PACS Photometry observing strategies

ESAC, June 2010

Bruno Altieri (HSC) & Nicolas Billot (NHSC)

Preliminary remarks and Useful Links

Documentation at HSC: http://herschel.esac.esa.int/Documentation.shtml

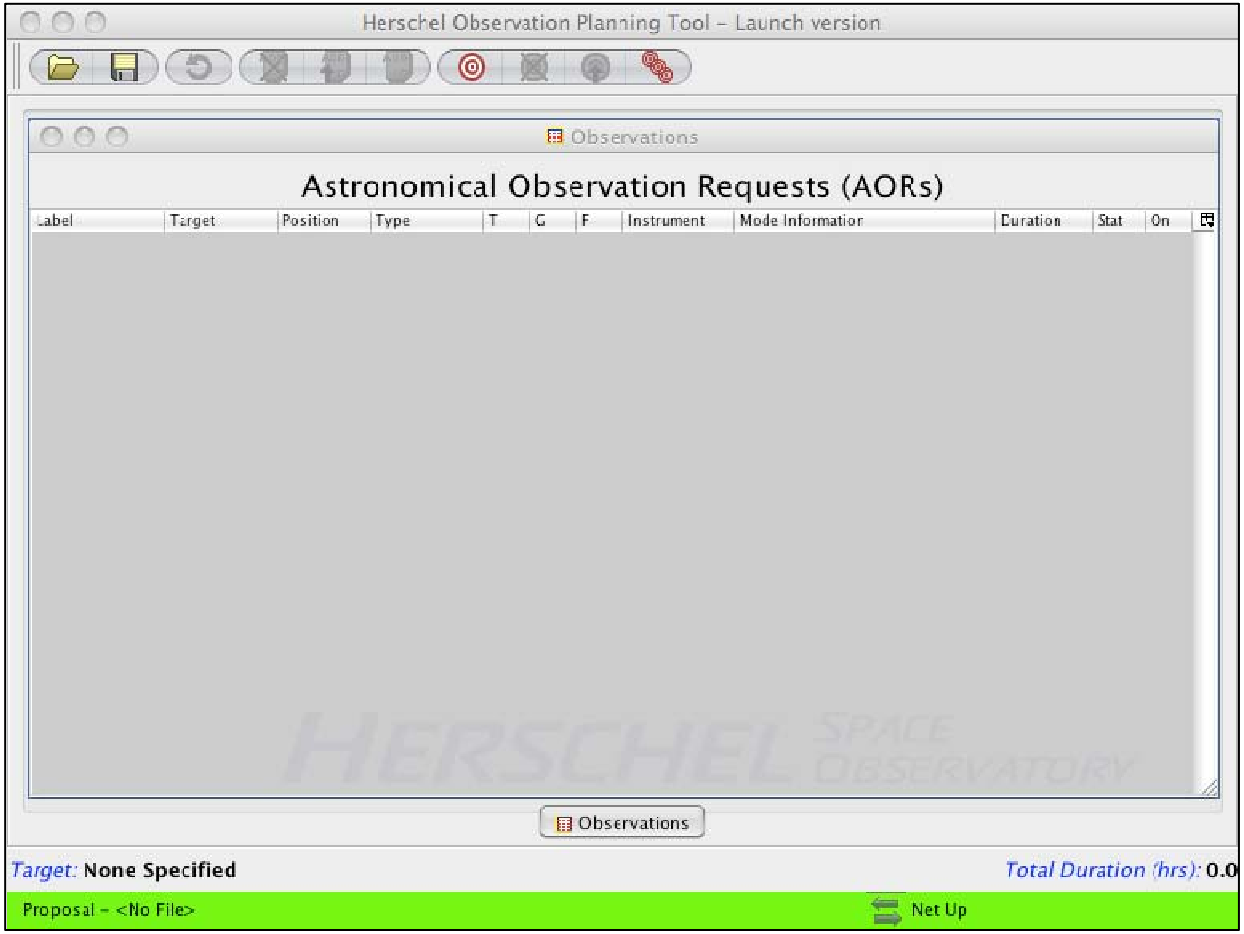
- HSpot User's guide:
  http://herschel.esac.esa.int/Docs/HSPOT/html/hspot-help.html
- PACS observer's manual:
  http://herschel.esac.esa.int/Docs/PACS/html/pacs_om.html
  http://herschel.esac.esa.int/Docs/PMODE/html/parallel_om.html
- Herschel Observer's manual:
  http://herschel.esac.esa.int/Docs/Herschel/html/observatory.html
- 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: https://nhscsci.ipac.caltech.edu/sc/

- Documentation Page:
  https://nhscsci.ipac.caltech.edu/sc/index.php/Pacs/HomePage
- Open Time 1 Proposals Page:
  https://nhscsci.ipac.caltech.edu/sc/index.php/Proposals/Proposals

HSpot User's Manual:

“HSpot is remarkably simple and a user-friendly piece of software.”



Enable automatic update feature under the “Options” menu on the HSpot toolbar.

Need version 5.0.x for current AO.

Planning an Observation with HSpot

1. Provide Target Information
2. Select the Instrument Settings (band, gain)
3. Select the Observing Mode and Setup Observational Parameters to Suit your Scientific Goal
4. Check AOR with Visualization Tools, Check Sensitivity Estimates
5. Concatenate/Chain AORs Together to Build your Observation

For comparison, or inspiration:

You can view accepted observing proposals + AORs:
"View Accepted Proposals" under the "File" menu

You will need the exact proposal name, e.g. KPGT_aabergel_1, that you can find at http://herschel.esac.esa.int/Key_Programmes.shtml

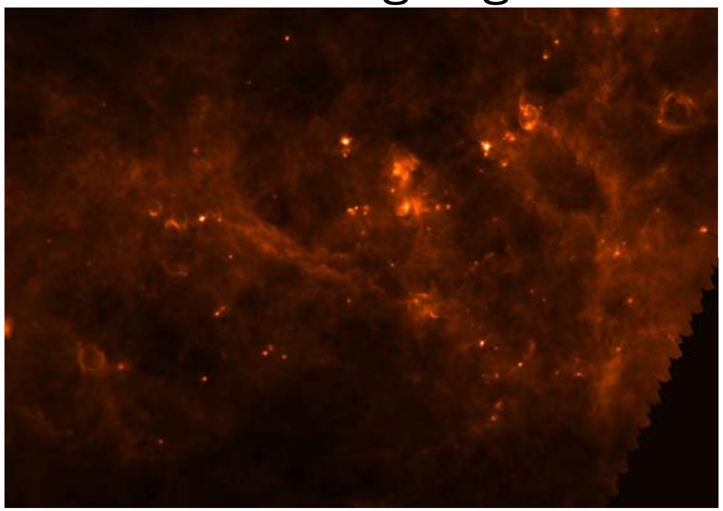
Two Science Cases to illustrate 2 AOTs

Only two observing modes survived the Performance Verification Phase:

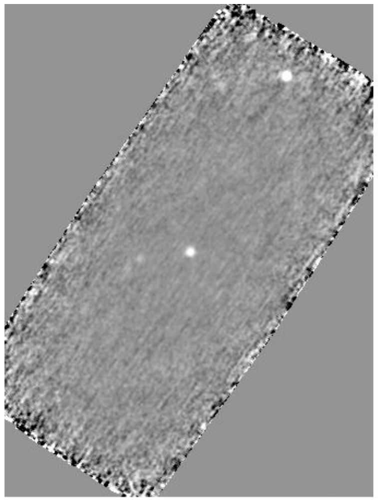
(Small-Source AOT and Raster Map AOT decommissioned)

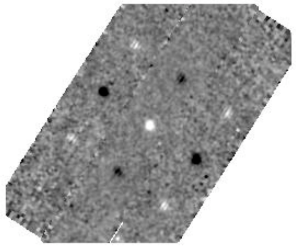
Scan Map and Chop/Nod

Scan-Map of a Galactic Star-Forming Region



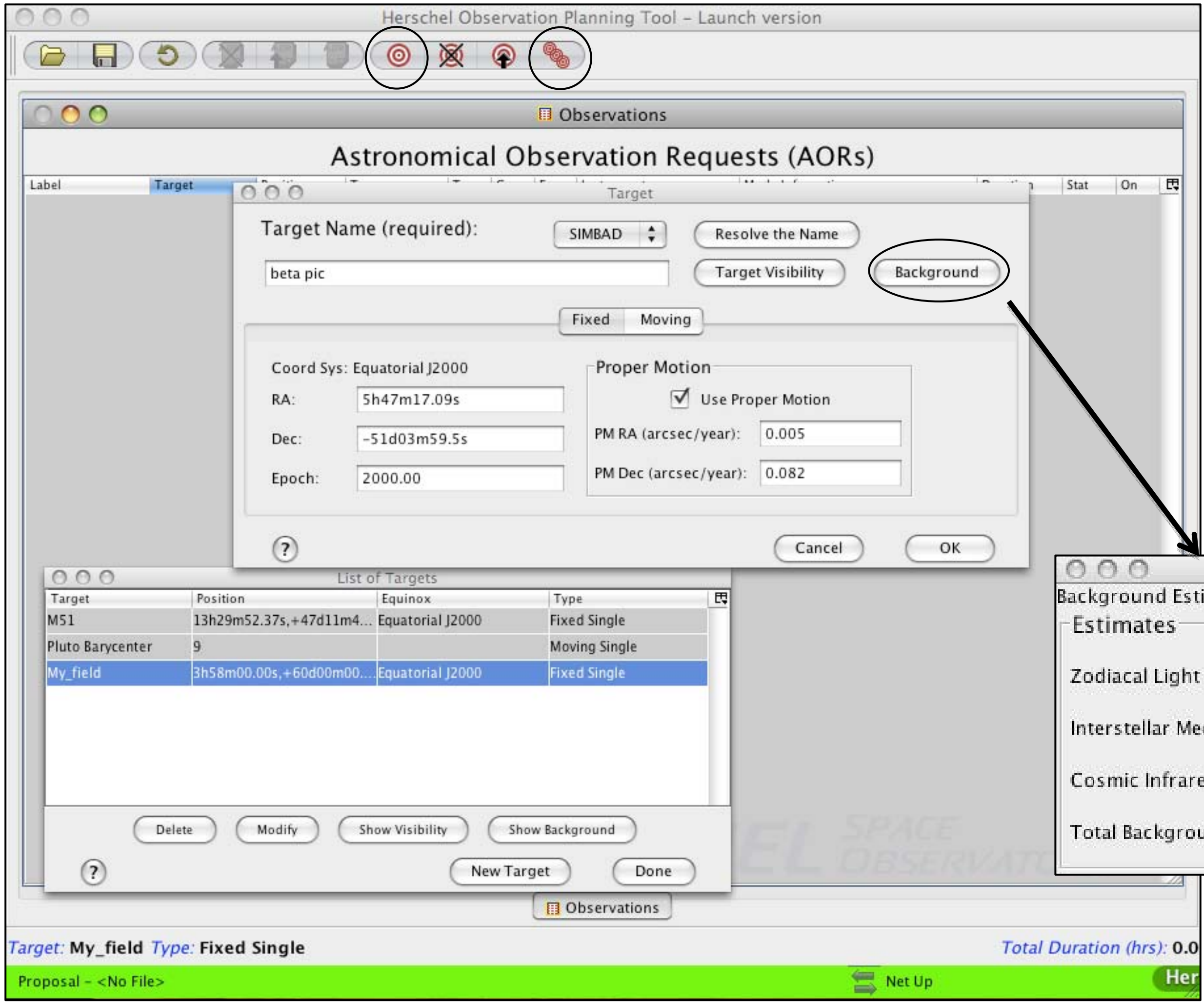
Point-Source Observation (Mini-Scan Map and Chop/Nod)

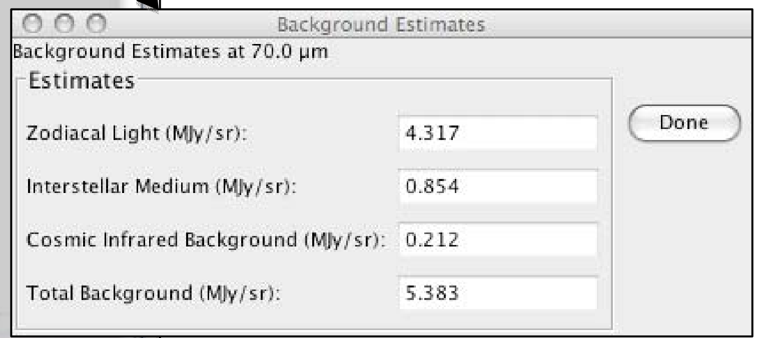




Define a Target or Target List

New Target   Target List



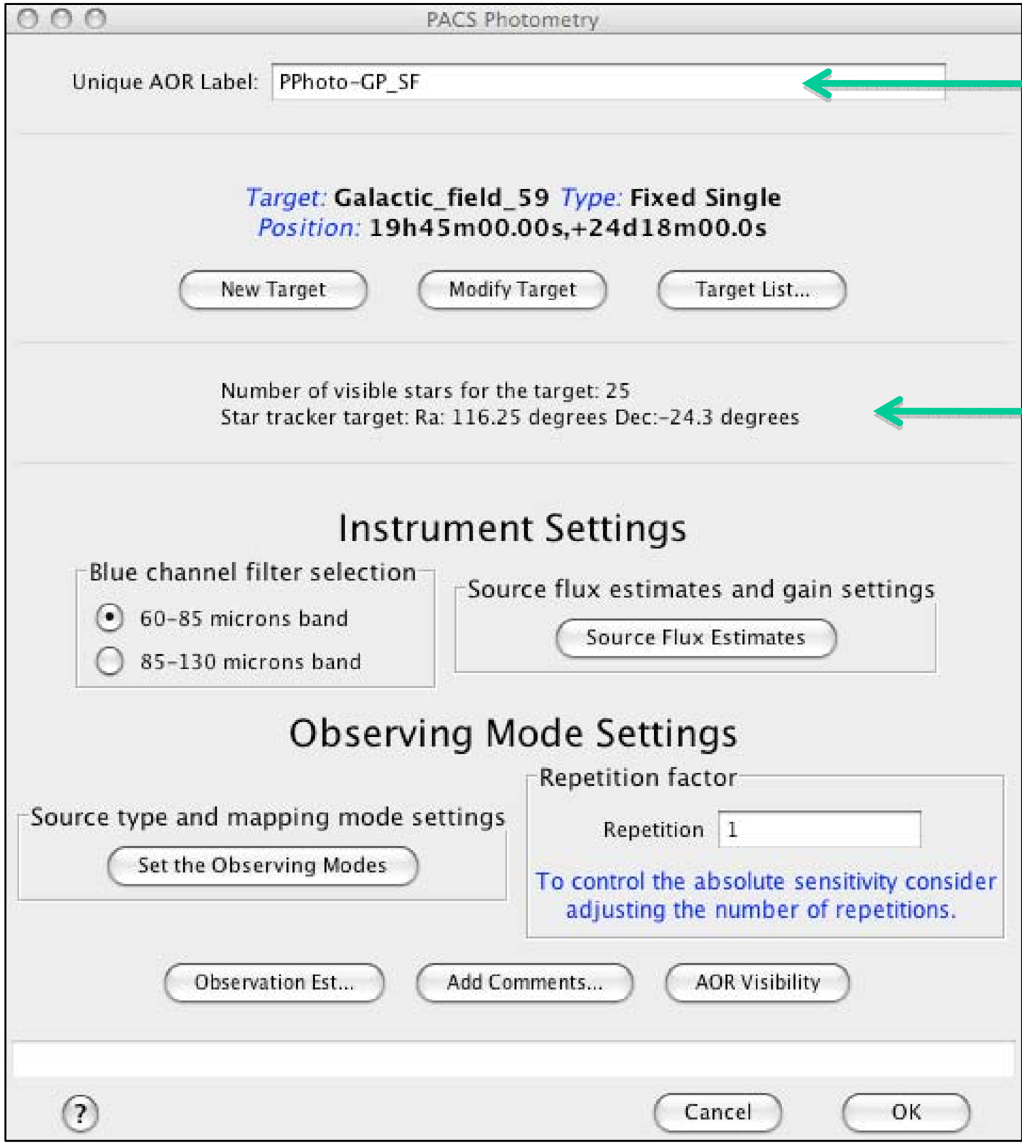


- Fixed or Moving Targets
- Resolve the Name
- Target Visibility
- Background

at given time, coordinate, and wavelength

Target and Instrument settings

"PACS Photometer…" under the "Observation" menu



Unique AOR Label

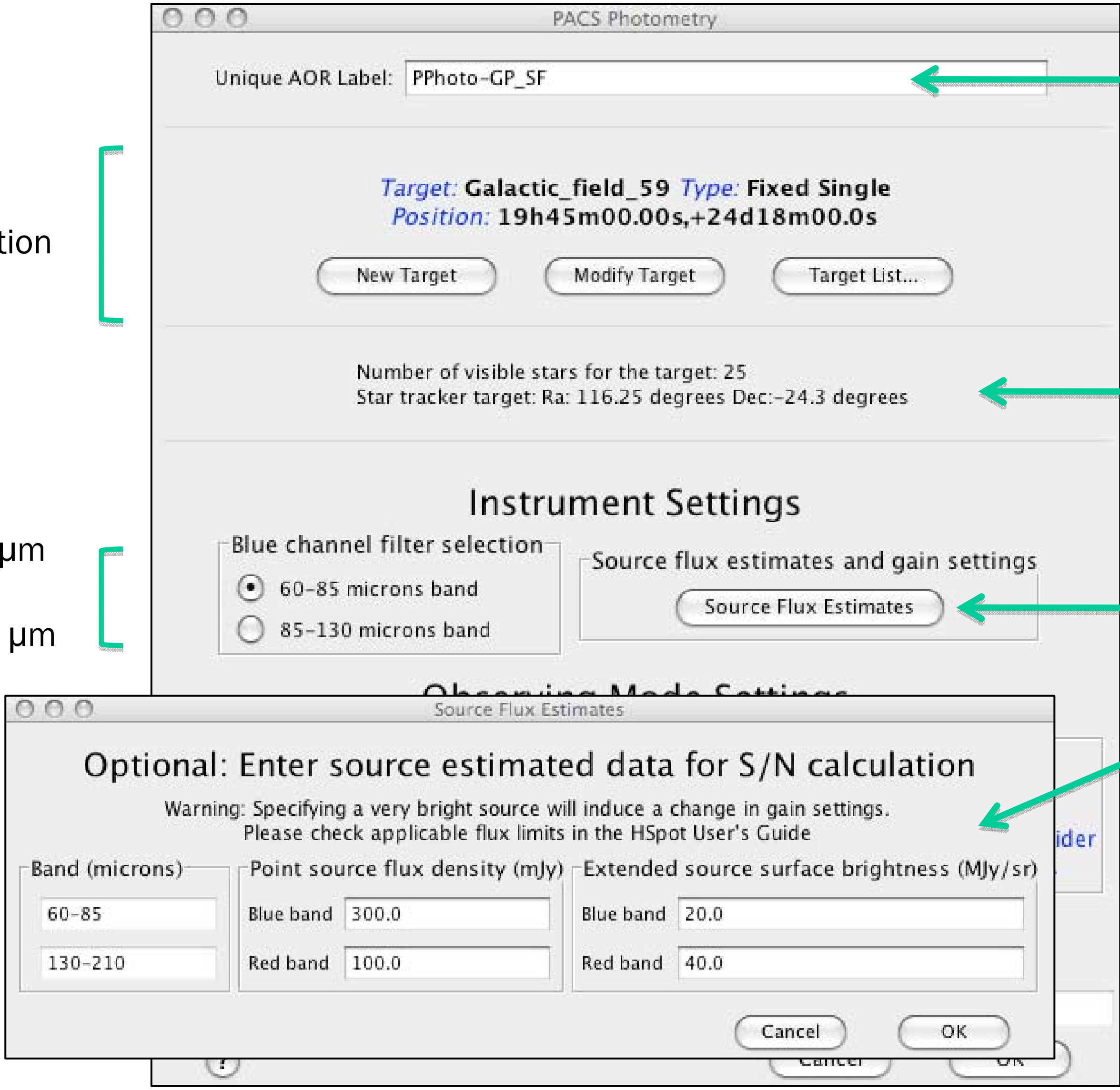
Target information

stars in Star Tracker
(better be >9)

70 and 160 μm
OR
100 and 160 μm

Target and Instrument settings

“PACS Photometer...” under the “Observation” menu



Unique AOR Label

Target information

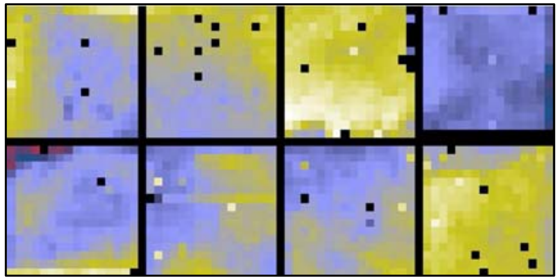
stars in Star Tracker (better be >9)

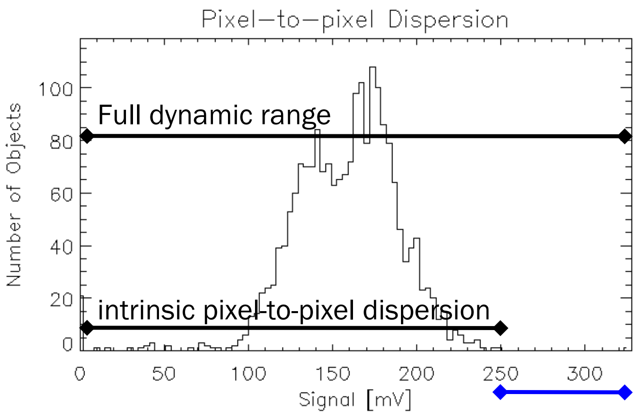
70 and 160 µm
OR
100 and 160 µm

Source Estimates:
Saturation limits drive the change of readout electronics gain.
Low-gain setting reduces sensitivity. Saturation limits are very conservative.

Target and Instrument settings

Gain Setting





Room left to accommodate the signal

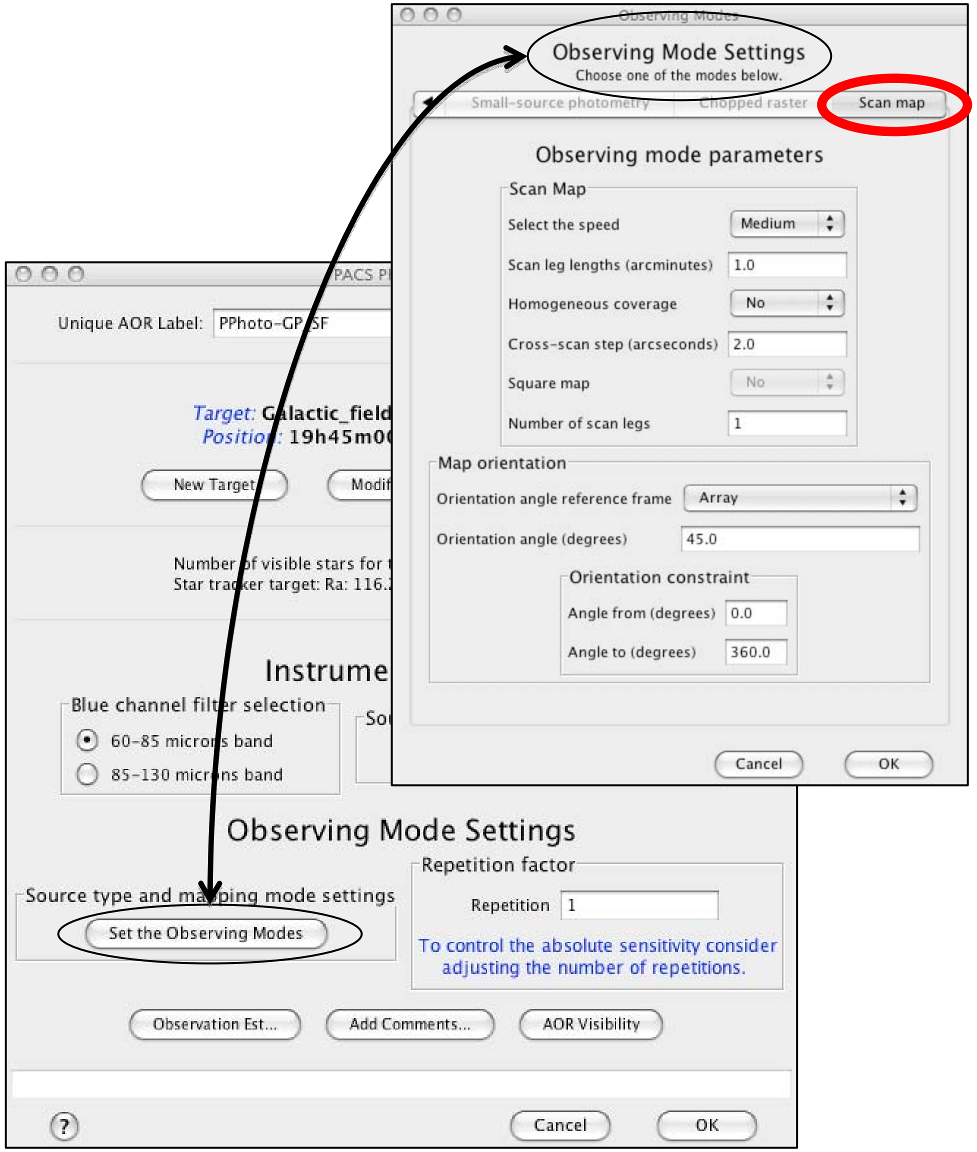
Filter	Point source [Jy]	Extended source [GJy/sr]
Blue	220	290
Green	510	350
Red	1125	300

- HSpot saturation limits are very conservative, they assume the peak of the PSF sits on the brightest pixel.
- Low-gain setting reduces the sensitivity (higher digitization noise).
- We recommend to switch to low-gain setting only if source flux significantly exceeds the official saturation limits.
- If source flux marginally above saturation limit, put in a lower flux to fool HSpot and avoid switching to low-gain setting.

WARNING: if you fool HSpot gain setting by putting in lower flux estimates, then SNR estimates become irrelevant!

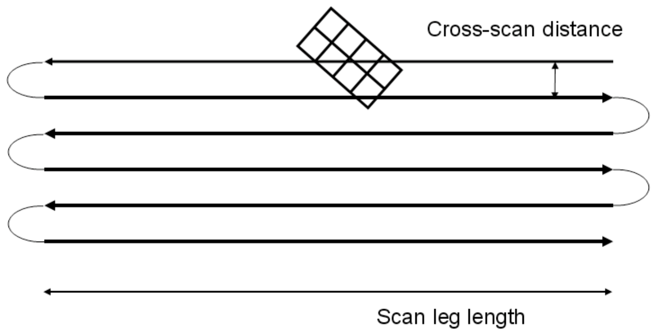
 See PACS Key Information on NHSC website: https://nhscsci.ipac.caltech.edu/sc/index.php/Pacs/InstrumentDetails

Scan Map AOT Settings



User input parameters for Scan Maps:

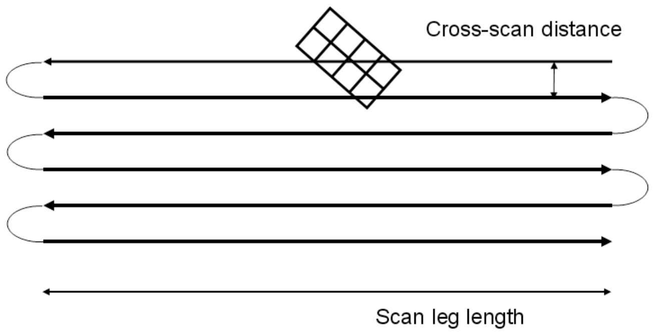
- Filter
- Scan Speed
- Scan Leg Length
- Cross-scan Distance
- Number of Scan Legs
- Square Map
- Homogeneous Coverage
- Orientation Reference Frame
- Orientation Angle
- Orientation Constraint
- Repetition Factor
- Source Flux Estimates (optional)



Scan Map AOT Settings

User input parameters for Scan Maps:

- Filter
- Scan Speed
- Scan Leg Length
- Cross-scan Distance
- Number of Scan Legs
- Square Map
- Homogeneous Coverage
- Orientation Reference Frame
- Orientation Angle
- Orientation Constraint
- Repetition Factor
- Source Flux Estimates (optional)



Choice of Scan Speed:

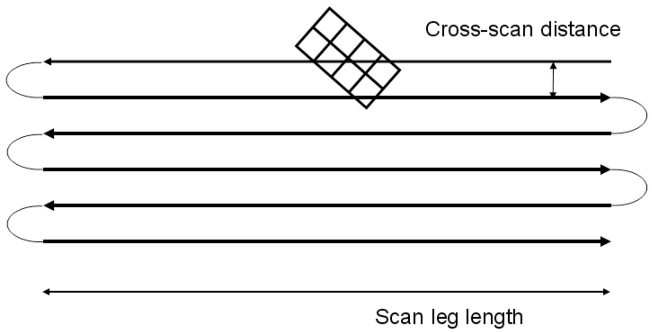
- Medium or Standard (20''/s) for optimum modulation of the signal from the telescope motion (in terms of 1/f noise).

- Fast (60''/s) for large maps at the expense of degraded PSFs (10% - 60% elongation in scan direction) and longer overheads due to longer turnover time.

Scan Map AOT Settings

User input parameters for Scan Maps:

- Filter
- Scan Speed
- Scan Leg Length
- Cross-scan Distance
- Number of Scan Legs
- Square Map
- Homogeneous Coverage
- Orientation Reference Frame
- Orientation Angle
- Orientation Constraint
- Repetition Factor
- Source Flux Estimates (optional)



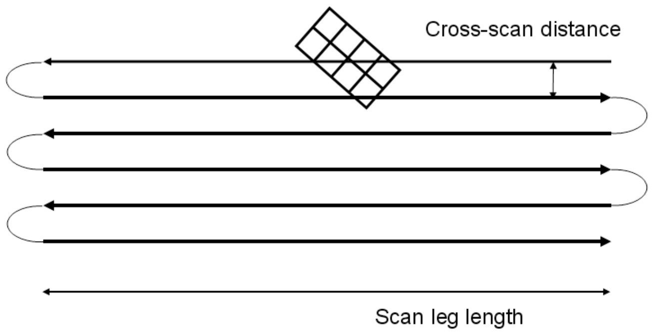
Choice of Map Size Parameters:

- Scan leg length sets dimension of one map side (< 20°).
- Use Homogeneous Coverage for large maps (Cross-scan distance is set automatically).
- Square Map makes observation scheduling easier (number of scan legs is set automatically).
- Cross-scan distance <105'' ensures overlapping between scan legs for all array-to-map angles (in sky coordinates).
- Cross-scan distance of 51'' (~sub-array size) gives relatively flat exposure maps in Sky coordinates, whatever the array-to-map angle.

Scan Map AOT Settings

User input parameters for Scan Maps:

- Filter
- Scan Speed
- Scan Leg Length
- Cross-scan Distance
- Number of Scan Legs
- Square Map
- Homogeneous Coverage
- Orientation Reference Frame
- Orientation Angle
- Orientation Constraint
- **Repetition Factor**
- Source Flux Estimates (optional)



Choice of Repetition Factor:

- This sets the sensitivity of the observation once the other parameters are set.

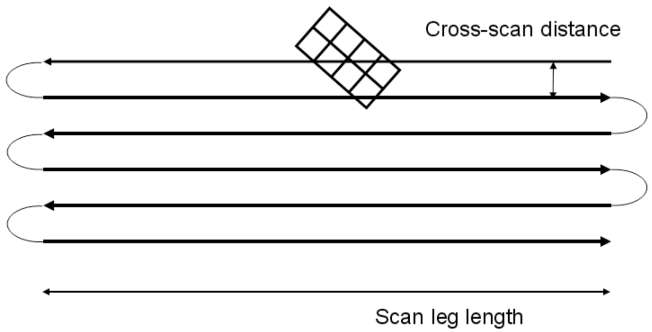
- If repetition factor >1, it is recommended to use an even number of scan legs to minimize satellite slew overheads.

- The repetition factor also offers flexibility when combined with other parameters, e.g. 1 repeat slow scan or 3 repeats fast scans.

Scan Map AOT Settings

User input parameters for Scan Maps:

- Filter
- Scan Speed
- Scan Leg Length
- Cross-scan Distance
- Number of Scan Legs
- Square Map
- Homogeneous Coverage
- Orientation Reference Frame
- Orientation Angle
- Orientation Constraint
- Repetition Factor
- Source Flux Estimates (optional)



Choice of Map Orientation Parameters:

- No magic angle like SPIRE (focal plane filled with bare pixels).

- Absolute flexibility: all scan directions are possible in array or sky reference frame, with optional constraints.

- BUT think twice before putting a constraint to your observation: Orientation constraints translates into scheduling constraints, hence in observing time penalties.

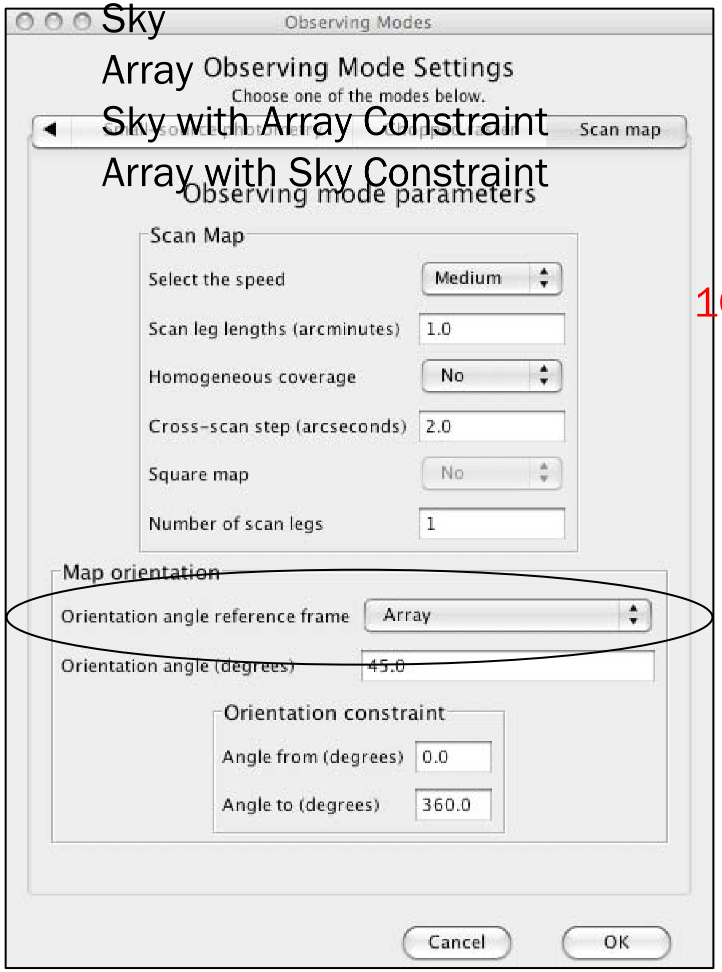
- Avoid scanning at array angles of 0° and 90° because of empty inter-module gaps.

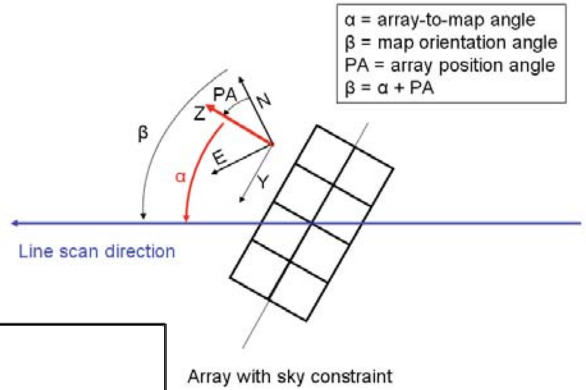
- If scan maps in Sky coordinates without array constraints, the map coverage depends on the exact observation date, and there is a risk that the array-to-map angle is 0° or 90°. Check the AOR overlay on image at given visibility windows.

Scan Map AOT Settings

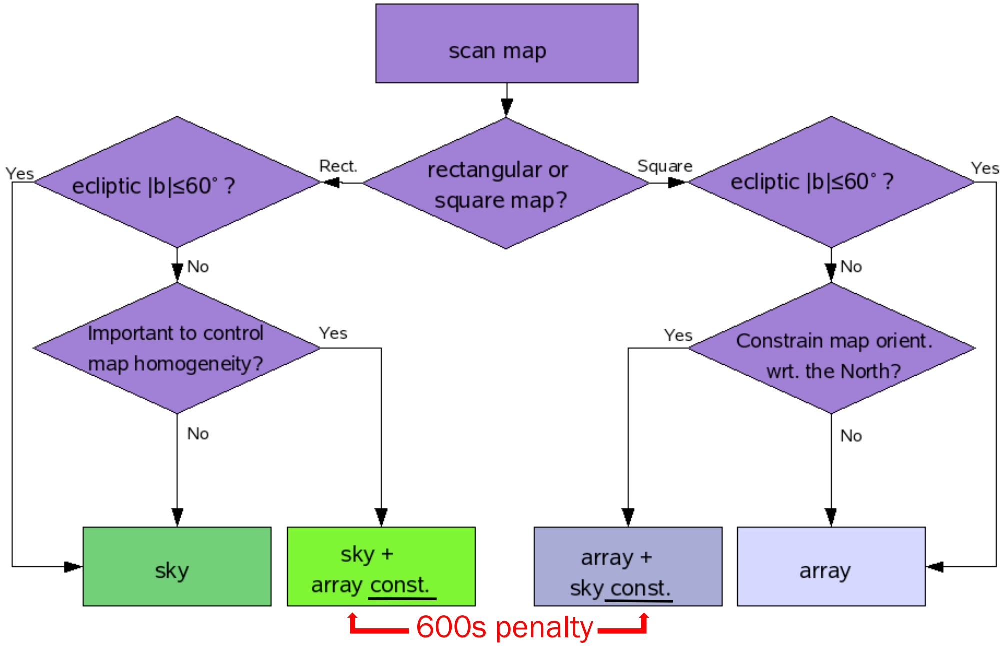
Orientation Angle Reference Frame Options:

- Sky
- Array
- Sky with Array Constraint
- Array with Sky Constraint

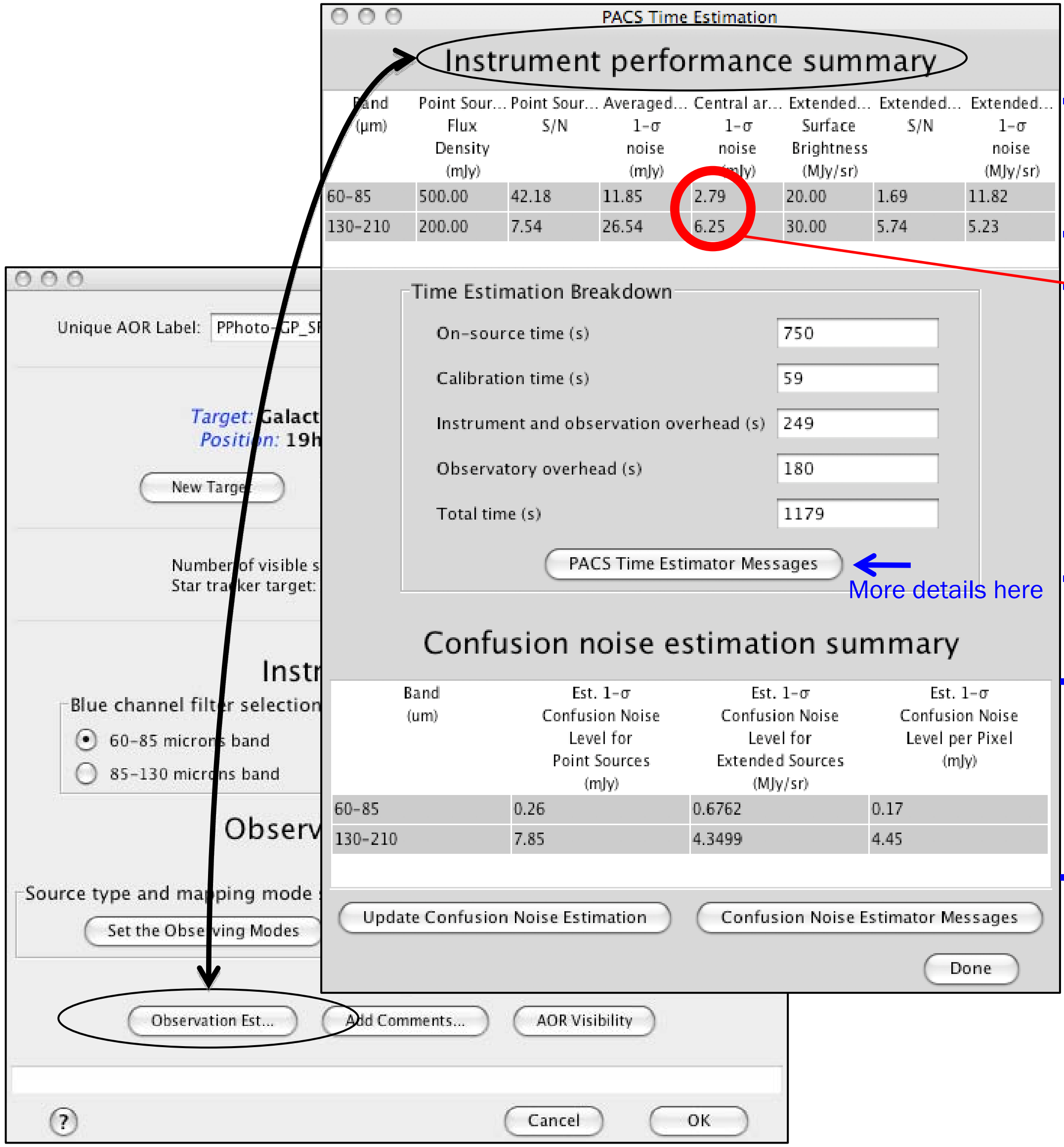




WARNING:
10 MINUTES PENALTY FOR CONSTRAINT



AOR Performance Estimate



Sensitivity estimates

only for mini-scan map mode

Details of AOR execution time

Confusion noise estimates

PACS Time Estimator Message

Messages

PACS Photometer AOT

ObsMode: **Large source, line scan mode (no chopping)**

ScanLeg: 1500.0 [arcsec]; number of legs: 10; leg separation: 154.9 [arcsec], scan speed: 20.00 [arcsec/sec]

PHOTO observed size: 1,605.00 x 1,612.71 [arcsec]

PHOTO observed area: 2,588,395 [arcsec2]

Nod pattern (as applicable)

No nodding, S/C is in line scan mode

Dithering information

Dithering information is not applicable.

Duration information

AOT duration (w/overheads): 1058 [sec]

(AOT duration comprises 'on-sky' plus setup and CAL during slew)

Breakdown of AOT duration:

- On-sky time (w/overheads): 999 [sec]
- (actual on-sky time: 750 [sec])
- Setup and CAL during slew (w/overheads): 59 [sec]
- (actual calibration time: 31 [sec])

AOT cost (includes time to slew to source): 999 + 180 = 1179 [sec]

Sensitivity information

Effective on-sky time (one spatial resolution element) : 6.7 [sec]

Effective on-sky time (central resolution element) : 120.0 [sec]

central area point-source sensitivity (red): 6.25 [mJy]

central area point-source sensitivity (blue): 2.79 [mJy]

map averaged point-source sensitivity (red): 26.54 [mJy]; extended surface brightness sensitivity: 5.23 [MJy/sr]

map averaged point-source sensitivity (blue): 11.85 [mJy]; extended surface brightness sensitivity: 11.82 [MJy/sr]

Save messages | Cancel | OK

Map geometrical parameters summary

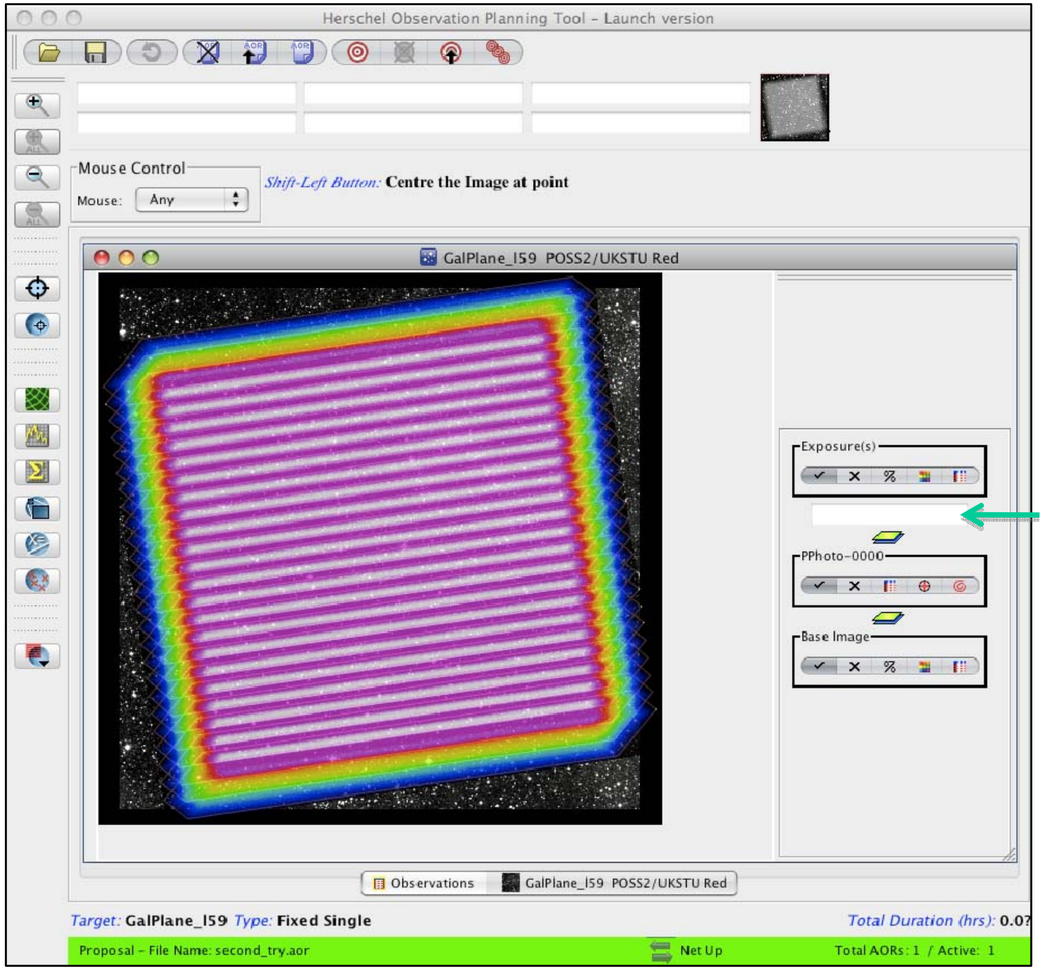
Total AOR duration

Average pixel exposure time

The final sensitivity of your observation depends to some extend on the data reduction, e.g. highpass filtering, MADMap, source registering to correct for pointing errors, etc.

Check your observation

Always visualize your observations and check the coverage maps.



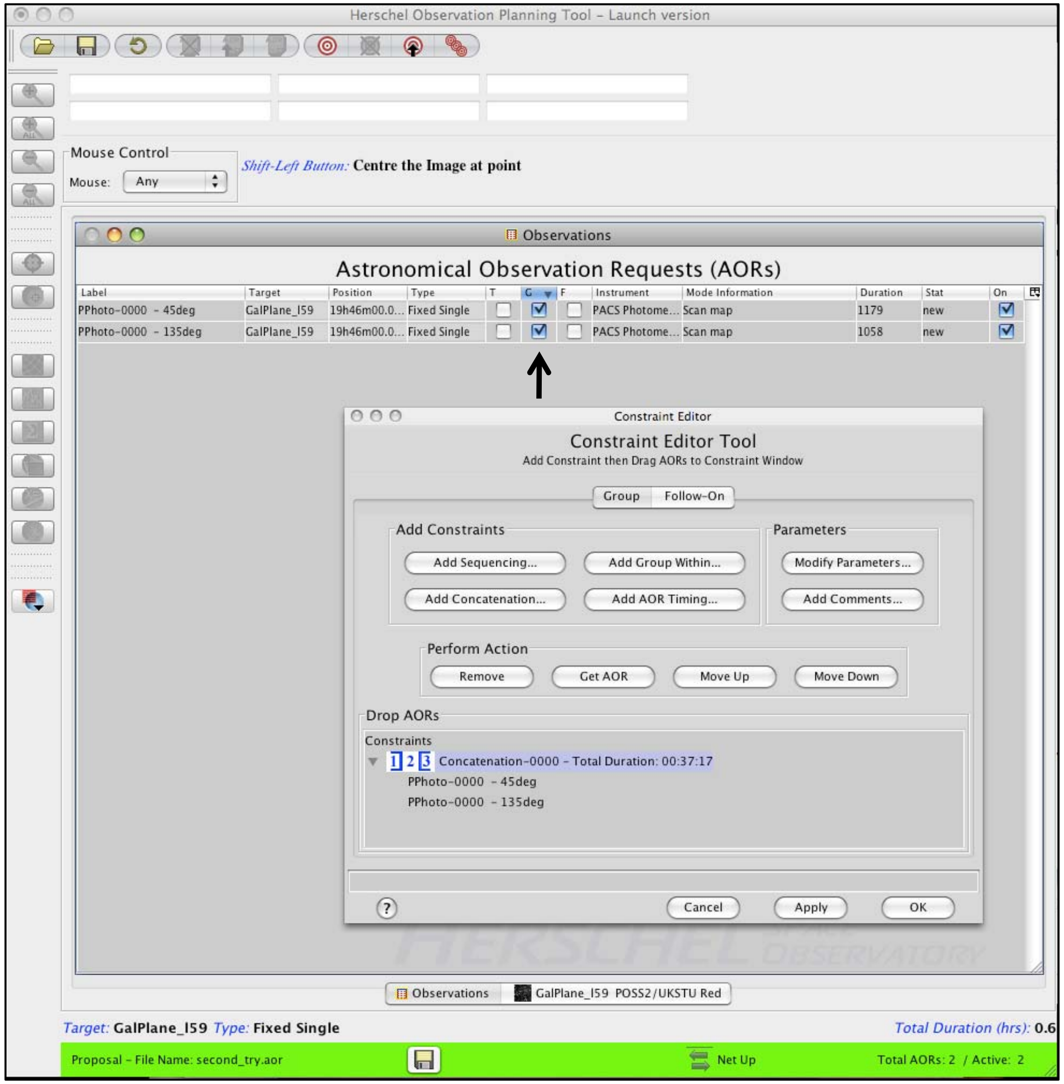
Check map orientation in chosen visibility window.

Check coverage homogeneity (exposure time per pixel in seconds).

If scan map in sky coordinates, check that the array-to-map angle is not 0° or 90°.

Scheduling Constraints

"Group/Follow-on Constraints…" under the "Tools" menu



Scheduling Constraints

Timing constraint: 600s overheads instead of 180s

AOR executed within specified time period (ABSOLUTE TIME, BEFORE or AFTER), e.g. period when moving target is out of Galactic Plane.

Grouping/Follow-on constraint:

- Sequence: 600s overheads instead of 180s
  sequence of AORs executed in specified order within a given period of time.
- Chain or Concatenation: Spare Observatory slew time (180s – CalBlock duration)
  AORs are executed in the order specified with NO interruption in the chain, e.g. scan and X-scans, or PACS 3-band observations.
- Group within: 600s overheads instead of 180s
  AORs executed within a given period of time but in any order.
- Follow-on: 600s overheads instead of 180s
  AORs observed in sequence at given intervals of time, appropriate for observation of variable targets, e.g. YSOVAR-like programs.

Science-driven Parameter Choices

for a Scan Map of a Star-forming Region

Safe choices for observing a star-forming region:

- 20''/s (or 60''/s or SPIRE/PACS Parallel mode if PSF quality not critical)
- Homogeneous coverage
- Square map
- Instrument reference frame is ARRAY, with array-to-map angle of 45°
- Concatenate X-scan with orientation angle of 135° (spare 2 minutes slew time)

  Map-making algorithms require the highest pixel and scan-direction redundancies possible, so that *scan and X-scan observations are highly recommended to preserve the extended emission*, i.e. separate 1/f noise from large scale structures in the data processing.

- Possibly Concatenate pairs of scan/X-scan AORs to observe in 3 bands,

  i.e. observing at 70/160 μm AND right after at 100/160 μm (spare another 2 minutes slew time)

Science-driven Parameter Choices

Other Tips and Tricks

For deep scan maps and best PSF reconstruction:

- Instead of multiple repeats at the same location, one should
  - decrease the cross-scan distance between legs to increase spatial redundancy within a single map.
  - dither the entire map by shifting slightly the center of the map, and concatenate pairs of scan/X-scan AORs.

Scenarios that give same sensitivity in final map:

- 1 Scan at 20''/s versus 3 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.

  $\text{overhead}_{60''/s} >> \text{overhead}_{20''/s}$

- 1 fine Scan (short cross-scan distance) versus 3 loose Scans (larger cross-scan distance) while covering the same area (it requires to un-tick homogeneous coverage) :

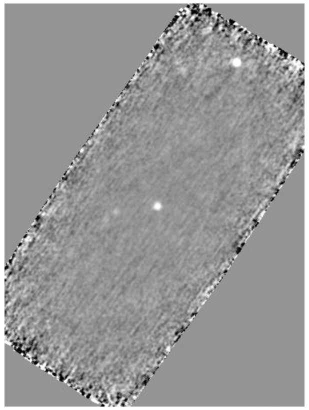
  AOR execution time is similar, but <u>fine scanning gives more homogeneous coverage</u>.

Point Source Observations

2 Options

Mini-scan Map

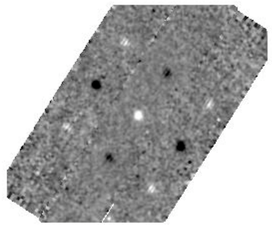
- Better characterization of target close vicinity
- Better characterization of larger scale structures
- Larger area of homogeneous coverage
- High redundancy as more pixels see the source
- Better sensitivity (efficient high-pass filtering)
- No negative beams in the map
- OK for targets with large positional uncertainty
- Relatively large overheads (still more sensitive!)



Chop/Nod point-source

Advantages for source fluxes in range (50mJy-50Jy):

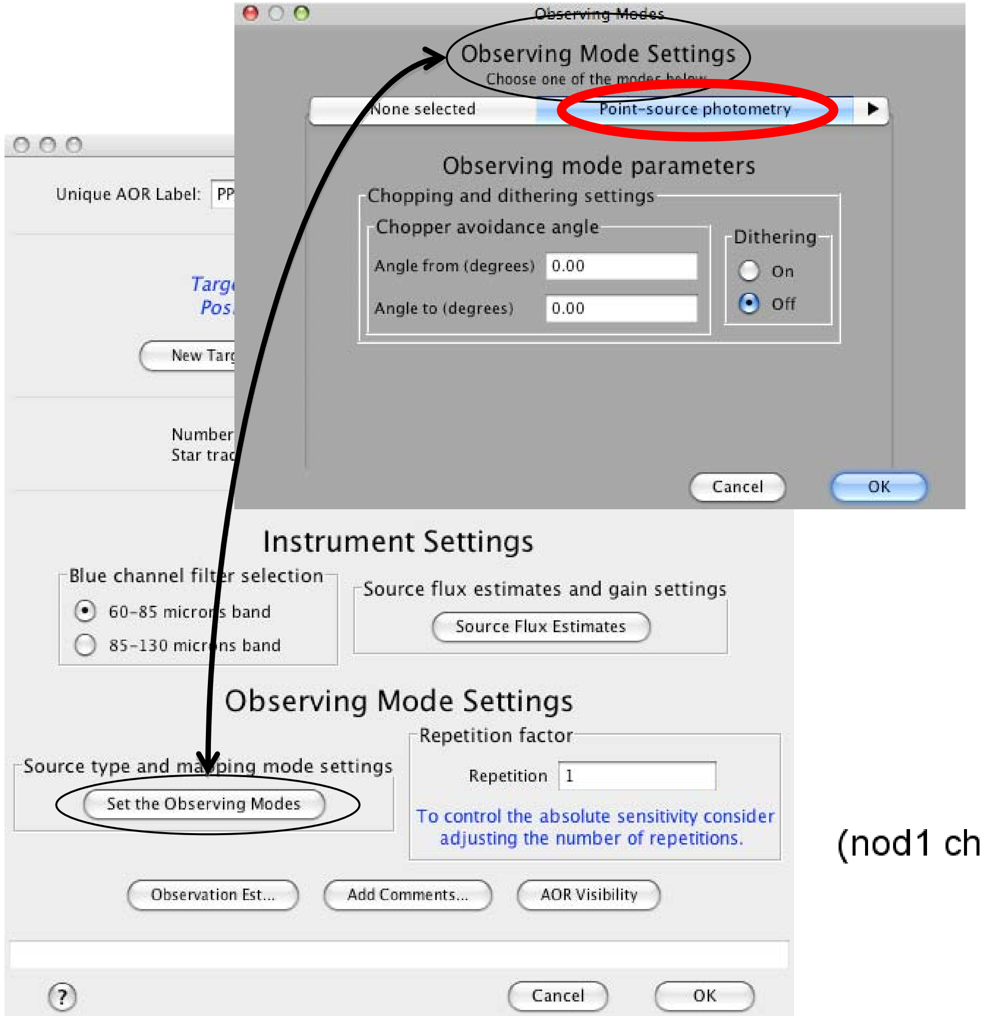
- Stability of reconstructed PSF (RPE<0.3'')
- High spatial resolution
- High photometric accuracy for isolated sources
- Actual sensitivity worse than HSpot numbers
- Rely on very few pixels
- Positive-negative beams in final image:
  - Limitations due to crowded backgrounds
  - Limited area of homogeneous coverage



Detailed comparison in AOT release note:
http://herschel.esac.esa.int/Docs/AOTsReleaseStatus/PACS_PhotChopNod_ReleaseNote_22Feb2010.pdf

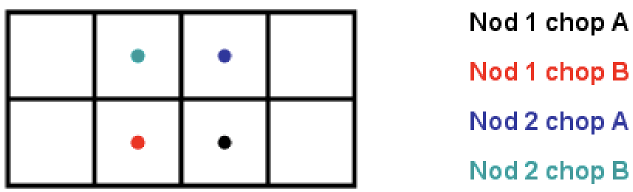
Point Source Observations

Chop/Nod mode



User input parameters for Chop/Nods:

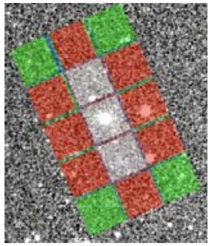
- Filter
- Dithering
- Chopper avoidance angle
- Repetition Factor
- Source Flux Estimates (optional)

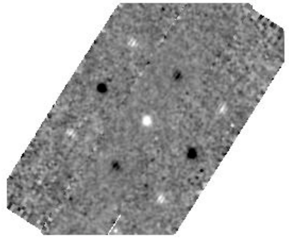


(nod1 chop A – nod1 chop B) – (nod2 chop A – nod2 chop B)

Point Source Observations

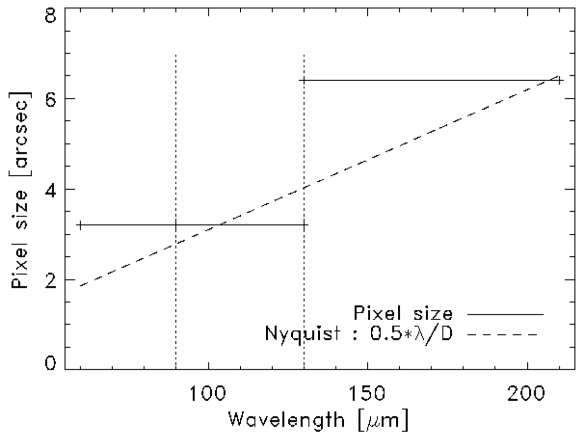
Chop/Nod mode





Dither is recommended for faint sources:

- 3-position dither along Y-axis of spacecraft using the chopper with 8.5'' throw
- Possible dither along Z-axis by concatenating AORs with slightly shifted target positions (spacecraft dithering rather than chopper dithering)
- Check AOR overlays and coverage maps



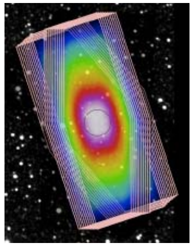
Chopper avoidance angle:

- Penalty of 600 seconds for scheduling constraint
- Constraint not fed back in HSpot visibility window

Repetition factor:

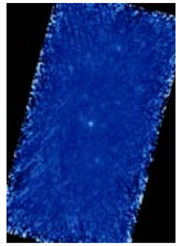
Number of AB nod cycles to reach required sensitivity

PACS



Point Source Observations

Mini-Scan Map



Same Template as the large scan map example presented previously.

Recommended parameters that make mini-scan maps the least inefficient possible in terms of overheads and idle-times:

- 20''/s scan speed
- Scan along the diagonal of the array, i.e. at 70° and/or 110° in array coordinates
- Concatenate X-scan map at 110°or 70°
  - Allows various kinds of mapmaking techniques, and provide higher quality photometry and better spatial characterization of the near source vicinity
- NO homogeneous coverage, and NO square map
- 10 scan legs with cross-scan distance of 4''
  - For shallow observations: less legs (but even number to minimize satellite movement) with larger cross-scan distances or skip cross-scan direction
- Scan leg length from 2' to 4':
  - 3' length: optimal usage of constant scan speed of 20''/s, but during idle-positions the source is outside the array
  - 2' length: Source is always on-array, but acceleration/deceleration of source on array might require more elaborated processing
- Repetition factor: as needed to reach the required sensitivity

Questions?

HSC website: http://herschel.esac.esa.int/esupport/

- Where to find this presentation