Herschel/PACS Status/Performance/Issues

SDP Workshop Dec 2009

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for the PACS Consortium

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- PACS Instrument Characterization Key Results/Issues
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  - Photometer
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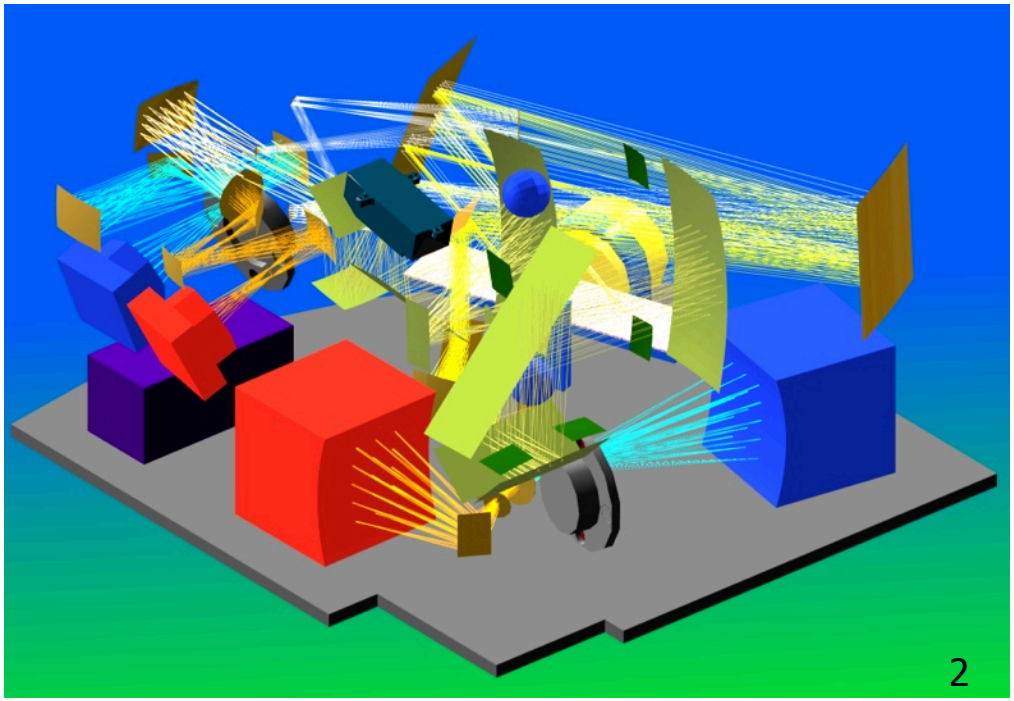


AOT Release Status

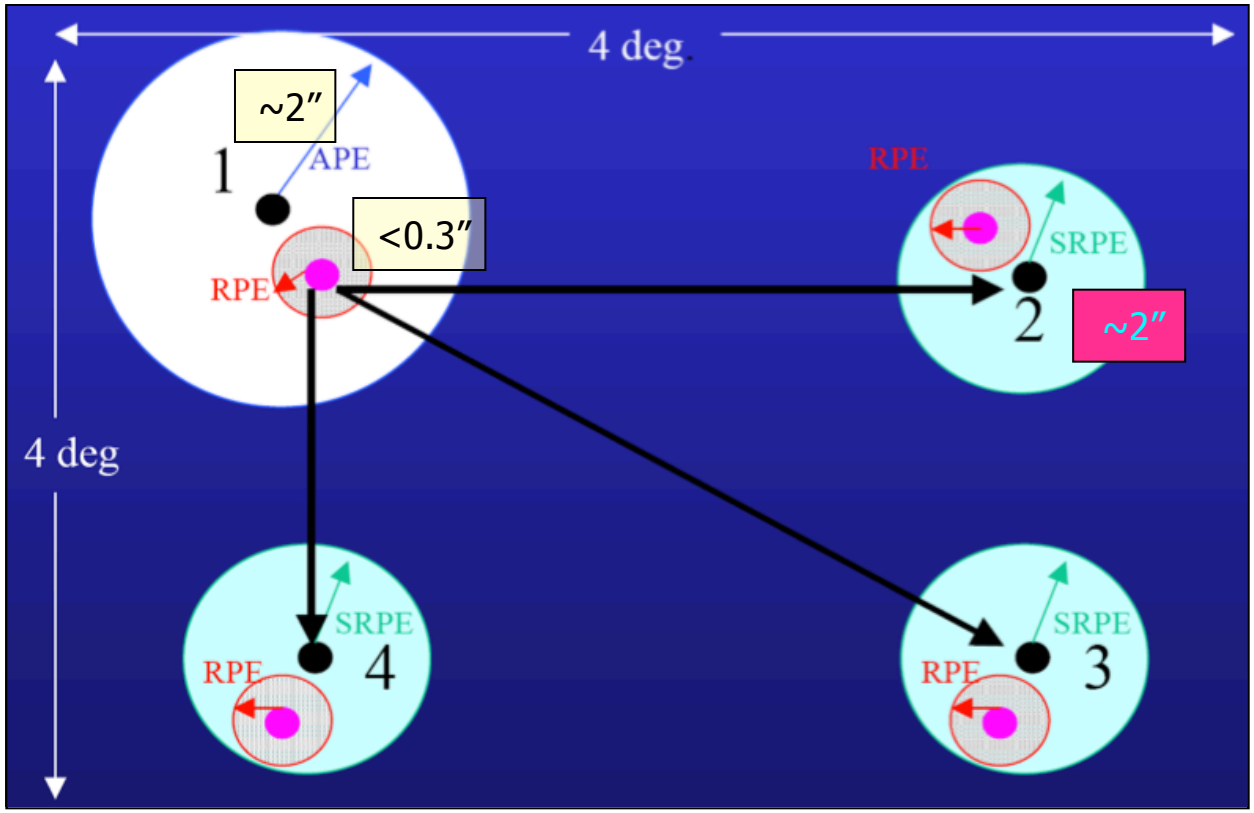
- All photometer AOTs have been released, but with modifications compared to pre-flight
  - scan speed optimization
  - replacement of all chopped observations by scan map mode, except for point source mode
- All but one spectrometer AOTs (SED mode) have been released, again, with some modifications
  - very bright sources not covered, yet
  - execution times of AOT "building blocks" have changed
- Pipeline versions in HIPE exist for all released modes, except for wavelength-switching line spectroscopy
  - demo available at DP workshop

Satellite Performance (1)

- Pointing Performance:
  - Relative Pointing Error (RPE): Requirement <0.3″ Goal <0.3″
  - Absolute Pointing Error (APE): Requirement <3.7″ Goal <1.5″
  - Spatial Relative Pointing Error: Requirement <1″

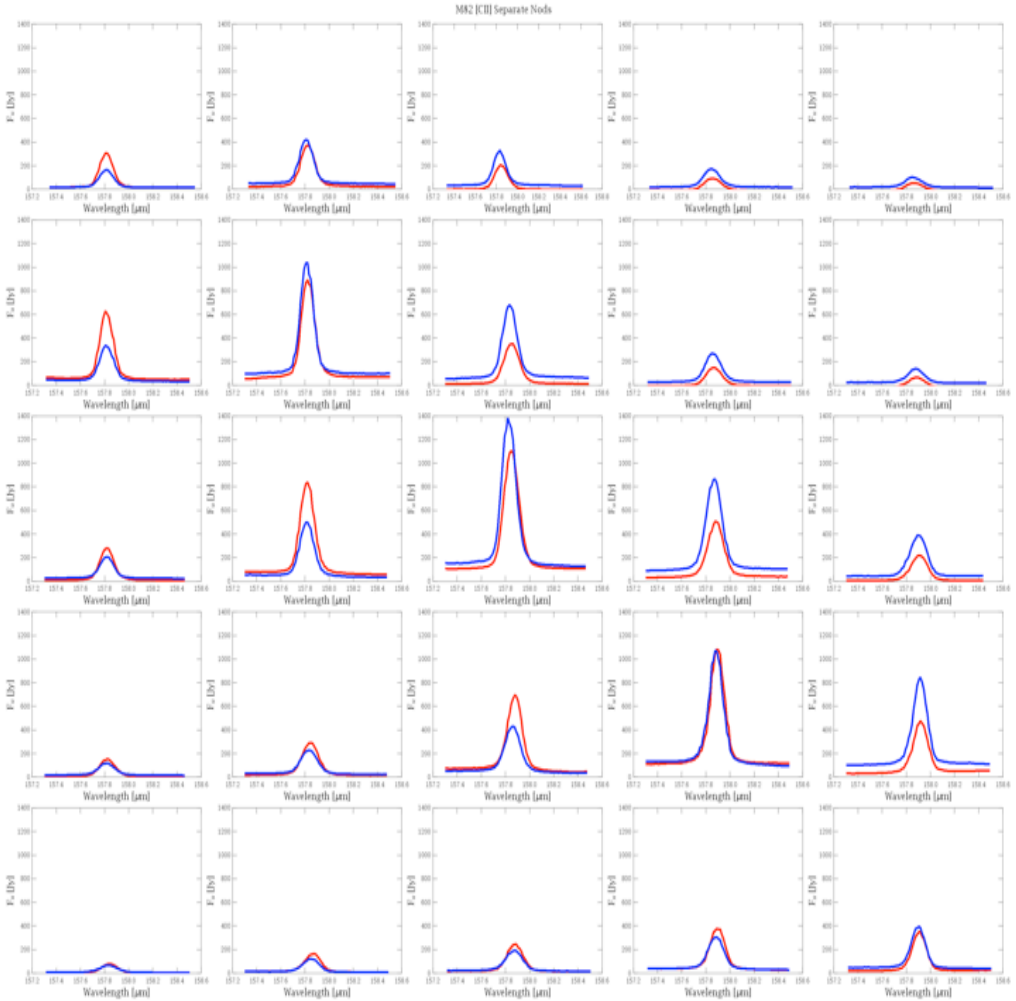
  - RPE Scanning:
    Requirement <1.2″
    Goal <0.8″

  - Solar Aspect Angle:
    Requirement:
    -30° to +30°
    Actual:
    -20° to +30°



Pointing Match Chop/Nod (Spectroscopy)

- From (still limited) statistics, no problem for small chopper throw
- With large chopper throw (±3’), APE seems to apply for “Nod A” and “Nod B” individually - sometimes ok, sometimes a problem



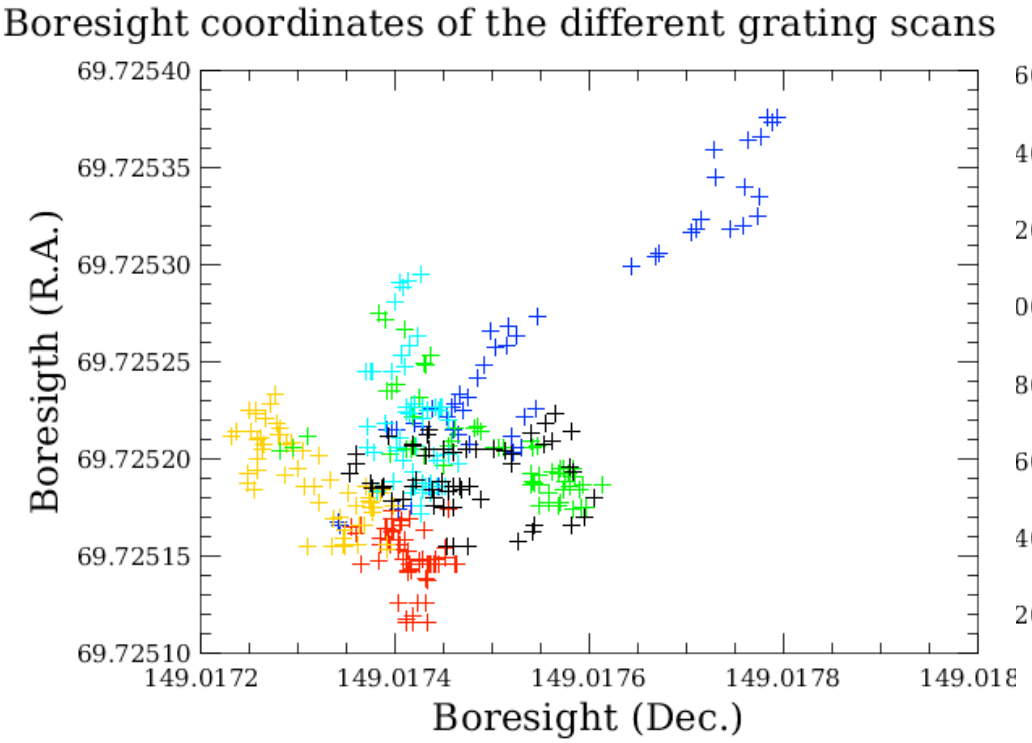
Pointing Products / Reported Coordinates

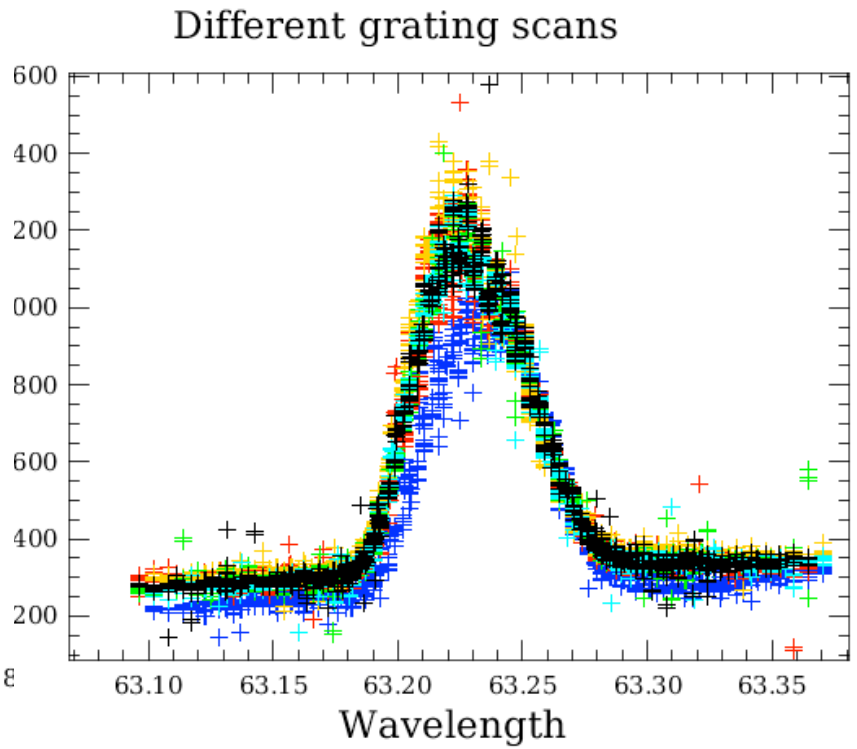
- There is an error in the reported coordinates, most of the time 1...2 arcsec, w.r.t. the commanded/observed coordinates, in spectroscopy only (we think)
- Larger excursions reported

- Sometimes, assignment of (nod) positions to science data messed up
- In case of doubt, check aux. data

- Slew (after nodding) may not have finished when observation continues. (Shows up in coordinates, at least.)

Pointing Products / Reported Coordinates





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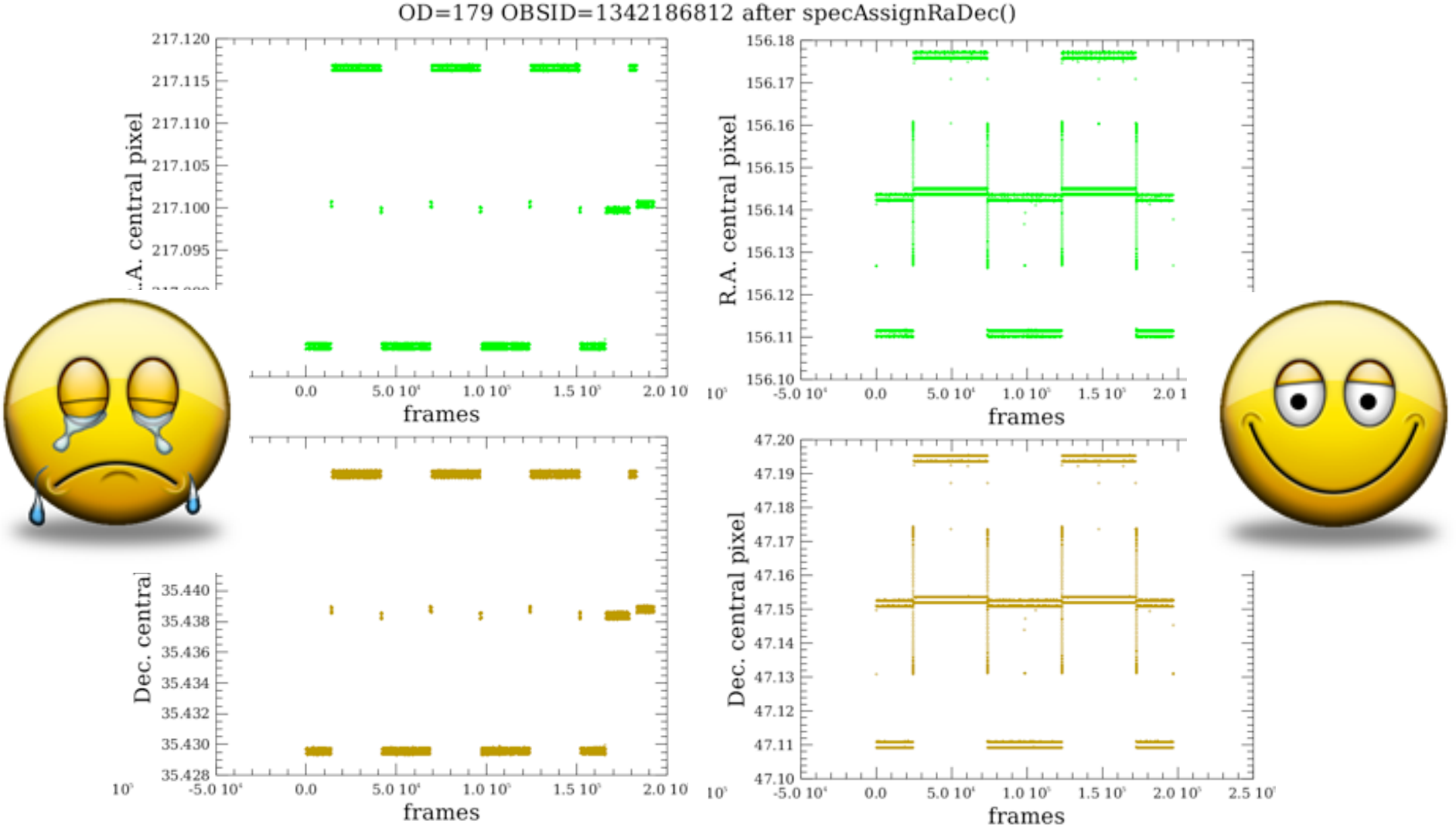
Chop/Nod-Pattern Check



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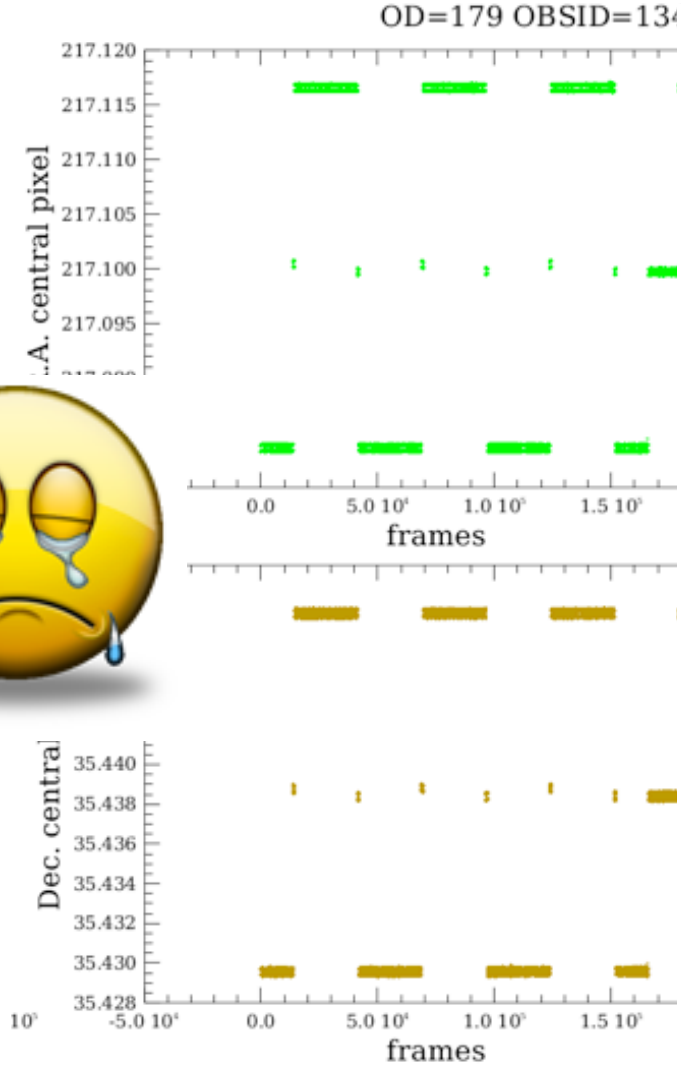
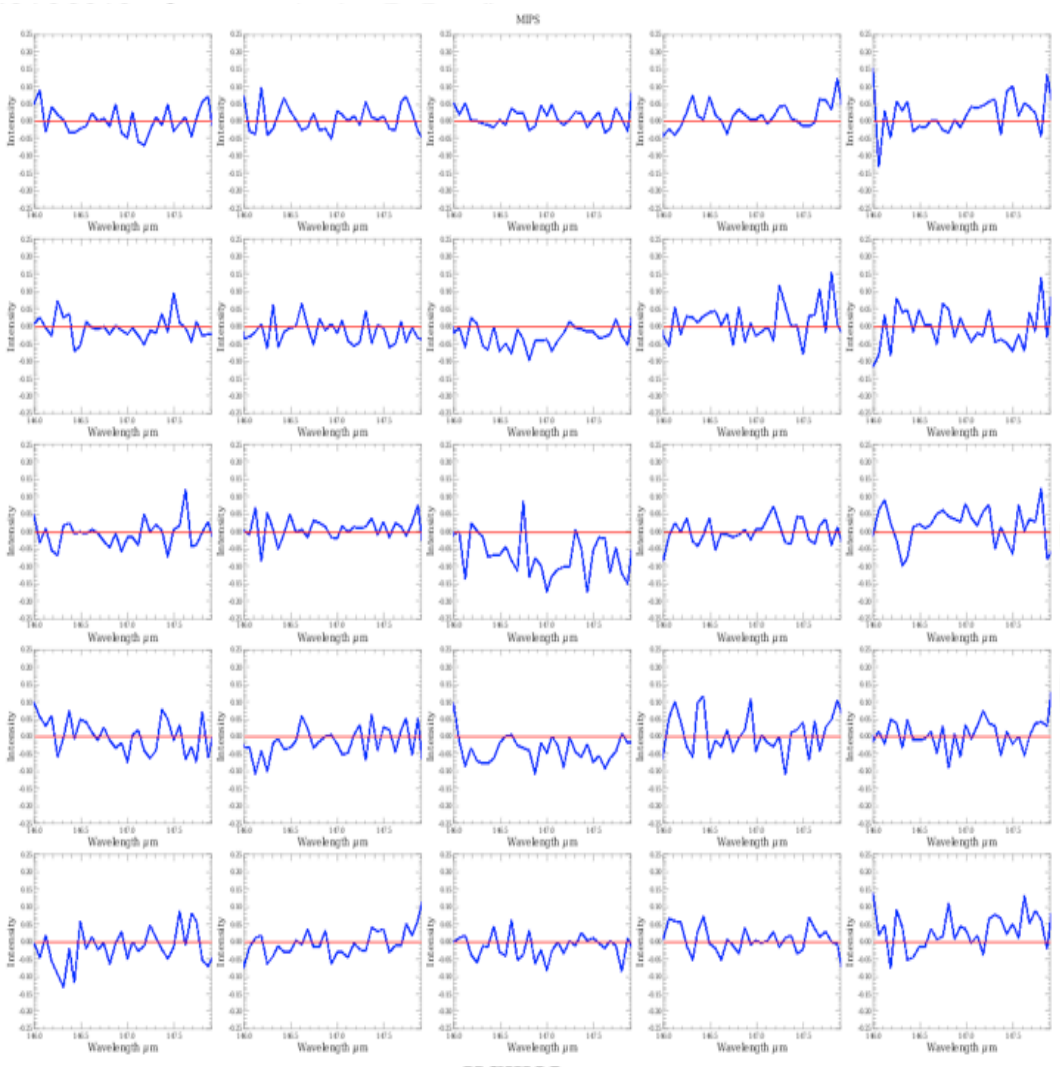
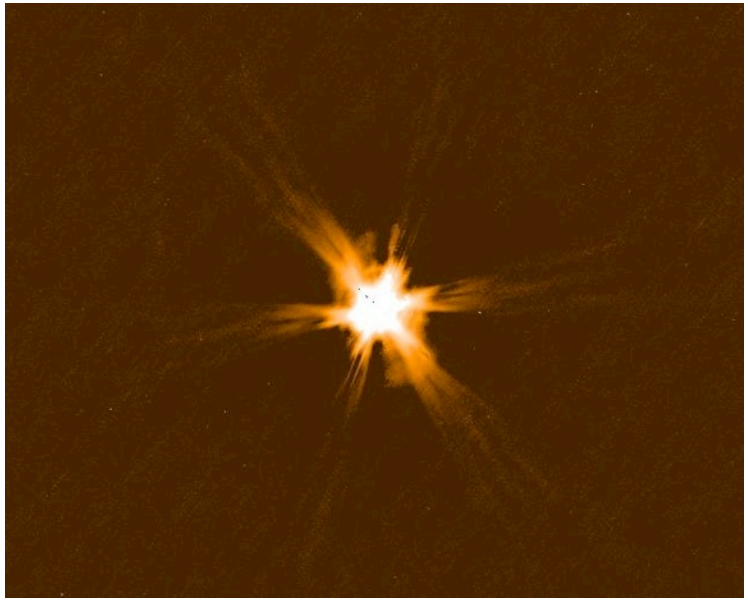
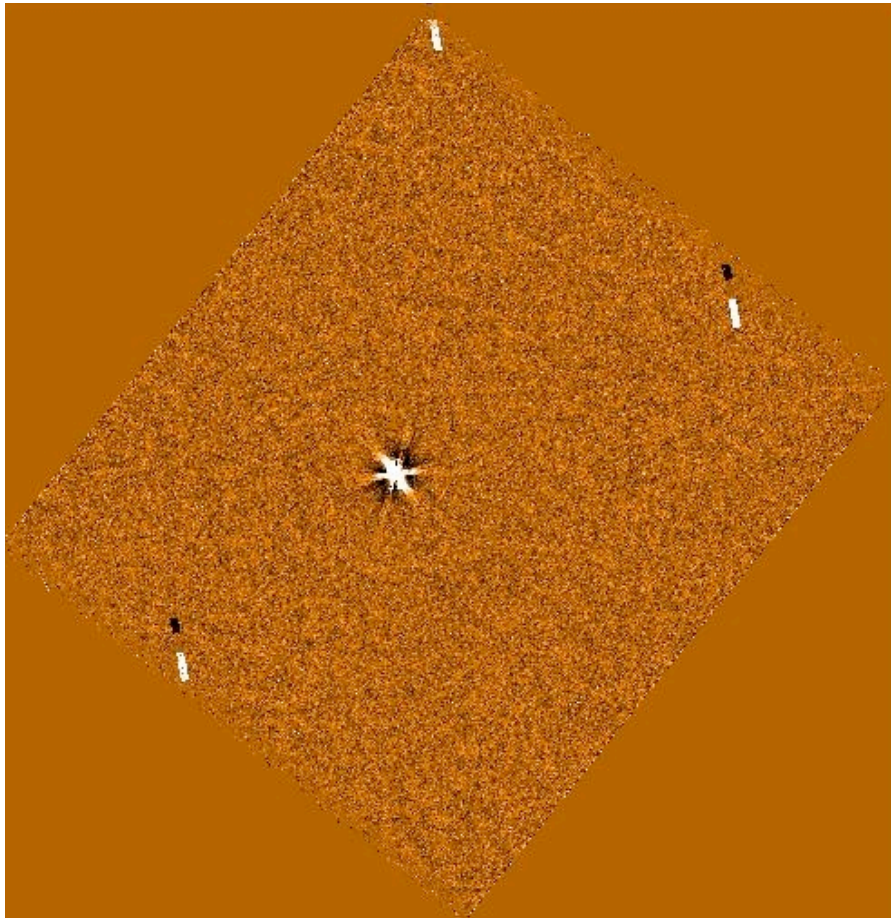




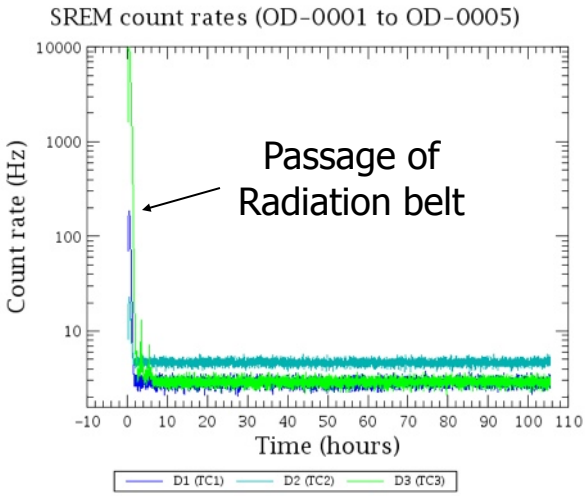
Satellite (+Instrument) Performance (4)

- Straylight
  - Observation of Mars
  - No hint of straylight around boresight

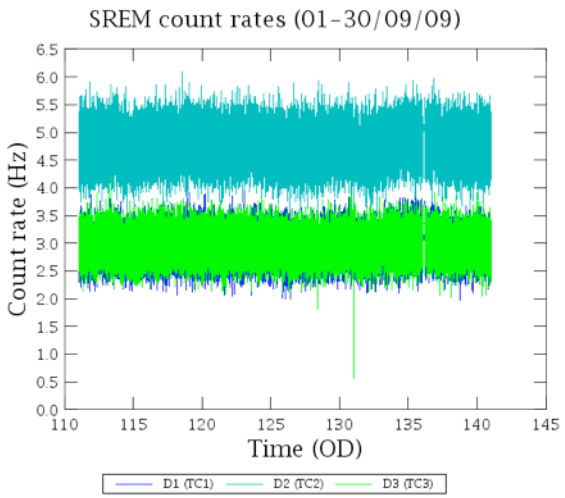


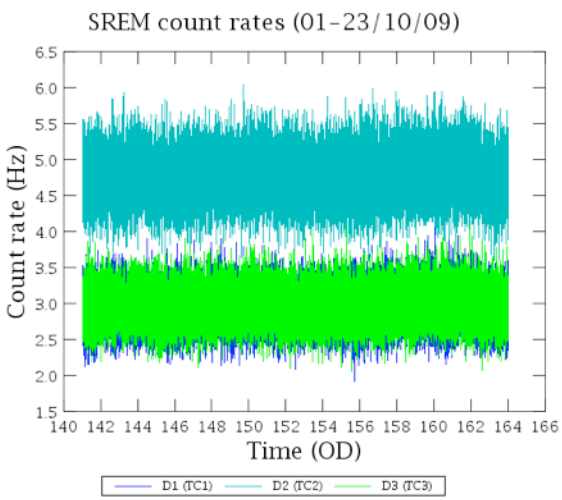


Space Weather and Glitch Rates



Nov-1997





Oct-2009

Observed Glitch rates on PACS:

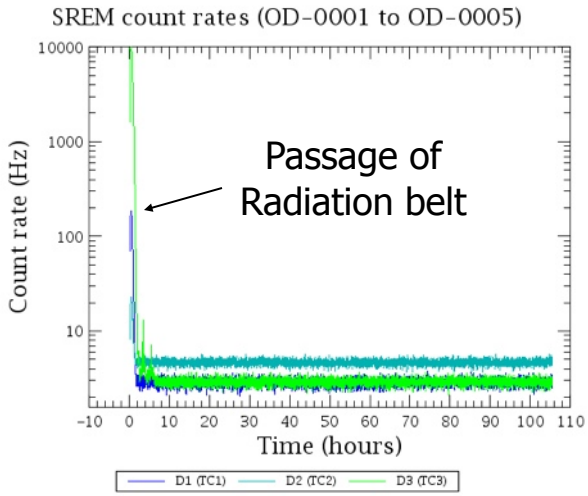
Bolometer: ~ 1 [hit/min/pixel]

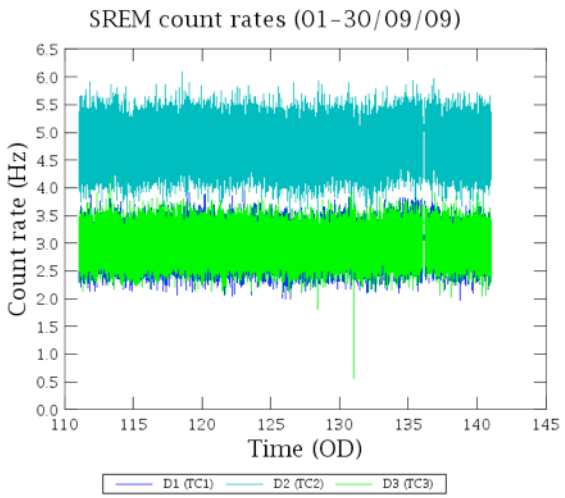
Ge:Ga: ~ 0.08-0.2 [hits/sec/pixel]

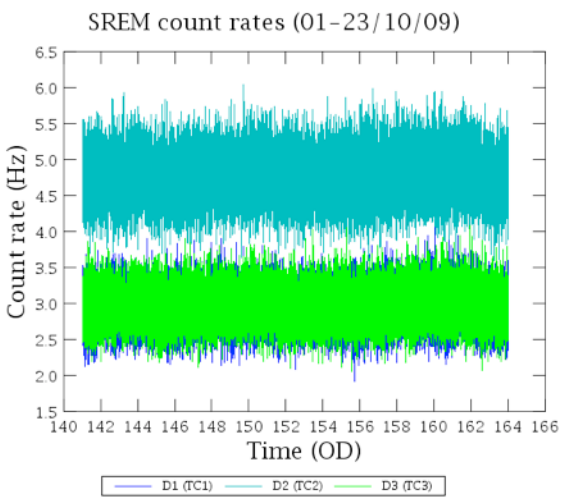
Electronics: no event seen until today

Large Angle Spectrometric Coronagraph (FOV = 32 solar radii), SOHO

Space Weather and Glitch Rates







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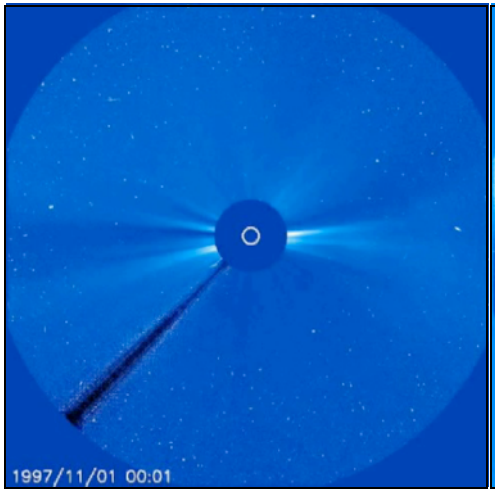

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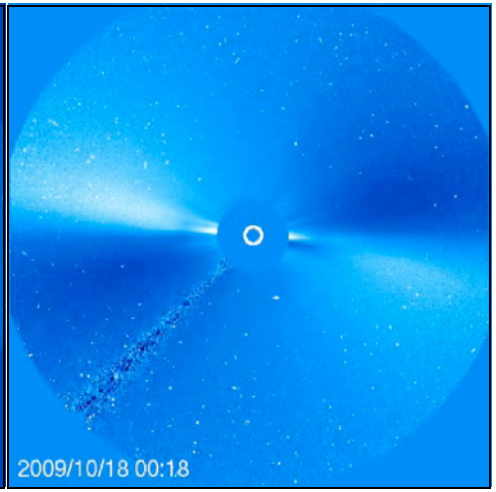

Large Angle Spectrometric Coronagraph (FOV = 32 solar radii), SOHO

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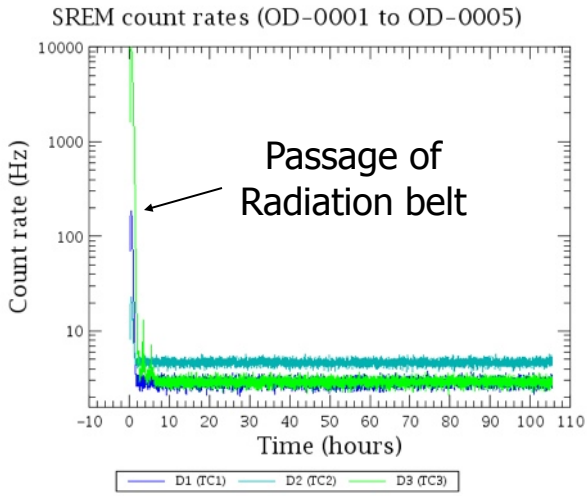

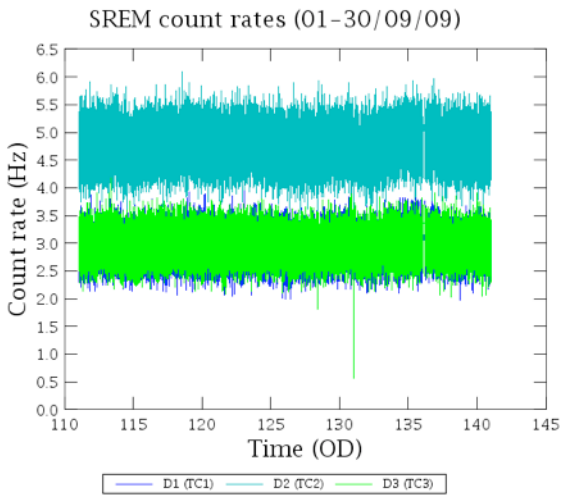

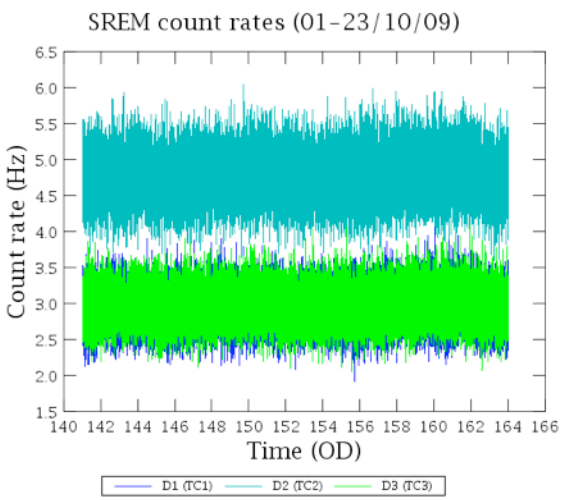

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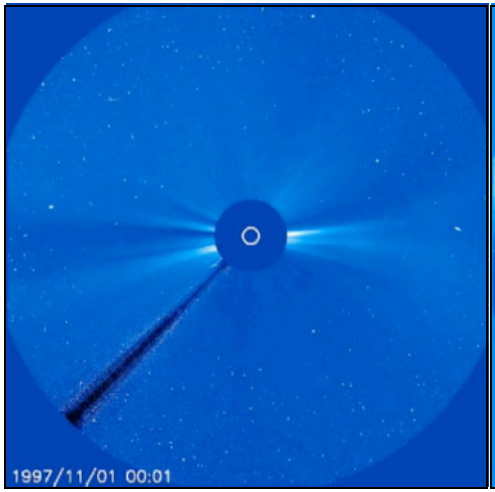

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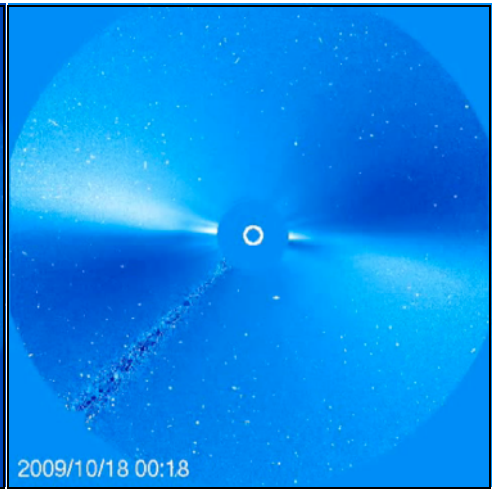

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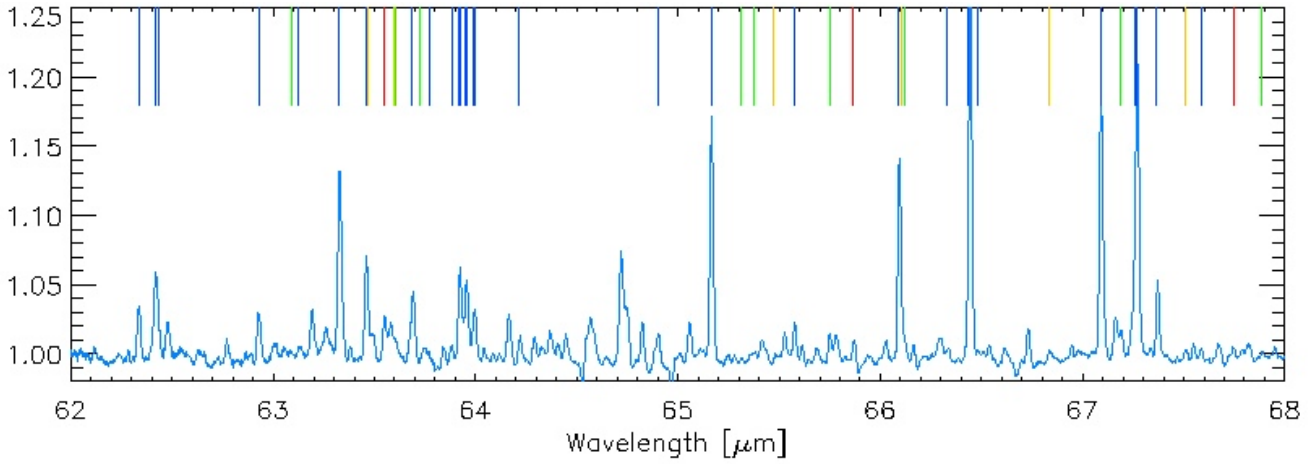
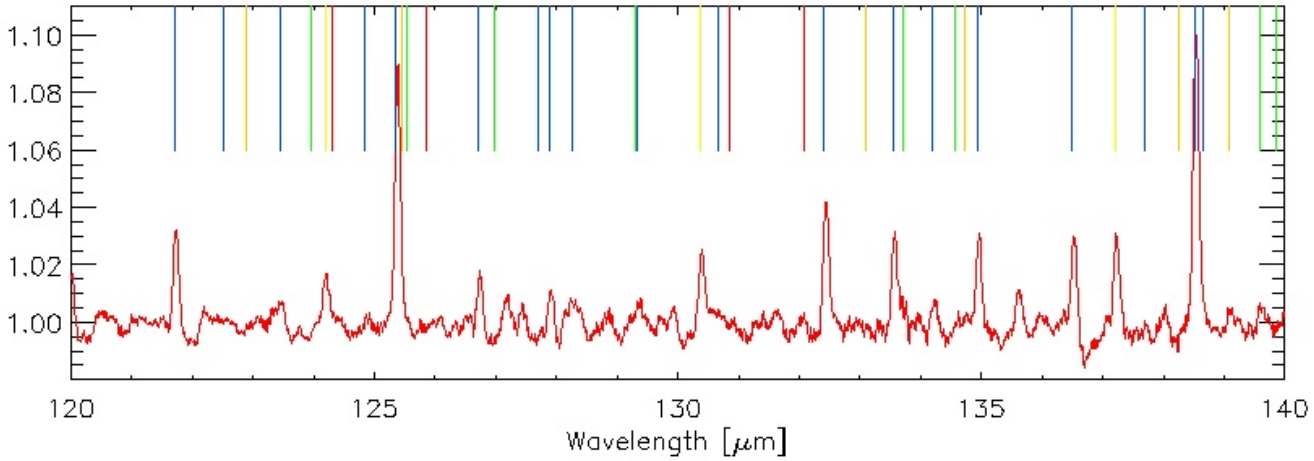
Spectrometer Wavelength Calibration





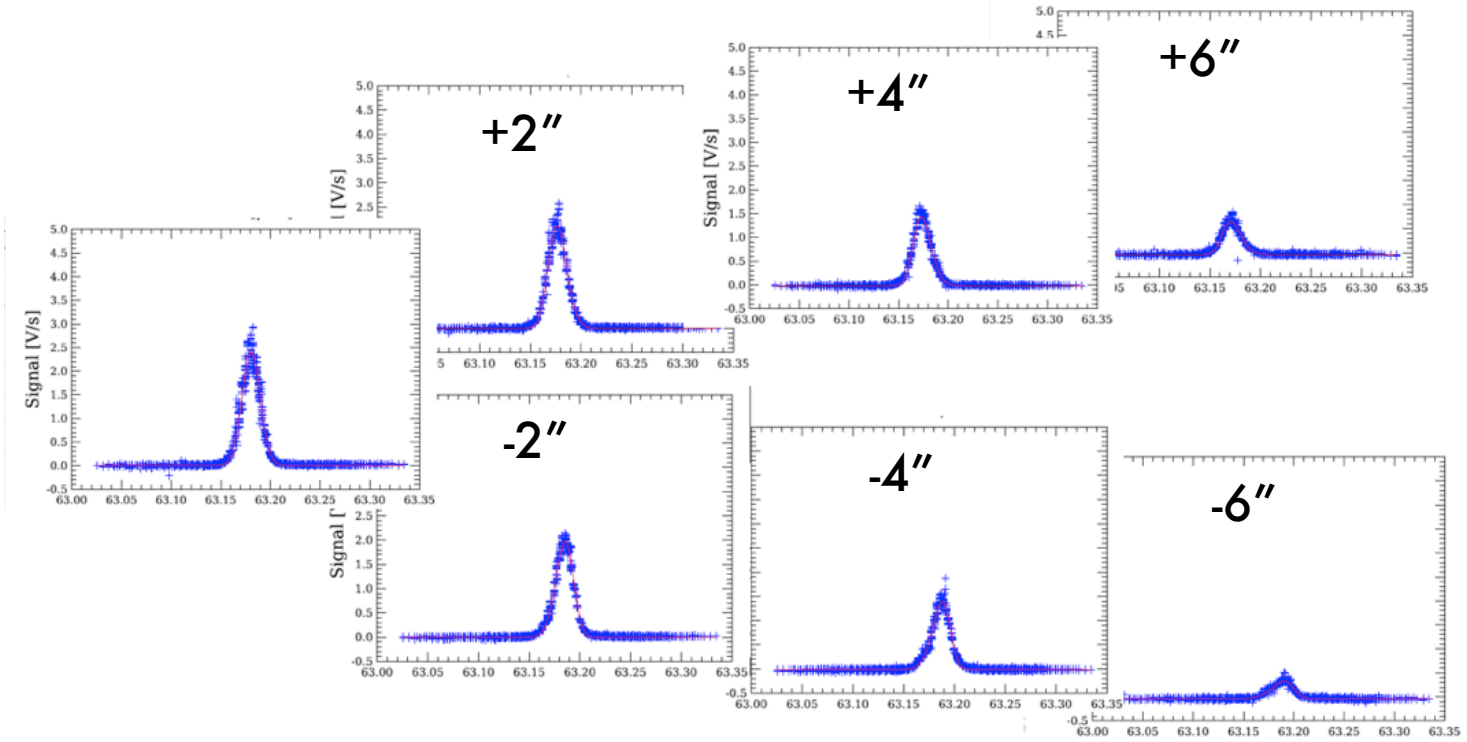
W Hya PACS observation, continuum divided

Velocities corrected to rest frame, strong water lines over-plotted;
$H_2{}^{16}O$=blue
$H_2{}^{18}O$=green
$H_2{}^{17}O$=orange
HDO=red
CO=yellow

Lines from 4 water isotopes are detected.

Wavelength calibration is quite good already, fine tuning to come still

Spectrometer Wavelength Calibration



- Wavelength shift + skew with source offset from slit center (cross-slit direction, not along slit)
- Characterization + corrections underway
- Do not over-interpret line shapes in maps

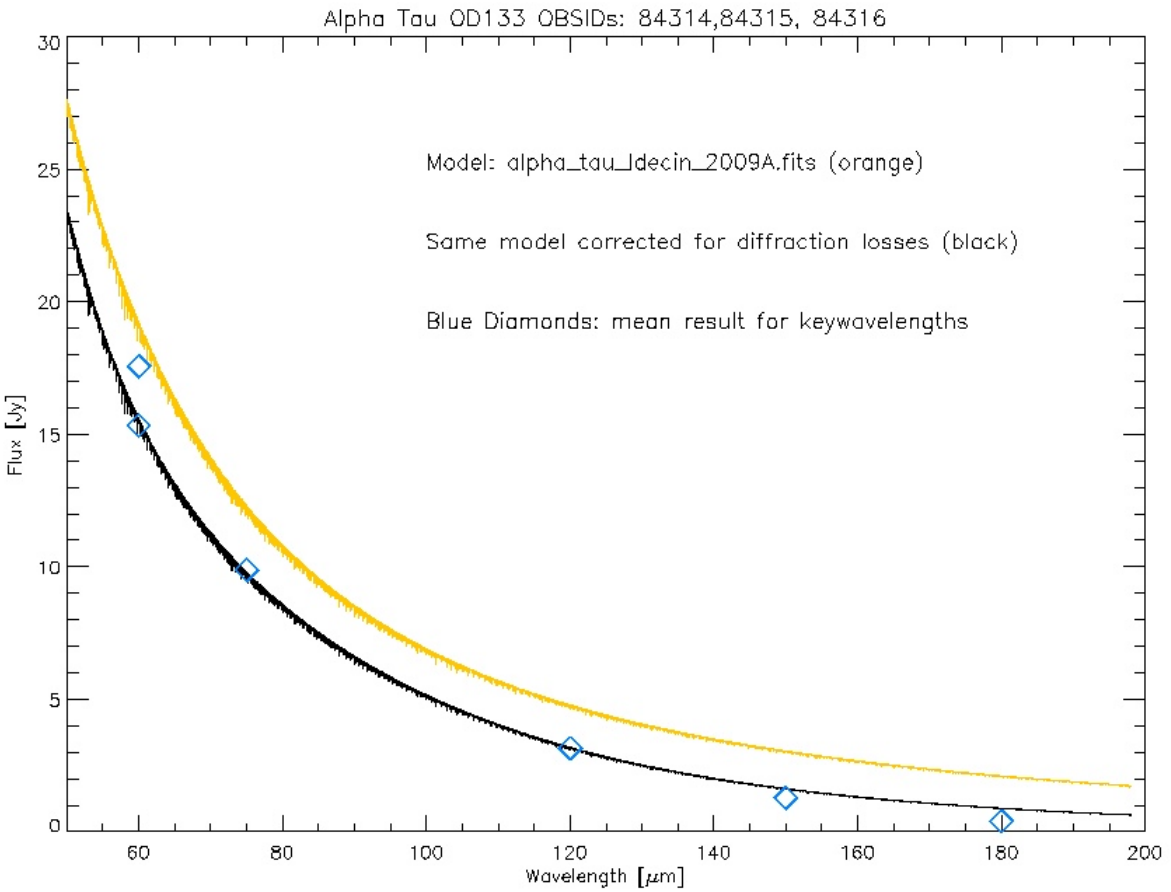
Spectrometer Flux Calibration: "Sanity Checks"

- Key Wavelength Observation on αTau.
- SED Scan on Fortuna
- Range scans on Vesta

- The resulting spectra are: (NodA+NodB)/2

- Conversion to Jy shows that ground based calibration from cryogenic blackbody seems to apply.

- However, response of detectors in flight has been found larger when comparing internal calibration source signal (factors ~1.2 [blue] and ~1.6 [red]).



Final, absolute flux calibrations pending!

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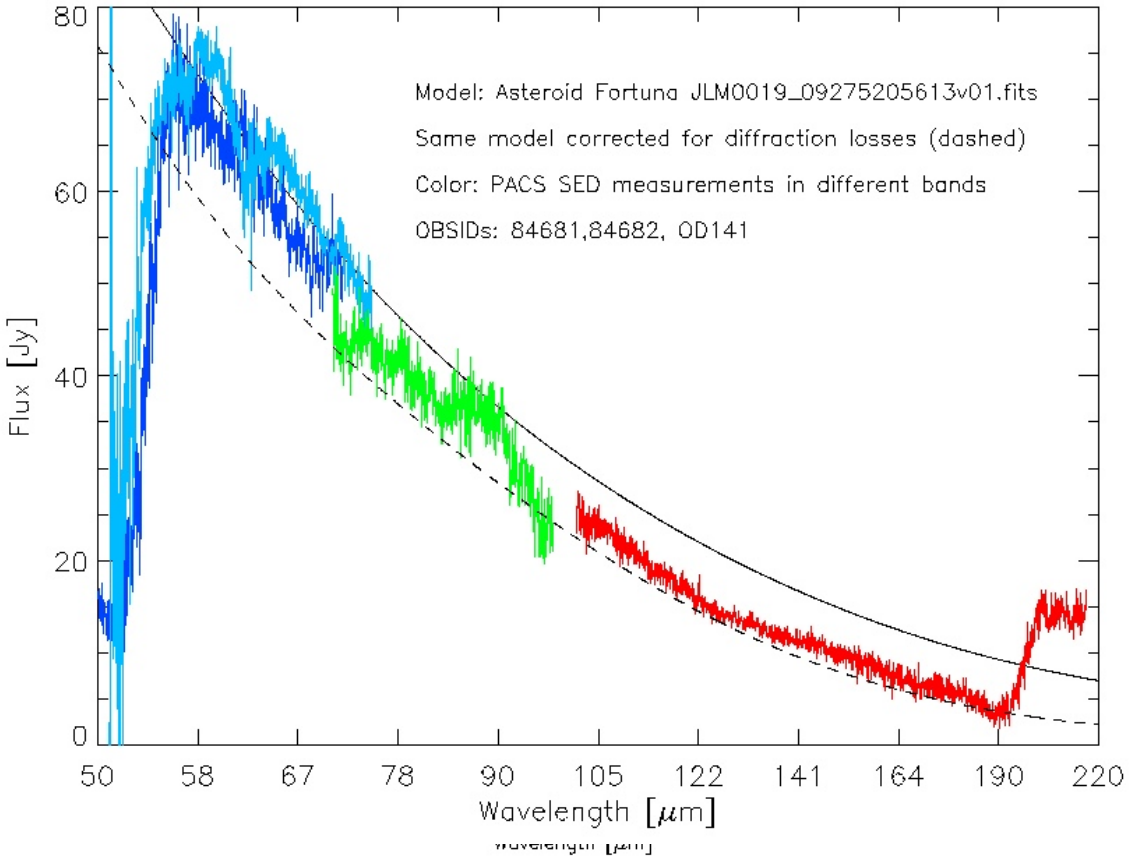

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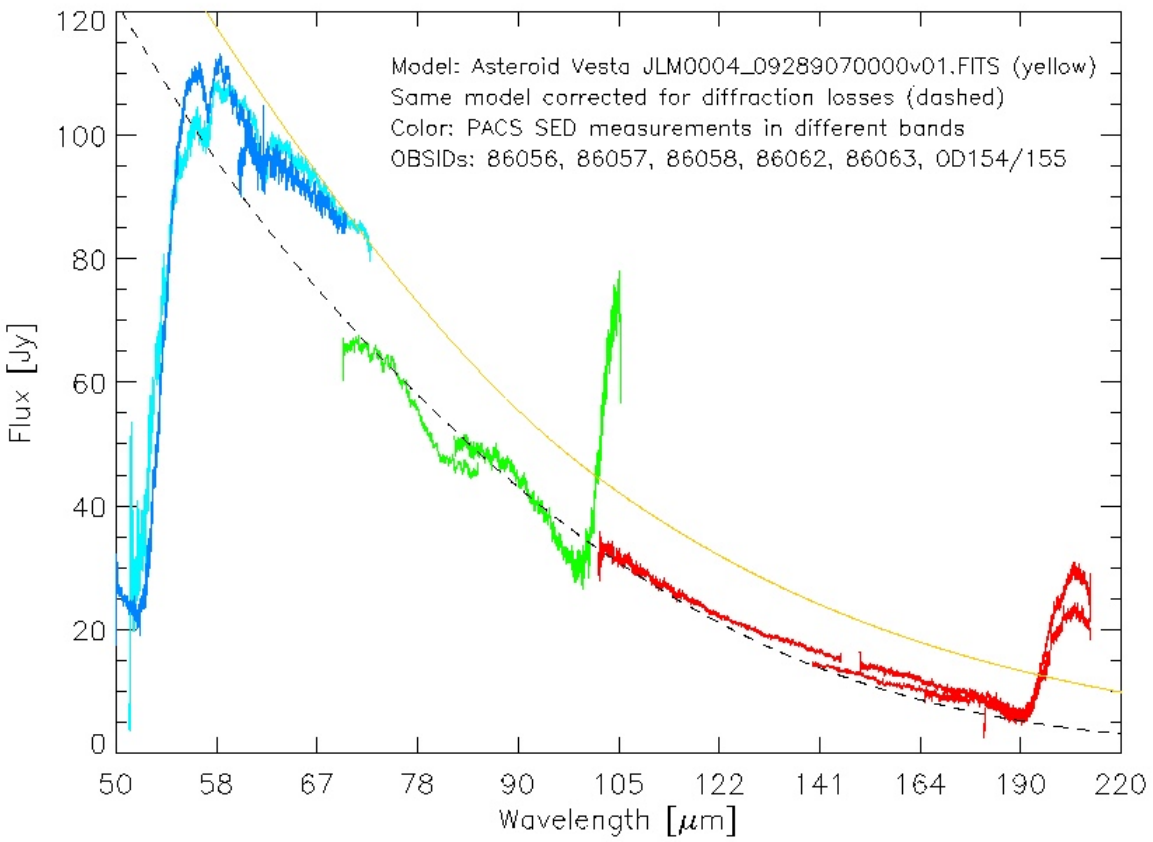

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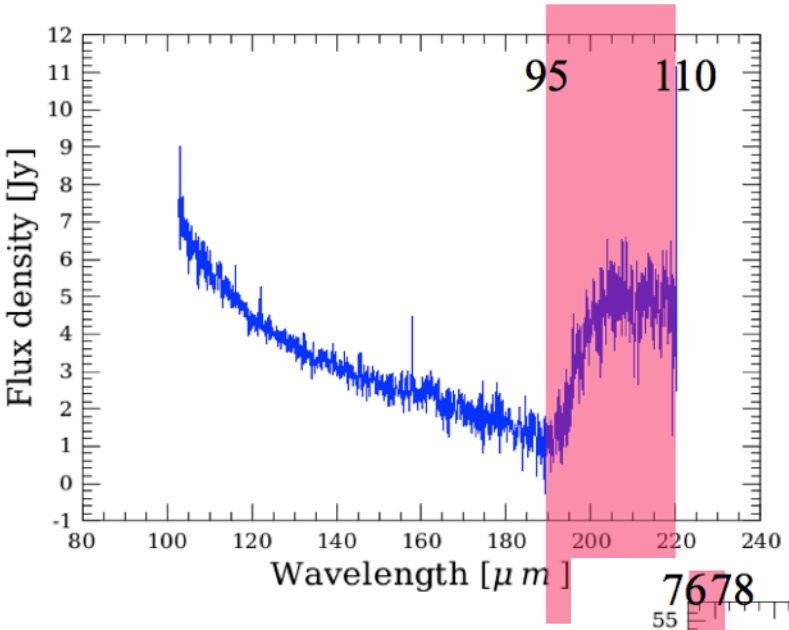
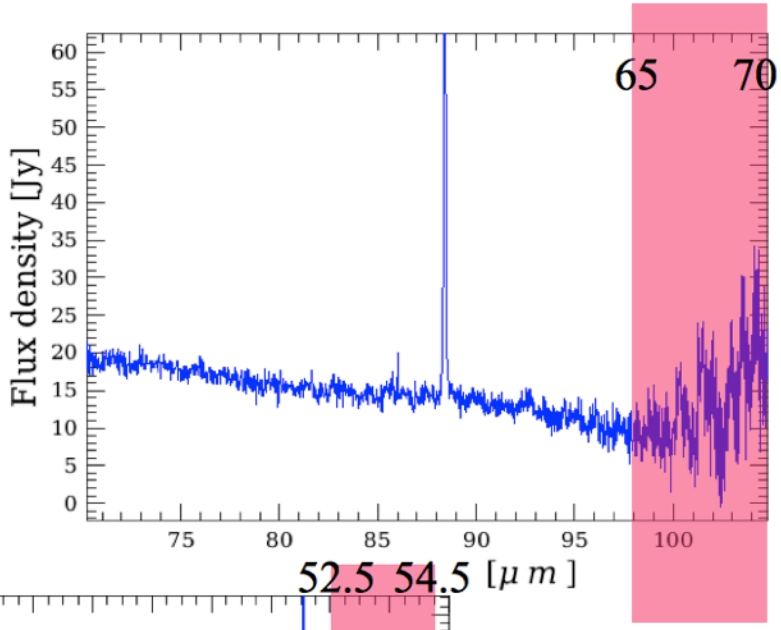
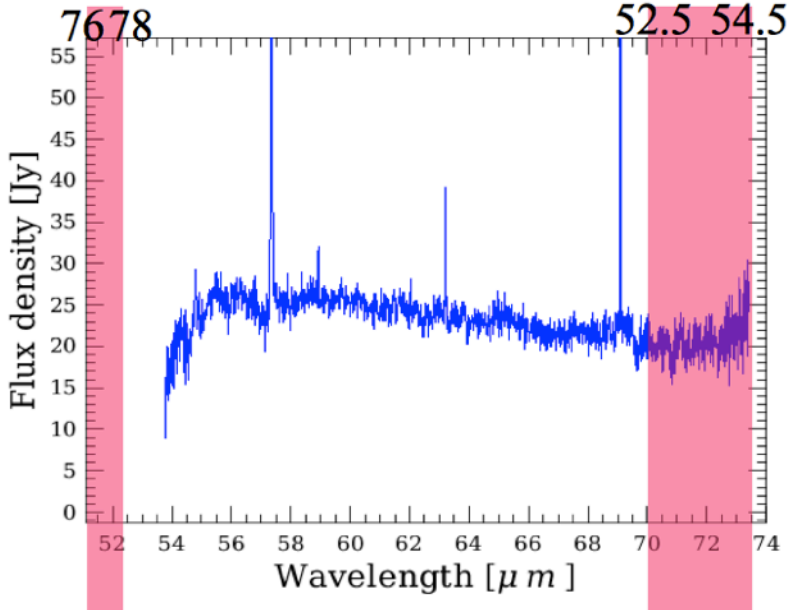
Spectrometer Problem Zones - Leakage

- Band R1: >190μm: low response, order 2 leak
  - 95-110 μm order 2 spectrum added to 190-220 μm order 1 spectrum
- Band B2B: >98μm: low response, order 3 leak
  - 65-70 μm order 3 spectrum added to 98-105 μm order 2 spectrum
- Band B3A: <52μm: low response, order 2 leak
  - 76-78 μm order 2 spectrum added to 51-52 μm order 3 spectrum
- Band B3A: >70μm: order 4 leak
  - 52.5-54.5 μm order 4 spectrum added to 70-73 μm order 3 spectrum

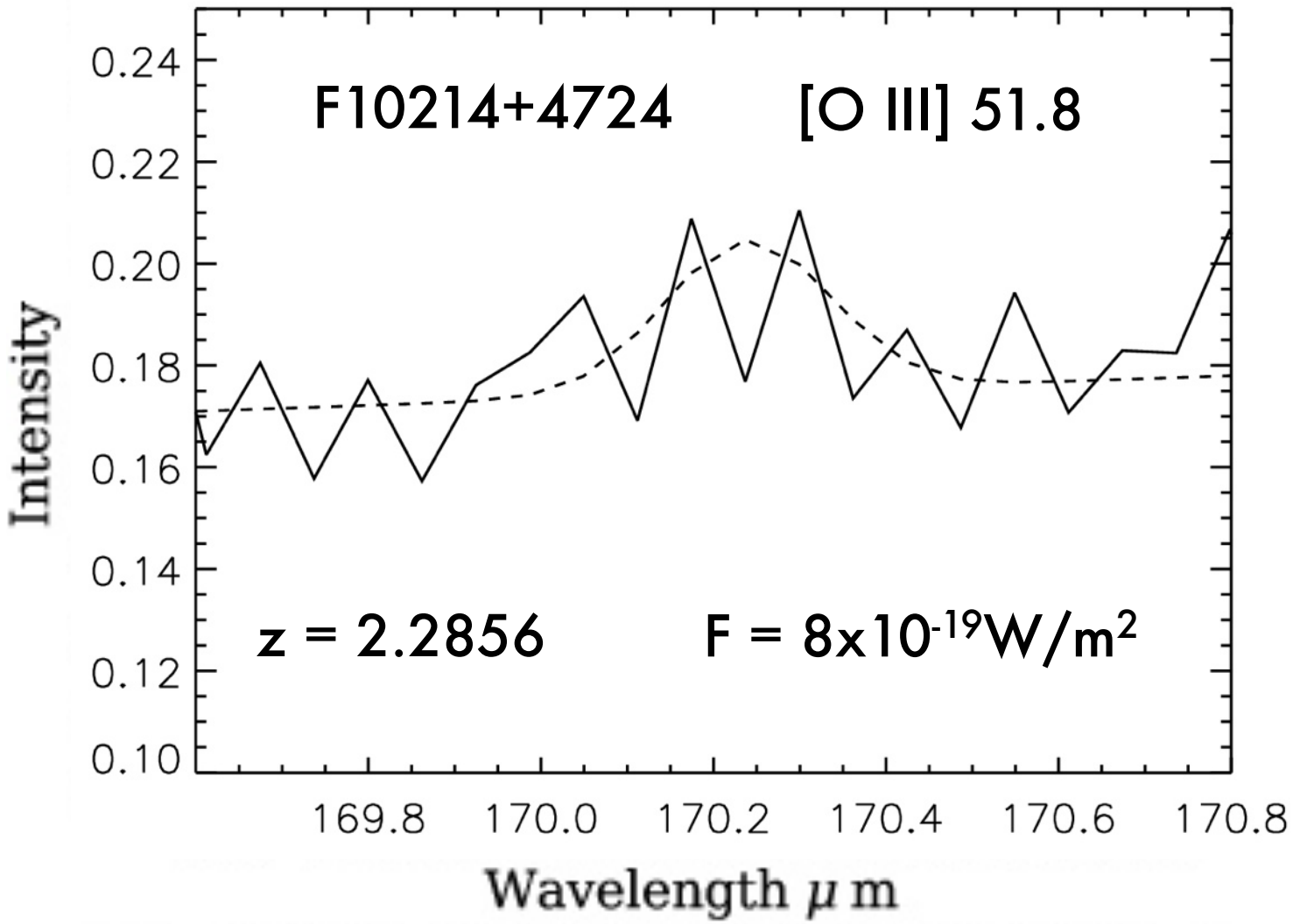
Spectrometer Problem Zones - Leakage







Spectrometer Sensitivity: Faint Source Detection



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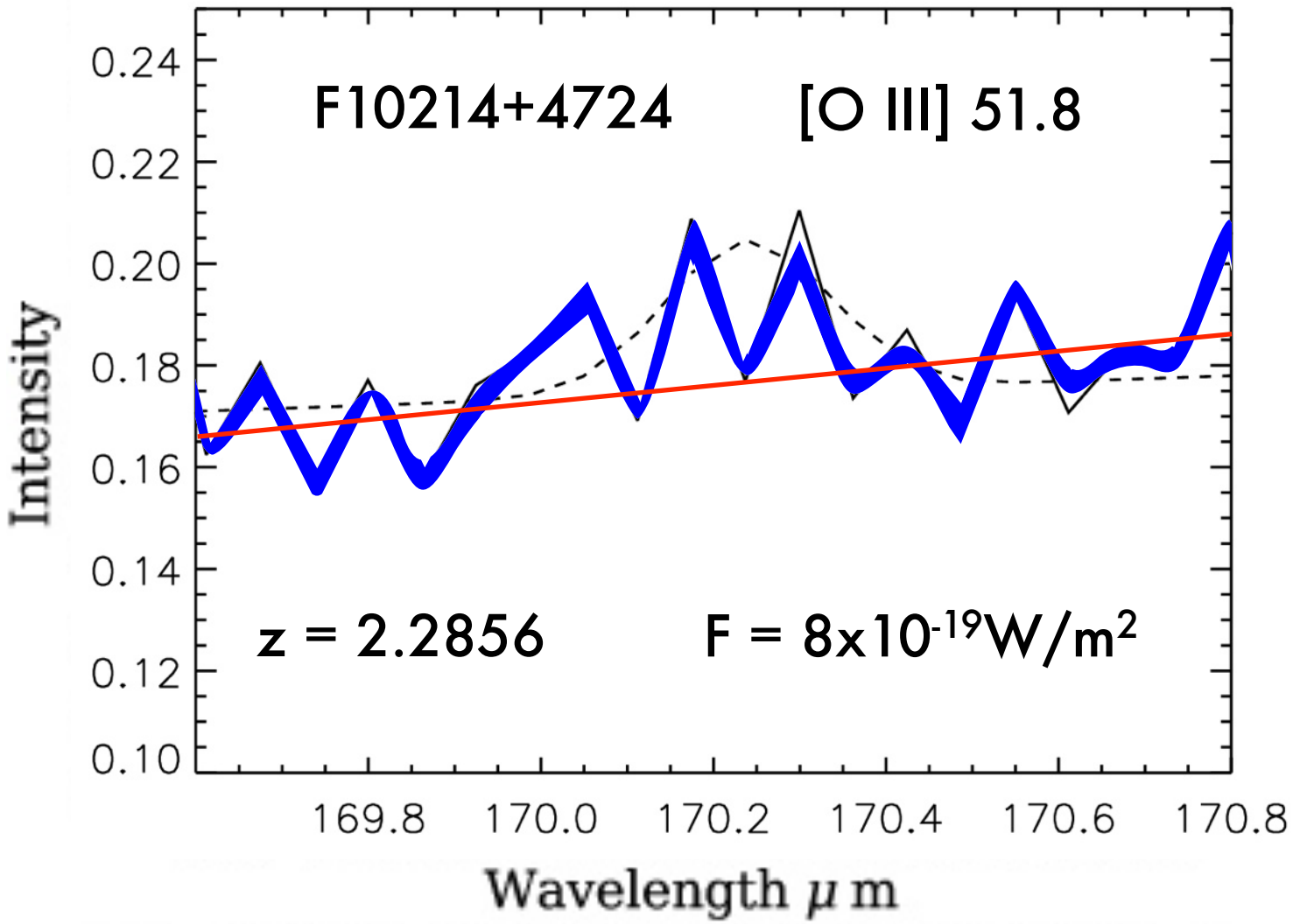

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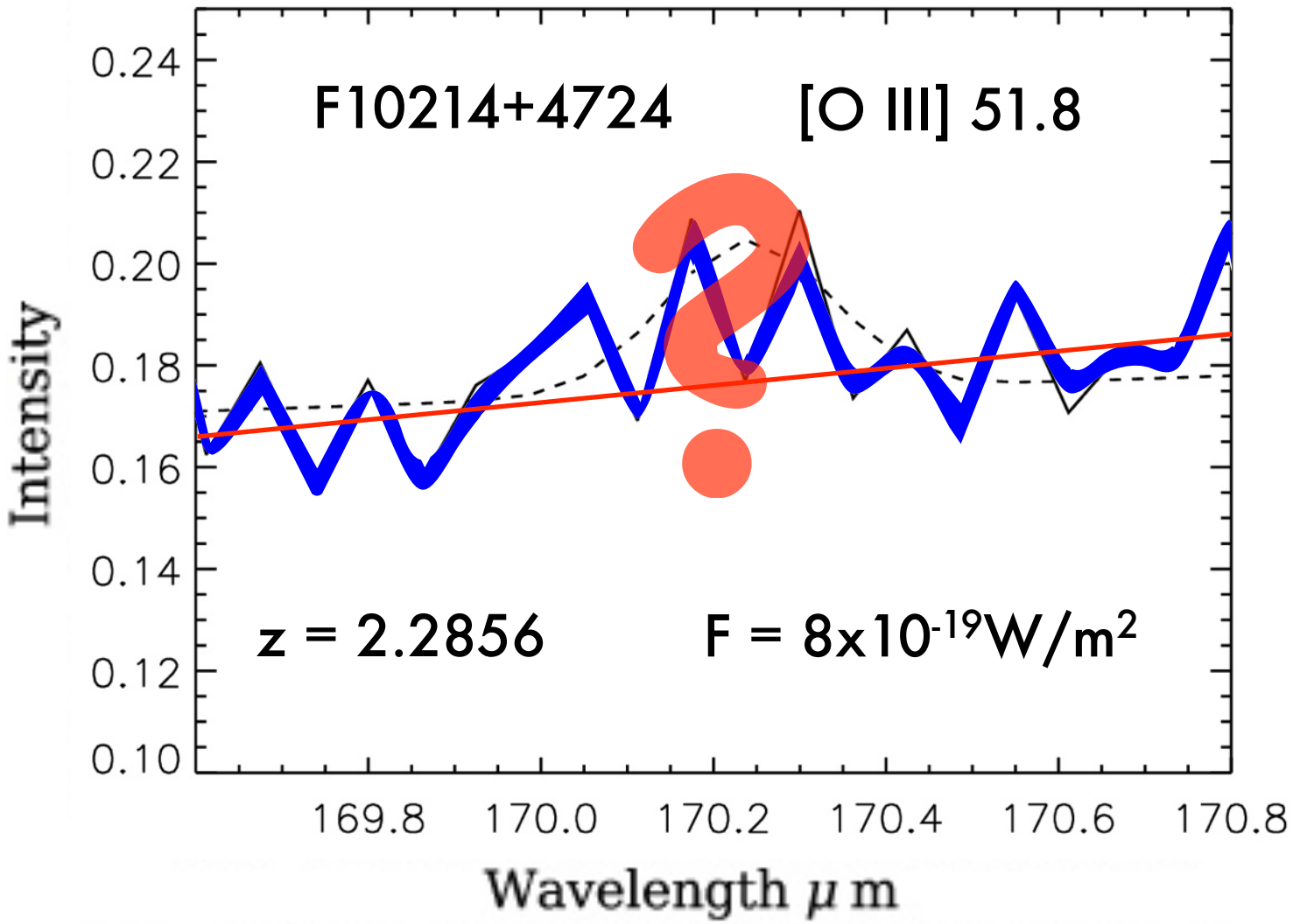

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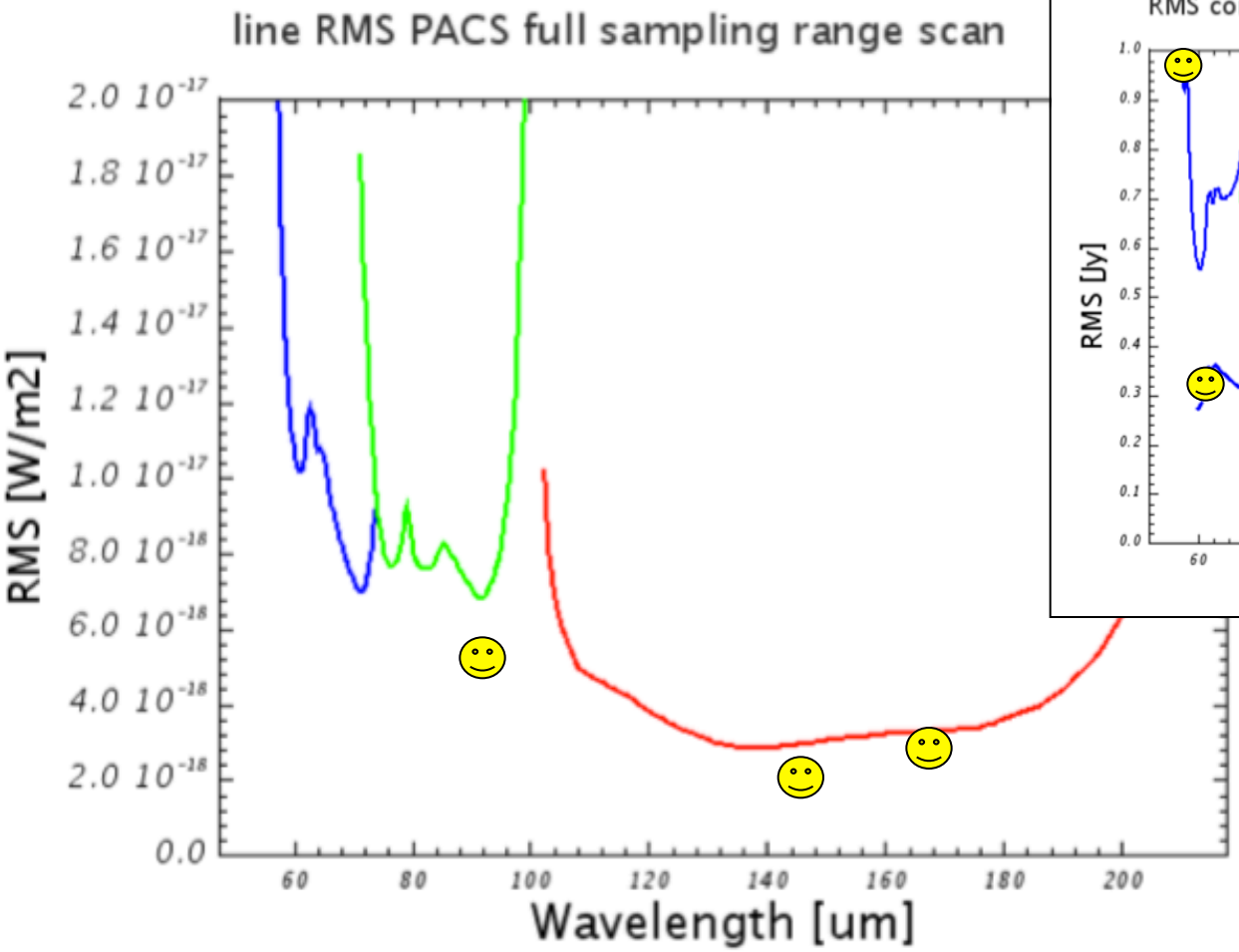


Fig.: 3.14 from PACS Observers Manual
= HSPOT sensitivity

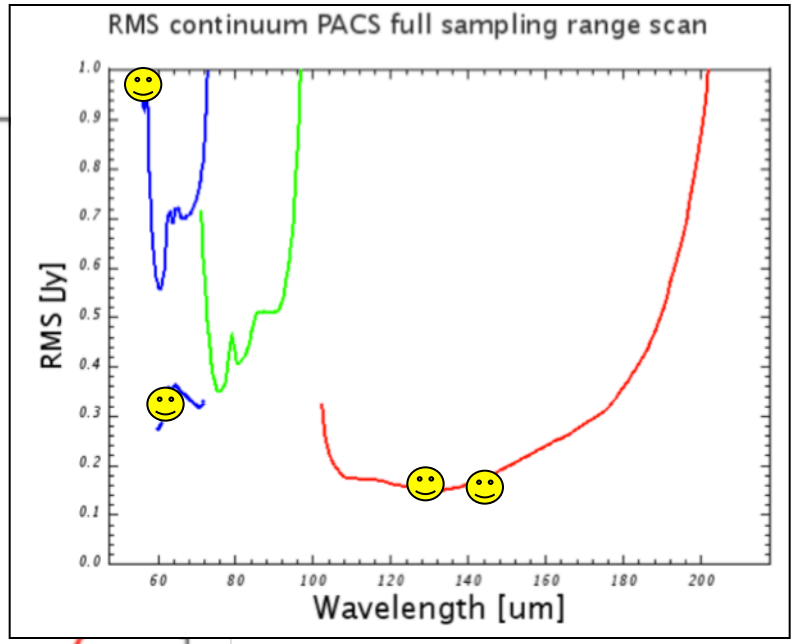
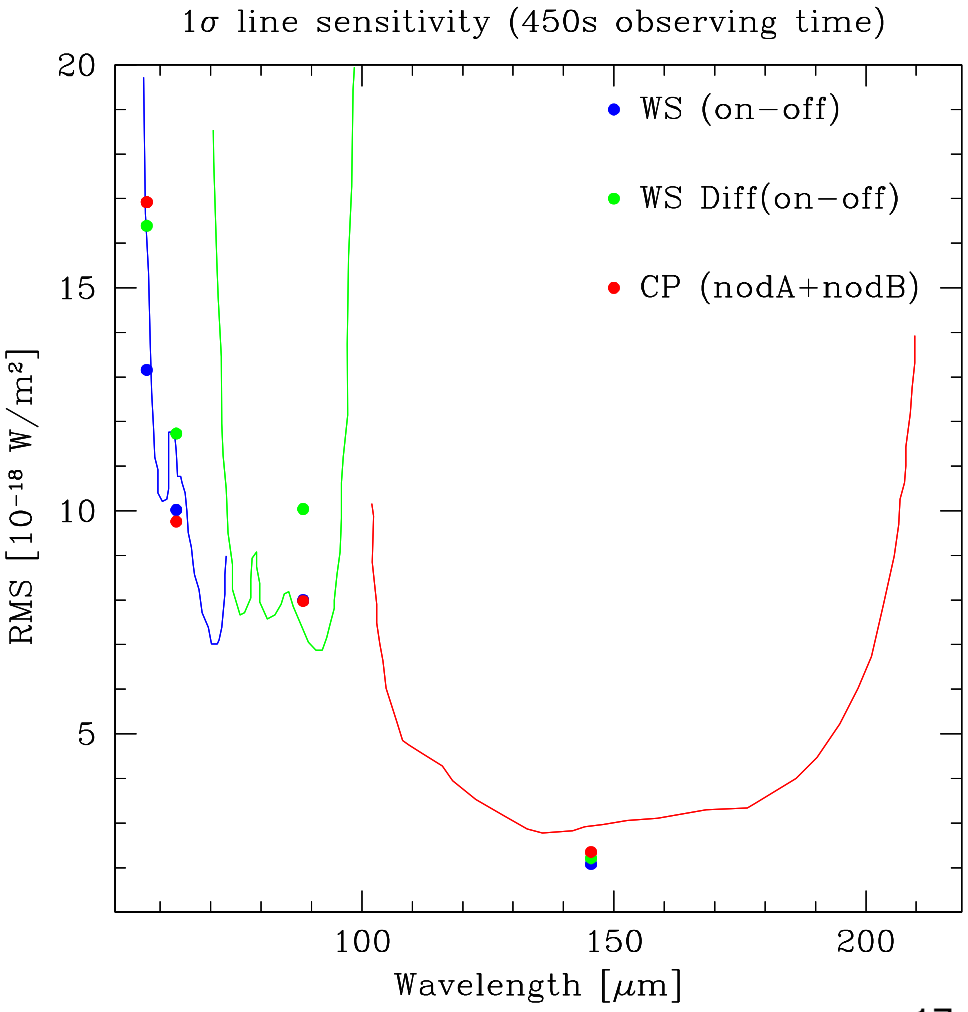


Fig.: 3.13 from PACS Observers Manual

Recalculated 1σ sensitivities from actual exposure time to HSPOT exposure (~450sec per 1nod and 1up-down).

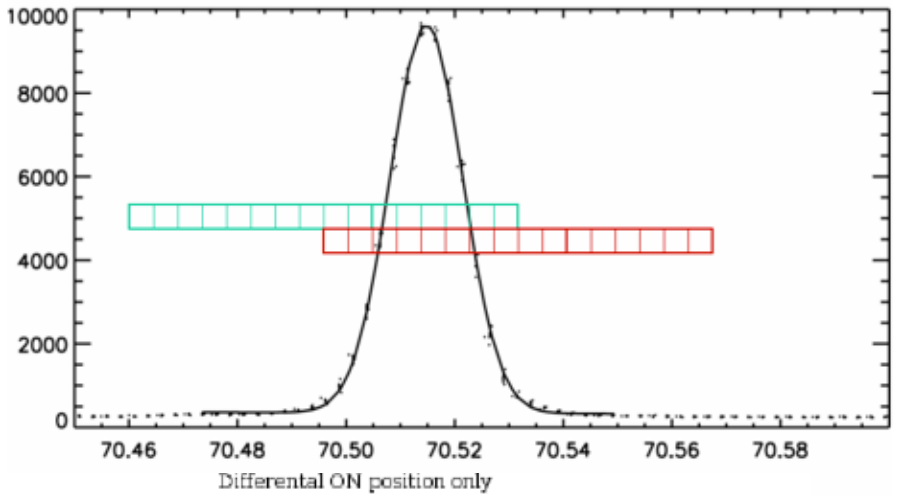
Chop/Nod vs. Wavelength Switching

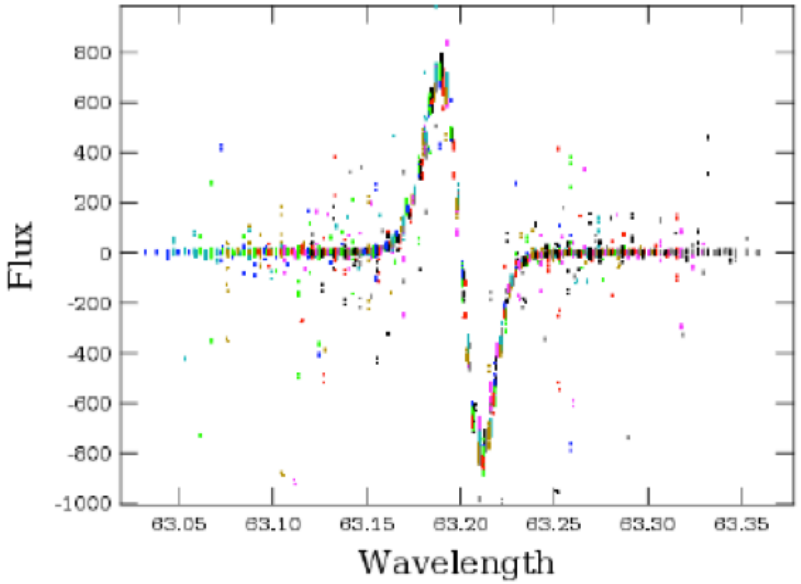
- No major degradation from wavelength-switching
- Pipeline provides different "demodulation" techniques



Wavelength Switching Scheme

- Pre-launch: Modulate between on-line and off-line in spectral domain
- Improved wavelength switching strategy (smaller jumps in flux on detectors):
  - Modulate with step of a fraction of the FWHM
  - Use differential profile



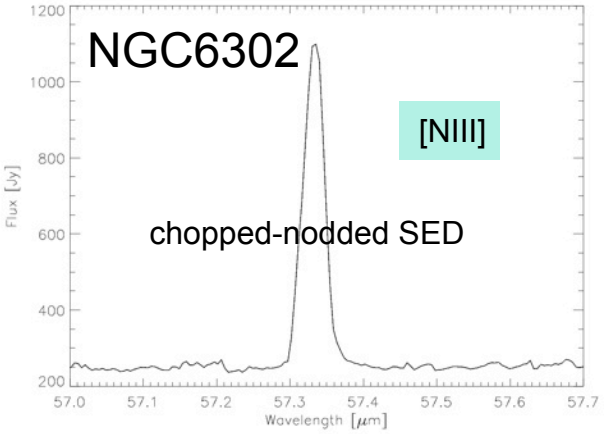


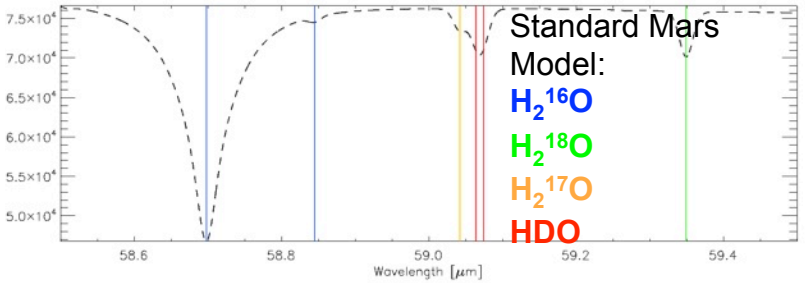
Spectrometer: Dynamic Range

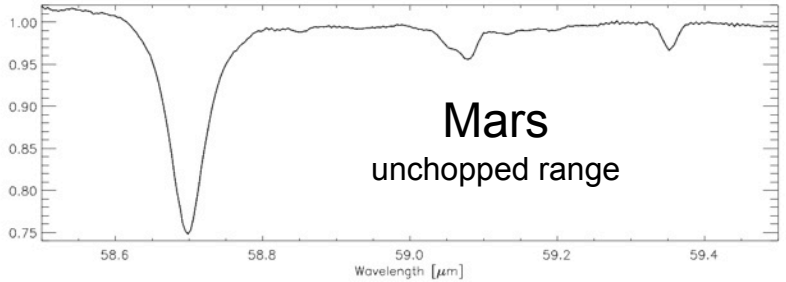
10^5 - $10^{<0}$

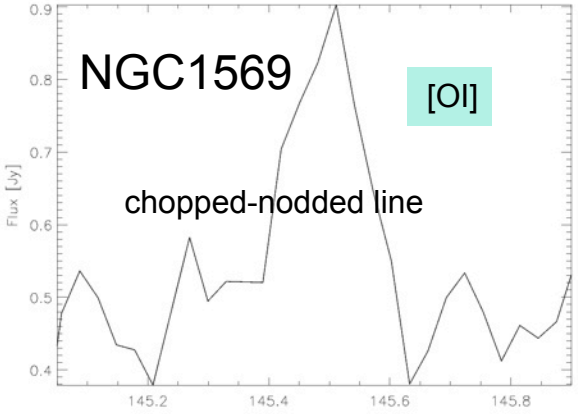
Mars: 75000 Jy
Orion: 10000 Jy
NGC6302: 1000 Jy
R Dor: 200 Jy
A Tau: 10 Jy
NGC1569: 0.35Jy

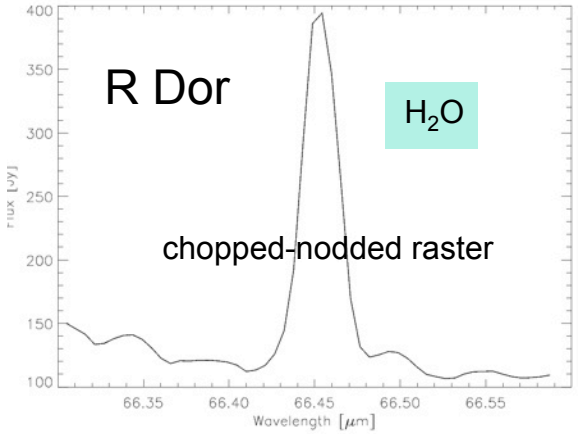
…but!

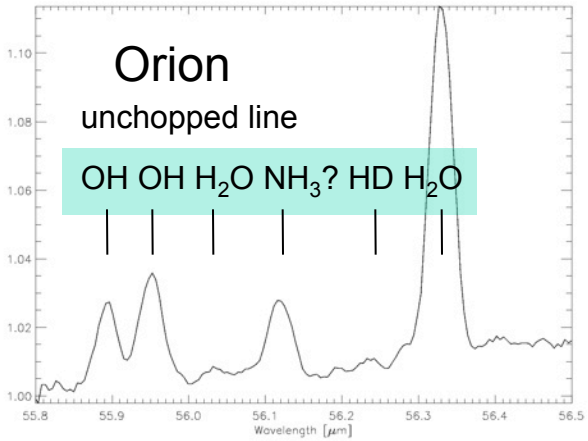






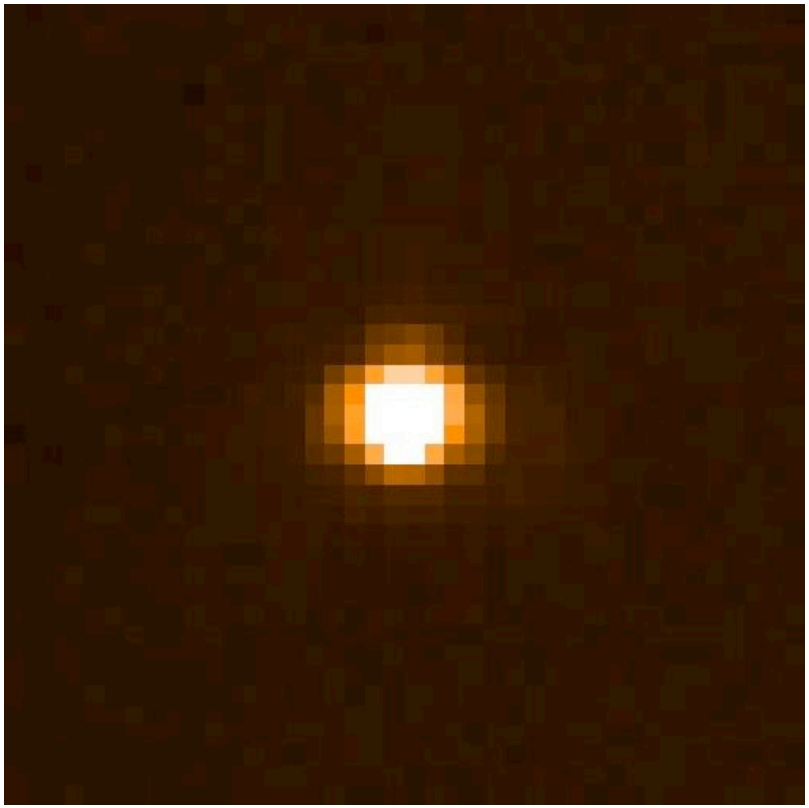


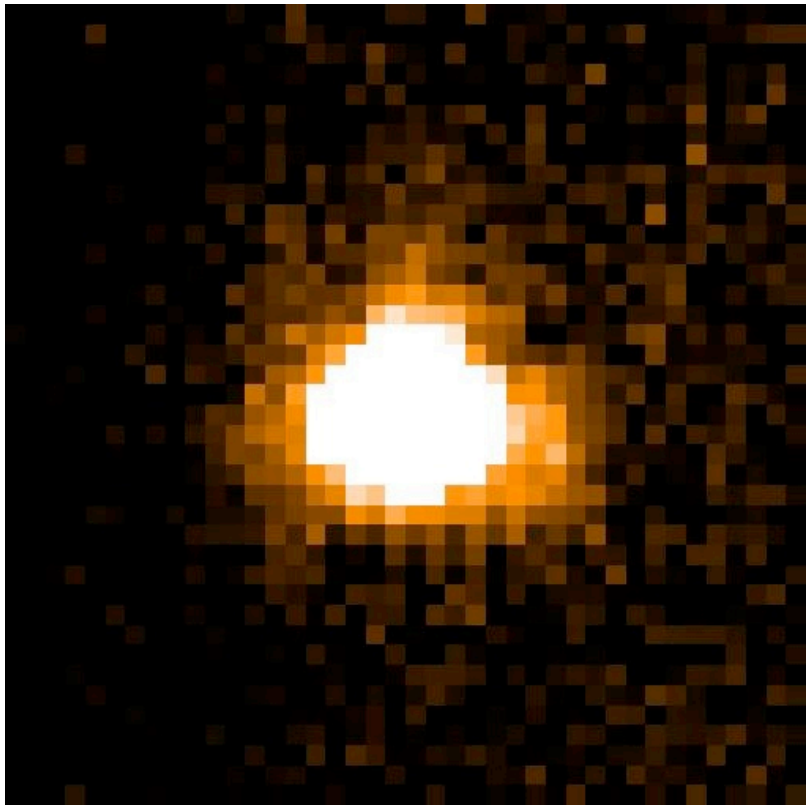




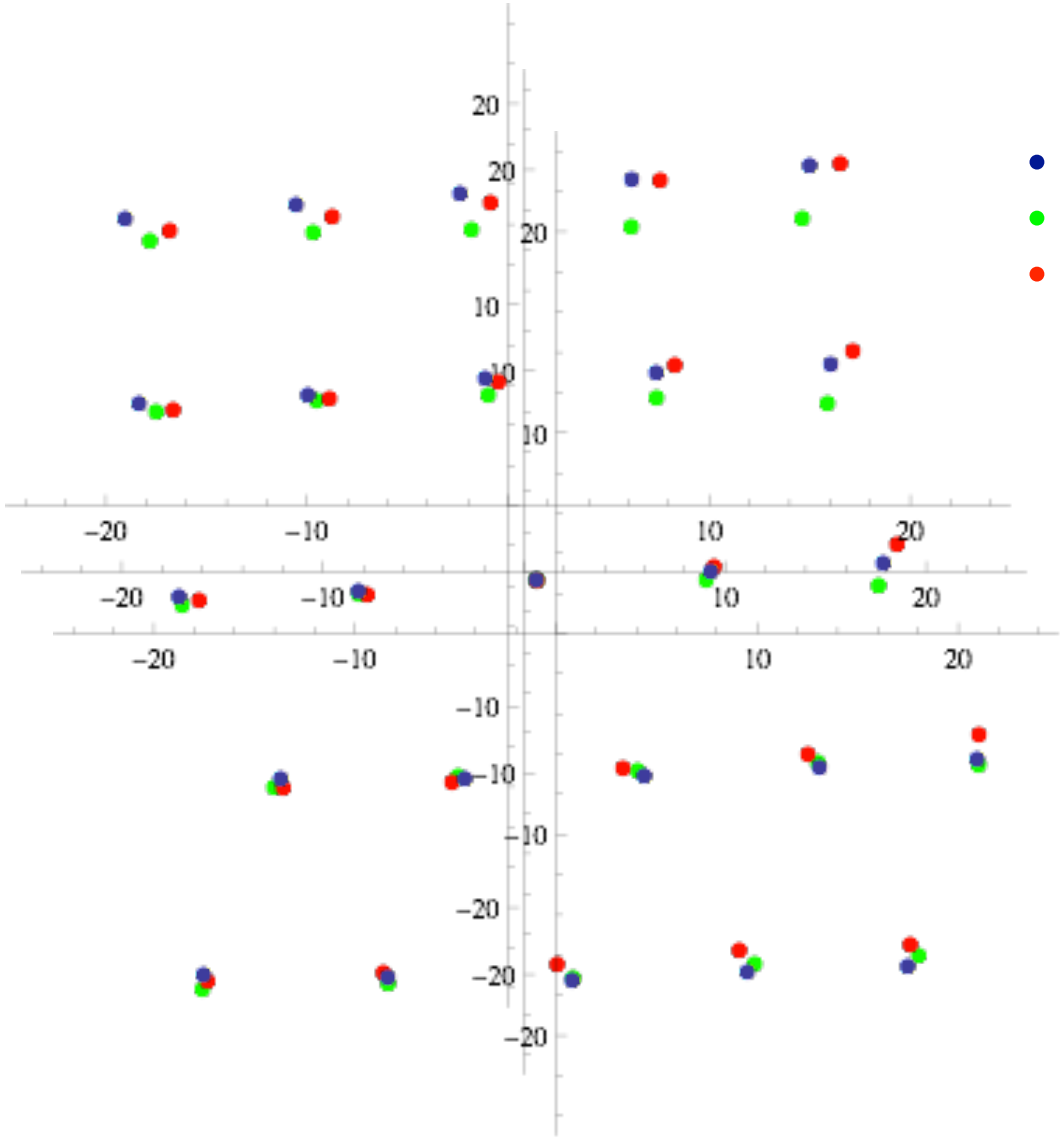
Spectrometer PSF

- Measured and analyzed at 62µm on Neptune
- Central peak ~8.4” (FWHM)
- “Trifoliate” structure, also seen in photometer





Spectrometer: Focal Plane Geometry (Chopped)



- Chop -3'
- Chop 0
- Chop +3'

➔ relative distortion left↔right ≈2 arcsec

(tolerable)

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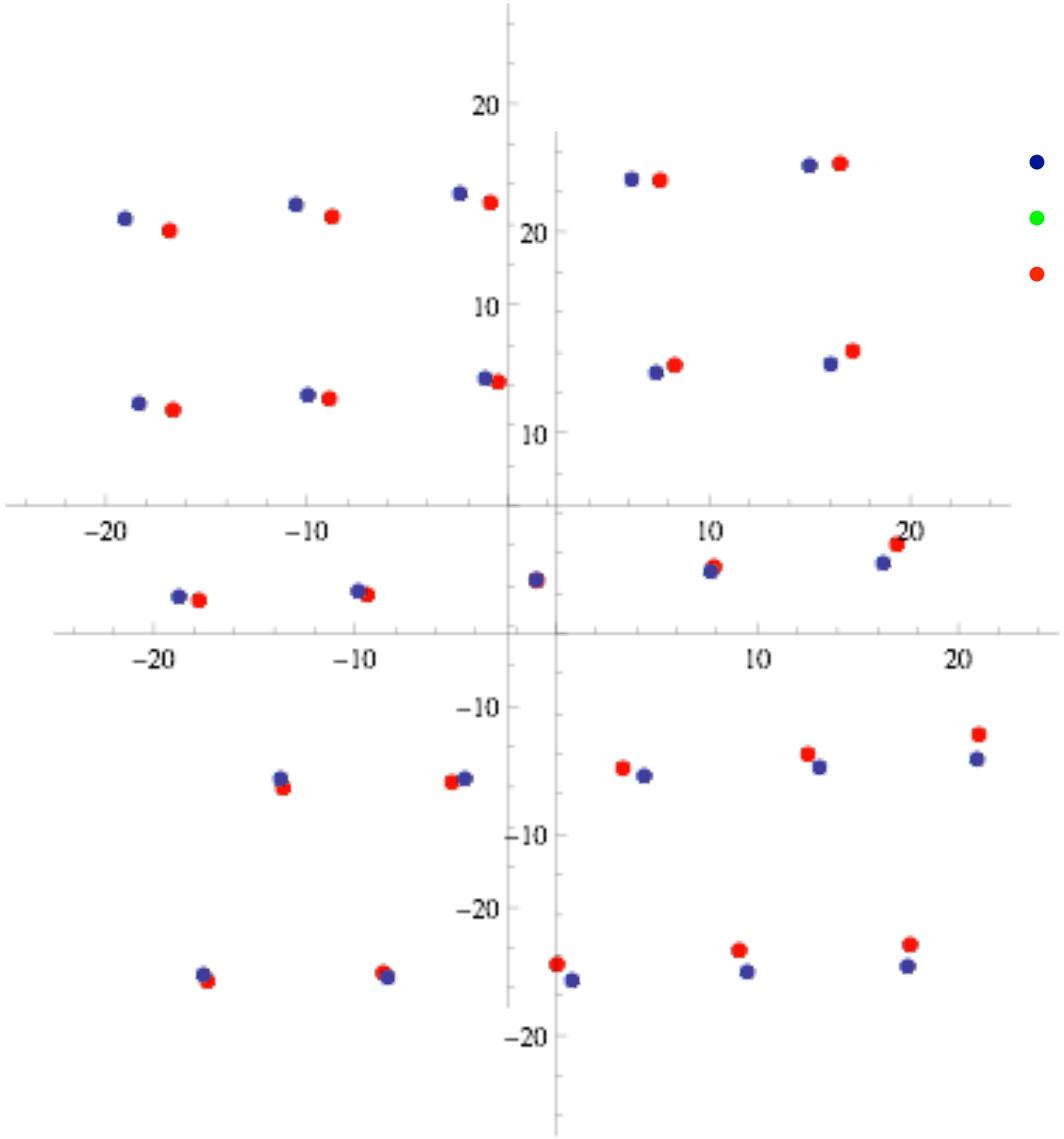


- Chop -3'
- Chop 0
- Chop +3'

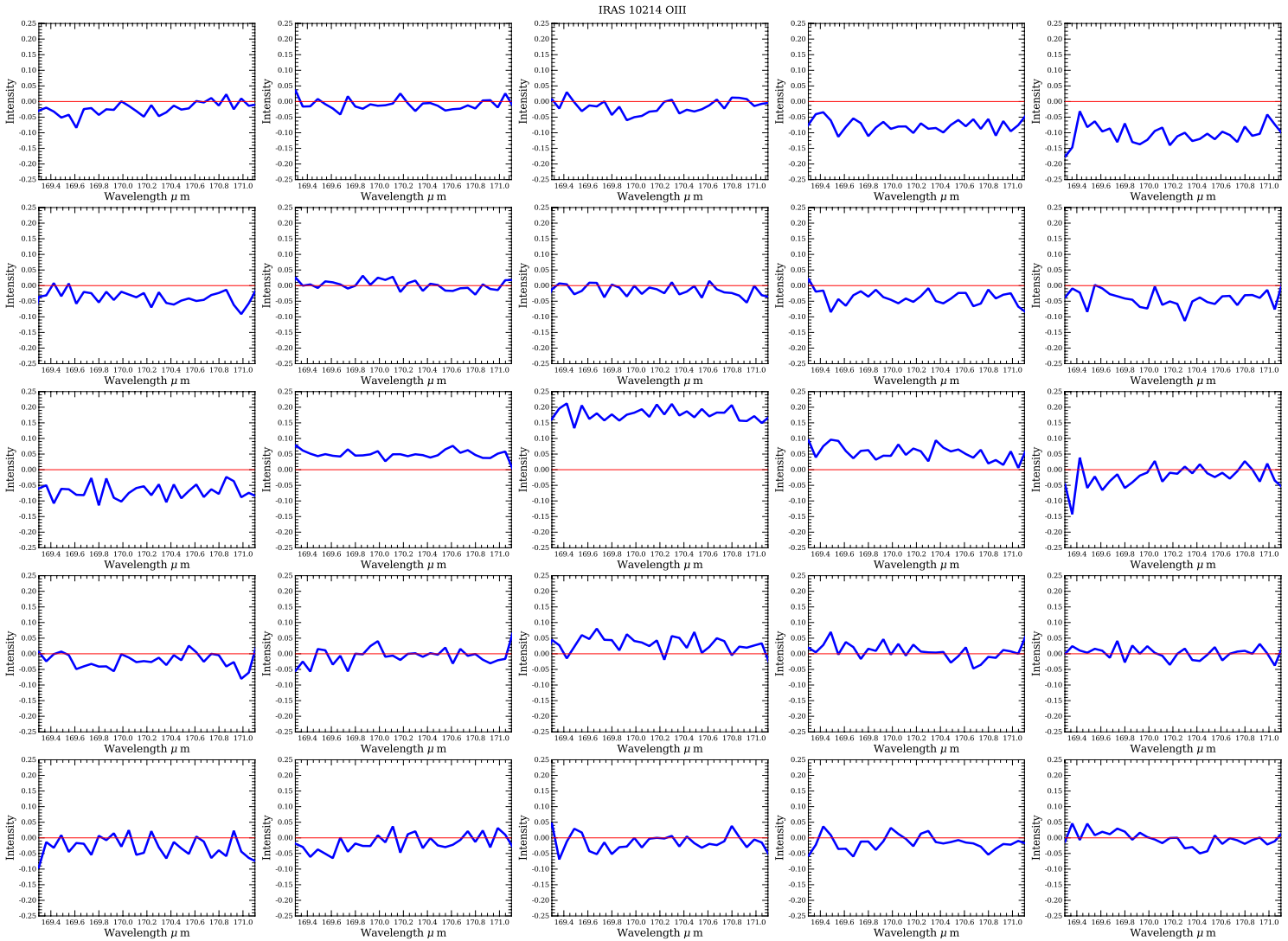
➔ relative distortion left↔right ≈2 arcsec

(tolerable)

Spectrometer "Flat-Field"

- Default: Use of "Relative Spectral Response Function", measured on ground for each detector element, + calibration block (not used presently)
  - gives absolute flux density (Jy), within ~20%
  - does not compensate for (short-term) time-variability of detector response (CR hits, memory effects)
  - may result - for faint sources - in insufficient cancelation of telescope background
- Alternative for faint sources: "Normalization"
  - ("left" - "right")/0.5("left" + "right")
  - continuously uses telescope background as calibrator
  - works only if source much fainter than telescope!
  - no absolute flux density - fraction of telescope background

RSRF vs. “Normalization” for Faint Source



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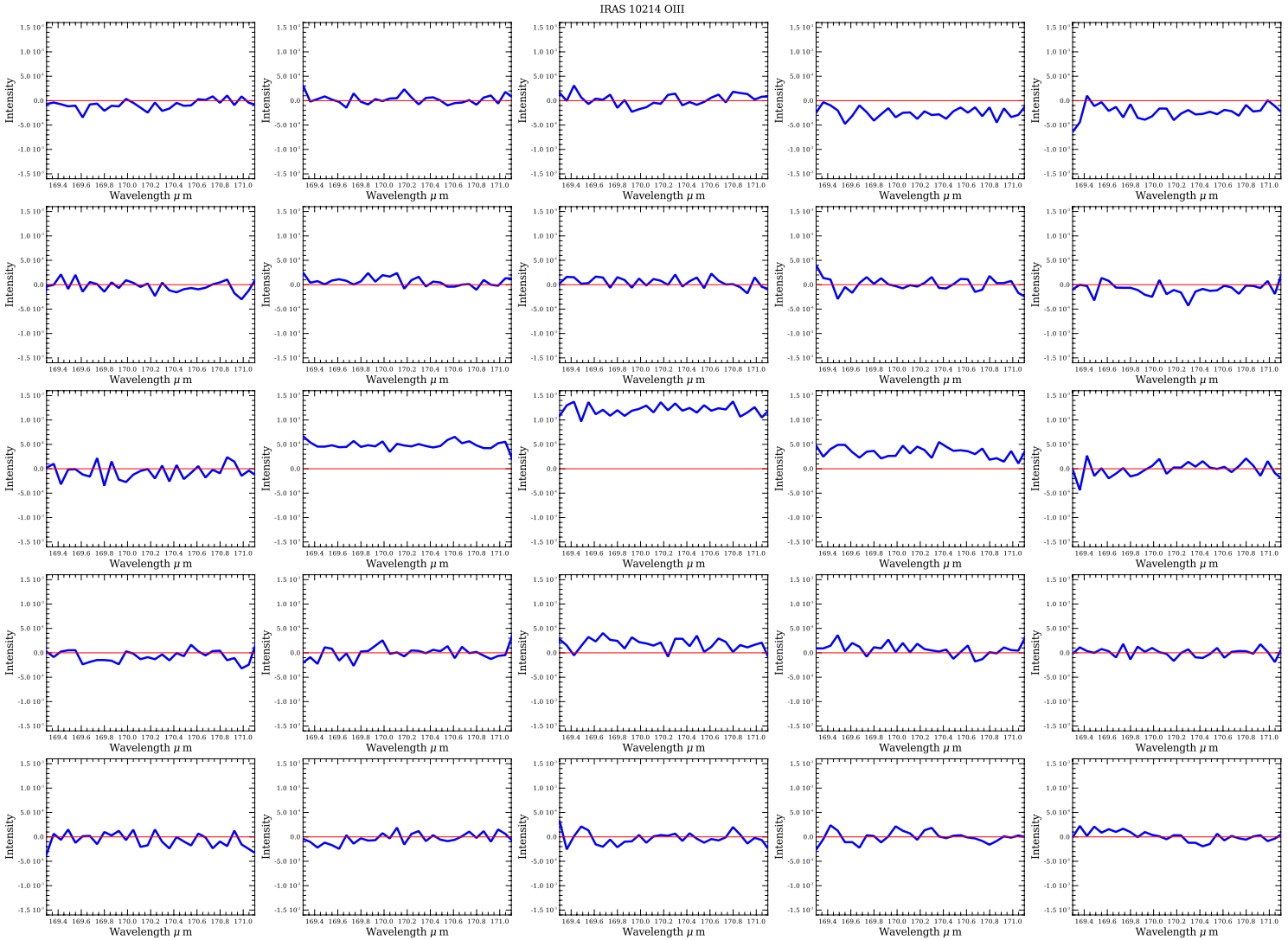
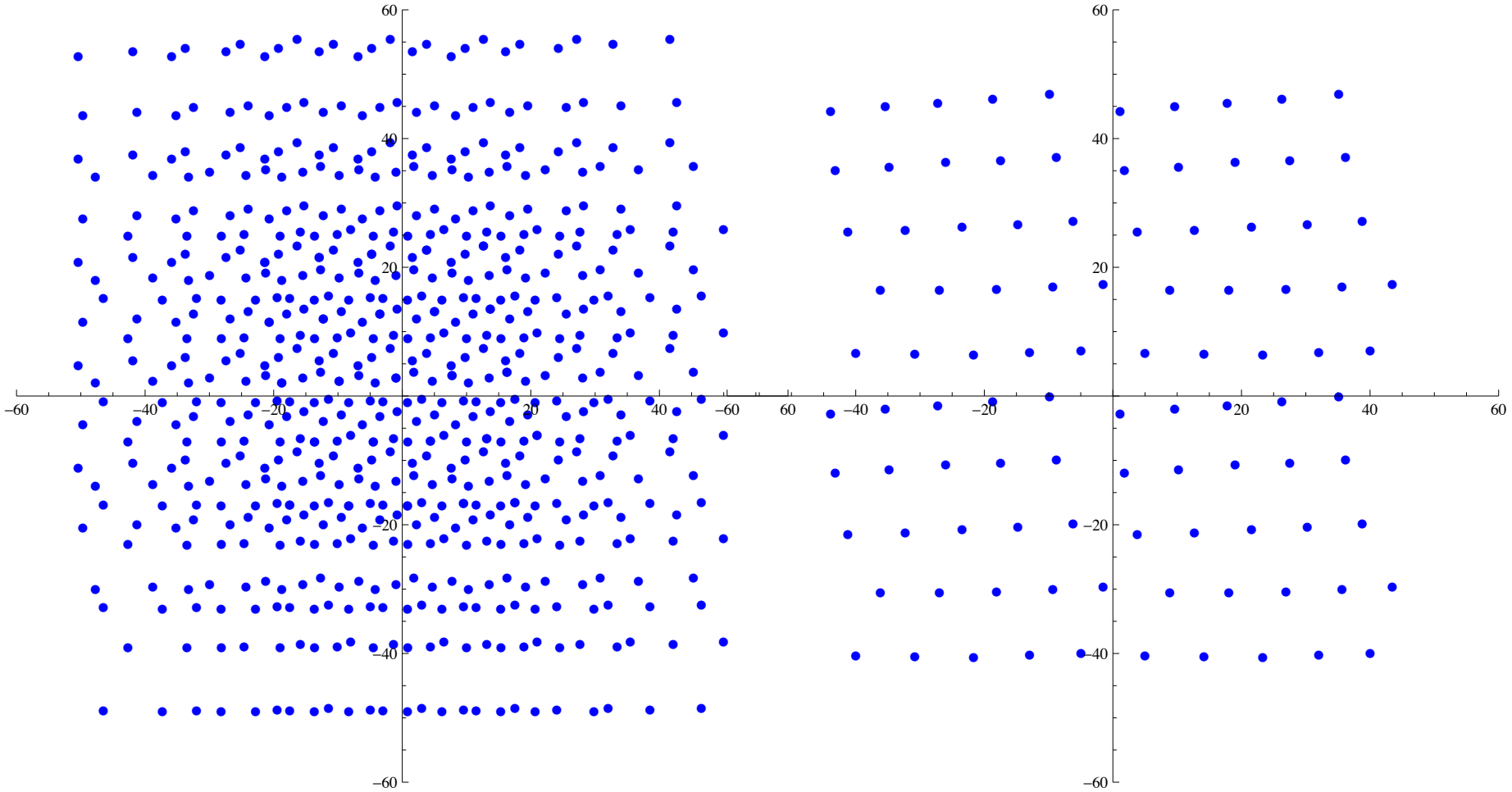
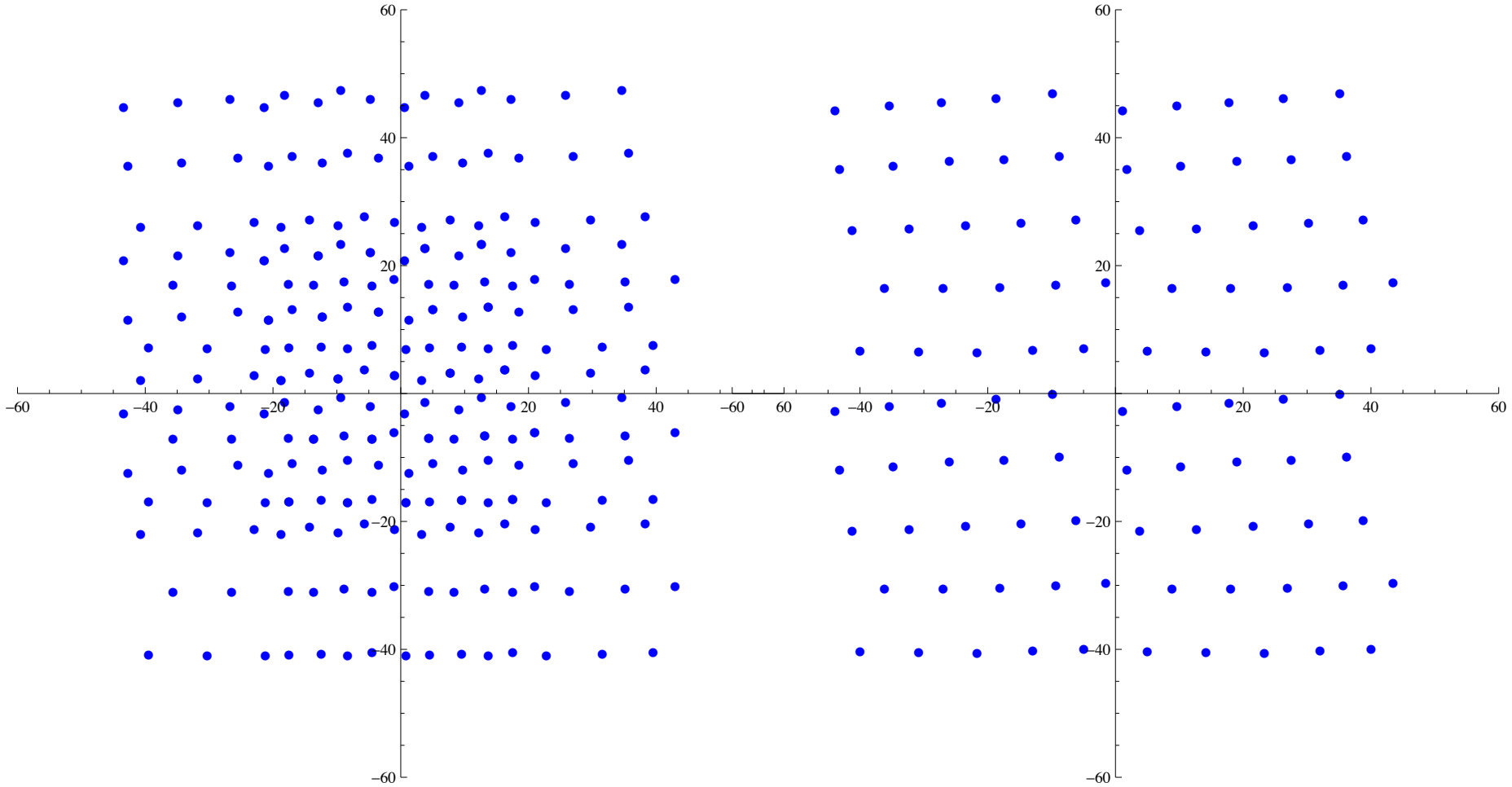


Extended Spectral Line Maps



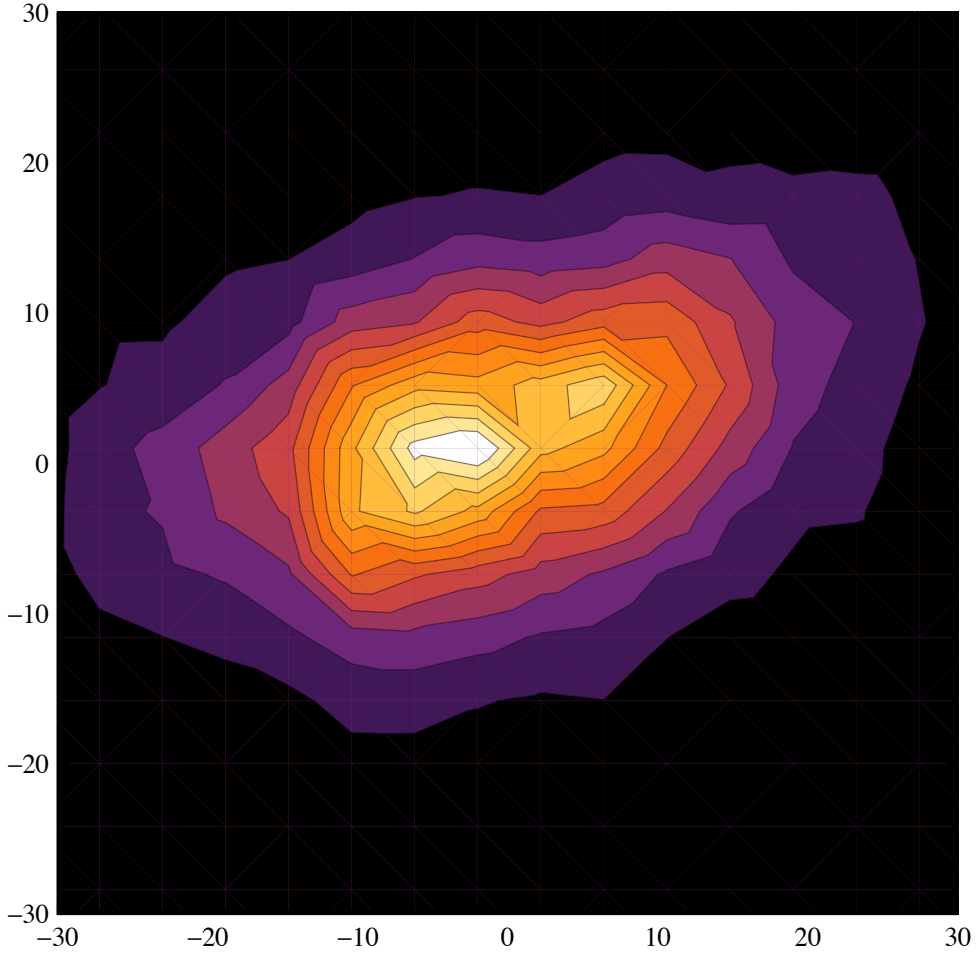
5x5 “oversampling” (short-λ) vs. 2x2 “tiling”

Extended Spectral Line Maps

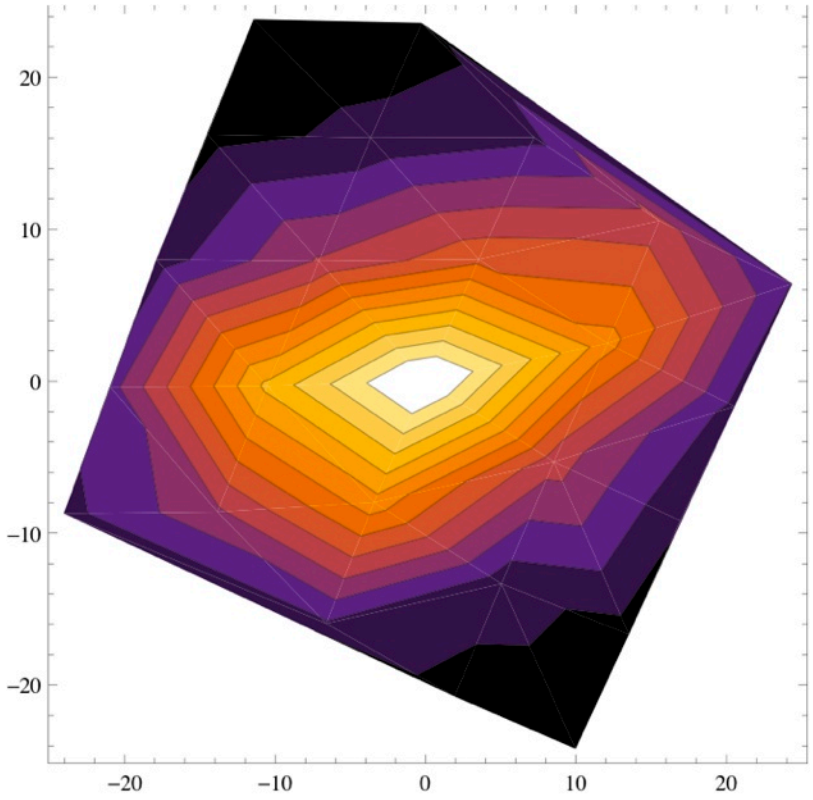


3x3 “oversampling” (long-λ) vs. 2x2 “tiling”

Snapshot vs. Mapping



M82 [O I] 63μm

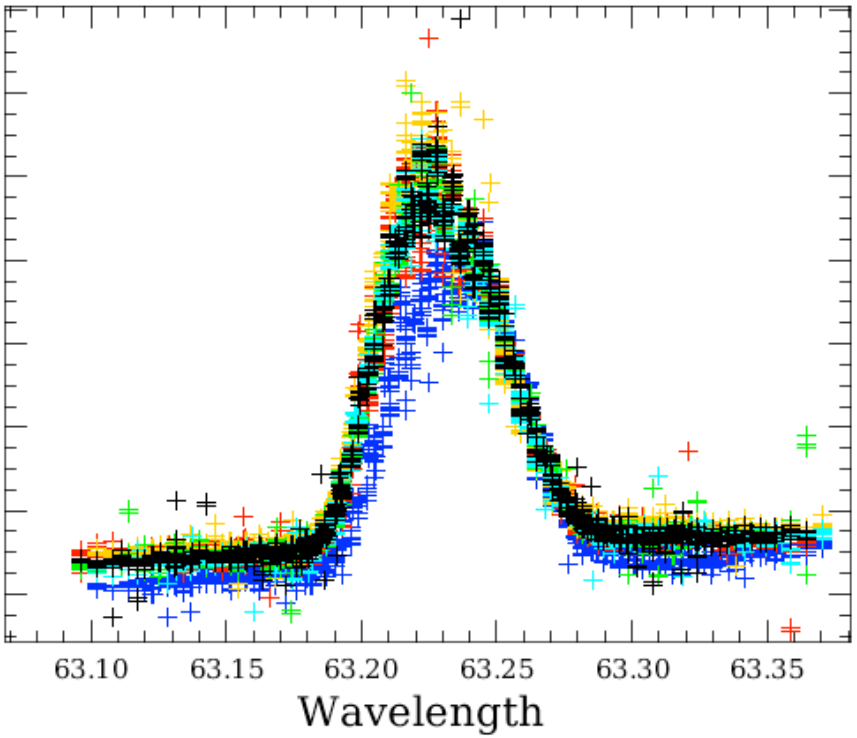


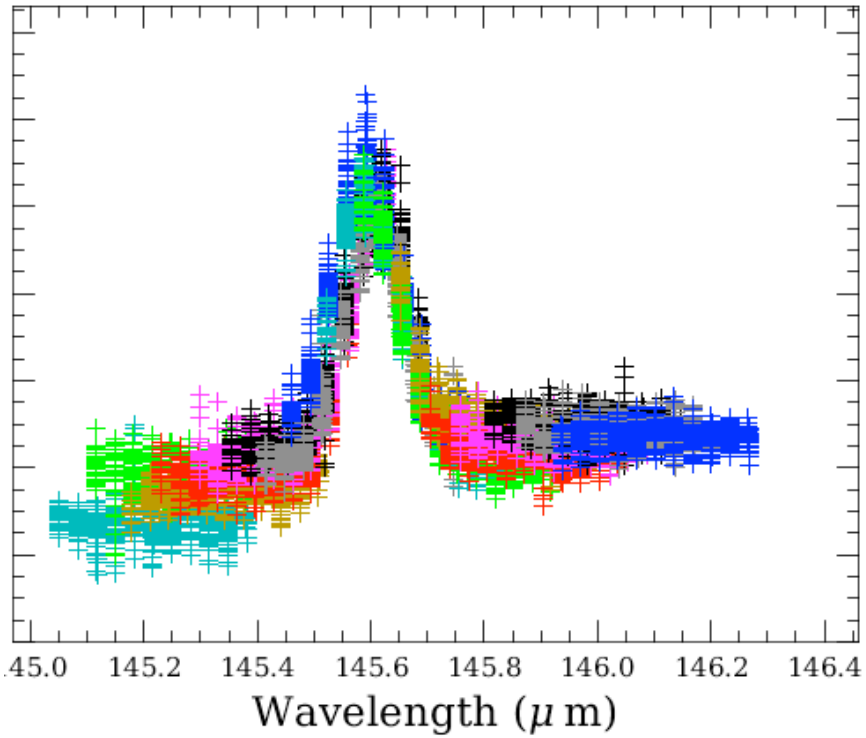
Map reconstruction under construction (in HIPE)

Spectrometer AOTs and Execution Times

- Prime goal during PV was optimum modulation scheme (chopper and grating) for best sensitivity per integration time **UNDER IN-ORBIT CONDITIONS**
- Result: "atomic unit" of observation requires more time than assumed before launch
- To allow observations within allocated budget, we have introduced "bright line" mode. For SDP, HSC has replaced AOTs when necessary (+sometimes when it wasn't...)
- Bright line mode may need further optimization; don't use it if you don't have to!

"Regular Line" vs. "Bright Line" Spectroscopy

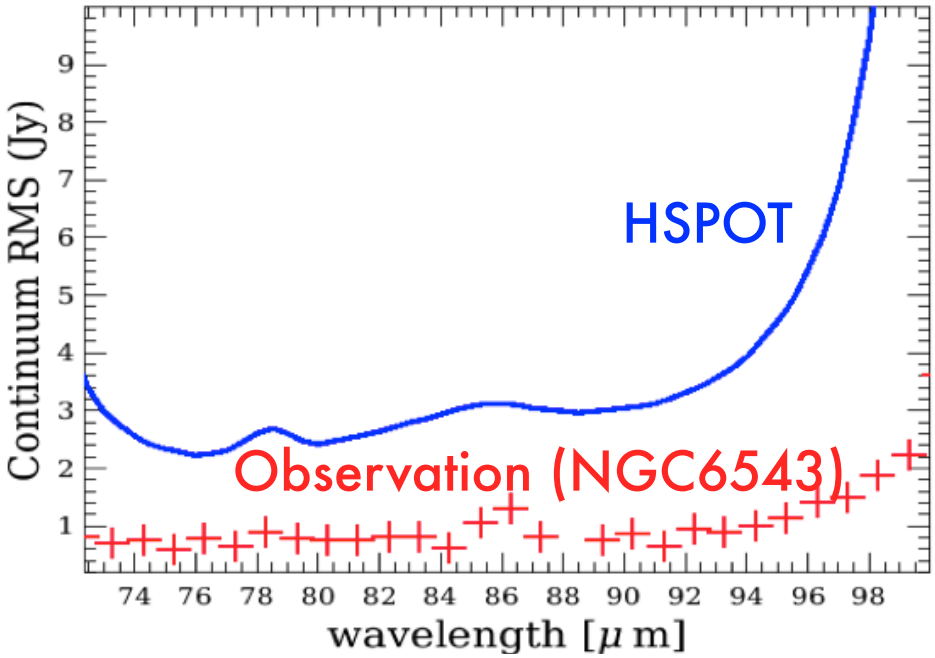




- Baseline offsets between detectors within one spaxel lead to "stitching" problem in "Bright Line" mode

Spectrometer SED Mode

- About to be released
- Performance evaluation looks very encouraging
- Example: continuum RMS of rebinned spectrum in NGC6543 SED measurement in B2B



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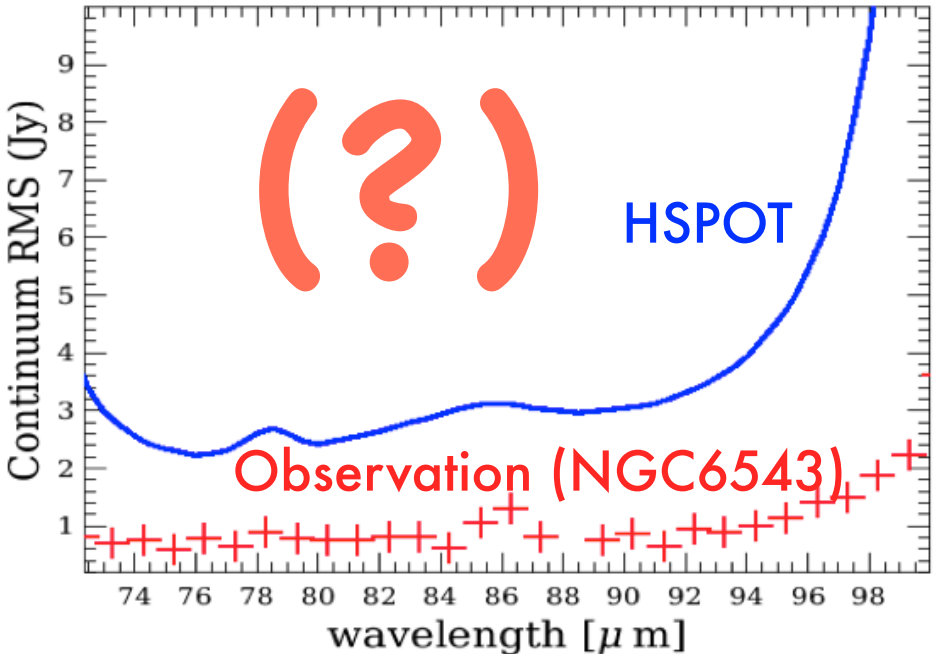

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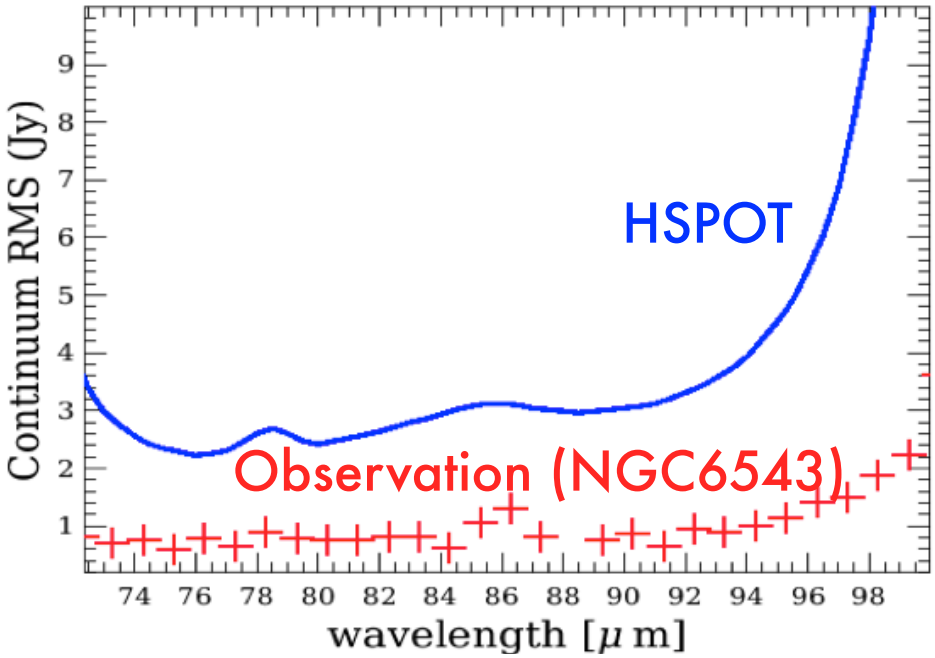
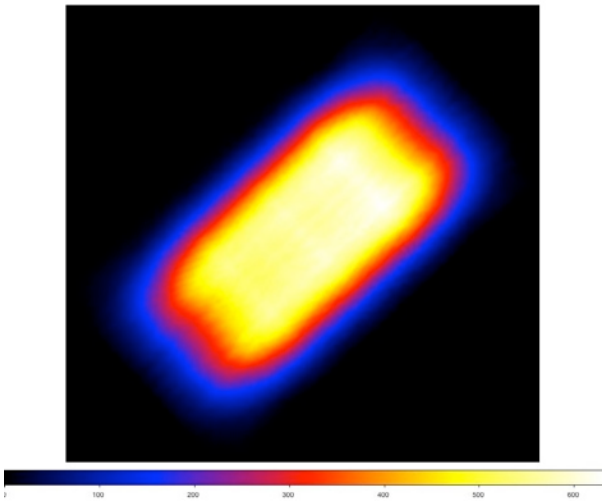
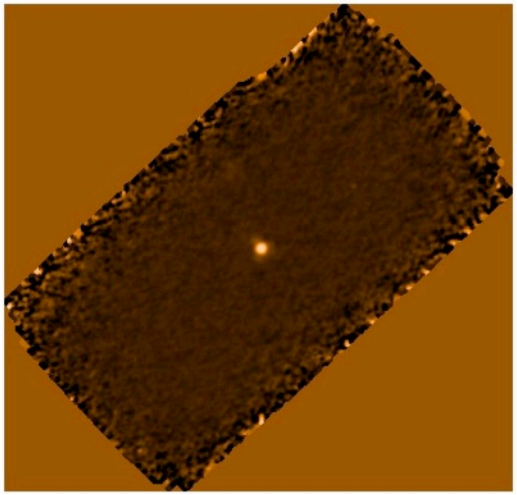


Photometer Observing Modes

- The size of the mapped region usually determines which mode is more efficient, originally:
  1. Point-source mode: unresolved single sources
  2. Small-source mode: single source <1'-1.5' in size: dropped
  3. chopped raster: sources >1' and <12': dropped
  4. Scan maps: Source > 12'
  5. Parallel mode: square degrees
     Offset in sky between PACS and SPIRE: 21'
- Alternative to point-source mode: mini-scan maps
  - Scanning at 63 & 117 degrees (w.r.t. Z axis), i.e. along detector diagonal
  - With 4 legs as minimum
  - Advantages:
    - slightly more sensitive than point-source mode since implementation of new slew-time predictor (Hspot v4.4, to be deployed)
    - no negative beams
  - Disadvantages:
    - possibly slightly degraded PSF

Photometer Observing Modes





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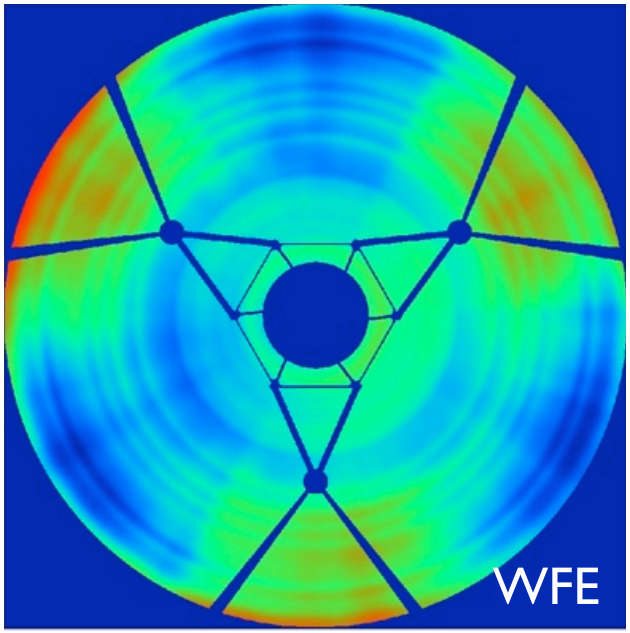
Photometer: Flux Calibration

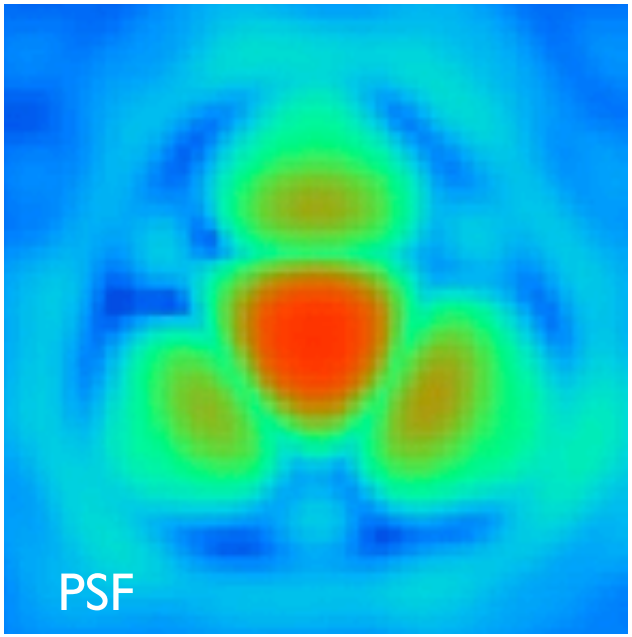
- Flux calibration is converging

obsid	od	source	speed "/sec	True_B Jy	True_G Jy	True_R Jy	Obs_blue Pseudo-Jy	Obs_green Pseudo-Jy	Obs_red Pseudo-Jy	Cal_blue V	Cal_green V	Cal_red V	Scale_B	Scale_G	Scale_R
1342182962	108	Bet Umi	20	2.759	1.368	0.552	1.832		0.459	-0.01220		-0.01514	1.506		1.203
1342182966	108	Bet Umi	20	2.759	1.368	0.552		1.188	0.490		-0.00986	-0.01516		1.152	1.127
1342182967	108	Bet Umi	20	2.759	1.368	0.552		1.265	0.538		-0.00986	-0.01517		1.081	1.026
1342182968	108	Bet Umi	20	2.759	1.368	0.552	1.945		0.491	-0.01219		-0.01518	1.419		1.124
1342182980	108	Gam Dra	20	3.310	1.645	0.666		1.121	0.493		-0.00986	-0.01514		1.467	1.351
1342182981	108	Gam Dra	20	3.310	1.645	0.666		1.168	0.486		-0.00986	-0.01516		1.408	1.370
1342182983	108	Gam Dra	10	3.310	1.645	0.666		1.196	0.470		-0.00986	-0.01517		1.375	1.417
1342182985	108	Gam Dra	20	3.310	1.645	0.666	1.873		0.478	-0.01218		-0.01517	1.767		1.393
1342182986	108	Gam Dra	20	3.310	1.645	0.666	1.830		0.466	-0.01220		-0.01517	1.809		1.429
1342182987	108	Gam Dra	20	3.310	1.645	0.666	1.871		0.459	-0.01220		-0.01518	1.769		1.451
1342182988	108	Gam Dra	10	3.310	1.645	0.666	1.858		0.466	-0.01220		-0.01518	1.781		1.429
1342182997	108	Gam Dra	20	3.310	1.645	0.666		1.069	0.476		-0.00984	-0.01518		1.539	1.399
1342183532	118	Alf Tau	20	14.244	7.085	2.870	7.948		1.973	-0.01221		-0.01527	1.792		1.455
1342183533	118	Alf Tau	20	14.244	7.085	2.870	7.986		1.943	-0.01222		-0.01526	1.784		1.477
1342183534	118	Alf Tau	20	14.244	7.085	2.870		4.823	1.985		-0.00988	-0.01523		1.469	1.446
1342183535	118	Alf Tau	20	14.244	7.085	2.870		4.845	1.974		-0.00987	-0.01520		1.462	1.454
1342183538	118	Alf Tau	20	14.244	7.085	2.870	8.047		1.980	-0.01218		-0.01520	1.770		1.449
1342183540	118	Alf Tau	10	14.244	7.085	2.870	7.949		1.981	-0.01220		-0.01517	1.792		1.449
1342183541	118	Alf Tau	20	14.244	7.085	2.870		4.880	1.966		-0.00987	-0.01521		1.452	1.460
1342183543	118	Alf Tau	10	14.244	7.085	2.870		4.843	1.958		-0.00987	-0.01520		1.463	1.466
1342183546	118	Alf Cma	20	3.002	1.476	0.588	1.771		0.442	-0.01220		-0.01522	1.695		1.330
1342183547	118	Alf Cma	20	3.002	1.476	0.588		1.055	0.461		-0.00987	-0.01520		1.399	1.275
1342183548	118	Alf Cma	20	3.002	1.476	0.588	1.721		0.429	-0.01221		-0.01521	1.744		1.371
1342183549	118	Alf Cma	20	3.002	1.476	0.588		1.202	0.431		-0.00985	-0.01518		1.228	1.364
												Mean	1.770	1.426	1.412
Excl. Bet Umi												Median	1.776	1.457	1.429

Photometer: PSF

- Remarkable agreement between predicted PSF, derived from measured/constructed telescope WFE map, and *central peak* of observed PSF
- Analysis of PSF "outskirts" should confirm (or not) the apparent (somewhat low) Strehl ratio or/and transmission (from point source flux calibration)





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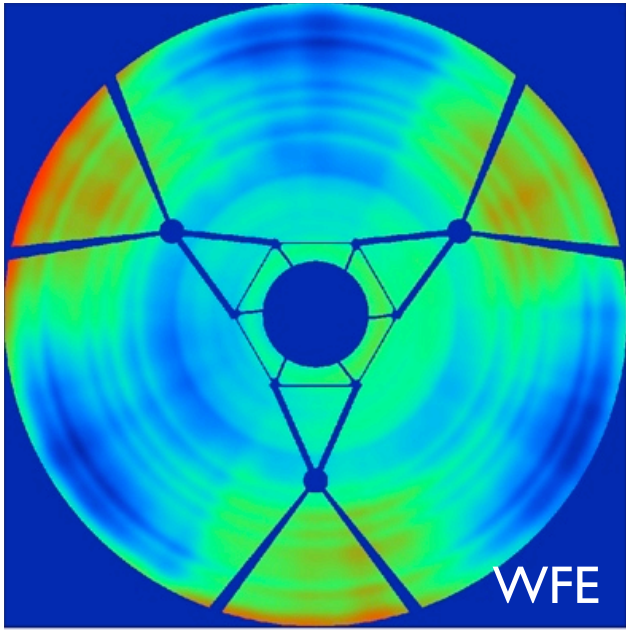

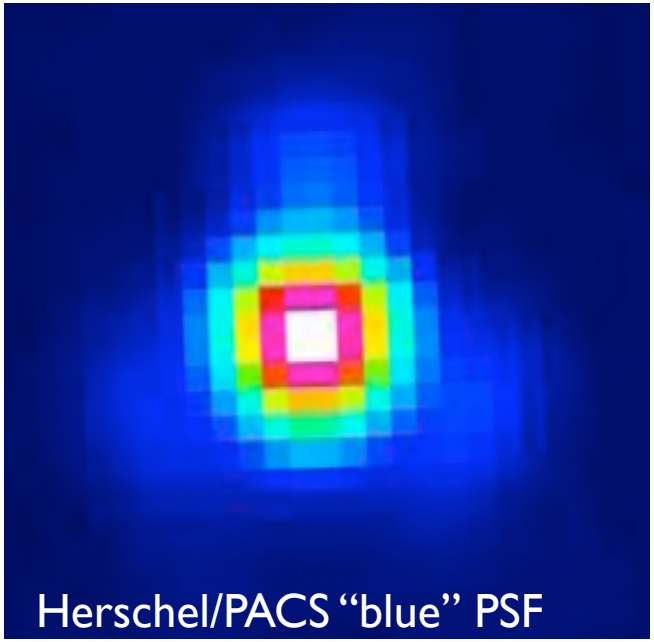

Core scaled to peak, Vesta

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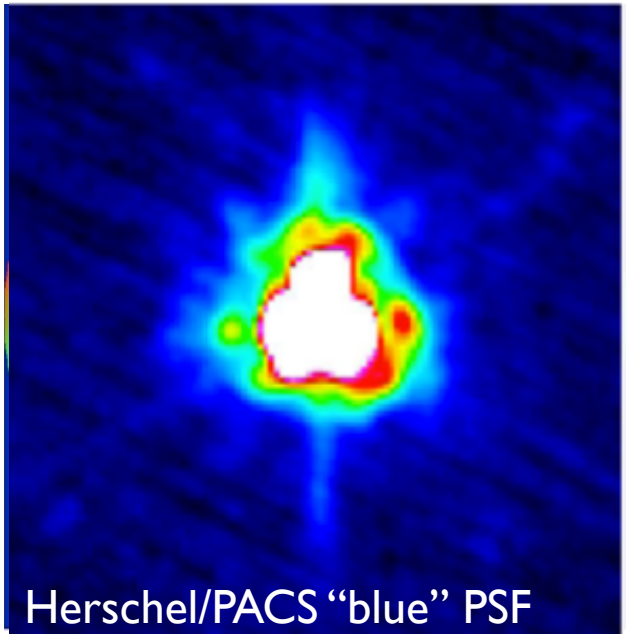
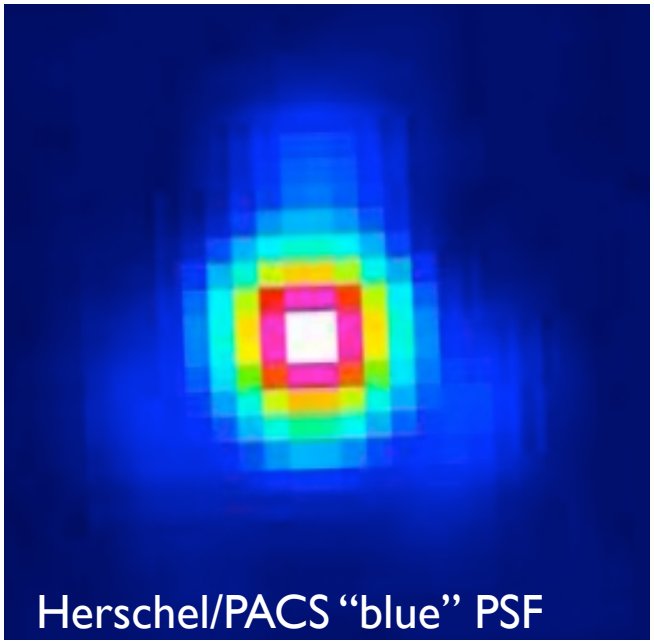


1% peak cut, wide range, Vesta



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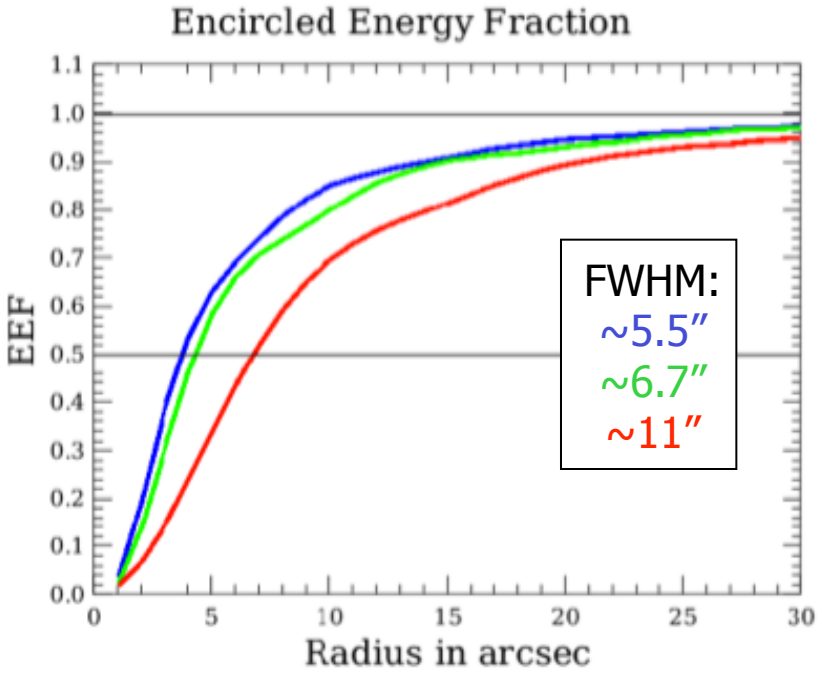
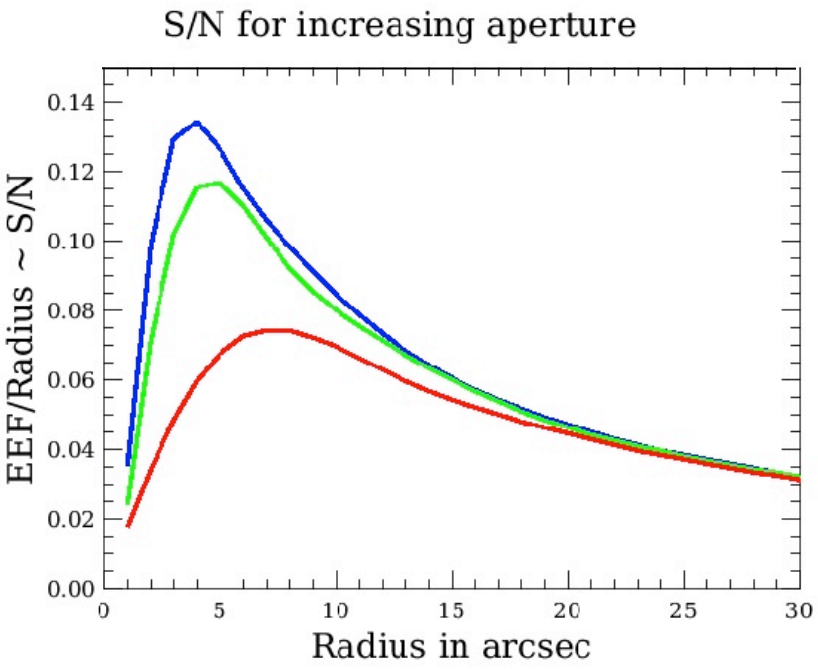
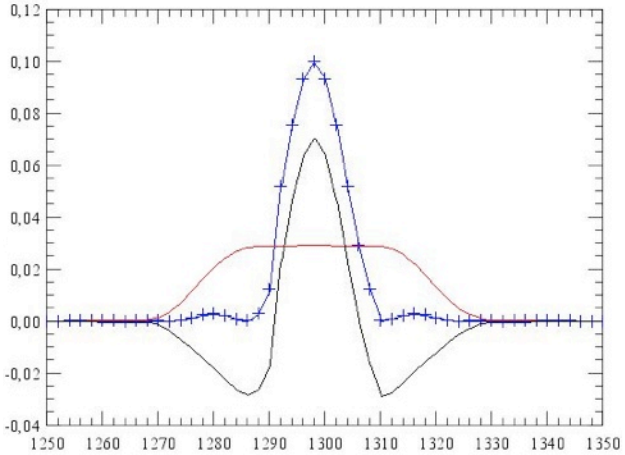
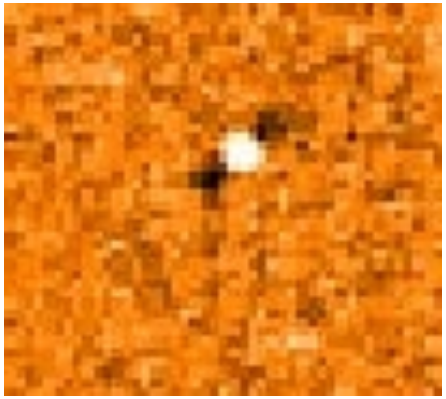


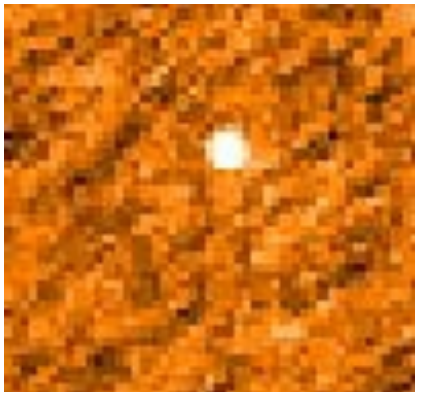


Scan Map Reconstruction

- PACS is presently using
  - "high pass" filtering (MPE)
  - MADmap (NHSC)
- Non-linear high-pass method creates artifacts around (bright) sources - can be eliminated by masking of such sources during filtering







- Mask to be deactivated in final map-making steps!

Scan Map Standard Pipeline

10 steps to PACS photo data cube (frames)

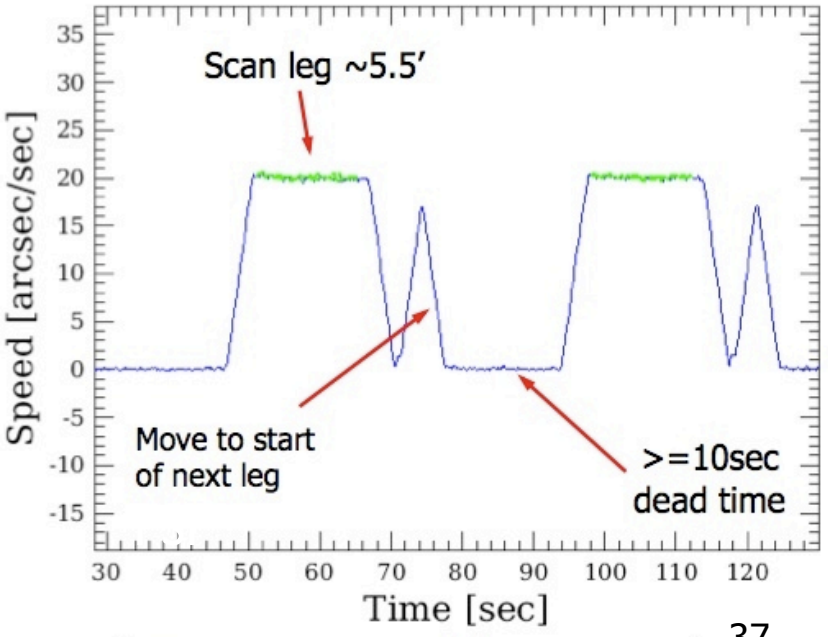
1. Flag bad pixels
2. Flag saturated pixels
3. Convert ADUs to Volts
4. Cross-talk correction
5. Pixel timeline deglitching (multi-median resolution)
6. Flat-field and responsivity correction: Jy/pixel
7. Get R.A/Dec. for virtual aperture (centre)
8. Assign R.A/Dec. to every pixel (spatial calibration)
9. Run high-pass filter, to filter 1/f noise
   - In two passes to mask out (bright) sources for high-pass
10. Project cube onto a grid to get WCS map

Pipeline Tuning

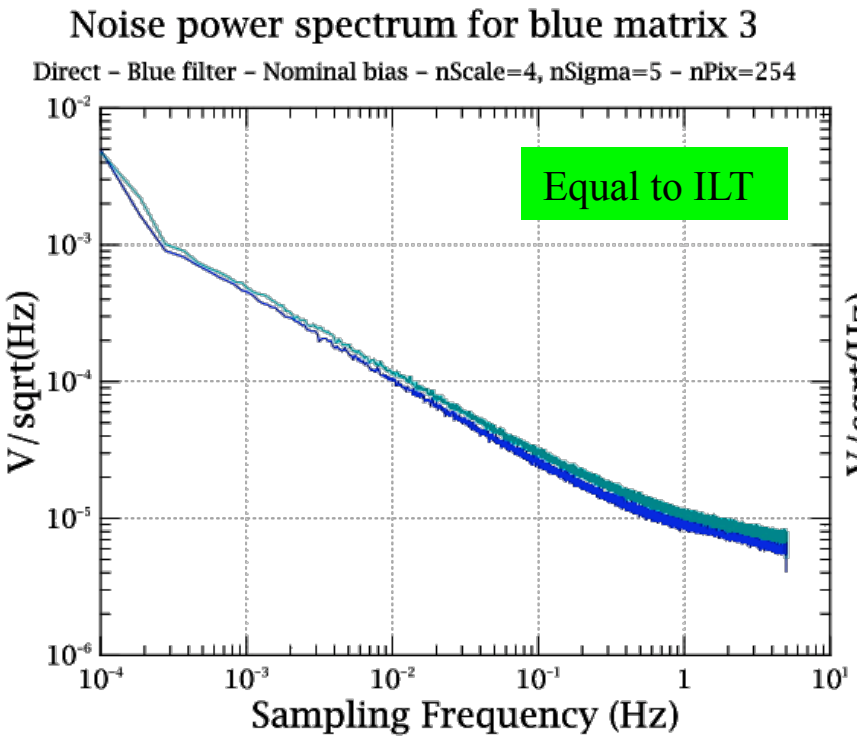
- Bad pixels
- Deglitching
  - Smaller scales / higher `nsigma` parameters at high speed or on bright sources (temporal deglitching)
  - 2nd order deglitching (experimental), taking advantage of spatial redundancy
- High-pass filter width
  - The shorter the better the 1/f noise is removed and striping removed
  - But at too short width PSF becomes distorted
  - Not suited for large extended emission
- Mask sources for high pass filtering
- Scan leg re-centering to mitigate PSF degradation/ smearing due to SRPE/RPE

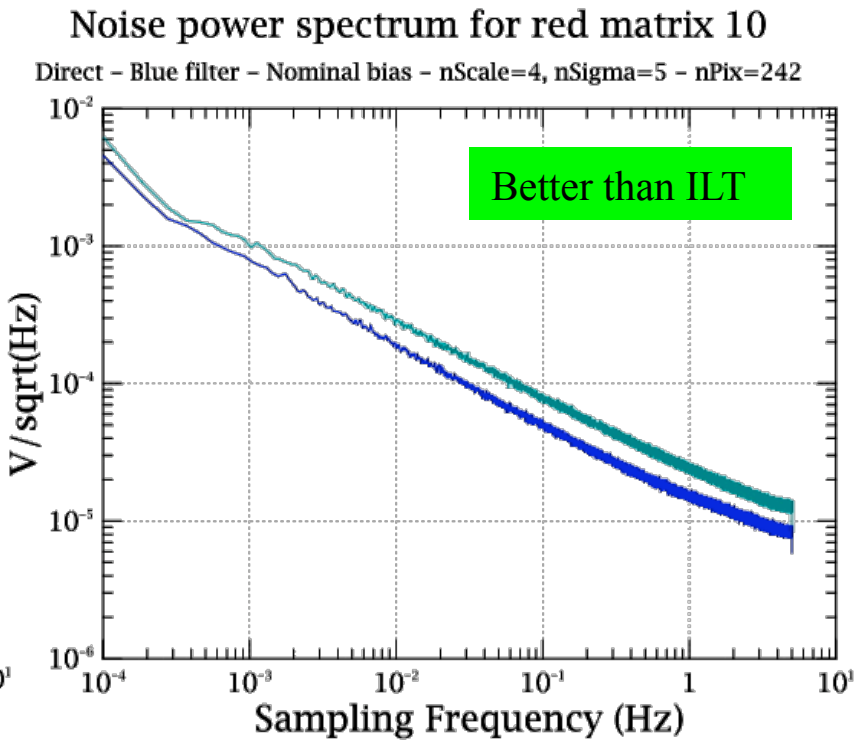
Photometer: Scan Map Sensitivity

- Most "deep" observations originally used for sensitivity evaluation were performed with "slow" scan speed (10"/s)
- Evidence for significant improvement in sensitivity by going to "medium" scan speed (20"/s)
- This is the official recommendation for scan maps now, at the cost of higher overhead. (Data processing might still improve, observing will not.)
- Reduction of the overhead: Each turn costs ~17s, of which only ~5s are "real". Extra dwell time has been removed as of OD221.



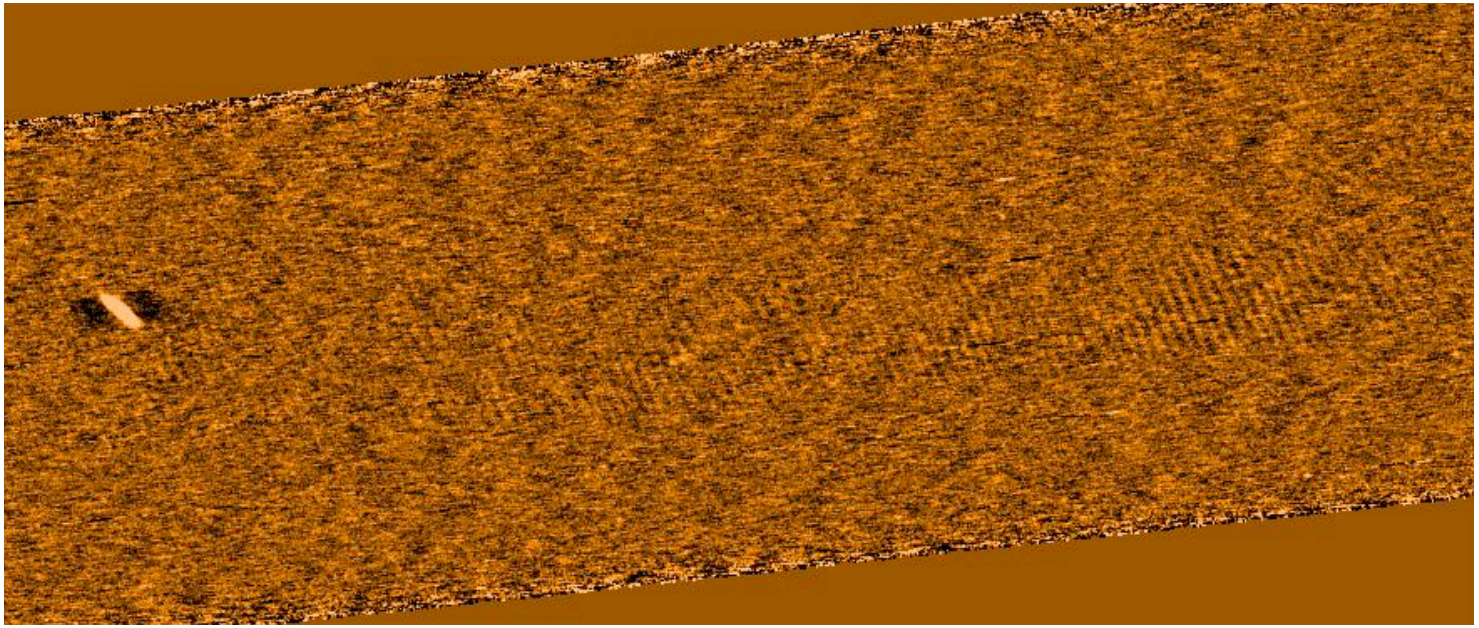
Photometer Noise Spectra





- Noise in the PACS bolometers is essentially 1/f1/2 over the whole accessible bandpass
- Basis for HSPOT numbers has been 3Hz (?)

Photometer: Interferences

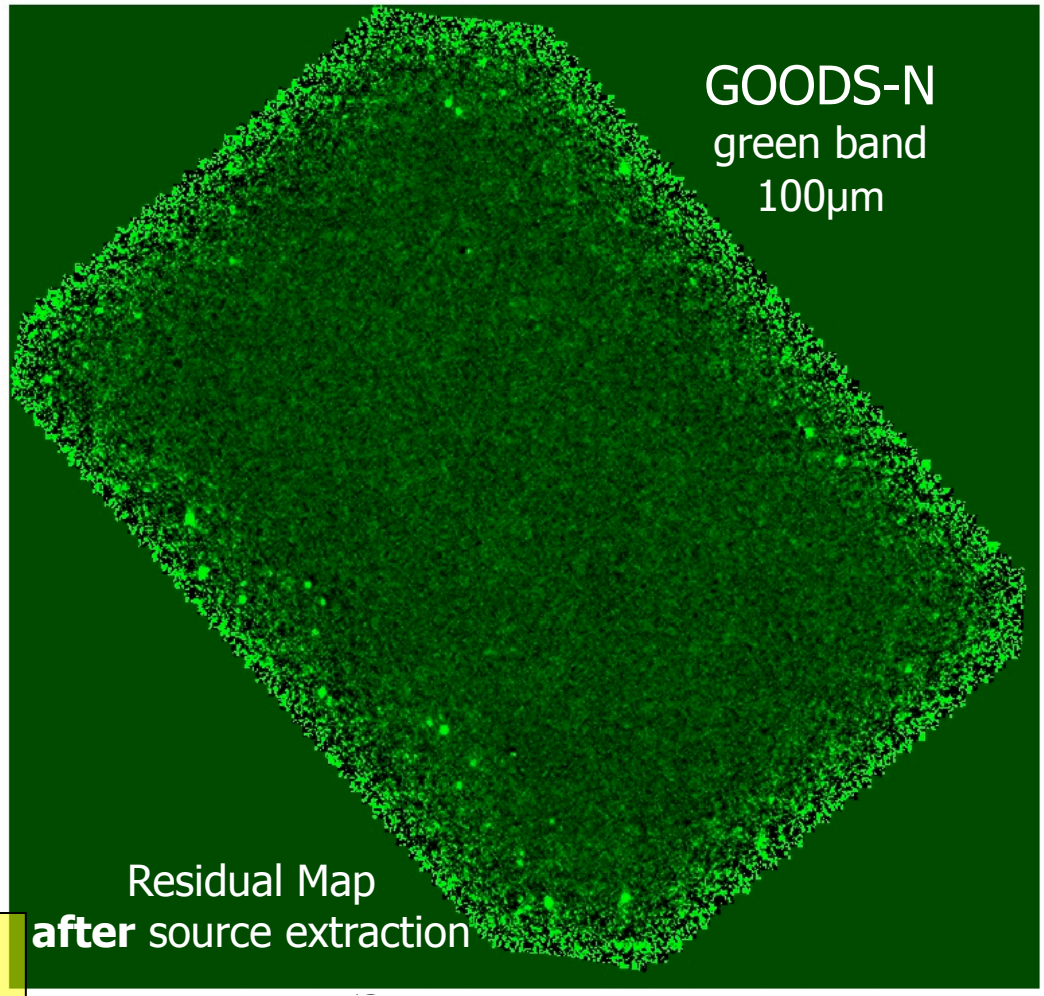


- They affect only the blue photometer
- Amplitude is variable (from faint to severe)
- They are intermittent (i.e. a large fraction of the observations is unaffected)
- The root cause has not yet been found

Photometer: Scan Map Sensitivity Analysis

- PEP expectation:
- Green: 5σ = 3.8 mJy
  Red : 5σ = 5.3 mJy

- Initial reduction of SDP data:
- Green: 5σ = 4.15 mJy
  Red : 5σ = 7.55 mJy
- Improvement going from slow to medium scan speed has materialized

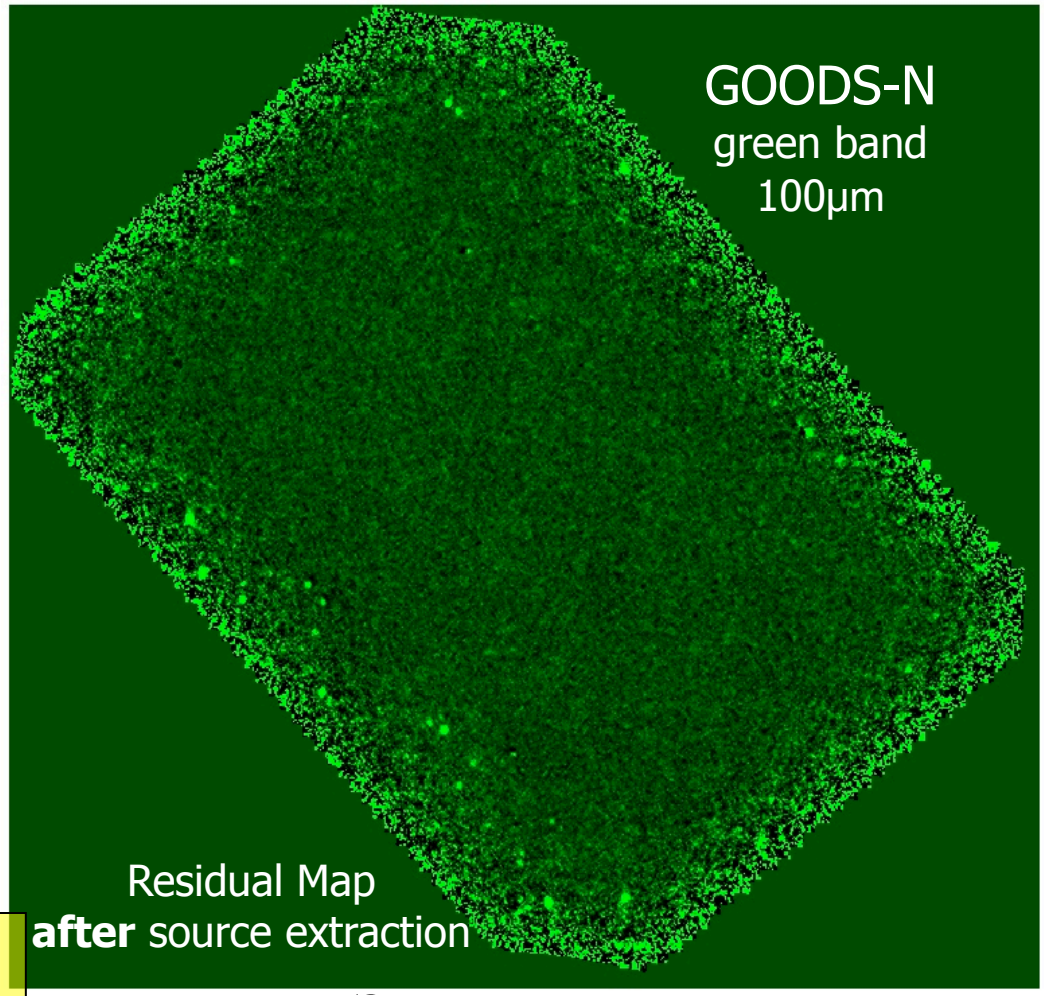


10000 random aperture extractions (R = 1.35 x HWHM)

Photometer: Scan Map Sensitivity Analysis

- PEP expectation:
- Green: 5σ = 3.8 mJy
  Red : 5σ = 5.3 mJy

- Initial reduction of SDP data:
- Green: 5σ = 4.15 mJy (10%)
  Red : 5σ = 7.55 mJy (40%)
- Improvement going from slow to medium scan speed has materialized



10000 random aperture extractions (R = 1.35 x HWHM)

Photometer: Point Source Sensitivity Analysis

- A variety of opinions appeared to converge in past few days:

  Previous believe in being close to HSPOT seems to fade away and majority of people seem to be convinced:

  - Factor 2-3 less sensitivity with respect to HSPOT expectations

  - 5mJy @ 5sigma 1 hour not seen but expected from HSPOT; are the
  - HSPOT predictions correct ?

  Examples:

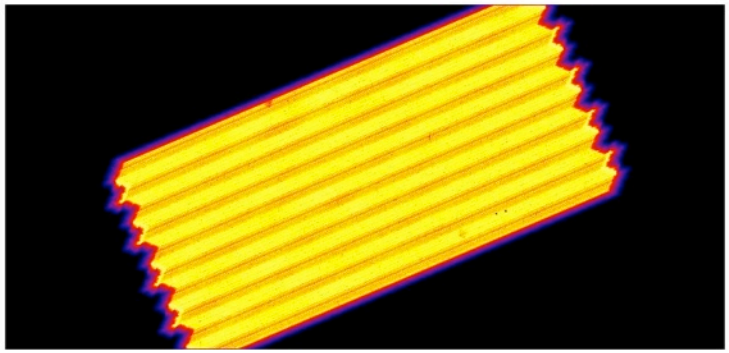
  - 50mJy source in red bolometer in 5 minutes (~3 sigma)
  - 22 mJy star in 25 min at ~7.5 sigma in blue, HSPOT gave 24 sigma
  - Not sure yet whether processing steps are optimum and whether there are still even some bugs
  - For sources brighter than 50mJy → chopped mode
  - For fainter sources → an adapted scan map strategy my be a way out

Photometer: Point Source Sensitivity Analysis

- Previous believe in being close to HSPOT seems to have disappeared and majority of people seem to be convinced:
- Factor 2-3 worse sensitivity with respect to pre-launch HSPOT expectations
- Not sure, yet, whether processing steps are optimum or whether there are still even some bugs
- For sources <50mJy, definitely use small scan map, instead

Parallel Mode

- Calibration blocks interleaved every hour
  - in parallel to PCAL flashes
  - nuisance because of transients effects
  - suppressed starting with OD228
- Homogeneity
  - not solved/implemented yet



-42.4 degrees

42.4 degrees (magic angle)

Outlook and Future Work

- Release of last PACS AOT (SED Mode) imminent
- Data processing within HIPE is improving continuously, but don't expect publication-ready results to drop out of standard pipeline!
- Integration of optimized (for PACS) MADMap implementation should receive high priority
- Final flux calibration in spectroscopy (including "telescope normalization" method) is urgent issue
- Spectral line mapping / full 3D data cube reconstruction is work in progress