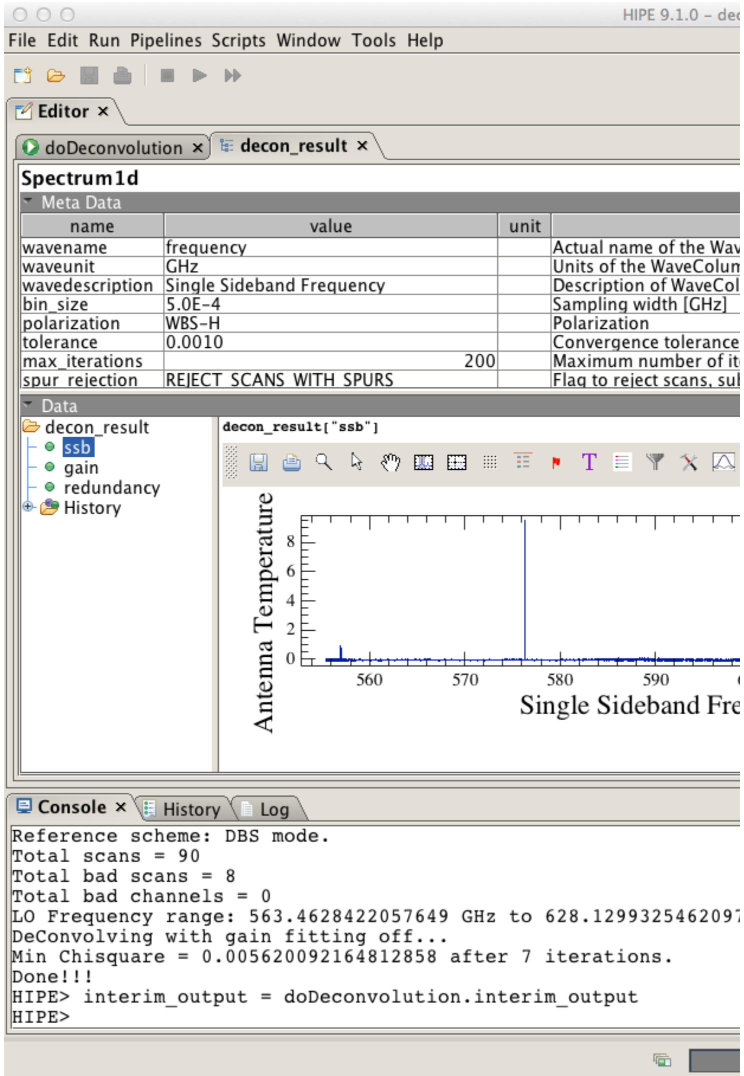


Spectral Scans and Sideband Deconvolution

Outline

- Data collection in the Spectral Scan mode.
- What is sideband deconvolution and why it is necessary for HIFI data?
- General description of the algorithm
- Implementation within HIPE
- Workflow for spectral scans

Heterodyne observations

- Detectors are not able to directly measure flux at the frequencies of interest. But by mixing the signal from the sky with a local oscillator, we `downconvert' the frequency.

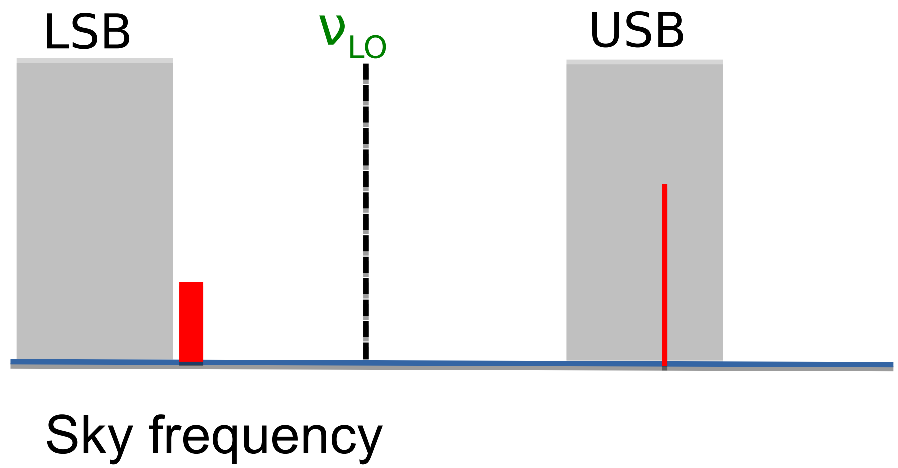
- $\cos(\omega)\cos(\nu_{LO})=0.5[\cos(\omega-\nu LO)+\cos(\omega+\nu LO)]$

- When ω is the entire, unfiltered sky frequency, you end up being sensitive to TWO bandpasses. ($\cos(\nu) = \cos(-\nu)$)

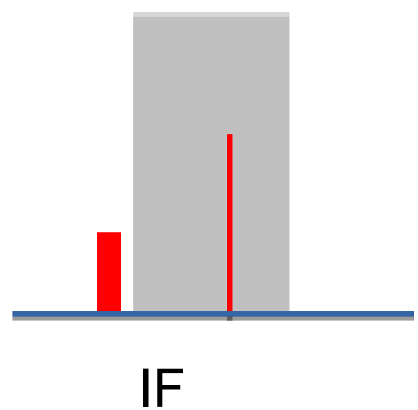
Related problem: How to observe a frequency range larger than the bandpass of the instrument?

Heterodyne observations

What is being measured ->

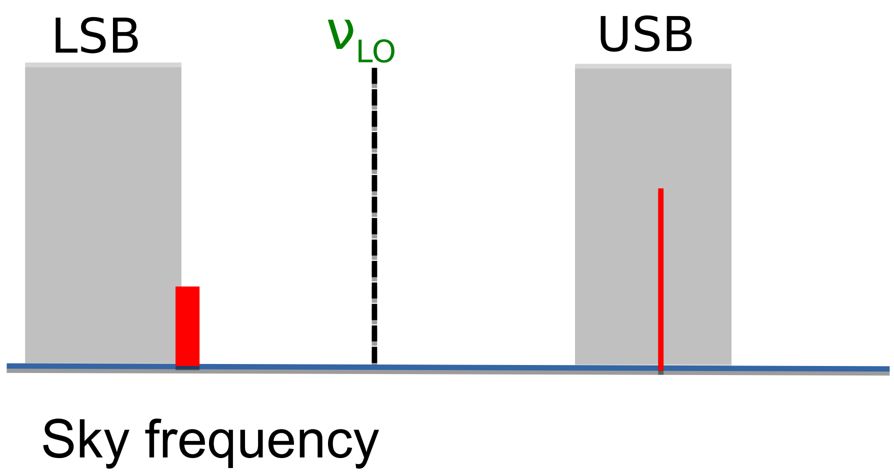


How it looks when collected->

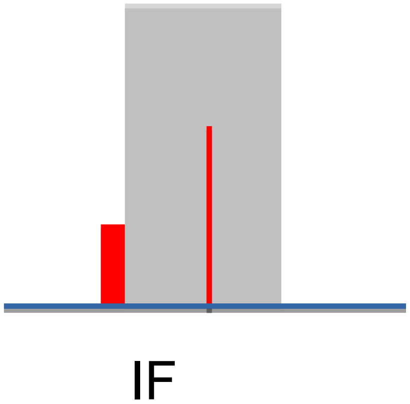


Heterodyne observations

What is being measured ->

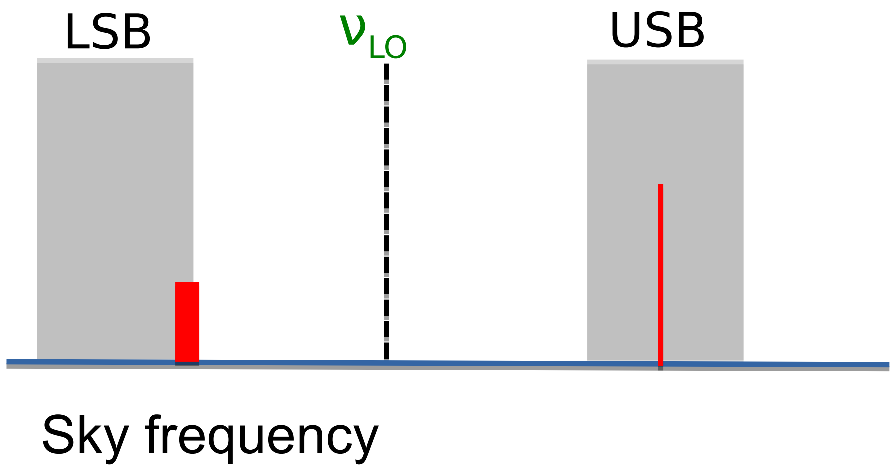


How it looks when collected->

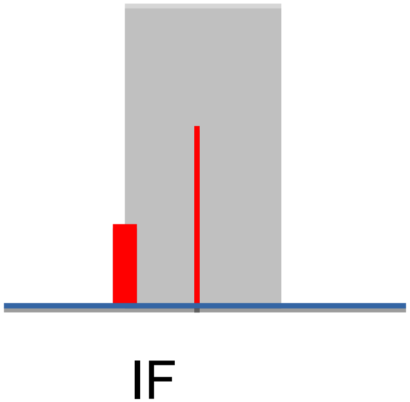


Heterodyne observations

What is being measured ->

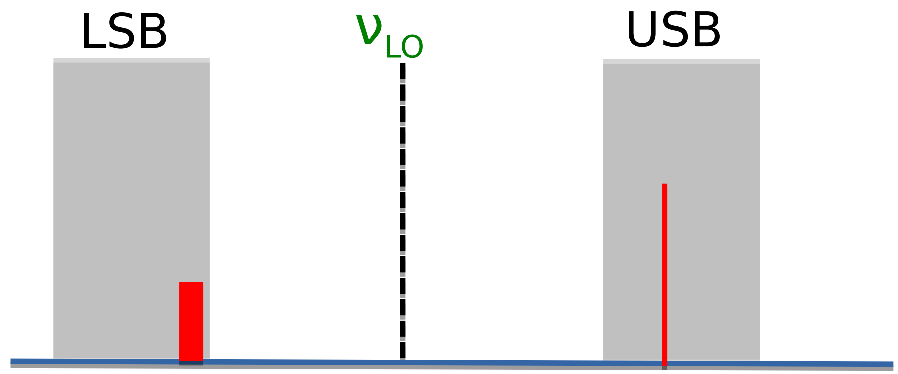


How it looks when collected->



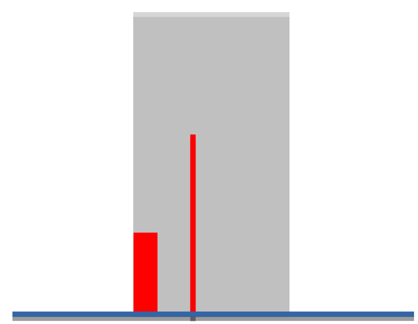
Heterodyne observations

What is being measured ->



Sky frequency

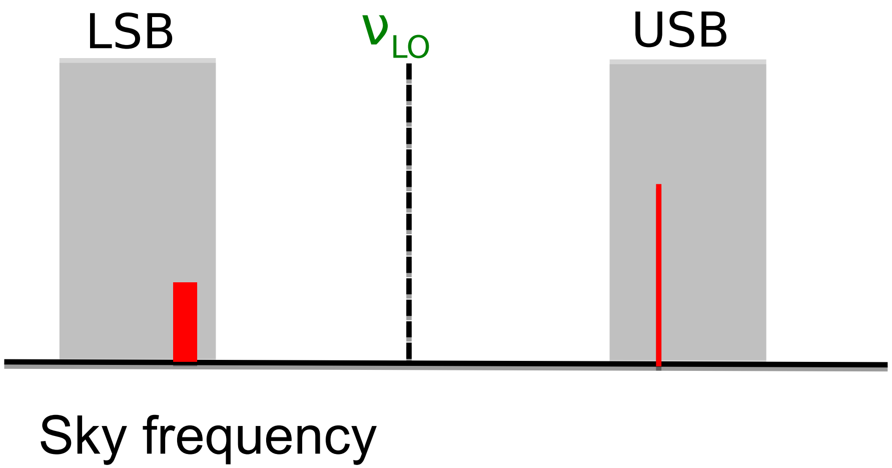
How it looks when collected->



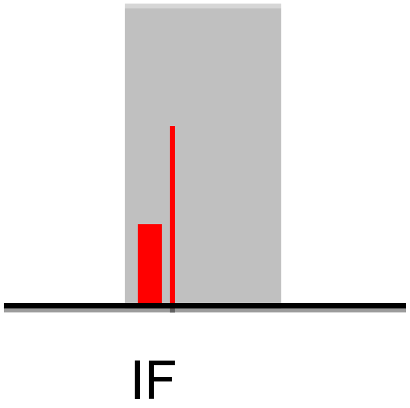
IF

Heterodyne observations

What is being measured ->

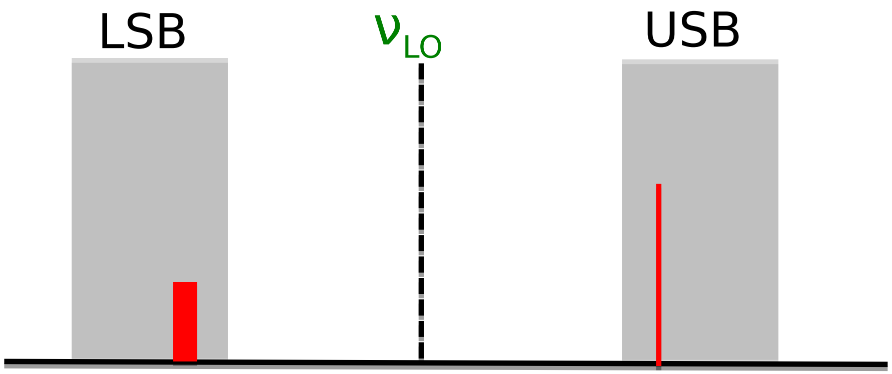


How it looks when collected->



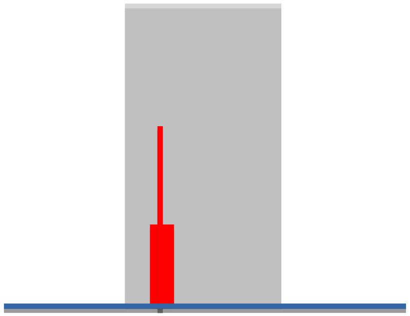
Heterodyne observations

What is being measured ->



Sky frequency

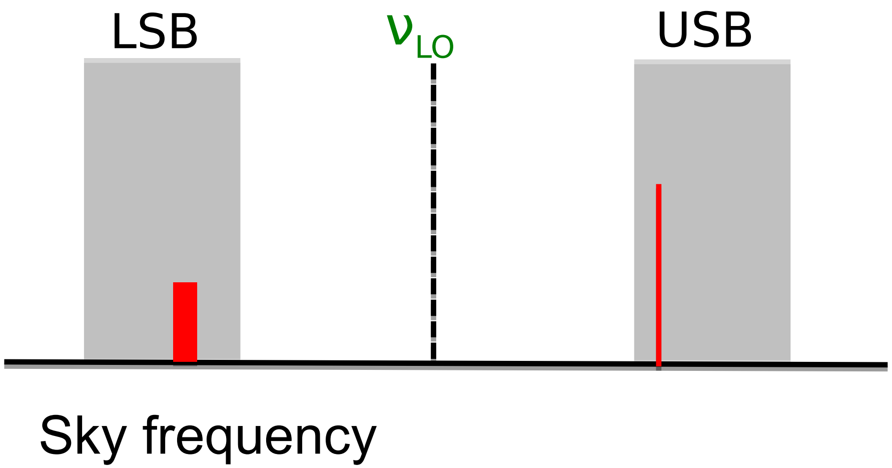
How it looks when collected->



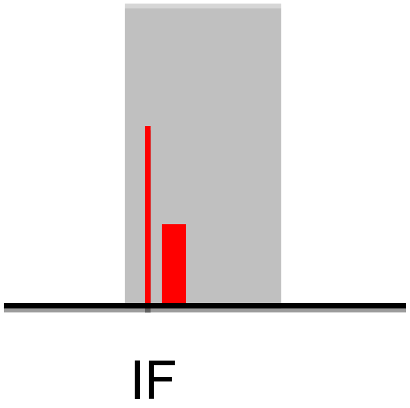
IF

Heterodyne observations

What is being measured ->

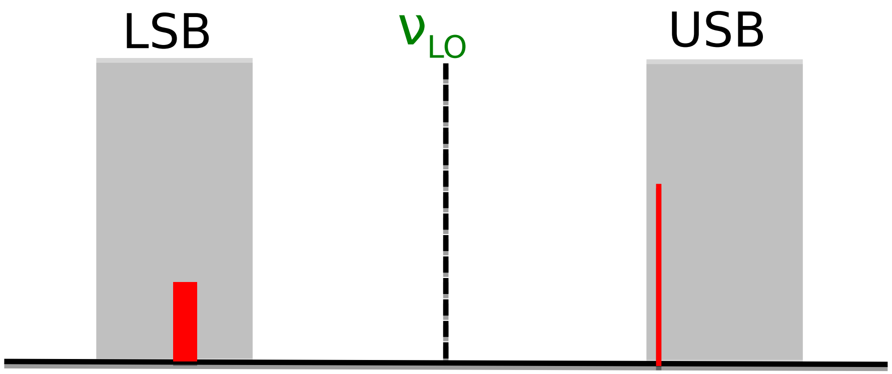


How it looks when collected->



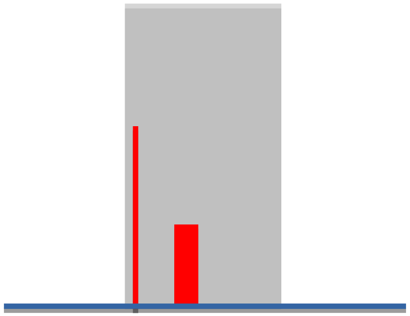
Heterodyne observations

What is being measured ->



Sky frequency

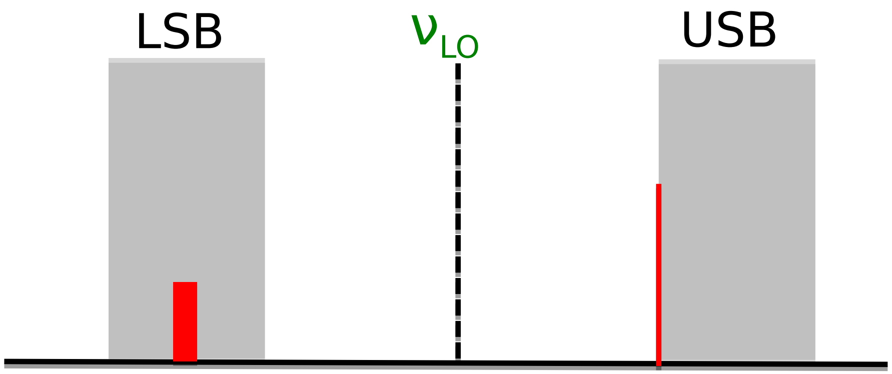
How it looks when collected->



IF

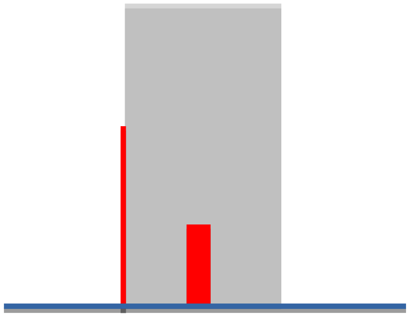
Heterodyne observations

What is being measured ->



Sky frequency

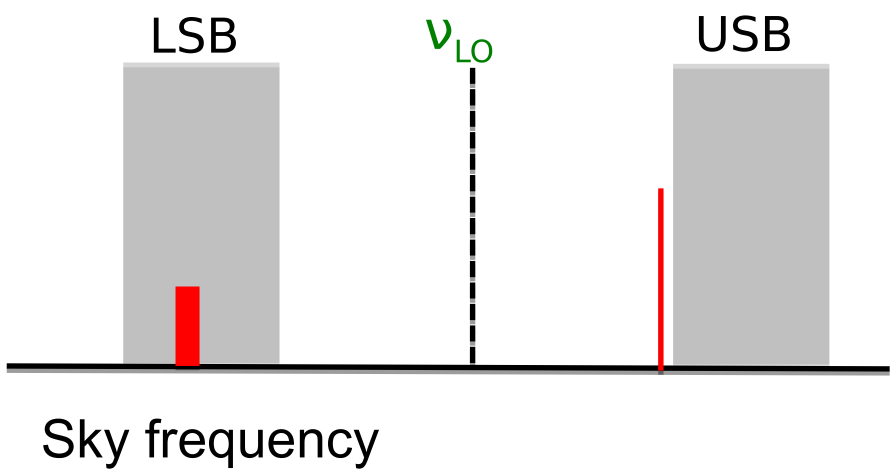
How it looks when collected->



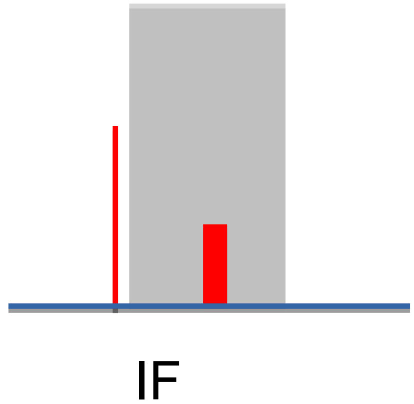
IF

Heterodyne observations

What is being measured ->

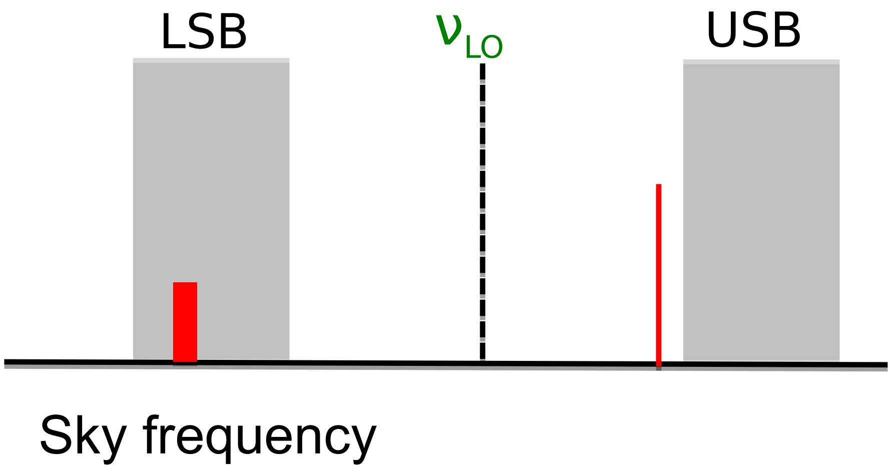


How it looks when collected->

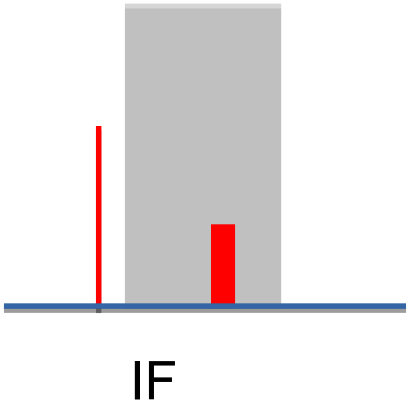


Heterodyne observations

What is being measured ->

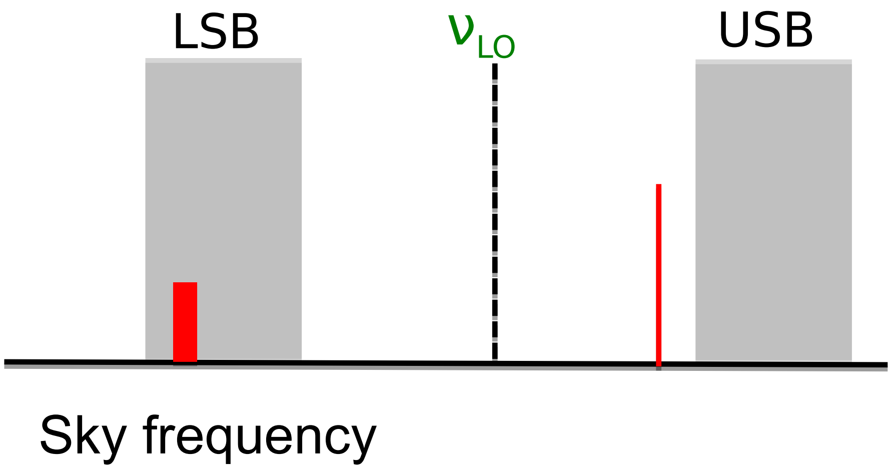


How it looks when collected->

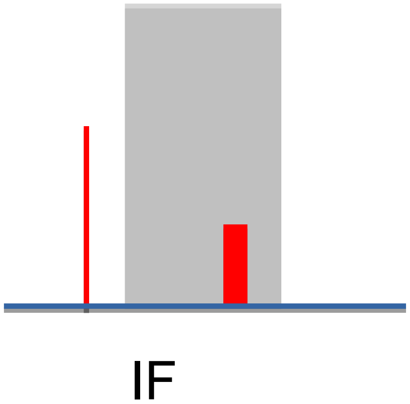


Heterodyne observations

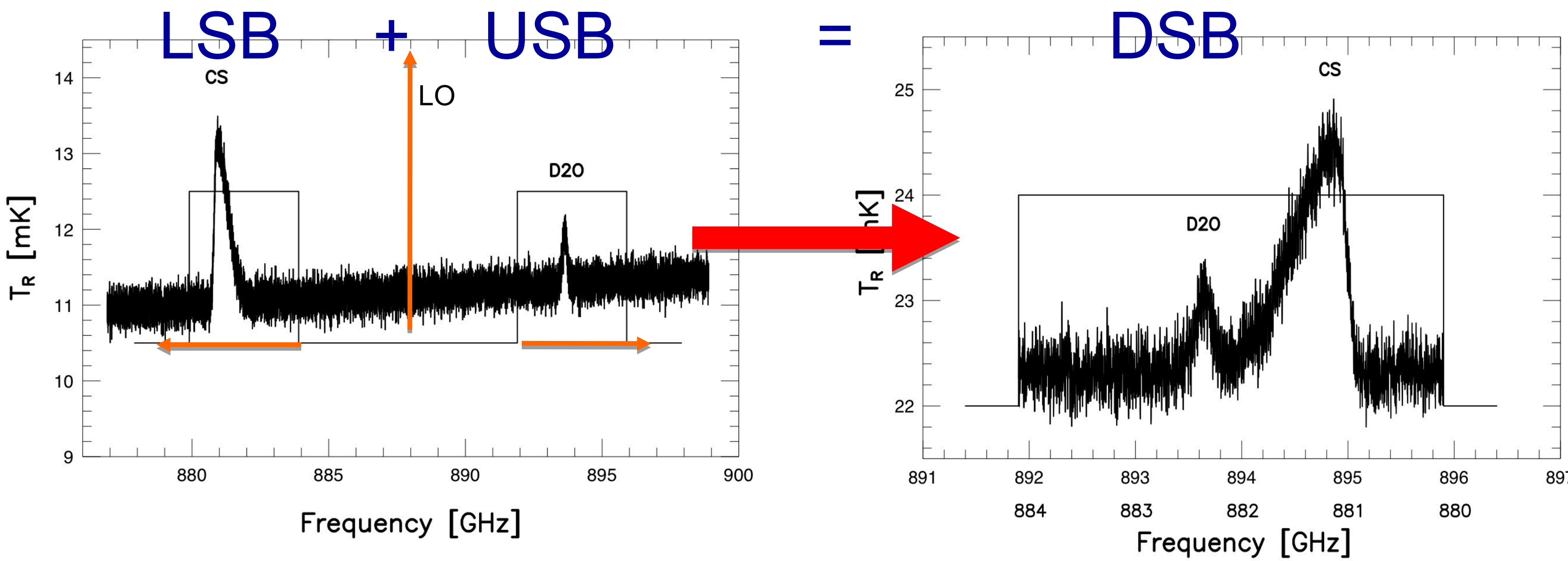
What is being measured ->



How it looks when collected->



Heterodyne observations



- Lower sideband spectrum is reversed and added
- Two frequency scales result in the DSB result
- The lines may blend but they can be recovered
- The continuum levels add (double) in the DSB
- The continuum slope is flattened but may be recovered (deconvolved)
- The noise adds in quadrature , increasing as sqrt(2)

Sideband Deconvolution

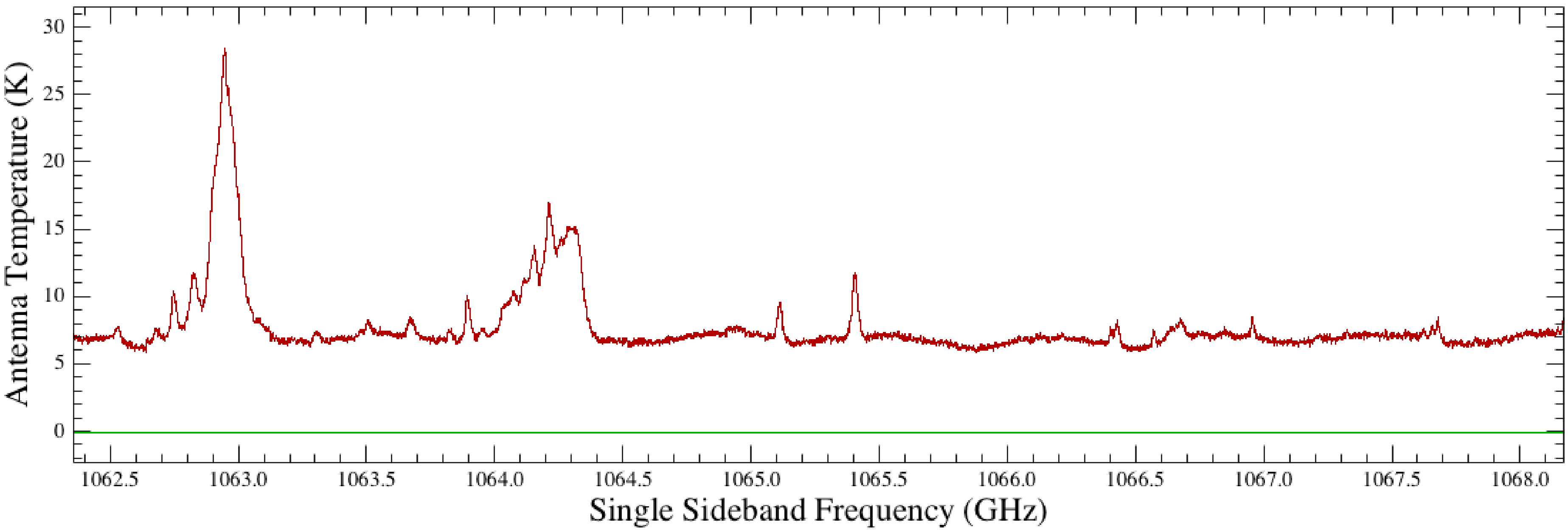
- The problem is the following: Given a collection of double sideband data taken over several LO tunings, how do we recover the original ‘sky’ spectrum?
- Comito & Schilke (2002) provide an algorithm which has been successfully employed with ground based heterodynes.
- Has been implemented in CLASS + X-CLASS (Fortran based) but was converted to JAVA for use within HIPE. Upgrades to the algorithm have been almost exclusively within HIPE.

Deconvolution Algorithm

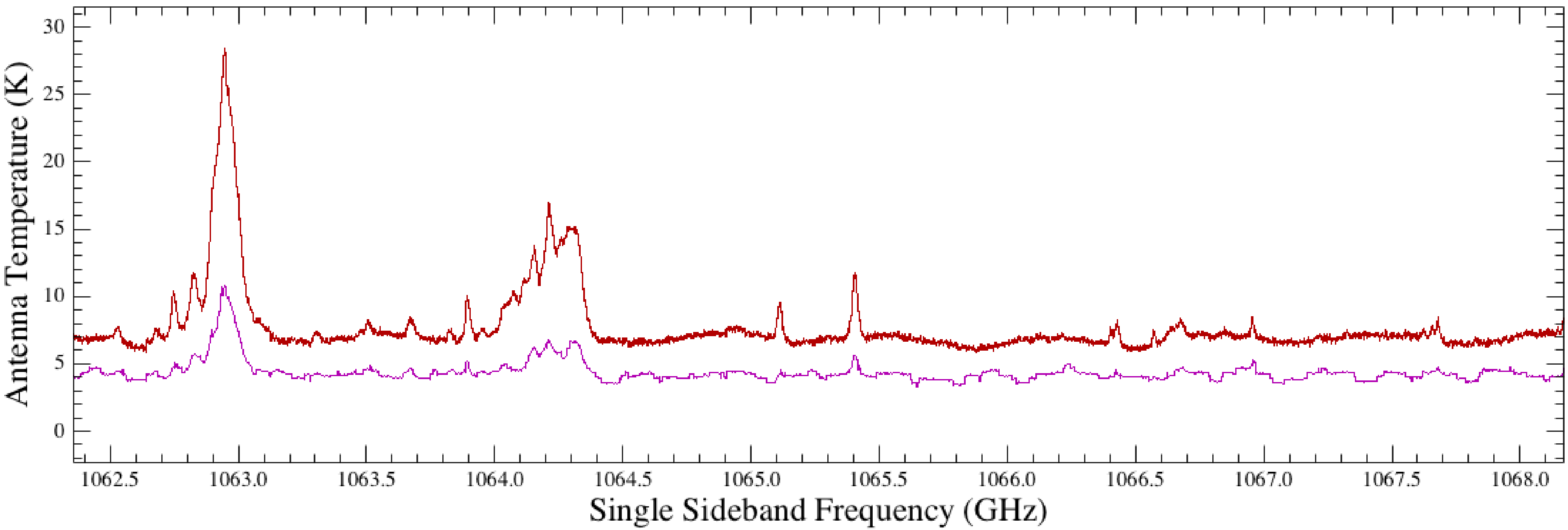
- Start with a guess of the answer – a model with no assumptions for the SSB spectrum – flat
- "Observe it" – using knowledge of the instrument
- compare the observations of the model with the real observations
- compute a chi square and a delta (differential) chi-square
- each model "spectral channel" was in part responsible for some of the chi square change
- follow the slope of the chi square downward (it's partial derivitive w.r.t. the channel flux (and optionally the sideband gain)
- new downward steps always move at right angles to previous ones in the *Conjugate Gradient Method*
- Stop, when solution converges asymptotically, as defined by the "tolerance"

It's iterative

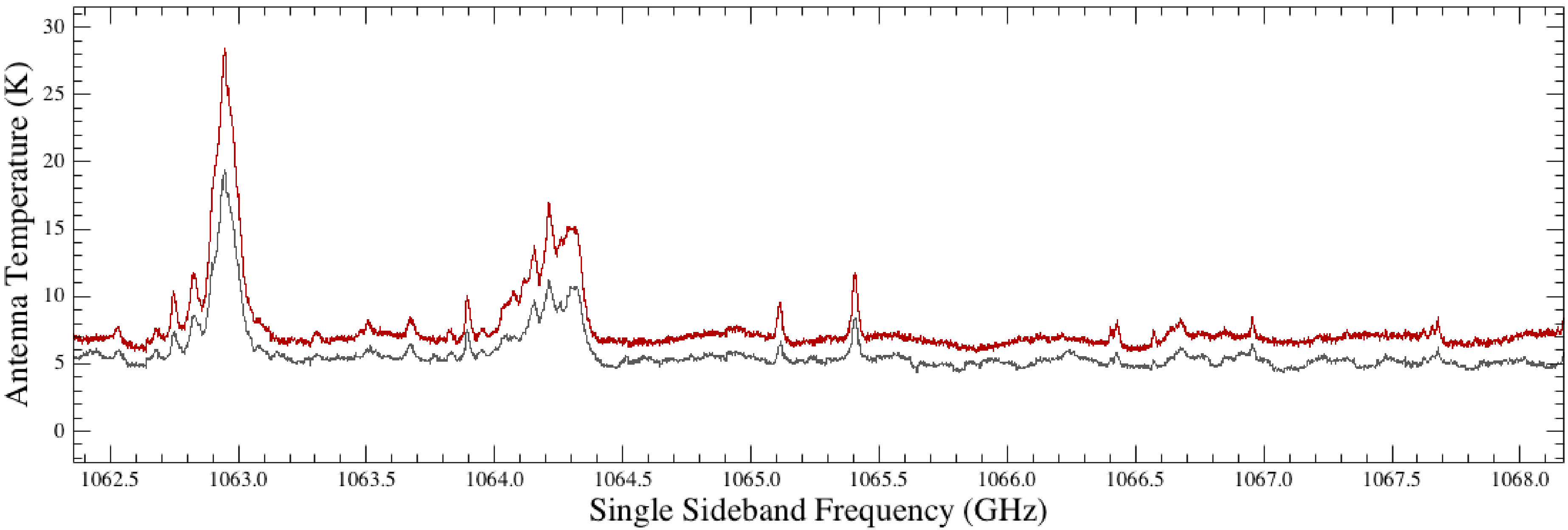
Example: Iteration 0



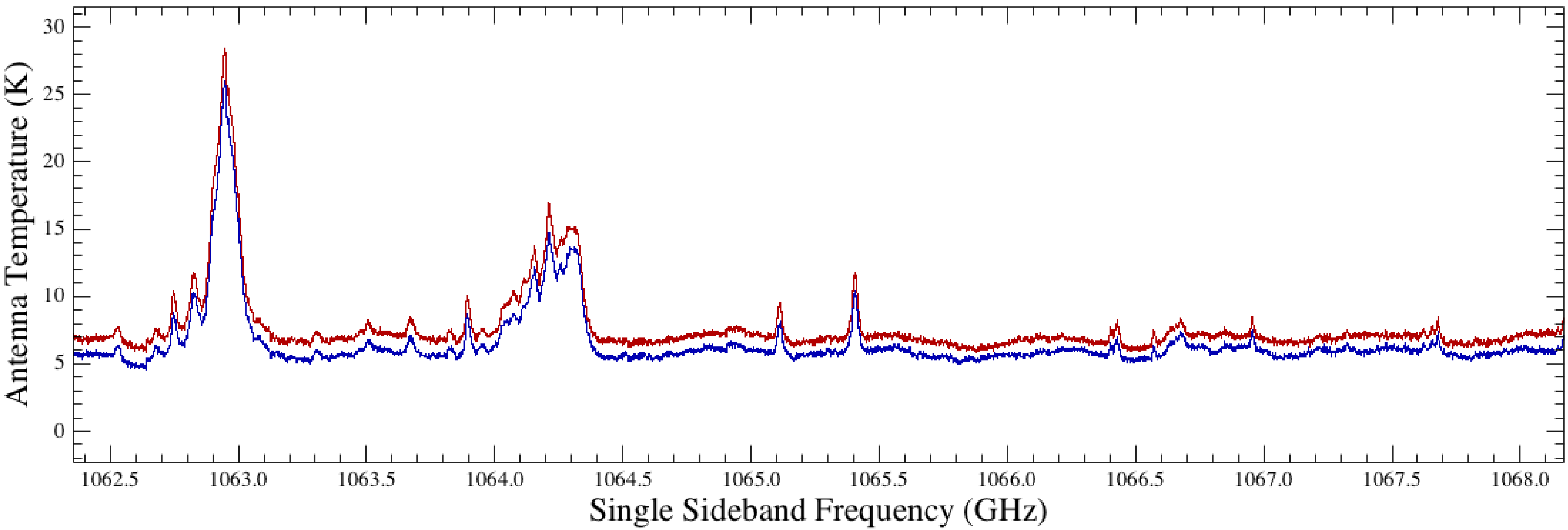
Example: Iteration 1



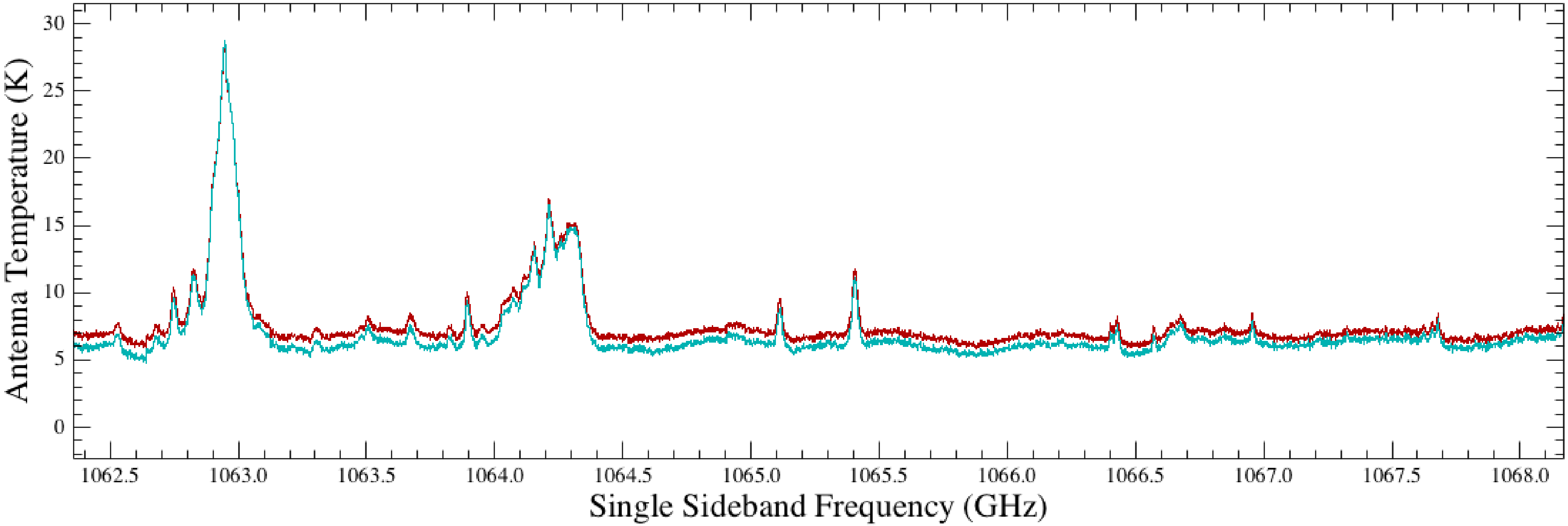
Example: Iteration 2



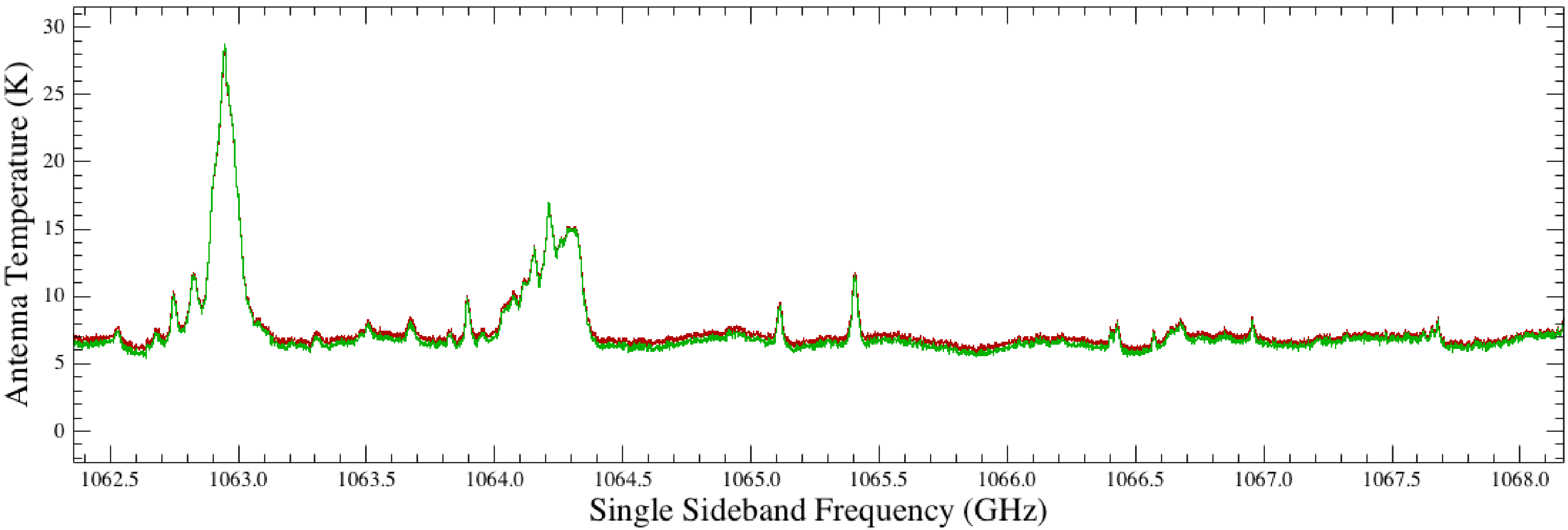
Example: Iteration 3



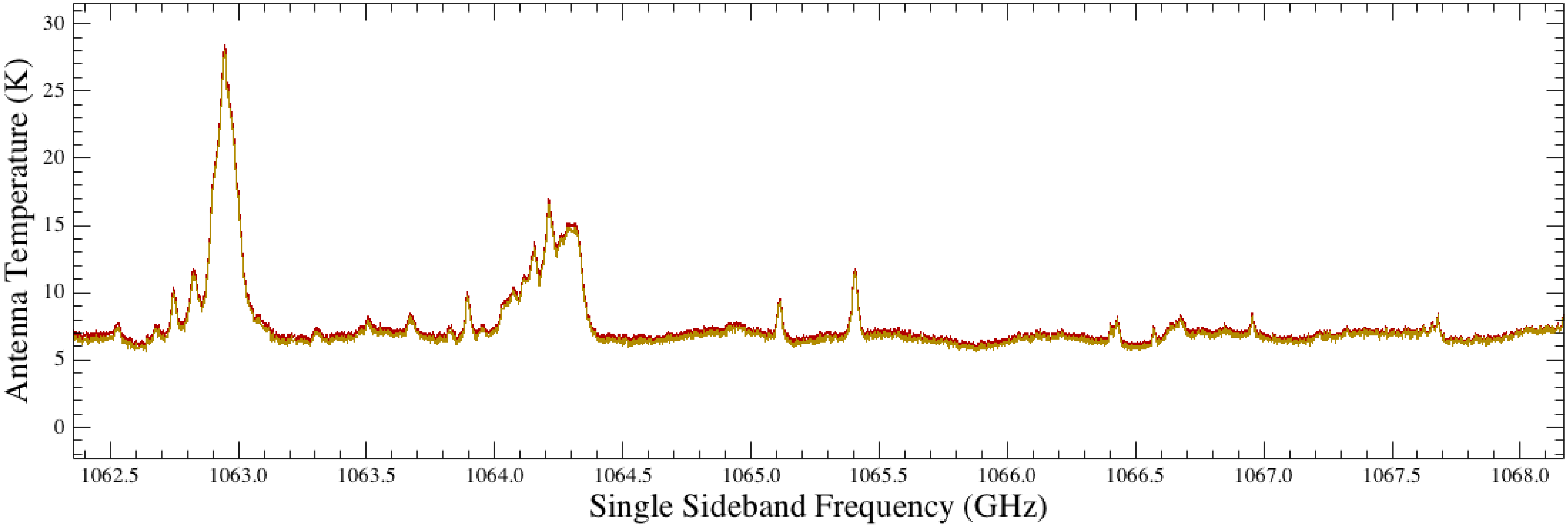
Example: Iteration 4



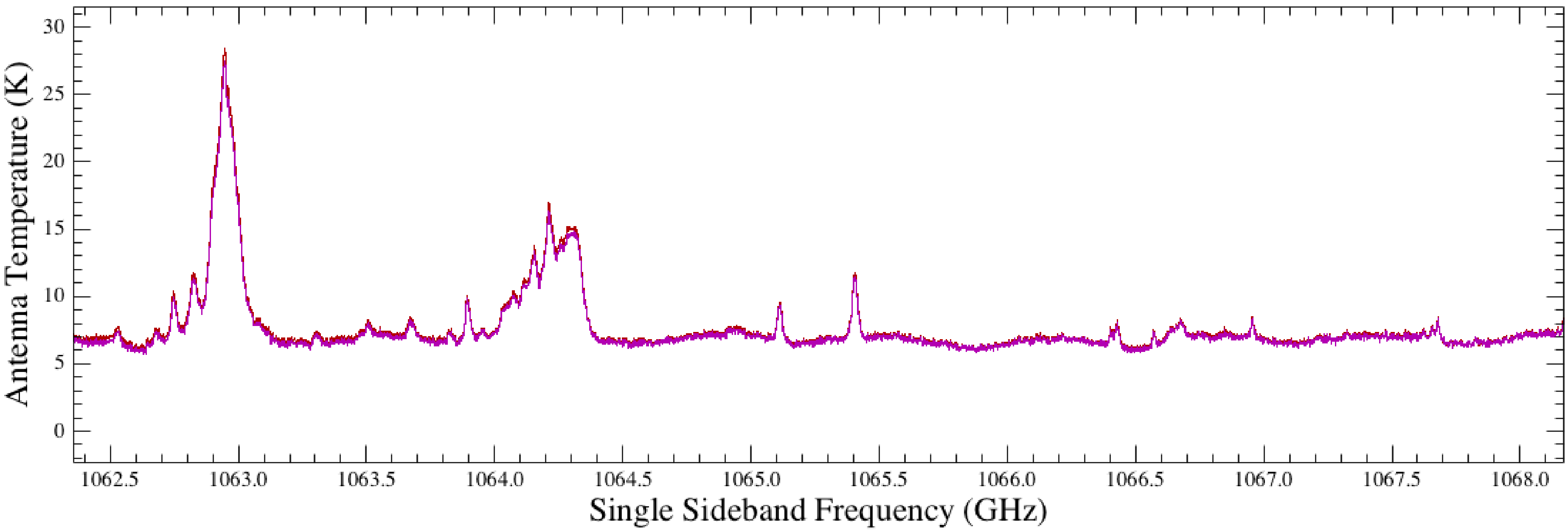
Example: Iteration 5



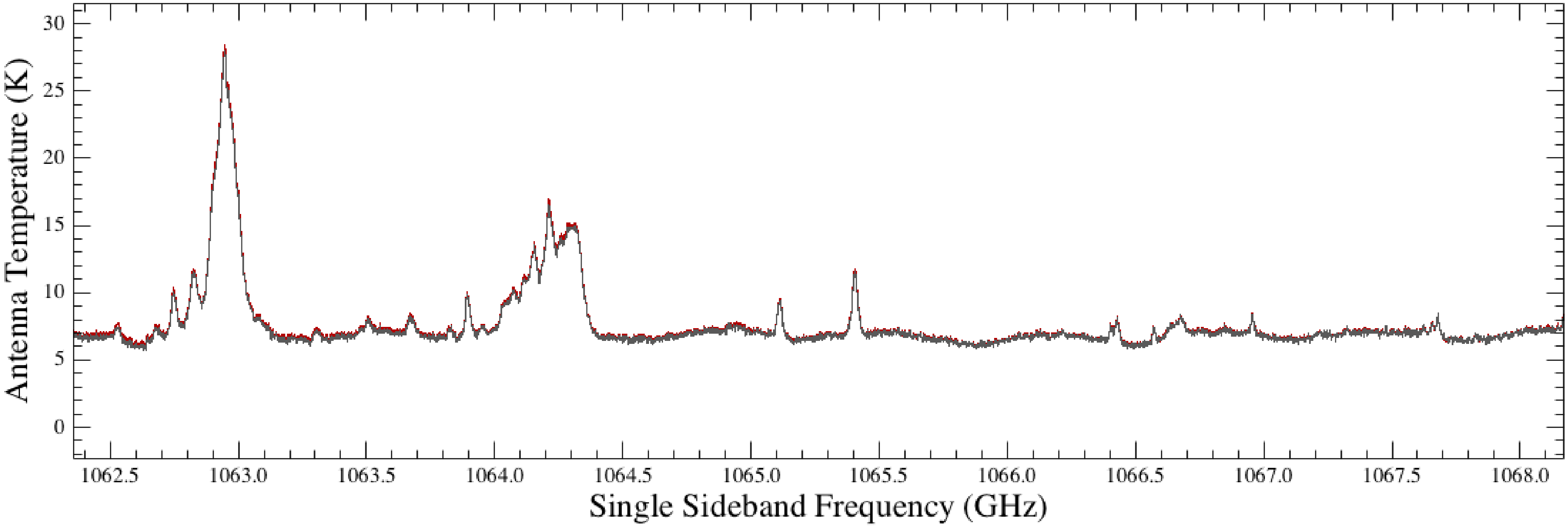
Example: Iteration 6



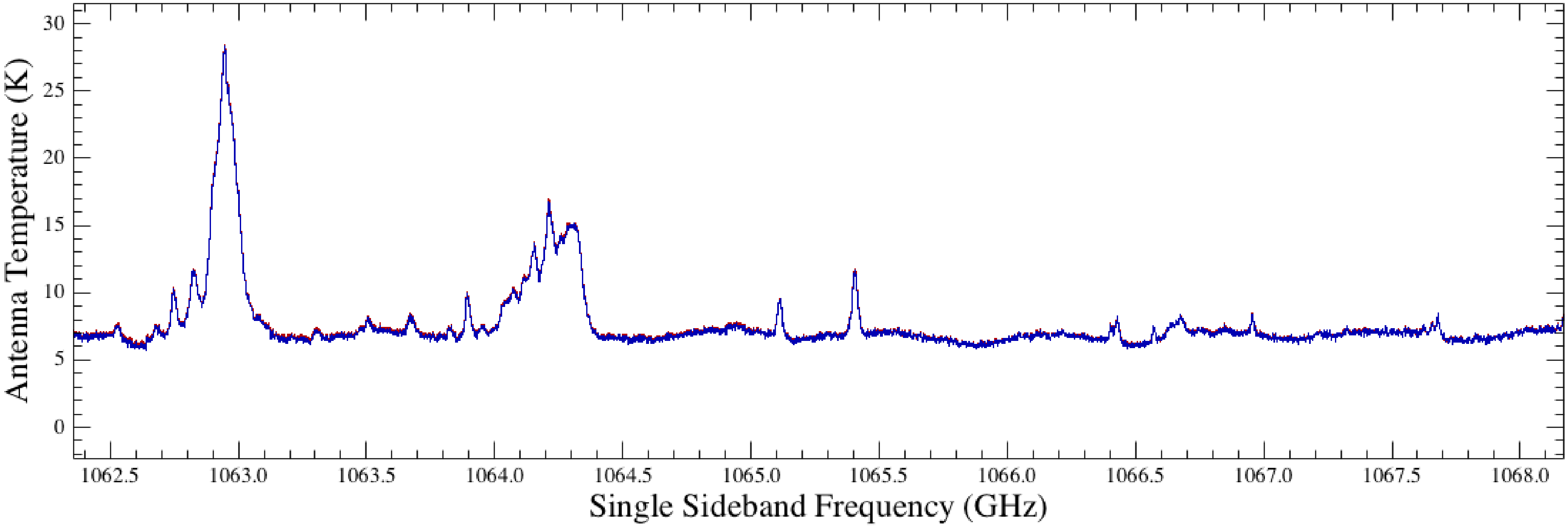
Example: Iteration 7



Example: Iteration 8



Example: Iteration 9

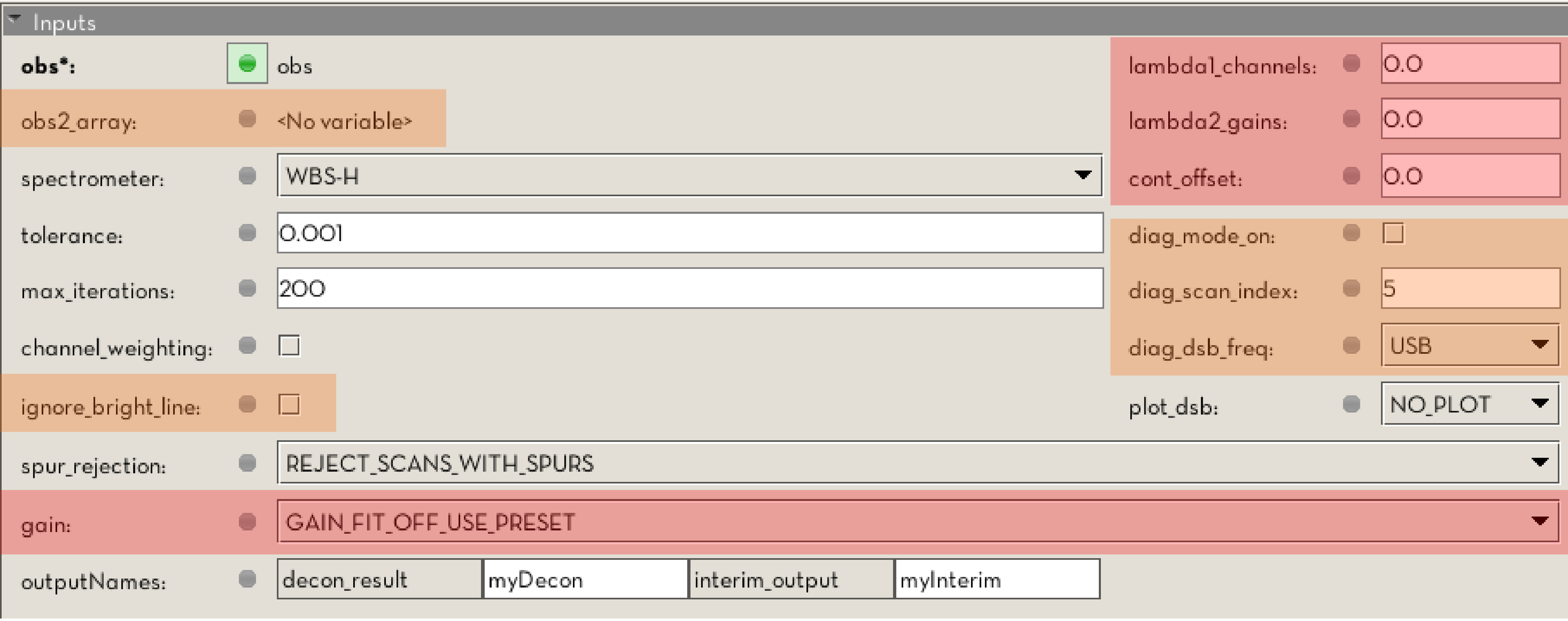


doDeconvolution caveats

- Iteration requires that the data make sense.
  - Sufficient redundancy (~100% of the time)
  - No spurs
  - Compatible baselines
  - No (or well behaved) standing waves

Most work is done before deconvolution

Decon GUI



atures not recommended at all (may be deprecated in a later re

ome features not used very often

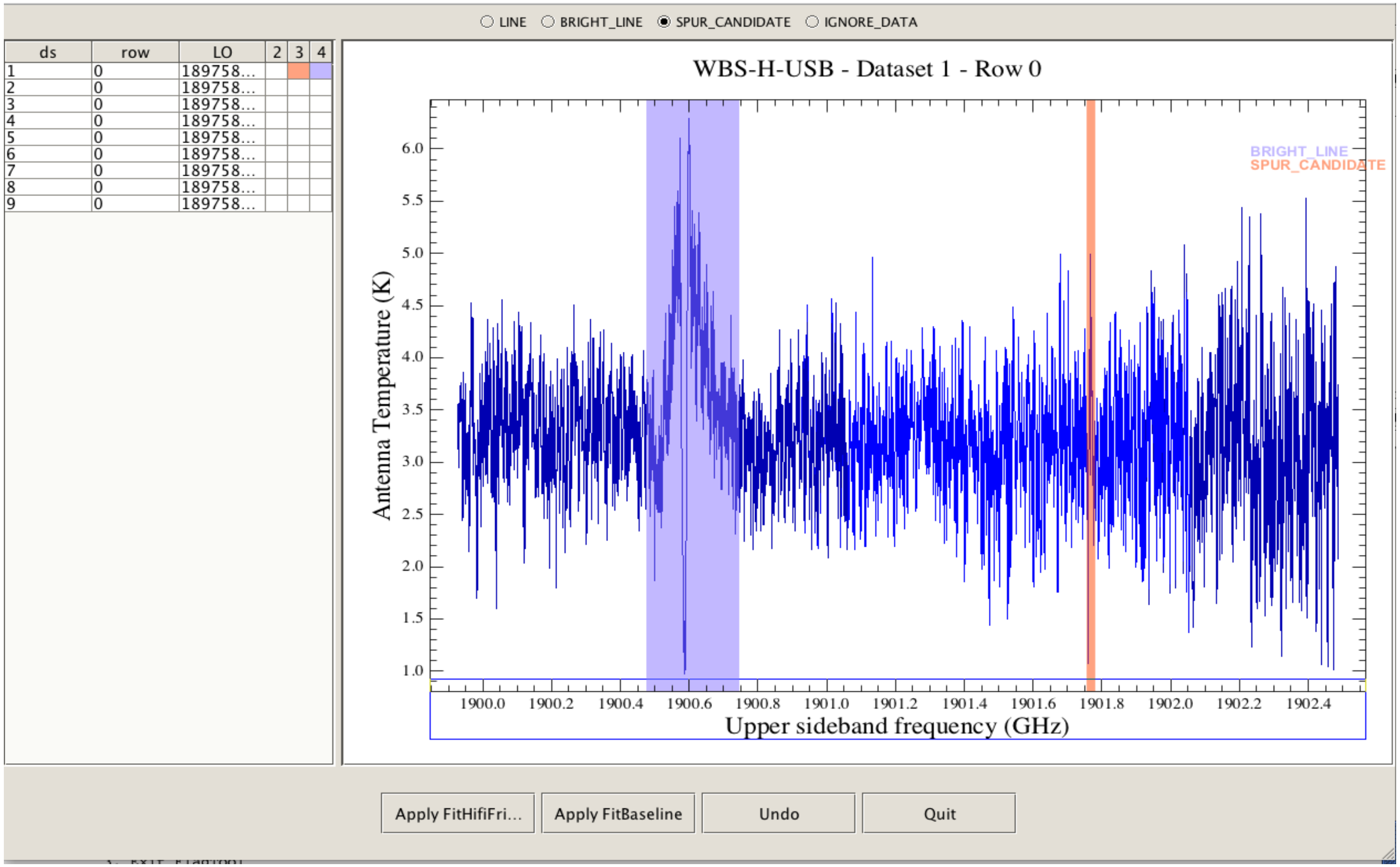
The big-three data cleaning tasks

In order of importance

Artifact	Solution
Spurs, etc	`FlagTool`
Baseline drift	`fitBaseline`
Standing waves	`fitHifiFringe`

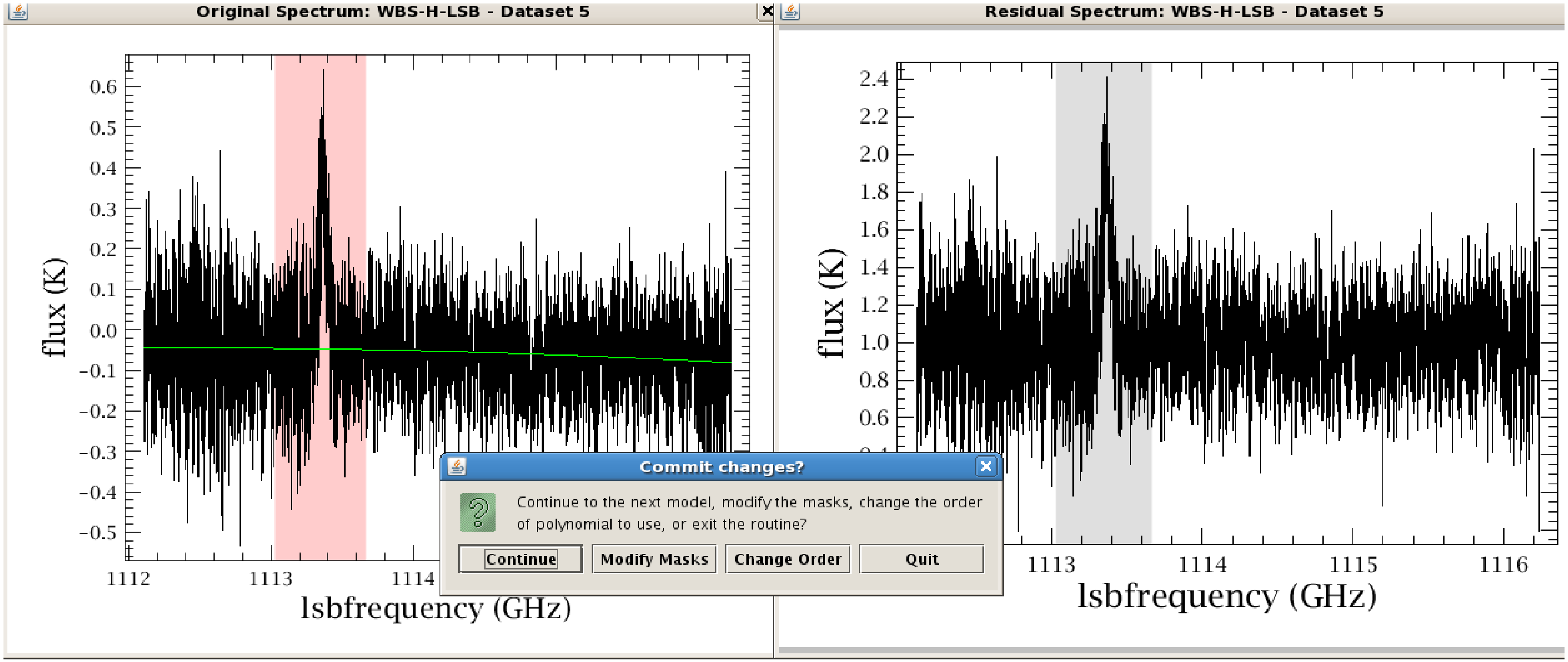
FlagTool

- The workhorse. Can also perform fitBaseline and fitFringe!



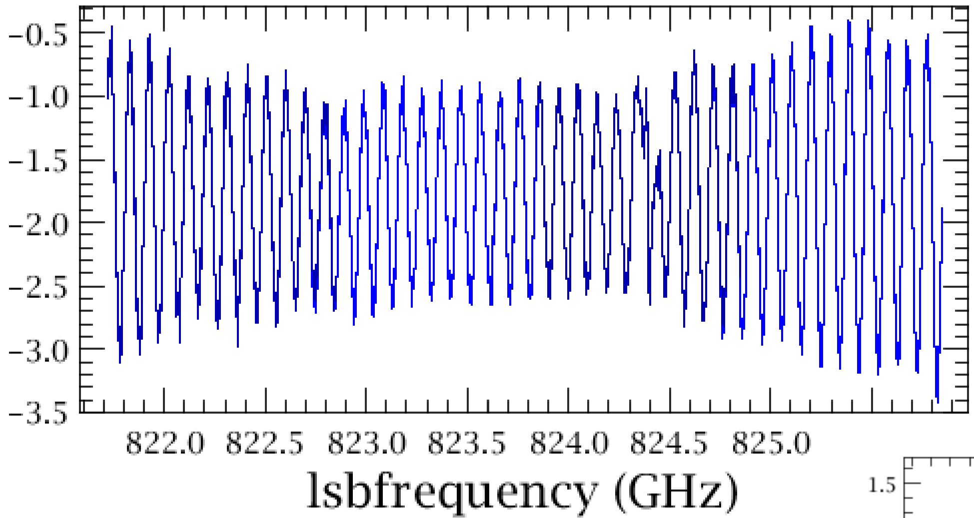
FitBaseline

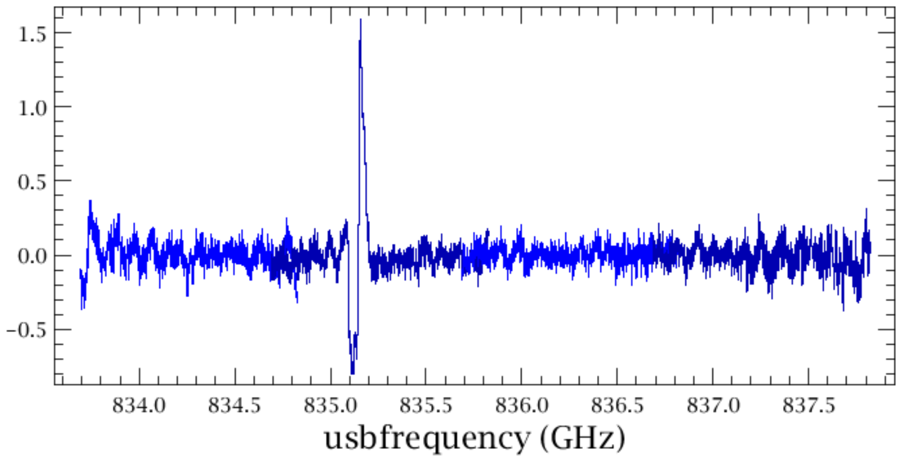
- 'intelligent' baseline subtraction



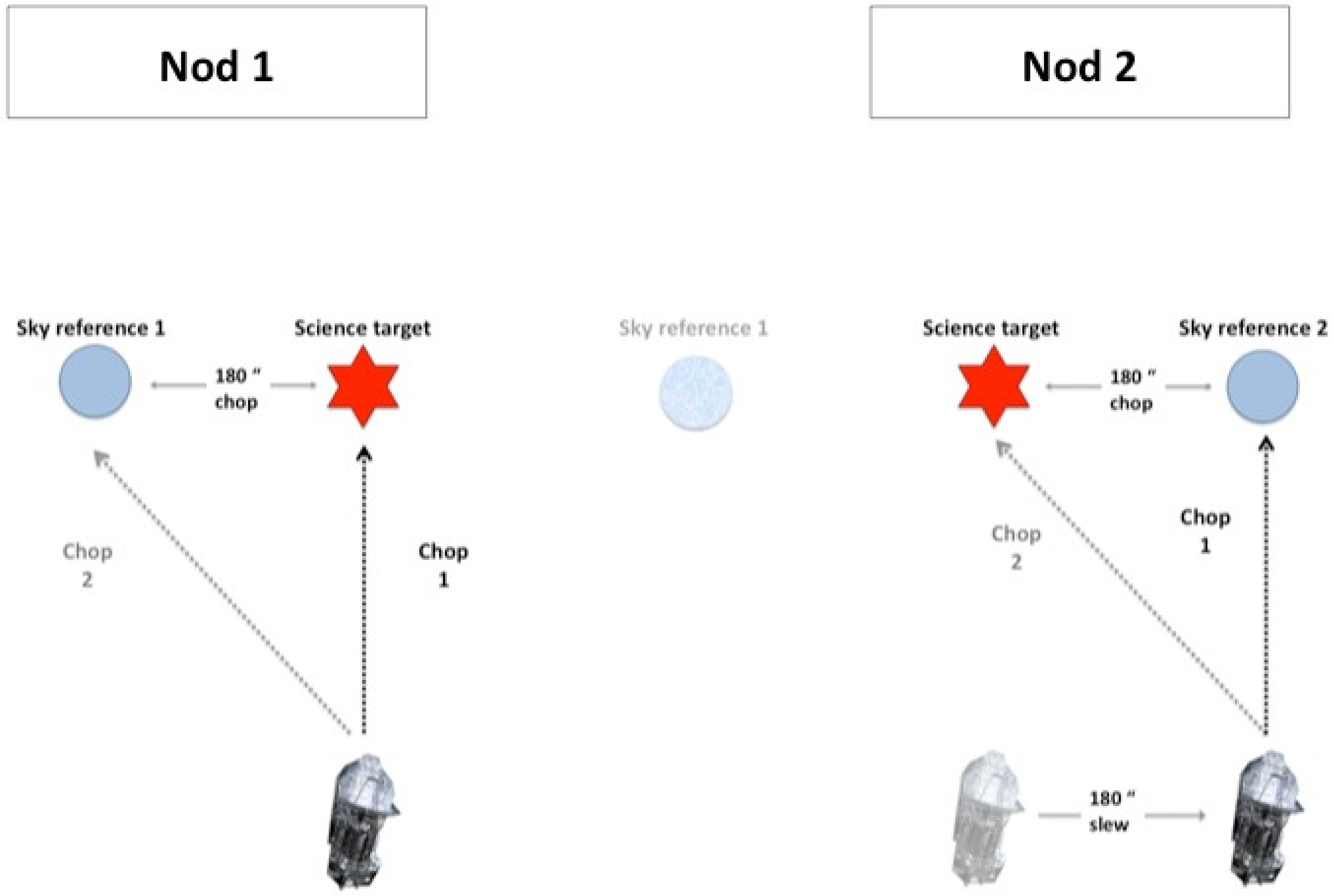
FitHifiFringe

- One approach to standing wave removal



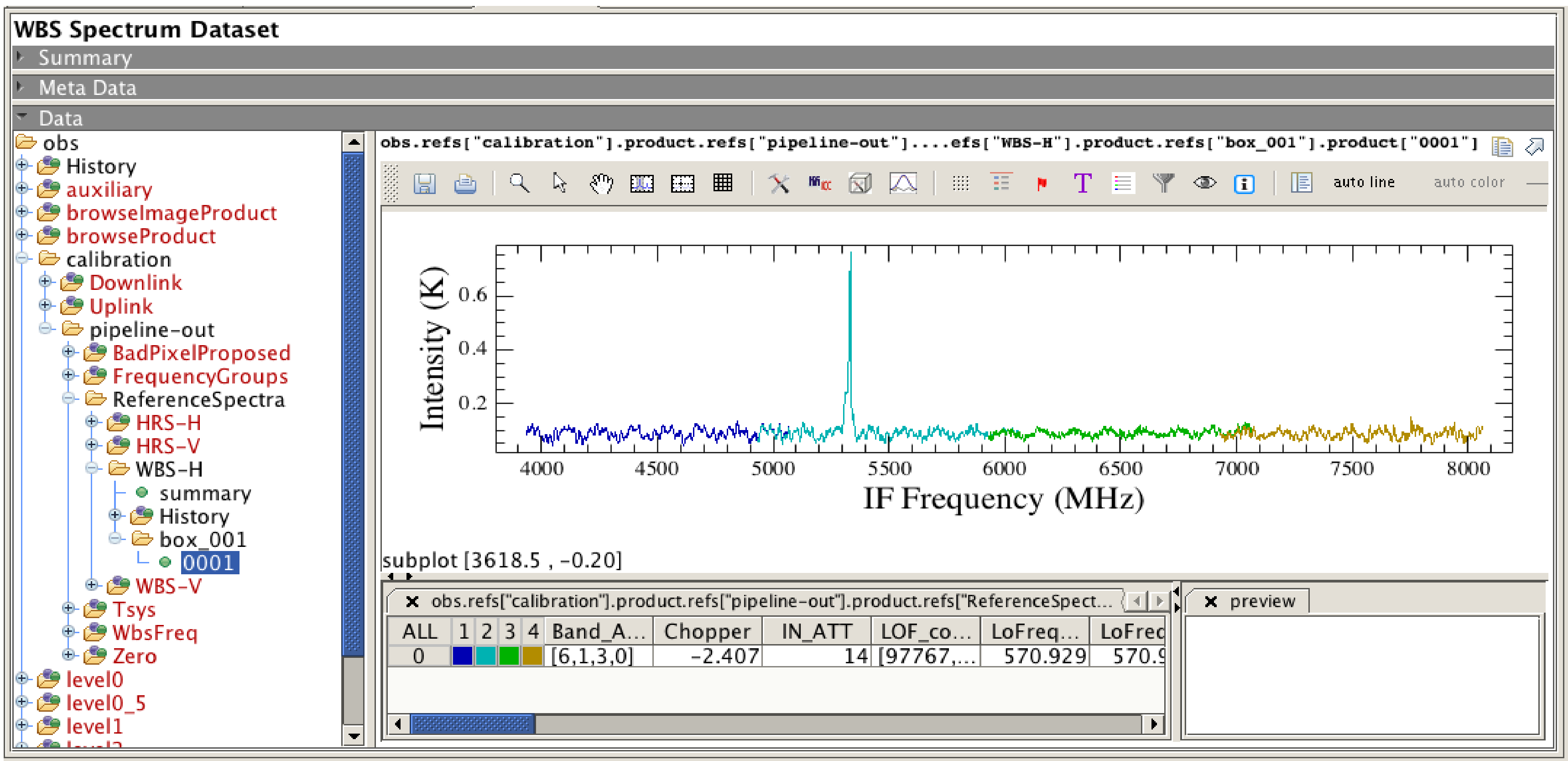


Line contamination (DBS)



Line contamination (DBS)

- DBS is the most common spectral scan mode.
- Chopping onto an area with line flux can happen and should be checked



Expert Reduced Products

- Legacy value products
  - Phase 1: flagging by ICC and KP experts
  - Phase 2: baseline and fringe removal by experts (tentative)
- HIPE 13 processed data (Spring 2015) should have a good fraction of all Spectral Scans carefully flagged.