SUBJECT:	**SPIRE Spectrometer Mapping Status (ICC Review)**
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1 INTRODUCTION ... 4
1.1 STRUCTURE OF THIS DOCUMENT ... 4
1.2 DOCUMENTS ... 4
1.2.1 Applicable Documents ... 4
1.2.2 Reference Documents ... 4
2 JIGGLE AND RASTER PATTERNS ... 5
2.1 JIGGLE PATTERNS ... 5
2.2 RASTER PATTERNS ... 7
3 UPLINK: BSM CALIBRATION AND COMMANDED POSITIONS ... 8
4 INITIAL PV MEASUREMENTS ... 9
5 NEW OBSERVATIONS ... 11
5.1 INITIAL SET OF OBSERVATIONS ... 11
5.2 MAIN OBSERVATION SET ... 11

1 INTRODUCTION

1.1 Structure of this Document

This document contains a summary of the status of the SPIRE Spectrometer Mapping mode. Currently this mode is not released, and the observations necessary to optimise, calibrate and release are planned for OD261 and after. This document gives a brief summary of the operation of the mode, describing the jiggle and raster patterns that will be used. It then describes the calibration used to convert these into uplink commands, and the preliminary data reduction that has been carried out using the first initial test observations. These results feed into the plans for the mapping mode optimisation measurements, which will be carried out in two sets, with data reduction feedback between them. The data reduction questions and plans are outlined for the planned observations.

1.2 Documents

1.2.1 Applicable Documents

AD1	SPIRE Pipeline Description (SPIRE-RAL-DOC-002437), Issue 2.1, 8 May 2009
AD2	SPIRE Spectrometer Pipeline Description (SPIRE-BSS-DOC-002966), Issue 1.3.1, 28 June 2008

1.2.2 Reference Documents

RD1	SPIRE FTS Mapping Modes (SPIRE-RAL-NOT-002801), v1.1 July 2009
RD2	SPIRE Detector Angular Offset and Instrument Mode Mask Calibration Products (SPIRE-RAL-NOT-003225), v1.1 July 2009

2 JIGGLE AND RASTER PATTERNS

2.1 Jiggle Patterns

Intermediate and Full spatial sampling within one field of view is achieved using the Beam Steering Mechanism (BSM). The commanded positions for the intermediate and fully sampled maps were calculated to minimise the number of jiggle positions required, whilst maintaining the correct beam spacing in the final map. This lead to a 4-point jiggle for intermediate sampling (1 beam spacing) and a 16-point jiggle for full sampling (1/2 beam spacing). A description of the optimisation for these patterns is given in RD1.

The BSM angles were calculated assuming an ideal hexagonally packed honeycomb pattern, based on the assumed FWHM of the SSW beam, Δ_{SSW}, where Δ_{SSW} = 16.25".

Intermediate Sampling (4 point jiggle)

Separation in Y-direction	$= 2 \times \Delta_{SSW} \times \cos(30)$	**= 28.1458"**
Separation in Z-direction	$= 2 \times 0.75 \times \Delta_{SSW}$	**= 24.375"**

Full Sampling (16 point jiggle)

Separation in Y-direction	$= \Delta_{SSW} \times \cos(30)$	**= 14.0729"**
Separation in Z-direction	$= 0.75 \times \Delta_{SSW}$	**= 12.1875"**

The detector positions as specified by the optical model (and contained in the Detector Angular Offset table, version 2) are rotated by ~3º from the ideal positions of a hexagonally packed honeycomb. In order to get a jiggle pattern with even spacing of the detector positions, the angular offsets of the BSM positions should also be rotated by 3º after calculating the pattern with the above offsets.

The rotated positions were calculated using:

$$y' = y\cos(\theta_{rot}) - z\sin(\theta_{rot})$$
$$z' = z\cos(\theta_{rot}) + y\sin(\theta_{rot})$$

The final positions to be used are shown below.

Intermediate sampling: 4 point jiggle

Position	Y-angle	Z-angle
1	0.0	0.0
2	28.1014	1.4707
3	15.3264	-23.5395
4	-12.7750	-25.0102

Full sampling: 16 point jiggle

Position	Y-angle	Z-angle
1	-7.6647	11.7697
2	6.3890	12.5052
3	20.4426	13.2407
4	34.4962	13.9762
5	28.1072	1.4710
6	14.0536	0.7355
7	0.0	0.0
8	-14.0536	-0.7355
9	-20.4426	-13.2407
10	-6.3890	-12.5052
11	7.6647	-11.7697
12	21.7183	-11.0341
13	15.3293	-23.5393
14	1.2757	-24.2748
15	-12.7779	-25.0103
16	-26.8315	-25.7458

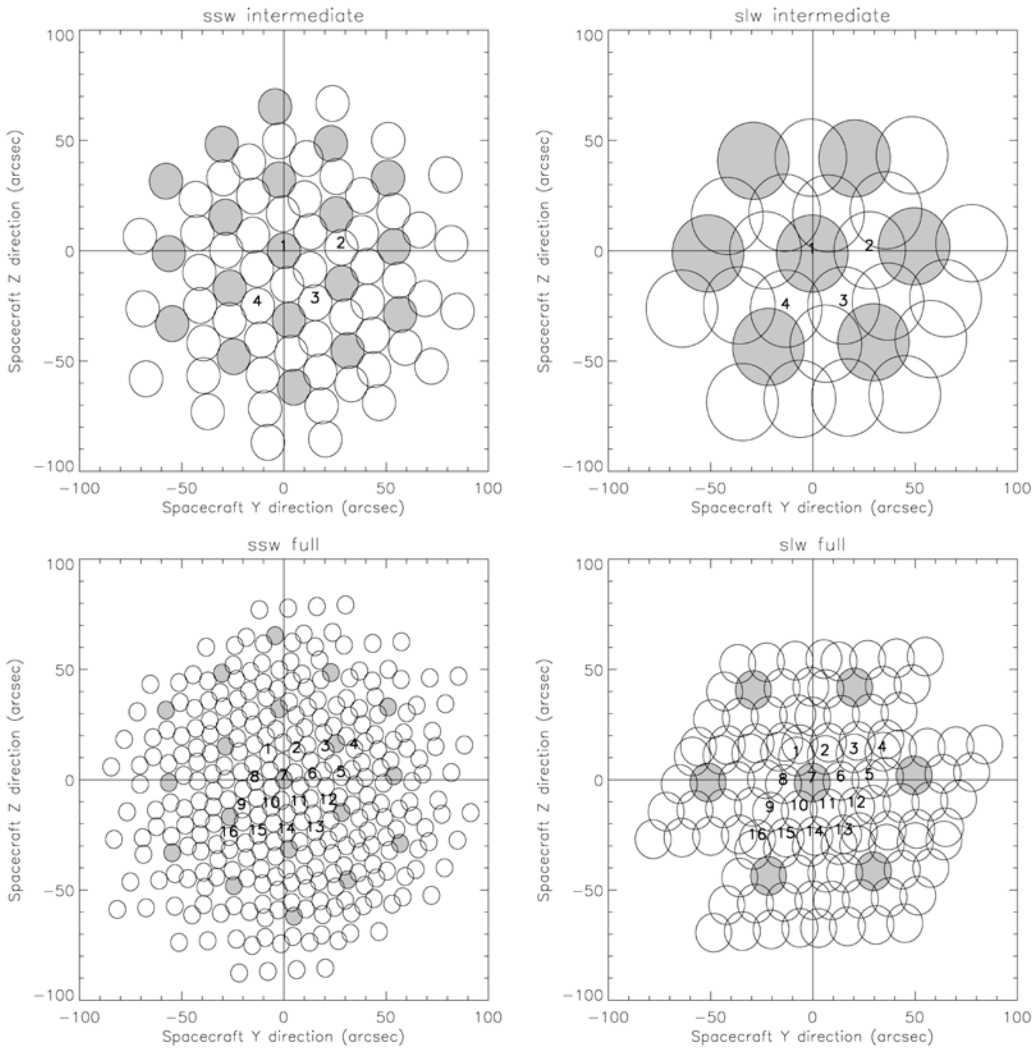

Figure 1: Diagram showing the final jiggle pattern. The central pixel is labelled with the jiggle position number from the above tables. The central pointing in the FOV is shaded.

2.2 Raster Patterns

Raster observations are carried out by moving the telescope to create a pattern of FTS fields of view. The raster pattern for all three spectrometer spatial sampling modes can be operated with the *same* offsets between the centres of the individual fields of view. These offsets are best calculated according to the FWHM of the SLW pixel size, Δ_{SLW}, where Δ_{SLW} = 25.25".

In the spacecraft Y-Z frame, these are:

ystep	$3.25\times\Delta_{SLW}$	= 82.06
zstep	$3.75\times\Delta_{SLW}\times\cos(30)$	= 82.00
yrowstep	$1\times\Delta_{SLW}$	= 25.25
zrowstep	$6\times\Delta_{SLW}\times\cos(30)$	= 131.20

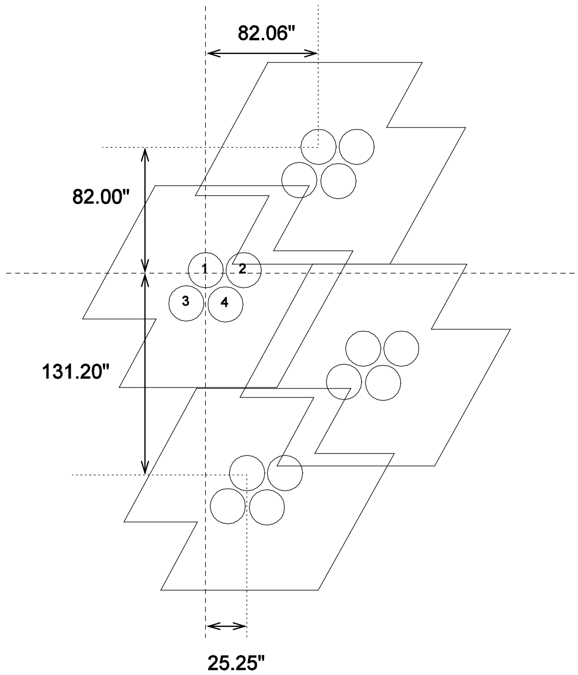

Figure 2: Diagram showing the offsets between individual raster fields of view for SLW. In this case each field of view is a 4-point jiggle and only the centre pixel of the array at each of the 4 positions is shown.

The full description of the raster mode, and how this is implemented in HSpot is given in RD1.

3 UPLINK: BSM CALIBRATION AND COMMANDED POSITIONS

In order to uplink the positions of the BSM for each jiggle position, they were converted to sensor signal in ADU using the calibration of the BSM derived from observations on OD176. Apart from the jiggle and raster pattern positions, the uplink for mapping modes (SOF2) is identical to that for the sparse mode (SOF1). The calibration used to convert the jiggle pattern in arcseconds to the uplink values in ADU are shown in Fig. 3. The changes since the ground based calibration are shown in Fig. 4 for the 4 and 16 point jiggle patterns. The most obvious change from the ground based pattern is a flip in both the Y (chop) and Z (jiggle) directions. This is due to the fact that the ground based BSM calibration had the wrong signs, and this has been corrected for the in-flight data.

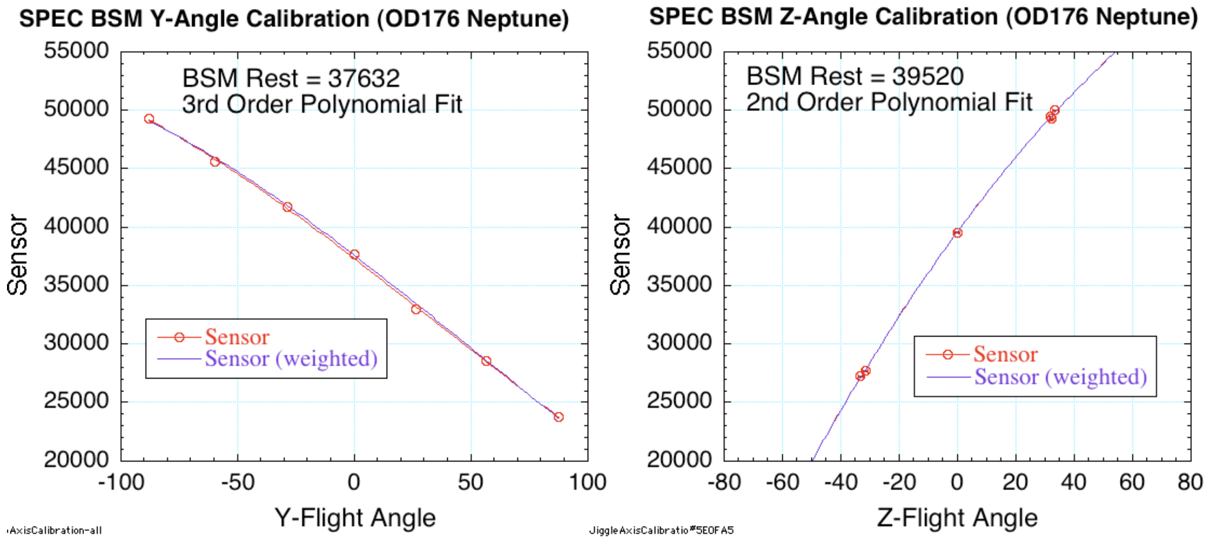

Figure 3: BSM angle to sensor calibration for the Y (chop) and Z(jiggle) axes. The final calibration used was the “weighted” fit (weighted to pass through 0,0 at the BSM rest position).

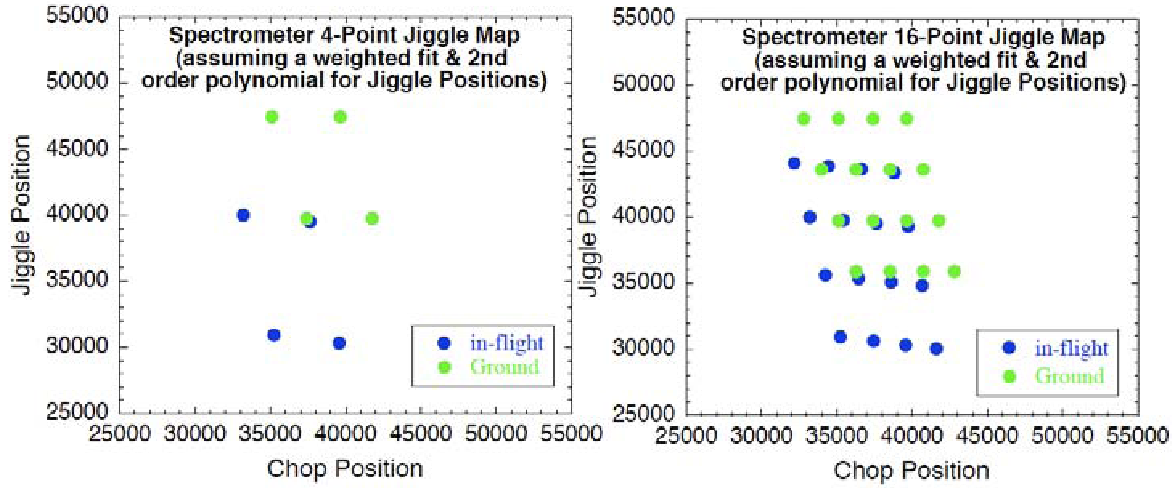

Figure 4: Difference between the in-flight calibration and the previous ground based jiggle pattern positions.

4 Initial PV Measurements

A few preliminary measurements were made during PV phase using the mapping AOT. These were done using positions and BSM calibration derived on the ground. The observations were:

Day	OBSID	Spatial Sampling	Source	Res.	Num. Reps.
OD123	0x50001988	Intermediate	Rosette	LR	2
OD123	0x50001989	Full	Rosette	LR	6
OD131	0x50001ADB	Sparse Raster 3x3	NGC7027	LR	20
OD189	0x50002665	Full	Vesta	LR	2
OD227	0x50002C7C	Intermediate	Arp220	HR	18

These observations have been checked to verify that the AOT was implemented correctly.

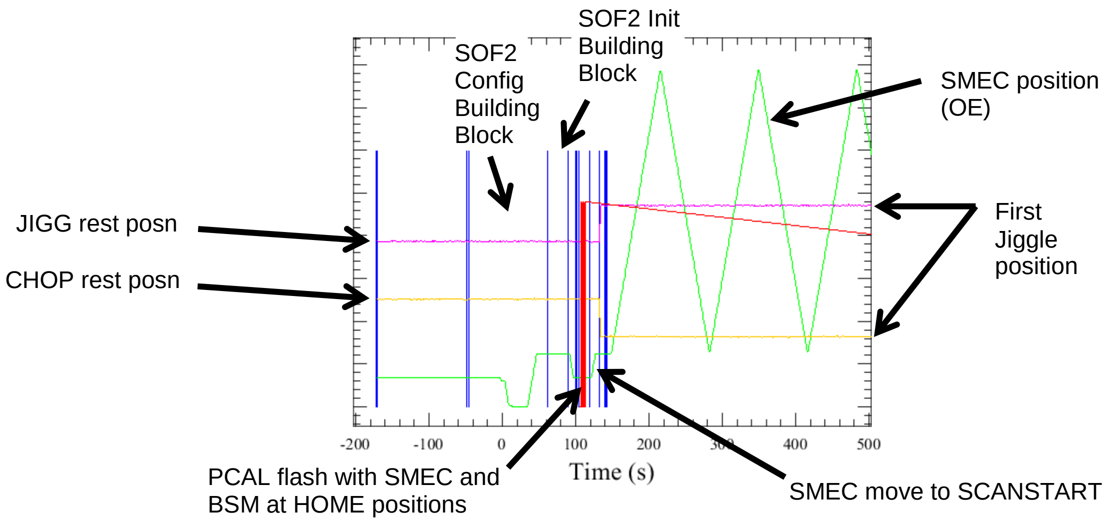

Figure 5: Housekeeping values from the beginning of the observation of Arp220.

The blue vertical lines in Fig. 3 show the start and end of each building block. There are 4 jiggle positions as expected. Each has 18 scan pairs as expected. At the end of each scan building block, there is a PCAL flash. The BSM and SMEC do go to their HOME positions for the PCAL flash. The SMEC does go to SCANSTART for the actual scans.

However, the first jiggle position (0,0) does not appear at the same place as the BSM rest position. This is related to the BSM calibration which was not yet complete (in the final calibration, the rest position should equal 0,0).

Analysis was also performed to investigate what happens to the background at different BSM positions. This was done by subtracting the same reference dark sky (with BSM at rest position) from every jiggle position.

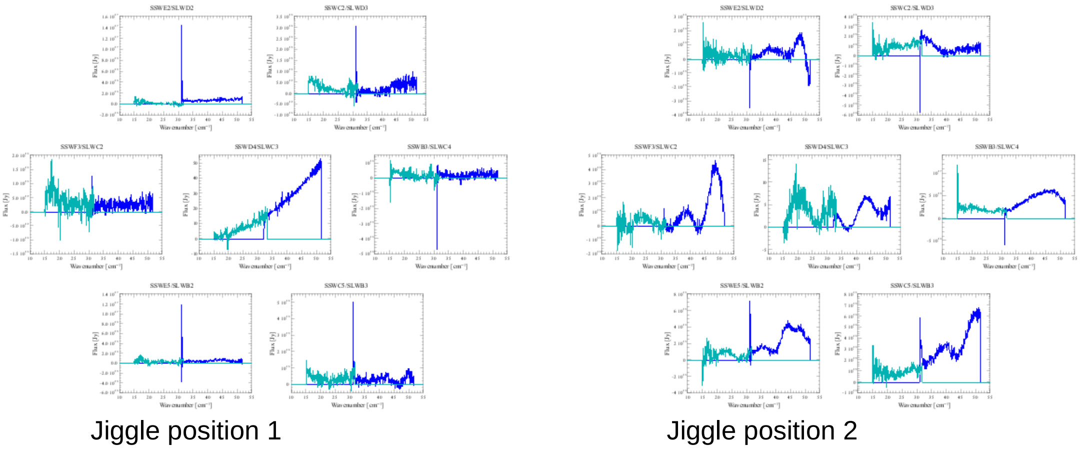

Figure 6: Spectra for the first two jiggle positions for the centre detector pair and the first ring of coaligned detectors.

Jiggle position 1 was done with the BSM approximately at the rest position, and shows good spectra for all detectors. However, the second jiggle position clearly shows that the background subtraction has not worked when the BSM is not at its rest position.

The plot below shows the interferogram for SSWD4 and SLWB4 at each jiggle position in detector offset space (i.e. raw ADU referenced to detector offset setting). It is clear that the amplitude at ZPD changes with BSM position (change of approx. 10% in amplitude). This effect is more apparent for SSW than SLW. In addition, the Pupil Effect Vignetting (see RD2) changes with BSM position. This effect is largest for SLW, although there is also some effect for SSW. This is expected and caused by the fact that the beam is moved over the array when the BSM position is changed, and that effectively changes the distance of the detector from the optical axis.

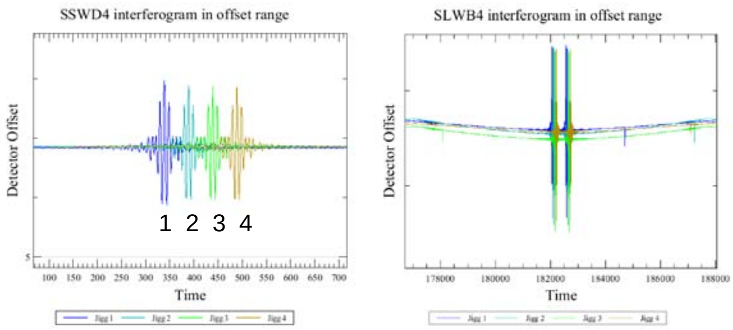

Figure 7: Interferograms for the 4 jiggle positions for SSWD4 and for vignetted detector SLWB4.

The results show that a dark sky measurement is needed at every position of the BSM.

5 NEW OBSERVATIONS

Feedback in the planning cycle is only required once: an initial set of observations are required to provide results that will feedback into the main observation set. Feedback should not be required in the main observation set unless something goes wrong.

5.1 Initial set of observations

The main focus of these measurements is on positions and redundancy, so low spectral resolution will be used. An extended source (NGC7023) will be observed as this will allow comparison with the existing photometer map. The OD261 observations are:

SinglePointing	Sparse	Dark Sky	LR	12
	Intermediate	Dark Sky	LR	12
	Full	Dark Sky	LR	12
Raster 2x2	Sparse	NGC7023	LR	4
	Intermediate	NGC7023	LR	4
	Full	NGC7023	LR	4

The peak of the NGC7023 emission was placed near the overlap region at the centre of the 2x2 raster.

Data reduction that will be required:

- Check spatial coverage in single pointing measurements at each sampling (dead detectors in SSW)
- Check redundancy in overlap regions of raster map
- Variations in dark sky with BSM position. Need to make a CR observation at every jiggle position in the main observations?

Feedback is required for the main observations if the positions (raster or BSM offsets) need to be adjusted, and also to confirm how to make dark observations.

5.2 Main observation set

The main set of observations are designed to answer the following questions:

- Is the flux and position of a point source correctly reproduced if placed at different offsets in the map (including small offsets)
- Is extended emission (structure and fluxes) reproduced after re-pointing the map to slightly different (but overlapping) positions
- To determine the flux calibration at different BSM positions
- To determine the obliquity correction at different BSM positions (the different BSM positions change the distance of each detector from the optical axis and so a different wavescale correction will be necessary for each)
- To determine the relative calibration between different detectors

Observations needed:

Source	Resolution	Details	Procedure	Reduction
Dark Sky	CR	Single Pointing, intermediate & full		
Point source	LR	Single Pointing, intermediate & full	Point source at nominal centre of map	
			Point source at 4 offset positions within jiggled FOV (range from 5” to couple of beam widths)	Compare flux and position of source with map with source at centre
Extended source with lines	HR	Raster 2x2, sparse, intermediate & full	2 offset positions within the map	Compare the two maps. Determine obliquity correction for every BSM position
Asteroid	HR	Single pointing, intermediate	Re-centre asteroid onto SSWD4/SLWC3 at each BSM position in the intermediate sampled map	Test the calibration on the centre detectors when BSM moved. Is a new CUS script required?

All sources should be bright so that only 3 or 4 repetitions on each position are needed. Dark sky observation need not be as long as previous measurements (~10 repetitions). Photometer maps of the sources used are required.

The results from looking at the flux calibration in off-axis detectors (observations from OD210), and at the telescope emission for different BSM positions in existing observations are needed to plan exactly how to do the asteroid observations above. This observation may need a dedicated AOT script to be written.