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PACS Spectrometer Calibration overview

Herschel Calibration Workshop
26-March-2013

Bart Vandenbussche on behalf of
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Overview

- Wavelength calibration
- Ghost characterisation
- Beam characterisation
- Absolute flux calibration
    - See Pierre Royer's talk
- RSRF calibration / broadband features
    - Red leak line flux
    - Pointing jitter flux modulation

- Pointing reconstruction
    - See Helmut Feuchtgruber's talk

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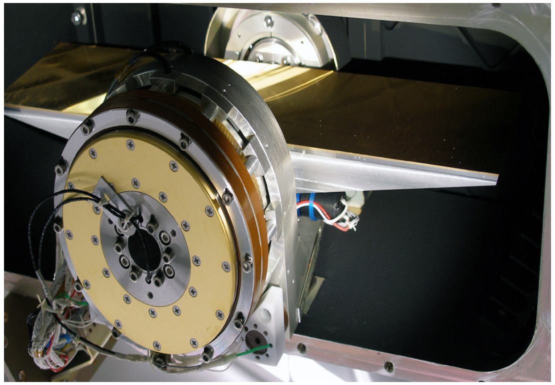
The PACS spectrometer in a nutshell

- Image slicer : 5x5 9.4” spaxels on the sky
- Reimaged onto a 1d-slit
- Slit image fed to a dispersion grating
- Dispersed spectral orders fed to 1 red and 1 blue detector arrays: 25 x 16
- (25 spatial x 16 instant spectral)
- Rotating the grating: step through the spectrum



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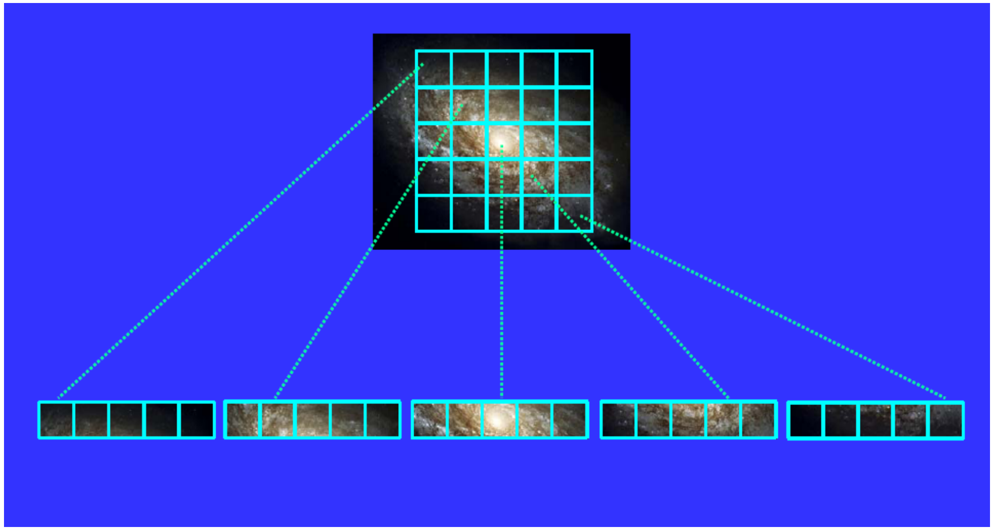
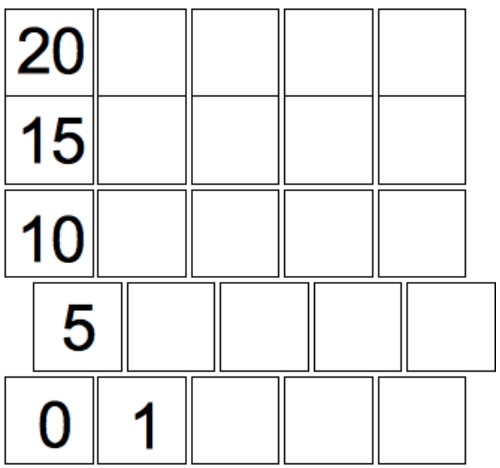
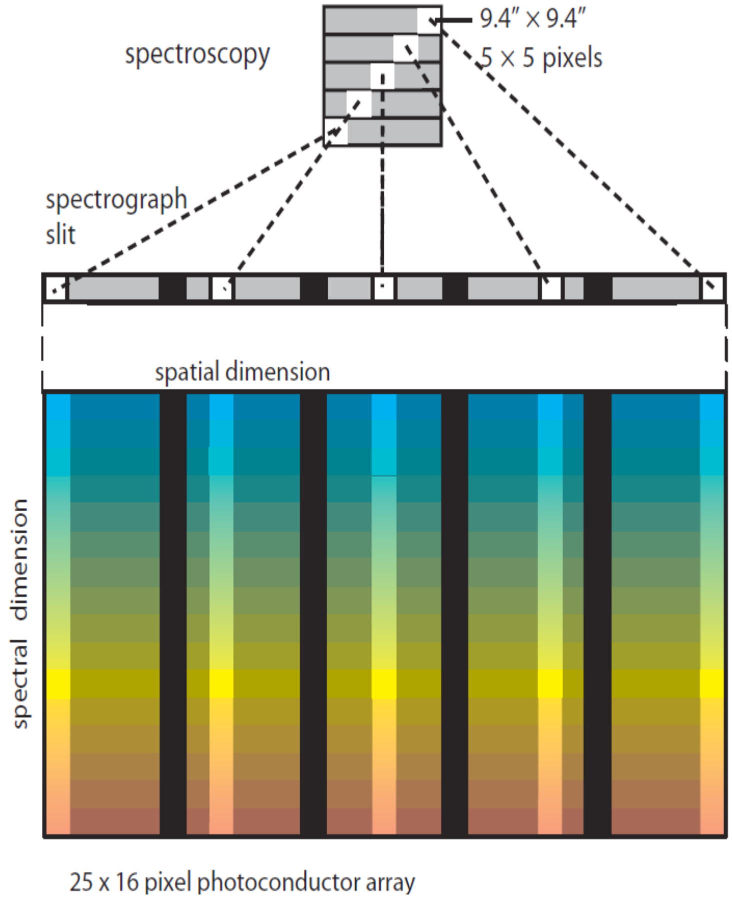
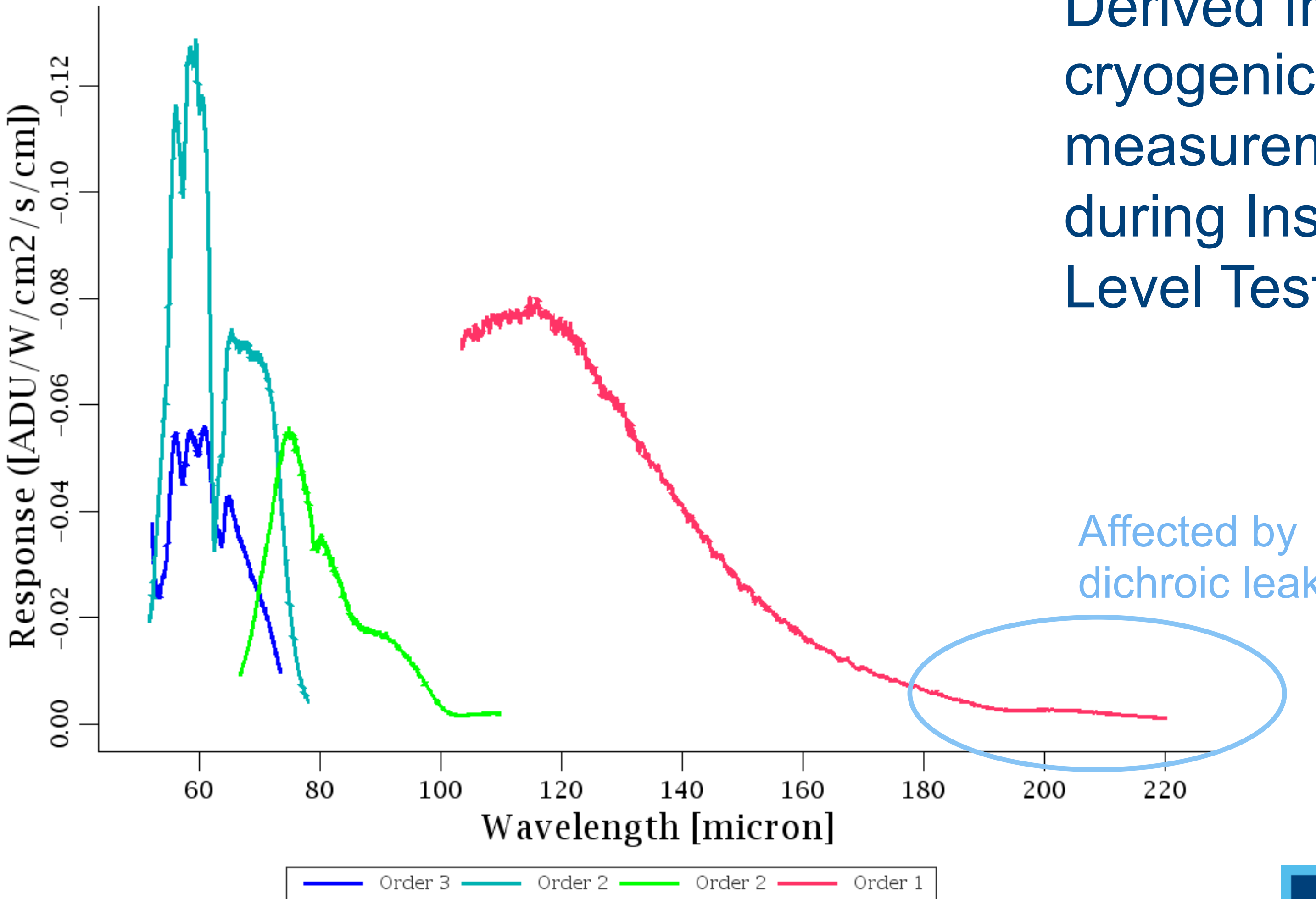
The PACS spectrometer in a nutshell







Relative Spectral response



Derived from cryogenic blackbody measurements during Instrument Level Tests

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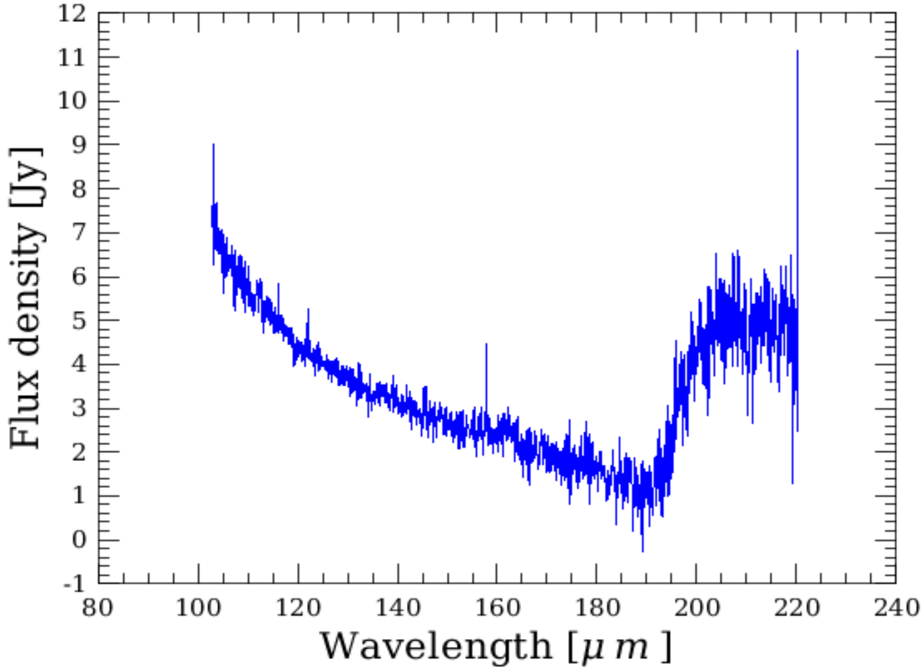
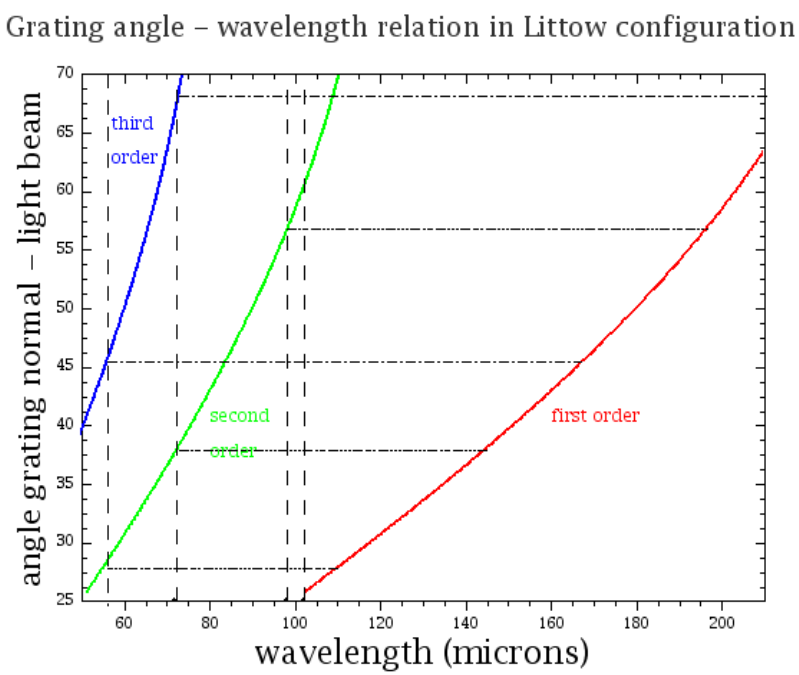
Order 2 leak

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





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From the spectra of 2 blackbodies we can disentangle leak response

$$S_{\lambda,T1} = B_{\lambda,T1}.R1_{\lambda} + B_{\lambda/2,T1}.R2_{\lambda/2}$$

$$S_{\lambda,T2} = B_{\lambda,T2}.R1_{\lambda} + B_{\lambda/2,T2}.R2_{\lambda/2}$$

$$R1_{\lambda}.B_{\lambda,T1} = S_{\lambda,T1} - B_{\lambda/2,T1}.R2_{\lambda/2}$$

$$R2_{\lambda/2} = \frac{S_{\lambda,T2} - B_{\lambda,T2}.R1_{\lambda}}{B_{\lambda/2,T2}}$$

$$R1_{\lambda}.B_{\lambda,T1} = S_{\lambda,T1} - B_{\lambda/2,T1}.\frac{S_{\lambda,T2} - B_{\lambda,T2}.R1_{\lambda}}{B_{\lambda/2,T2}}$$

$$R1_{\lambda}.B_{\lambda,T1}.B_{\lambda/2,T2} = S_{\lambda,T1}.B_{\lambda/2,T2} - B_{\lambda/2,T1}.S_{\lambda,T2} + B_{\lambda/2,T1}.B_{\lambda,T2}.R1_{\lambda}$$

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From the spectra of 2 blackbodies we can disentangle leak response (ctd)

$$R1_{\lambda}.[B_{\lambda,T1}.B_{\lambda/2,T2} - B_{\lambda/2,T1}.B_{\lambda,T2}] = S_{\lambda,T1}.B_{\lambda/2,T2} - B_{\lambda/2,T1}.S_{\lambda,T2}$$

$$\boxed{R1_{\lambda} = \frac{S_{\lambda,T1}.B_{\lambda/2,T2} - B_{\lambda/2,T1}.S_{\lambda,T2}}{B_{\lambda,T1}.B_{\lambda/2,T2} - B_{\lambda/2,T1}.B_{\lambda,T2}}}$$

$$R2_{\lambda/2}.B_{\lambda/2,T2} = S_{\lambda,T2} - B_{\lambda,T2}.R1_{\lambda}$$

$$R2_{\lambda/2}.B_{\lambda/2,T2} = S_{\lambda,T2} - B_{\lambda,T2}.\frac{S_{\lambda,T1} - B_{\lambda/2,T1}.R2_{\lambda/2}}{B_{\lambda,T1}}$$

$$R2_{\lambda/2}.B_{\lambda/2,T2}.B_{\lambda,T1} = S_{\lambda,T2}.B_{\lambda,T1} - B_{\lambda,T2}.S_{\lambda,T1} + B_{\lambda,T2}.B_{\lambda/2,T1}.R2_{\lambda/2}$$

$$R2_{\lambda/2}.[B_{\lambda/2,T2}.B_{\lambda,T1} - B_{\lambda,T2}.B_{\lambda/2,T1}] = S_{\lambda,T2}.B_{\lambda,T1} - B_{\lambda,T2}.S_{\lambda,T1}$$

$$\boxed{R2_{\lambda/2} = \frac{S_{\lambda,T2}.B_{\lambda,T1} - B_{\lambda,T2}.S_{\lambda,T1}}{B_{\lambda/2,T2}.B_{\lambda,T1} - B_{\lambda,T2}.B_{\lambda/2,T1}}}$$

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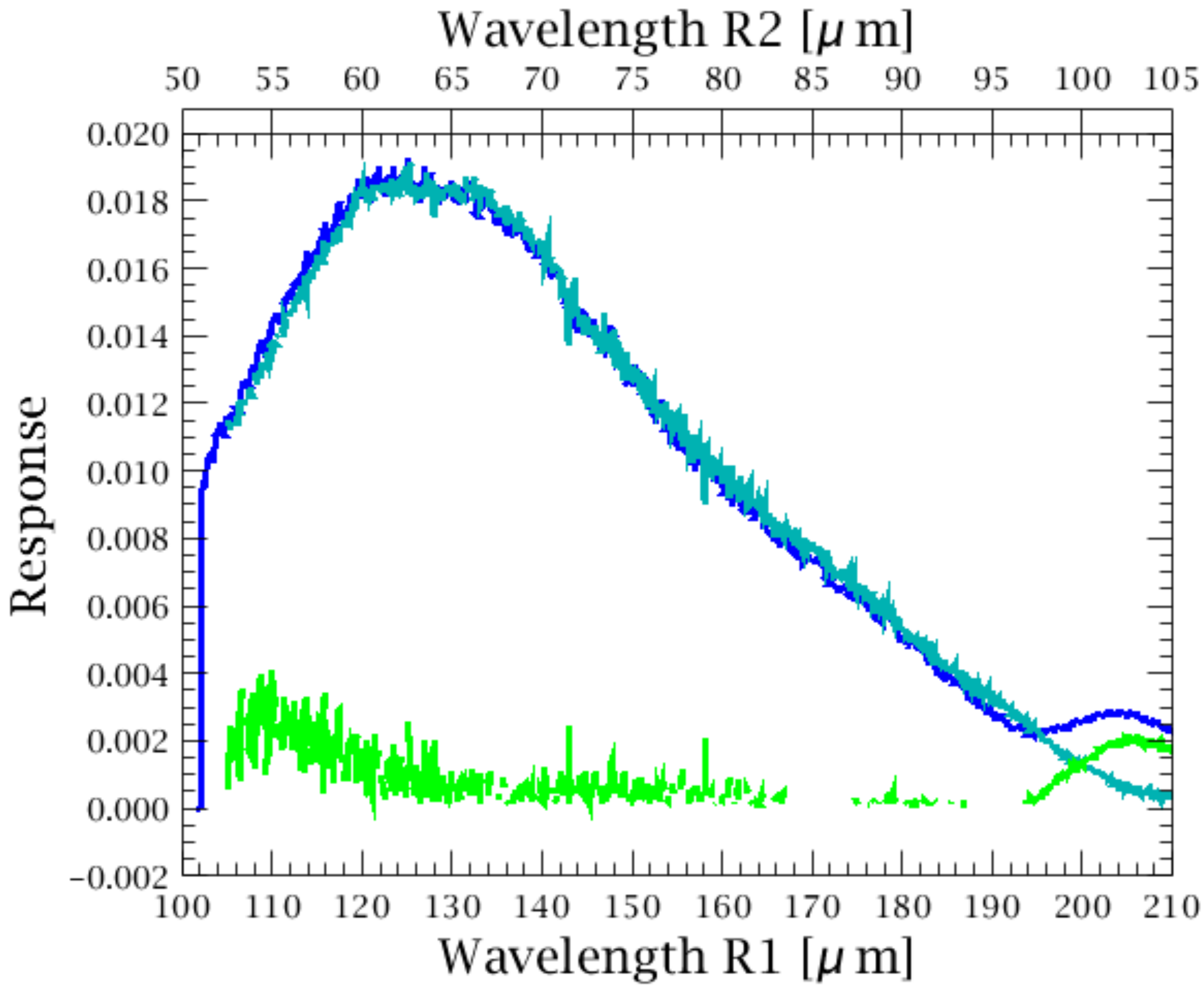
RSRF order 1 + leak order 2 disentangled



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RSRF version 4

- Deep ILT RSRF measurement measured on 1 BB temperature only
- Different Blackbody scans only in SED mode
- Keep global shape of low res RSRF LR (leak corrected)
- Keep details of full res ILT RSRF HR
- Wavelet decomposition of RSRFs, 12 levels
- Smoothed RSRF = residual + 5 slowest levels
- RSRF = HR * smooth(LR/HR)   (<150 um d(smooth)~0)

- RSRF v4 currently under test – should recover line fluxes >180um -- see presentation Elena Puga

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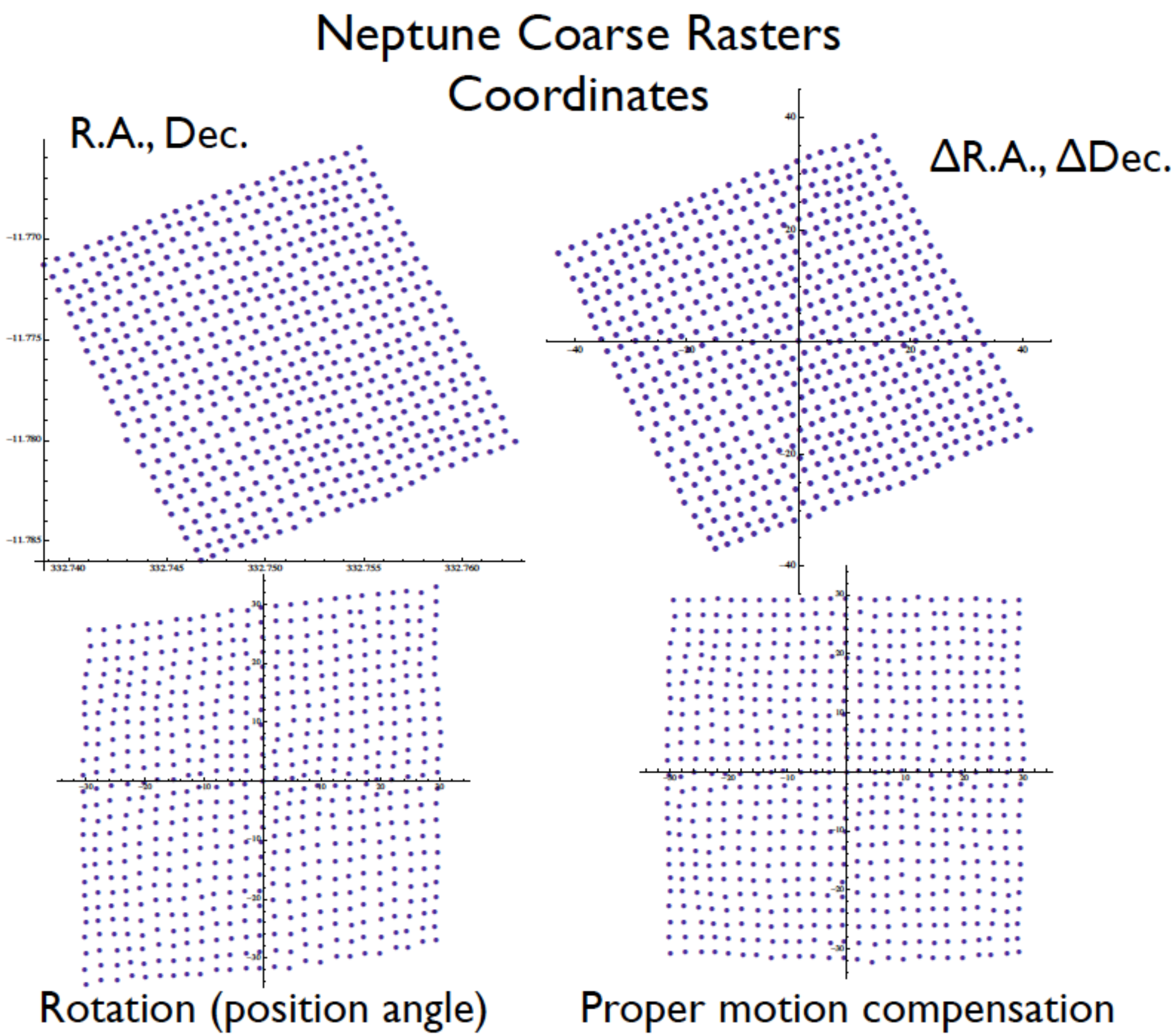
Beam characterisation

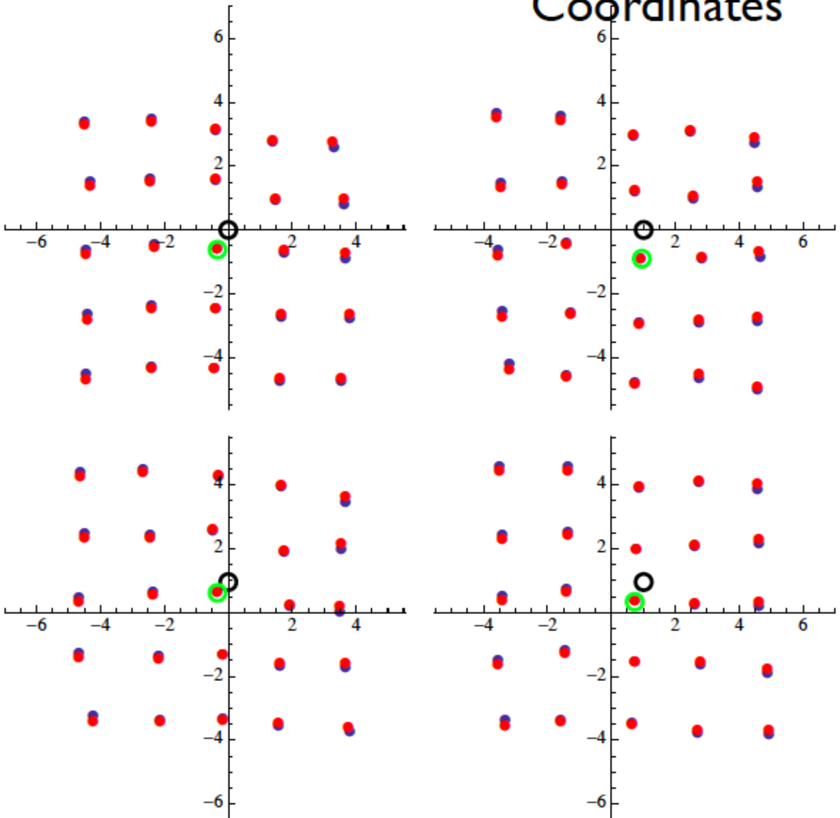
- Neptune Rasters, coarse & fine
  - Coarse rasters: 25x25x2.5” OD 174 - 751
  - Fine rasters: 4x[5x5x2”] OD 1311/1312
- Pointing reconstruction Helmut
  - STR subpixel distortion correction
  - Gyro filter
- Mean-averaged signals after masking unstable data
- Normalized fluxes, correction for assymetric chopping

Raster position reconstruction

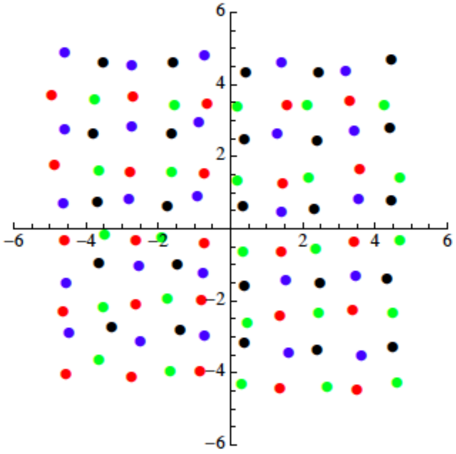


Combining 4 fine rasters

Neptune Fine Rasters Coordinates



4 5x5x2.5" rasters, offset by 1", proper motion compensated



Combined raster positions (in spacecraft coordinates)

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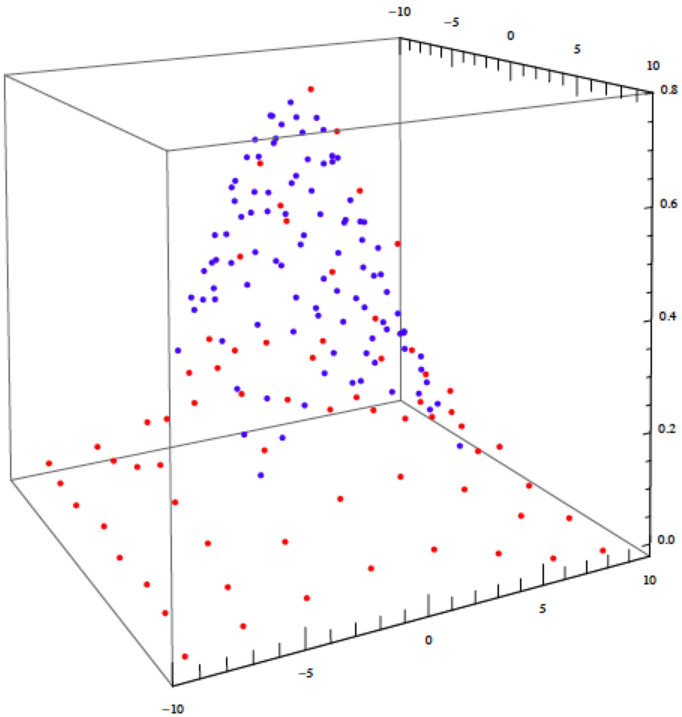
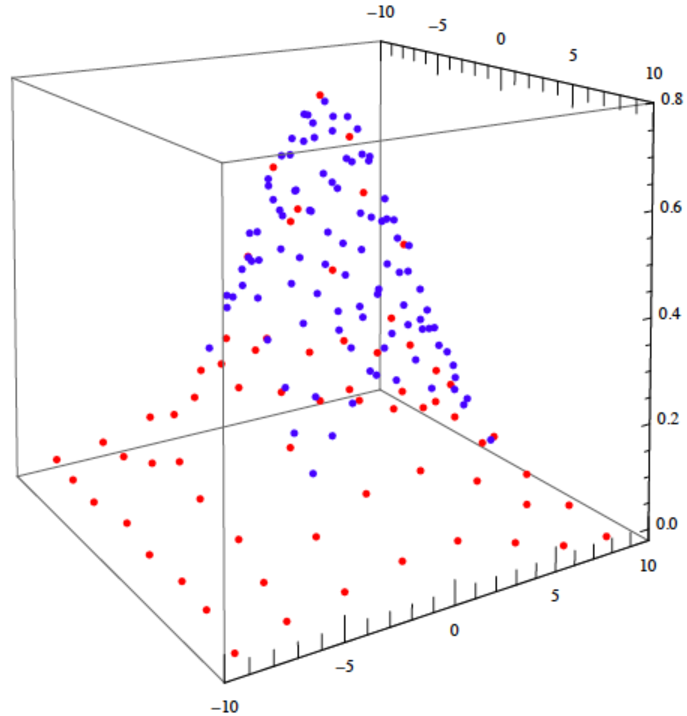
Combining coarse and fine rasters

Measured fluxes in coarse (red) and fine (blue) Neptune rasters @ 94μm



Plotted without any correction



Coordinates and gain corrected (least-square) by (0.8", 0.7", 1.02)

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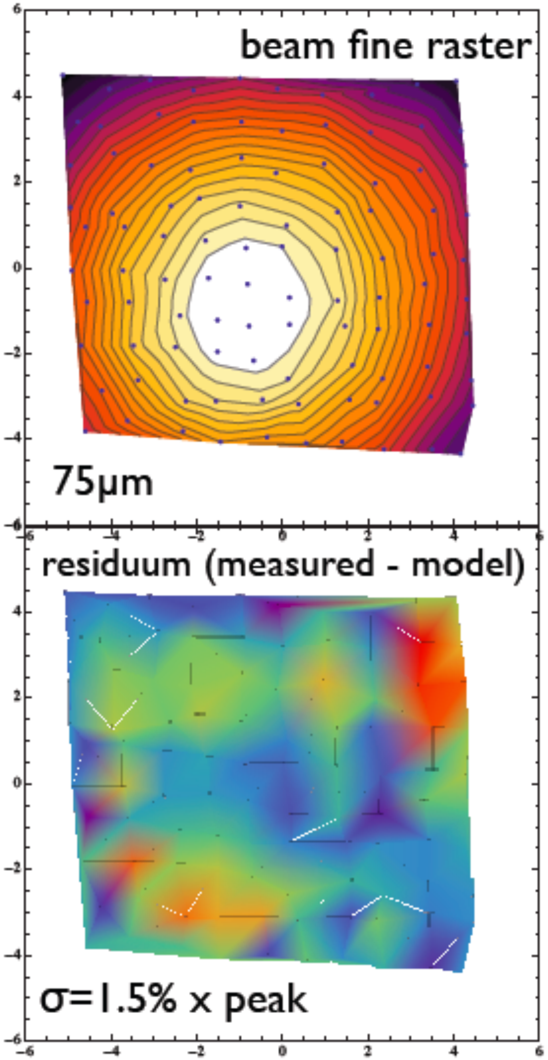
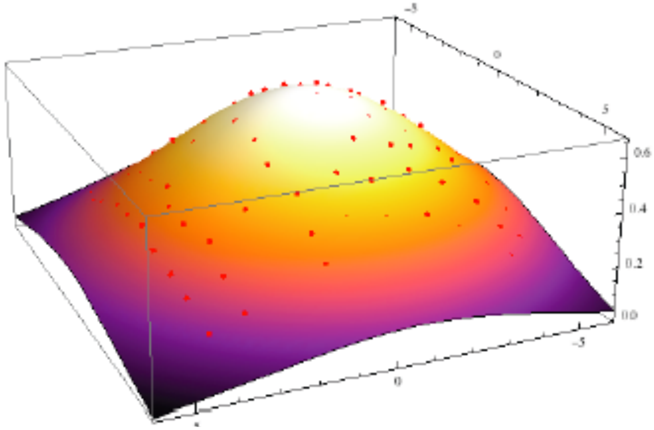
Equidistantly sampled beams delivered to the users





- Equidistant sampling on the sky 0.5”
- Central part: gaussian model
  - Difference gaussian approximation – measurements <80um: 1.5-2%
- Outer part: interpolated values

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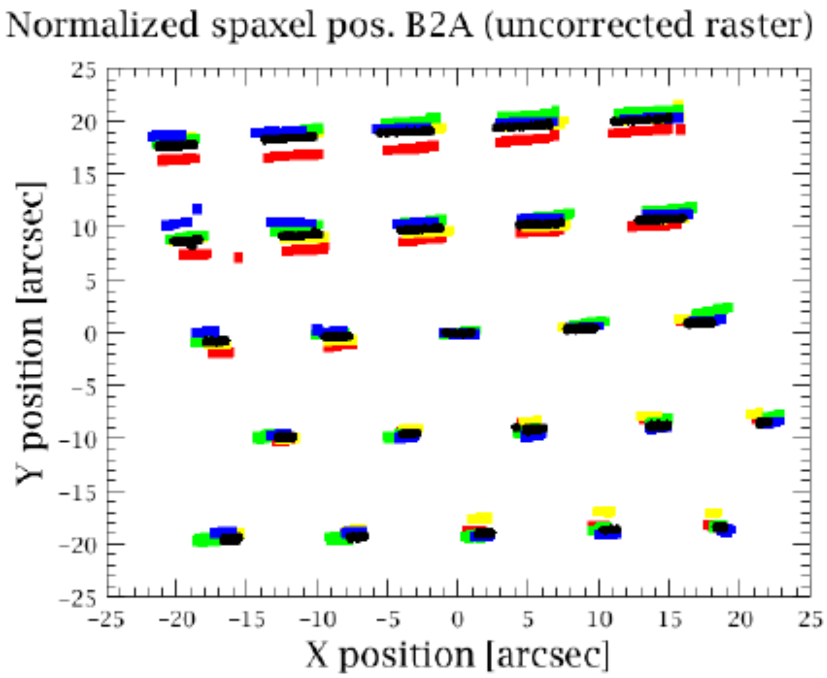
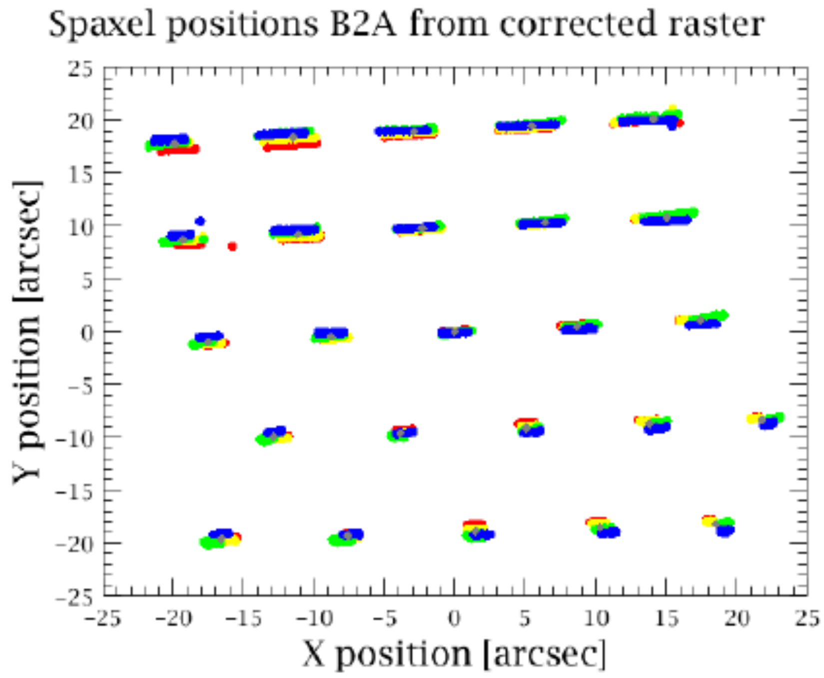
Fitting / correcting pointing offset from distribution flux over IFU

- Refinement of spectrometer beams using ACMS telemetry reconstruction Helmut:





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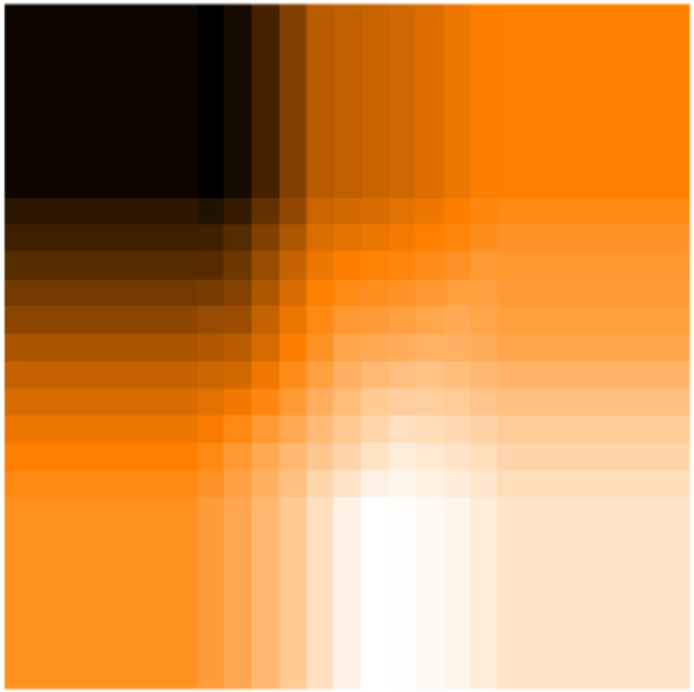
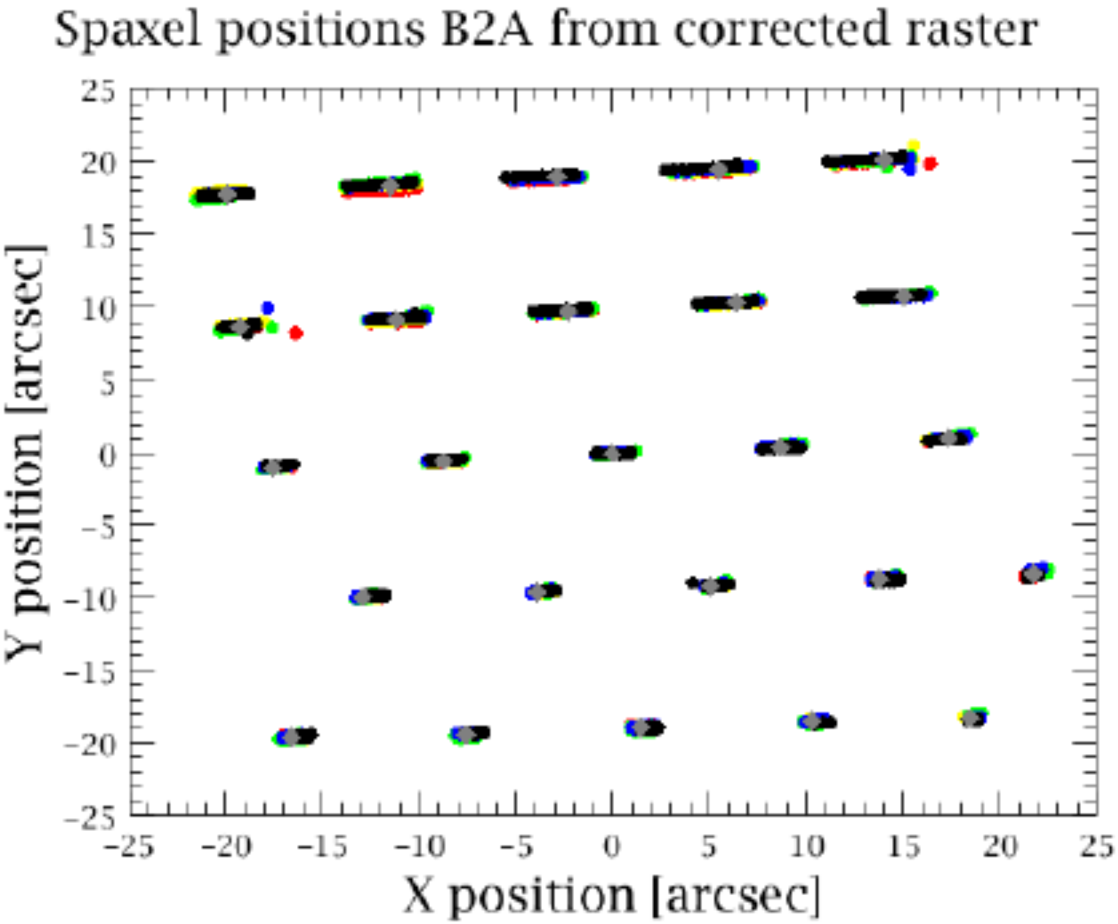
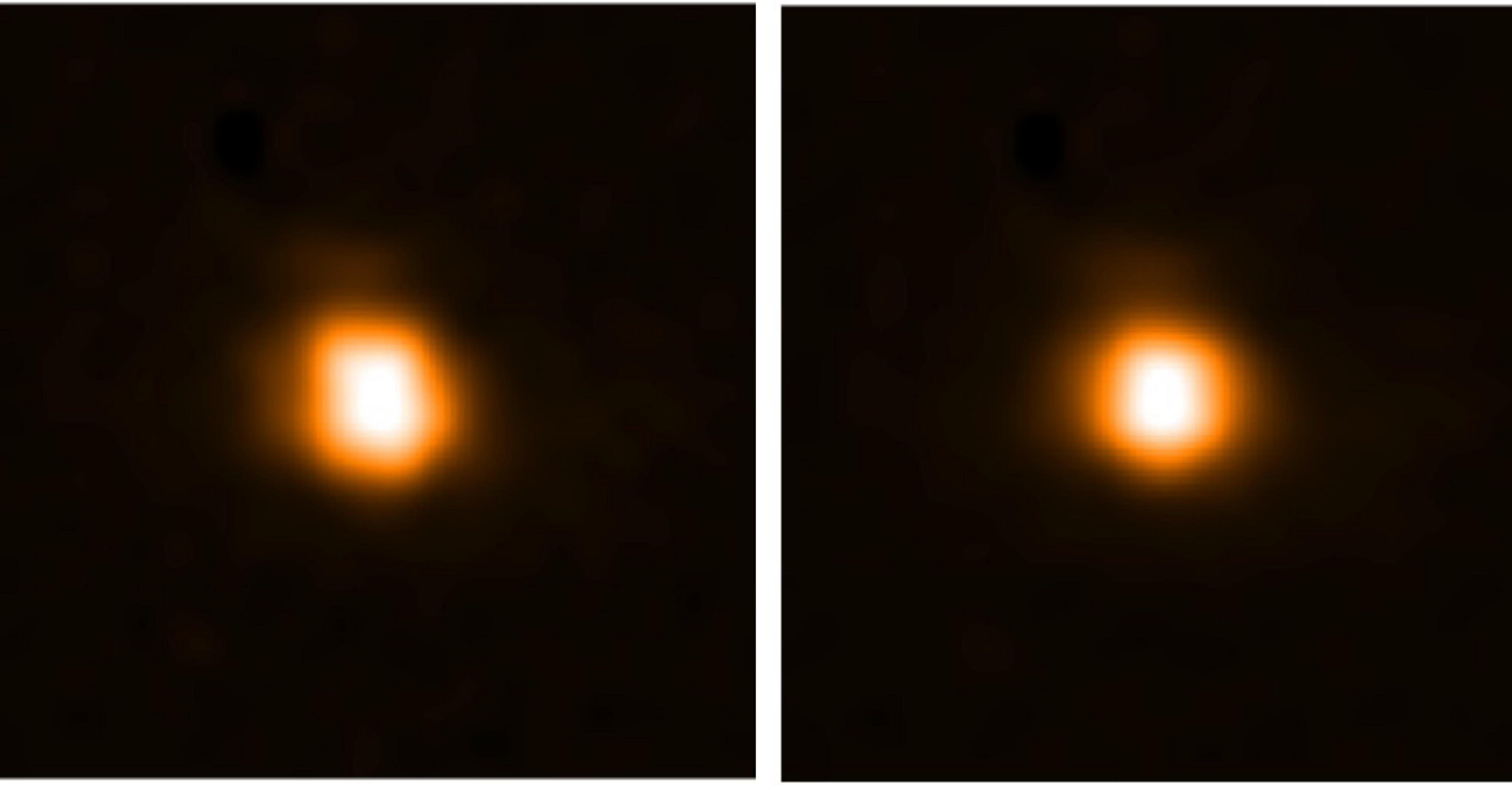
Further refinement: match mean position pixels measured on ground





Additional shift (<0.2”) throughout raster brings mean position detectors to ground measurements.

Beam before / after pointing correction



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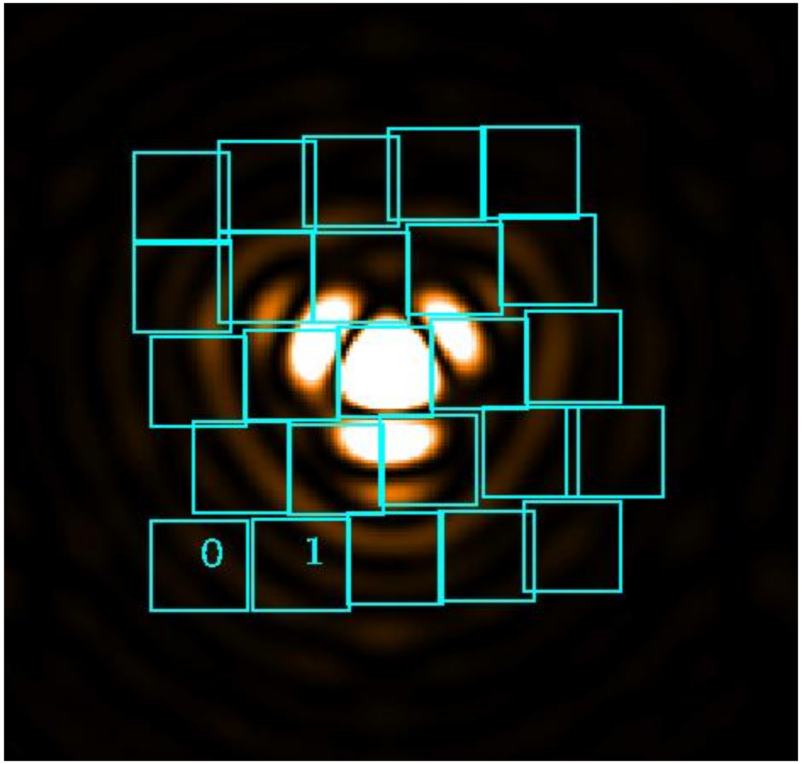
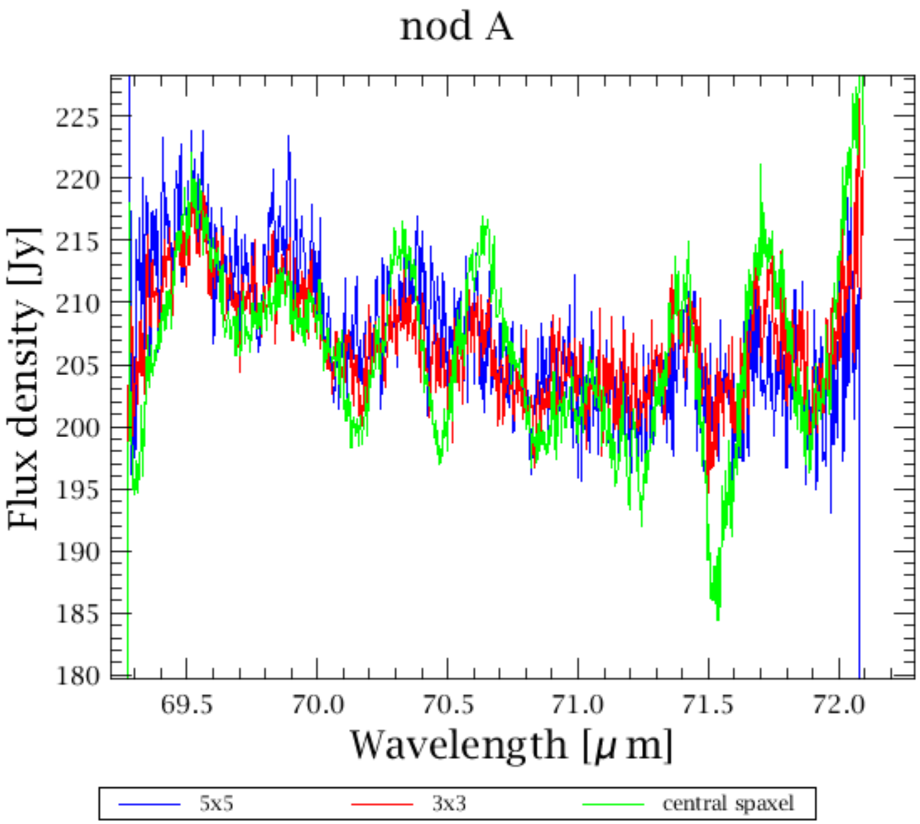
Flux losses due to pointing offsets and jitter





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Dealing with flux losses due to pointing

- Hipe 10: use sum of central 3x3 for absolute reference
  - see talk Pierre
- Bright sources (~100 Jy)
  - Determine pointing jitter from signal distribution in IFU
  - Calculate correction for pointing offsets from beams
- Fainter sources
  - Determine pointing + jitter from ACMS [Helmut method]
  - Calculate correction for pointing offsets from beams

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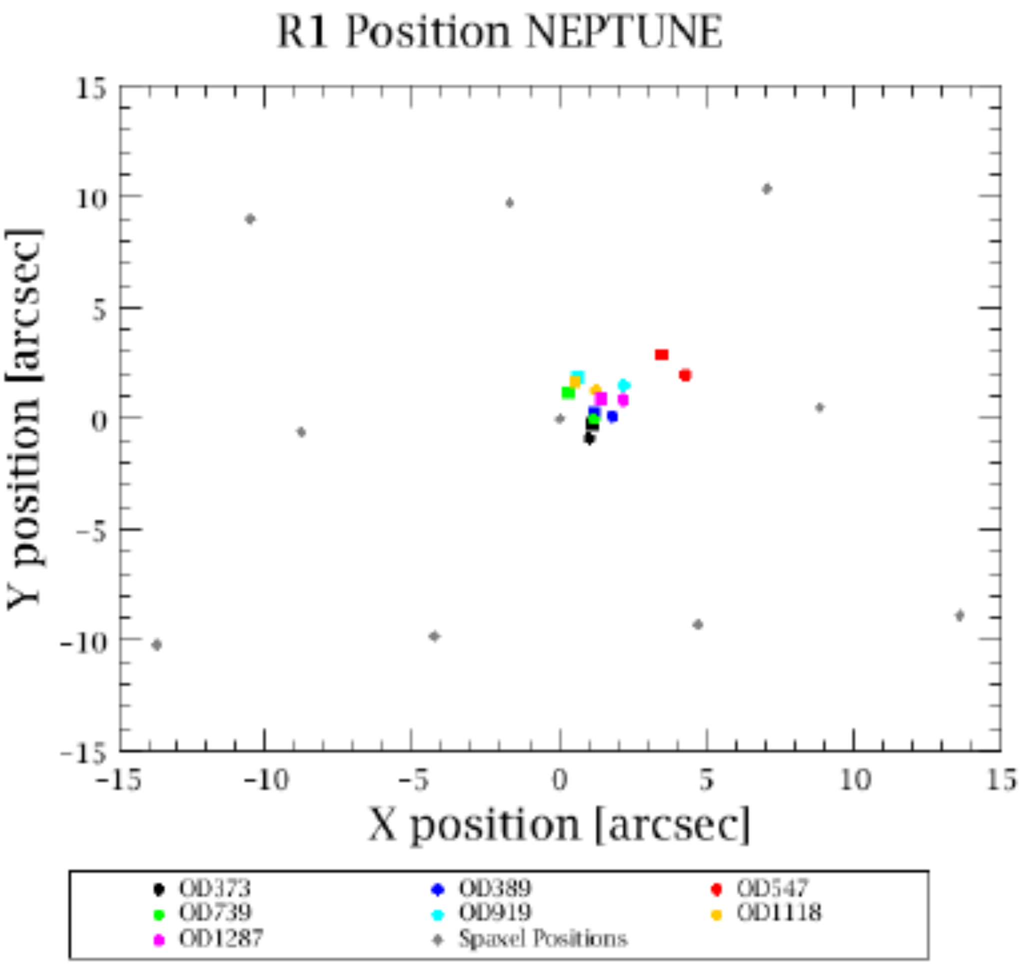
Pointing reconstruction of 7 Neptune SED scans from flux distribution IFU



New corrected beams
Telescope normalisation

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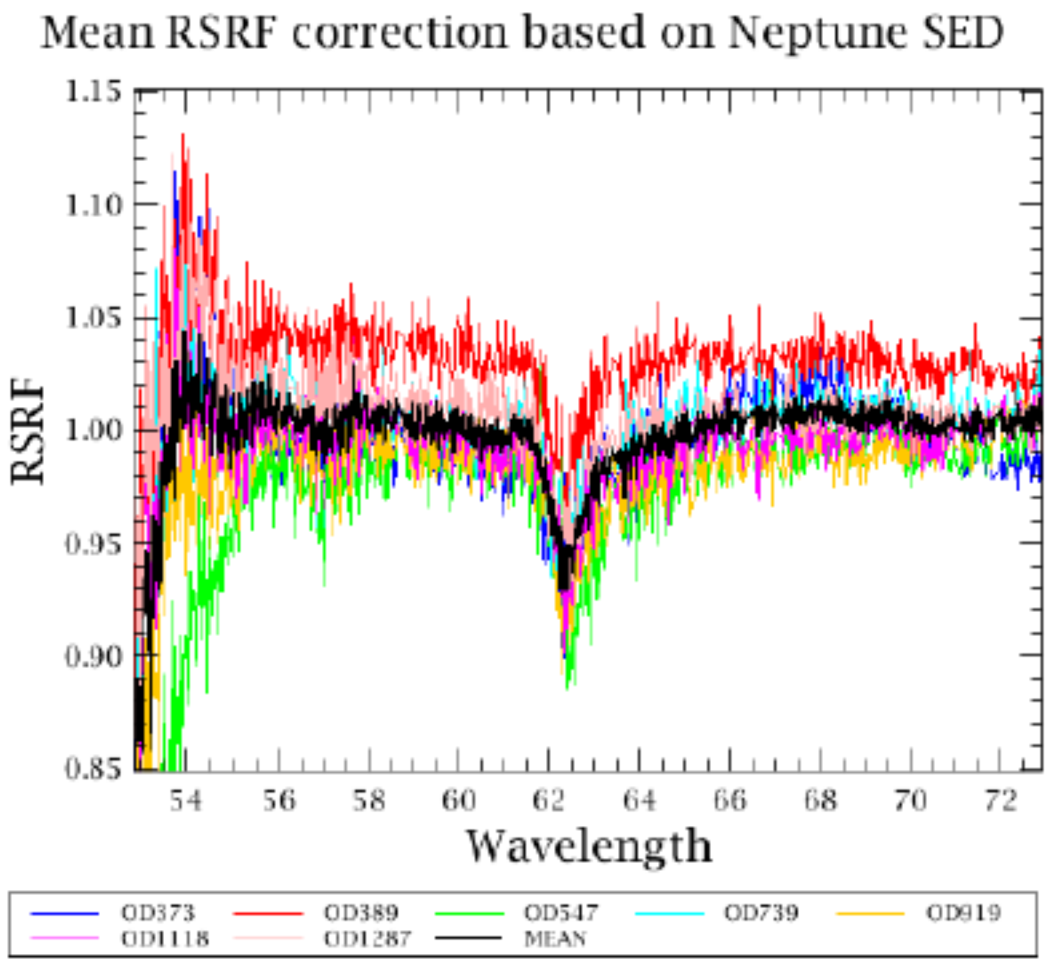
Residus RSRF / telescope background model after pointing flux loss correction



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Preview – PACS solid state spectroscopy of protoplanetary disk

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