SPIRE Calibration Strategy

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on behalf of the SPIRE Calibration Team

The SPIRE Consortium

Canada 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
- Hogwarts School of Witchcraft and Wizardry
- Observatoire de Paris, Meudon, Paris
- Rutherford Appleton Laboratory, Oxfordshire, UK
- Stockholm Observatory, Sweden
- UK Astronomy Technology Centre, Edinburgh
- University of Lethbridge, Canada
- Universitàdi Padova, Italy

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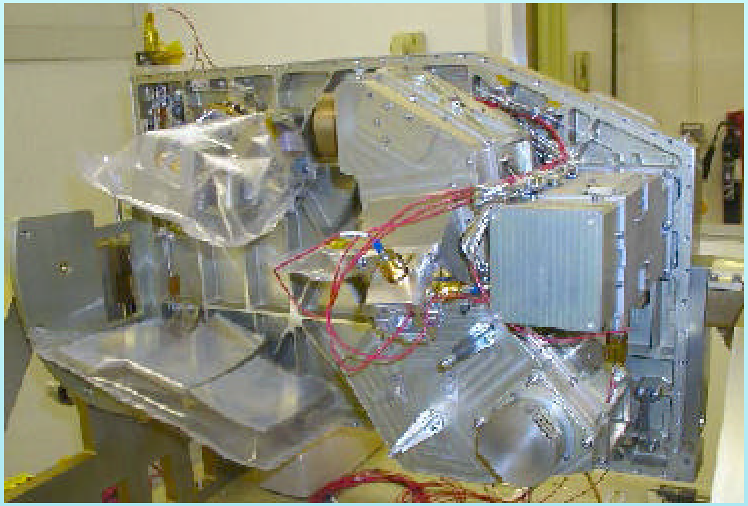
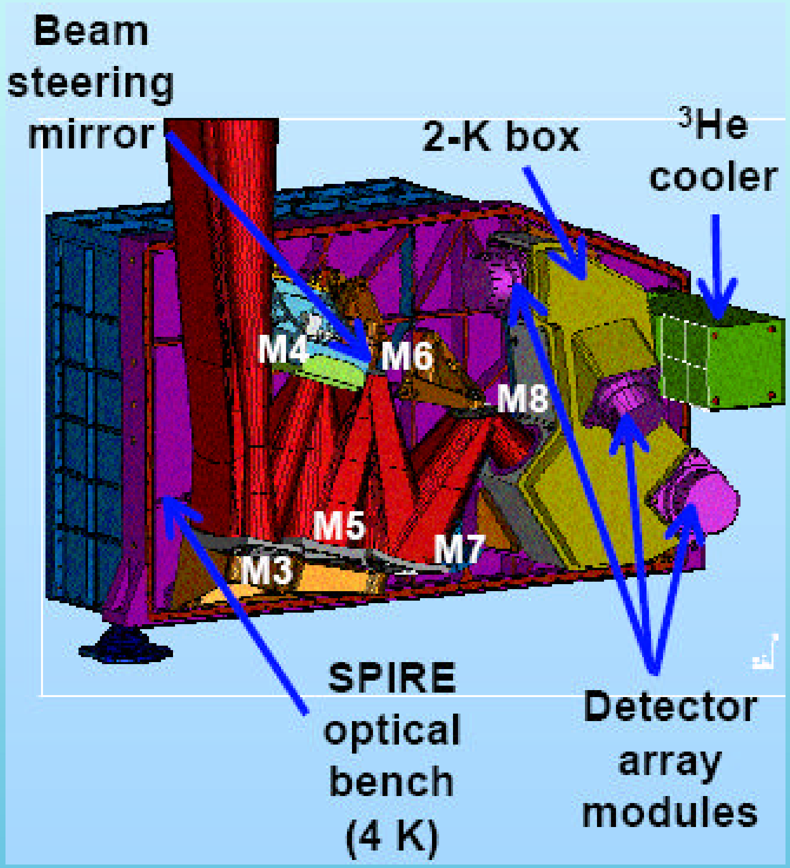
SPIRE Photometer

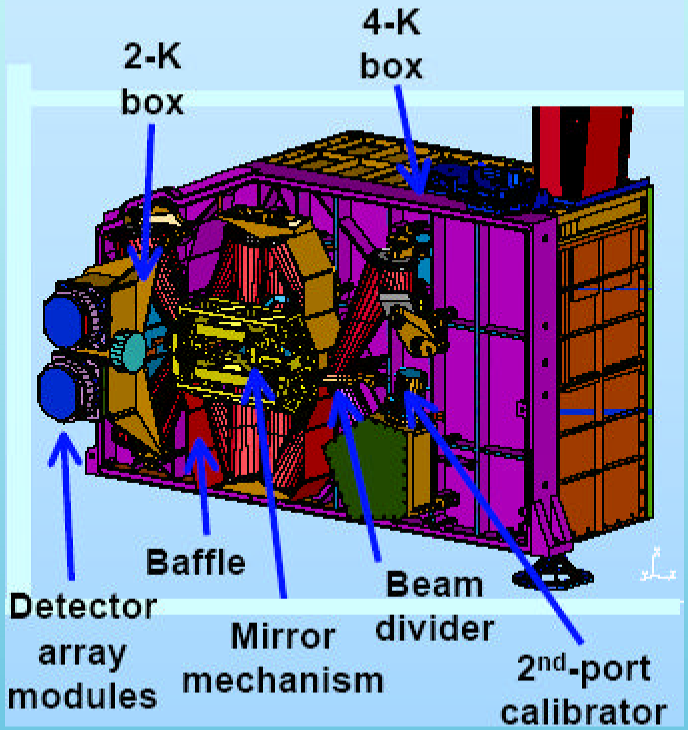


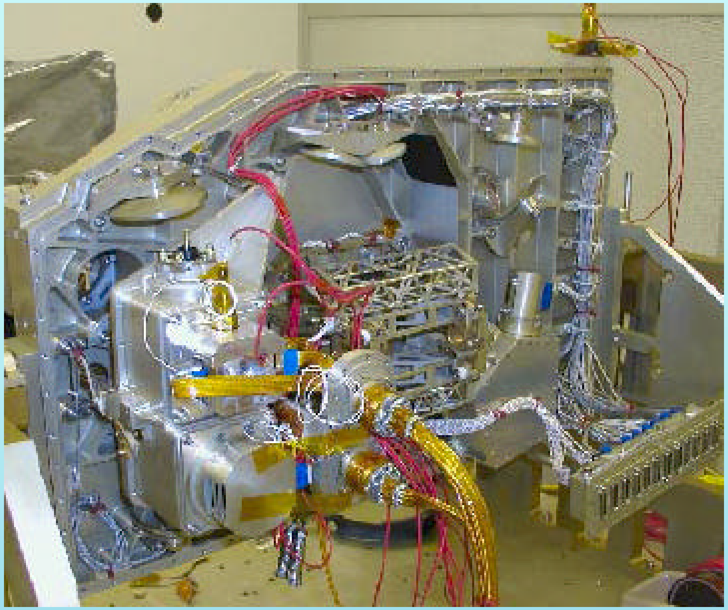


3-band imaging photometer

- **250, 360, 520 μm (simultaneous)**
- ?/??~ **3**
- **4 x 8arcminutefield of view**
- **Diffraction limited beams (18”, 25”, 36”)**

SPIRE Spectrometer

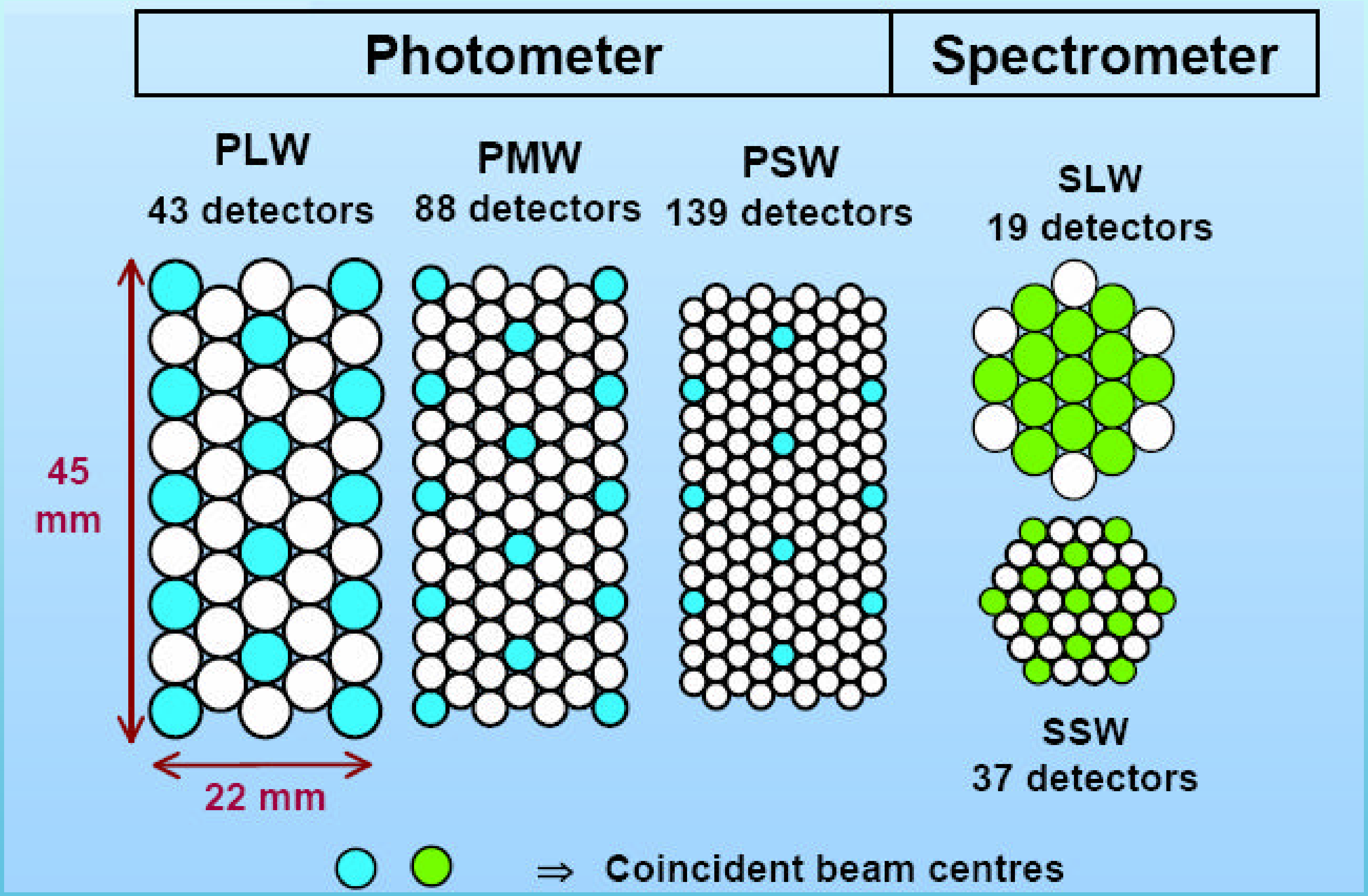




Imaging FTS

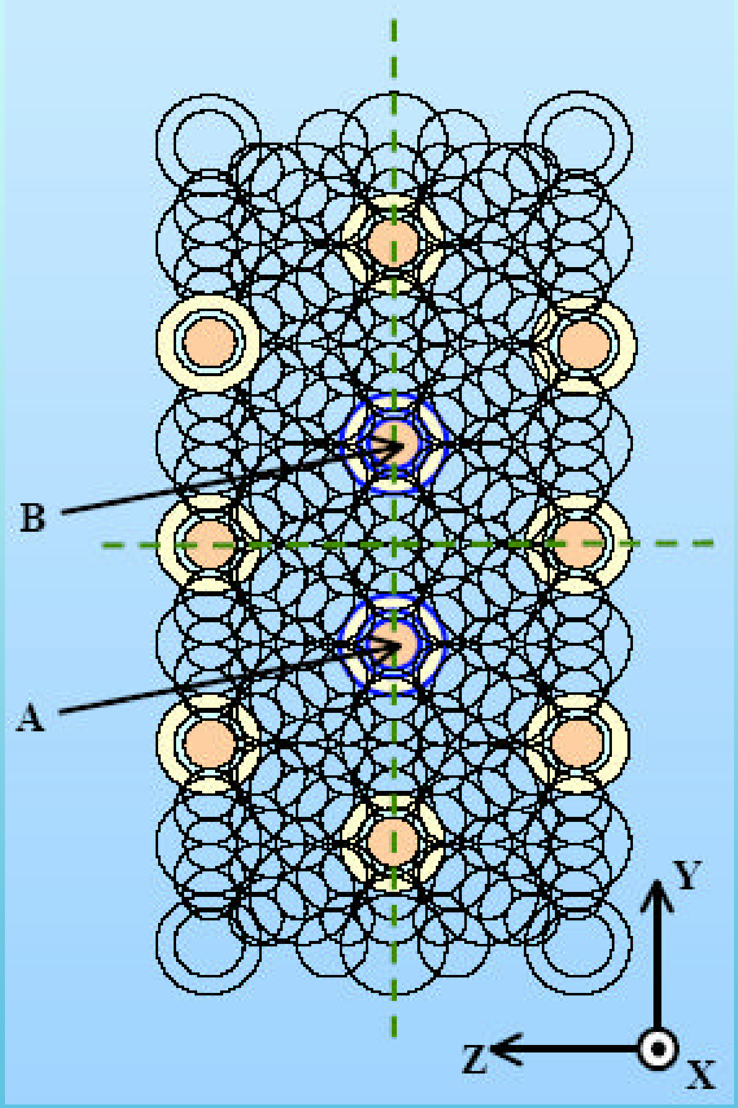
- **200 -670 μm**
- **2.6 arcminute field of view**
- **Adjustable spectral resolution**
- ?s **= 0.04 cm-1 :** ?/?? **= 370 -1250 from 670 -200 μm)**
- ?s **= 1 cm-1 :** ?/?? **= 15 -50 from 670 -200 μm)**

Detector Arrays (2*F*?Feedhorns)



Point Source Photometry

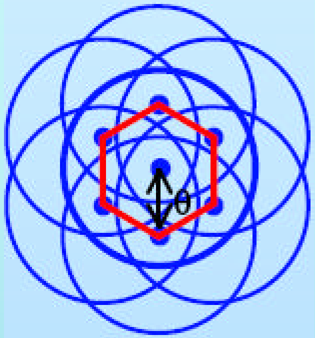
- **Telescope pointing fixed**
- **Chopping in Y-direction between A and B (126")**
- **<u>Simultaneous</u> observation in the <u>three bands</u> with two sets of co-aligned detectors**
- **OK if the pointing is accurate enough (~ 1.5")**

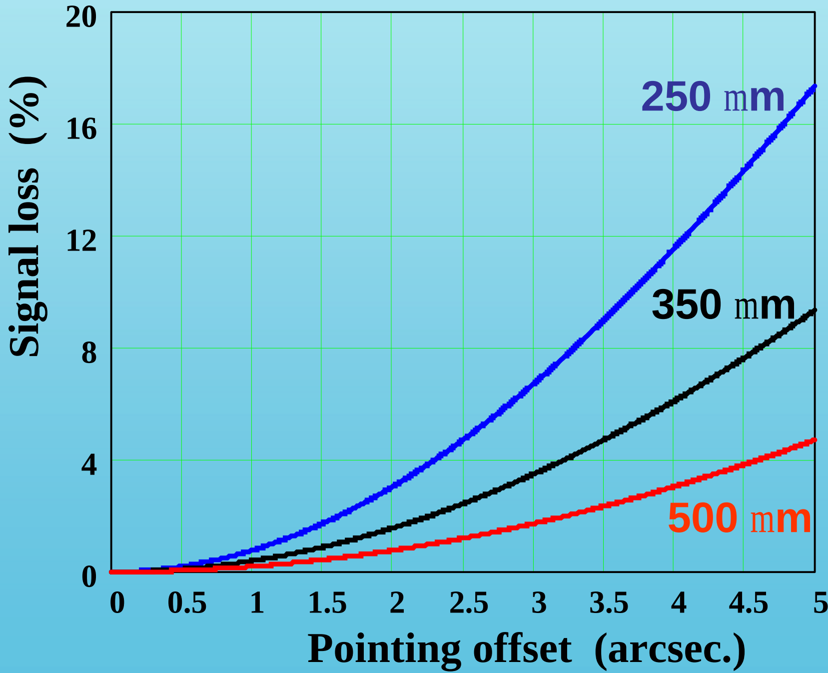


Seven Point Jiggle Map

- **Chopping 126”**
- **7-point jiggle pattern**
- **Angular step q ~ 4 - 6 arcseconds (> pointing or positional error)**
- **Total flux and position can be fitted**
- **Compared to single accurately pointed observation, S/N for same total integration time is only degraded by**

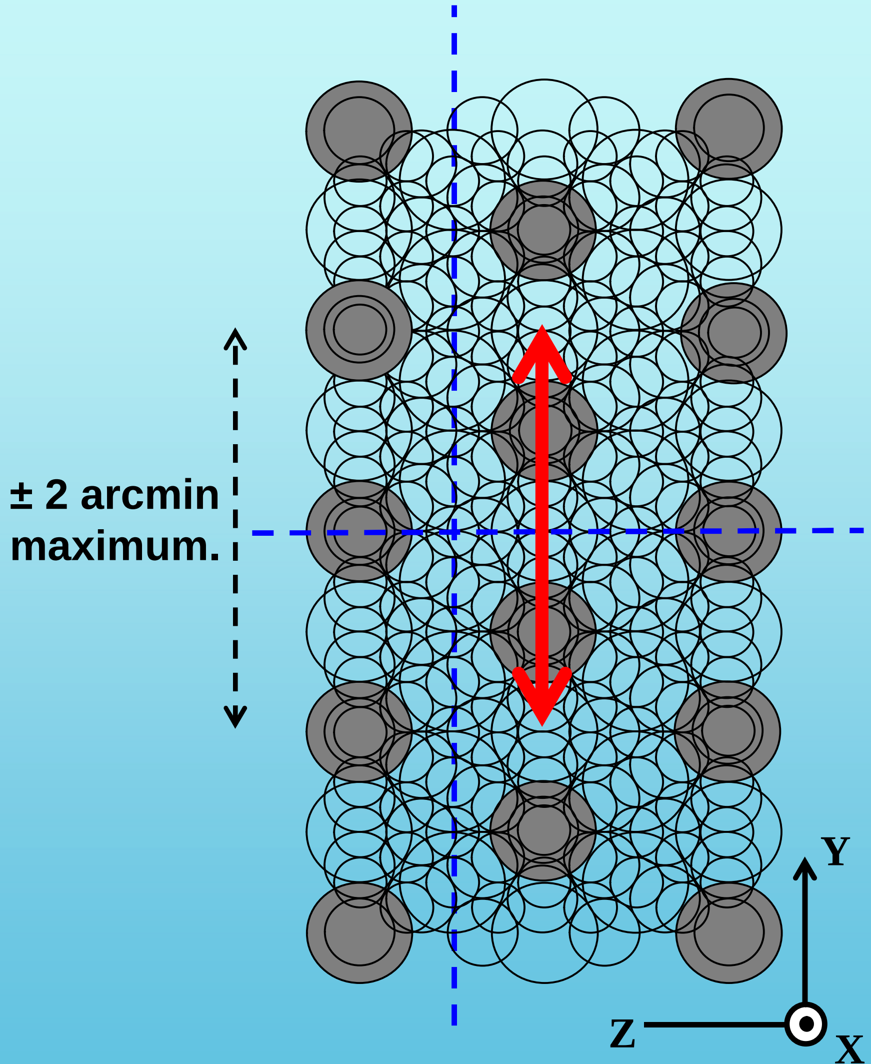
~ 20%	**at**	**250 mm**
~ 13%	**at**	**360 mm**
~ 6%	**at**	**520 mm**





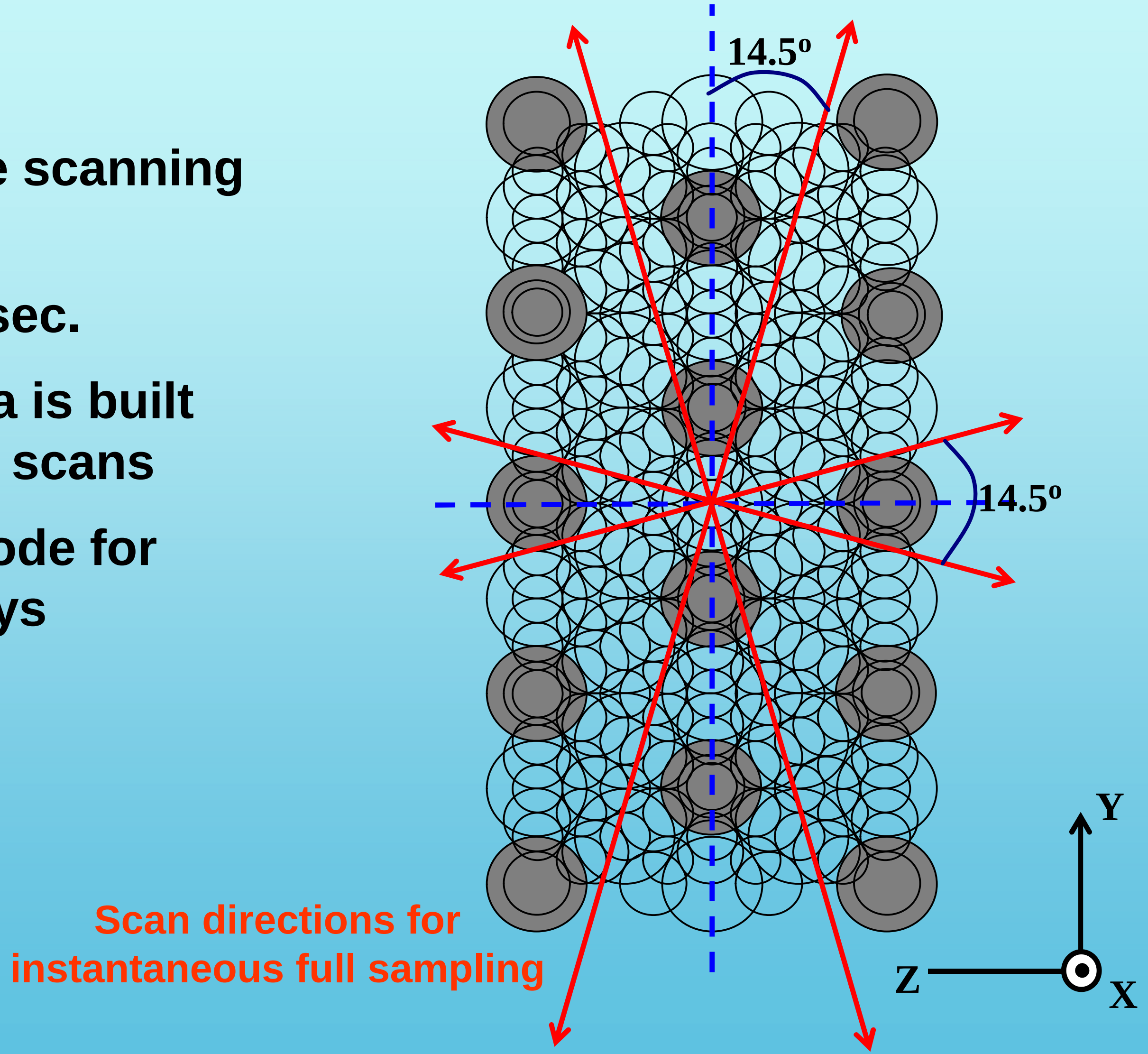
Field (Jiggle) Mapping

- **Telescope pointing fixed**
- **Chopping ± 2 arcmin amplitude in Y direction**
- **64-point "jiggle" pattern for full spatial sampling**
- **Available fov = 4 x 4 arcmin**

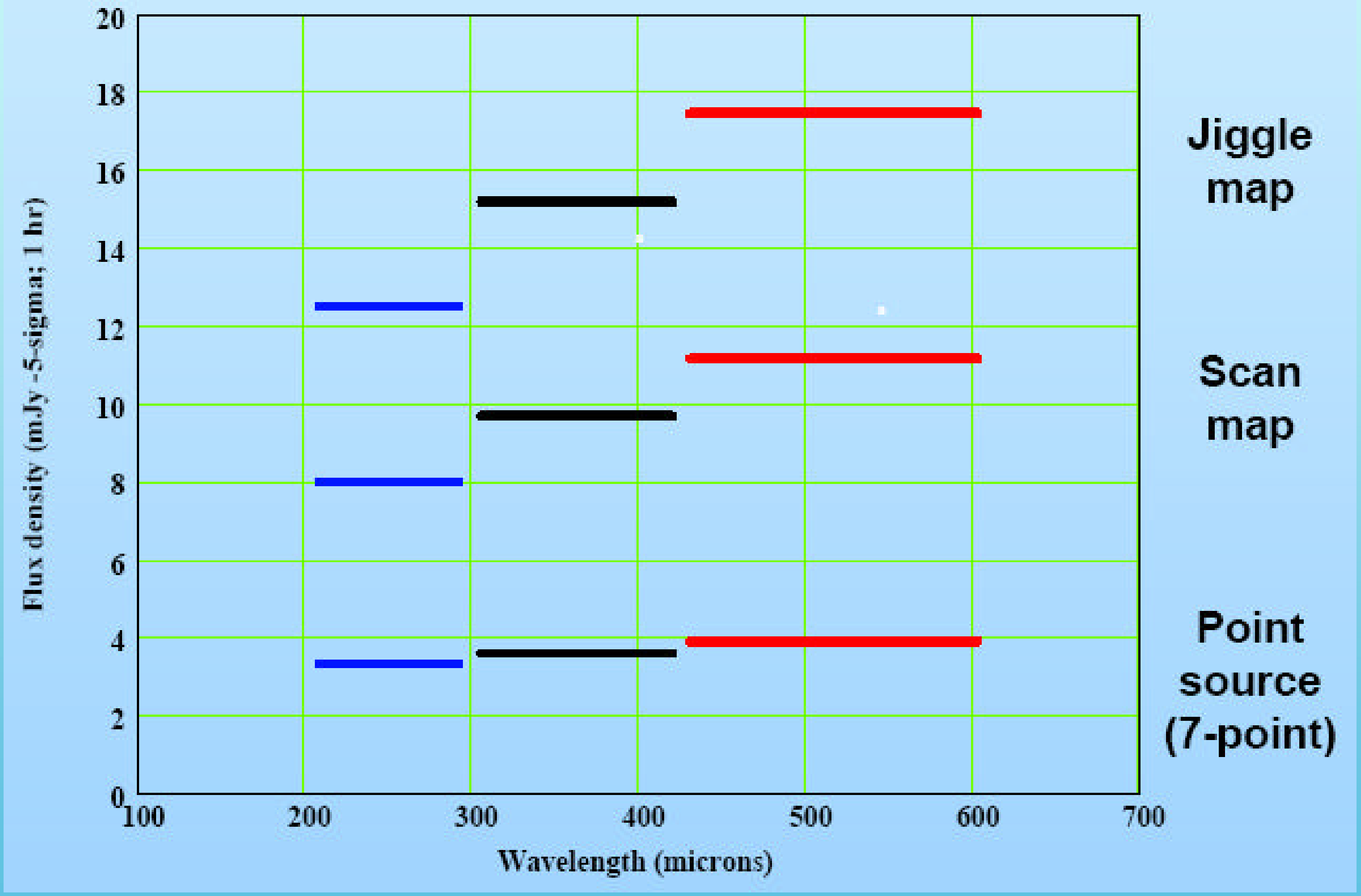


Scan Mapping

- **Telescope in line scanning mode**
- **Scan rate ~ 30”/sec.**
- **Map of large area is built up from multiple scans**
- **Most efficient mode for large-area surveys**



Sensitivity: Photometry (5 s ; 1 hr)



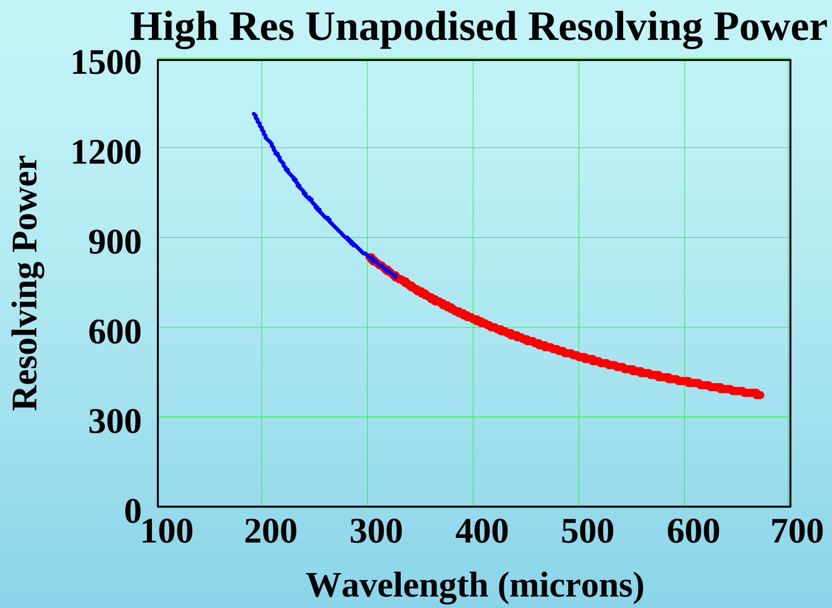
FTS Observing Modes

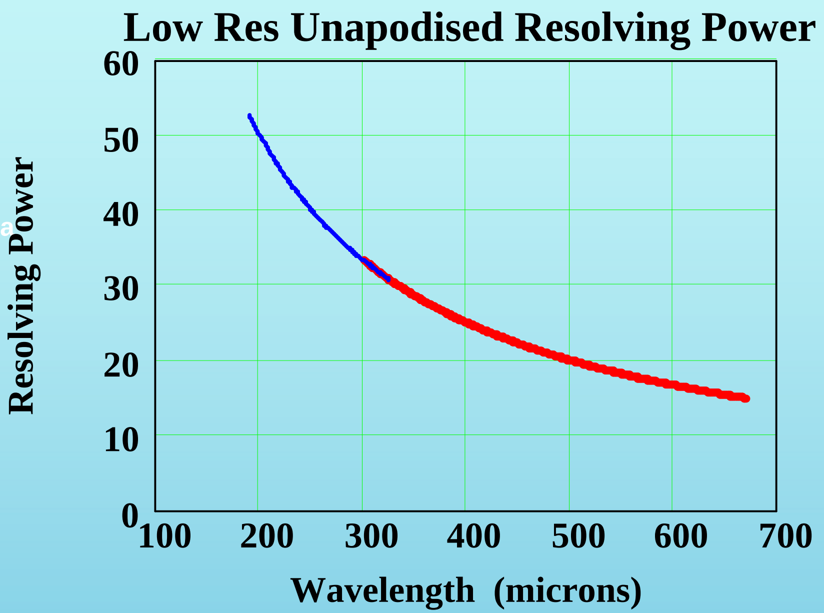
- Ds **= 0.04 - 2 cm^{-1} by adjusting scan length**

- **Point source or sparse map spectroscopy/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**

FTS Resolving Power

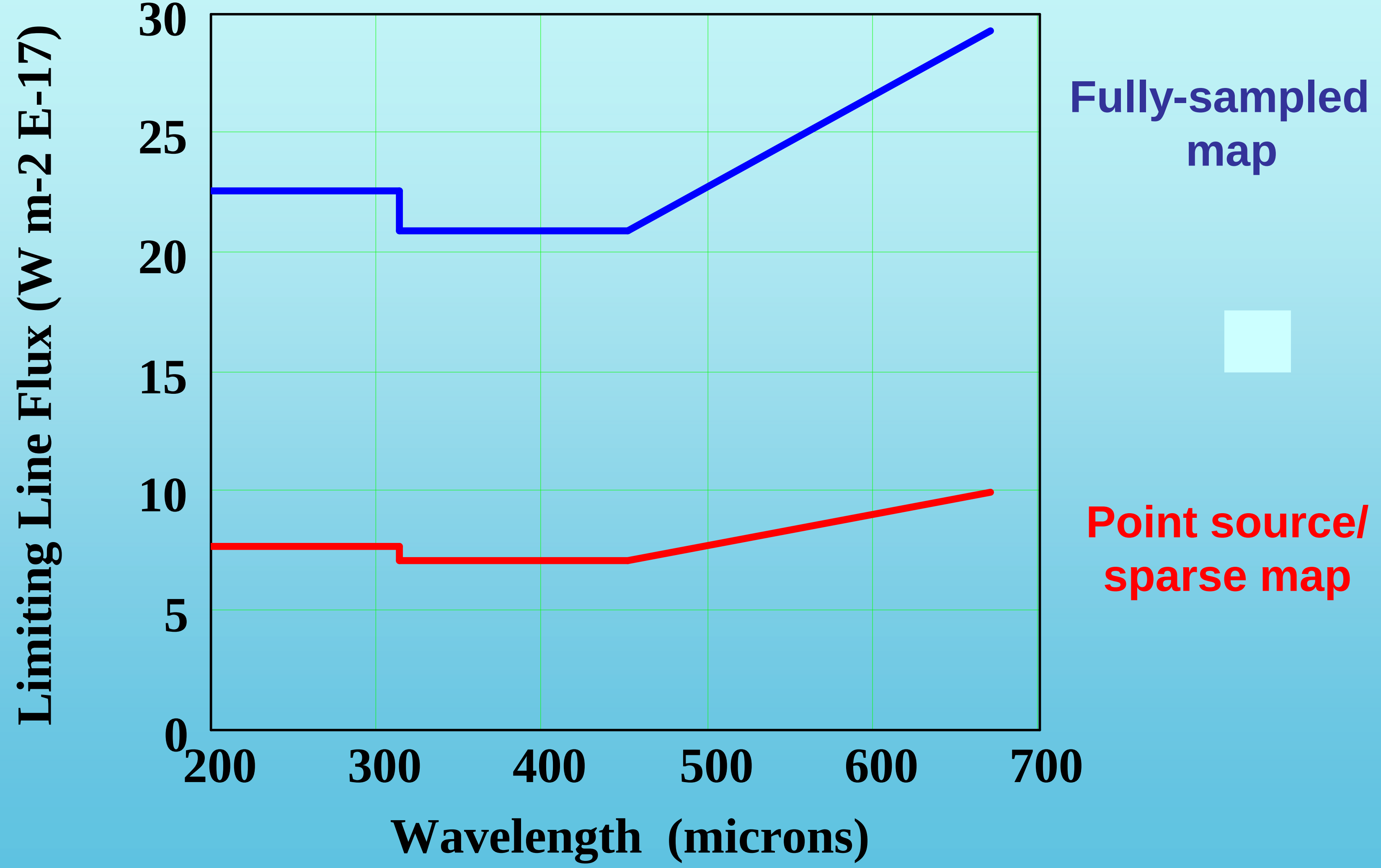




FTS Spectral Resolving Power (0.04 cm-1resolution)

FTS Spectral Resolving Power (1 cm-1 resolution)

Sensitivity: Line Spectroscopy (5 σ ; 1 hr)



Accuracy

Requirements

- SPIRE absolute photometric accuracy is required to be 15% or better at all wavelengths with a goal of 10%
- The relative photometric accuracy is required to be better that 10% with a goal of 5%
- SPIRE photometry must be linear over a dynamic range of 4000 for astronomical signals (confusion limit ~15 mJy - ~ few 10’s Jy)

Expectations

- We expect to achieve a highly stable calibration
- The expectation is that there will be significant improvements on the 10-20% currently achieved by ground-based facilities.

Calibration needed in the 'three' mission phases

Ground Calibration – uses known laboratory sources

- will provide fundamental detector characterisation
- will provide only measurement of spectral response of the photometer

PV Phase – fundamental calibration of the instrument, types of measurements include…

- Instrument characterisation, mainly mechanisms, minimum resolution etc
  - *likely to require bright stable point sources*
- Detector characterisation – *dark sky for load curves*
- Photometric calibration – *point sources, range of known fluxes*
- Spectral calibration – *bright sources with known spectrum*,
  - *desirable to have a range of spectral shapes*
  - *Desirable to have both line and continuum sources*

Calibration needed in the three mission phases

PV Phase

Optical characterisation –

- requires bright stable point sources, plus a known extended source to check coupling,
- multiple sources in same field to check spatial characteristics desirable

Routine Phase – ensuring instrument fundamental calibration remains valid

- Routine monitoring of instrument e.g. calibrator output darks etc
- Routine photometric monitoring of standards
  - requires high visibility, preferably done with a range of fluxes e.g. 3-5 sources
- Infrequent checks of fundamental calibration
- *It may be necessary to use some of routine phase calibration time for ongoing fundamental calibration work e.g. if sources were not visible during PV phase*

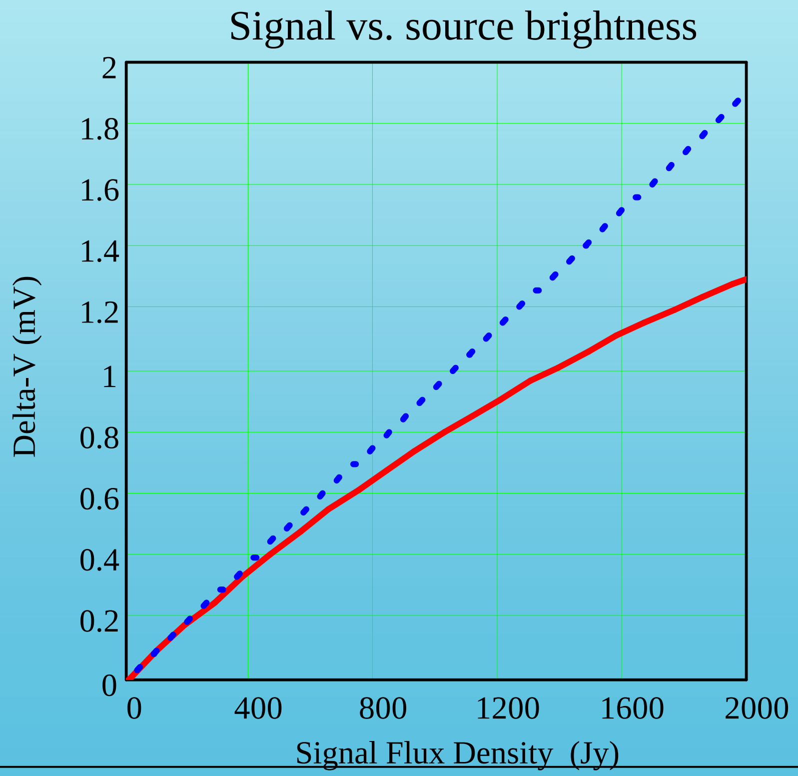
What is a bright source for SPIRE?

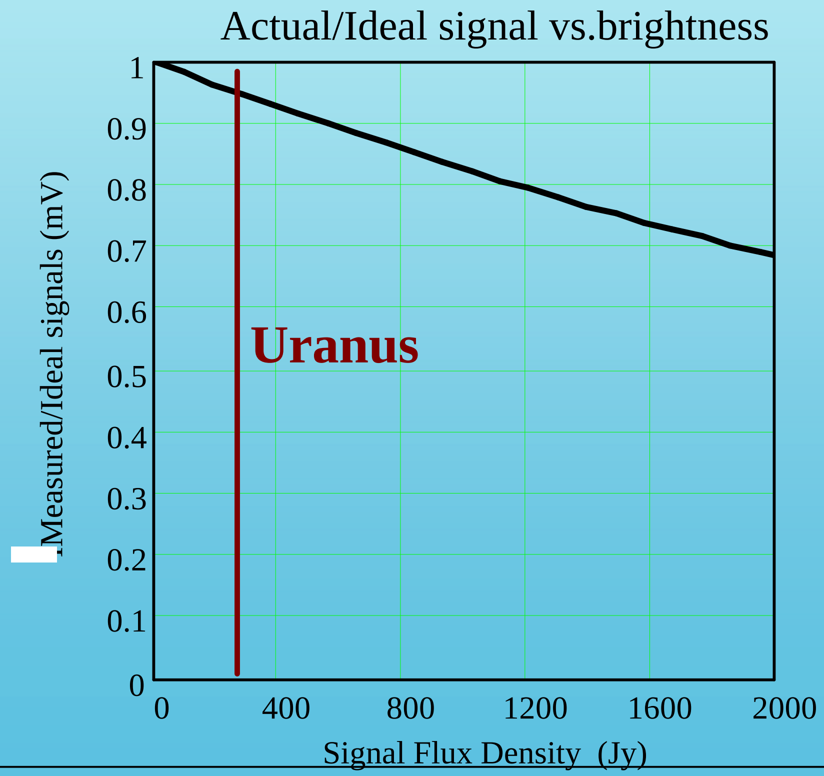
Faint calibrators – stars, lowest ~100 mJy

Intermediate – asteroids / Jovians satellites, a few Jy – 200 Jy

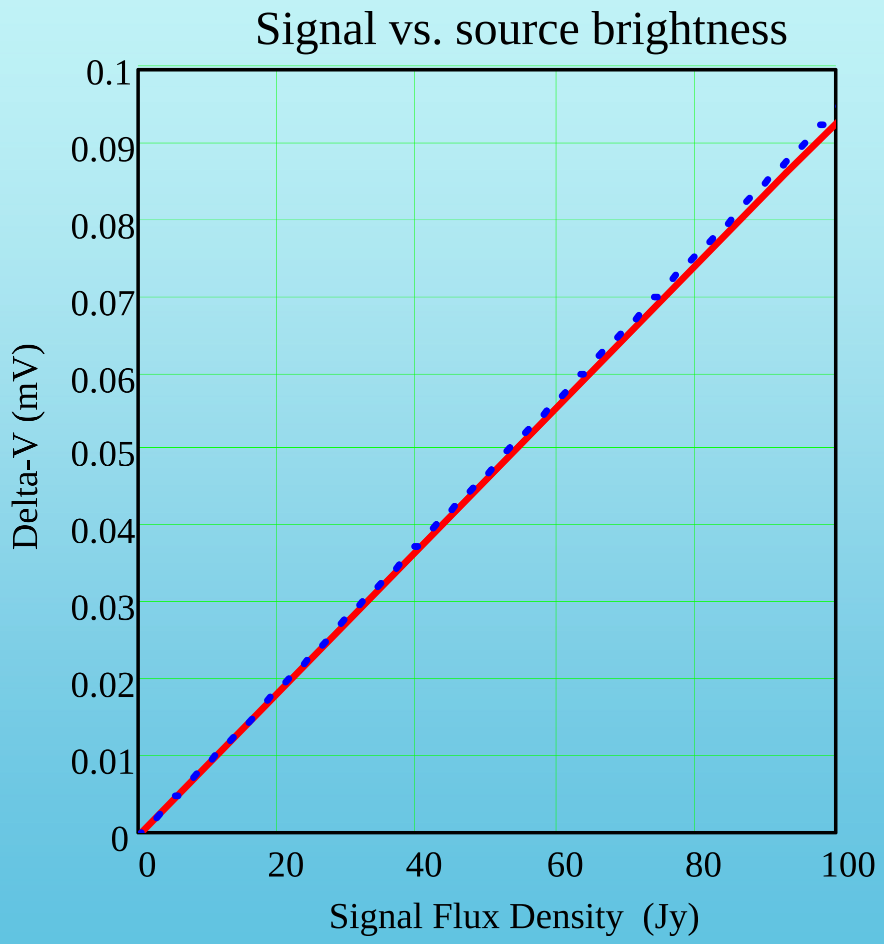
Highest - Neptune a few 100Jy

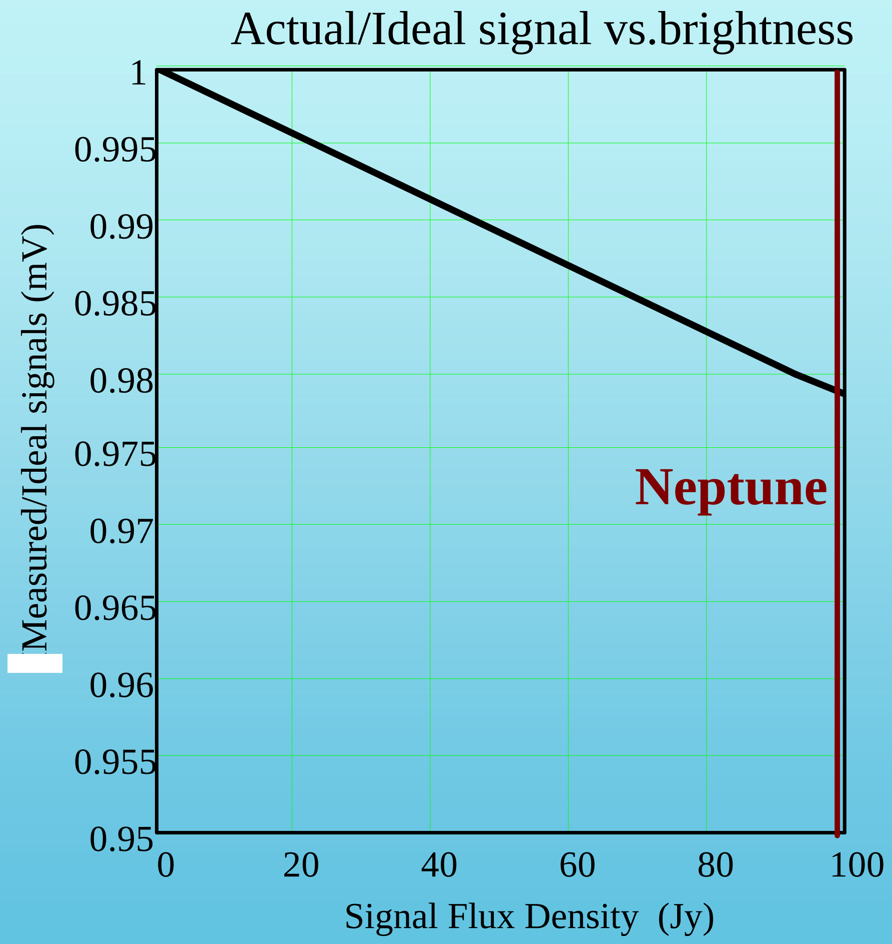
Very high - OMC1, W51, W49 ~ 1000 Jy





Photometer (PMW band)





Sources - Planets

Mars

Too bright for SPIRE

Uranus

Too bright to be the primary calibrator for the photometer and spectrometer, provides spectrum with fewer features than Neptune

Neptune

Primary source for both the photometer and spectrometer, likely to used as a spatial calibrator i.e. for PSF measurements

To what accuracy is the brightness temperature spectrum known – how well do the models agree?

How well can it provide a check of the relative spectral response?

How good is the visibility?

Sources – Solar System

Asteroids and Galilean Satellites

Used to provide range of flux sources, will be photometrically tied to Neptune by SPIRE observations including variability

We will have to understand how the instrument can be used to tie the asteroid and planet calibrations together

What accuracy models can be achieved at what flux levels?

How well can asteroids provide a check of the relative spectral response?

Sources – Stars

Stars

Used to provide range of low flux well known sources

Possible use for spatial checks

Again we will have to understand how the instrument can be used to tie the calibrations together

How many?

What accuracy models can be achieved?

How can we validate them at SPIRE wavelengths?

Summary

High accuracy requirements mean that we require primary calibrators which are well understood.

- Neptune models – main priority for SPIRE how well do these compare, how can we verify them?
- Stars – how many and to what accuracy?
- Asteroids – what can be done ahead of Herschel?