

# **PACS chopped line scan and high sampling range scan AOT release note**

*PICC-KL-TN-038*

Prepared by	Bart Vandenbussche Alessandra Contursi Helmut Feuchtgruber Ulrich Klaas Albrecht Poglitsch Pierre Royer Roland Vavrek	
Approved by		
Authorised by		

## Distribution List

<i>Recipients</i>	<i>Affiliation</i>	<i>Nr. of Copies</i>

## Document Change Record

<i>Issue</i>	<i>Date</i>	<i>Description</i>
1.0	06-11-2009	Release of simple pointed and tiled maps
2.0	17-11-2009	Release of oversampled maps
2.1	18-11-2009	Description of Level-2 products added
2.2	03-12-2009	Corrected Figure 4 (saturation limits for unresolved line fluxes)

## Table of Contents

1 Introduction.....	3
2 Sensitivity.....	3
3 Saturation limits.....	5
4 Spatial and Spectral resolution.....	6
5 Pointing.....	6
6 Mapping.....	7
7 Calibration and pipeline status.....	8
8 Remarks on unreleased flavours of the chopped line and range scan modes.....	9
9 Recommendations for HSpot AOR updates.....	9
10 Level 2 standard products generated with HCSS v1.2.....	10

## 1 Introduction

The following PACS spectroscopy AOTs have been released for scheduling of observations:

- ❑ Chopped line scan / standard faint line mode
- ❑ Chopped line scan / bright line mode
- ❑ Range scan / high sampling density for short ranges

These modes have been released for the following pointing modes

- ❑ Simple pointed observations
- ❑ Raster mapping

This note provides a brief summary of the relevant performance parameters of these modes, gives guidelines to adapt AOR parameters in HSPOT to cope with changes in the scanning strategy, describes the status of the data reduction pipeline and calibration for these modes, and outlines prospects for the release of the dither and oversampled mapping pointing modes for these AOTs.

## 2 Sensitivity

a) The line and continuum sensitivities as a function of observing time have been verified in-orbit and are consistent with pre-launch predictions. Figure 1 and figure 2 show the comparison of pre-launch sensitivity predictions as documented in the PACS observers manual to noise determinations on in-orbit line scan observations.

b) Optimisation of integration ramp length, chopping frequency and grating scanning strategy have lead to a longer duration of a single line scan. The observer can therefore reduce the number of scan or nod repetitions to obtain the same observation sensitivity within the allocated observing time (see section 9: Recommendations for HSPOT AOR updates).

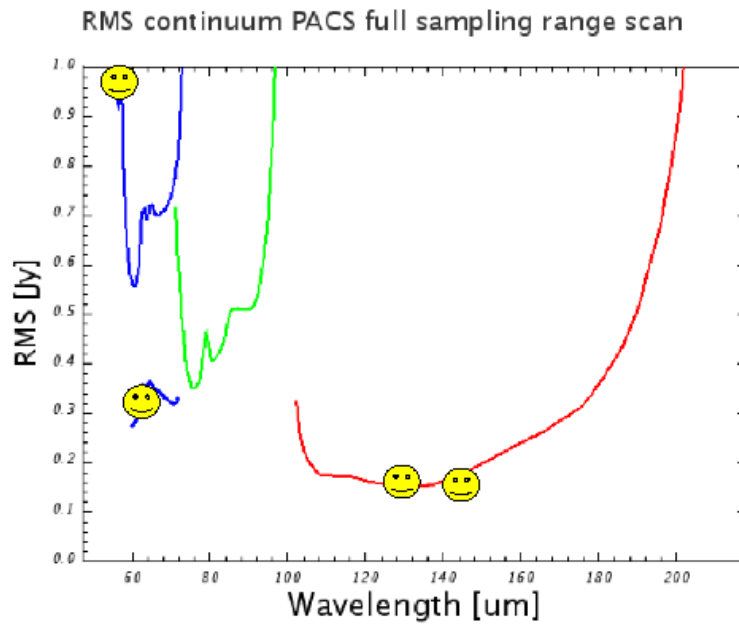


Figure 1: Continuum sensitivity predicted pre-launch compared to in-orbit spot checks

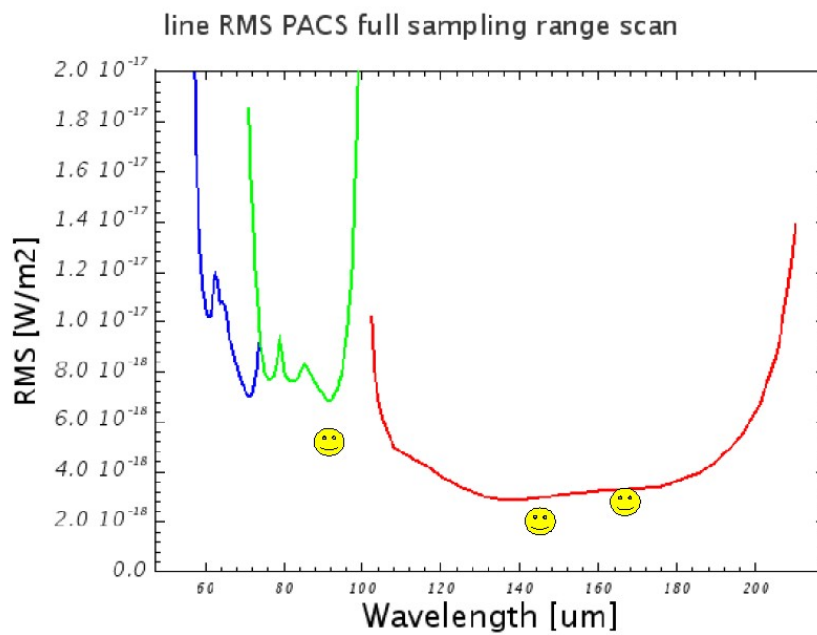


Figure 2: Line sensitivity predicted pre-launch compared to in-orbit spot checks

### 3 Saturation limits

The automatic selection of integrating capacitance based on estimated continuum and line fluxes in the uplink logic is still being implemented based on in-orbit measurements of the telescope background and detector responses. Until this is implemented, only observations within the saturation limits of the default, smallest capacitance are to be scheduled.

Figure shows the saturation limit in jansky for the default integration capacitance. This is the limit for continuum and peak line flux together. Figure shows the saturation limits for unresolved lines on a zero continuum. Both figures should allow to judge if the observation can be executed with the default integration capacitance.

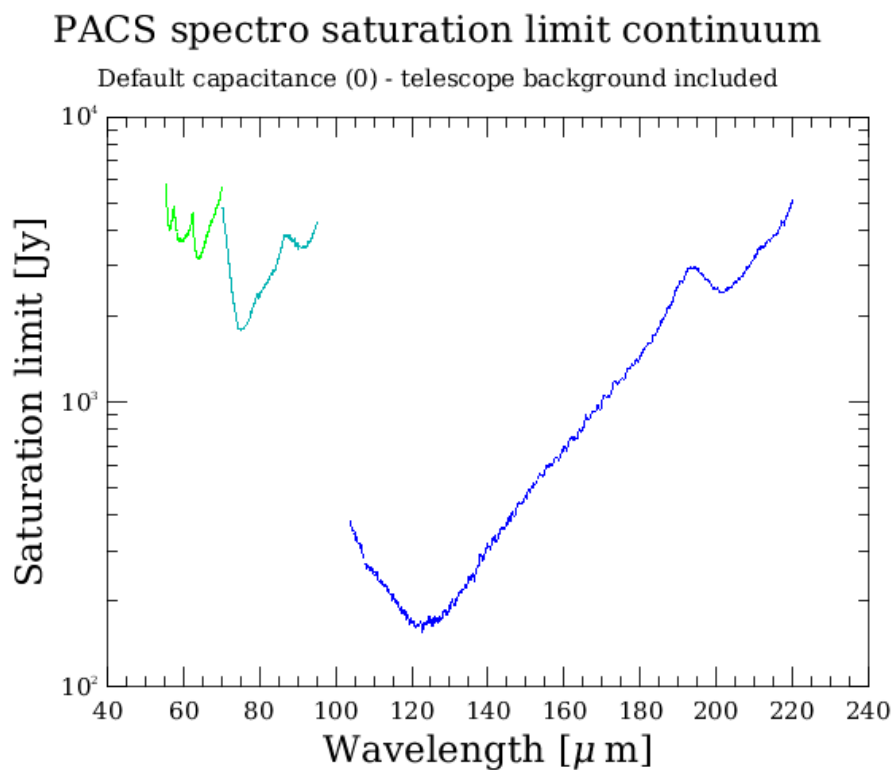


Figure 3: Saturation limits for the default integrating capacitance

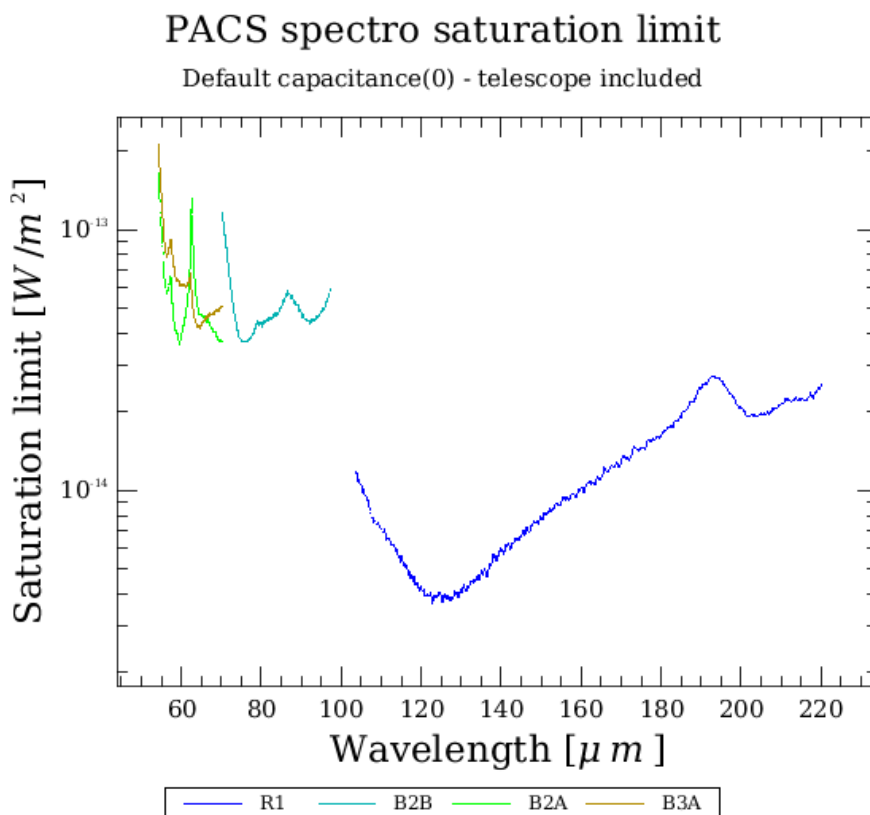


Figure 4: Saturation limits for the smallest capacitance for unresolved lines

## 4 Spatial and Spectral resolution

The spatial and spectral resolving power have been verified in-orbit and are consistent with the values given in the observers manual.

## 5 Pointing

The focal plane geometry for the three chopper throws has been established, and the uplink logic parameters have been updated accordingly. The two nod positions center the intended target coordinates to about  $\sim 2$  arcseconds. This has been evaluated to provide the necessary accuracy to combine the spectra obtained at the two nod positions and establish the full power flux calibration for point sources, compensating for differences in the telescope background seen in the two chop positions.

## 6 Mapping

The PACS spectrometer "spaxels" of ~9.4"x9.4" size are undersampling the diffraction beam of the Herschel telescope. With several observations (the number depending on wavelength), offset by fractional pixel size steps, the full spatial information can be retrieved. The raster pointing mode is used to generate a suitable set of pointings. Depending on the purpose of the raster map, different raster step sizes are recommended.

Note that these mapping strategies do not depend on whether the signal modulation is done with the grating (i.e. wavelength switching) or with the chopper. Therefore the same recommendation will be valid for mapping in wavelength switching mode, when released.

### 6.1 Tiling the sky

For raster maps with stepsize >30" (i.e tiling the sky rather than oversampled rasters) there are no particular recommendations for step sizes. Typical step sizes are 47" (no overlap between the different raster positions) and 38" (approximately one row or column of spatial pixels overlap between the different raster positions).

### 6.2 Nyquist sampling map of extended objects

For extended objects, mapping with oversampling, i.e. with step size smaller than one spaxel, may be very time consuming. Therefore we have tested a mapping strategy with step sizes larger than one spaxel, but such that the beam is nyquist sampled.

Since the PACS Spectrometer projected pixels in the sky are not square, the best recommended step sizes are not equal in Y and Z dimension, (YZ being the spacecraft axes where Y corresponds to the PACS chopping direction) and of course the optimal size changes with the beam size at different wavelengths.

The recommended step sizes (in YZ instrumental coordinates) are:

**BLUE:**

raster step size in z direction = 16.0"  
raster step size in y direction = 14.5"

**RED:**

raster step size in z direction = 24.0"  
raster step size in y direction = 22.0"

Examples of resulting spaxel pointing patterns are shown in Figure 5. This requires also that maps are commanded as rasters in spacecraft coordinates only. (See also section 9)

### 6.3 Full PACS spatial resolution Mapping of compact objects

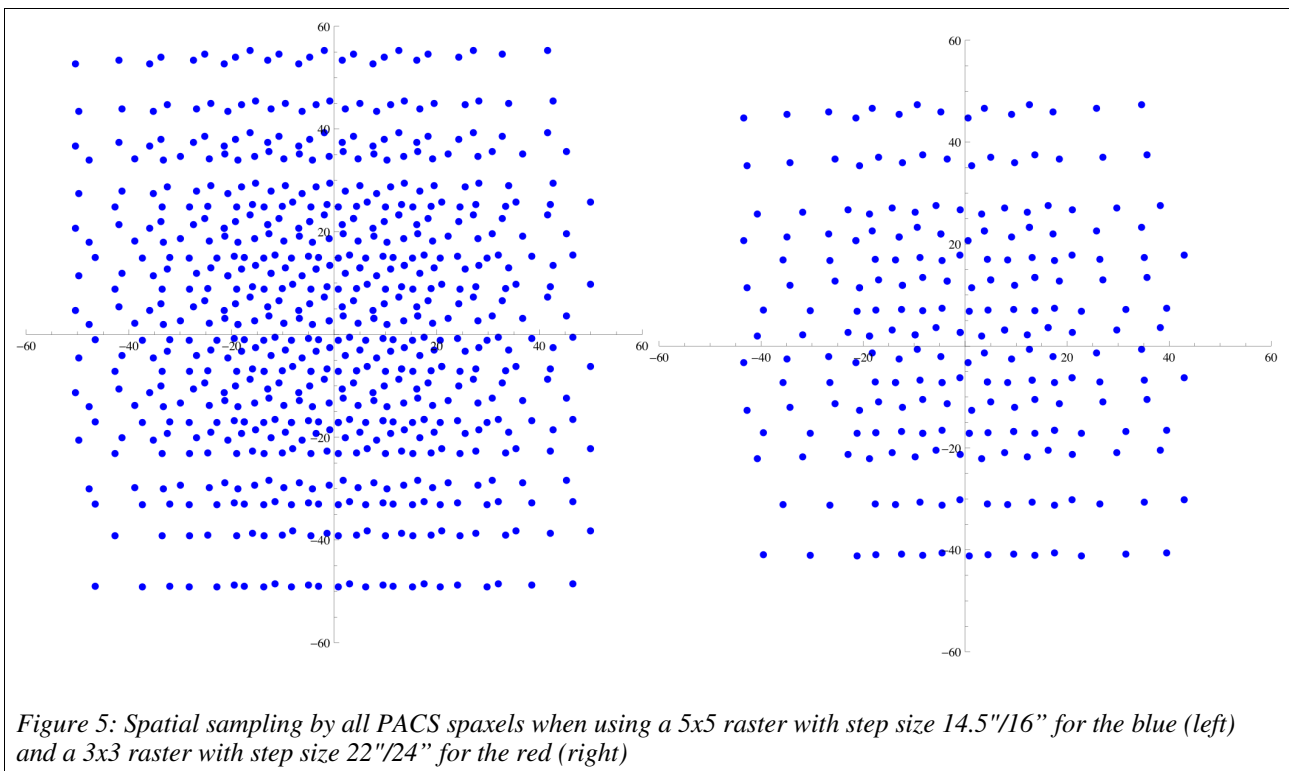
In order to map the sky at full PACS spatial resolution, step sizes smaller than

a spaxel have to be used. Since this increases the observing time, this mode is strongly suggested to be used only for mapping point-like or almost point-like objects.

In order to recover the best PACS resolution we recommend the following minimum number of raster positions AND maximum step sizes.

BLUE: 3x3 raster with step size equal to 3.0" in both directions

RED: 2x2 raster with step size equal to 4.5" in both directions



## 7 Calibration and pipeline status

The 1.2 track of the PACS spectrometer pipeline, which is at the moment the operational pipeline at the HSC used to provide the observer with data, provides level1 and level2 data which allows the user to verify the successful execution of the observation. Deep observations of faint lines might require interactive inspection using the 2.0 track of the Herschel dp system. This will be done routinely at the HSC as part of the quality checks on every observation.

Important sky calibration sources for the wavelength, flux and spatial calibration only became visible in the course of October. Therefore the 1.2 pipeline is still based on ground calibration values. The wavelength calibration accuracy is well within the uncertainties in wavelength imposed by the dependence on source position in the slit. The ground flux calibration is estimated to be valid for in-orbit conditions to within 50%. The spatial calibration applied in the pipeline is accurate to ~2 arcseconds, partly due to the limited



accuracy of the early implementation of the aberration correction algorithm, partly due to alignment differences of the instrument-level ground test setup versus the integrated instrument-telescope system.

Updates to these three calibration aspects is well under way, and is expected to be available in the 2.0 track of the herchel dp system by the end of November. The HSC will provide stable beta-versions of the 2.0 track to the observers as the updates to the calibration are validated. The PACS data reduction guide documents well how to reprocess data of the released observation modes from level-0 to rebinned spectra in the individual spaxels, and how the observer can inspect and verify the success of the intermediate processing stages.

## 8 Remarks on unreleased flavours of the chopped line and range scan modes

### *Dithering*

The dithering scheme of PACS performs a small 1x3 raster with 2" stepsize. For sources with a well known and confined photocenter, observers can use the released simple pointing mode, increasing the nod or scan repetitions by a factor of 3 to maintain the observation integration time needed for the required observation sensitivity.

Offsets of the source photocenter with respect to the center of the spectrometer (in IFU terms: the center of the central spaxel) induce a shift in observed wavelength and line shape. Therefore further recommendations on the use of dithering depend on ongoing analysis.

### *Extended ranges and SEDs*

As part of the ongoing activities towards the release of the SED mode, the PACS ICC is working on a scanning strategy to cover the full range within the pre-launch time budgets.

## 9 Recommendations for HSpot AOR updates

- As a general rule, the sensitivity for a given observing time has remained unchanged with respect to pre-launch predictions. Scan and nod repetitions need to be adapted to remain within the originally allocated time for the programme, but the intended sensitivity in the observation will be achieved.
- Faint line mode: Nod repetitions and/or scan repetitions should be lowered until the original observing time is maintained.
- Faint line observations with a single scan / single nod cycle can be replaced by two repetitions in bright line mode
- Bright line mode: Scan repetitions should be lowered until the original observing time is maintained. The observer's manual recommended to have a minimum of 2 repetitions. Should your observations have one repetition anyway, then programme should be revised to compensate for the ~10% observing time increase. The exact fraction depends on the overheads in the observation (map size, number of lines, etc)
- Range scan / high sampling mode: Scan/nod repetitions should be lowered until the original observing time is maintained
- Range scans with a single scan / single nod cycle : wavelength range should be adapted, map

sizes decreased or sources dropped from the programme.

- Dithering observations: for sources with a well confined photocenter (see above), the pointing mode can be changed from 'Pointed with dither' to 'Pointed'. To maintain the observation integration time, nod repetition and/or scan repetitions should be increased until the original observing time is reached. Nod repetition x 3 should be the appropriate change for most observations.
- Raster maps: taking into account that what is defined as raster point step in HSpot corresponds to the spacecraft Z axis, and the line step to the Y axis, the recommended raster step sizes for nyquist sampled maps of larger areas translate to the following HSpot settings:
  - Raster in spacecraft coordinates (not fixed on the sky)
  - BLUE:
    - point step =16.0"
    - line step =14.5"
  - RED:
    - point step =24.0"
    - line step =22.0"

## 10 Level 2 standard products generated with HCSS v1.2

There are two types of products in the level 2 produced by the pipeline for the PACS spectrometer in scan map mode.

These products are produced by automatic pipeline scripts and shall only be considered as a preview, and not for science directly.

### 10.1 HPS3DR

HPS3DRB and HPS3DRR stand for "Herschel Pacs Spectroscopy 3D Rebinned" for data in the Blue and Red channels.

This product of *PacsRebinnedCube* type consists nine datasets: `image`, `ra`, `dec`, `qualityControl`, `noise`, `exposure`, `ImageIndex`, `waveGrid` and `History`. The dataset 'image' carries the scientific data created by the 'specWaveRebin' pipeline task. This task constructs the  $\lambda \times 5 \times 5$  size IFU cube which is in general the 25 spatial pixels (spaxels) of the PACS spectrometer over the full the depth of the observed wavelength range. Samples from the 16 spectral pixels are rebinned in a grid which is dependent on the actual wavelengths and the oversampling/upsampling factors. The oversample factor is used to increase the number of wavelength bins by the formula  $\text{bins} \times \text{oversample}$ , where the number of bins is based on the theoretical resolution of your observation. The upsample factor specifies how many shifts per wavelength bin to make while rebinning. Standard products are generated with  $\text{oversample}=2$  and  $\text{upsample}=3$  values.

The cube flux values are in Jy/pixel units, the wavelength is in microns. Important notes on flux- and wavelength calibration see in Section 7.

In case the observation consists several spectral ranges and/or raster positions then the product is sliced into datasets of logical blocks. Such a block contains a single spectral range for a single raster

position.

## 10.2 HPS3DP

HPS3DPB and HPS3DPR stand for “Herschel Pacs Spectroscopy 3D Projected” for data in the Blue and Red channels.

This product of *SpectralSimpleCube* type consists four datasets: `image`, `exposure`, `ImageIndex` and `History`. The dataset 'image' carries the scientific data created by the `specProject` pipeline task. This task projects a rebinned cube (the HPS3DR product) onto a regular RA/Dec grid on the sky. The grid size (corners) are determined by the task using the RA and Dec information from the rebinned cube, the output pixel size (`dx,dy`) is the default 3 arcseconds for standard products. In this projected cube the number of bins and resolution in the wavelength domain do not change, the cube size is  $\lambda \times N \times M$ , where 'N' and 'M' mean the resampled grid size.

In case of mapping observations, 'specProject' loops over all raster positions and combine rasters into a single grid by adding up for each spaxel the fluxes of the contributing spaxels multiplied by their overlap weights.

The cube flux values are in Jy/pixel units, the wavelength is in microns. Important notes on flux- and wavelength calibration see in Section 7.

The HPS3DP product is worth using even for pointed observation because it does not just add together, or mosaic, multiple pointings, but also sets the correct spatial grid for each wavelength of your cube. For the PACS spectrometer, each wavelength sees a slightly different spatial position, even for spectra within a single spaxel.

In case the observation consists several spectral ranges then the product is sliced into datasets of logical blocks. Such a a block contains a single spectral range combined for all raster positions.