PACS Photometer pipeline products

Luca Calzoletti

PACS Instrument and Calibration Scientist
PACS pipeline and products

- Telemetry
  - Pre-processing
    - Level 0
      - Raw data cubes
    - Level 0.5
      - Coordinates added
    - Level 1
      - Instrumental effects removed
      - Data cube calibrated (Jy/pixel)
      - Starting point for mapmakers
    - Level 2
      - High-pass filtering
      - Projection onto a map
      - Science grade products for point sources
    - Level 2.5
      - Different mappers:
        - High-pass filter
        - Jscanam
        - Unimap
    - Level 3
      - Different mappers:
        - Jscanam
        - Unimap
  - Engineering conversions
    - First calibrations
      - Advanced processing
        - Combined scan and Xscan obs of the same target
        - Combined Level 2.5 maps for the same FoV taken over the mission
  - Quality control
    - qualitySummary
      - Automatic flags
      - Manual quality inspection
Mapmakers project the timeline scanning data (instrumental effects and noise removed) onto 2D maps.

Remove low frequency noise by preserving large scale structure.

*1/f noise*

*Thermal drift*

No thermal probed, as it is in SPIRE, to subtract detector drifts.

Other sources of noise: White noise, glitches, pixelisation noise, ....
• Masked **high-pass filtering** with photProject
  Brute force: large scale structures are removed by means of a sliding median filter on individual bolometer timeline

• **JScanam**, the Java implementation of Scanamorphos (IDL)
  De-striper: it does not rely on any noise model nor filtering. It exploits the redundancy to derive the drifts from the data

• **Unimap**, a MATLAB implementation of a Generalized Least Square (GLS) mapmaker

Both JScanam and Unimap perform an accurate preprocessing fine tuned for PACS data

See the PACS Data Reduction Guide for details and references about these mappers
PACS maps: Level 2 products

**High-pass filtering** on a single observation (obsID)

- **image**: scientific map
- **coverage**: measurement of the amount of data that falls onto one spatial pixel of the final map
- **HPFmask**: mask of the sky regions where the high-pass filter is not applied
- **stDev**: standard deviation map of the flux computed in the sky pixels
- **error**: error map obtained by using the photCoverage2Noise task (coverage map plus calibration file)

**Blue camera**: 70 µm or 100 µm map depending on the adopted filter. See the Meta Data `blue` keyword.

<table>
<thead>
<tr>
<th>Meta Data</th>
<th>name</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>blue</td>
<td>blue1</td>
<td>70 µm</td>
</tr>
<tr>
<td></td>
<td>blue2</td>
<td>100 µm</td>
</tr>
</tbody>
</table>

**Red camera**: always the 160 µm filter

PACS is a dual-band photometer
PACS maps: Level 2.5 products

Combination of scan and cross-scan observations (2 obsIDs) of the same target, acquired in the same observing mode:

- **HPPHPFMAP[B|R]**: average map of the two HPF Level 2 maps
- **HPPJSMAP[B|R]**: JScanam map
- **HPPUNIMAP[B|R]**: Unimap map

Level 2.5 maps of SSOs are generated in the system of the moving target.

Hartley comet

TNO
Maps of a *given* field belonging to a *certain* program are combined (just JScanam and Unimap)

- **NOT** necessarily all PACS observations of a field are combined

**KPOT_delbatz**
GOODS-S 3 times deeper
Mosaic of 100 obsids

**KPVT_dlutz**
GOODS-S and surroundings
Mosaic of 118 obdids
Level 3 products not necessarily contain the Blue Camera map.

The product naming convention reflects the adopted filter (differently from the previous Level maps).

- 'G' = 100 \mu m
- Otherwise 'B' = 70 \mu m
PACS maps: Level 3 products

- Level 3 products not necessarily contain the Blue Camera map

- The product naming convention reflects the adopted filter (differently from the previous Level maps)

same target

<table>
<thead>
<tr>
<th>obsID 1</th>
<th>obsID 2</th>
<th>obsID 3</th>
<th>obsID 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue Red</td>
<td>Blue Red</td>
<td>Green Red</td>
<td>Green Red</td>
</tr>
</tbody>
</table>

Spurious Level 2 map

level3

- HPPJSMAPG
- HPPJSMAPR
- HPPUNIMAPG
- HPPUNIMAPR

'G' = 100 µm
Otherwise
'B' = 70 µm
Which mapmaker to use?

JScanam and Unimap products (Level 2.5 and Level 3) are reliable on both point-like and extended sources and they can be used instead of the HPF products

• JScanam and Unimap products **must** be used for recovering extended emission;

• JScanam is the stable from SPG12, Unimap is still under development and the release used in SPG14.2 is the 6.4.4

• The Standard Browse Product (default one) is the Level 2.5 Jscanam map.
JScanam and Unimap

RCW120

Unimap distortions (WGLS- rebin)

- JScanam doesn’t introduce distortions
- The Unimap post-processing can fail in removing the distortions introduced by the GLS, especially in signal dominated fields (e.g. galactic fields)
- The Pixel Noise compensation in Unimap avoids the distortions, but it can be very time consuming. It is not always applied for HSA products
- Unimap maps are less noisy with respect JScanam in background dominated fields
- Unimap provides a proper error maps by taking into account the whole processing chain
• Unimap uses the turnaround frames and it can combine any number of obsIDs
• JScanam is fully integrated within HIPE and it depends on a limited number of parameters
• Unimap is spawned from HIPE and depends on several parameters that are optimized, but they can be also fine tuned in a reprocessing
Calibration remarks

- PACS maps are **not** absolute calibrated. The zero level is unknown and arbitrarily set by the mapmaker.
- There is **not a unique** standard PSF, as it depends on several factors (observing mode, scan angle, scan speed, data processing ...)
- Vesta PSFs and the **EEF** tables for all the scanning modes are available at the PACS Calibration Wiki page.
- **Photometric accuracy** is about 5%, mainly limited by the uncertainty of the standard models. Relative accuracy (repeatability) is about 1%.
- PACS maps are in **Jy/pixel** (standard pixel scale is 3.2”, 1.6” for the Blue camera in Prime mode).

<table>
<thead>
<tr>
<th>PSF</th>
<th>PRIME</th>
<th>PARALLEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue 60”/s</td>
<td>5.75 x 9.0</td>
<td>5.86 x 12.16</td>
</tr>
<tr>
<td>Red 60”/s</td>
<td>11.31 x 13.32</td>
<td>11.64 x 15.65</td>
</tr>
</tbody>
</table>
### Science readiness of the PACS Photometer products

<table>
<thead>
<tr>
<th>Level</th>
<th>Point sources analysis</th>
<th>Extended source analysis</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 2</td>
<td>Yes</td>
<td>No</td>
<td>Maps for each obsID Science grade, low quality If no L2.5: Default Product</td>
</tr>
<tr>
<td>Level 2.5 HPF</td>
<td>Yes</td>
<td>No</td>
<td>Combination of Level 2 maps</td>
</tr>
<tr>
<td>Level 2.5 JScanam</td>
<td>yes</td>
<td>Yes</td>
<td>Default Product (SBP)</td>
</tr>
<tr>
<td>Level 2.5 Unimap</td>
<td>yes</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Level 3 JSCanam/Unimap</td>
<td>yes</td>
<td>yes</td>
<td>Higher S/N No SSOs</td>
</tr>
</tbody>
</table>

- There are not differences in products between Prime (only PACS) and Parallel (together with SPIRE) observations
- If Level 2.5 products don’t exist and the target is extended, the Level 2 products are not science ready (look if HPDPs, if exist)
Thanks for your attention!

Questions?