HETERODYNE DATA REDUCTION

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JCMT HETERODYNE SUITE

- Single-pixel receivers at 230 and 690 GHz
- 16-pixel 345GHz array receiver HARP
- ACSIS multi-channel digital spectrometer

HETERODYNE OBS MODES

- Observing patterns:
  - Stare: Single array position integration- single pixel output (16 positions for HARP)
  - Jiggle-map: moves secondary to fill in the 30" spacing between HARP receptors to make a 2' x 2' map. Two main spacings (HARP4 - 4 x 4 jiggle, undersampled, 7.25" pix, and HARP5 - 5 x 5 jiggle, oversampled, 6" pix)
  - Raster: scan or 'on-the-fly' technique, with HARP array rotated at 14.04 deg to scan direction, resulting in 7.3" pixels - often repeated with 90 deg rotation to create 'basket- weave' maps
- Spectrometer options 250MHz - 1860 MHz bandwith, 1 or 2 sub-bands (eg for 13CO, C18O simultaneous observing), resolution from 0.0305 MHz - 0.977 MHz

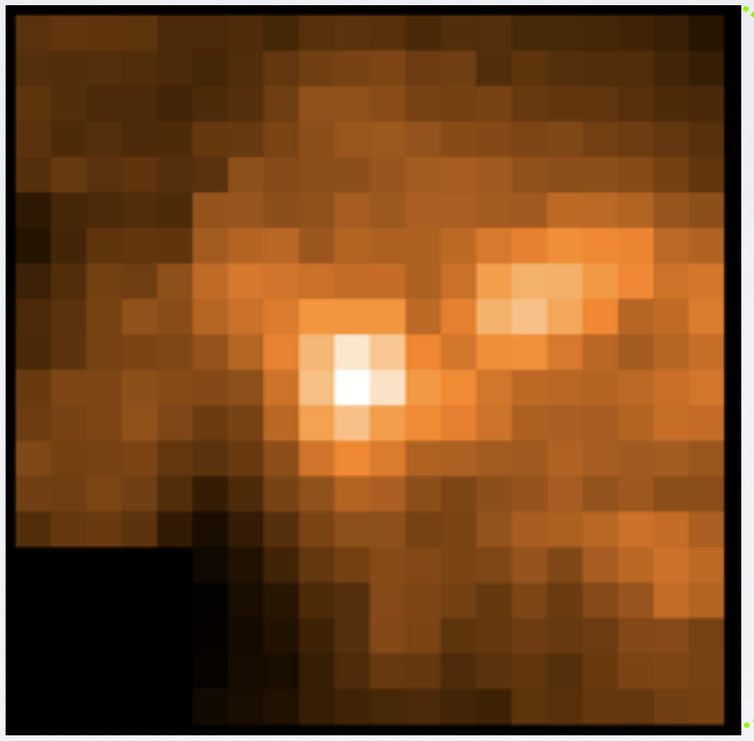
Example: G34.3 integrated intensity images

HARP Stare

2 arcmin

30” pixels

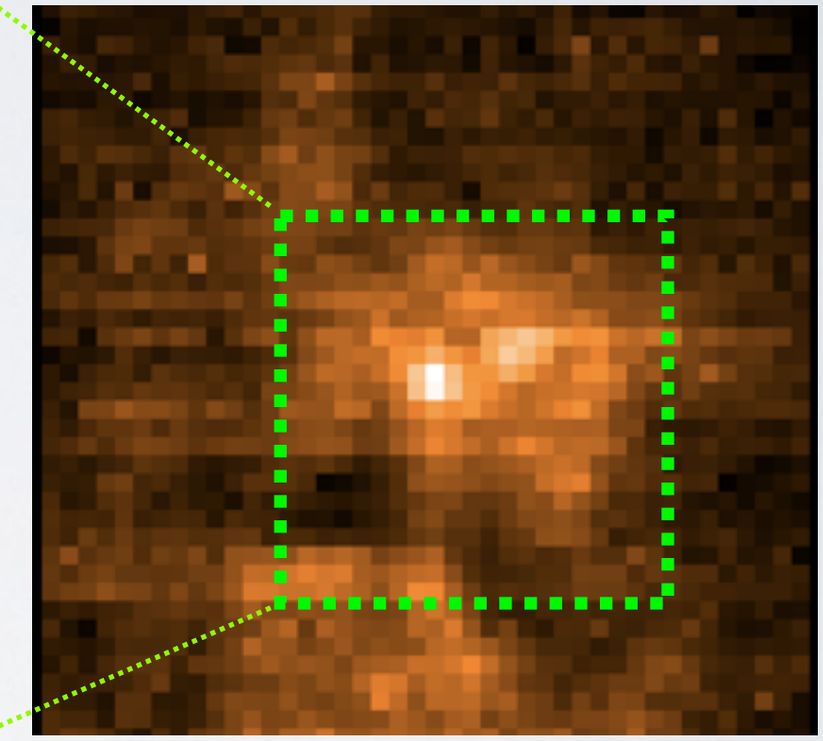
HARP Jiggle-map



2 arcmin

6” pixels

HARP Raster map

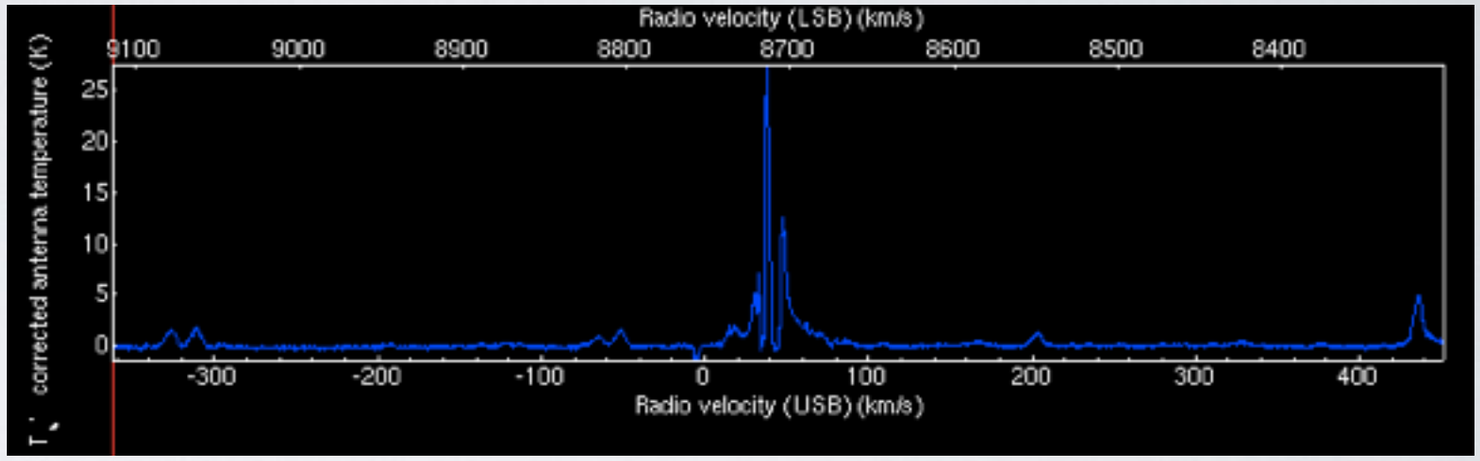


5 arcmin

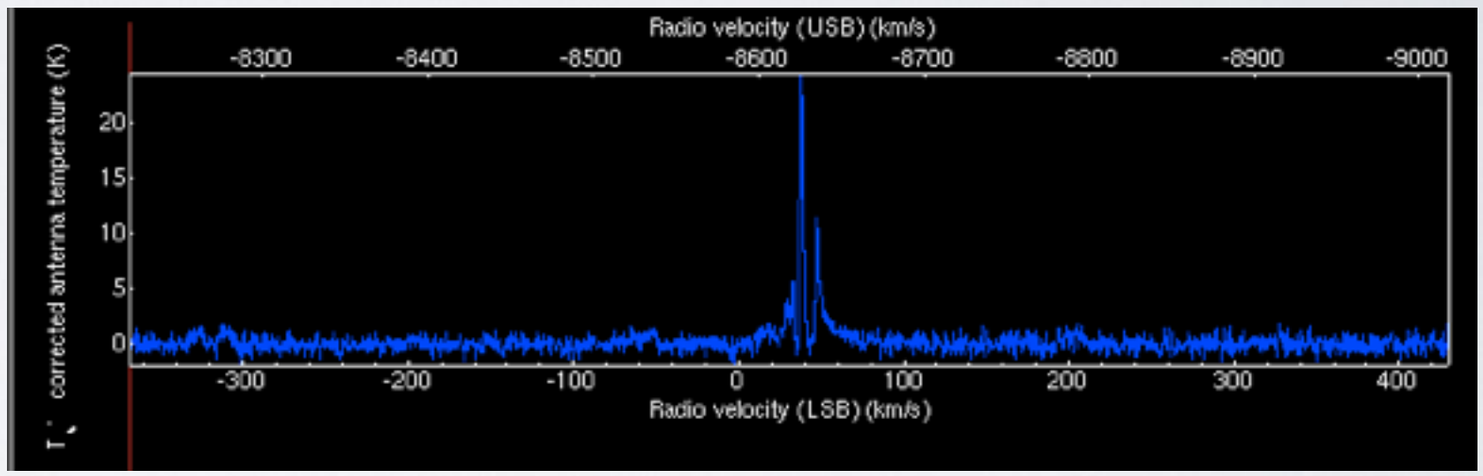
7.25” pixels

Example: G34.3 peak spectrum

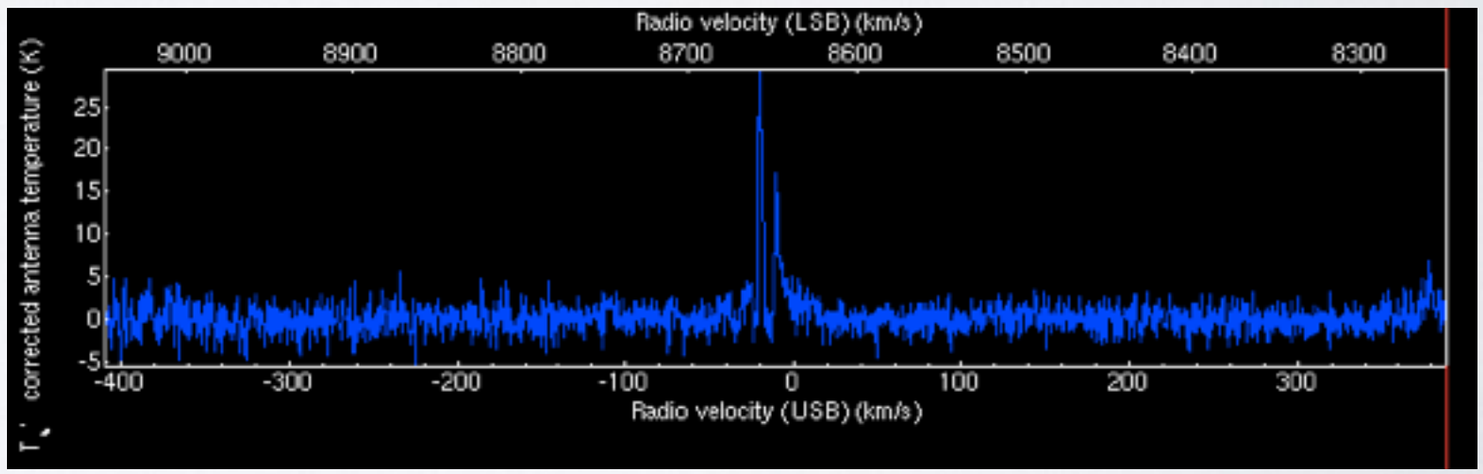
Stare: 0.14 K rms



Jiggle: 0.5 K rms



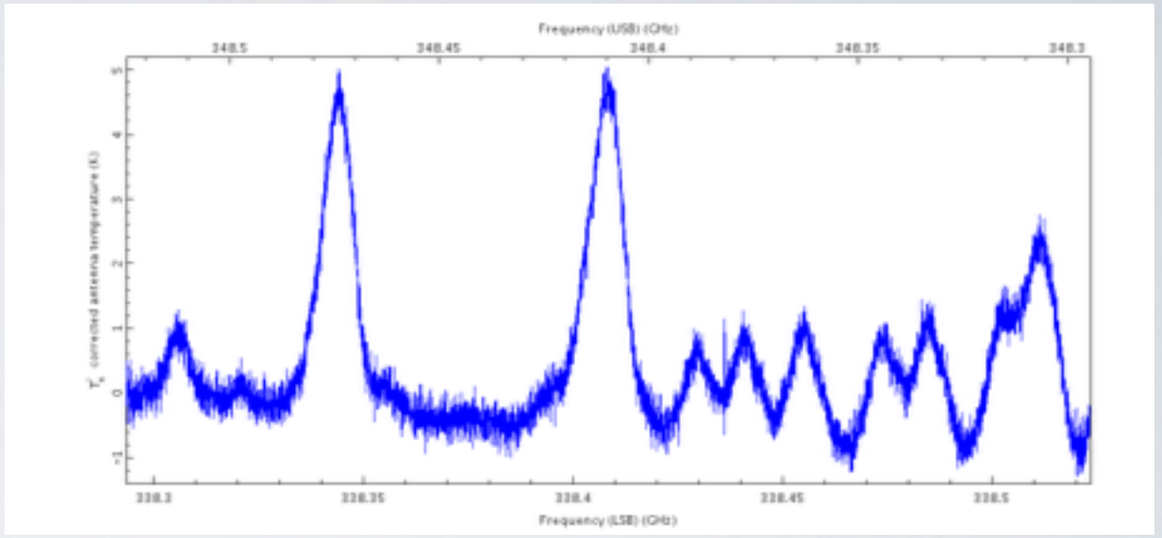
Raster: 1.6 K rms

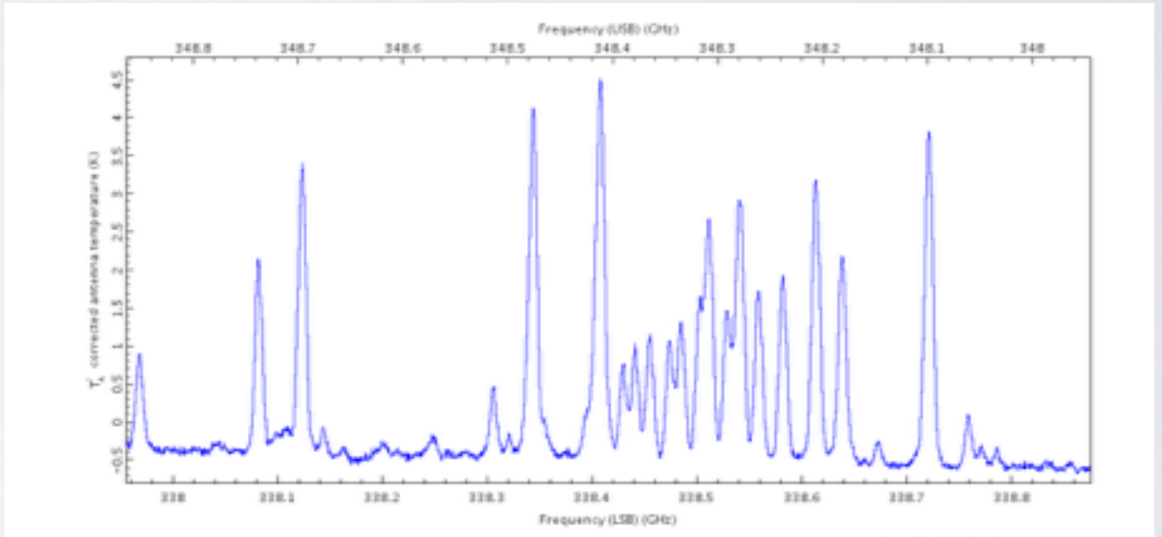


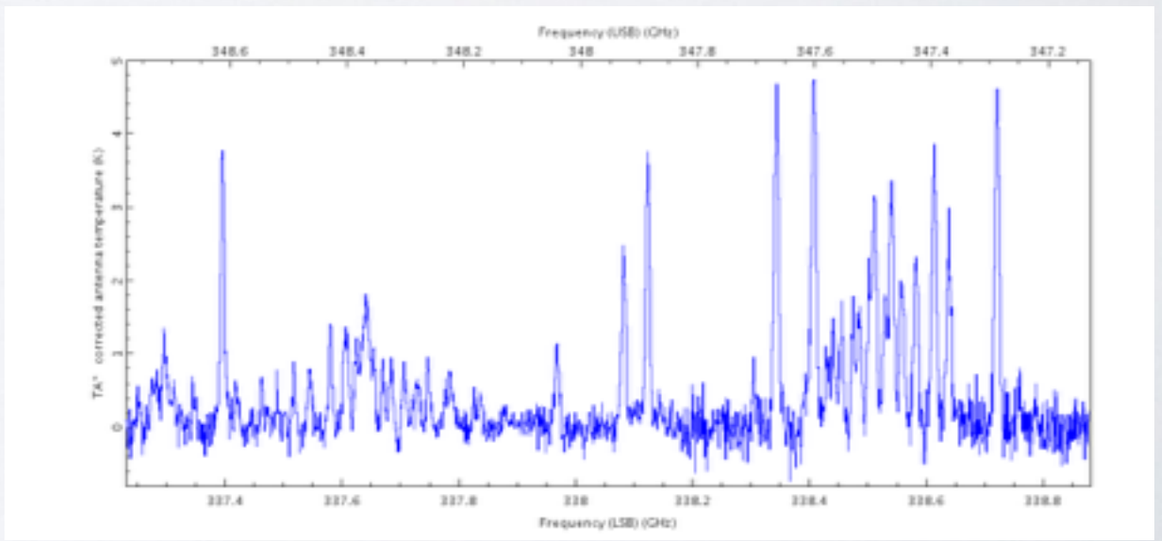
1 GHz bandwidth, 0.488MHz spectal resolution

BANDWIDTHS

- G34.3 CH3OH line-forest observed at 338 GHz with bandwidths 250 MHz (top) 1 GHz (centre) and 1.6 GHz (bottom)

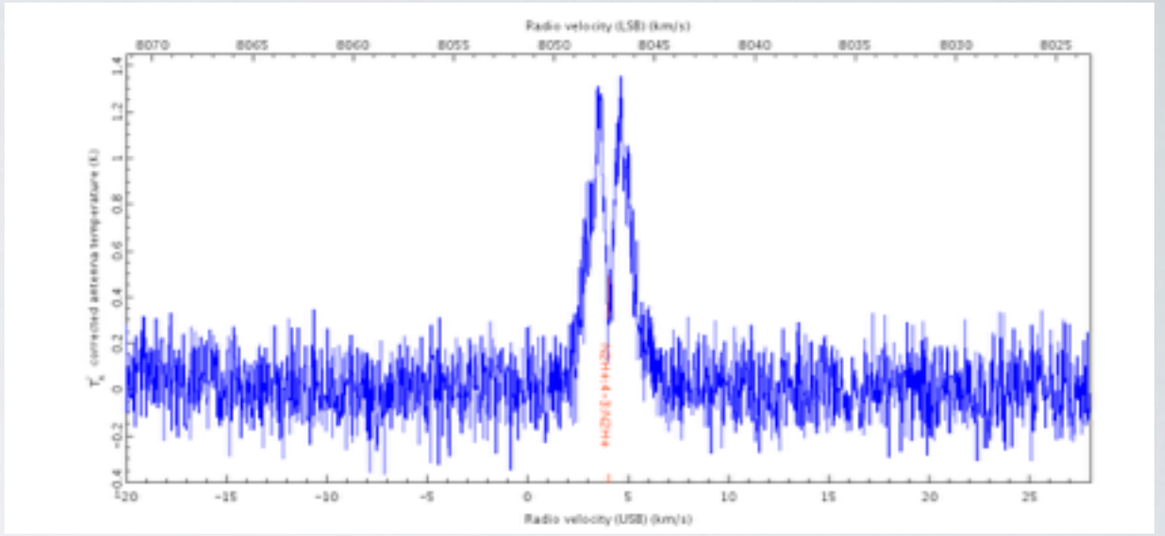




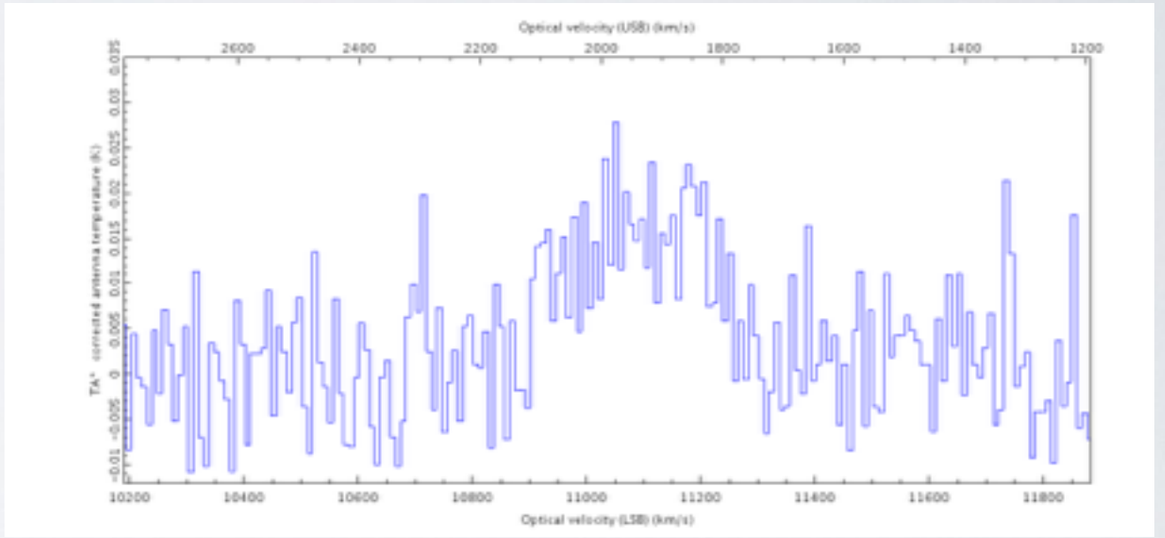


OTHER MODES

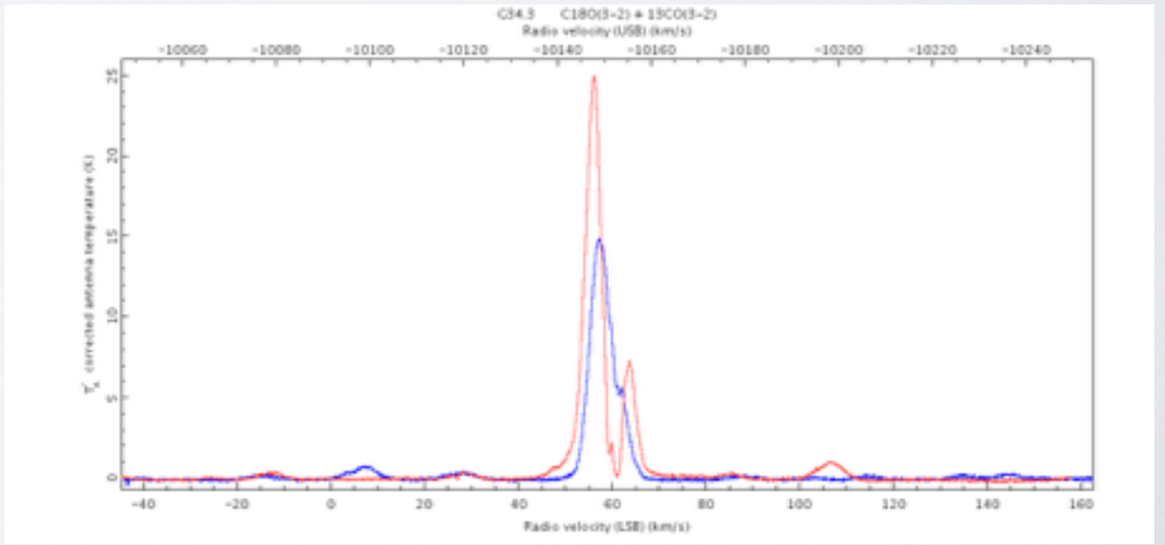
- N2H+ at 372GHz - requires best weather but is attainable



- Wide-band observations of galaxies



- Simultaneous observation of 13CO(3-2)/C18O



DATA ACQUISITION

- Summit QA pipeline produces information on the receiver performance and baseline quality

- Summit pipeline reduces the data without complex techniques for baseline correction etc

- Produces output to the JCMT Tonight page and OMP page

- More sophisticated reduction is completed in Hilo, with any user-specified recipe parameters, and is made available to the P.I. at CADC JCMT Science Archive

JCMT SCIENCE RECIPES

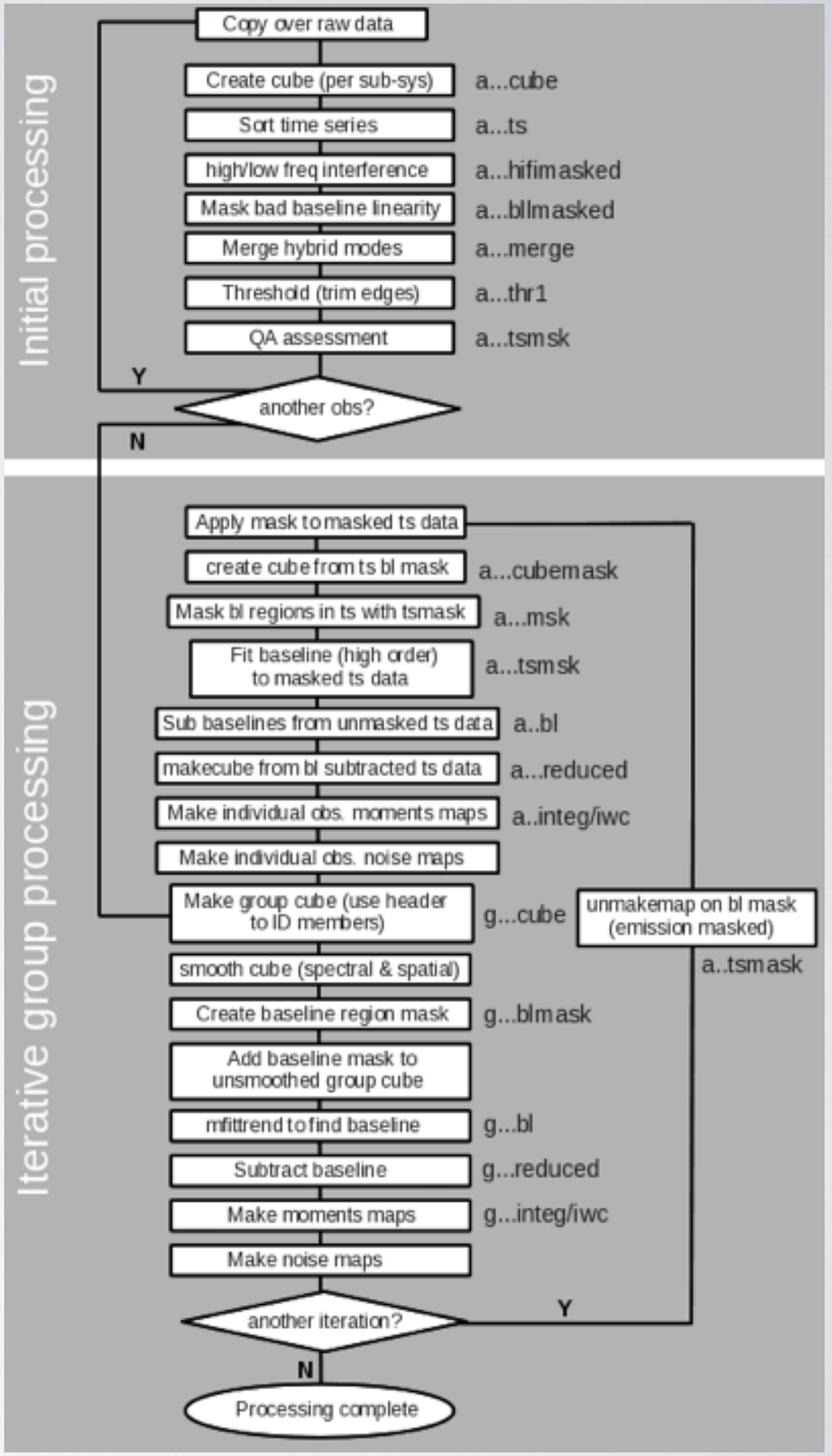
- A number of default recipes are found in the JCMTOT during program construction and this selection is used for the reduced files that project then downloads from the archive

- Tailored recipes can also be applied, at request, and are encouraged

RECIPE	DESCRIPTION	BASELINE DETERMINATION
NARRLOWLINE	One of more narrow lines are expected across the band. Select this recipe if the expected lines are less than about 20 channels wide.	Smoothing: spatial = 5×5 pixels frequency = 10 channels
BROADLINE	The line is so wide that it extends over a large fraction of the band. Since it also typically is too weak to clearly see in a single observation, a pre-determined and fixed baseline window and linear baselines need to be used. The central regions of active galaxies fall in this category, as well as certain outflow sources.	Uses the outer 10% of the spectra to fit a single order polynomial.
GRADIENT	Typically one moderately wide line is expected, for which the center velocity varies significantly across the field. The baseline window changes across the field. Nearby galaxies often fall in this category. The expected lines should be wider than 20 channels and probably not wider than 20% of the available bandwidth	Smoothing: spatial = 3×3 pixels frequency = 25 channels
LINEFOREST	A forest of strong and weak lines is expected across the observed band. Bright, nearby star formation sources may fall in this category. This recipe also creates a separate moments map for each line (as defined by the parameter PER_LINE).	Smoothing: spatial = 5×5 pixels frequency = 10 channels

THE PIPELINE

- > oracdr_acsis -cwd
- >oracdr -loop file -files <in.txt>
- Range of recipe parameters that can be adjusted including baseline trimming, QA parameters, rebinding factors, and more
- See Heterodyne observing manual for details



```
Quality assurance with masking
------------------------------------------

Retrieving Tsys values from a20080903_00022_01_thr001.
 Tsys for entire array:   1032.63 K
 Tsys values for each receptor:
      H00      H02      H04      H05      H06      H08      H09      H10      H11
 1057.305 1233.972  862.486  795.125  977.215  841.287 1740.310  974.778  979.218
      H12      H13      H15
 1012.982  902.390 1014.460

Calculating RMS values for a20080903_00022_01_thr001.
 RMS for entire array:      4.16 K
 RMS values for each receptor:
      H00      H02      H04      H05      H06      H08      H09      H10      H11
    3.035    3.635    2.553    2.155    2.571    2.505   10.831    2.652    2.946
      H12      H13      H15
    2.827    2.561    2.942

QA results for CO 3-2:
 Time-series QA  passed  for Telescope.
  RMS statistics: minimum: 2.15 maximum: 3.63 mean: 2.76
  Tsys statistics: minimum: 795.13 maximum: 1740.31 mean: 1032.63
  QA note:
   Receptor-to-receptor RMS value test passed after removing receptor H09

Using Telescope results to mask out receptors H09
a20080903_00022_01_thr001 to a20080903_00022_01_rmsk001:
 Masked receptor H09.
```

- Calculates Tsys and RMS for all receptors - and compares to any quality assurance parameters set by the pipeline

- Baselines, finds emission regions using Clumpfind, and creates moments maps, velocity maps and integrated intensity images

```
Creating baseline region mask.
 Smoothing cube ga20080903_22_1_reduced001 with [3,3,25] tophat.
 ga20080903_22_1_blmask001: baseline region mask created.

Creating moments maps for ga20080903_22_1_reduced001.
 Smoothing cube with [3,3,25] tophat.
 Masking out lines using ga20080903_22_1_blmask001.
Median RMS in smoothed observation is 0.143.

Clump finding in ga20080903_22_1_reduced001
 Finding clumps higher than 3.0-sigma using clumpfind.
 Masking non-clump data.
 Collapsing to form temporary integ map.
 Finding clumps higher than 4.0-sigma using clumpfind.
 Masking non-clump data.
 Collapsing to form temporary iwc map.

Created integ map in ga20080903_22_1_integ.
ga20080903_22_1_integ to ga20080903_22_1_rimg:
 Tagged as representative.

Creating new object for KAPVIEW
ga20080903_22_1_rimg to ga20080903_22_1_rimg_64.png: Created graphic.
 Adding EXIF header to ga20080903_22_1_rimg_64.png.
ga20080903_22_1_rimg to ga20080903_22_1_rimg_256.png: Created graphic.
ga20080903_22_1_rimg to ga20080903_22_1_rimg_1024.png: Created graphic.
Spectrum created from pixel co-ordinates (5,2) created in ga20080903_22_1_sp001.
ga20080903_22_1_sp001 to ga20080903_22_1_rsp:
 Tagged as representative.

ga20080903_22_1_rsp to ga20080903_22_1_rsp_64.png: Created graphic.
 Adding EXIF header to ga20080903_22_1_rsp_64.png.
ga20080903_22_1_rsp to ga20080903_22_1_rsp_256.png: Created graphic.
ga20080903_22_1_rsp to ga20080903_22_1_rsp_1024.png: Created graphic.

Created iwc map in ga20080903_22_1_iwc.
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Create noise maps
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Creating noise map for ga20080903_22_1_reduced001.
 Using variance array in ga20080903_22_1_reduced001 to create temporary noise map.
Created noise map in ga20080903_22_1_noise.

Checking RMS spatial uniformity for ga20080903_22_1_noise.
 Using central 50% of map.
 minimum: 1.21 maximum: 2.56 mean: 1.65
 Number of pixels used:   420
 Number of bad pixels:      0
 Percentage bad: 0.00%

 Spatial RMS uniformity passed for Telescope for ga20080903_22_1_noise.
 QA based on bad pixels in final map passed for Telescope for ga20080903_22_1_noise.

Checking RMS uniformity for ga20080903_22_1_reduced001.
 Masking out lines using ga20080903_22_1_blmask001.
 RMS map from lower 10% of frequency range created in ga20080903_22_1_rmslo.
 RMS map from upper 10% of frequency range created in ga20080903_22_1_rmshi.
 Median RMS in lower 10%: 1.9199K
 Median RMS in upper 10%: 1.4993K
 Percentage difference: 28.06%
 Frequency RMS uniformity passed for Telescope for current map.
```
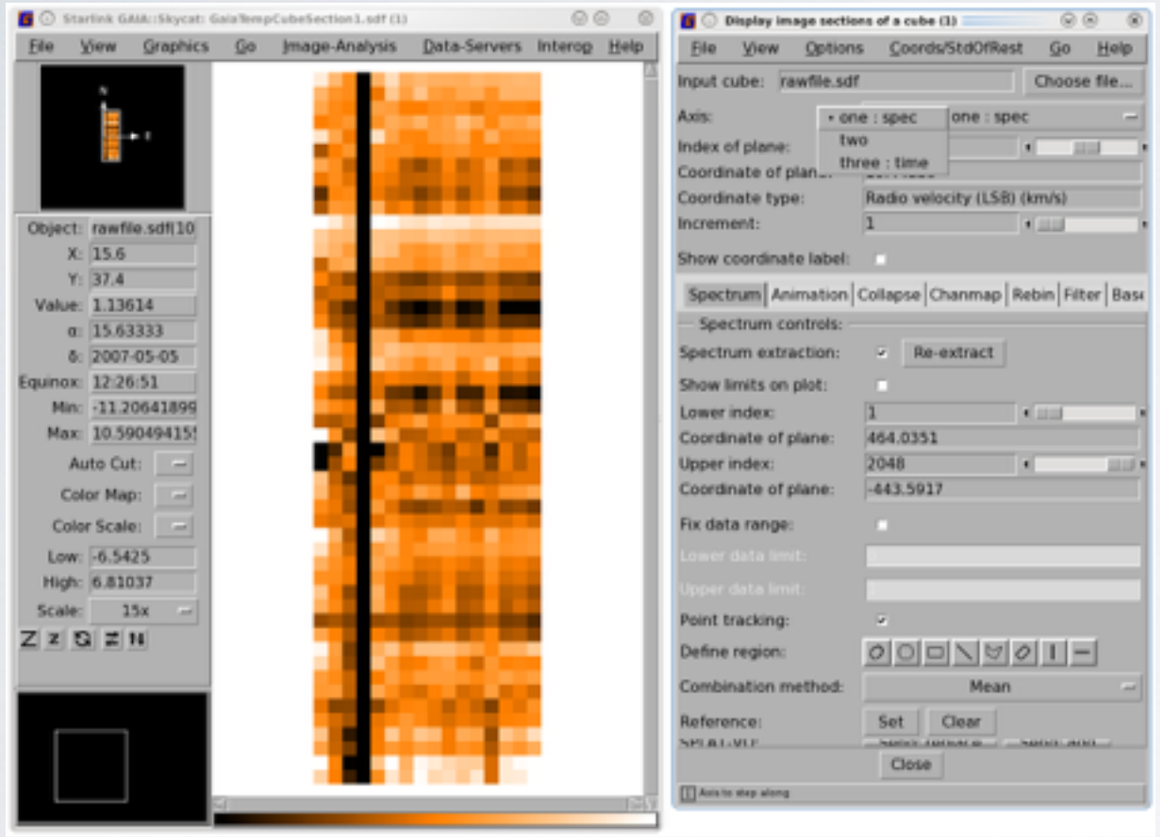
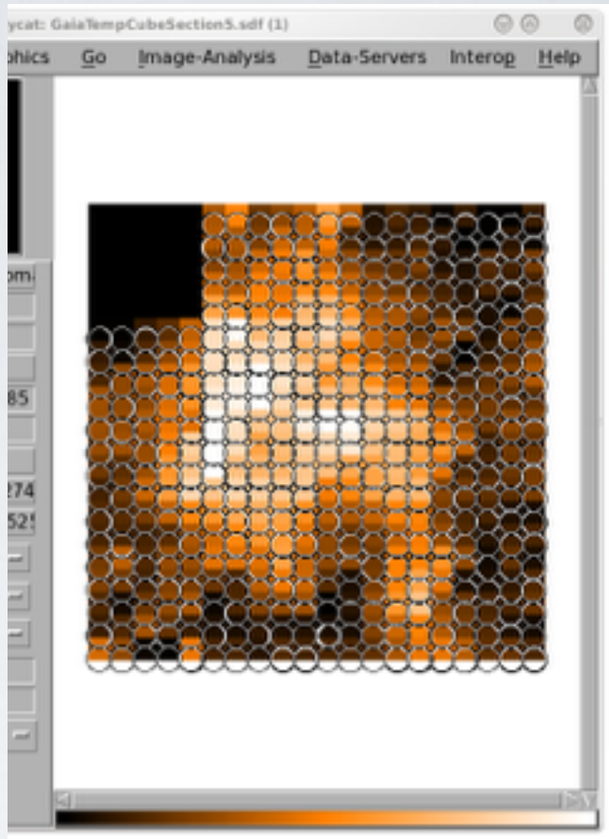
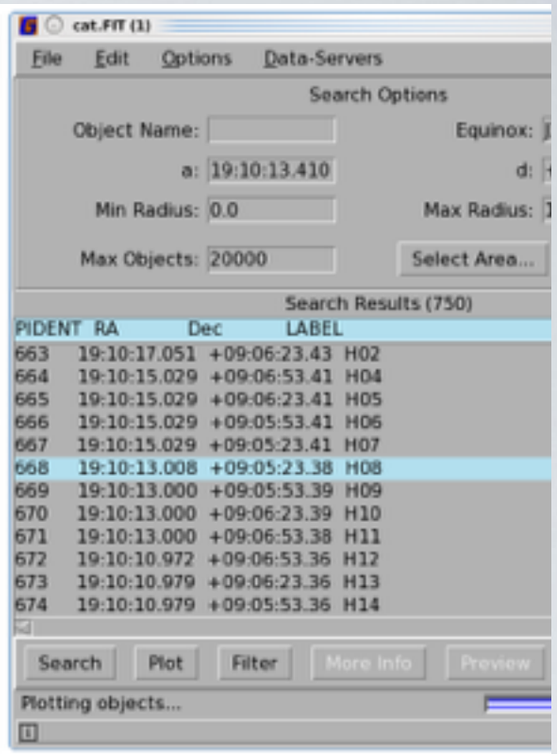

- Produces noise map and applies any QA rms tests

INVESTIGATING THE DATA

- Perusing raw file with gaia
- Running a basic makecube
- An output cube
- Inspecting baselines and flagging bad receptors and regions
- Creating an integrated intensity image


File View Graphics Go Image-Analysis Data-Servers Interop Help
Object: rawfile.sdf[10
X: 15.6
Y: 37.4
Value: 1.13614
α: 15.63333
δ: 2007-05-05
Equinox: 12:26:51
Min: -11.20641899
Max: 10.59049415
Auto Cut:
Color Map:
Color Scale:
Low: -6.5425
High: 6.81037
Scale: 15x
File View Options Coords/StdOfRest Go Help
Input cube: rawfile.sdf
Choose file...
Axis:
one : spec
two
three : time
Index of plane:
Coordinate type:
Radio velocity (LSB) (km/s)
Increment:
Show coordinate label:
Spectrum Animation Collapse Chanmap Rebin Filter
Spectrum controls:
Spectrum extraction:
Re-extract
Show limits on plot:
Lower index:
Coordinate of plane:
464.0351
Upper index:
2048
Coordinate of plane:
-443.5917
Fix data range:
Point tracking:
Define region:
Combination method:
Mean
Reference:
Set
Clear
Close


Go Image-Analysis Data-Servers Interop Help


File Edit Options Data-Servers
Search Options
Object Name:
Equinox:
a: 19:10:13.410
d:
Min Radius: 0.0
Max Radius:
Max Objects: 20000
Select Area...
Search Results (750)
PIDENT RA Dec LABEL
663 19:10:17.051 +09:06:23.43 H02
664 19:10:15.029 +09:06:53.41 H04
665 19:10:15.029 +09:06:23.41 H05
666 19:10:15.029 +09:05:53.41 H06
667 19:10:15.029 +09:05:23.41 H07
668 19:10:13.008 +09:05:23.38 H08
669 19:10:13.000 +09:05:53.39 H09
670 19:10:13.000 +09:06:23.39 H10
671 19:10:13.000 +09:06:53.38 H11
672 19:10:10.972 +09:06:53.36 H12
673 19:10:10.979 +09:06:23.36 H13
674 19:10:10.979 +09:05:53.36 H14
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GAIA ADVANCED

- Contouring
- Displaying observation regions/receptors
- Displaying clumps and catalogues
- Channel maps
- Animations
- 3D rendering and visualization