PACS spatial coordinates cheat-sheet

PICC-ME-TN-027

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March 29, 2011

Document Change Record

First draft	30 October 2008	First draft	
Second draft	7 Nov 2008	Inverted matrices 9 and 10 and added	
		cluster of bad pixels in matrix 10 after	
		comments by Koryo O.	
Version 1.0	11 Dec 2008	Indicated orienation of misalignment	
Version 2.0	24 March 2011	Added relation between spec and bol PSF orientation and coordinates	

Contents

1 Relation between the PACS "PSF" orientation delivered from the spectrometer and the photometer. 4 Figure 1 shows of the location of the PACS detectors as projected onto the sky, in the classical astronomical convention of looking at the inside of the sky, where an 'east of north' position angle will run counterclockwise.

The location of the blue detector matrices 1–8, the red matrices 9 and 10 and of the spectrometer modules 0-24 is indicated. The blue line indicates the dead column in matrix 8. The blue diagonal box indicates the bad pixel cluster of matrix 10 (see figure 1.107 of the FMILT report PICC-ME-TR-006 version 0.1)¹ The axis directions (not the zero points) of various coordinate systems are indicated, with meaning as follows:

- X_{stage} , Y_{stage} refer to the ILT XY stage plus hole setup. The hole source as projected on the array will move in the directions indicated, if the XY stage is commanded.
- Z_{Tel} , Y_{Tel} are coordinates in the Herschel telescope focal plane, as measured by the Telescope XYZ coordinate system (right-handed orthogonal system with X along the Herschel optical axis, towards the Herschel target source/boresight, Z pointing at the sun and Y completing the right handed orthogonal system). ² ³
- Z_{Sky}, Y_{Sky} show the projection of the Herschel Telescope YZ coordinate directions onto the sky, around the telescope target source. If the Telescope position angle (in the definition used by HSPOT) is 0, positive Z_{Sky} points north.
- +Chop indicates the direction to which the projected PACS field of view will be moved when commanding the chopper to more positive CPR values. Note that, as usual, this definition is opposite to the corresponding apparent movement of a source across the array pixels. ⁴
- Referring to the Herschel Focal Plane defined in HSPOT, chopper position off is toward what is defined as Calibration Field 2 and it corresponds to commanded negative CPRs. This definition is consistent with CS2 being what is called Calibration Field 2 in the HSPOT Herschel focal plane.

 $^{^1\}mathrm{Note}$ the different relative arrangements of matrices 9 and 10 in the Bolometer User's manual SAp-PACS-MS-0616-06 fig.4.6

²This coordinate system is called XYZ_{sat} in the Herschel Observer's manual and IID-A, while a different meaning of XYZ_{SAT} is used in PACS-ME-DS-003 and based on it in PICC-ME-TN-019.

 $^{^3}$ The relation of \mathbf{y}_{stage} and \mathbf{Y}_{tel} directions shown here is the one of PACS-ME-TN-073 Issue 1 and replaces the opposite one shown in PACC-ME-DS-003 and also adopted in PICC-ME-TN-019 up to issue 0.6.

 $^{^{4}}$ The +chop direction here is opposite to the one in Fig. 2.3 of Version 1.2 of the PACS observers manual. N. Geis (creator of that figure) says its sign definition was not checked w.r.t. the CPR readout and could be either sign.

1 Relation between the PACS "PSF" orientation delivered from the spectrometer and the photometer.

For a clarification of the terms used in the following, let's agree that a 'PSF' is the apparent shape of a point source in the sky, as it appears in a map of the sky made by some mapping algorithm based on raster/scan observations with PACS. This is *not* the same as what we here call a 'beam pattern', which is something like the spatial response function of a given spaxel to any position around the nominal line of sight. This is illustrated below.

In this section we show the orientation of the spectrometer "PSF" (which should be called beam pattern by our definition) measured on Neptune and published in Poglitsch et al. 2010 paper (their fig. 11). In particular we show how it is related with the telescope (or spacecraft) and sky coordinates and with the PSF derived from the photometer.

According to the orientation of the spectrometer F.O.V. shown in figure 1, a point source observed by the spectrometer with a raster on the sky should show up on the bottom left in module 0 and on the top right in module 24, when intensity is plotted vs. raster position for each spaxel, to reproduce our F.O.V. footprint. (In other words, not a map of the sky, which should result in one source, but a beam map of each spaxel in the F.O.V.) Figure 2 shows the same as figure 1 where the schematic representation of the spectrometer F.O.V. has been replaced with a real observation of the spectrometer F.O.V. obtained with a 40x40 raster on Neptune with 2.5" of step size in spacecraft coordinates in the red channel. We can see that the orientation of the beam pattern in each spaxel is correct because the source is observed on the bottom left on module 0, on the top right in module 24 and the slice from 5 to 9 is displaced to the right.

The PACS PSF (for both photometer and spectrometer) has a triangular shape. In the representation of figure 2, what we call a beam pattern, the right orientation is with the apex toward North (as shown in figure 2). But this is NOT what one would have on a map of Neptune on the sky, which is how the photometer PSF has been derived. A graphical explanation of the reason why it is so is shown in figure 3. Let's suppose we have a very weird beam, composed of a big square and a smaller circle on the top, as shown in figure 3. Suppose now to take a raster or to scan the telescope to look at a point source (the star in the figure). In position 3 the big square of the beam is on the star and detects high flux with respect to positions 1 and position 2. This is reproduced by the star in the sky representation in the bottom left part of the figure. When the telescope is in position n the small circle of the beam is on the star and it detects some flux that is represented as a smaller star on the *bottom* of the big star. The same logic would apply to circles left/right of the big square.

This means that if with a beam that looks like that in figure 2 we image a point source on the sky, the sky map of the point source will be flipped in z and y direction. This is schematically shown in figure 4 where on the left the beam is shown and the map of a point source in the sky observed with this beam is on the right. This latter corresponds to the PSF delivered by the photometer.

The raster on Neptune executed with the spectrometer was obtained with a non-standard AOR. The reduction of these observations is also not standard, and this prevents to build a sky map in HIPE. In fact, the representation of Neptune in each spaxel as shown in figure 2 is in raster position not in sky coordinates. This means that each little stamp corresponding to a spaxel is a 40x40 image, corresponding to the 40x40 raster executed.

The Neptune observations done with the photometer have been done with a standard scan map, and therefor the PSF is the image of Neptune in the sky. This is why the two PSF delivered from the two instruments are flipped with respect to each other in z and y directions as shown in figure 4. Therefore, we conclude that the figure shown in figure 11 of Poglitsch et al. 2011 should be considered a beam pattern, which is related to the Y and Z telescope as shown in figure 5.



Figure 1: PACS FOV fingerprint and coordinate directions. See text for details. No attempt is made to visualize distortions and slight misalignments. The main misalignment between focal plane and Sky YZ would corrspond to a few degree counterclockwise rotion of the arrays in this diagram (for example, matrix 4 would be a little higher than matrix 1.



Figure 2: Same as figure 1 with the spectrometer focal plane beam maps (see text for details) shown, from the real Neptune observations.



Reconstruction of the sky image

Pos	intensity	
1	0.	
2	0.	
3	100	
		n
•••		
n	70	
•••		

Figure 3: Schematic representation of the difference between a beam pattern on the sky and the map reconstruction of a point source as seen by this beam.



Figure 4: Schematic representation of a beam as shown in figure 2 for the spectrometer and the image in the sky of a point source observed with such a beam (as delivered from the photometer pipeline.



Figure 5: The PACS spectrometer beam pattern oriented as shown in figure 11 of Poglitsch et al. 2010 and its relation with the telescope and sky coordinates (in case of P.A.=0).