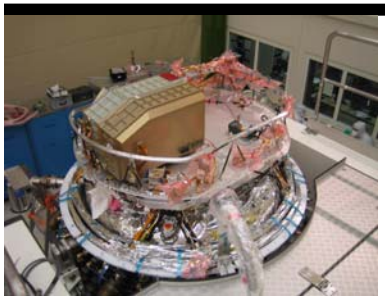


SPIRE Overview

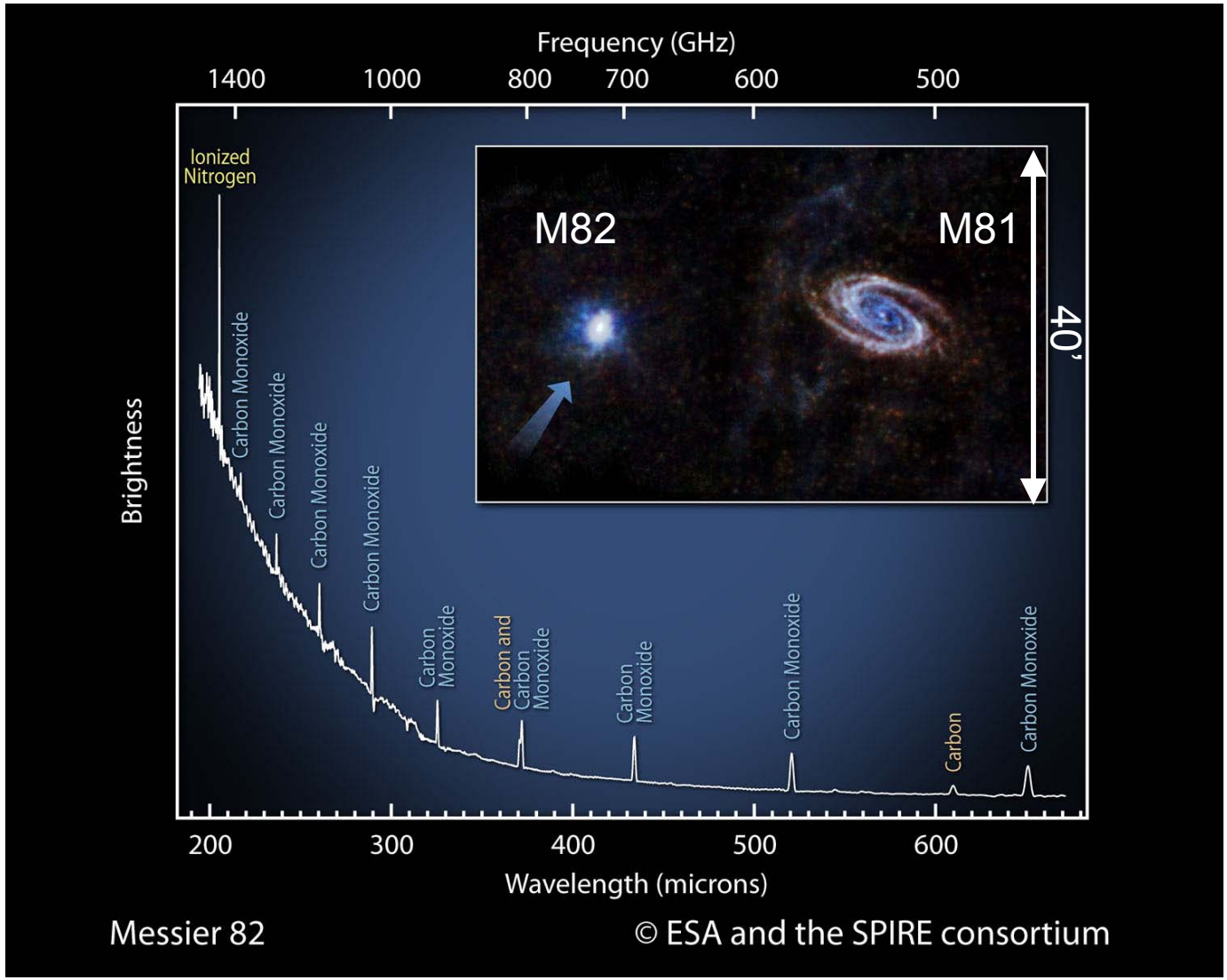
Bernhard Schulz,
Nanyao Lu, Kevin Xu, Dave Shupe,
Lijun Zhang, Arnie Schwartz

NASA Herschel Science Center

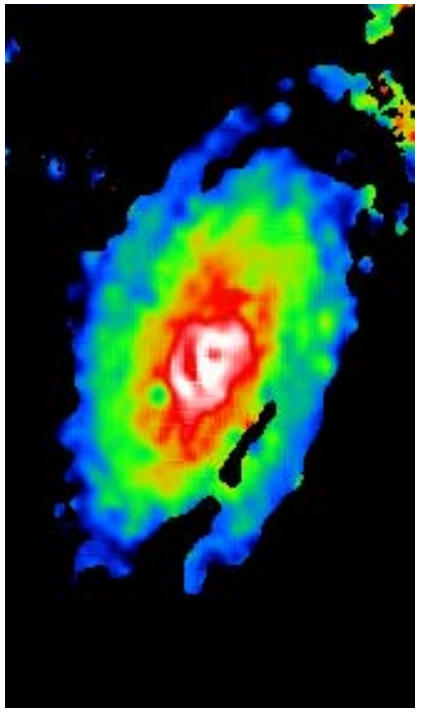
Dust in our own Galaxy

- PACS and SPIRE parallel mode observation of the galactic plane
- Two colors from two PACS bands and one color from three SPIRE bands.

SPIRE ICC



M 81

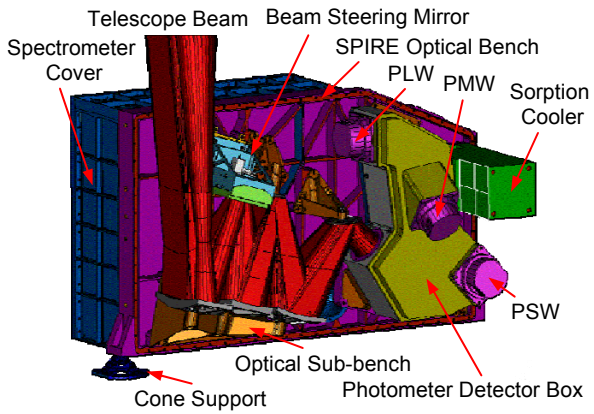


SPIRE 250/350

D=3.2 Mpc

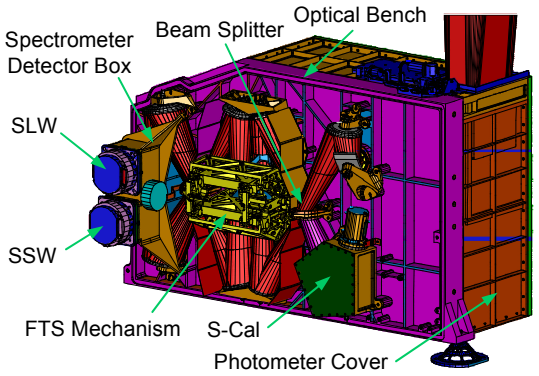
Chris Wilson and the SAG2 Consortium

The SPIRE Instrument



Imaging Photometer

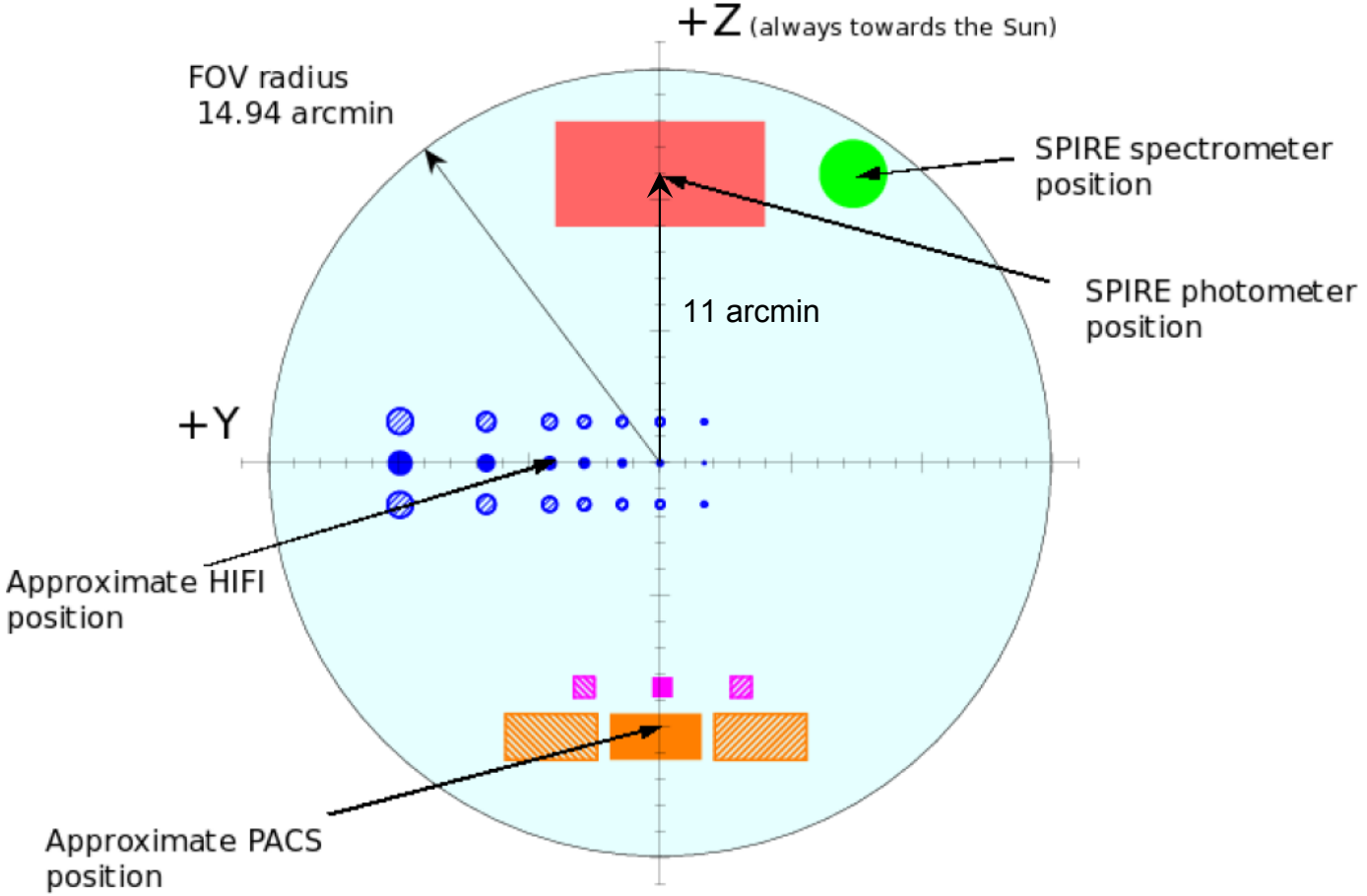
Simultaneous observation in 3 bands
139, 88, and 43 pixels
Wavelengths: 250, 350, 500 μm
$\lambda/\Delta\lambda \sim 3$
FOV 4' x 8', beams 18.1", 25.2", 36.6"



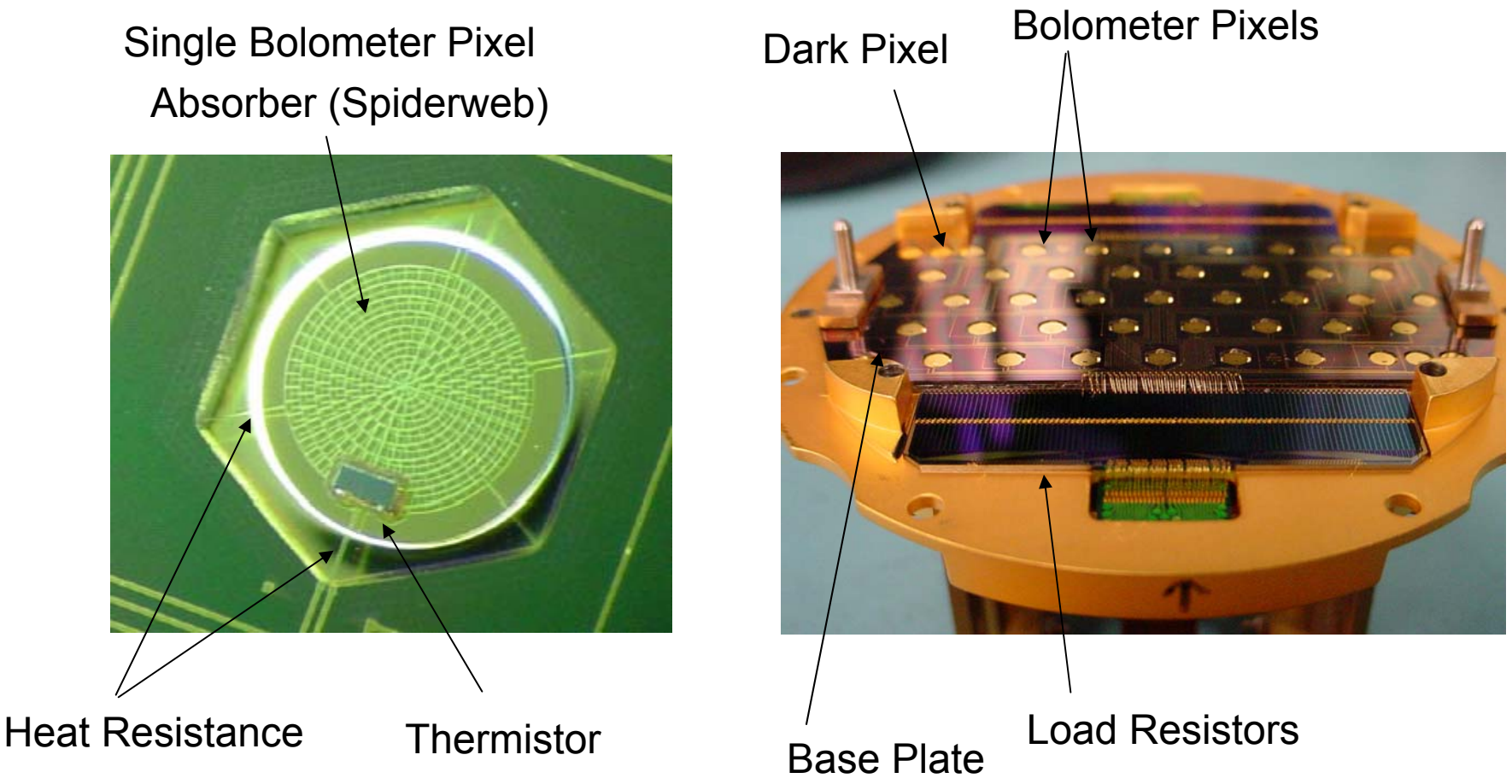
Imaging Fourier Transform Spectrometer

Simultaneous imaging observation of the whole spectral band
37 and 19 pixels
Wavelength Range: 194-313, 303-671 μm
Resolution: 0.04, 0.24, 0.83 cm^{-1}
Circular FOV 2.0‘ diameter,
beams 17-21”, 29-42”

SPIRE in the Herschel Focal Plane

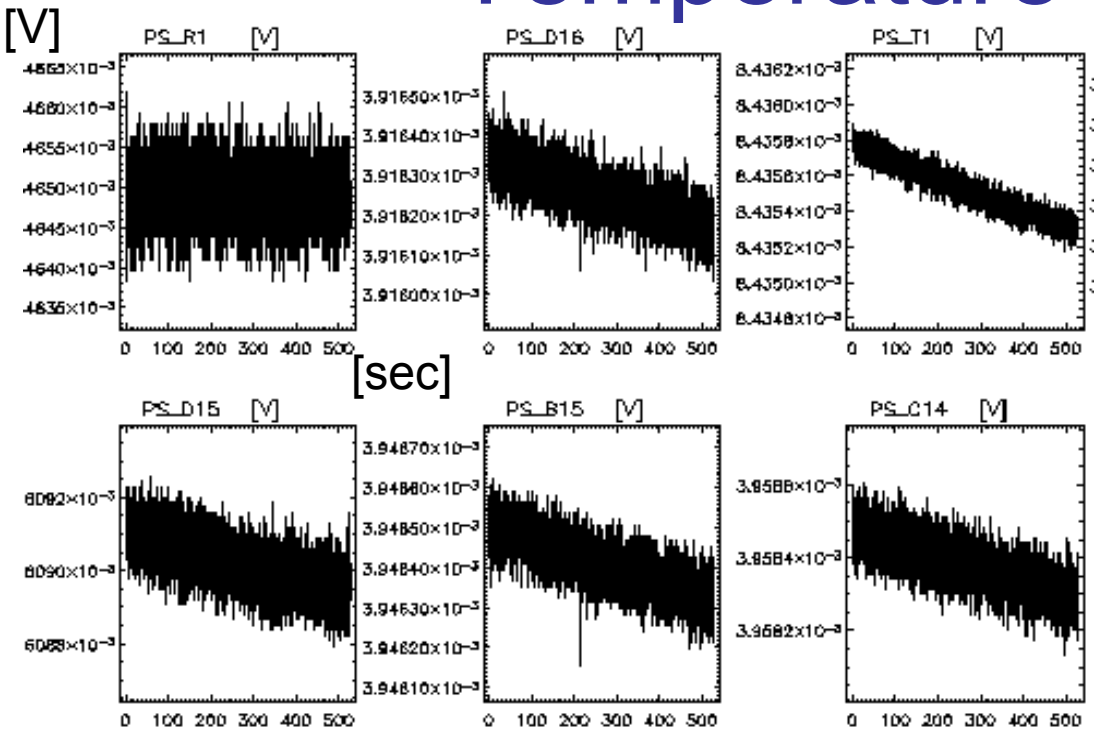


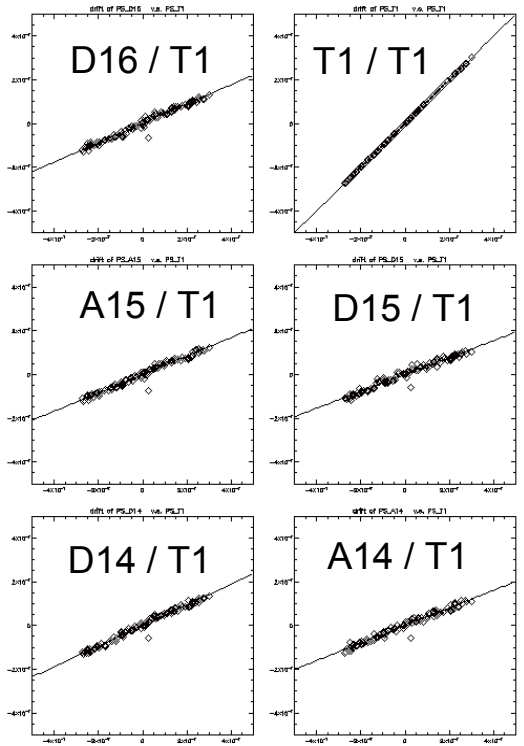
Components of the BDA



Temperature Drifts

PSW array

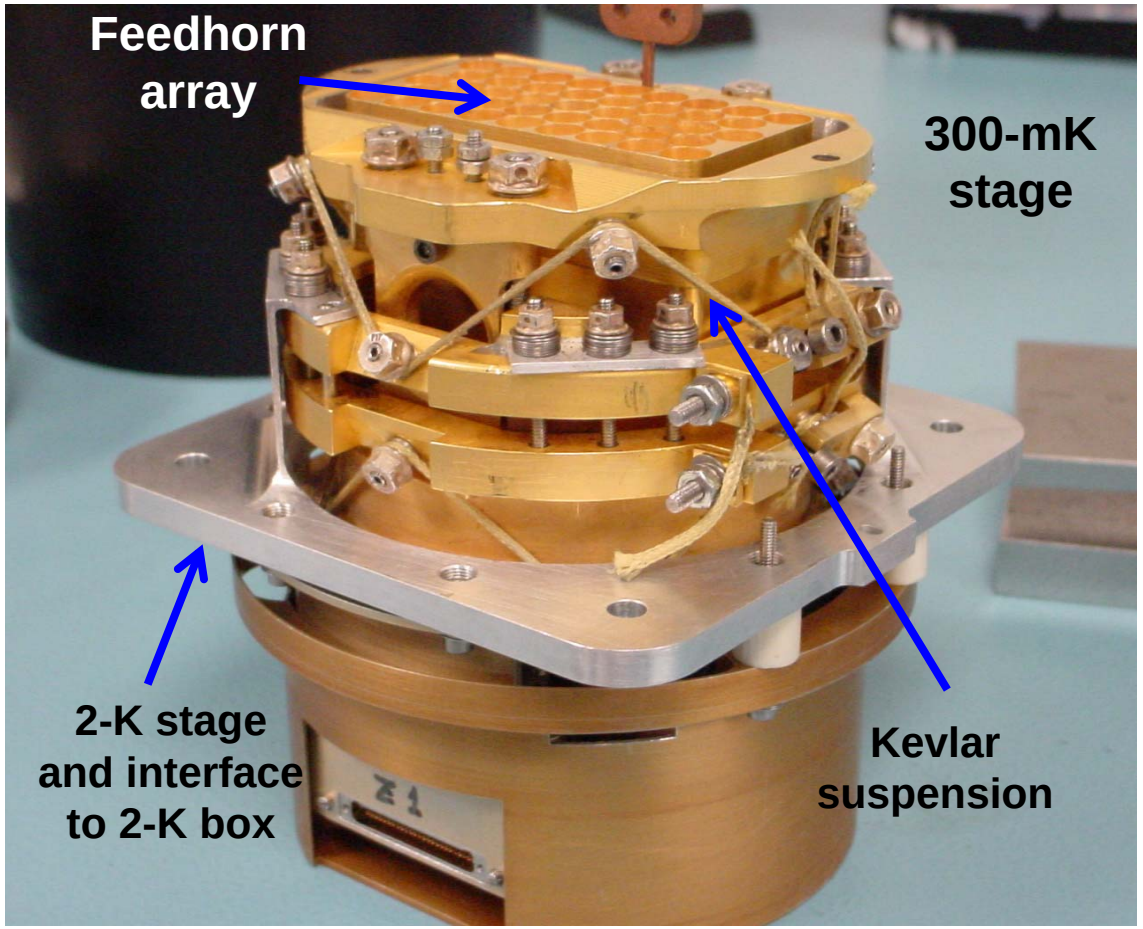




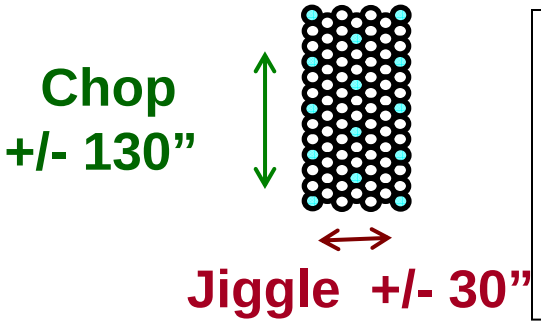
Most signal drifts come from temperature changes, as shown by the perfect correlation of thermistor pixel T1 and detector signals. The resistor pixel R1 does not vary with temperature.

Signal is very stable after correction with thermistor signals (1/f knee < 10mHz).

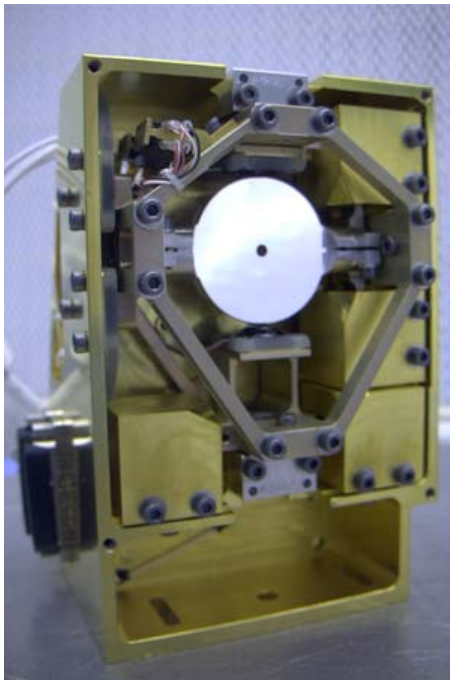
Bolometer Detector Array (BDA)

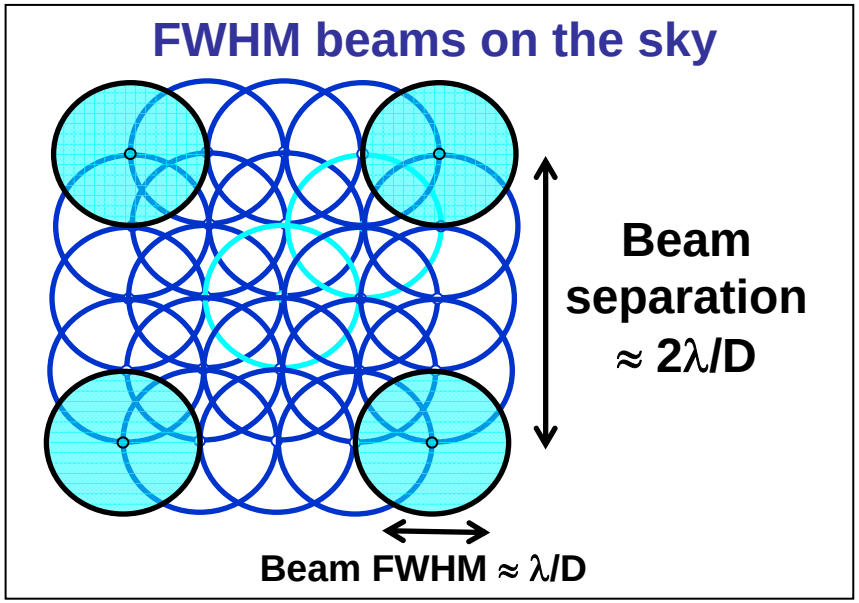


Beam Steering Mechanism



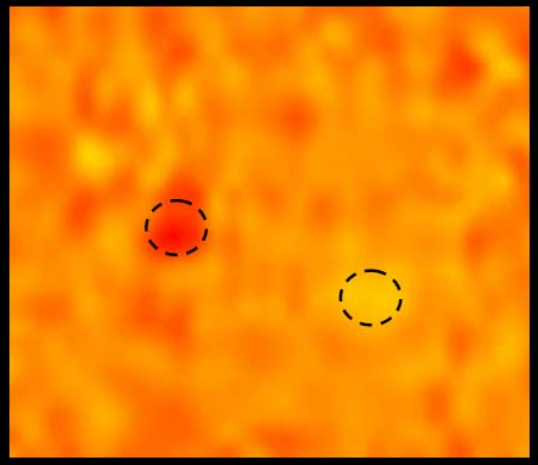
Includes also PCAL calibration source that illuminates all detectors simultaneously.

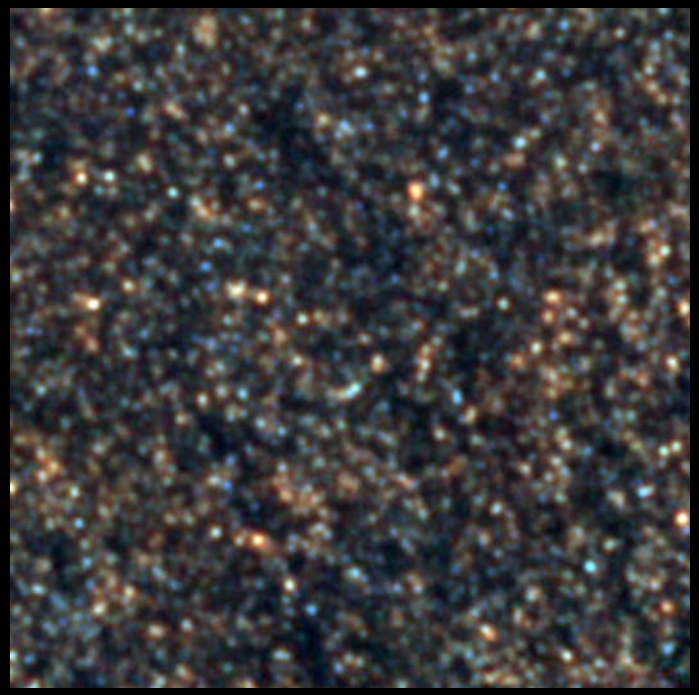


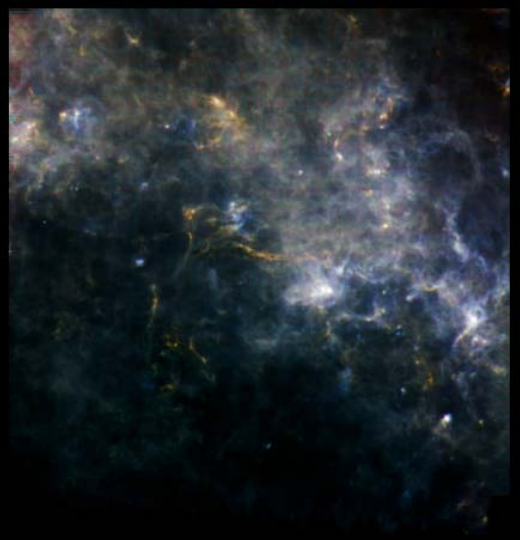


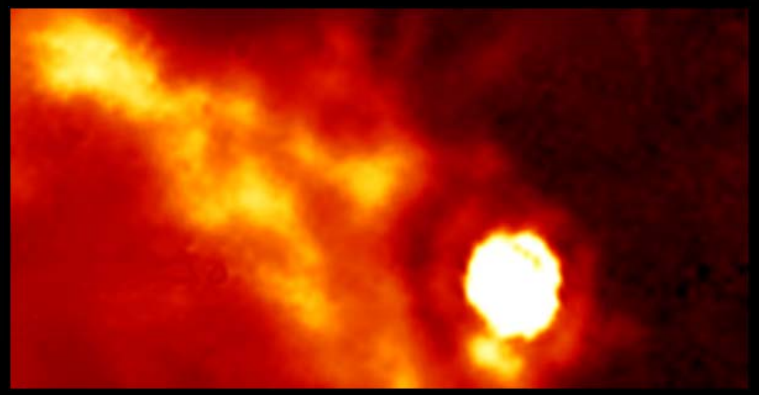
- Point source photometery
  - 7 point jiggle, chop/nod
- Spectrometer mapping
  - No chop/nod

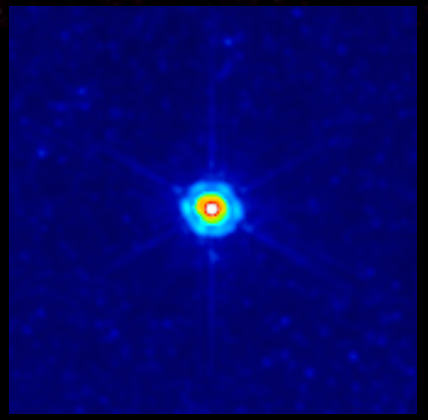
Photometer











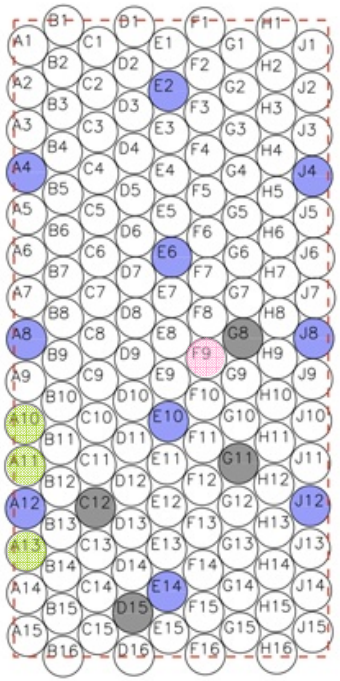
Detector Arrays

- Slow
- Noisy
- Dead
- Overlap

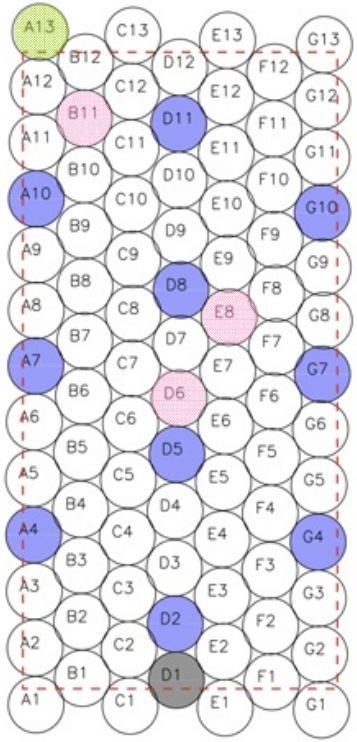
+Y
+Z

Note: Projection down focal plane not onto sky

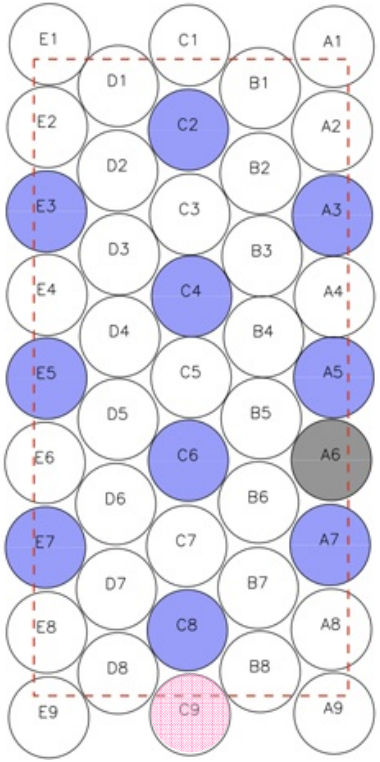
PSW

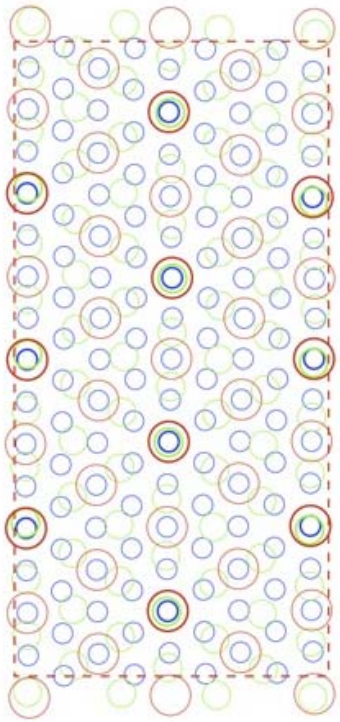


PMW



PLW





Overlapping Detectors

Photometer Sensitivities

Wavelengths (μm)	250	350	500
Point Source (mJy, 7-point mode, one repeat ABBA)	7.0	7.0	7.0
Small and Large Map (mJy, 1σ, one repeat A+B scan, nominal speed)	9.0	7.5	10.8
Extragalactic confusion noise (mJy 1σ)	5.8	6.3	6.8

HSpot provides more specific values depending on parameter selection

Photometer Flux Calibration

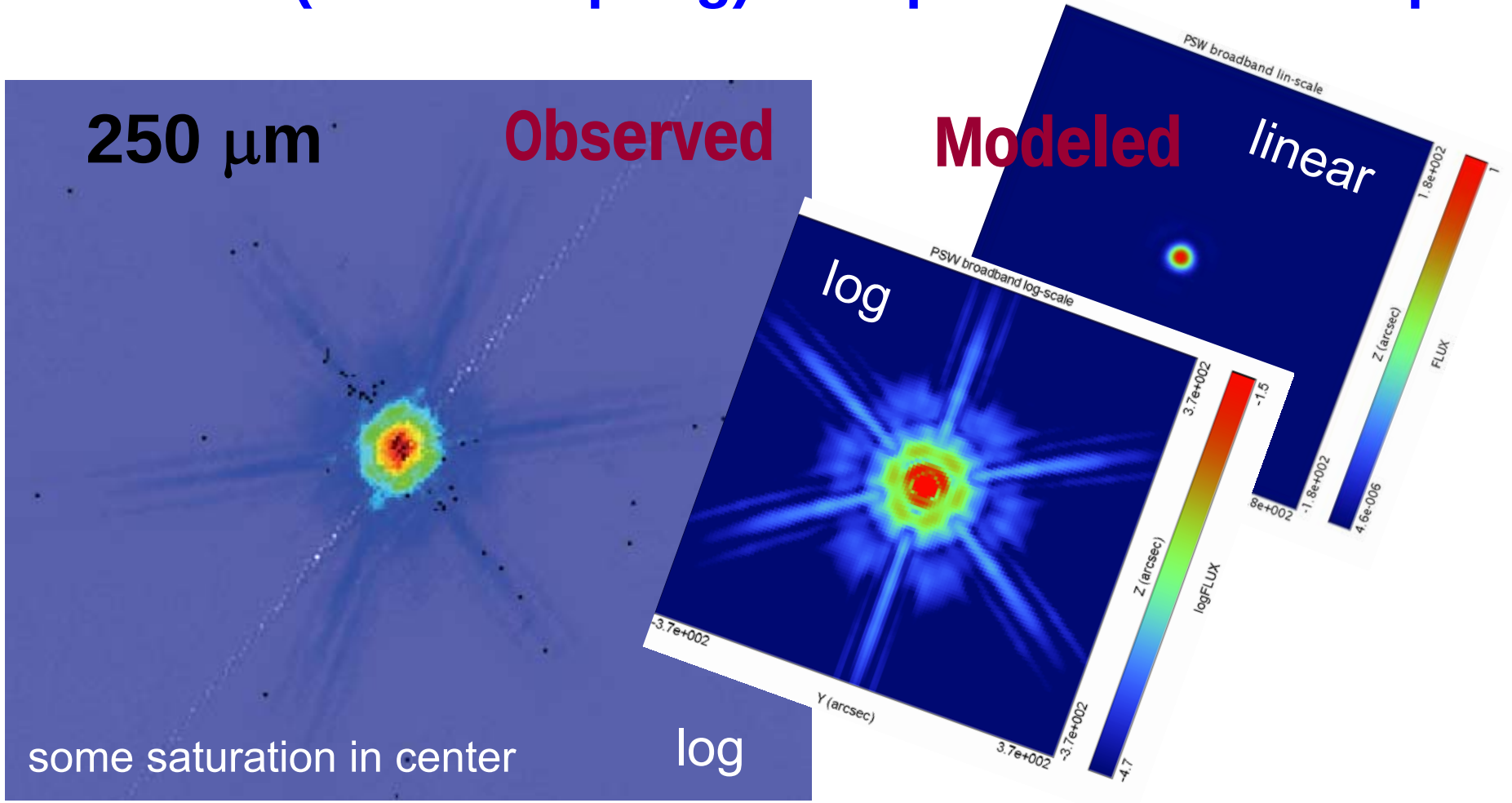
- SPIRE uses Neptune as primary flux calibration standard for the photometer.
- Neptune model estimated absolute accuracy = ± 5% (correlated over the SPIRE range – i.e., whole spectrum moves up or down)
- SPIRE measurements are reproducible to better than 2%.
- The current overall absolute calibration accuracy is ± 7%.
- This calibration with consistent linearization and array flatfields became available with HIPE V5. The newest released version of the data reduction software is HIPE V7.
- See SPIRE Observers' Manual for further details

Beam Profiles

Band (μm)	Major Axis FWHM (arcsec)	Minor Axis FWHM (arcsec)	Mean Ellipticity (%)
250	18.3	17.0	8.1
350	24.7	23.2	6.6
500	37.0	33.4	10.9

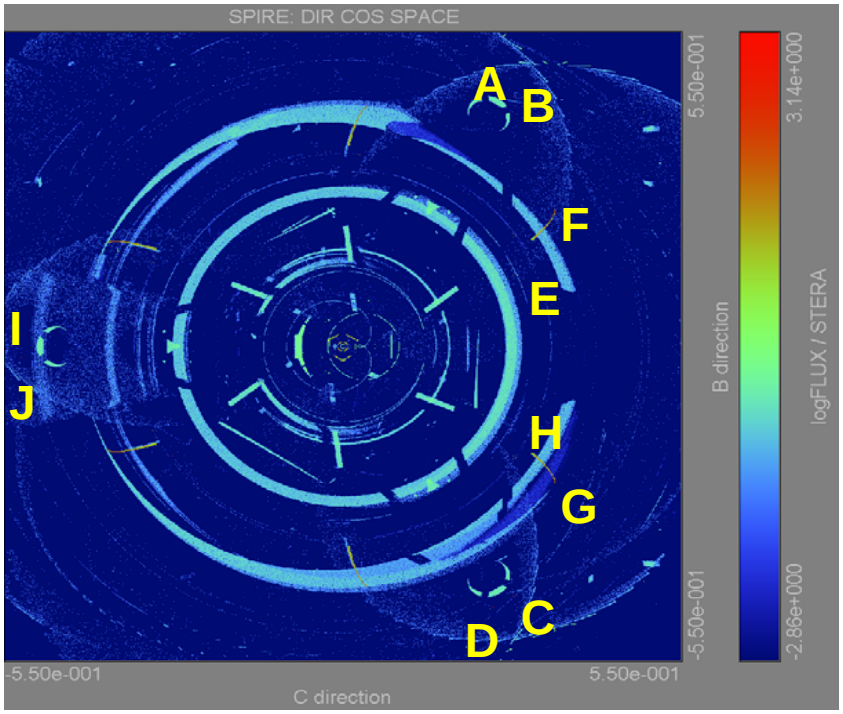
- Very close to Gaussian
- Modeled and empirical beam profiles available

Model (at 6” sampling) Compared to Mars Map

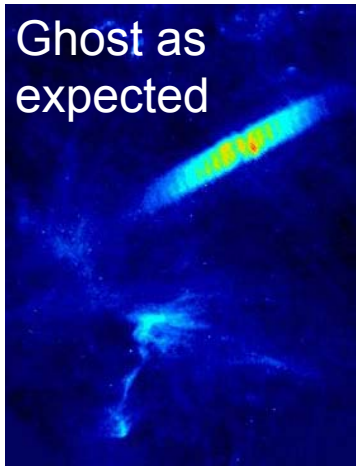


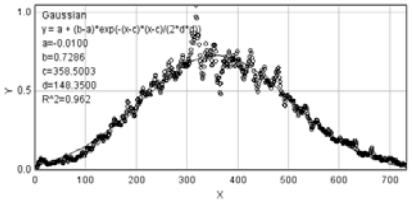
Far Field Beam

PSW OD136



Simulated sky map over ~66degx66deg around boresight (log scale) of hot spots/stray paths





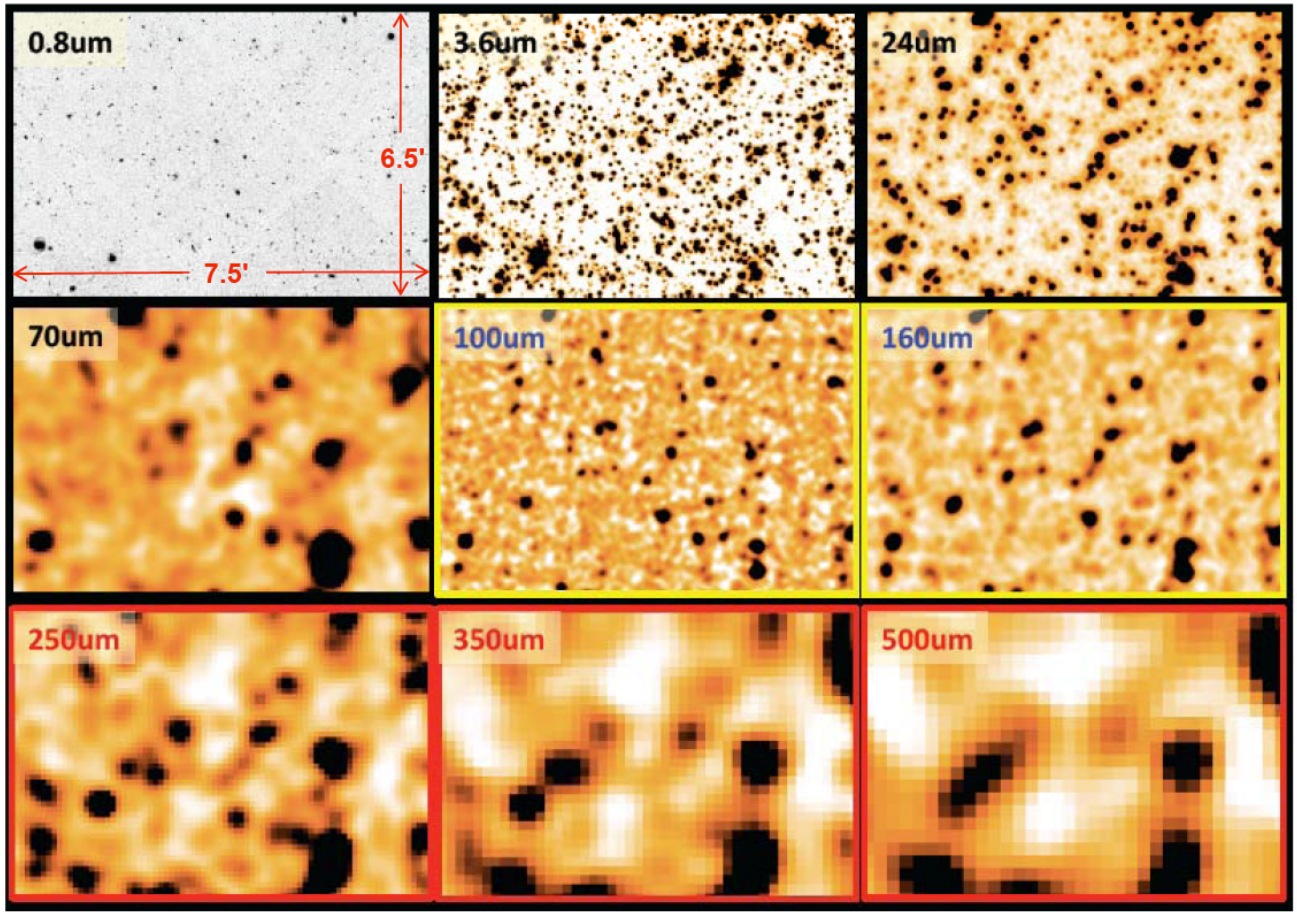
Amplitude: ~0.74 (+/-10%)

Extent, as fitted FWHM of the long dimension distribution: ~34.9arcmin (+/-10%)

Width: ~6.5arcmin (+/-10%)

- Hot Spot "I" verified with Jupiter in all 3 SPIRE wavelengths and by PACS with 2x2deg map in parallel mode.
- PACS found attenuation $5*10^{-4}$
- Good and Bad news: Measurement consistent with telescope model
- Low probability for Moon to enter, but observers should be wary of other bright sources close to telescope hot spots.

The Confusion Challenge

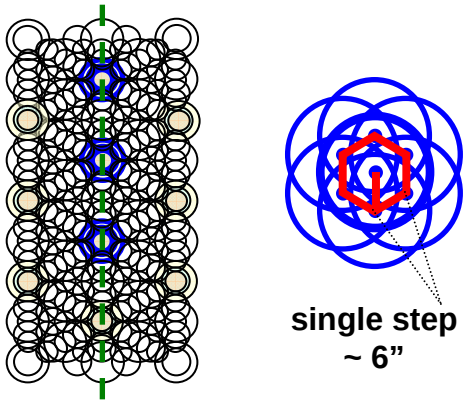


D. Elbaz

Photometer AOT

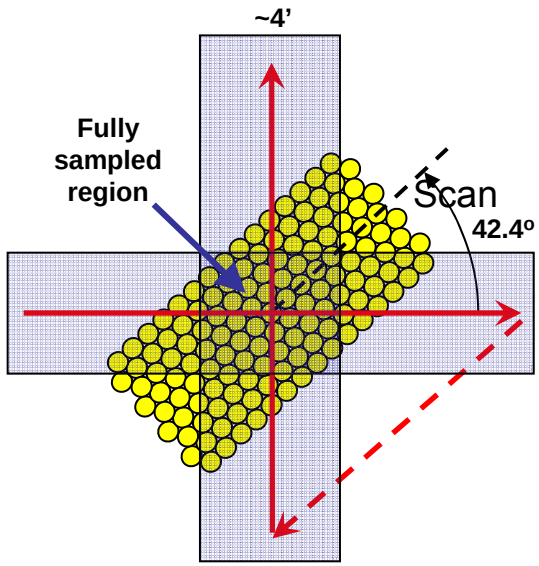
7 point jiggle (point source)

126” chop + nod



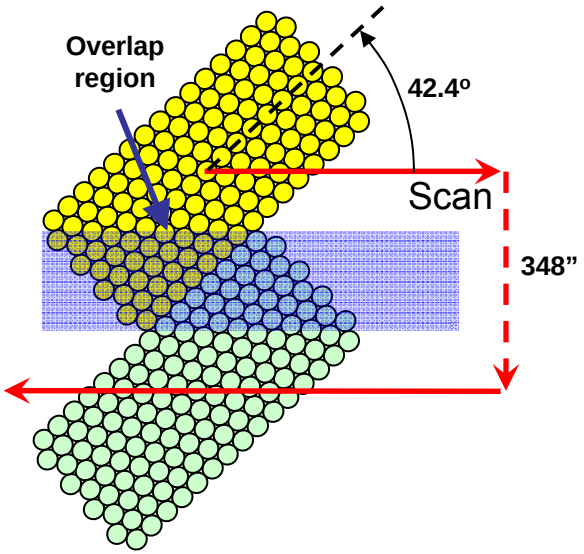
7-point jiggle for **point source photometry**, to compensate pointing error and under-sampling. Chopping and nodding at each jiggle position.

small map



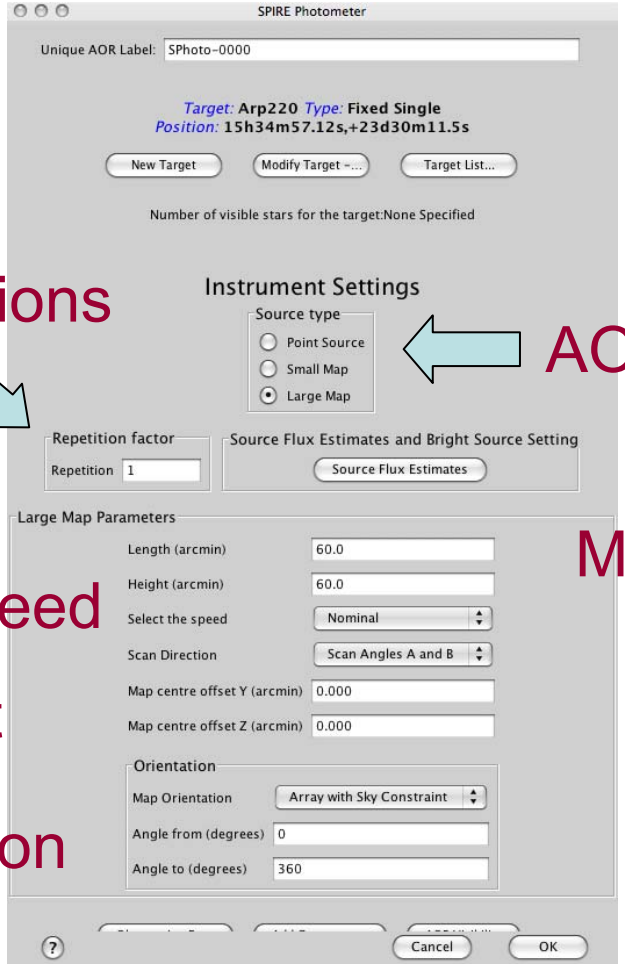
Single cross scan **at 84.8º** replaces Jiggle map. Scan map at speeds of **30** and **60 ”/sec.** Full spatial sampling in center of scans.

scan (large) map



Scan map at speeds of **30** and **60 ”/sec** is most efficient mode for **large-area surveys**. Parameters are optimized for full spatial sampling and uniform distribution of integration time. **Cross scan capability** (**84.8º**)

The SPIRE Photometer in HSpot



Repetitions

Scan Speed

Offset

Orientation

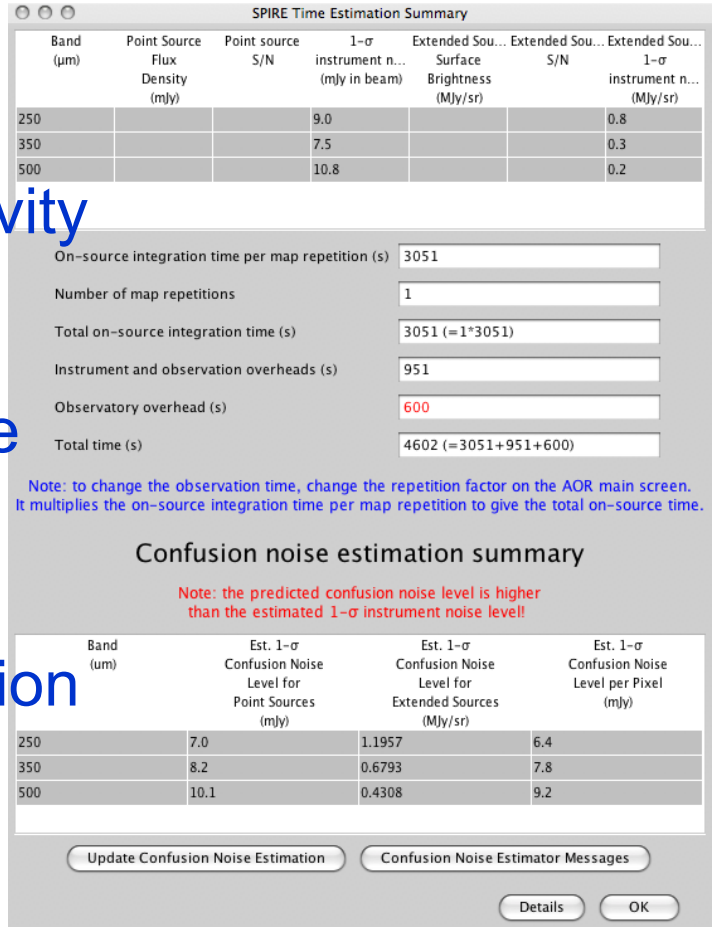
AOT Mode

Map Size

Sensitivity

Time

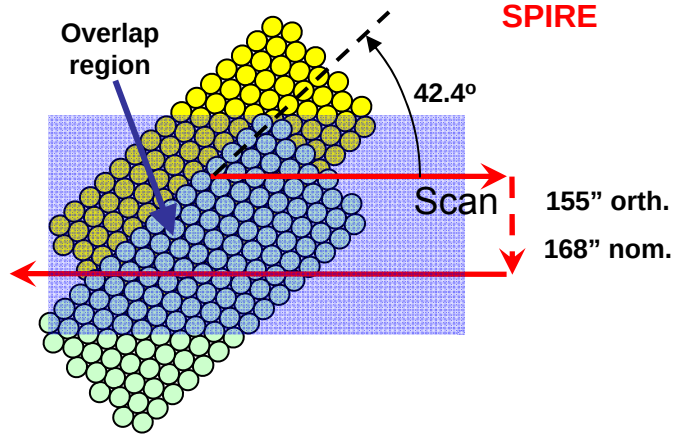
Confusion Noise



Parallel Mode SPIRE and PACS

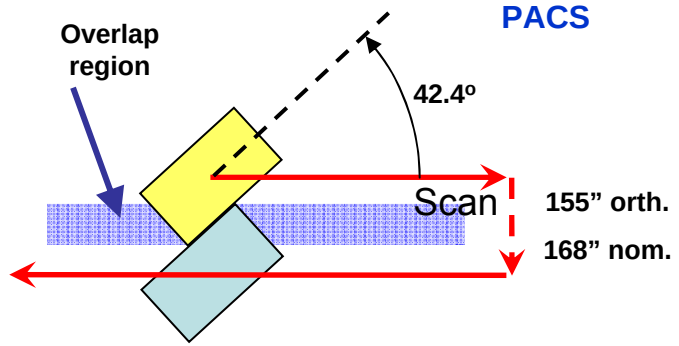
• Scan maps at speeds of **20** and **60"/sec** with PACS and SPIRE active in parallel are useful for **large-area surveys**.
• The distance between PACS and SPIRE apertures is 21 arcmin.
• Two almost orthogonal (**84.8°**) directions for **cross scanning** are available.

SPIRE Geometry



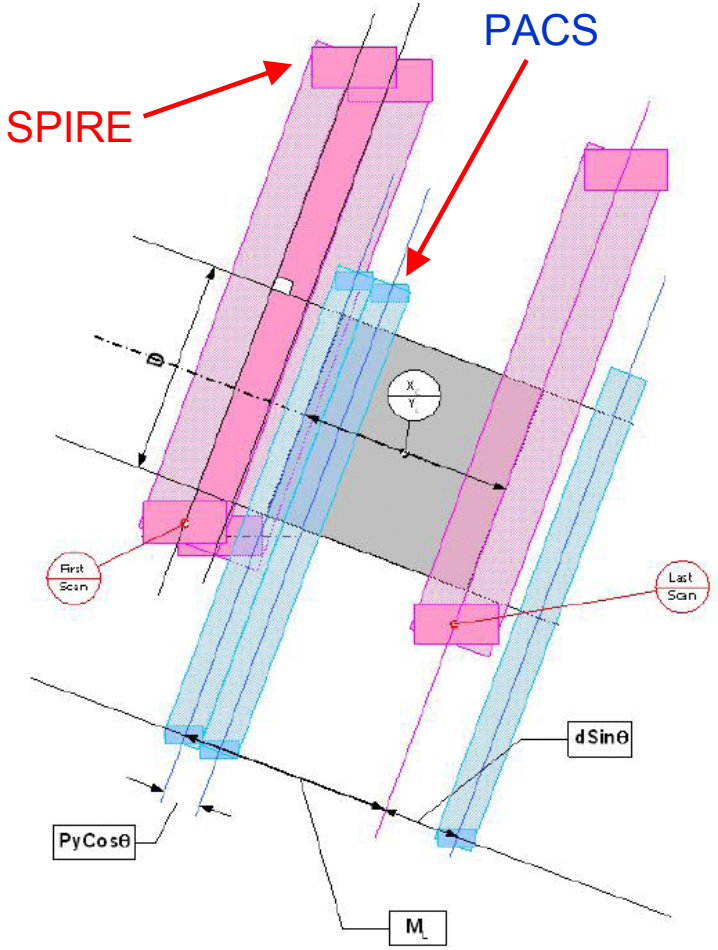
Considerable **redundancy** for SPIRE due to smaller scan distance needed by PACS arrays. **Sample rate lowered** from 16 to 10Hz.

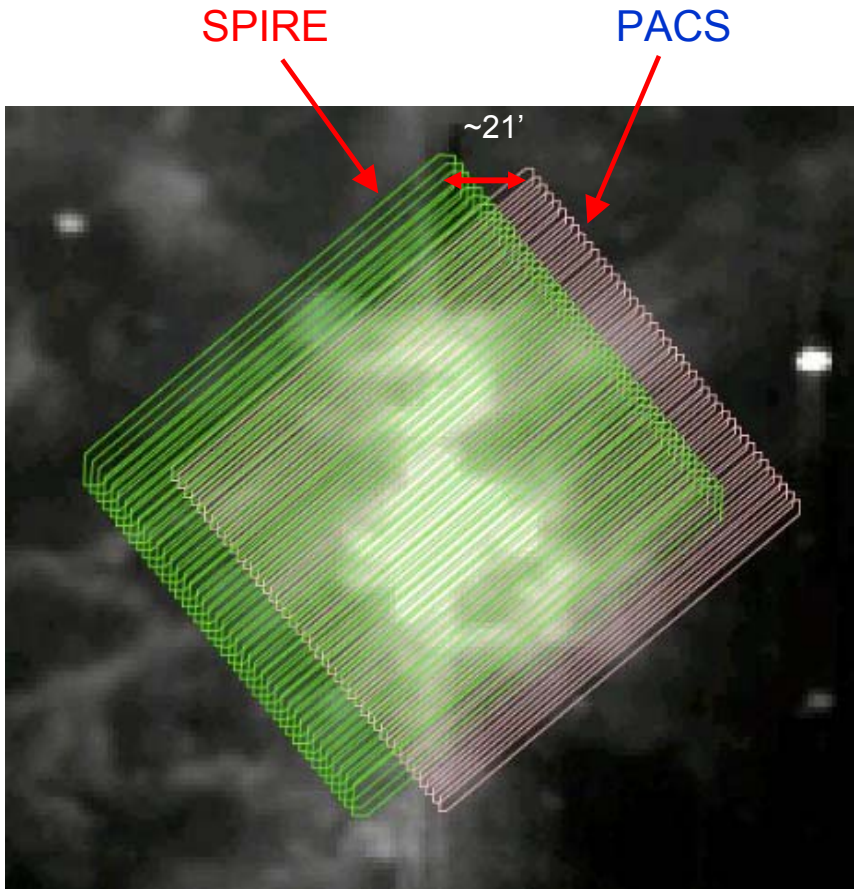
PACS Geometry



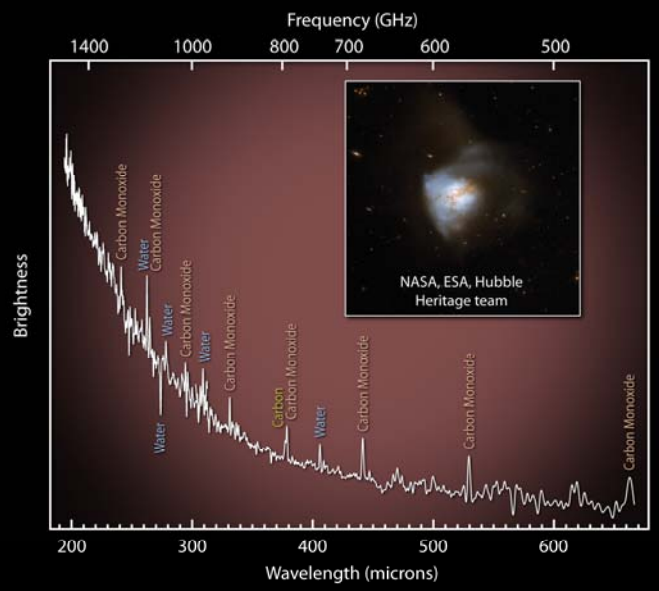
Even field coverage for PACS. **Additional frame averaging needed to keep data rate down.** Blue array frames are averaged by additional factor two compared to PACS only mode.

Parallel Mode SPIRE and PACS

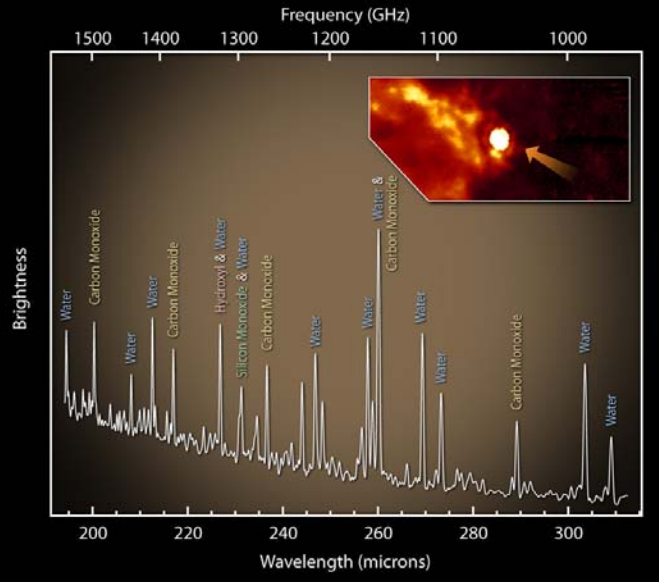




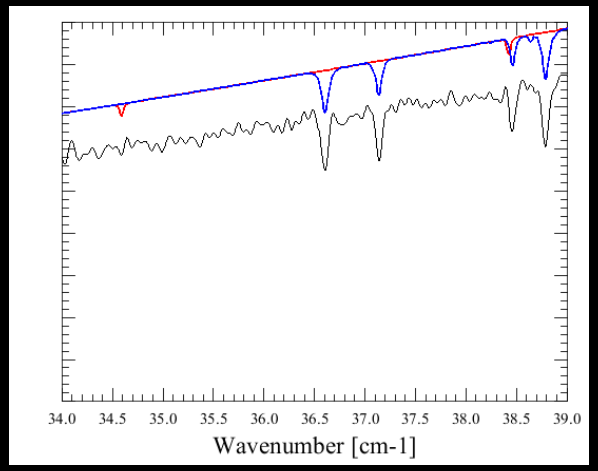
Spectrometer

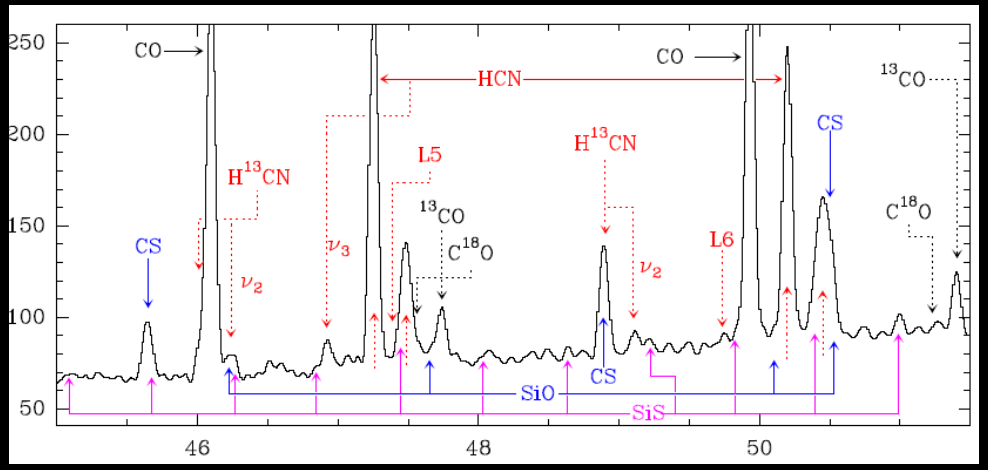


Arp 220

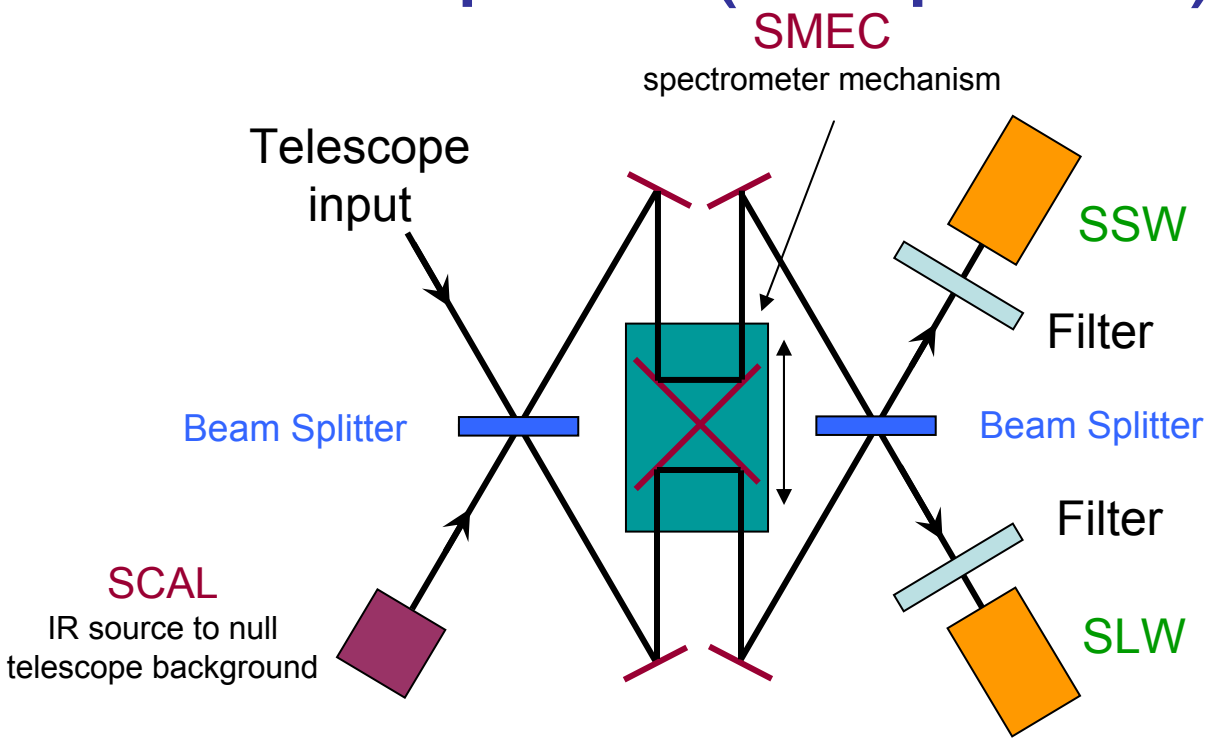


VY Canis Majoris





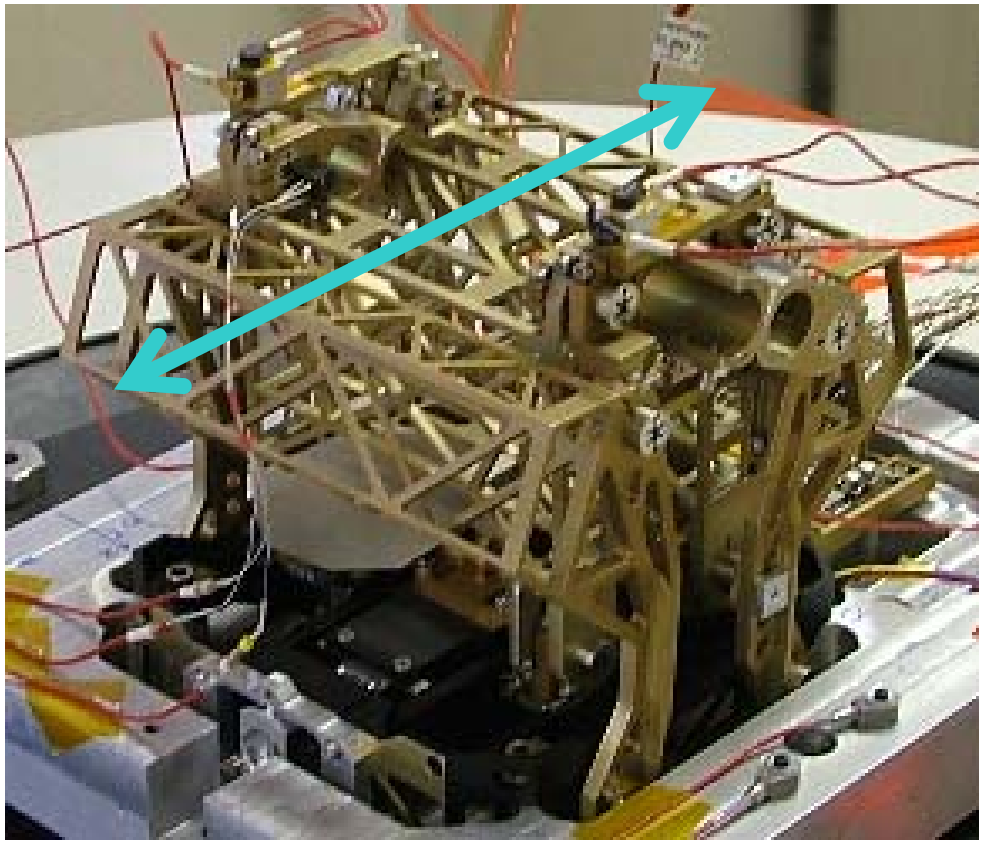
FTS Optics (simplified)



Mach-Zehnder type design
broad band intensity beam splitters (200-700mm)
two input ports and two output ports
no sensitivity to polarisation of incident radiation

FTS Scan Mechanism

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

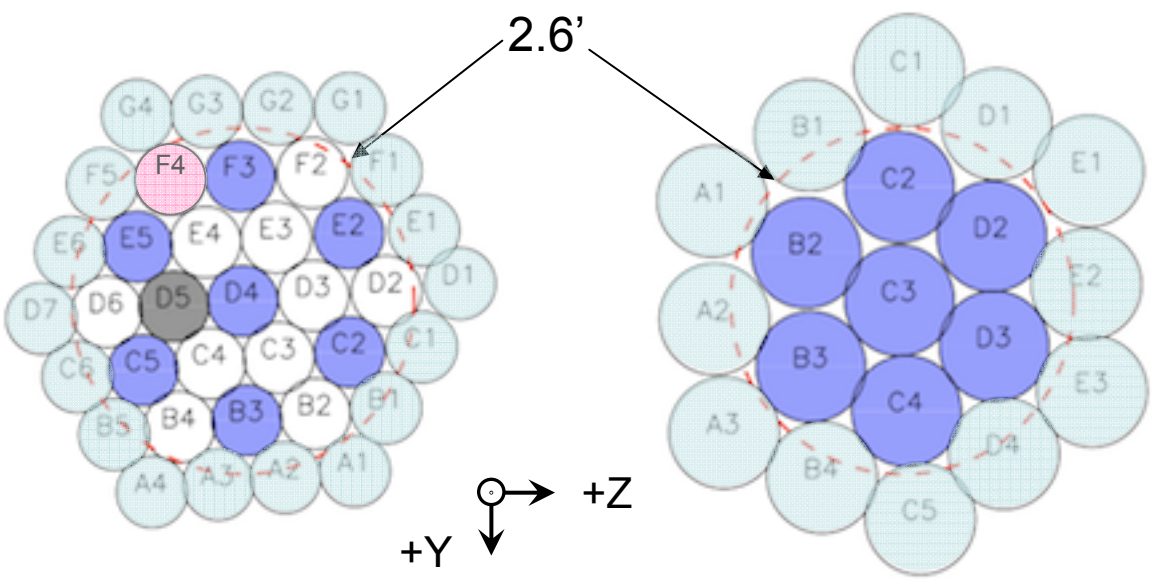


Detector Arrays

- Slow
- Noisy
- Dead
- Vignetted
- Overlap

SSW

SLW

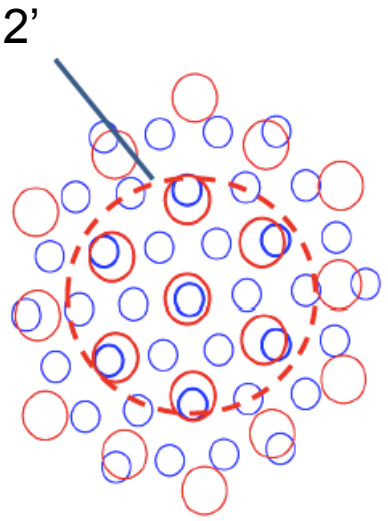


194 – 313 microns

Beam = 17”- 21”

303 – 671 microns

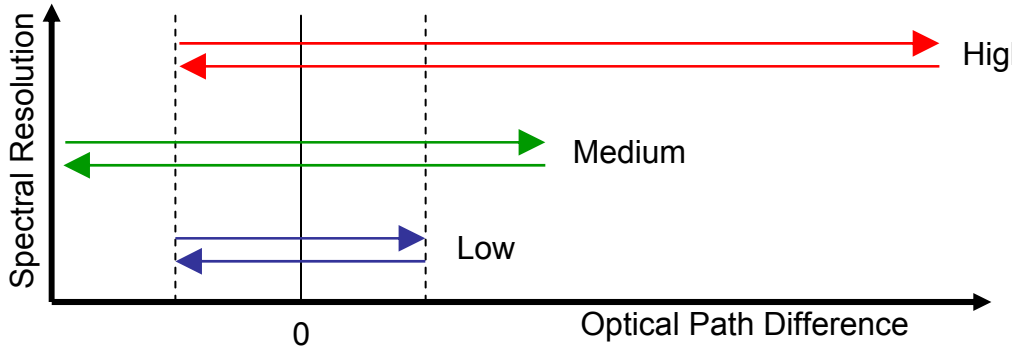
Beam = 29”- 42”



Overlapping Positions

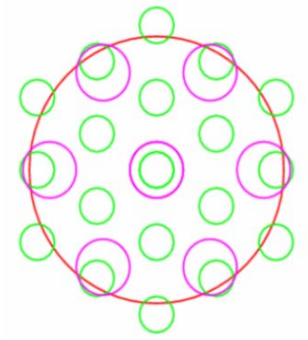
SMEC Scans & Spectral Map Coverage

Differences in SMEC scan pattern for different spectral resolutions.



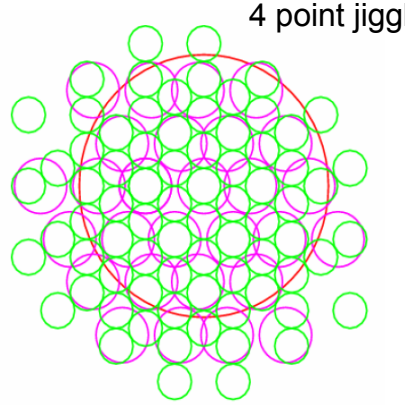
Sparse

no jiggling



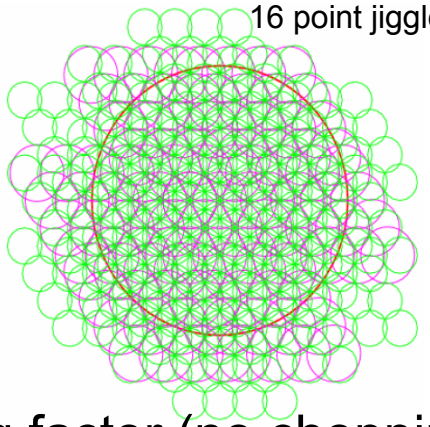
Intermediate

4 point jiggle



Full

16 point jiggle

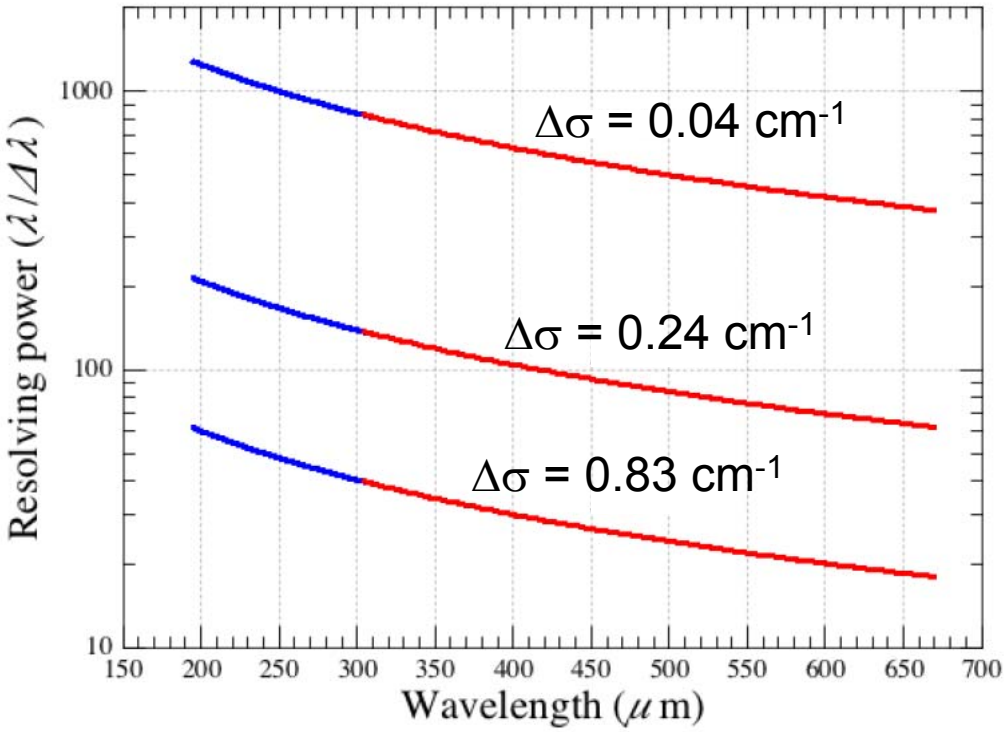


SLW FWHM

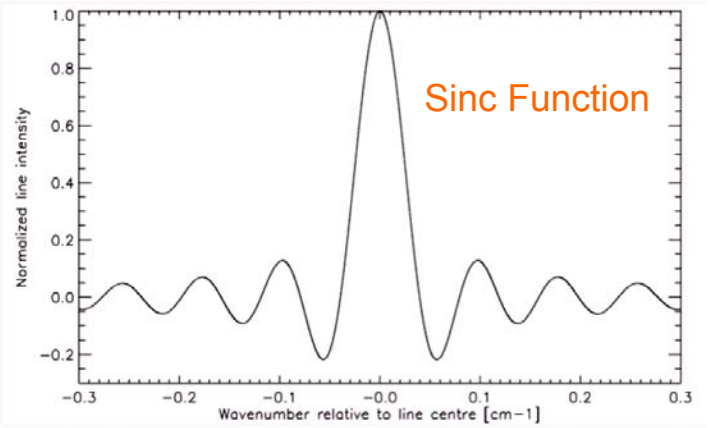
SSW FWHM

BSM used to increase filling factor (no chopping)

Spectral Resolution



Unapodized Line Profile



Apodization will convert into “normal” line profile but spectral resolution will be lost.

Spectrometer Sensitivities

HR, $\Delta\sigma$=0.04 cm^{-1} **MR**, $\Delta\sigma$=0.24 cm^{-1} **LR**, $\Delta\sigma$=0.83 cm^{-1}

Band	Wn [cm^{-1}]	λ [μm]	ΔF,5σ;1h [10^{-7} W m^{-2}] HR	ΔF,5σ;1h [Jy] HR	ΔF,5σ;1h [Jy] MR	ΔF,5σ;1h [Jy] LR
SSW	51.5	194	2.15	1.79	0.28	0.083
	46.7	214	1.56	1.30	0.22	0.063
	35.5	282	1.56	1.30	0.22	0.063
SLW	32.0	313	2.04	1.70	0.28	0.082
	25.5	392	0.94	0.77	0.13	0.037
	14.9	671	2.94	2.20	0.37	0.106

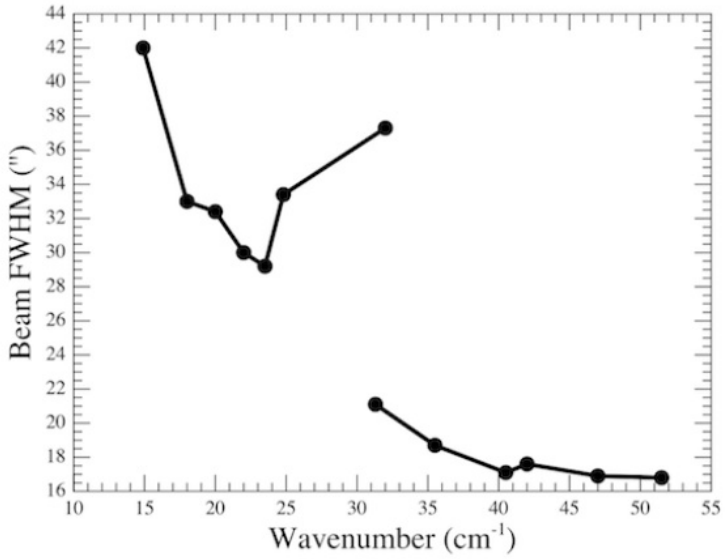
- **Sensitivities substantially better than pre-flight estimates.**
- **Sensitivities are limited by systematic noise associated with channel fringing and imperfect RSRF removal.**
- **Noise currently integrates down as $N_{Reps}^{1/2}$ for at least ~4h (100 repeats back and forth).**

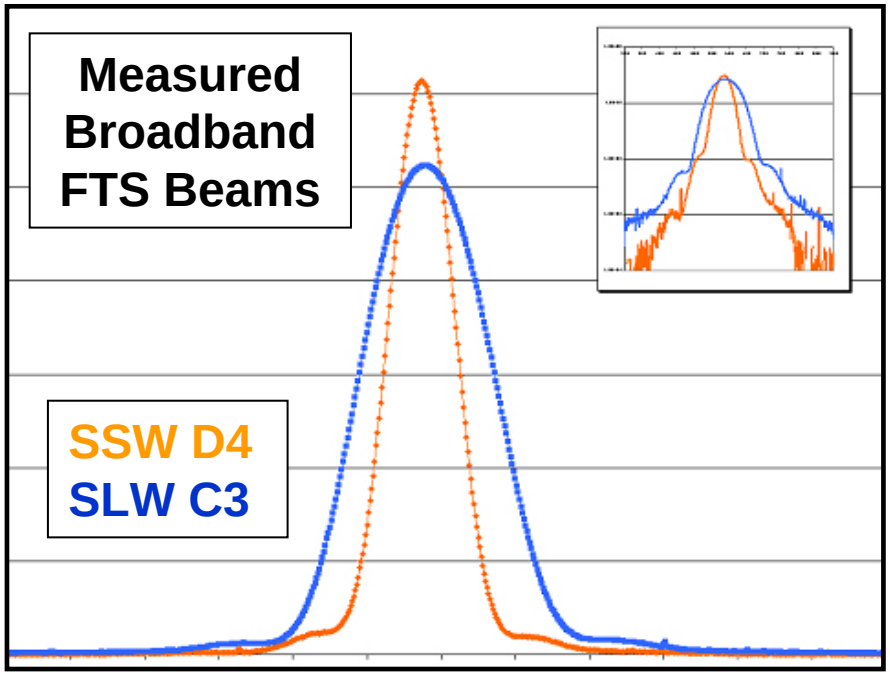
Flux Density Calibration

- Primarily based on Uranus
  - 7% absolute accuracy based on consistency with Neptune model (achievable for >100Jy sources)
- Telescope/Instrument background subtraction
  - Dominant factor for continuum accuracy, especially at long wavelengths
  - More systematic uncertainty at long wavelength end
  - Continuum accuracies of ~1Jy are typical (SLW)
- Spectral Mapping
  - Additional 10-15% uncertainty from flatfield
- Telescope pointing accuracy
  - 6'' deviation from point sources reduces flux by 20-30% for SSW

Beams

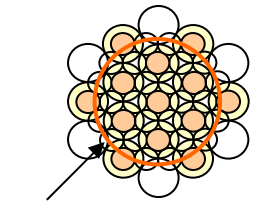
FTS Beams	Broad-band FWHM	Average
SSW D4	19 ± 1”	17.4 ± 0.8
SLW C3	35 ± 1.5”	33.9 ± 4.4





- Multimoded feedhorns cause structured response function and beam profiles
- Extended sources will need special care in that respect

Spectrometer AOT



Overlapping spectrometer arrays projected on the sky

Image Sampling

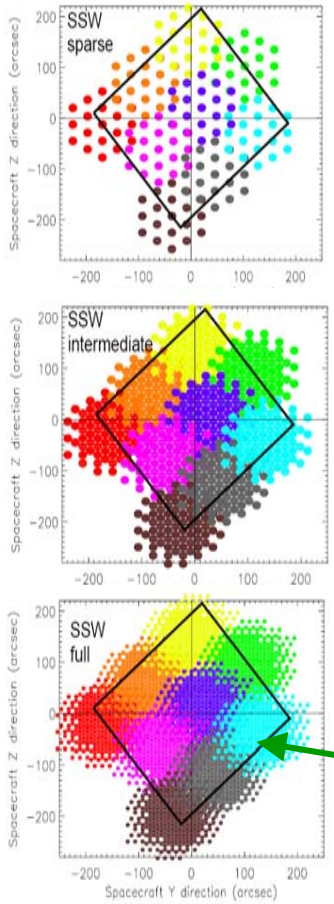
- Sparse
- Intermediate
- Full

Pointing Mode

- Single Pointing
- Raster Pointing

example 3 x 3 map

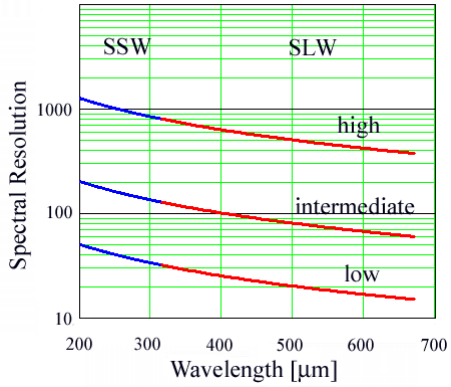
any combination allowed



Each color shows the unvignetted beams of the same array for all sampling positions (jiggles) at one raster position.

Spectral Resolution

- High 0.04 cm^{-1}
- Medium 0.25 cm^{-1}
- Low 0.83 cm^{-1}
- High & Low 0.04/0.83 cm^{-1}



The SPIRE Spectrometer in HSpot

Image Sampling

Pointing Mode

Repeats

Spectral Resolution

Sensitivity

Time