Workshop – SCUBA-2 Data Reduction

Harriet Parsons, JAC/EAO

To implement the topics covered in this workshop you will need:

- Some raw SCUBA-2 data to play with
- STARLINK software installed on your computer
- Memory available: www.starlink.ac.uk/docs/sc21.htx/node6.html

Reduction type	Memory
Large maps (PONG)	96 GB
Small maps (DAISY)	32 - 64 GB
850um data only	32 - 64 GB
Blank fields	32 - 64 GB

helpdesk@eaobservatory.org

Useful webpages/resources include:

Cornell University Library

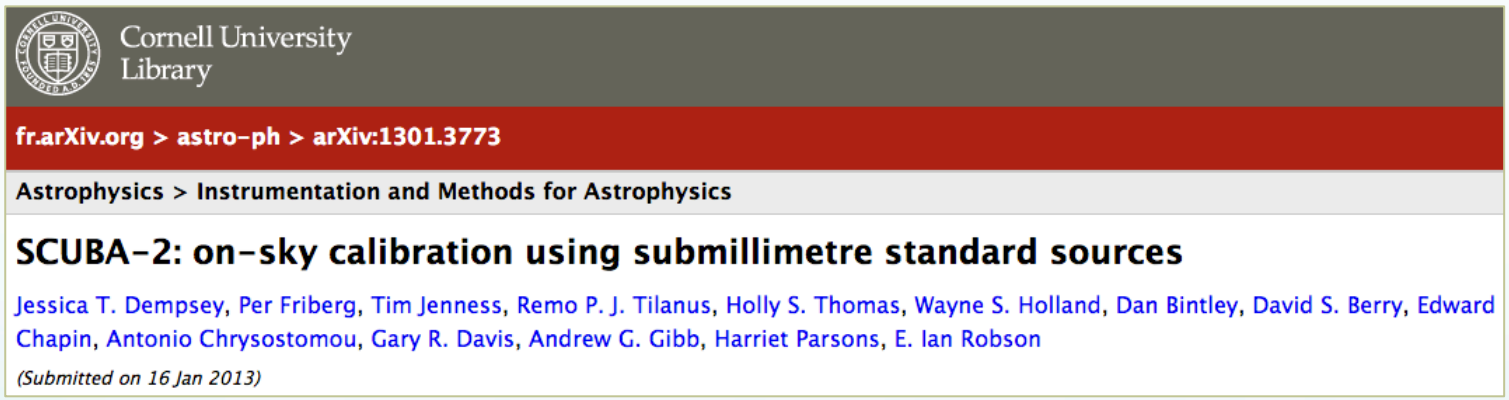
fr.arXiv.org > astro-ph > arXiv:1301.3652

Astrophysics > Instrumentation and Methods for Astrophysics

SCUBA-2: iterative map-making with the Sub-Millimetre User Reduction Facility

Edward L. Chapin, David S. Berry, Andrew G. Gibb, Tim Jenness, Douglas Scott, Remo P. J. Tilanus, Frossie Economou, Wayne S. Holland

(Submitted on 16 Jan 2013 (v1), last revised 25 Mar 2013 (this version, v2))



Cornell University Library

fr.arXiv.org > astro-ph > arXiv:1301.3773

Astrophysics > Instrumentation and Methods for Astrophysics

SCUBA-2: on-sky calibration using submillimetre standard sources

Jessica T. Dempsey, Per Friberg, Tim Jenness, Remo P. J. Tilanus, Holly S. Thomas, Wayne S. Holland, Dan Bintley, David S. Berry, Edward Chapin, Antonio Chrysostomou, Gary R. Davis, Andrew G. Gibb, Harriet Parsons, E. Ian Robson

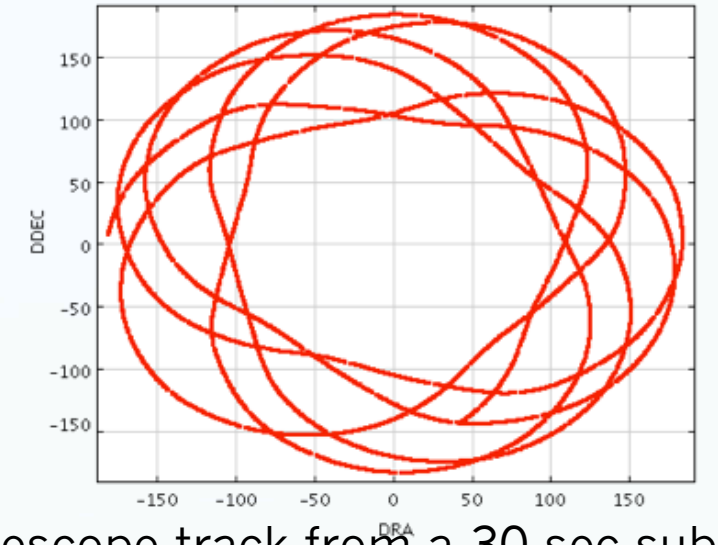
(Submitted on 16 Jan 2013)

www.jach.hawaii.edu/JCMT/continuum/workshop-feb2013/Basic-map-making.pdf
www.jach.hawaii.edu/JCMT/continuum/workshop-feb2013/Advanced-map-making.pdfwww.pipelinesandarchives.blogspot.com/
www.eaobservatory.org/jcmt/instrumentation/continuum/scuba-2/data-reduction/

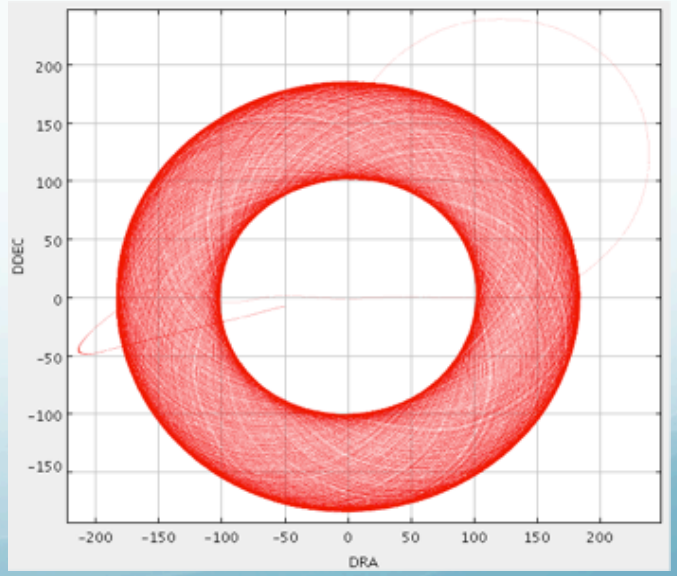
Observing Modes

- Get away from sky chopping and telescope nodding
- Developed scanning strategies that modulate the sky spatially and temporally
- Cover the same region at different position angles and cross link scans

Constant “velocity” “Daisy” pattern for small fields



Telescope track from a 30-sec sub-scan



Telescope track from 30-min observation

Field Coverage: Daisy

Maximises the exposure time in the centre of the image, for example:

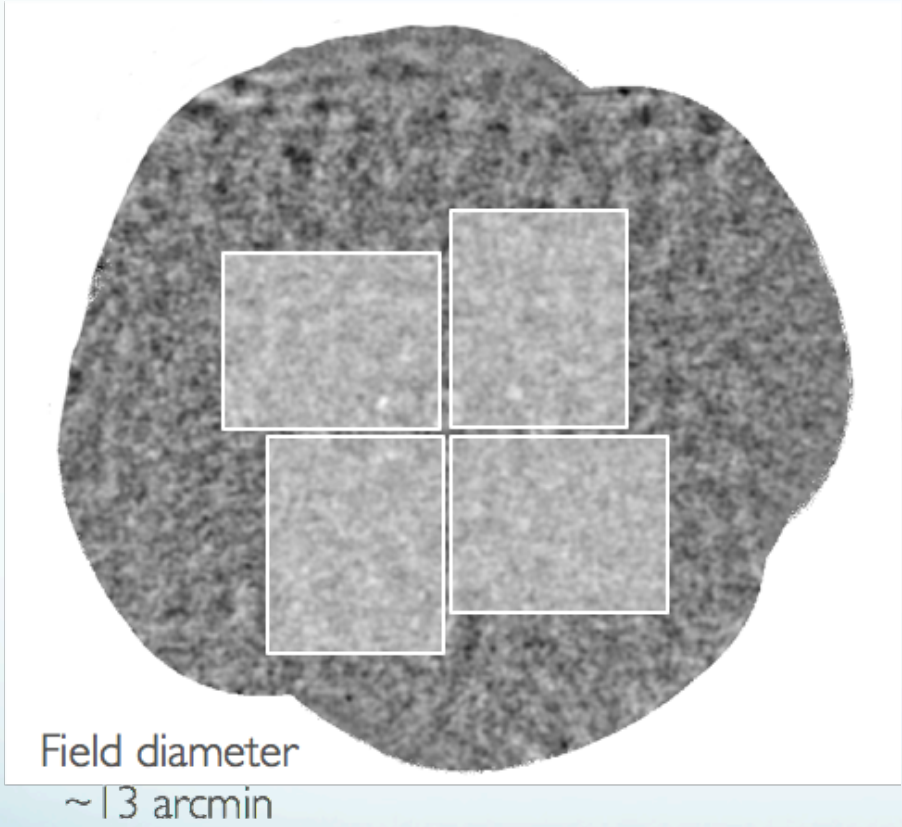
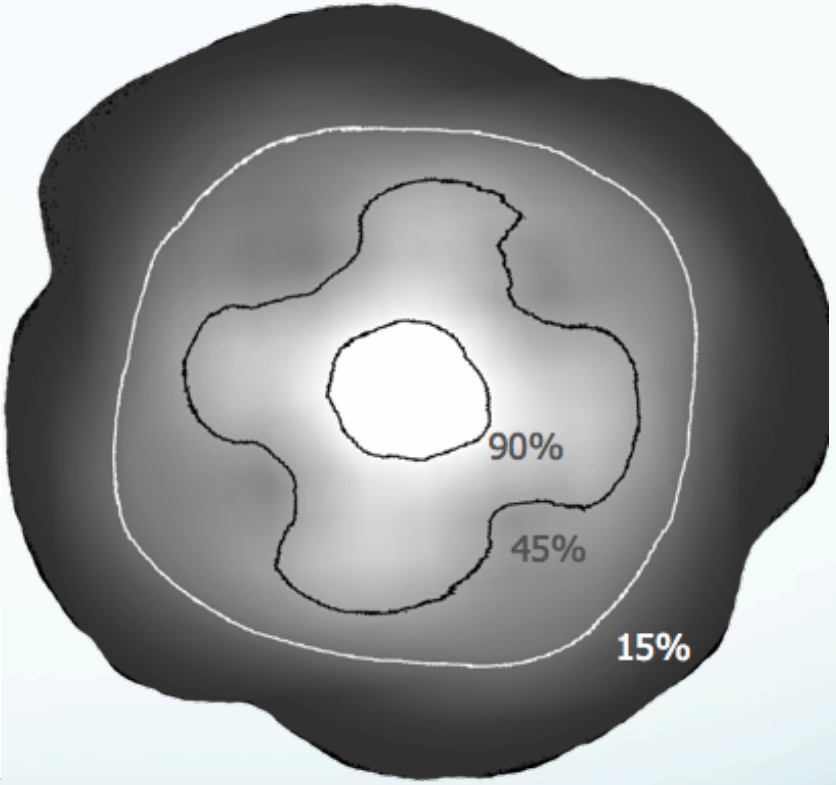


Image plane



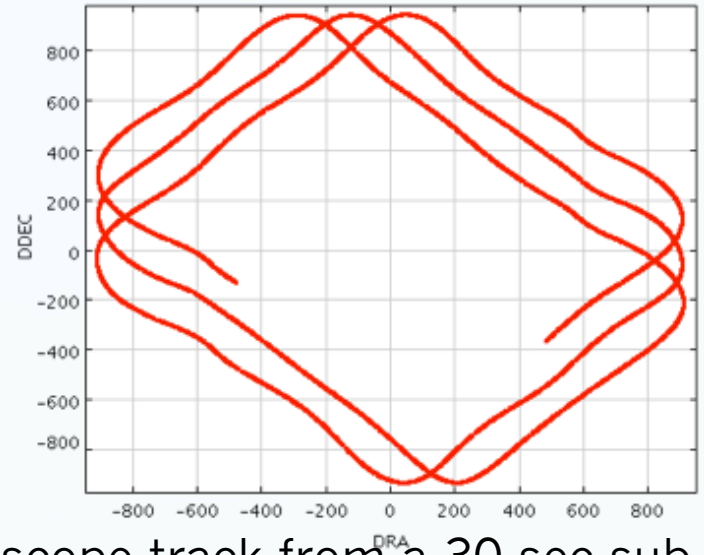
Exposure time

For a Nyquist sampled output map, exposure time in central 3’ region ~0.25 × elapsed time

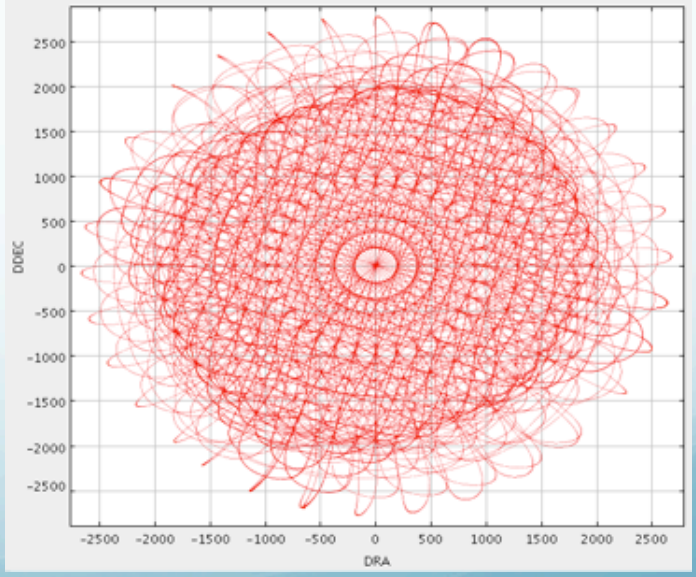
Observing Modes

- Get away from sky chopping and telescope nodding
- Developed scanning strategies that modulate the sky spatially and temporally
- Cover the same region at different position angles and cross link scans

Rotating “Pong” pattern for large fields



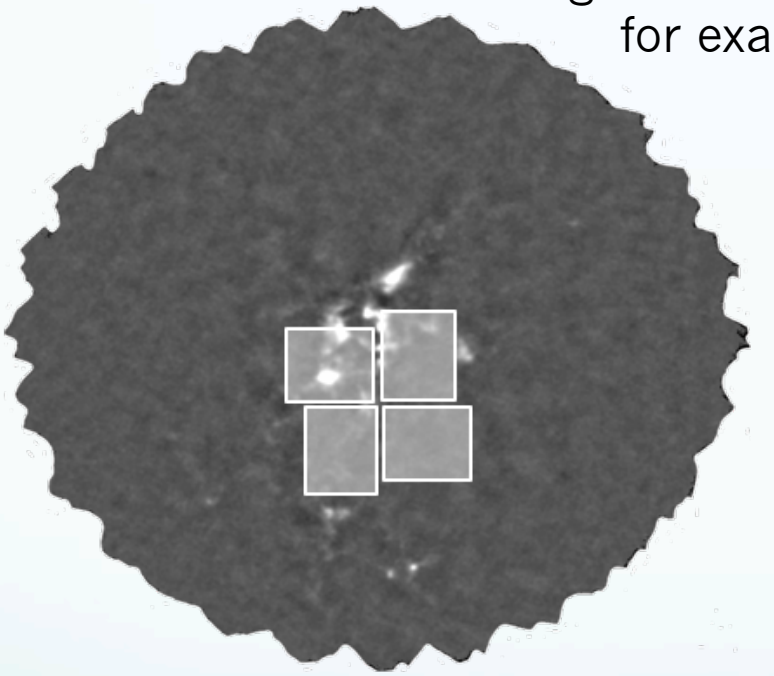
Telescope track from a 30-sec sub-scan



Telescope track from 40-min observation

Field Coverage: Pong

Maximises the field coverage and maintains exposure time uniformity, for example:



Field diameter
30 arcmin

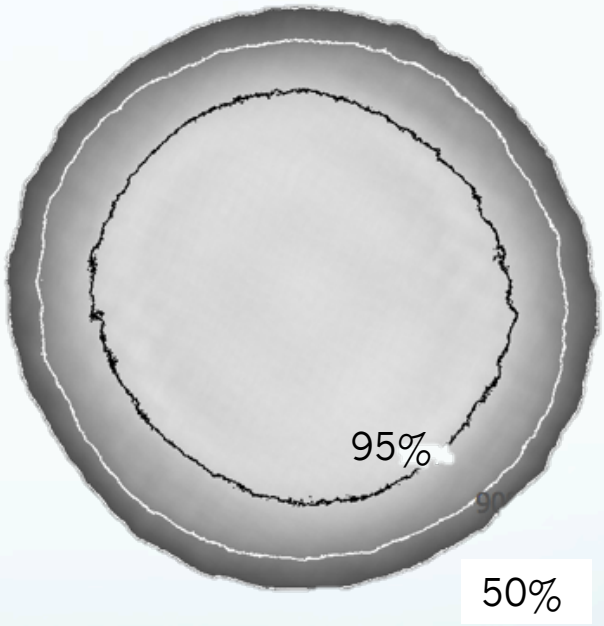
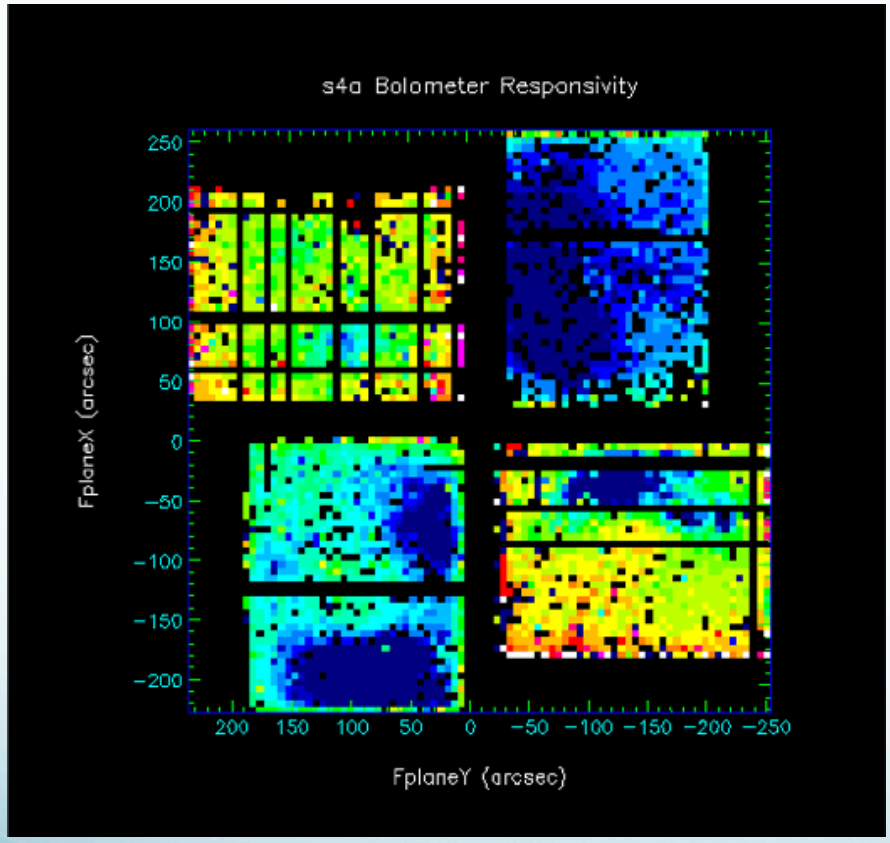


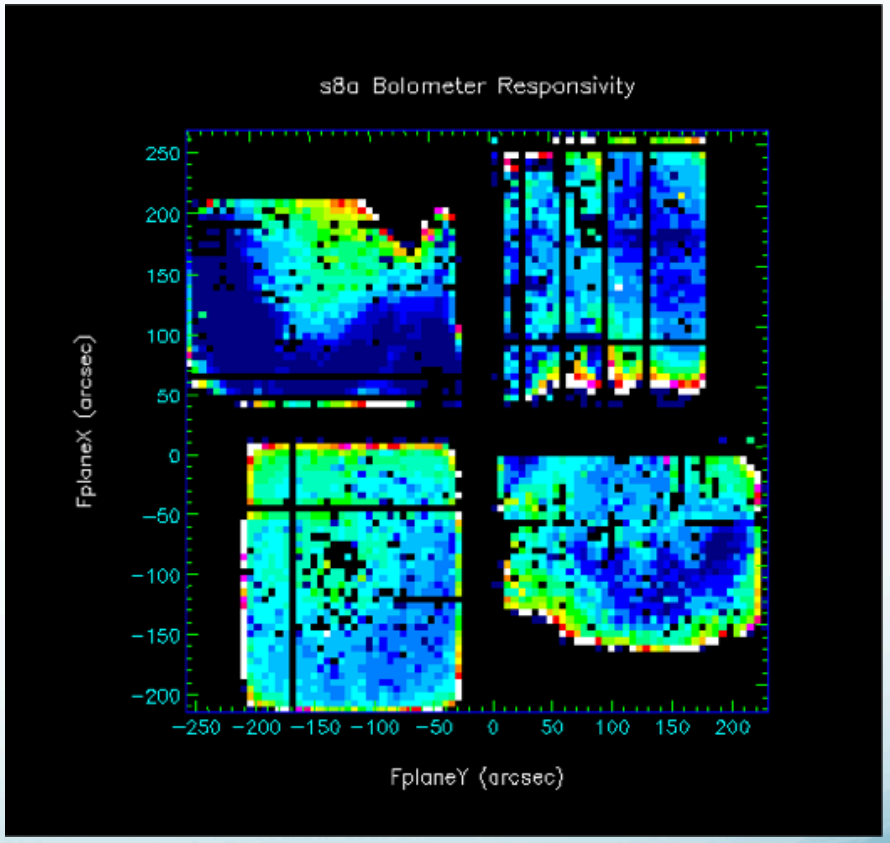
Image plane

Exposure time

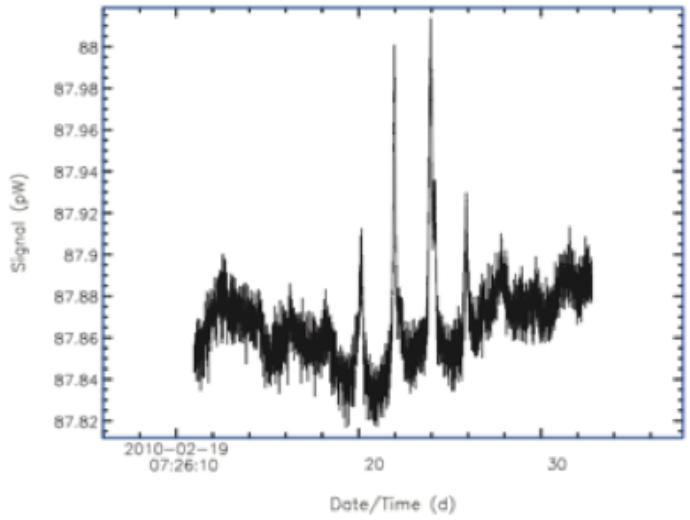
For a Nyquist sampled output map, exposure time in central 3’ region ~ 0.014 × elapsed time

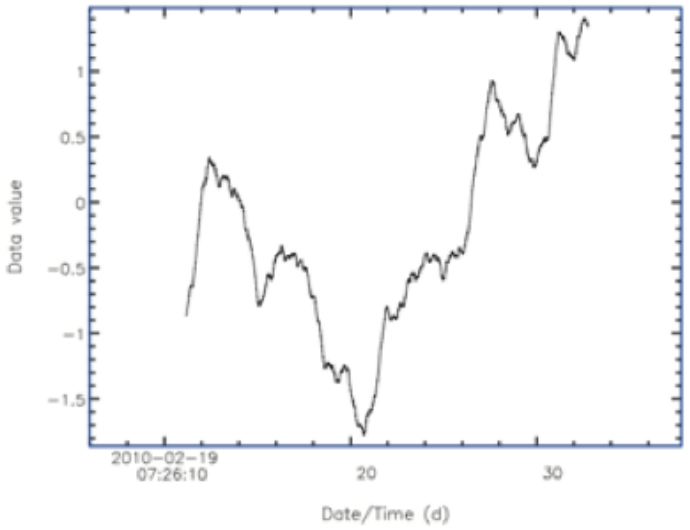
Map Making

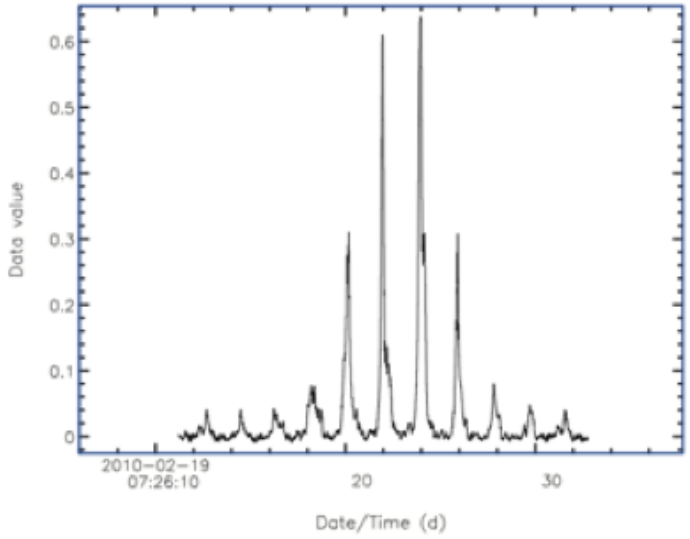

s4a Bolometer Responsivity
FplaneX (arcsec)
FplaneY (arcsec)
250
200
150
100
50
0
−50
−100
−150
−200
200 150 100 50 0 −50 −100 −150 −200 −250

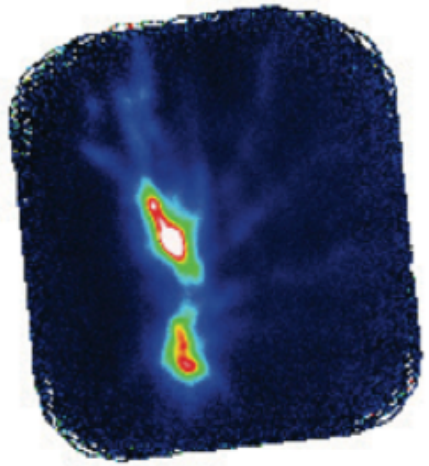

s8a Bolometer Responsivity
FplaneX (arcsec)
FplaneY (arcsec)
250
200
150
100
50
0
−50
−100
−150
−200
−250 −200 −150 −100 −50 0 50 100 150 200

Map Making


Signal (pW)
88
87.98
87.96
87.94
87.92
87.9
87.88
87.86
87.84
87.82
2010-02-19
07:26:10
20
30
Date/Time (d)


Data value
1
0.5
0
−0.5
−1
−1.5
2010-02-19
07:26:10
20
30
Date/Time (d)


Data value
0.6
0.5
0.4
0.3
0.2
0.1
0
2010-02-19
07:26:10
20
30
Date/Time (d)



$$b(t) = f * [\, e(t)a(t) + N(t) \,]$$

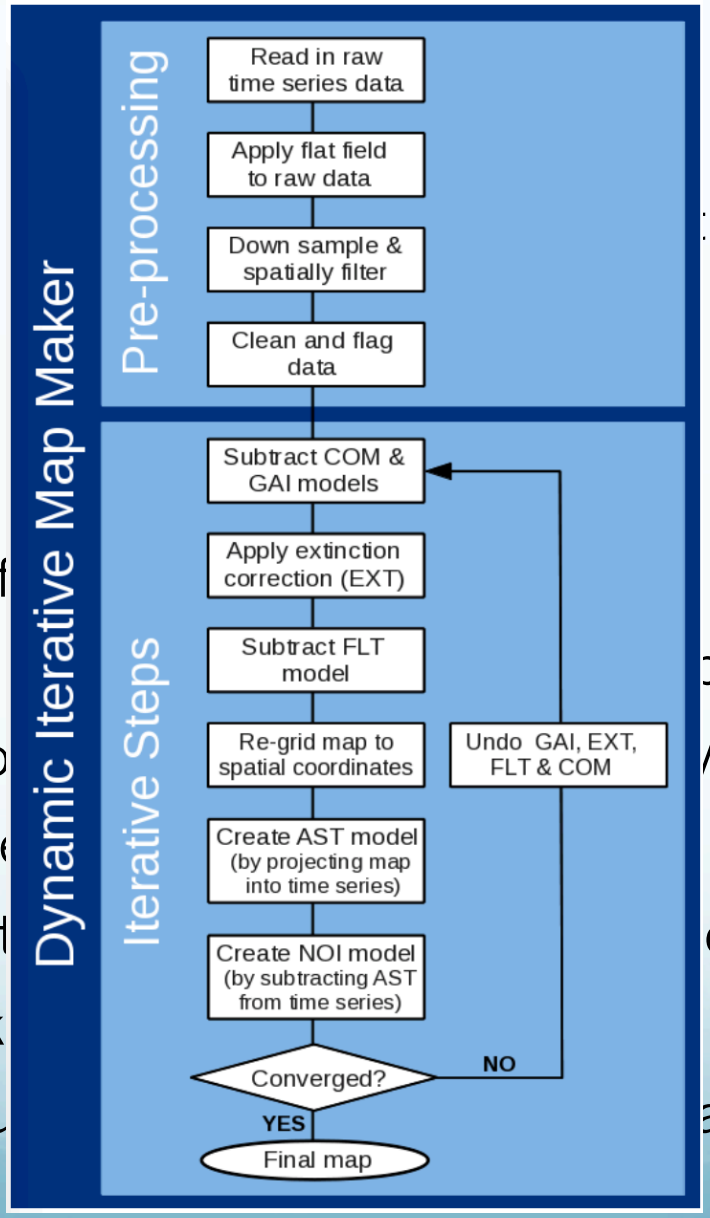
b(t) = bolometer signal
f = responsivitiy / DAC constant
e(t) = time varying atmospheric extinction
a(t) = astronomical signal
n(t) = noise

- Divide b(t) by f (fixed quantity)
- Remove most of n(t) with common-mode subtraction
- Divide by e(t) (noisy measurement from WVM)
- Remove remainder of low-f noise in n(t) with high-pass filter
- Regrid what's left over (a(t) + ~white noise) to estimate map, and remove back-projected signal from time streams
- Astronomical sources cause ringing - So iterate!

$$b(t) = f * [\, e(t)a(t) + N(t) \,]$$

b(t) =
f =
e(t) =
a(t) =
n(t) =

inction



- Divide b(t) by f (f
- Remove most of
- Divide by e(t) (no
- Remove remainde
- Regrid what's left
  and remove back
- Astronomical sou

traction

M)

high-pass filter

o estimate map,

streams

ate!

Setting Up

First need to run up the starlink software:

On cshell or tcsh:

```
>> setenv STARLINK_DIR /star-2014A
>> source $STARLINK_DIR/etc/login
>> source $STARLINK_DIR/etc/cshrc
```

On bash (or sh like shells):

```
>> export STARLINK_DIR=/star-2014A
>> source $STARLINK_DIR/etc/profile
```

The command line method of data reduction will then require the following:

```
>> kappa
>> smurf
```

Running SCUBA-2 DR

ORAC-DR – the pipeline reduction method

>> oracdr_scuba2_850 –cwd

>> oracdr -file mylist -loop file

you may also be asked to specify ORAC_DATA_IN:

>> setenv ORAC_DATA_IN folder/

or (for bash):

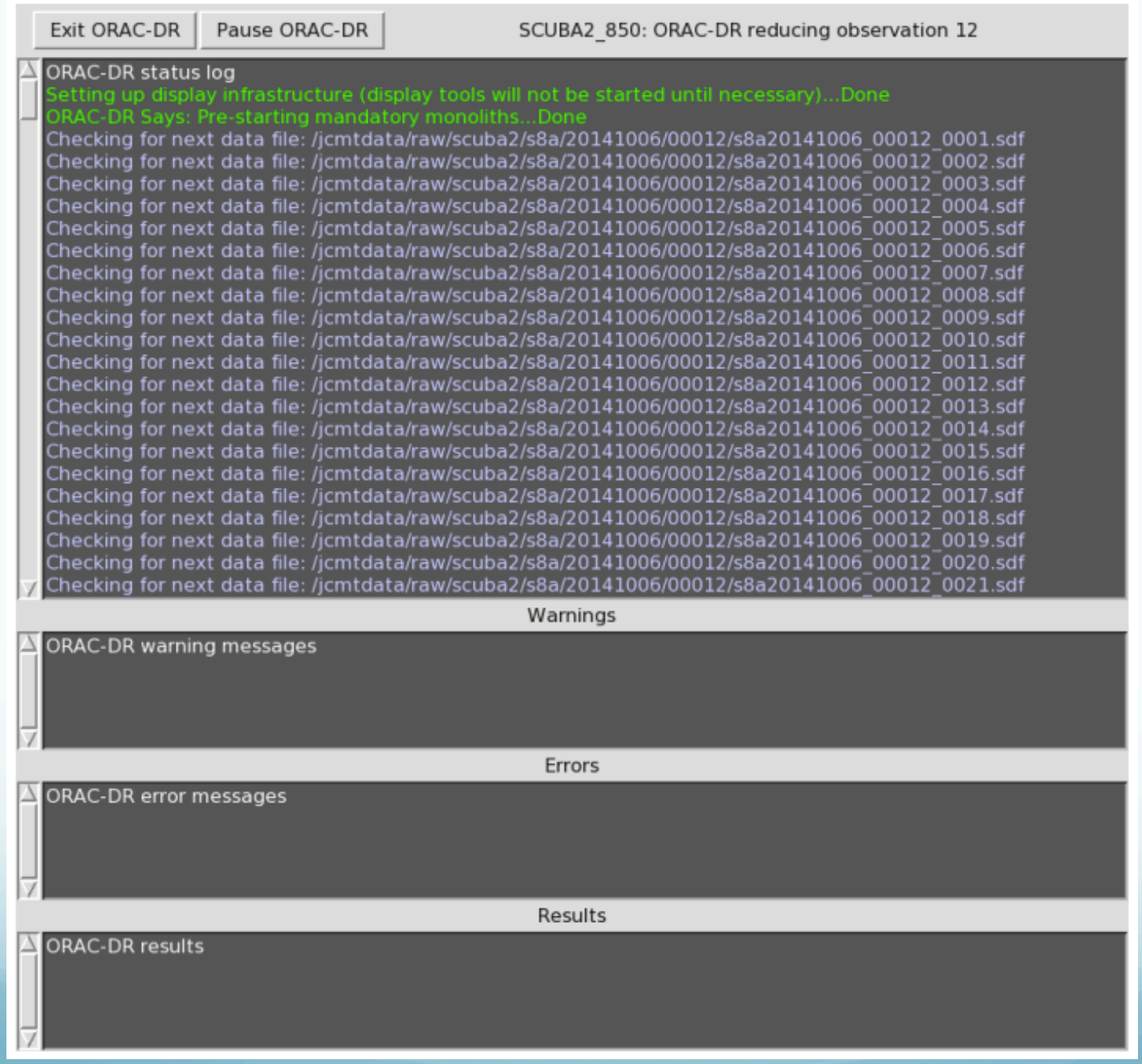
>> export ORAC_DATA_IN=folder/

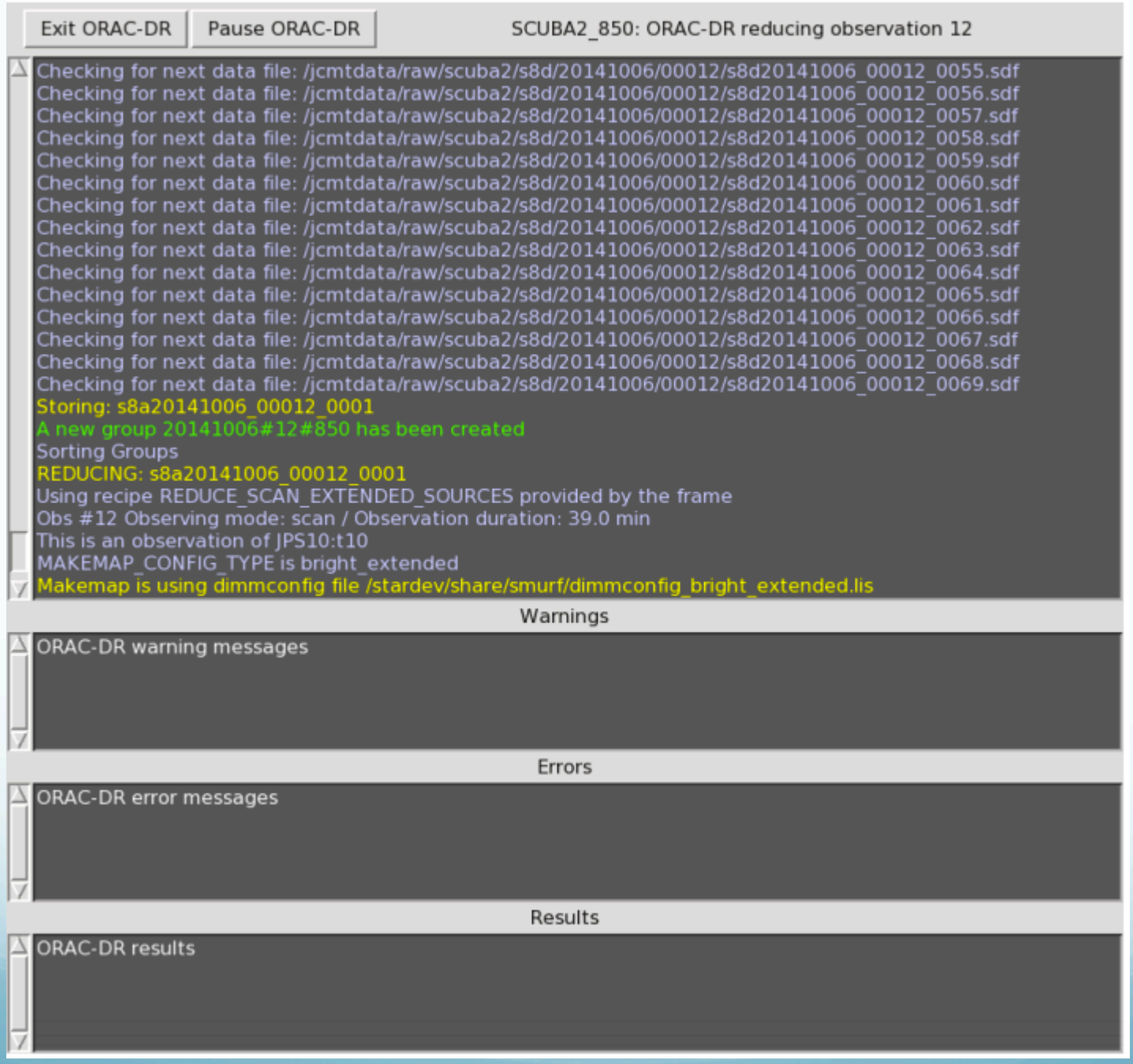
The map maker is the command line instructions for reducing raw data.

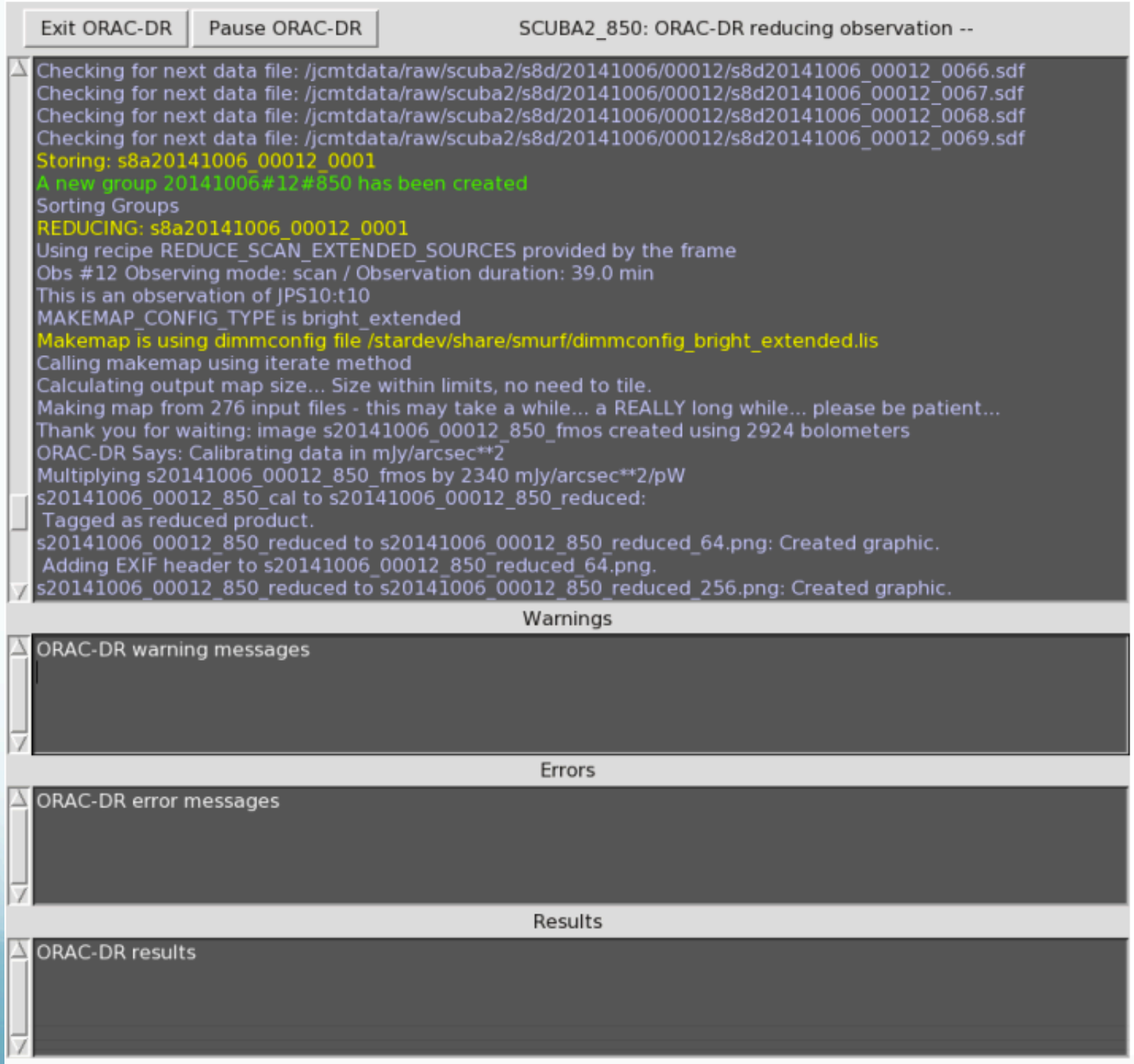
>> makemap in=/directory/in*.sdf out=out.lis config=^/stardev/share/smurf/dimmconfig.lis

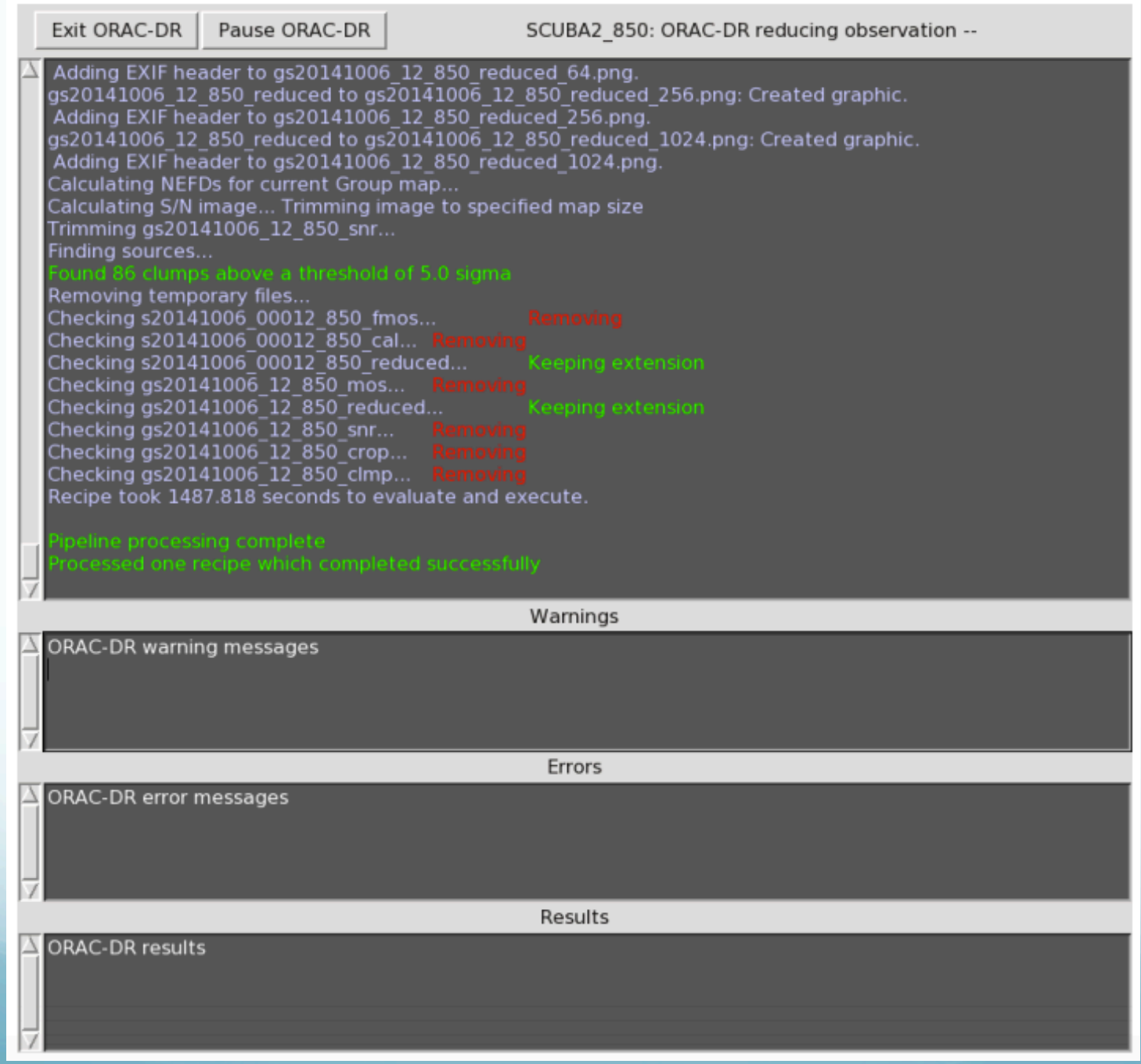
Example – running the pipeline

Let's take a moment to see how we run ORAC-DR on an observation taken by SCUBA-2


Exit ORAC-DR
Pause ORAC-DR
SCUBA2_850: ORAC-DR reducing observation 12
ORAC-DR status log
Setting up display infrastructure (display tools will not be started until necessary)...Done
ORAC-DR Says: Pre-starting mandatory monoliths...Done
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0001.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0002.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0003.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0004.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0005.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0006.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0007.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0008.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0009.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0010.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0011.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0012.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0013.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0014.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0015.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0016.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0017.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0018.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0019.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0020.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8a/20141006/00012/s8a20141006_00012_0021.sdf
Warnings
ORAC-DR warning messages
Errors
ORAC-DR error messages
Results
ORAC-DR results


Exit ORAC-DR
Pause ORAC-DR
SCUBA2_850: ORAC-DR reducing observation 12
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0055.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0056.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0057.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0058.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0059.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0060.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0061.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0062.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0063.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0064.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0065.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0066.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0067.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0068.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0069.sdf
Storing: s8a20141006_00012_0001
A new group 20141006#12#850 has been created
Sorting Groups
REDUCING: s8a20141006_00012_0001
Using recipe REDUCE_SCAN_EXTENDED_SOURCES provided by the frame
Obs #12 Observing mode: scan / Observation duration: 39.0 min
This is an observation of JPS10:t10
MAKEMAP_CONFIG_TYPE is bright_extended
Makemap is using dimmconfig file /stardev/share/smurf/dimmconfig_bright_extended.lis
Warnings
ORAC-DR warning messages
Errors
ORAC-DR error messages
Results
ORAC-DR results


Exit ORAC-DR
Pause ORAC-DR
SCUBA2_850: ORAC-DR reducing observation --
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0066.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0067.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0068.sdf
Checking for next data file: /jcmtdata/raw/scuba2/s8d/20141006/00012/s8d20141006_00012_0069.sdf
Storing: s8a20141006_00012_0001
A new group 20141006#12#850 has been created
Sorting Groups
REDUCING: s8a20141006_00012_0001
Using recipe REDUCE_SCAN_EXTENDED_SOURCES provided by the frame
Obs #12 Observing mode: scan / Observation duration: 39.0 min
This is an observation of JPS10:t10
MAKEMAP_CONFIG_TYPE is bright_extended
Makemap is using dimmconfig file /stardev/share/smurf/dimmconfig_bright_extended.lis
Calling makemap using iterate method
Calculating output map size... Size within limits, no need to tile.
Making map from 276 input files - this may take a while... a REALLY long while... please be patient...
Thank you for waiting: image s20141006_00012_850_fmos created using 2924 bolometers
ORAC-DR Says: Calibrating data in mJy/arcsec**2
Multiplying s20141006_00012_850_fmos by 2340 mJy/arcsec**2/pW
s20141006_00012_850_cal to s20141006_00012_850_reduced:
Tagged as reduced product.
s20141006_00012_850_reduced to s20141006_00012_850_reduced_64.png: Created graphic.
Adding EXIF header to s20141006_00012_850_reduced_64.png.
s20141006_00012_850_reduced to s20141006_00012_850_reduced_256.png: Created graphic.
Warnings
ORAC-DR warning messages
Errors
ORAC-DR error messages
Results
ORAC-DR results


Exit ORAC-DR
Pause ORAC-DR
SCUBA2_850: ORAC-DR reducing observation --
Adding EXIF header to gs20141006_12_850_reduced_64.png.
gs20141006_12_850_reduced to gs20141006_12_850_reduced_256.png: Created graphic.
Adding EXIF header to gs20141006_12_850_reduced_256.png.
gs20141006_12_850_reduced to gs20141006_12_850_reduced_1024.png: Created graphic.
Adding EXIF header to gs20141006_12_850_reduced_1024.png.
Calculating NEFDs for current Group map...
Calculating S/N image... Trimming image to specified map size
Trimming gs20141006_12_850_snr...
Finding sources...
Found 86 clumps above a threshold of 5.0 sigma
Removing temporary files...
Checking s20141006_00012_850_fmos... Removing
Checking s20141006_00012_850_cal... Removing
Checking s20141006_00012_850_reduced... Keeping extension
Checking gs20141006_12_850_mos... Removing
Checking gs20141006_12_850_reduced... Keeping extension
Checking gs20141006_12_850_snr... Removing
Checking gs20141006_12_850_crop... Removing
Checking gs20141006_12_850_clmp... Removing
Recipe took 1487.818 seconds to evaluate and execute.
Pipeline processing complete
Processed one recipe which completed successfully
Warnings
ORAC-DR warning messages
Errors
ORAC-DR error messages
Results
ORAC-DR results

Running the map maker - Ready made configuration files

Dimmconfig = Dynamic Iterative Map Maker configuration file. This is where you tell the map maker what to do!

- **dimmconfig_blank_field.lis** – for blank fields – such as cosmological fields

- **dimmconfig_bright_compact.lis** – for bright compact sources – such as calibrator sources used at the JCMT. Masks out the central bright region of a map (i.e. Central 60") to improve the background and get a better fit to the peak.

- **dimmconfig_bright_extended.lis** – for bright "extended" objects – such as galactic emission regions

- **dimmconfig_jsa_generic.lis** – used to reduce all data made public through the JCMT Science Archive. Good results although would recommend a more bespoke file depending on the intention for your data.

>> oracdr -loop file -files mylist -recpars mypars.ini REDUCE_SCAN

with mypars.ini containing:

```
[REDUCE_SCAN]
CALUNITS = BEAM
```

If we wish to run with a different dimmconfig file than is automatically used we can add:

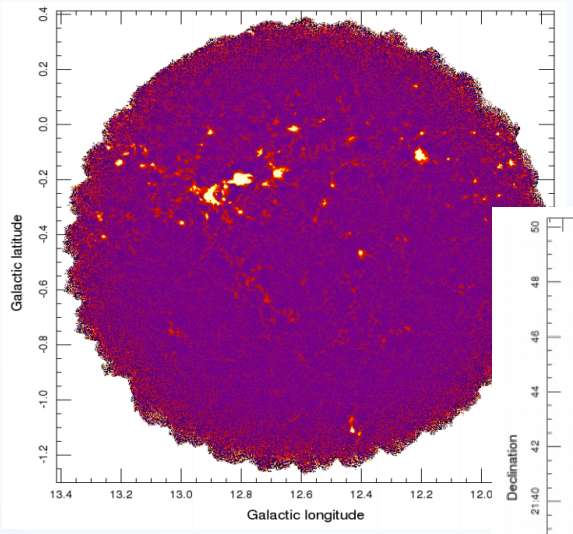
```
[REDUCE_SCAN]
MAKEMAP_CONFIG = dimmconfig_blank_field.lis
CALUNITS = BEAM
```

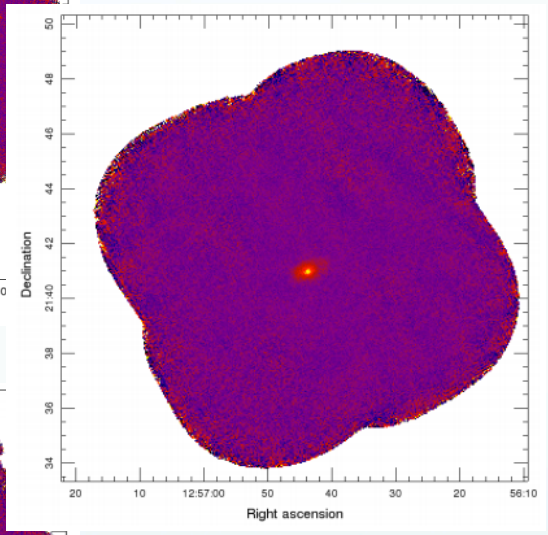
this will search STARLINK's default files to find dimmconfig_blank_field.lis.

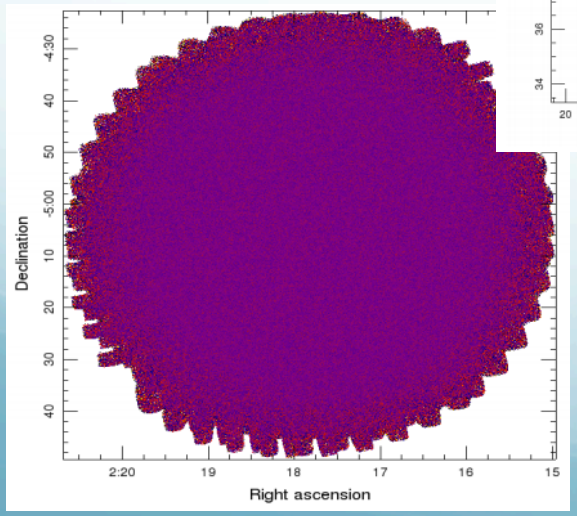
Example – different configuration files

Let's take a moment to run the SCUBA-2 reduction pipeline using a different configuration file:

Running the Pipeline: example outputs



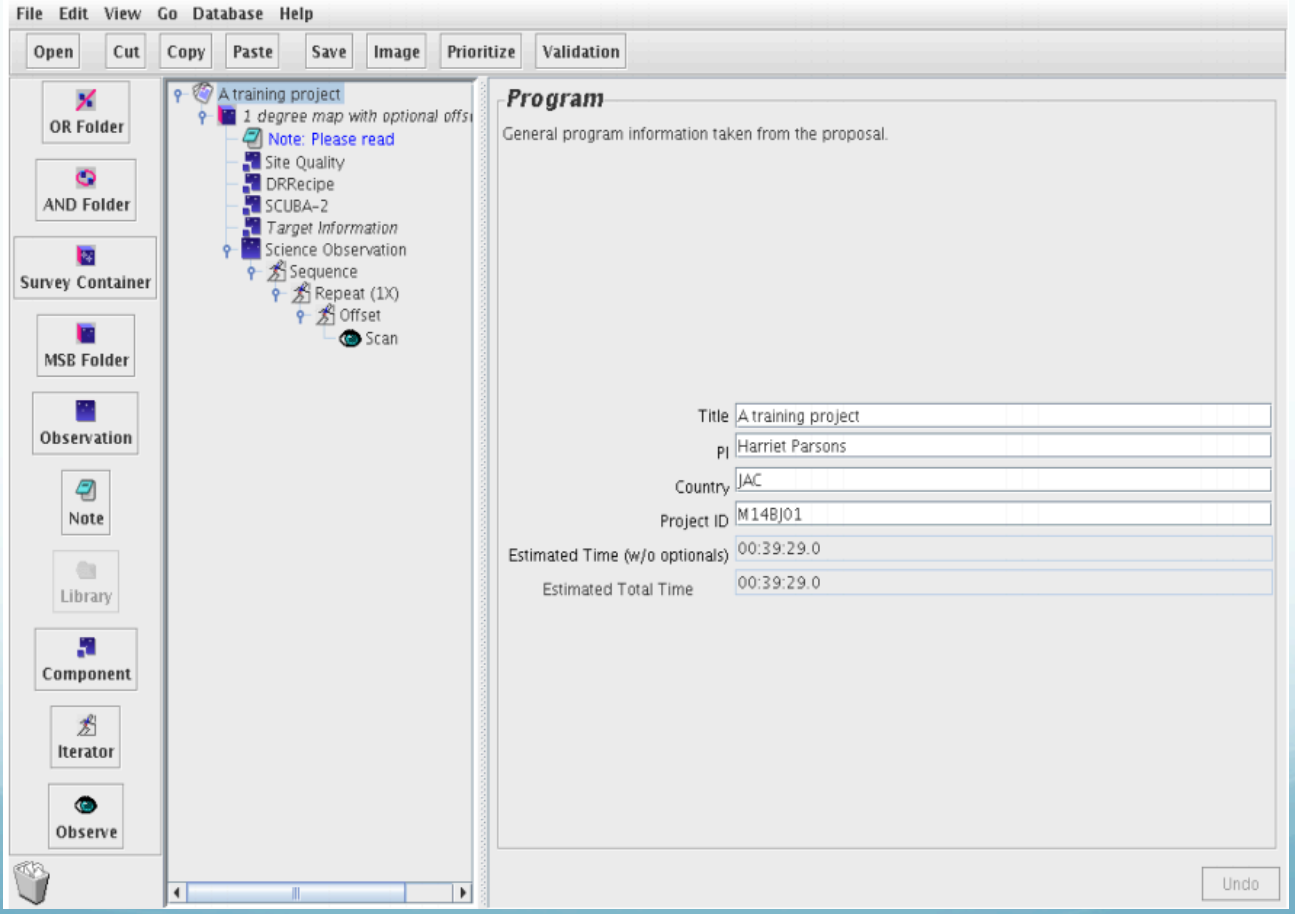


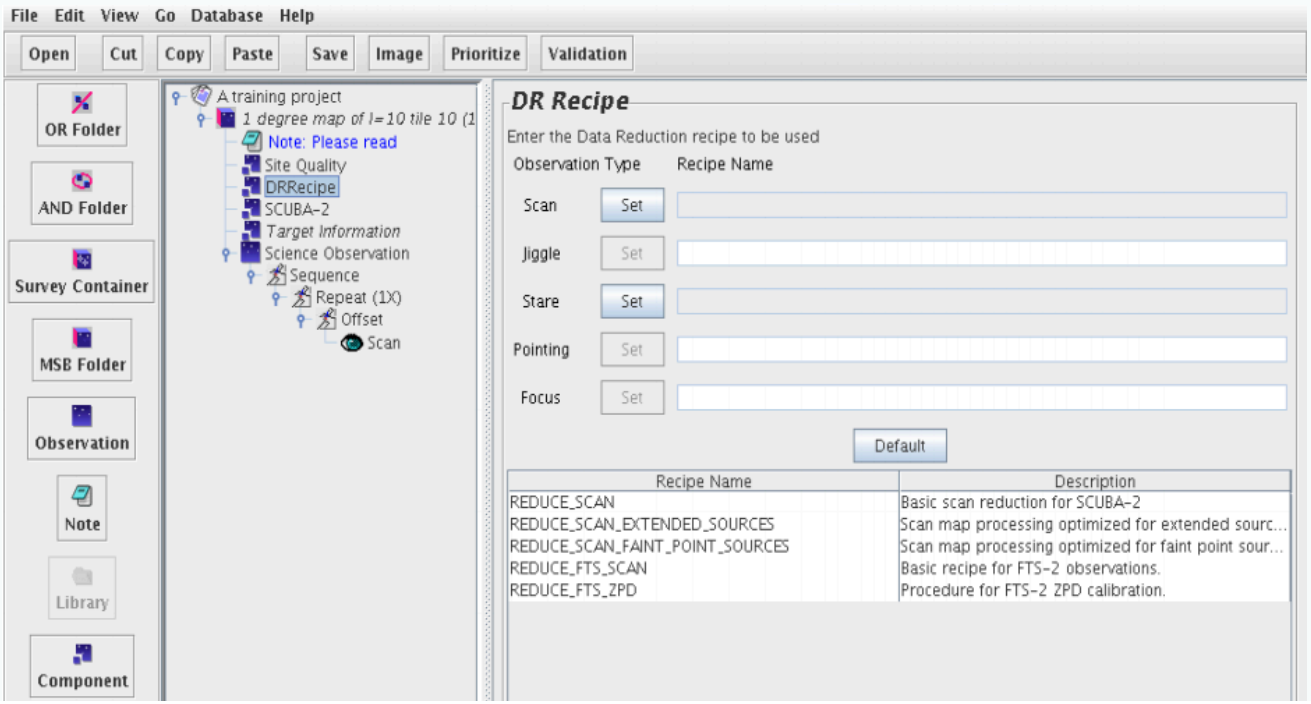


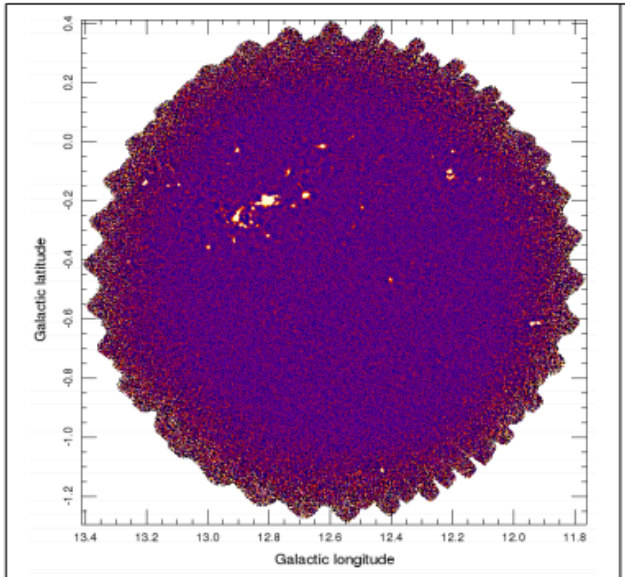
1. A busy field in the Galactic Plane (JPS)
2. A Nearby Galaxy (NGLS)
3. A cosmological field (CLS)

Reminder: DR in relation to the JCMT OT

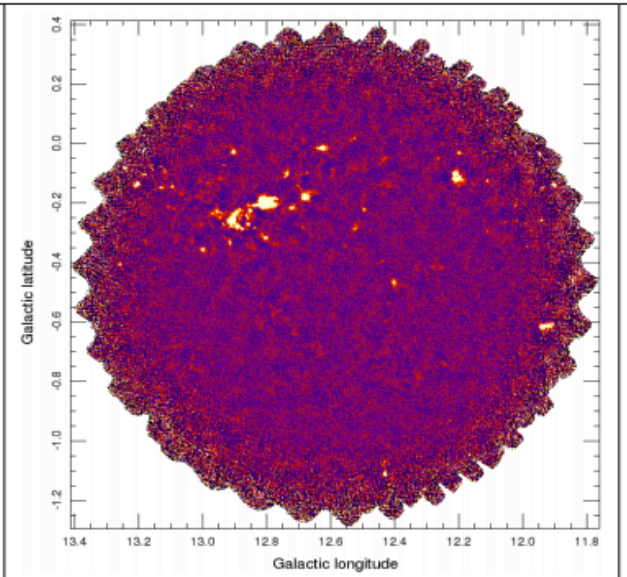
This is where several of the points I have been talking tie together. If you recall prior to this point we used the OT to produce msb's for a specific object of choice.



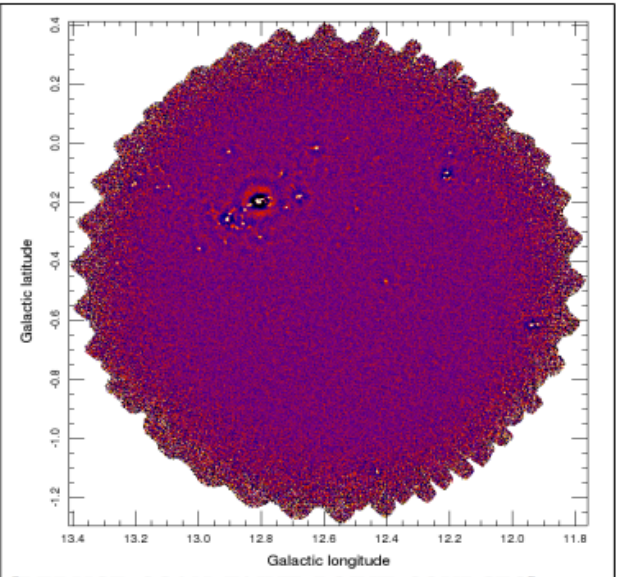




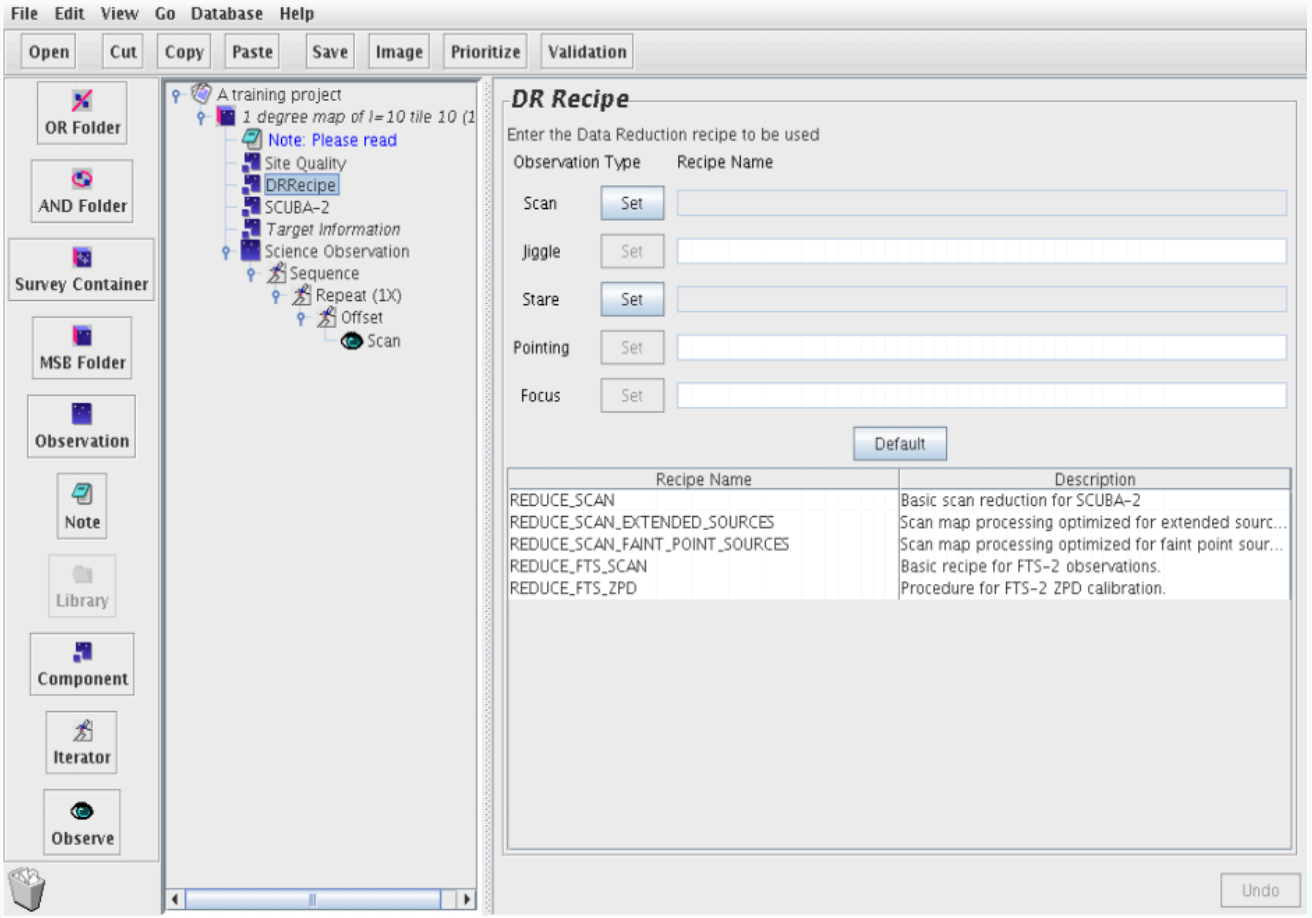
[REDUCE_SCAN]
dimmconfig_jsa_generic.lis



[REDUCE_SCAN_EXTENDED_SOURCES]
dimmconfig_bright_extended.lis



[REDUCE_SCAN_FAINT_POINT_SOURCES]
dimmconfig_blank_field.lis



Any point in the process you might come up with additional/ alternative configuration parameters for the reduction pipeline. Tell your FOP and these can be implemented from that point onwards (and we can do a re-reduction of data that has already been taken).

Let us do the work for you!

mydimmconfig.lis

^/star-2014A/share/smurf/dimmconfig_bright_extended.lis
numiter=-200

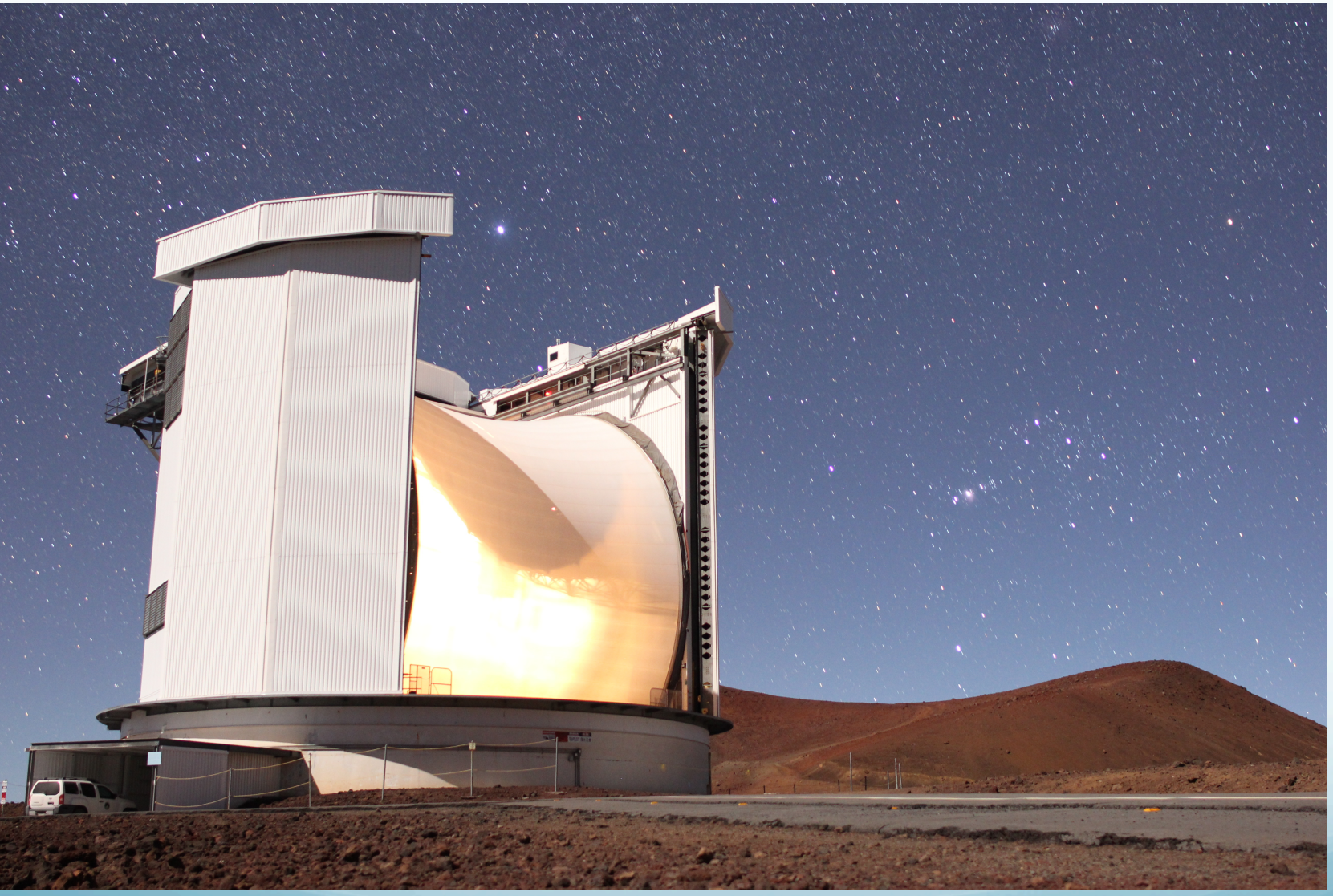
Update mypars.ini file to read:

[REDUCE_SCAN]
MAKEMAP_CONFIG = mydimmconfig.lis
CALUNITS = BEAM

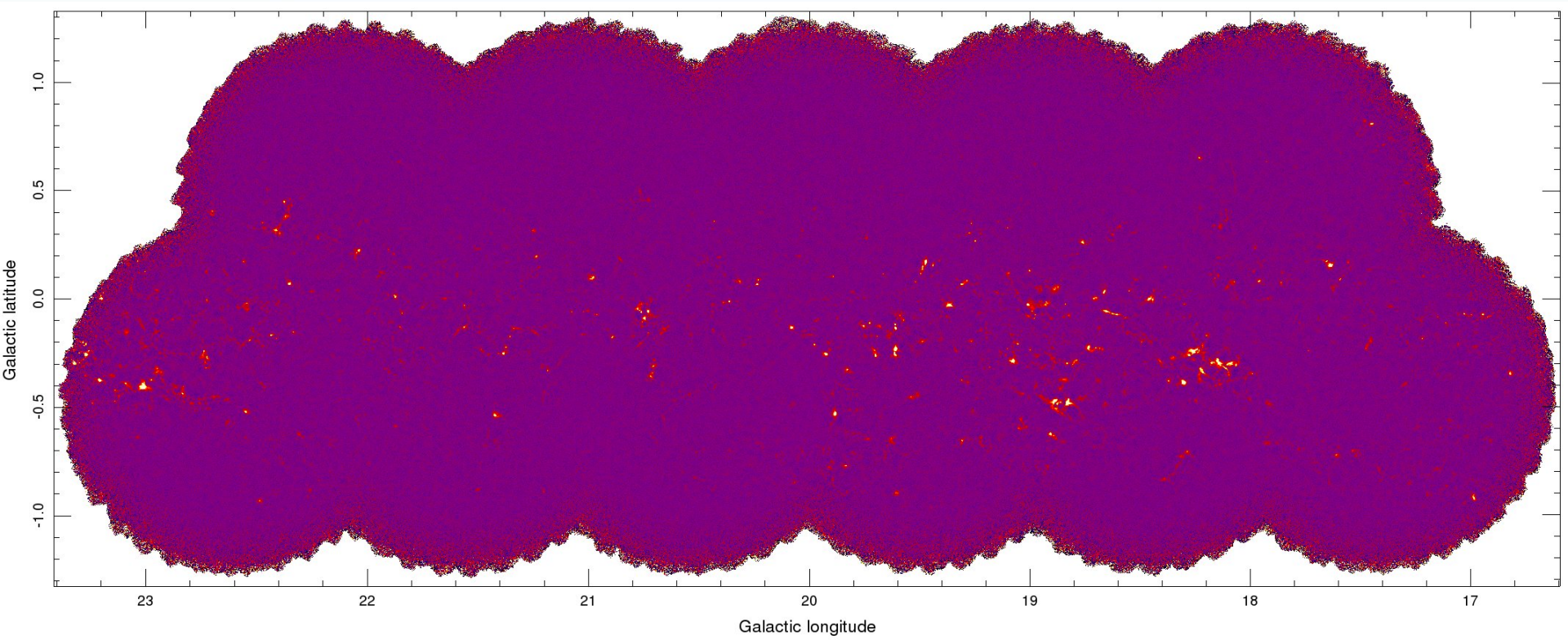
>> oracdr -loop file -files mylist -recpars mypars.ini REDUCE_SCAN

- **dimmconfig_fix_blobs.lis** – for problematic fields where blobs of fake emission have appeared · simply add this to your configuration file.

- **dimmconfig_fix_convergence.lis** – for fields with convergence issues · simply add this to your configuration file to remove low level changes that prevent the map from converging.



JPS Reduction of the Galactic Plane:



My *current* bespoke Galactic Plane reduction

^dimmconfig_bright_extended.lis
^dimmconfig_fix_blobs.lis
numiter = -100
maptol = 0.01
flt.filt_largescale_last = 100

dimmconfig_bright_extended.lis:

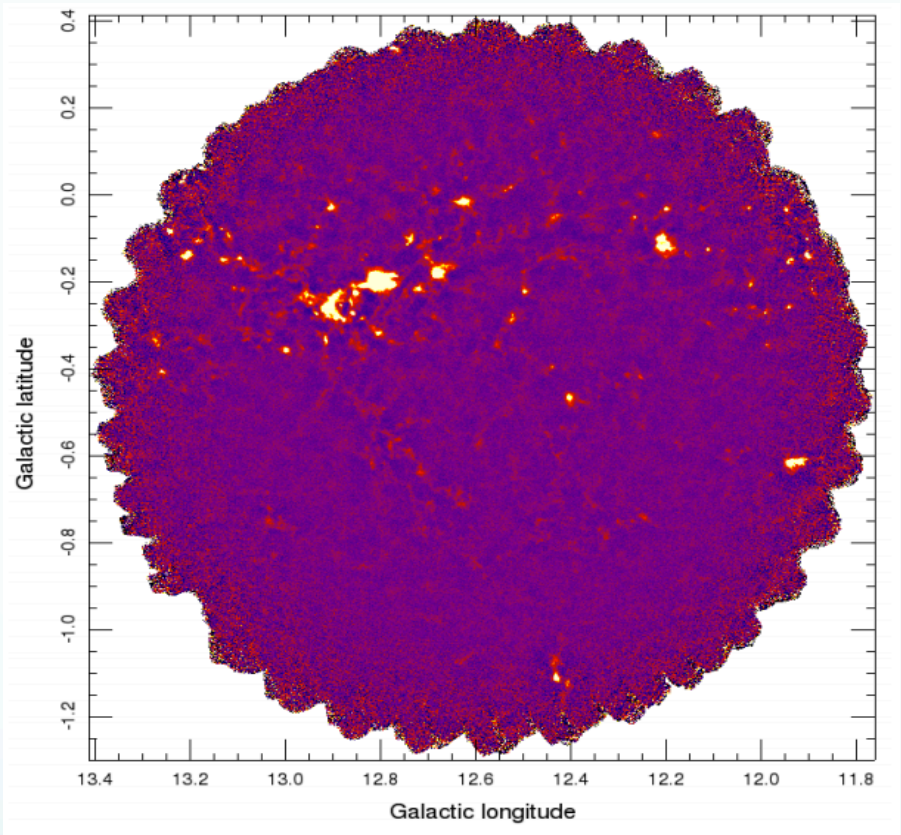
^dimmconfig.lis
numiter=-40
flt.filt_edge_largescale=480
ast.zero_snr = 3
ast.zero_snrlo = 2

ast.skip = 5
flt.zero_snr = 5
flt.zero_snrlo = 3

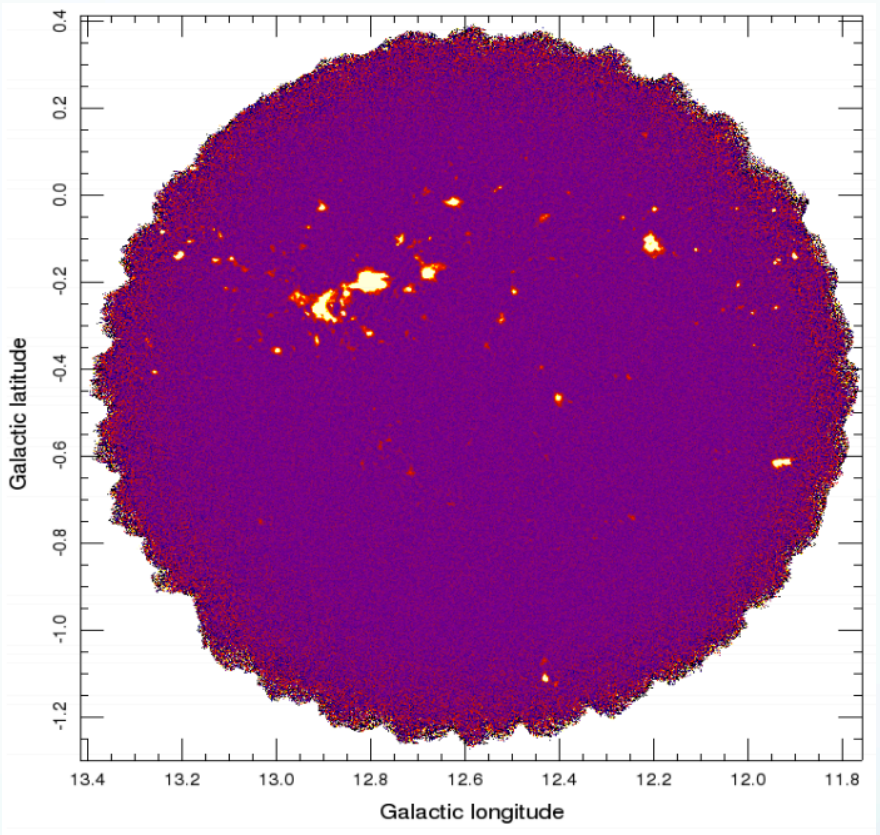
dimmconfig_fix_blobs.lis:

flt.ring_box1=0.5
flt.filt_order=4
com.sig_limit=5

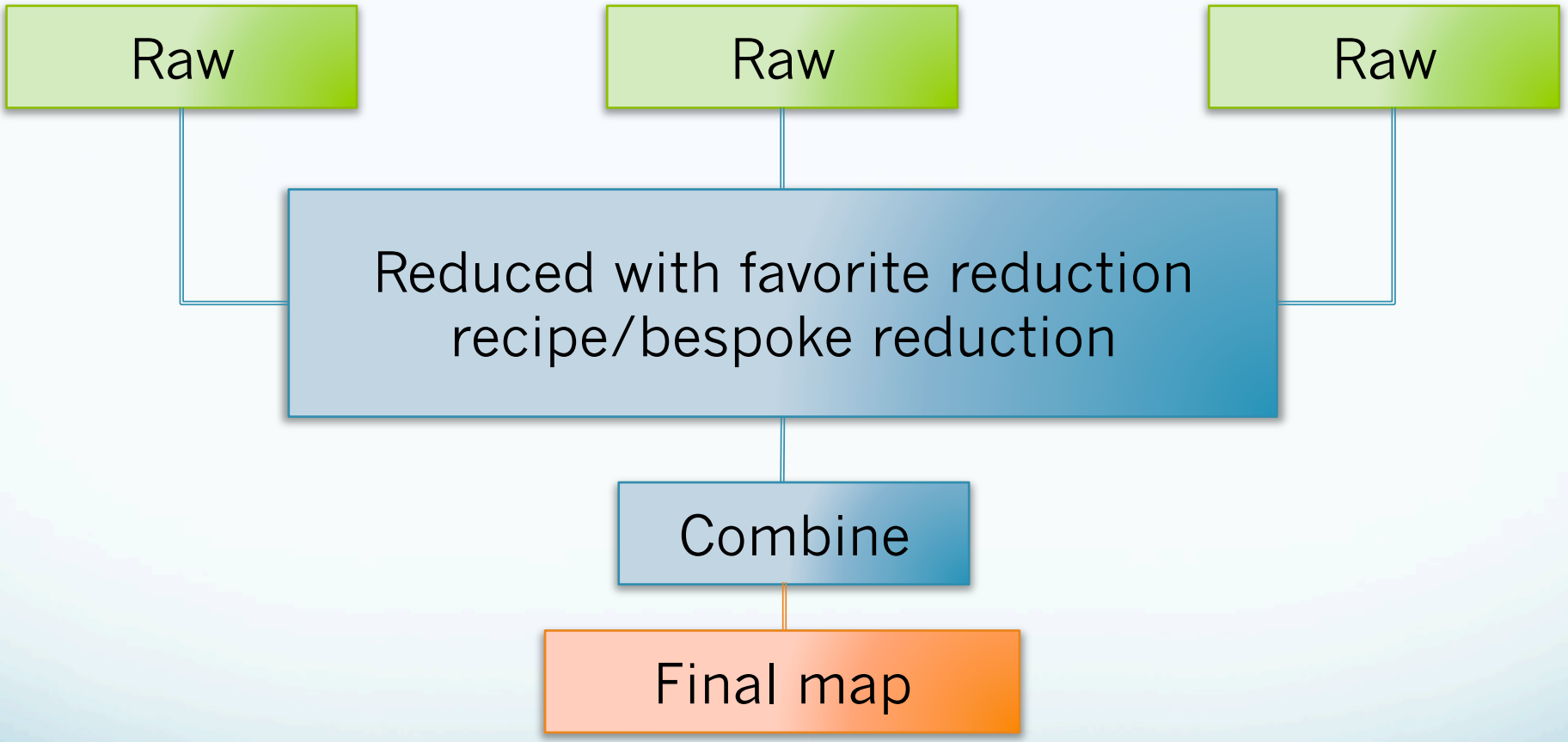
Bright Extended



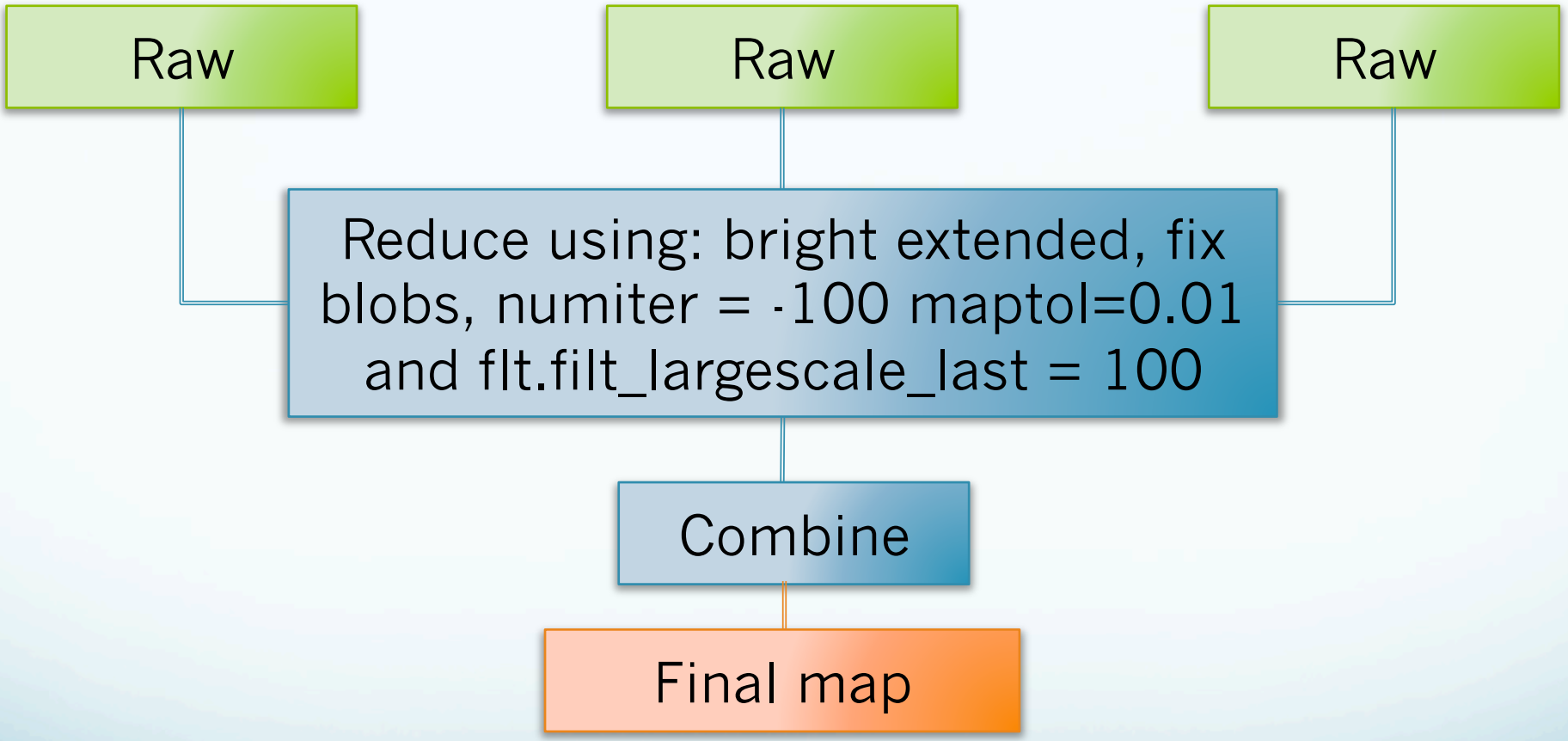
Bright Extended + additions



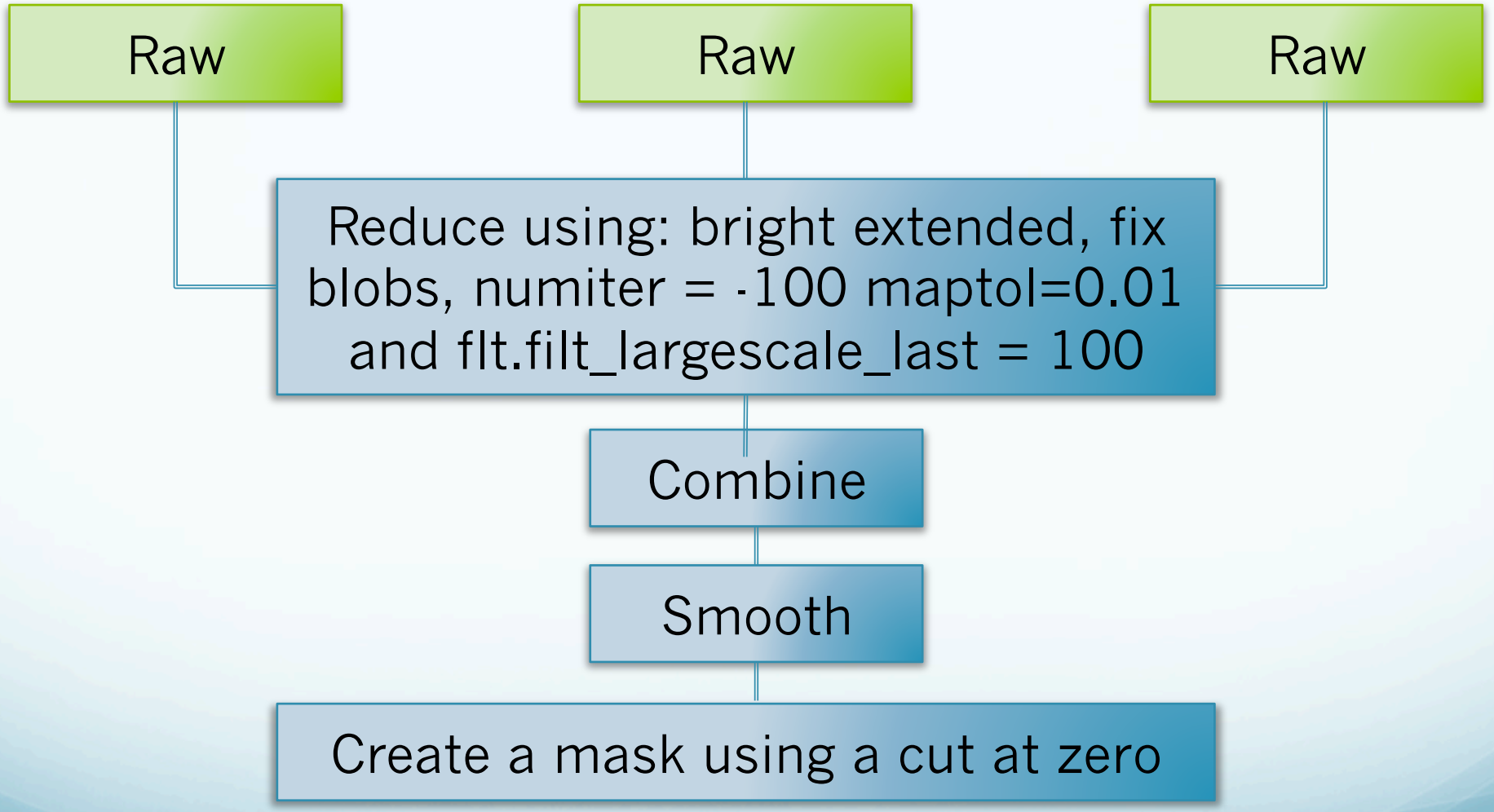
Typical SCUBA-2 multi observation reduction



My current “first pass” reduction

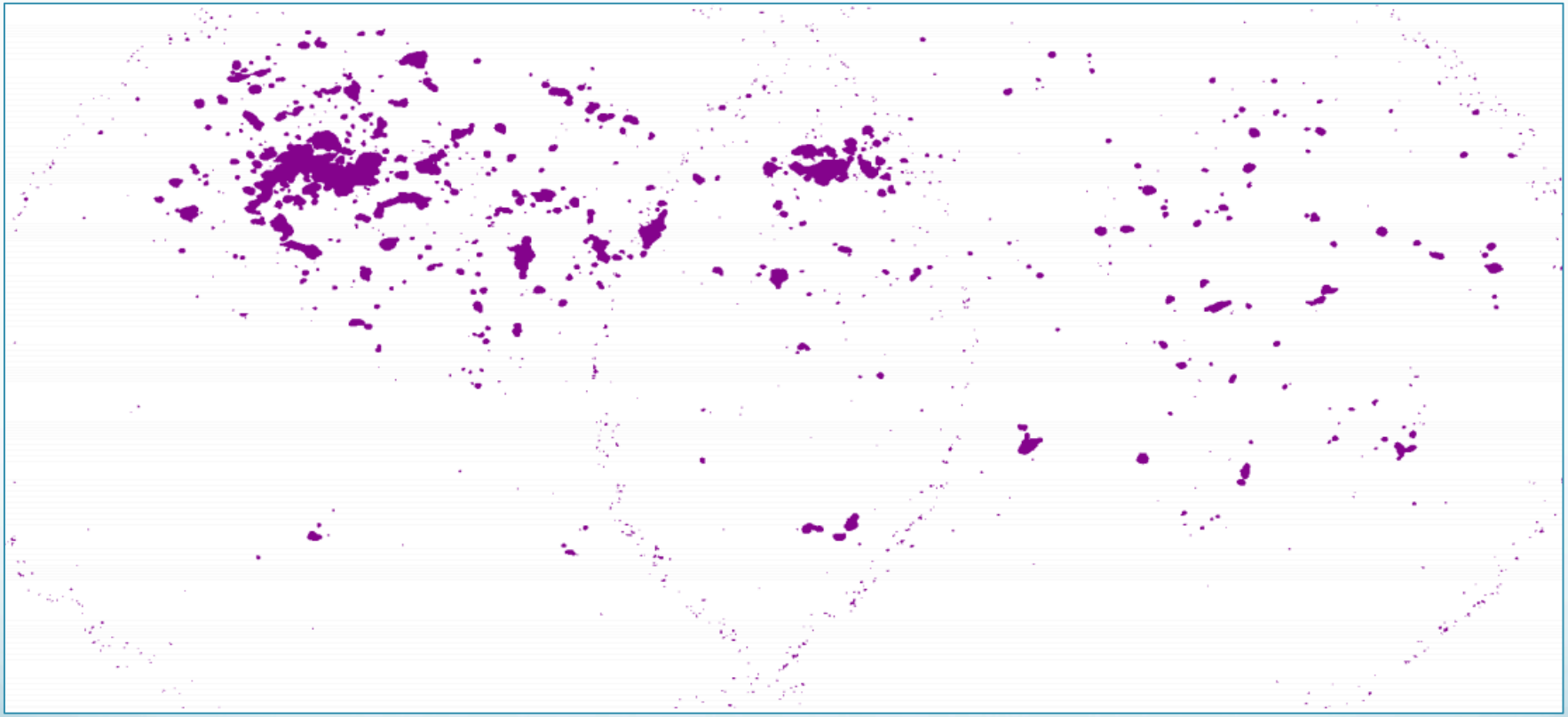


Creating an external mask

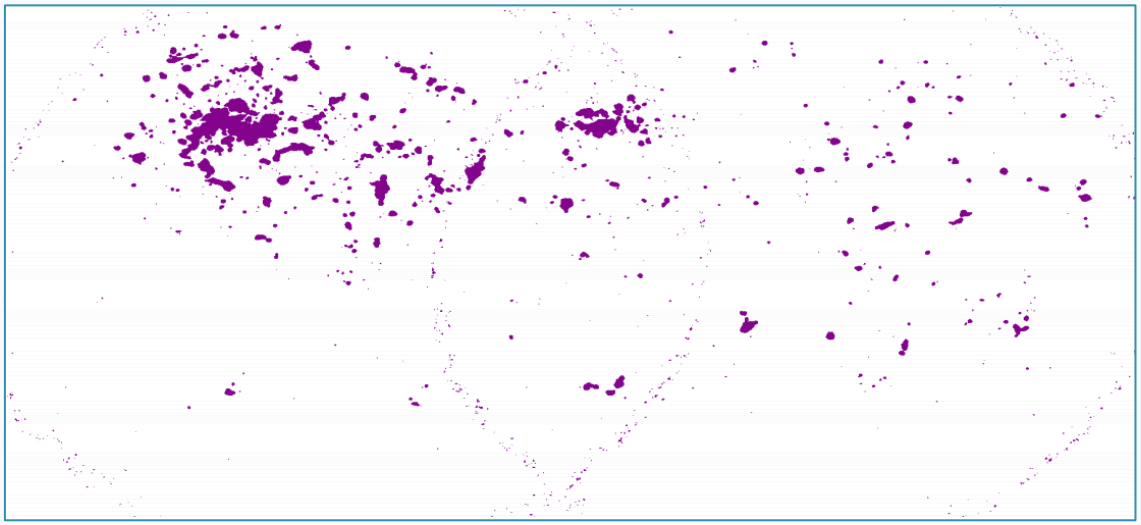


Pro: i) you can combine information from multiple observations which provides additional information for the second round of data reduction

An example of an external mask:



“Classical method” – Take data > SNR > thresh at 3 sigma > smooth image > make another thresh/cut to the image.



>> makesnr in=file.sdf out=file_snr minvar=0.0

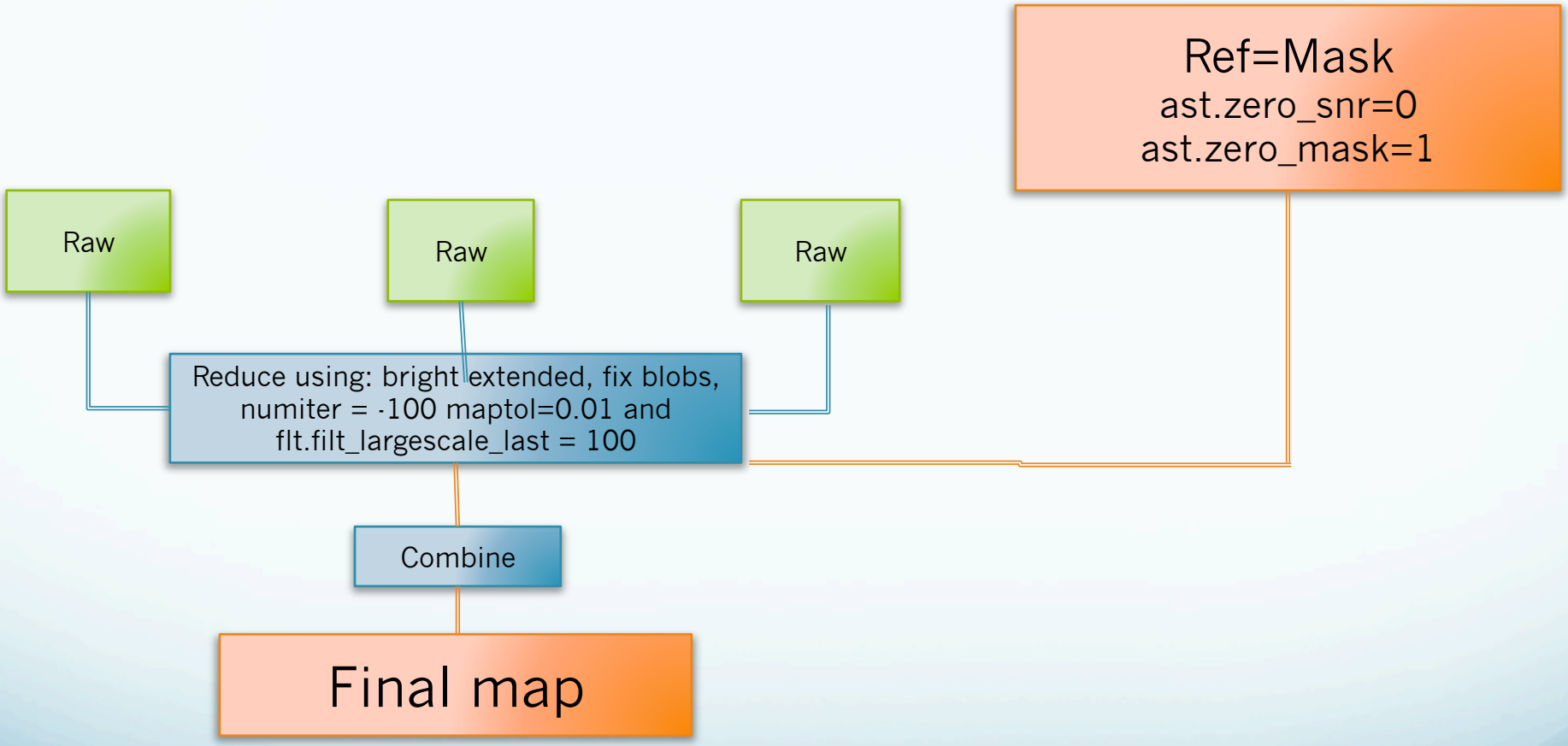
>> thresh in=file_snr.sdf out=file_cut.sdf thrhi=3 thrlo=3 newhi=1 newlo=0

>> gausmooth fwhm=5 in=file.sdf out=file_sm.sdf

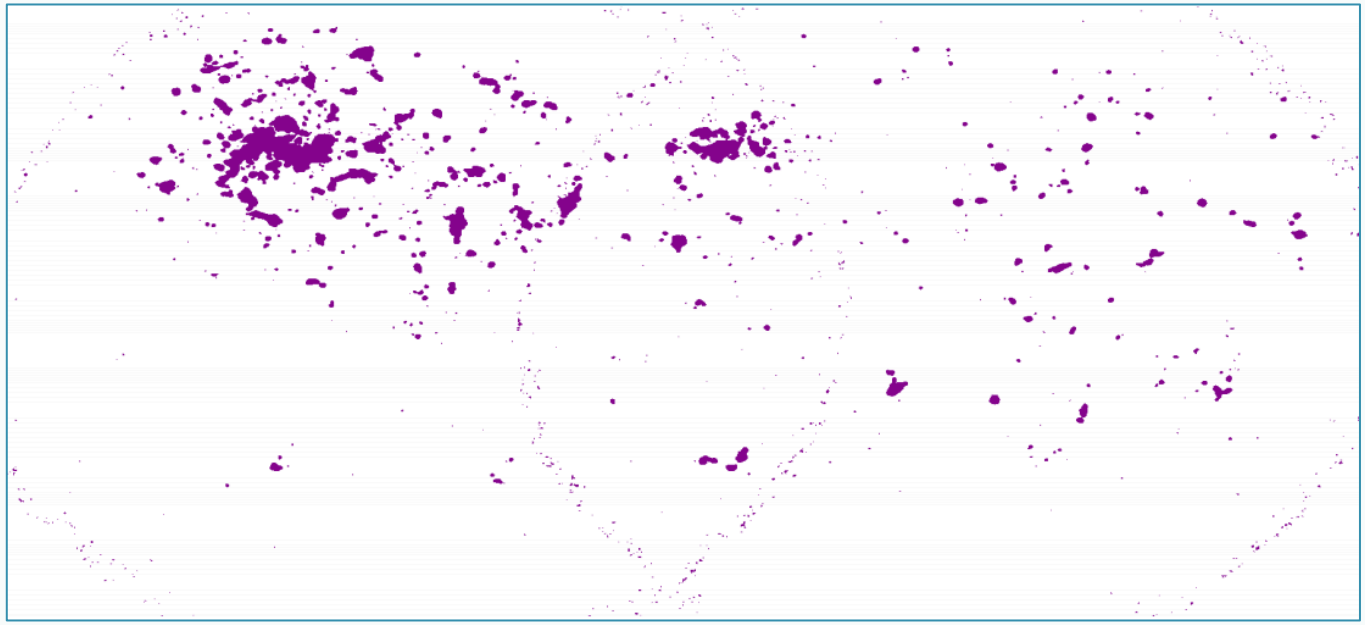
>> thresh in=file_sm.sdf out=mask.sdf thrhi=3 thrlo=3 newhi=1 newlo=bad

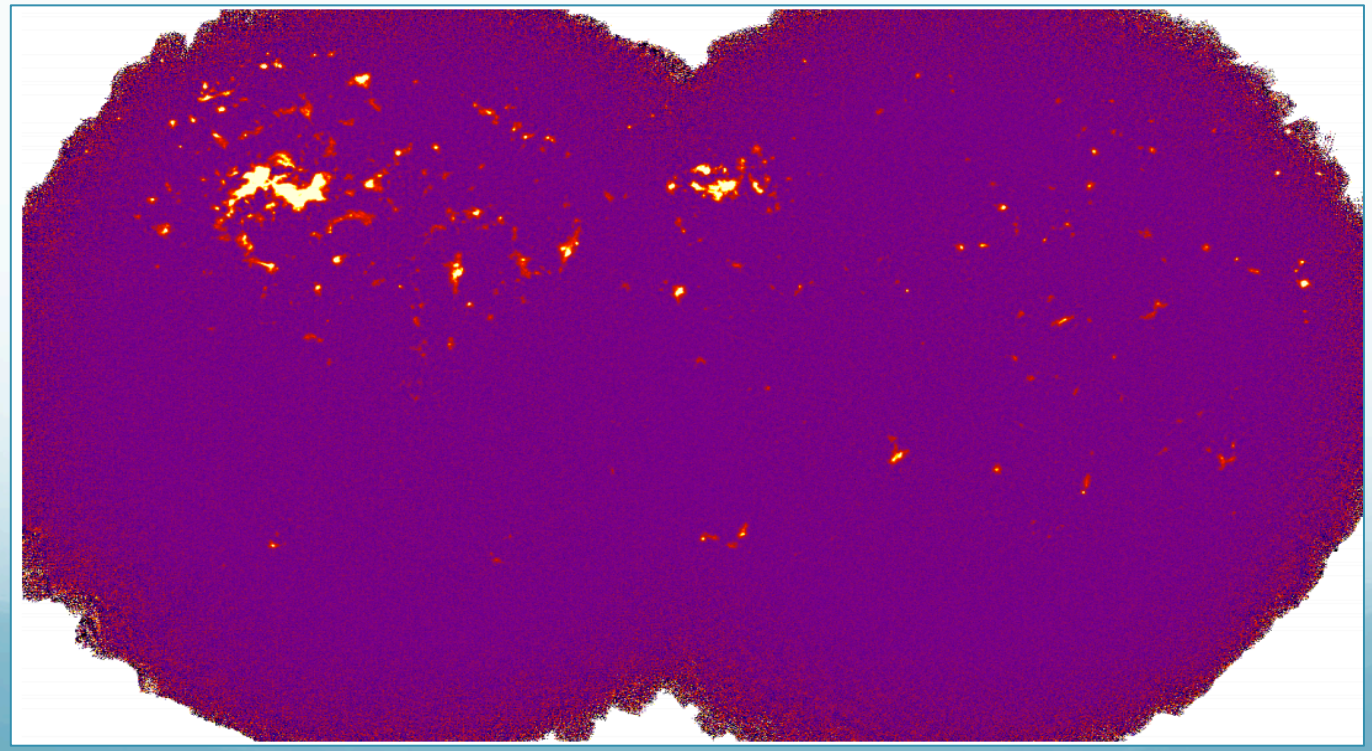
>> in=/directory/in*.sdf out=out.sdf config=^/stardev/share/smurf/dimmconfig_external.lis ref=mask.sdf

Using the external mask

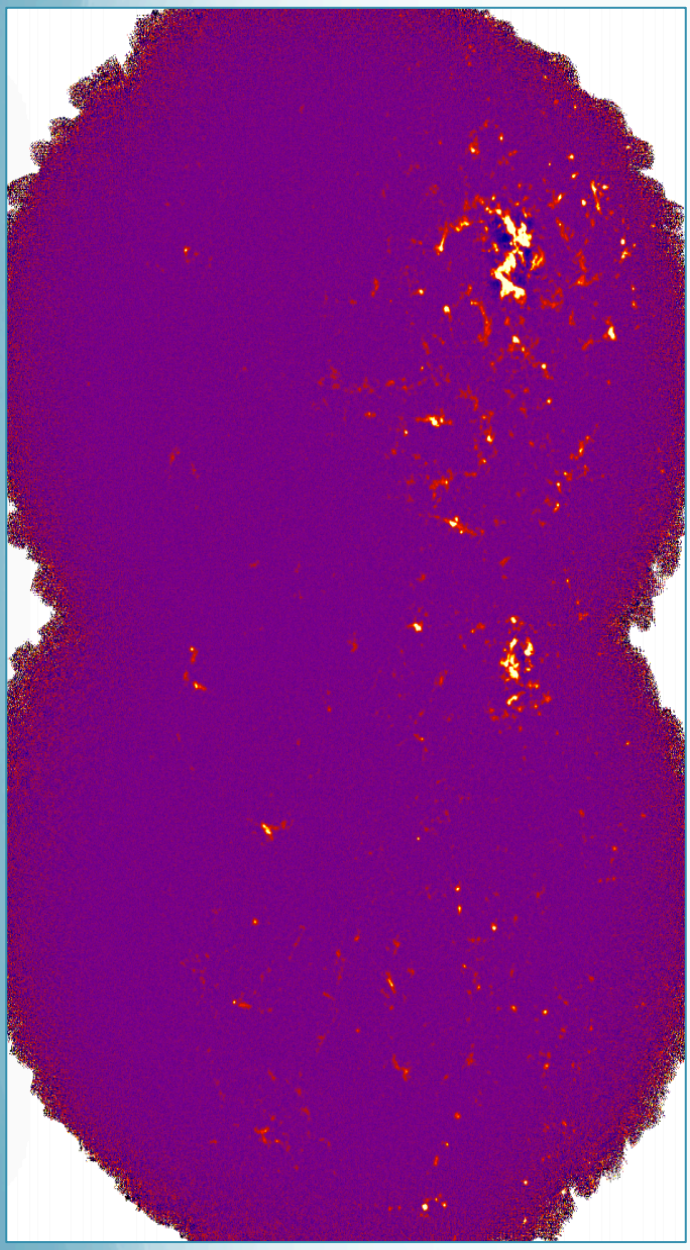


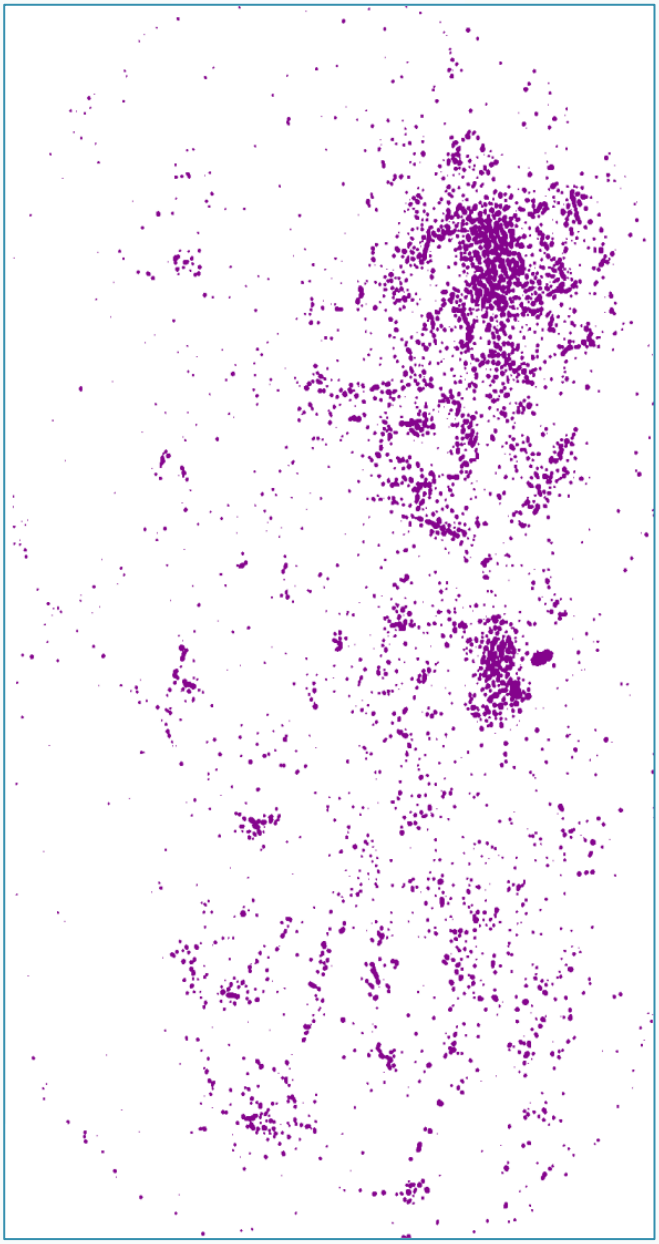
Cut at 3sigma



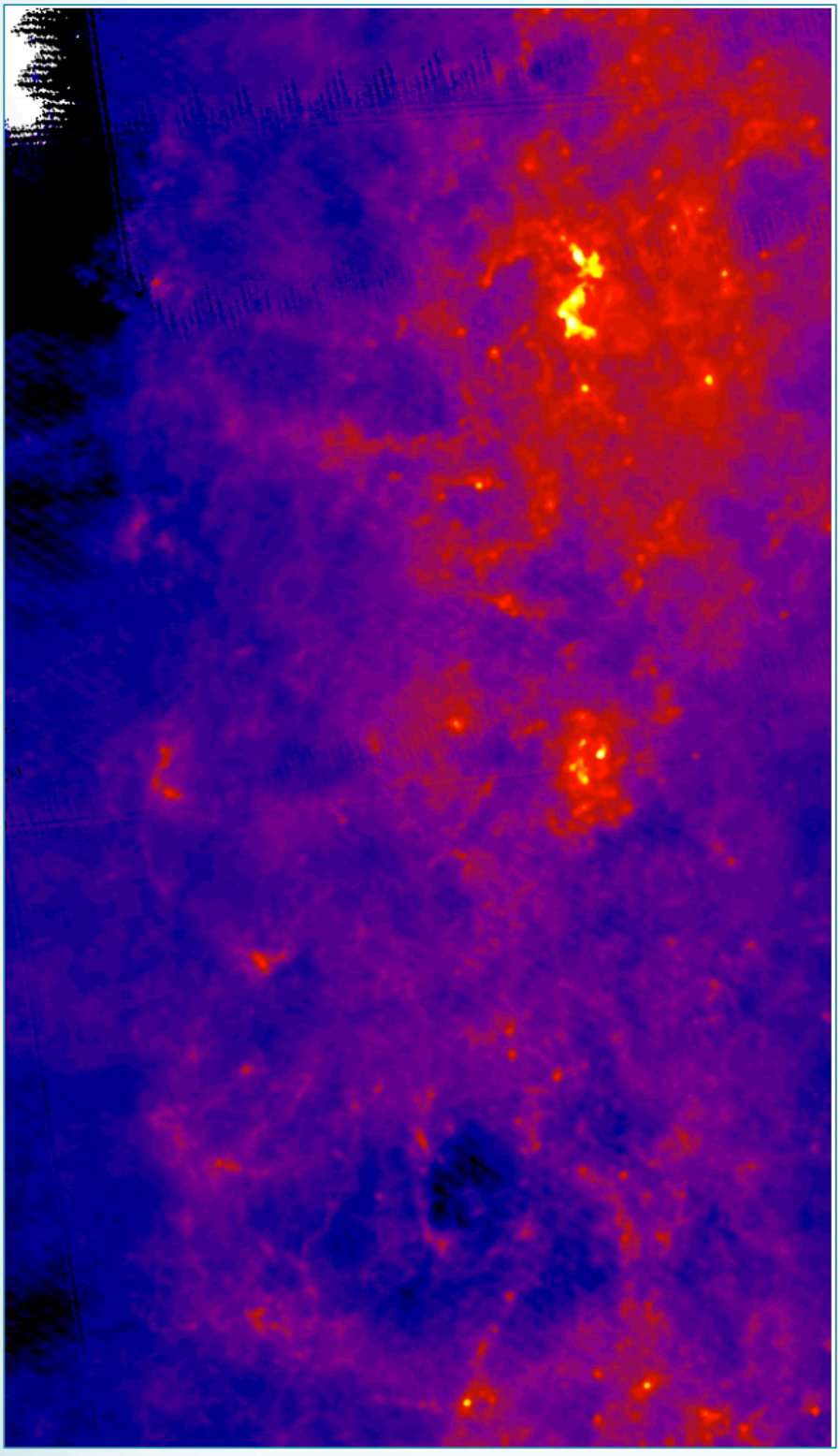


Match filter then cut at 3 sigma

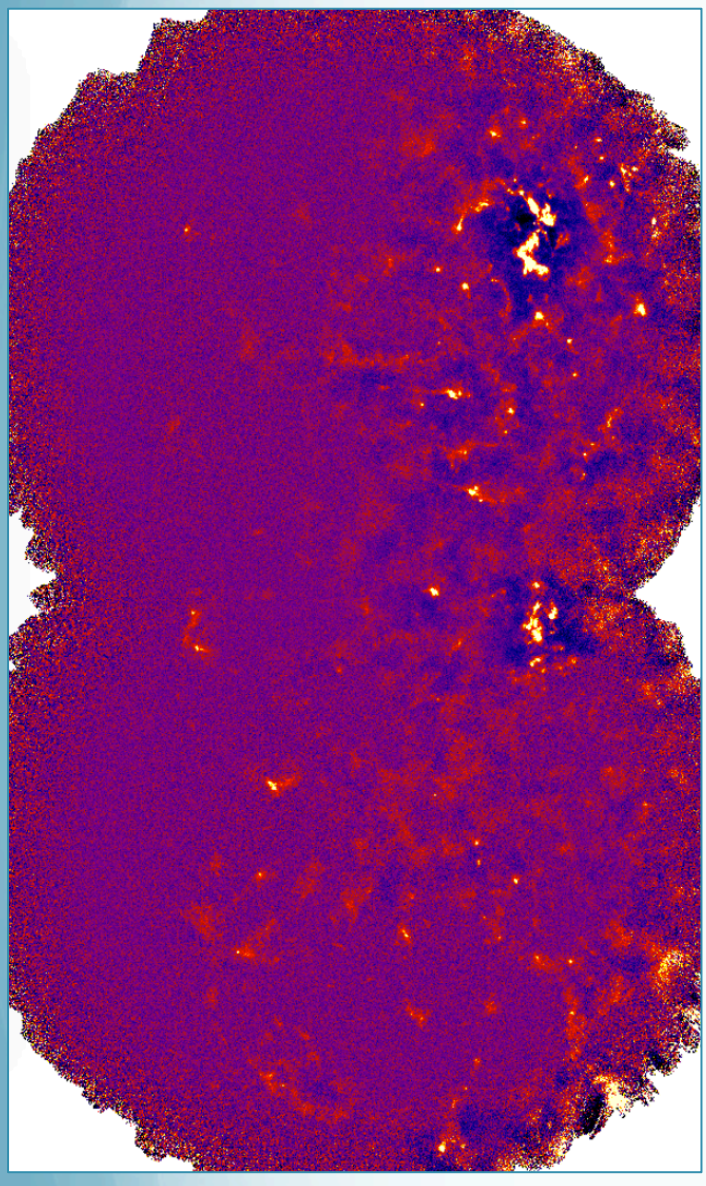


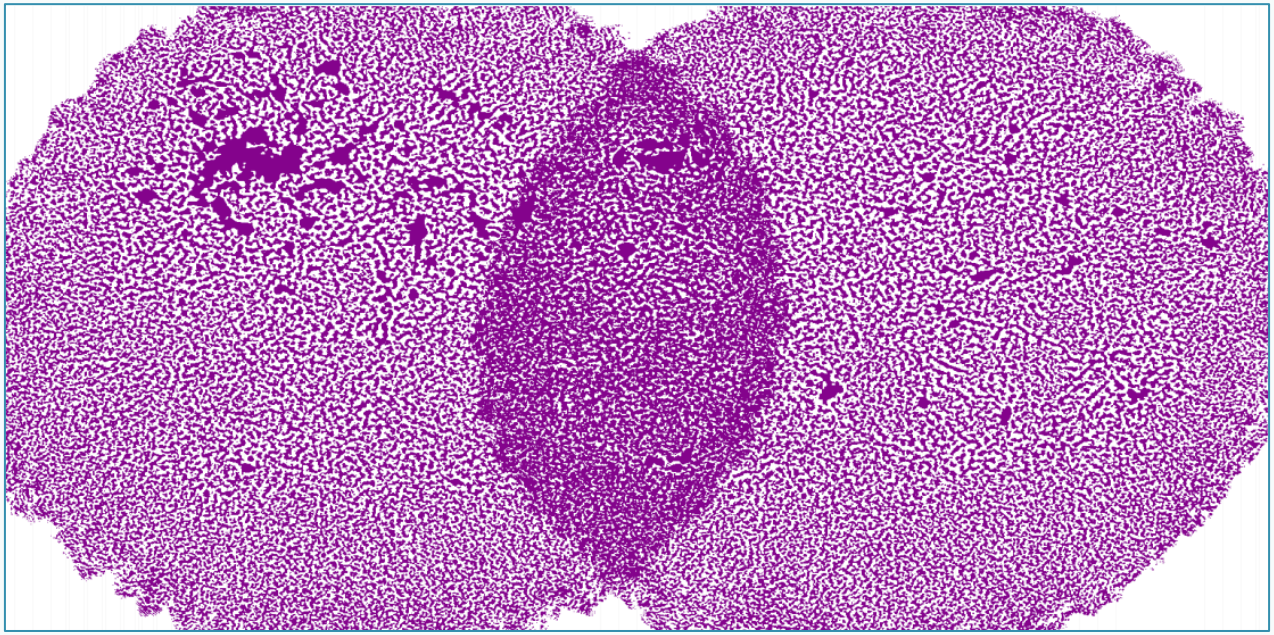


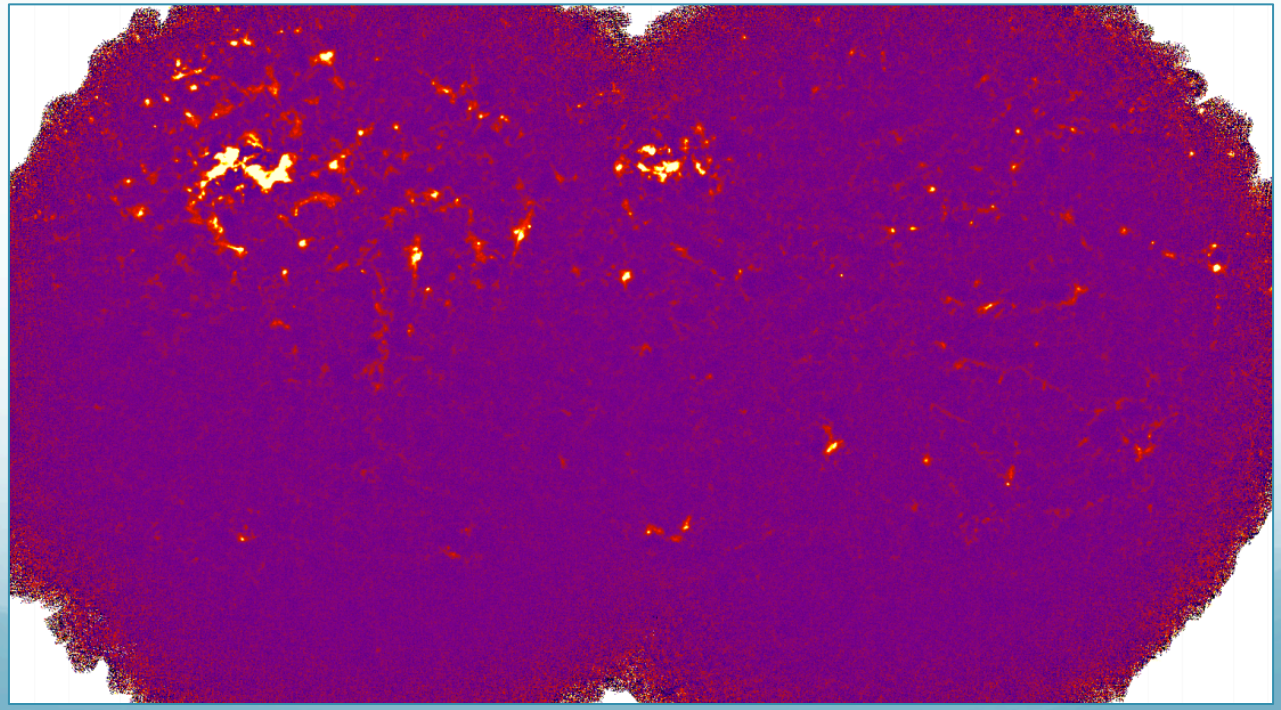
Arbitrary Herschel Spire 500 mask



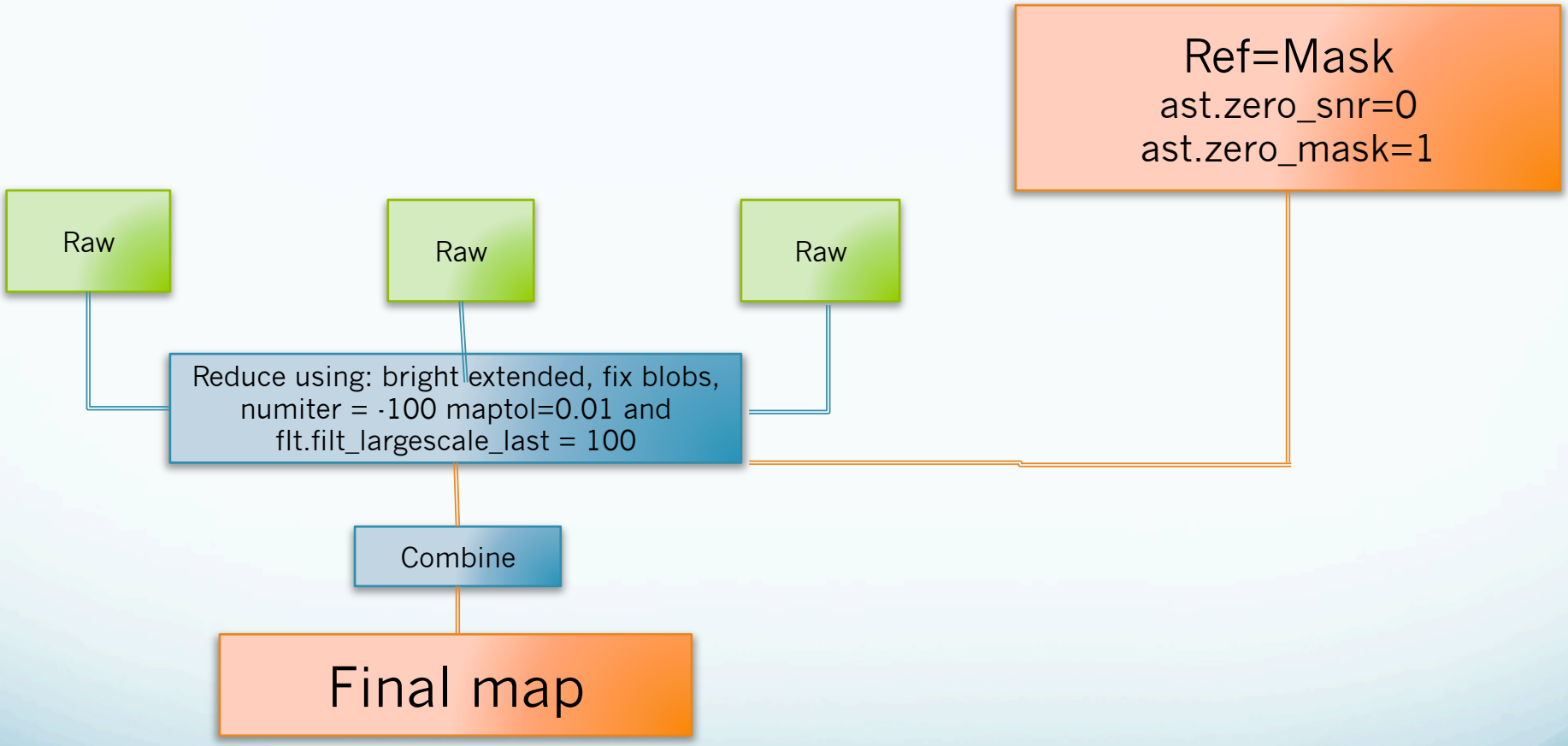
Arbitrary Herschel Spire 500 mask







Using the external mask



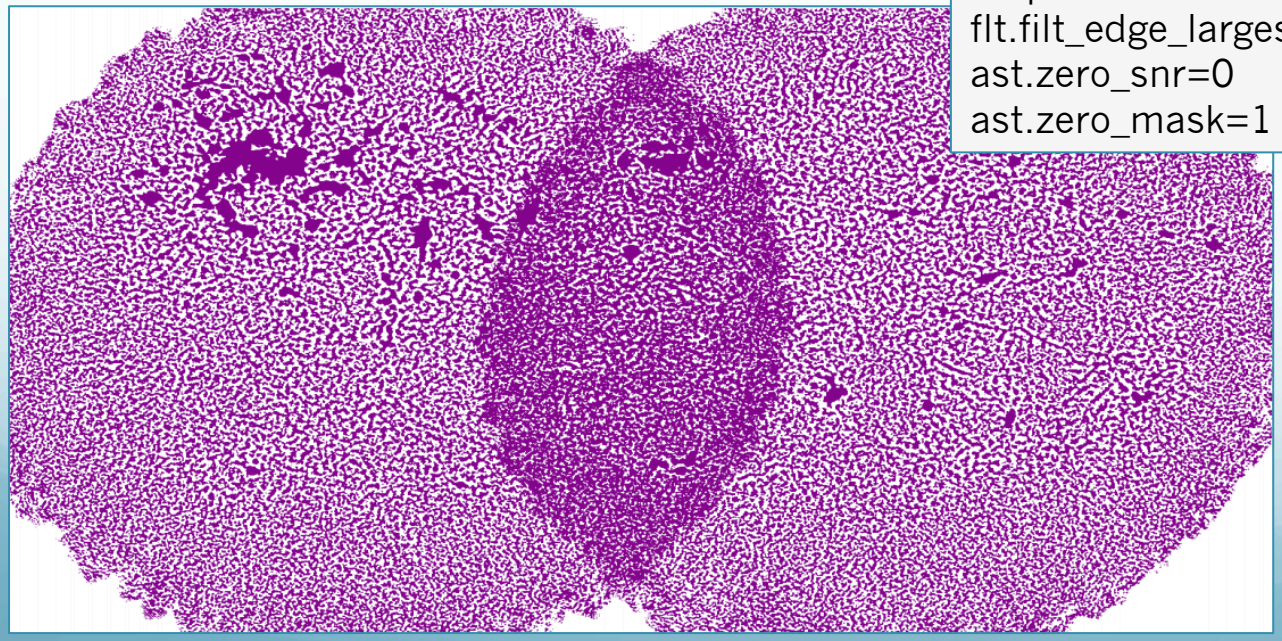
Start with a field that has been reduced by an appropriate method. For the "zero masking"...

>> gausmooth fwhm=5 in=file.sdf out=file_sm.sdf

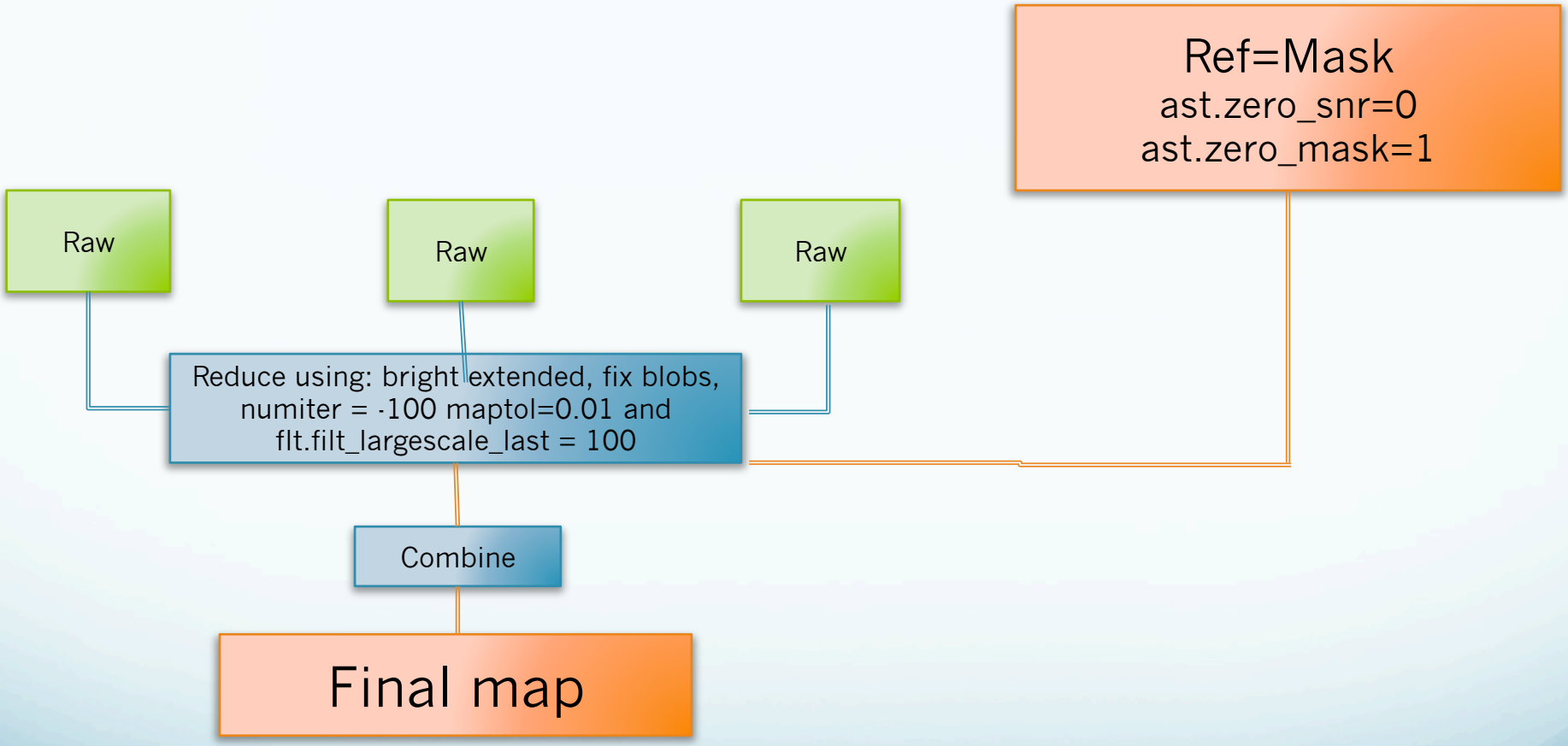
>> thresh in=file_sm.sdf out=mask.sdf thrhi=0 thrlo=0 newhi=1 newlo=bad

>> in=/directory/in*.sdf out=out.sdf config=^/stardev/share/smurf/dimmconfig_external.lis ref=mask.sdf

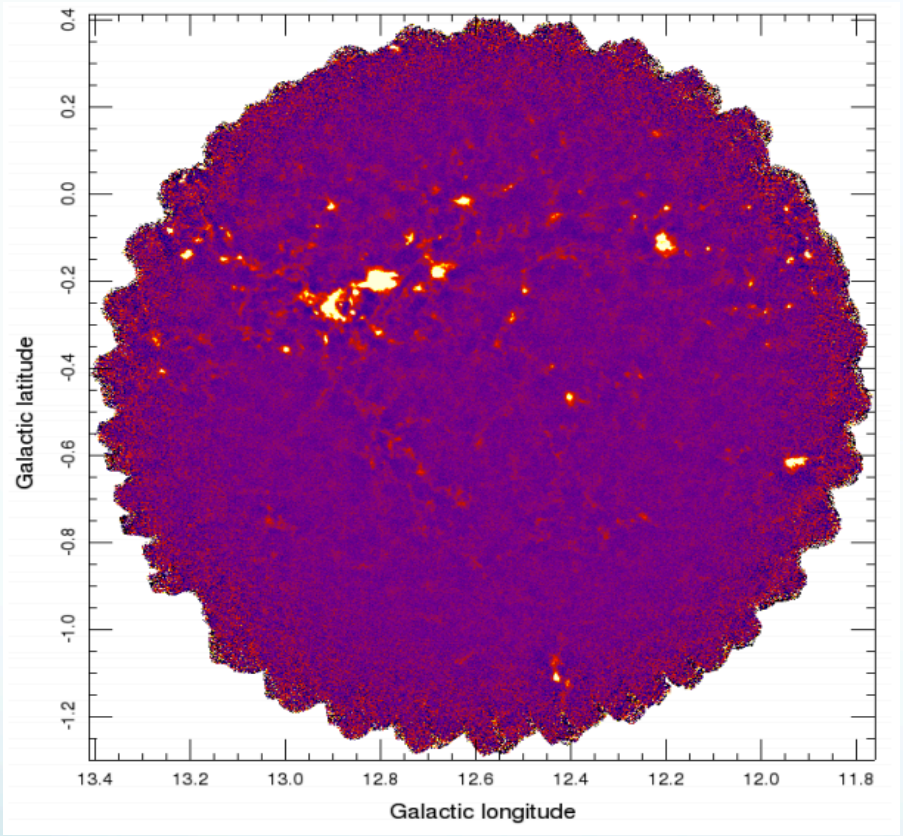
```
^dimmconfig_bright_extended.lis
numiter=-100
maptol=0.01
flt.filt_edge_largescale_last=100
ast.zero_snr=0
ast.zero_mask=1
```



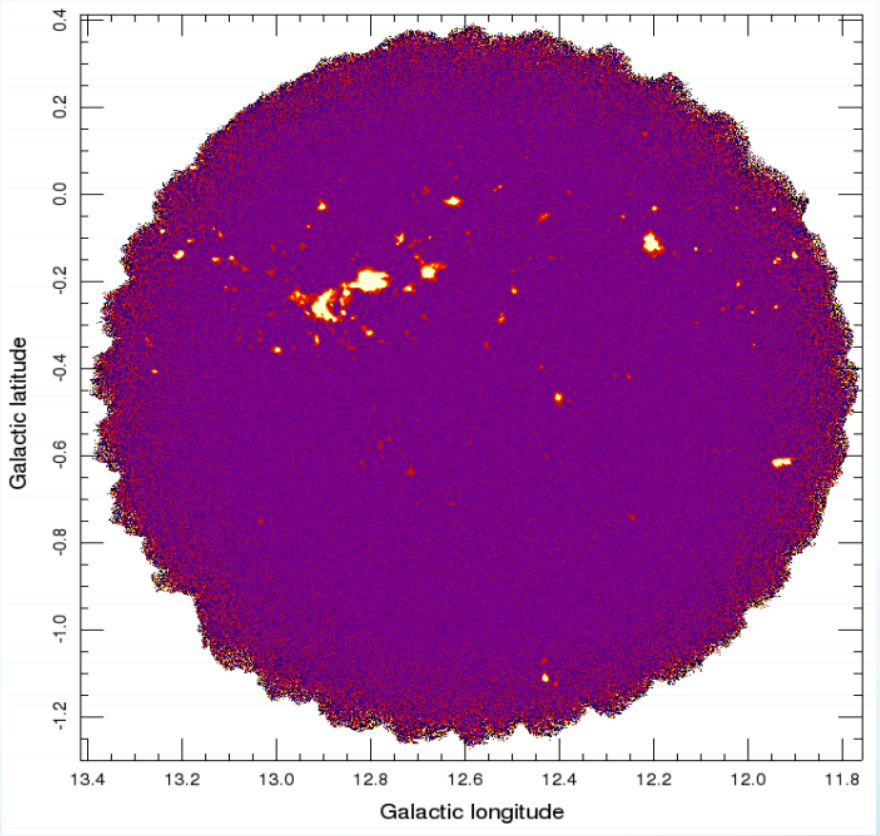
Using the external mask



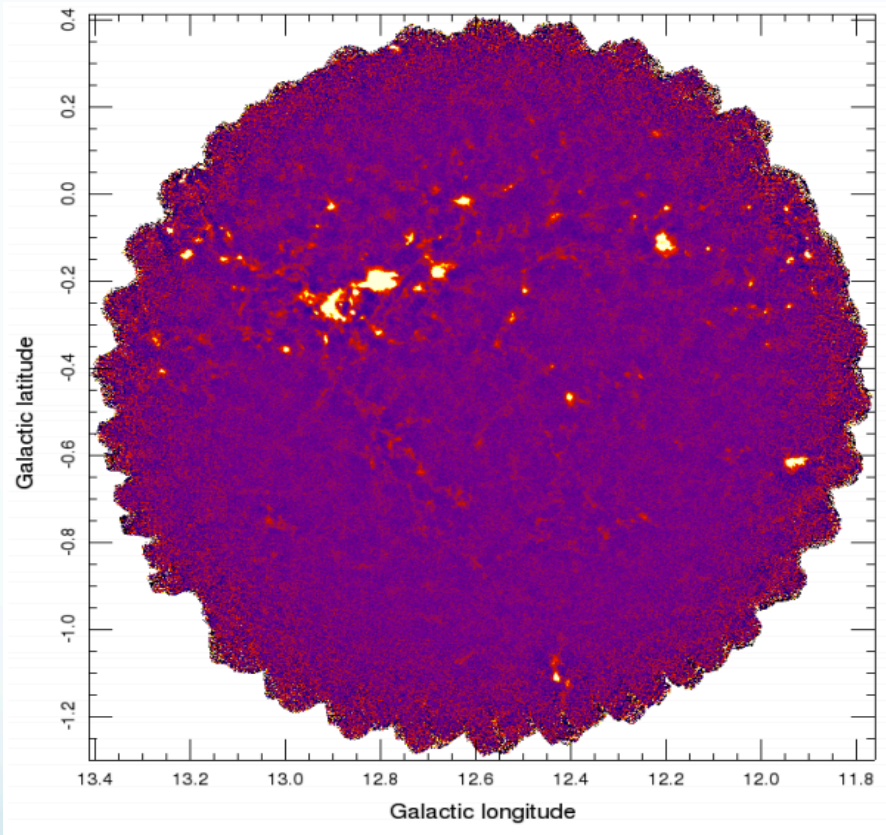
Bright Extended



Bright Extended + additions



Bright Extended



Bright Extended + additions & external masking