PACS Spectroscopy AOR Update Guide
for Routine Phase Observations

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Change Log			
Issue	**Date**	**Comment**	**Applicable for HSpot version**
1.0	15 Feb 2010	Initial post-PV issue	v4.4.4
1.1	10 Mar 2010	In Range Spectroscopy AOT the following updates have been implemented in the Time Estimator logic: (1) SED mode observing time increased due to improved spectral sampling (2) In Nyquist sampling mode the instrument overheads increase due to improved spectral dithering for repeated ranges. Spectral sampling has been changed as well (similar to the SED mode) (3) The adjustment of dynamic range (capacitance selection) based on user flux estimates has been implemented	V4.4.4

Reference Documents				
ID	**AOT Release Notes**	**Reference**	**Issue**	**Date**
RD-1	PACS chopped line scan and high sampling range scan AOT release note	PICC-KL-TN-038	2.3	19 Jan 2010
RD-2	PACS Wavelength Switching AOT release note	n/a	1.1	20 Jan 2010
RD-3	PACS SED and large range scan AOT release note	PICC-KL-TN-039	1.3	10 Mar 2010
	Manuals			
RD-4	PACS Observers Manual	HERSCHEL-HSC-DOC-0832	1.5	17 Oct 2007
RD-5	HSpot Users Guide	HERSCHEL-HSC-DOC-0788	3.3	07 Oct 2009

1 See author lists of the respective AOT Release Notes (RD-1-2-3)

Table of Contents

1 Scope of the document

This reference of post-PV Phase HSpot updates should be used as a starting point in the process of adapting AOR parameters and observing strategy for Routine Phase observations. The in-depth description of the AOT logic and detailed update guidelines are provided in the AOT Release Notes (RD-1-2-3) and in the PACS Observers Manual (RD-4). The description of HSpot functionalities and useful tips and hints can be found in the HSpot Users Guide (RD-5).

2 Line Spectroscopy AOT

2.1 General issues

2.1.1 HSpot user interface changes

- Updated wavelength ranges
  - 70-220 μm (2^{nd} + 1^{st} orders)
  - 51-73 and 103-220 μm (3^{rd} + 1^{st} orders)
- In mapping mode a new sub-panel is available for "Map reference frame" (only applicable in Wavelength Switching mode)

2.1.2 Sensitivities

As a general rule, the sensitivity for a given integration time per resolution element has remained unchanged with respect to pre-launch HSpot predictions. However, scan and nod repetitions need to be lowered because the duration of the atomic observing block (a single grating up/down scan) has been increased. By adjusting repetition factors you can keep within the originally allocated time for the programme and the intended sensitivity in the observation will be achieved. Sensitivities has been verified for a number of wavelengths, results can be found in RD-1-2-3.

2.1.3 Adjusting observation depth

For low number of repetitions (<5-6) it is recommended to repeat line scans (increase line repetition factor), while for deeper observations line repetitions should be combined with a number of nod cycles.

2.1.4 Flux estimates and dynamic range

The uplink logic automatically selects the integrating capacitance based on estimated continuum and line fluxes. If continuum and expected line fluxes are higher than the saturation limits for the default capacitance, it is mandatory to enter the expected continuum and line flux for every range in HSpot. **Observations that are saturated because no HSpot flux estimates were entered by the observer will not be considered as failed for technical reasons. Please carefully check saturation limits in RD-1-2-3.**

If an observation contains lines that fall in different flux regimes, the largest applicable capacitance will be chosen for the entire observation. If lines in the same observation fall in different flux regimes, it is recommended to split the observation into separate observations per flux regime. The HSpot Time Estimator Message (click on "Observation Estimation / PACS Time Estimator Messages") indicates if other than the default capacitance has been selected for a given combination of lines.

Please note, a single bright line could trigger capacitance switching in both read and blue channels, i.e. capacitances are always kept in synch between the two channels. In case a bright red line is grouped together with faint lines in the blue channel then the observation will be sub-optimal in the blue. In such a case it is recommended to regroup lines per channel in two separate AORs.

2.1.5 Spectral leakage regions

Spectral regions affected by leakage are shown in Figures 9-11 in RD-3. The measured spectrum in these regions may contain superimposed flux originated in the parallel channel, the interpretation of spectral features (unresolved or continuum fluxes) should be avoided without consulting a PACS expert (i.e. contact Helpdesk).

2.2 Observing mode guidelines

2.2.1 Faint line mode

Nod repetitions and/or scan repetitions should be lowered until the original observing time is maintained. The integration time per resolution element has been increased twice as long as it was before (pre-PV Phase) but the exact fraction you may want to reduce depends on the overheads in the observation (map size, number of lines, etc). Faint line observations with a single scan / single nod cycle can be replaced by two repetitions in bright line mode (see more about bright line mode below).

In case an AOR contains a mix of lines with single repetition and multiple repetitions then you may consider one of the following options: (1) split up the observation and group lines in two AORs, one should be defined in bright line mode and the other one in faint line mode; or alternatively (2) you may define all lines in bright line mode and increase repetition factor to reach the intended sensitivity. Please note, it is not recommended to use the bright line mode with high repetition factor (<4-5) required for fainter lines.

2.2.2 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 but not more than 4-5 repetitions. Should your observations have one repetition anyway, then programme should be revised to compensate for the ~10% observing time increase. Note that bright line mode scans 1/4th of the wavelength range scanned in faint line mode. For broadened lines this might limit the wavelength extent of the baseline measured. In this setup, the central 3-4 pixels (out of 16) in a spectrometer module may only scan over the line profile but not the continuum.

2.2.2 Wavelength switching mode

In the current AOT logic the WS mode has been substantially revised (see RD-2), however, there are no major changes required in terms of AOR parameters. In the updated HSpot front-end it is recommended to switch the map reference frame to instrument coordinates. In this setup the map orientation angle is fixed zero, the raster pattern rotates with the array position angle applicable for the day of the observation. The recommended raster step sizes should provide optimum coverage only for this angle.

The atomic observing time in wavelength switching mode has increased by 10% including instrument and observing overheads (180 sec). This is because the integration time per spectral resolution element has been increased from 33 seconds to 40 seconds in the new logic. The shortest duration of 385 seconds has increased to 420 seconds. Observers need to revise the repetition factor, but only if old_repetition ≥ 5 then new_repetition = old_repetition - 1 otherwise new_repetition = old_repetition.

Please note the new map orientation reference frame possibility (i.e. map angle fixed at zero degrees in instrument frame, see Sections 4.1.1 and 4.1.2).

2.2.3 Dithering mode

It has been proven during the Performance Verification Phase that flux reconstruction from a single pointed observation is as good as in dithering mode, therefore dithering option is not recommended anymore. For sources with a well confined photocenter (point- or compact sources), 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 or line repetition x 3 should be the appropriate change for most observations. Observations requiring spatial oversampling should use a minimum 2x2 size raster with recommended step sizes (see Section 4.2.2)

2.2.1 Mapping settings in Line Spectroscopy

See Section 4

3 Range Spectroscopy AOT

3.1 General issues

3.1.1 HSpot user interface changes

- Updated wavelength ranges:
  - 70-105 and 102-220 µm (2^{nd} + 1^{st} orders)
  - 51-73 and 102-220 µm (3^{rd} + 1^{st} orders)
- New SED options:
  - SED B2A + short R1: 51-73 µm + 102–146 µm
  - SED B2B + long R1: 70-105 µm + 140–219 µm
  - SED B3A + long R1: 51-73 µm + 153–219 µm
- Old SEDs are deprecated

3.1.2 Sensitivities

As a general rule, the sensitivity for a given integration time per resolution element has remained unchanged with respect to pre-launch HSpot predictions. However, scan and nod repetitions need to be lowered because the duration of the atomic observing block (a single grating up/down scan) has been increased. By adjusting repetition factors you can keep within the originally allocated time for the programme and the intended sensitivity in the observation will be achieved.

3.1.3 Adjusting observation depth

For low number of repetitions (<5-6) it is recommended to repeat range scans (increase range repetition factor), while for deeper observations range repetitions should be combined with a number of nod cycles.

3.1.4 Flux estimates and dynamic range

Based upon source flux estimates in the Range Editor Table the uplink logic optimizes the dynamic range by switching integration capacitor. **Observations that are saturated because no HSpot flux estimates were entered by the observer will not be considered as failed for technical reasons. Please carefully check saturation limits in RD-1 & 3.**

For bright sources where the default integrating capacitance will result in saturation you need to enter the expected continuum flux, line flux and line width at a reference wavelength in the selected spectral channel: this can be either the nominal or parallel channel. We advise to select the reference wavelength at the highest risk of saturation (see figures in Section 3 of RD-3).

You may consult the PACS Observers Manual how to compute the wavelength range in the parallel channel (Section 2.4.2 Fig 2.7), or alternatively, the parallel coverage is shown in the HSpot "Range sensitivity plot" as well as printed in the "PACS time estimator message".

The provided continuum flux estimates are used to scale a Rayleigh-Jeans law SED. Then the RJ-law SED is evaluated at the wavelength of the peak response in the red and in the blue range, and in case a non-zero line flux is provided then the peak flux falling on a single resolution element will be added to the continuum (after the RJ-law extrapolation). These flux estimates are used to select the optimal integration capacitor.

If an observation contains nominal and parallel ranges that fall in different flux regimes, the largest capacitance will be chosen for the entire observation. If ranges in the same observation fall in different flux regimes, it is recommended to split the observation into separate observations per flux regime. Saturation limits are provided in RD-1.

Please note, the SED mode templates in the Range Editor Table do not accept line flux estimates, in these modes you could only specify a continuum flux density estimate at a given reference wavelength.

3.1.5 Spectral leakage regions

Spectral regions affected by leakage are shown in Figures 9-11 in RD-3. The measured spectrum in these regions may contain superimposed flux originated in the parallel channel, the interpretation of spectral features (unresolved or continuum fluxes) should be avoided without consulting a PACS expert (i.e. contact Helpdesk).

3.2 Observing mode guidelines

3.2.1 High sampling density, small ranges

Scan/nod repetitions should be lowered until the original observing time is maintained. The integration time per resolution element has been increased twice as long as it was before (pre-PV Phase) but the exact fraction you may want to reduce depends on the overheads in the observation (map size, number of ranges, etc). In case the range has been defined with a single scan or single nod cycle the the wavelength range should be adapted, map sizes decreased or sources dropped from the programme.

3.2.2 High sampling density, long ranges

Scan/nod repetitions should be lowered until the original observing time is maintained. Range scans with a single scan / single nod cycle can be replaced by Nyquist sampled ranges with a repetition factor until the original observing time is maintained.

3.2.3 High sampling density, full PACS range

These scans scans can be replaced by SED AOTs A, B and C with an increased range repetition factor.

3.2.4 Nyquist sampling density, medium and long ranges

Scan/nod repetitions should be lowered until the original observing time is maintained. In case the range has been defined with a single scan or single nod cycle the the wavelength range should be adapted, map sizes decreased or sources dropped from the programme. Nyquist sampling mode provides identical grating scan pattern than the SED mode but for a limited range. Also here a spectral dithering scheme has been implemented: for repeated ranges the subsequent scans are performed with a small offset so that one spectral resolution element is seen by as many pixels as possible. Nyquist sampling AORs which are defined to cover the entire PACS range in the fastest possible way should be redefined using the new, optimized SED options (see below).

3.2.5 SED mode

The user interface for entering SED observations in HSPOT has been updated. AORs defined in the old scheme are no longer valid and time estimation is not possible. However, HSPOT can load these AORs to facilitate updating the programme manually.

A full PACS SED is obtained in ~1 hour in order 1 (red detector) and order 2 (blue detector) with two PACS range spectroscopy AORs (timings are applicable for small chopper throw):

- AOT-A: 1310 seconds range: SED B2A + short R1: 51-73 μm + 102-146 μm
- AOT-B: 2438 seconds range: SED B2B + long R1: 70-105 μm + 140-219 μm

For sources where the order 3 spectral resolution is required (see observers manual) e.g. because you look at a source with a rich line spectrum where lines can be blended, an additional AOT can be added:

- AOT-C: 3110 seconds range: SED B3A + long R1: 51-73 μm + 153–219 μm

Deeper observations can be obtained by increasing the repetition factor of the range, and / or increasing the nod repetition factor. In SED mode a spectral dithering scheme is being implemented: the different scans will be performed with a small offset so that one spectral resolution element is seen by as many pixels as possible.

3.2.6 Dithering mode

It has been proven during the Performance Verification Phase that flux reconstruction from a single pointed observation is as good as in dithering mode, therefore dithering option is not recommended anymore. For sources with a well confined photocenter (point- or compact sources), 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 or range repetition x 3 should be the appropriate change for most observations. Observations requiring spatial oversampling should use a minimum 2x2 size raster with recommended step sizes (see Section 4.2.2)

3.2.7 Mapping settings in Range Spectroscopy

See Section 4

4 Mapping settings for spectroscopy modes

4.1 General issues

4.1.1 Map orientation reference frame

Raster step/line size settings (see below) have been optimised only for zero degree map orientation in instrument coordinates. In case you switch to sky reference frame then optimal spatial sampling cannot be guaranteed because the PACS footprint rotation with respect to the raster line orientation depends on the day of the observation. The sky reference frame can be selected only in wavelength switching mode and in mapping with off-position (the latter is a non-released mode, see Section 5).

Please note, in Wavelength Switching mode the HSpot default option is 'sky' reference, but we highly advise to switch to 'instrument' mode unless the science case falls into the category described below in 4.1.2.

4.1.2 Map orientation in unchopped modes

In wavelength switching mode, if an AOR raster covers an elongated area (e.g. a nearby edge-on galaxy) then you might have no other option then using sky reference frame and turn the raster to the right direction. If the target is at higher ecliptic latitudes then you may select instrument reference frame and put a time constraint on the AOR. The time window can be identified in HSpot "Overlays/AORs on images..." option by changing the tentative epoch of observation. This way the array can be rotated to the desired angle by the time dependent array position angle. Please consult the RD-4 and RD-5 for a detailed description how to set time constraints and what consequences applies.

4.1.3 Map orientation in chopped modes

Chopped rasters cannot be rotated with a specific orientation angle, the chop direction is hard-coded in instrument reference frame with zero angle orientation (i.e. the chop direction is perpendicular to a raster line). If the target is at higher ecliptic latitudes then you may select instrument reference frame and put a time constraint on the AOR. This way the array and the whole raster can be rotated to the desired angle by the time dependent array position angle.

4.2 Raster settings in instrument reference frame

For oversampled maps (see 4.2.2 and 4.2.3 below) the optimum separation between raster points has been optimised to a reference beam size in the blue and red channels. In case an AOR contains a mix of blue and red lines/ranges then it is recommended to adopt the blue settings.

4.2.1 Sky mosaics

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).

4.2.2 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 suggest this mapping strategy with step sizes larger than one spaxel, but such that the beam is Nyquist sampled. 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:

- Blue:
  - point step=16.0"
  - line step =14.5"

- Red:
  - point step=24.0"
  - line step =22.0"

4.2.3 Full PACS spatial resolution 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

5 Unreleased spectroscopy modes in HSpot

In the current HSpot version the range spectroscopy "Mapping with off-position" mode is enabled, however, this mode has neither been validated nor released, and time estimation could be inaccurate. In case your programme is aiming for crowded-field long range spectroscopy then please contact Helpdesk for up-to-date guidelines.