What I know (and don't know*) about Wavelength Scales, Bandpasses, and Dichroics

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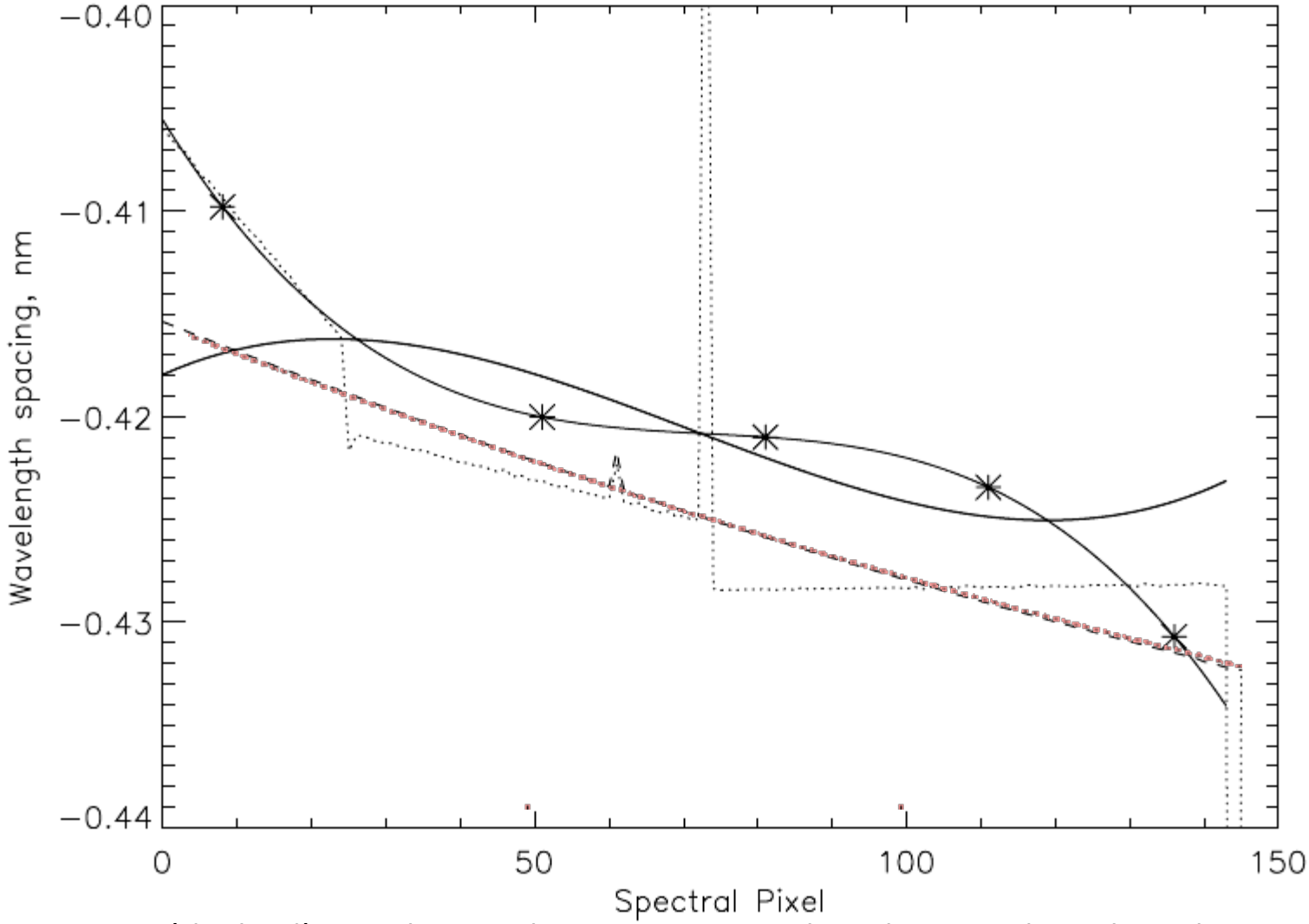
* Not an exhaustive list.

Wavelength Scales (Pixel Centers)

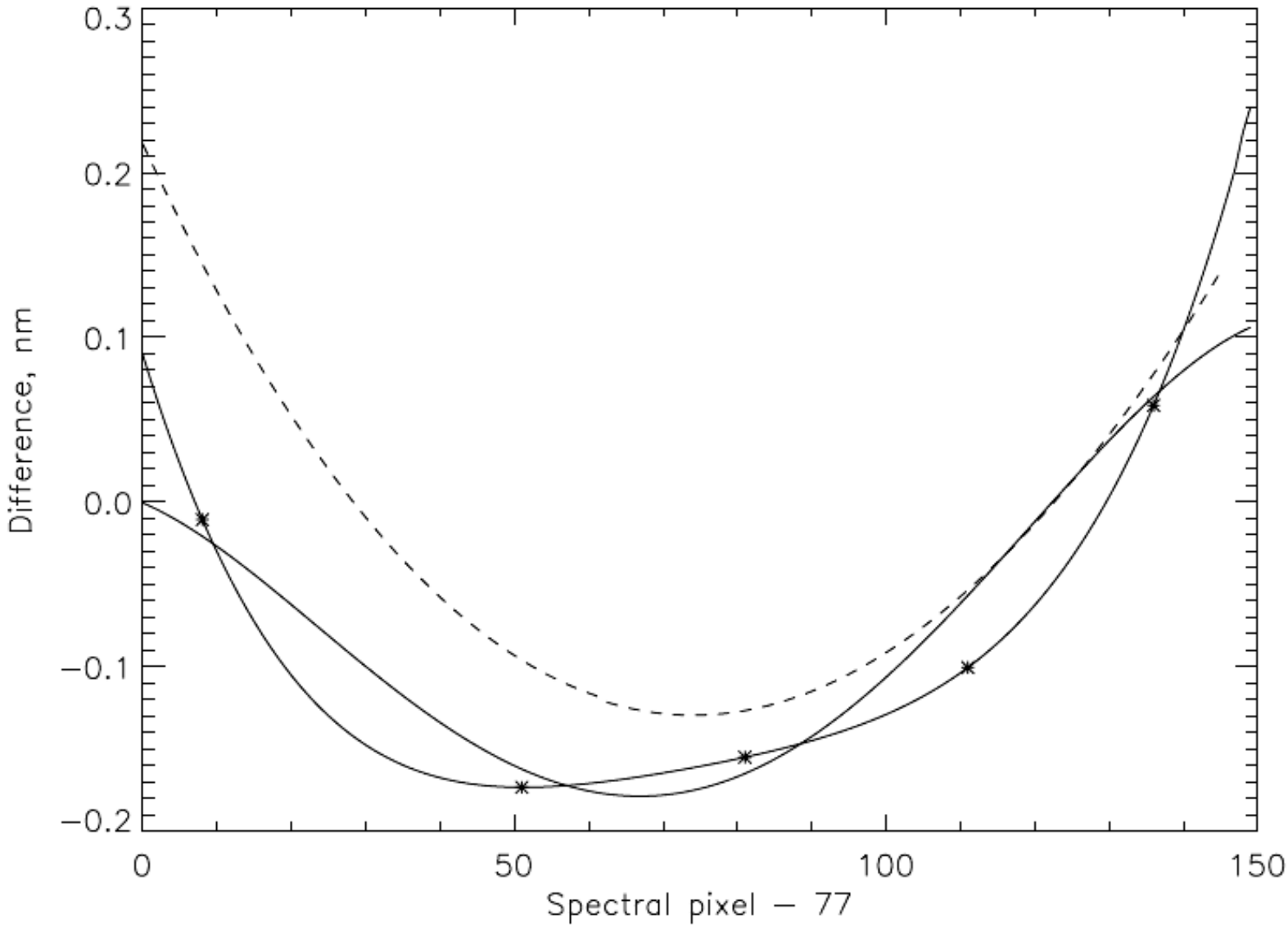
- The response of the instrument to a monochromatic input (Tunable Laser) at a range of spectral and spatial locations is obtained.
- For each spatial row (or perhaps collection of adjacent spatial rows) above a threshold signal, the corrected counts are used to find the weighted-average pixel, P, for each input wavelength, λ.
- This gives a two dimensional data set of the form,

  $\{(\lambda_{i,j}, P_{i,j})\}$ for input wavelength i and for spatial row j .
- Inverting this, considering wavelength as a function of pixel instead of pixel a function of wavelength, and fitting with a two-dimensional model provides a way to assign wavelengths to pixels over the full active region. These are used to produce the CBC data sets.
- The figures on the following slide compare the wavelength scales for NP for S-NPP and J-1 to a simple linear model by examining their spacing. That is, the plots show the differences in the band centers of adjacent pixels for spatial rows (or macropixels). If the wavelength scales were linear, these curves would be constants. The figure on the slide after that one show the difference of the wavelength scales with linear ones.



The S-NPP steps (dashed) are close to linear meaning that the wavelength scale is quadratic while the J01 steps (solid) follow a cubic meaning that its wavelength scale is quartic. The solid line without symbols are the J01 CBC data. The solid line with symbols are the J01 CBC data adjusted by the bandpass-weighted average wavelengths. The symbols in the figure show the locations of the five J01 spectral measurement sets. The red line is the S-NPP data adjusted by its bandpass-weighted average offsets.

Wavelength Scale versus Linear



Wavelength Scale Notes

- The CBC data set from this analysis is good in that it should provide an accurate estimate of the wavelength that would have a weighted average response at a selected pixel's center.
- The analysis* method is insensitive to throughput variations with wavelength. For example, the results would be the same with or without a dichroic in the system in terms of throughput – the dichroic may also act as a broadening or scattering optical component.
- The CBC data does not give the wavelength that would represent a pixel's weighted-average response wavelength (its bandpass-weighted wavelength centroid).

* This assumes the that analysis works with corrected counts (or counts converted to radiance by using the instrument's throughput for the input wavelength, not by using each pixel's average calibration coefficient).

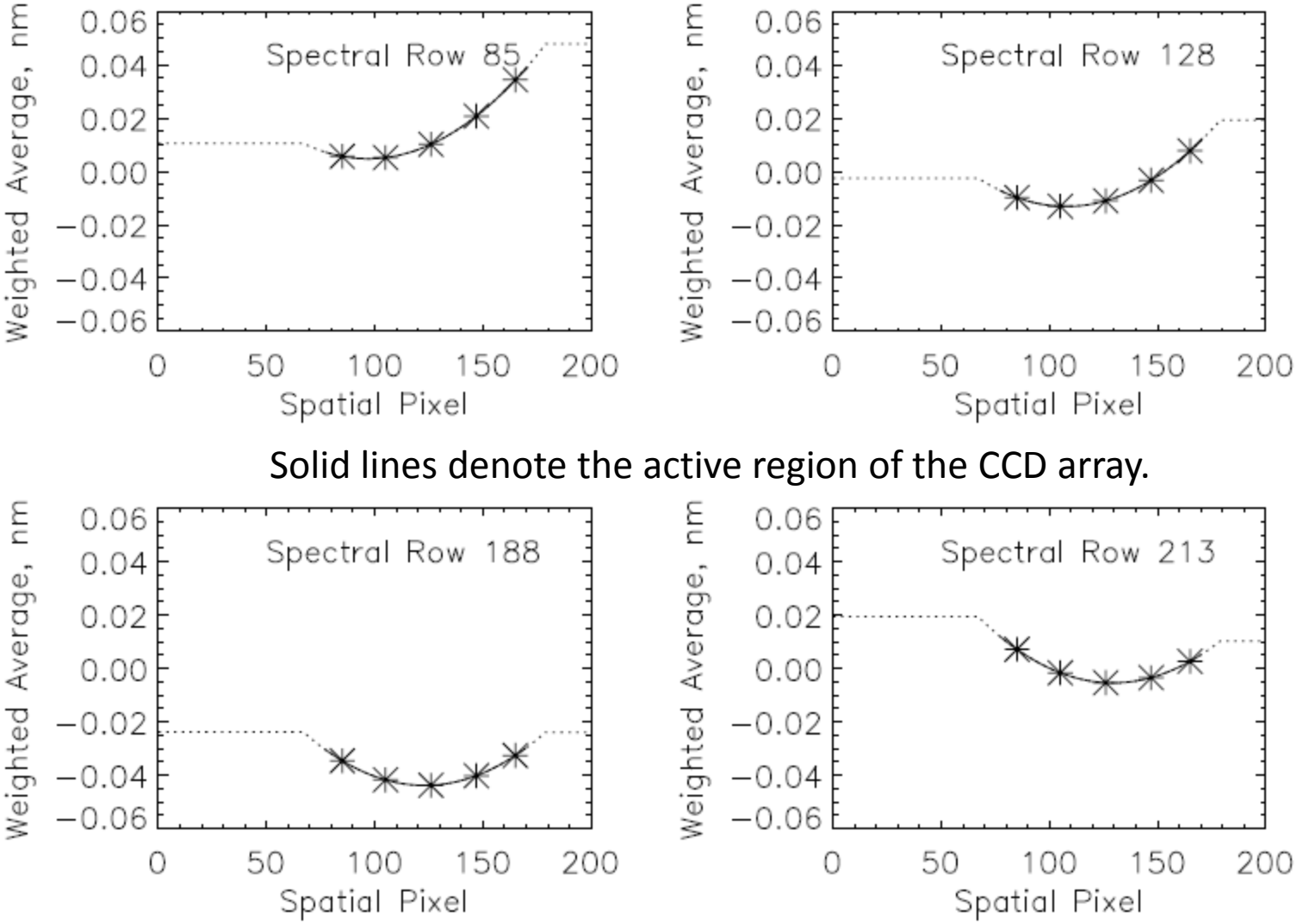
Bandpass offsets

- The bandpass-weighted average wavelength offsets in nm are computed as

  $$\mathrm{sum}\{BP_k * w_k\}/\mathrm{sum}\{BP_k\}$$

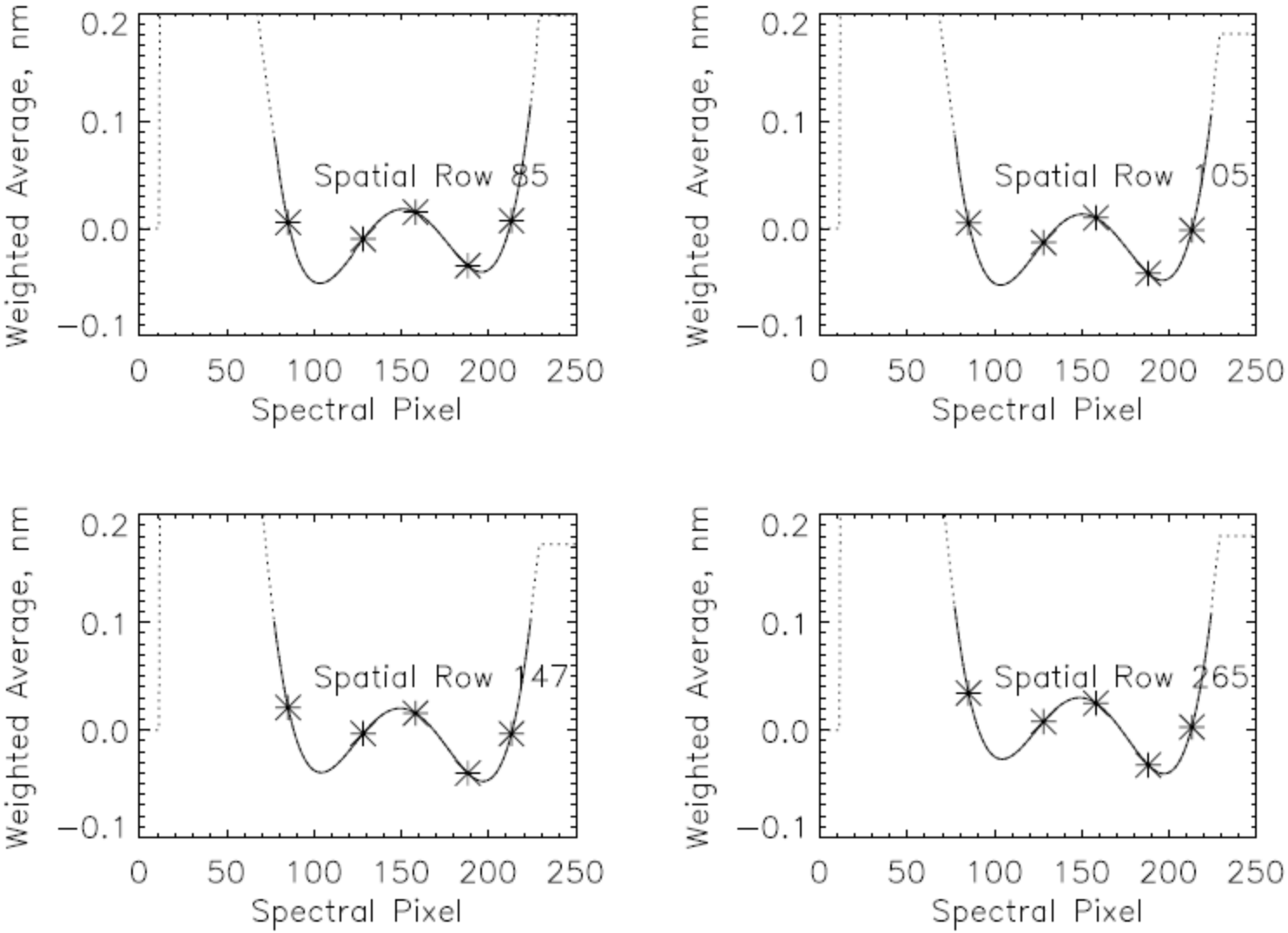
  with $w_k = (i-25)*0.1$ and the sums taken over k=0 to 50, where BP is a set of 51 bandpass response values given every 0.1 nm centered at the pixel band centers from the earlier computations. Slices though the 2-D bandpass offset surface for J01 NP are displayed on the next two slides.

Weighted-Average Bandpass Offsets for J01 Versus Cross-track Spatial Pixel



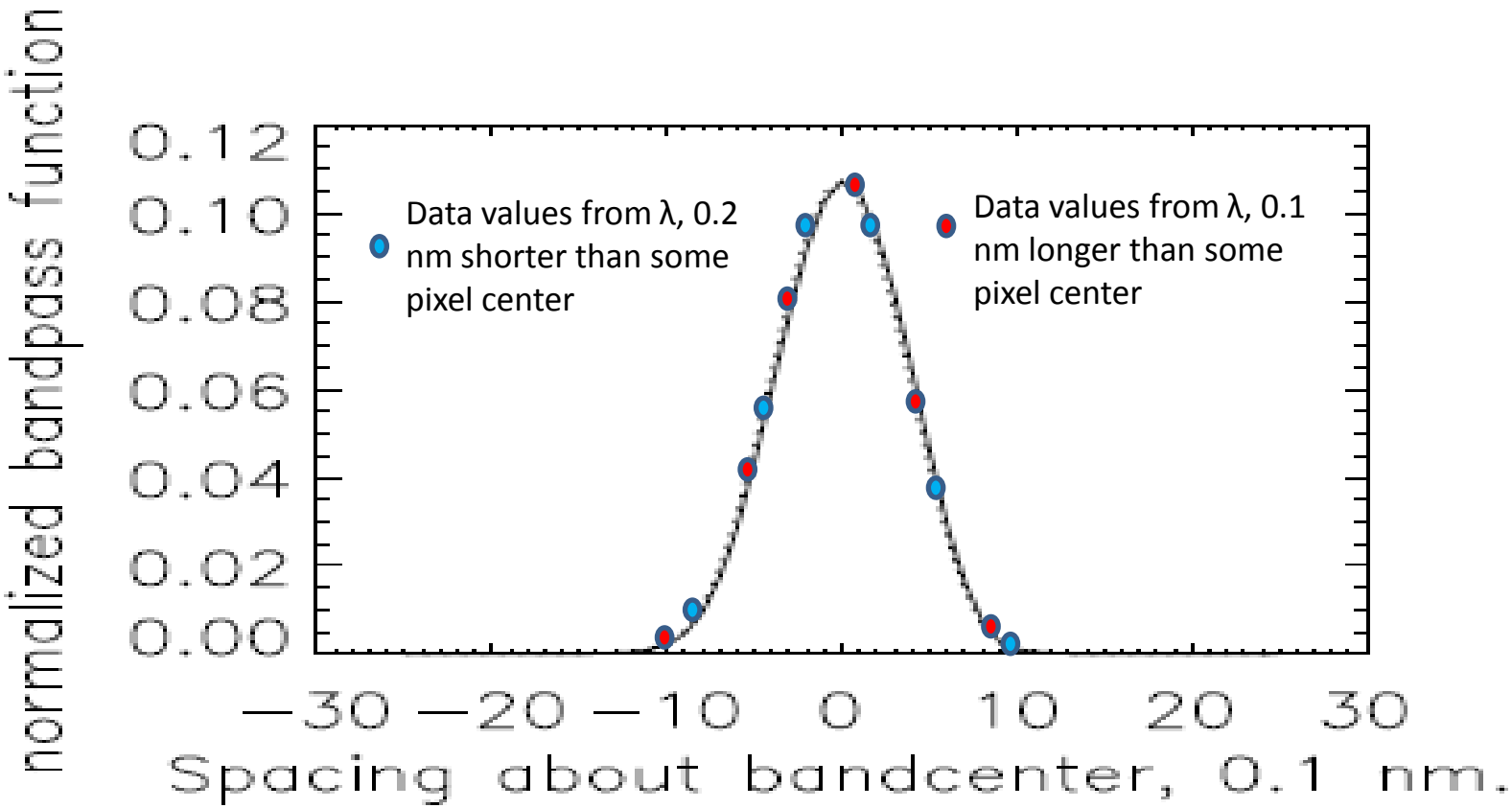
Solid lines denote the active region of the CCD array.

Weighted Average Bandpass Offsets for J01 Versus Wavelength Pixel



Bandpass Estimation (1)

- The same data used to get the wavelength scales can be used to get the non-wavelength-throughput-dependent bandpasses. One takes the measurements for a given laser wavelength input and again normalizes the total counts over some localized spectral and spatial region. The result is used to provide data points by using the laser input wavelength relative to the pixel centers computed earlier.



Bandpass Estimation (2)

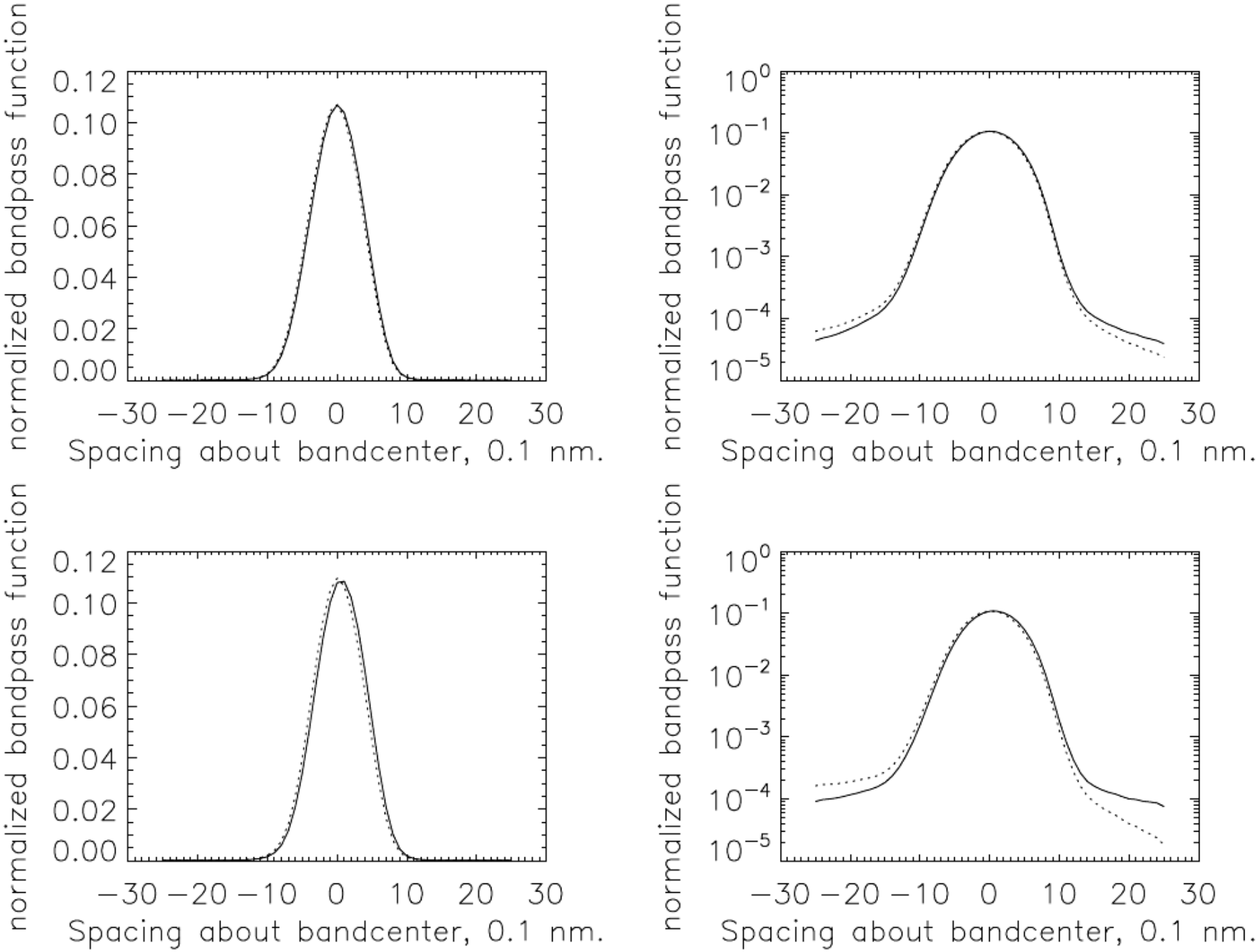
- There are two implicit key assumptions in this approach:

1. That the bandpasses change slowly in both spectral and spatial dimension so one can work over 12 spectral pixels and 8 spatial pixels.
2. That the normalization of a bandpass as sampled every 0.42 nm provides comparable values as the sampling is shifted relative to the center. (For the JPSS bandpasses, I have checked this by comparing the sums of every fourth bandpass value and it holds at the 0.2 % level.)

- There is the further assumption that the count responses for different pixels are consistent for a given specific photon energy / wavelength over the local analysis region.

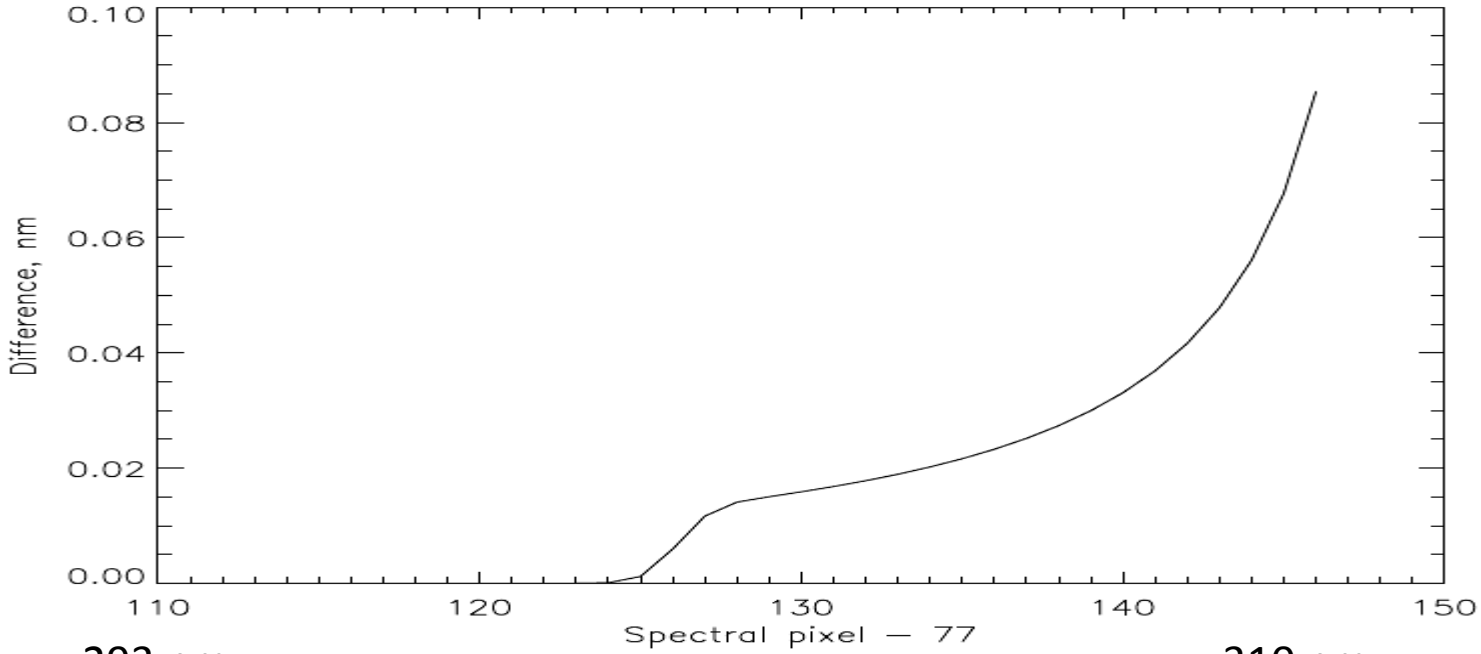
Bandpass Estimation (3)

- Again, these bandpasses will be the idealized instrument response functions without taking into account the wavelength-dependent throughput. One can adjust the bandpasses by using the relative wave-length dependent throughput to create the expected instruments bandpasses but this requires some assumptions about how the pixel count to radiance data are constructed from measurements.
- The pixel-dependent calibration constants were used as a proxy for wavelength-dependent throughput variations to see how much the real bandpasses would be changed. The pixel level constants were used by assigning the conversion value to the central wavelength. These were linearly interpolated to create a set of values with 0.1-nm spacing about the central wavelength of a pixel. The full set of values are convolved with the current bandpass data for that pixel and central wavelength to produce throughput weighted bandpass values.
- The figures on the next page compare unadjusted (Solid) and adjusted (Dotted) bandpasses with linear (Left) and log (Right) scales for 305 nm (Top) and 308 nm (Bottom) for OMPS NP on S-NPP.


normalized bandpass function
0.12
0.10
0.08
0.06
0.04
0.02
0.00
−30 −20 −10 0 10 20 30
Spacing about bandcenter, 0.1 nm.
normalized bandpass function
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
−30 −20 −10 0 10 20 30
Spacing about bandcenter, 0.1 nm.
normalized bandpass function
0.12
0.10
0.08
0.06
0.04
0.02
0.00
−30 −20 −10 0 10 20 30
Spacing about bandcenter, 0.1 nm.
normalized bandpass function
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
−30 −20 −10 0 10 20 30
Spacing about bandcenter, 0.1 nm.

Bandpass Offsets from the Dichroic

- The adjustments creates bandpasses with different centering – different weighted-average bandpass wavelength offsets. The figure below shows the differences in the weighted-average bandpass centers, old – new, for S-NPP .

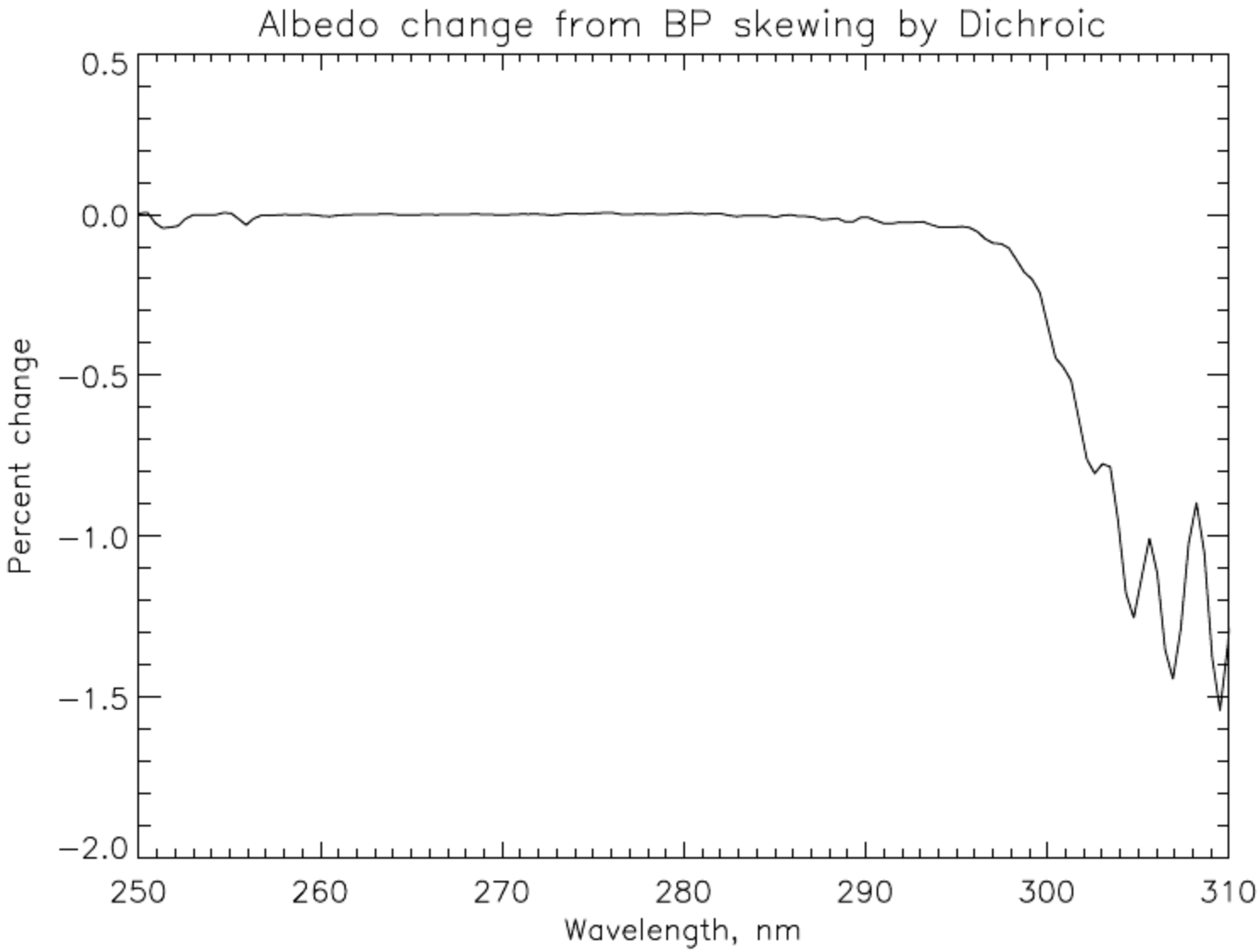


293 nm

310 nm

Applying the new Bandpasses

- Since the albedo is rapidly changing over the 300 nm to 310 nm interval, changing the bandpasses will affect the Solar and Earth View data differently leading to changes in the expected albedo. That is, there will be significant differences in an RT instrument table created by the two sets of bandpasses.
- The figure on the next slides uses a single set of measured NP radiance and irradiance spectra interpolated to higher density and convolved with the old and new bandpasses to estimate the albedo changes.
- The sign of these changes will switch from the NP to the NM as the throughput gradients are in the opposite directions.


Albedo change from BP skewing by Dichroic
0.5
0.0
−0.5
−1.0
−1.5
−2.0
Percent change
250
260
270
280
290
300
310
Wavelength, nm

Open Questions

- Why does the S-NPP data show a good fit by a quadratic in wavelength and the bandpasses have small offsets*? Or, Why do the J01 data need a quartic to get a good fit and the bandpasses have large offsets^?
- Why don't the provided bandpasses show the dichroic skewing? Will the throughput adjustments by using skewed bandpasses improve the RT forward model albedo comparisons and OMPS NM/NP agreement in the overlap region for S-NPP?
- How accurately can we estimate the wavelength scales in-orbit?

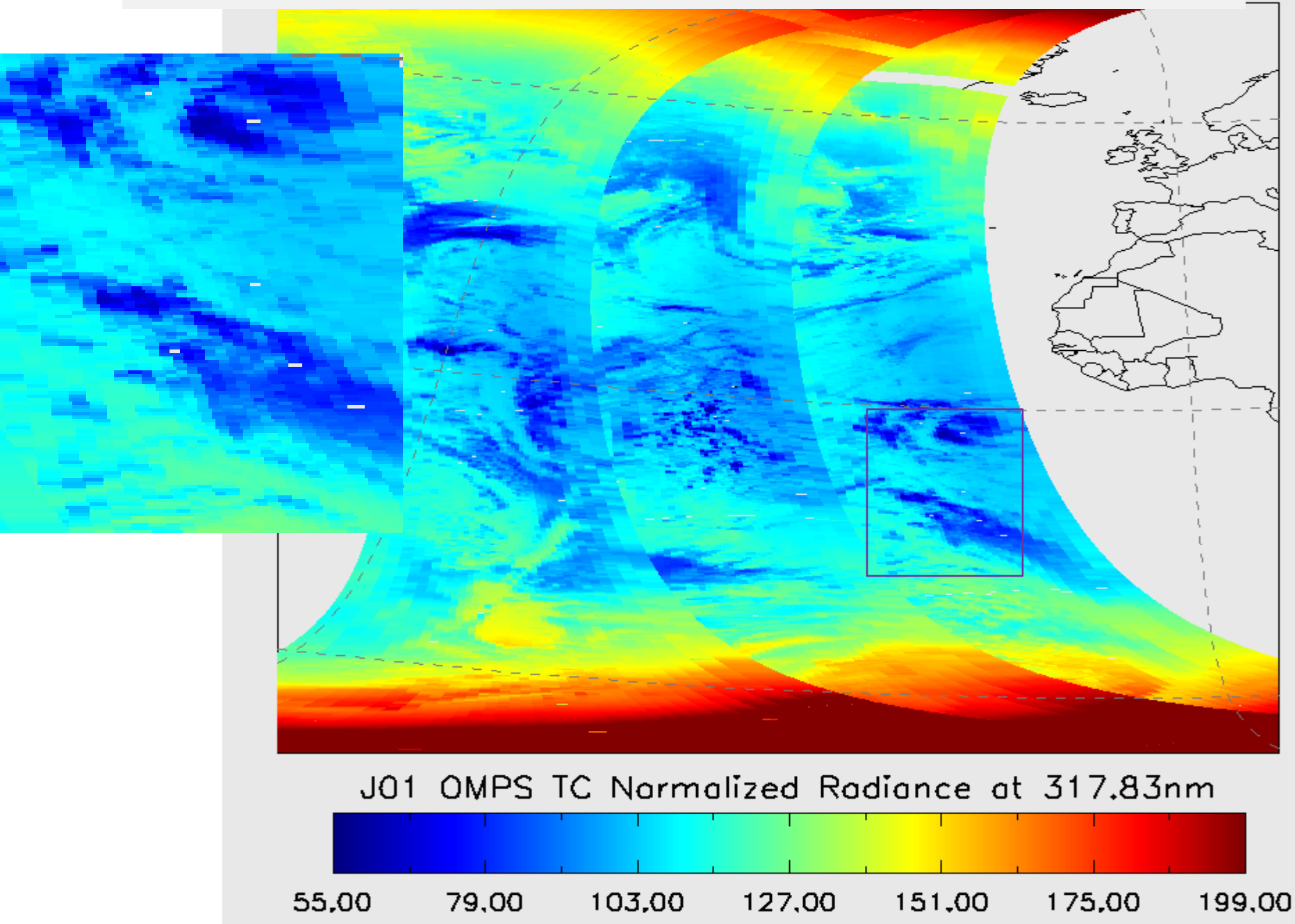
* I still need to check the S-NPP data to see how well the observed values are fit by the provided characterizations.

^ I expect/assume that the bandpasses should be consistent with the bandcenters from the analysis of the same set of laser measurements.

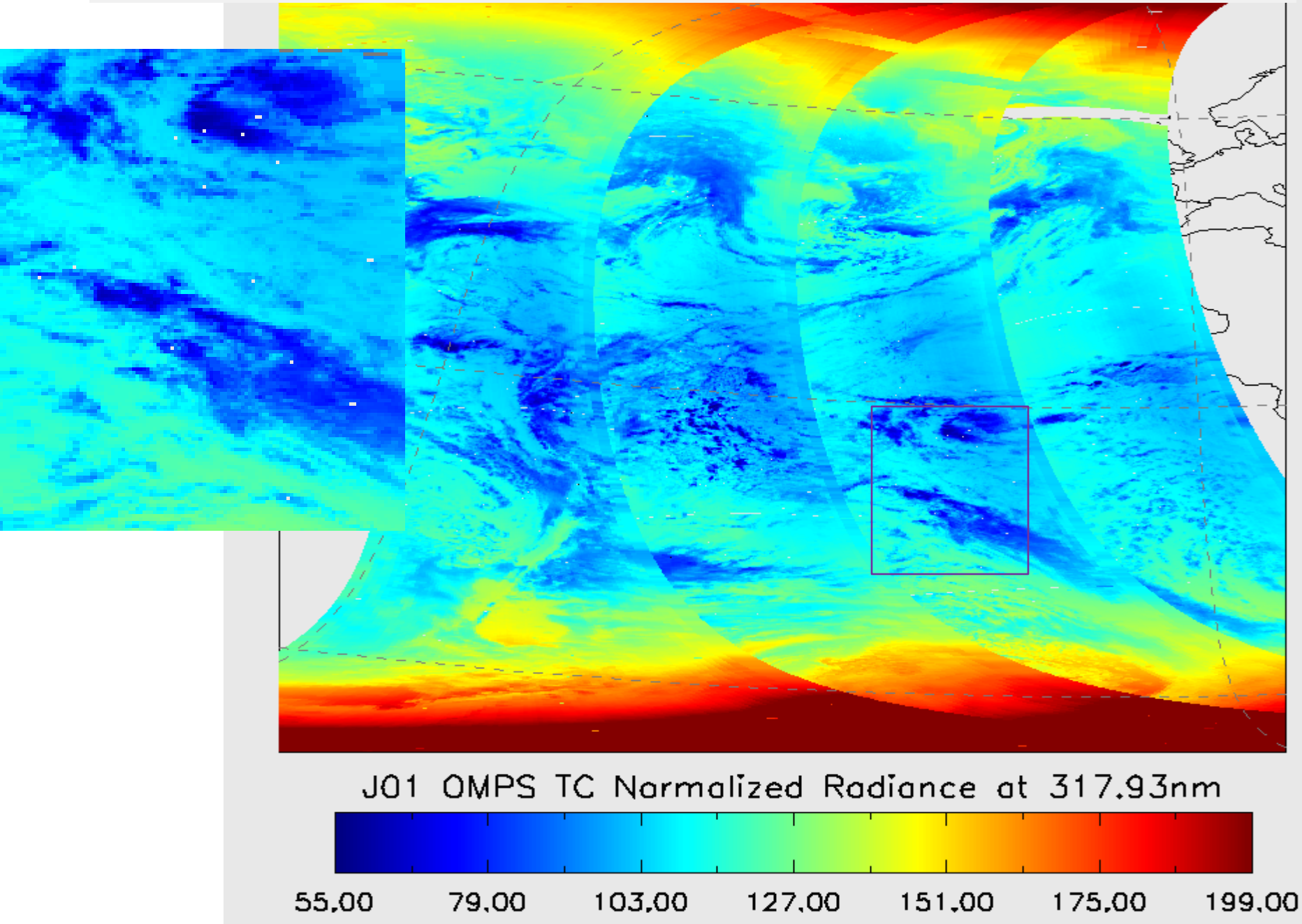
Different Topic on Higher Resolution

- How should 103 cross-track macropixels be made for OMPS NM FOVs?
  - 7 spatial pixels for all FOVs with ~17 km at nadir and much larger sizes at the edges
  - 10 spatial pixels with ~25 km at nadir (to keep consistent with 50 km NP) and progressively fewer spatial pixels off nadir keeping CT sizes less than ~30 km at all view angles

Three orbits with current low resolution 35 cross-track x 5 along-track FOVs.

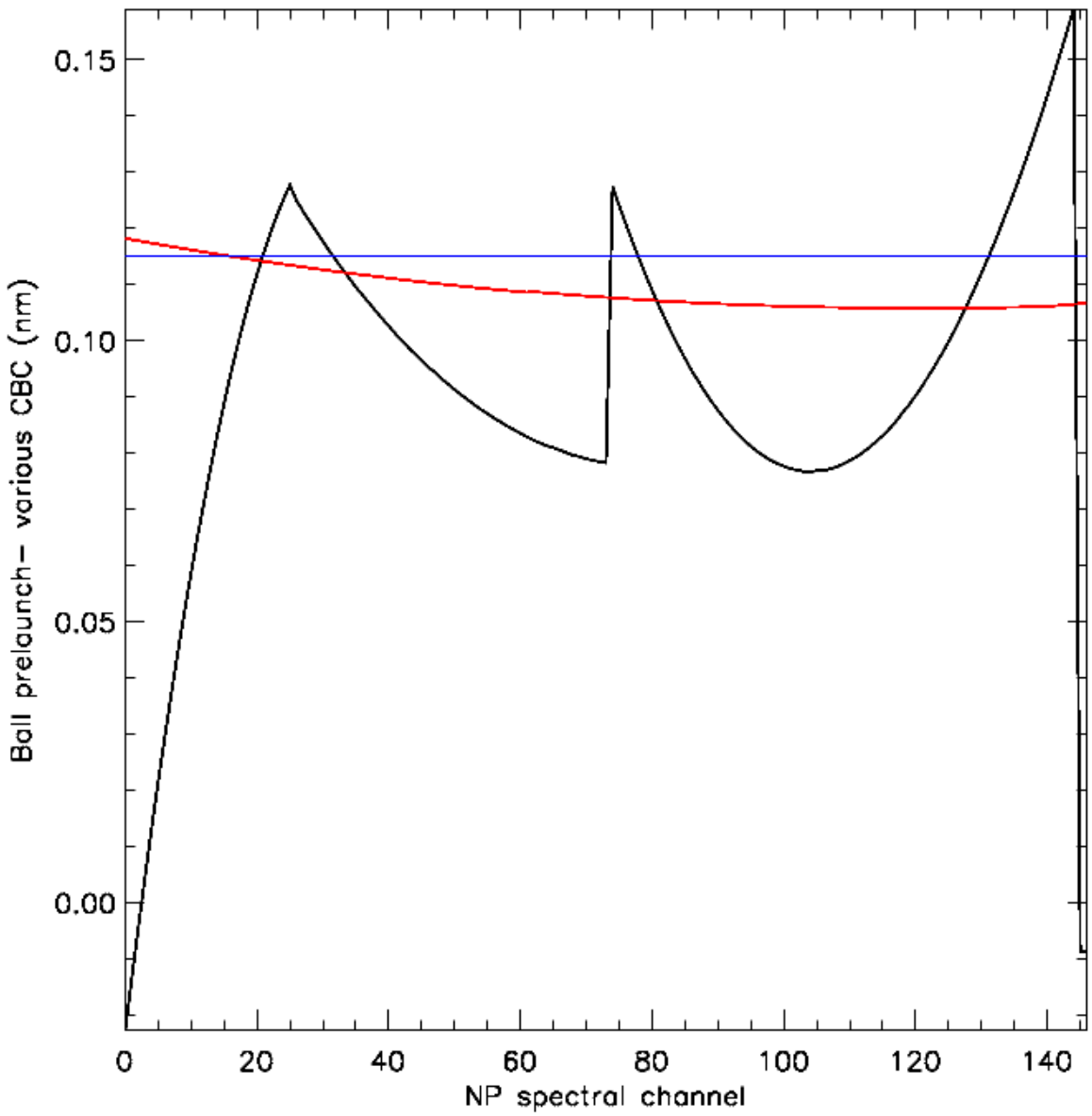


Four orbits with new medium resolution 103 cross-track x 15 along-track FOVs.



Back up slides

NP Wavelength Scale Differences with BATC



Blue = CCR 2052
= 2014 IDPS

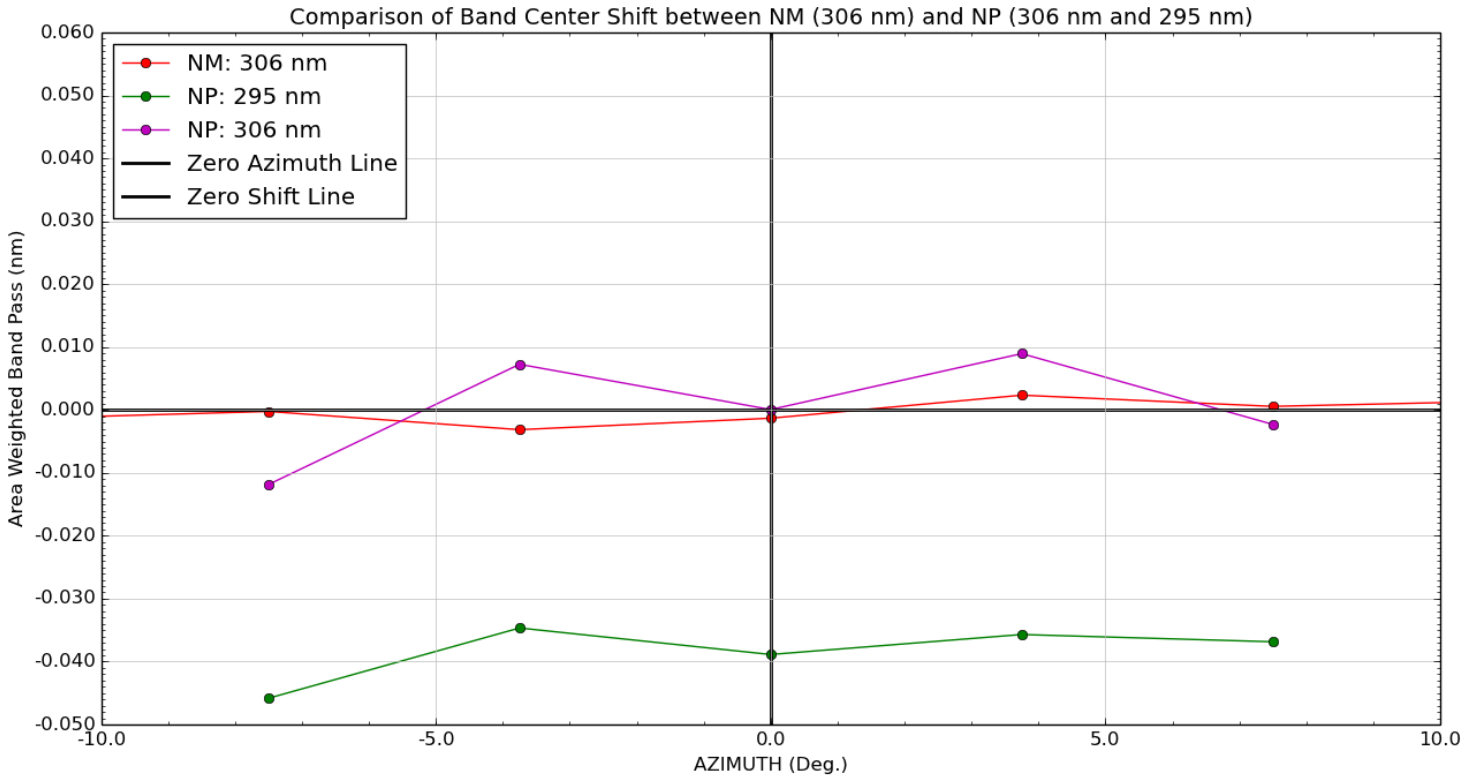
Red = Peate
2015 delivery

Black = Peate
2012 delivery

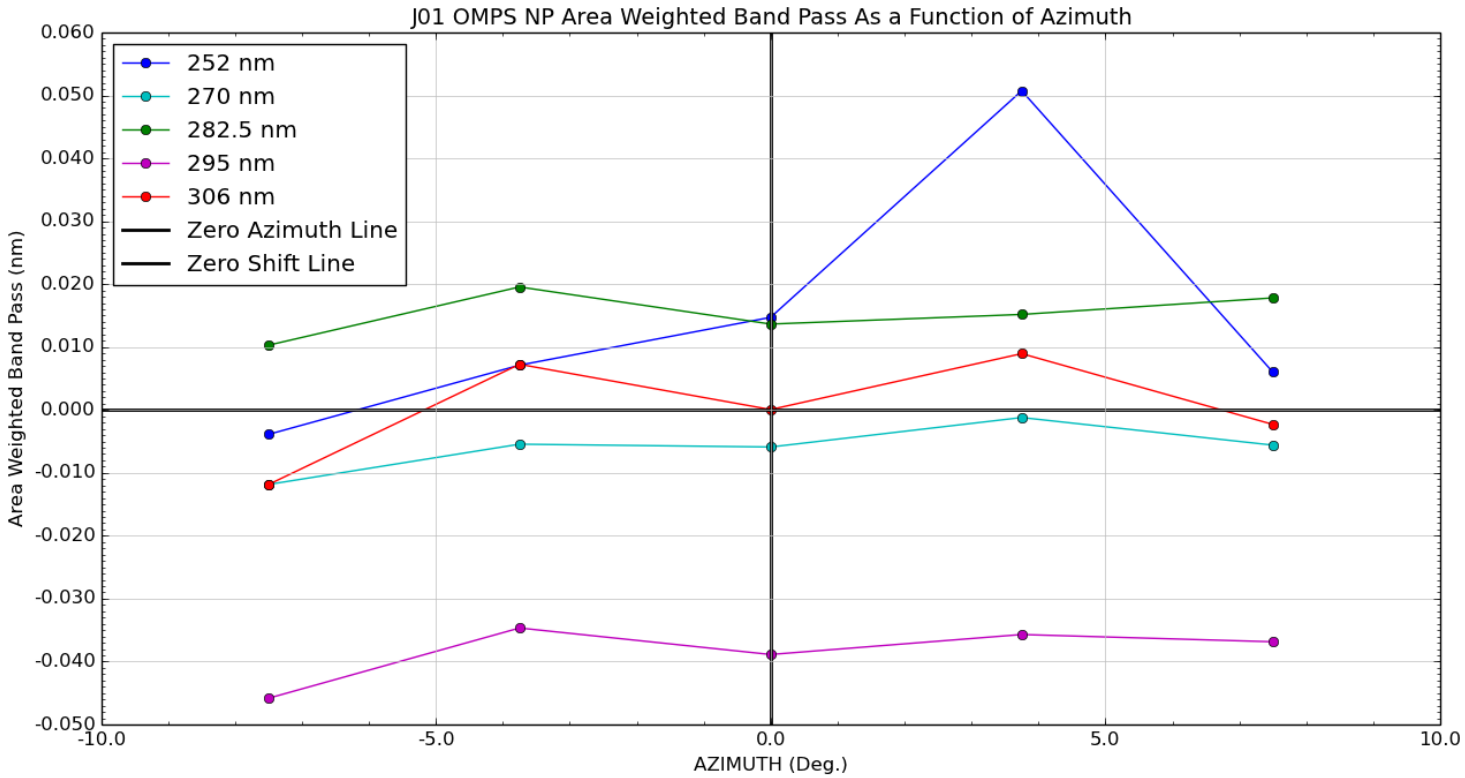
BAND PASS COMPARISON

Rama Mundakarra

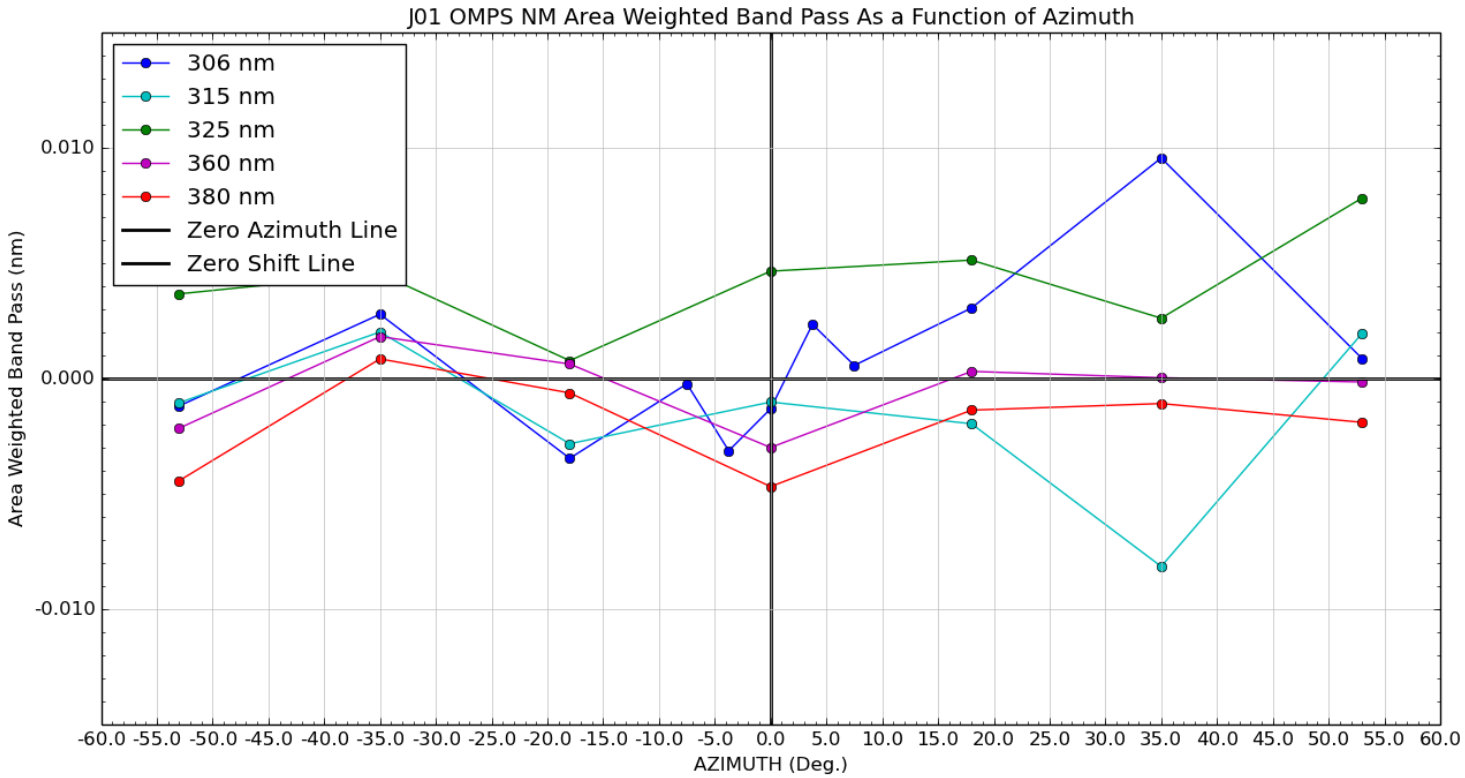
J01 OMPS NM and NP OBSERVED BAND PASS at 306 nm

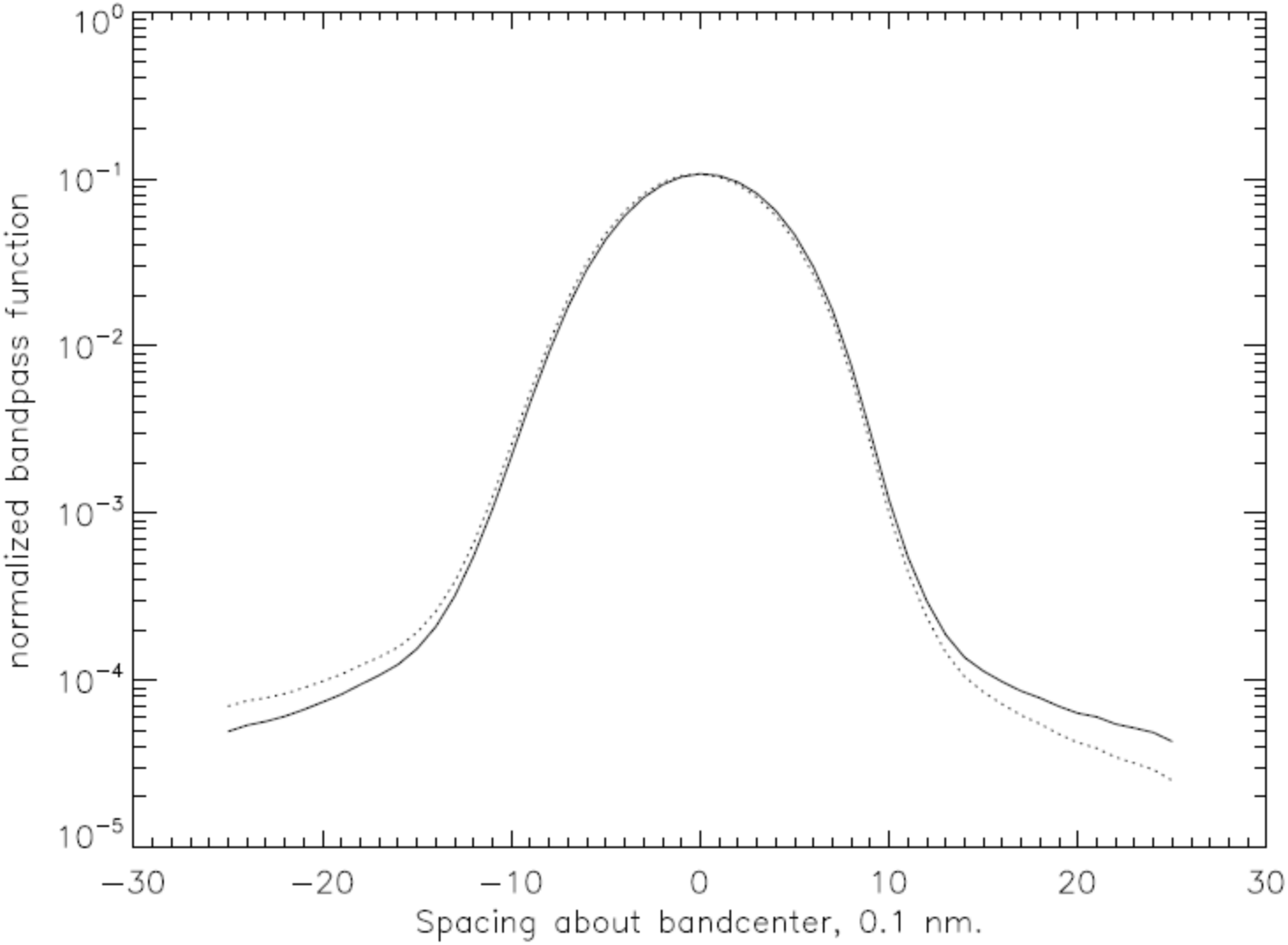


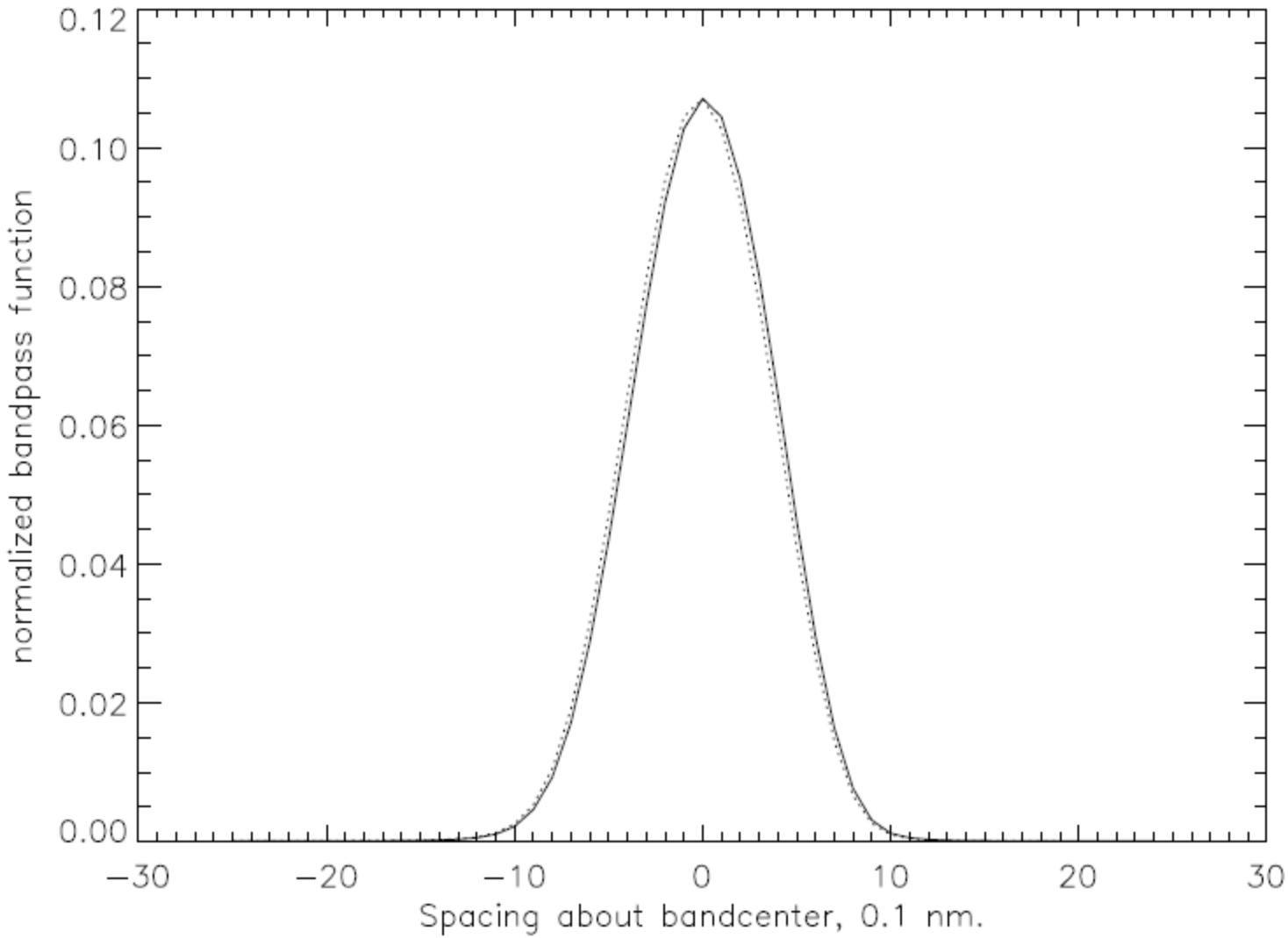
J01 OMPS NP OBSERVED BAND PASS



J01 OMPS NM OBSERVED BAND PASS




normalized bandpass function
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
−30
−20
−10
0
10
20
30
Spacing about bandcenter, 0.1 nm.


0.12
0.10
0.08
0.06
0.04
0.02
0.00
normalized bandpass function
−30
−20
−10
0
10
20
30
Spacing about bandcenter, 0.1 nm.