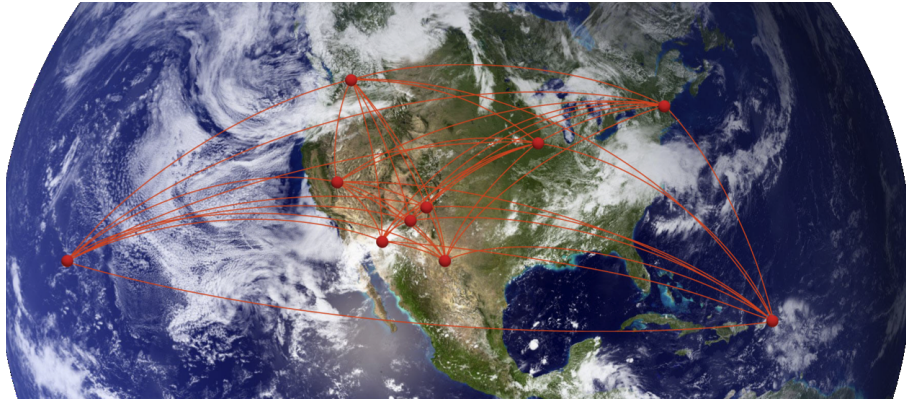


# National Radio Astronomy Observatory



**Dyas Utomo (OSU) & Angus Mok (Toledo)**



Atacama Large Millimeter/submillimeter Array  
Karl G. Jansky Very Large Array  
Very Long Baseline Array



# NRAO: One Observatory, Three World Class Facilities



Other Affiliated Telescopes and Observatories include the Green Bank Observatory (<http://greenbankobservatory.org/>). The VLBA was incorporated back into NRAO last year.

# NRAO: One Observatory, Three Facilities



Atacama Large Millimeter/submillimeter Array:  
a 66-antenna array in Chile

Penetrates Earth Atmosphere?



Wavelength (meters)



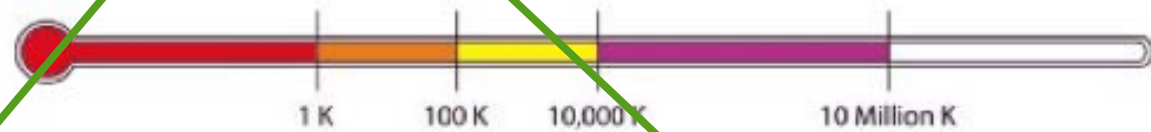
About the size of...



Frequency (Hz)



Temperature of bodies emitting the wavelength (K)



**VLA**  
~1 - 50 GHz  
~300 - 6 mm

**ALMA**  
~84 - 950 GHz  
~3 - 0.3 mm



# Broad Science Topics with NRAO Telescopes

- ◆ **Sun** – coronal mass ejections, magnetic field activity
- ◆ **Solar system, KBOs** – atmospheres, astrometry, composition
- ◆ **Star-forming regions** – dust and gas environment, kinematics (infall, outflows, jets), proto-planetary disks, cores, chemistry, feedback, and natal cloud / star interactions
- ◆ **Exoplanets** – direct imaging, gaps in disks, kinematics
- ◆ **Pulsars** – neutron star physics, pulse morphology, gravity, ISM probe
- ◆ **Galactic structure** – spiral arms, bars, global atomic and molecular gas properties
- ◆ **Nearby galaxies** – molecular / atomic gas content and kinematics, dynamics of galaxies at high resolution, star formation, obscured SF, gas flow
- ◆ **Galaxy groups and clusters** – atomic and molecular gas across systems, star formation efficiency, kinematics, dynamical mass measurements
- ◆ **Black holes** – mass measurements, kinematics
- ◆ **High redshift galaxies** – extragalactic background light, source counts, star formation history and efficiency, evolution of gas content (atomic and molecular)
- ◆ **Cosmology** –  $H_0$  measurement, SZE

# What is ALMA?

A global partnership to deliver a revolutionary millimeter/submillimeter telescope array (in collaboration with Chile)

- ◆ North America (33.75% time)
- ◆ Europe (33.75%)
- ◆ East Asia (10%)

66 reconfigurable, high precision antennas  
 $\lambda \sim 0.32 - 8.5\text{mm}$ . Array configurations between 150 meters and >16 kilometers: 192 possible antenna locations:

- ◆ Main Array: 50 x 12m antennas
- ◆ Atacama Compact Array (ACA): 12 x 7m antennas
- ◆ Total Power Array: 4 x 12m antennas
- ◆ TP + ACA (Morita Array)

Array Operations Site is located at 5000 m elevation in the Chilean Andes

Provides unprecedented imaging & spectroscopic capabilities at mm/submm  $\lambda$



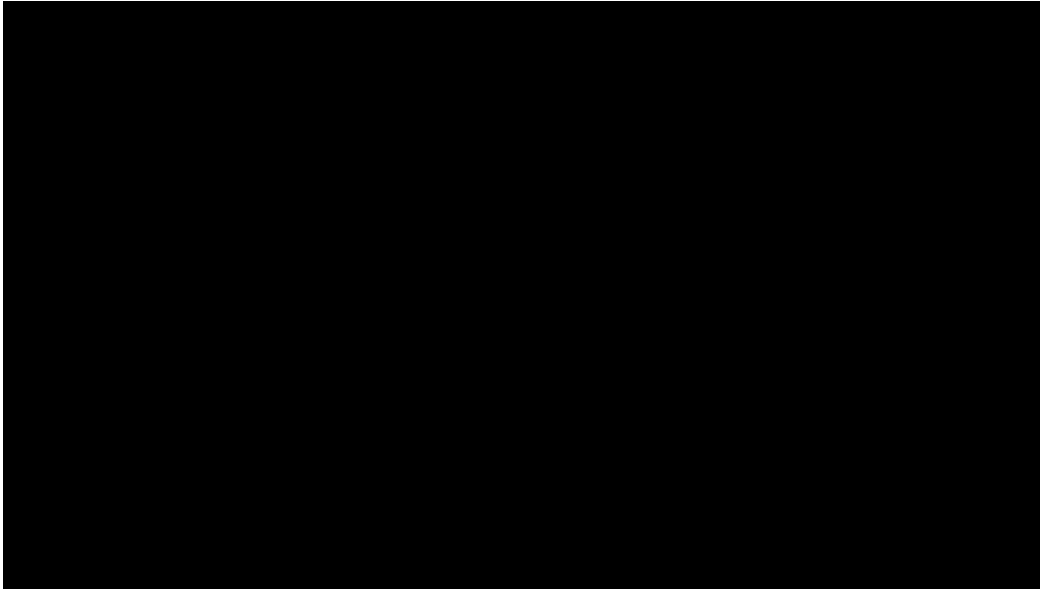
# ALMA Antenna Configuration



The ALMA 12-m Array in its compact configuration (left hand side of the image). The **ACA** with all 7 m antennas (**dashed orange circles**) and **four single-dish 12 m antennas (blue circles)** are distributed in the right hand side of the image. A few unoccupied stations can be seen, to which antennas of the 12-m Array can be moved by the transporter as the array is being reconfigured. At its most extended configuration, antennas in the 12-m Array will be about 16 km apart.

# What is ALMA?

Array configurations between 150 meters and >16 kilometers: 192 possible antenna locations:



Transporter



<http://youtu.be/YMISe-C8GUs>



### Documentation

### Proposals

Information supporting the current ALMA Call for Proposals – **Cycle 5**. Documents from previous Cycles are provided [here](#).

	Description
Proposer's Guide	Contains all pertinent information regarding the ALMA Call for Proposals
Observational Handbook	A comprehensive description of the ALMA observatory and its components
ALMA Policies	The long-term core policies for use of the ALMA and ALMA data by the science community
Getting Started with ALMA - A Primer	Introduction to interferometry and how to use ALMA
Proposal Template	LaTeX format. Recommended but not mandatory
Proposal Review Process	An updated ALMA Principles of the ALMA Proposal Review Process

Contents

1. Call for Proposals
2. Phase 1 & 2
3. Guides to the ALMA Regional Centers
4. ALMA Science Data Tracking, Data Processing and Pipeline, Archive, QA2 Data Products
5. ALMA Reports, Memos and Newsletters



ALMA is a telescope for *all* astronomers



literally, not only radio astronomers

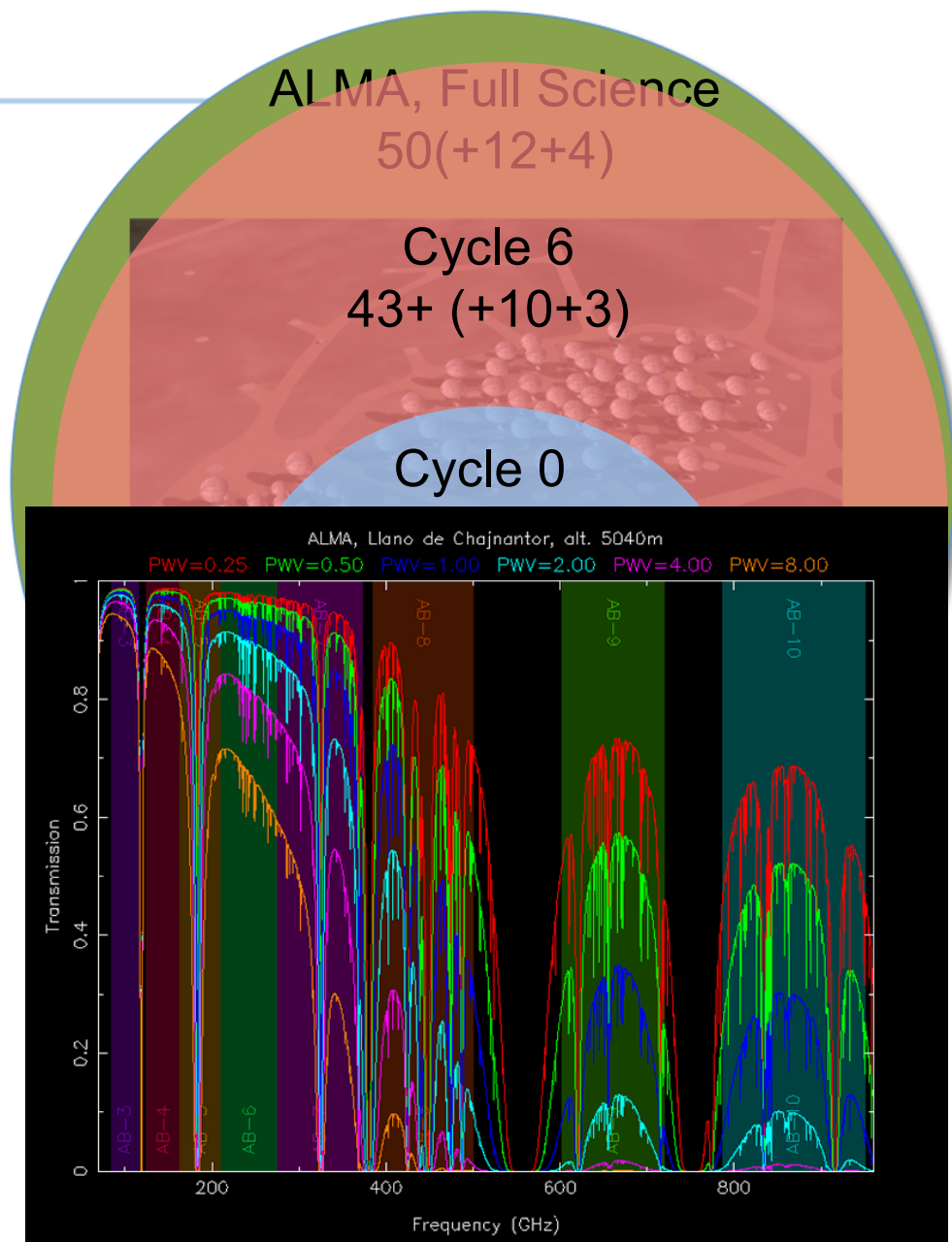
# What is ALMA?

## Collecting Area

Not only sensitivity but the collecting area (1.6 acres or 6600+ m<sup>2</sup>) + huge number of baselines **provides excellent image fidelity**

**Spectral Coverage** - Covers ten atmospheric windows with 50% or more transmission above 35 GHz

<https://almascience.nrao.edu/proposin/g/about-almata/atmosphere-model>



# ALMA in a Nutshell...

- ◆ Angular resolution down to 0.015" (at 300 GHz)
- ◆ Sensitive, precision imaging 84 to 950 GHz (3 mm to 320  $\mu\text{m}$ )
- ◆ State-of-the-art low-noise, wide-band receivers\* (8 GHz bandwidth)
- ◆ Flexible correlator with high spectral resolution at wide bandwidth
- ◆ Full polarization capabilities including circular.
- ◆ Estimated 1 TB/day data rate
- ◆ All science data archived
- ◆ Pipeline processing

**ALMA is 10-100 times more sensitive and has 10-100 times better angular resolution than current mm interferometers\***

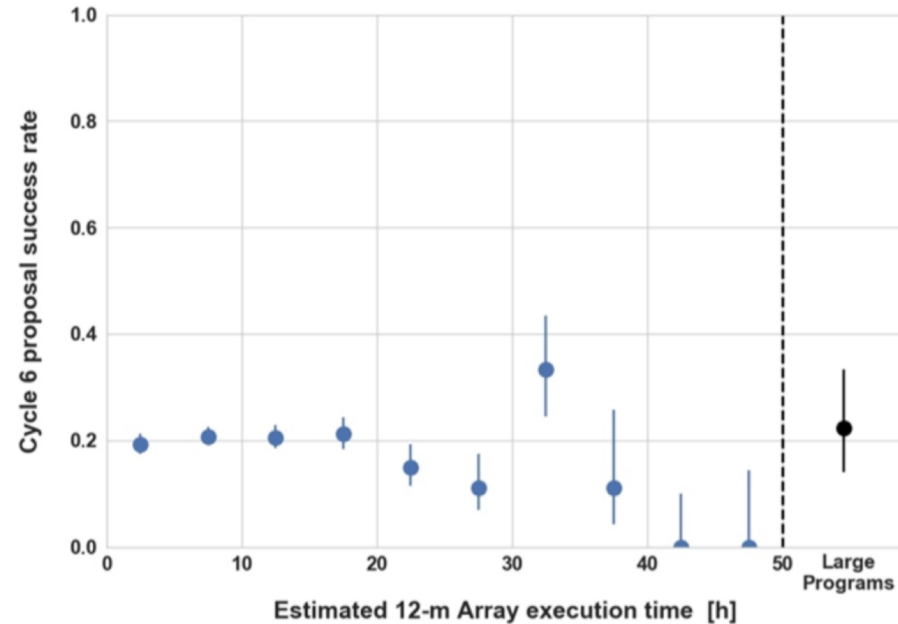
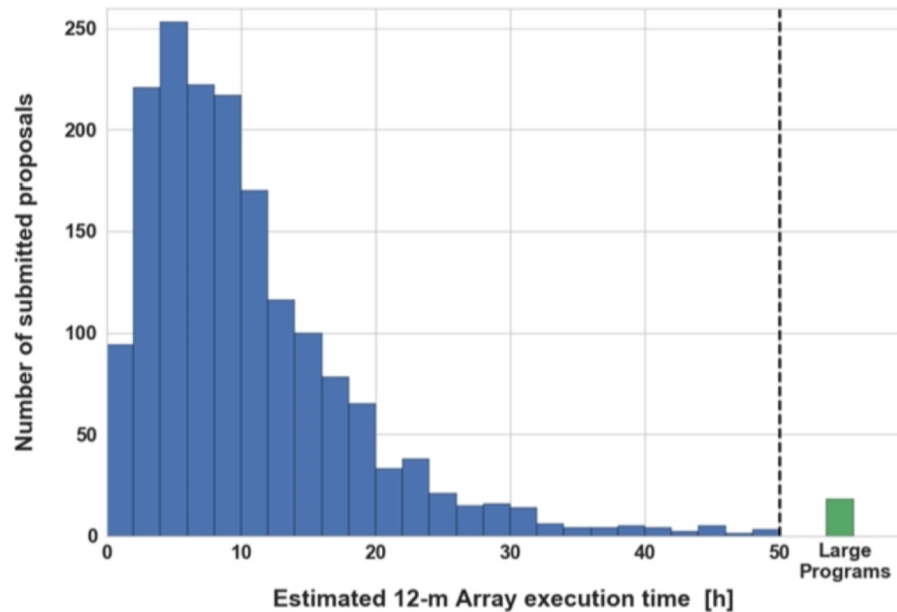
\*In Bands 9 and 10, we can get 16 GHz of instantaneous bandwidth.



# ALMA Proposal Records

## Observing Time:

- Strongly encourage ACA only observations in a wide range of science and large observing times.
- ALMA continues to encourage the community to submit Regular Proposals that request over 10 hours of 12-m Array time.



(Left) Number of proposals submitted as a function of the 12-m Array execution time in Cycle 6.

(Right) The fraction of proposals (with 1σ confidence intervals) that are assigned priority Grade A or B as a function of the estimated 12-m Array time.



# ALMA Cycle 7 Capabilities

The Cycle 7 capabilities are fully described in Appendix A of the ALMA Proposers Guide available at: <https://almascience.nrao.edu/documents-and-tools>



# ALMA New Capabilities

## Long baseline (up to 16 km; C43-9, C43-10) in Band 7.

- For the first time, Band 7 will be available out to 16 km as a standard mode if a suitable calibrator is found within 5 degrees. If not, it will be a non-standard mode.
- **NOTE: There will be NO C43-9 or C43-10 in Cycle 8! If you want/need those longest baselines, request them for Cycle 7 or wait until Cycle 9.**

## Improved Spectral Scan Mode.

- The Spectral Scan observing mode has been refined and it is now 25% faster and will be offered as a standard observing mode.

## Solar Observations for Band 3 (C43-4) and Band 7 (C43-1, C43-2).

- Band 7 continuum observations will be available for Solar observing. This will also include the full continuum single-dish map of the sun (always available for Solar).

## Relaxed restrictions on data rates.

- Previous restrictions on observing modes set from the ALMA data rate is removed. Users should no longer be limited by data rate restrictions or warnings when proposing.

## Improved sensitivity limit for full spectral resolution linear polarization observations.

Observations in Band 7 at baselines  $> 5$  km become a standard mode if there is a phase calibrator within 5 degrees of the science target.



# ALMA Capabilities

## Number of antennas

- At least forty-three (43) antennas in the 12-m Array
- At least ten (10) 7-m antennas (for short baselines) and three (3) 12-m antennas (for making single-dish maps) in the ACA

## Receiver bands

- Receiver Bands 3, 4, 5, 6, 7, 8, 9, and 10 ( $\lambda$  of 3.1, 2.1, 1.6, 1.3, 0.87, 0.74, 0.44, and 0.32 mm, respectively)

## 12-m Array Configurations

- Maximum baselines for the antenna configurations between 0.15 km and 16 km
- Maximum baseline for most extended configuration in Bands 8, 9 and 10 is 3.6 km
- Maximum baseline for for most extended configuration in Bands 3, 4, 5, 6 and 7 is 16 km



# ALMA Capabilities

## Spectral line, continuum, and mosaic observations

- Spectral line and continuum observations with the 12-m Array and the 7-m Array in all bands
- Mosaic observations in Bands 3 to 9 with the 12-m Array and the 7-m Array
- Total power antenna for spectral line observations in Bands 3 to 8

## Polarization

- Single pointing, full (including circular) polarization for both continuum and spectral-resolution observations in Band 3, 4, 5, 6, and 7 are offered on the 12-m Array.
- The minimum detectable degree of circular polarization is currently 1.8 % of the peak flux.
- Circular polarization will be offered only for sources with angular size  $< 10\%$  of the FWHM primary beam.

## Observing Time:

- 4300 hours for successful proposals of PI programs expected on the 12m Array (includes DDT, Cycle 6 Carryover and resubmissions)
- 3750 hours available on the ACA
- 3750 hours available on the Total Power Array
  - ~750 hours of ACA time will be available through the Supplemental Call in mid-Cycle 7.

Up to 15% of time may be allocated to Large Program





# ALMA Capabilities

## Standard vs Non-Standard modes:

Non-standard mode means takes additional observatory resources to calibrate, image and deliver the data.

Non-standard mode does NOT mean it can't be run through the ALMA calibration pipeline.

Cycle 7 should still be around **20% of the time going to non-standard modes.**

## Non-Standard Observing Modes include:

- Band 7 observations with baselines longer than 5 km and the phase calibrator is expected to be further than 5 degrees from the science target
- Bands 9 and 10 observations
- All polarization observations
- Solar observations
- VLBI observations
- Non-standard calibrations (user-defined calibrations selected in the OT)
- Astrometric Observations

# ALMA Timelines and Milestones

## The ALMA Cycle 7 Timeline

Date	Milestone
19 March 2019 (15:00 UT)	Release of Cycle 7 Call for Proposals, Observing Tool & supporting documents and Opening of the Archive for proposal submission
<b>17 April 2019</b> <b>(15:00 UT)</b>	Proposal submission deadline (no excuse!)
End of July 2019	Announcement of the outcome of the Proposal Review Process
5 September 2019	Deadline for Submission of Phase 2 (if accepted)
1 October 2019	ACA Supplemental Proposal Deadline Start of ALMA Cycle 7 Science Observations
September 2020	End of ALMA Cycle 7 Observations

**Table A-1: Angular Resolutions (AR) and Maximum Recoverable Scales (MRS) for the Cycle 7 Array configurations**

**ALMA Array Configuration**

Config	Lmax		Band 3	Band 4	Band 5	Band 6	Band 7	Band 8	Band 9	Band 10
	Lmin		100 GHz	150 GHz	183 GHz	230 GHz	345 GHz	460 GHz	650 GHz	870 GHz
7-m Array	45 m	AR	12.5"	8.4"	6.8"	5.4"	3.6"	2.7"	1.9"	1.4"
	9 m	MRS	66.7"	44.5"	36.1"	29.0"	19.3"	14.5"	10.3"	7.7"
C43-1	161 m	AR	3.4"	2.3"	1.8"	1.5"	1.0"	0.74"	0.52"	0.39"
	15 m	MRS	28.5"	19.0"	15.4"	12.4"	8.3"	6.2"	4.4"	3.3"
C43-2	314 m	AR	2.3"	1.5"	1.2"	1.0"	0.67"	0.50"	0.35"	0.26"
	15 m	MRS	22.6"	15.0"	12.2"	9.8"	6.5"	4.9"	3.5"	2.6"
C43-3	500 m	AR	1.4"	0.94"	0.77"	0.62"	0.41"	0.31"	0.22"	0.16"
	15 m	MRS	16.2"	10.8"	8.7"	7.0"	4.7"	3.5"	2.5"	1.9"
C43-4	784 m	AR	0.92"	0.61"	0.50"	0.40"	0.27"	0.20"	0.14"	0.11"
	15 m	MRS	11.2"	7.5"	6.1"	4.9"	3.3"	2.4"	1.7"	1.3"
C43-5	1.4 km	AR	0.54"	0.36"	0.30"	0.24"	0.16"	0.12"	0.084"	0.063"
	15 m	MRS	6.7"	4.5"	3.6"	2.9"	1.9"	1.5"	1.0"	0.77"
C43-6	2.5 km	AR	0.31"	0.20"	0.16"	0.13"	0.089"	0.067"	0.047"	0.035"
	15 m	MRS	4.1"	2.7"	2.2"	1.8"	1.2"	0.89"	0.63"	0.47"
C43-7	3.6 km	AR	0.21"	0.14"	0.11"	0.092"	0.061"	0.046"	0.033"	0.024"
	64 m	MRS	2.6"	1.7"	1.4"	1.1"	0.75"	0.56"	0.40"	0.30"
C43-8	8.5 km	AR	0.096"	0.064"	0.052"	0.042"	0.028"	N/A	N/A	N/A
	110 m	MRS	1.4"	0.95"	0.77"	0.62"	0.41"			
C43-9	13.9 km	AR	0.057"	0.038"	0.031"	0.025"	0.017"	N/A	N/A	N/A
	368 m	MRS	0.81"	0.54"	0.44"	0.35"	0.24"			
C43-10	16.2 km	AR	0.042"	0.028"	0.023"	0.018"	0.012"	N/A	N/A	N/A
	244 m	MRS	0.50"	0.33"	0.27"	0.22"	0.14"			

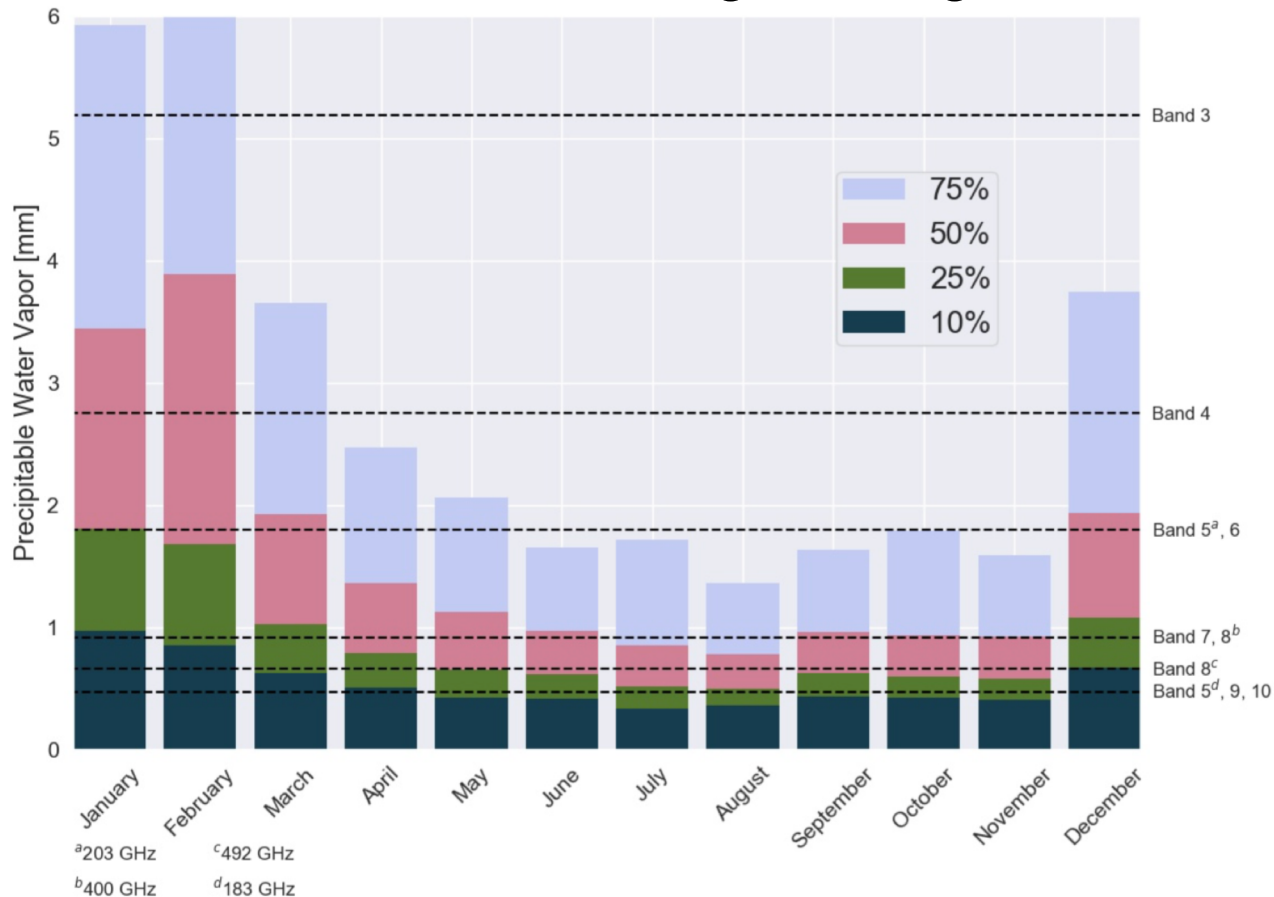


# ALMA Array Configuration Schedule (Cycle 7)

- For Cycle 7, the long baseline array configurations will be in the southern hemisphere winter in order to accommodate high spatial resolution observation. The array configuration schedule will cycle every couple years to accommodate the range of LST.
- LST limits are not applied to lower frequency bands.
- You may submit band 9 proposal during daytime, however the chance for observation is very small, regardless of the grade.

Start date	Configuration	Longest baseline	LST for best observing conditions
2019 October 1	C43-4	0.78 km	~ 22h – 10h
2019 October 20	C43-3	0.50 km	~ 23h – 11h
2019 November 10	C43-2	0.31 km	~ 1h – 13h
2019 November 30	C43-1	0.16 km	~ 2h – 14h
2019 December 20	C43-2	0.31 km	~ 4h – 15h
2020 January 10	C43-3	0.50 km	~ 5h – 17h
2020 February 1-28	No observations due to February Maintenance		
2020 March 1	C43-4	0.78 km	~ 8h – 21h
2020 March 20	C43-5	1.4 km	~ 9h – 23h
2020 April 20	C43-6	2.5 km	~ 11h – 1h
2020 May 20	C43-7	3.6 km	~ 13h – 3h
2020 June 20	C43-8	8.5 km	~ 15h – 5h
2020 July 11	C43-9	13.9 km	~ 16h – 6h
2020 July 30	C43-10	16.2 km	~ 17h – 7h
2020 August 20	C43-9	13.9 km	~ 19h – 8h
2020 September 10	C43-8	8.5 km	~ 20h – 9h

# ALMA Observing Strategies



Fraction of time that the PWV falls below a given value along the year. The percentages shown indicate the fraction of time that the PWV is under the PWV value indicated on the y-axis. For example, in March 75% of the PWV measurements are under 3.6 mm, and in June 75% of the PWV measurements fall below 1.6 mm. The data were obtained between September 2010 and February 2019. The horizontal dashed lines show the PWV observing limits adopted for the ALMA bands for an elevation of 60 degrees.

# ALMA Correlator Modes

Table A-4: Properties of ALMA Cycle 7 Correlator Modes, dual-polarization operation <sup>1,2</sup>

Bandwidth (MHz)	Channel spacing <sup>(3)</sup> (MHz)	Spectral resolution (MHz)	Number of channels	Correlator mode <sup>(4)</sup>
1875	15.6	31.2	120	TDM
1875	0.488	0.976	3840	FDM
938	0.244	0.488	3840	FDM
469	0.122	0.244	3840	FDM
234	0.061	0.122	3840	FDM
117	0.0305	0.061	3840	FDM
58.6	0.0153	0.0305	3840	FDM

# NAASC Sources of Support

- **ALMA Helpdesk:** User support is a priority so questions are usually answered within 48 hours (with around the clock staffing in the week leading up to the proposal deadline) - <https://help.almascience.org>
- **Student Observing Support:** Successful ALMA proposals will be invited to apply for up to \$35k to support undergraduate or graduate student involvement - <https://science.nrao.edu/opportunities/student-programs/sos>
- **Page Charges:** Upon request NRAO covers page charges for authors at US institutions when reporting results from ALMA/VLA - <https://library.nrao.edu/pubsup.shtml>
- **Face-to-face Visitor Support:** Upon request NRAO will cover the travel expenses of up to 2 people from 2 teams per week to come to the NAASC to get support for data reduction, proposal preparation, etc... We also have long term visitor support as well - <https://science.nrao.edu/facilities/alma/visitors-shortterm>
- **Postdoc ALMA Ambassadors:** You too can become an ALMA Ambassador. For program eligibility visit - <https://science.nrao.edu/facilities/alma/ambassadors-program>



[www.nrao.edu](http://www.nrao.edu)  
[science.nrao.edu](http://science.nrao.edu)





# ALMA Capabilities

## Full ALMA Operations (All Cycle 7 Capabilities plus):

### Receiver bands:

- Include Bands 1 and 2

### Baselines:

- All bands out to 16 km. Some may never be considered a standard mode

### Standard vs Non-Standard modes:

- Fraction of non-standard modes should decrease to about 10%

### Observing Time:

- Up to 4500 hours+ for successful proposals of PI programs expected on the 12m Array (includes DDT, Cycle 7+ Carryover and resubmissions)

### Observing Modes:

- Wide field polarization capabilities (12m + 7m arrays)
- Full operations include full Stoke plus circular polarization at all observing bands including mosaics and Total Power



# ALMA Capabilities

## ACA Supplemental Call:

- In Cycle 7, ALMA will offer a stand-alone ACA Supplemental Call for Proposals.
- It is anticipated that the Supplemental Call will be issued on 3 September 2019 with a proposal deadline on 1 October 2019.
- A minimum of 750 h of observing time on the ACA will be allocated through the Supplemental Call for observations between January 2020 and September 2020.
- Proposals may be submitted that use the 7-m Array only or the 7-m Array plus the Total Power array and with the same technical capabilities offered for the ACA in the Main Call.
- The prioritization of ACA observations in Cycle 7 will be as follows: proposals which require ACA time (in combination with the 12-m Array or stand-alone ACA observations only) will only be eligible for "A" or "B" priority in the Main Call; in the Supplemental Call, stand-alone ACA proposals accepted to the scheduling queue will be all given priority "C".
- Proposals submitted to the Supplemental Call will be peer reviewed through a distributed system.
- More information about the supplemental call can be found at:  
<https://almascience.nrao.edu/proposing/7m-array-supplemental-call>

# ALMA Timelines and Milestones

## The ALMA Cycle 7 Supplemental Call Timeline

Date	Milestone
03 September 2019	Call for Proposals and Supplemental Call submission server opened
01 October 2019	Deadline to submit Supplemental Call proposals
15 October 2019	Proposals released to reviewers
22 October 2019	Deadline for reviewer to report conflicts of interest on proposal review assignments
12 November 2019	Deadline to submit reviews and ranks
Early December 2020	Notification emails sent to PIs
January 2020	Successful Supplemental Call proposals enter the observing queue