PACS Spectroscopy – AOT and Calibration status after PV

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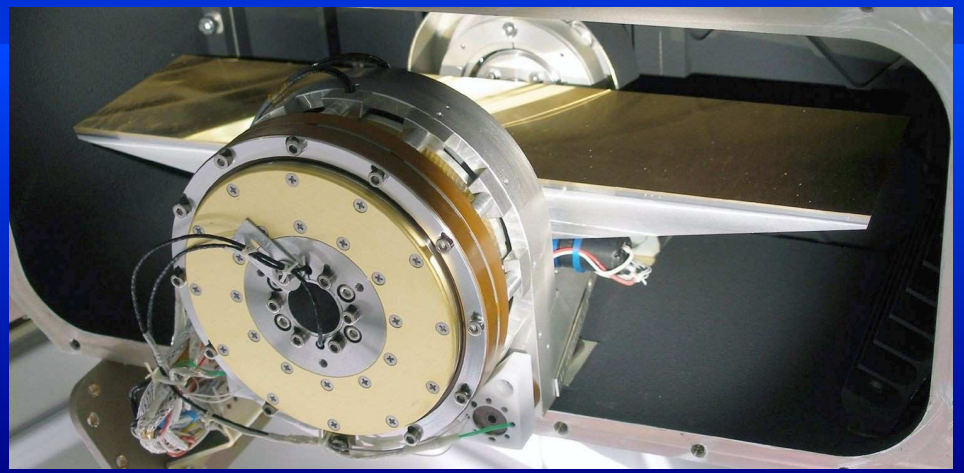
Fundamental uplink parameters

- Mechanism settings
- Detector settings
- Focal plane geometry
- Optimal chopping / scanning pattern
- Optimal wavelength switching pattern

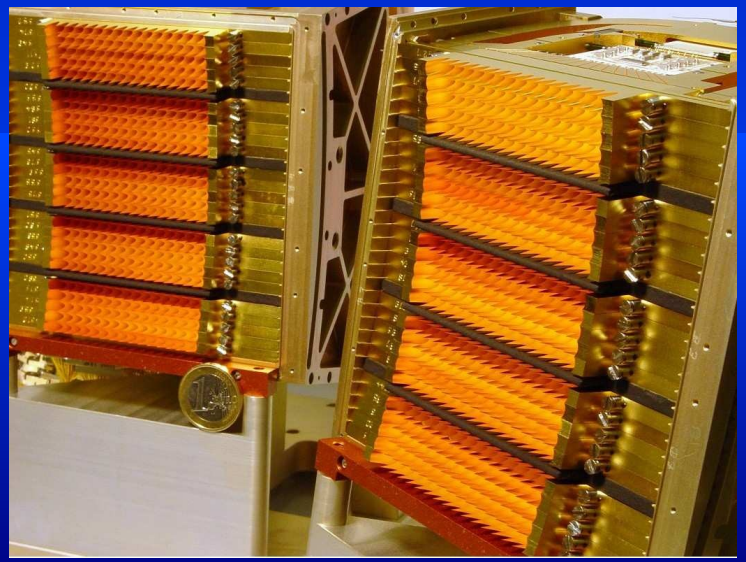
Mechanism settings

- Chopper and grating mechanisms
- Optimised for zero-G and new thermal environment
- Duty cycle / transition times well within spec
- Same or better performance than during ground tests



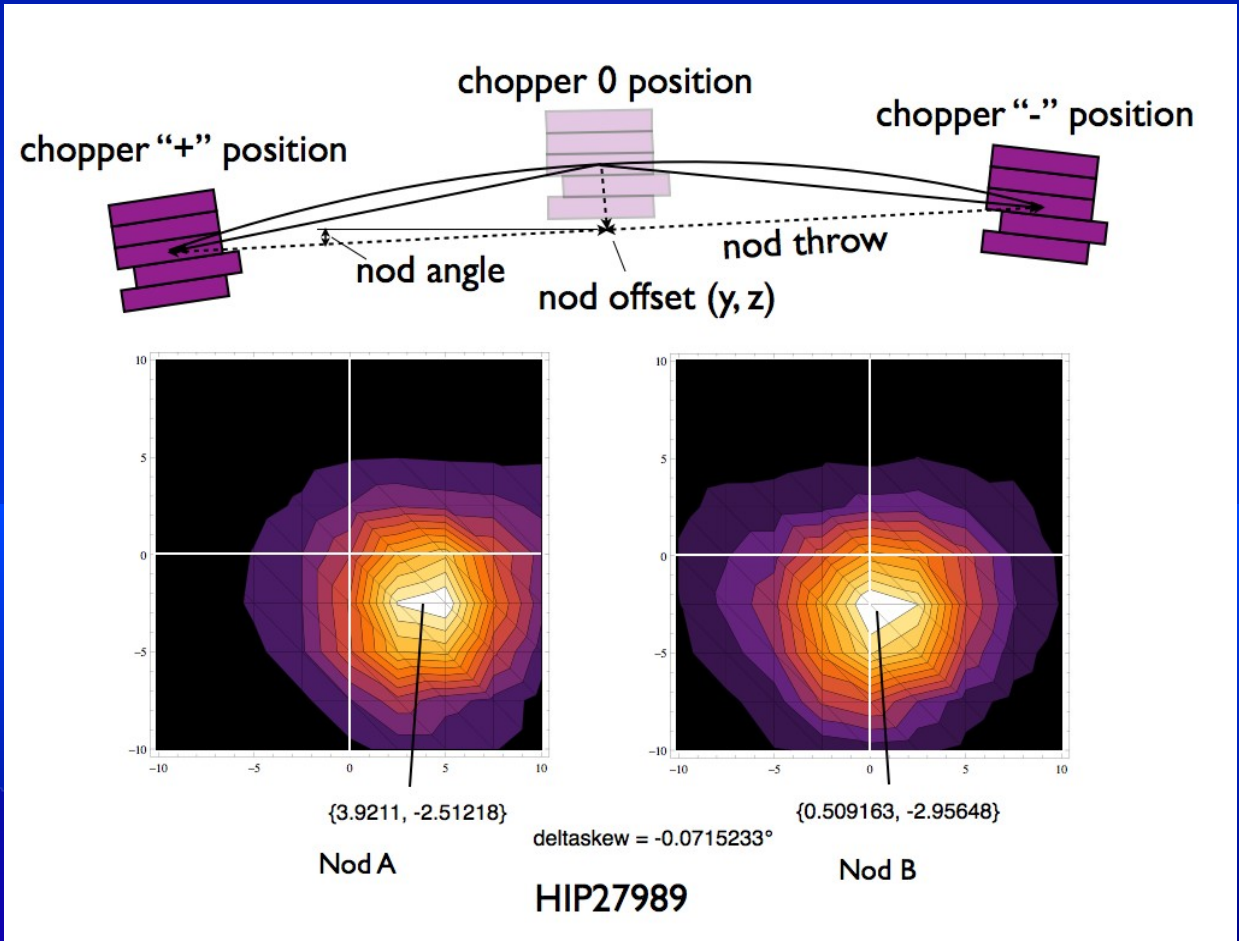
Detector settings

- Commissioning phase: grid of calibration source / telescope background measurements with different detector settings (esp. Bias voltages, ramp length,...)
- Optimal settings determined for flight conditions (radiation environment)
- With these settings Noise Equivalent Power (NEP) comparable to NEP measured on ground



Focal plane geometry

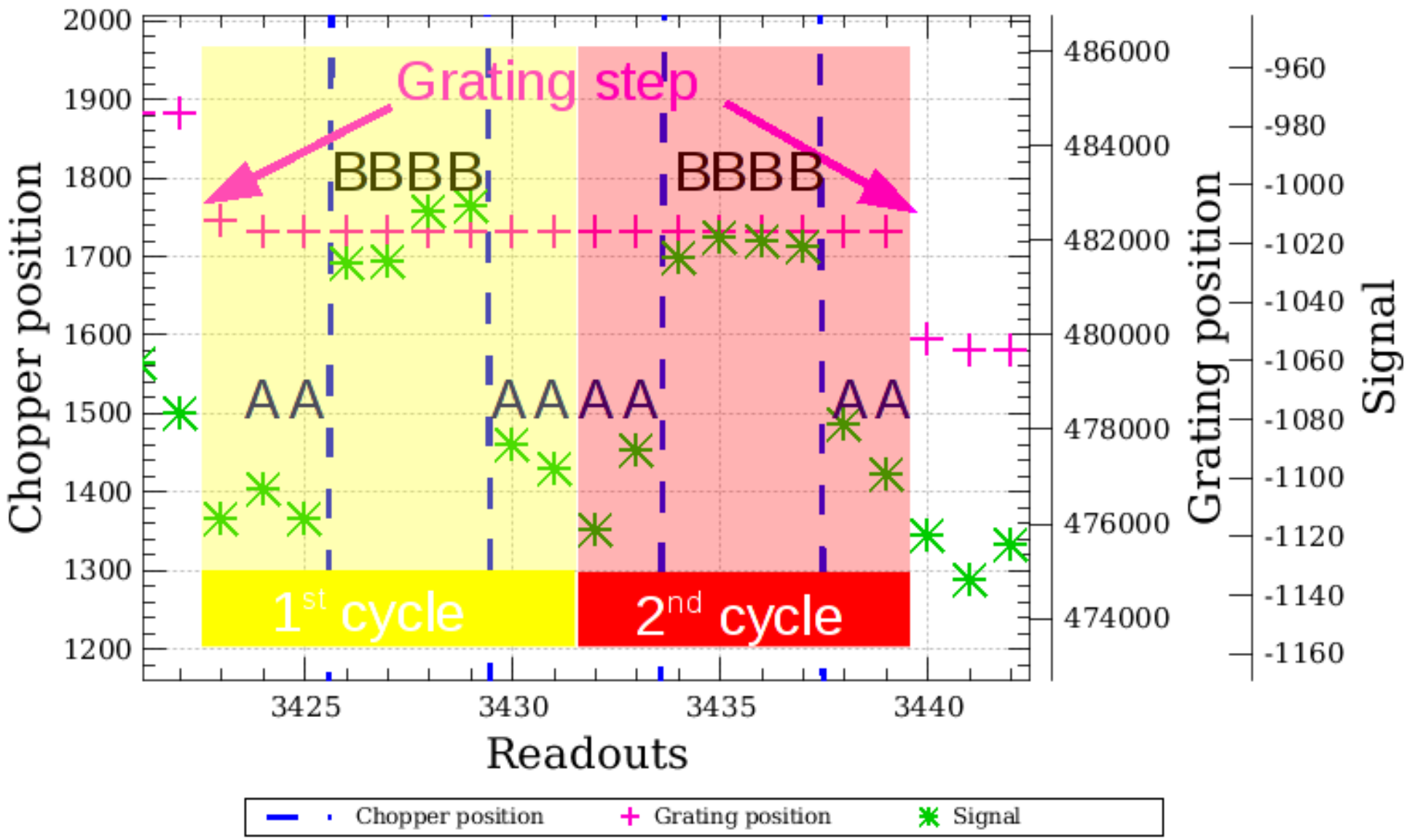
- Spacecraft – instrument alignment
- Offsets PACS boresight – central pixel at 3 chopper throws
- PACS chop – spacecraft nod Matching
- Based on rasters Continuum / line



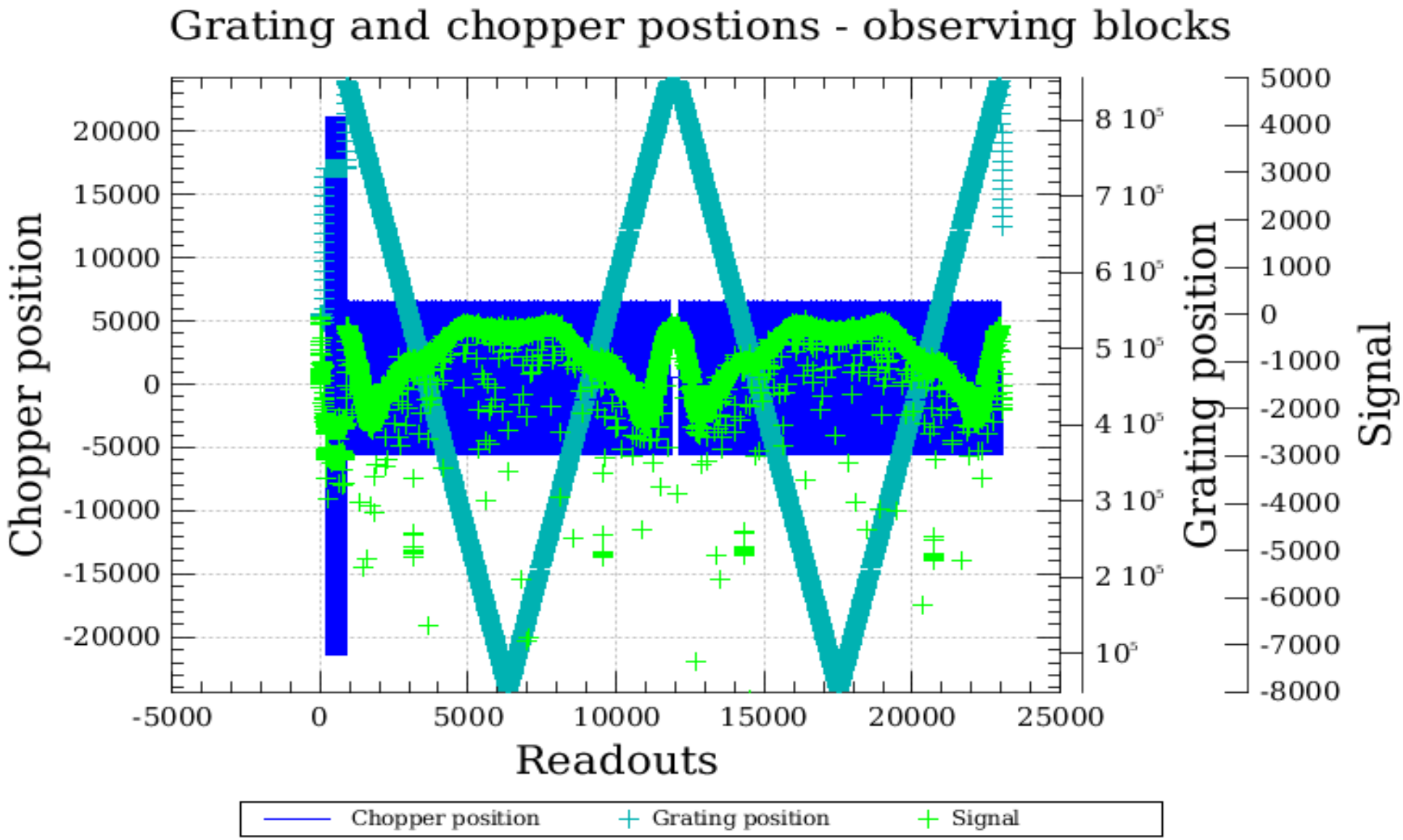
Optimal chop / scan pattern

- We observed the same set of spectral lines (bright, faint, high/low continuum) with a grid of scanning parameters:
  - varying integrating ramp length
  - chopping frequency
  - cycle repetition
- Best S/N in co-added line profiles with:
  - Integration time of 1/8th second (32 samples)
  - 2 integration ramps per chop plateau
  - 2 ABBA chopping cycles per grating position

Optimal scan – chop pattern

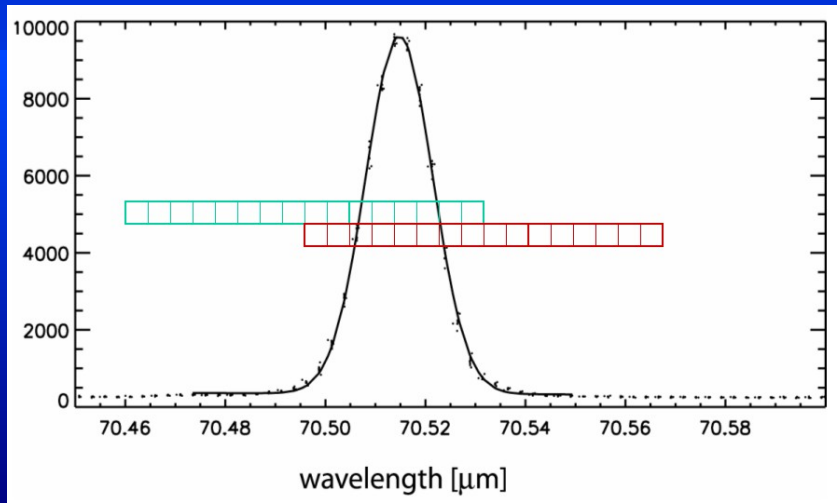


Optimal scan – chop pattern



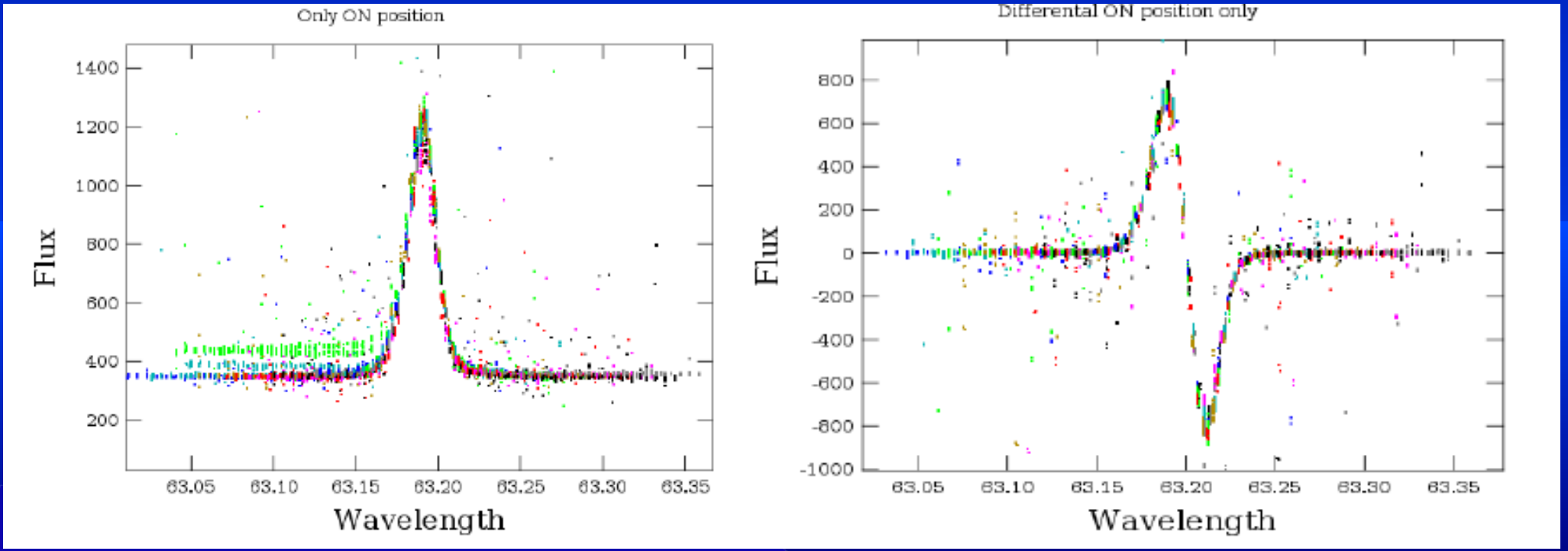
Wavelength switching pre-launch

- Modulate between on-line and off-line in spectral domain
  - on-line: E(line) + E(continuum) + E(background)
  - off-line: E(continuum) + E(background)
  - on-line – off-line: E(line)
- Loose continuum information but ok for line flux.



Wavelength switching: new concept

- Wavelength switching strategy changed:
  - Modulate with wavelength step a fraction of the FWHM
  - Use differential profile



Optimal wavelength switching pattern

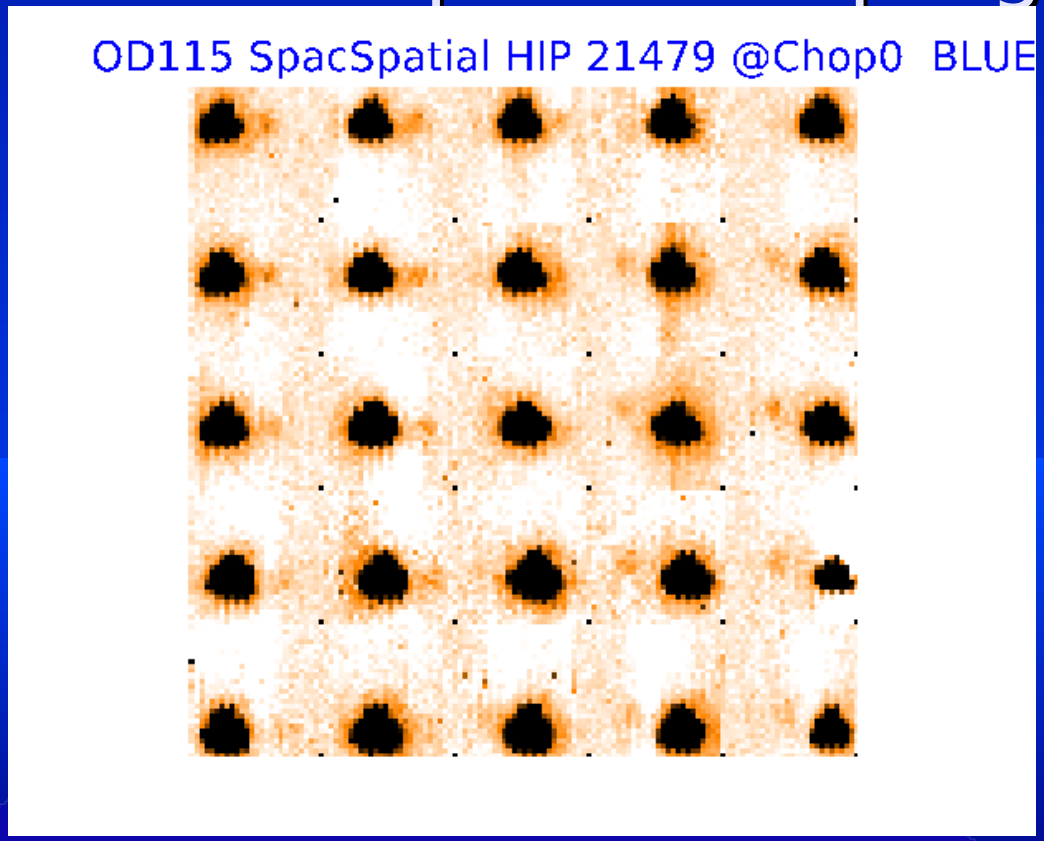
- We observed the same set of spectral lines (bright, faint, high/low continuum) with a grid of wavelength switching parameters:
  - Wavelength switching amplitude
  - Grating step size
- Amplitude / step size chosen from best S/N in the differential profile

Instrument performance & calibration

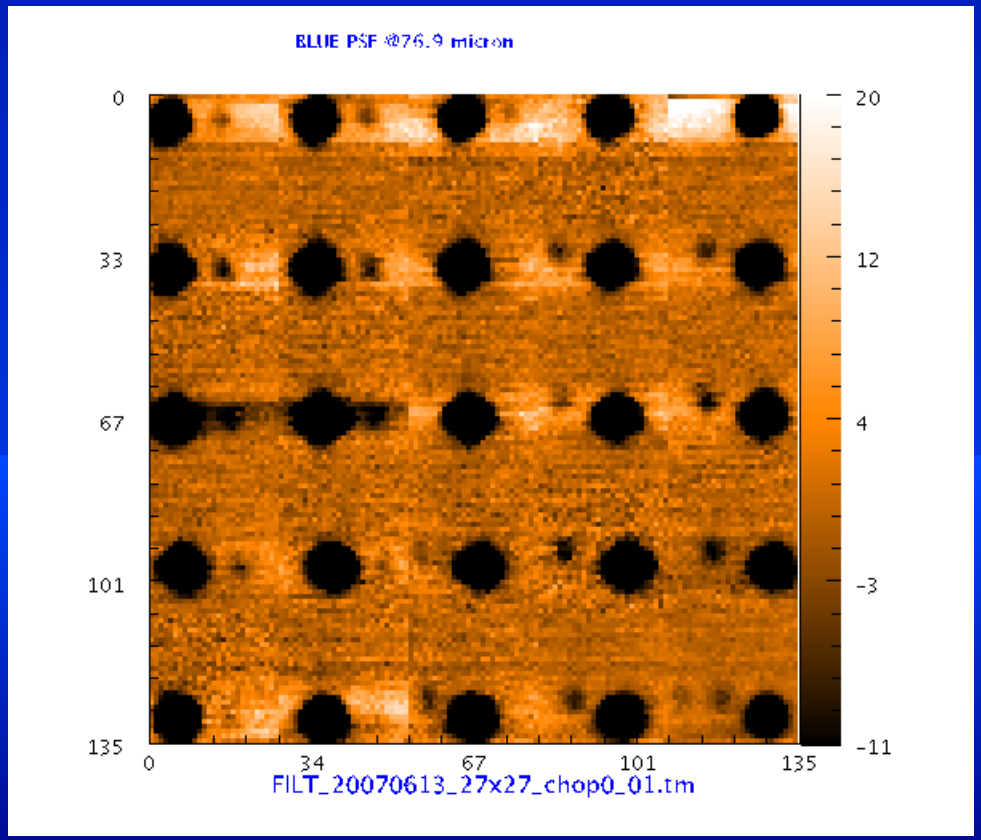
- Spatial calibration
  - Implications for chopped measurements & raster step sizes
- Wavelength calibration
  - spectral ranges & leakage
  - spectral resolution
  - Wavelength shift with pointing offset, dithering
- Flux calibration
  - Stability, transients, linearity
  - Saturation limits & sensitivity

Spatial calibration

- Spaxel offsets wrt central spaxel via rasters on bright point sources – confirm ILT results
- Calfile updates in progress



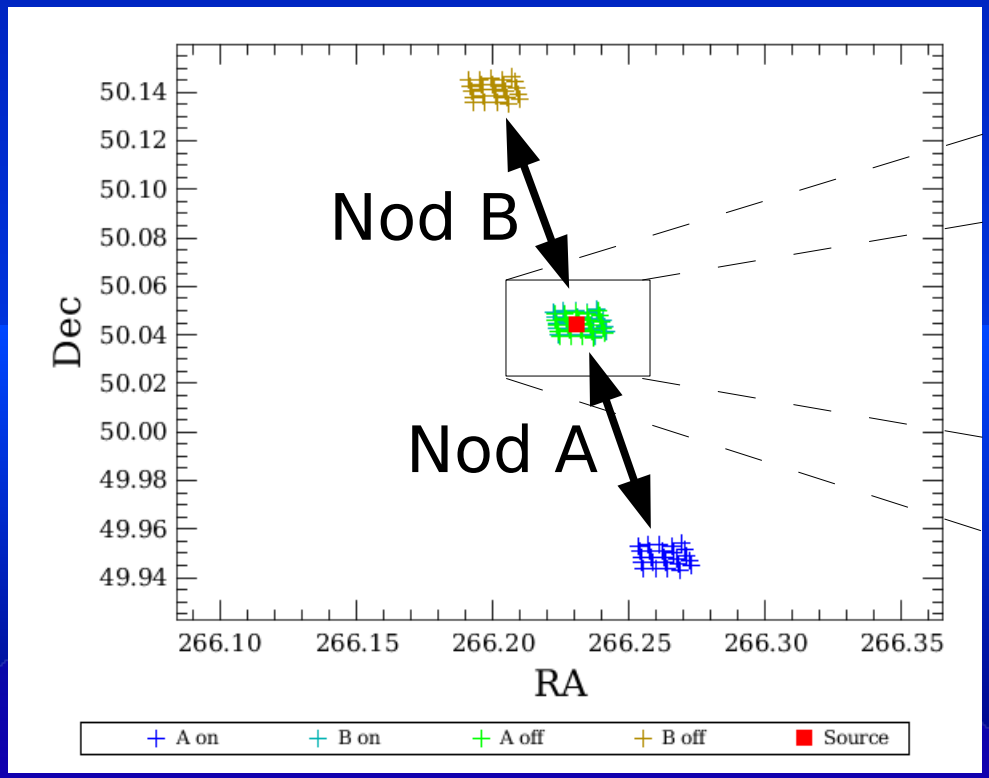
FLIGHT (R Dor 27x27 raster)

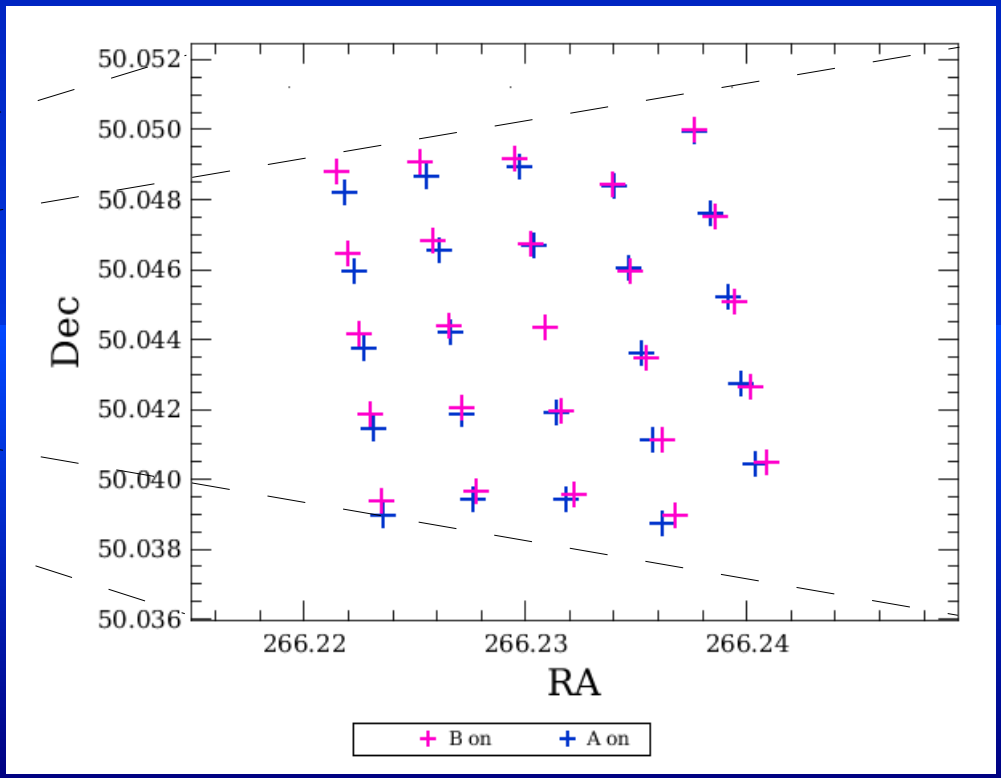


GROUND (lab point mask on XY)

Rotation of on-field in nod positions

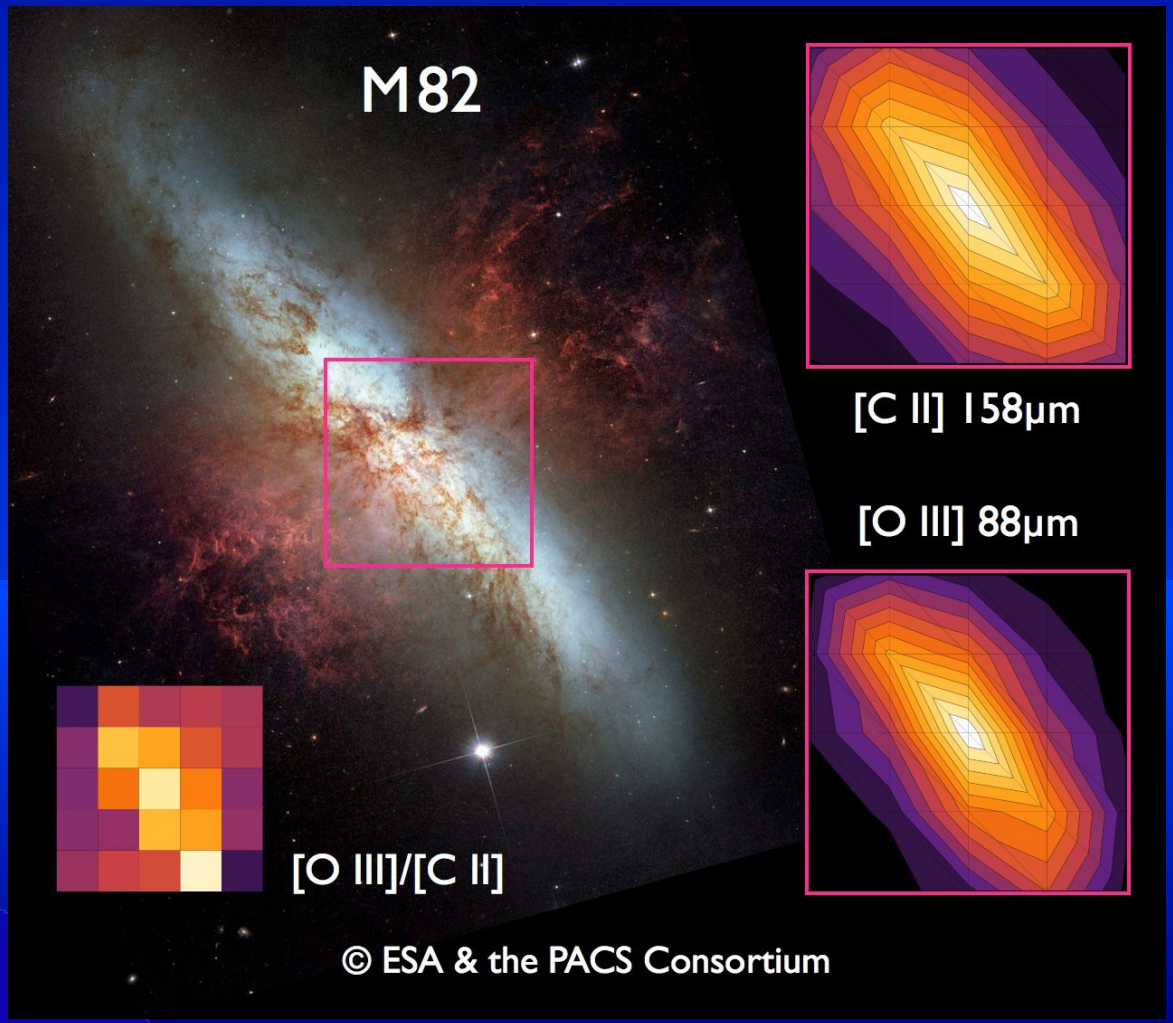
- Chopper throw is 'curved' on the sky – nodA/nodB on-source footprint are rotated
- Effect smaller with small chopping angle – prefer small over large chop throw in AORs





Recommended raster step sizes

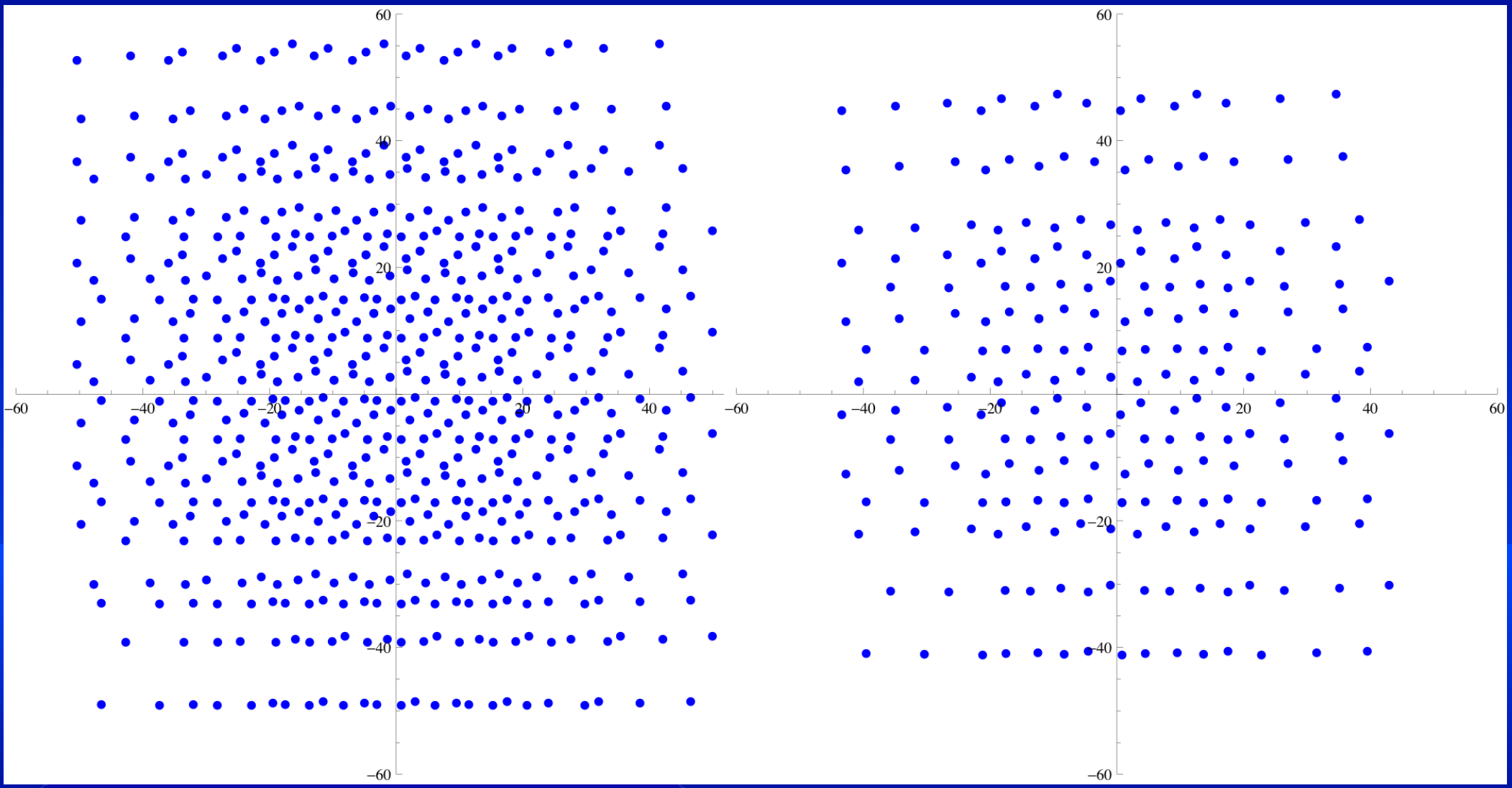
- PACS pixels (9.4”x9.4”) are undersampling the beam
- With raster maps, offset by fraction of pixel, you can recover the full spatial information



Recommended raster step sizes

- Tiling the sky: Good raster step sizes are
  - 47” - no overlap between the tiles
  - 38” - approx. 1 row of spaxels overlap
- Homogeneous maps extended objects:
  - Blue: dz = 16.0”, dy = 14.5”
  - Red: dz = 24”, dy = 22.0”
- Small source mapping at full spatial resolution
  - Blue: 3x3 raster, dz=dy=3”
  - Red : 2x2 raster, dz = dy = 4.5”
- Overlap rasters: use spacecraft coordinates !

Homogeneous coverage extended objects - recommended steps



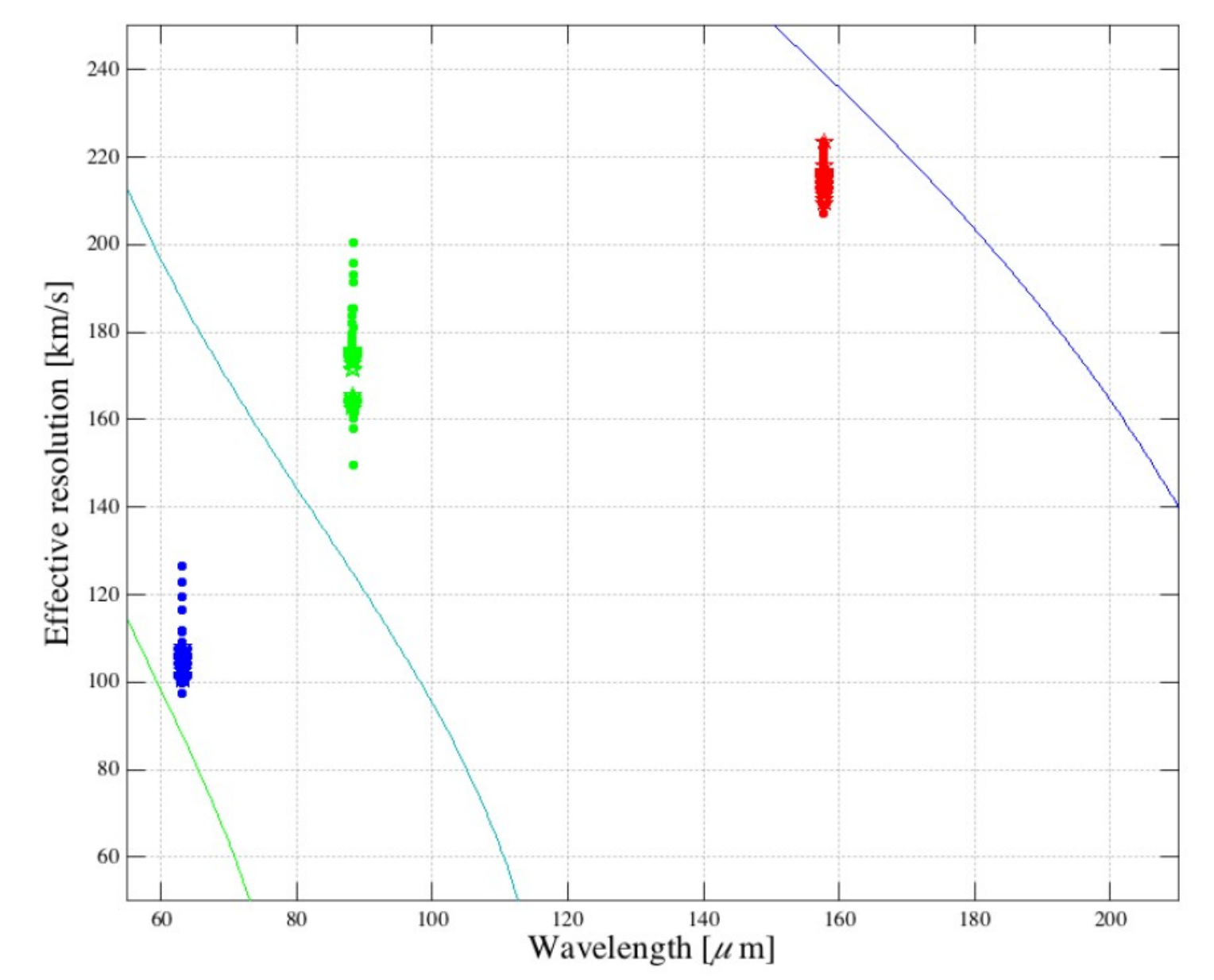
5x5 raster BLUE

3x3 raster RED

Wavelength calibration

- Pipeline 2.0.0 uses wavelength calibration (relating grating position to wavelength seen in every pixel) base on ground measurements of gas cel and laser spectra
- In-orbit measurements of Jupiter, Mars and late-type stars confirm ground calibration accurate to ~1/3rd resolution element for co-added spectrum
- Work on update to wavelength calibration has started based on in-orbit measurements
- Spectral resolution as expected

Predicted resolution compared to FWHM of gaussian fit to lines in NGC5315

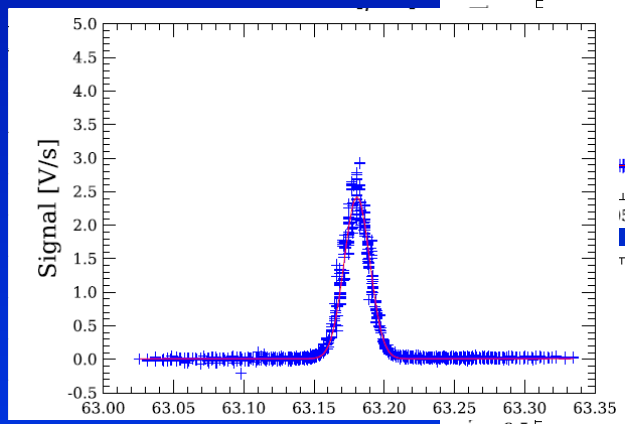


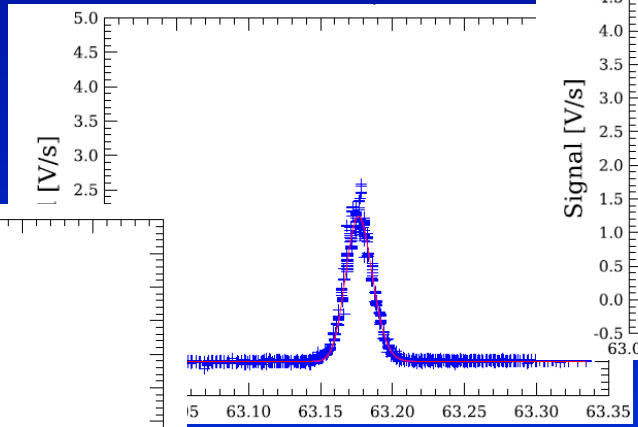
Wavelength shift + skew with source offset to center slit

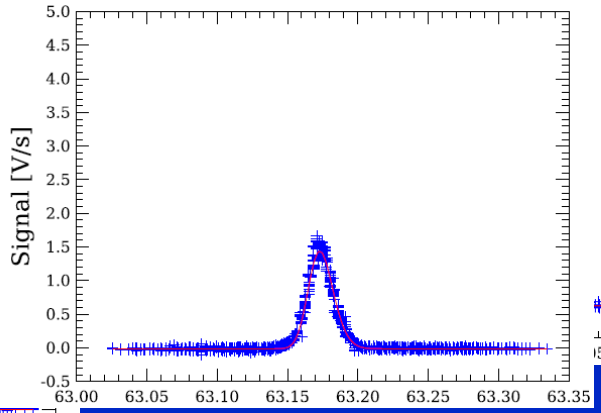
+6”

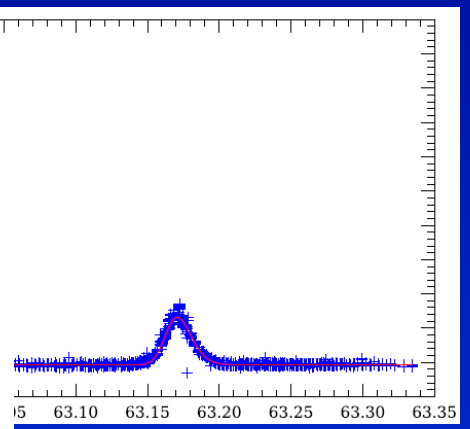
+4”

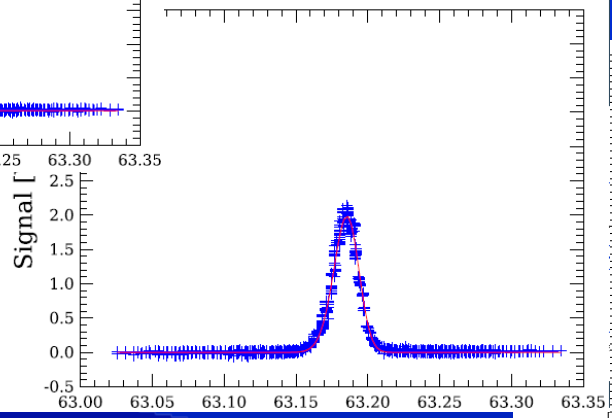
+2”

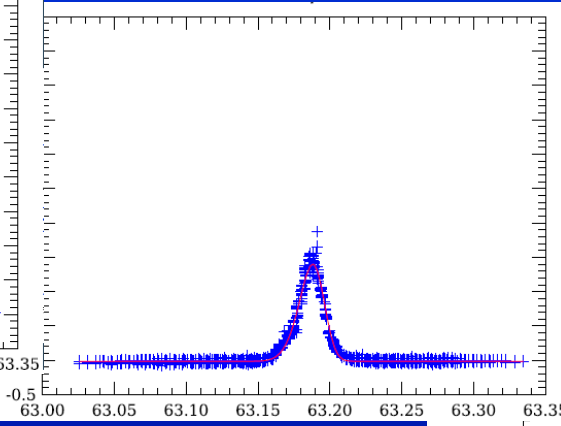


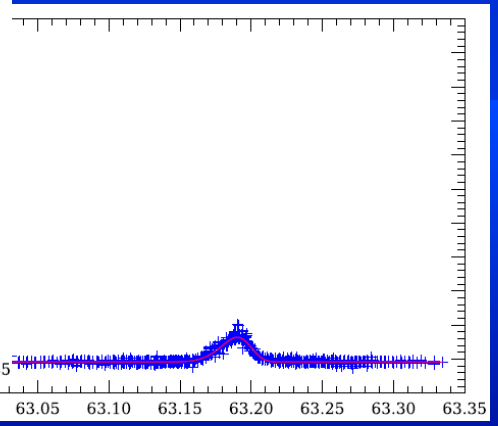












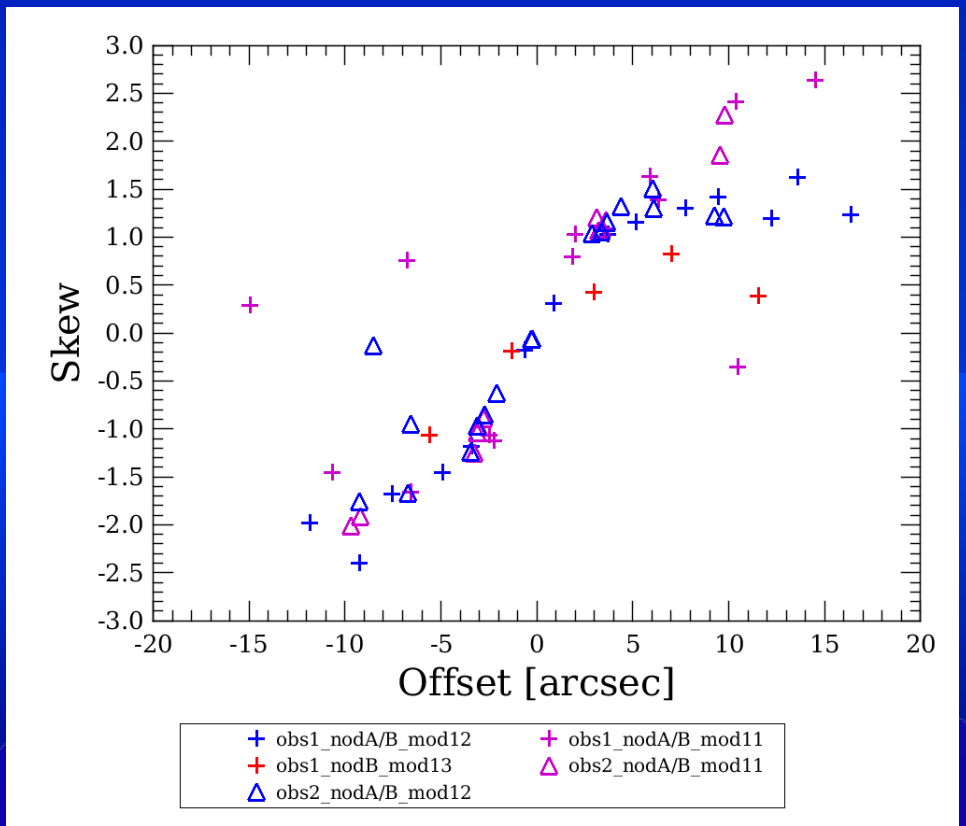
-2”

-4”

-6”

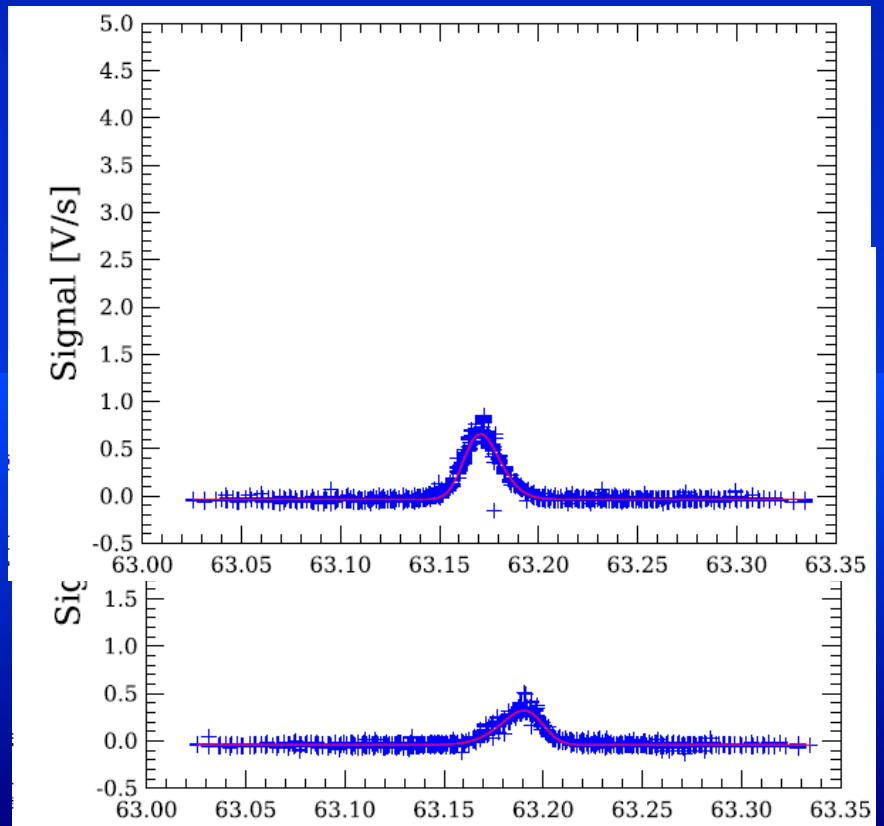
Wavelength shift + skew with source offset to center slit

- Characterisation + corrections underway
- Only dither if photocenter uncertain
- Do not over-interpret line shapes in maps



+6”

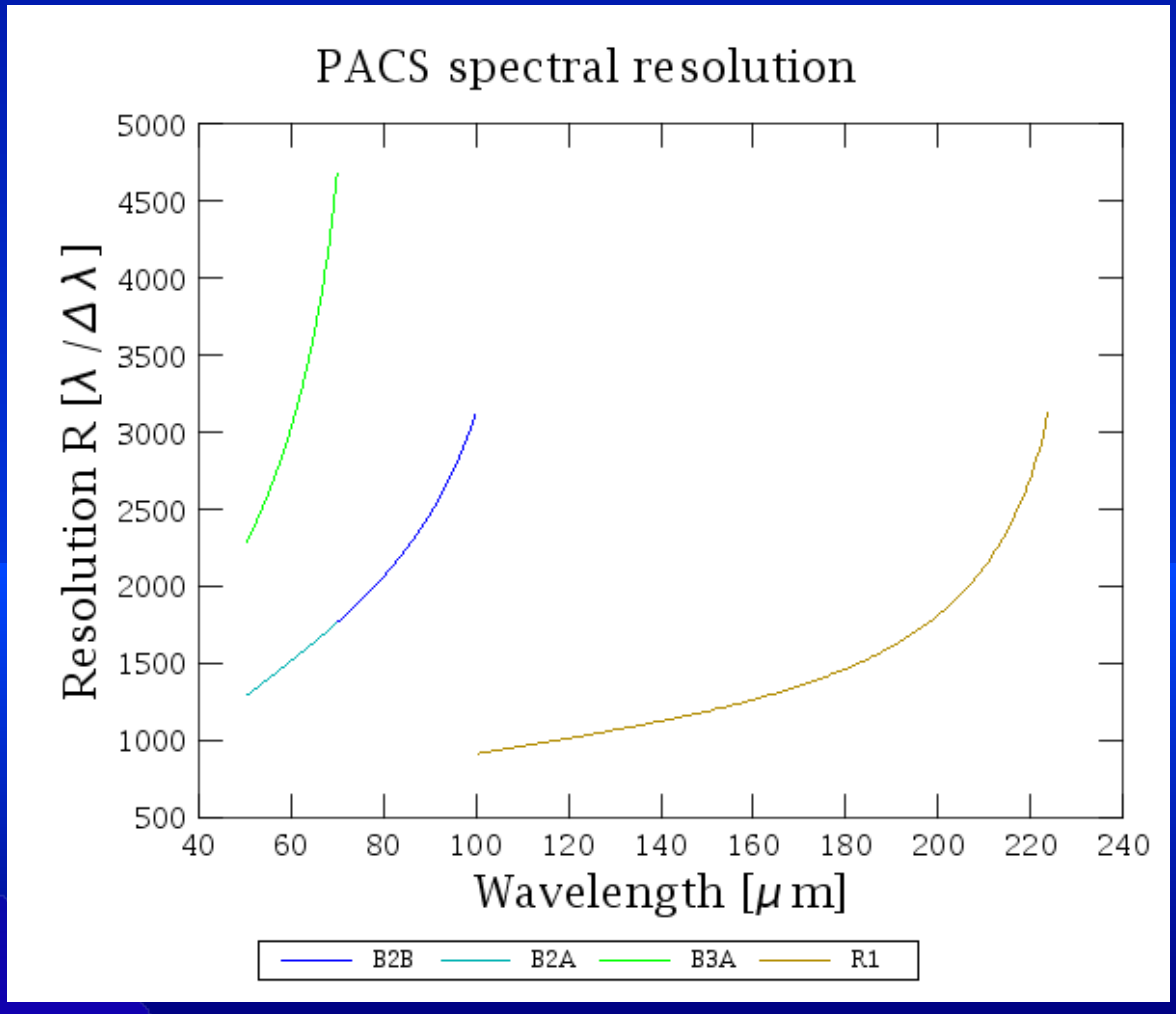
-6”



Accessible wavelength ranges

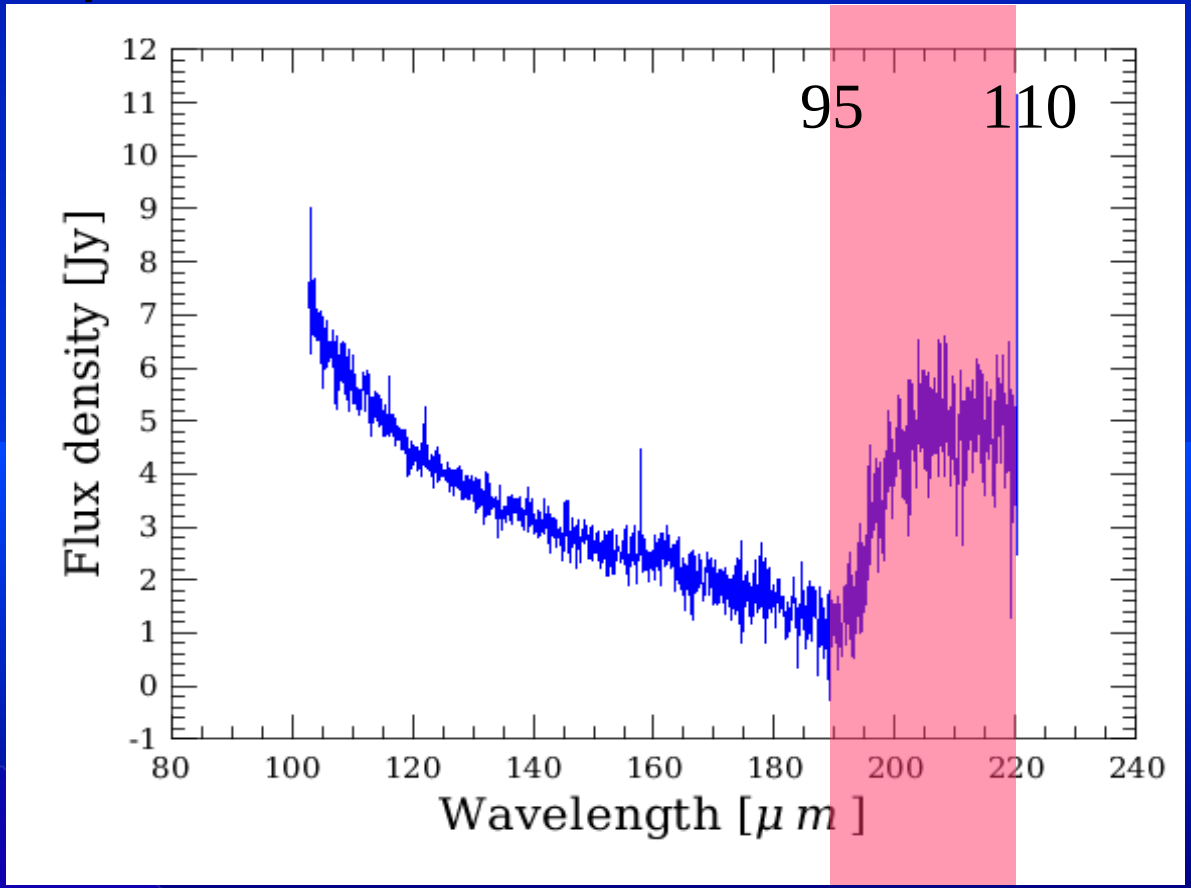
- Extended short wavelength range
  - OIII line at 51.8um accessible

- B3A 51 – 73 um
- B2A 51 – 73 um
- B2B 70 – 105 um
- R1 102 – 220 um



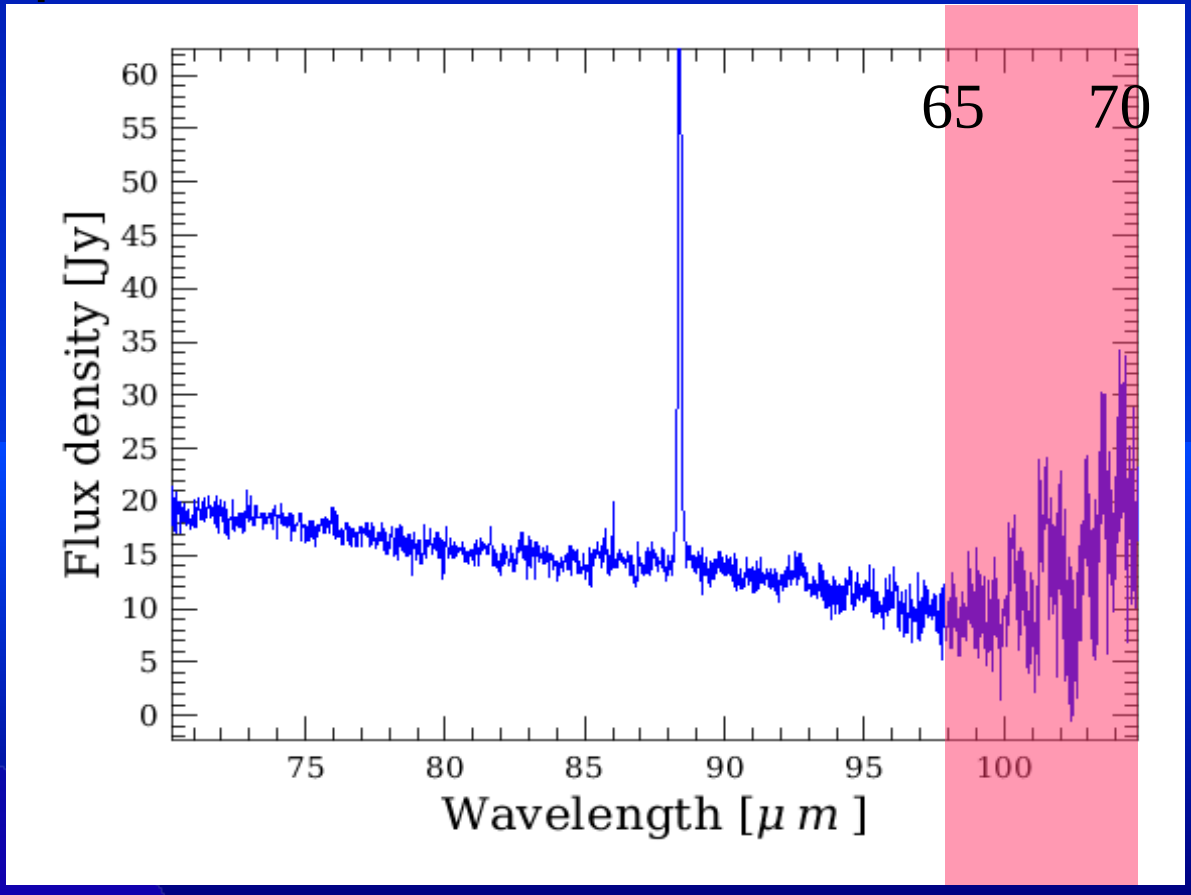
Problematic wavelength regions – leakage

- Band R1: >190um: low response, order 2 leak
  - 95-110 um order 2 spectrum added to 190-220 order 1 spectrum



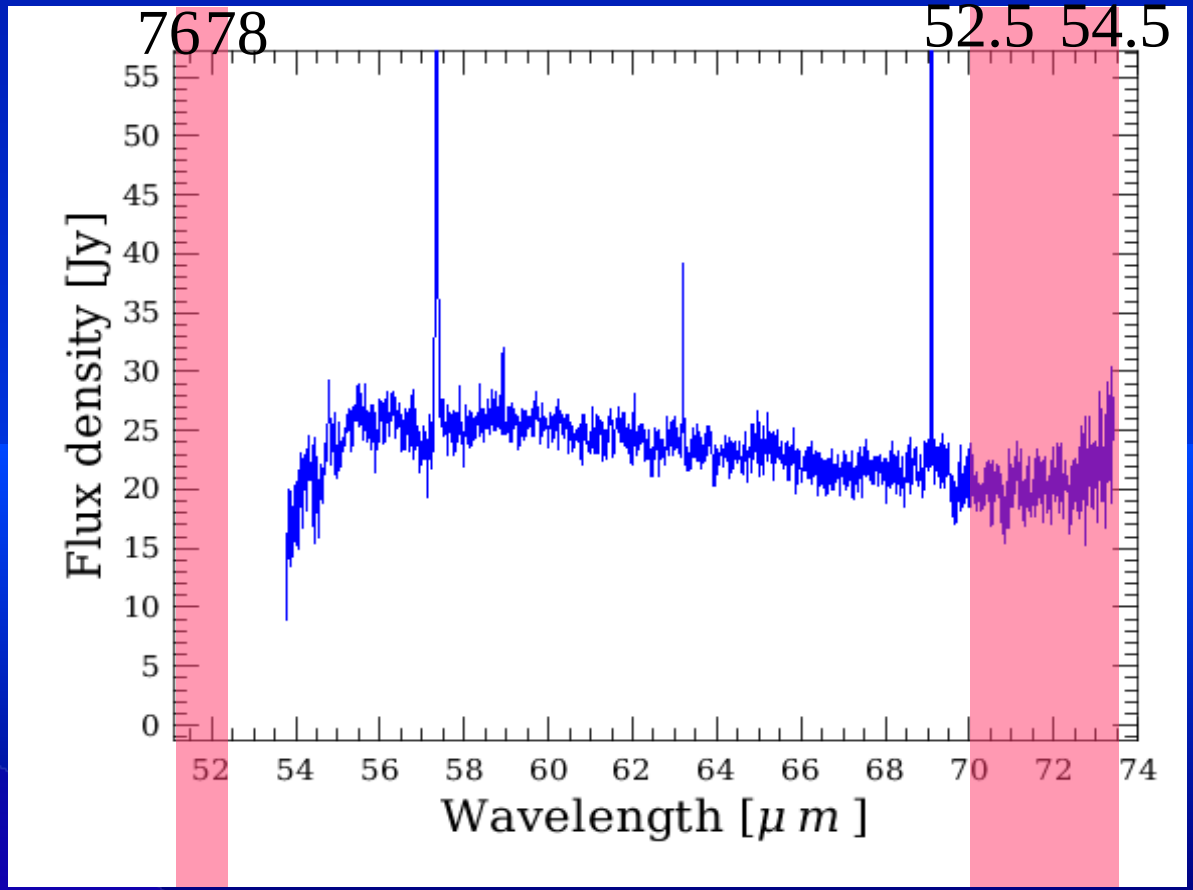
Problematic wavelength regions – leakage

- Band B2B: >98um: low response, order 3 leak
  - 65-70 um order 3 spectrum added to 98-105 order 2 spectrum



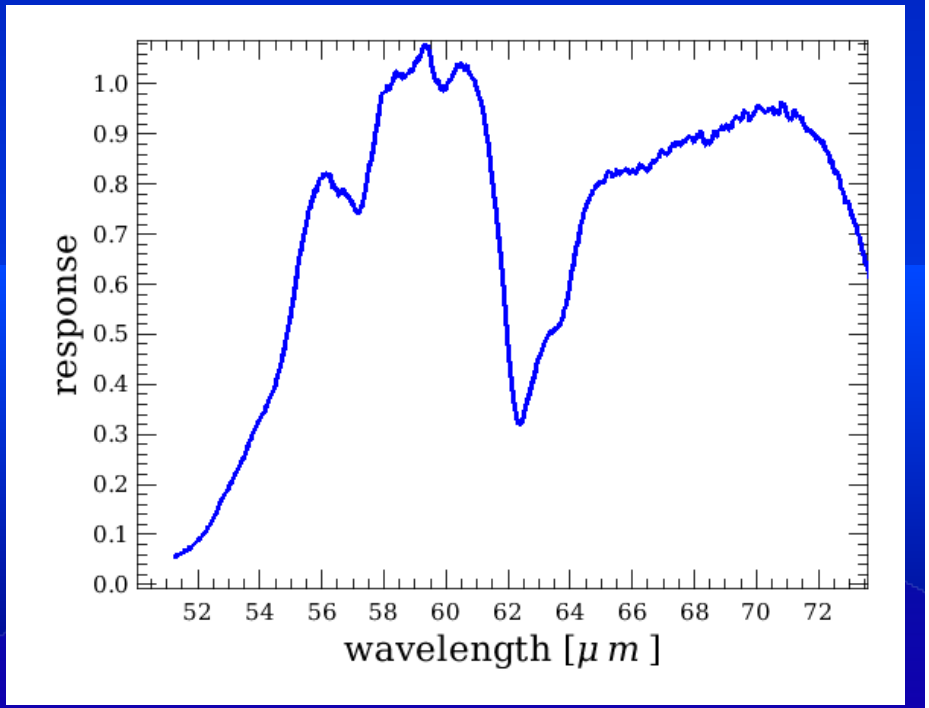
Problematic wavelength regions – leakage

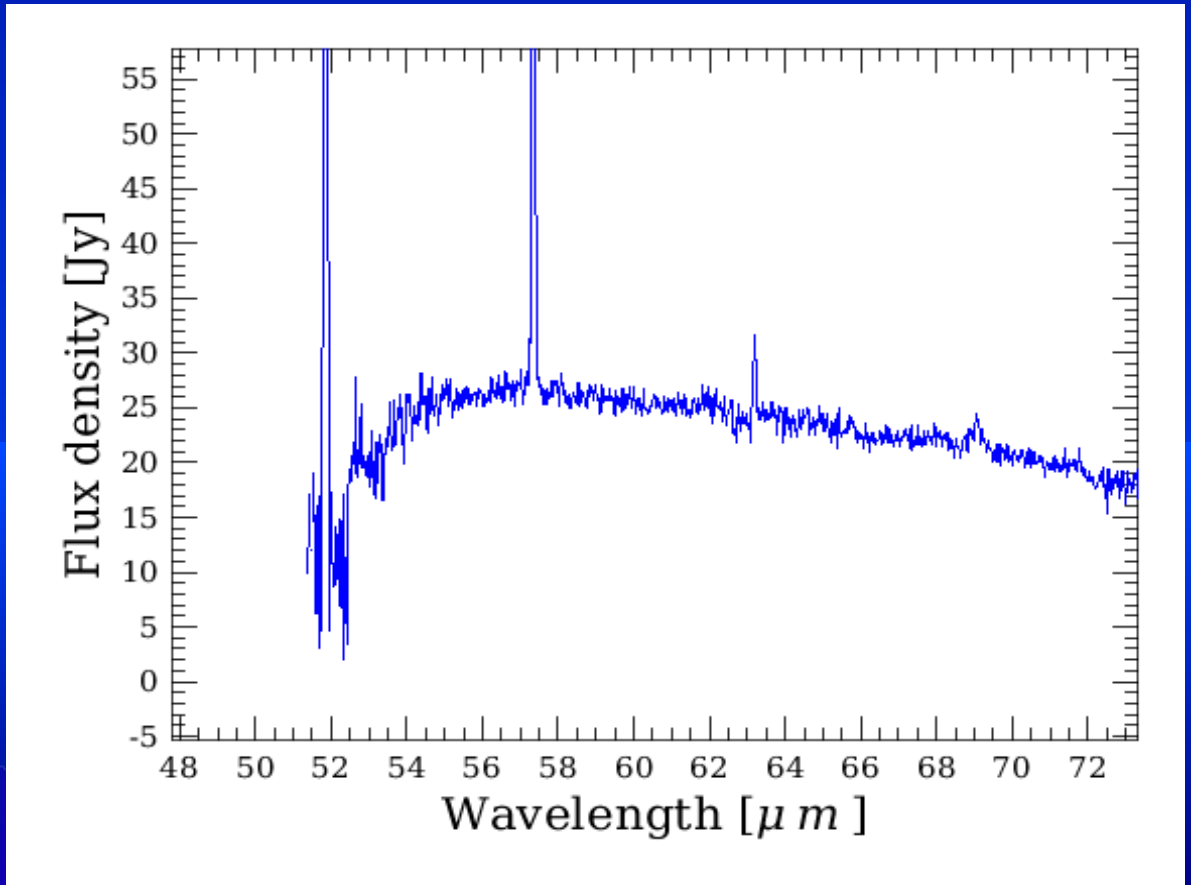
- Band B3A: <52um: low response, order 2 leak
  - 76-78 um order 2 spectrum added to 51-52 order 3 spectrum
- Band B3A: >70um: order 4 leak
  - 52.5-54.5um order 4 spectrum added to 70-73 order 3 spectrum



Problematic wavelength regions – leakage & response

- Band B2A: clean of leakage, but low response <52um (factor 40-60 compared to 60um)

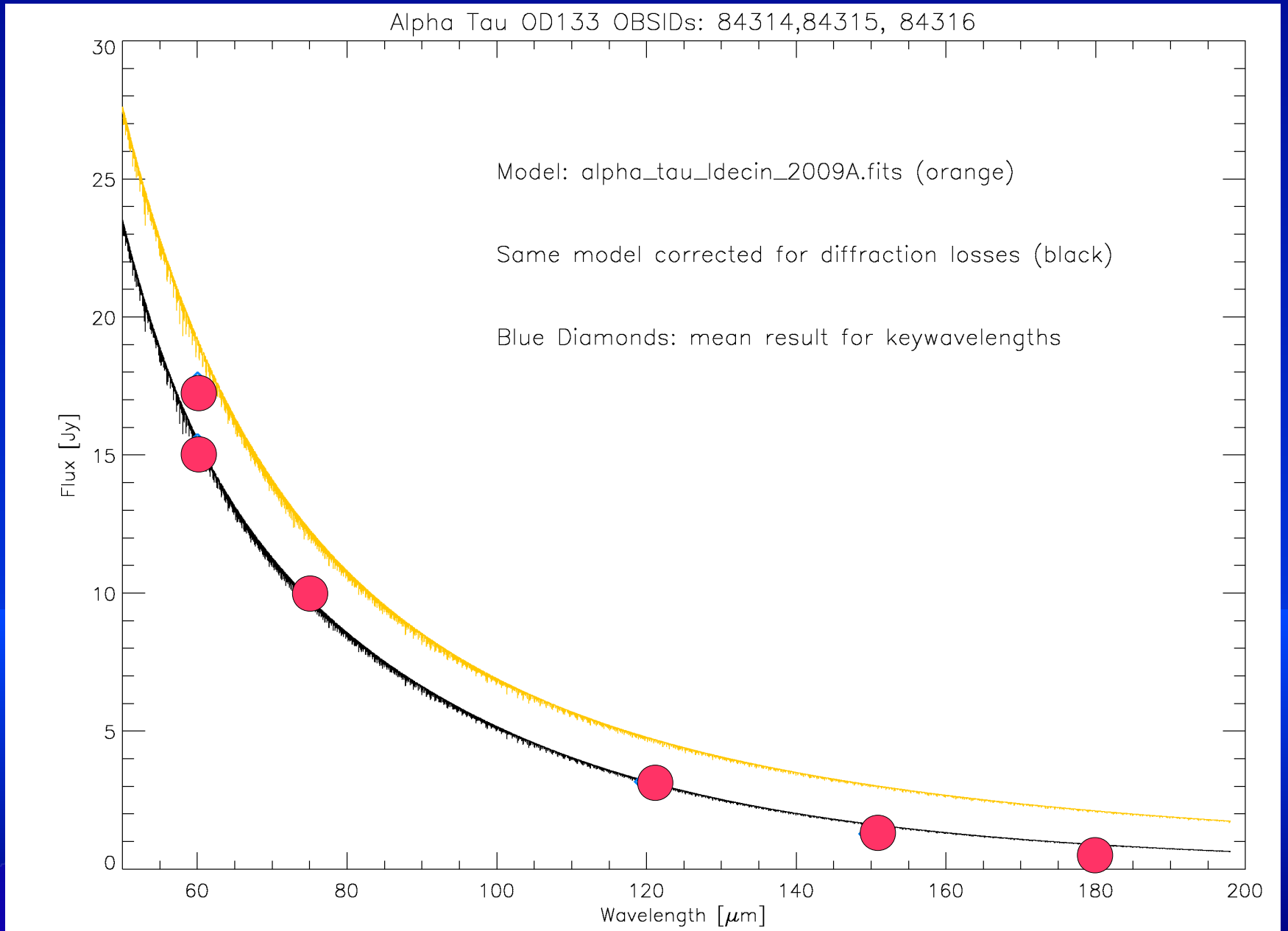




Flux calibration 2.0.0 pipeline

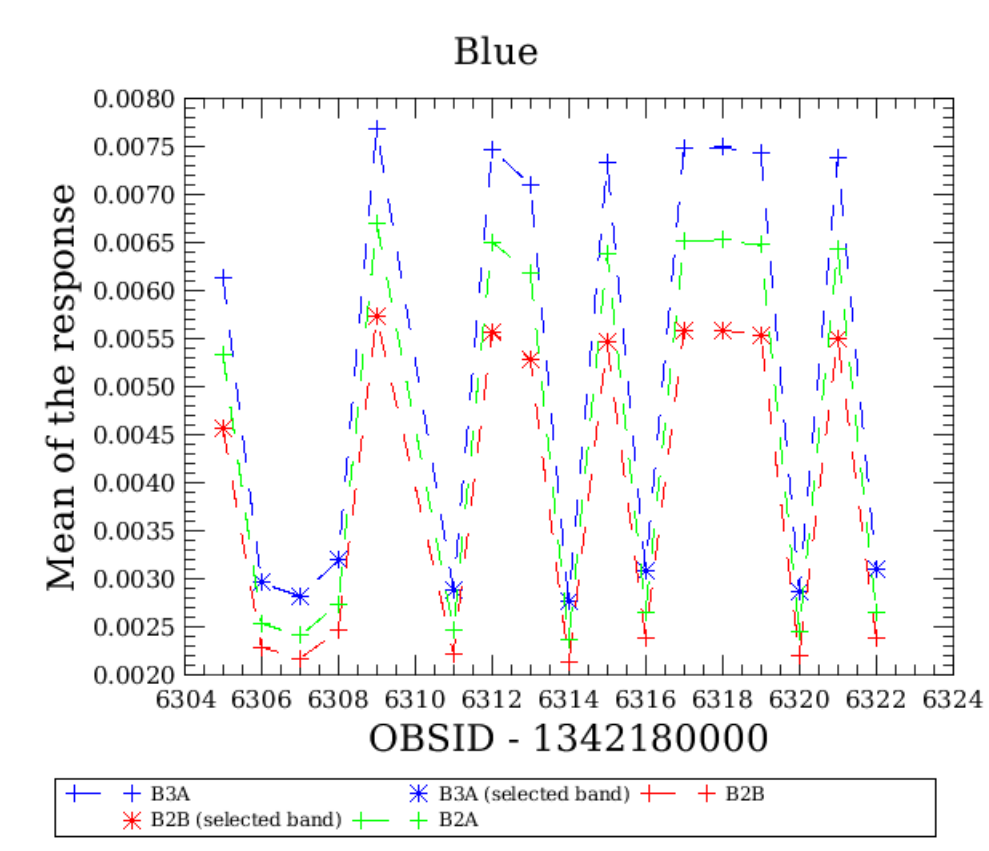
- Pipeline 2.0.0 uses nominal absolute response and relative spectral response determined on ground
- No use of internal calibration block yet, no compensation for detector drifts
- In-orbit measurements of flux calibrators (asteroids, Neptune, Uranus, fiducial stars) indicates ground flux calibration accuracy ~50%
- Work on flux calibration based on flight measurements in progress

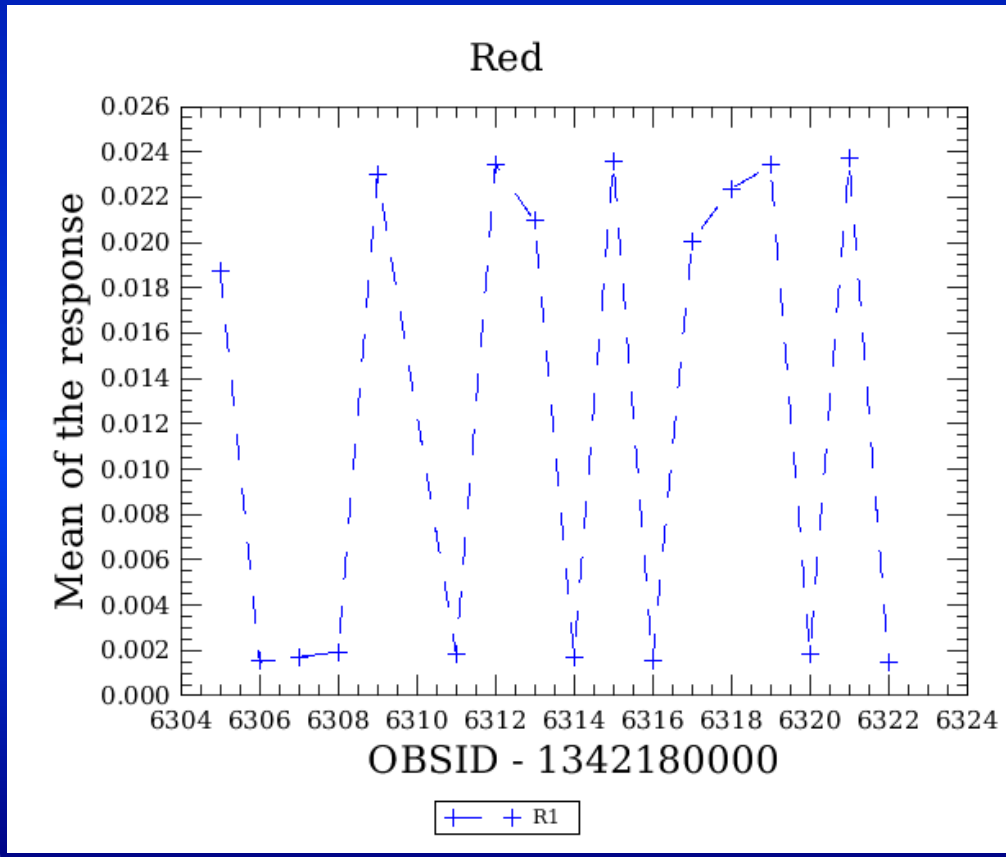
Example: comparison Alp Tau model (Decin) – continuum flux in short PACS range scans



Response change over 1 day

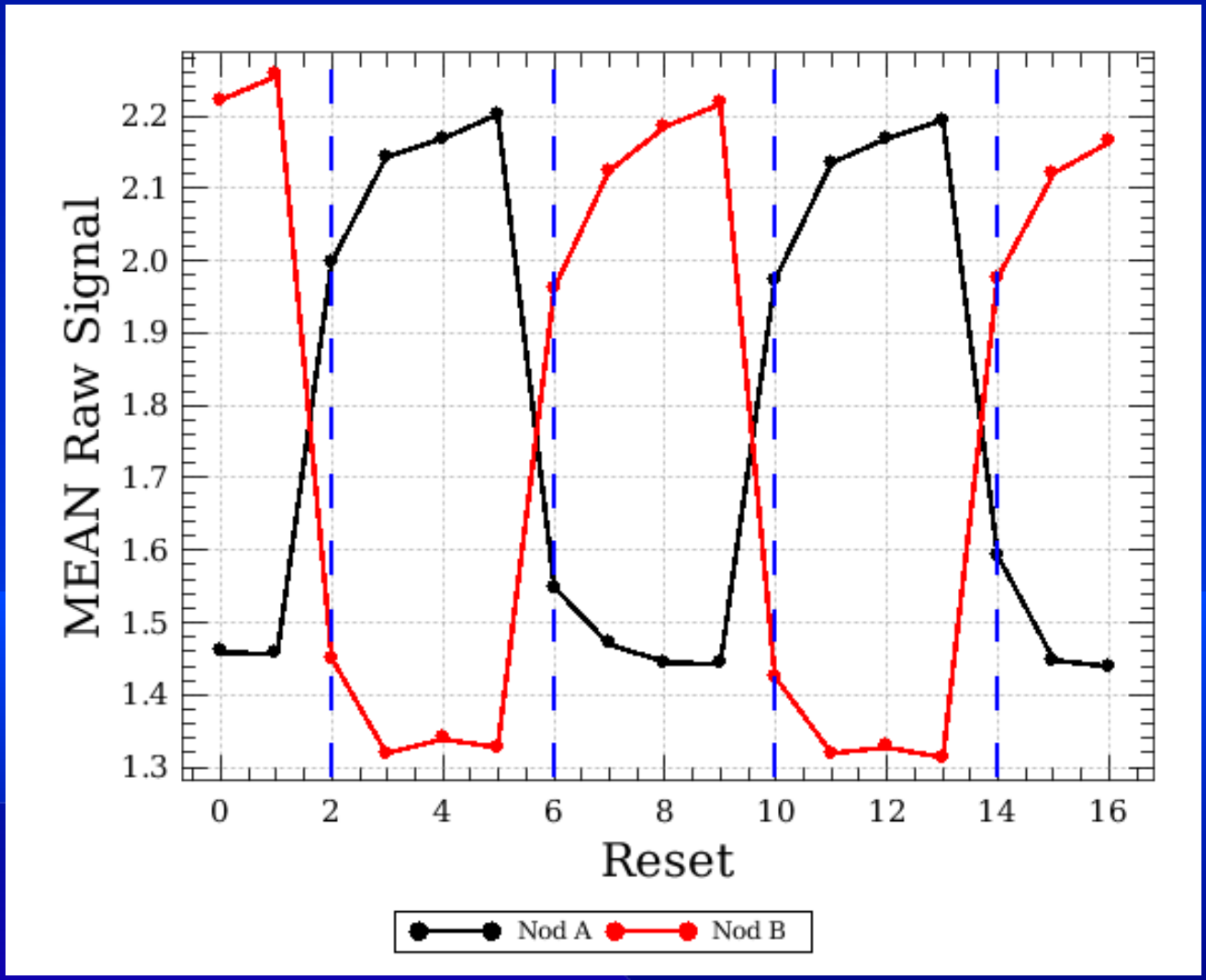
- Response from internal calibration sources during OD 165
- Blue: ~5% variation; Red: ~25% variation





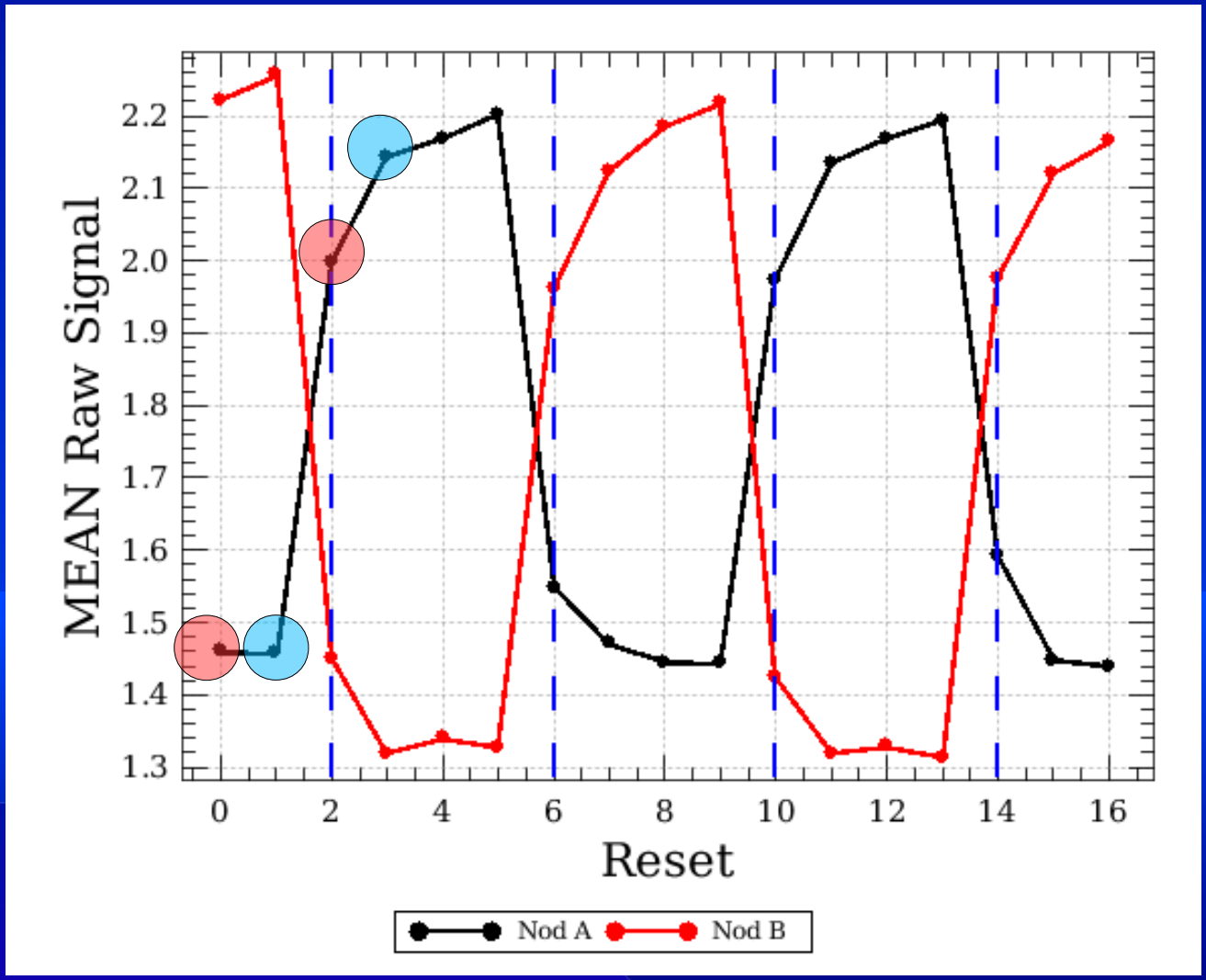
Transients in chopping pattern

- Results in 'populations' of on-off signals



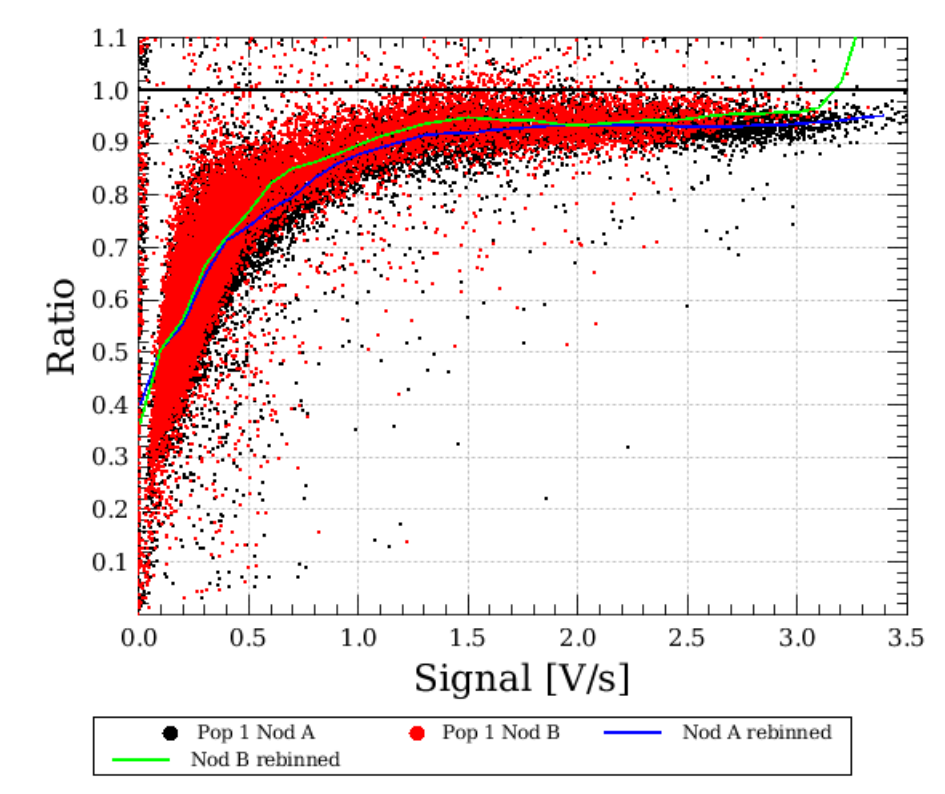
Transients in chopping pattern

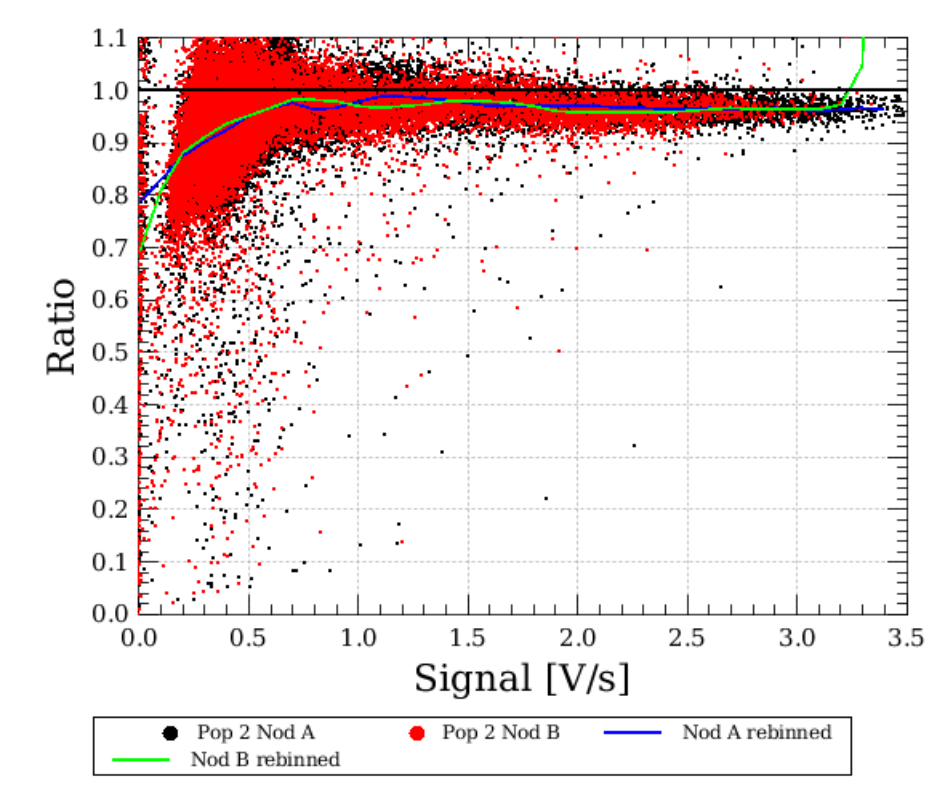
- Results in 'populations' of on-off signals



Transients in chopping pattern

- Differences B1-A1, B1-A2, B2-A1, B2-A2 are systematical as a function of signal
- Calibration / pipeline step in development



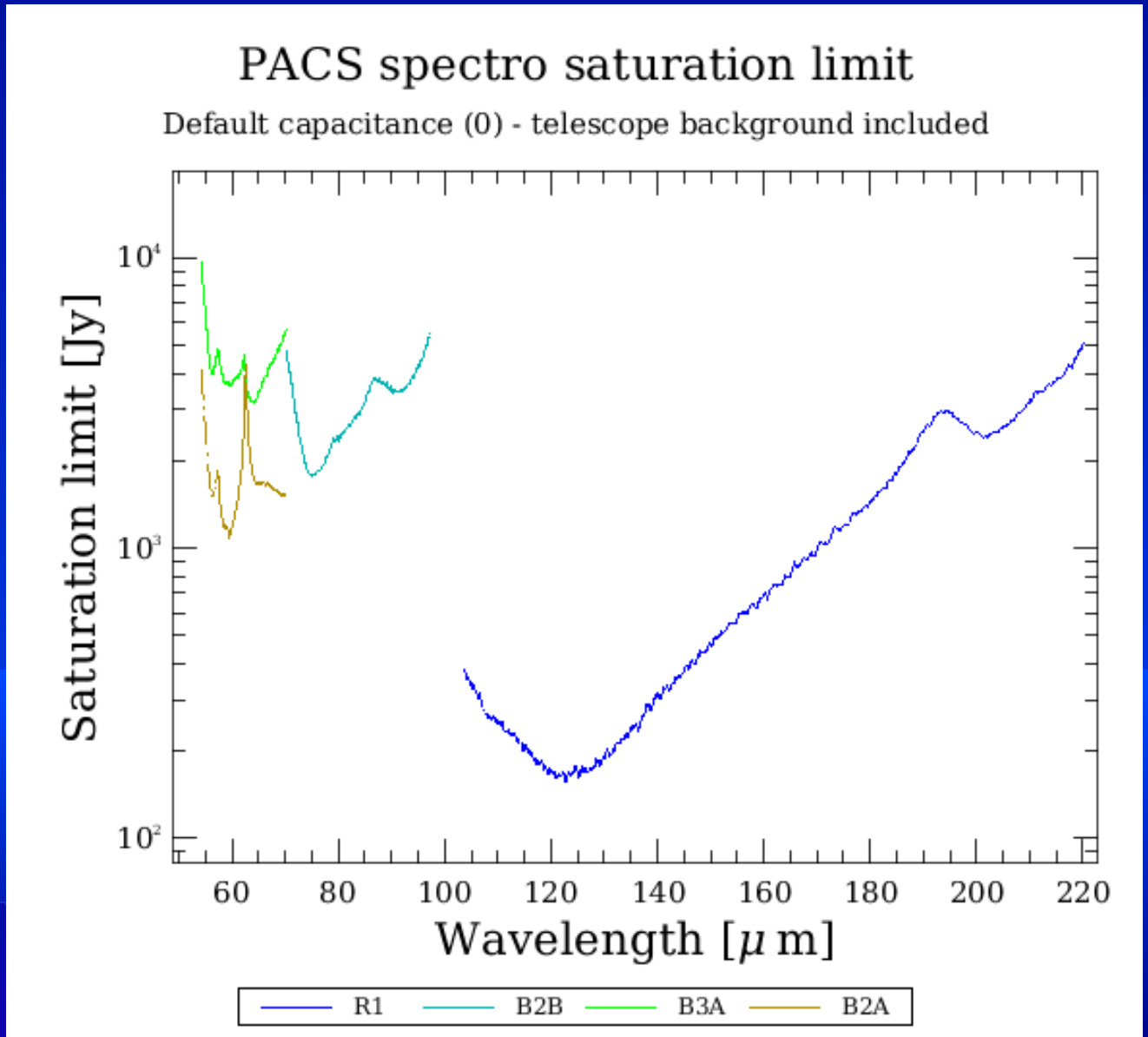


Transients in chopping pattern

- Awaiting proper correction, transients in chopping pattern lead to uncertainties when comparing pacs fluxes
- In SED scan on one source, signal varies with relative spectral response → awaiting transient correction, broadband SED shape not reliable.
- Linearity corrections on integration ramp level based on in-orbit measurement underway.

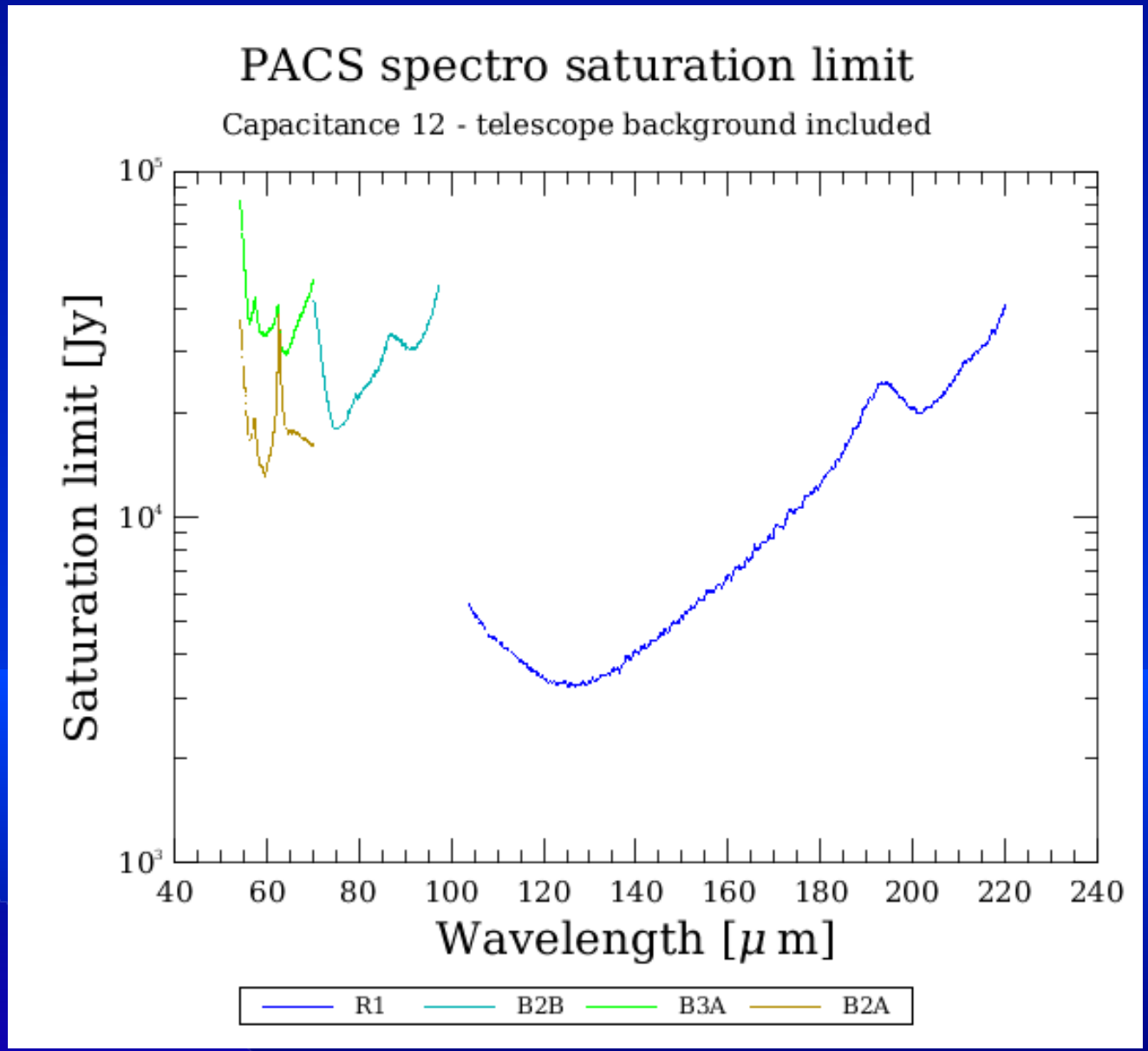
Saturation levels

- Currently all measurements are done with default (smallest) integration capacitance, limiting brightness of observable targets without saturating



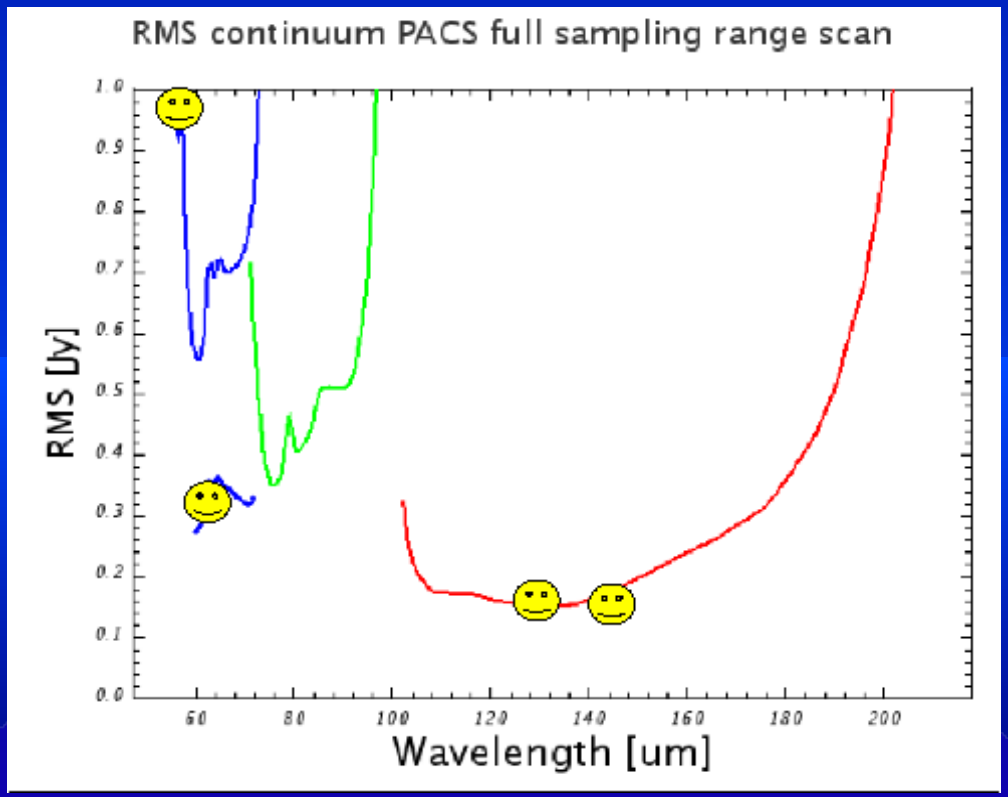
Saturation levels

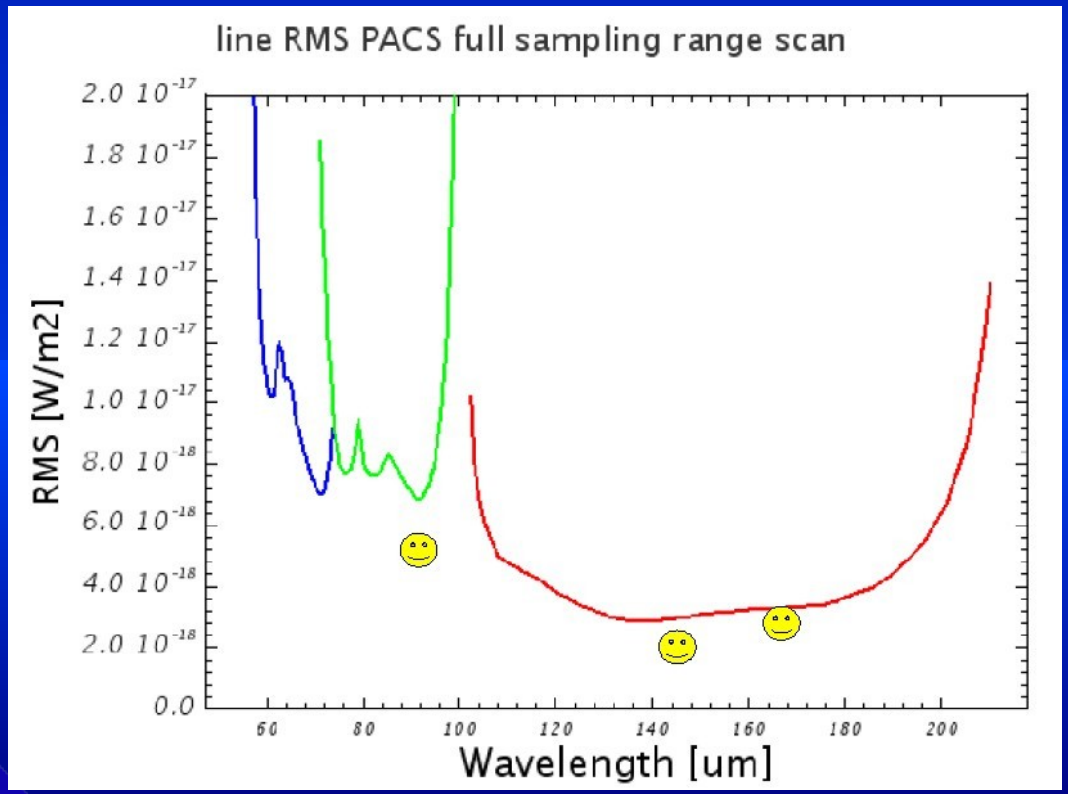
- Automatic switching of integrating capacitance under test.
- Observable targets limited by saturation limit largest integrating capacitance



Sensitivity

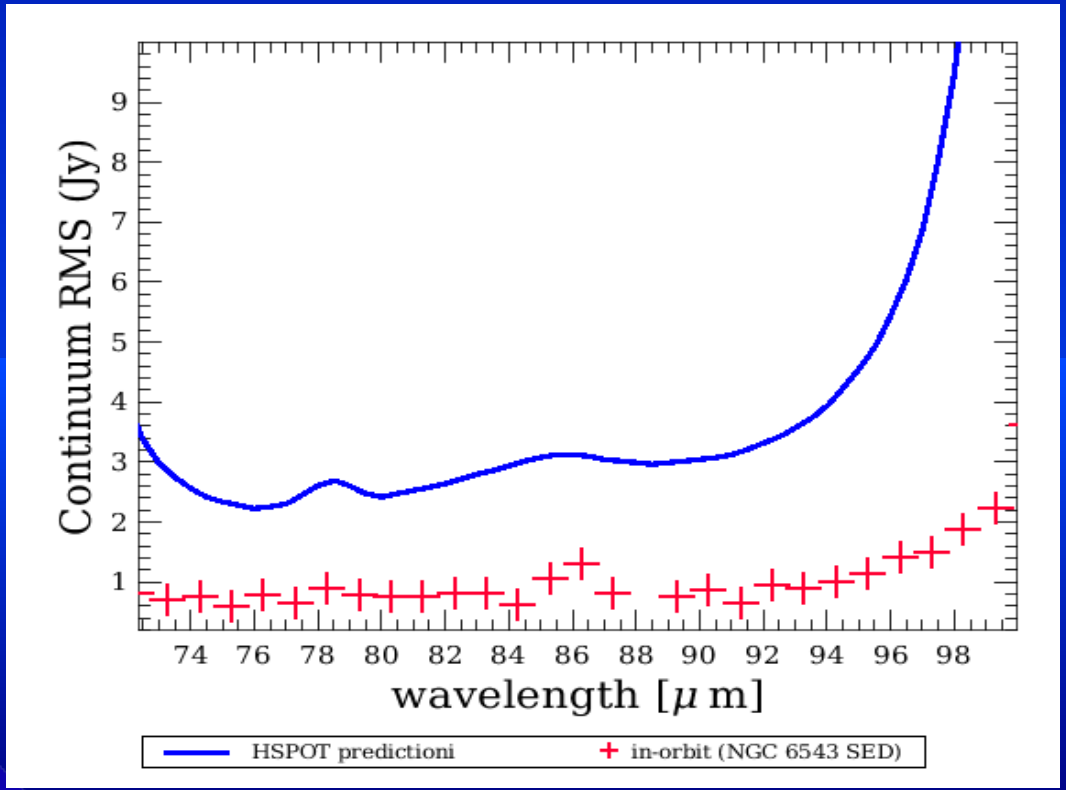
- Line spectroscopy / deep range spectroscopy: Sensitivities cfr pre-launch (HSPOT) predictions





Sensitivity

- SED / Nyquist range spectroscopy: Sensitivities cfr pre-launch (HSPOT) predictions
- Example: continuum RMS of rebinned spectrum in NGC6543 SED measurement in B2B



Conclusion

- PACS performing according to expectations
- Several caveats on calibration – but first analysis and interpretation is possible
- Get yourself a new Hipe installation and look at it yourself !