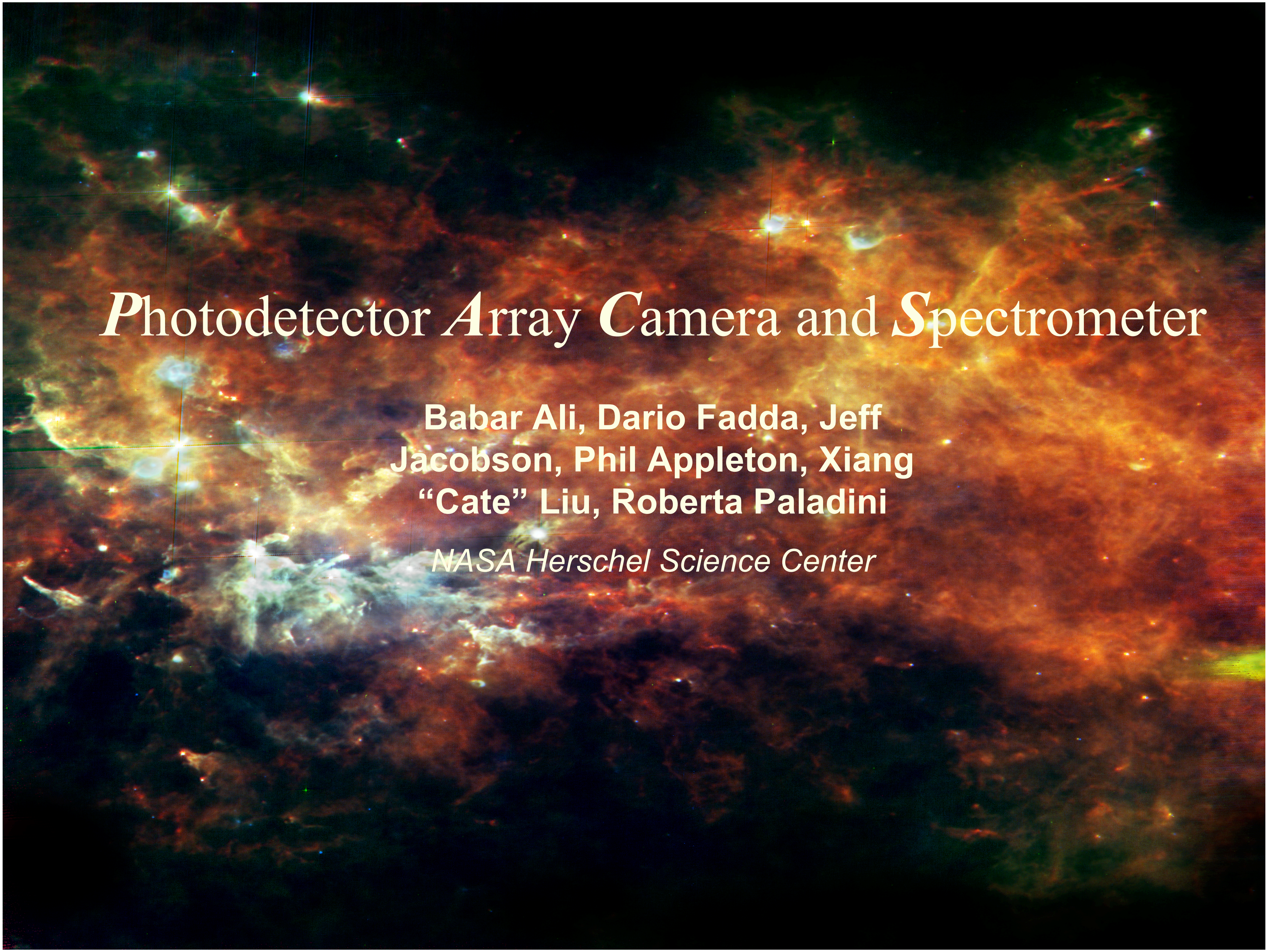


*P*hotodetector *A*rray *C*amera and *S*pectrometer

Babar Ali, Dario Fadda, Jeff Jacobson, Phil Appleton, Xiang "Cate" Liu, Roberta Paladini

NASA Herschel Science Center

Outline

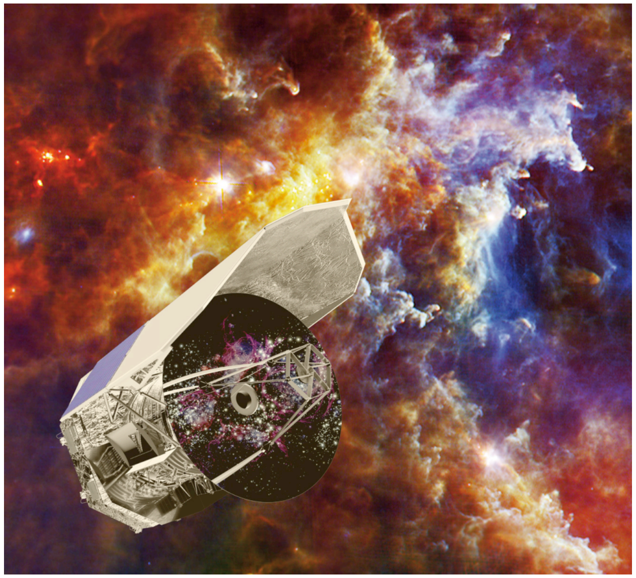
I. **Description & Capabilities of the PACS instrument**

II. **Results from in-flight performance**

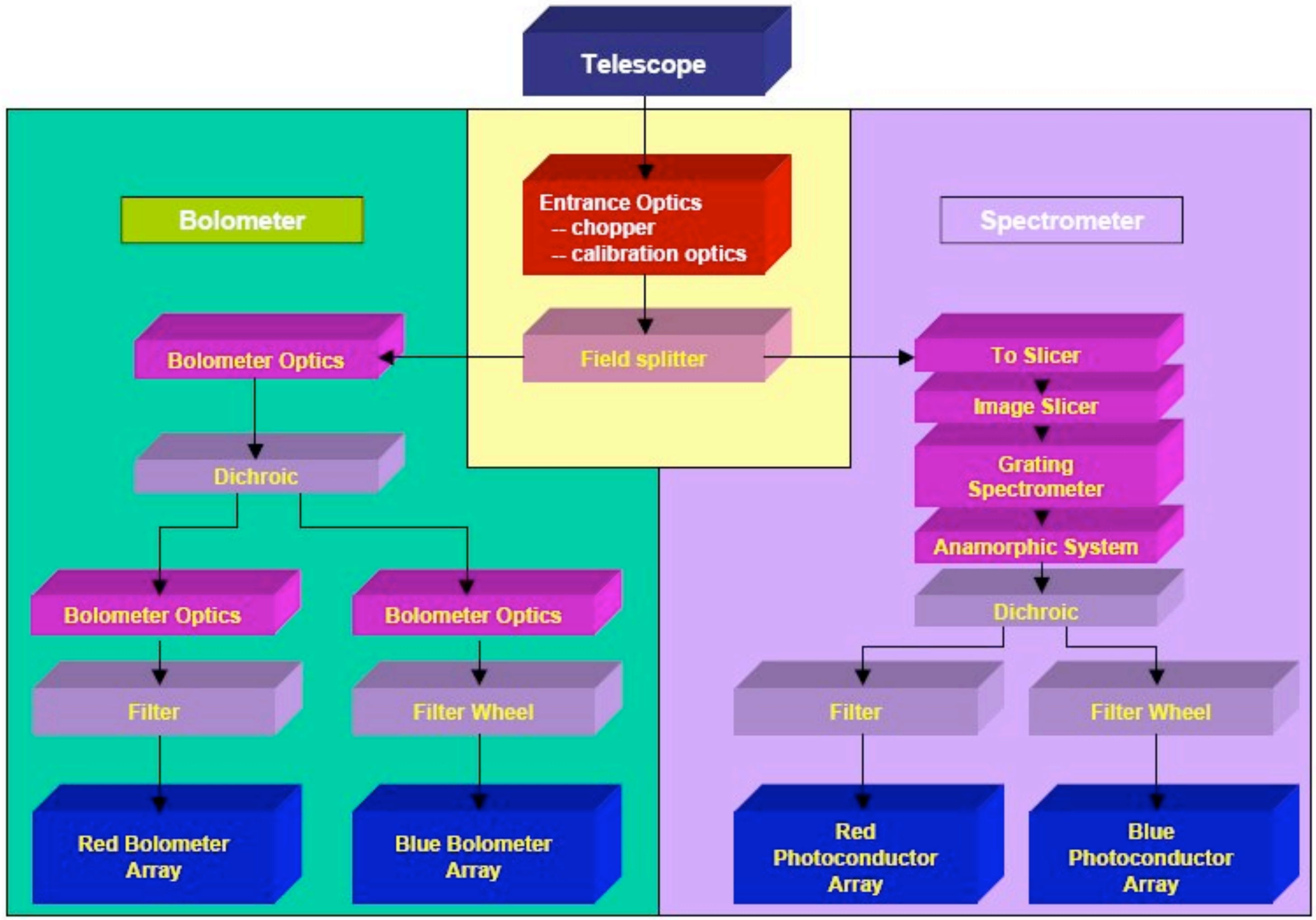
- Optical performance
- Sensitivity
- Calibration

III. **Observing with PACS**

IV. **Summary & Links**

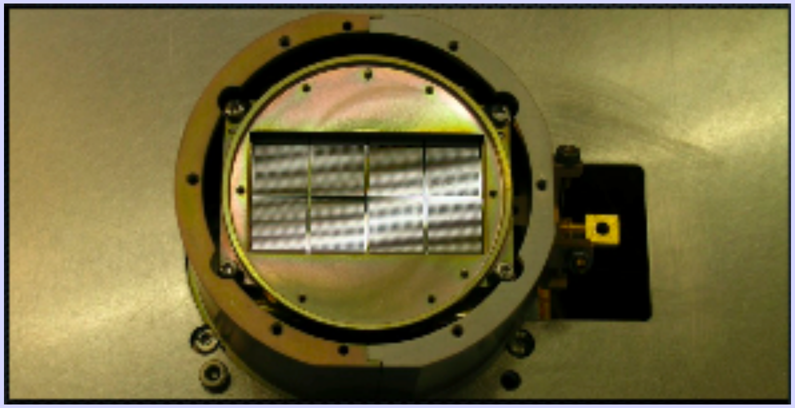


PACS Schematic View



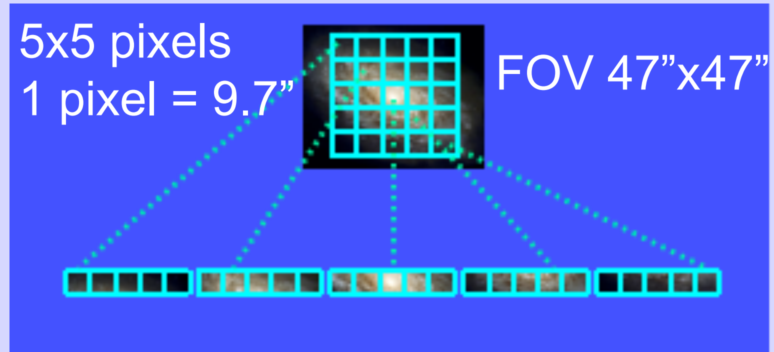
PACS

Photometer



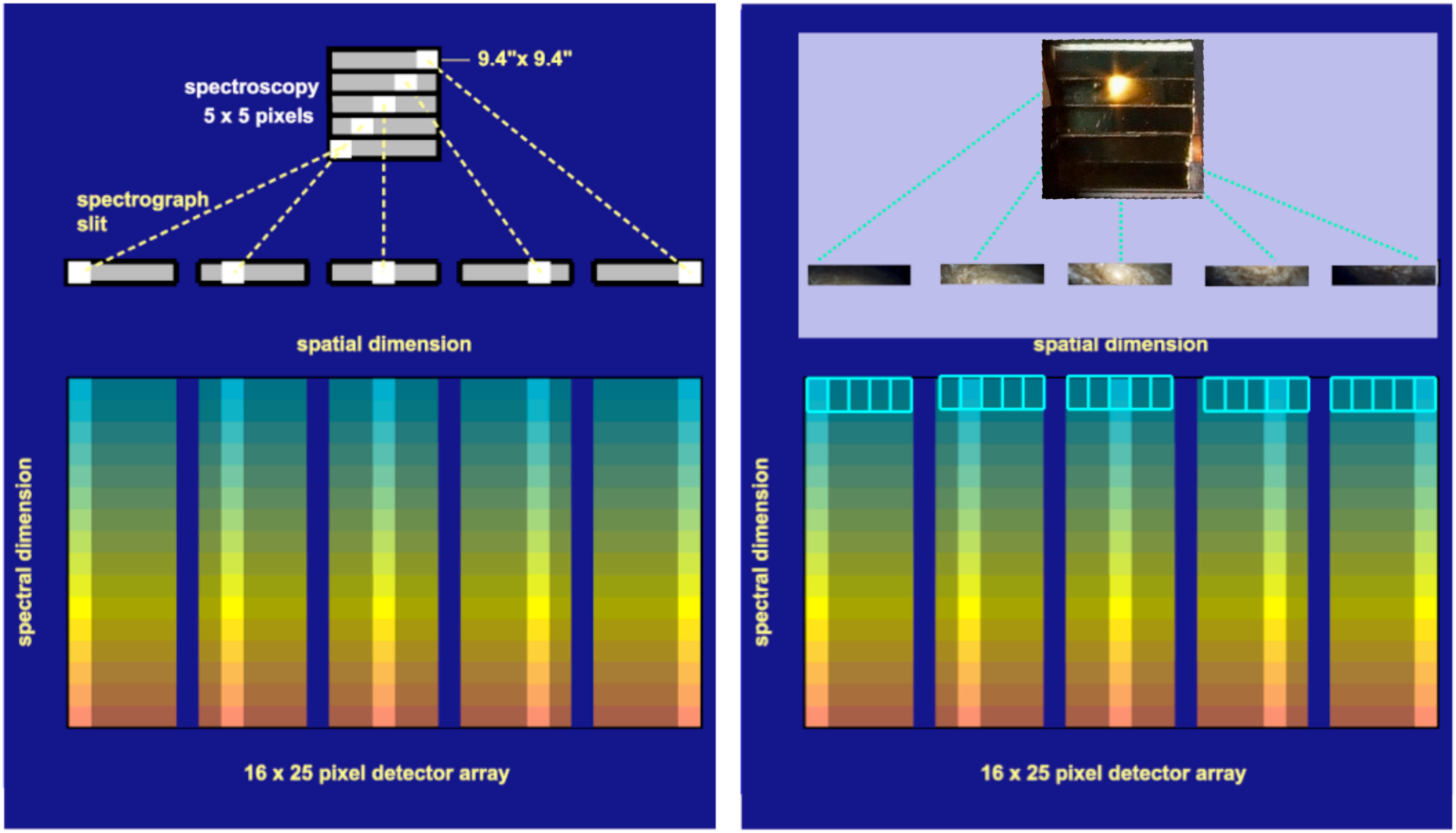
- Two filled Si bolometer arrays observe blue and red channels simultaneously
- 64x32 pixels (blue = 60-85 μm OR green = 85-130μm)
- 32x16 pixels (red = 130-210 μm)
- Beams: 5.2”, 7.7” and 12”
- FOV: 1.75 x 3.5 arcminutes^2

Integral Field Spectrometer



R = 1000-5000 (300-55 km/s)
ΔV(inst) = 1500km/s
Simultaneous Blue (51-98 μm) and Red (102-220μm) coverage

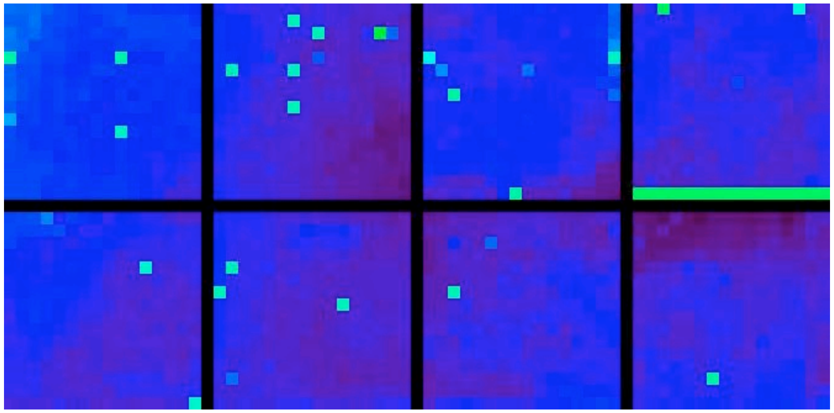
Two instruments in one box



Mapping between the integral field optics and the 25x16 Ge:Ga detector arrays.

Some Bolometer Characteristics

- Thermal noise from telescope dominates. You must mitigate by chopping or scanning (better).
- Correlated signal drift and 1/f noise are dominant instrument signatures in time domain.
- Individual readouts are dominated by electronic offsets.
- One matrix row is unusable in blue, but few dead pixels overall.
- Glitch frequency ~1/module/sec; rarely affect more than one pixel.



Some Spectrometer Characteristics

- Ge:Ga is completely different technology than bolometers.
- As for the photometer, must mitigate against bright telescope; chopping is the nominal method for the spectrometer.
  - Unchopped off-position subtraction is an alternative
- PSFs are under-sampled by pixels.
- Grating movements and strong lines introduce Ge:Ga transients which must be accounted for in un-chopped observing modes (more later).

II. In-Flight Performance

Overall Assessment

- After ~1.5 years of routine operations ...
  - Most instrument effects are understood or resolved.
    - Some notable exceptions exist.
  - AOTs have matured dictated both by efficient observing practices and data processing considerations.
    - Heed the instrument team recommended settings
  - Absolute flux calibration is well understand ...
    - some issues remain for spectrometer continuum calibration
  - HSpot sensitivity estimates are now vetted by in flight measurements but can still be modified by data processing considerations / capabilities.

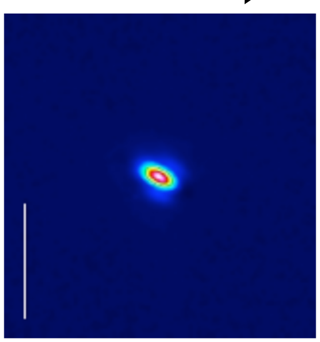
PACS is doing great!!

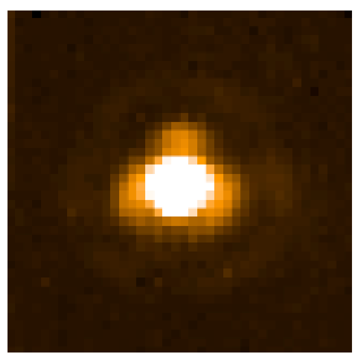
Eagle Nebula

Spectral mapping of M82

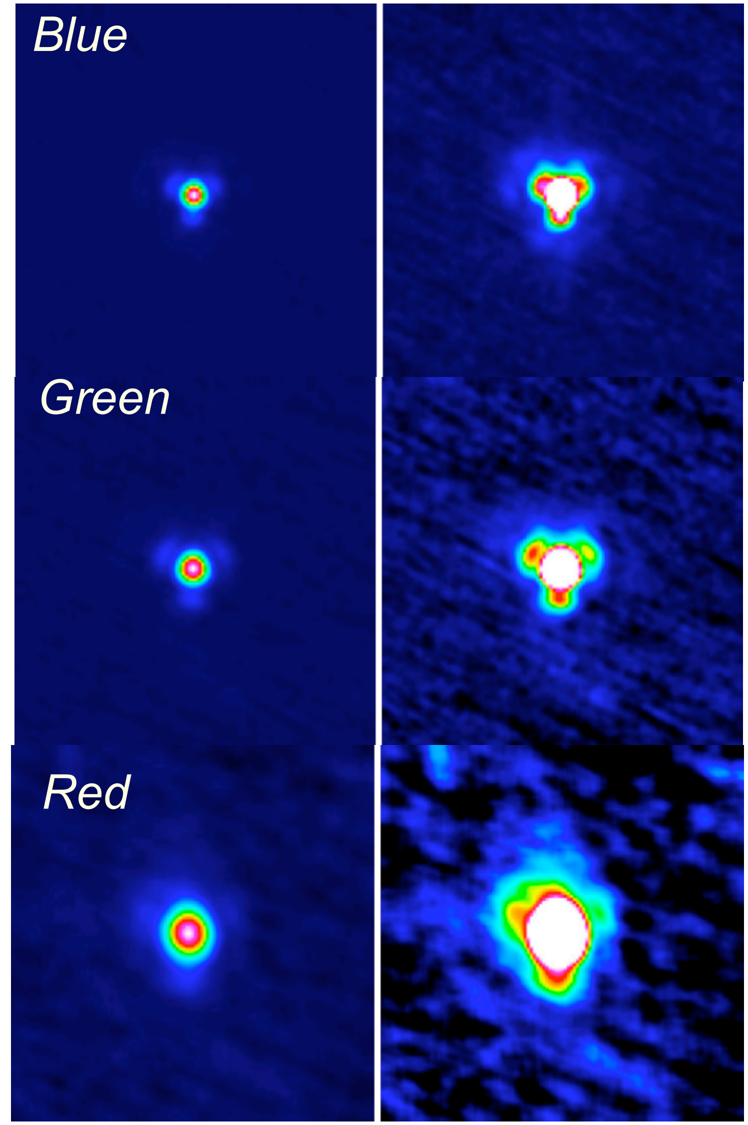
PACS Point Spread Function:

- Diffraction limited
- Shows faint side lobes due to primary mirror support
- Smeared at high scan speeds due to data averaging and telescope motion.

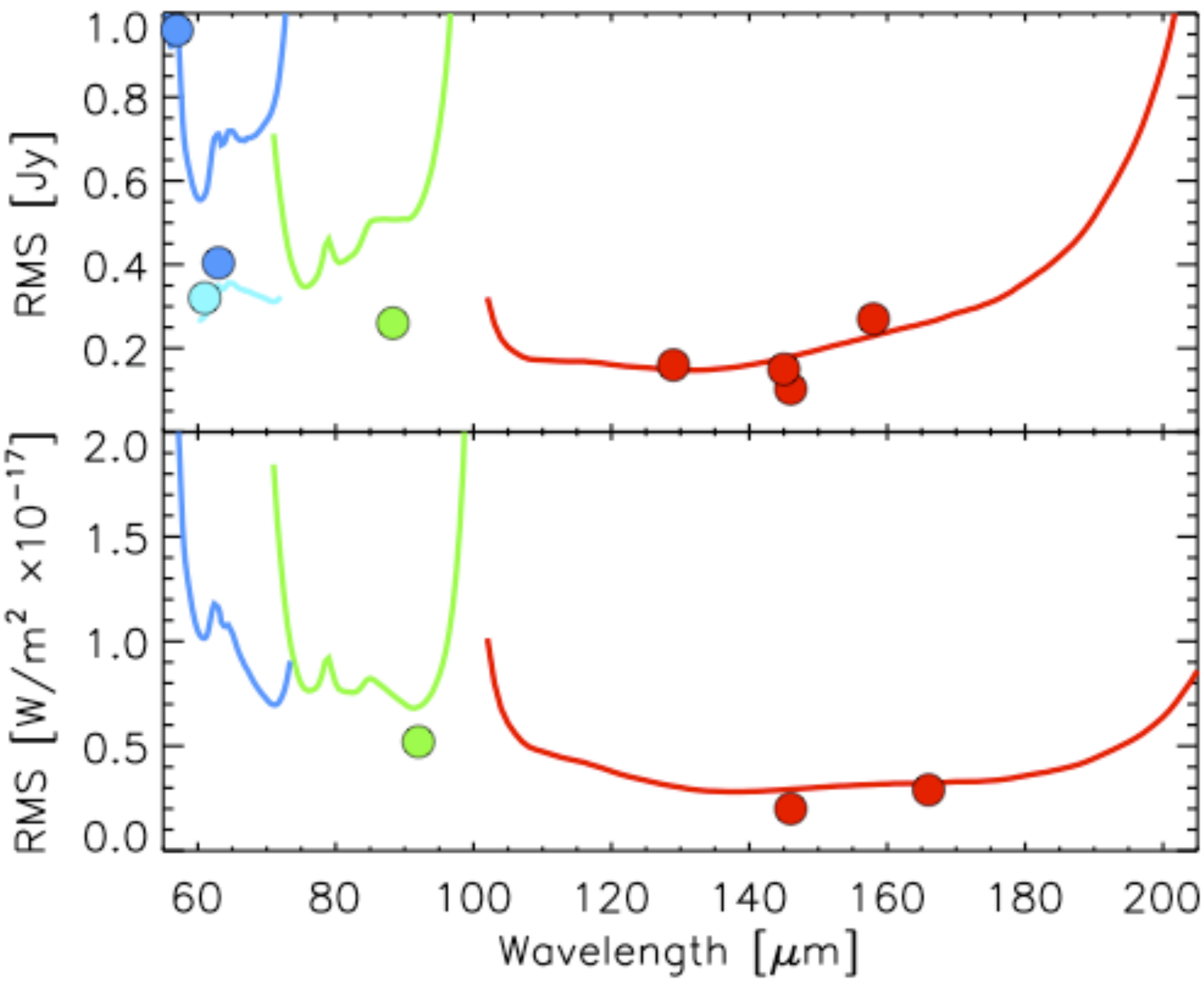




Spectrometer at 125 microns



Spectrometer Sensitivity



Photometer Sensitivity

Band	Mini-scan center	Scan Map (nominal)	Scan Map (parallel)
	1σ/rep	5σ/30h	1σ/3h
Blue	3.9 mJy	3.7 mJy	19.8 mJy
Green	4.5 mJy	5.0 mJy	n.a.
Red	8.6 mJy	9.5 mJy	116 mJy

HSpot has the “final word” on sensitivity. Use HSpot estimates over all else.

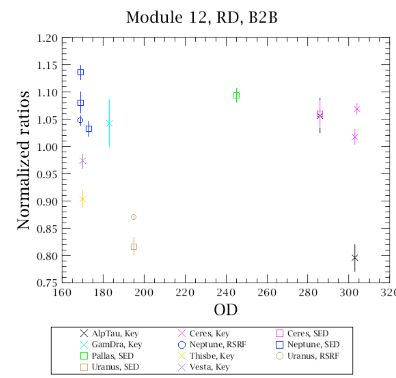
Sensitivity is based on actual in-flight measurements of calibration stars and deep fields.

- Sensitivity is dependent on observing and reduction strategies and astrophysical source

Blue filter is dominated by instrument noise.

Confusion noise is important for deep red band observations. Little confusion noise is detected in the Green band.

Flux Calibration



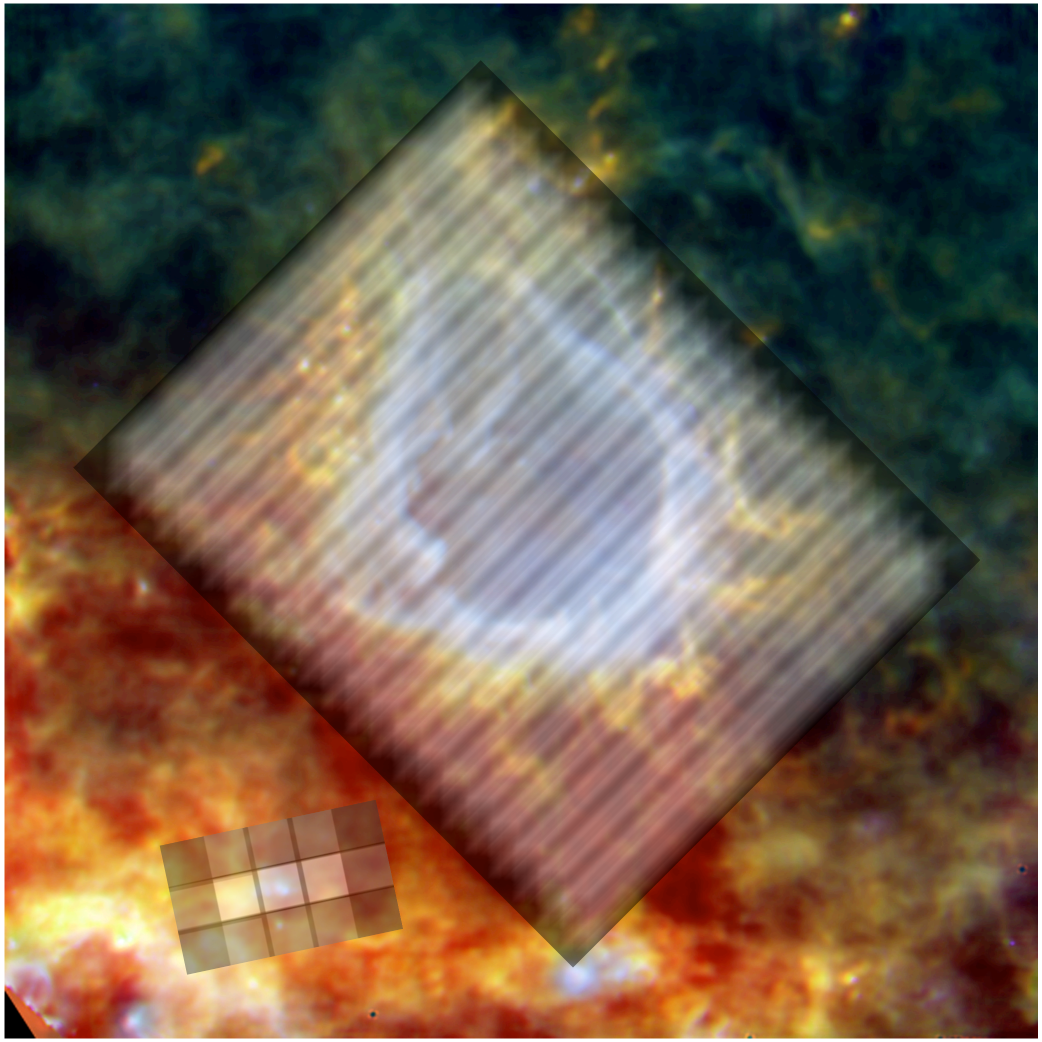
- Prime calibrators
  - *Photometer*: stars
  - *Spectrometer*: stars, asteroids, Neptune, Uranus
- Secondary calibrators are: more stars and asteroids.
- Reference wavelength for the PACS filters: 70, 100 and 160 µm.
  - Chosen to minimize the color corrections.
  - All transmission curves available in *HIPE*.
- Photometer absolute accuracy in all filters is estimated (from inter-comparison of calibration observations) at 5-10%
  - Spectrometer is ~30%
- Spectrometer wavelength calibration is 1/3 of resolution element.

III. Observing with PACS

Photometer AOTs

<u>Point source photometry</u>:

Use mini scan map



<u>Extended source Mapping:</u>

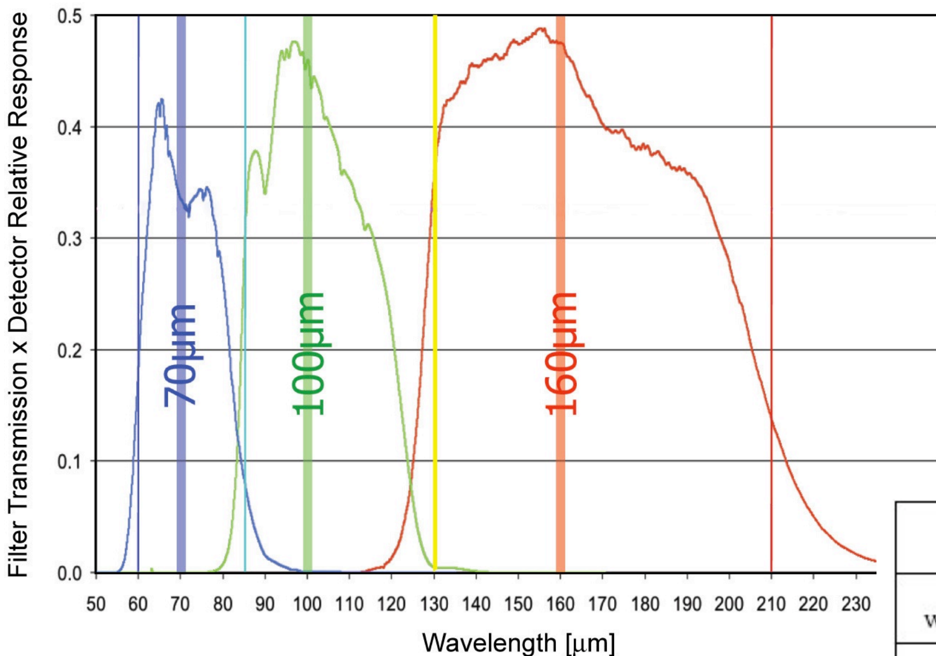
Scan at 20”/sec. OR 60”/sec.

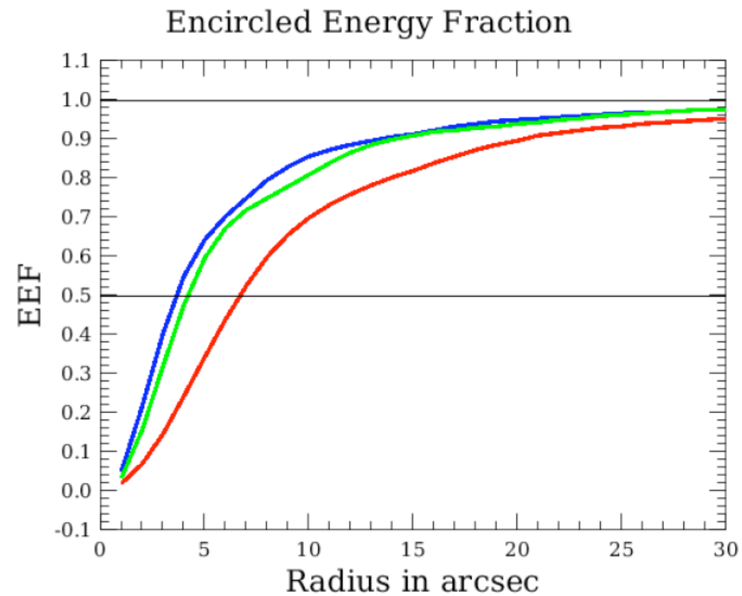
Users control map parameters.

Not confusion limits at 70 μm

Confusion limit 0.1 and 0.7 mJy at 100 and 160 μm

Photometer Filters

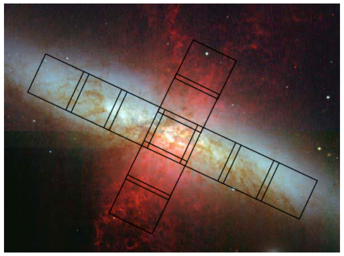


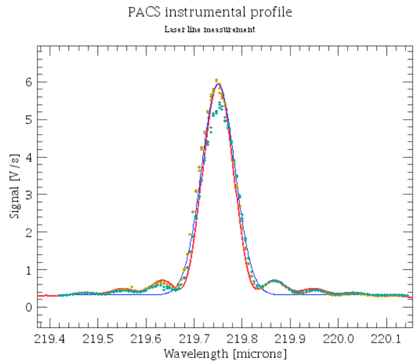


	70μm	100μm	160μm
wavelength range (μm)	60-85	85-130	130-210
Resolution	~3		~2
pixel size (arcsec)	3.2		6.4
FOV (arcmin)	3.5 x 1.75		
FWHM (arcsec)	5.2	7.7	12

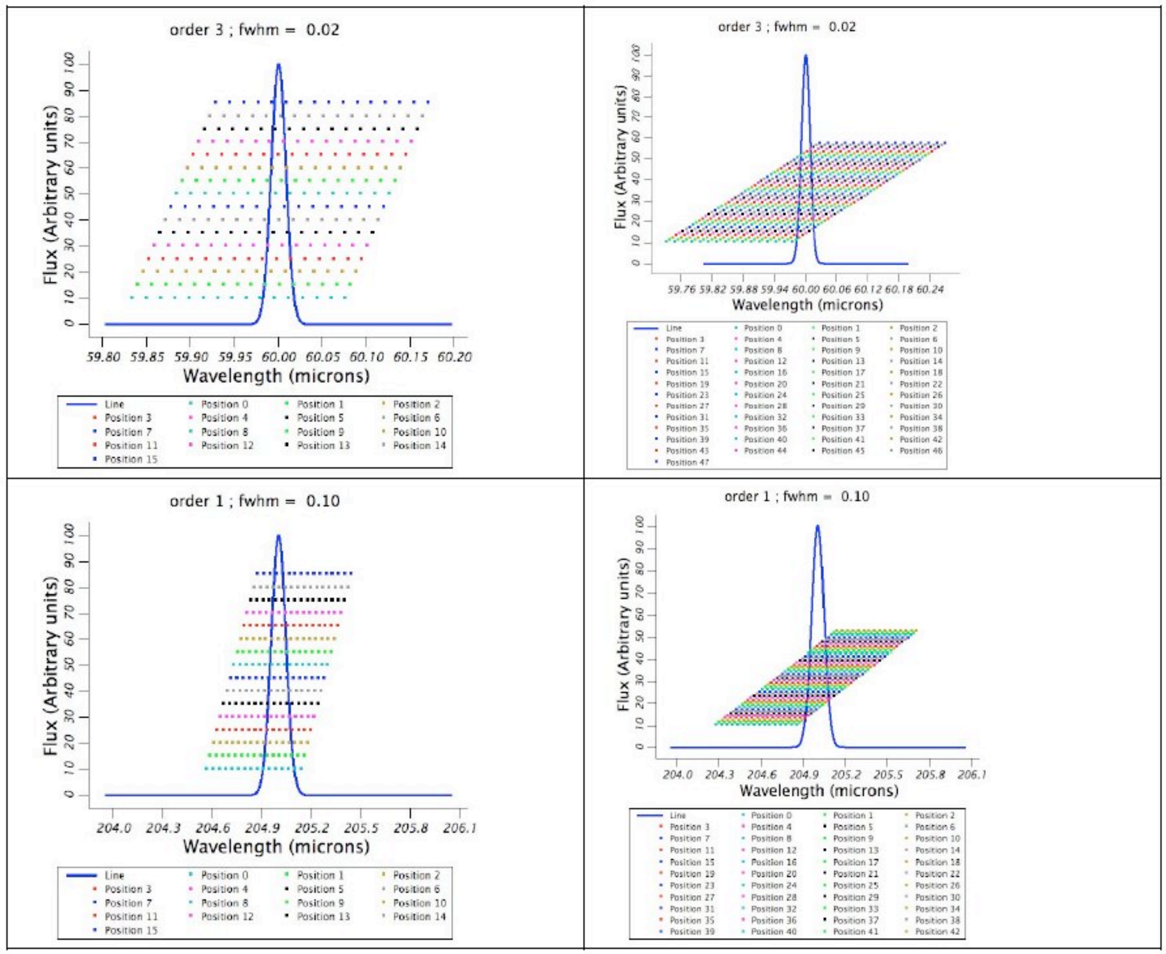
PACS Spectrometer AOTs

- ***Line Spectroscopy***: observation of individual lines combined with:
  - Chopping/nodding, OR
  - Unchopped scan combined with an OFF position.
- ***Range Spectroscopy***: observations of extended wavelength regions, broad-lines and continuum:
  - SED sub-modes to cover full wavelength range
  - Chop OR use an OFF position for background removal.
- All modes may be **combined with mapping options**





How PACS observes a line

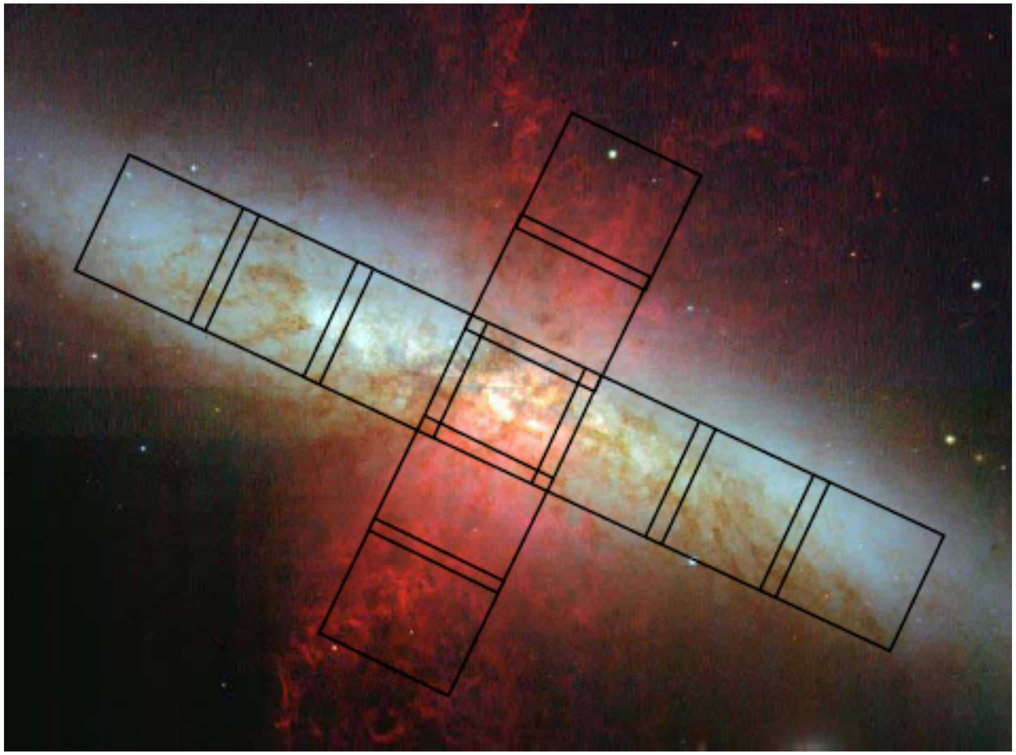


Mapping in Spectroscopy AOTs

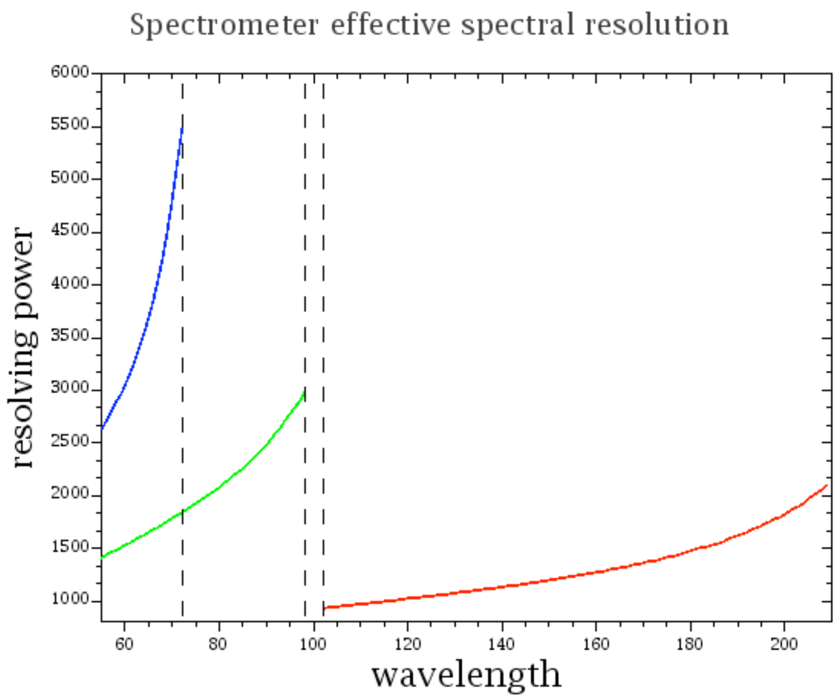
Example: Spectroscopic line mapping of a galaxy (M82)

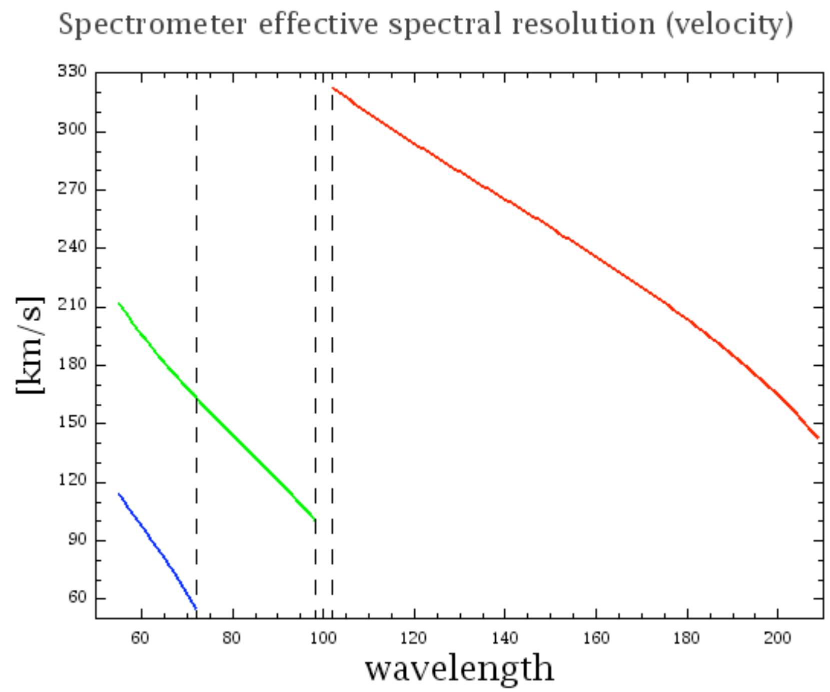
Map transition from the central starburst to the molecular ring to quiescent disk along major axis in NIII/NII.

Map cooling of gas and shock vs. ionization along super wind outflow in CII/OI



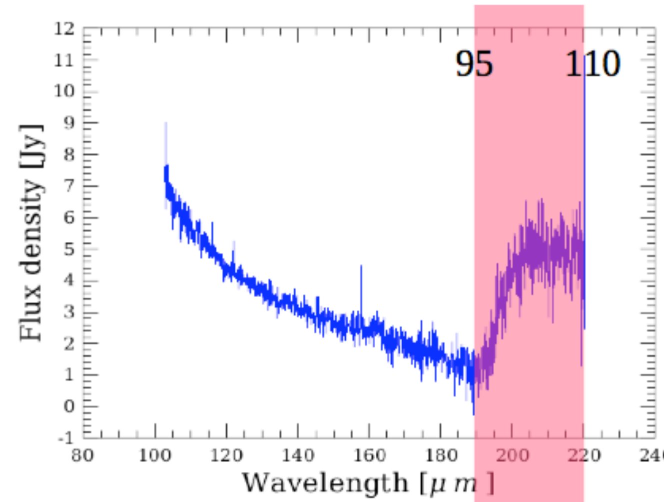
Spectrometer Resolution

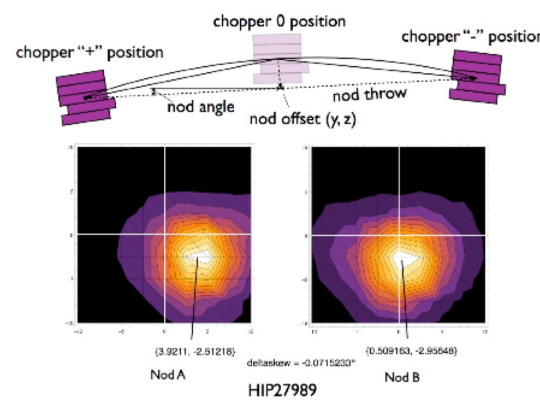




Concerns for Observers

- Spectrometer light leak
  - E.g. Order 2 light added to order 1 at λ > 190μm
- Spacecraft instrument alignment creates offsets in nod A vs B
- See the PACS Observer Manual for a complete list.



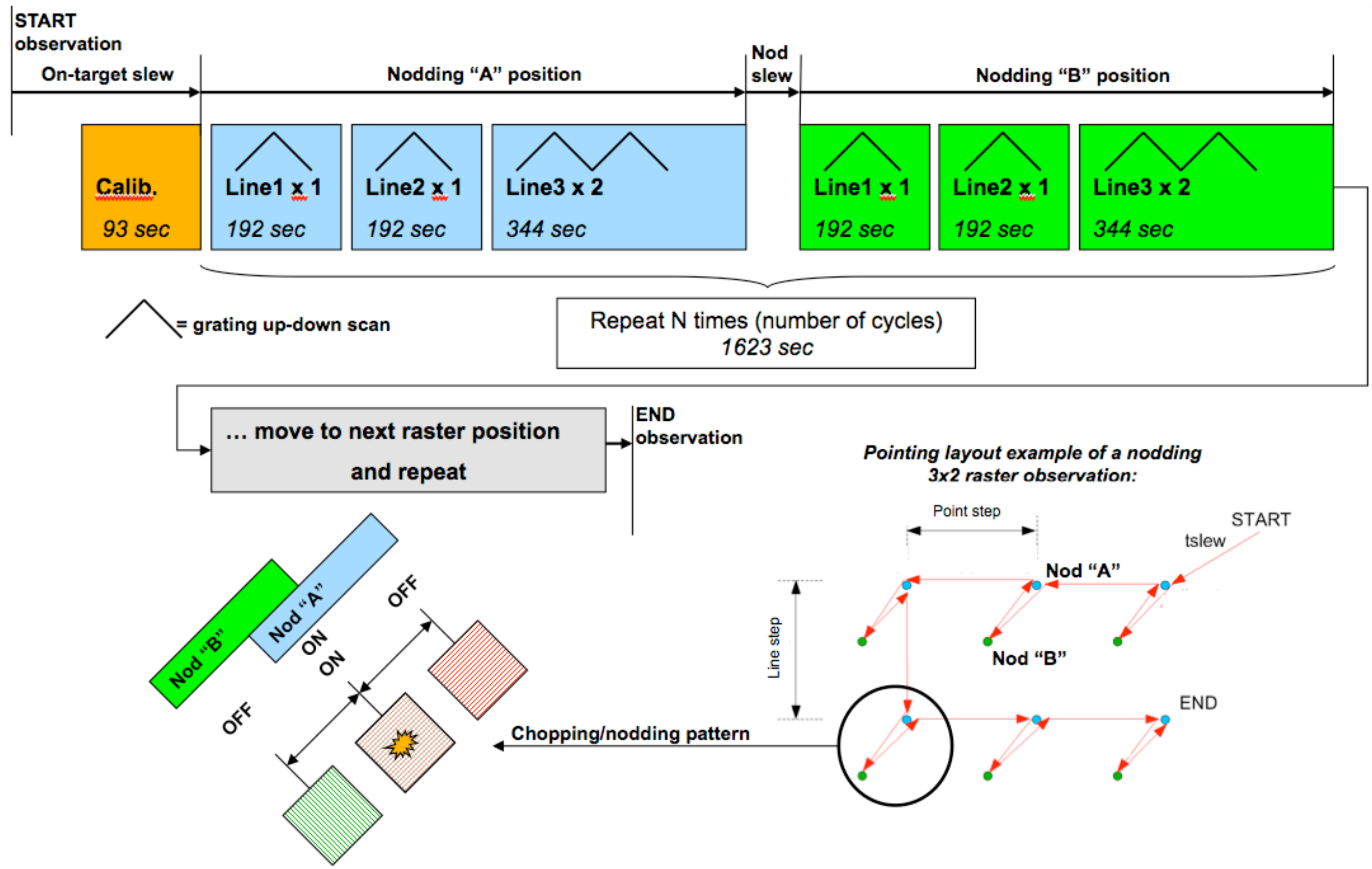


IV. Summary & Links

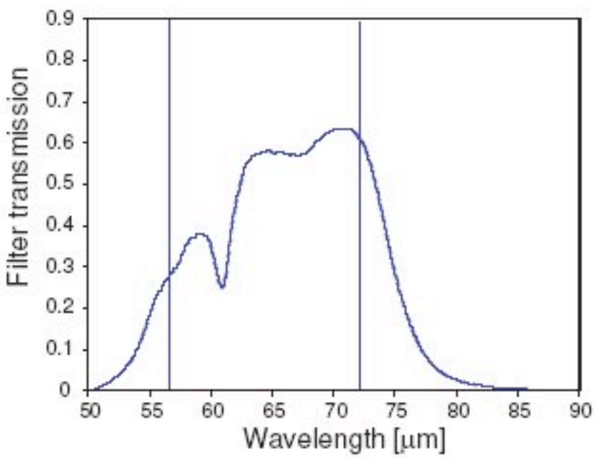
For more PACS information

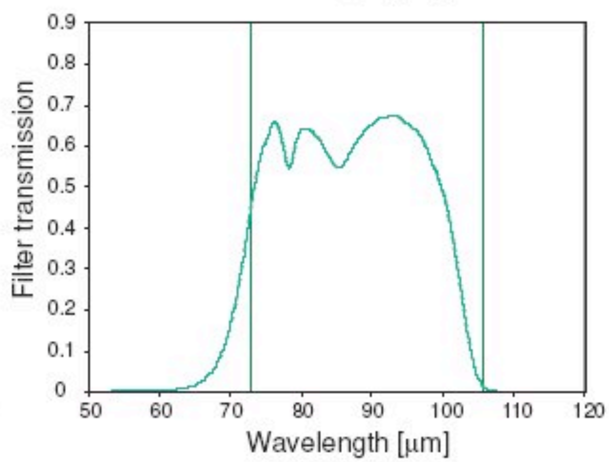
- NHSC
  - Helpdesk http://nhsc.ipac.caltech.edu/helpdesk/index.php
  - Website: http://www.herschel.caltech.edu/
- HSC
  - Helpdesk http://herschel.esac.esa.int/
  - Website: http://herschel.esac.esa.int/
- Poglitsch et al. 2010 paper in A&A letters, special Herschel edition
  - http://arxiv.org/pdf/1005.1487

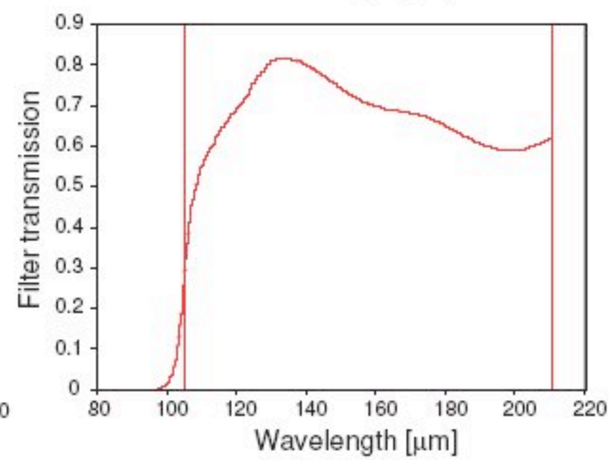
Backup Slides


START
observation
On-target slew
Nodding "A" position
Nod
slew
Nodding "B" position
Calib.
93 sec
Line1 x 1
192 sec
Line2 x 1
192 sec
Line3 x 2
344 sec
Line1 x 1
192 sec
Line2 x 1
192 sec
Line3 x 2
344 sec
= grating up-down scan
Repeat N times (number of cycles)
1623 sec
… move to next raster position
and repeat
END
observation
Pointing layout example of a nodding
3x2 raster observation:
Point step
START
tslew
Nod "A"
Nod "B"
Line step
END
Chopping/nodding pattern
Nod "B"
Nod "A"
OFF
ON
ON
OFF

Spectrometer Filters







PACS Spectrometer Pipeline

Level 0

PACS data, House Keeping

Pointing

Flag Data

Permanently Bad pixels (few)
When grating or chopper moving
Saturated data
When glitches present
Open and dummy channels (spec 0, 17)

Convert DNs to Volts/s

Assign observing block labels

(e. g. Nod positions, grating scan direction, calibration block, scan mode)

Assign RA/Dec > pixel

Level 0.5 Uncalibrated Data Frame

Wavelength Calibration

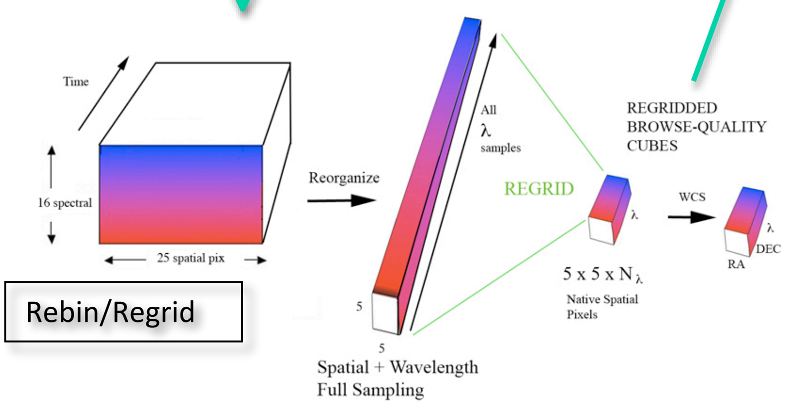
Nonlinearities and Spatial Distortions

Apply RSRF

Flat Field correction

Subtract On and Off Chop and Convert to Jy

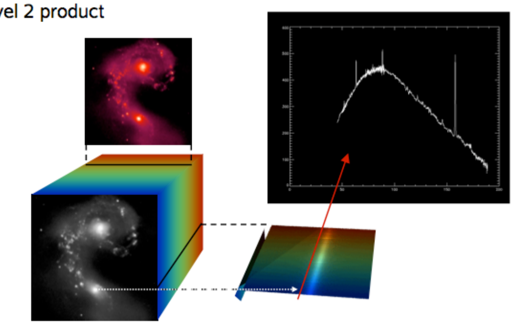
Level 1 Calibrated Data Frames (25 x 16 x time = grating movement)



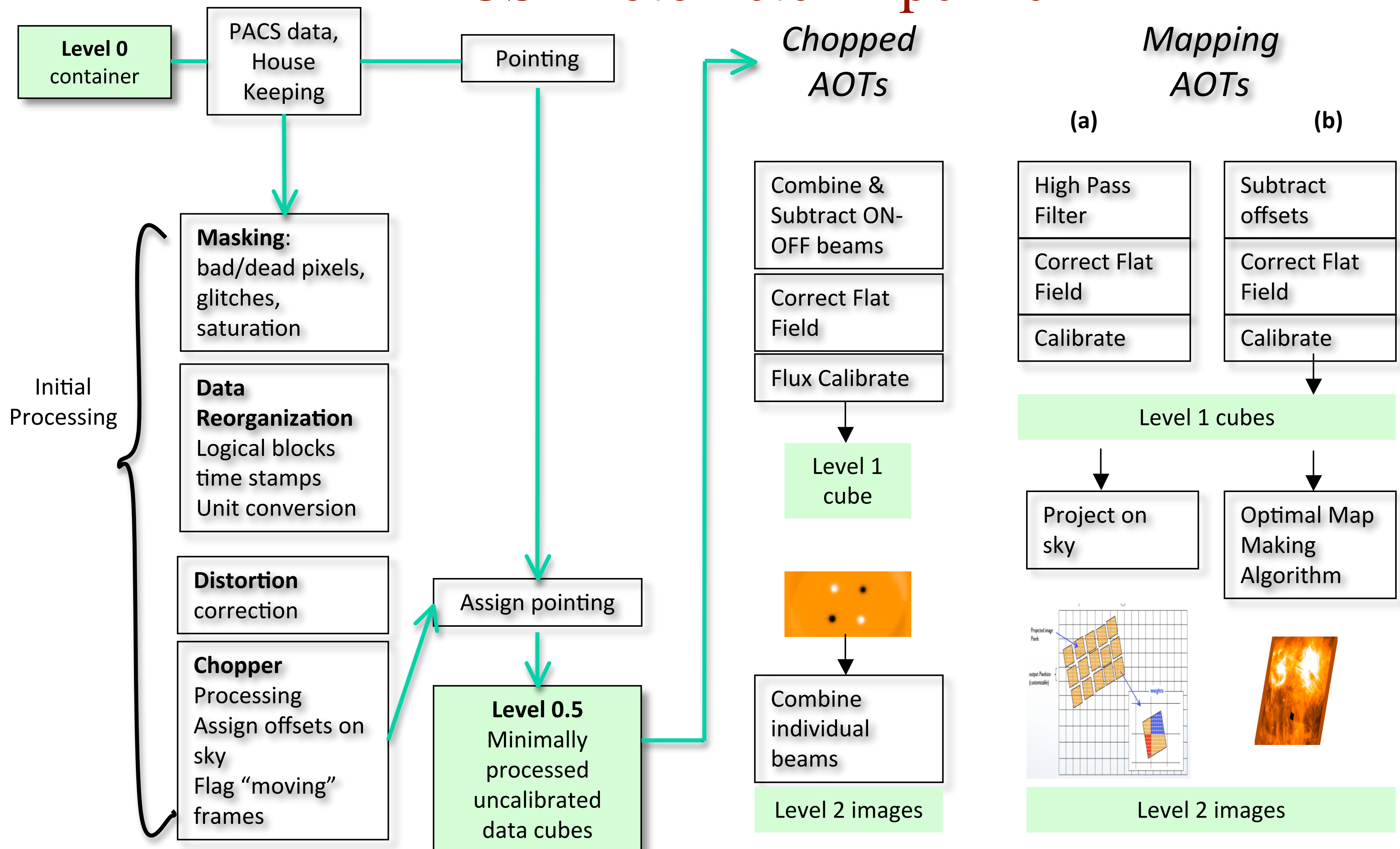
Rebin/Regrid

Level 2: Fully calibrated mapped spectral cube

Level 2 product

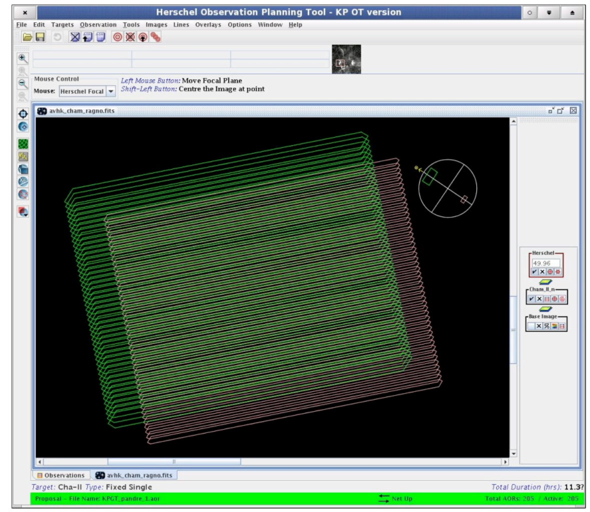


PACS Photometer Pipeline



PACS/SPIRE Parallel AOT

- Possibly more efficient utilization of the cryogen
- Scan-maps only (No chopping)
- Choice of slow (30”/s) or fast (60”/s) speed
- Near simultaneous data in 5 bands
  - Must select either blue or green PACS filter
- PACS must use “double-lossy” compression of data
- Sensitivities are significantly different between PACS & SPIRE
- Only efficient for large surveys
  - PACS & SPIRE FOVs are separated by 20’ on sky



Example of PACS+SPIRE parallel mode footprint.