PACS Spectroscopy
Chop/nod LineSpec Demo

Herschel Science Demonstration Phase
Data Processing Workshop

ESAC, Madrid, Spain
15 December 2009

Roland Vavrek (HSC)

on behalf of the PACS ICC

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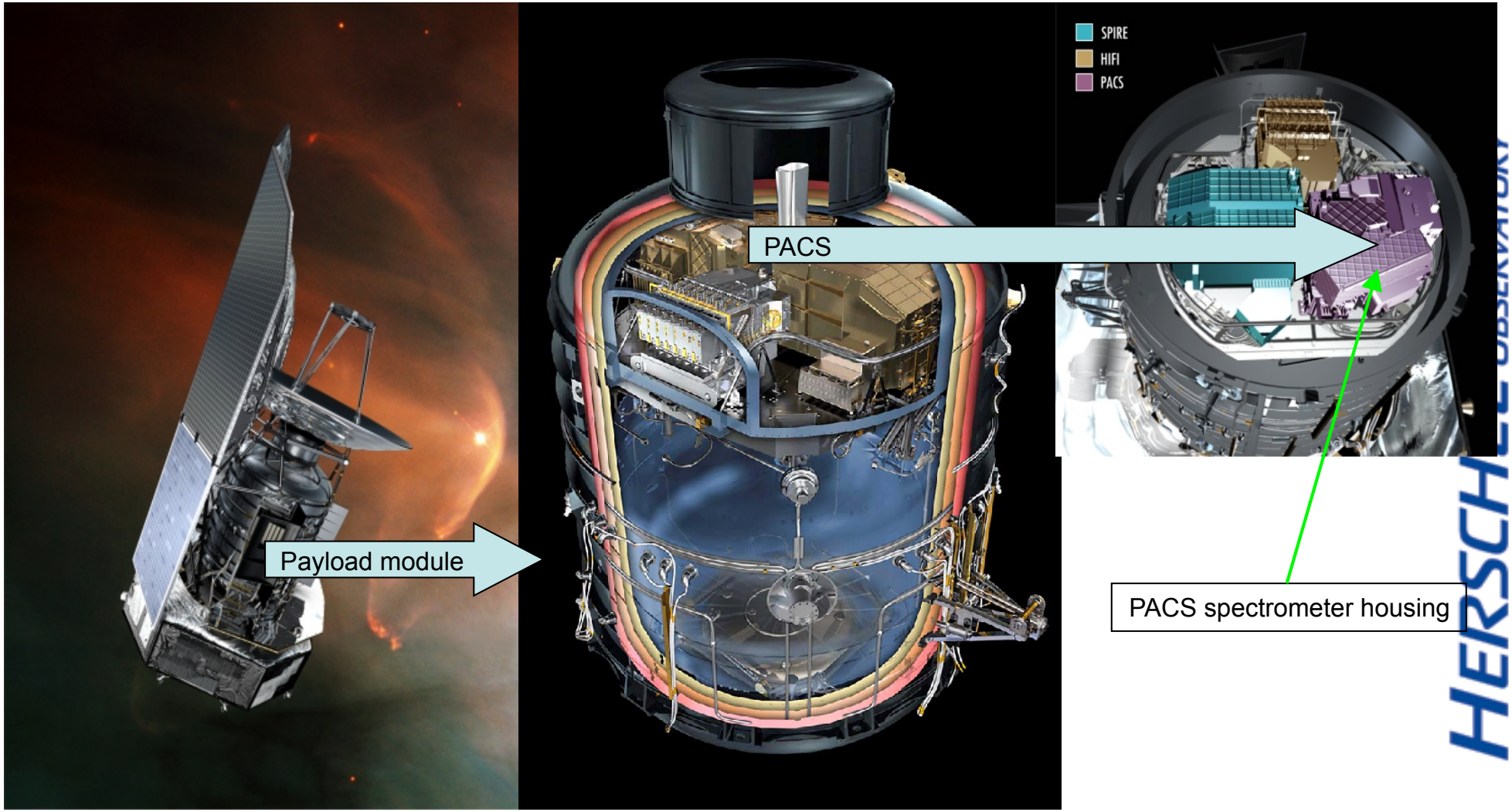
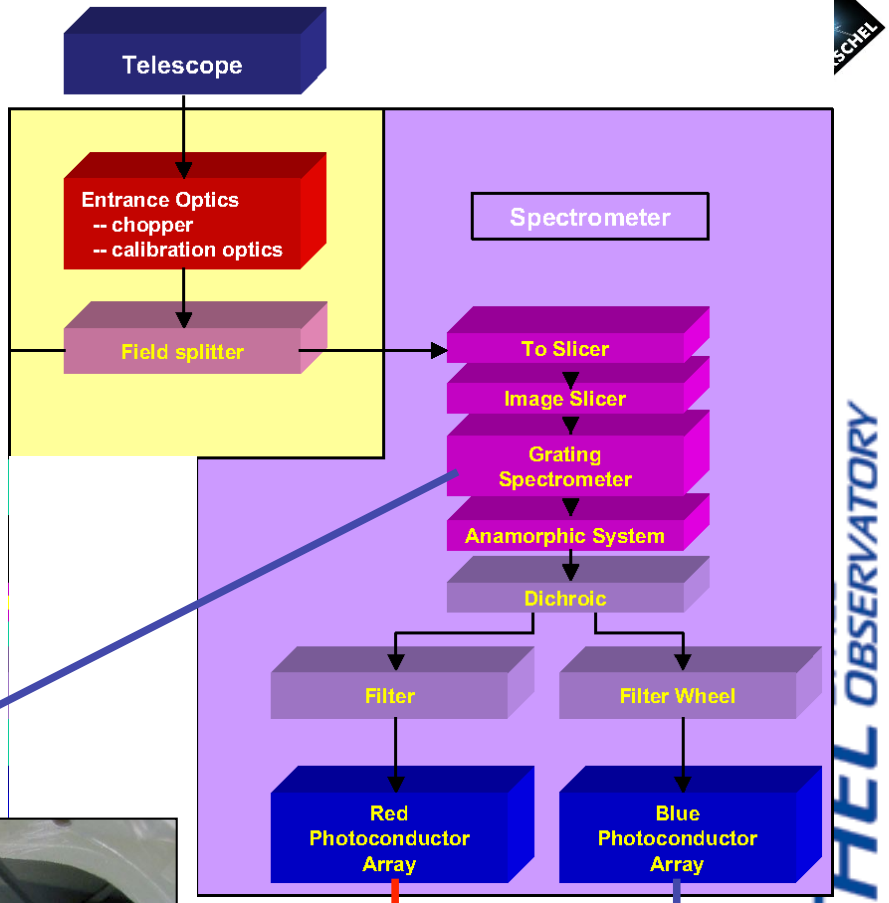
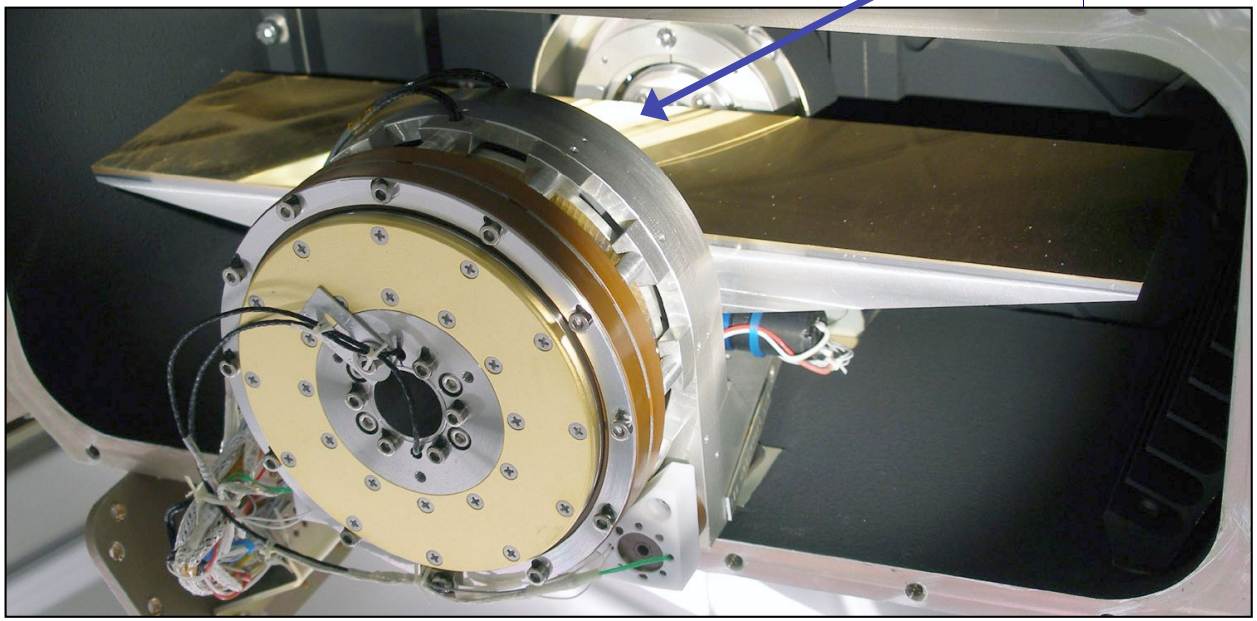
PACS Spectrometer concept

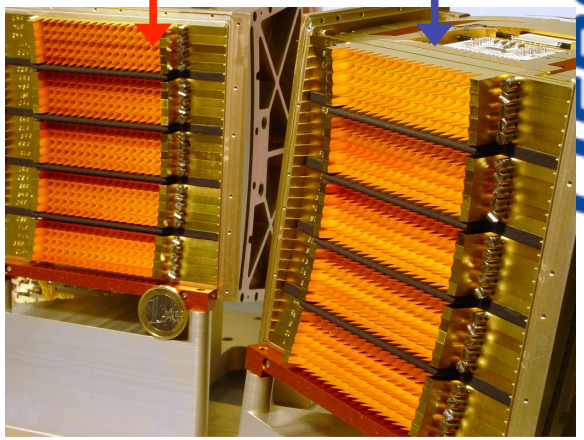


Diffraction grating spectrometer with high- and low-stressed Ge:Ga detector arrays



Grating: diffraction element used in 3 orders





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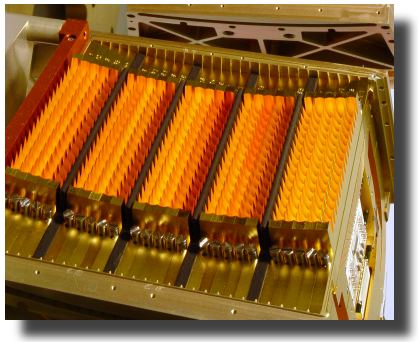
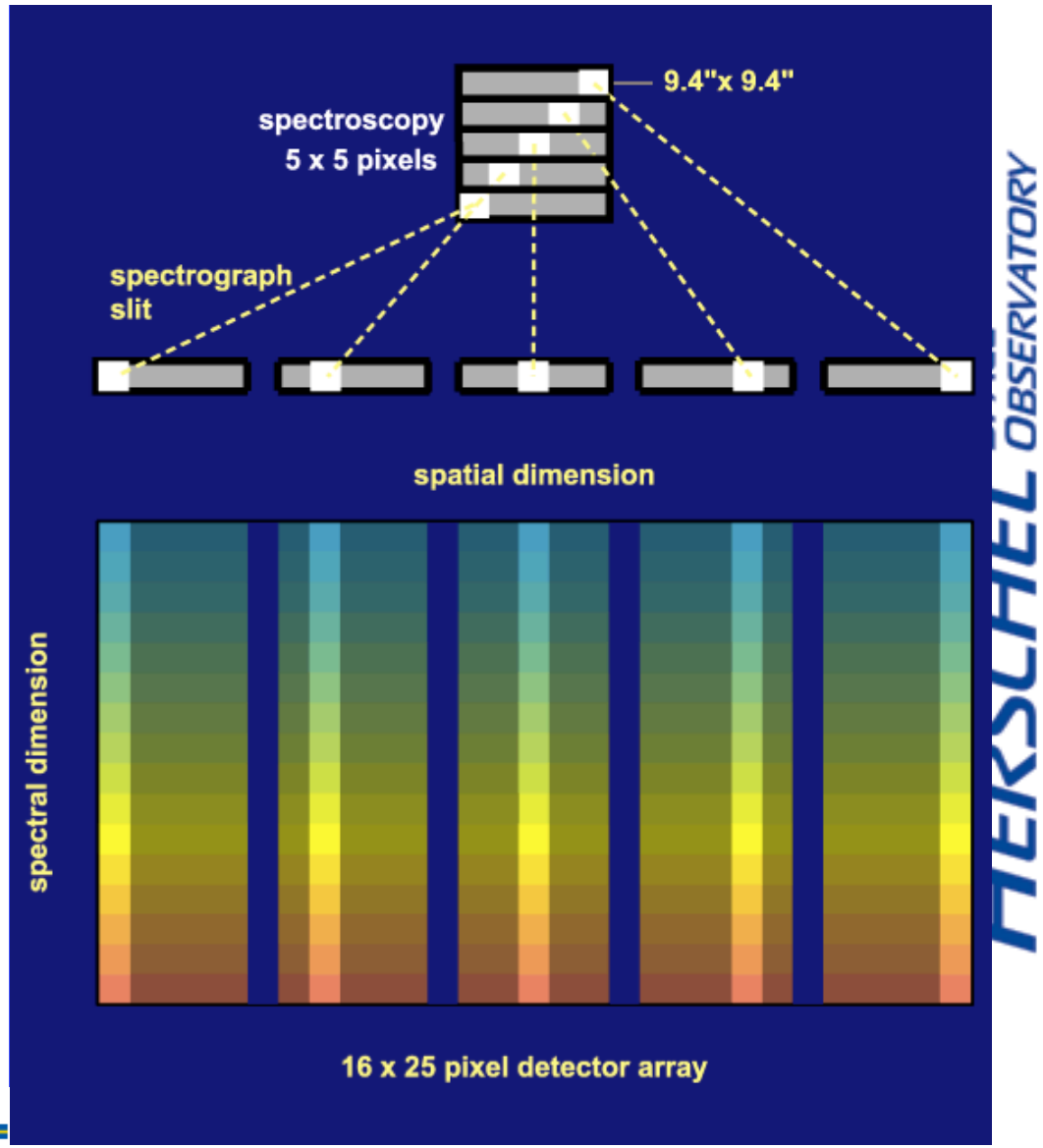
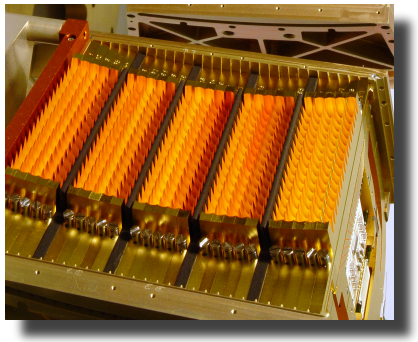
Integral-field concept



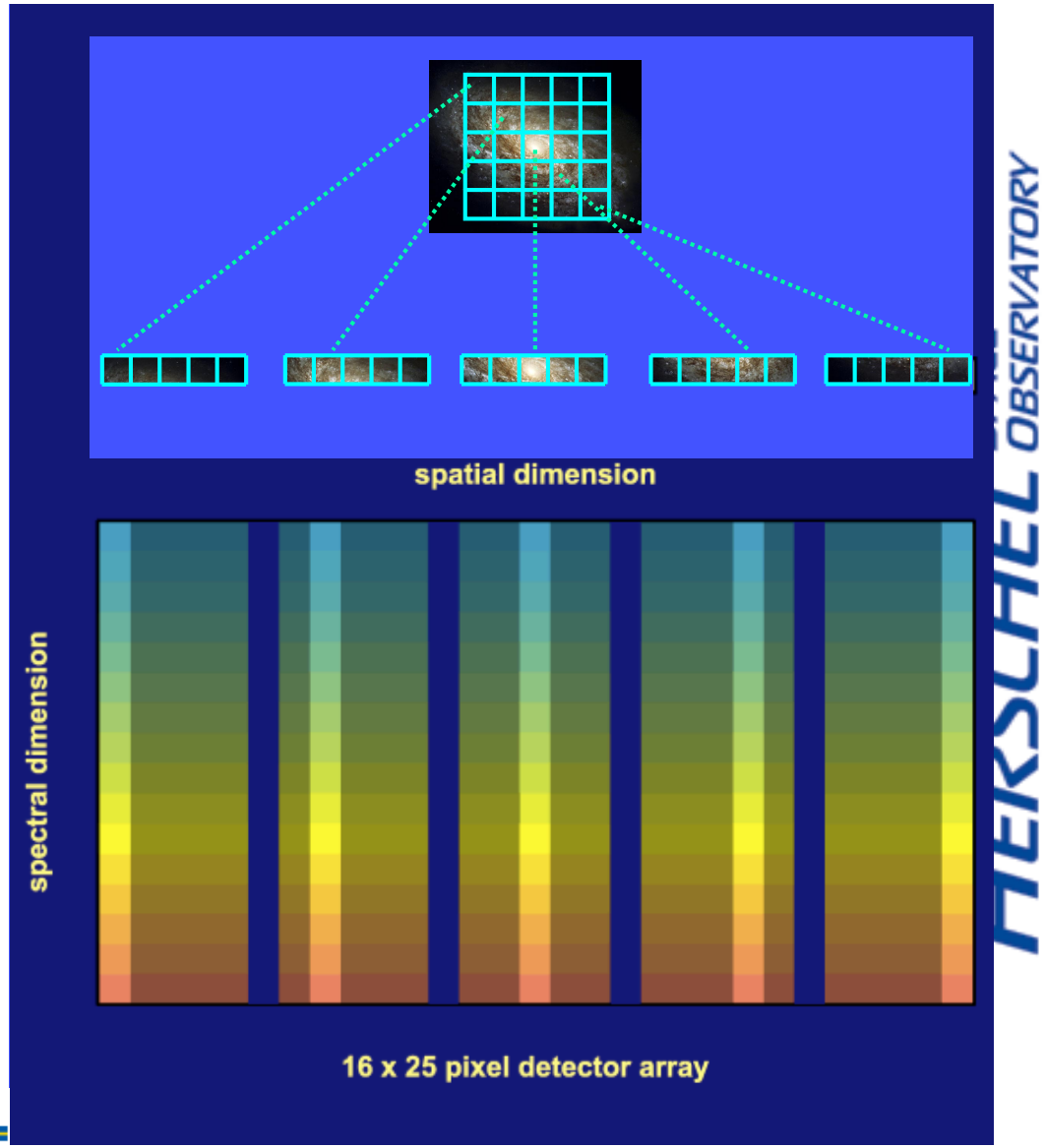
47”x47” (5x5 pixels) FOV rearranged via an image slicer on two 16x25 detector arrays



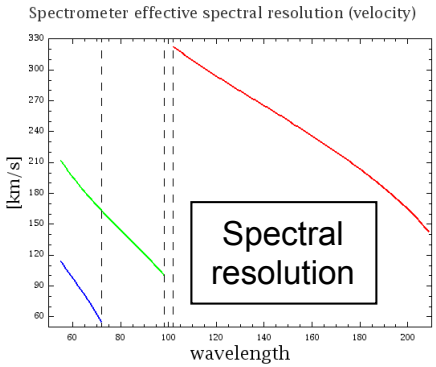
Integral-field concept

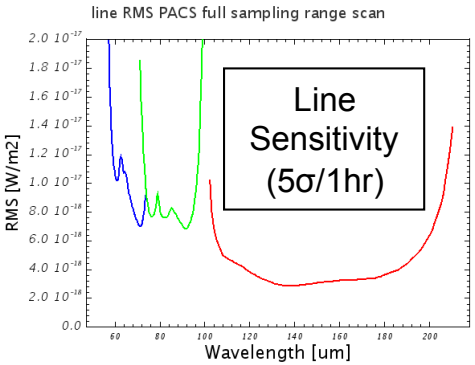


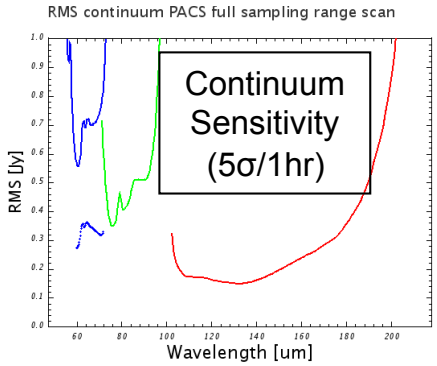
- Simultaneous 55-98 & 102-210 μm spectroscopy
- Performance:
  - λ/Δλ ~ 1500
  - Sensitivity: ~5x10-18 W/ m2 (5σ, 1h)

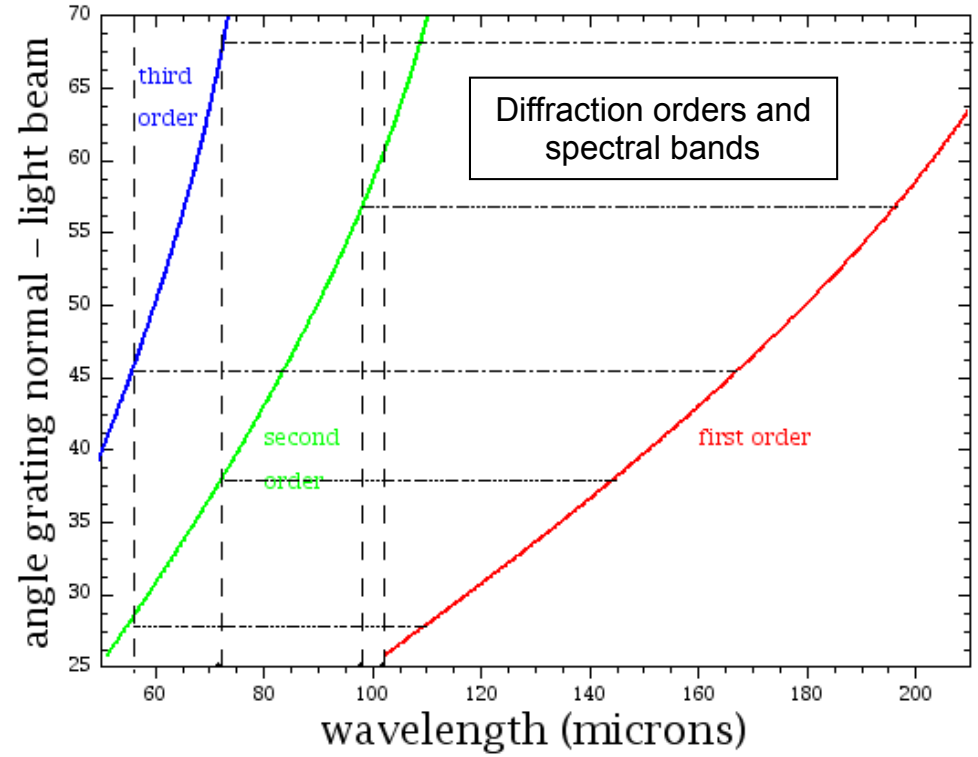


PACS spectral bands

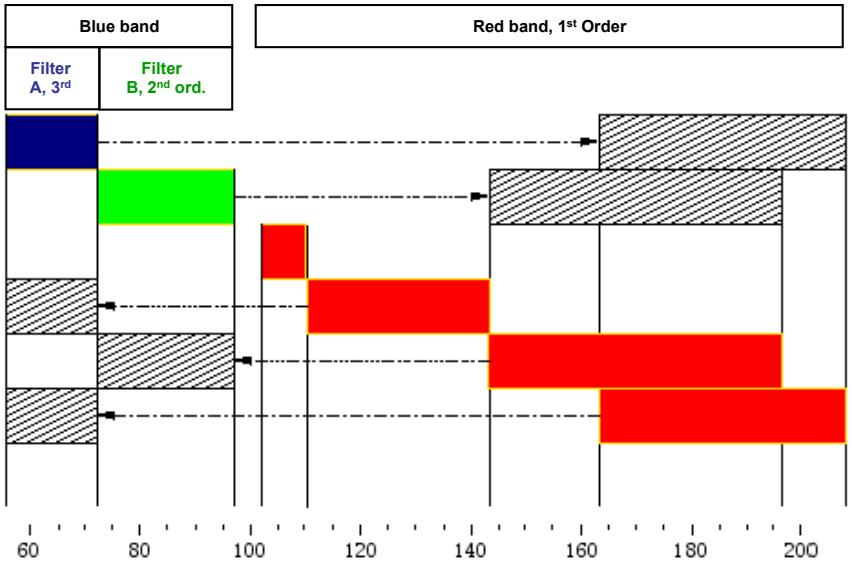








Nominal bands and parallel data



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Spectrometer Astronomical Observing Templates (AOTs)

- **Line Spectroscopy AOT:** ***observation of individual narrow lines:***

Signal modulation Techniques

  - **Chopping/nodding**
    - Pointed, dithered and mapping modes
    - For isolated sources and rasters ≤ 6 arcmin
    - Variable grating sampling for faint and bright lines
  - **Wavelength switching**
    - For mapping observations of crowded fields
    - Mandatory off-position

- **Range Spectroscopy AOT:** ***observation of extended ranges, broad lines or continuum***

Range definition

  - **Range scan** (same concept as Line Spectroscopy) *for broad lines*
  - **SED** mode (1st and 2nd orders [71-105,103-220 μm] or 3rd order [51-73 μm]) *for continuum*
  - **SED blue sensitive** mode (extended 2nd order [51-73 μm]) *for continuum*
  - **Nyquist sampling** same as SED mode for restricted ranges *for continuum and bright lines*

Signal modulation Techniques

  - **Chopping/nodding**
    - Pointed, dithered and mapping modes
    - For isolated sources and rasters ≤ 6 arcmin
    - For broad lines, multiple line coverage or continuum studies
  - **Off-position**
    - For mapping observations of crowded fields

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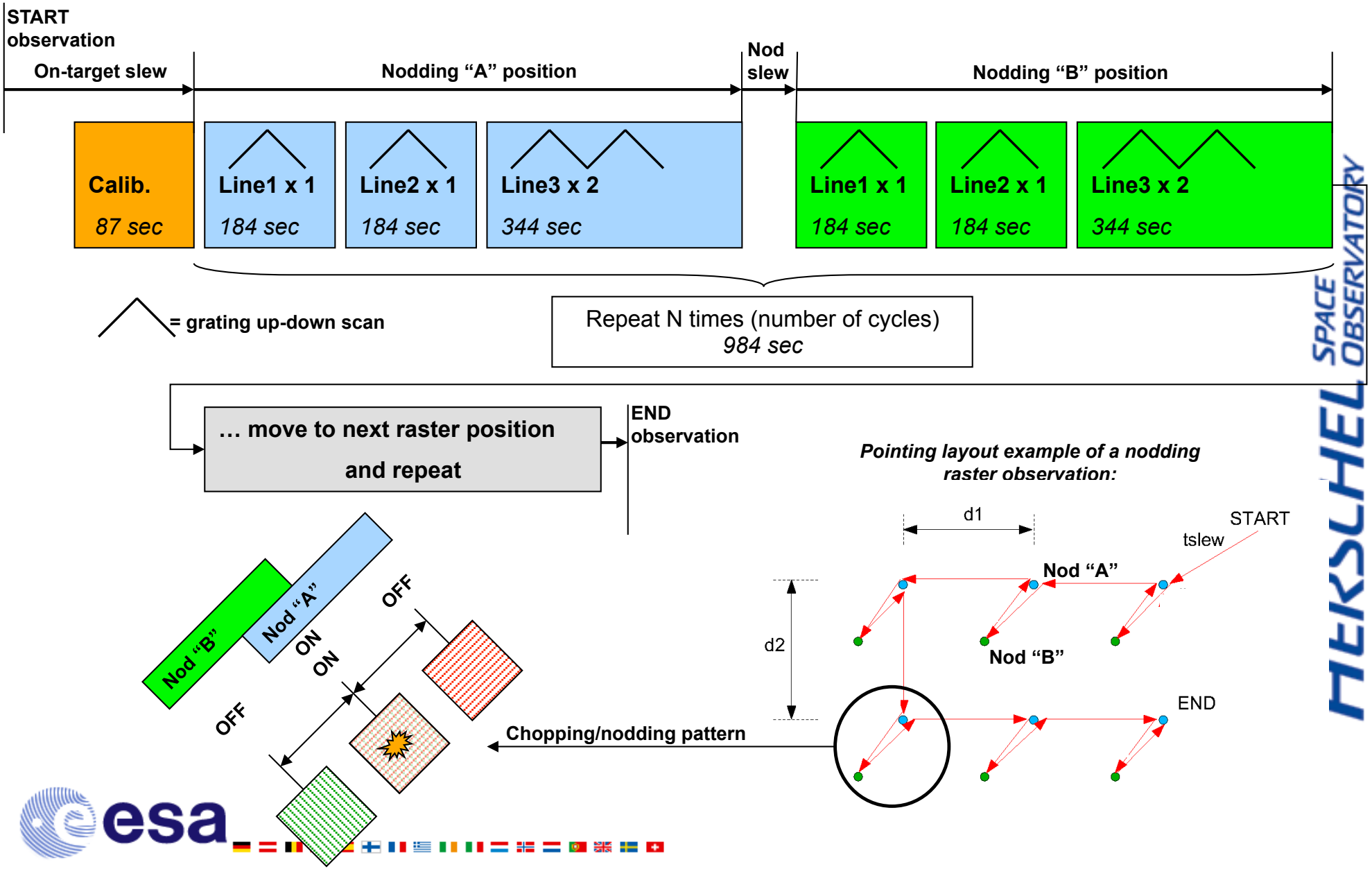
Chop/nod AOT blocks



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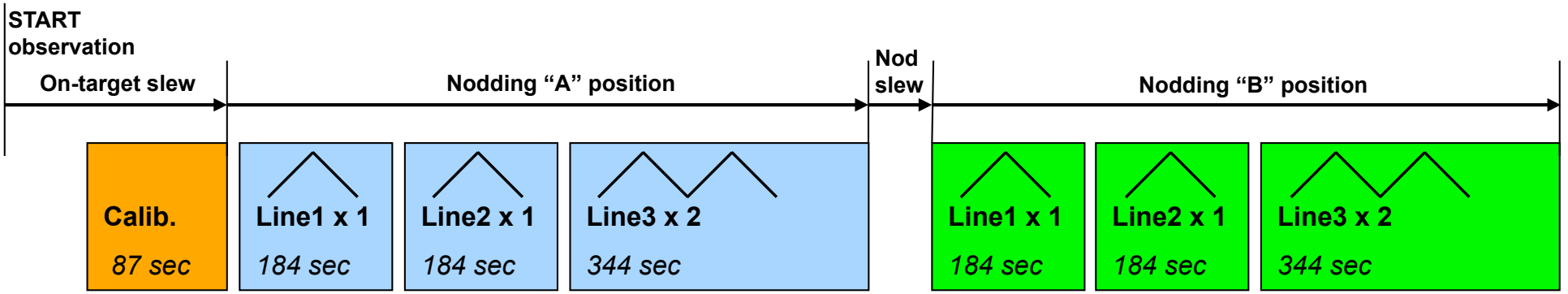
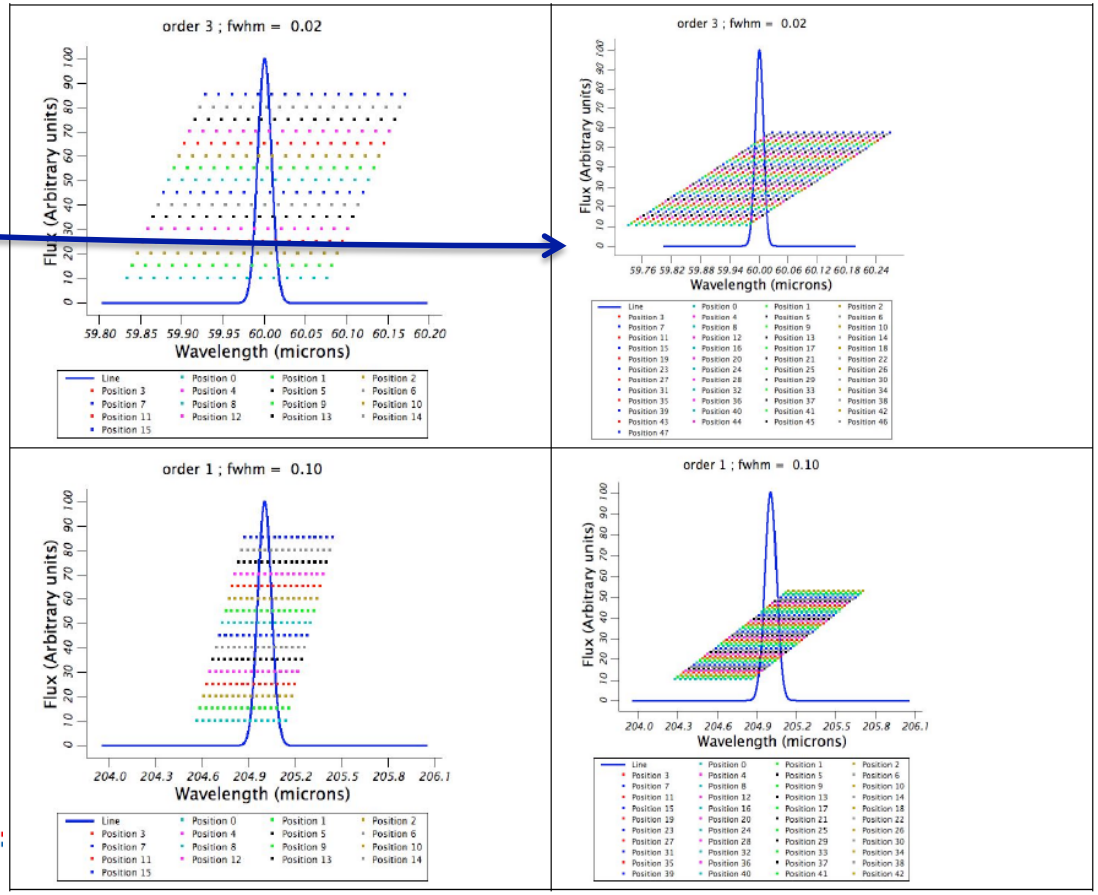
Chop/nod AOT blocks



= grating up-down scan



Grating sampling in a single up-scan for bright line and high sampling modes

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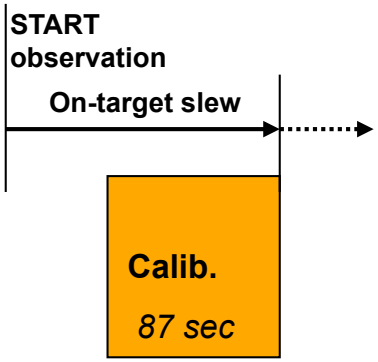
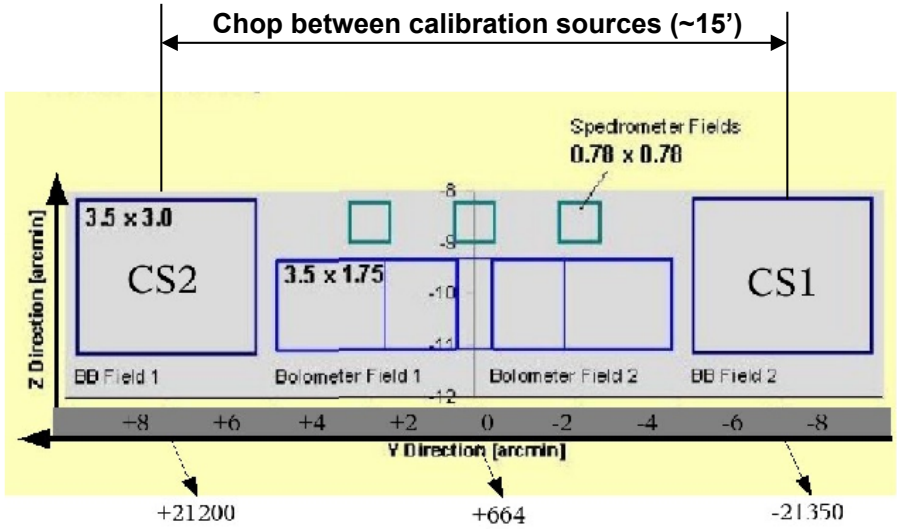
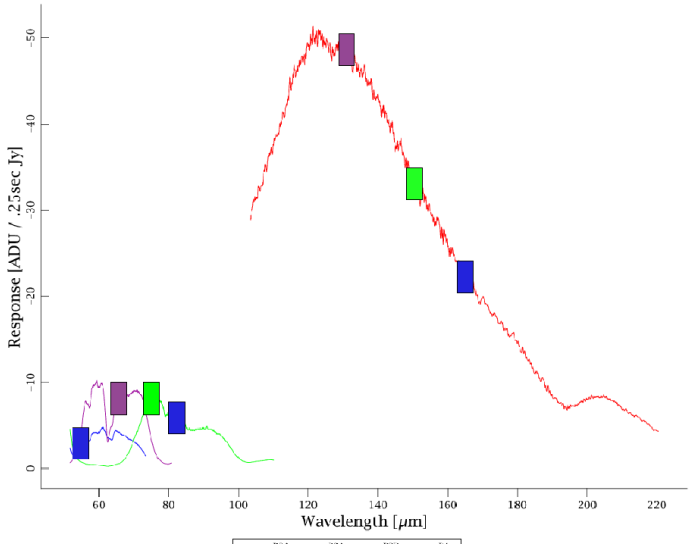
AOT calibration block



- On-target slew calibration block(s) on key wavelengths
- Calibrate the response on one point of the RSRF, we believe the RSRF does not change (a lot) over the mission lifetime
- Chopping between the calibration sources and grating up/down scans
- Homogeneous dataset over the entire mission lifetime
- One key wavelength per diffraction order:
  - flat part of the RSRF
  - close to the most frequently used lines



Key wavelengths
on the Relative Spectral Response Function (RSRF)



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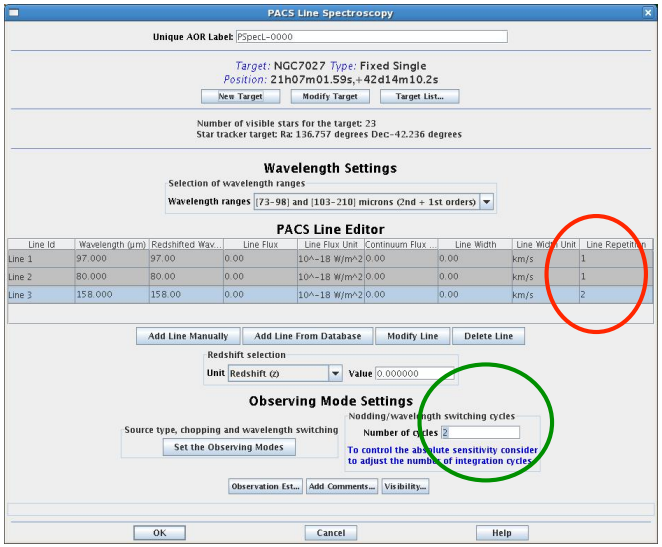
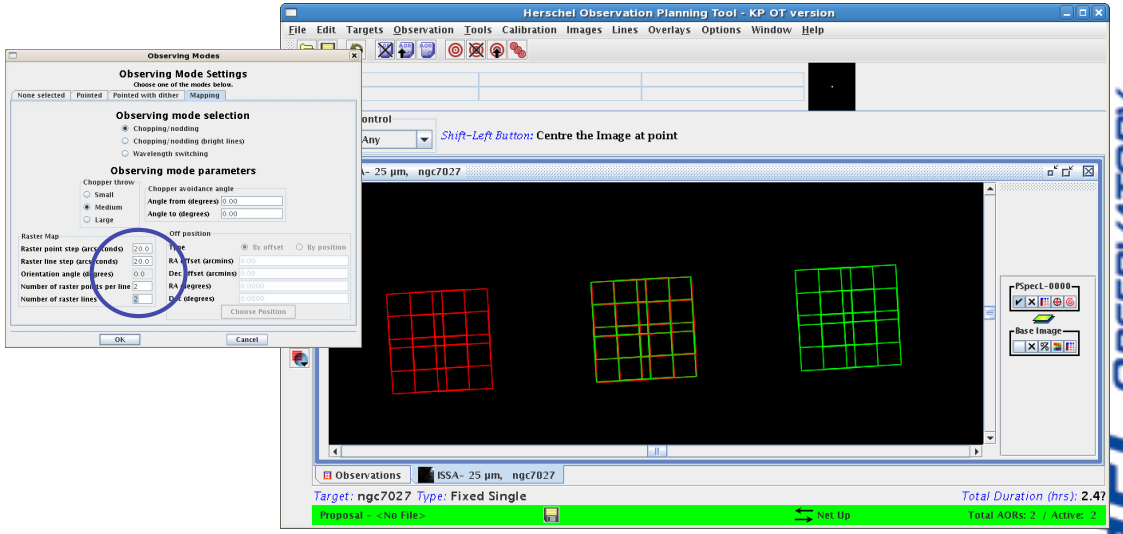
… and how blocks are defined in HSpot

Nodding blocks

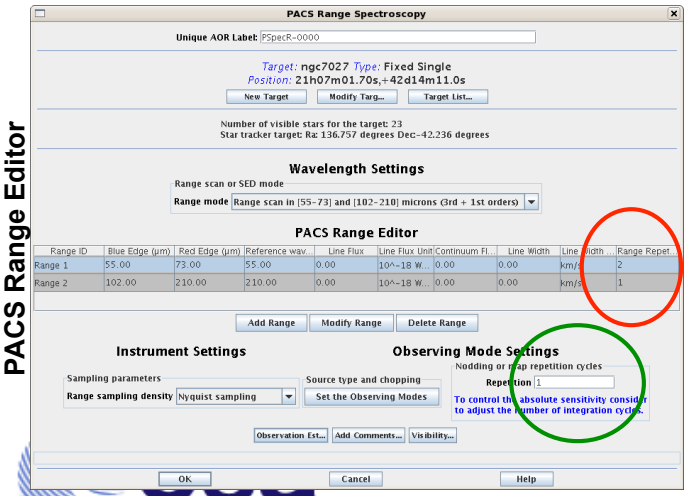
PACS Line Editor



Pointing blocks



PACS Range Editor



Depth of the observation is set via repetition factors:

- *Line/Range repetition for relative Line/Range strength, total number of repetitions is ≤ 10 to limit the maximum block duration*
- *Single repetition in SED mode block*
- *Nodding/switching/mapping cycles define how many times a block has to be repeated*
- Overlap between pointing blocks (d1, d2 step size < 47”)

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Data Structure (Obs. Context)

- **Level-0**
  - + instrument detector readout timeline
  - + instrument housekeeping
  - + other instrument-specific data
- **Auxiliary**
  - + Pointing
  - + Orbit
  - + spacecraft housekeeping
  - + ...
- **Level-1**
  - + All instrument effects taken out
- **Level-2**
  - + Rebinned, publishable products
- **Calibration**
  - + Calibration products used to process level-1 and level-2 delivered by the HSA

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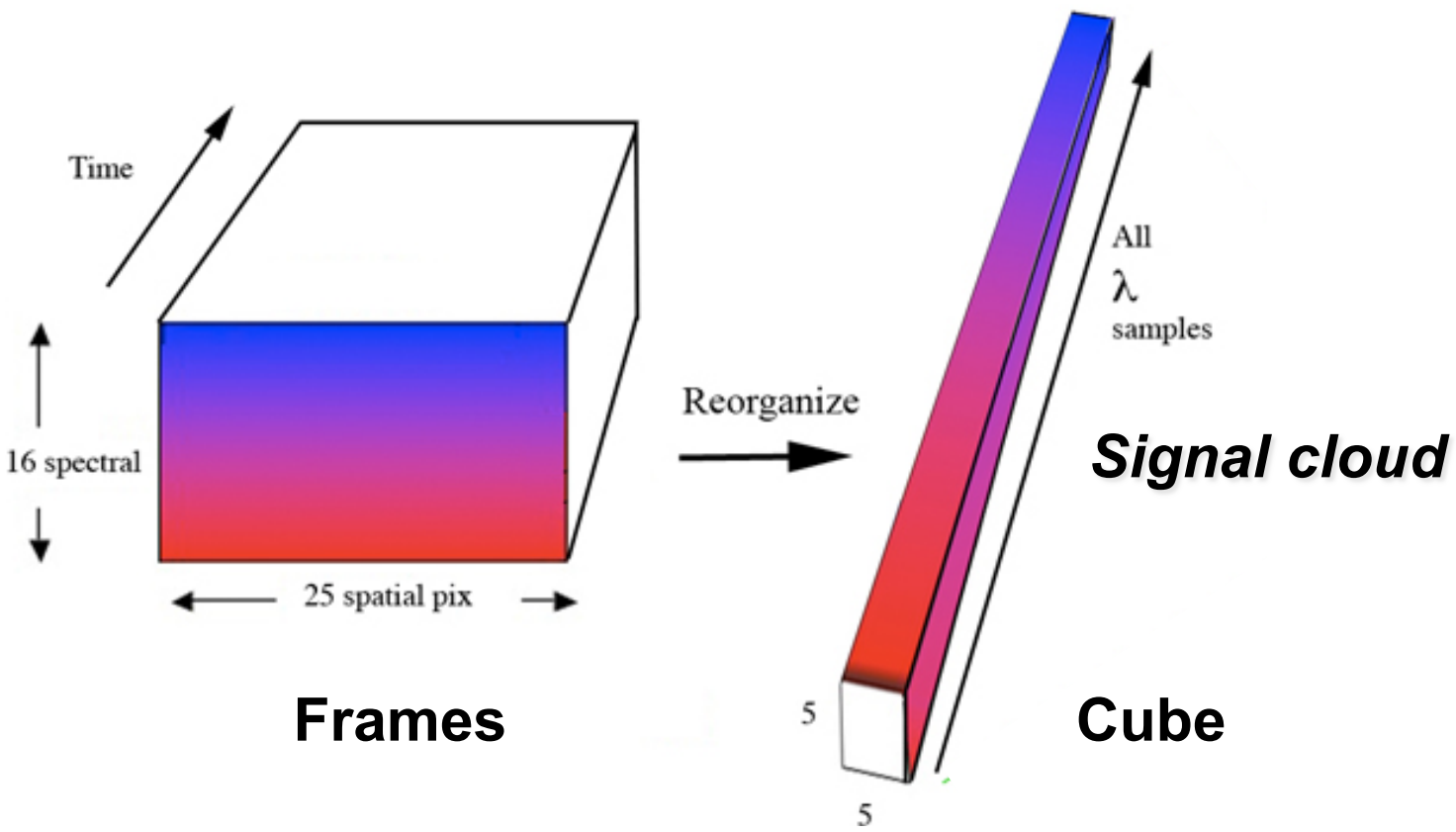
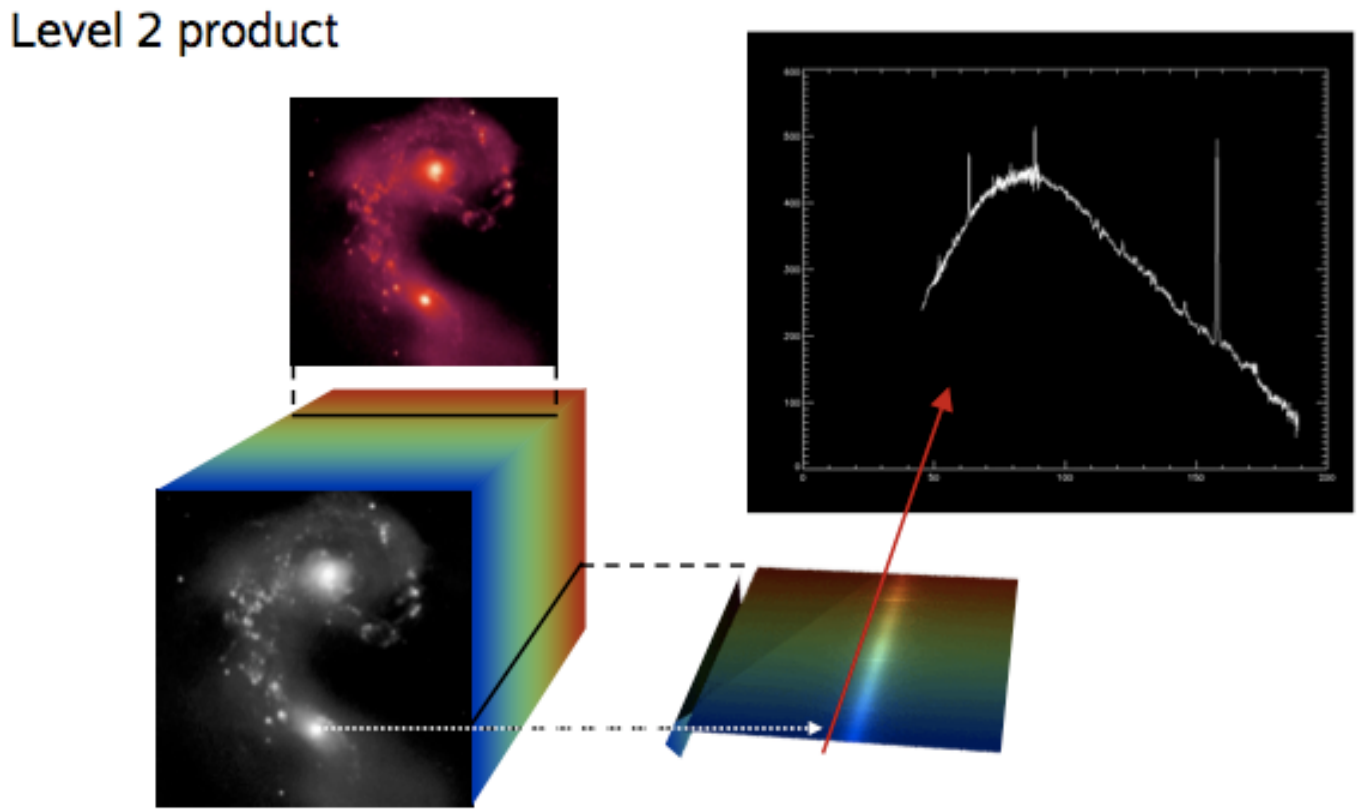
PACS frames and cube – Level 1



25x18xN ⟶ 5x5xNX16

Rebinned cube and projected cube – Level 2



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Demo package on your machine

- /home/.hcss/lstore/1342187201

- */home/.hcss/lstore/1342187202*
- */home/.hcss/lstore/1342187203*
- */home/.hcss/lstore/1342187204*

- */IN/YOUR/WORK/DIRECTORY/*
- demoPacsSpectro_chopNod_ipipe_15DEC2009.py
  - Change “homedir” in the script to */IN/YOUR/WORK/DIRECTORY/*

- demoPacsSpectro_chopNodSED_ipipe_15DEC2009.py
- demoPacsSpectro_chopNod_tools_15DEC2009.py
- gridFunctions.py

- pdrg.pdf DOCUMENTATION / PIPELINE HOWTO

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Documentation: pdrg.pdf

PACS Data Reduction Guide

Issue dev, Version 1.2, Document Number:
09 Dec 2009


```
  titleText="title",line=0)
p.xaxis.title.text="Wavelength [$\mu$m]"
p.yaxis.title.text="Signal [Jy]"
```

Now, depending on what type of observation you are looking at (e.g. SED vs. line scan) and at what stage you are looking at your plotted spectrum, it is possible that you will see something that does not look quite like right. When you plot using the command above, you are plotting everything that is in your dataset. This can include: data from the calibration sources (take at the key wavelengths only); multiple spectra/spectral lines if your observation includes more than one field-of-view (for rastered/dithered observations); data taken while the telescope was slewing; data from the two chop positions and from the two nod positions (chops and nods are not combined until the next stage of the pipeline). In addition, if you have several grating runs (if you sampled the wavelength domain more than once), then each spectrum will be multiple and it is possible that the spectra from multiple grating runs will not be exactly at the same "counts" levels. So, if you have a line scan and you see this:

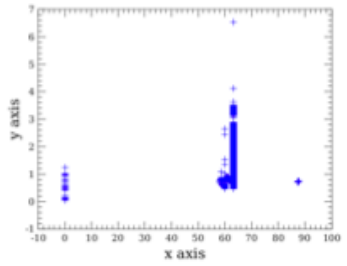

Figure 3.2. Level 0.5 line scan spectrum: entire dataset

try to zoom in on the wavelength you requested in your AOR, when you should see this:

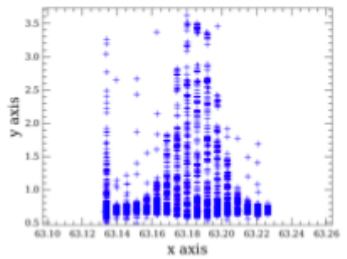

Figure 3.3. Level 0.5 line scan spectrum: zoom

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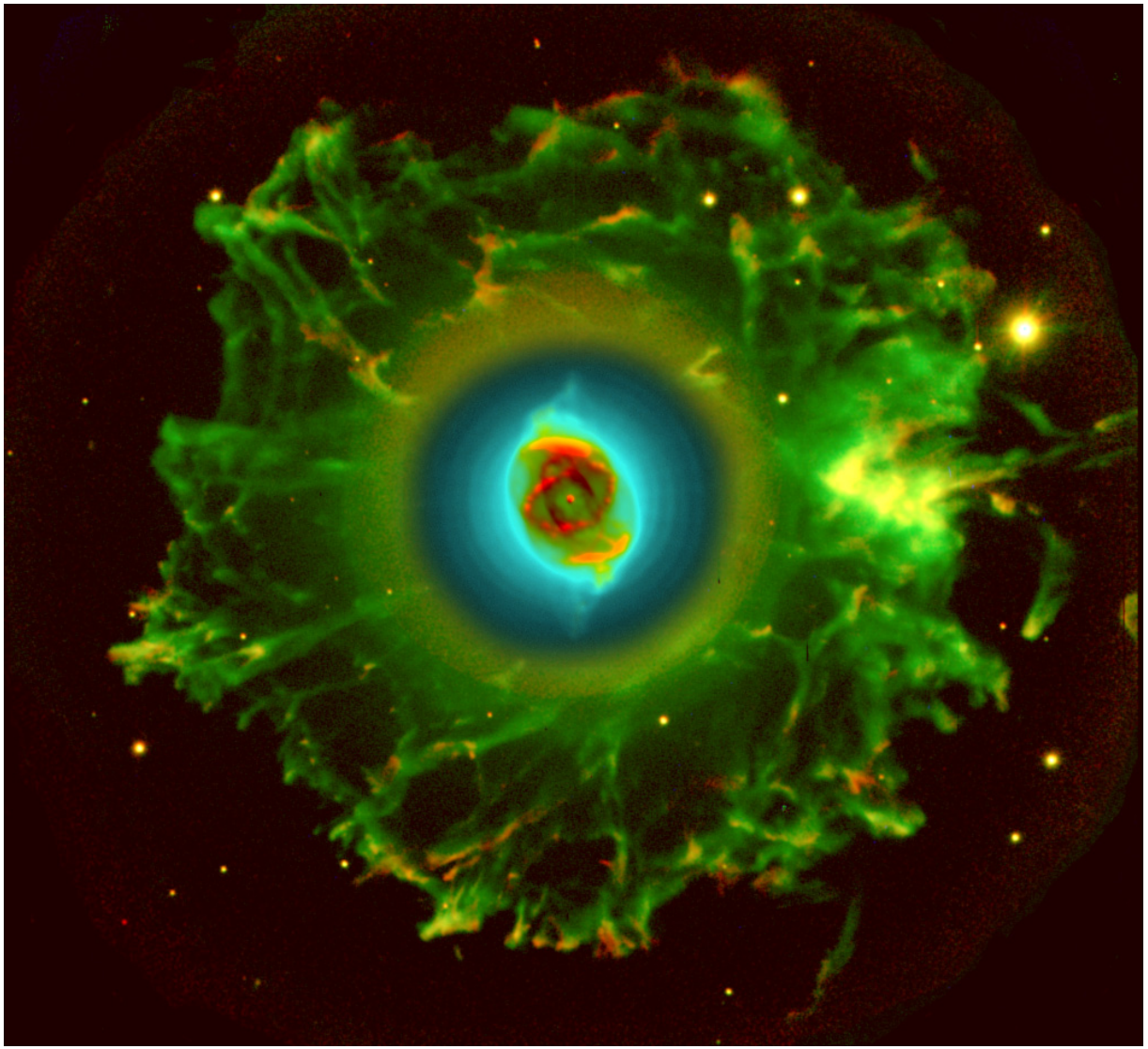
Demo data: NGC 6543
The “Cat eye” planetary nebula



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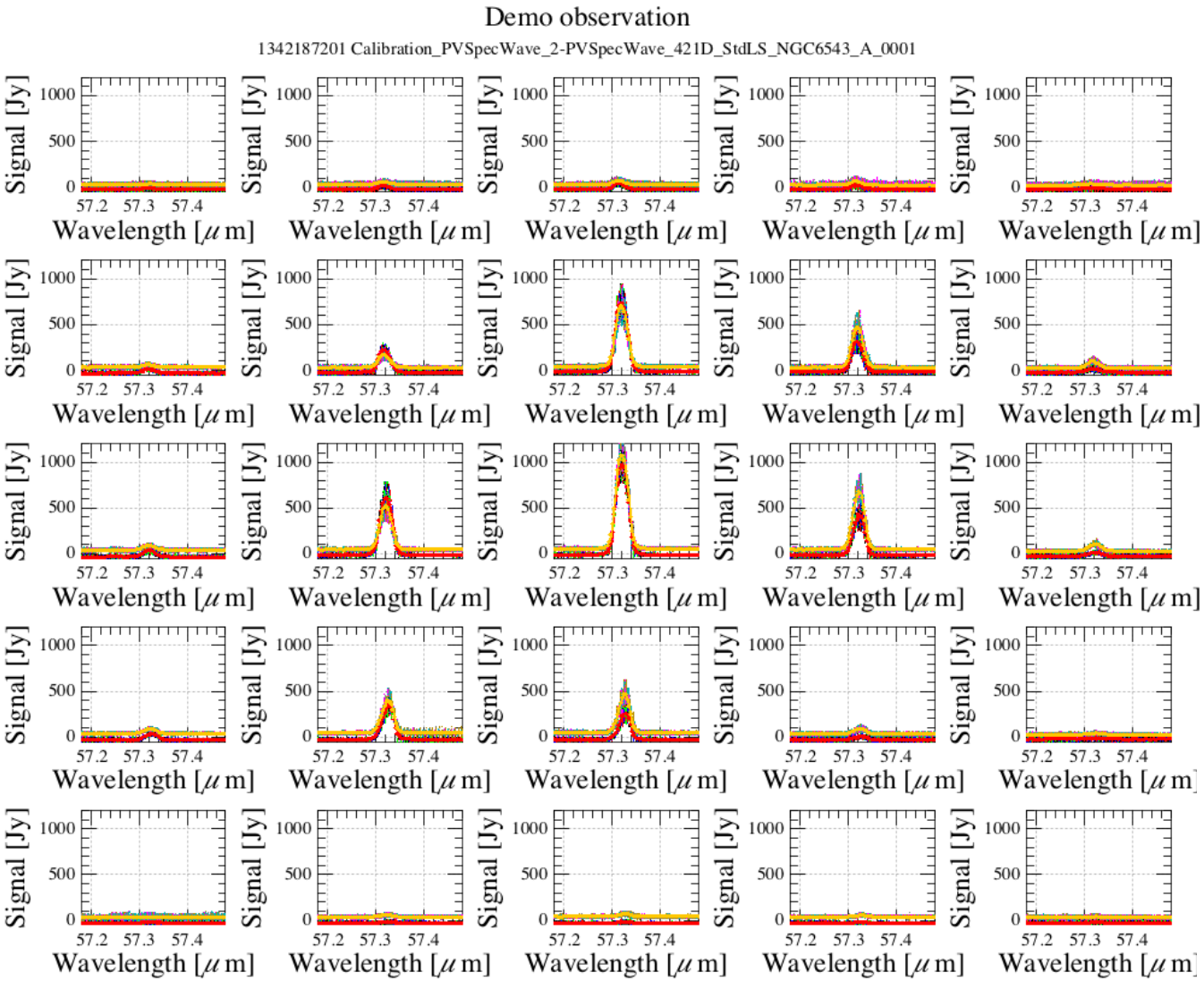
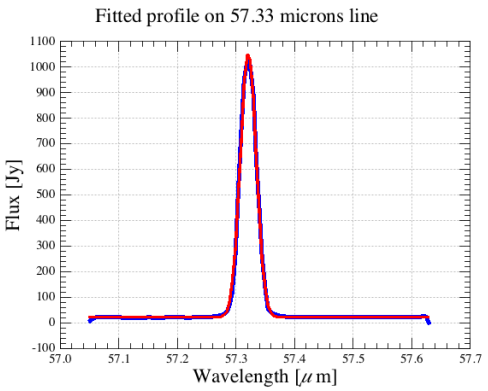
Demo data: NGC 6543



57.3 microns:
N III 2P3/2-2P1/2



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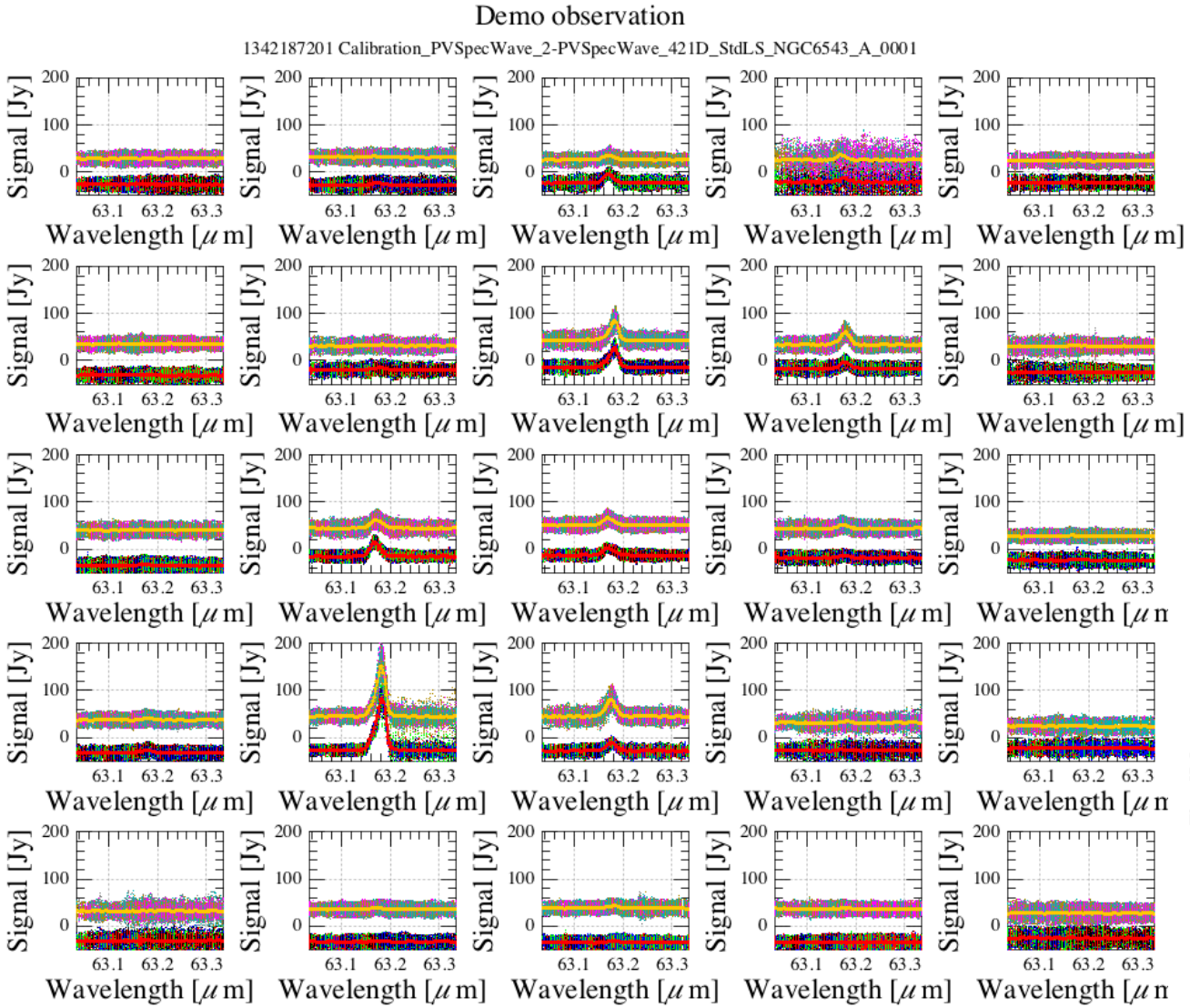
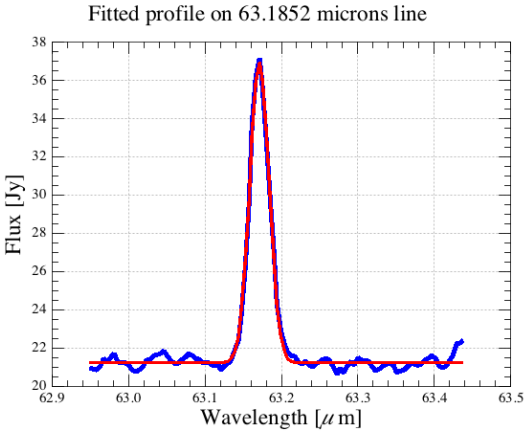


63.18 microns:
O I 3P1-3P2



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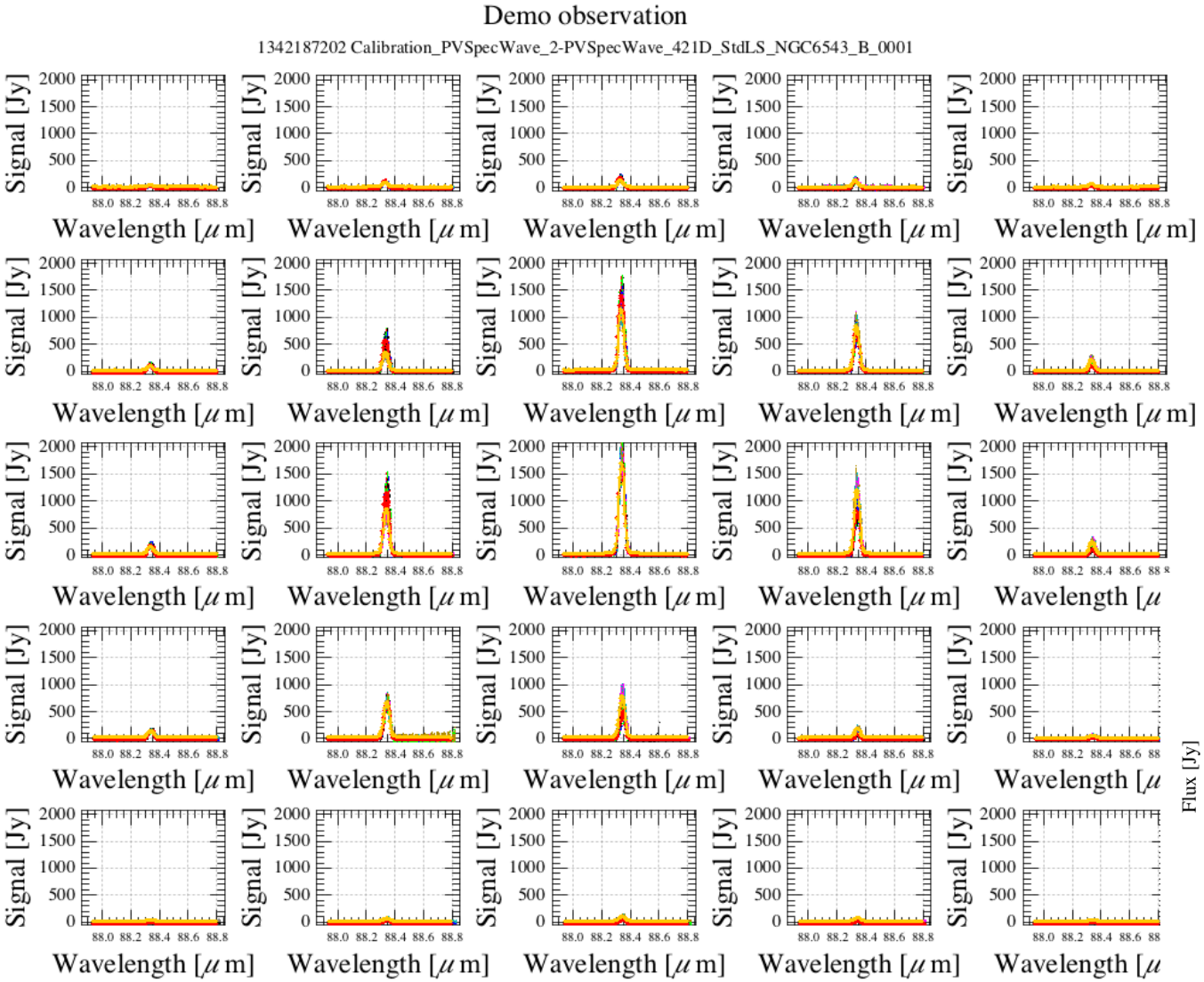
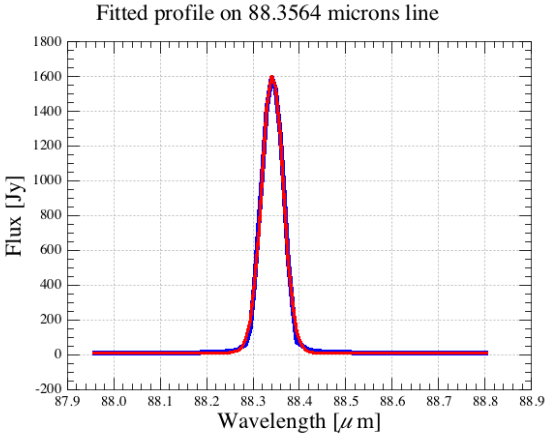
Demo data: NGC 6543



88.36 microns:
O III 3P1-3P0



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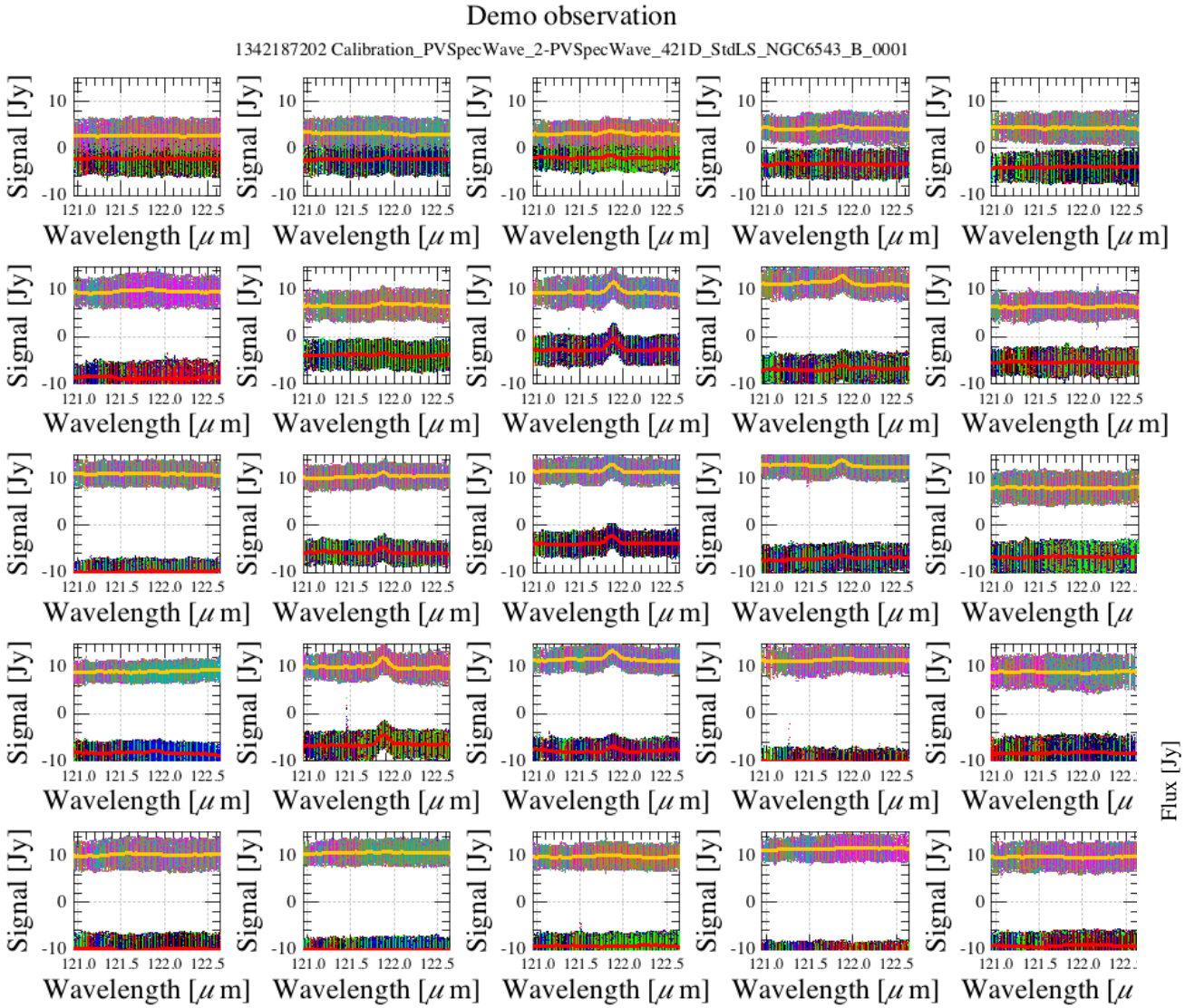
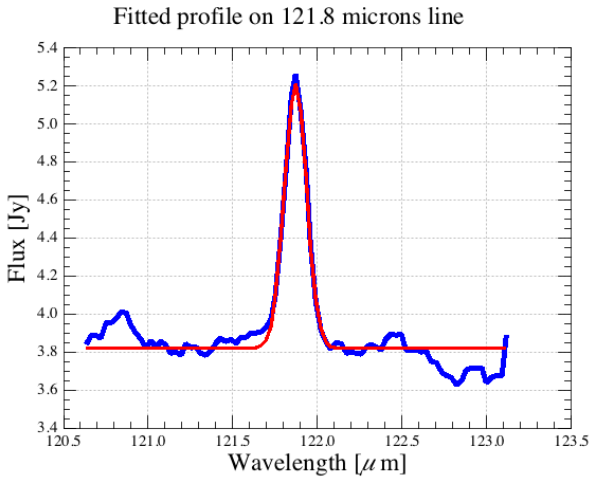
Demo data: NGC 6543



121.8 microns:
N II 3P2-3P1



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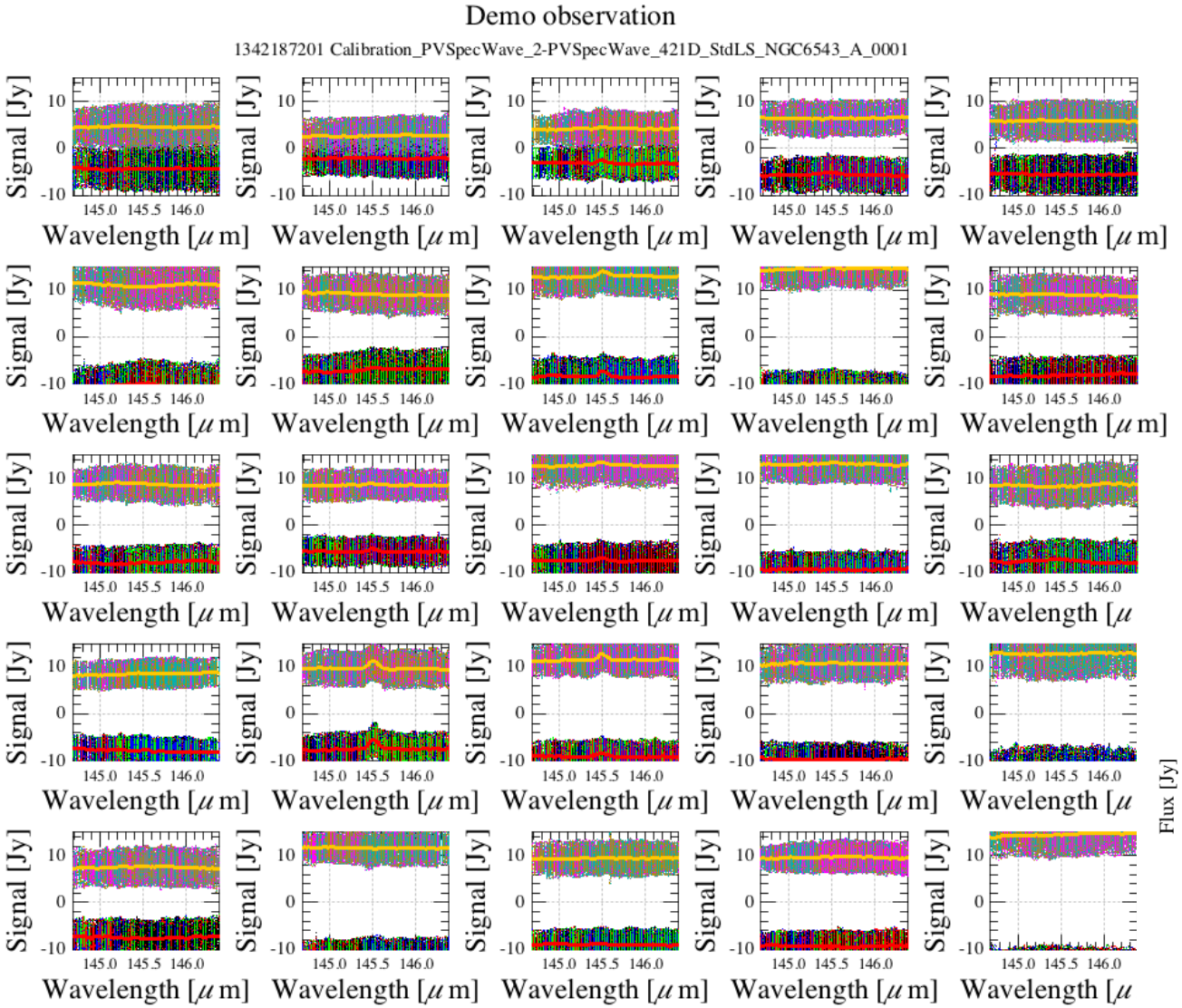
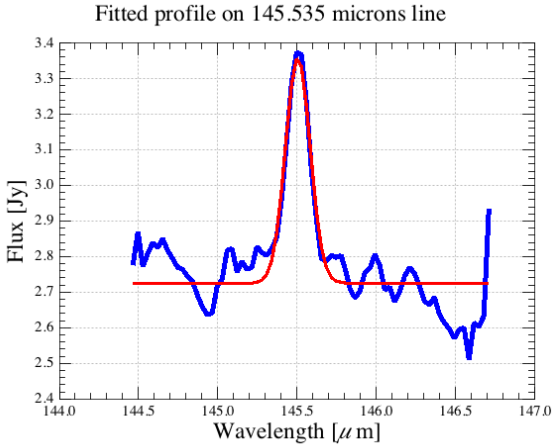
Demo data: NGC 6543



145.53 microns:
O I 3P0-3P1



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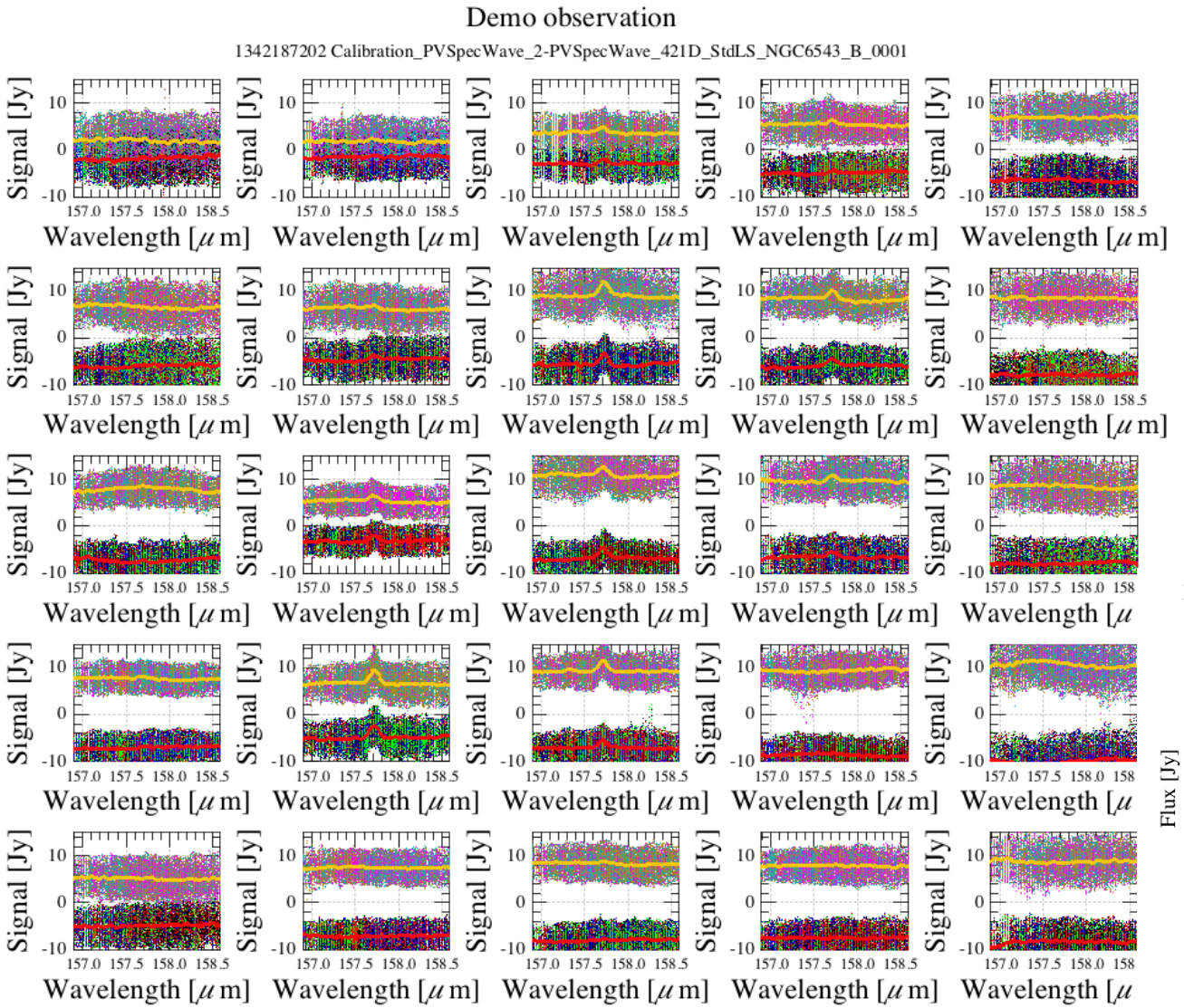
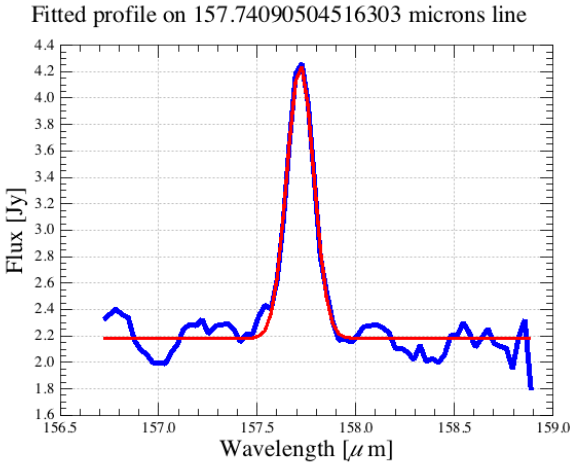


157.74 microns:
CII C+



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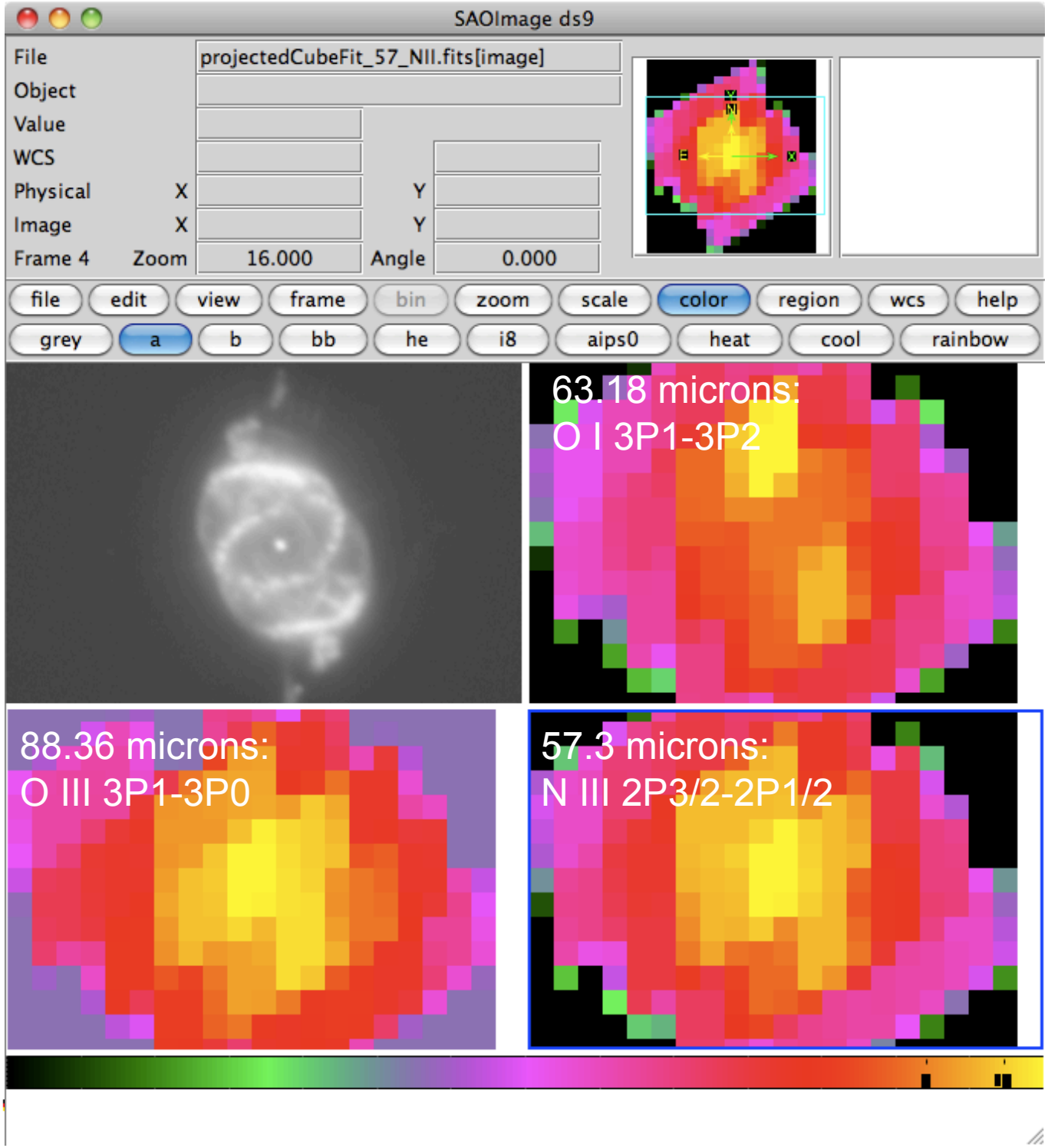

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