Spectrometer Wavelength Calibration

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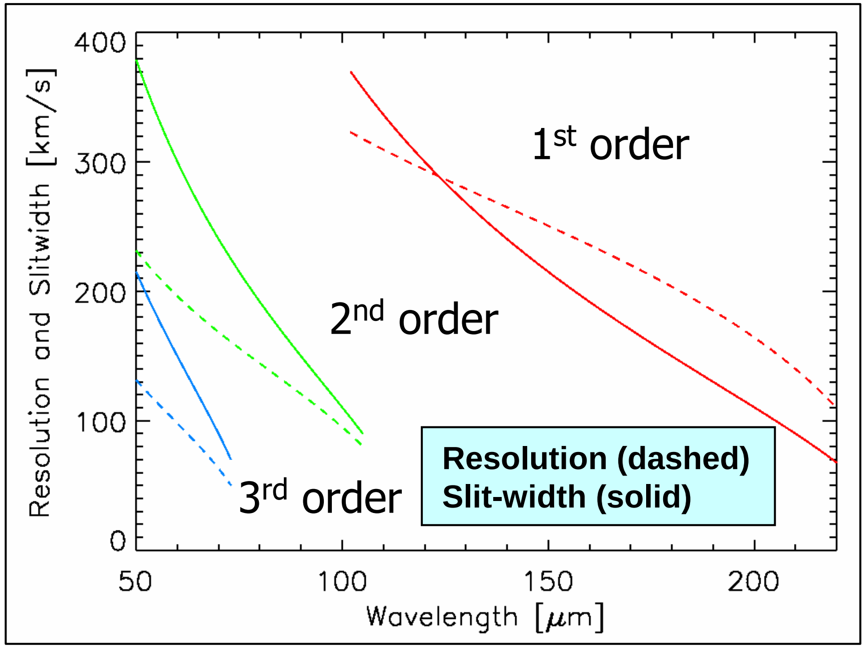
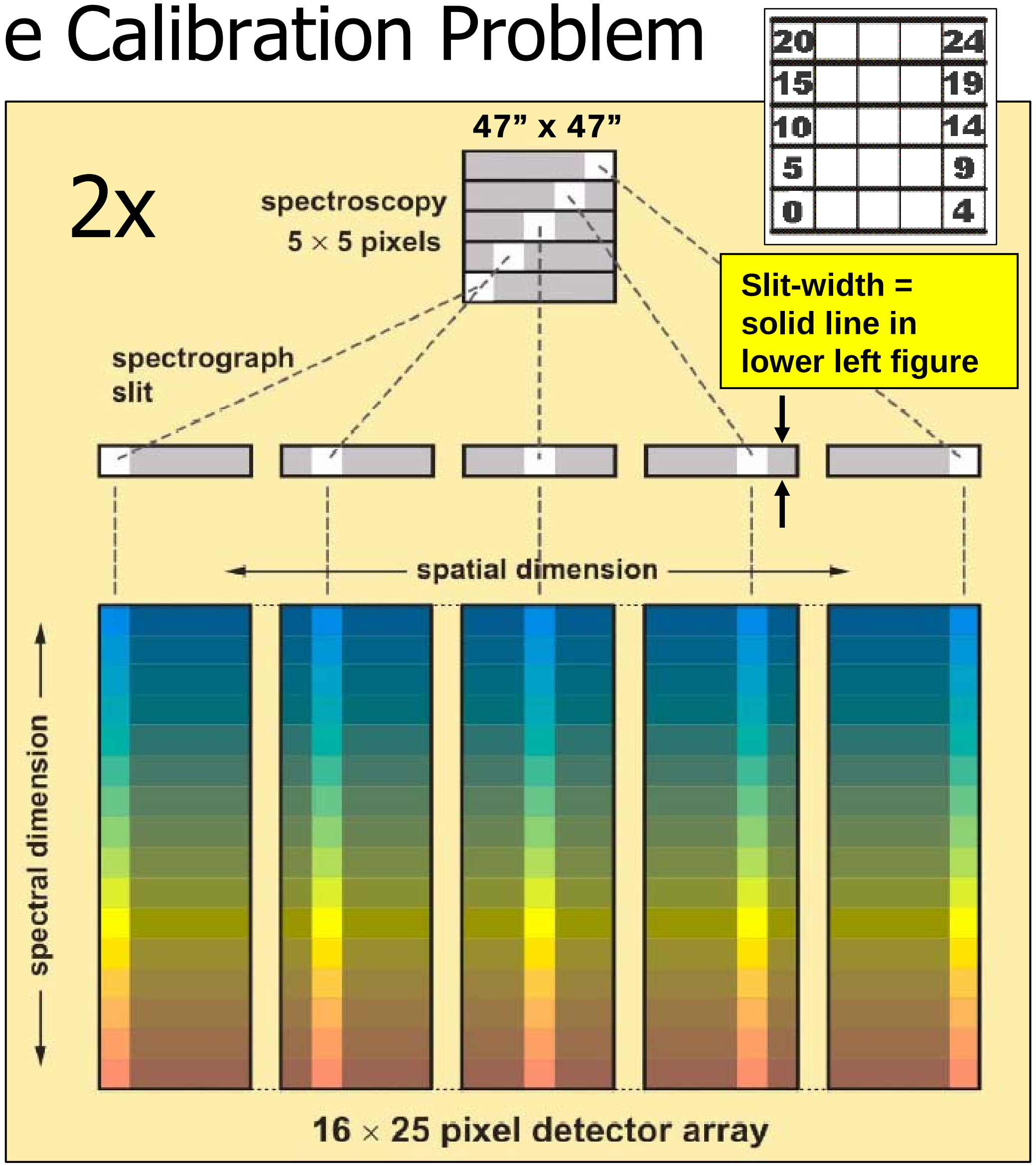
Description of the Calibration Problem

- Blue array: 400 pixels
- Red array: 400 pixels
- 2 different blue filters
- 3 grating orders
- Grating range:
  32000-1064000 positions
- Spectral resolution elements:
  ~3650 (x sampling x time)





PCD Requirements

Req. 4.2.1 Grating Wavelength calibration

Objectives

Determine the relation between the grating angle and the central wavelength of the grating response. This has to be done for each different pixel as the central wavelength is shifted as function of pixel in a module and module specific second order distortions and residual misalignments. The amplitude of the shift is related to the grating angle.

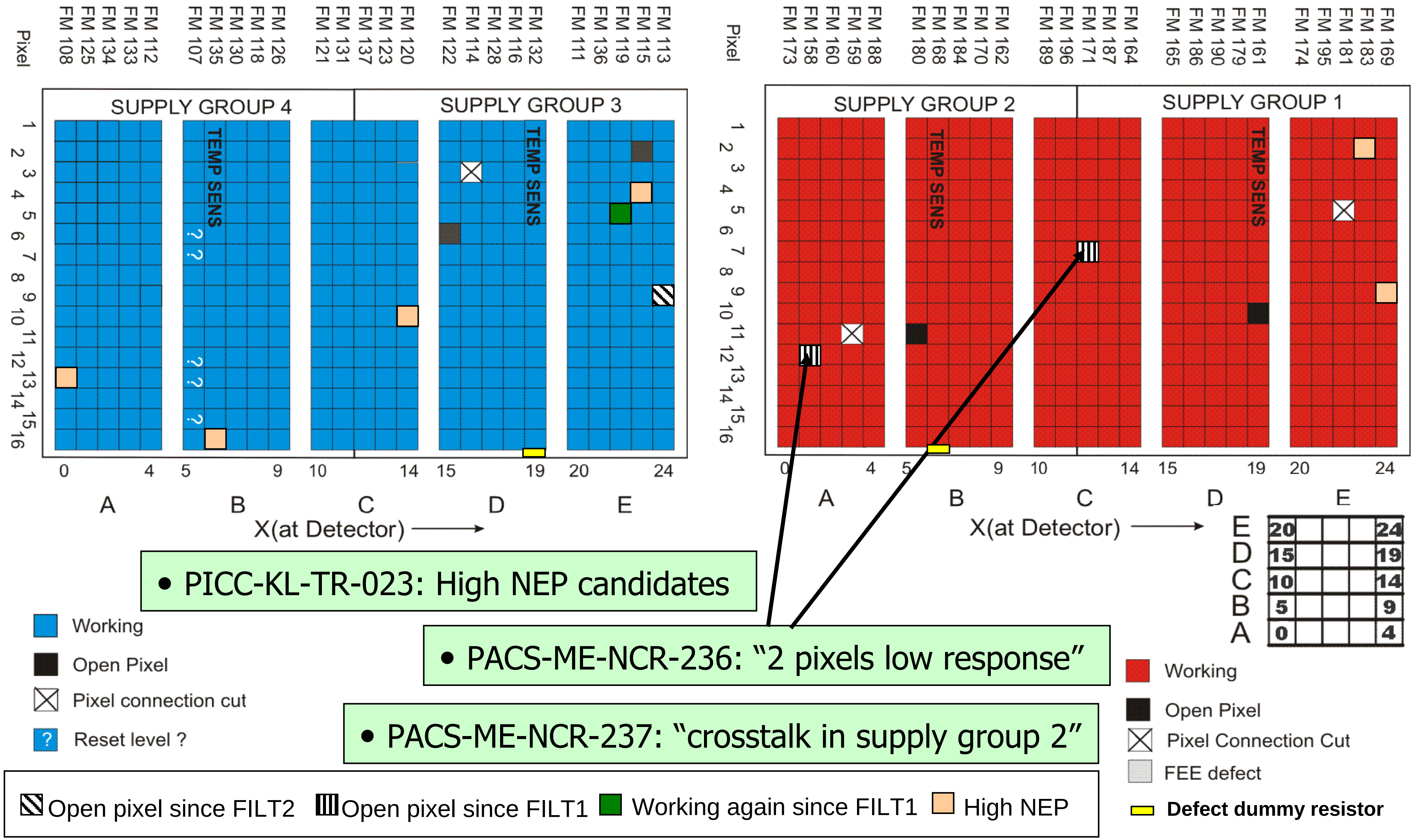
Req. 4.2.5 Grating Wavelength calibration, dependence on source position in slit

Objectives

Determine the relation between the grating angle and the central wavelength of the grating response as a function of the position of a point source within the spectrometer slit. Due to similarity with other pixels, it is assumed that a detailed characterization on the central spatial pixel shall provide sufficient information for the entire spatial field of view.

- PCD sec. 4.2.1:
  Required accuracy: "Peak position to within 10-20% of a spectral resolution element"

Photoconductor Arrays: Status 20090813



- PICC-KL-TR-023: High NEP candidates
- PACS-ME-NCR-236: “2 pixels low response”
- PACS-ME-NCR-237: “crosstalk in supply group 2”

Initial In-Flight Calibration

- in principle the pre-launch statement of accuracy is still valid:

  "In general the requirement is met throughout all bands however at band borders, due to leakage effects and lower S/N the calibration accuracy (in terms of σ over all pixels) is closer to 20% of a spectral resolution element, while in band centers, σ values even better than 10% are obtained.
  σ=stdev(all_pixels residual λ-shift vs. model) "

  However:
  The pre-launch calibration has been obtained with an ideal extended absorption source and a reference measurement on the same source without the absorber. No such measurement can be carried out in-flight.

Observations

Proposals:

- PVSpecWave
- RPSpecWave

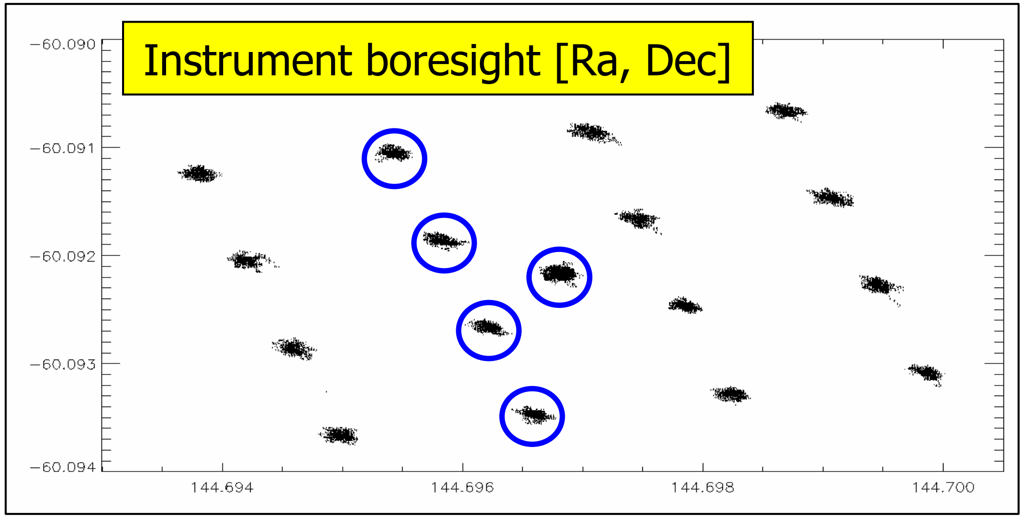
PNs / NGC6543: Routine monitoring of fine-structure lines

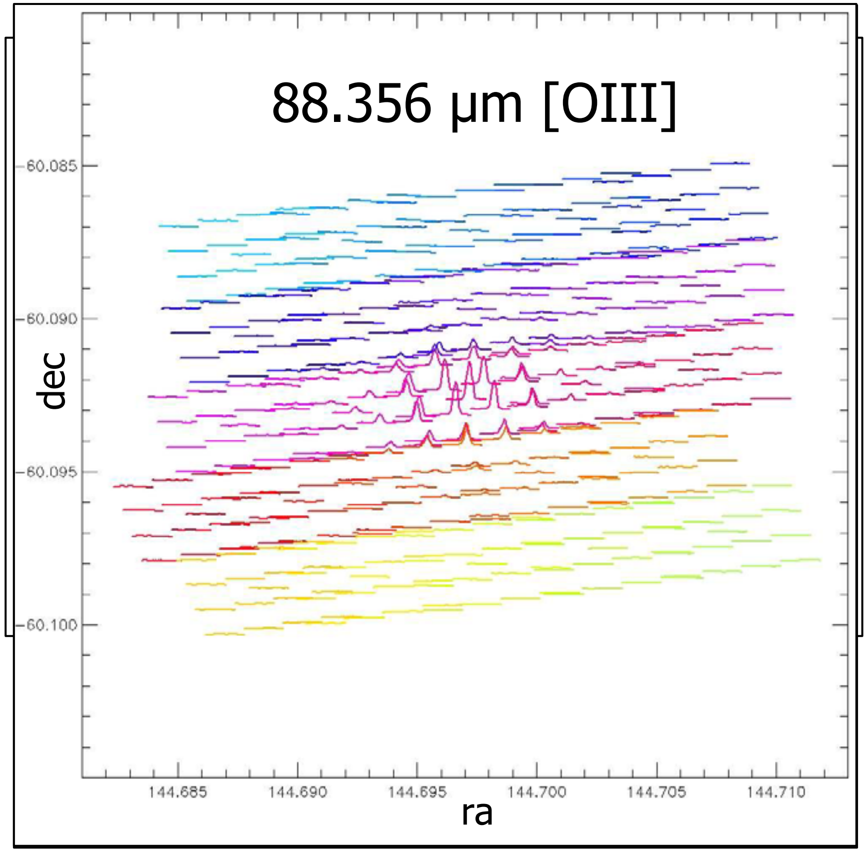
Target	Source diameter (optical)	Target LSR velocity [km/s]	Herschel LSR velocity [km/s]	OBSID	OD and Exposure Time [sec]
R Cas	Point source	+25	+28.5	80109	OD64: 4774
IC2501	2"	+22	-24.1	81177	OD79: 5490
IC2501	2"	+22	-24.1	81178	OD79: 5491
IC2501	2"	+22	-24.1	81179	OD79: 5490
W Hya	Point source	+42.7* (+45.0)	-25.8	81935	OD90: 15555
W Hya	Point Source	+42.7* (+45.0)	-25.8	81936	OD90: 15555
NGC40	48"	-13.4	+23.8	81958	OD90: 1063
NGC6302	>155" (optical)	-32.2# (-28.9)	-21.0	82790	OD102: 1173
NGC6302	>155" (optical)	-32.2# (-28.9)	-21.1	84330	OD133: 520
NGC6302	>155" (optical)	-32.2# (-28.9)	-21.1	84331	OD133: 520
Mars	6.23"	-11.45$	+18.0	83972	OD126: 4135
Jupiter	41.4"	+26.7$	-22.04	86573	OD170: 7825
Jupiter	41.4"	+26.7$	-22.04	86574	OD170: 7825
Jupiter	36.9"	+24.5$	-19.23	87848	OD208: 23538
Jupiter	36.6"	+24.0$	-18.62	88042	OD211: 15257

* Value is taken from A&A, 211, 187 (1989), value in brackets is from SIMBAD
# Value is taken from RD 3, ESO/Acker ref. STPP83
$ Value is from Horizons System: "deldot" (positive velocity means target moves away from observer)

Dependence on Source Position within Slit (1)

- 4x4 + OFF Raster on IC2501



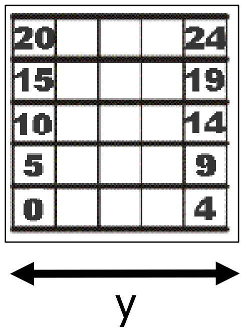


- Raster step sizes:
  3" in S/C-Y ; 3" in S/C-Z
- Line scans without chopping
- Wavelengths:
  57.330 µm [NIII]
  88.356 µm [OIII]
  157.741 µm [CII]

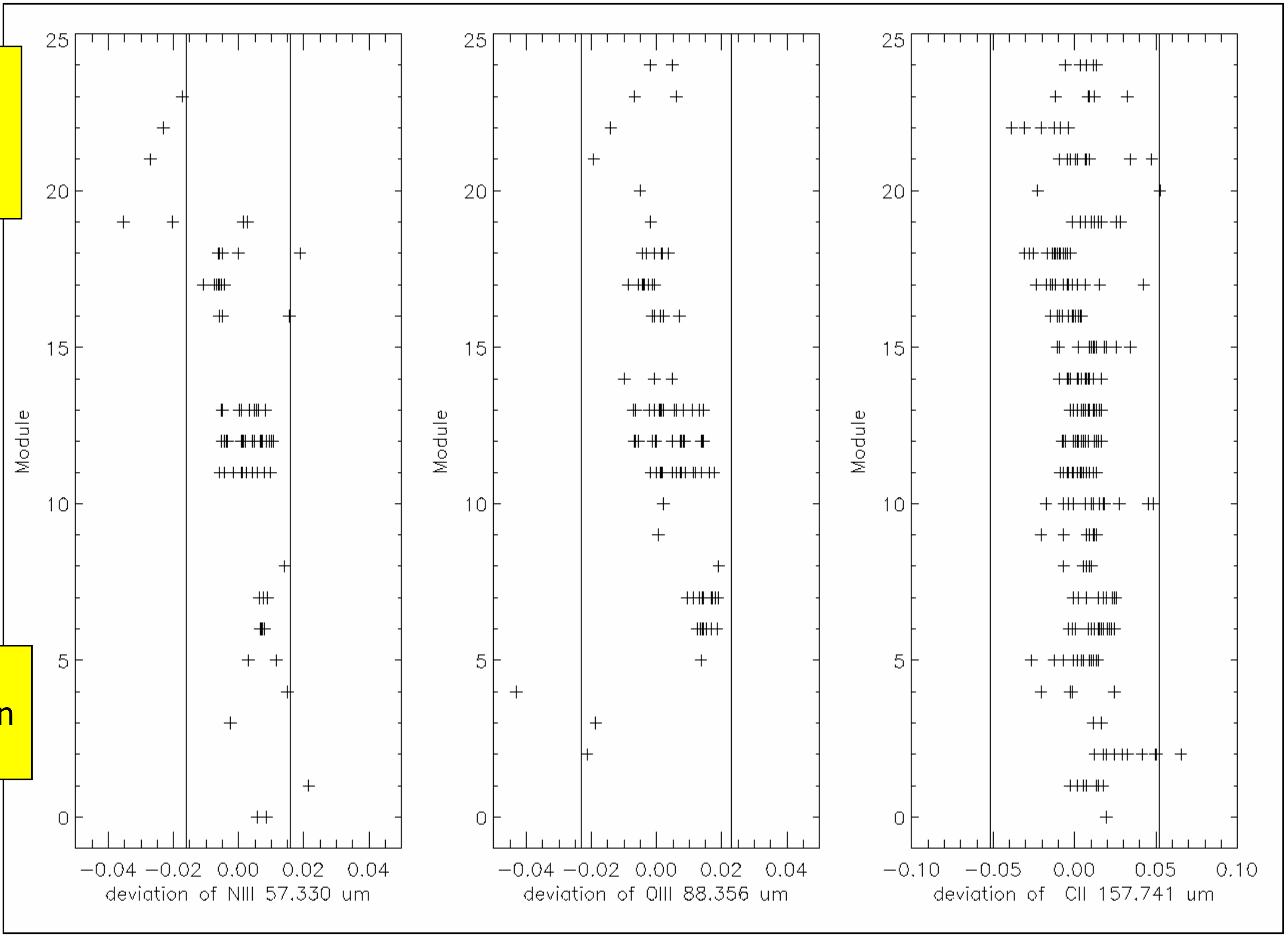
Dependence on Source Position within Slit (2)

Result of automated fitting of gaussians to all rebinned spectra of all modules

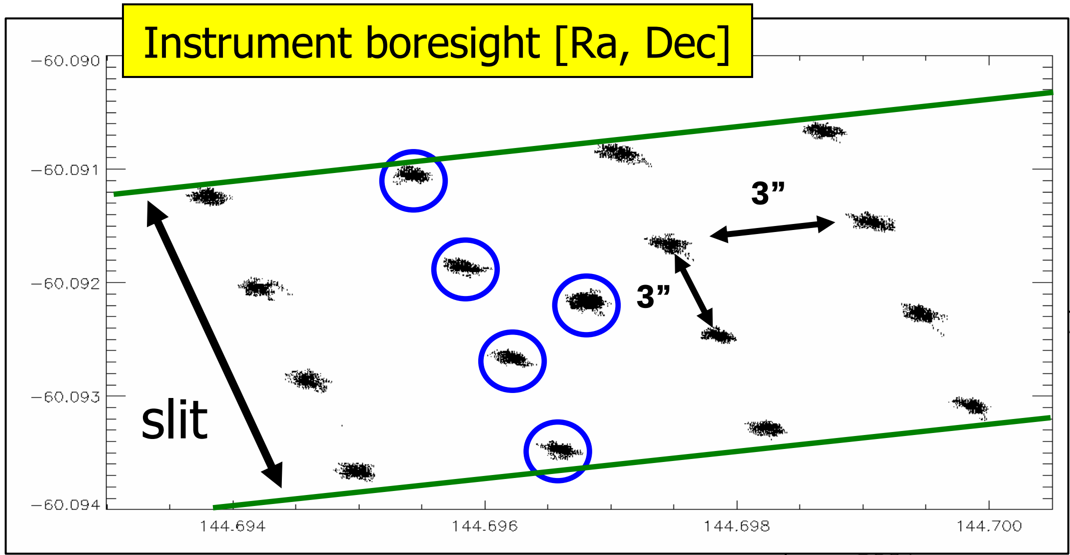
Module numbering:



Vertical lines indicate effective slit borders in units of micron

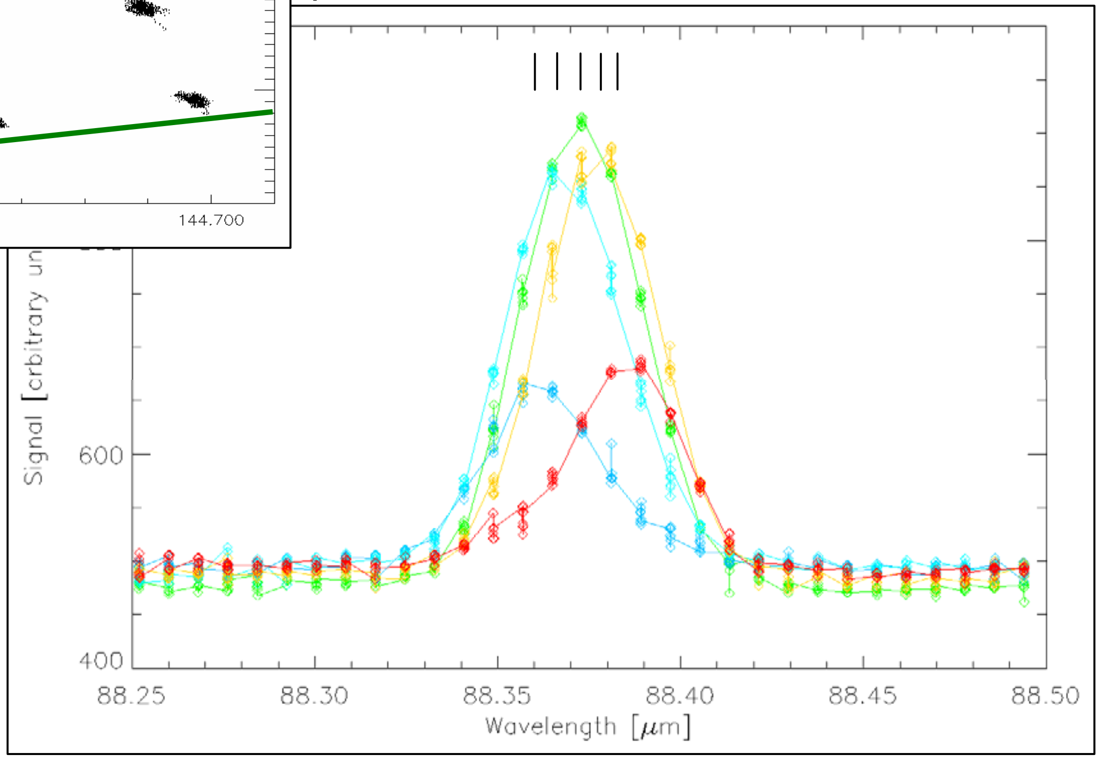


Dependence on Source Position within Slit (3)



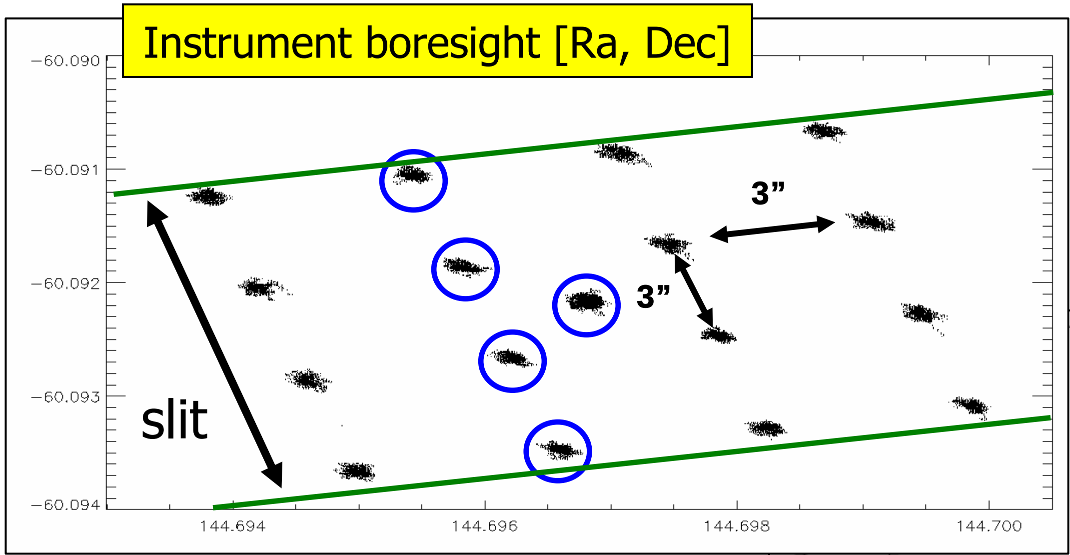
IC2501 raster:
OBSIDs: 81177, 81178, 81179

Pixel 8 of module 12 at the 5 encircled raster positions



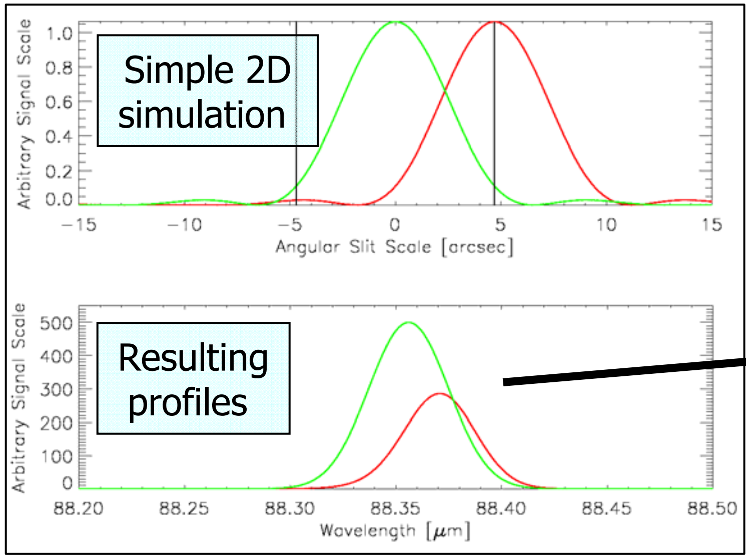
- Observed wavelength shifts are consistent with raster positions inside the slit
- Line shape asymmetries appear at off-center slit positions

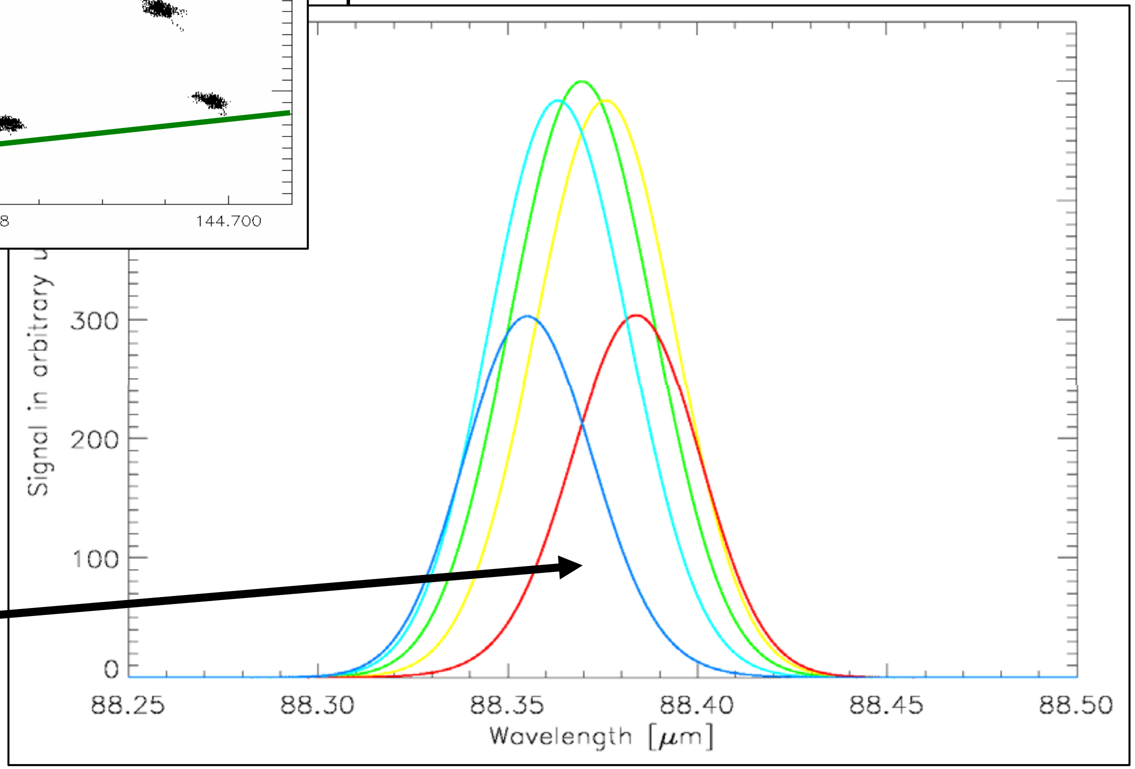
Dependence on Source Position within Slit (4)



IC2501 raster:
OBSIDs: 81177, 81178, 81179

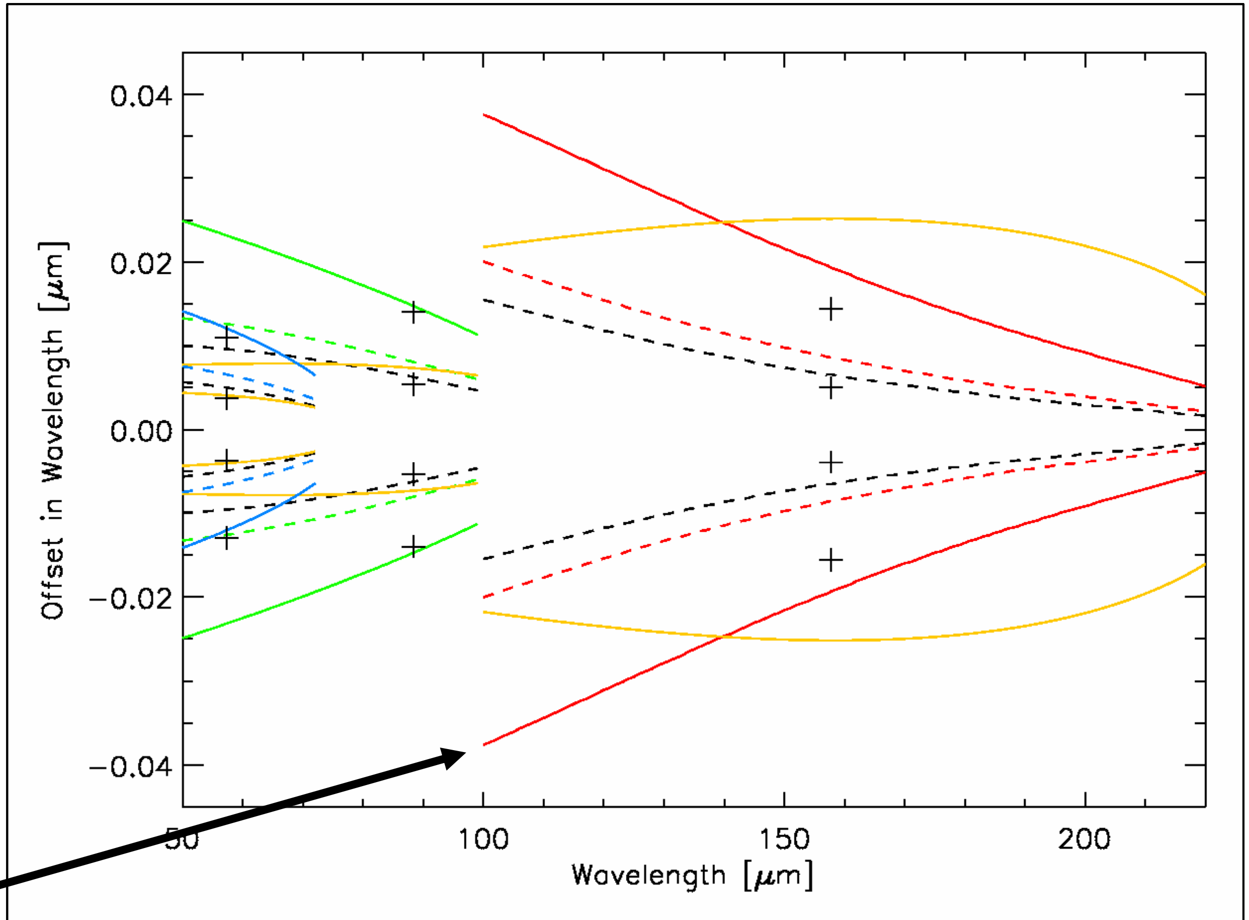
Simulated profiles at the 5 encircled raster positions



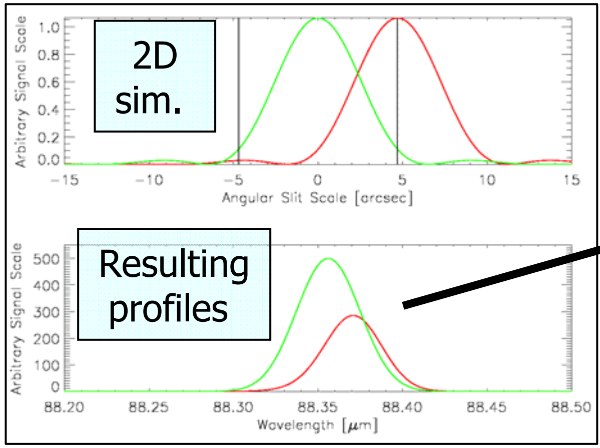


Dependence on Source Position within Slit (5)

- Requirement
- Slit borders
- Pointing uncertainty
- IC2501 measurement



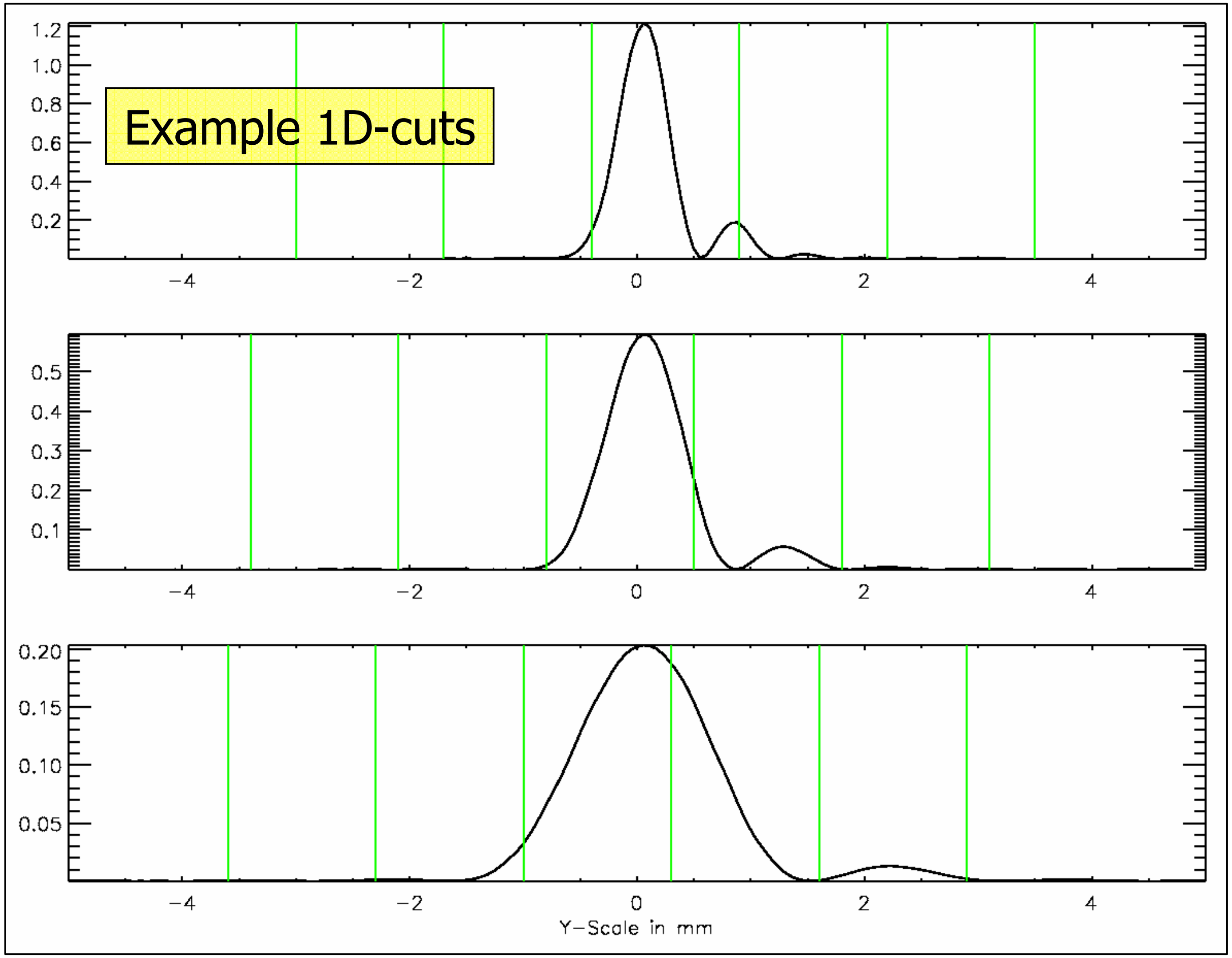
68% of pointings will fall within 1.8" of the target coordinates
98% of pointings will fall within 3.6" of the target coordinates
99.8% of pointings will fall within 5.4" of the target coordinates



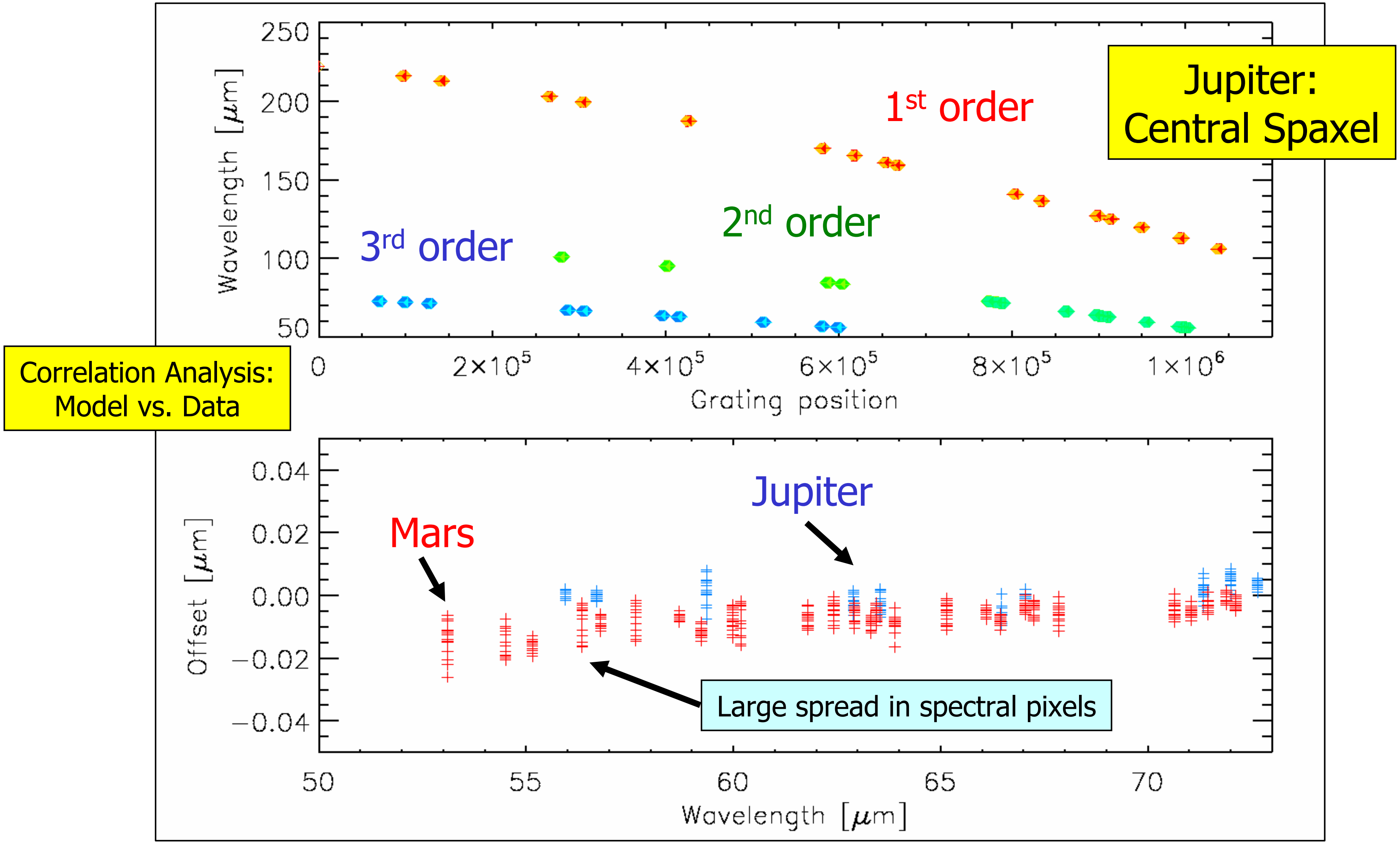
Wavelength Calibration

Numerical PSF Calculations (N. Geis)

- Lambda = 57 µm
- Lambda = 88 µm
- Lambda = 157 µm

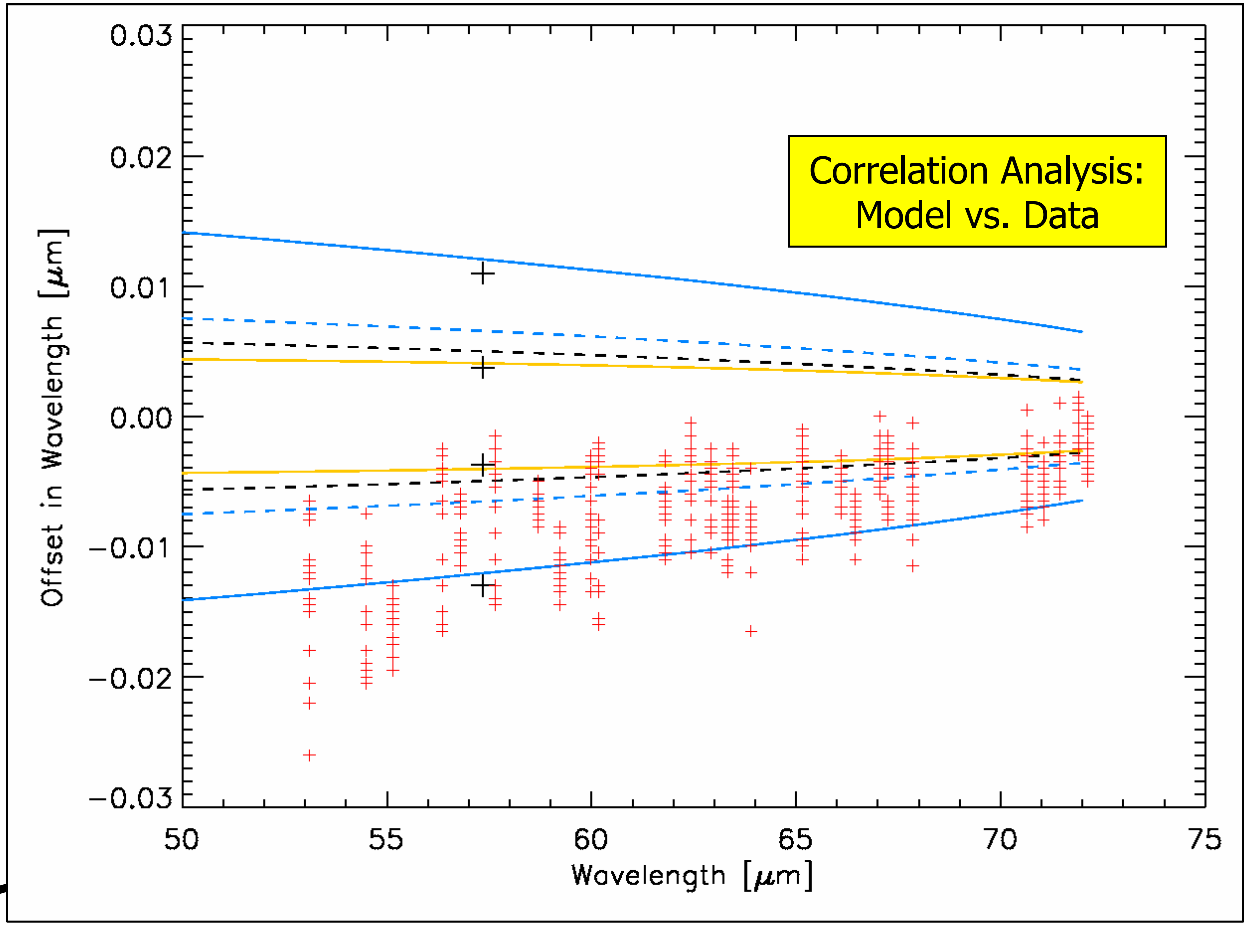


Absolute Calibration

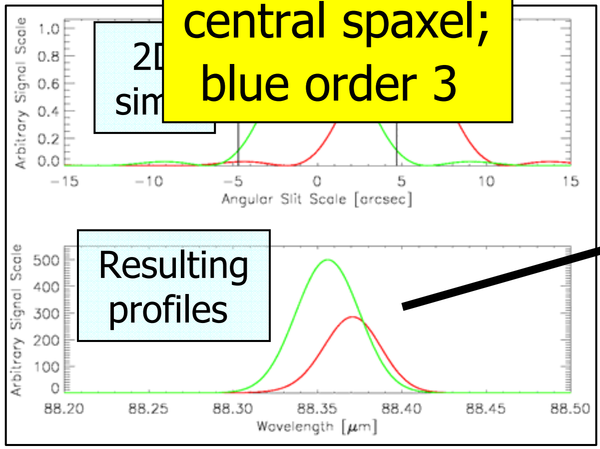


Dependence on Source Position within Slit (6)

- Requirement
- Slit borders
- Pointing uncertainty
- IC2501 measurement
- Mars measurement

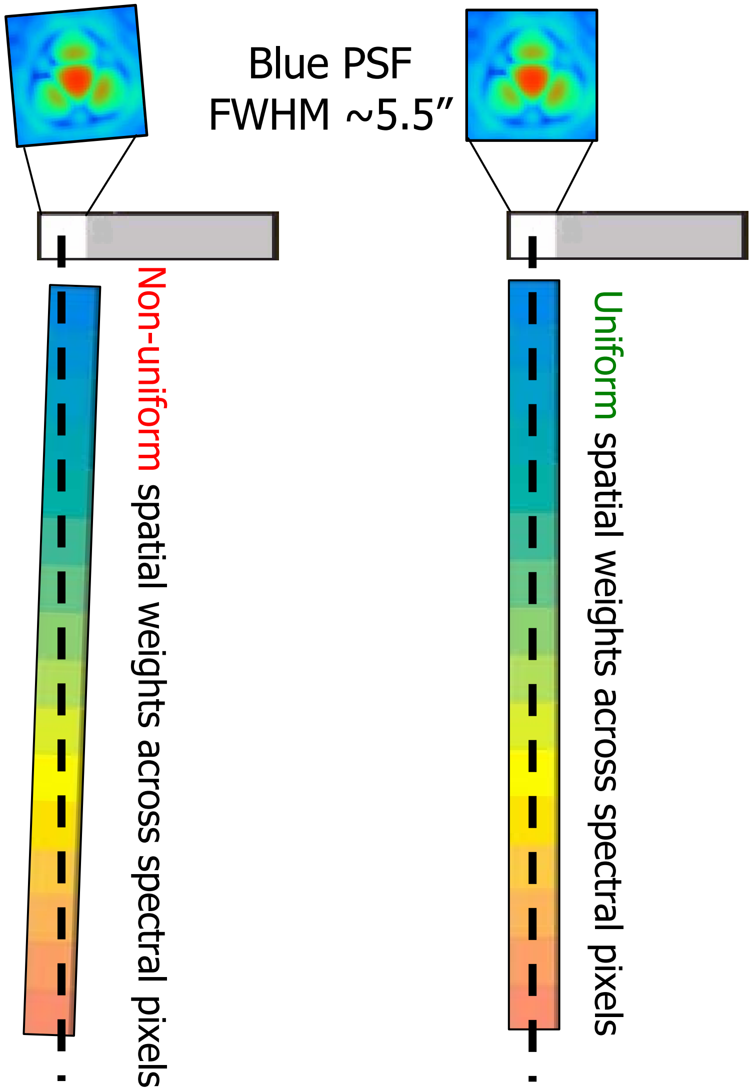


16 pixels of central spaxel; blue order 3

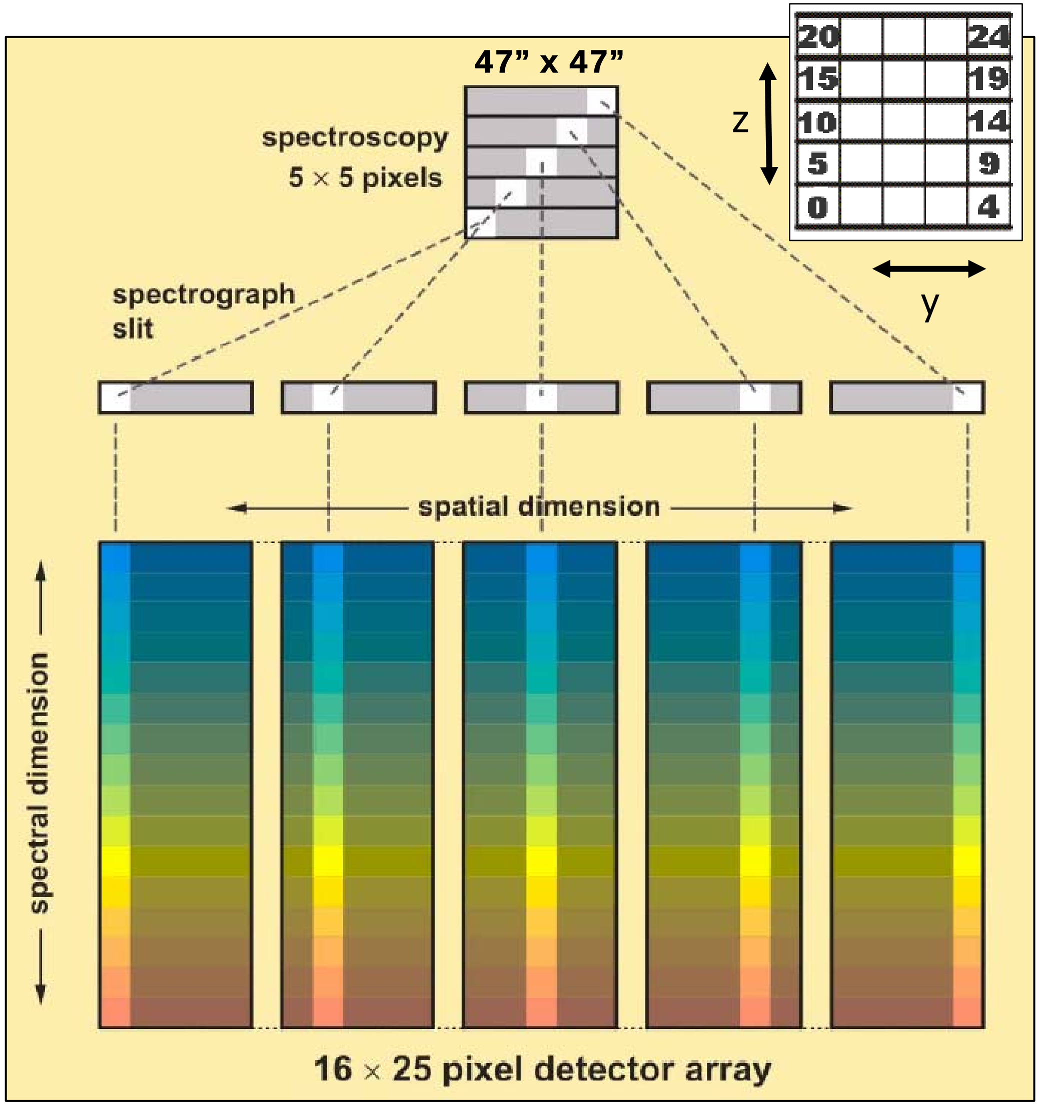


68% of pointings will fall within 1.8" of the target coordinates
98% of pointings will fall within 3.6" of the target coordinates
99.8% of pointings will fall within 5.4" of the target coordinates

Alignment Effects on λ-Calibration

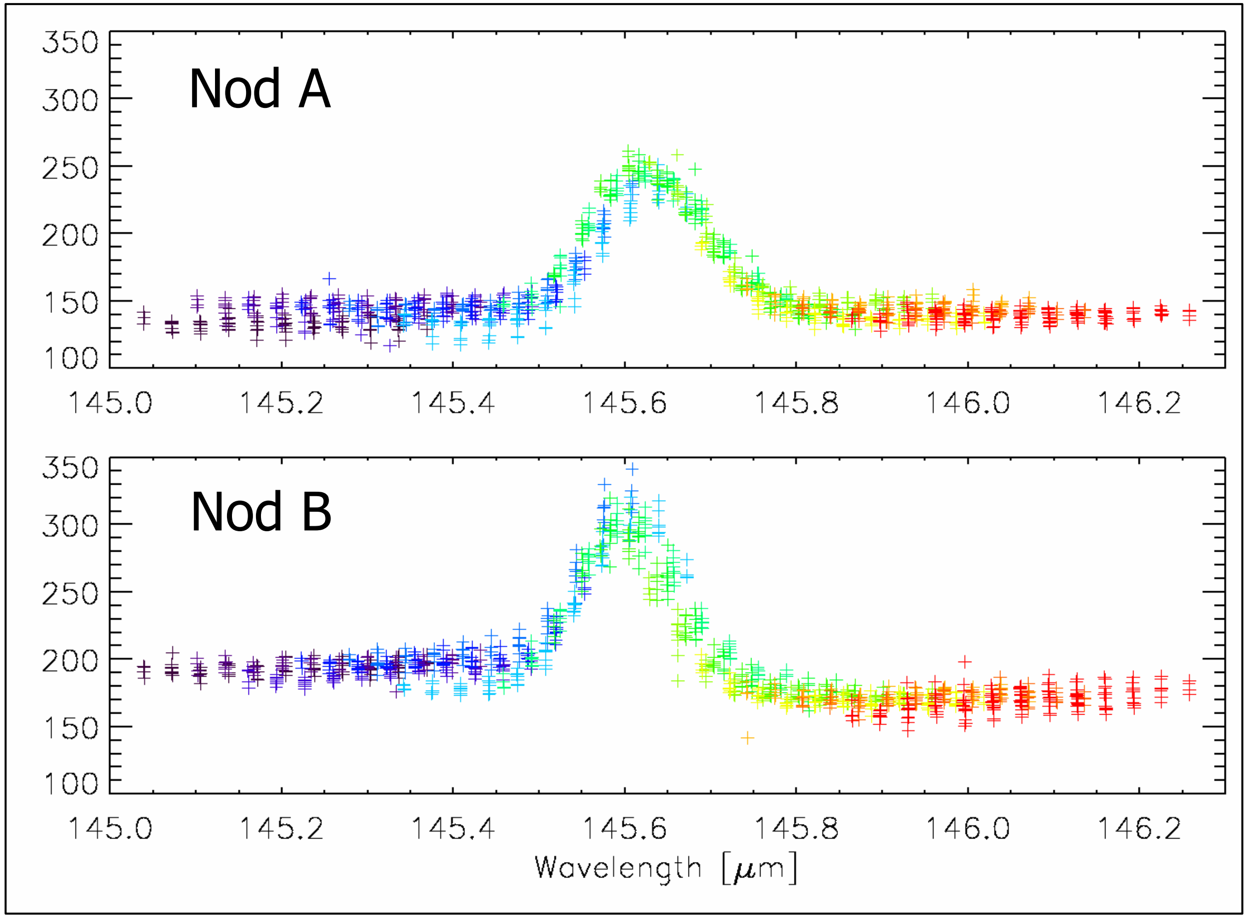


Wavelength Calibration



Alignment Effects on λ-Calibration

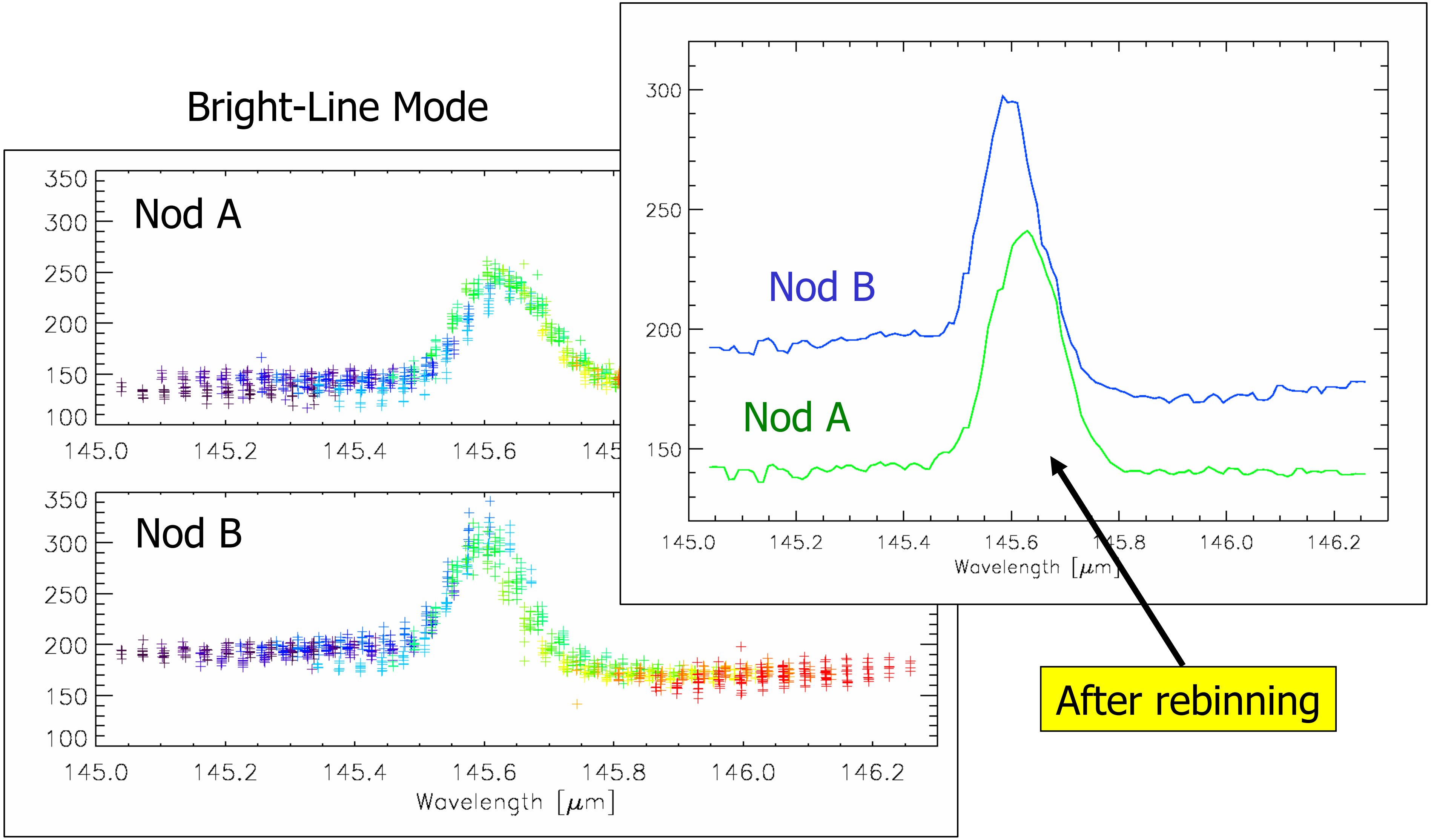
Bright-Line Mode



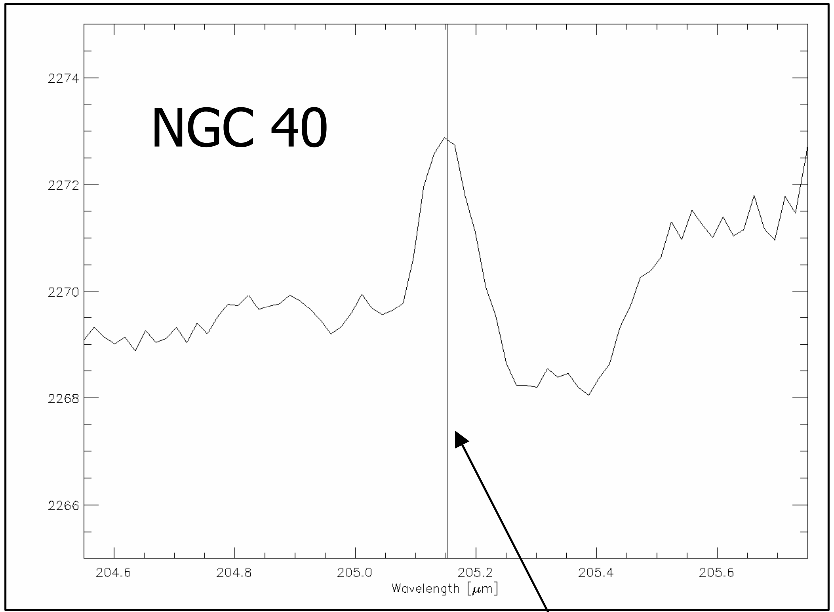
- Single spectral pixels are color coded
- Different baselines for different spectral pixels
- Reasonable match for Nod A
- Significant offsets for Nod B

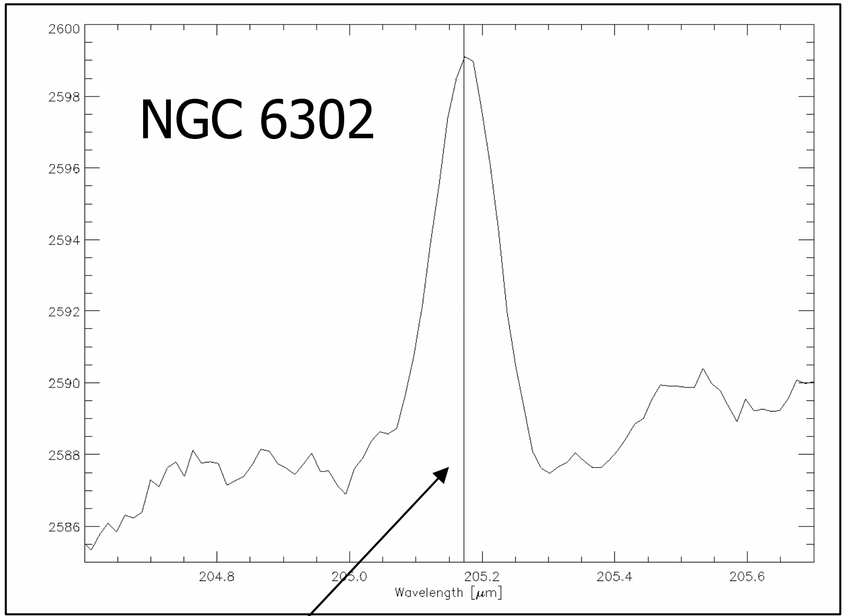
Alignment Effects on λ-Calibration

Bright-Line Mode



Calibration at long wavelengths





All velocity components corrected

- Lambda = 205.178 μm N[II]

Concluding Remarks

- Absolute calibration can't be improved since it is dominated by the pointing
- The discussed phenomenology has also significant impact on spectrometer line profiles, line and continuum fluxes and relative spectral response functions

- Further calibration efforts will focus on individual spectral pixel outliers

- Think about observing strategy: Small maps provide the spatial information for a better understanding of the wavelength scale

- Simplify code → Transform code from semi-analytical (Littrow equation + polynomial correction) into polynomial expression only.

  [Code is available and tested; SCR PACS-2488 in implementation]