The ALMA Observing Tool

Cycle-2 Proposal Submission

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Overview

- The OT is used for
  - preparation of ALMA **proposals**
  - the resultant observing **programs** (not covered in this talk)
- Two design goals
  - Detailed knowledge of radio/submm interferometry should not be necessary to apply for ALMA time
  - Expert users and observatory staff should be able to create any kind of observing program
- Solution
  - Scientific requirements are captured in Science Goals (SGs)
  - Technical information contained in Scheduling Blocks (SBs)
  - OT automatically converts Science Goals into Scheduling Blocks

Installation

- The OT is a Java-based application
  - Must be downloaded to one's computer
  - User must have Java 6 or 7 installed
- Java Web Start is recommended
  - One-click installation (from Science Portal)
  - Updates automatically
  - Tarball also available (inc. Linux version with own Java)
- Troubleshooting guide available in Science Portal
  - http://almascience.eso.org/call-for-proposals/observing-tool/troubleshooting

http://www.java.com

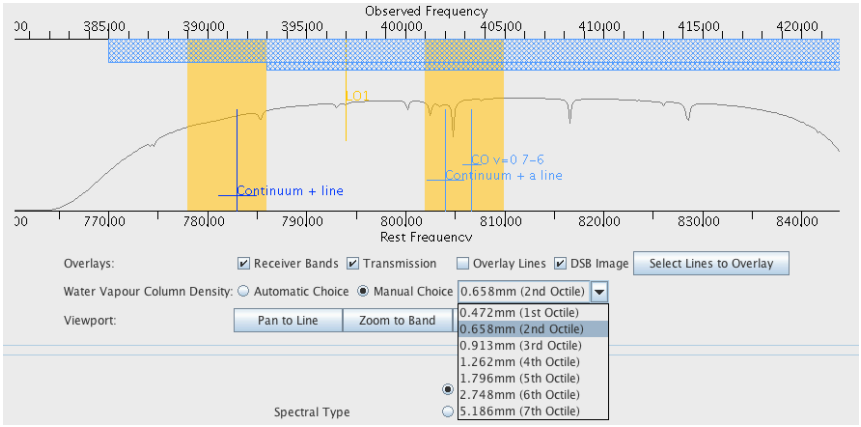
Proposal Creation

- Proposal preparation and submission is referred to as Phase 1
- Include usual proposal details
  - PI and co-I names, abstract, scientific category, keywords, ...
  - Attach scientific justification as PDF
  - This should all be very straightforward
- **Science Goals** describe the scientific requirements
  - Angular resolution, largest angular scale -> required configurations
  - Desired sensitivity, frequency, bandwidth -> required time
- No limit on number of SGs per proposal

Sensitivity request

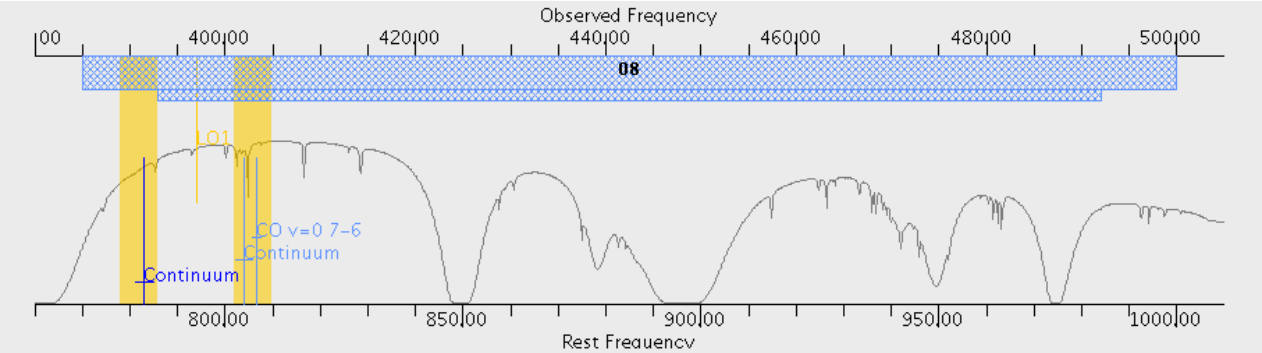
- ALMA users request a sensitivity, not an amount of time
  - Different to most other telescopes
  - Due to large and variable atmospheric absorption
  - ALMA guarantees the requested sensitivity
- SB will be repeated until sensitivity is achieved
  - QA2 checks that this is the case

Precipitable Water Vapour

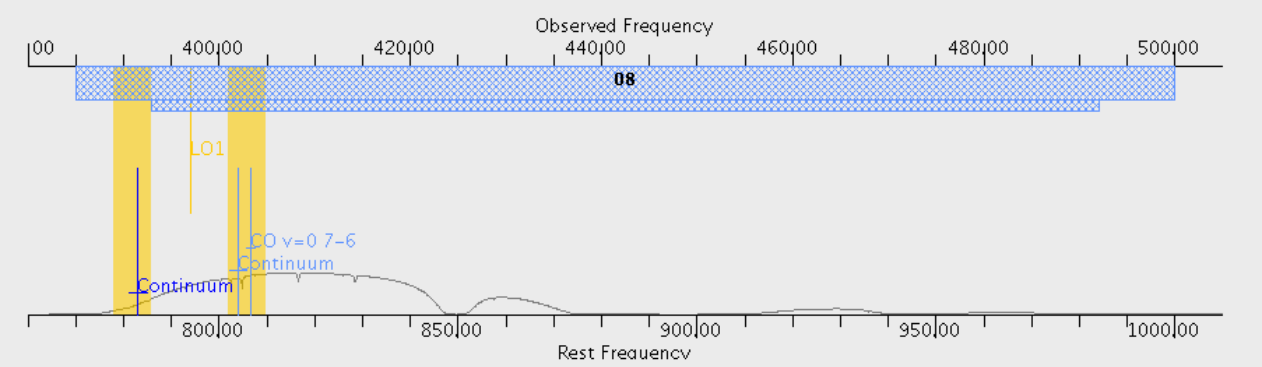


- Water vapour is bad
  - Absorbs astronomical signal
  - Re-radiates, increasing T_{sky}
  - Changes rapidly with time
- Weather characterised using PWV octiles
  - PWV = Precipitable Water Vapour
  - 1st octile: expect PWV ≤ 0.472 mm 12.5% of the time
  - 2nd octile: expect PWV ≤ 0.658 mm 25% of the time, etc.
- OT chooses appropriate octile based on requested frequencies
  - Can be changed, but for comparison only
- SB will be repeated until sensitivity is achieved

Atmospheric Transmission



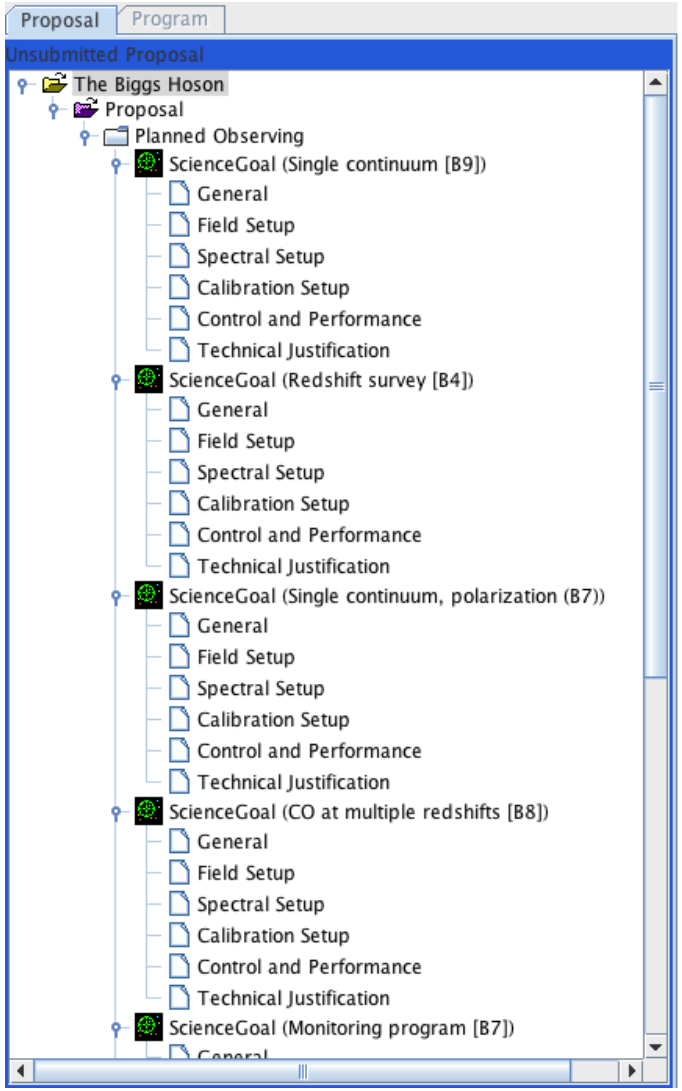
Band 8 in 2nd octile – assumed weather conditions



Band 8 in 7th octile – hopefully never used!

Science Goal

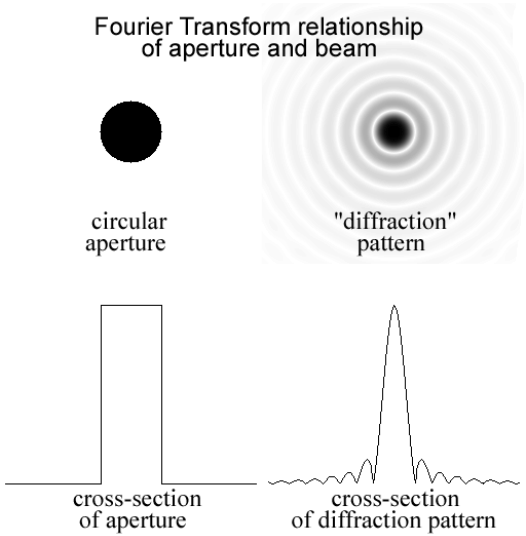
- A Science Goal contains 6 “nodes”
  - *General (optional description)*
  - Field Setup
  - Spectral Setup
  - *Calibration Setup (can probably ignore)*
  - Control and Performance
  - Technical Justification (new!)

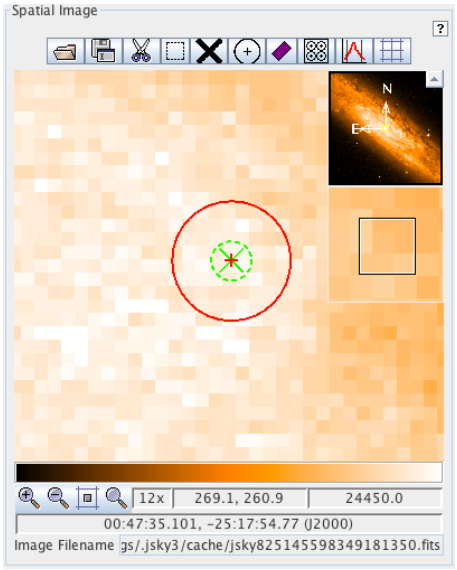


Field Setup

- Each source can be observed as
  - Individual pointings (i.e. ≥1, set manually by user)
    - Pipeline will process separately unless “custom mosaic” ticked
  - 1 Rectangular field
    - OT automatically calculates a 12-m (and 7-m) mosaic pattern
    - Pointings will always be mosaiced together by Pipeline
- Maximum of 150 pointings per Science Goal
- All pointings must lie within 10 degrees of each other

Antenna Beamsize / FOV

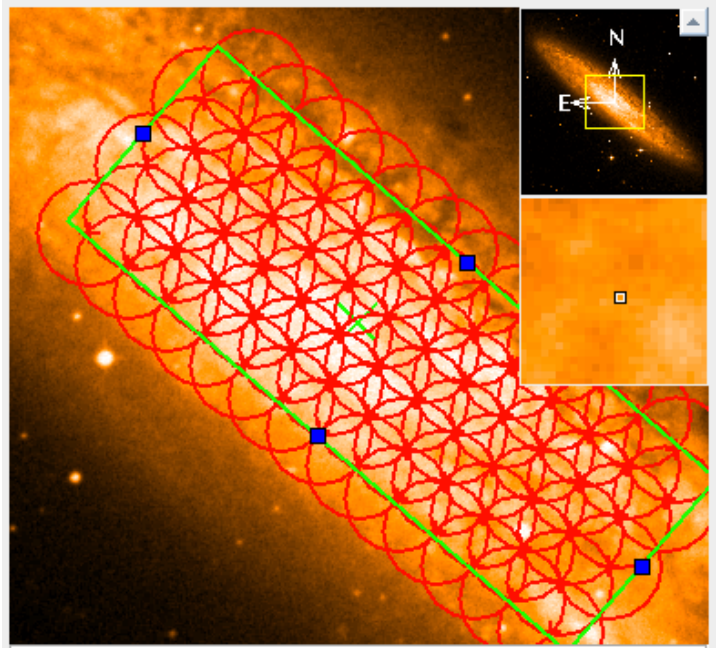




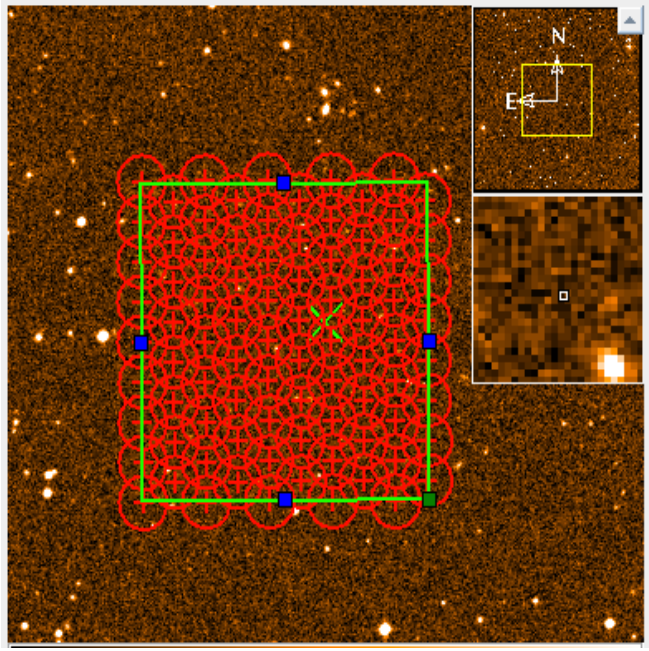
- Each antenna has an approximately Gaussian beam
  - OT assumes FWHM = 1.2 λ / *D* where *D* is dish diameter
    - ≈ 1 arcmin at Band 3, ≈10 arcsec at Band 9
  - Sets the field of view of the observation
  - Only achieve requested sensitivity at centre of pointing
    - Dashed circle on spatial visualizer shows 1/3 FWHM

Mosaicing

Nyquist

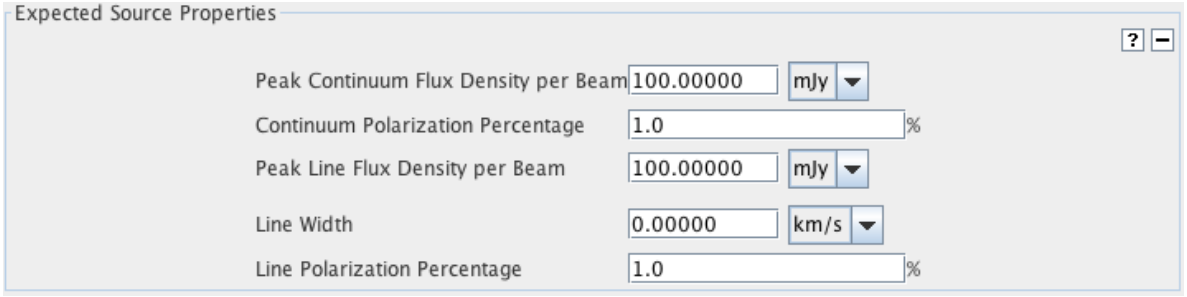


Non-Nyquist



- Large sources must be mosaiced!
  - Overlapping produces more uniform sensitivity
- Nyquist sampling is the default (≈ 0.5 λ / *D*)
  - Required for large sources
  - Point sources can use larger separations (≈ 0.7-0.8 λ / *D*)

Expected source properties

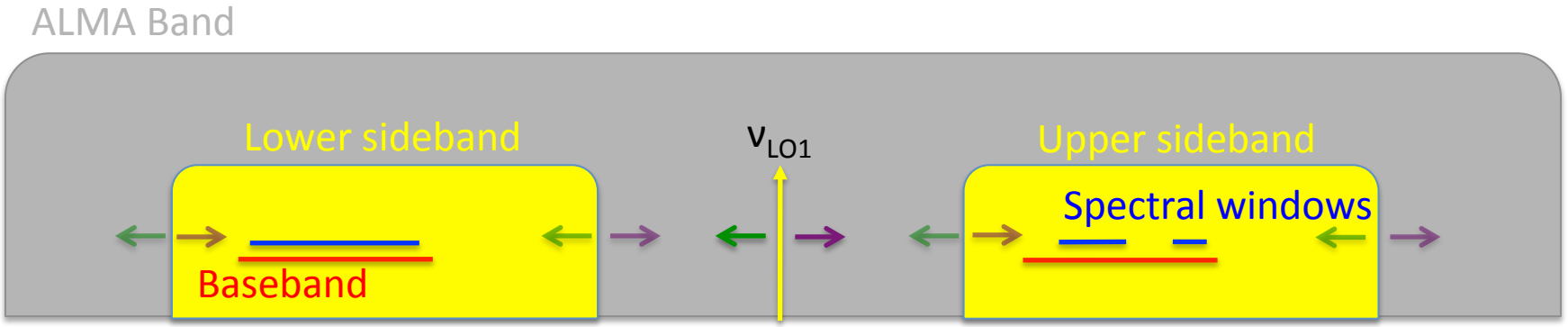


- Various source properties must be entered
  - Flux density (line and/or continuum)
  - Line width (usually given in km/s)
  - Polarization (given in %)
- Enter the most challenging measurement
  - Narrowest line, weakest source component, etc.
- Values will be used for Technical Assessment
  - Reappear on Technical Justification node
  - Must be entered for all sources

Spectral Setup

- Three choices
  - Spectral Line
    - Most general interface
  - Single Continuum
    - Shortcut to widest-bandwidth, low spectral-resolution mode
  - Spectral Scan
    - Shortcut to multi-tuning, contiguous frequency-coverage mode
- Problems
  - ALMA backend is fairly complicated
  - ALMA correlator is very flexible

ALMA Backend basics

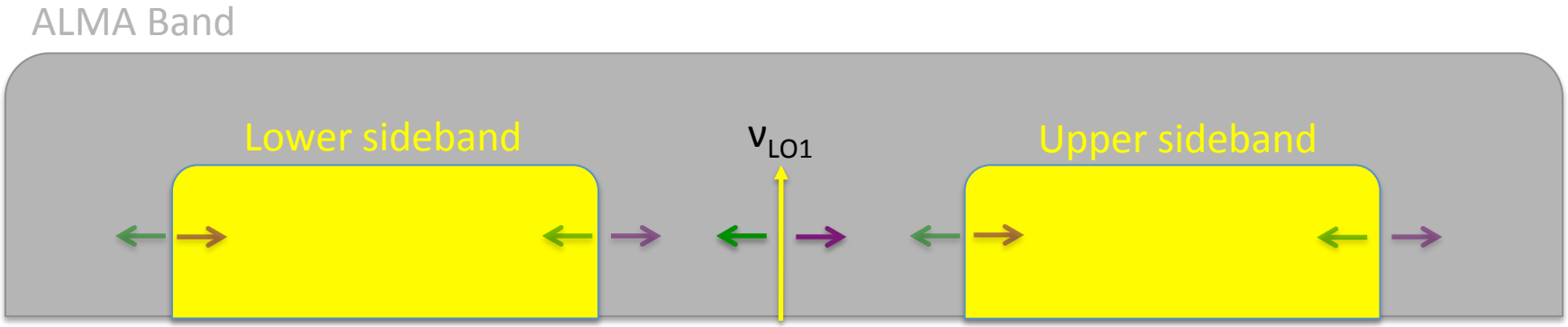


- User defines Spectral Windows
  - Central frequency, bandwidth, spectral resolution
- Spectral windows lie within Basebands
  - Each baseband is 2-GHz wide
- Basebands lie within the receiver Sidebands
  - Each receiver has two sidebands
  - Widths and separations of sidebands vary by receiver

Spectral Concepts: Bands

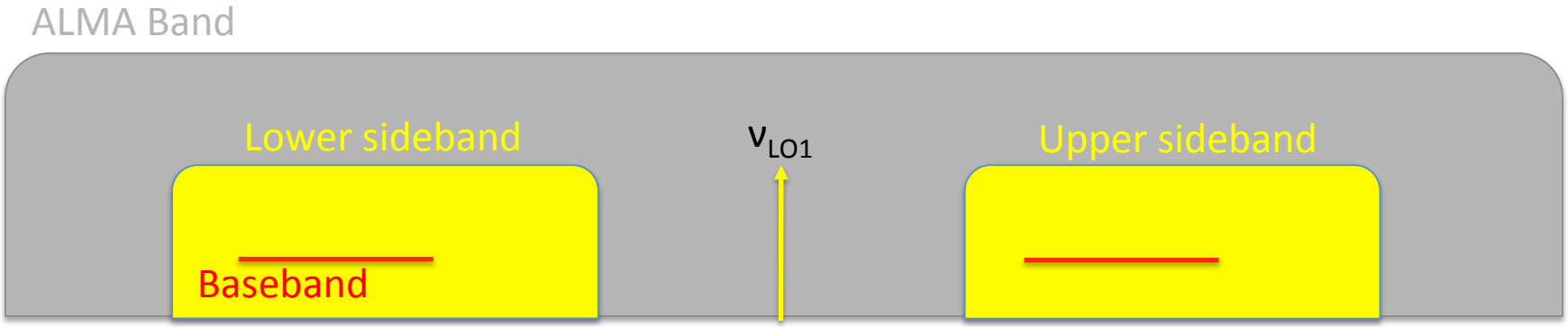
- Each receiver can potentially detect a fixed range of frequencies
  - Band 3: 84-116 GHz
  - Band 9: 602-720 GHz

Spectral Concepts: Sidebands



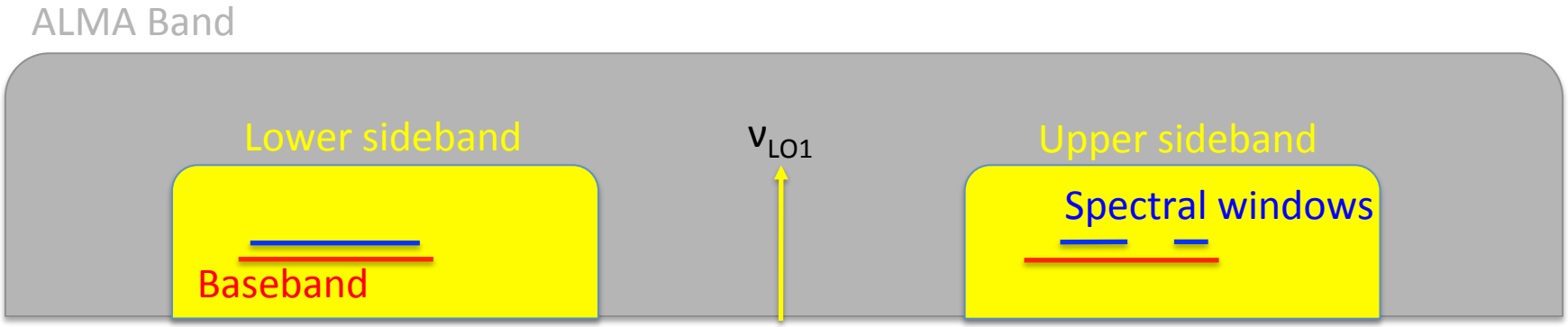
- At any one time, a receiver can only detect a fraction of a band
- The available frequency space is restricted to two **sidebands**
- Their location within the band is set using ν_{LO1}
  - ν_{LO1} = first local oscillator frequency
- Sideband widths and separations depend on band
  - Band 3: width = 4 GHz, separation = 8 GHz
  - Band 9: width = 8 GHz, separation = 8 GHz

Spectral concepts: Basebands



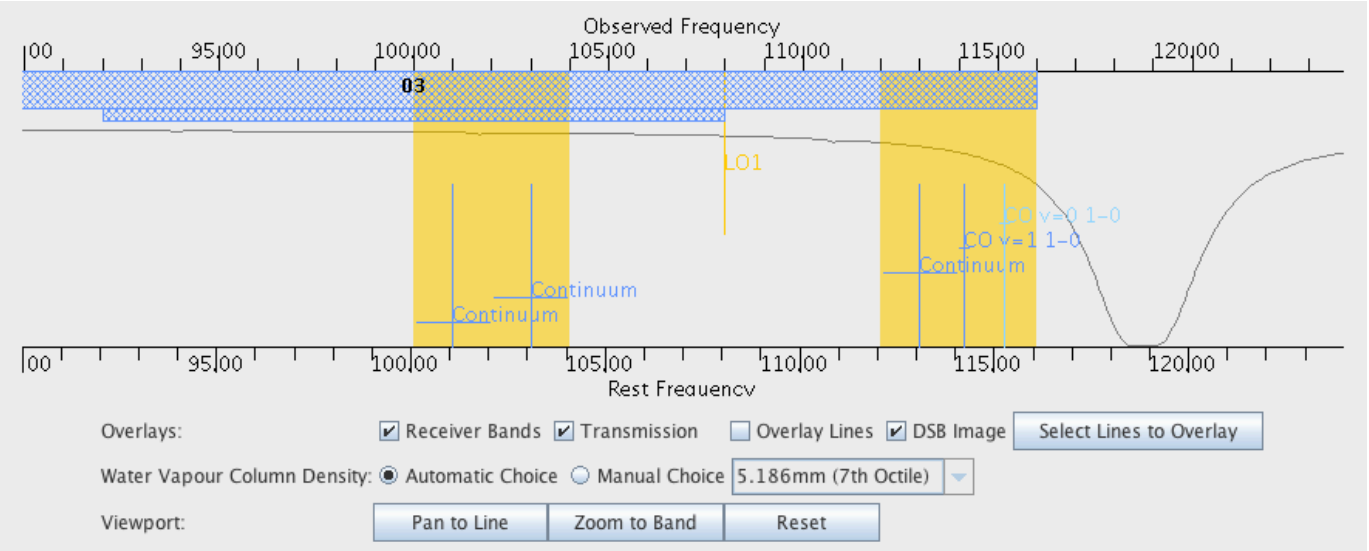
- **Basebands** then select a desired fraction of a sideband
- Up to four basebands are available
- Each baseband
  - has a fixed width of 2 GHz (max bandwidth = 8 GHz)
  - can be placed anywhere within a sideband (must fit completely)
  - can overlap
- Baseband signals are fed into the correlator

Spectral concepts: Spectral windows



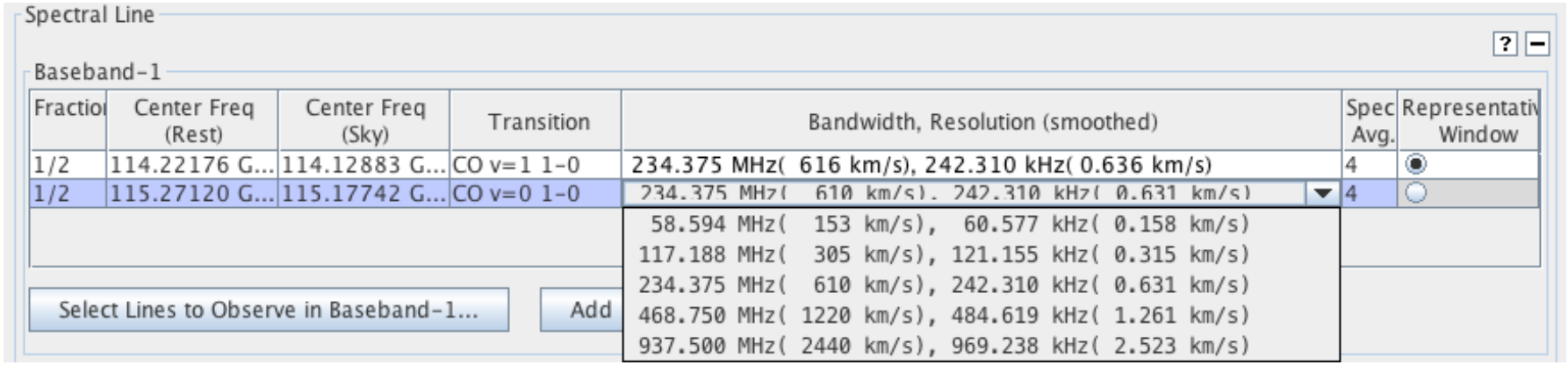
- Finally…
- The correlator samples each baseband using **spectral windows**
- Each spectral window (spw)
  - has a variable width (59 MHz – 2 GHz)
  - can be placed anywhere within a baseband (must fit completely)
  - can overlap (wouldn't normally do this)
  - can be split into multiple regions

Spectral Setup help



- Don't panic!
  - **A user only sets the spectral window frequencies**
    - Tuning (setting of basebands and sidebands) is done automatically
  - OT includes a spectral visualizer
    - For illegal setups the sidebands are coloured grey
  - Setups that are illegal cannot be submitted

Correlator modes



- A spw can use one of two types of correlator mode
  - High spectral resolution (FDM)
    - 8192 channels, bandwidths between 59 and 1875 MHz
  - Low spectral resolution (TDM)
    - 256 channels, fixed bandwidth of 2 GHz
    - Only central 1875 MHz is usable

Polarization

- Three options available
  - Single: hardly ever required
  - Dual: maximum sensitivity (default)
  - Full: for detecting **linear** polarization
- Full-polarization restrictions
  - Single-continuum setups only
  - Band 3, 6 and 7 defaults only
  - No ACA
  - Detection of circular polarization not officially supported at Cycle 1

Decreasing spectral resolution

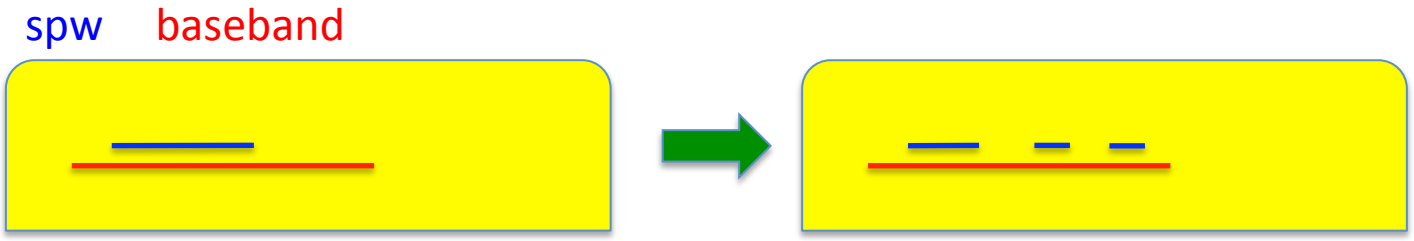
e.g. FDM

1 x 8192 channels

2 x 4096 channels

4 x 2048 channels

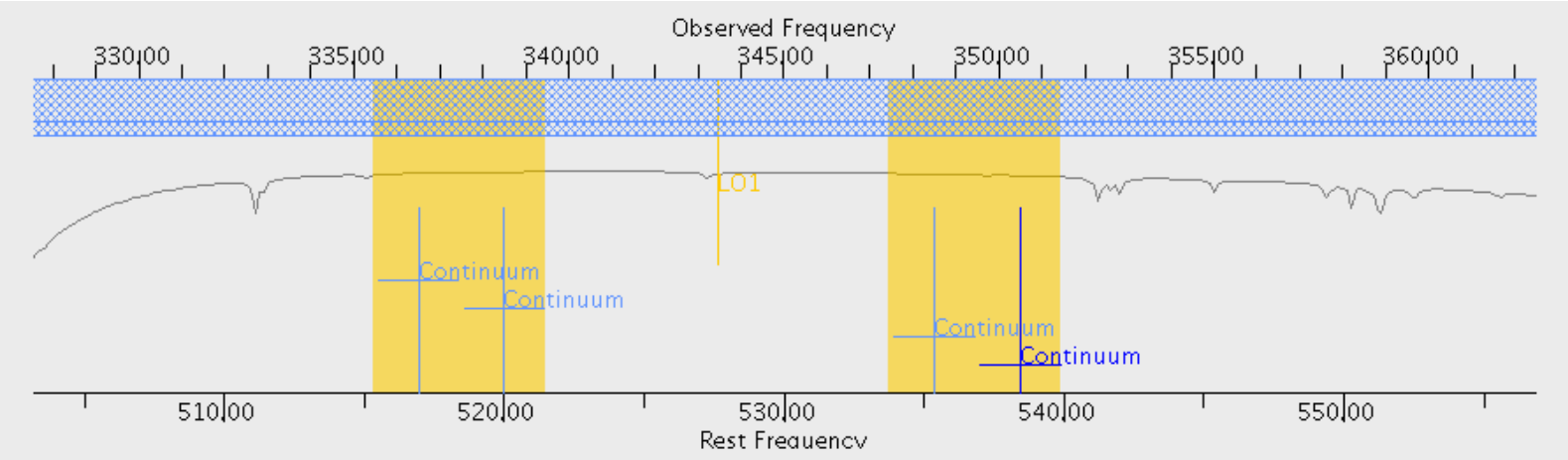
Multi-region modes



- Each Baseband can use a single correlator mode
  - For example: 937.5 MHz / 244.141 kHz (4096 channels)
- Each mode can be split into up to 4 spws
  - Each must have the same spectral resolution
  - Must set the “Fraction” parameter for each
  - For example:
    - 1 x 468.75 MHz / 244.141 kHz / fraction=½ (2048 channels)
    - 2 x 234.375 MHz / 244.141 kHz / fraction=¼ (1024 channels)

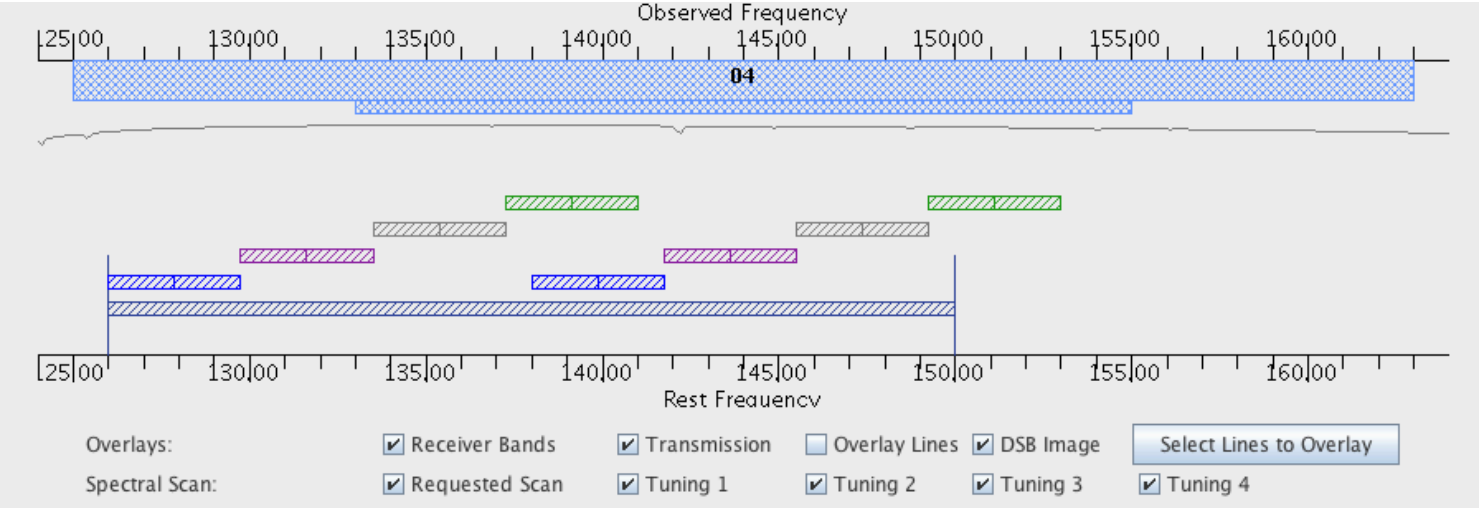
Single Continuum

- Shortcut to a maximum-bandwidth setup
  - 4 2-GHz wide spectral windows
  - 64-256 channels, depending on polarization selection (TDM)
- Each band has a default set of spws
  - Chosen so as to maximise sensitivity



Spectral Scan

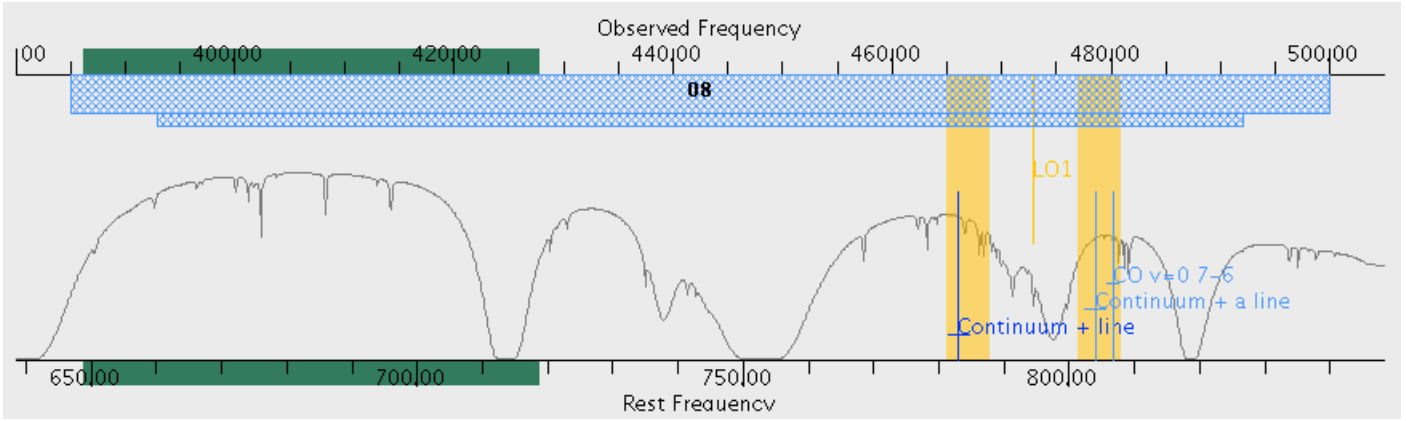
- Shortcut to a multi-tuning setup
  - Enter start and stop <u>observed</u> frequencies plus correlator mode
    - Only a selection of the widest modes are available
  - OT will use a maximum of 5 tunings to cover this range

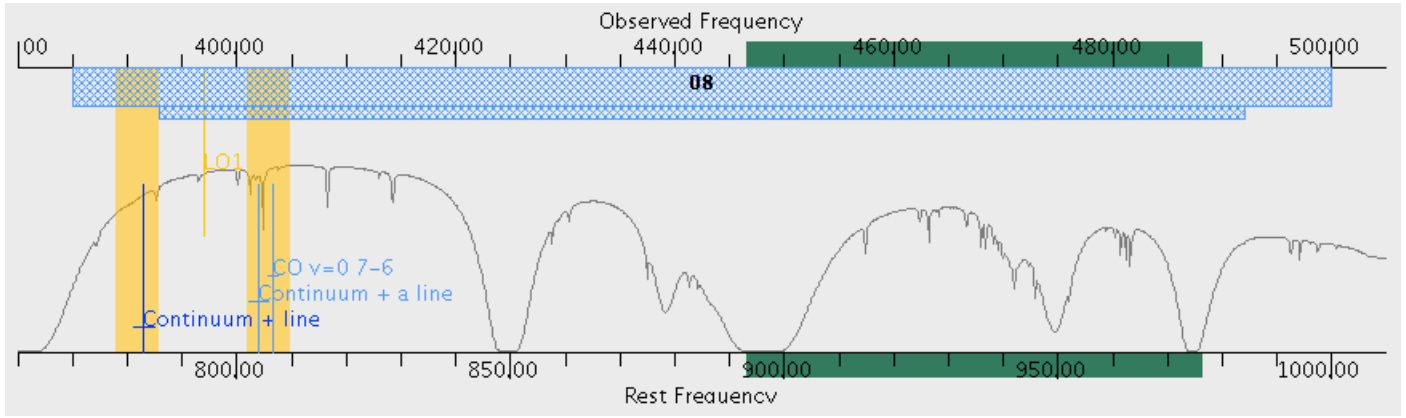


Velocities/tunings

- Only one Spectral Setup allowed per SG
  - One set of **rest** frequencies
- Sources can have different velocities
  - Tuning is (obviously) done with **sky** frequencies
  - It must be possible to find a tuning for each set of sky frequencies
- Maximum of 5 tunings per SG allowed
  - OT has an algorithm to check how many tunings are required
  - Similar velocities can share the same tuning
- Only one ALMA band allowed

Multiple Velocities/Tunings





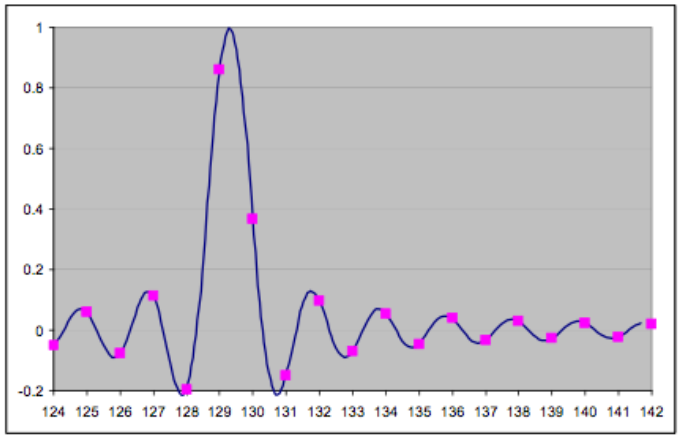
Spectral windows are closer together for a higher redshift source

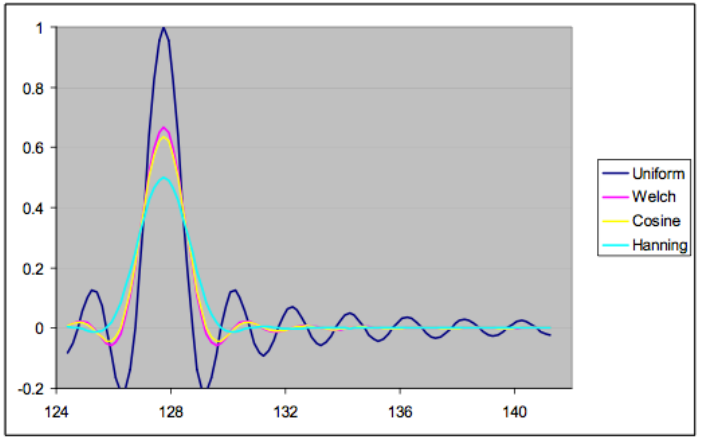
Representative Frequency

Source Name	Velocity		System	Representative Frequency (Sky)
V1	14989...	km/s	lsrk	403.3259 GHz
V2	13947...	km/s	lsrk	431.3646 GHz
V3	12134...	km/s	lsrk	480.1499 GHz

- Defaults to centre of "Representative Window"
  - Spectral window of greatest interest
  - Can be moved anywhere within that spw
- Time estimates are calculated at the RF
- For "Spectral Line" RF is a rest-frame quantity
  - Converted into the sky (observed) frame for each velocity
  - Be careful in bands with variable atmospheric transmission!

Hanning smoothing

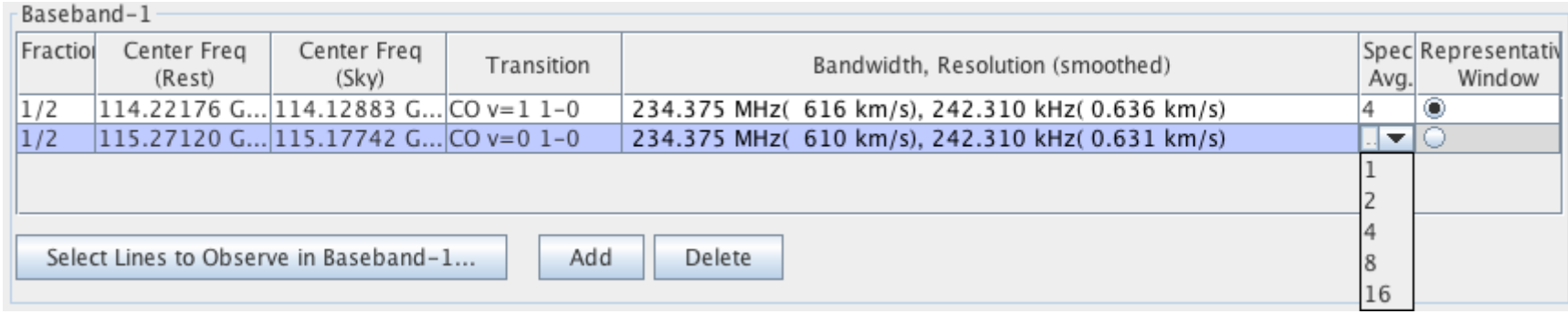




Figures courtesy of R. Hills

- Each spectral line has a sinc(x) form
  - Caused by limitations of correlator
- Hanning smoothing is applied by default
  - Reduces ringing in spectra
  - Reduces spectral resolution (x 1.67 compared to no smoothing)
- Correlator is capable of other smoothing functions
- ACA correlator has a $\mathrm{sinc}^2(x)$ form

Spectral averaging



- Often desirable as native resolution can be very high
  - 2-GHz wide spw has either 128 or 4096 channels (dual pol)
  - High data rates must be justified!
- Not available with TDM
- Spectral averaging is applied after Hanning smoothing
  - Final resolution is not linearly proportional to averaging factor

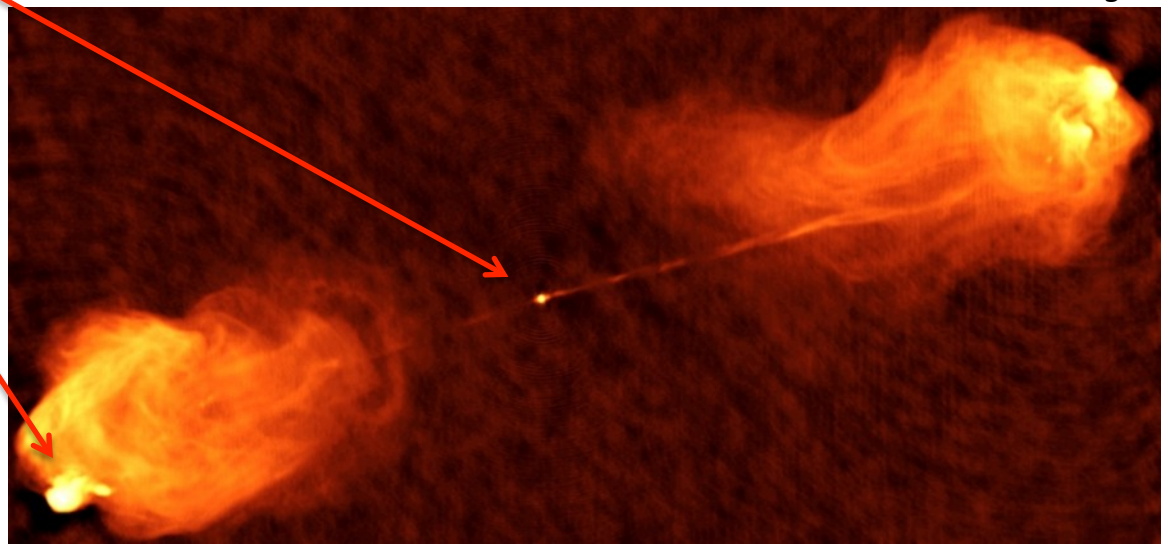
Control & Performance

- Interferometry array characteristics
  - Longest baseline (L_{max}) sets angular resolution
  - Shortest baseline (L_{min}) sets max recoverable scale
    - An object of this size can be reliably imaged
- Configurations are chosen such that
  - λ / L_{max} < requested angular resolution
  - λ / L_{min} > requested largest angular scale
- Up to 2 12-m configurations are possible
- If ACA is required, get 7-m and TP arrays
  - TP not available for Band 9 or single continuum

Source angular scales

Hot spots and core are compact – “seen” by all baselines

VLA image of Cygnus A

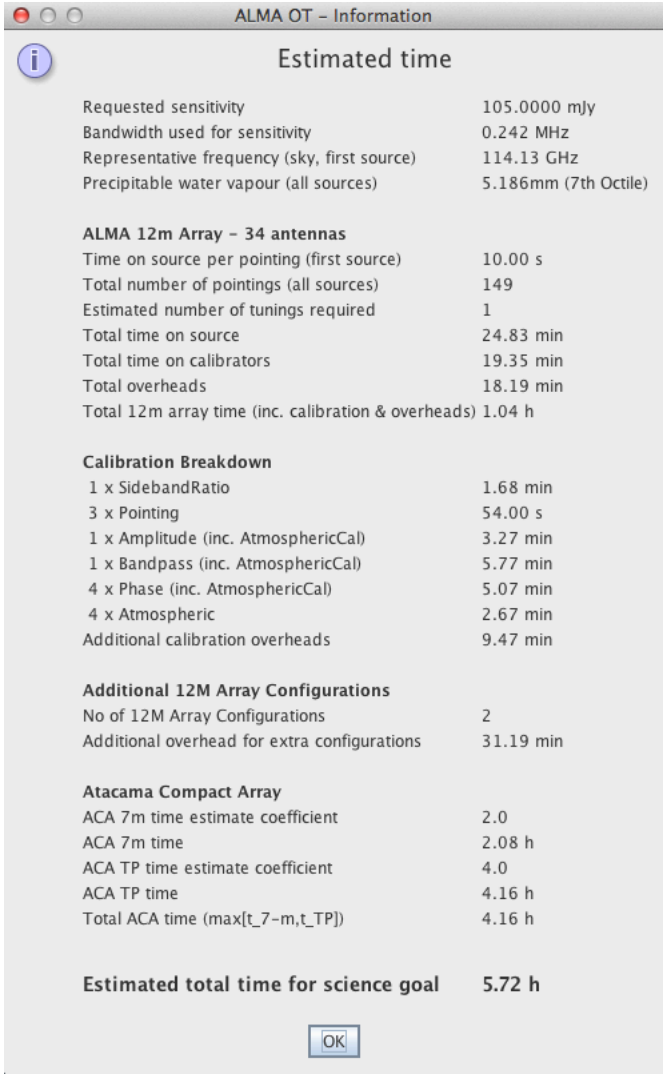


Lobes are much larger – only shorter baselines see this emission

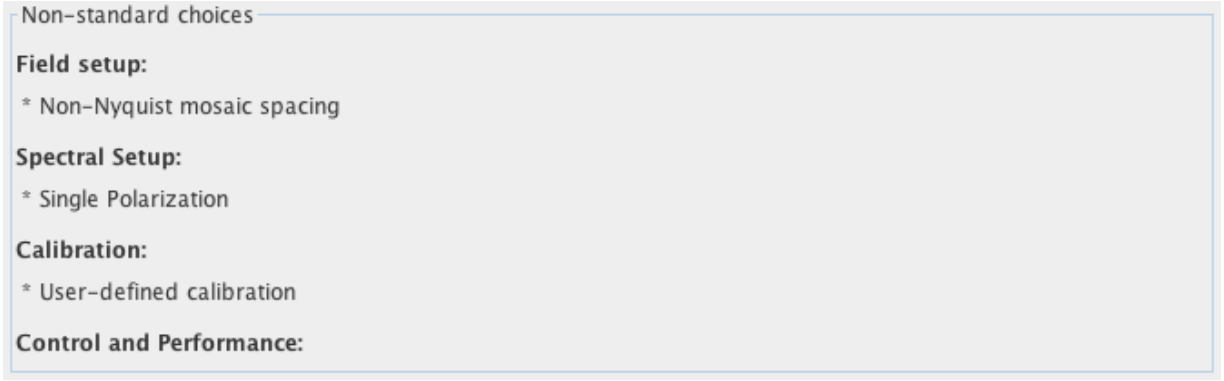
If the short baselines were missing, the lobes would be completely invisible!

Time Estimate

- Time estimate shown in detail for most-extended 12-m array
  - Include calibration and overheads
- Other arrays multiple of this time
  - $t_{12\text{-m (com.)}} = 0.5 \times t_{12\text{-m (ext.)}}$
  - $t_{7\text{-m}} = 2 \times t_{12\text{-m (ext.)}}$
  - $t_{TP} = 4 \times t_{12\text{-m (ext.)}}$
- Assume TP and 7-m observe simultaneously
  - $t_{ACA} = \max(t_{7\text{-m}}, t_{TP})$



Technical Justification

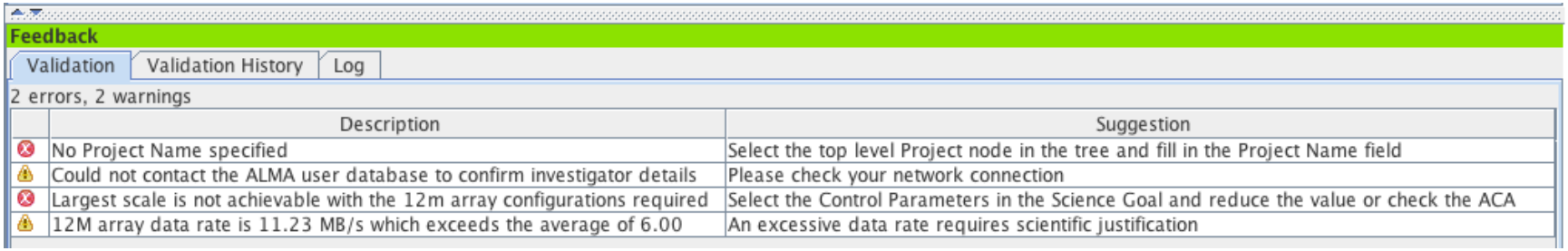


- Now a separate Science Goal node
  - At Cycles 0 and 1, this was part of the Scientific Justification
- The following are shown on a single page
  - Important input parameters (sensitivity, channel width, ACA use, etc.)
  - Source properties (including SNR estimations)
  - Non-standard choices
  - Box for 4000 characters of plain text
- The idea is to help improve the writing of technical cases

Validation and Submission

- A project should be validated before submission
  - "Tick" button on Tool bar

- Feedback panel will display
  - Errors (must be fixed)
  - Warnings (not necessarily a problem)
- Validation happens automatically during submission
- Re-submission allowed
  - Maybe best to submit early and work with version in archive



Known Issues

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Known Issues

Known Issues affecting the Cycle 2 release of the ALMA Observing Tool

Issue	Description	Resolved?	Deployed?
C1_001	Although it is indicated that copy and paste operations in a Mac use the "command" key, often the "control" key is required, particularly for text copy/paste.		
C1_017	The tarball version of the OT with its own Java is 32-bit only. A 64-bit version should be provided.		
C1_023	Calibration searches may crash due to problems with the database. Reducing the number of results may avoid the problem.		
C1_032	Leaving the OT open for days at a time can cause an error upon saving. Saving to another file, closing the OT and re-opening produces a "ZLIB input stream" error i.e. the project is unreadable. This issue is yet to be satisfactorily characterised.		
C1_037	The OT will crash if, within the same session, the display is changed between a laptop's own screen and an external screen (and vice versa). This has only been reported on a Mac running Java 7.		

- There are some known bugs with the Cycle-2 OT
  - Time estimates for polarization and spectral scans were in error
- A list is kept on the Science Portal
  - http://almascience.eso.org/documents-and-tools/cycle-2/known-issues
- An OT update was released on 18 November