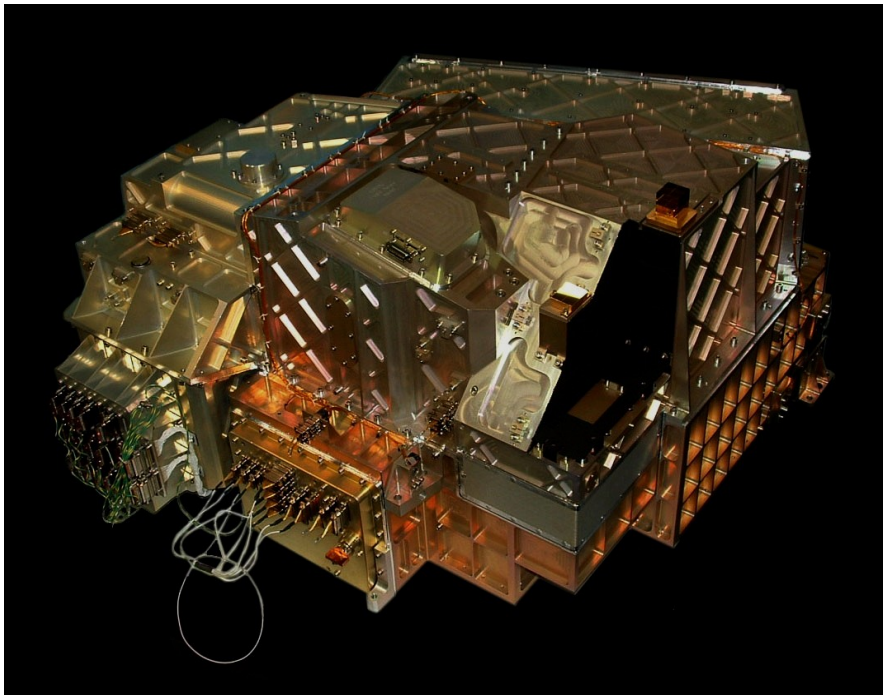
KATHOLIEKE UNIVERSITEIT LEUVEN

PACS Spectrometer data processing concept and pipeline implementation

Herschel Dataprocessing Workshop
ESAC, 26 June 2013



PACS signal to spectrum summary

- Determine pixel position on the sky at any time
- Determine wavelength seen in any pixel at any time from grating position
- Filter (bad pixels, mechanism moves, cosmic rays,...)
- Subtract telescope background
- Convert signal to Jy
  - wavelength dependent
- Wavelength grid nyquist sampling the spectral resolution
- Noise filter + rebin all data to the wavelength grid
- Interpret spectrum seen in every spaxel
  - correct for flux outside pixel for point source
  - spectral map for extended sources

Observing modes

Combination of 3 choices :

- Background measurement
  - chopped or unchopped with off position
- Spectral coverage & sampling
  - Centered on line (faint line, bright line) or broader range
  - Range only: Spectral sampling step: deep or nyquist
- Pointing
  - single staring pointing or raster

Each observing mode has its own pipeline and interactive pipeline script (ipipe) in hipe

Pixel position in the sky

- specAddInstantPointing
  - From the spacecraft pointing product, determine the reference pixel position in the sky for every frame.
- convertChopper2Angle
- specAssignRaDec
  - Calculate from reference pixel position + chopper angle + detector offsets the Ra, Dec for every pixel

Wavelength calculation

- waveCalc
  - From Grating positions + filter wheel position + detector offsets: calculate wavelength seen in every pixel in every frame
- specCorrectHerschelVelocity
  - LSR correction, using the Herschel orbit product + pointing

Filtering and slicing

- specFlagSaturationFrames
  - Flag Saturated integration ramps
- specFlagBadPixelsFrames
  - Flag bad pixels
- flagChopMoveFrames
  - Flag chopper movements
- flagGratMoveFrames
  - Flag grating movements

- Slice per range / line

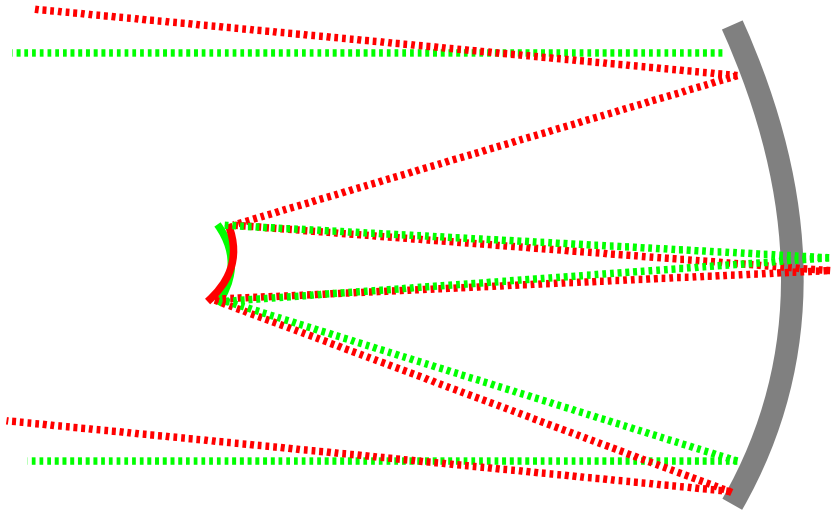
- specFlagGlitchFramesQTest
  - Flag cosmic ray glitches

Background determination

- The warm telescope emits ~200Jy backgrond per spectrometer pixel
- We need to measure this to subtract it from the source
- Chopped
  - switching beam on / off during spectral scan
  - On/off beam switching at 2 pointings (nod A/B)
- Unchopped:
  - repetition of the same scan at an off position

Chopping/Nodding

- Primary mirror 'used' at two chopping mirror positions is different
- Hence telescope background is different (~tens of Jy)
- Average on-off in two telescope nod positions cancels difference in background at two chop positions



Chop/Nod combination

$N_{Aon} = (E_O + E_S + E_{T+})$

$N_{Aoff} = (E_S + E_{T-})$

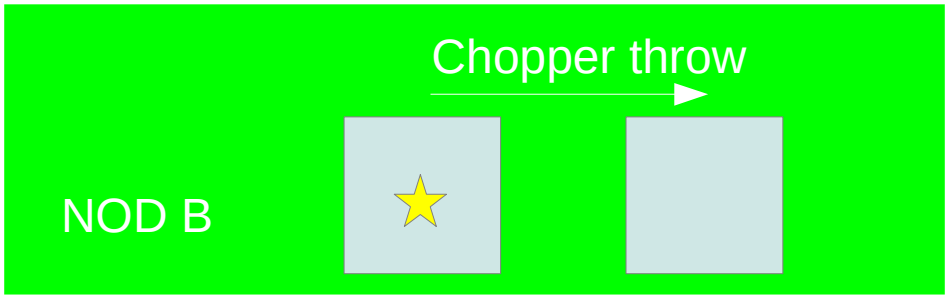
$N_{Bon} = (E_O + E_S + E_{T-})$

$N_{Boff} = (E_S + E_{T+})$

$(N_{Aon} - N_{Aoff}) + (N_{Bon} - N_{Boff})$

$= (E_O + E_S + E_{T+} - E_S - E_{T-}) +$
$(E_O + E_S + E_{T-} - E_S - E_{T+})$

$= (E_O + E_{T+} - E_{T-}) +$
$(E_O + E_{T-} - E_{T+}) = 2E_O$



E_O: Flux density object

E_S : Flux density sky

E_{T+} : Flux density telescope mirror part seen at chopper +

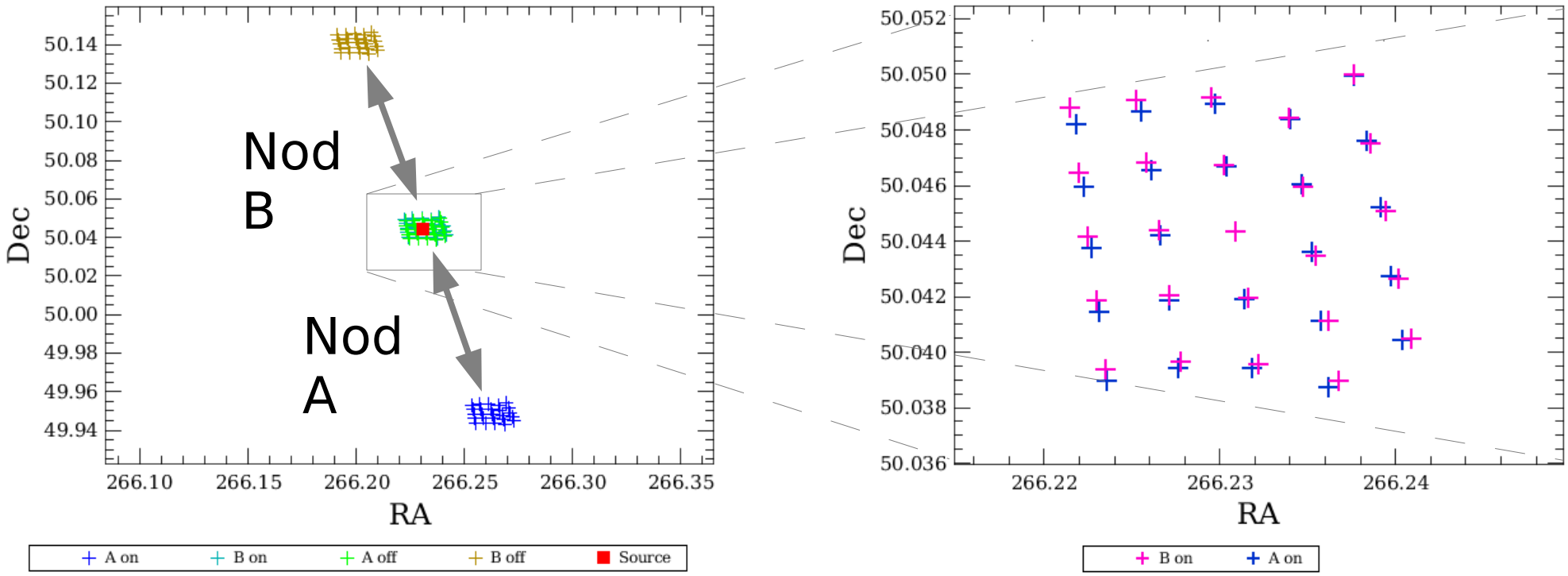
E_{T-} : Flux density telescope mi part seen at chopper -

Background subtraction chopped observations

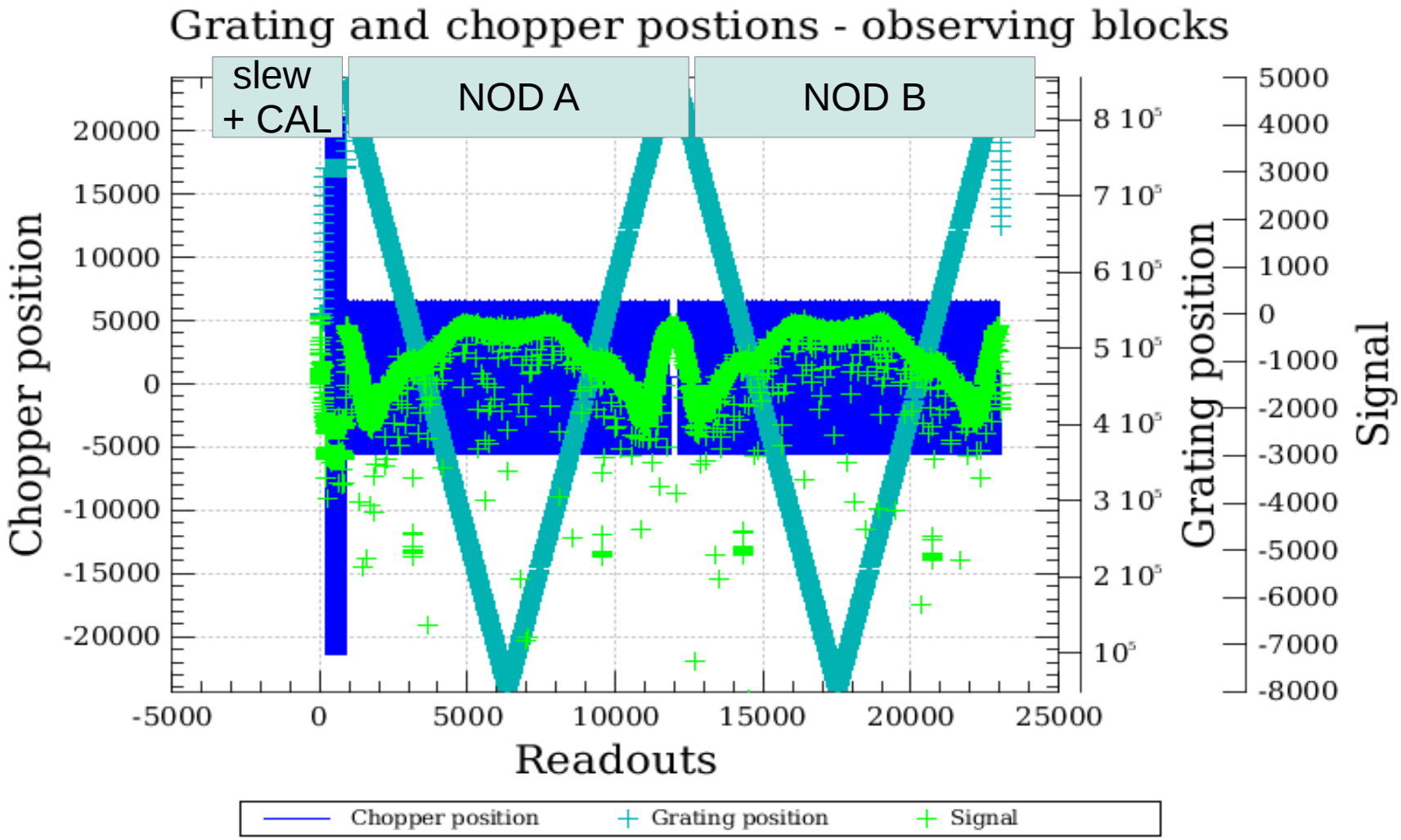
- SpecDiffChop
  - $(N_{Aon} - N_{Aoff})$ and $(N_{Bon} - N_{Boff})$
- AddNodCubes
  - at the end, when we have the spectra of the two nod positions rebinned to the same wavelength grid
  - $[(N_{Aon} - N_{Aoff}) + (N_{Bon} - N_{Boff})] / 2$

Chopping at two nod positions

- Especially at large (6') chopping angle, the positions seen by the spaxels is not identical

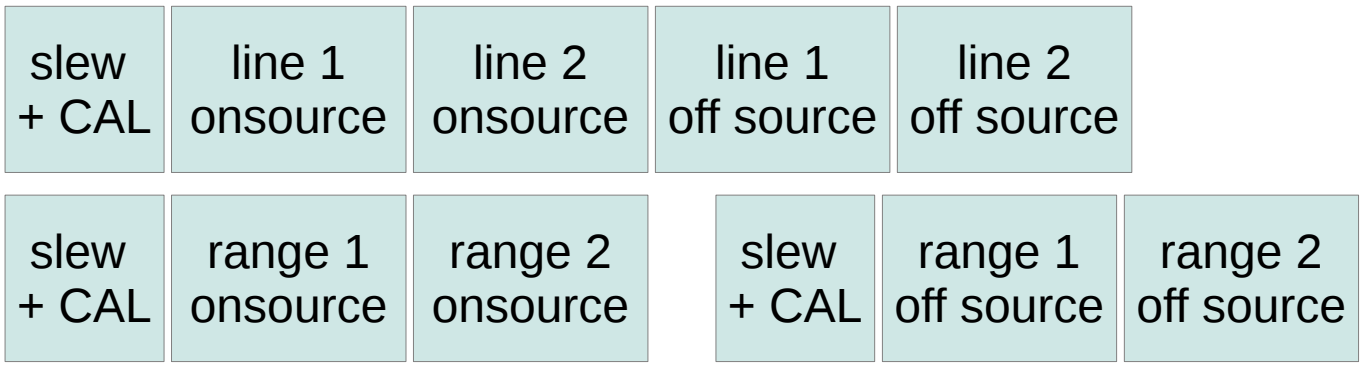


Chopped line scan observation



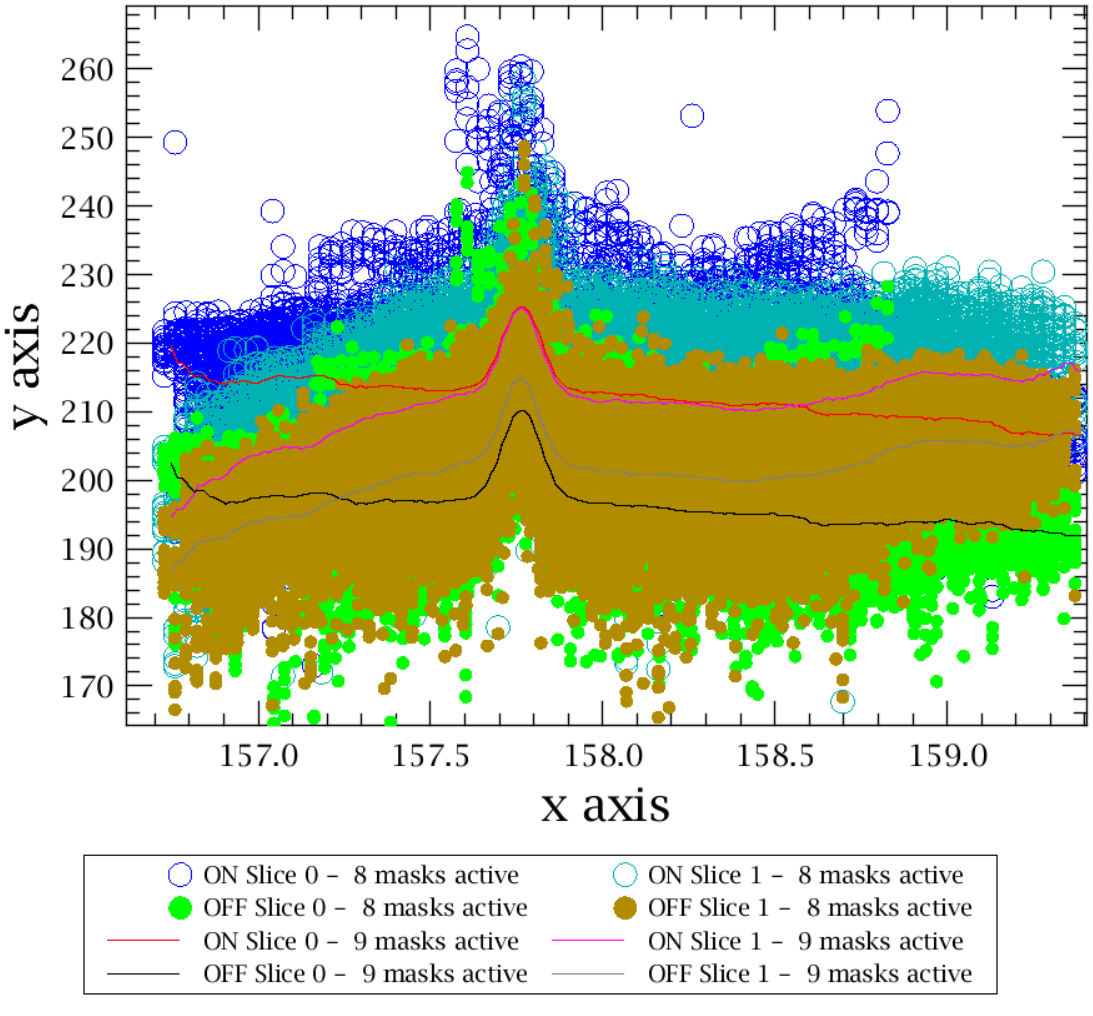
Unchopped

- Background measured with a repetition of the same scan at blank sky position
  - Line scan: part of the AOR
  - Range scan: separate AOR
- Full power (continuum) less accurate (~20 Jy) than chopped measurements
- Reduce spectrum on, reduce spectrum off, then subtract



Sky background contamination

- Beware of possible contamination background spectrum
- Dedicated ipipe script: split on/off



Flux conversion (calblock + RSRF)

- specDiffCs
  - Differential signal between the 2 calibration sources
  - From calibration files: signal – flux density scaling
- rsrfCal
  - Divide by the wavelength dependent relative spectral response function (calibration files)
- respCal
  - Apply signal-flux density scaling

Flux conversion – telescope normalisation

- specDiffChop(normalize=True)
  - Calculates norm/(1-norm/2)
  - See also Calibration Document
- specAddNodCubes
  - Average normalised cubes in nod A and B
- specRespCalToTelescope
  - Multiplies with telescope spectrum (calfile)

Spectral coverage

- Faint line

Centered on line, every pixel samples line + continuum

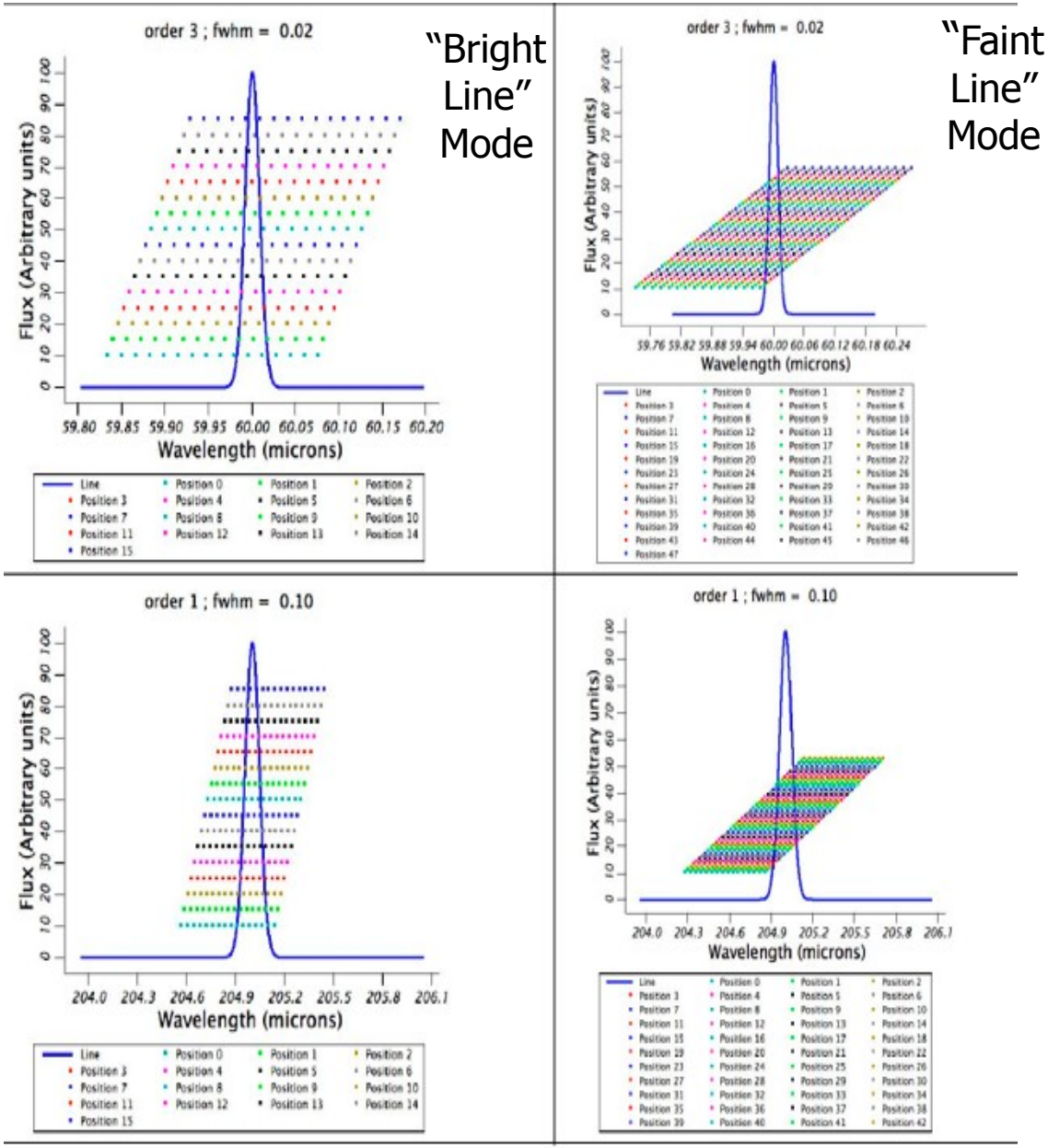
- Bright line

Centered on line, a single pixel samples only part of the line or continuum

- Range

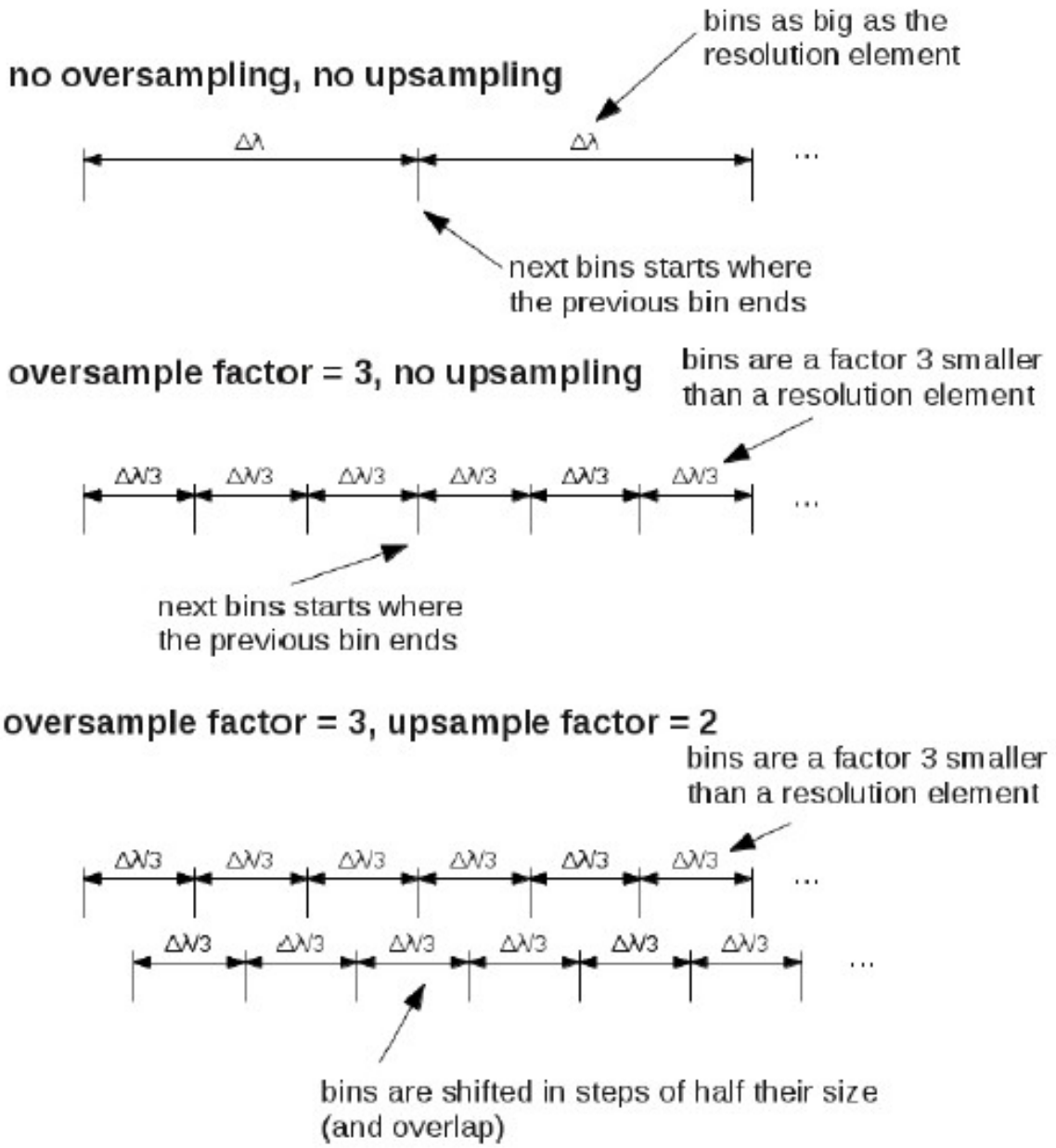
Several lines, features or full SED

The coverage is lower at the range edges, hence noise is higher !



Spectral rebinning & noise filter per bin

- Construct wavelength grid
  - At least nyquist sampling the spectral PACS resolution
  - Upsample
  - Oversample = 2
- Sigma clipping : mask points sigma*stddev away from mean in each bin
- Average all (unmasked) samples in the bin



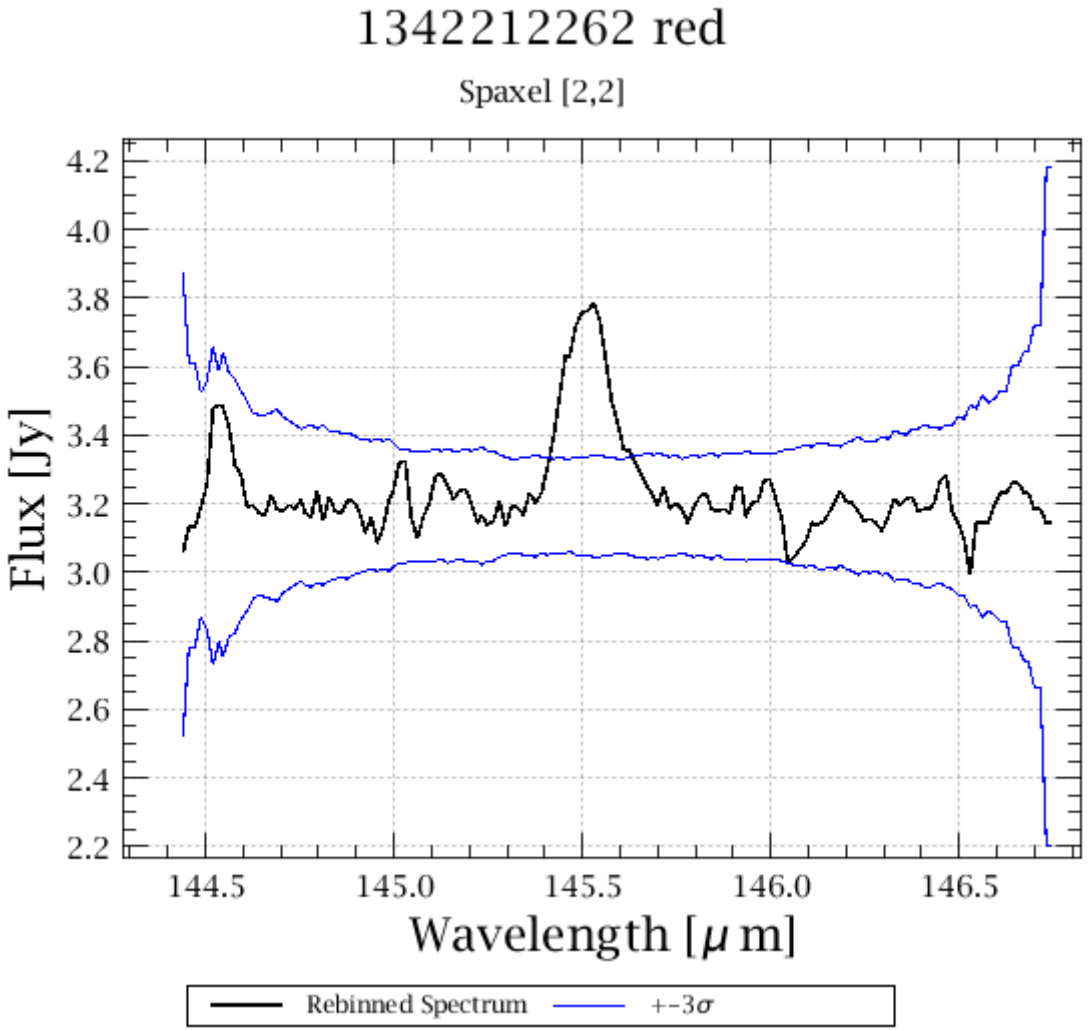
Wavelength grid, sigmaclip and rebin

- wavelengthGrid
- specFlagOutliers
- specWaveRebin

Assessing the S/N in your spectrum

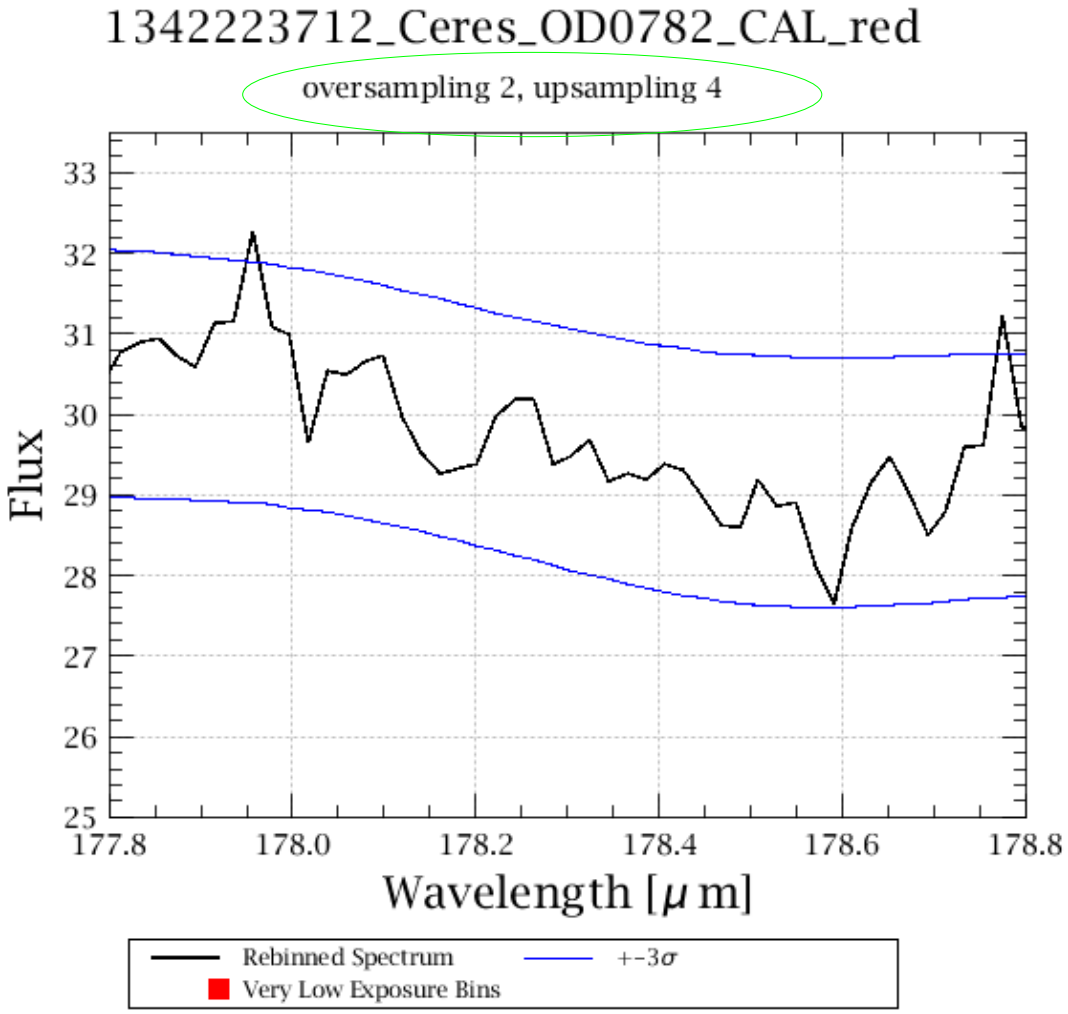
plotCubesStddev

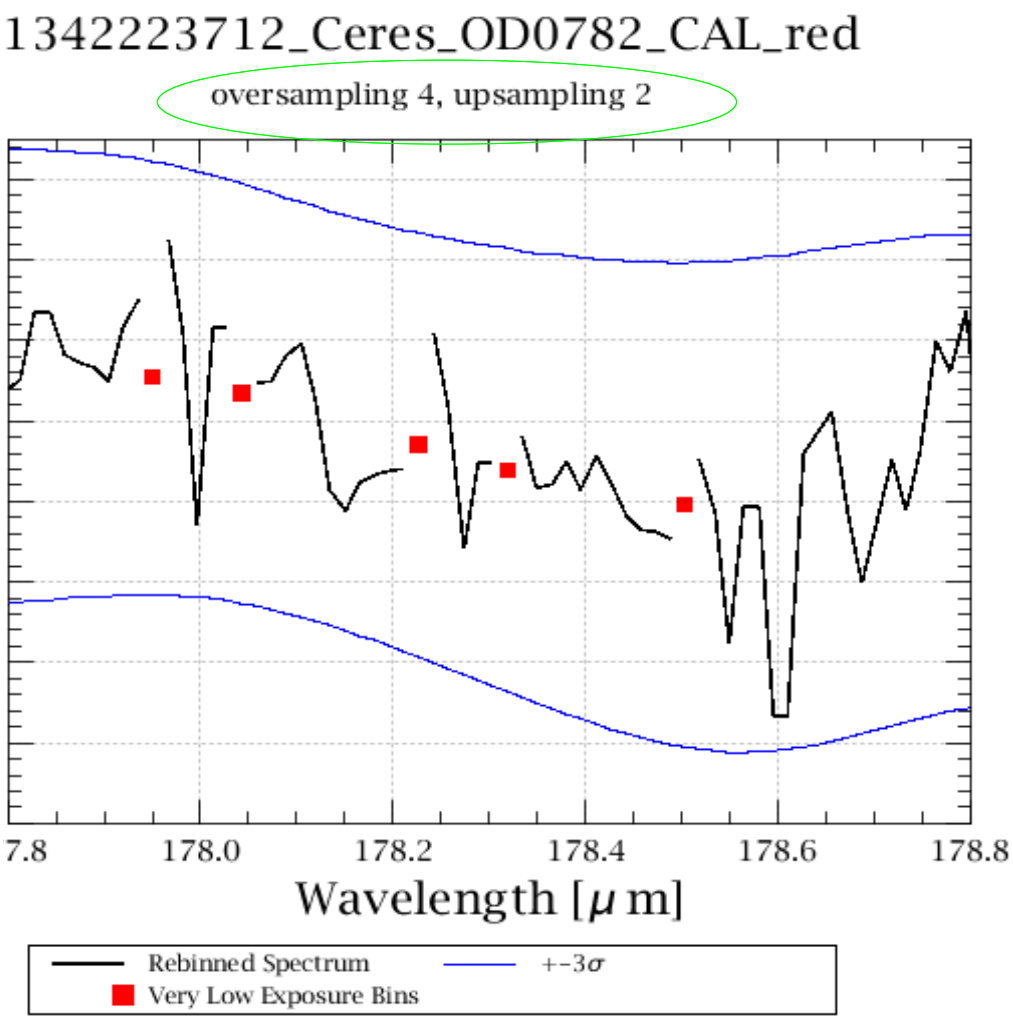
- Line detection
- Straight continuum fit
- Plot continuum +/- stddev



Beware of undersampling

In Nyquist range scans, don't use aggressive oversample. plotCubesStddev marks the bins with low / no exposure



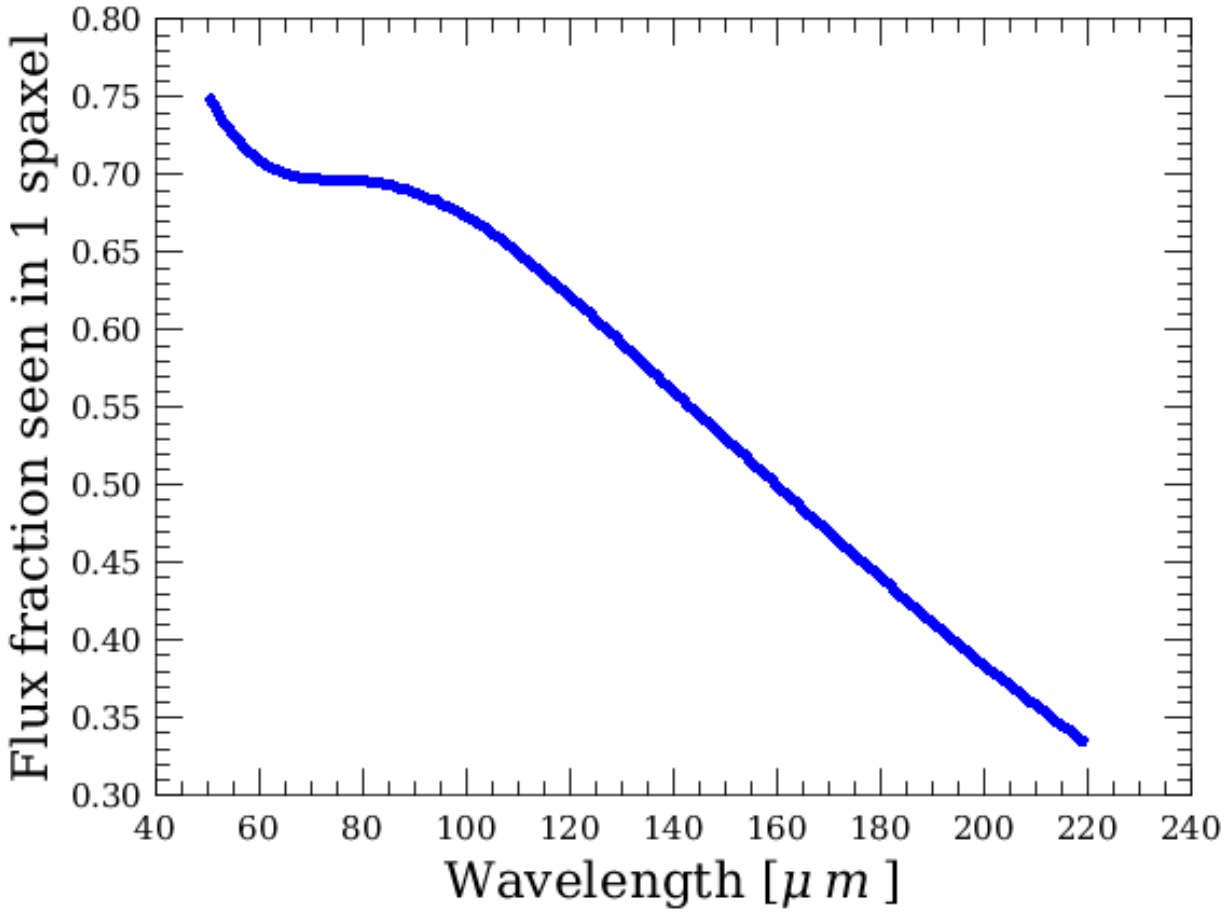


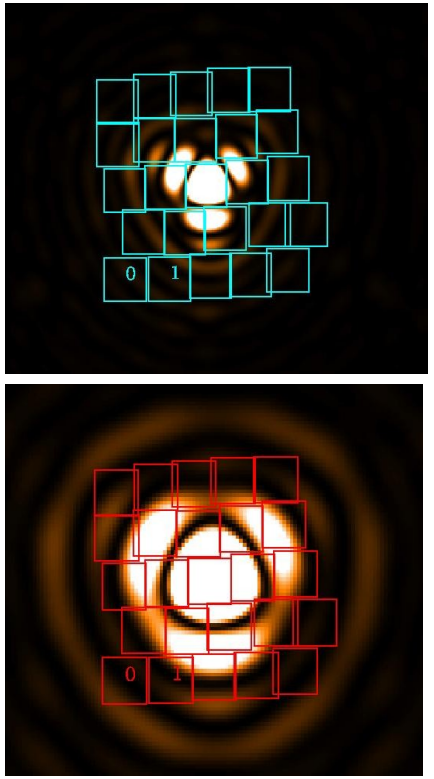
Using the 5x5 spectra – extended sources

- Raster observations: project the cube
  - See mapping presentation / demo
- Pointed observations extended source
  - Interpretation knowing beam size (PACS CAL web)

Point sources

- extractCentralSpectrum
  - Choice to use central spaxel or central 3x3 spaxels
  - Apply point source correction for part of the beam outside
  - 3x3 more robust against pointing errors





Summary

- See ipipe scripts + demos
- See Pacs Data Reduction Guide