

JCMT DR1: HETERODYNE DR

FROM DATA TO SCIENCE

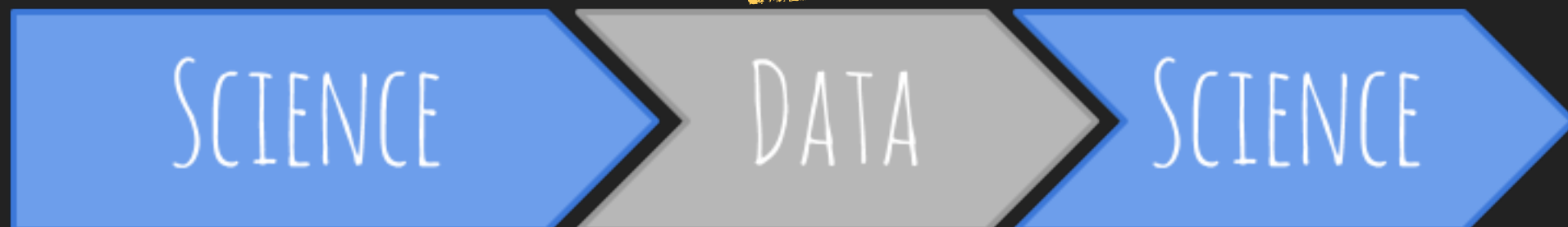
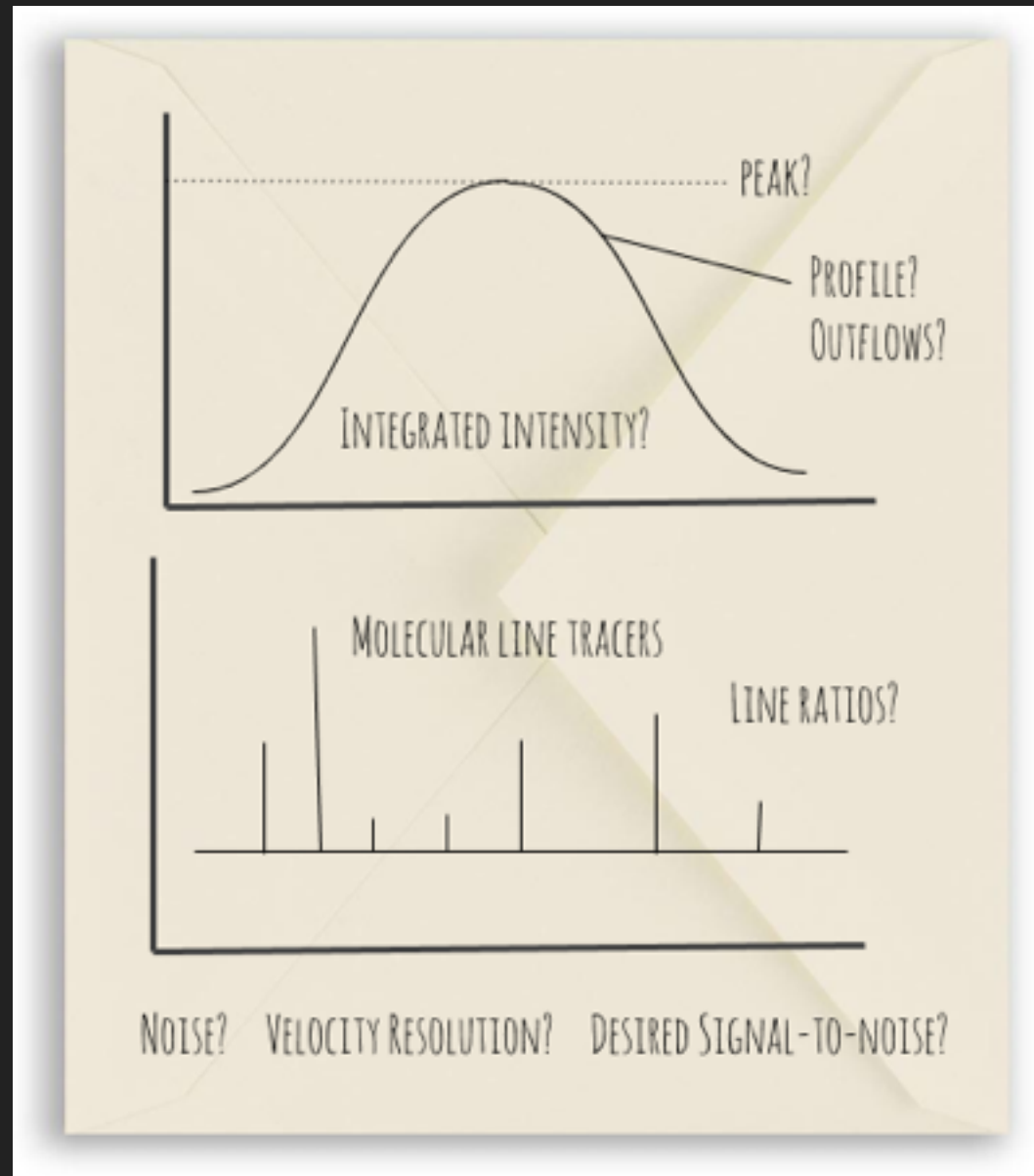
SCIENCE

DATA

SCIENCE

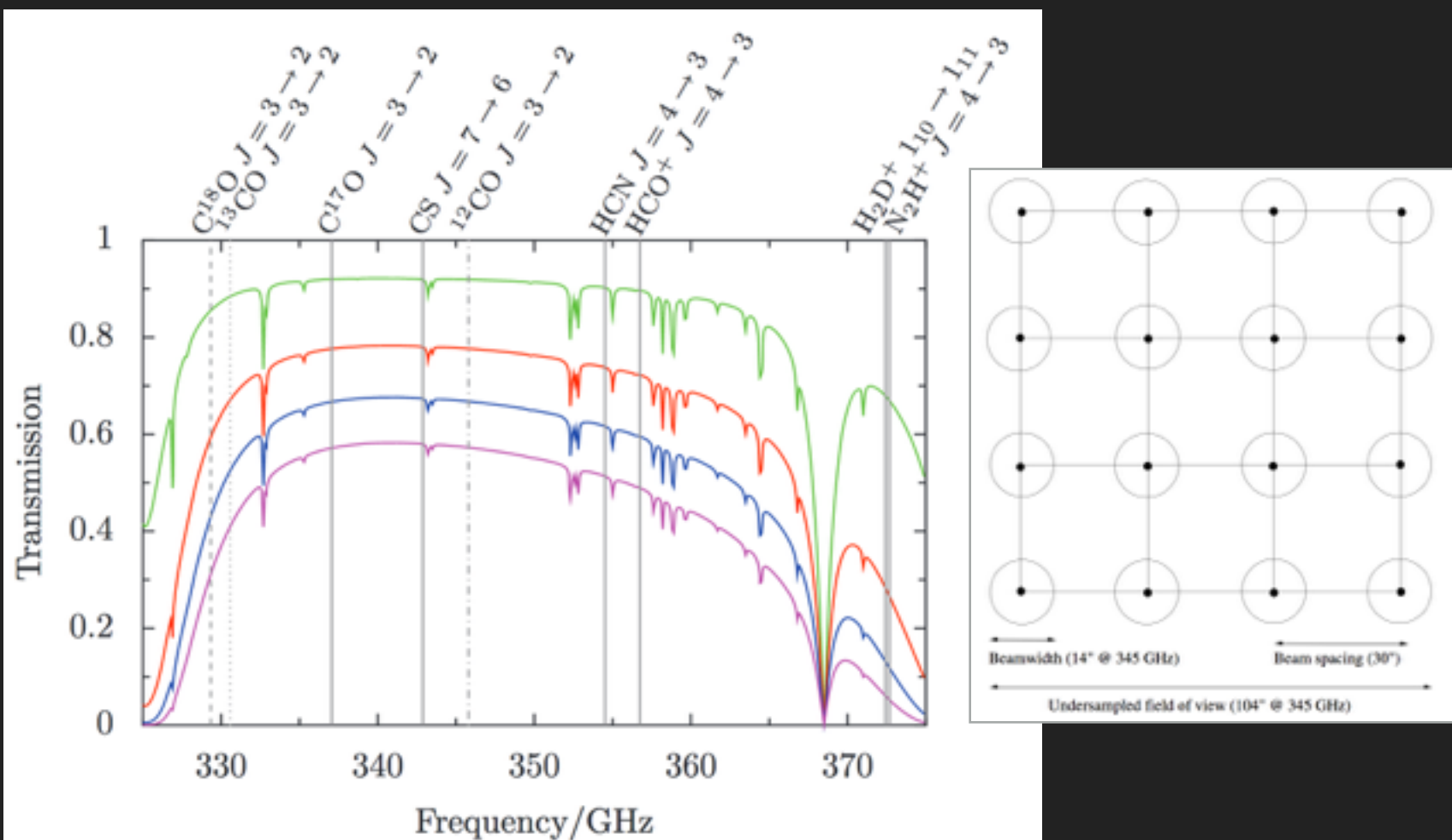
JCMT DR1 - TIARA RADIO ASTRONOMY SUMMER SCHOOL

<https://proposals.eaobservatory.org/>



THE DATA – HARP

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



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

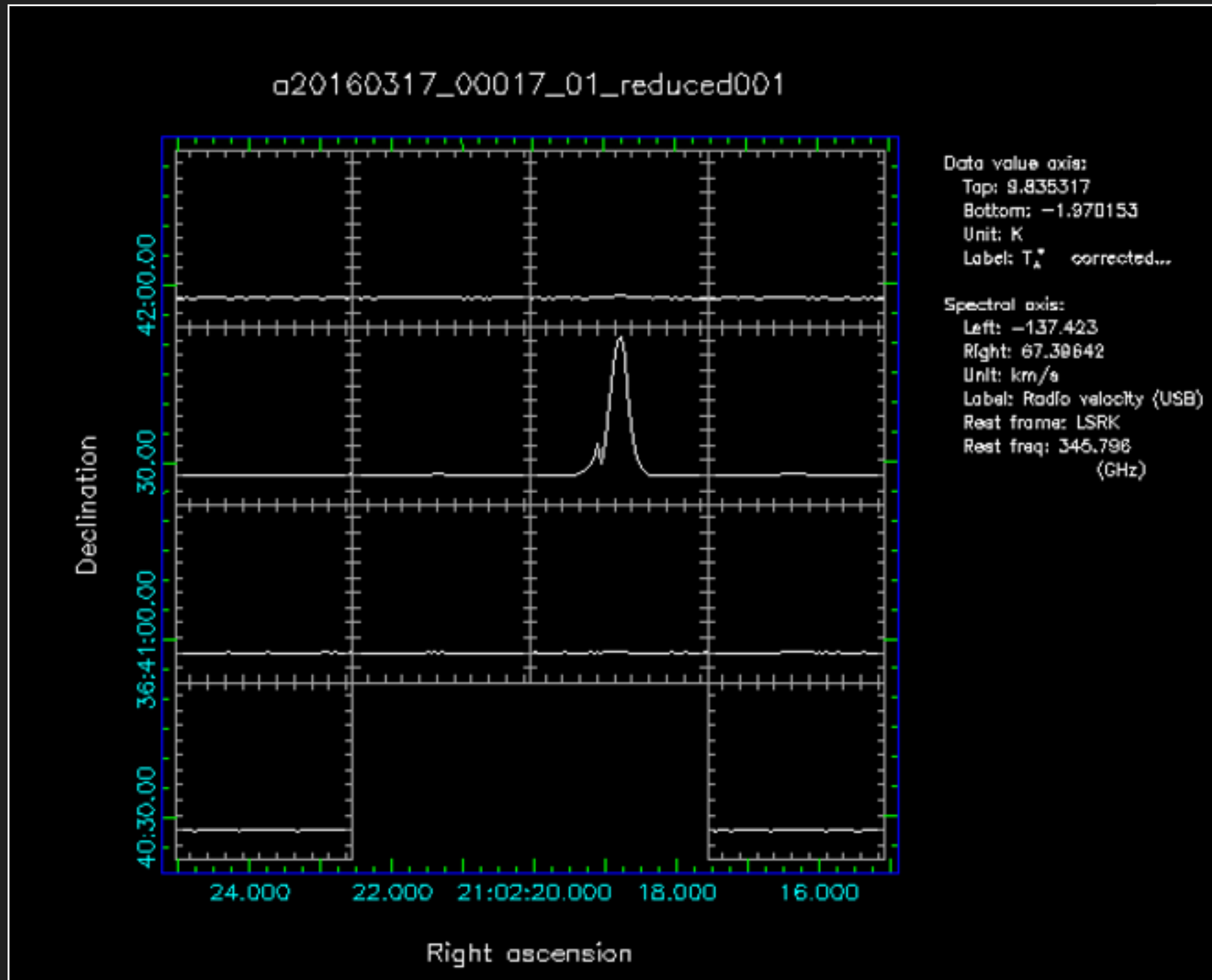


<http://cdsads.u-strasbg.fr/abs/2009MNRAS.399.1026B>

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

THE DATA - HARP

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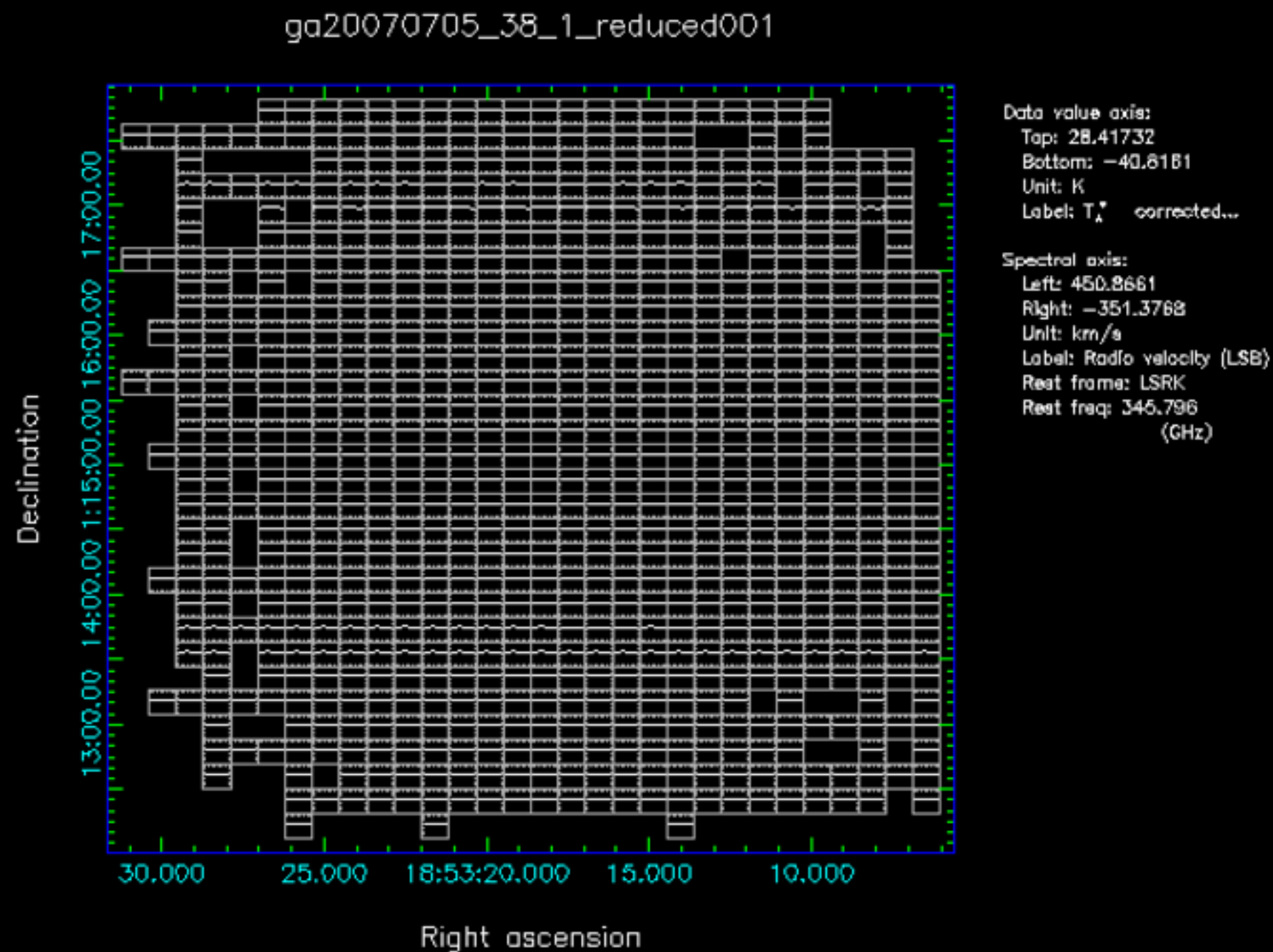


bg.fr/abs/2009MNRAS.399.1026B

[instrumentation/heterodyne/harp/](#)

THE DATA – HARP

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arxiv.org/abs/2009MNRAS.399.1026B
[instrumentation/heterodyne/harp/](http://www.eaobservatory.org/instrumentation/heterodyne/harp/)

- ▶ Pointing
- ▶ Focus
- ▶ Calibration
- ▶ The data

The Observatory

The Astronomer

First Session

Second Session

▶ Raw data format

▶ Reduce the data

▶ Examine the reduced data

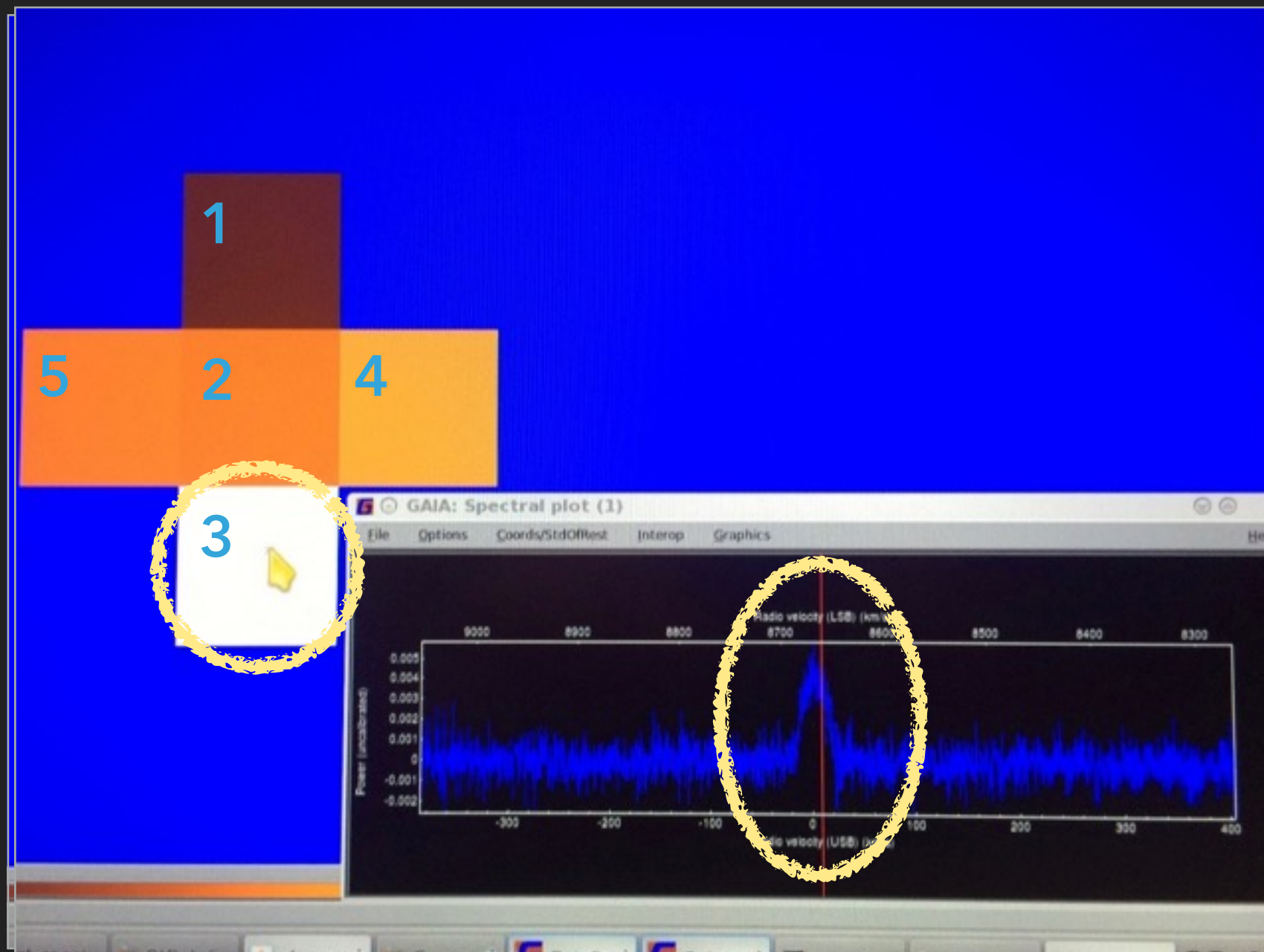
POINTING

- ▶ 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

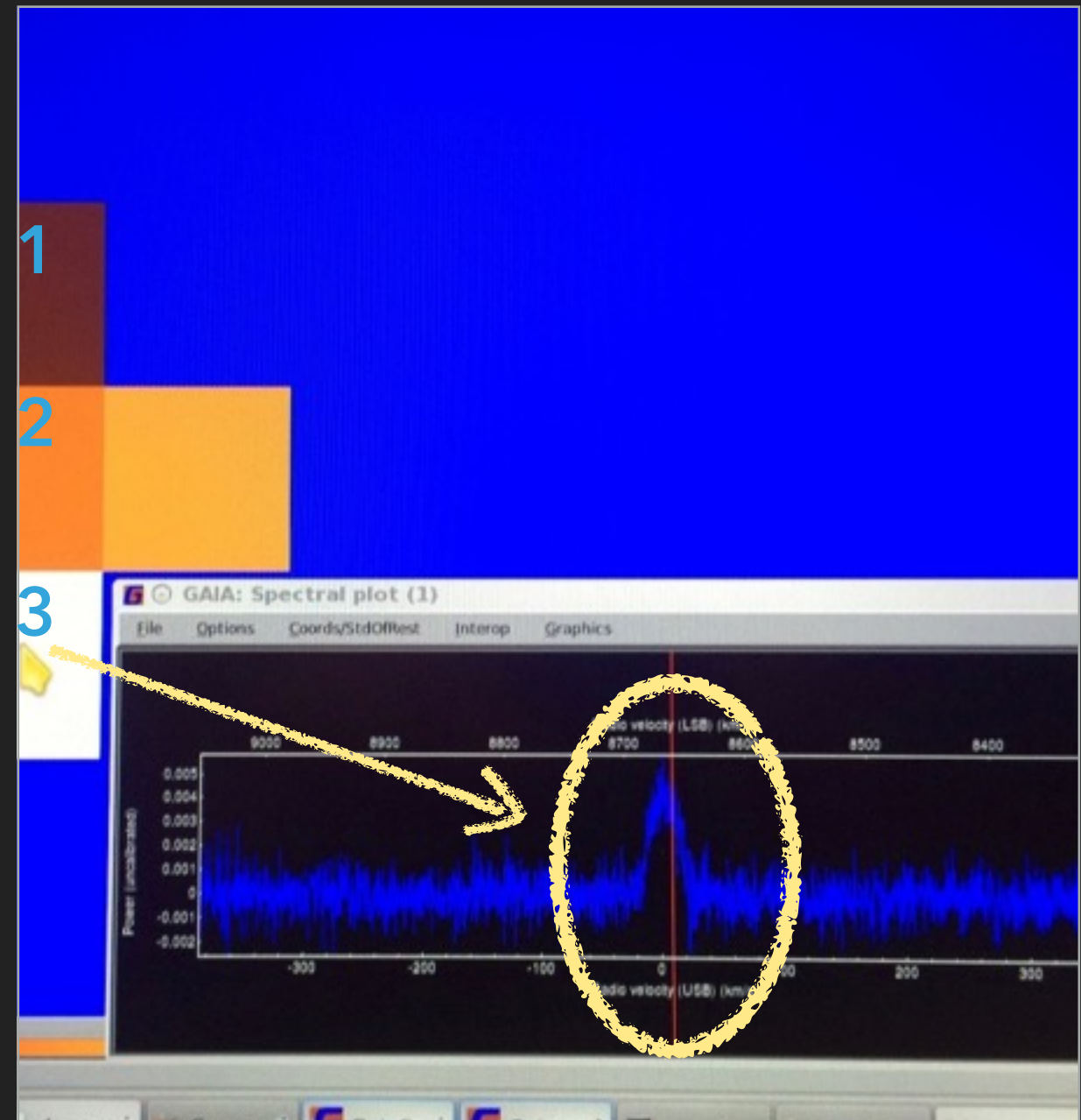
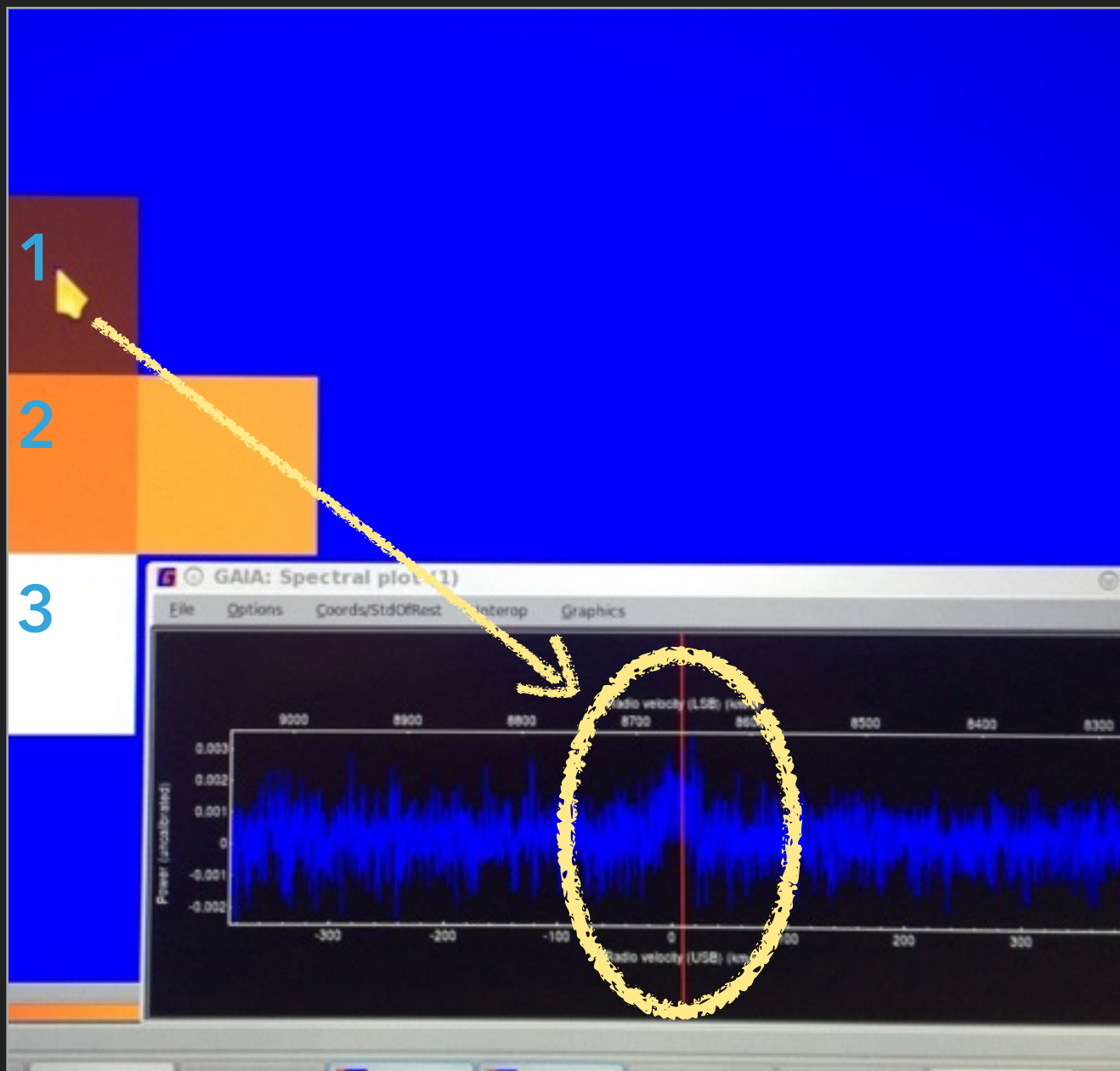
Investigation via GAIA. A clear difference in line intensity can be seen when comparing the left vs. right spectra from our five point pointing pattern (meaning a pointing change is expected):



POINTING

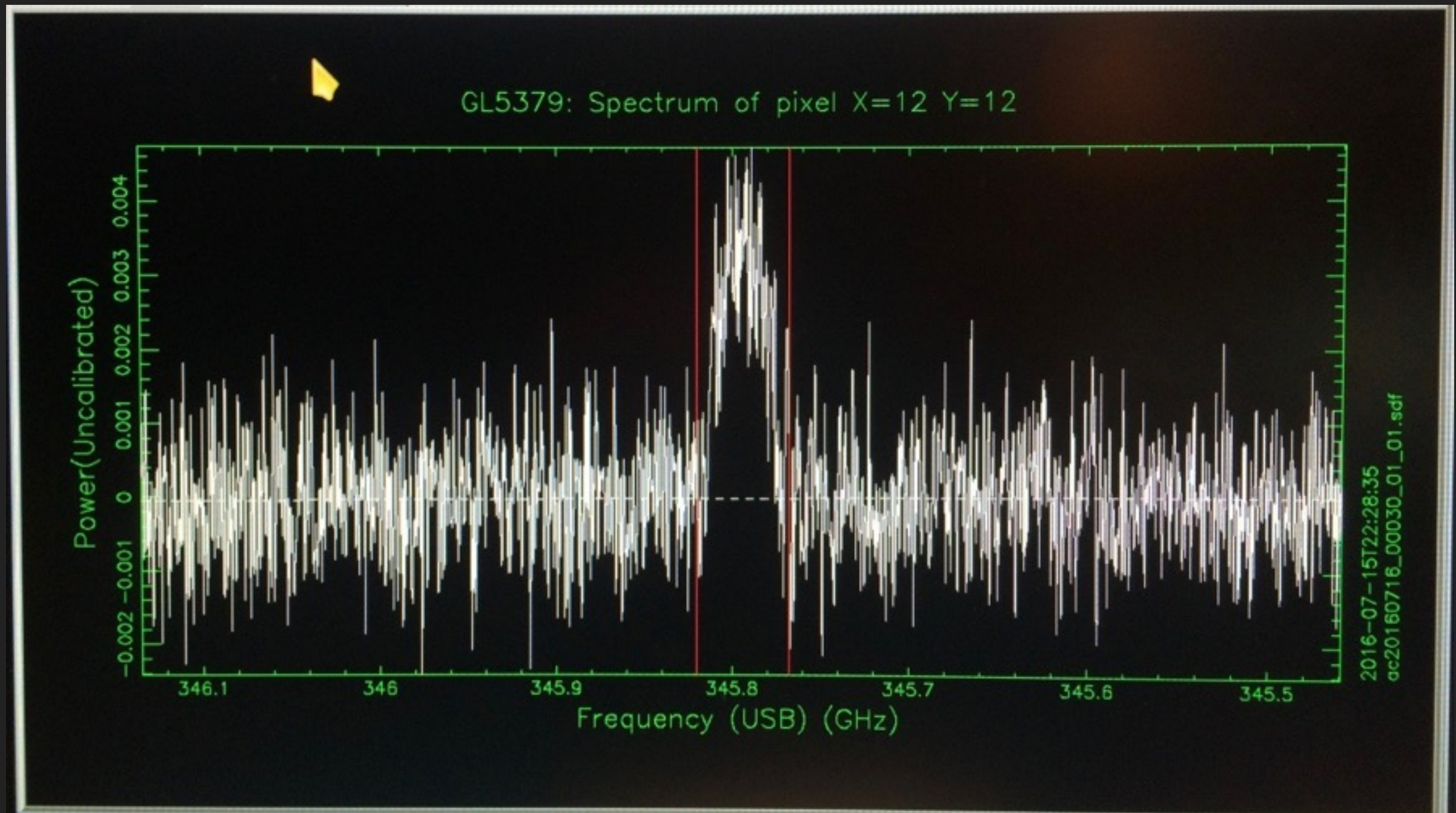
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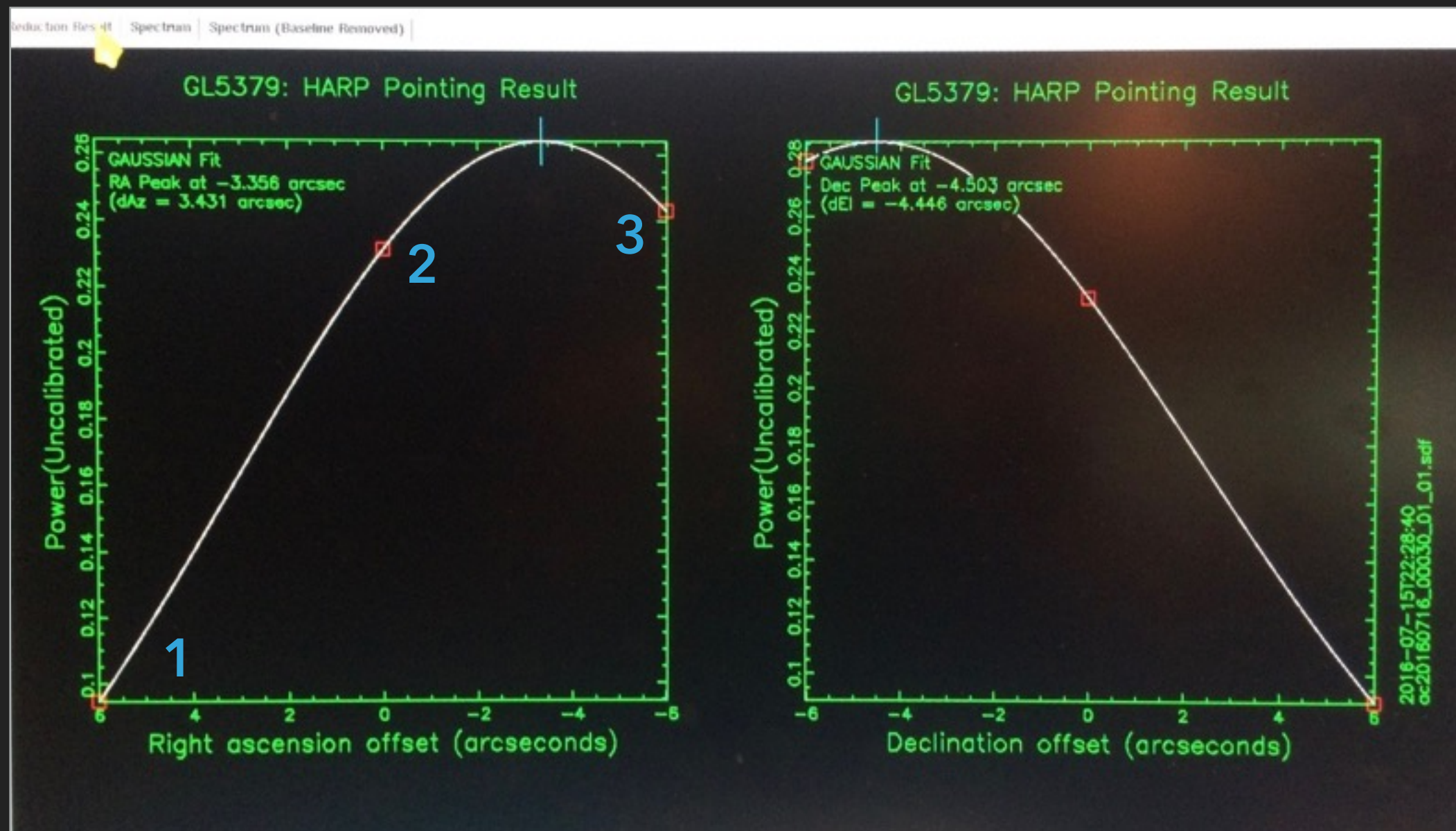
POINTING

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):



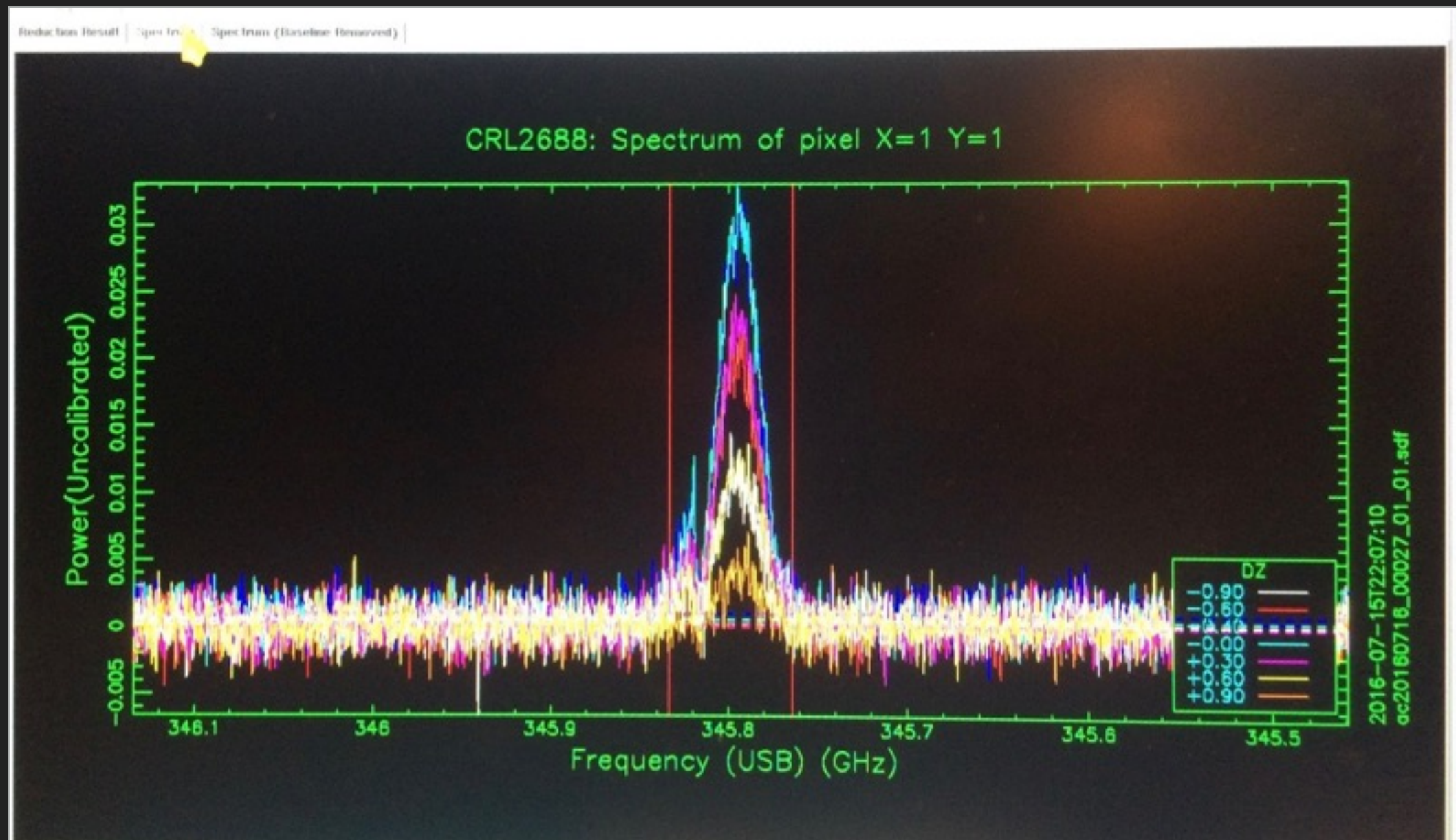
with requested changes: 3.43 arcsec in AZ and -4.45 arcsec in EL

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.

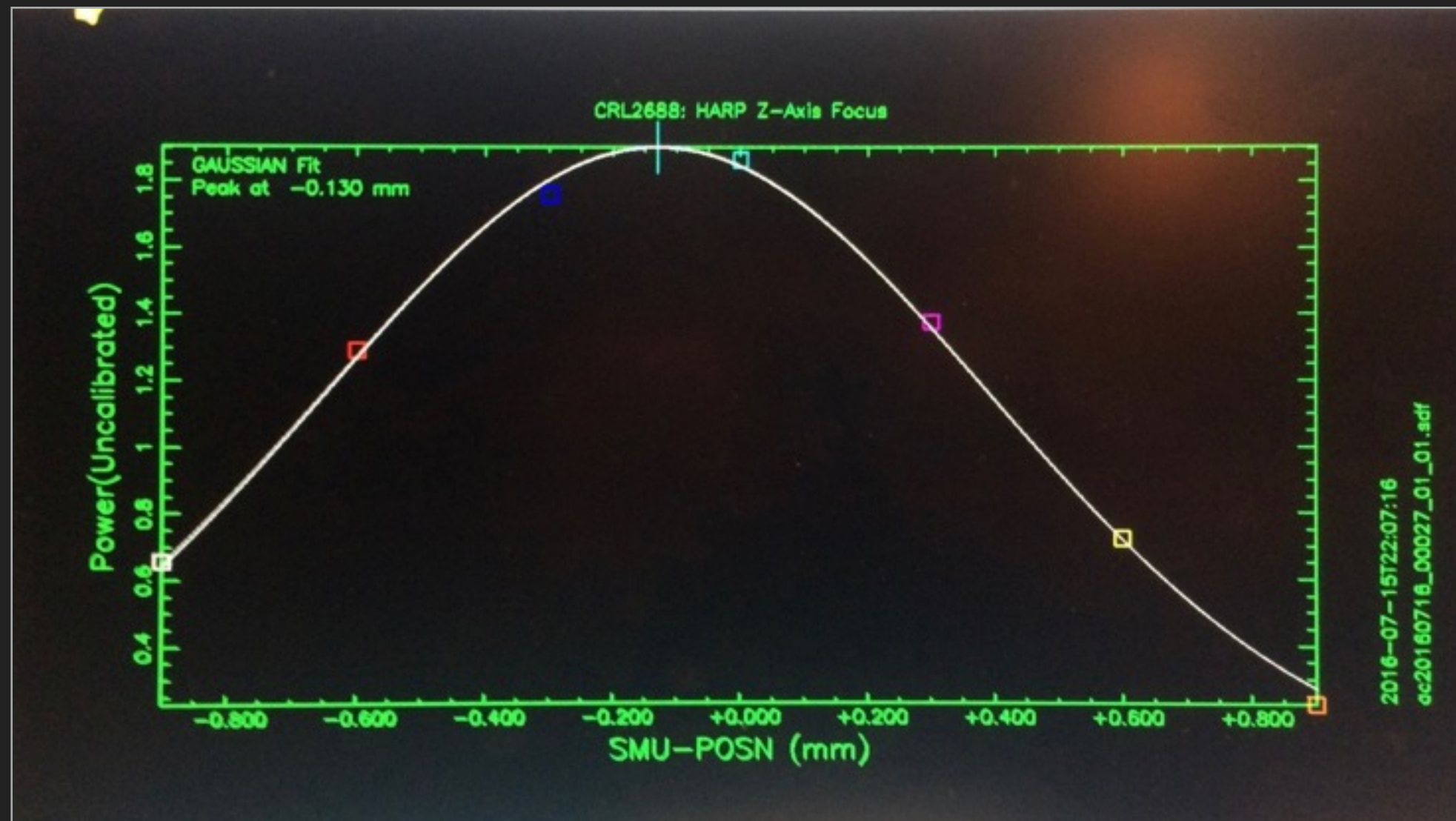
FOCUS

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



FOCUS

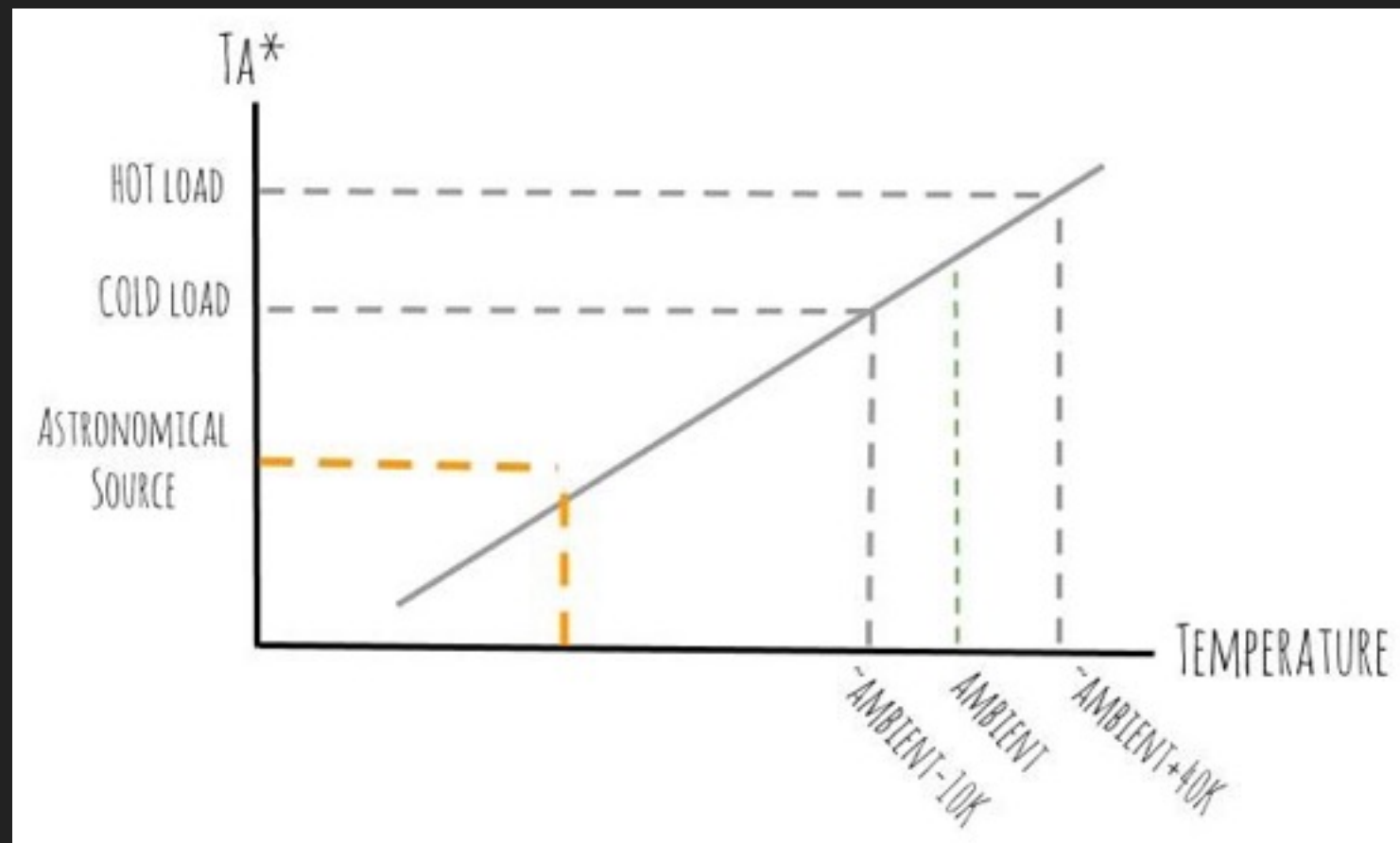
Focus reduction result (Gaussian fit to seven points representing the line peak of each of seven spectra):



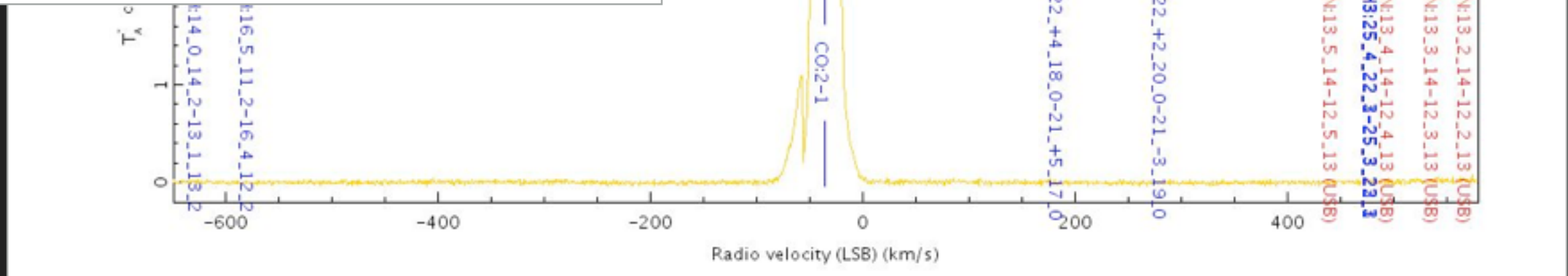
Done in "the blink of an eye" by the Telescope Operator - typically nothing you need to worry about as an observer

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.



THE DATA – INSPECTING THE RAW DATA

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

software: STARLINK, packages:

KAPPA

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

GAIA

- ▶ GUI based visualization and analysis, including data cubes

SPALT

- ▶ GUI based visualization and analysis for spectra

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

THE DATA – INSPECTING THE RAW DATA

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

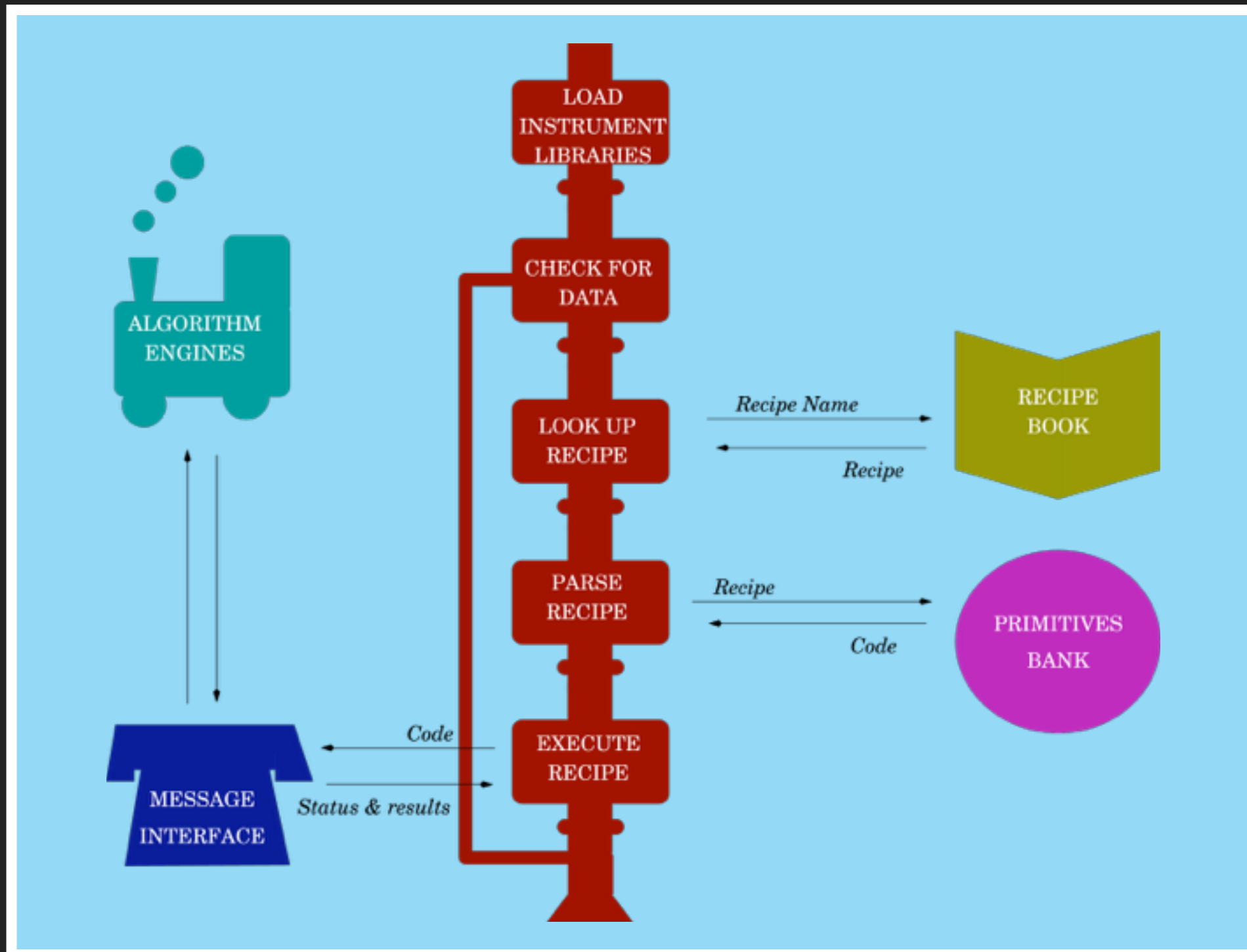
AIM (1/2) - By the end of this session you should know:

- ▶ 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?

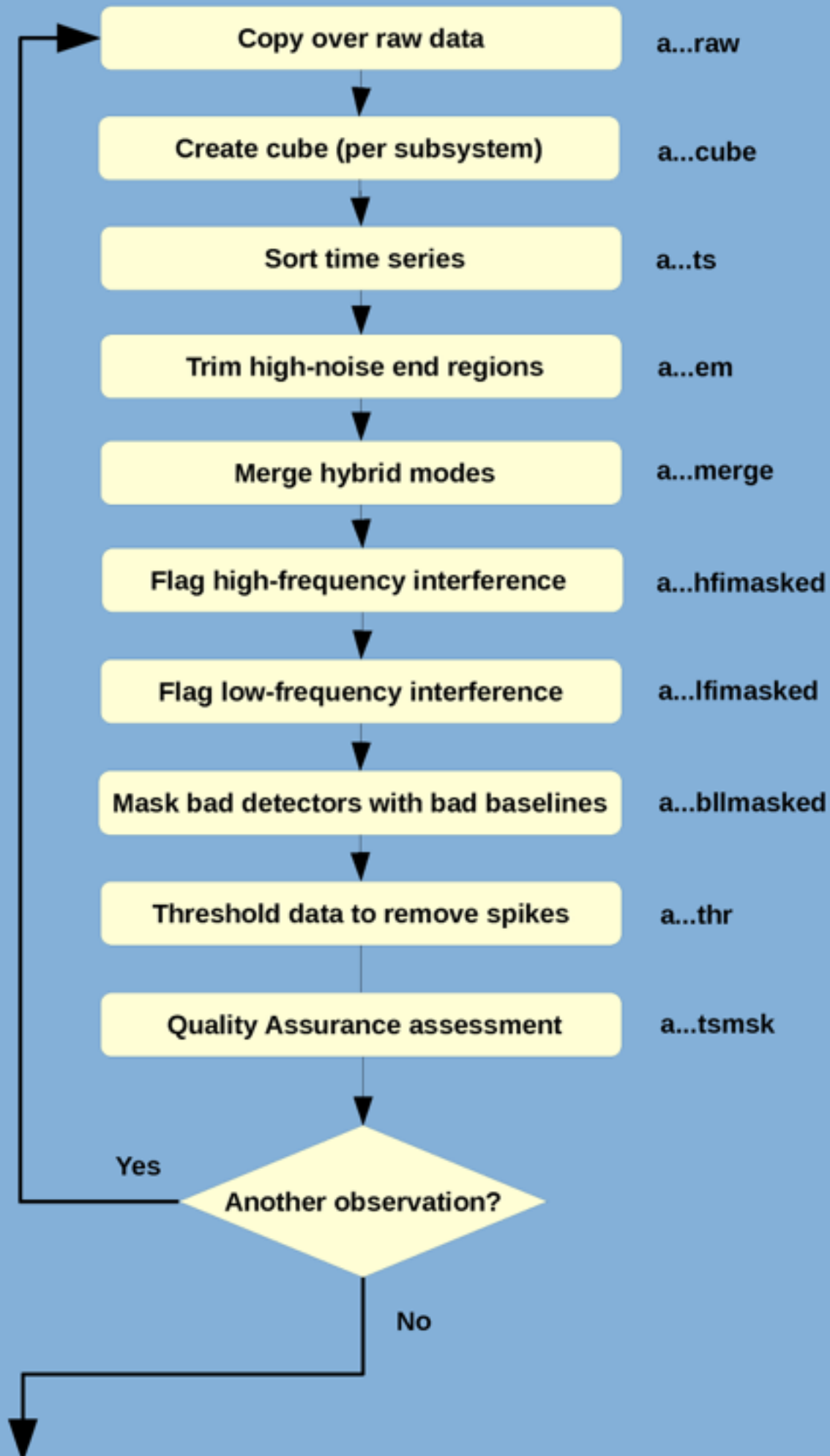
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THE DATA – GENERIC REDUCTION

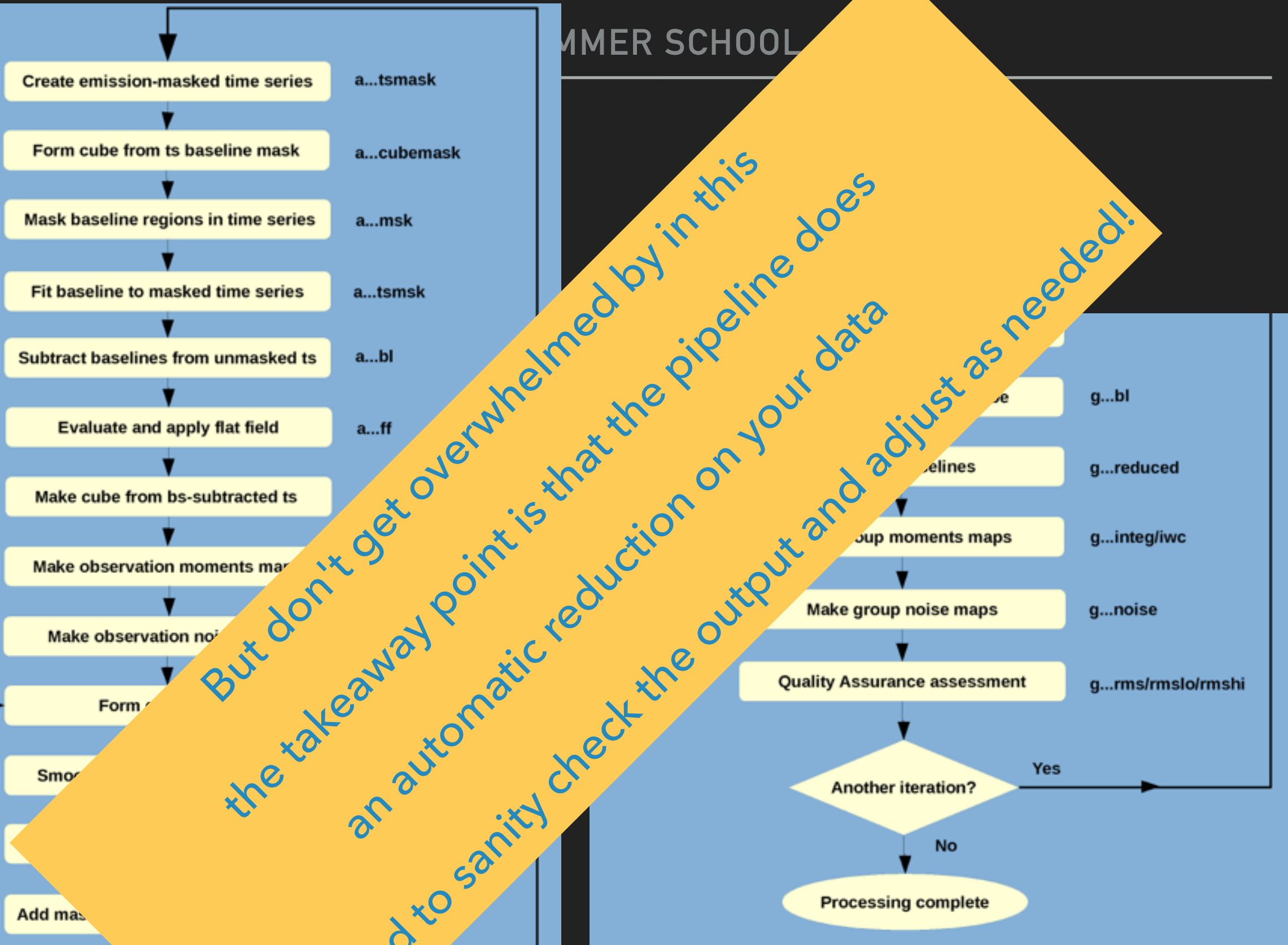
When reducing our HARP data we will be running a Data reduction pipeline



Initial Processing



Iterative Group Processing

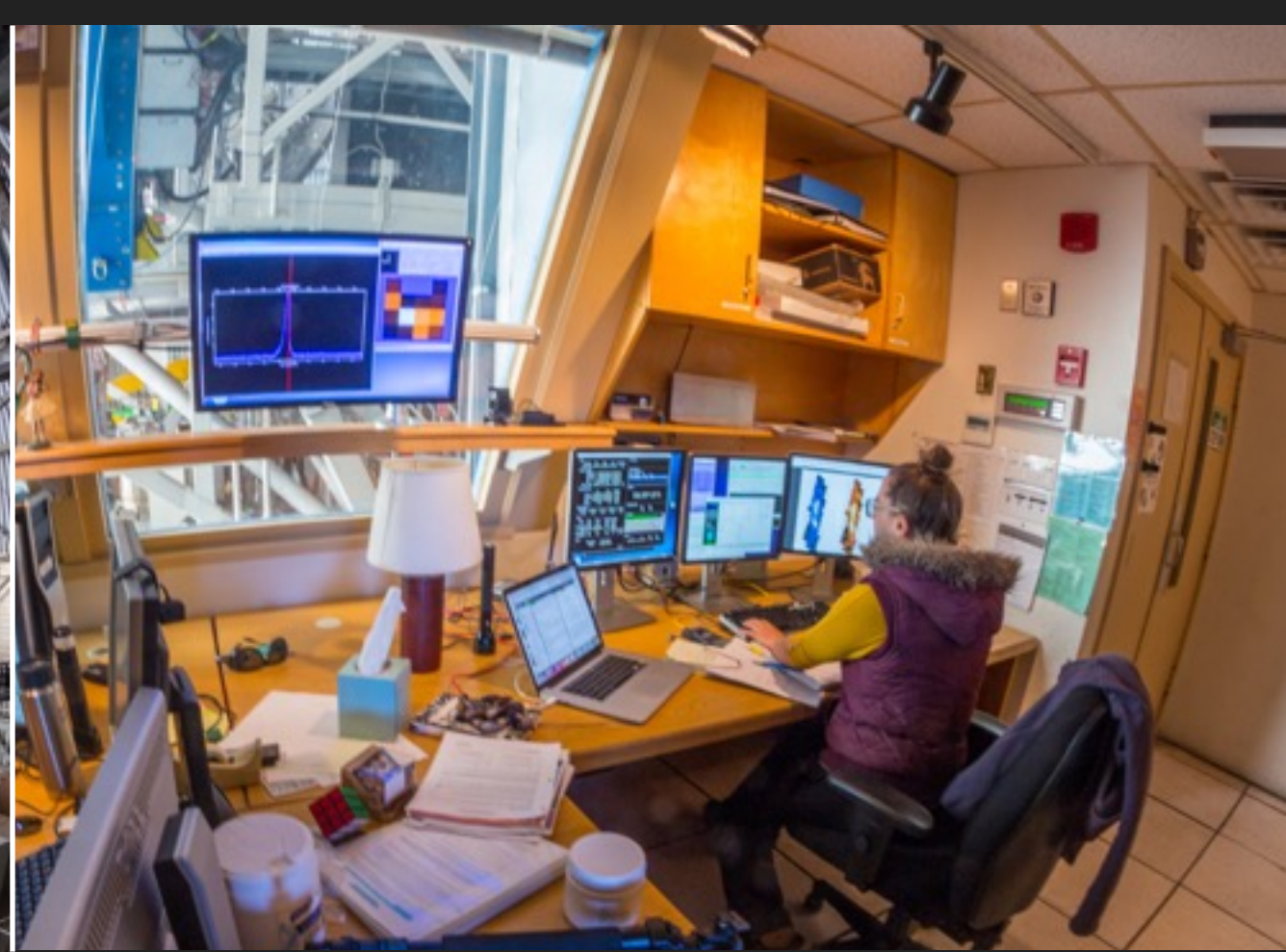


THE DATA – GENERIC REDUCTION

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

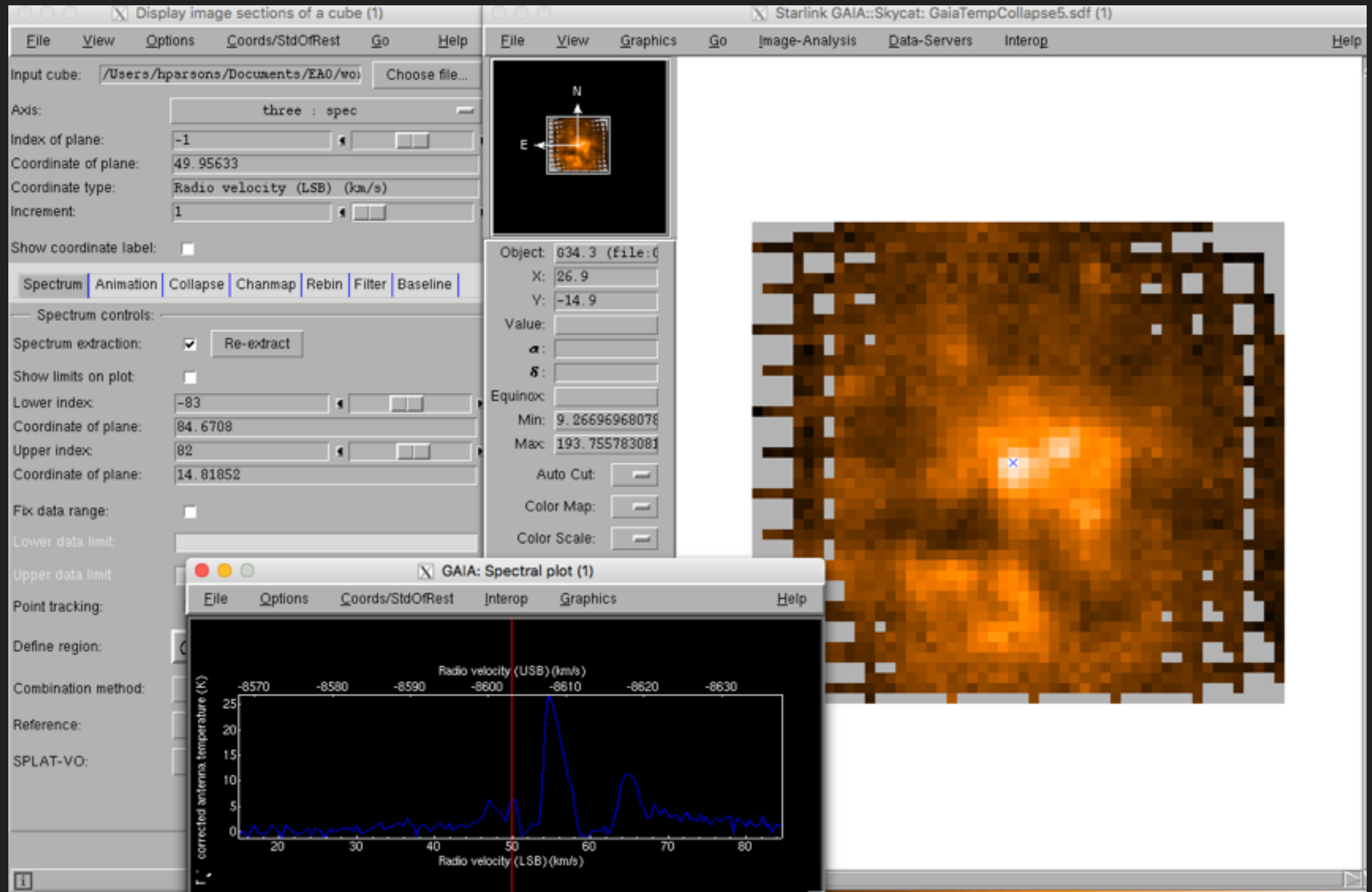
SCIENCE

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

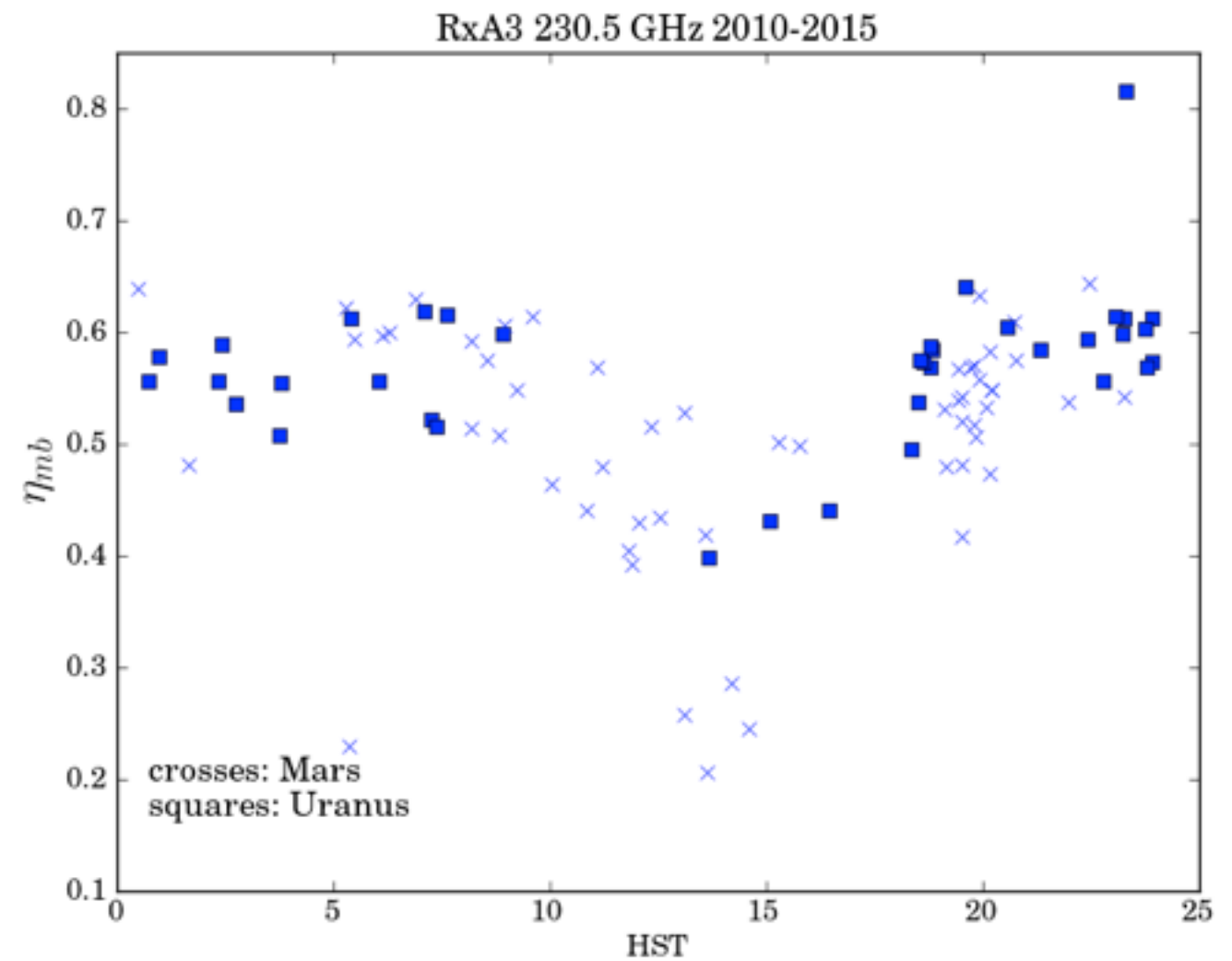
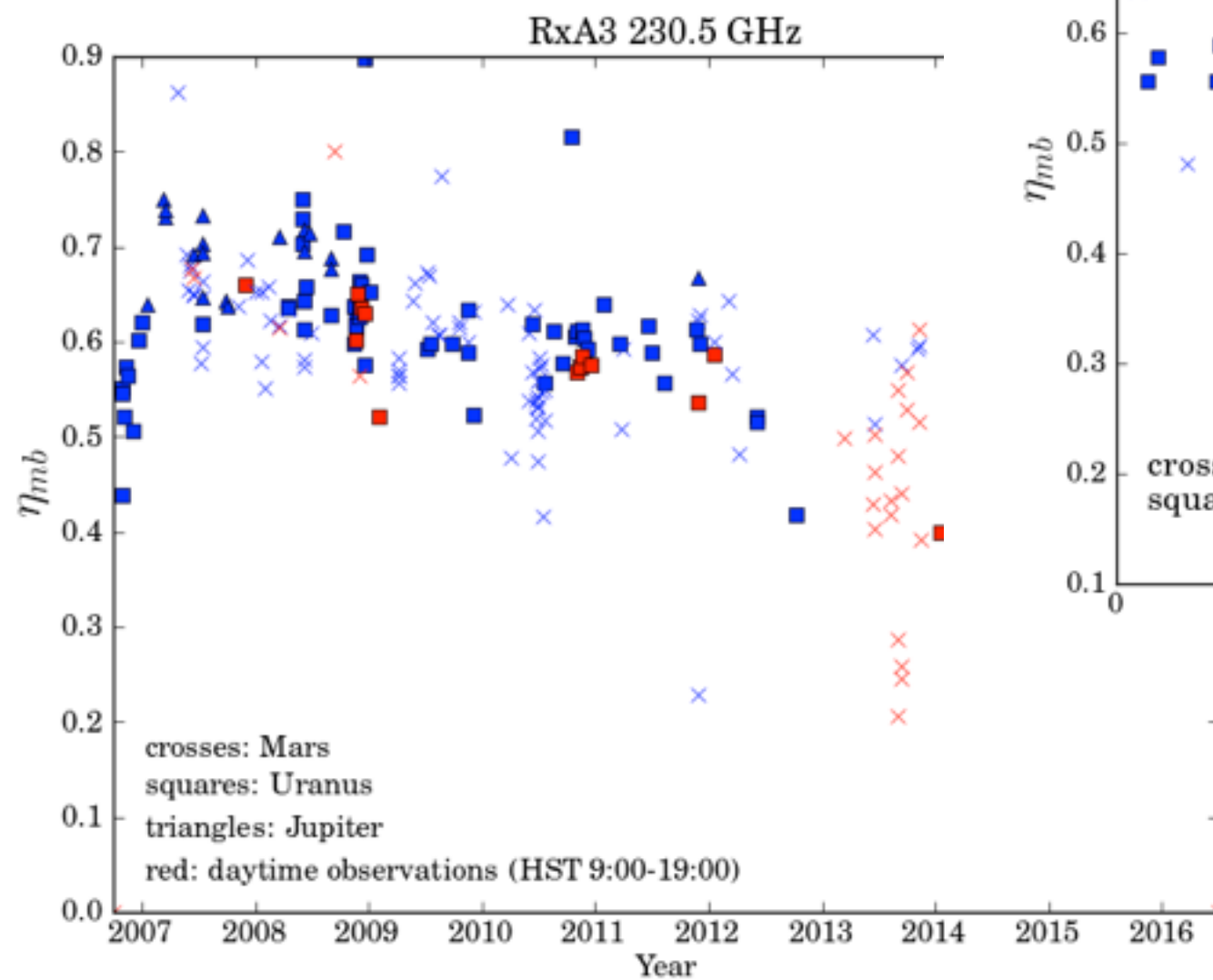
η_{MB} - converting to T_{MB}

- ▶ 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



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 GAlA's tools - catalogs, GAlA3D, contouring...