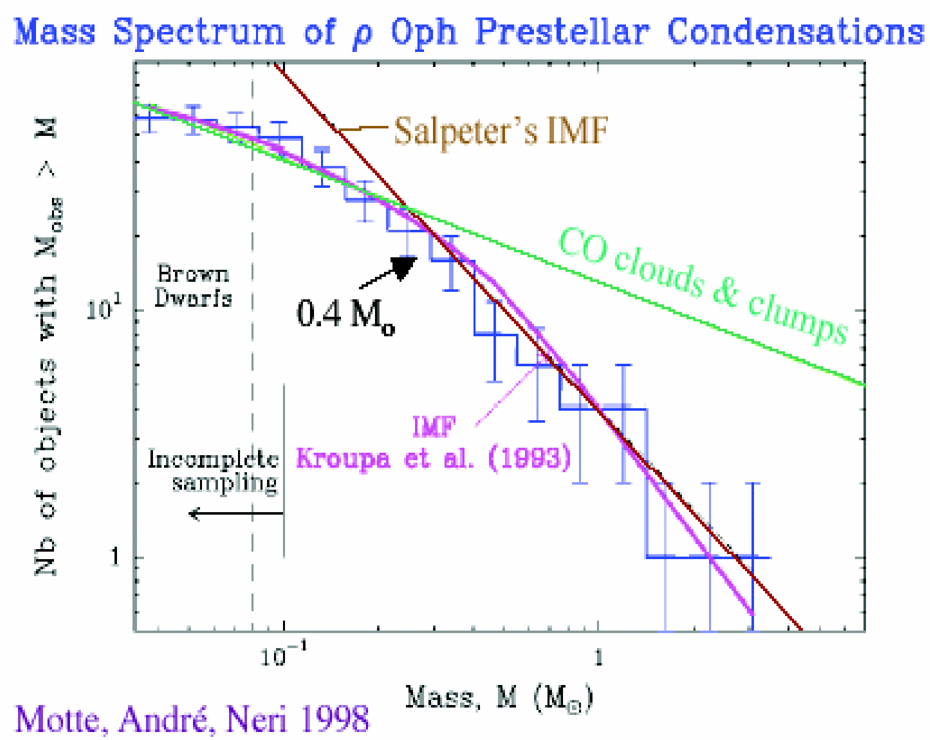
Protostars and YSOs

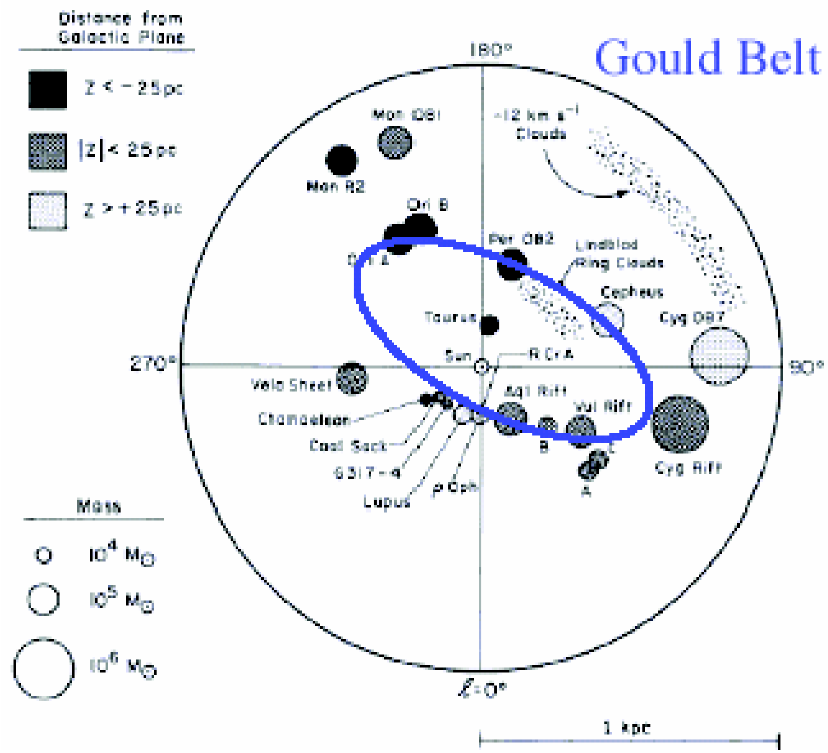




Gould Belt Survey (SPIRE + PACS)

- Complete samples of protostars and pre-collapse condensations down to $M_{proto} \sim 0.03\ M_{\odot}$ and D ~ 1 kpc
- SED coverage of spectral peak
- Accurate mass, luminosity, temperature, lifetimes
- IMF down to brown dwarf mass regime
- Temperature and density profiles for nearby sources

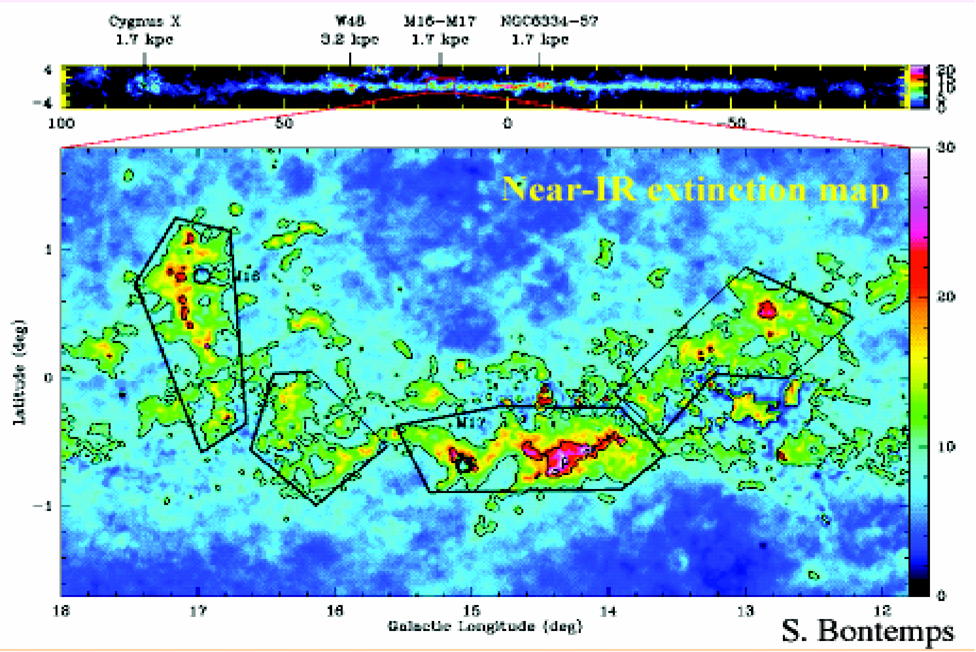




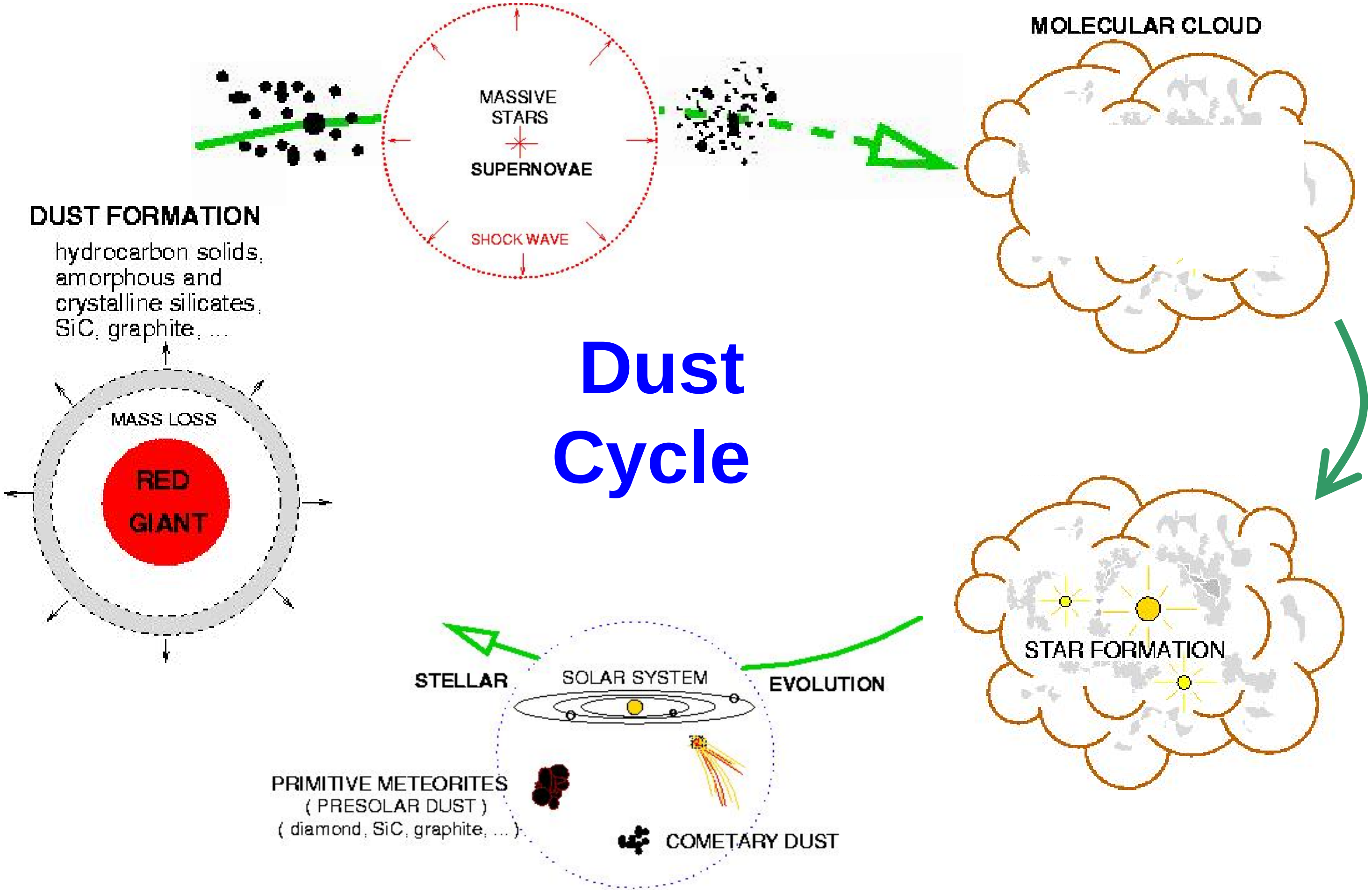
High-mass SF (SPIRE + PACS)

- **Imaging and spectroscopy covering ~ 20 sq. deg. area**

- **Unbiased census of OB star precursors**
- **Initial conditions and evolutionary sequence**
- **Templates for extragalactic SF**
- **Role of external triggers in massive SF**



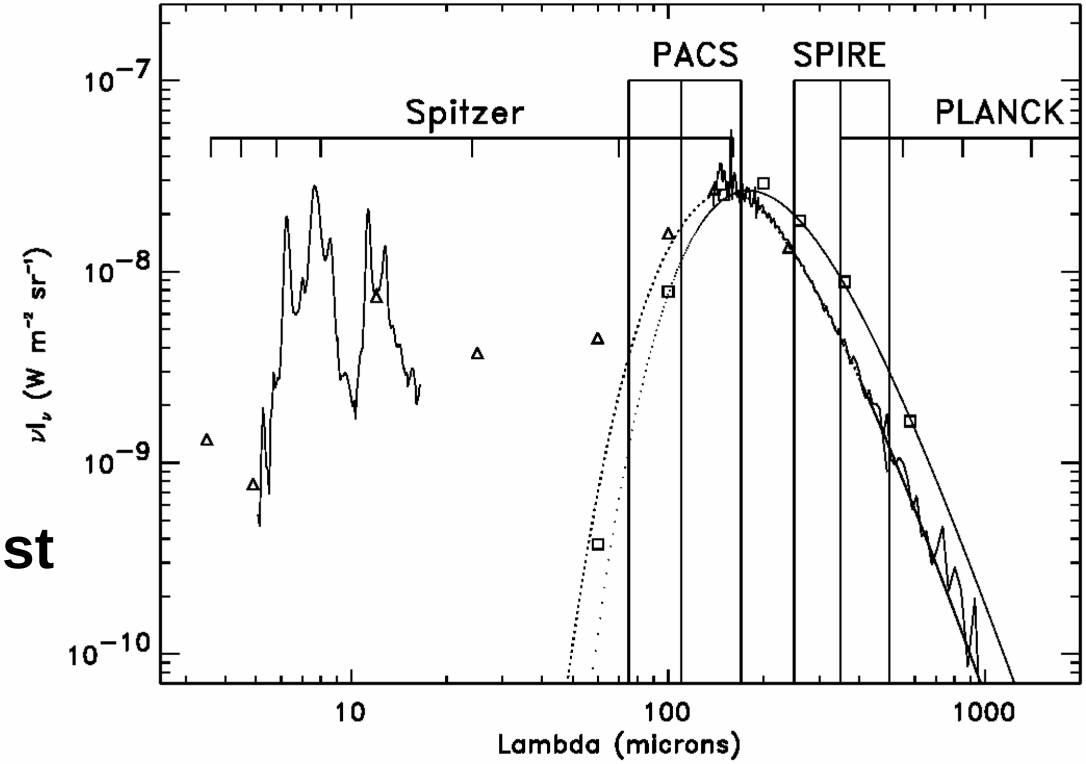
Physics and Evolution of Interstellar Dust



Interstellar Dust

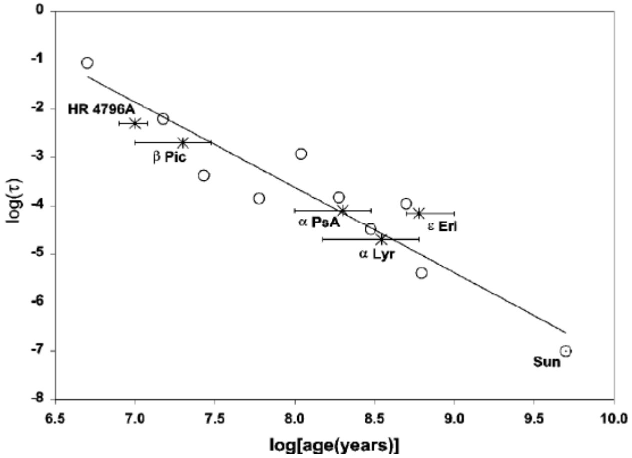
- **Unbiased surveys of regions with different A_V, illumination, density, history, SF activity**
  - **Dust SED and gas physics**

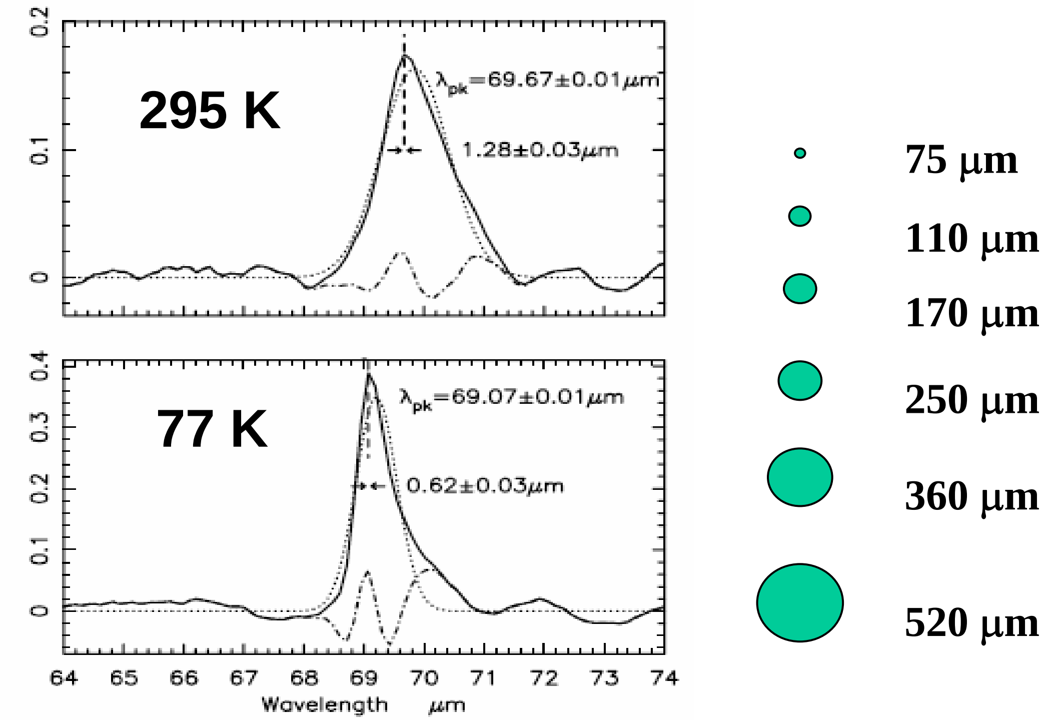
- **Processes**
  - **Fragmentation**
  - **Coagulation**
  - **Condensation**
  - **Evaporation**
  - **Photo processing**
- **Environments:**
  - **Shock processed dust**
  - **Cirrus**
  - **Molecular clouds**
  - **PDRs**
  - **Pre-stellar cores and protostars**

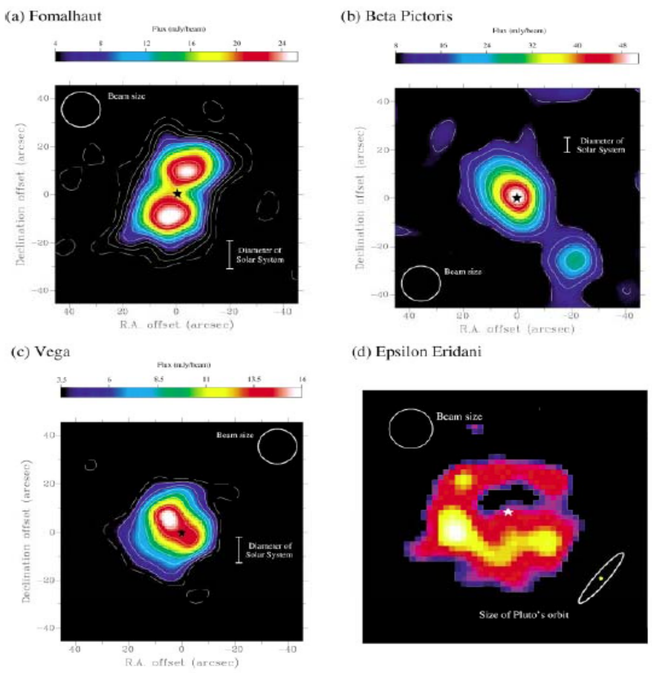


Debris Disk Evolution

- **PACS + SPIRE mapping**
  - Dust mass vs. evolutionary state
  - Dust morphology and properties
- **PACS + SPIRE spectroscopy**
  - Dust features

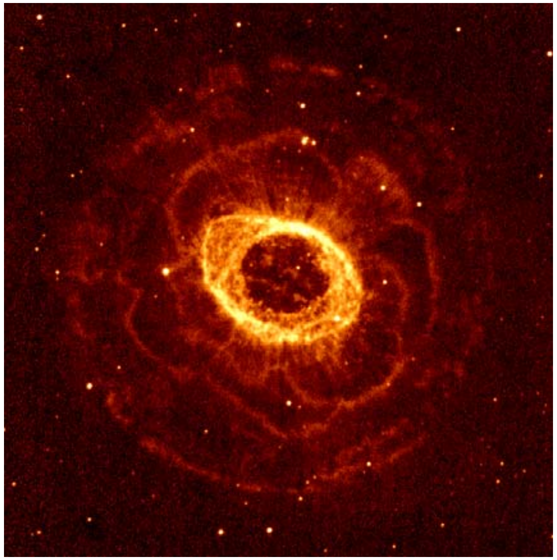




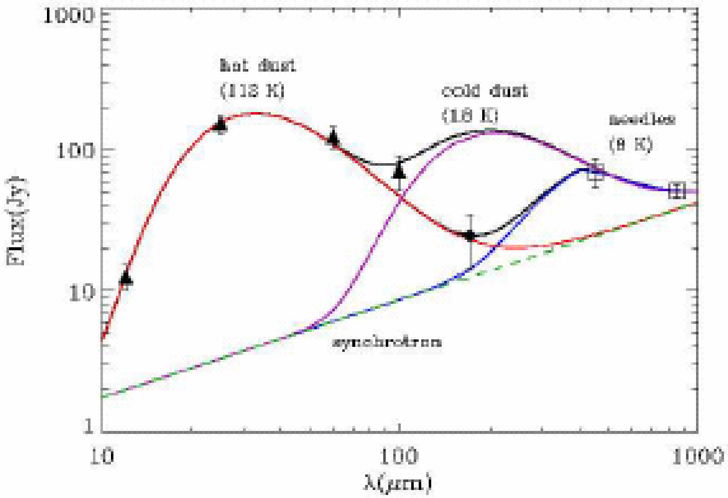


Dust Production by Stars and Supernovae

- **Post-AGB stars extended dust shells**
  - Mass, temperature, morphology via multi-wavelength photometric imaging



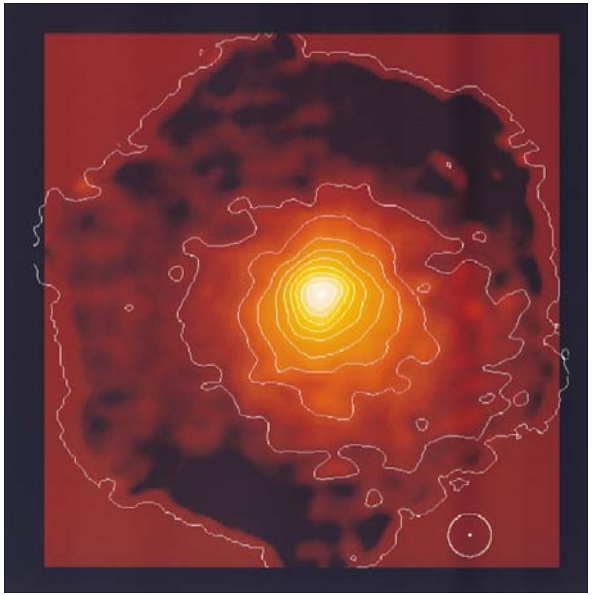
- **Evolved star chemistry**
  - Spectroscopy of evolved objects with specific dust chemistries
  - O- and C-rich stars, post-AGB objects, planetary nebulae
  - 1 - 8 $M_{\odot}$ objects most important fo
    contributing dust to the Galaxy

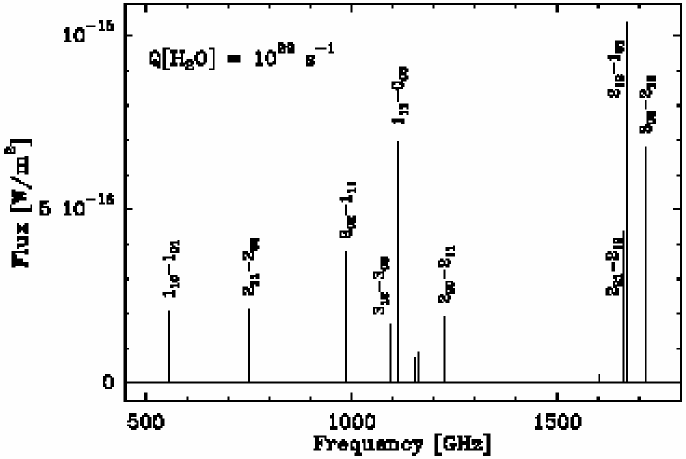


- **Dust production by supernovae**
  - Nearby SNRs (Cas A, Kepler, Tycho, Crab, etc.)
  - Detection of emission from dust produced and/or swept up

Solar System Observations

- **HIFI + SPIRE programme on Water in the Solar System**
  - SPIRE observations of
    - Uranus and Neptune
      - Full-resolution spectroscopy
    - Titan
      - Full-resolution spectroscopy
    - Comets
      - High resolution spectroscopy
      - Dust emission mapping





- **See posters or contact programme coordinators for further details**

SAG 1 High-redshift galaxies

Coordinators: Jamie Bock and Seb Oliver

SAG 2 Local galaxies

Coordinators: Walter Gear and Suzanne Madden

SAG 3 Star formation

Coordinators: Philippe André and Paolo Saraceno

SAG 4 Interstellar medium

Coordinators: Alain Abergel and Jean-Paul Baluteau

SAG 5 Solar system

Coordinators: Regis Courtin and Bruce Swinyard

SAG 6 Stellar & circumstellar

Coordinators: Mike Barlow and Göran Olofsson