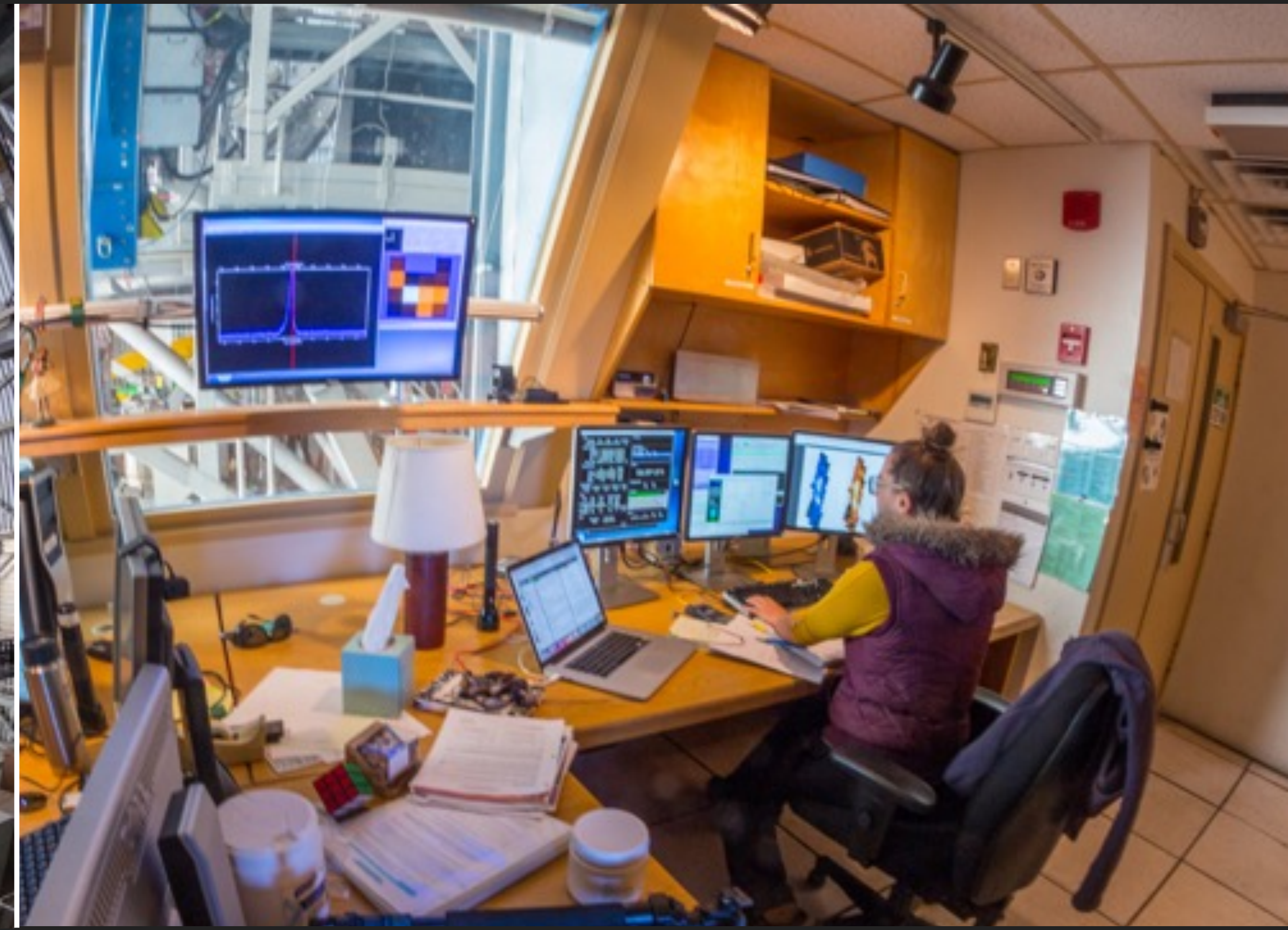
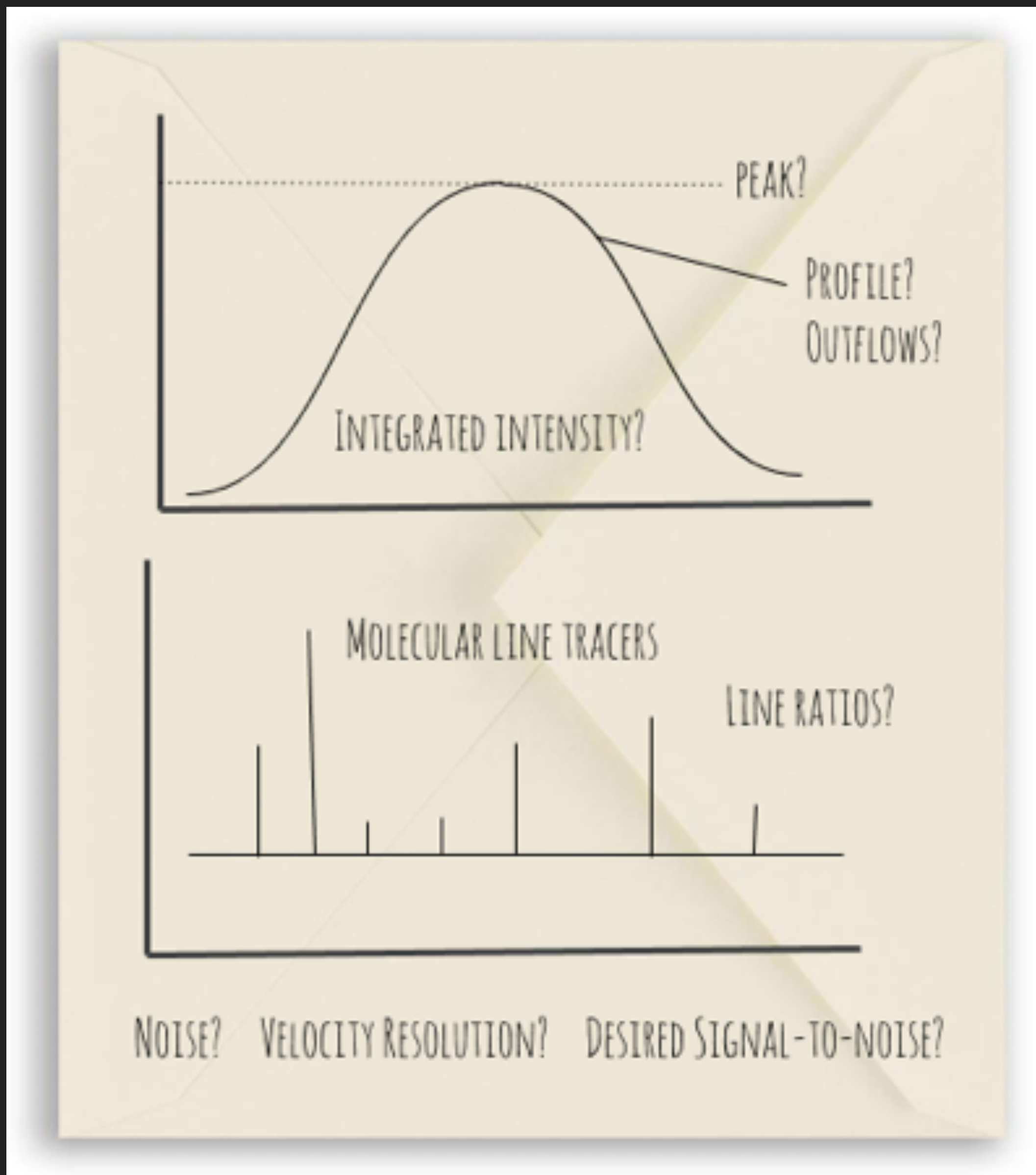
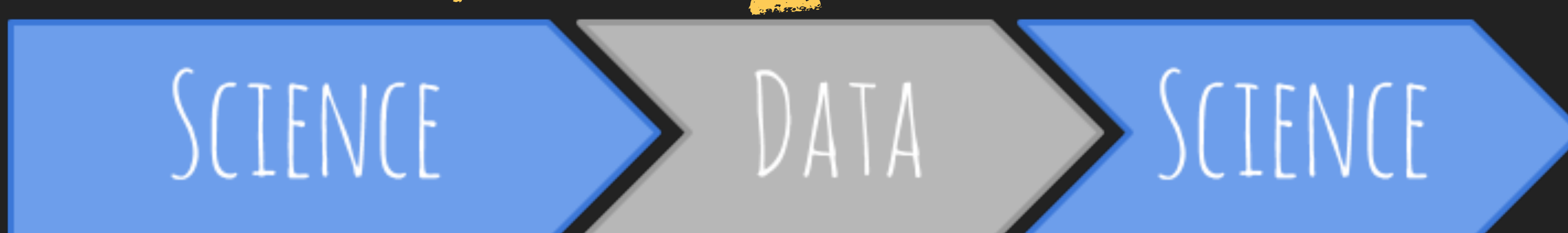


JCMT HETERODYNE DR

FROM DATA TO SCIENCE



https://proposals.eaobservatory.org/

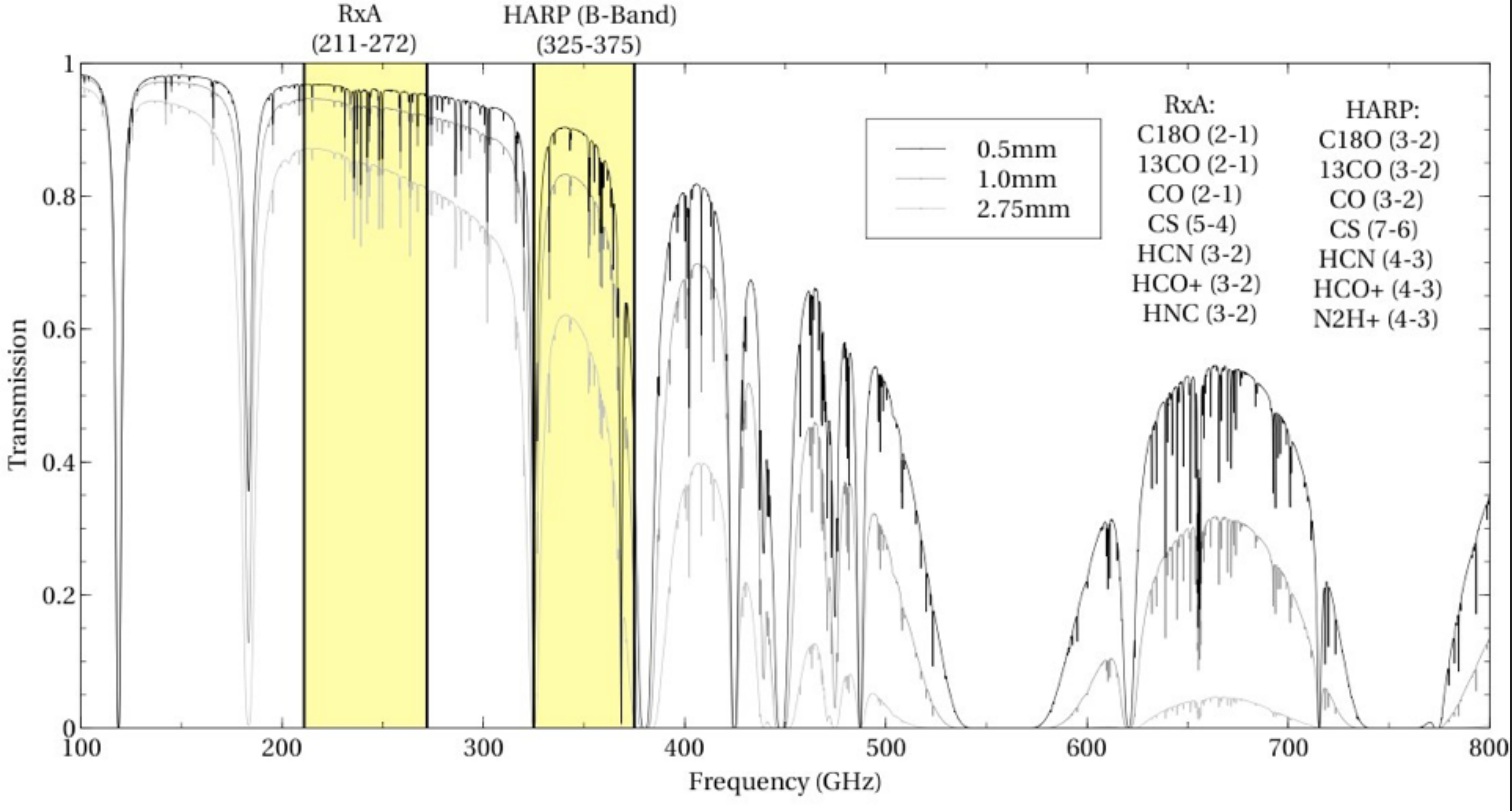


JCMT HETERODYNE INSTRUMENTATION

www.eaobservatory.org/jcmt/science/reductionanalysis-tutorials/

- RxA – Single pixel receiver 230 GHz
- HARP – 16 pixel 345 GHz array receiver
- ACSIS multi-channel digital spectrometer

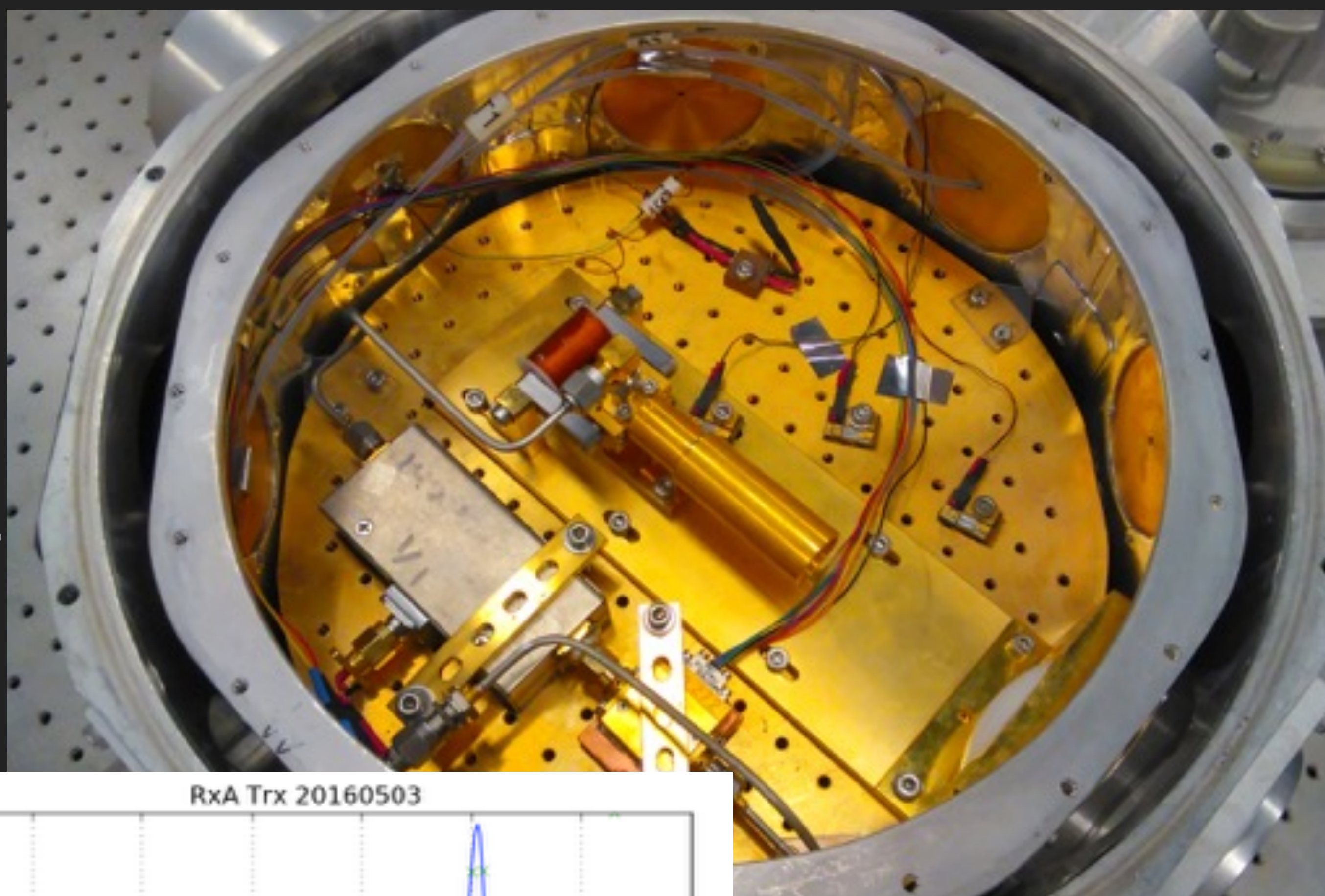
JCMT HETERODYNE INSTRUMENTATION

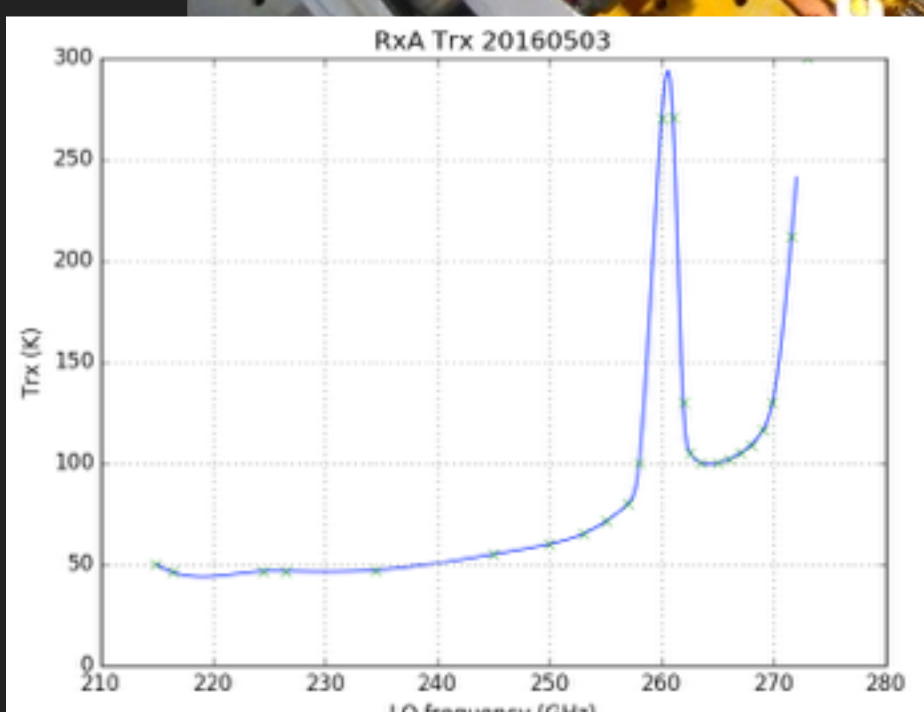


www.eaobservatory.org/jcmt/instrumentation

THE DATA -RXA

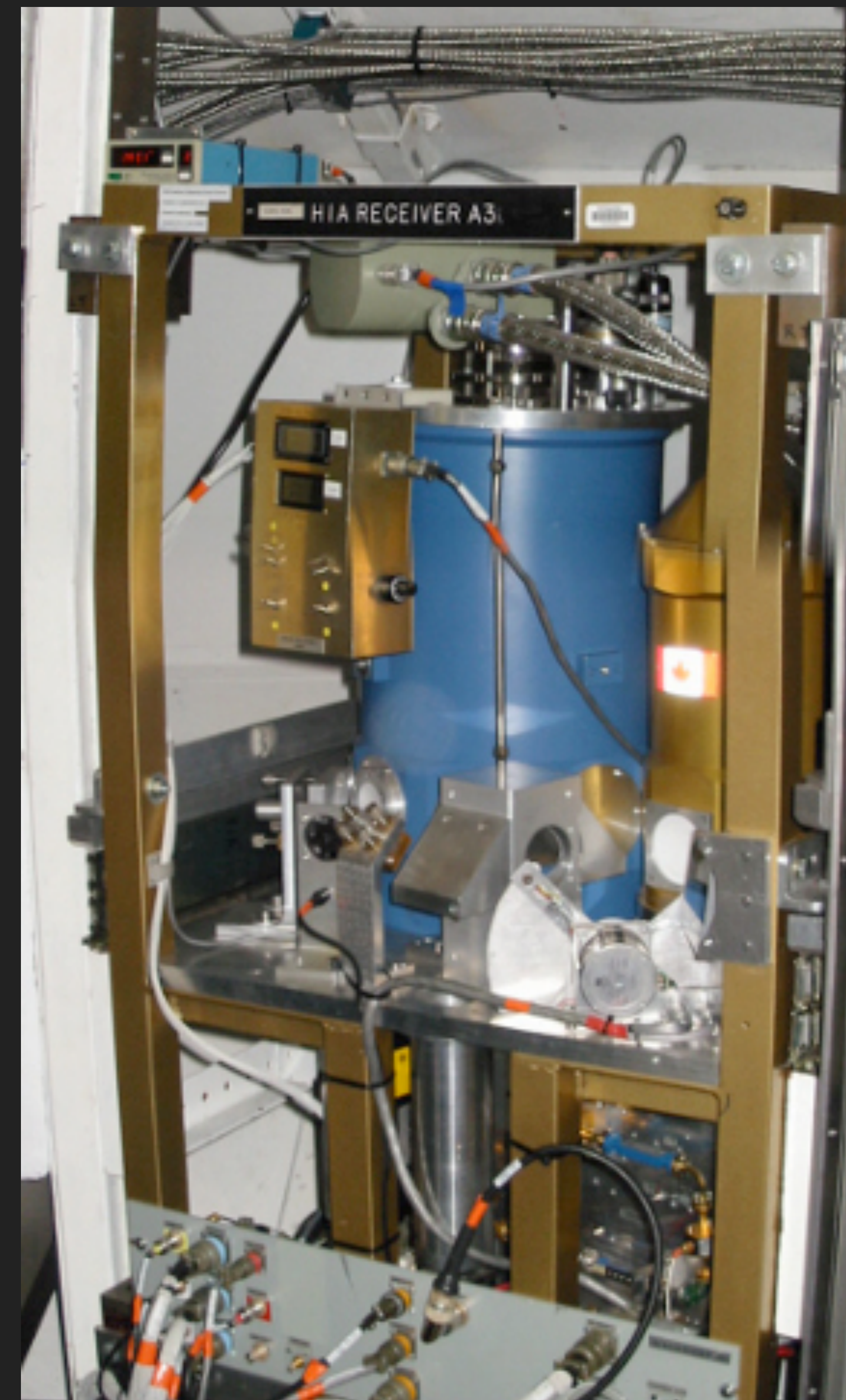
Heterodyne recieven at ASIAA





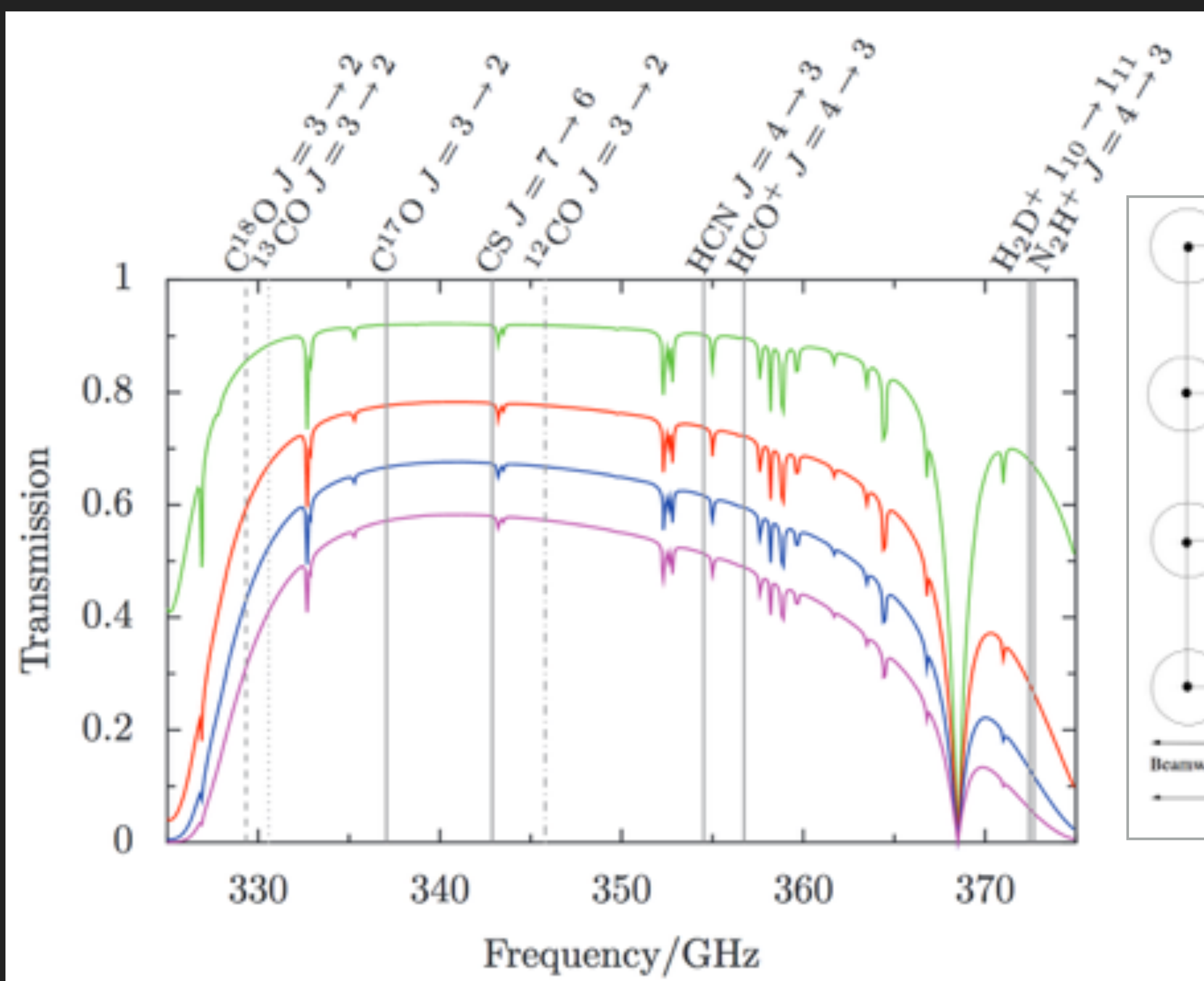
RxA: 211-276 GHz Single Side Band receiver.

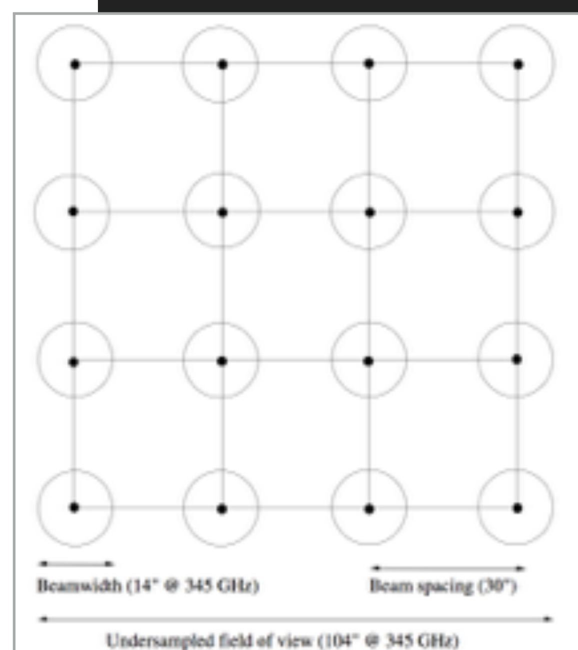
Beam is ~20" at 230GHz.

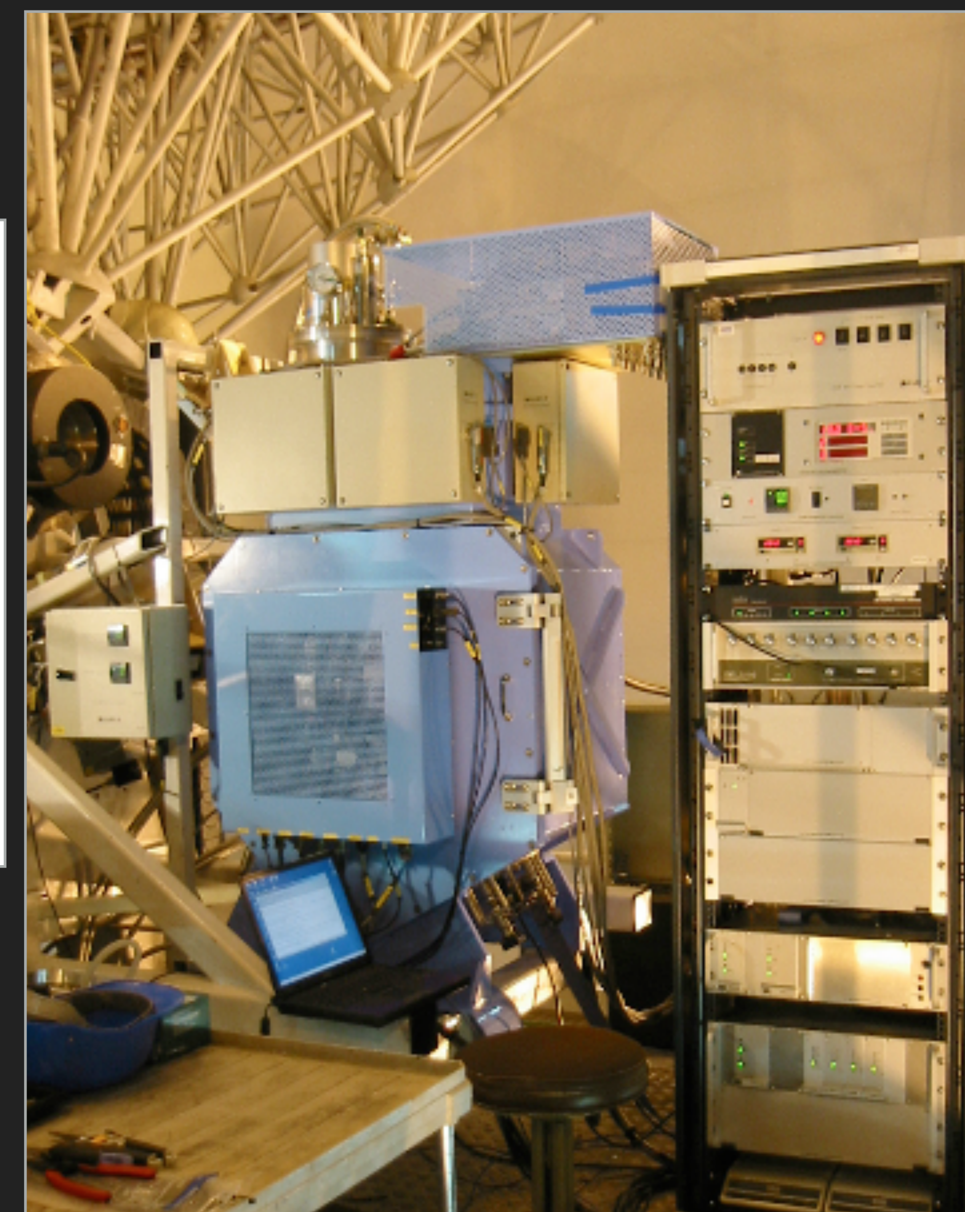


www.eaobservatory.org/jcmt/instrumentation/heterodyne/rxa/

THE DATA – HARP





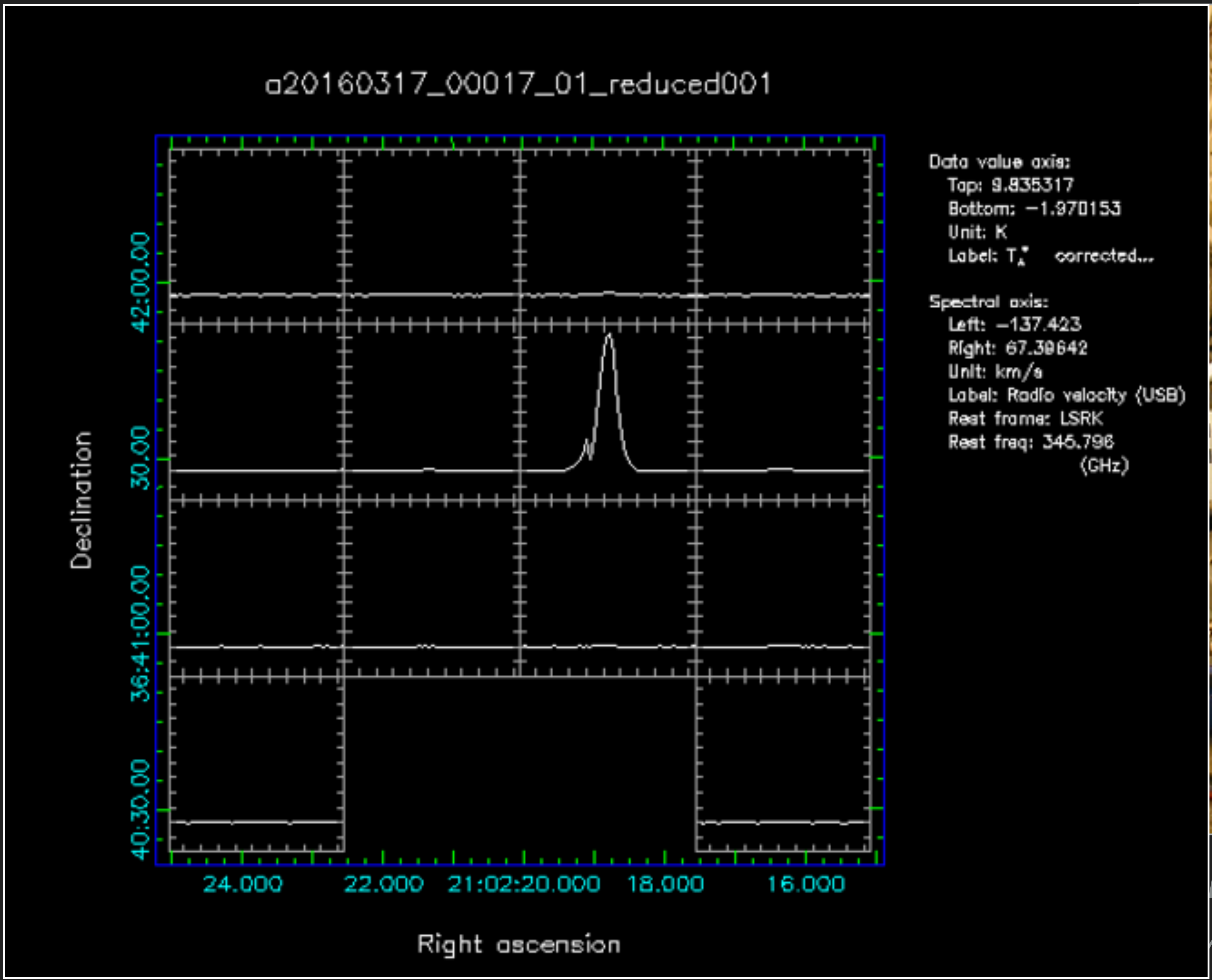


HARP: 325-375 GHz Single Side Band receiver. Has a instantaneous bandwidth of ~ 2 GHz and an Intermediate Frequency (IF) of 5 GHz.

http://cdsads.u-strasbg.fr/abs/2009MNRAS.399.1026B

www.eaobservatory.org/jcmt/instrumentation/heterodyne/harp/

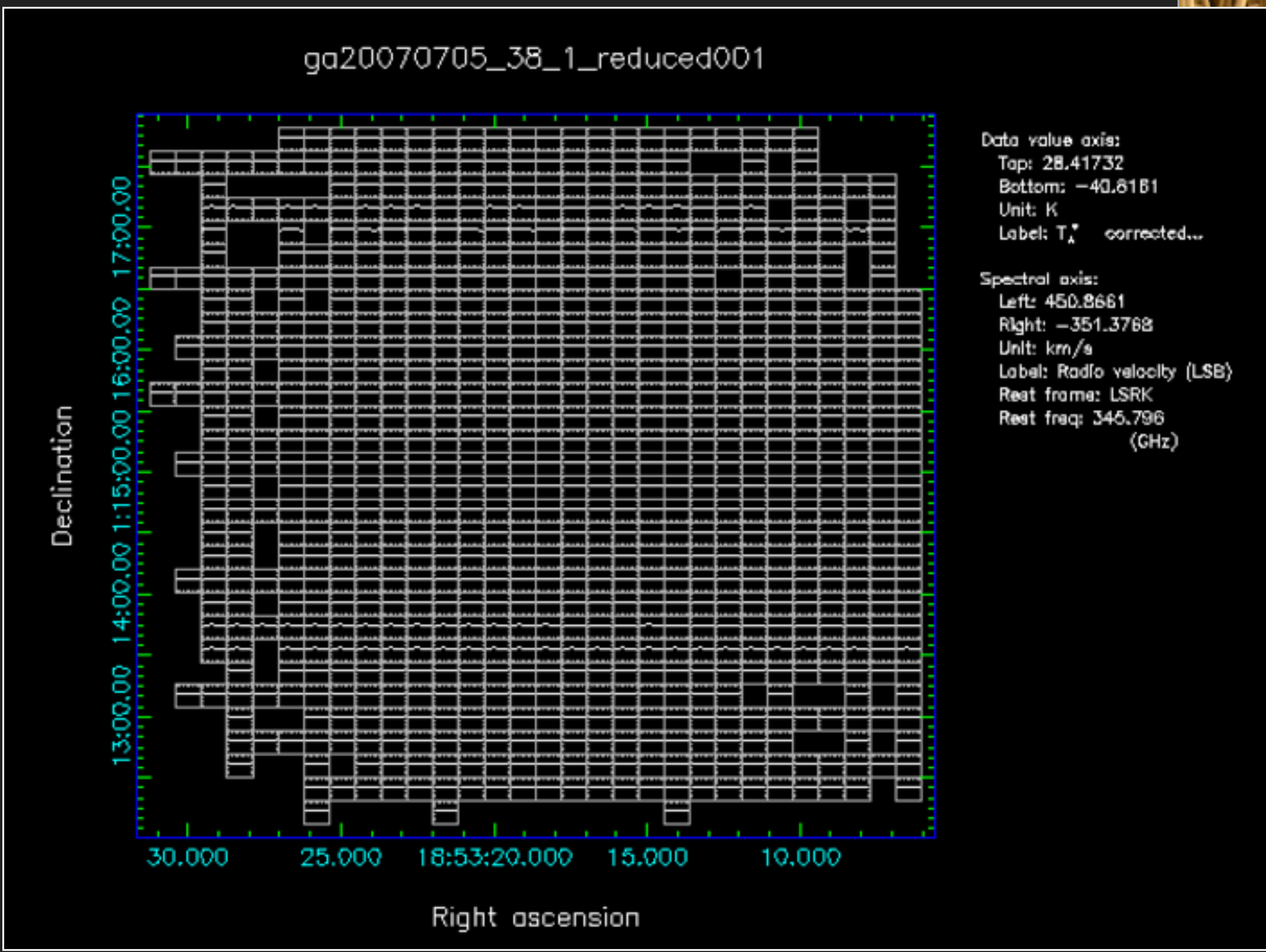
THE DATA – HARP

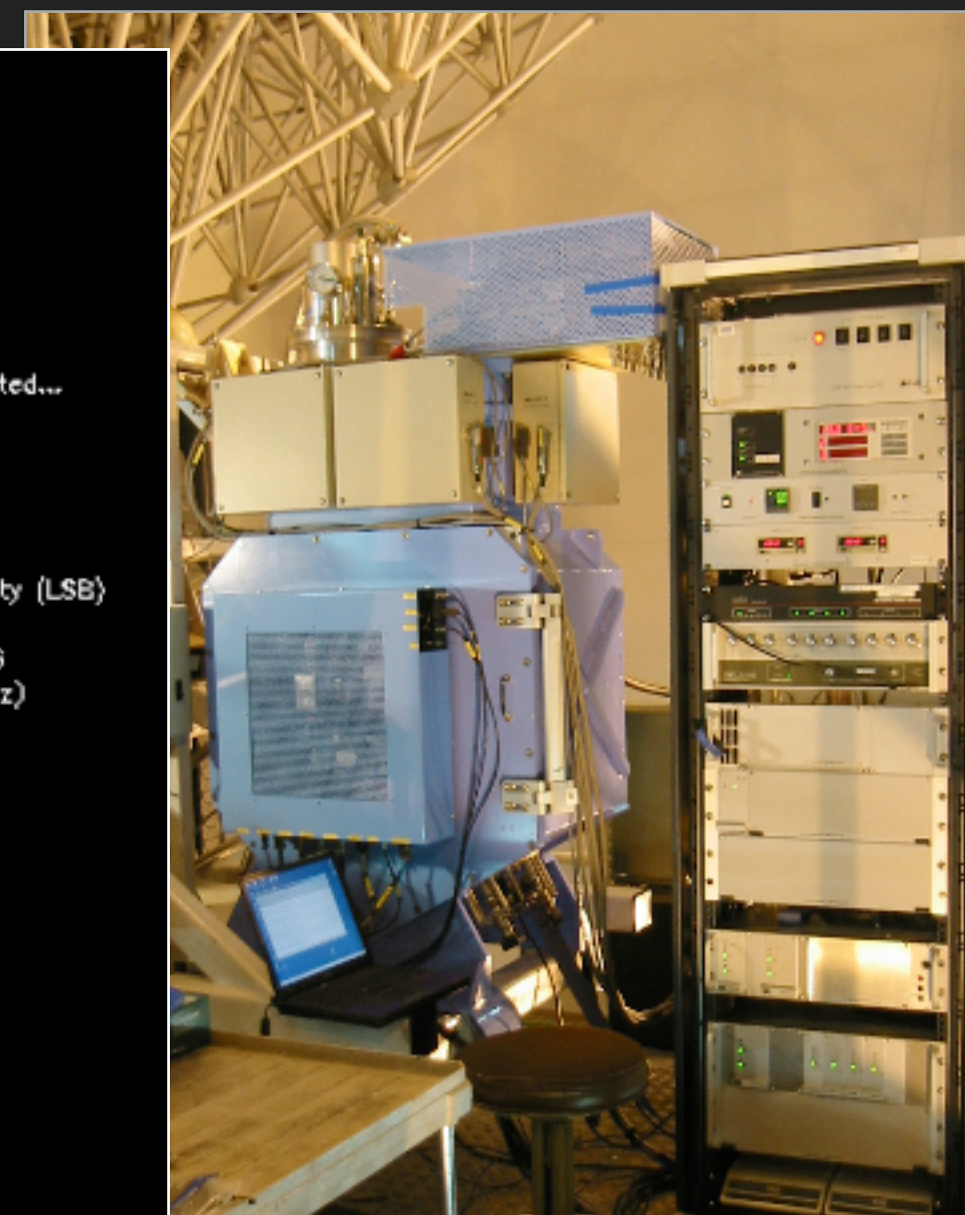


bg.fr/abs/2009MNRAS.399.1026B

/instrumentation/heterodyne/harp/

THE DATA – HARP



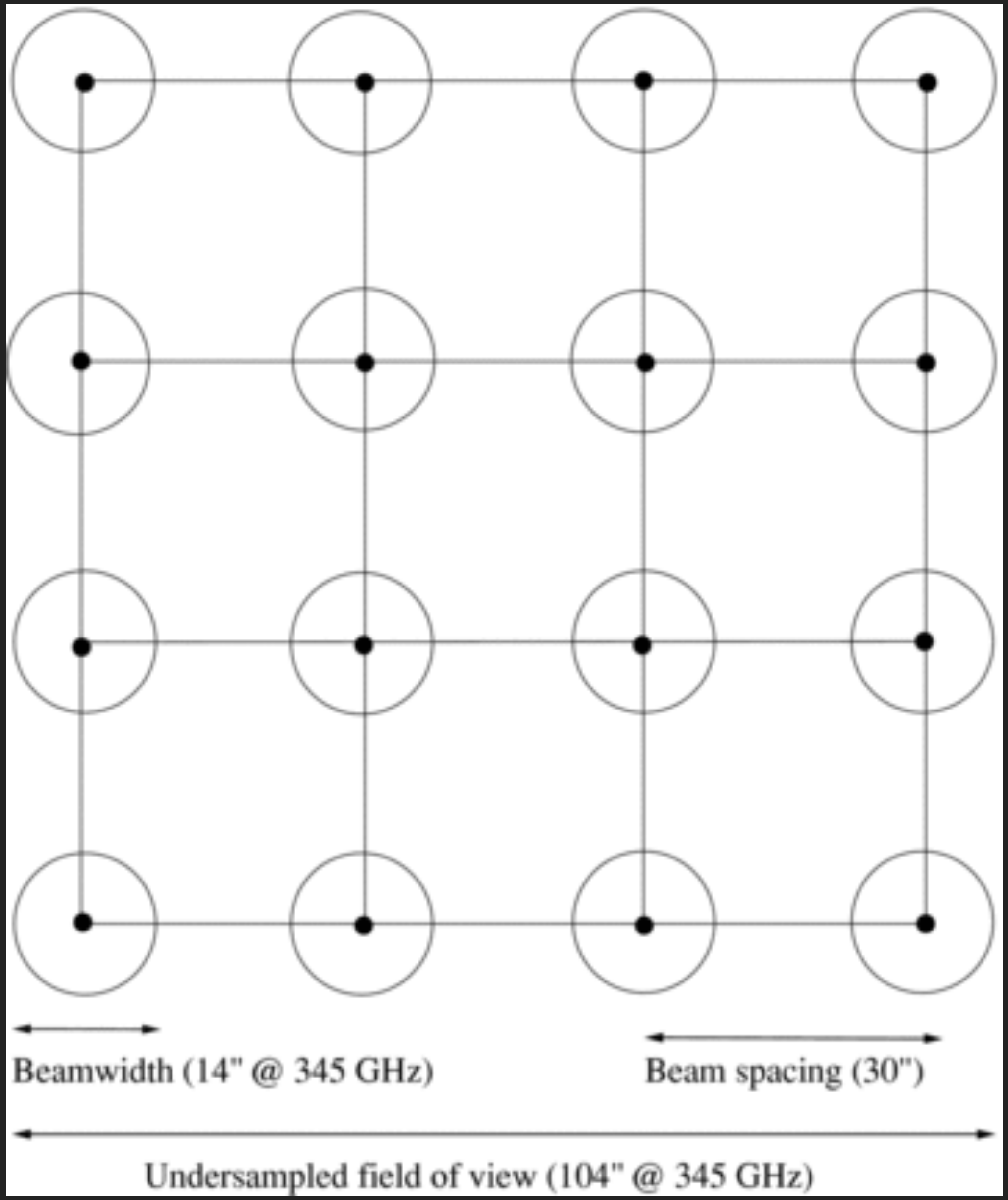


g.fr/abs/2009MNRAS.399.1026B

strumentation/heterodyne/harp/

THE DATA – HARP – OBSERVING MODES: STARE

Compact source? Use a stare.

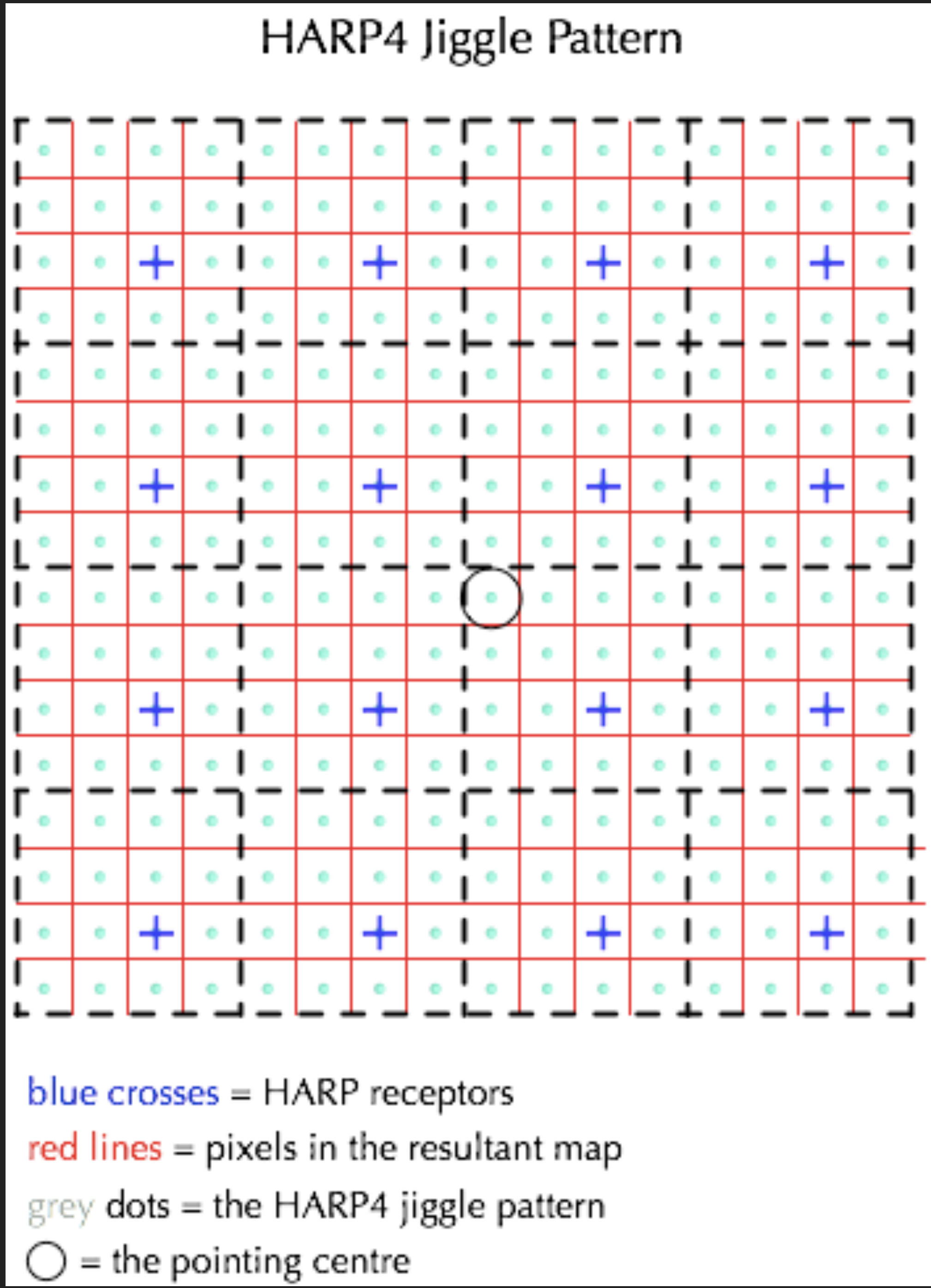


http://cdsads.u-strasbg.fr/abs/2009MNRAS.399.1026B

www.eaobservatory.org/jcmt/instrumentation/heterodyne/harp/

THE DATA - HARP - OBSERVING MODES: JIGGLE

Moderate extent (less than 2 arcmins)? Use a jiggle



Jiggle:

moves secondary mirror to fill in the 30'' spacing between HARP receptors to make a 2'x2' map.

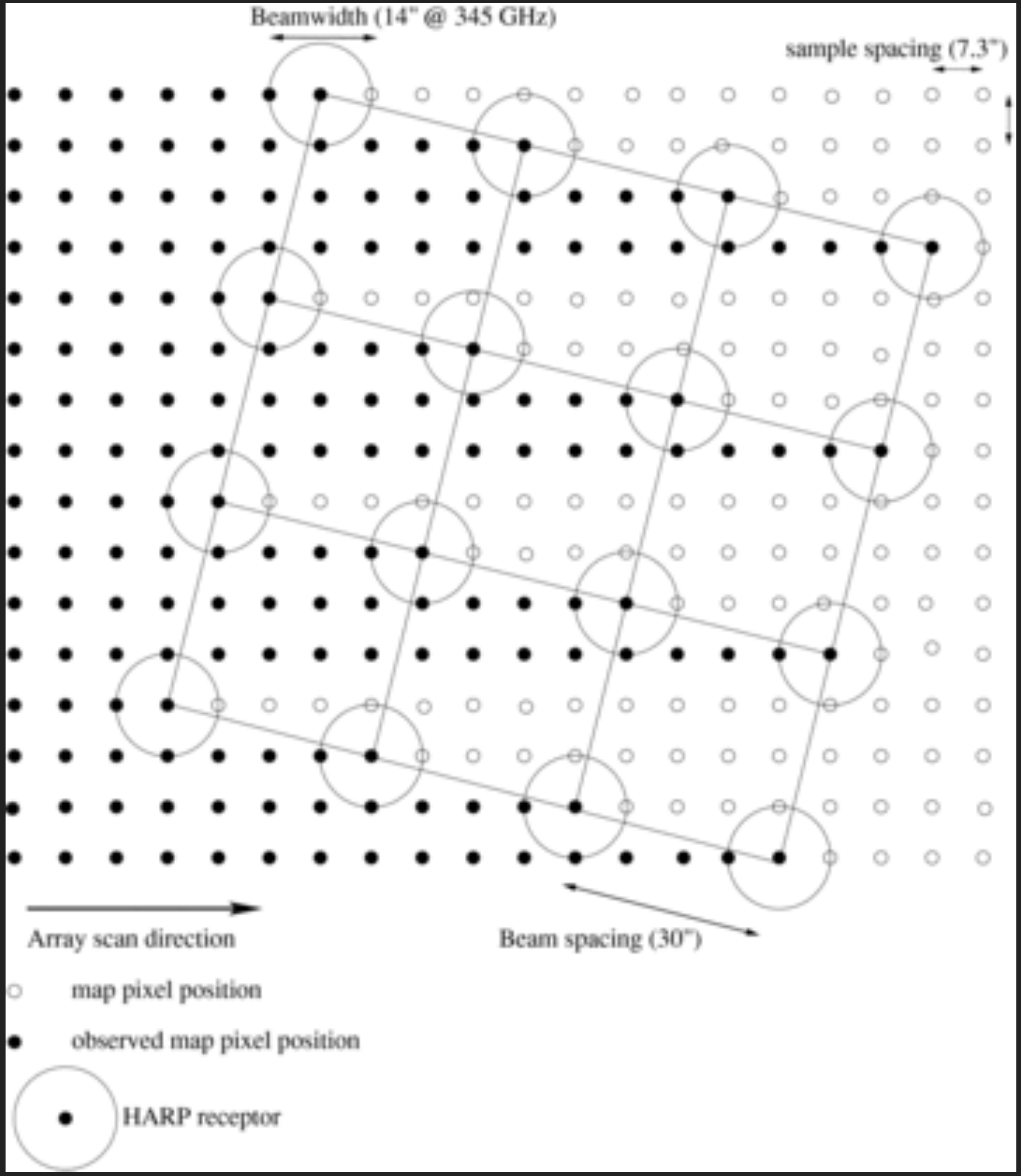
Two main spacings: HARP4 – 4x4 jiggle, undersampled. 7.25'' pixels
HARP5 – 5x5 jiggle, oversampled, 6'' pixels

http://cdsads.u-strasbg.fr/abs/2009MNRAS.399.1026B

www.eaobservatory.org/jcmt/instrumentation/heterodyne/harp/

THE DATA – HARP – OBSERVING MODES: RATSER

Large extent (greater than 2 arcmins)? Use a raster



Raster:

Scan or 'on-the-fly' technique.

HARP: array rotated at 14.04 deg to scan direction, with 7.3'' pixels often repeated with 90 deg rotation to create 'basket-weave' maps

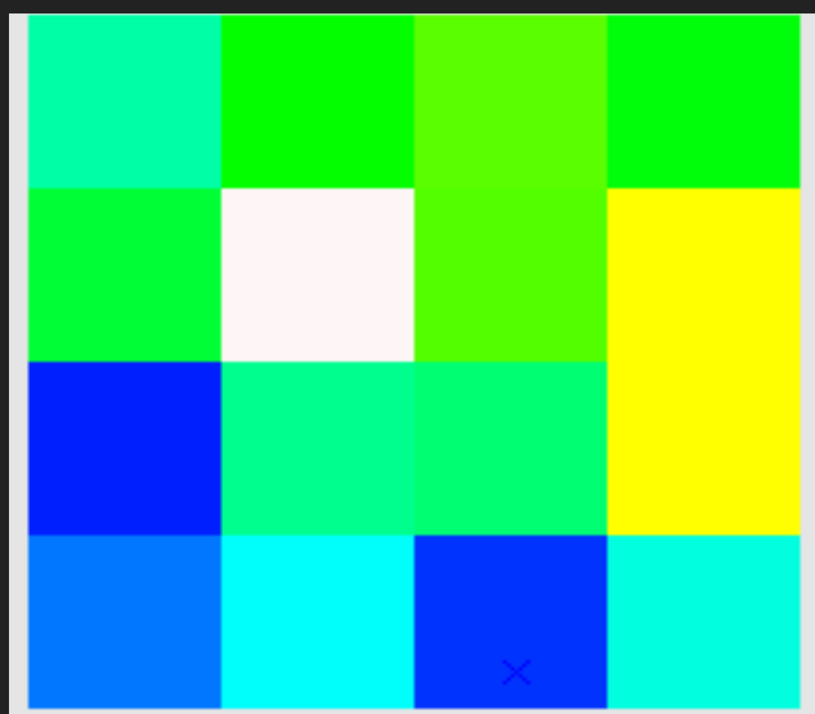
http://cdsads.u-strasbg.fr/abs/2009MNRAS.399.1026B

www.eaobservatory.org/jcmt/instrumentation/heterodyne/harp/

THE DATA – HARP

Example: G34.3 integrated intensity images

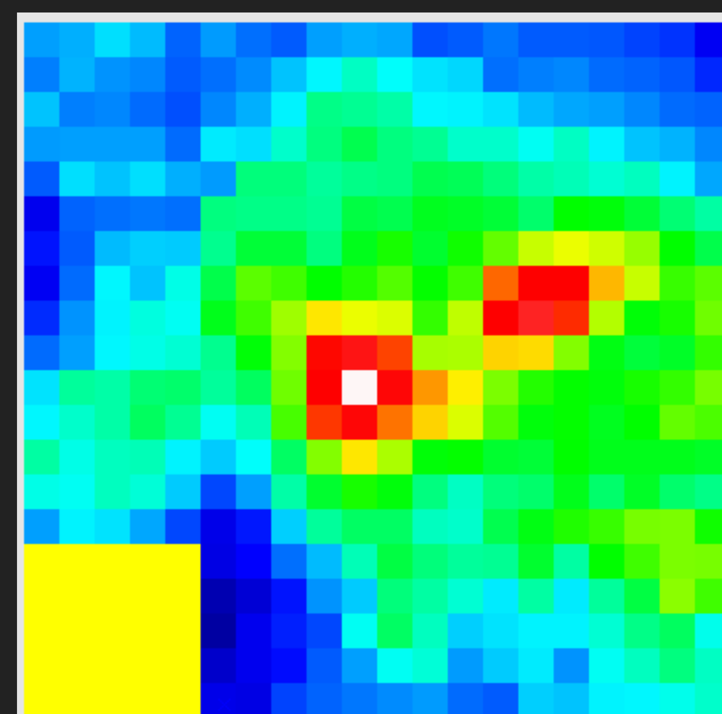
HARP Stare



2 arcmin

30'' pixels

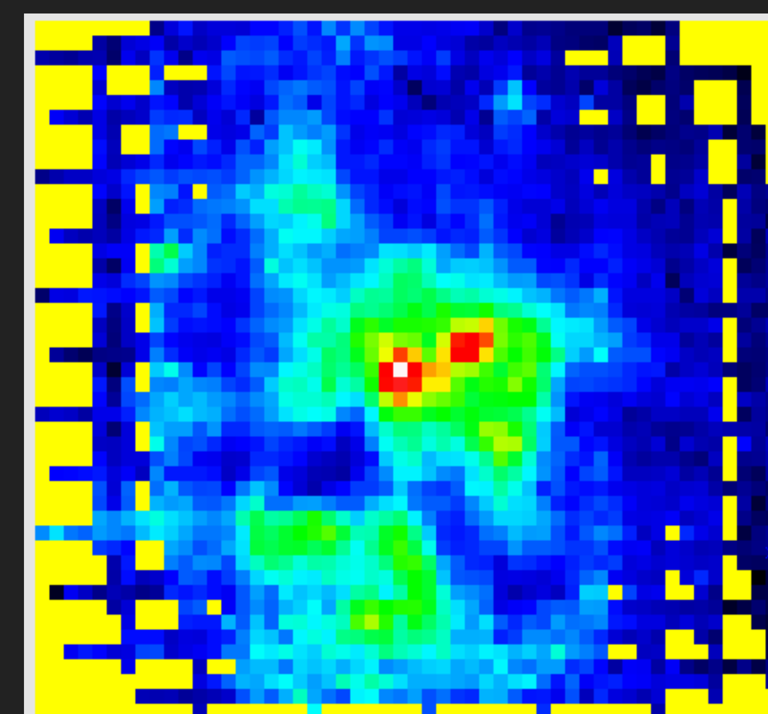
HARP Jiggle-map



2 arcmin

6'' pixels

HARP Raster map

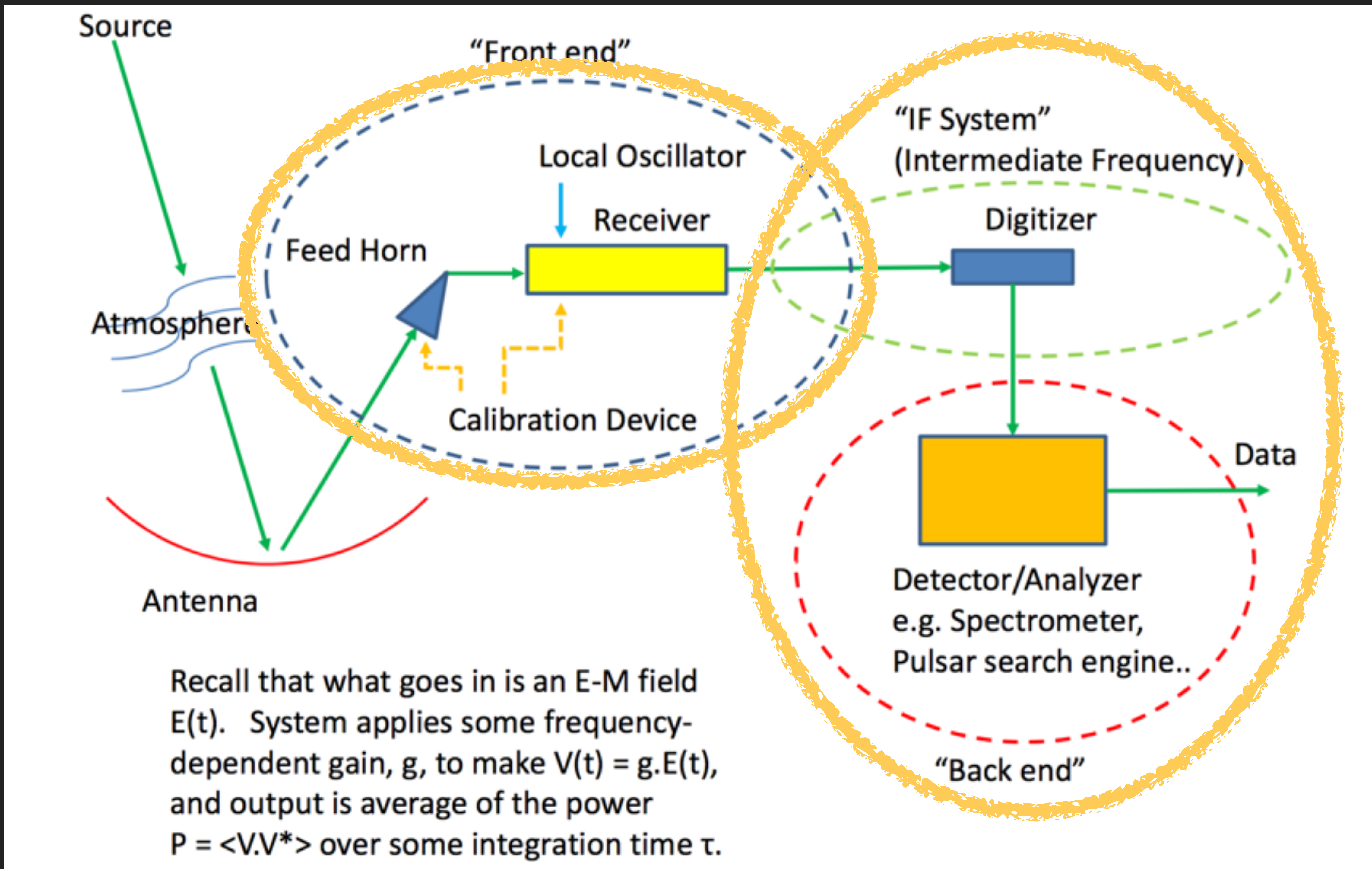


6 arcmin

7.25'' pixels

www.eaobservatory.org/jcmt/instrumentation/heterodyne/harp/

THE SIGNAL PATH



Slides take from: Richard Hills Talk, TIARA Summer School, Taiwan 2016

THE DATA - ACSIS

ACSIS spectrometer options:

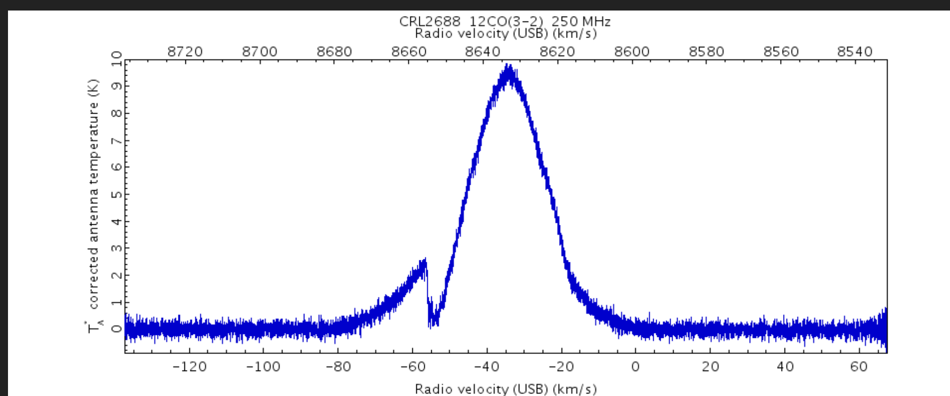
250 MHz bandwidth; spectral resolution 0.0305 MHz
1000 MHz bandwidth; spectral resolution 0.488 MHz
1 - 4 subbands (RxA3)
1 - 2 subbands (HARP) (for 2 subbands resolution 0.061/0.977 MHz)
e.g. for simultaneous observations of $C^{18}O$ and ^{13}CO
for 420 MHz (2x250) and 1800 MHz (2x1000) modes the two subbands have to be merged in the reduction

www.eaobservatory.org/jcmt/instrumentation/heterodyne/harp/

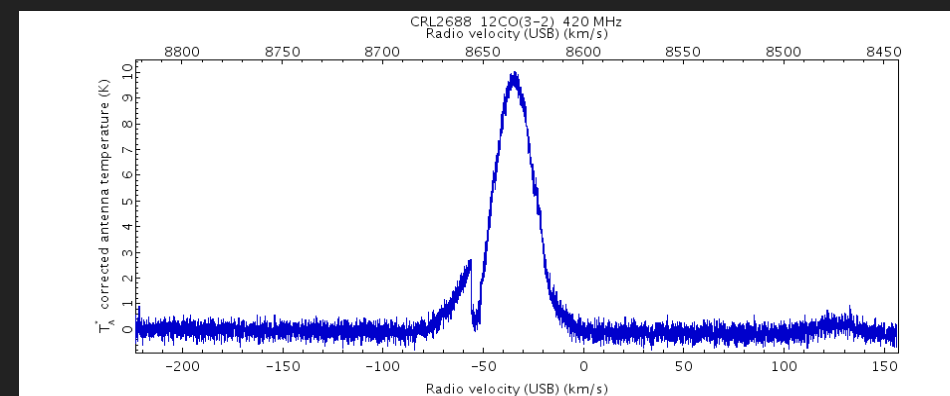
www.eaobservatory.org/jcmt/instrumentation/heterodyne/acsis/#ACSIS_Special_Configurations

THE DATA - ACSIS

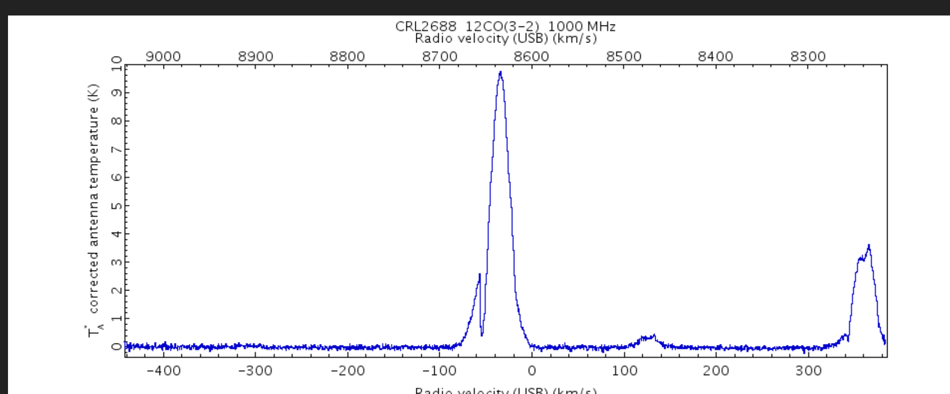
CRL2688 ACSIS examples (HARP)



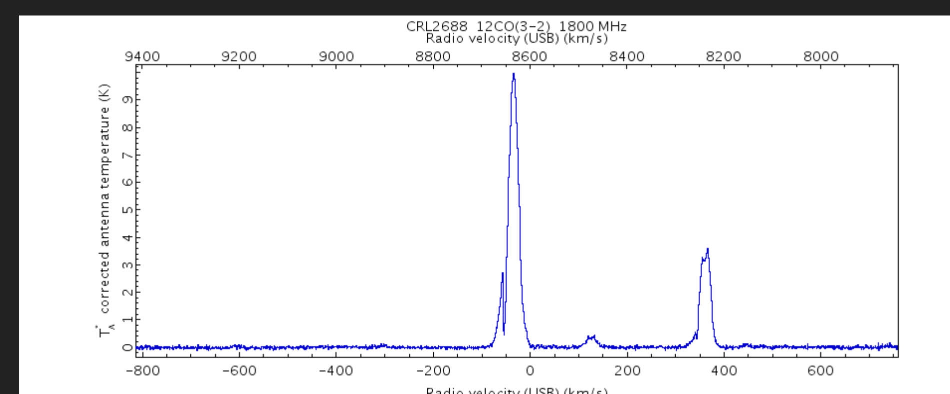
250 MHz (0.0305 MHz)



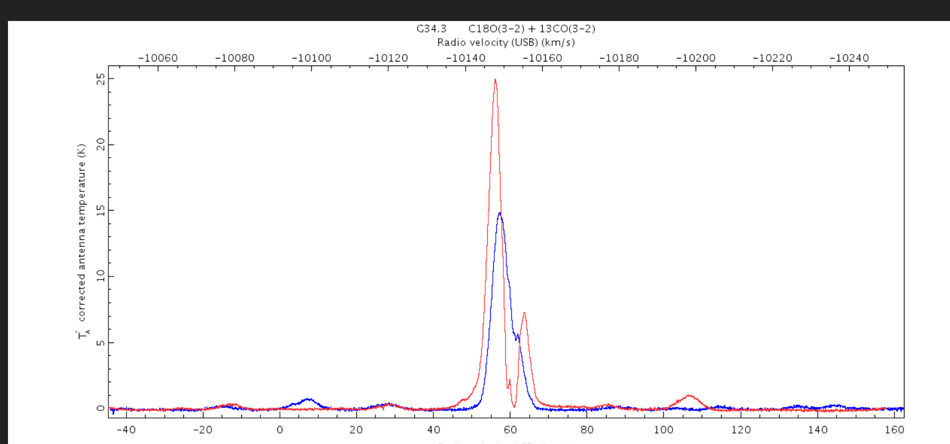
420 MHz (0.061 MHz)



1000 MHz (0.488 MHz)



1800 MHz (0.977 MHz)



G34.3 2x250 MHz (0.061 MHz)
$^{13}CO(3\text{-}2)+C^{18}O(3\text{-}2)$

www.eaobservatory.org/jcmt/instrumentation/heterodyne/harp/

- Pointing
- Focus
- Calibration
- The data
  - Raw data format
  - Reduce the data
  - Examine the reduced data

The Observatory

The Astronomer

First Het DR Session

Second Het DR Session

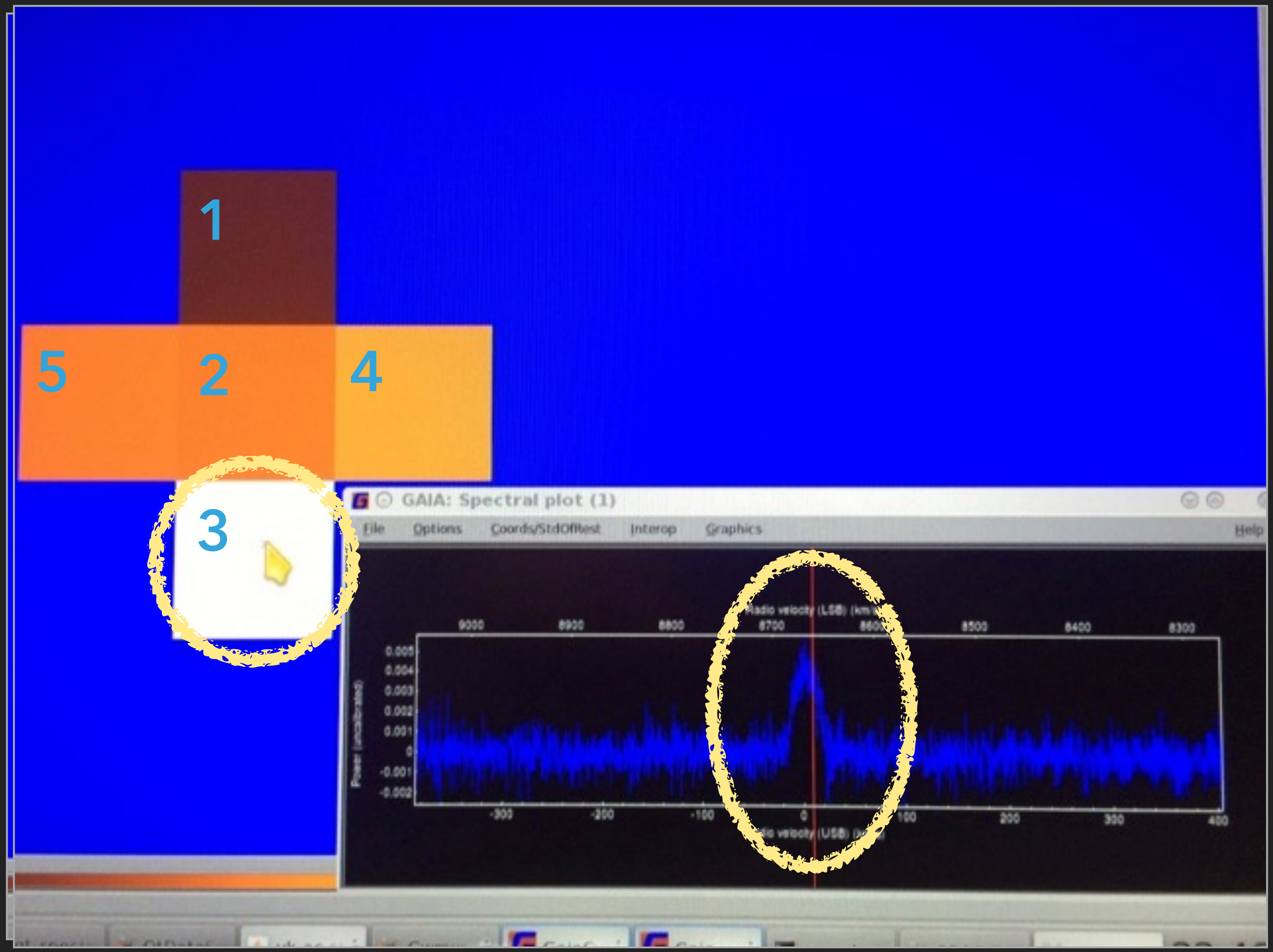
POINTING

- We have a known position, converted from sky frame to azimuth and elevation taking into account several locational, time and astronomical factors
- The telescope is imperfect
  - uneven track, temperature changes between front and back legs (6”/degree) etc
- We must therefore point (and re-point throughout the night typically every hour to two hours or so).
- The observatory monitors nightly/weekly pointing offsets to look for systematic offsets/trends in this data

POINTING

Observe bright point source: GL5379

Investigation via GAIA. A clear difference in line intensity can be seen when comparing the left vs. right spectra from our five point pointing pattern (meaning a pointing change is expected):



POINTING

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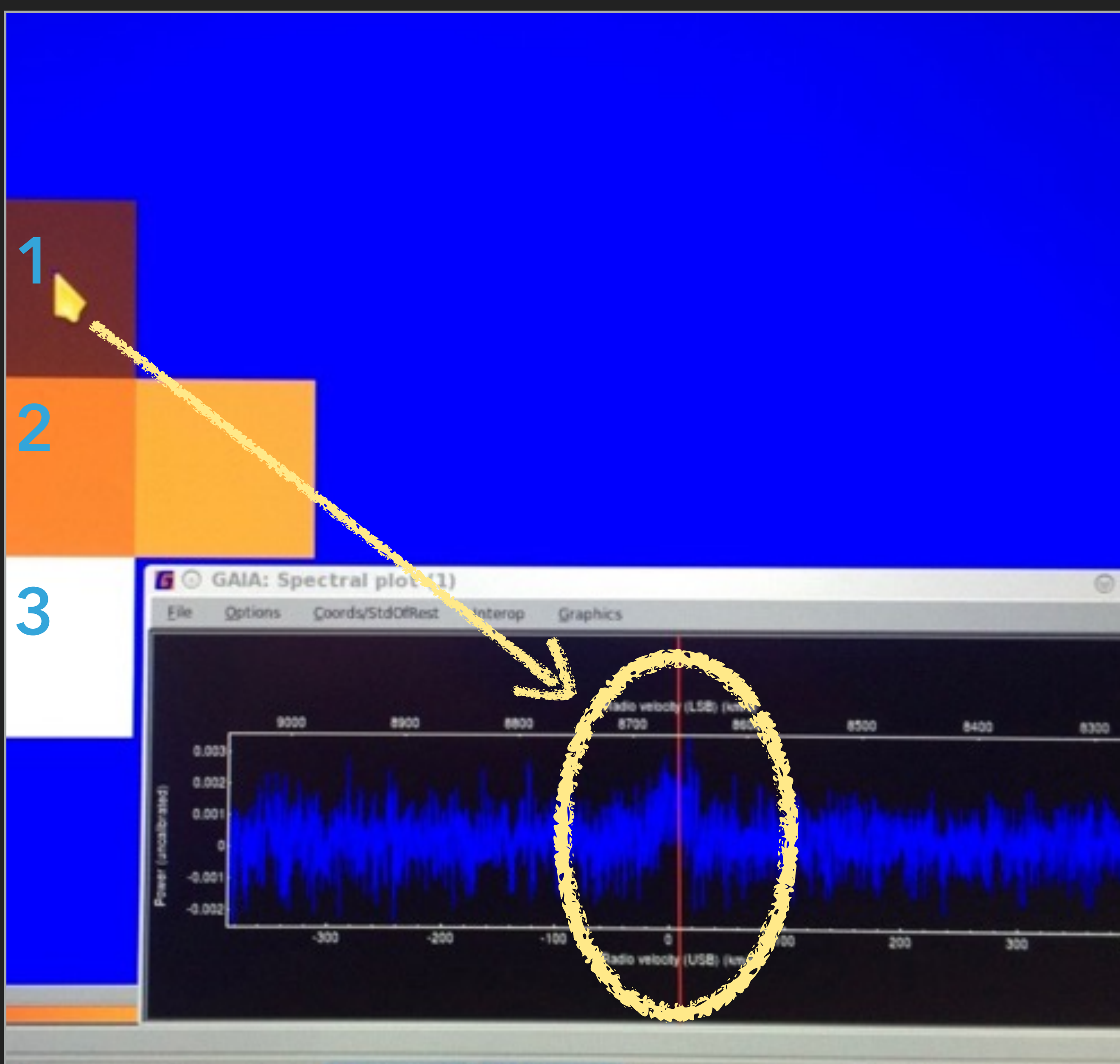
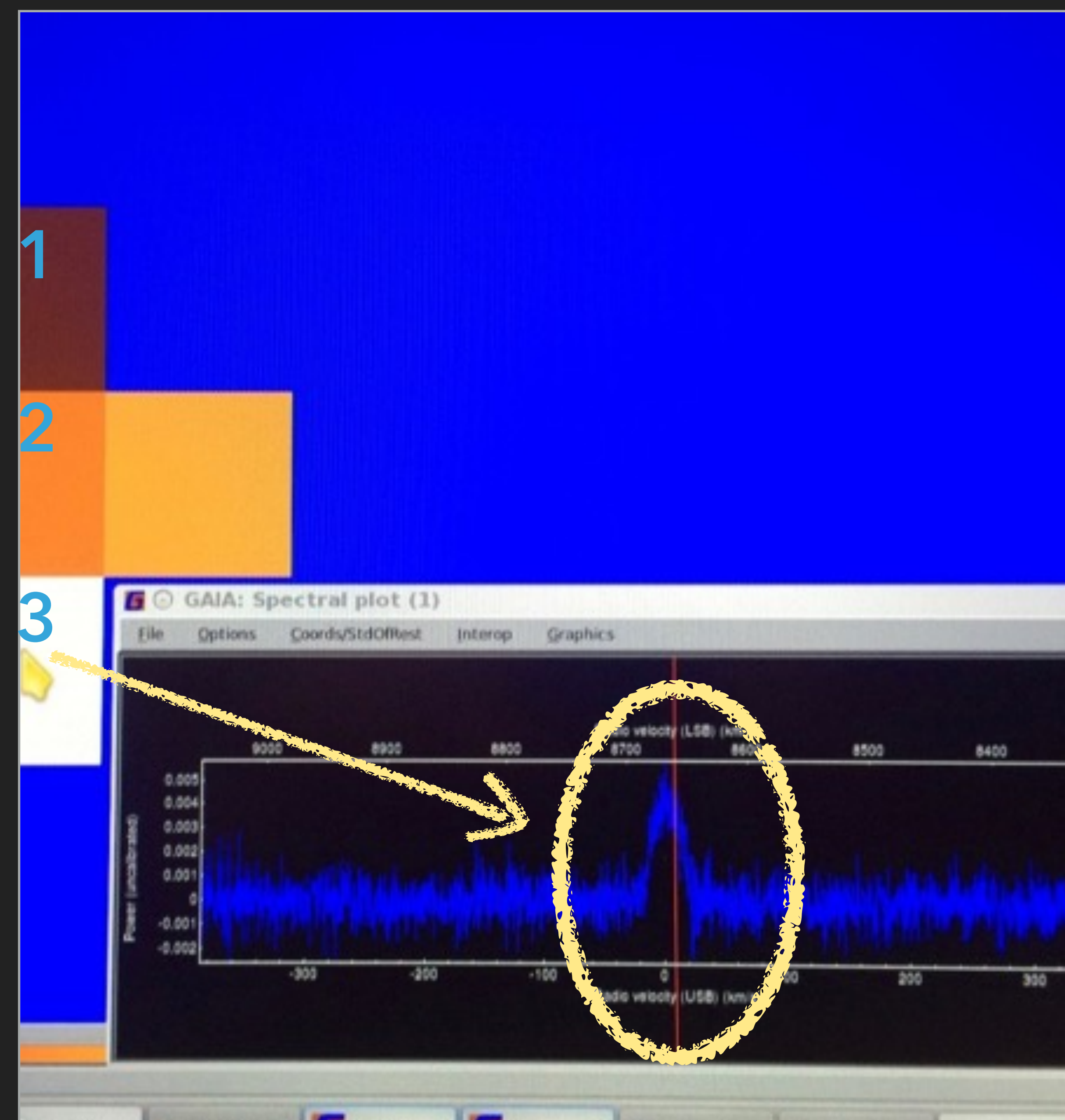
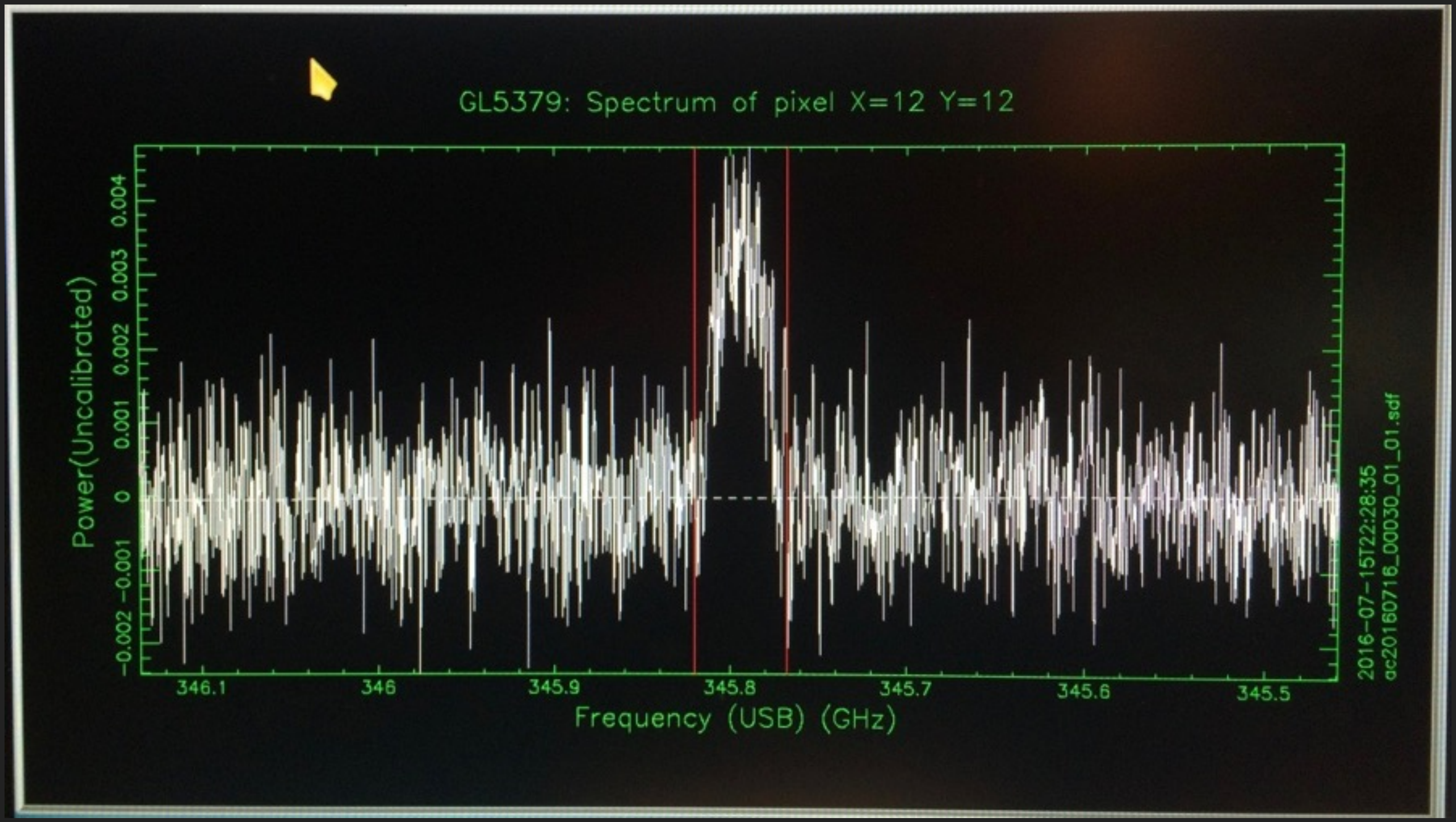




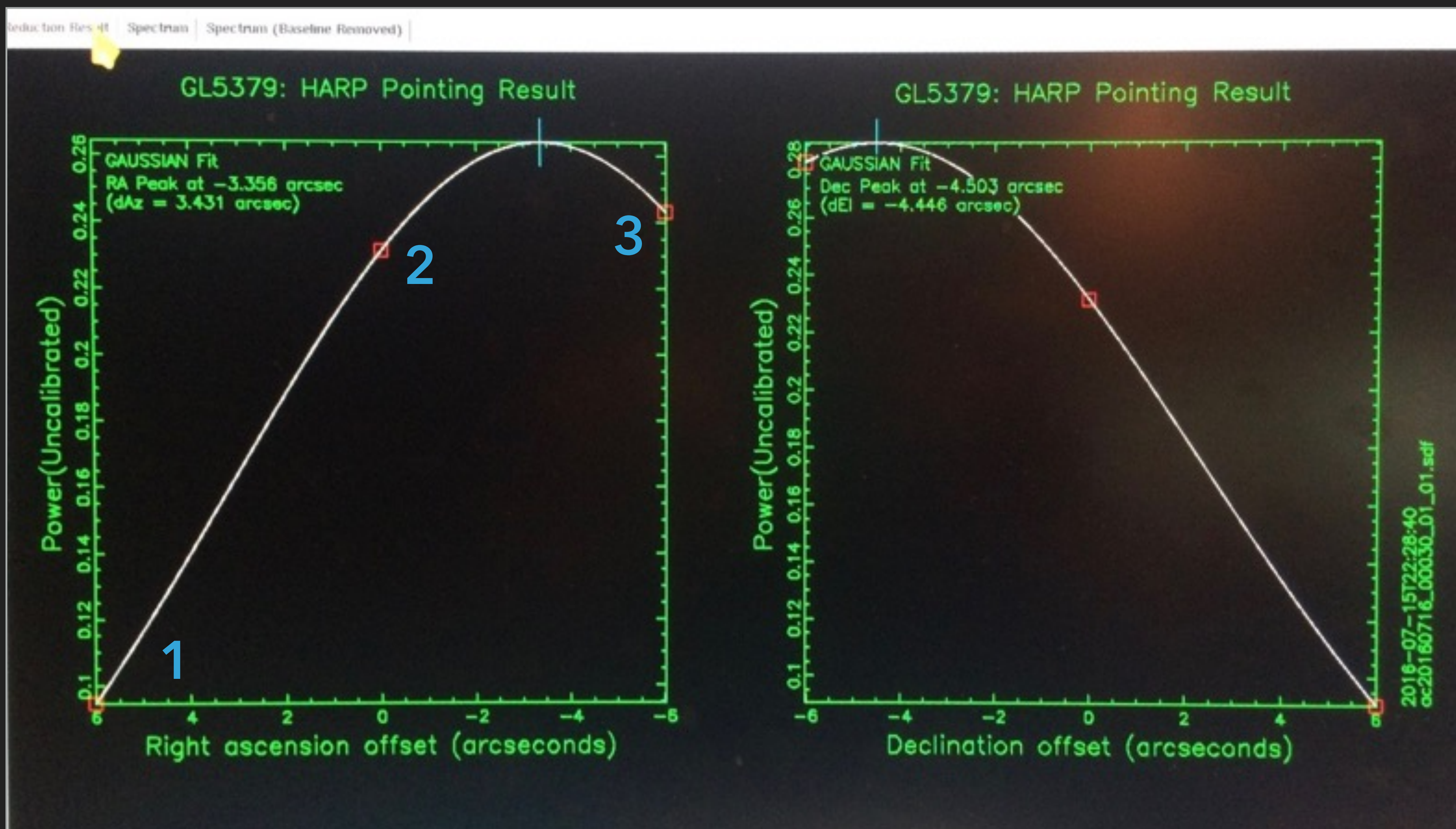
POINTING

Identify/select spectral line to analyze for pointing (remember *we know* the expected line brightness):



POINTING

Reduction result - with current peak and requested peak change (with the knowledge of the expected intensity):



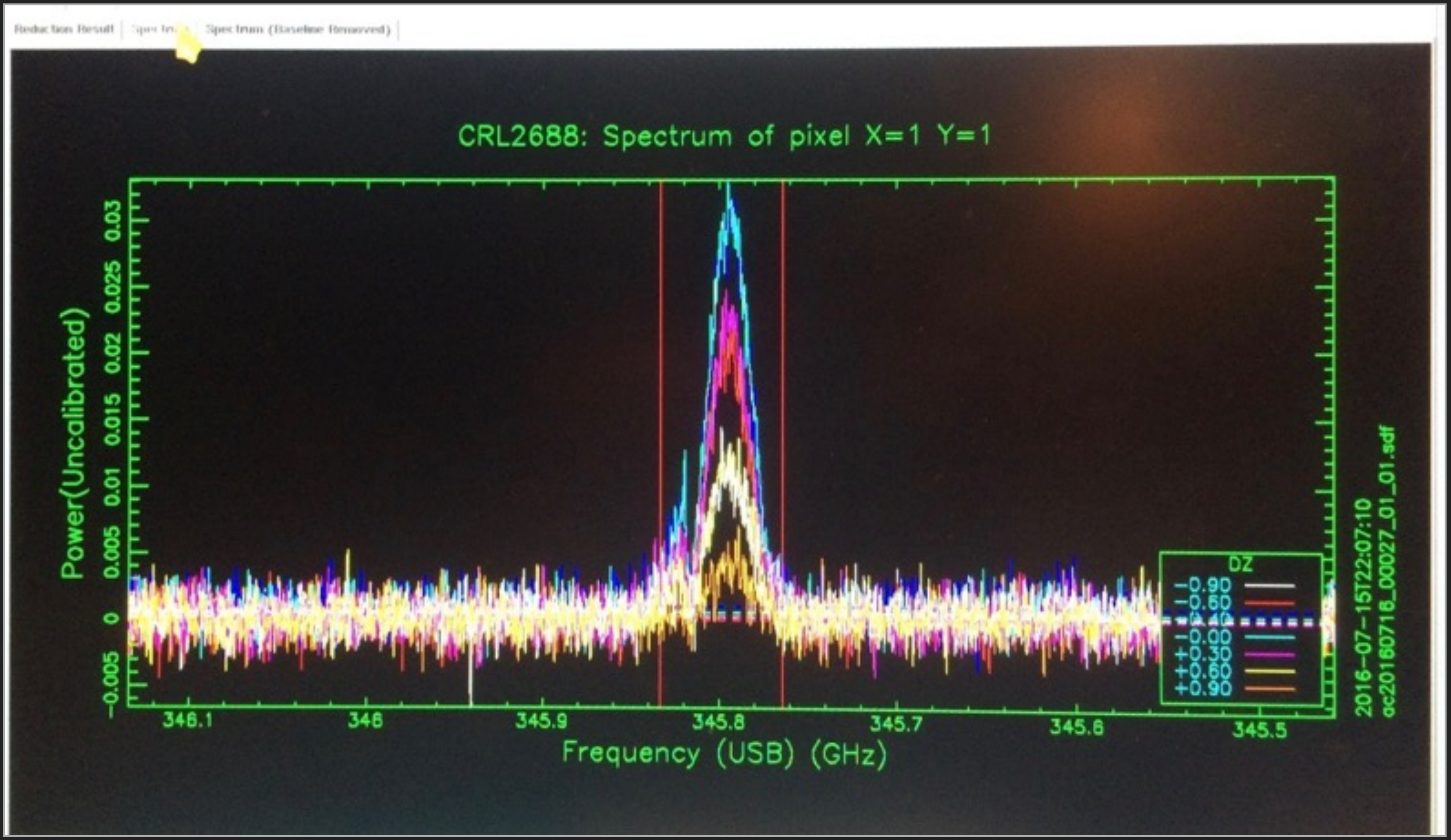
with requested changes: 3.43 arcsec in AZ and -4.45 arcsec in EL

FOCUS

- During a focus the secondary mirror is moved in 0.3mm increments closer and further away the nominal position through a total of seven positions. A gaussian fit to the result enables us to establish where the signal strength is the strongest. we do this in x y and z-axis.
- We do a single x, y and z-axis focus at the start of every night
- The telescope is imperfect and so we require repeated z-axis focus taken throughout the night as the dome temperature changes.

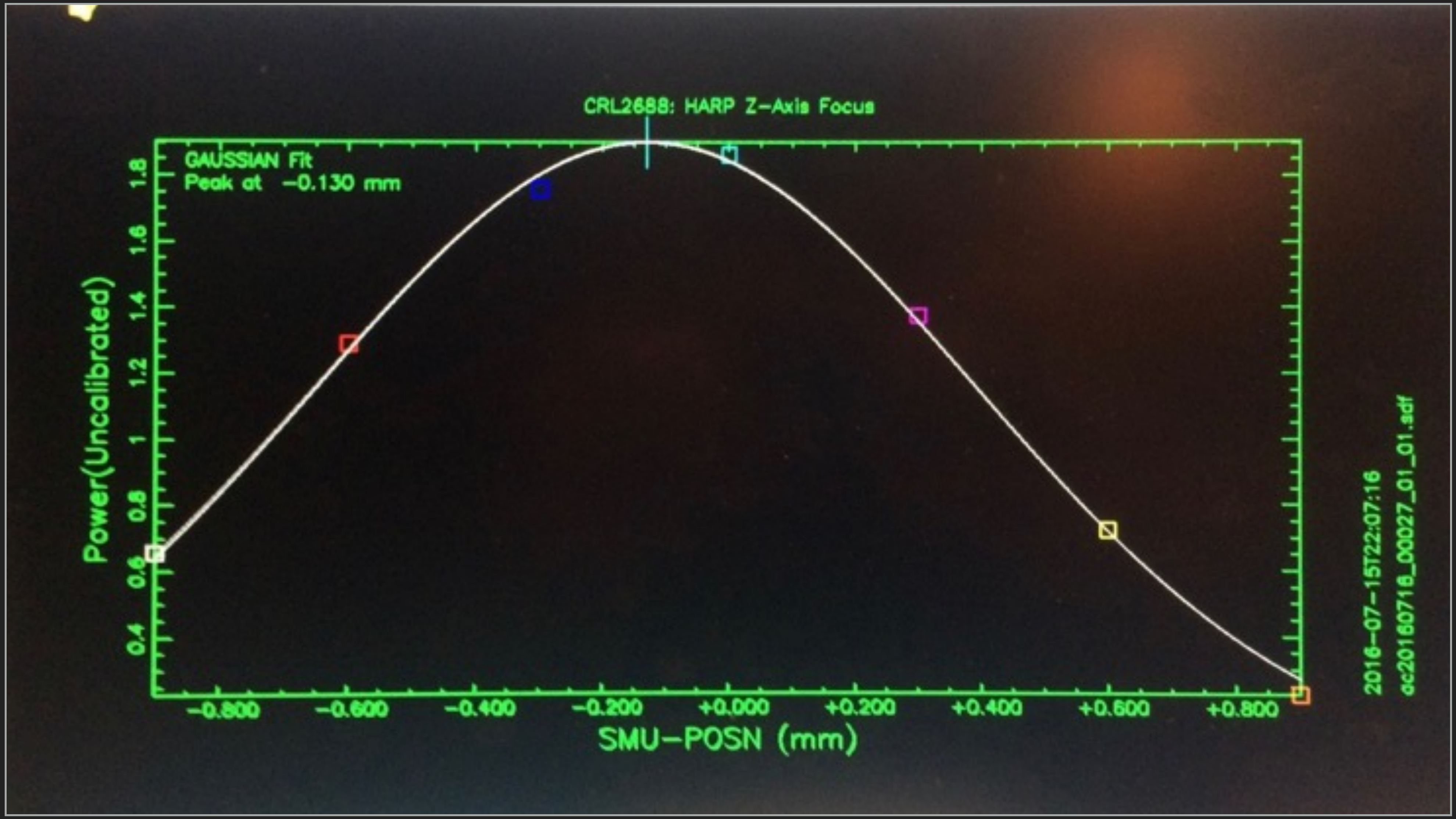
FOCUS

Seven focus spectra stacked(CRL2688); again selecting spectral line:



FOCUS

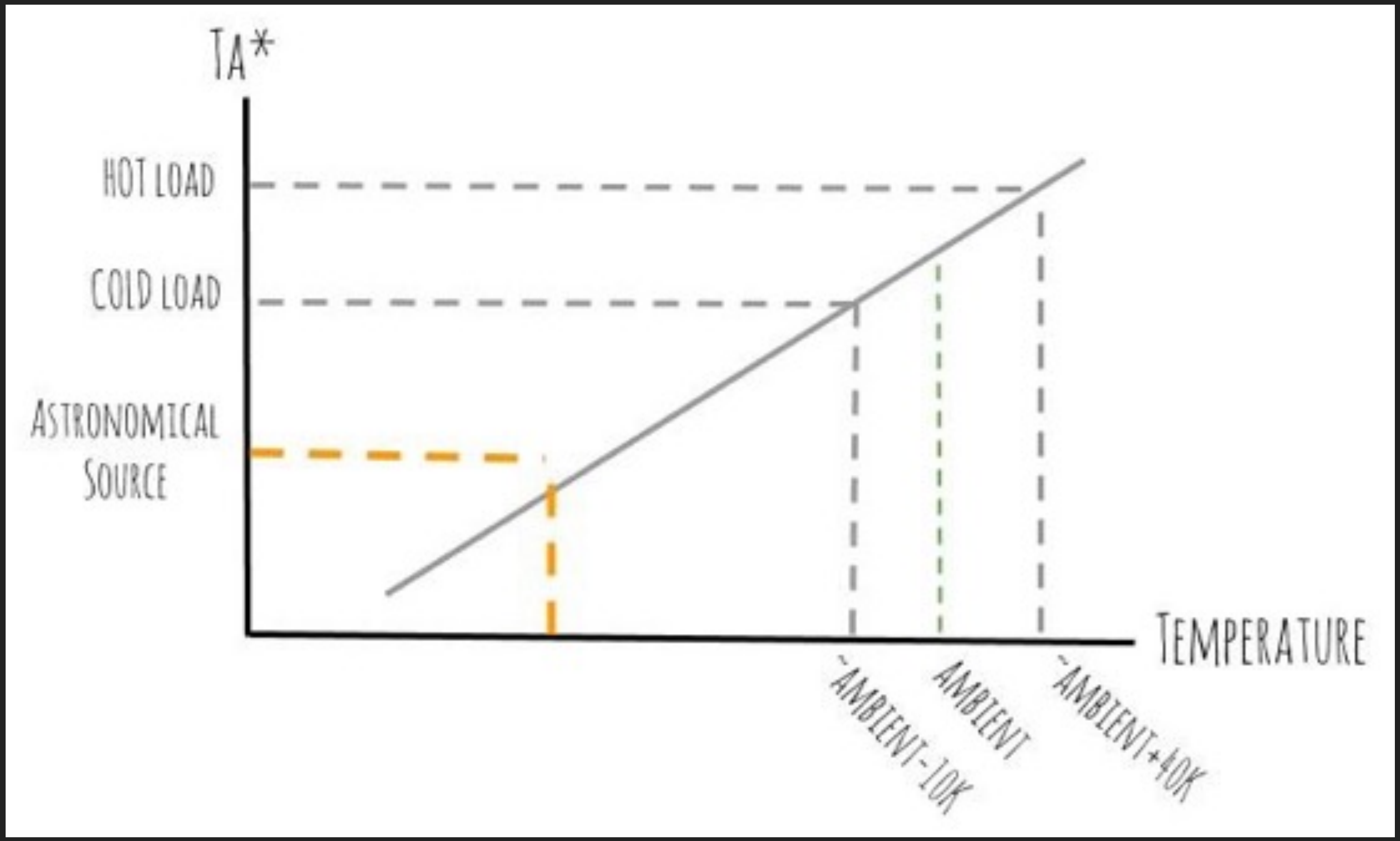
Focus reduction result (Gaussian fit to seven points representing the line peak of each of seven spectra):



Done in "the blink of an eye" by the Telescope Operator - typically nothing you need to worry about as an observer

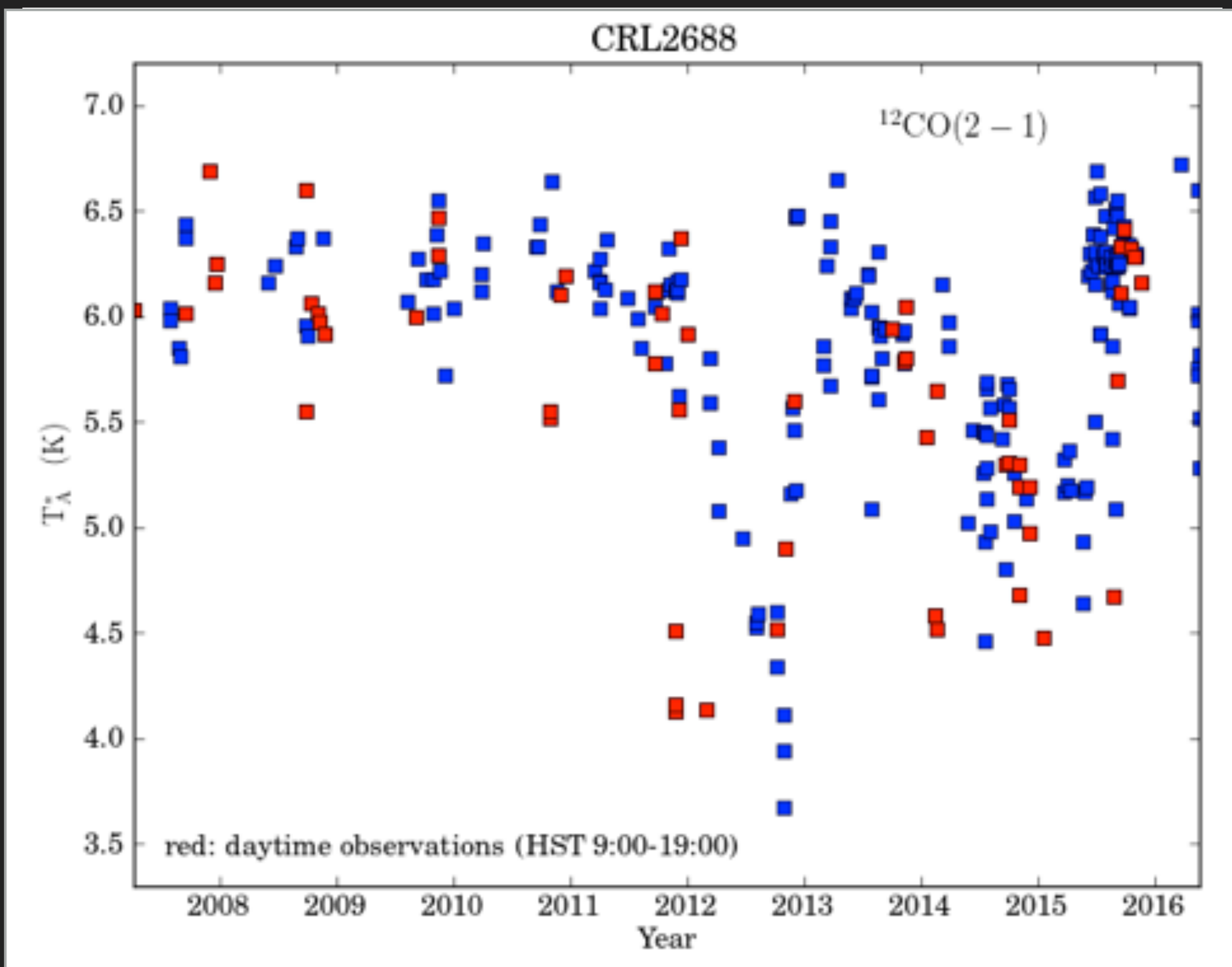
CALIBRATION INTERNAL - DATA INTO T_A*

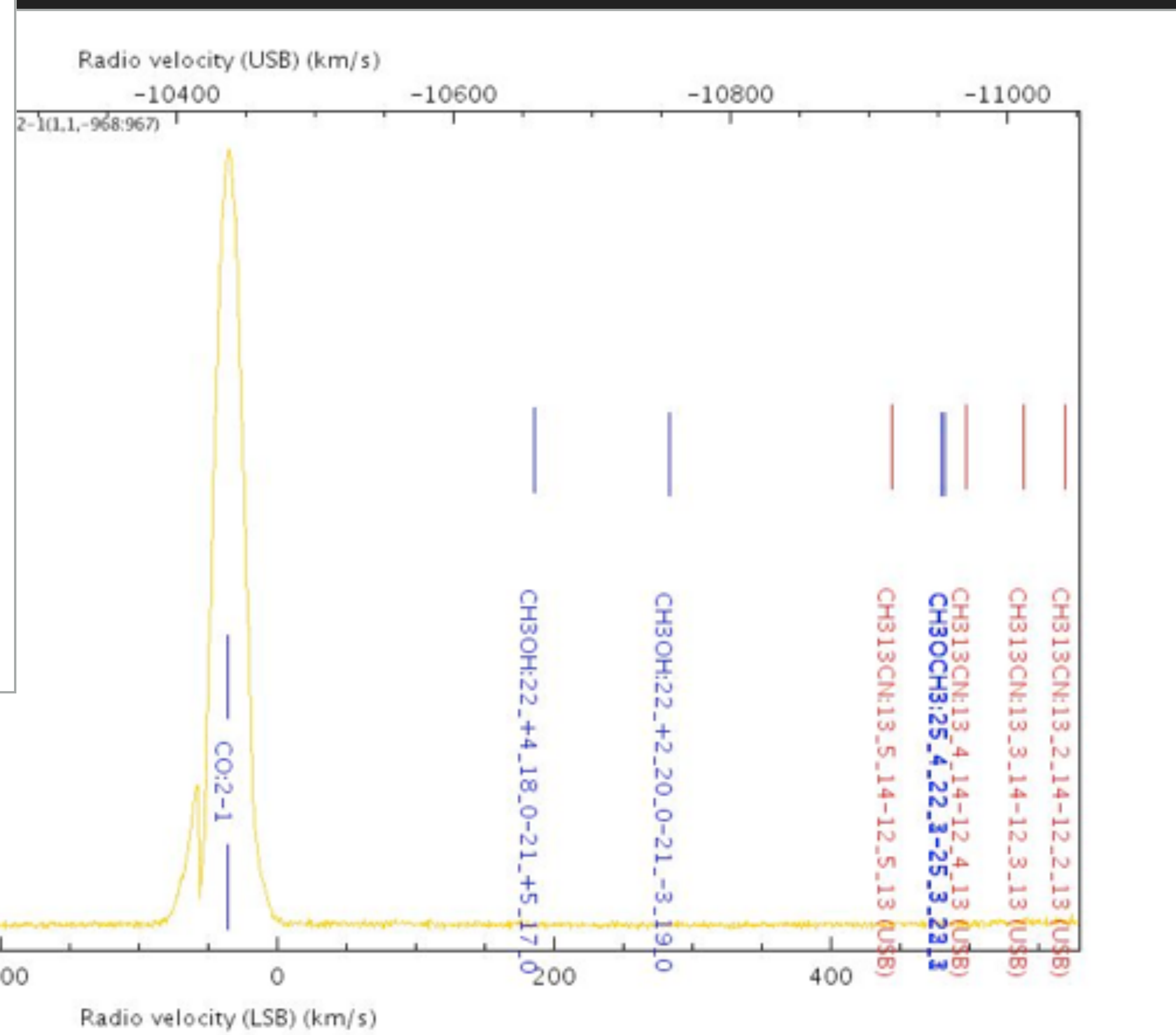
- Every observation is calibrated to T_A* (a reminder you are a Radio Astronomer!)
  - We know the temperature based on internal instrument calibration on hot and cold loads and knowledge of the ambient temperatures.



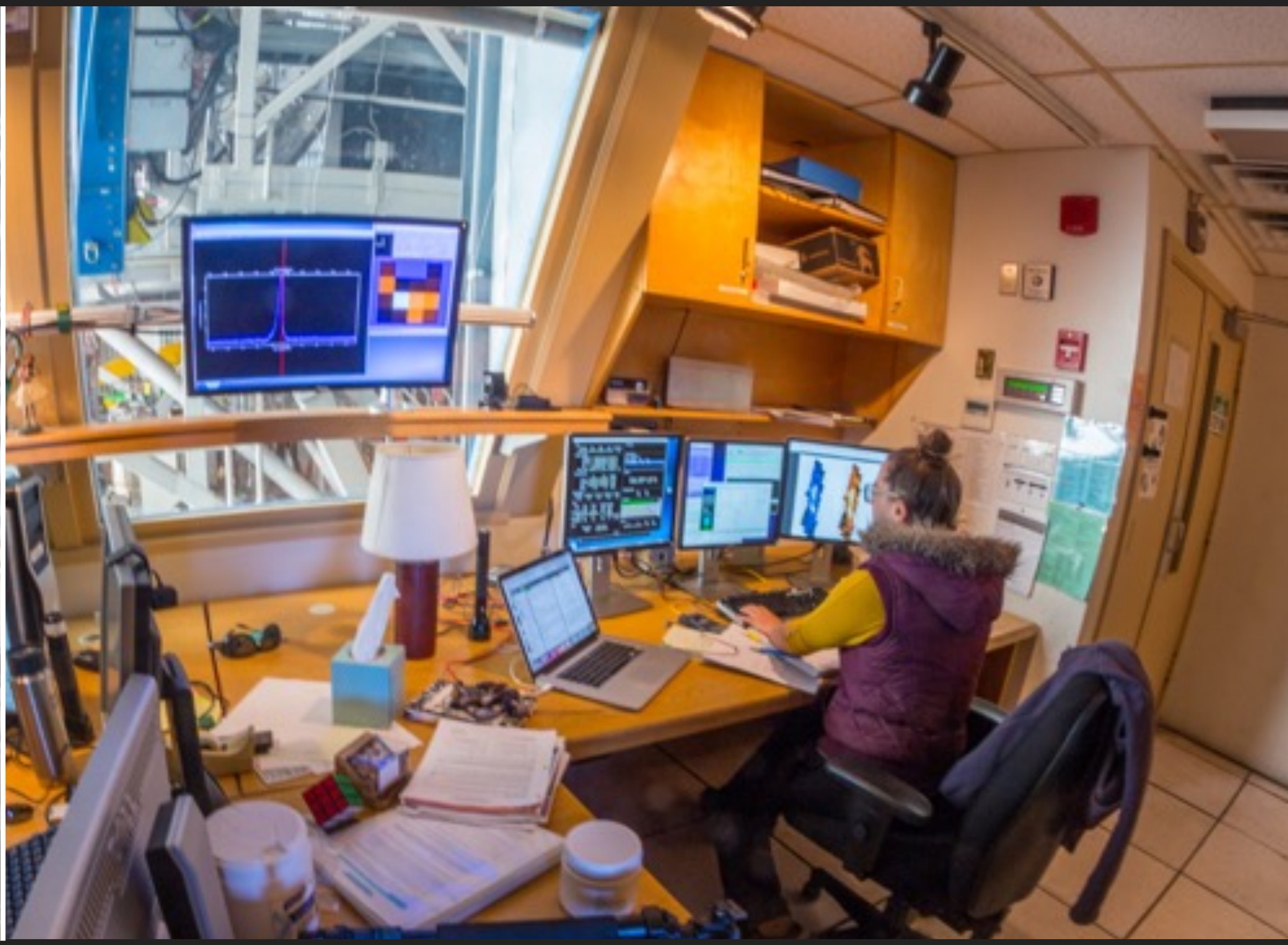
- We check this temperature scale against sources of known brightnesses. We do this throughout the night for various frequencies and bandwidths. From these observations we also monitor the calibration of the telescope over a longer period of time.

CALIBRATION SOURCES - CHECK FOR PERFORMANCE





www.eaobservatory.org/jcmt/instrumentation/heterodyne/calibration/



JCMT DR1: HETERODYNE DR

FROM DATA TO SCIENCE

THE DATA – INSPECTING THE RAW DATA

software: STARLINK, packages:

KAPPA

- various analysis tools, i.e. fitslist, hdstrace, ndftrace

GAIA

- GUI based visualization and analysis, including data cubes

SPLAT

- GUI based visualization an analysis for spectra

THE DATA - THE RAW DATA - FILENAMES

One subband:
a20140201_00006_01_0001.sdf

Two subbands:
a20140201_00006_01_0001.sdf
a20140201_00006_02_0001.sdf

Large maps:
a20140201_00006_01_0001.sdf
a20140201_00006_01_0002.sdf
etc

a (ACSIS)
UT-date
Scan number
Subband number
File number

Easiest is to make a text file myfiles.list with a list of file names to be reduced.

Files are cubes with dimensions Velocity/Receptor/Time, viewable with GAIA.

THE DATA – INSPECTING THE RAW DATA

www.eaobservatory.org/jcmt/science/reductionanalysis-tutorials/heterodyne-dr-tutorial-1/

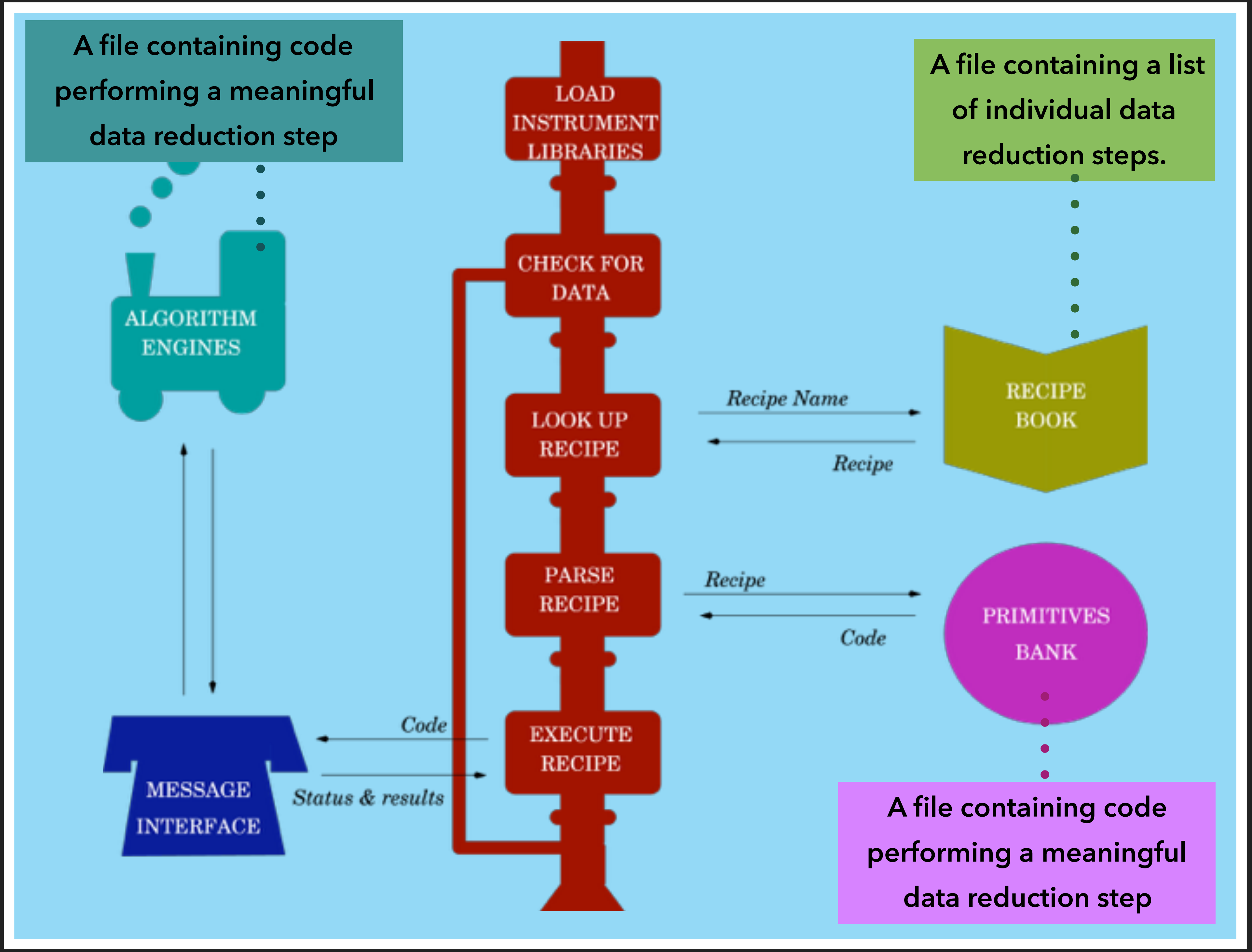
AIM (1/2) - By the end of this session you should know:

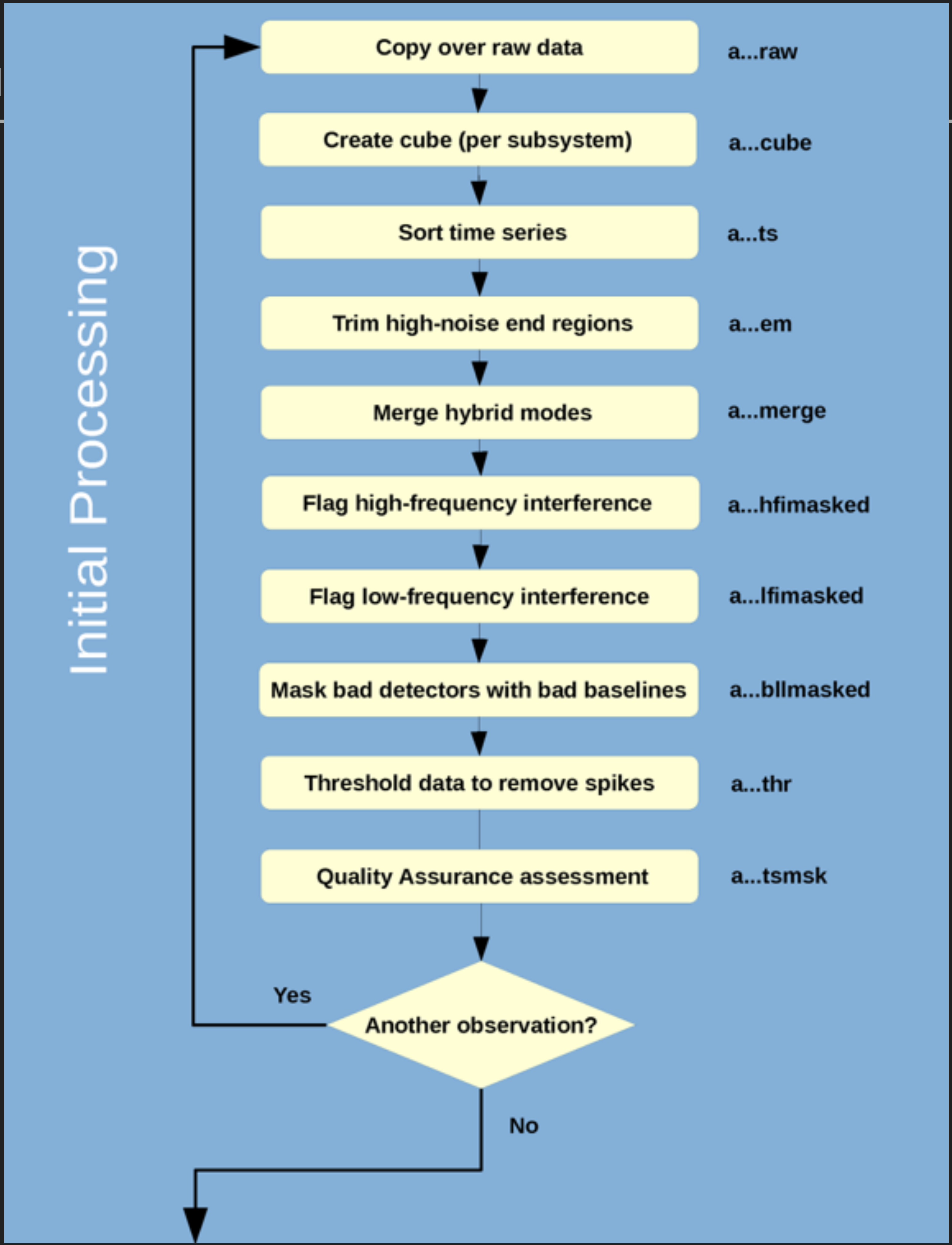
- How are the raw data arranged?
- What were the typical system and receiver temperatures observed?
- What object/frequency did you look at?
- What was the 225GHz opacity of the observation (how transparent was the atmosphere)?
- What was the elevation when the observation was taken?

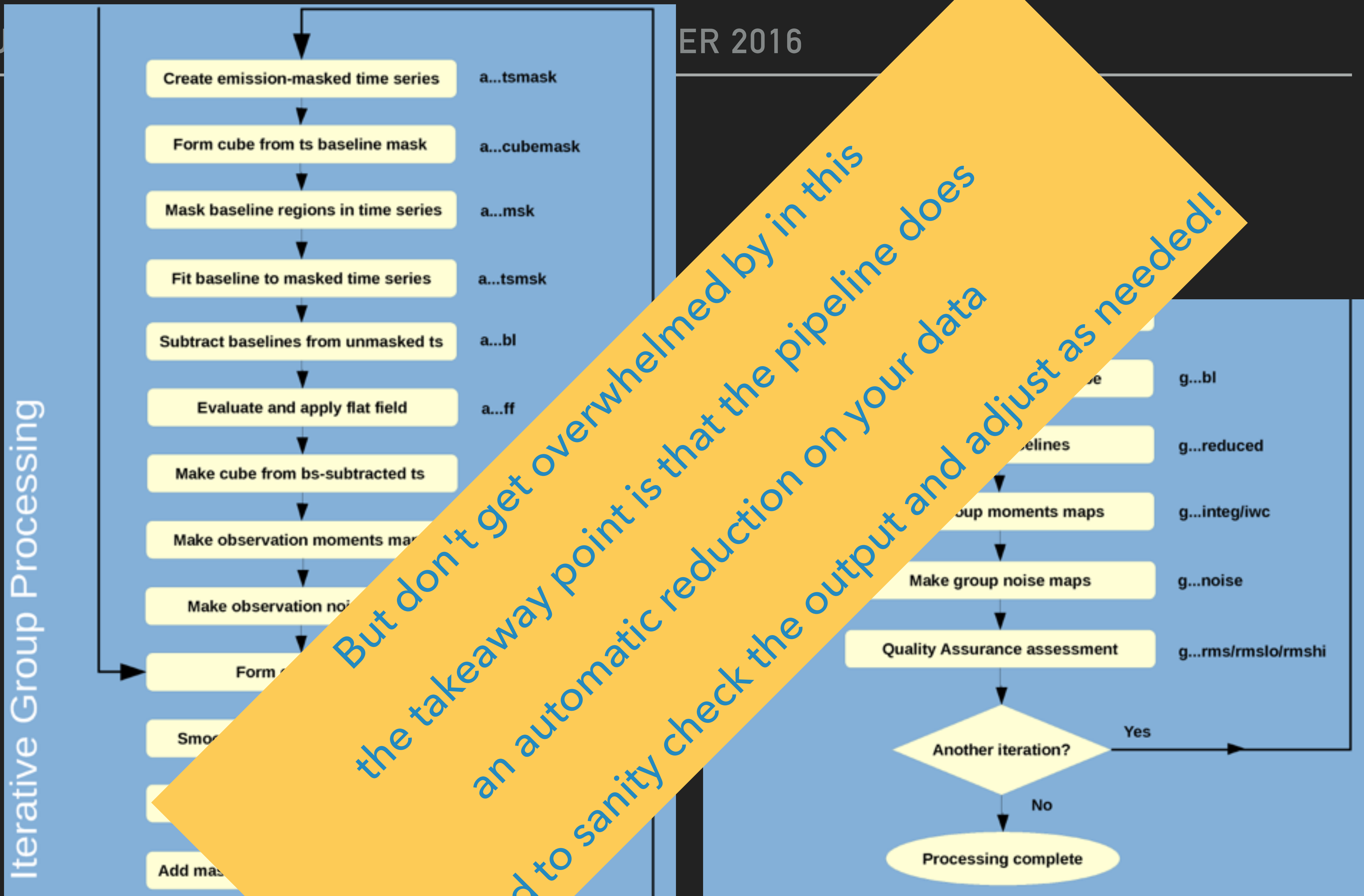
https://proposals.eaobservatory.org/jcmt/calculator/heterodyne/time - estimate of the expected rms

THE DATA – GENERIC REDUCTION

When reducing our HARP data we will be running a Data reduction pipeline - ORACDR - a data driven pipeline




Initial Processing
Copy over raw data
a...raw
Create cube (per subsystem)
a...cube
Sort time series
a...ts
Trim high-noise end regions
a...em
Merge hybrid modes
a...merge
Flag high-frequency interference
a...hfimasked
Flag low-frequency interference
a...lfimasked
Mask bad detectors with bad baselines
a...bllmasked
Threshold data to remove spikes
a...thr
Quality Assurance assessment
a...tsmsk
Another observation?
Yes
No



But don't get overwhelmed by in this

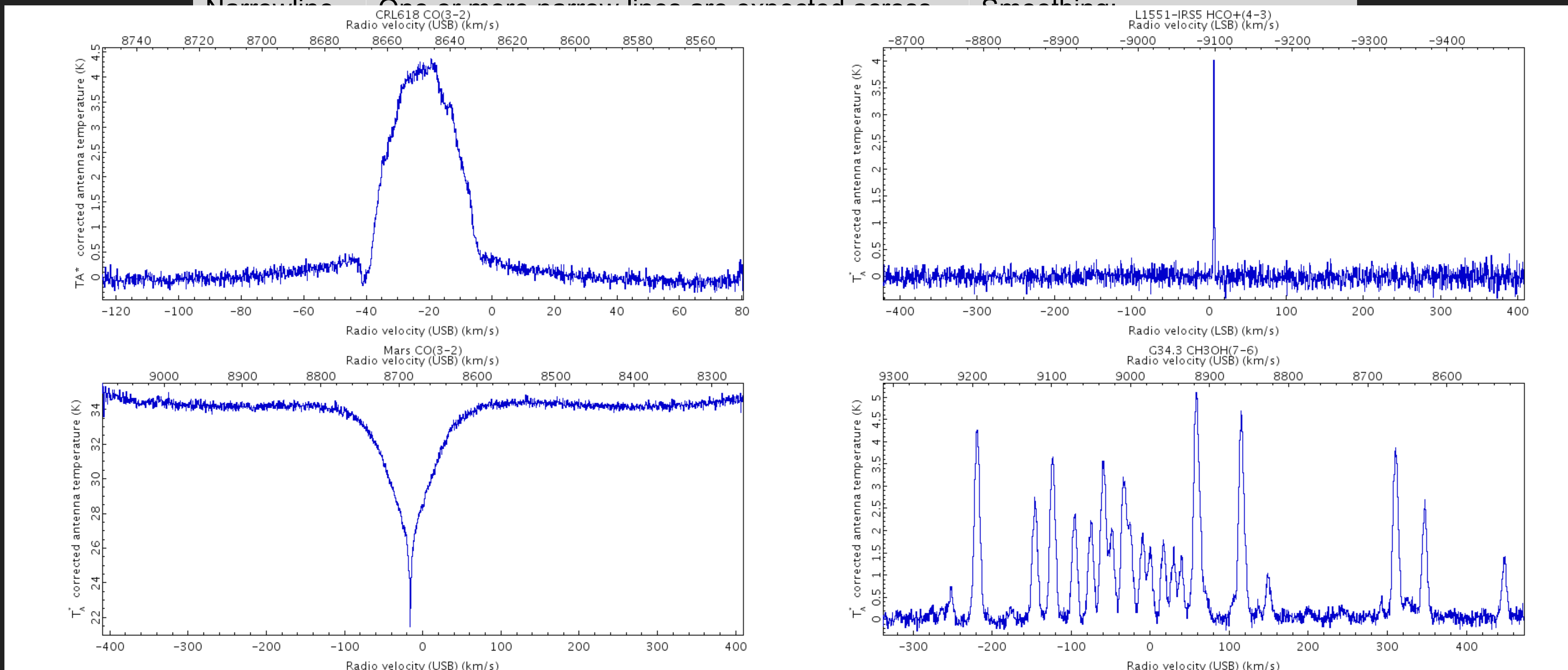
the takeaway point is that the pipeline does

an automatic reduction on your data

you need to sanity check the output and adjust as needed!

for more info: [http://s[illegible]nk.eao.hawaii.edu/devdocs/sc20.htx/sc20.html](http://s[illegible]nk.eao.hawaii.edu/devdocs/sc20.htx/sc20.html)

Recipe	Description of emission	Baseline method
Narrowline	One or more narrow lines are expected across	Smoothing:



Examples of typical spectra for broadline, narrowline, continuum, lineforest recipes
Narrowline: linewidth < 8 km/s
Gradient: 8 km/s < linewidth < 40 km/s
Broadline: linewidth > 40 km/s (but those limits are not well-defined)

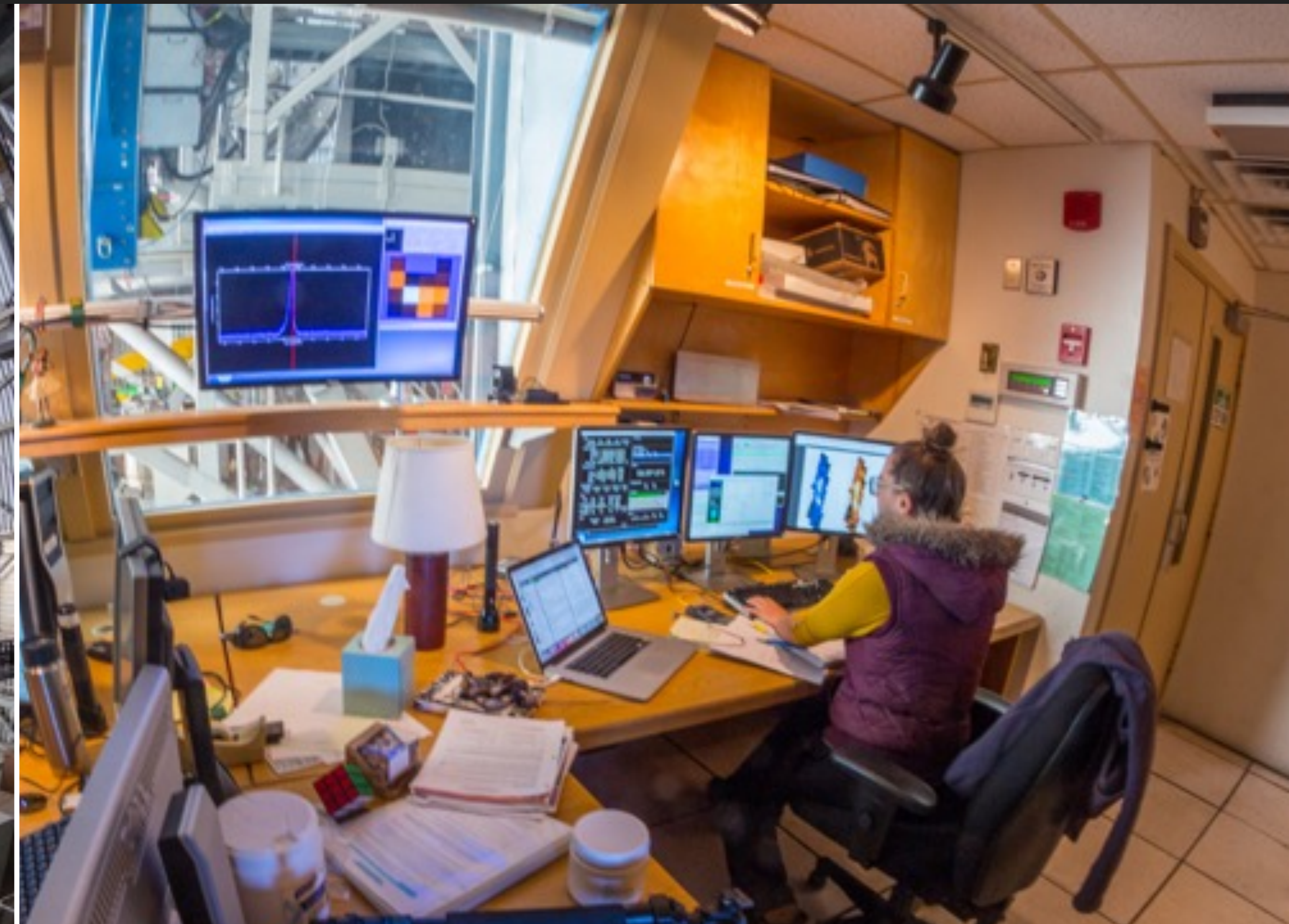
for more info: http://starlink.eao.hawaii.edu/devdocs/sc20.htx/sc20.html

THE DATA – GENERIC REDUCTION

www.eaobservatory.org/jcmt/science/reductionanalysis-tutorials/heterodyne-dr-tutorial-1/

AIM (2/2) - By the end of the session you should:

- Run the raw data through the ORAC-DR pipeline
- Obtained a reduced cube of your chosen object
- Opened up your cube in >> gaia
- Examined a spectrum in >> splat
- Calculated the rms in your spectrum, for a given resolution
- If you have a single line: Estimate the peak temperature, if you have a basket weave produce an integrated intensity map.



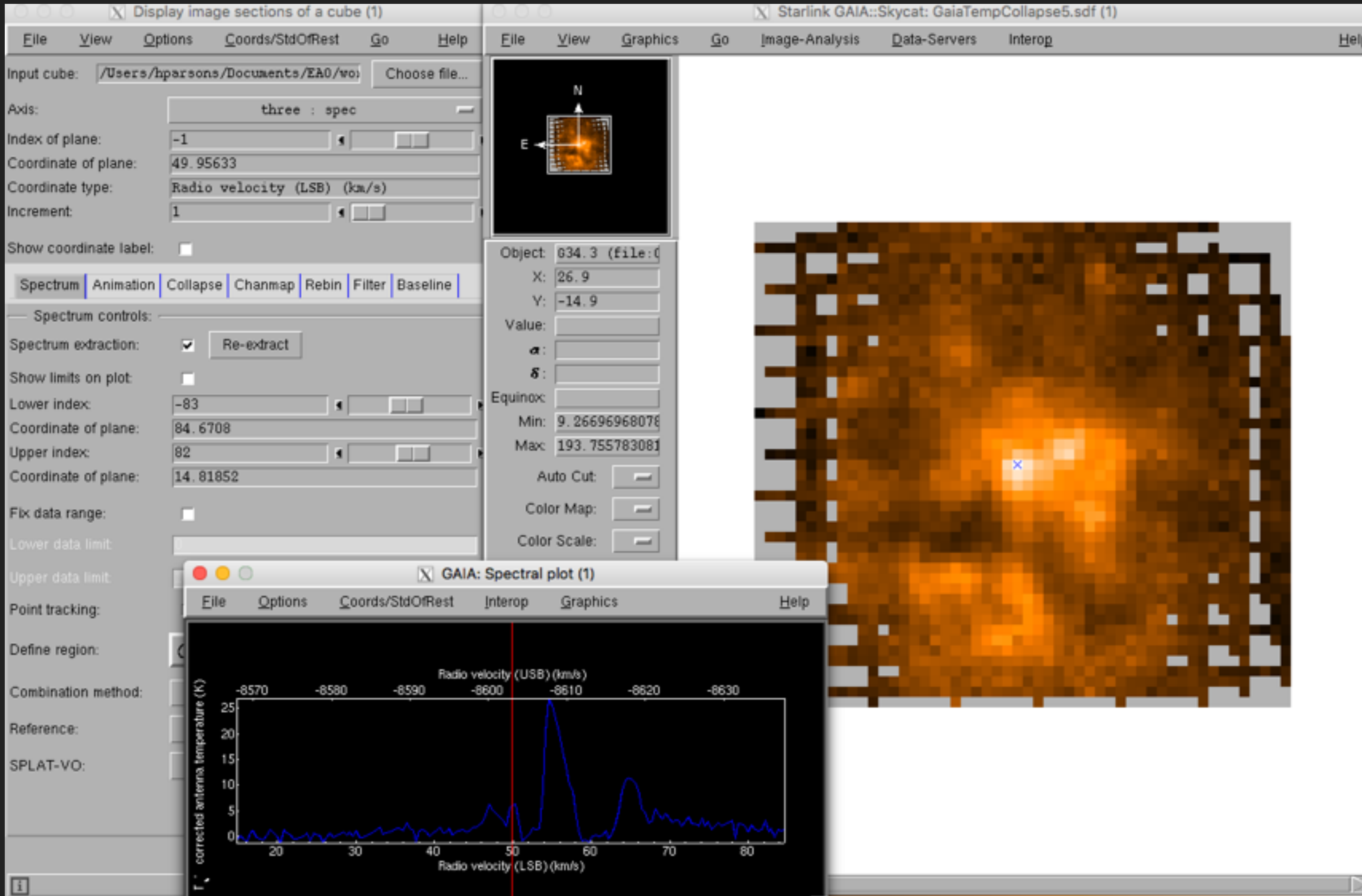
JCMT DR2: HETERODYNE DR

FROM DATA TO SCIENCE

Science → Data → Science

- Tailoring the reduction
  - Reduction recipes offered
  - Bespoke reduction
- Checking the calibration
- Applying correction factors
- Examining the data
- Extracting the science!

INITIAL REDUCTION – FROM DR1 SESSION



T_A* TO SOURCE TEMPERATURE

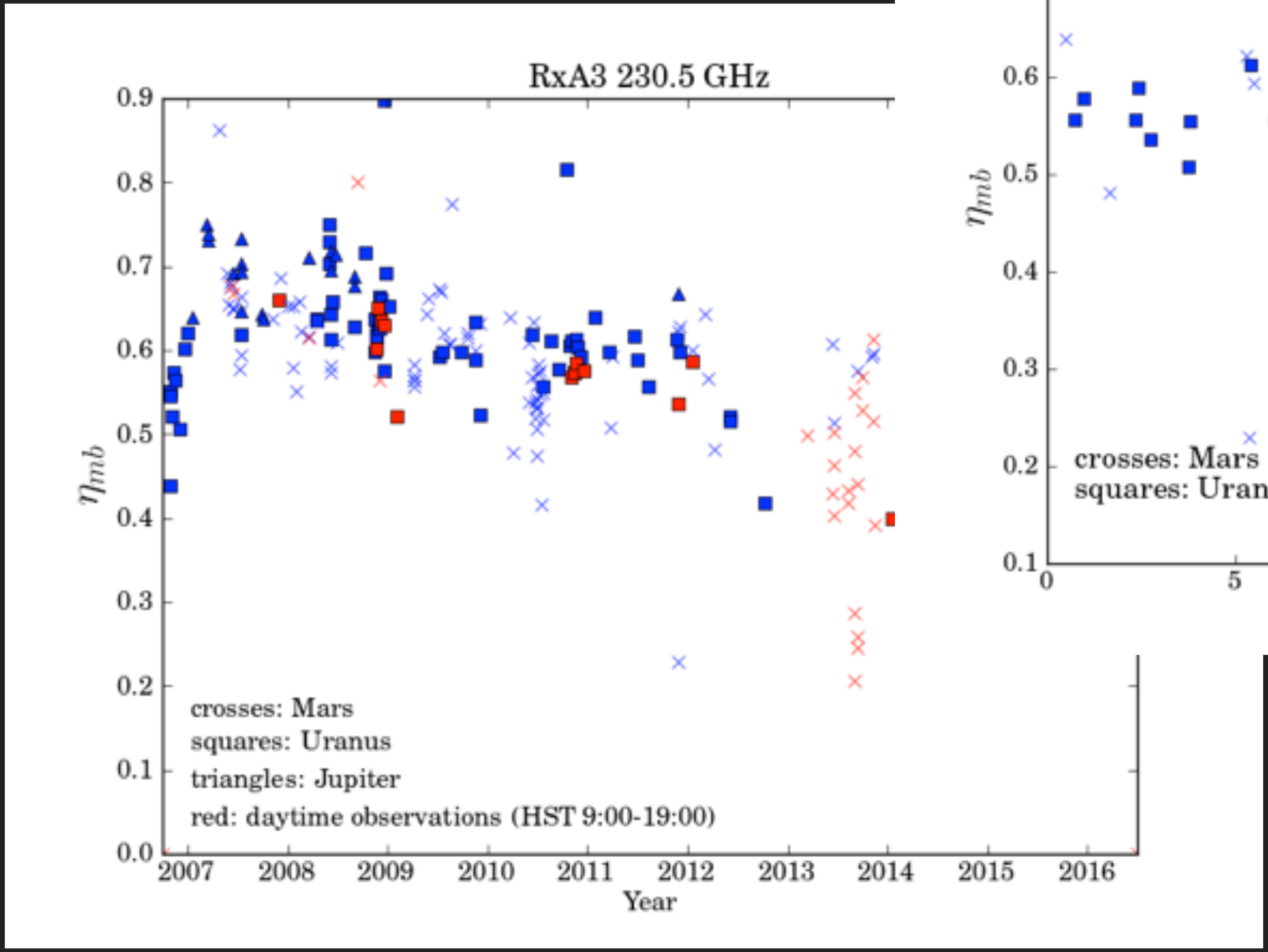
η_{MB} - converting to T_{MB}

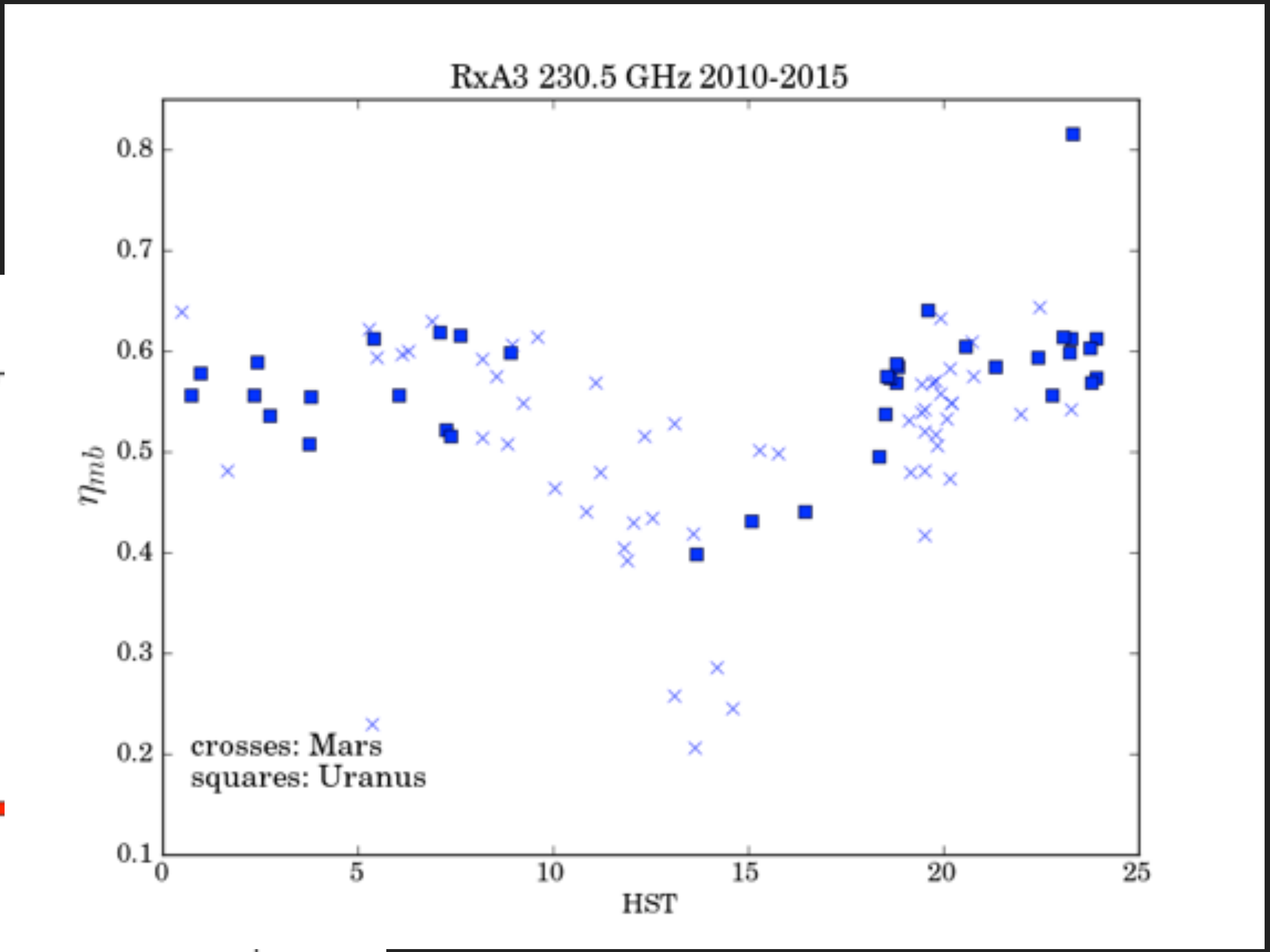
- efficiency - looking at the Power from central telescope main beam
- use if source size < main beam size
- estimates come from planet observations

η_{fss} - converting to T_R*

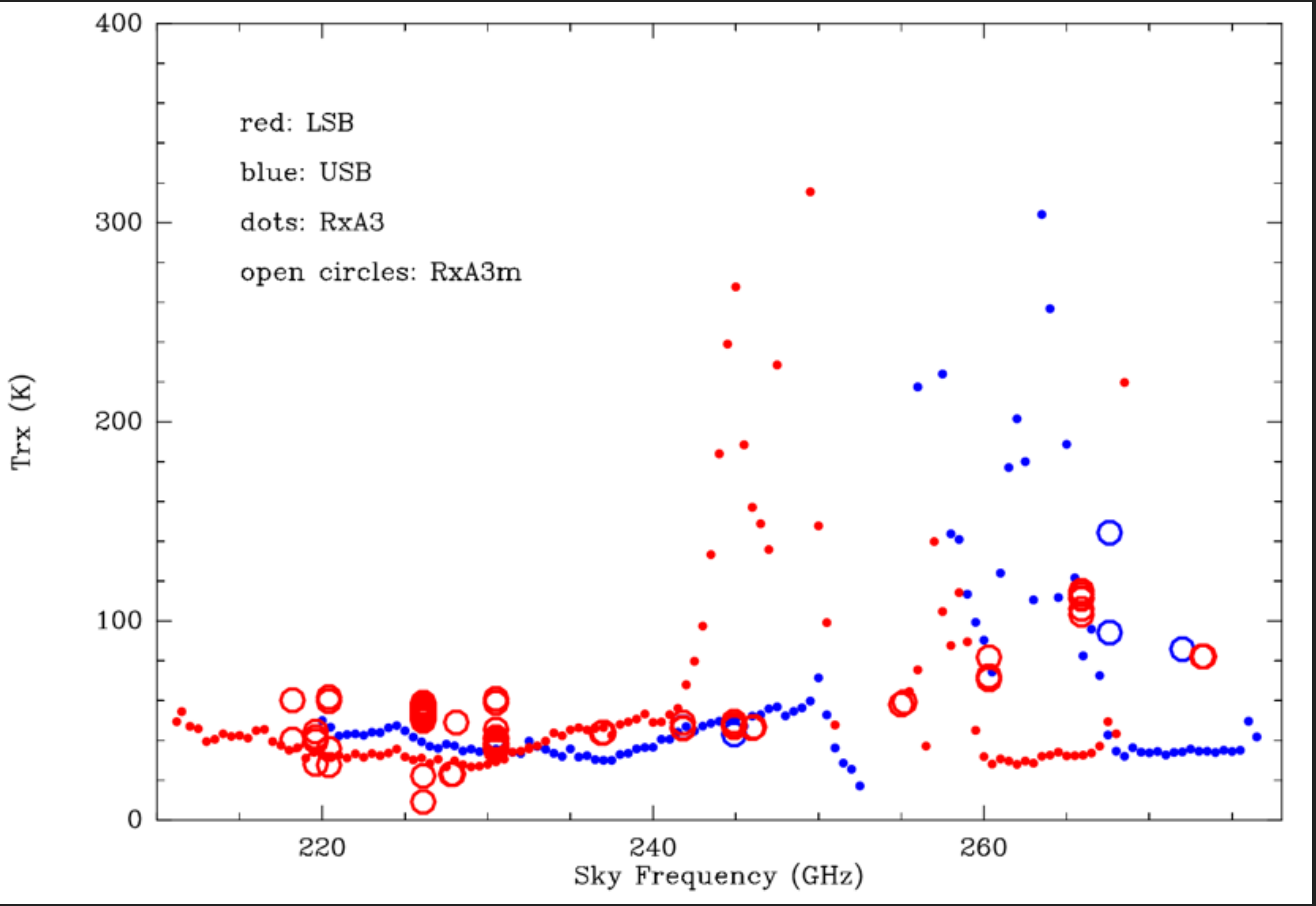
- efficiency - looking at the Power from across the main beam and side lobes
- use if source size > main beam size
- estimates come from moon observations

PLANETARY EFFICIENCIES

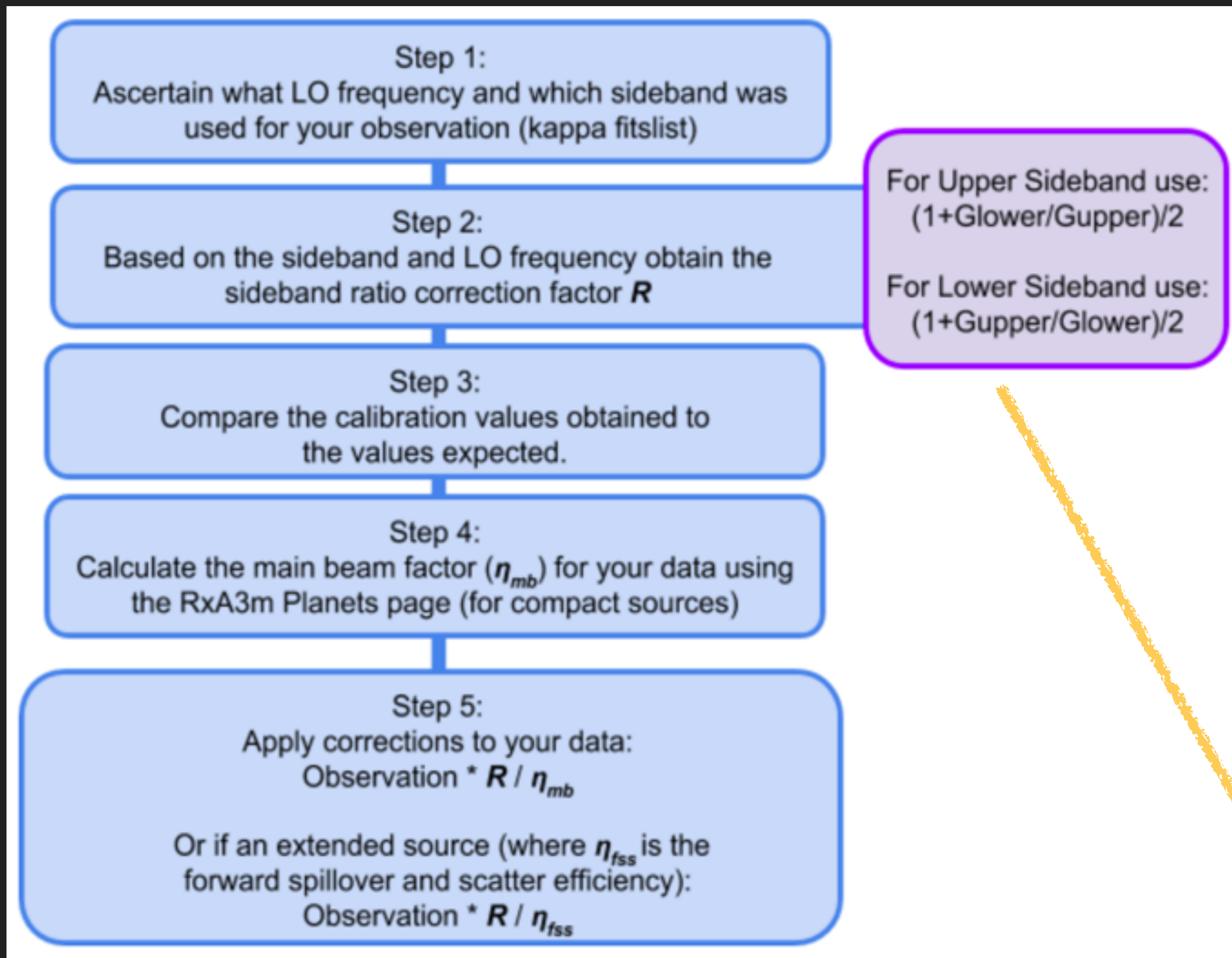




AN ADDITIONAL STEP: RXA – SIDEBAND RATIO CORRECTION



AN ADDITIONAL STEP: RXA – SIDEBAND RATIO CORRECTION



http://www.eaobservatory.org/jcmt/instrumentation/heterodyne/rxa/

THE DATA – ADVANCED REDUCTION

www.eaobservatory.org/jcmt/science/reductionanalysis-tutorials/heterodyne-dr-tutorial-2/

AIM (1/2) - By the end of this session you should know:

- How to run with a reduction of your choosing or a different reduction to the one specified
  - *beware unless reduced in new directory files will be overwritten*
- Choose a specific recipe, specify the binning/pixels
- Apply an efficiency factor to your data

THE DATA – EXTRACTING SCIENCE

www.eaobservatory.org/jcmt/science/reductionanalysis-tutorials/heterodyne-dr-tutorial-2/

AIM (2/2) - By the end of this session you should know:

- How to produce channel maps (cube)
- How to produce position-velocity diagrams (cubes)
- How to find clumps
- How to produce a grid of spectra

if time:

- Investigate GAIA's tools - catalogs, GAIA3D, contouring…