

Cycle 13 Observing Capabilities

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1. ALMA Basics

ALMA Arrays

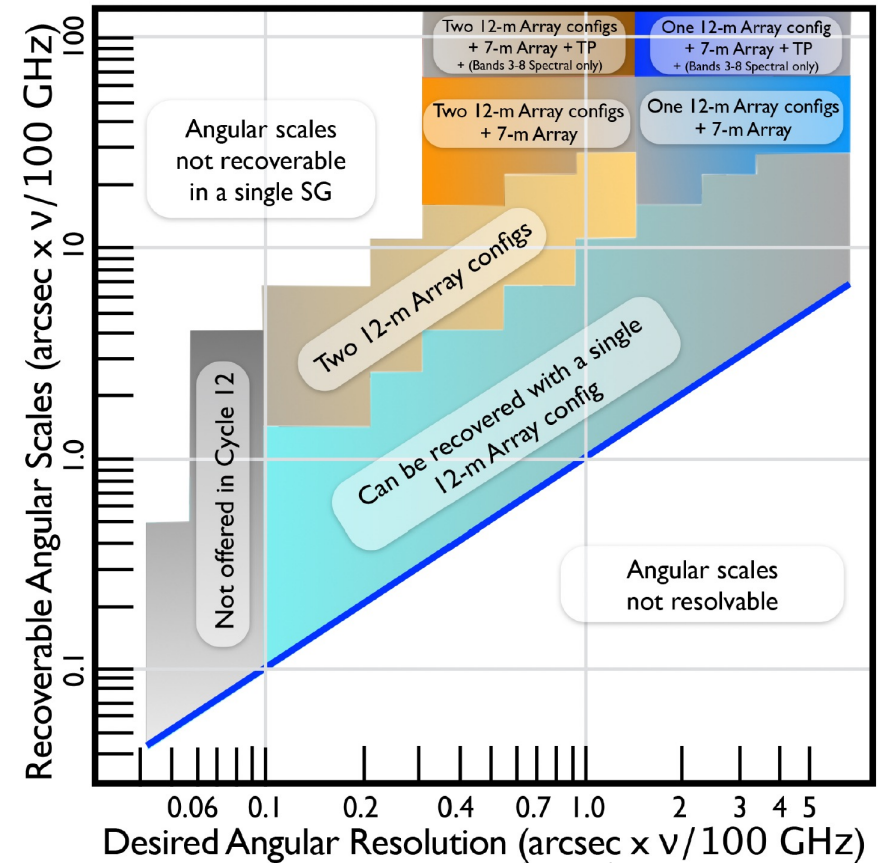


- 50 antennas for 12-m Array
- 12 antennas of 7-m Array
- 4 12-m antennas for single-dish observations
(Total Power; TP)

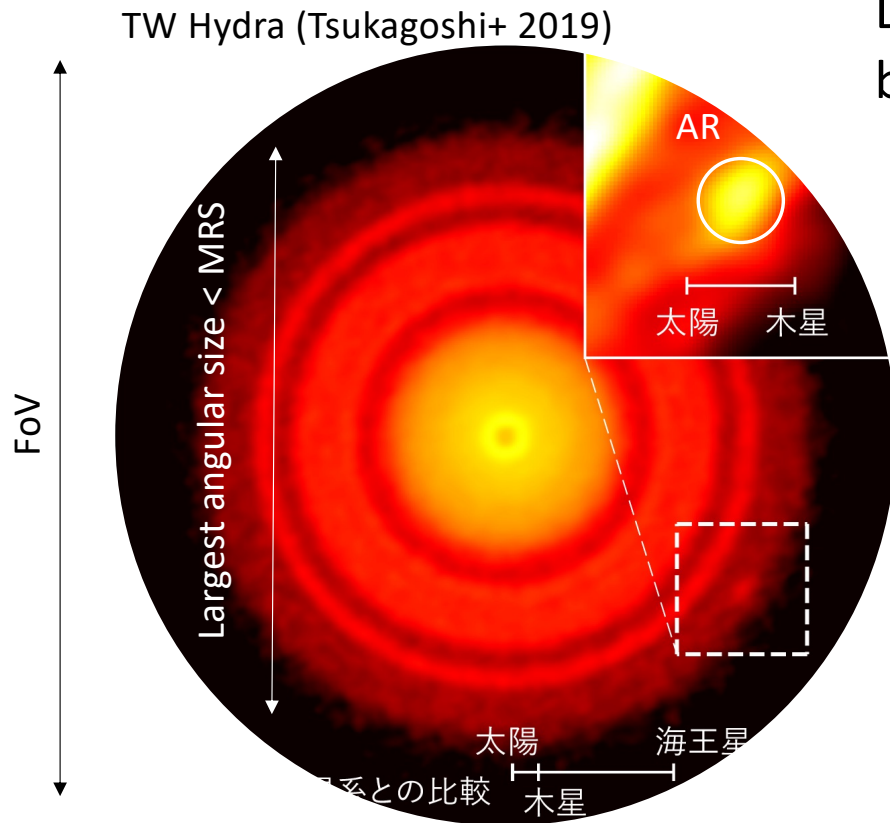


The Atacama Compact Array (ACA)

See Cycle 13 “A Primer”



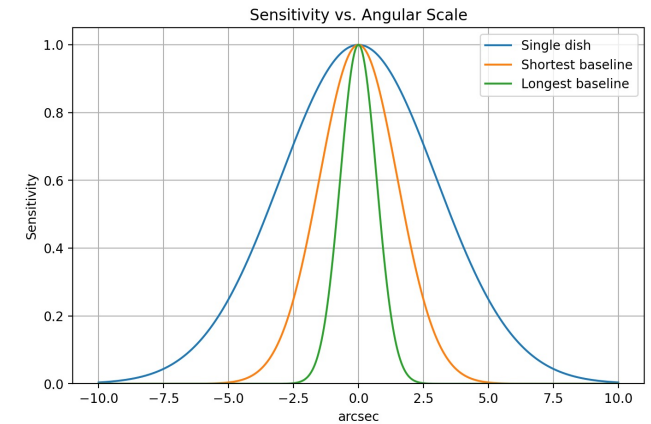
Three Important Angular Scales



Smoothly distributed emission over the disk with some variation.

$$\vartheta = 1.22 \times \lambda / D$$

D: dish diameter or baseline length



Angular Resolution (AR)

- Resolution element of image
- Determined by the maximum baseline length (λ/D_{\max})

Maximum Recoverable Scale (MRS)

- The largest structure that can be imaged without missing flux
- Determined by the minimum baseline length (λ/D_{\min})

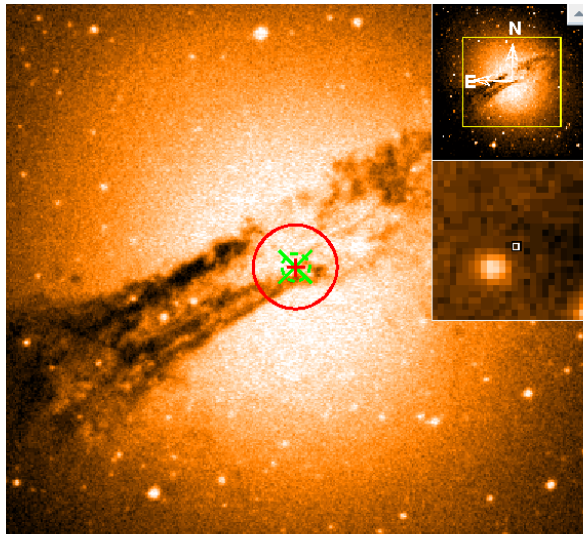
Field of View (FoV)

- FoV of a single telescope pointing
- Equal to antenna beam size

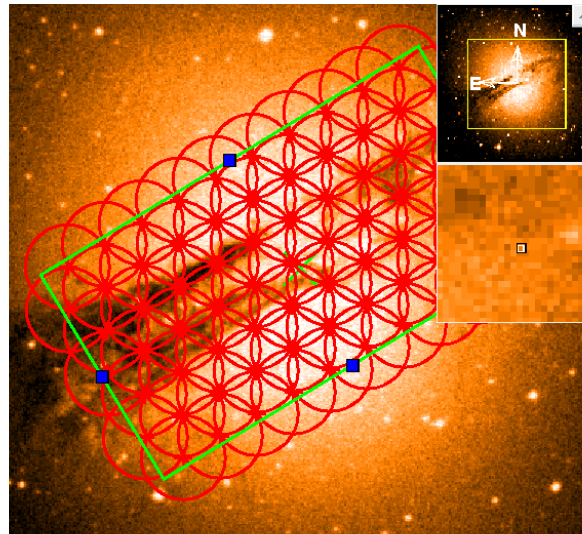
Mosaicking / Multiple Pointing

- Angular structure that is larger than single pointing FoV, or multiple sources spread over a larger area, must be mosaicked or used multiple-pointing observations.

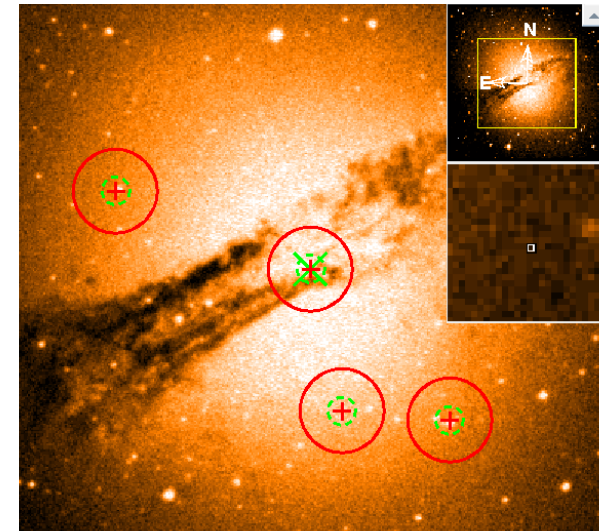
Single pointing



Mosaicking

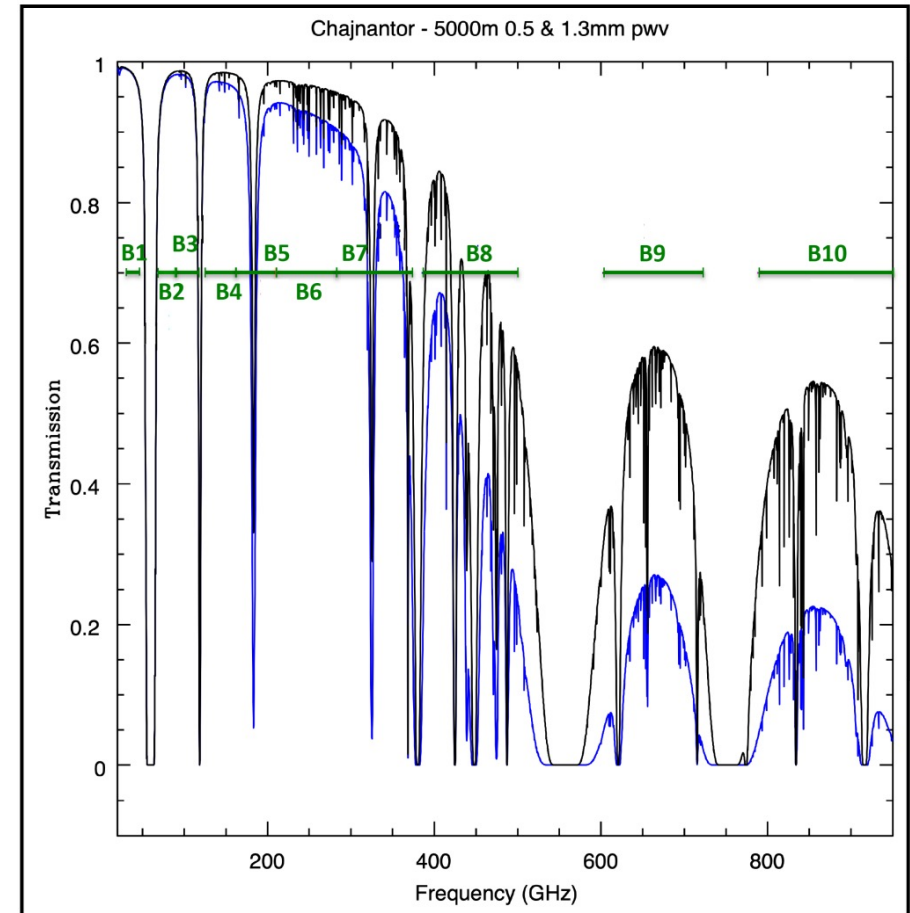


Multiple pointing



Frequency Bands

- 10 receiver bands (**Band 2 is available from Cycle 13**)
- Multiple band data cannot be taken simultaneously in a single execution (except for B2B phase transfer)
- Atmospheric opacity and phase stability tends to be poor at higher frequencies and at frequencies absorption lines
 - ✓ Requires good weather condition



Cycle 13 "A Primer"

Receivers

$\nu_{IF} = |\nu_{sky} - \nu_{LO}|$ so we have, $\nu_{sky} = \nu_{LO} + \nu_{IF}$ (USB) and $\nu_{sky} = \nu_{LO} - \nu_{IF}$ (LSB)

Band	Frequency range (GHz)	Wavelength range (mm)	Intermediate Frequency (IF) range (GHz)	Type
1	35 – 50	8.5 – 6	4 – 12	SSB
2	67 – 116	4.5 – 2.6	4 – 12	2SB
3	84 – 116	3.6 – 2.6	4 – 8	2SB
4	125 – 163	2.4 – 1.8	4 – 8	2SB
5	158 – 211	1.9 – 1.4	4 – 8	2SB
6	211 – 275	1.4 – 1.1	4.5 – 10	2SB
7	275 – 373	1.1 – 0.8	4 – 8	2SB
8	385 – 500	0.78 – 0.60	4 – 8	2SB
9	602 – 720	0.50 – 0.42	4 – 12	DSB
10	787 – 950	0.38 – 0.32	4 – 12	DSB

Frequency vs. Weather

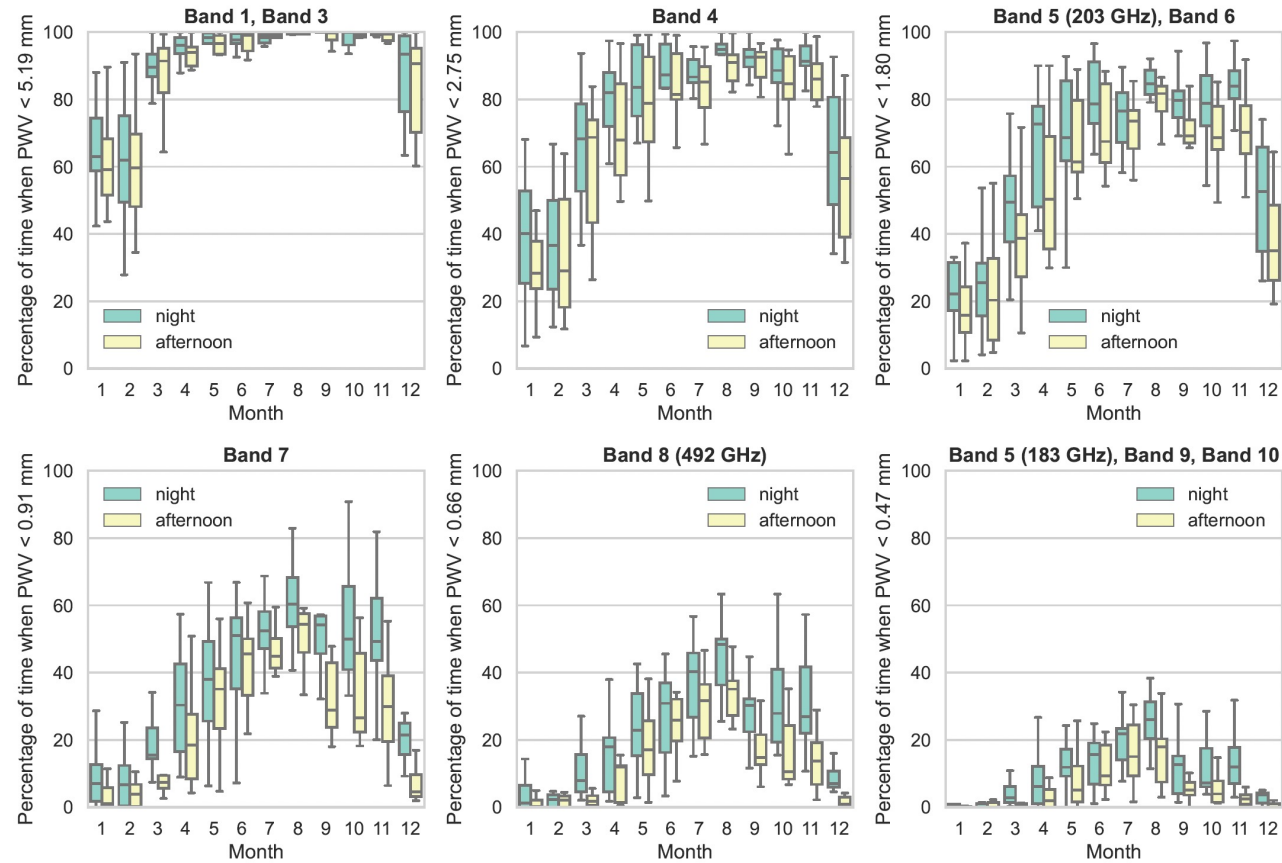
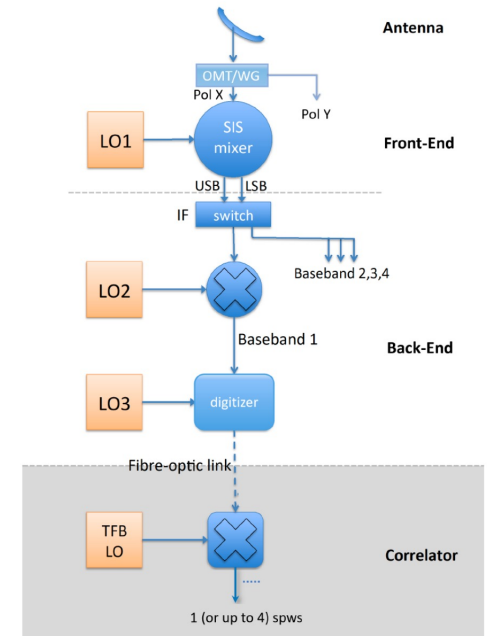
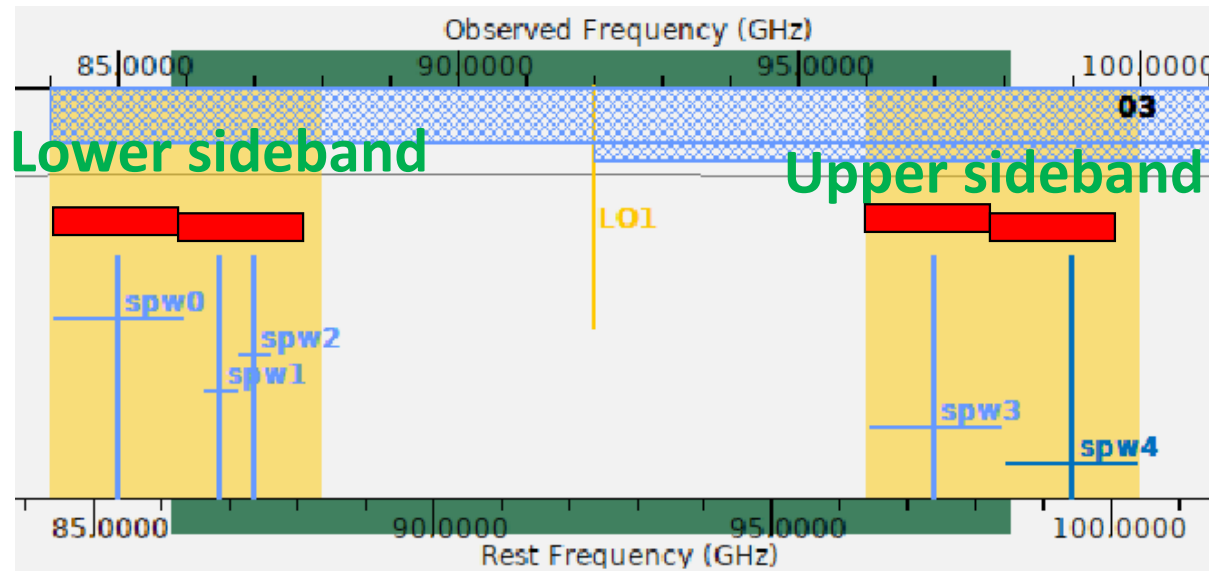


Figure 3: The percentage of time when the PWV is below the observing thresholds adopted for the various ALMA bands for afternoon (yellow; based on 17:00–21:00 UTC) and night (green; based on 01:00–05:00 UTC) and for an elevation of 60 degrees. The horizontal line within the box indicates the median. Boundaries of the box indicate the 25th- and 75th-percentile, and the whiskers indicate the highest and lowest values of the results. The data were obtained with the APEX weather station, ALMA measurements, and weather forecast data between January 2010 and January 2022.

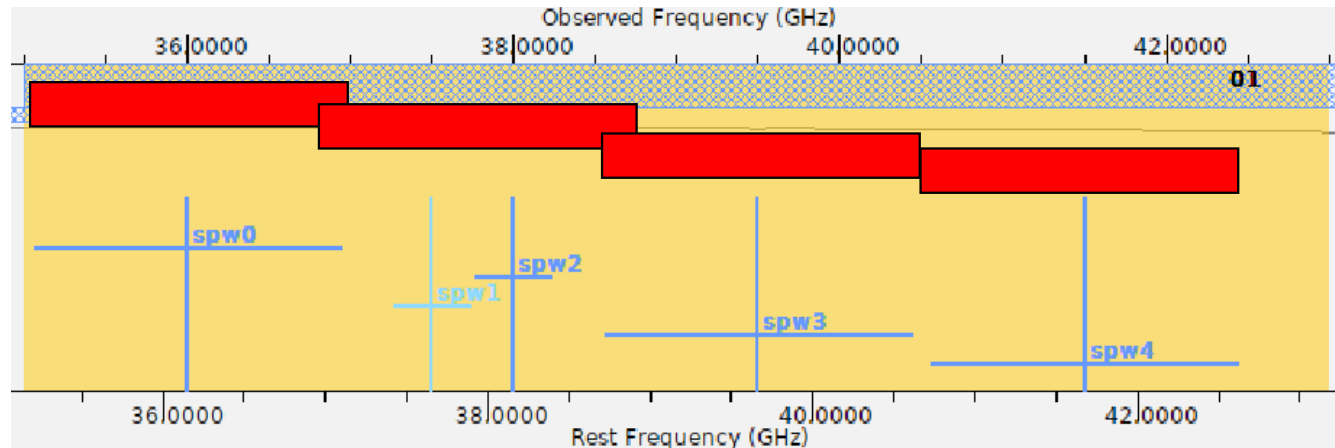
Instantaneous frequency coverage (2SB: B2-8)



- ALMA receives signals in two **sidebands** (yellow bars).
- Up to four **basebands with 2-GHz width** can be placed either in a sideband or two sidebands. (**Red boxes**. Not possible to put 3 in one sideband and 1 in the other.)
- **User:** Up to four **spectral windows** (spws) in each of basebands (blue bars) .
- Each spw forms a final contiguous spectrum (**You will not receive data outside of spws**)

Instantaneous frequency coverage (SSB: B1)

Single sideband

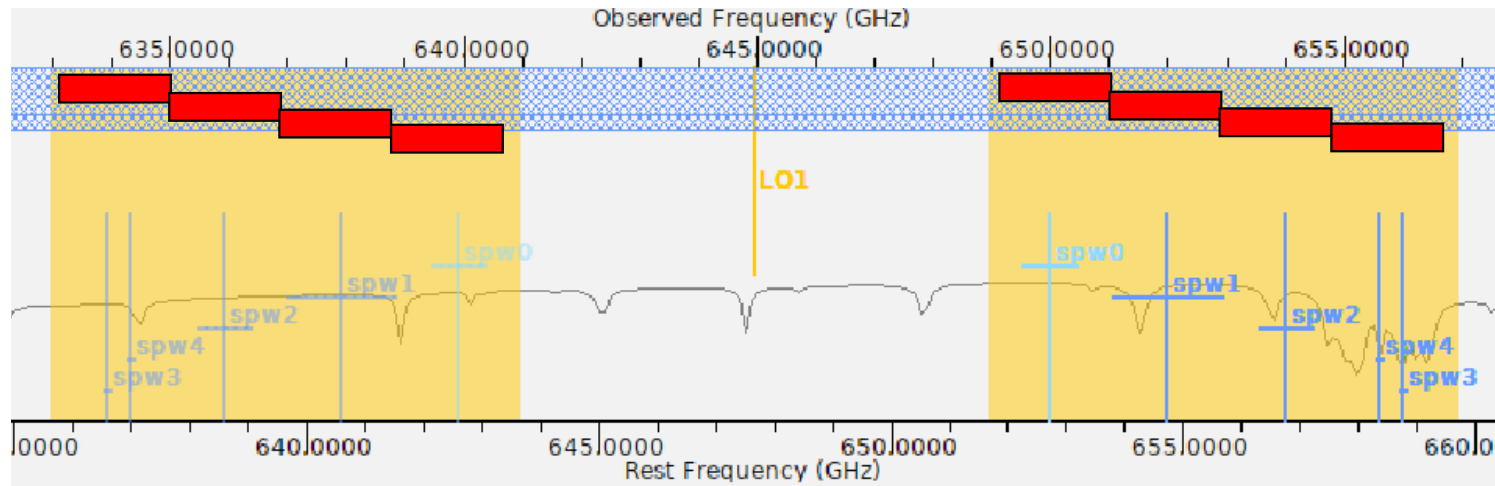


- Band 1 employs single-sideband system (SSB) , so one sideband is selected and the other is rejected in the receiver.
- Up to 4 basebands with 2-GHz width are placed in a sideband.
- Allows to place up to four **spectral windows** (spws) in each of these basebands (blue bars) .

Instantaneous frequency coverage (DSB: B9-10)

Lower sideband

Upper sideband



- Bands 9 and 10 use a double-sideband receiver, so each baseband contains both USB and LSB signals mixed together.
- Up to four basebands can be defined, with a mirrored placement in the opposite sideband.
- Each baseband can contain up to four spws.
- With TDM or 1.875 GHz FDM, one sideband can be rejected using LO offsetting; otherwise, sideband separation relies on 90-degree Walsh switching.

Correlator Setup

TDM = better for **broadband continuum**, lower spectral detail, lighter data volume.

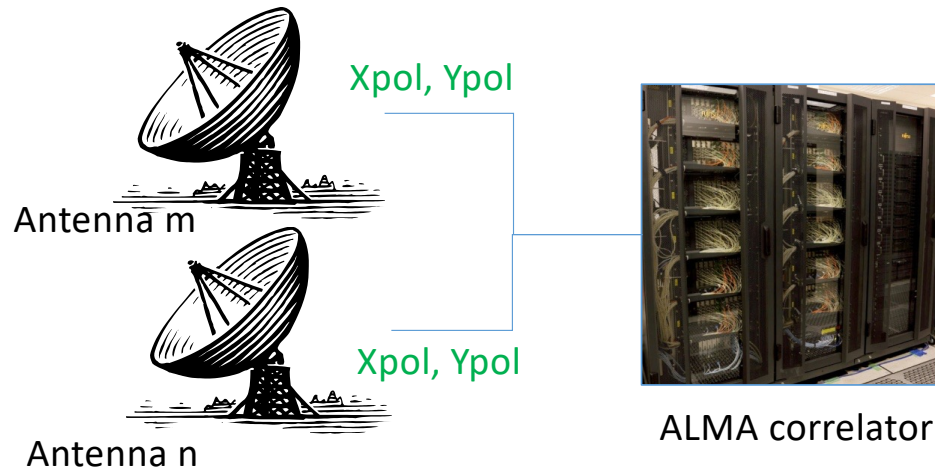
FDM = better for **spectral lines**, finer channel spacing, heavier data volume.

The **4x4 bit** modes

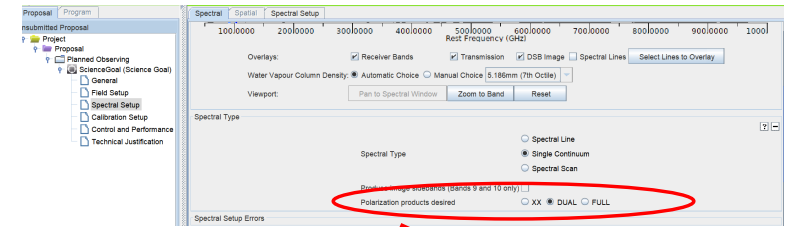
- ✓ are only available for the 64-input Correlator
- ✓ provide higher correlator efficiency for a given spectral resolution and integration time compared with the 2x2 bit mode

Bandwidth (MHz)	Channel spacing (MHz)	Spectral resolution (MHz)	Number of channels	Correlator mode	Bit Mode
1875	15.6	31.2	120	TDM	
938	0.976	1.952	960	FDM	4x4
1875	0.488	0.976	3840	FDM	2x2
469	0.488	0.976	960	FDM	4x4
938	0.244	0.488	3840	FDM	2x2
234	0.244	0.488	960	FDM	4x4
469	0.122	0.244	3840	FDM	2x2
117	0.122	0.244	960	FDM	4x4
234	0.061	0.122	3840	FDM	2x2
58.6	0.061	0.122	960	FDM	4x4
117	0.0305	0.061	3840	FDM	2x2
58.6	0.0153	0.0305	3840	FDM	2x2

Polarization



OT⇒



$$\begin{aligned}
 X_m X_n^* &= I + Q \rightarrow XX \\
 Y_m Y_n^* &= I - Q \\
 X_m Y_n^* &= U + iV \\
 Y_m X_n^* &= U - iV
 \end{aligned}
 \left. \begin{array}{l} \\ \\ \\ \end{array} \right\} \text{Dual} \left. \begin{array}{l} \\ \\ \\ \end{array} \right\} \text{Full}$$

- ALMA can provide full polarization products (XX, YY, XY, YX) so that one can produce Stokes I, Q, U, and V images.
- At least ~3-hrs observation is required to calibrate instrumental polarization.

2. Cycle 13 Capabilities

What's New in Cycle 13?

- Band 2, covering 67–116 GHz, is offered for the 12-m Array, including full polarization with a single pointing.
- Web-based ALMA Observing Tool
 - ✓ See OT documentation in Section 4.6.1.

Capabilities Offered in Cycle 13

(Section 4.2 of Cycle 13 Proposer's Guide)

- **Number of antennas**
 - ≥ 43 antennas in the 12-m Array.
 - ≥ 10 7-m antennas (for short baselines) and 3 12-m antennas (for single dish) in the ACA.
- **Receiver bands**
 - Bands 1 (no TP), 2 (no TP/7-m), 3, 4, 5, 6, 7, 8, 9 (no TP), and 10 (no TP).
- **12-m Array Configurations**
 - C-1 through C-10.
 - C-7 ~ C-10 are considered “long-baseline configurations” .

Capability of band 2 in Cycle 13

Mode	Band 2 status
12-m spectral-line / continuum	Yes
12-m single-field interferometry	Yes
12-m mosaics (XX/YY)	Yes
12-m single-pointing full linear + circular polarization	Yes
12-m continuum full polarization mosaics	No
7-m spectral-line / continuum	No
7-m single-field interferometry	No
7-m mosaics	No
7-m linear polarization	No
Single-dish spectral-line	No

Compare Band 2 and Band 3

- Band 2 (67–116 GHz) overlaps Band 3 (84–116 GHz) with comparable sensitivity.
- Band 3 is used by default when the requested setup is feasible in Band 3.
- Band 2 is selected only when Band 3 cannot realize the requested frequency setup.
- Band 2 is particularly useful for:
 - setups extending **below 84 GHz**
 - **multi-line combinations** not reachable with Band 3, e.g., $^{13}\text{CO}(1-0)$, $\text{C}^{18}\text{O}(1-0)$, $\text{CO}(1-0)$
 - **wide spectral scans** requiring broader, more contiguous coverage
- Current Band 2 limitations:
 - **12-m only**
 - **no 7-m / TP**
 - **no polarization mosaics**
 - **no VLBI/phased-array**
 - **no Solar**

Spectral scans

- **Use Band 2 for:**
 - start frequency < **84 GHz**
 - **SPW width > 1 GHz**
- **Use Band 3 for:**
 - start frequency > **84 GHz**
 - **SPW width < 1 GHz**

Capabilities Offered in Cycle 13 – Dual Polarization

(Section 4.2 of Cycle 13 Proposer's Guide)

System	Supported observations
12-m Array	Spectral-line and continuum observations in Bands 1–10 ; single-field in Bands 1–10 ; mosaics in Bands 1–9 (no band 10 mosaic) .
7-m Array	Spectral-line and continuum observations in Bands 1 and 3–10 ; single-field in Bands 1 and 3–10 ; mosaics in Bands 1 and 3–9 (no band 2, 10 mosaic) .
Single-dish	Spectral-line observations in Bands 3–8 .

Polarization Capabilities Offered in Cycle 13

(Section 4.2 of Cycle 13 Proposer's Guide)

System

Supported polarization observations

12-m Array single pointing (on-axis) of continuum/line polarizaiton

Linear polarization is limited to the inner 1/3 of the primary beam, circular polarization to the 1/10, with a minimum detectable circular polarization of 1.8% of the peak flux (**no band 8-10**).

12-m Array polarization mosaics

Continuum linear polarization mosaics in Bands 1 and 3–7 (no band 2, 8-10).

Stand-alone 7-m Array

Single-pointing, on-axis **linear polarization in Bands 1 and 3–7**, limited to the inner **one third** of the primary beam (**no band 2, 8-10, no polarization mosaic in all bands**).

Config. Schedule

- **Winter -> LB**

Start date	Configuration	Longest baseline	LST for best observing conditions
2026 October 1	C-3	0.50 km	~ 22—10 h
2026 October 20	C-2	0.31 km	~ 23—11 h
2026 November 10	C-1	0.16 km	~ 1—13 h
2026 November 30	C-2	0.31 km	~ 2—14 h
2026 December 20	C-3	0.50 km	~ 4—15 h
2027 January 10	C-4	0.78 km	~ 5—17 h
2027 February 1	<i>No observations due to maintenance</i>		
2027 March 1	C-4	0.78 km	~ 8—21 h
2027 March 20	C-5	1.4 km	~ 9—23 h
2027 April 20	C-6	2.5 km	~ 11—1 h
2027 May 20	C-7	3.6 km	~ 13—3 h
2027 June 20	C-8	8.5 km	~ 14—5 h
2027 July 11	C-9	13.9 km	~ 16—6 h
2027 July 30	C-10	16.2 km	~ 17—7 h
2027 August 20	C-9	13.9 km	~ 19—8 h
2027 September 10	C-8	8.5 km	~ 20—9 h

Configuration

Angular Range that can be achieved with the operational configurations assuming a source at -23 deg Decl.

The actual angular resolution will additionally depend on multiple factors including: the source declination, hour angle of the observation, and observing frequency within the band. For sources transiting at lower elevations, the North-South angular measures will increase proportional to $1/\sin(\text{elevation})$.

See Table A-1 in the proposer guide

		Band	1	2	3	4	5	6	7	8	9	10
Config.	L_{\max}	Freq. (GHz)	40	75	100	150	185	230	345	460	650	870
7-m	45 m	θ (")	31.8	16.9	12.7	8.47	6.87	5.52	3.68	2.76	1.95	1.46
C-1	161 m	θ_{\max} (")	8.28	4.42	3.31	2.21	1.79	1.44	0.96	0.72	0.51	0.38
		θ_{\min} (")	7.69	4.10	3.07	2.05	1.66	1.34	0.89	0.67	0.47	0.35
C-2	314 m	θ_{\max} (")	7.96	4.24	3.18	2.12	1.72	1.38	0.92	0.69	0.49	0.37
		θ_{\min} (")	7.31	3.89	2.92	1.95	1.58	1.27	0.85	0.64	0.45	0.34
C-3	500 m	θ_{\max} (")	5.97	3.19	2.39	1.59	1.29	1.04	0.69	0.52	0.37	0.27
		θ_{\min} (")	4.79	2.55	1.91	1.28	1.03	0.83	0.55	0.42	0.29	0.22
C-4	784 m	θ_{\max} (")	3.54	1.88	1.41	0.94	0.76	0.61	0.41	0.31	0.22	0.16
		θ_{\min} (")	2.99	1.60	1.20	0.80	0.65	0.52	0.35	0.26	0.18	0.14
C-5	1.4 km	θ_{\max} (")	2.22	1.18	0.89	0.59	0.48	0.39	0.26	0.19	0.14	0.10
		θ_{\min} (")	1.80	0.96	0.72	0.48	0.39	0.31	0.21	0.16	0.11	0.083
C-6	2.5 km	θ_{\max} (")	1.34	0.72	0.54	0.36	0.29	0.23	0.16	0.12	0.082	0.061
		θ_{\min} (")	0.99	0.53	0.40	0.26	0.21	0.17	0.11	0.086	0.061	0.046
C-7	3.6 km	θ_{\max} (")	0.74	0.39	0.30	0.20	0.16	0.13	0.086	0.064	0.046	0.034
		θ_{\min} (")	0.67	0.36	0.27	0.18	0.14	0.12	0.077	0.058	0.041	0.031
C-8	8.5 km	θ_{\max} (")	0.50	0.27	0.20	0.13	0.11	0.087	0.058	0.043	0.031	0.023
		θ_{\min} (")	0.31	0.17	0.12	0.083	0.067	0.054	0.036	0.027	0.019	0.014
C-9	13.9 km	θ_{\max} (")	0.19	0.10	0.074	0.049	0.040	0.032	0.021	0.016	0.011	0.0085
		θ_{\min} (")	0.16	0.083	0.062	0.041	0.034	0.027	0.018	0.013	0.010	0.0071
C-10	16.2 km	θ_{\max} (")	0.14	0.076	0.057	0.038	0.031	0.025	0.017	0.012	0.0088	0.0066
		θ_{\min} (")	0.13	0.068	0.051	0.034	0.028	0.022	0.015	0.011	0.0078	0.0059

Configuration -Maximum Recoverable Scale (MRS)

		Band	1	2	3	4	5	6	7	8	9	10
Config.	L_{\min}	Freq. (GHz)	40	75	100	150	185	230	345	460	650	870
7-m	9 m	θ_{MRS} (")	167	88.9	66.7	44.5	36.1	29.0	19.3	14.5	10.3	7.67
C-1	15 m	θ_{MRS} (")	71.2	38.0	28.5	19.0	15.4	12.4	8.25	6.19	4.38	3.27
C-2	15 m	θ_{MRS} (")	56.5	30.1	22.6	15.0	12.2	9.81	6.54	4.90	3.47	2.59
C-3	15 m	θ_{MRS} (")	40.5	21.6	16.2	10.8	8.73	7.02	4.68	3.51	2.48	1.86
C-4	15 m	θ_{MRS} (")	28.0	14.9	11.2	7.50	6.08	4.89	3.26	2.44	1.73	1.29
C-5	15 m	θ_{MRS} (")	16.8	8.93	6.70	4.47	3.62	2.91	1.94	1.46	1.03	0.77
C-6	15 m	θ_{MRS} (")	10.3	5.48	4.11	2.74	2.22	1.78	1.19	0.89	0.63	0.47
C-7	64 m	θ_{MRS} (")	6.45	3.44	2.58	1.72	1.40	1.12	0.75	0.56	0.40	0.30
C-8	110 m	θ_{MRS} (")	3.55	1.89	1.42	0.95	0.77	0.62	0.41	0.31	0.22	0.16
C-9	368 m	θ_{MRS} (")	2.03	1.08	0.81	0.54	0.44	0.35	0.24	0.18	0.13	0.093
C-10	244 m	θ_{MRS} (")	1.25	0.67	0.50	0.33	0.27	0.22	0.14	0.11	0.077	0.057

See Table A-2 in the proposer guide

- Cycle 13 documentation

<https://almascience.nao.ac.jp/documents-and-tools>

- FAQ and known issues

<https://almascience.nrao.edu/proposing/observing-tool/faq-and-known-issues>

- Technical handbook (advanced)

<https://almascience.nao.ac.jp/documents-and-tools/cycle13/alma-technical-handbook>

- Science primer (beginner)

<https://almascience.nao.ac.jp/documents-and-tools/cycle13/alma-science-primer>

Web OT

<https://cycle-13.sps.alma.cl/>

<https://almascience.nao.ac.jp/documents-and-tools>