Brief Overview of the Chop/Nod Spectrometer Pipeline and Data Products

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

Red and blue arrays see the same area of sky simultaneously.

47″x47″ (5x5 pixels) FOV rearranged via an image slicer on two 16x25 detector arrays.
Spectrometer Astronomical Observing Templates (AOTs)

- **Line Spectroscopy AOT:** *observation of individual narrow lines:*
  - Chopping/nodding
    - Pointed, dithered and mapping modes pipeline
    - For isolated sources and rasters ≤ 6 arcmin
    - Variable grating sampling for faint and bright lines
  - **Wavelength switching (Now no longer offered)**
    - For mapping observations of crowded fields
    - Mandatory off-position
  - **Unchopped mode**
    - For mapping observations of crowded fields
    - Optional off-position

- **Range Spectroscopy AOT:** *observation of extended ranges, broad lines or continuum*
  - Range scan (same concept as Line Spectroscopy) *for broad lines*
  - **SED blue sensitive** mode *for continuum*
  - Chopping/nodding
    - Pointed, dithered and mapping modes
    - For isolated sources and rasters ≤ 6 arcmin
  - **Unchopped mode**
    - For mapping observations of crowded fields
    - Optional off-position
Example of Chop/nod AOT blocks

- **START observation**
  - On-target slew

- **Nodding “A” position**
  - Calib.
    - 87 sec
  - Line1 x 1
    - 184 sec
  - Line2 x 1
    - 184 sec
  - Line3 x 2
    - 344 sec

- **Nod slew**
  - Line1 x 1
    - 184 sec
  - Line2 x 1
    - 184 sec
  - Line3 x 2
    - 344 sec

- **Nodding “B” position**

- **Repeat** N times (number of cycles)
  - 984 sec

- **END observation**

- **... move to next raster position and repeat**

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**Pointing layout example of a nodding raster observation:**

- **Chopping/nodding pattern**
  - Nod “B”
  - Nod “A”
  - OFF
  - ON
  - OFF

- **Nodding**
  - Nod “A”
  - Nod “B”

- **START**
  - tslaw

- **END**
  - d1
  - d2
Spectrometer Data

• PACS raw data is integration ramps with typically
  – 1/8 second reset interval (32 readouts) for bright sources/lines
  – the dynamic range can be adjusted by four integration capacitors

• On-board averaging is required to fit within the allowed downlink telemetry rate
  – 32 readouts averaged
  – several “raw” ramps are downloaded in their entirety to provide “saturation” information. The raw pixels cycle through the array with time.
Spectrometer Pipeline

**Level 0 first processing**

**Level 0**
- PACS data, House Keeping
- Flag Data
  - Permanently Bad pixels (few)
  - When grating or chopper moving
  - Saturated data
  - When glitches present
  - Open and dummy channels (spec 0, 18)
- Convert DNs to Volts/s
- Assign observing block labels
  - (e.g. Nod positions, grating scan direction, calibration block, scan mode)

**Pointing**
- Assign RA/Dec > pixel

**Level 0.5**
Uncalibrated Data Frame
Steps to Calibrated Frame

- **Level 0.5**
  - Wavelength Calibration
  - Nonlinearities and Spatial Distortions
    - Apply RSRF
    - Flat Field correction
      - Subtract On and Off Chop and Convert to Jy
        - Transient Corrections
          - Level 1 Calibrated Data Frames (25 x 16 x time = grating movement)

Currently combined

Under investigation
Wavelength calibration

Use water vapor lines to provide initial wavelength calibration

Neptune in-orbit measurements
Spatial Distortion

Measured positions of individual 5x5 integral field pixels
What are Level 1 Frames?

Calibrated Frame is time history of spectral scan as seen by each pixel.
RAMPS → FRAMES

averaged ramps provide frames

16 spectral pixels

25 spatial pixels

Grating scan = time
Level 0 -1 and 2 Products

PACS PIPELINE

RAW
Level 0
To Level 0.5

To calibrated L1 FRAMES

CUBE BUILDING

Reorganize

REGRID

All λ samples

5 x 5 x N_λ
Native Spatial Pixels

Projected to 3” x 3” pixels

CALIBRATED
PROJECTED
PACSCUBE

REBINNED

CUBE
Level 1
CUBE
Level 2
Level 2 Spectral Cubes
Spectral Analysis Toolbox
PACS SPECTROMETER
SLICING FRAMES and CUBES
when rasters are needed
Why do we need to slice?

• Level0 frame often comes with more than one raster position
• Level0 frame often comes with more than one line observed in one band

>> We need to separate these out in order to make a projected map on the sky of each line
How is this accomplished in current CIB 5.0 323 build

**Observational Context**

*e.g.* (2 x 1 raster and 2 line obs)

- **APPLY SLICING RULE** by Nod Position and LINE_ID

- **NODA/NODB** LINE 1 and 2

<table>
<thead>
<tr>
<th>LINE 1</th>
<th>LINE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>slicedFrame[0]</td>
<td>slicedFrame[0]</td>
</tr>
<tr>
<td>slicedFrame[1]</td>
<td>slicedFrame[1]</td>
</tr>
</tbody>
</table>

- **slicedFrames** = SlicedFrames(level0.fitted.getCamera(camera).product)

Each slice represents both lines in given raster

- perform Level 0.0-0.5 pipeline steps
- CALBLOCK REMOVED

- CalBlock is all merged with two rasters into one single frame until level 0.5

- perform Level 0.5-1.0 pipeline steps
Manually select given line by line ID

convert all raster frames and nod frames into sliced cubes for that line ID

Level 1-2 pipeline

Rebinned cubes gathered into LIST Context

FINAL LINE Projected CUBES

GRID RASTERS ONTO WCS

SpecProject

Repeat for line 2

Make sliced rebinned cubes for all rasters and nods for given line ID

SpecProject