A check for timing shifts of PACS photometer data vs. pointing product

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1 Summary

A large sample of ∼600 scan maps is used to search for timing offsets between PACS data and pointing information. This is done by comparing the positions measured in separate maps created from the 'odd' scanlegs for which the telescope is moving in one direction and the 'even' scanlegs where it is moving in the opposite direction. While these positions clearly differ by ∼1 arcsec RMS, likely due to pointing uncertainties, there is no clear systematic offset in scan direction, as would have been expected in case of a systematic timing difference. The results are consistent, however, with the presence of small known random synchronisation offsets within PACS.

2 Background

The very first PACS observations for the M51 'sneak preview' discovered a timing shift between PACS data and pointing, which led to incorrect source positions in maps. The causes of an ∼0.3 sec offset were quickly identified with sources both within the Aperture History File (243msec) and within PACS (50msec, PACS-1729), and fixed.

A suspicion remained about a possible remaining ∼50 msec timing offset (DL presentation at ICC meeting #33, PACS-2511) but was essentially based on few observations of a single source on a single OD. The purpose of this note is to follow this up which much better statistics.

It should be noted that there are three known sources of a timing offset which are inevitable given PACS design and the current status of PACS data processing: (1) Commanding of the PACS DECMEC unit leads to a random synchronisation offset between bolometer readouts and pointing. This random offset between 0 and 25 msec applies now every time an AOR is started, for observations very early in the mission it applies to every scanleg independently (see PACS-1845). (2) The current pipeline does not consider the fact that the columns of each bolometer matrix are read sequentially during 25 msec rather than at the same time. For the analysis discussed below, this will often average out, however. (3) The PACS bolometer system response has a finite time constant of order tens of msec (e.g. thesis of N. Billot).

3 Method and Data used

Scanmaps of bright point sources are analysed using a script starting from Level 0. The script uses a fairly straightforward masked highpass-filtered mapping. It combines elements of the PSF derivation script (by DL) and of the flux calibration script (by MN). At the end, three maps are created from the same processed frames, representing (1) all scanlegs of the observation, and separately (2) the 'odd' and (3) the 'even' numbered scanlegs. ScanLineNumber in the PCSS frames status starts counting from 1, i.e. the 'odd' frames include the first scanleg. Some basic analysis, in particular 2-D gaussian fitting, is applied. Processing was done in build 9.0 2794, freshly downloading the observations from HSA. The SPG versions of the HSA retrieved data range between 8.2.1 and 9.1.0.

The end results for each obsid are:

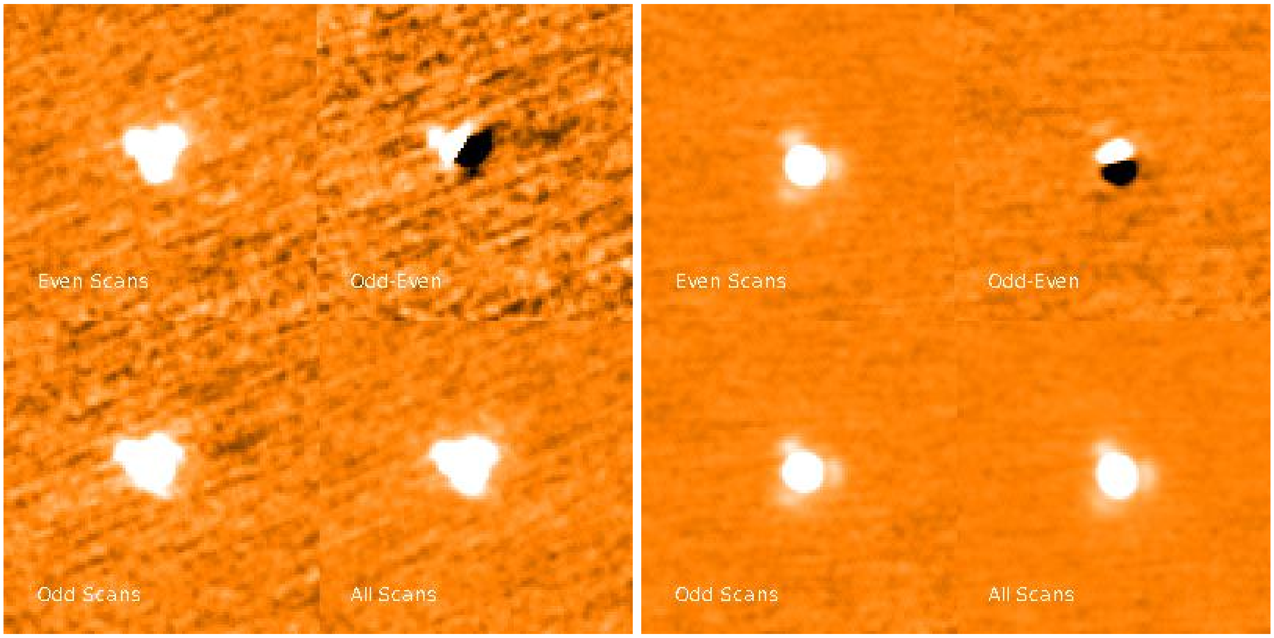

Figure 1: Total, 'odd scans only', 'even scans only' and difference maps for obsid 1342182968 (left) and 1342187155 (right)

- Three fits frames for the total, odd, even scans (blue/green filter only).
- One overview figure for these maps and for the difference odd-even (See Fig. 1 for two examples).
- A figure summarizing the path of the virtual aperture taken according to the pointing product (See Fig 2 for a normal and a rather pathological example).
- A 1-row table summarizing main parameters of the observation and results, to be then combined for all observations. The entries in this table are:

```
OBSID           LONG       1342179008
OD              INT            41
STARTDATE       STRING    '2009-06-24T01:49:18.000000'
FINETIME        LONG64         1624499392000000
TARGET          STRING    'gamma_draconis'
PROPOSAL        STRING    'Calibration_coppacs_12'
BLUEBAND        STRING    'blue '
RA_REQ          DOUBLE          269.15150
DEC_REQ         DOUBLE          51.488828
SAA             DOUBLE         -15.173338
SPEED           DOUBLE          10.000000
SCANANGLE       DOUBLE          45.000000
SCANANGLEREF    STRING    'inst'
LEGSEP          DOUBLE          15.000000
LEGLENGTH       DOUBLE          5.0000000
NUMLEGS         INT            20
REPFACTOR       INT             1
CREATOR         STRING    'SPG_v8.3.0'
```

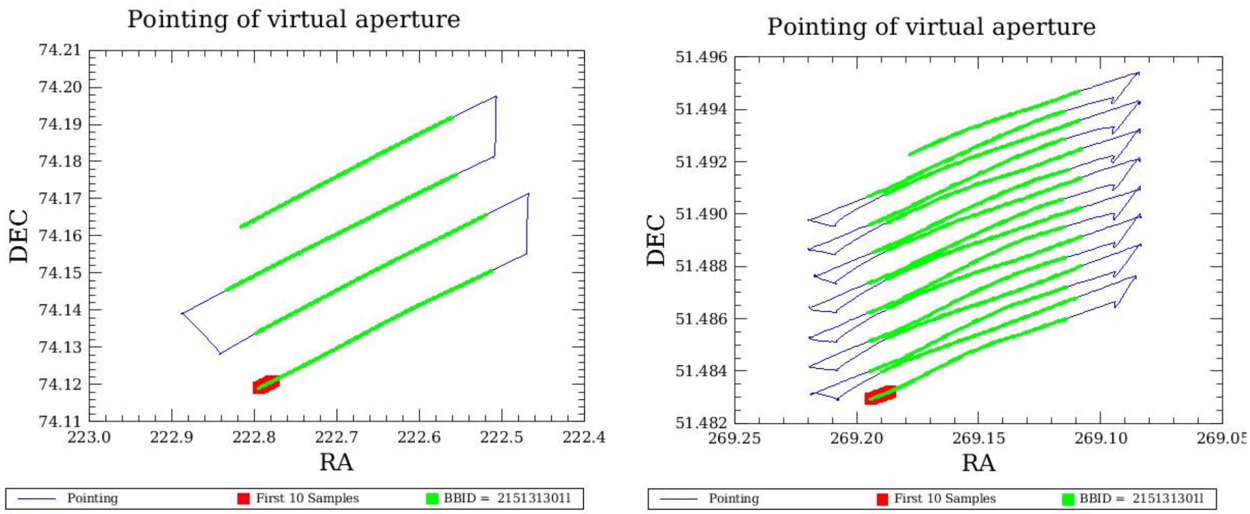

Figure 2: Scanpaths for obsid 1342182968 (left) and 1342187155 (right)

POSANG	DOUBLE	356.70949
APPHOT	DOUBLE	2.8750000
RA_ALL	DOUBLE	269.15136
DEC_ALL	DOUBLE	51.488259
FWHMX_ALL	DOUBLE	5.4340000
FWHMY_ALL	DOUBLE	6.4820000
PA_ALL	DOUBLE	-92.929000
RA_ODD	DOUBLE	269.15136
DEC_ODD	DOUBLE	51.487946
FWHMX_ODD	DOUBLE	5.3020000
FWHMY_ODD	DOUBLE	5.3500000
PA_ODD	DOUBLE	-79.952000
RA_EVEN	DOUBLE	269.15137
DEC_EVEN	DOUBLE	51.488598
FWHMX_EVEN	DOUBLE	5.4240000
FWHMY_EVEN	DOUBLE	5.4350000
PA_EVEN	DOUBLE	-80.088000
SCANDIR	DOUBLE	41.709000
ODDEVENDIR	DOUBLE	1.0089999
SCANTOODDEVEN	DOUBLE	319.29901
INSCAN	DOUBLE	1.7800000
ORTHSCAN	DOUBLE	-1.5310000

The merged table is available on request. Most of the entries are self-explanatory, some comments:
RA_REQ and DEC_REQ are for the epoch of the observation and computed from the position and proper motion specified in HSPOT, as echoed in the meta data of the observation context.
APPHOT is a simple 20arcsec radius aperture photometry, intended simply as a quick indicator of flux.
The fitted RA, DEC, FWHMX, FWHMY, PA are given separately for the maps from all, odd, and even scanlines.
SCANDIR is the direction of the first scanleg in degrees ccw from north.
ODDEVENDIR is the direction from odd peak to even peak in degrees ccw from north.

SCANTOODDEVEN is the angle from SCANDIR to ODDEVENDIR in degrees CCW.
INSCAN is the in-scan component of the offset odd to even peak, in arcsec.
ORTHSCAN is the orthogonal-to-scan component of the offset odd to even peak, in arcsec.

The procedure was applied to the following observations:

- All scanmaps of the original list of fiducial PACS flux calibration stars: βAnd, αBoo, αCet, αCMa, γDra, βPeg, αTau, βUmi, in total about 250 obsids.
- 8 scanmaps of R Dor taken for a variety of test purposes and in one GT KP.
- Scanmaps of a variety of pointing stars taken for the purpose of routine phase pointing checks, in total about 160 obsids
- Scanmaps of nearby AGN from OT1_lho 1 (in total about 350)
- About 50 scanmaps of some possible debris disk stars from KPOT_bmatthew_1, selected with help of a quick inspection of archive postcards.

Sources with less than 0.1Jy blue/green flux according to a simple automated aperture photometry, as well as some problematic observations that missed pipeline level 2 data, were discarded by the processing script.

The automatic procedure provided results for 623 different obsids. In three obsids, the fitted positions were offset by more than 18 arcsec from the HSPOT request, and differed by more than 6 arcsec between odd and even. Map inspection showed these to be nondetections where the automatically estimated aperture flux must have been erroneous. They were not used further. Another 12 obsids were offset by more than 18 arcsec from the HSPOT request, but have consistent odd/even positions. Map inspection shows these to be detections for which either the hspot position must have been erroneous, or where the automatic procedure has detected a neighbouring source. These were kept for the purposes of this purely technical analysis.

Results for the 6 αTau observations quoted in PACS-2511 were reconfirmed, i.e. the differences between suspecting a possible offset then, and the conclusions below from the larger sample are due to the enhanced statistics.

In total 620 observations are finally used in the analysis below. Sources from OT1_lho 1 and KPOT_bmatthew_1 are more likely to be extended and should only be used for analysis of positional offsets, not for any information related to FHWM. Some pointing stars may also be extended.

4 Results

An analysis of the type presented here should show in the differences of source positions between the 'odd' and 'even' maps:

1. Random direction offsets related to the pointing accuracy in a rather complex way. Their magnitude is both a function of the time behaviour of pointing offsets, and layout of the individual observation (number

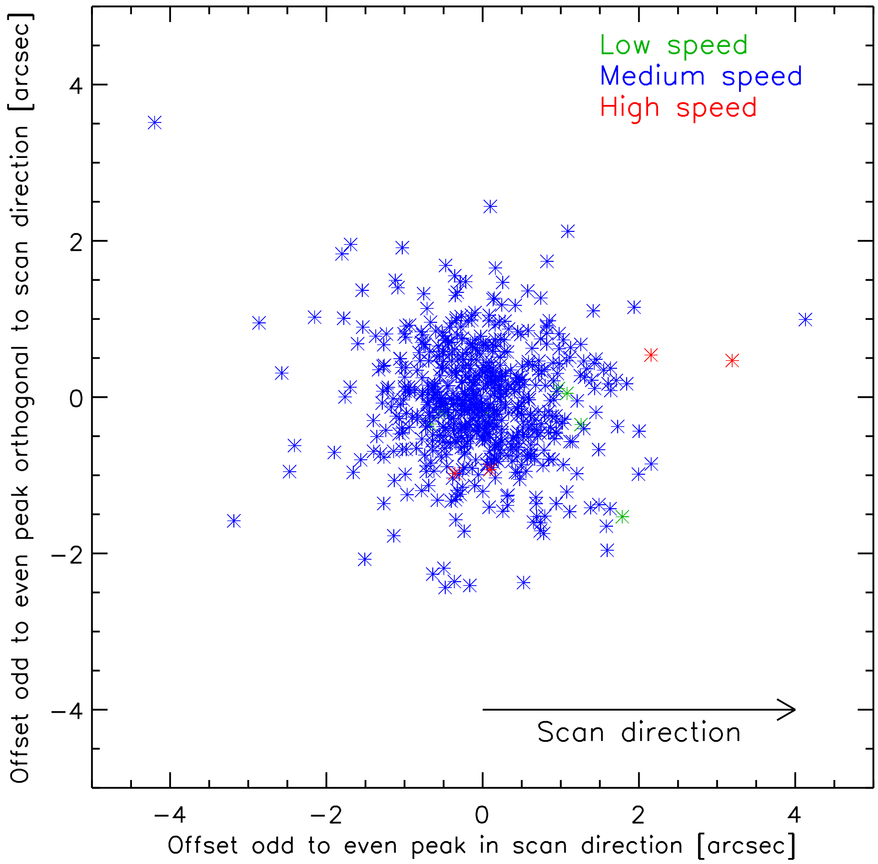

Figure 3: Offsets from source peak measured in the 'odd scanlegs only' to 'even scanlegs only' maps for 620 scanmaps.

and spacing of scanlegs, number of map repetitions, etc.). No attempt is made here to interpret the origin of those random offsets in detail.

2. Systematic offsets could in principle be caused by residual errors in the calibration of the photometer FOV distortion. This can be noticeable if different obsids sample the FOV in a comparable way and with large scanleg separation, so that 'odd' and 'even' are differently affected. This effect is expected to be minor for the mix of AORs used here.

3. In case of timing differences between PACS data and pointing, the odd-even offsets should show a systematic shift (for a constant timing offset) and/or widening (for random timing offsets) **in the scan direction only**

Quantity	In scan direction arcsec	Orthogonal to scan arcsec
Median	-0.076	-0.079
Mean	-0.042	-0.068
Stdev	0.799	0.739

Table 1: Statistical properties of offsets from source peak measured in the 'odd scanlegs only' to peak measured in 'even scanlegs only' maps

The key result is shown in Fig. 3 and Table 1. While there is considerable scatter in the relative positions of odd and even peaks (1.09 arcsec RMS adding the two directions in quadrature), there are no clear systematic offsets, with measured median/mean values below 0.1 arcsec in both directions. Considering the in-scan standard deviation from the 620 scanmaps, the median (mean) offsets are insignificant at 2.4σ (1.3σ). Since the measurements are vastly dominated by medium scanspeed (20arcsec/sec) AORs, these nominal offsets of ~0.05arcsec correspond to few milliseconds of time only. No attempt is made here to verify whether this excellent agreement is due to perfect consideration of all the factors involved, or e.g. due to a fortuitious cancellation of effects from commanding and from detector time constant. Fast scanspeed observations could help checking, but are too scarce in the set of observations considered here.

As mentioned above, PACS commanding should lead to random timing offsets between 0 and 25msec for each AOR. Spatially, this should separate the odd and even peaks between 0 and 1 arcsec for medium speed (20 arcsec/sec, both peaks move, in opposite directions). This is consistent with the slightly enlarged dispersion of measured offsets in scan direction (convolving a 0.74 arcsec dispersion gaussian with a 1 arcsec full width boxcar results in dispersion 0.8 arcsec).

The pointing quality as measured by the odd-even offsets seems to be better after OD≈300 (Fig. 4).

The fact that considerable few arcsecond offsets orthogonal to the scan direction are sometimes observed may relate to the occasionally observed cases where the distances between scanlegs (as reported in the pointing product) alternate between small and large despite being requested to be identical by the pointing request. If this is true, Fig. 3 suggests that this occurs with similar probability in any direction rather than being due to some special phenomenon in orthogonal-to-scan direction. As a first test, Fig. 5 shows the scan paths as reported from the pointing product for 9 of the 10 obsids with largest odd-even offsets orthogonal to the scan direction (>2 arcsec). The tenth (1342187155) was already shown in Fig. 2 right. While some obsids have only two scanlegs (thus not allowing this test), the others appear peculiar. Large offsets seem to preferentially occur for certain sources/ODs, perhaps suggesting a relation to the star tracker.

Fig. 6 compares the offset between odd and even peak with the FWHM measured directly from the total map. Ignoring some outliers which are likely related to some pointing sources that are not true pointsources, a relation is clearly apparent at least for the blue filter. Since the offset odd to even peak is dominated by pointing effects, this is evidence that a Herschel pointing reconstruction that were improved by use of the gyro information and improved star tracker data handling could yield quite significantly reduced PSF widths in a few cases with bad pointing, and slightly reduced FWHM in many cases. Some short term pointing jitter will already be absorbed in the width of 'odd' and 'even' peaks here, for another look at the potential improvement one may compare standard and 'recentered' PSF widths from the PSF technical note PICC-ME-TN-033 (Version 2.0).

5 Document change record

Version	Date	Initials	Comment
0.1	2012-11-11	DL	Draft
1.0	2012-11-16	DL	Including comments

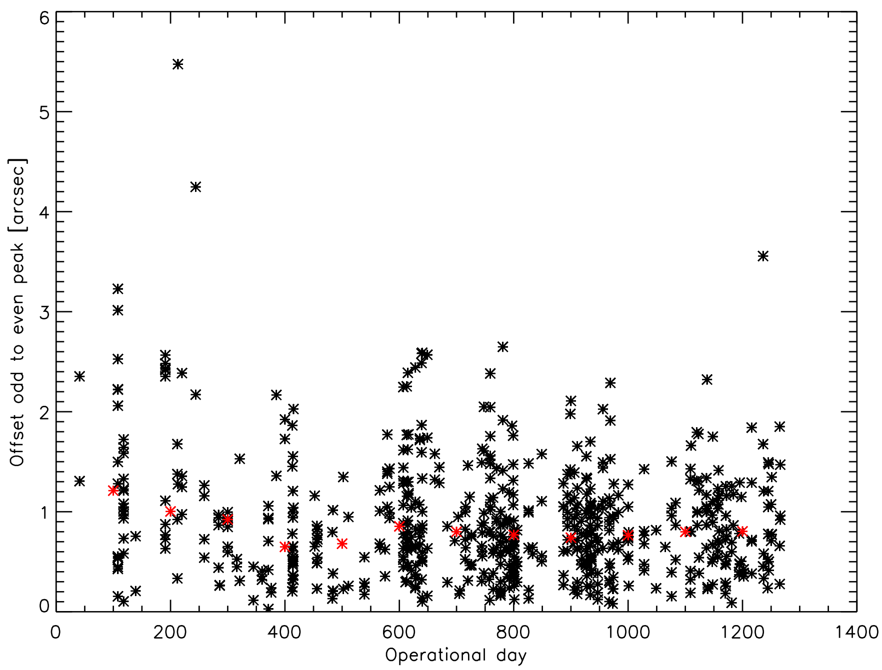

Figure 4: Offsets from source peak measured in the 'odd scanlegs only' to 'even scanlegs only' maps as a function of operational day OD. Red symbols are median values in a time window of ±100 ODs.

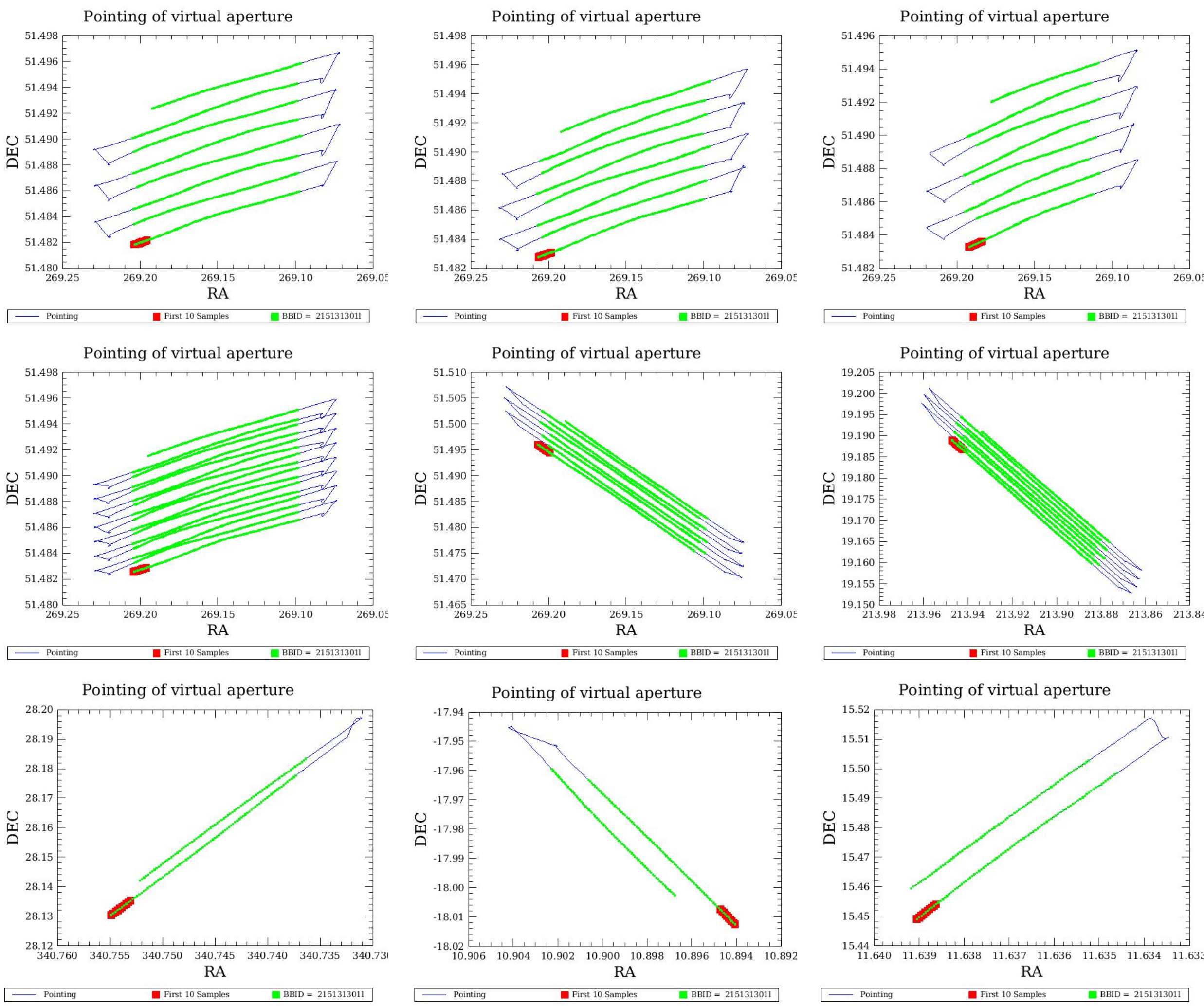

Figure 5: Scan paths as reported by the pointing product, for 9 of 10 obsids with odd-even offsets larger than 2 arcsec. The tenth is in Fig. 2 right. The obsids show are 1342187147, 1342187149, 1342187151, 1342187153, 1342188070, 1342188246, 1342212453, 1342213056, and 1342213578.

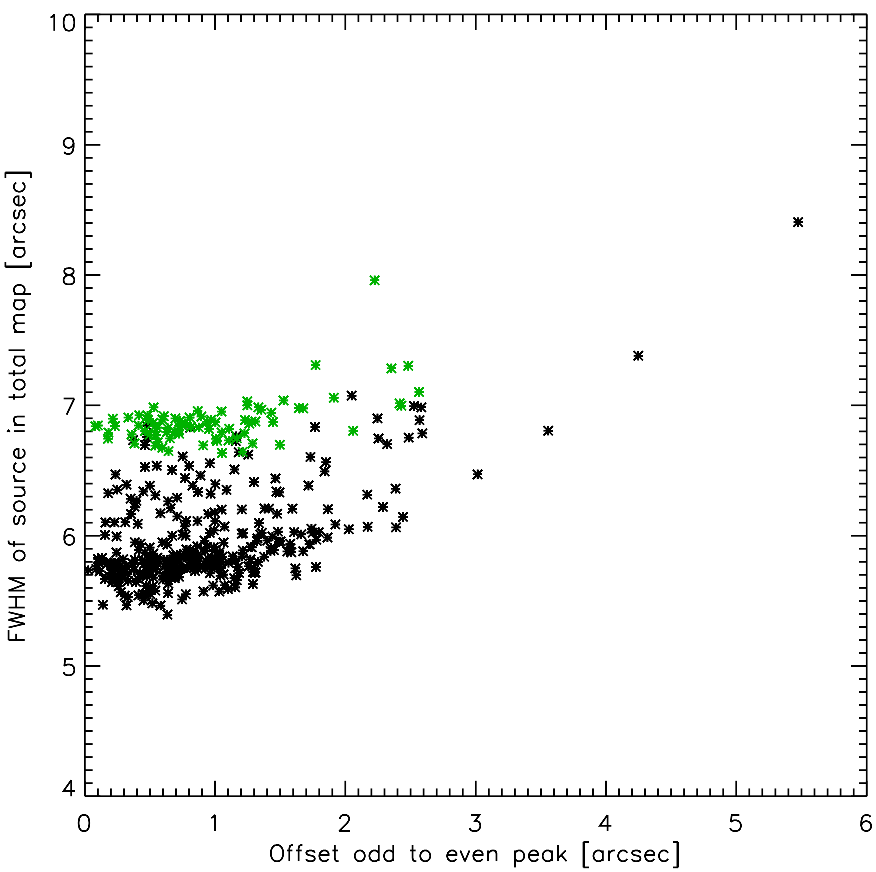

Figure 6: FHWM in total maps vs. offsets from source peak measured in the 'odd scanlegs only' to 'even scanlegs only' maps, for medium speed scanmaps. Sources from OT programs with a larger fraction of extended sources were excluded for this plot. Black symbols are for the blue (70μm) filter, green for the green (100μm) filter.