

# SPIRE Photometry & SPIRE/PACS Parallel Mode Observing Strategies

Luca Conversi Herschel Science Centre Herschel Observation Planning Workshop ESAC, 3-4/06/2010

# Useful Línks

- Documentation at HSC: http://herschel.esac.esa.int/Documentation.shtml
- HSpot User's guide: <u>http://herschel.esac.esa.int/Docs/HSPOT/html/hspot-help.html</u>
- SPIRE Observer's manual: http://herschel.esac.esa.int/Docs/SPIRE/html/spire\_om.html
- SPIRE/PACS Parallel Mode Observer's manual: http://herschel.esac.esa.int/Docs/PMODE/html/parallel om.html
- Herschel Observer's manual: <u>http://herschel.esac.esa.int/Docs/Herschel/html/observatory.html</u>
- AOT release notes: http://herschel.esac.esa.int/AOTsReleaseStatus.shtml
- Herschel Reserved Observation Search Tool: http://herschel.esac.esa.int/Tools.shtml#HROST
- NHSC website: <u>https://nhscsci.ipac.caltech.edu/sc/</u>
- Documentation Page: https://nhscsci.ipac.caltech.edu/sc/index.php/Pacs/HomePage
- Open Time 1 Proposals Page: <u>https://nhscsci.ipac.caltech.edu/sc/index.php/Proposals/Proposals</u>

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### esa SPIRE characterístics - 1

- 2 sub-instruments operating at 300mK: imaging photometer & imaging Fourier Transform Spectrometer (FTS)
- SPIRE Spectrometer:
  - separated input and output ports: one input port views a 2' diameter field of view on the sky; the other is fed by an on-board reference source, in order to null the telescope emission
  - two detector arrays at the output ports cover overlapping bands of 194-324 μm and 316-671 μm
  - spectral resolution is set by the total optical path difference: can be adjusted between 0.04 and 0.83 cm<sup>-1</sup>



# Gesa SPIRE characterístics - 2

### • SPIRE Photometer:

- 3 bolometer arrays used for broad-band photometry: spectral bands centred on 250, 350 and 500 µm
- 4'x8' field of view observed simultaneously in the 3 bands
- signal modulation provided by the Beam Steering Mirror (BSM) or scanning the telescope
- internal thermal source available to provide a repeatable calibration signal
- SPIRE photometer allows 3 observing modes: large map, small map and point source



### Large map AOT - 1

- This AOT produces a fully sampled map centred on the selected target
- As the SPIRE arrays are not fully filled, the telescope scans at constant speed and at an angle of ±42.4° w.r.t. the spacecraft Z-axis; scan lines are separated by 348" to provide overlap and good coverage for fully sampled maps in the 3 bands
- Cross-linked scanning is achieved by scanning at +42.4° (Scan A) and then at -42.4° (Scan B). Cross-scans minimises 1/f noise and improves maps coverage: it is strongly suggested to use it!





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5

### Large map AOT - 2

• User input parameters:

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- Map dimensions (*Height* and *Length*): this sets the guaranteed observed area; the actual observed area will be slightly larger
- Scan speed: Nominal (30"/s) or Fast (60"/s). N.B.: for SPIRE, there is no huge side effect in using the fast scan speed, i.e. the S/N decreases as  $(T_{obs})^{-1/2}$
- Scan direction: the astronomer can choose to observe only in the A or B direction; <u>it is</u> suggested to use the default A+B cross-scanning
- Optional parameters:
  - Repetition factor: used to increase the integration time. <u>Note that after only ~5</u>
    repetition, the SPIRE instrumental noise is equivalent to the extragalactic confusion noise!
  - *Map centre offset*: introduce an offset, in spacecraft coordinates (Y,Z), w.r.t the target position. Useful e.g. dithering or split observations
  - Map orientation: if Array with Sky constraint is selected, the given pair of angles defines the range between which the scan leg can lie along
  - Source flux estimates: used to estimates the S/N of the observation and eventually set the Bright Source Setting



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### Large map AOT - 4

In the new window, select Fixed or Moving, depending if your target is a moving one or not

Fixed targets:

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000 Target ш Target Name (required): SIMBAD Resolve the Name I. insert the Target Name Goods-N Target Visibility Background II. eventually select the catalogue Fixed Moving (SIMBAD or NED) Coord Sys: Equatorial 12000 Proper Motion RA: ☑ Use Proper Motion 12h36m49.49s III. then click on Resolve the Name button: PM RA (arcsec/year): 0.000 Dec: +62d12m58.0s RA and Dec fields will be filled PM Dec (arcsec/year): 0.000 Epoch: 2000.00 IV. Click OK ? Cancel OK

Target Name (required): Uranus Fixed Moving NAIF ID: 799 ()	Resolve To Naif ID Farget Visibility Background Get Target Name Cancel OK	Moving targets: I. insert the <i>Target Name</i> II. then click on <i>Resolve To Naif ID</i> button: the <i>NAIF ID</i> field will be filled III. Click OK
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### Large map AOT - 5

000	SPIKE Photometer
Unique AOR Label:	SPhoto-0000
	Target: Goods-N Type: Fixed Single
	Position: 12h36m49.49s,+62d12m58.0s
Ne	w Target Modify Target Target List
Num Star t	ber of visible stars for the target: 9 tracker target: Ra: 9.206 degrees Dec:-62.216 degrees
	Instrument Settings
	Source type
	Small Map
	Large Map
Repetition fa	ctor Source Flux Estimates and Bright Source Settin
Repetition	Source Flux Estimates
Large Man Parame	tars
Lenge Map Farante	ath (arcmin)
Heid	aht (arcmin)
Sele	ct the speed Nominal 🗧 5
Scar	Direction 6 Scan Angles A and B 🛟
Map	centre offset Y (arcmin) 0.000
Map	centre offset 7 (arcmin) 0.000
Ori	entation
Ma	p Orientation Array
An	gle from (degrees) 0
An	gle to (degrees) 360
<u> </u>	
Obser	vation Est Add Comments AOR Visibility
2	Cancel OK

- 4. Set map Length and Height. N.B.: L<sub>max</sub> = 1186' & H<sub>max</sub> = 240' for A or B scans only; these are reduced to 226' for A+B cross-scans
- 5. Set scan speed: Nominal (30"/s) or Fast (60"/s)
- 6. Set scan direction (A, B or A+B)
- 7. Optional parameters:
  - Repetition factor: it increases the on-source integration time; for cross-scans observations, each repetition consist of a full A+B coverage
  - *Map centre offset*: introduces an offset (given in spacecraft coordinates) w.r.t. target position. Useful e.g. for dithering
  - Map Orientation: constrain the observation orientation. <u>N.B.: setting an avoidance will raise</u> the AOR penalization to 10 min!
  - Source Flux Estimates: see slides on Bright Sources

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9

### Small map AOT - 1

- This AOT produce a fully sampled, 5' map around the selected target. For most cases, this is the ideal AOT for observing point sources: you get better sensitivity, a fully sampled map and a faster observation (1 rep. needs 169s)
- This is achieved scanning the telescope at a fixed speed of 30"/s along 2 almost orthogonal directions: the scan angle is fixed at ±42.4° w.r.t. the spacecraft Z axis
- Hence, each repetition is made of 2 cross-scans, at +42.4° and at -42.4°.

10

Note that after only ~5 repetition, the SPIRE instrumental noise is already equivalent to the extragalactic confusion noise!

Coverage maps for a small map AOT (PSW, PMW & PLW)



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#### esa Small map AOT - 2 SCIENCE Observation Tools Calibration 1. In HSpot, select SPIRE HIFI Single Point... Photometer from the HIFI Mapping... Observation menu HIFI Spectral Scan... SPIRE Photometer PACS Photometer... Unique AOR Label: SPhoto-0000 PACS Line Spectroscopy... 2. In the pop-up window, PACS Range Spectroscopy... Small Map is already Target: None Specified SPIRE Photometer... SPIRE Spectrometer... selected New Target Modify Target SPIRE PACS Parallel Mode... 3. Set the target by clicking on the New Target button

### 4. Optional parameters:

- Repetition factor: it increases the on-source integration time; each repetition consist of a 1x1 scans
- Map centre offset: introduce an offset (given in spacecraft coordinates) w.r.t. target position.
  Useful e.g. for dithering
- Source Flux Estimates: see slides on Bright Sources



### Point source AOT - 1

This AOT involves jiggling, chopping and nodding

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- Cycle A: target is centred on detector 1, BSM moved in 7 positions (jiggling) and chopped in each of them
- Cycle B: after moving the telescope (nodding) at +126", target is centred on detector 2, BSM moved in 7 positions (jiggling) and chopped in each of them
- 1 repetition is made of an ABBA cycle and requires 380s



### Point source AOT - 2

- The chop and nod axes are the same and are parallel to the long (Y) axis of the array to allow switching between co-aligned pixels
- As Herschel moves in its orbit, the orientation of the array on the sky changes. To avoid chopping nearby bright sources onto the arrays, pairs of angles can be defined (up to 3) which will prevent the observation being made when the long axis of the arrays lies between the specified angles
- This mode is recommended for bright, isolated sources in the range 0.2-4 Jy, where the astrometry is accurately known and accurate flux measurement is required
- For sources fainter than 200mJy (where the background produces a significant contribution) or at fluxes higher than ~ 4 Jy (where pointing jitter can introduce large errors) the Small Map mode is preferable
- Note that with this mode will not provide a fully sampled map!

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- nearby sources. You can set up to 3 avoidance regions (it includes regions at ±180°).
  - N.B.: setting an avoidance will raise the AOR penalization to 10 min!
- Source Flux Estimates: see slides on Bright Sources

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Avoidance

From 0

**To** 0

Add Comments...

Avoidance

From 0

To 0

Cancel

AOR Visibility

OK

Avoidance

From 0

0

Observation Est...

?

### PMODE AOT -1

- Parallel mode AOT allows the users to observe with both SPIRE & PACS on, covering a total of 5 bands: the 3 SPIRE ones, the PACS red channel (130-210µm) and a selection between the blue filter (85-130µm) and the green filter (60-85µm)
- User requested area will be covered by both SPIRE & PACS
- To achieve this, the S/C will cover an area ~15' bigger than the user requested one (being ~15' the distance between SPIRE and PACS footprints on the sky)
- Hence, this mode is efficient only for large observation and cannot be used for fields <u>smaller than 30'x30'!</u>



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### PMODEAOT-2

• Parallel Mode vs SPIRE Large Scan AOTs:

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- To fit within the bandwidth limits, SPIRE sampling rate is reduced from 18.2Hz to 10Hz while PACS data frames are averaged on-board
- Same scan angles: +42.4° in the Nominal direction; -42.4° in the Orthogonal one
- Scan leg separation is smaller (longer on-source observing time): 168" in *Nominal* direction, 155" in *Orthogonal* one vs 348" for SPIRE-only AOT
- Scan speed: Nominal (30"/s) is replaced by Slow (20"/s); Fast (60"/s) is also available. <u>N.B.</u>: this will degrade PACS PSF; for SPIRE it is more difficult to identify detectors' glitches due to the reduced data rate
- Neither the repetition factor nor the cross-scanning are available. <u>However, to achieve</u> better coverage and reduce the 1/f noise, it is strongly suggested to do 2 observations in crossscan configuration (i.e. one in Nominal and one in Orthogonal direction): they can be combined during the data analysis
- Other parameters are the same as per SPIRE Large Scan AOT
- Data processing is exactly the same as per SPIRE Large Scan AOT
- From the downlink point of view, users will get 2 observations: one for SPIRE and one for PACS: these will have same obs. ID



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17

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## Bright Sources

- For sources brighter than 200 Jy in any SPIRE band, it is suggested to use the Bright Source Setting
- This changes the detectors bias to optimize their response to bright sources. However, the sensitivity degrades by a factor (3.8, 3.2, 2.6) for (250, 350, 500)  $\mu$ m respectively
- To set it:

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- 1. Click on the Source Flux Estimates button: a new window will pop-up
- 2. From the pull-down menu Use Bright Source Setting, select Yes
- 3. The other fields a optional and are o used to estimates S/N in the Observa Estimates window (see next slide)

re	Image: Organization of the second							
only	Optional: Enter source estimated data if required							
s the	Band (µm)	Point source flux density (mJy)	Extended source surface brightness (MJy/sr)					
ation	250	20.0						
/	350	15.0						
	500	10.0						
	Optional: Use Bright Source Setting? Warning: Selecting yes below will induce a change in the instrument settings and sensitivity of the observation. Please check applicable flux threshold in Yes Use Bright Source Setting V No Cancel OK							
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### Verifying yourAOT -1

- Once you filled in SPIRE Photometer window, click on the Observation Est... button: a new window will pop-up, presenting the details of the planned observation
- The upper table (1) reports the 1σ instrument noise for the observation
- If you filled the Source Flux Estimates, the values are reported in the upper table (1) and the S/N is estimated
- Clicking the Update Confusion Noise Estimation button will calculate the expected confusion noise for the observed area and reported in the lower table (2).

Note that after only ~5 repetition, the SPIRE instrumental noise is already equivalent to the extragalactic confusion noise!

\varTheta 🔿 🔿 SPIRE Time Estimation Summary								
Band (µm) <b>1</b>	Point Source Flux Density	Point source S/N	1-σ instrument (mJy in beam)	Extended S Surface Brightness	Extended S S/N	Extended S 1- $\sigma$ instrument		
250	(m)y) 20.0	4 9	4.0	(MJy/sr)		(MJy/sr)		
350	15.0	4.5	3.4			0.2		
500	10.0	2.1	4.8			0.1		
On-source integration time per map repetition (s) 1698								
Number of map repetitions				5				
Total on-source integration time (s)				8490 (=5*1698)				
Instrument and observation overheads (s)			3721					
Observatory overhead (s)				180				
Total time (s)				12391 (=8490+3721+180)				

Note: to change the observation time, change the repetition factor on the AOR main screen. It multiplies the on-source integration time per map repetition to give the total on-source time.

#### Confusion noise estimation summary



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# Verífying yourAOT - 2

• Finally, check the coverage!

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- 1. Load an image of the region. E.g. select ISSA/IRIS under *Images* HSpot menu, and click OK in the pop-up window
- 2. Select AORs on *images...* from the Overlay menu, select a date and check the coverage
- 3. Try different dates (especially at the visibility window edges!) to see if you always cover your target, otherwise increase the map dimension or constrain the observation (10 min penalization!)
- If you need to constrain the map orientation:
  - 1. find a day in which the orientation is fine
  - 2. check the position angle in that day: you can do it selecting the AOR Visibility from SPIRE Photometer AOT window
  - 3. add 42° degrees to get the central value of the range to set in Array with Sky Constrain: allow a range of ~10° at least
- Other possible constrains: timing, group, follow-in, etc. Check Bruno's presentation



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### Conclusions

- SPIRE is a very sensitive instrument: in most cases, it is useless to do many repetitions due to low instrumental noise but high confusion noise
- Instead of multiple repeats at the same location, it is better to dither the entire map by shifting slightly the center of the map and concatenate AORs. Ideally, add follow-on constraints to pairs of AORs, i.e. repeat AORs at different epochs to allow the scan direction to rotate (but it costs 10 min extra penalization)
- If you are interested in point sources, in the majority of the cases the Small Map mode is the right choice. The Point Source AOT is suggested only for sources in the range 0.2-4Jy of which you want to accurately know the flux
- For large maps, it is good to use Parallel Mode: it will not affect SPIRE data and you will get PACS one "for free". Remember: in terms of on-source integration time (i.e., S/N), I Parallel Mode observation is roughly equivalent to repeat a SPIRE observations 2-3 times
- Scenarios that give same sensitivity in final map:

I Scan at 30"/s vs 2 Scans at 60"/s

AOR execution time is significantly higher in case of fast scan due to longer turnover times between scan legs. It is prohibitive for small maps:  $Overhead_{60^{n}/s} >> Overhead_{20^{n}/s}$ 

Hence, much better to go for the less scans at slower scan speed!

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