**HCSS-16724: New Pointing Products Test:**

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**Introduction:**
During the period following the change in STR temperature, the distortion parameters in the ACMS system remained unchanged. However, this lead to an incorrect effective focal length being used for the STR. In situations where the stars used for tracking are not evenly distributed across the STR CCD this lead to offsets in the pointing.

Later studies indicated there was a tilt (2D) to the distortion and even higher dimensional levels of distortion to the plane of the STR CCD. These have now been installed in the ACMS system on board the Herschel spacecraft and, together with the removal of some 73 suspect stars in the catalog used for identifying tracking stars, forms the basis of the current pointing system with an APE of approximately 1".

For the period OD320 to OD761 not even the 1D focal length correction was available on board the spacecraft. This produces the largest offsets for pointing in the system up to 7-8". Since the correction factor is known, it is possible to change the pointing information on the ground to adjust to what the STR was seeing at the time of all observations when this correction was not being applied.

New pointing products have been created for the time period OD320 to OD761 that can potentially bring all observations up to the level of pointing accuracy available when the correct focal length of the STR system is used. For the period up to OD1011 there are further, higher dimensional, corrections that can be applied. These will be the subject of future improvements.

This short report indicates the effect of using the updated pointing products in reprocessing data both interactively and using the standard pipelines, together with an evaluation of the pointing performance produced once applied to all observations in the time period.

**Interactive Test Cases:**

**All PACS-P pointing calibration observations.**
Pointing calibration observations have always used the PACS photometer. New pointing products were used with these observations. Results indicated that the APE was improved when measured using just these PACS observations. The improvement went from 2.″3 to 1.″6 (see Figure 1).
Figure 1: Pointing offsets for pointing calibration stars showing Gaussian distribution and overall APE improvement to 1.’6. This is similar to the results obtained directly after the STR focal length correction was applied on board the spacecraft on OD762.

**Specific PACS-P and SPIRE-P Observations.**

It was noted through a variety of Helpdesk tickets that certain areas of the sky appeared to be affected by poorer than expected pointing. A particular area of concern is in Taurus. Particular observations of point sources in this area have been considered. A total of 10 PACS and SPIRE observations of objects with significant predicted shifts have been checked individually.

An example is shown in Figure 2 for the star (UZ Tau) in OD684, on the left the current HSA level 2 blue channel (70 microns) maps and in the right processed with the new pointing product. The absolute astrometry offset is reduced from 7.5 arcsec to 1 arcsec.
Figure 2: UZ Tau before and after application of the new pointing products. The SIMBAD position is indicated by a green circle with the original pointing on the left and update pointing shown on the right. The star Gamma Dra has been the most frequently observed star for flux monitoring purposes. It has shown a small offset over from nominal for most of the mission. In Figure 3 it can be shown that this quite small offset has been due to STR distortion.

Figure 3: Gamma Dra as seen with SPIRE-P with the new pointing product applied (left) and with the original pointing product (right).

**SPIRE FTS Checks:**
Checks were made with respect to all FTS measurements made in the time period associated with the pointing product updates. Figure 4 shows the sizes of the offsets associated with SPIRE FTS measurements.
The largest predicted offset is 5.5" for obsid 1342213373 (a low resolution mapping observation on OD625). The effect is seen in reprocessed data as an update to the “ra” and “dec” metadata.

For SOF1 (pointlike) observations, two observations checked particularly.

**Obsid 1342219551 (High Resolution):** predicted 5.1
\( \Delta \text{Dec}=0.3", \Delta \text{RA}=-5.1" \) (old - new)

**Obsid 1342219572 (Low Resolution):** predicted 5.3
\( \Delta \text{Dec}=1.0", \Delta \text{RA}=-5.2" \) (old - new)

For mapping observations (e.g. SOF2) the WCS coordinate system will be shifted in the spectral cubes created.

**Obsid 1342213373 (Low resolution, mapping):** predicted 5.5" offset. WCS offset check
\( \Delta \text{Dec}=-1.8", \Delta \text{RA}=-5.2" \) (old - new)

These results are precisely in line with expectations. The SPIRE-S products are updated as predicted.

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**Figure 4:** The offsets for SPIRE-FTS for the more than 400 obsids in the time period OD320 to OD761.
**HIFI Checks:**

An extensive set of tests on most of the HIFI observations taken in the period OD320 to OD761 has been done. The initial checks compared the computed expected shifts with the metadata information checks of source position information within reprocessed HIFI data.

The following figures illustrate the distribution of the predicted shifts in bins of 0.5 arcsec, separated per HIFI AOT type, and target type (fixed or moving).

**Fig. 1:** Histograms of predicted astrometry shifts for HIFI obsids

As can be seen, astrometry shifts of up to 8 arcsec are expected from the improved pointing products. The next figure illustrates how these shifts are distributed on the sky. It shows that the largest shift is experienced in the Taurus area, that was already known to be affected by the effect one aims at correcting here.
The bulk reprocessing was performed from the level0 products as of the last BKRP 8.2.1. The following syntax was used in order to apply the new astrometry to the level 0 products, and the HIFI pipeline was then run up to level 2.5 with standard parameters.

The same kind of statistics as above can be performed based on the effectively measured shift. Note that this shift applies to the average of all ON-target positions observed over the obsid. The overall distribution is confirmed.
One can directly compare the predicted shifts by MSP to those reported by the pipeline, and form the difference.

The agreement is very good. There are some outliers, mostly in maps, due to a non-optimum call to the doPointing task. Revised plots will be generated with the output of the corrected bulk reprocessing (TBB). As that stage, the conclusion is that the HIFI pipeline is making a totally consistent use of the new pointing products, so that the E2E validation is considered successful.

The following examples illustrate the way the reconstructed pointing positions will change after the reprocessing.

The generated plots display the following:

- In blue filled circles, the positions of the individual frames with the old pointing products, as of 8.2.1 bulk reprocessing
- In red filled circles, the position of the individual frames with the new pointing products, reprocessed with 9.0
- As a black filled circle, the R.A./Dec nominal, i.e. the intended position
- In open circle, joined by a solid line, the initial (i.e. Ra/Dec nominal) and predicted new position according to MSP’s computation

**DBS point observation:**

This case is considered to illustrate the obsid (1342203230) for which the discrepancy between MSP’s prediction and the pipeline-computed shift is the largest (~2.3 arcsec). The left plot below shows that both ON-target and OFF-target positions experience the same shift in this region of the sky.

![Old vs new pointing in obsid 1342203230](image)

**Fig.5:** Old and new positions for level 0 science frames (left) and level1 ON-target science frames (right)

**DBS raster map:**

A similar check is shown in a DBS raster map (obsid 1342205482). The match between the predicted and computed astrometry shift of the overall map is here excellent (0.07 arcsec).
Fig. 6: Old and new positions for science frames at level0 in a DBS raster

**OTF maps:**

The following plots show a gallery of various types of OTF maps (single strip line, odd/even number of legs, tilted scan lines wrt the Eq. frame, etc). In all those examples, the predicted shift matches very well the computed one on average, which indicates that the astrometry shift applies similarly to all points in the map. This is not however always the case (see next section).
**Fig. 7:** Old and new positions for level 2 science frames in an OTF stripe maps.

**Fig. 8:** Old and new positions for level 2 science frames in a 2-D OTF maps. Note the large offset for the right obsid (Taurus area).
**Fig. 9:** Old and new positions for level2 science frames in the Orion Bar case highlighted for its problematic zig-zag effect in structure (HIFI-4252)

**Inhomogeneous position shift over the map:**

There exist cases where the improved pointing will imply some discontinuous shift over a portion of the map. Some such cases as illustrated below. In such cases, it is expected that the shift predicted at the very centre of the map by MSP can differ from that obtained from the average of all shifts, leading to the outliers in Fig. 4.
Fig. 10: Illustration of discontinuous position shift over an OTF map

Fig. 11 also shows the shift that was predicted over an area covering the map in the left of Fig. 10, demonstrating again that the effect computed by the pipeline is perfectly in line with the updated pointing product in this field.

Fig. 11: Position shift expected for the field applying to obsid 1342207386 (left plot of Fig. 10). The vectors indicate the direction of the expected position shift (note that the R.A./Dec positions refer to the ACA frame, so they differ slightly from those of the aperture in use for obsid 1342207386)

SPG Testing:
Pointing products have been checked against all observing modes in the SPG. Results are identical to interactive processing and there have been no failures with any of the observing modes.

Results from interactive and SPG testing are indistinguishable – as should be expected since the interactive reprocessing simply uses the pipeline processing from the command line with the additional line of code for inserting the new pointing product.
Conclusion:
Instructions for using the new pointing products interactively are contained on the Twiki at http://herschel.esac.esa.int/twiki/bin/view/Public/HowToUseImprovedPointingProducts

The intention is that these products can also be used in standard processing in the bulk reprocessing exercise associated with HCSS 9.1.

Testing has illustrated that interactive or standard pipeline processing can use the new pointing products equally well and there are no indications of problems using any of the observing modes on board Herschel. It is therefore requested that the updated pointing products be placed in the archive as the latest version of pointing products for the ODs 320 to 761.