North American ALMA Science Center

ALMA Correlator Capabilities for Early Science (Cycle 0)

NAASC Memo #105

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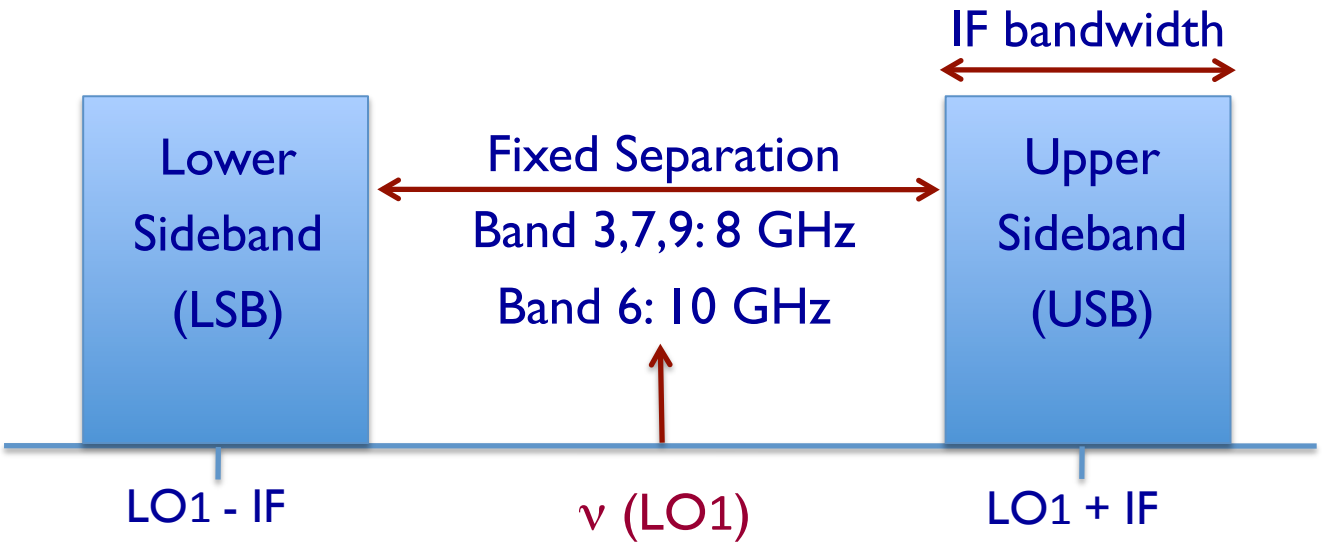
ABSTRACT

The following slides summarize the Cycle 0 capabilities of the ALMA correlator. They compile the basic information from the ALMA Science Portal and the Cycle 0 Technical Handbook, and include some correlator set-up examples with screenshots from the ALMA Observing Tool. These slides are meant to be included in the NA presentations for ALMA Community Days Events.

A power point version of the slides can be found at https://sites.google.com/site/almacommunityoutreach/slides-folder/alma-capabilities.

Receivers: mixers



- The first Local Oscillator (LO1) can be tuned at different frequencies
- The Sky Frequencies will be: $\nu_{sky} = \nu_{LO1} - \nu_{IF}$ (LSB)
  $\nu_{sky} = \nu_{LO1} + \nu_{IF}$ (USB)
- Data will be collected setting-up different spectral windows within one or both sidebands

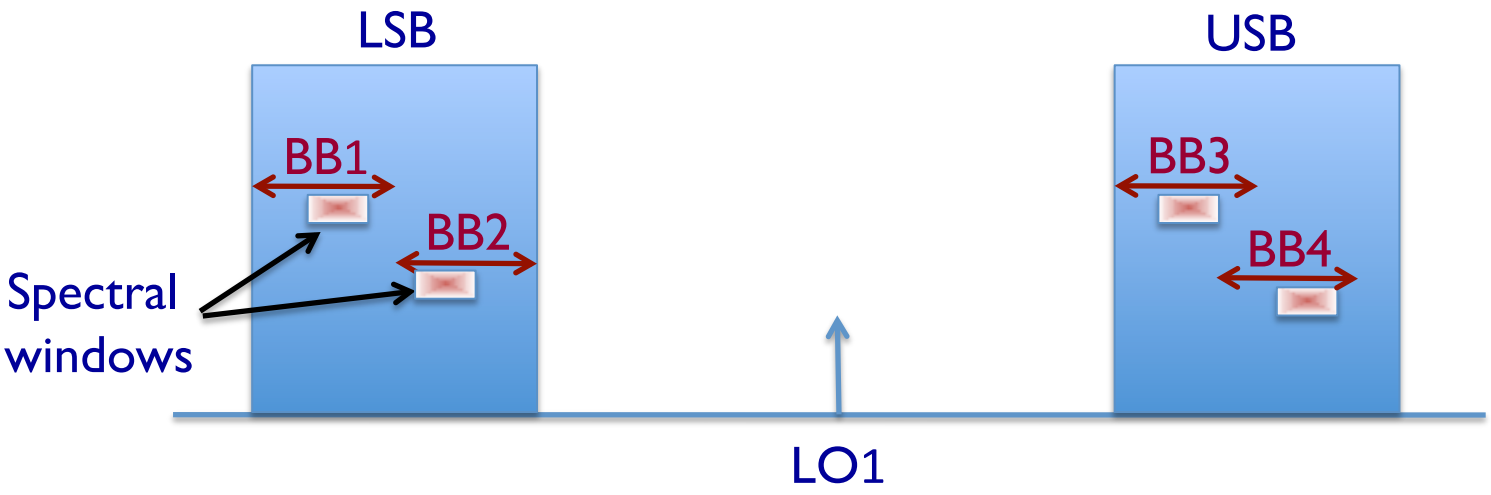
Cycle 0 Receivers

Band	Freq Range (GHz)	Wavelength range (mm)	Receiver type	IF range (GHz)	Inst. IF bandwidth (GHz)
3	84-116	3.6-2.6	2SB	4-8	8
6	211-275	1.4-1.1	2SB	5-10	8
7	275-373	1.1-0.8	2SB	4-8	8
9	602-720	0.5-0.4	DSB	4-12	8*

- Dual side-band (2SB): two separated sidebands available simultaneously
- Double side-band (DSB): LSB and USB are super-imposed out from the receiver but can be separated in later processing.

* Cycle 0: In Band 9, only one sideband per spectral window will be correlated. In future cycles both sidebands will be simultaneously separated and correlated.

Correlator Set-up



- Up to 4 basebands available which can be moved within the sideband width; spectral windows can be moved within the baseband (2 GHz wide)
- Setup limits: Edges of the baseband cannot lie outside the IF range & edges of the spectral window cannot lie outside the baseband

* Cycle 0: only one spectral window per baseband & all spectral windows with the same configuration (bandwidth and spectral resolution)

Correlator Set-up

- Correlator modes:
  - Time division mode (TDM): low-spectral resolution → continuum observations and sources with very broad spectral lines.
  - Frequency division mode (FDM): high-spectral resolution mode
  * Cycle 0: One TDM and 6 FDM set-ups available
- Dual or Single Polarizations can be processed:
  - Dual Polarization: separate spectra obtained for each linear polarization → can be combined to improve sensitivity
  - Single Polarization: only a single polarization is analyzed → poorer sensitivity but provides twice as many channels

Cycle 0 Correlator Modes

Dual Polarization

Bandwidth (MHz)	Channel spacing (MHz)	Number of channels
2000	**15.6**	128*
58.6	**0.0153**	3840
117	**0.0305**	3840
234	**0.061**	3840
469	**0.122**	3840
938	**0.244**	3840
1875	**0.488**	3840

Single Polarization

Bandwidth (MHz)	Channel spacing (MHz)	Number of channels
2000	**7.8**	256*
58.6	**0.0076**	7680
117	**0.0153**	7680
234	**0.0305**	7680
469	**0.061**	7680
938	**0.122**	7680
1875	**0.224**	7680

* Correlator mode for ***continuum*** observations (TDM), effective bandwidth is only 1875 MHz

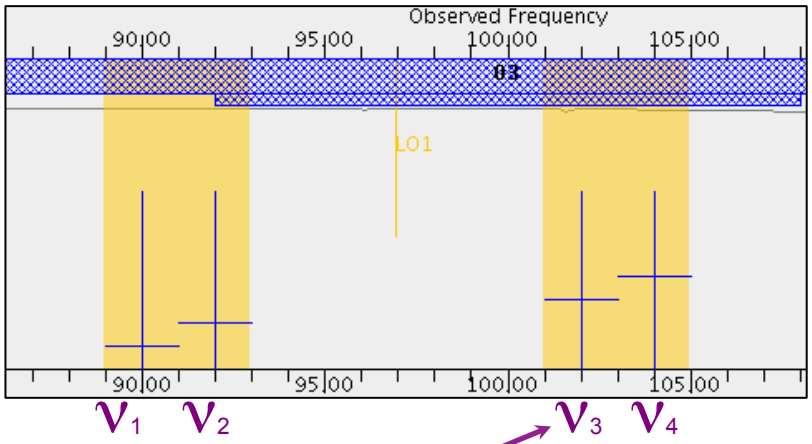
In all cases, the effective resolution is twice the channel spacing

Correlator set-up: line vs. continuum

- "continuum mode": automatically place 4 spectral windows, with the largest bandwidth, across the sidebands

Band 3 (or 7)

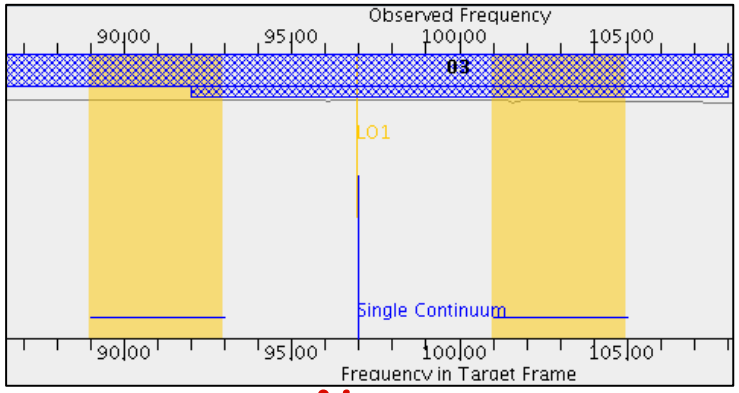
Spectral line mode:



ν_1 ν_2 ν_3 ν_4

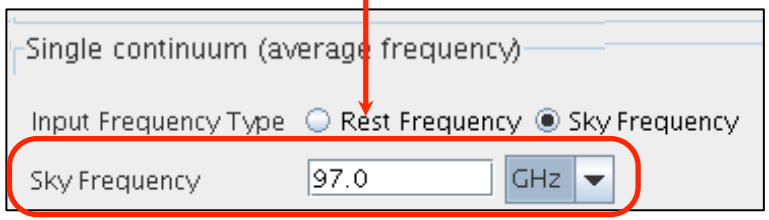
Center Freq Sky	...	Bandwidth, Channel Spacing
90.00000 GHz		1875.000 MHz(6246 km/s), 488.281 kHz...
92.00000 GHz		1875.000 MHz(6110 km/s), 488.281 kHz...
102.00000 GHz		1875.000 MHz(5511 km/s), 488.281 kHz...
104.00000 GHz		1875.000 MHz(5405 km/s), 488.281 kHz...

Continuum mode:



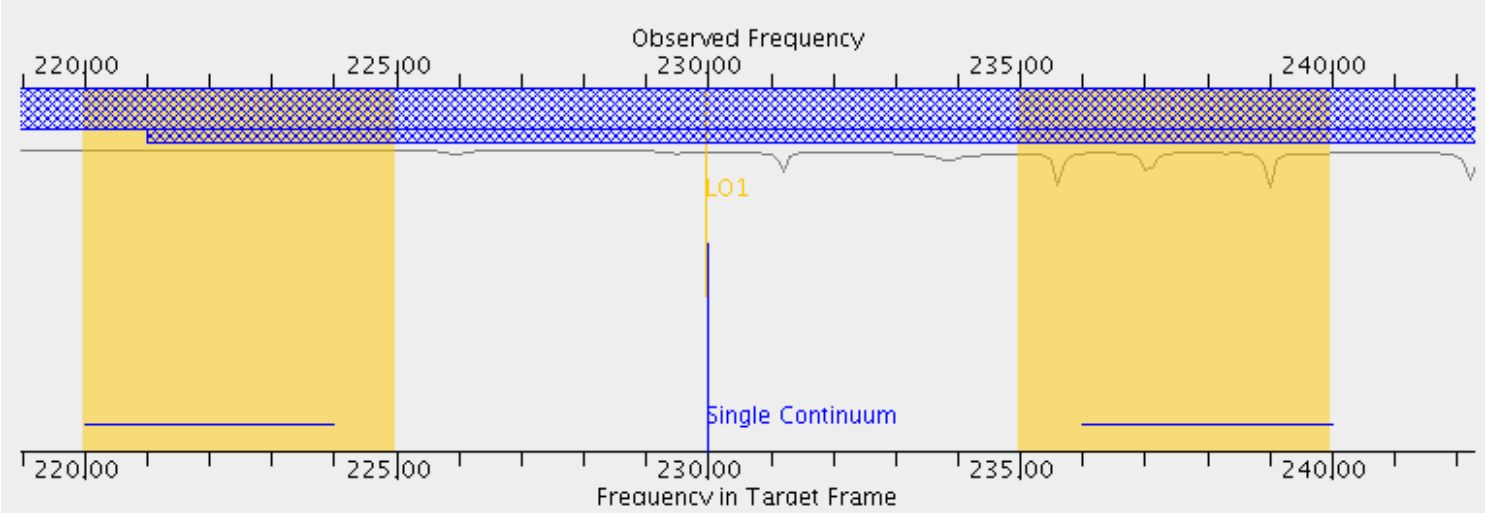
ν_{sky}

2000 MHz bandwidth, 15.625 MHz channels



Correlator set-up: continuum

Standard continuum placement in Band 6



- Even in "spectral line mode", can choose a continuum setup (drop-down menu)
- Use if you want to manually place spws (e.g., to avoid a bright line in Band 6)

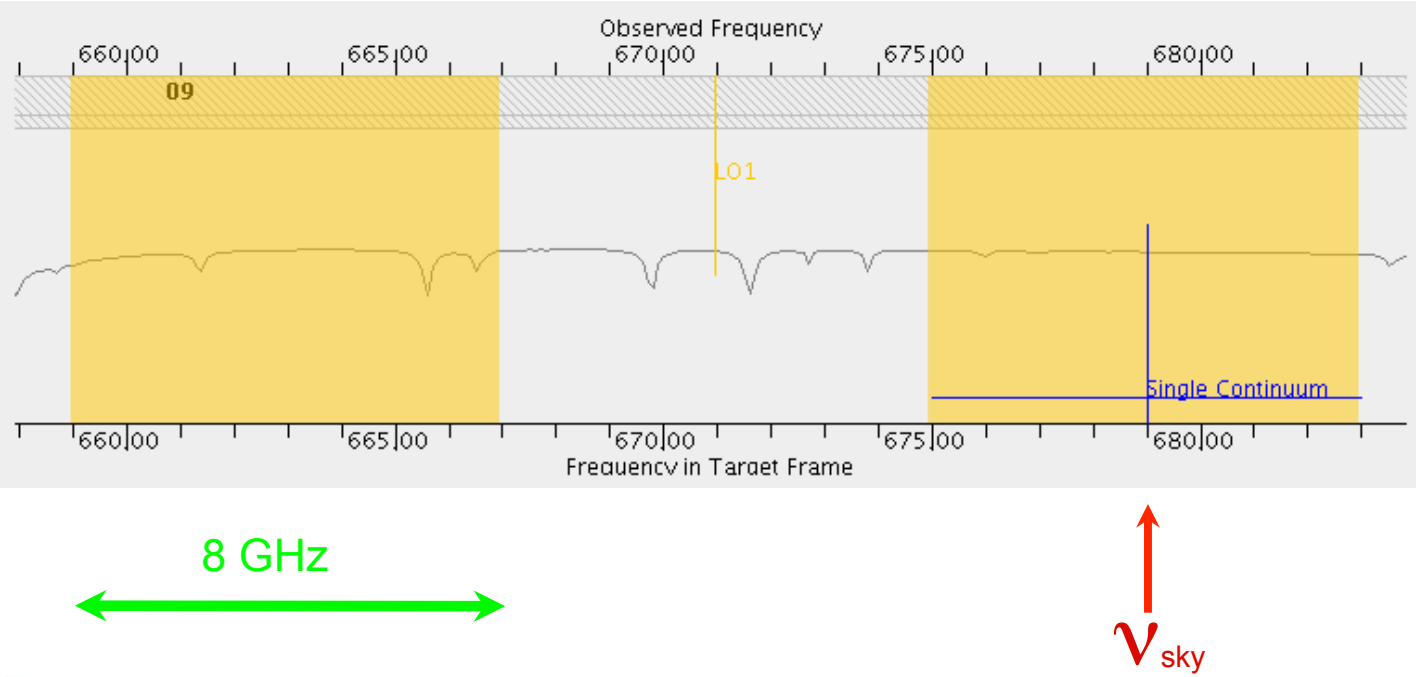
Bandwidth,Channel Spacing

58.594 MHz(	74 km/s),	15.259 kHz(	0.019 km/s)
58.594 MHz(	74 km/s),	15.259 kHz(	0.019 km/s)
117.188 MHz(	148 km/s),	30.518 kHz(	0.039 km/s)
234.375 MHz(	296 km/s),	61.035 kHz(	0.077 km/s)
468.750 MHz(	593 km/s),	122.070 kHz(	0.154 km/s)
937.500 MHz(	1186 km/s),	244.141 kHz(	0.309 km/s)
1875.000 MHz(	2372 km/s),	488.281 kHz(	0.618 km/s)
2000.000 MHz(	**2530 km/s),**	**15.625 MHz(**	**19.765 km/s)**

Correlator set-up: continuum

- Band 9: 8 GHz continuum, but all in one sideband

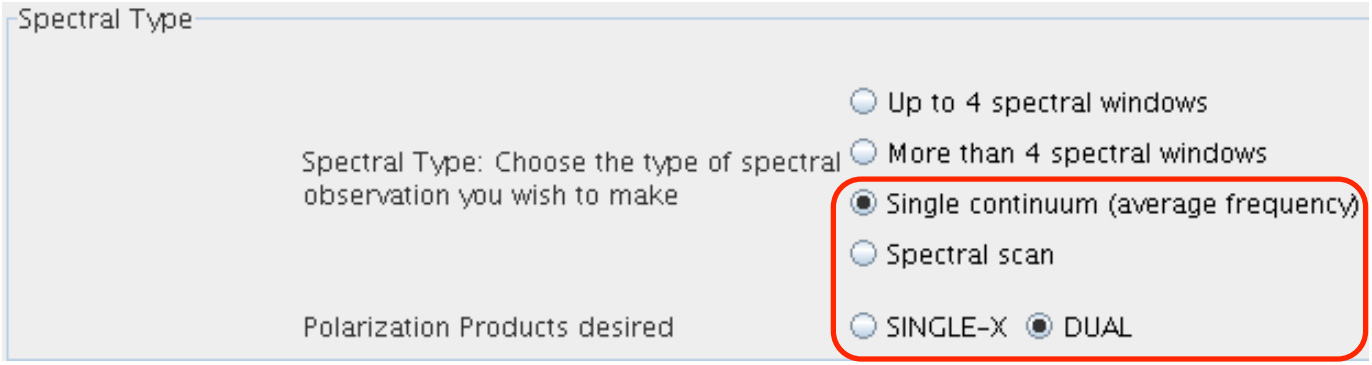
Continuum placement in Band 9



Correlator set-up: continuum

NAASC

- Select “single continuum” in OT
- Single vs Dual polarization allowed



- Single polarization provides same total bandwidth, but twice the spectral resolution: lower sensitivity for averaged continuum!
- (Unless your science case is very special, you should always select Dual polarization for continuum observations.)

NRAO

Survey of carbon isotopologues and other species in old planetary nebula

Observe molecular gas in NGC 7293 (Helix Nebula) in Band 7

Main species of interest

Lower sideband (LSB)

CO (J=3 → 2) : 345.795 GHz

$H^{13}CN$ (J=4 → 3) : 345.339 GHz

$H^{13}CO^+$ (J=4 → 3): 346.998 GHz

Upper sideband (USB)

HCO^+ (J=4 → 3): 356.734 GHz

Other interesting molecular species present within the spectral setup

CS, CS^+, HCP, MgCCH, NaCN, MgH, SiH, MgNC, KC, AlNC, SO, ^{34}SO

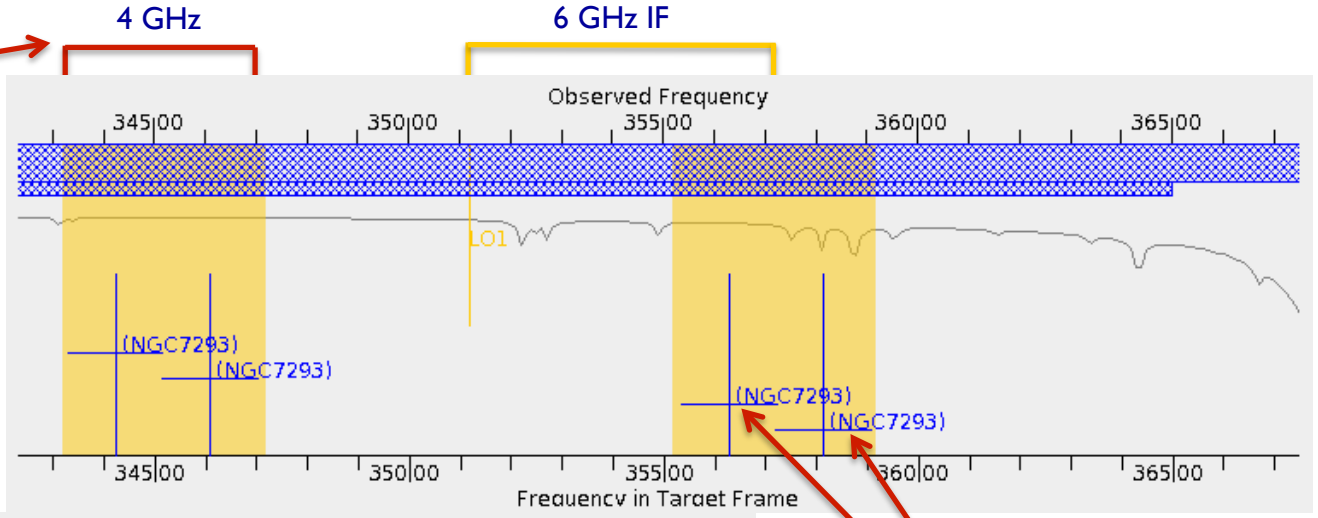
Correlator Setup

LSB Rest Frequency coverage: 343.281-347.021 GHz

USB Rest Frequency coverage: 355.343-359.076 GHz

Band 7:

4 GHz each sideband double pol. mode



Spectral Type

Spectral Type: Choose the type of spectral observation you wish to make

- Up to 4 spectral windows
- More than 4 spectral windows
- Single continuum (average frequency)
- Spectral scan

Polarization Products desired: SINGLE-X DUAL

Up to 4 spectral windows

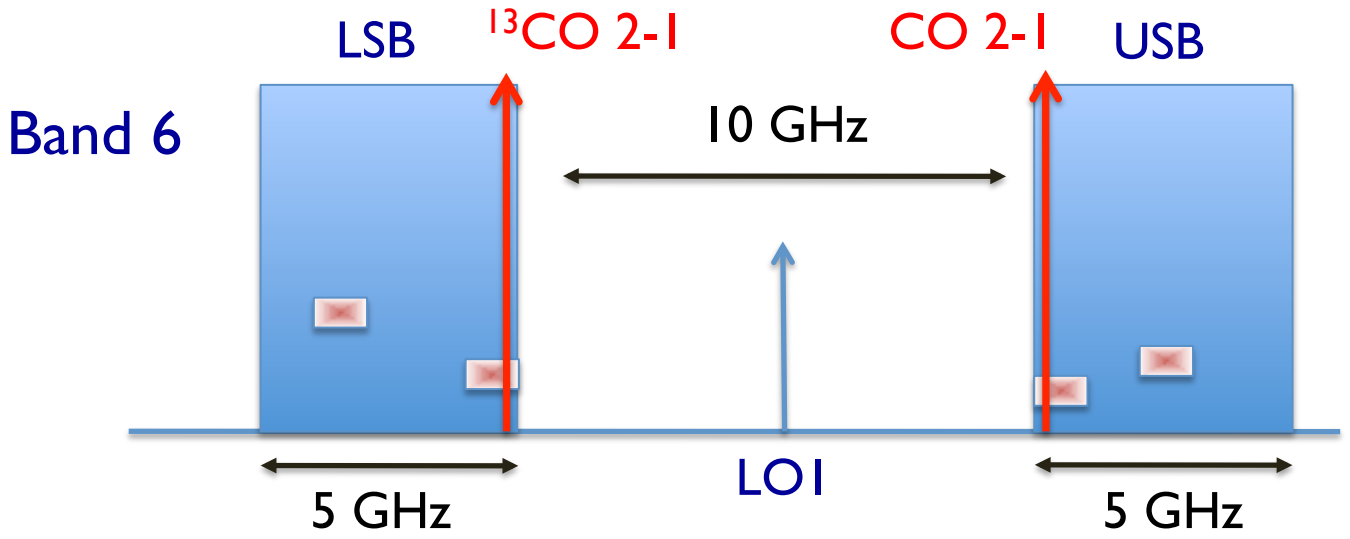
Center Freq Rest	Center Freq Sky	Transition	Bandwidth,Channel Spacing	Process As Continuum
358.13800 GHz	358.15592 GHz		1875.000 MHz(1569 km/s), 488.281 kHz(0.409 km/s)	
356.28000 GHz	356.29783 GHz		1875.000 MHz(1578 km/s), 488.281 kHz(0.411 km/s)	
346.08300 GHz	346.10032 GHz		1875.000 MHz(1624 km/s), 488.281 kHz(0.423 km/s)	
344.21800 GHz	344.23522 GHz		1875.000 MHz(1633 km/s), 488.281 kHz(0.425 km/s)	

Select Lines to Observe... Add Delete

1.875 GHz spw

Channel Spacing of ~488 kHz or ~0.4 km/s

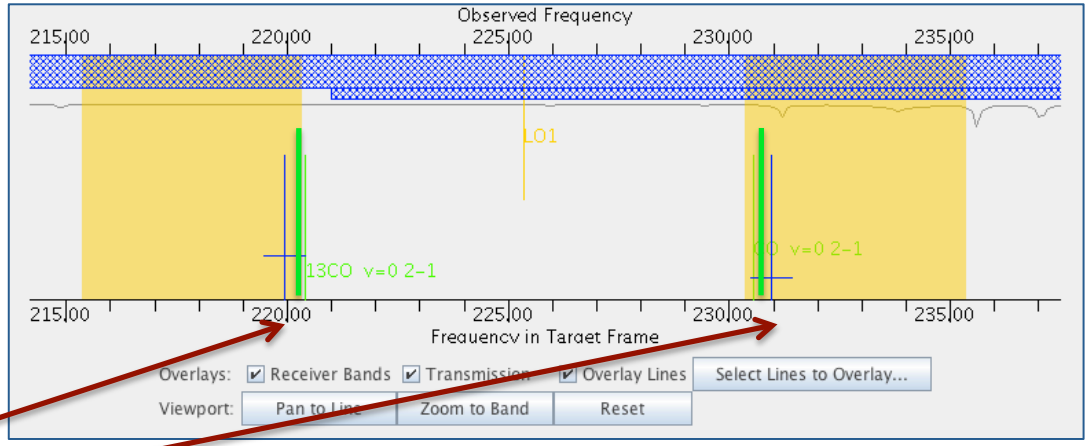
Example: ^{12}CO and ^{13}CO in Band 6



- 2 spectral windows, 0.9375 GHz wide, 0.3 km/s spectral resolution
- Can observe both ^{13}CO 2-1 (220.4 GHz) and CO 2-1 (230.5 GHz) *only* at low z
  - MUST set rest frequency for spectral windows such that the windows remain entirely within the sidebands, e.g. can't center on lines for wider spectral windows
  - can place 2 additional windows to observe CH_3OH, SO_2, etc.

Example: ^{12}CO and ^{13}CO in Band 6

In the OT spectral setup:



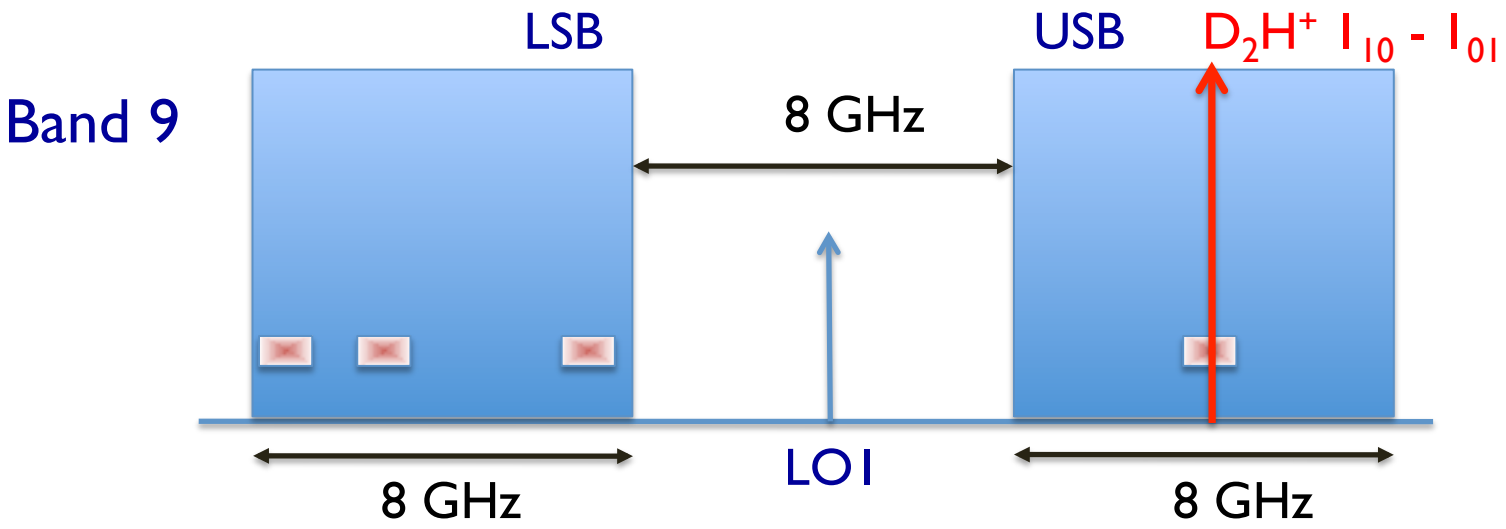
Up to 4 spectral windows

Center Freq Rest	Center Freq Sky	Transition	Bandwidth,Channel Spacing	Process As Continuum
230.95000 GHz	230.95000 GHz		937.500 MHz(1217 km/s), 244.141 kHz(0.317 km/s)	
219.95000 GHz	219.95000 GHz		937.500 MHz(1278 km/s), 244.141 kHz(0.333 km/s)	

Select Lines to Observe... | Add | Delete

- MUST set rest frequency for spectral windows such that the windows remain entirely within the sidebands (i.e. not centered on lines)
- can place 2 additional windows to observe CH_3OH, SO_2, etc.

Example: Spectral Lines in Band 9



- for Band 9, there is full flexibility in that **each baseband can be connected to either one or the other sideband**
- in Cycle 0, **only one sideband** per spectral window will be correlated
  - e.g. Observe D_2H^+ at 691.66 GHz with one spectral window
  - can place 3 additional windows in USB or LSB