ALMA Basics and Cycle 9 Capabilities

Charles Law (Harvard/CfA) & Hansung Gim (MSU)
Atacama Large Millimeter/submillimeter Array (ALMA)
Karl G. Jansky Very Large Array (VLA)
Very Long Baseline Array (VLBA)
ALMA Basics and Cycle 9 Capabilities – April 5, 2022

- **Radio**: $10^3$ meters
- **Microwave**: $10^{-2}$ meters
- **Infrared**: $10^{-5}$ meters
- **Visible**: $0.5 \times 10^{-6}$ meters
- **Ultraviolet**: $10^{-8}$ meters
- **X-ray**: $10^{-10}$ meters
- **Gamma ray**: $10^{-12}$ meters

**Approximate Scale of Wavelength**
- Buildings
- Humans
- Butterflies
- Needle Point
- Protozoans
- Molecules
- Atoms
- Atomic Nuclei

**Frequency (Hz)**
- VLA: $10^{4}$ Hz
- ALMA: $10^{12}$ Hz

**Temperature of objects at which this radiation is the most intense wavelength emitted**
- VLA: $1 K$ (273 °C)
- ALMA: $84 - 950$ GHz (300 – 6 mm)

- $10^4$ Hz: Absolute Zero
- $10^8$ Hz: Liquid Nitrogen
- $10^{12}$ Hz: Liquid Helium

- $1 K$: $-273 ^\circ C$
- $100 K$: $-173 ^\circ C$
- $10,000 K$: $9,727 ^\circ C$
- $10,000,000 K$: $10,000,000 ^\circ C$
Broad science topics with ALMA (and NRAO telescopes)

Sun — coronal mass ejections, magnetic field activity

Solar system, KBOs — atmospheres, astrometry, composition

Star-forming regions — dust and gas environment, kinematics (in-fall, outflows, jets), protoplanetary 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 of North America, Europe, East Asia, and Chile

66 reconfigurable, high precision antennas with array configurations between 150 m and >16 km: 192 possible antenna locations

- **Main Array**: 50 × 12m antennas
- **Total Power Array**: 4 × 12m antennas
- **Atacama Compact Array (ACA)**: 12 × 7m antennas

Located at 5000 m elevation in Chilean Andes

Provides unprecedented imaging & spectroscopic capabilities at mm/submm wavelengths
What is ALMA?

Angular Resolution
ALMA is an interferometer, which means that the angular resolutions goes as wavelength / largest baseline

Collecting Area
Not only sensitivity but the collecting area (1.6 acres or 6600+ m$^2$) & large number of baselines provides excellent image fidelity

Spectral Coverage
Atmospheric windows with >50% transmission above 35 GHz
Interferometry aside

Signal arrives at each antenna at a different time (due to different travel lengths) depending on location of antenna in the array.

Signals are then combined in a correlator, where the time delay is measured and compensated for.
To measure arrival times, we need accurate clocks

At Band 10, one wavelength error = 1 picosecond = $10^{-12}$ s (!!)

Need $\ll 1$ wavelength timing precision, so each antenna has an on-board clock with high sampling rates

Once determined, the reference time is distributed to all antennas
Signals from each antenna are digitized and sent to the correlator. For ~50 antennas, data rate is 600 GB/sec.
Angular scales of an interferometry

Angular resolution of an array:
\[ \sim \frac{\lambda}{B_{\text{max}}} \]  
\( (B_{\text{max}} = \text{longest baseline}) \)

Maximum angular scale:
\[ \sim \frac{\lambda}{B_{\text{min}}} \]  
\( (B_{\text{min}} = \text{shortest distance between antennas}) \)

Field of view (FOV):
\[ \sim \frac{\lambda}{D} \]  
\( (D = \text{antenna diameter}) \)

*Sources more extended than the FOV can be observed using multiple pointing centers in a mosaic

An interferometer is sensitive to a range of angular sizes:
\[ \frac{\lambda}{B_{\text{max}}} < \theta < \frac{\lambda}{B_{\text{min}}} \]
ALMA 12m shows smaller spatial scales (denser / clumpier emission)

ACA 7m data shows larger spatial scales (diffuse / extended emission)

To get both — you need a combined image!
Interferometers act as spatial filters - shorter baselines are sensitive to larger targets.

Spatial scales larger than the smallest baseline cannot be imaged.

Spatial scales smaller than the largest baseline cannot be resolved.

Table A-1: Angular Resolutions (AR) and Maximum Recoverable Scales (MRS) for the Cycle 9 configurations

<table>
<thead>
<tr>
<th>Config</th>
<th>Lmax</th>
<th>Band 3</th>
<th>Band 4</th>
<th>Band 5</th>
<th>Band 6</th>
<th>Band 7</th>
<th>Band 8</th>
<th>Band 9</th>
<th>Band 10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L.min</td>
<td>100 GHz</td>
<td>150 GHz</td>
<td>185 GHz</td>
<td>230 GHz</td>
<td>345 GHz</td>
<td>460 GHz</td>
<td>650 GHz</td>
<td>870 GHz</td>
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<tr>
<td>7-m</td>
<td>45 m</td>
<td>12.5&quot;</td>
<td>8.35&quot;</td>
<td>6.77&quot;</td>
<td>5.45&quot;</td>
<td>3.63&quot;</td>
<td>2.72&quot;</td>
<td>1.93&quot;</td>
<td>1.44&quot;</td>
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<tr>
<td></td>
<td>9 m</td>
<td>MRS</td>
<td>66.7&quot;</td>
<td>44.5&quot;</td>
<td>36.1&quot;</td>
<td>29.0&quot;</td>
<td>19.3&quot;</td>
<td>14.5&quot;</td>
<td>10.3&quot;</td>
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<tr>
<td>C-1</td>
<td>161 m</td>
<td>AR</td>
<td>3.38&quot;</td>
<td>2.25&quot;</td>
<td>1.83&quot;</td>
<td>1.47&quot;</td>
<td>0.98&quot;</td>
<td>0.74&quot;</td>
<td>0.52&quot;</td>
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<tr>
<td></td>
<td>15 m</td>
<td>MRS</td>
<td>28.5&quot;</td>
<td>19.0&quot;</td>
<td>15.4&quot;</td>
<td>12.4&quot;</td>
<td>8.25&quot;</td>
<td>6.19&quot;</td>
<td>4.38&quot;</td>
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<tr>
<td>C-2</td>
<td>314 m</td>
<td>AR</td>
<td>2.30&quot;</td>
<td>1.53&quot;</td>
<td>1.24&quot;</td>
<td>1.00&quot;</td>
<td>0.67&quot;</td>
<td>0.50&quot;</td>
<td>0.35&quot;</td>
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<td></td>
<td>15 m</td>
<td>MRS</td>
<td>22.6&quot;</td>
<td>15.0&quot;</td>
<td>12.2&quot;</td>
<td>9.81&quot;</td>
<td>6.54&quot;</td>
<td>4.90&quot;</td>
<td>3.47&quot;</td>
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<tr>
<td>C-3</td>
<td>500 m</td>
<td>AR</td>
<td>1.42&quot;</td>
<td>0.94&quot;</td>
<td>0.77&quot;</td>
<td>0.62&quot;</td>
<td>0.41&quot;</td>
<td>0.31&quot;</td>
<td>0.22&quot;</td>
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<tr>
<td></td>
<td>15 m</td>
<td>MRS</td>
<td>16.2&quot;</td>
<td>10.8&quot;</td>
<td>8.73&quot;</td>
<td>7.02&quot;</td>
<td>4.68&quot;</td>
<td>3.51&quot;</td>
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<td>C-4</td>
<td>784 m</td>
<td>AR</td>
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<td>0.61&quot;</td>
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<td>0.40&quot;</td>
<td>0.27&quot;</td>
<td>0.20&quot;</td>
<td>0.14&quot;</td>
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<tr>
<td></td>
<td>15 m</td>
<td>MRS</td>
<td>11.2&quot;</td>
<td>7.50&quot;</td>
<td>6.08&quot;</td>
<td>4.89&quot;</td>
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<tr>
<td>C-5</td>
<td>1.4 km</td>
<td>0.55&quot;</td>
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<td>0.24&quot;</td>
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<td>0.084&quot;</td>
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<tr>
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<td>15 m</td>
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<td>6.70&quot;</td>
<td>4.47&quot;</td>
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<td>C-6</td>
<td>2.5 km</td>
<td>0.31&quot;</td>
<td>0.20&quot;</td>
<td>0.17&quot;</td>
<td>0.13&quot;</td>
<td>0.089&quot;</td>
<td>0.067&quot;</td>
<td>0.047&quot;</td>
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<tr>
<td></td>
<td>15 m</td>
<td>MRS</td>
<td>4.11&quot;</td>
<td>2.74&quot;</td>
<td>2.22&quot;</td>
<td>1.78&quot;</td>
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<td>0.89&quot;</td>
<td>0.63&quot;</td>
</tr>
<tr>
<td>C-7</td>
<td>3.6 km</td>
<td>0.21&quot;</td>
<td>0.14&quot;</td>
<td>0.11&quot;</td>
<td>0.092&quot;</td>
<td>0.061&quot;</td>
<td>0.046&quot;</td>
<td>0.033&quot;</td>
<td>0.024&quot;</td>
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<tr>
<td></td>
<td>64 m</td>
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<td>2.58&quot;</td>
<td>1.72&quot;</td>
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<tr>
<td>C-8</td>
<td>8.5 km</td>
<td>0.096&quot;</td>
<td>0.064&quot;</td>
<td>0.052&quot;</td>
<td>0.042&quot;</td>
<td>0.028&quot;</td>
<td>0.021&quot;</td>
<td>0.015&quot;</td>
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<td>110 m</td>
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<td>1.42&quot;</td>
<td>0.95&quot;</td>
<td>0.77&quot;</td>
<td>0.62&quot;</td>
<td>0.41&quot;</td>
<td>0.31&quot;</td>
<td>0.22&quot;</td>
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<tr>
<td>C-9</td>
<td>13.9 km</td>
<td>0.057&quot;</td>
<td>0.038&quot;</td>
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<td>0.025&quot;</td>
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<tr>
<td></td>
<td>368 m</td>
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<td>0.54&quot;</td>
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<td>0.35&quot;</td>
<td>0.24&quot;</td>
<td>0.18&quot;</td>
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<td>C-10</td>
<td>16.2 km</td>
<td>0.042&quot;</td>
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<td>0.023&quot;</td>
<td>0.018&quot;</td>
<td>0.012&quot;</td>
<td>0.0091&quot;</td>
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<td>N/A</td>
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<td>0.22&quot;</td>
<td>0.14&quot;</td>
<td>0.11&quot;</td>
<td>N/A</td>
</tr>
</tbody>
</table>

From ALMA Cycle 9 Proposer’s Guide
Array configurations between 150 m and >16 km and 192 possible antenna locations
Imaging highlights: dust in protoplanetary disks

ALMA has enabled studies of disk demographics to highly detailed views of substructure in individual disks.

![Image of ALMA observations and a graph showing dust mass vs. disk mass. The graph indicates a spread of data points for different disk systems, with labels such as Upper Sco, ρ Oph, Cha I, Lupus, Orion Class 0, and SODA. The image also shows a collection of infrared and optical images of protoplanetary disks with annotations like HT Lup, GW Lup, HD 142666, and SODA, van Terwisga+22.]

DSHARP, Andrews+18, Huang+18
Imaging highlights: gas in galaxies

ALMA can study nearby galaxies in molecular line emission in detail and detect gas in high-z sources.

Gas in dusty star-forming galaxy at z~7
Jarugula+21

PHANGS, Leroy+21

NGC 4303/M61
NGC 4254/M99
NGC 628/M74
NGC 3627/M66
Not only imaging, but 3D info in spectra

Output of interferometric observation is a “cube” of data – the third dimension is frequency

Object seen in combined light

Image slice at single wavelength

Spectral slice across the entire object
Often most interesting science is in 3rd dimension

Young Low Mass Stars: IRAS 16293

High degree of chemical complexity, including lines from complex organic molecules
Often most interesting science is in 3rd dimension

Lines are detectable in high redshift sources and upcoming upgrades will only improve similar searches

UV-bright galaxies which emit [C II] strongly

![Graph showing redshift and flux density](image)

**Redshift**

13.3

13.2

**Flux density [mJy]**

-2

-1

0

1

2

236 237 238 239

$\nu_{\text{obs}}$ [GHz]

tentative [O III] 88 μm line at $z = 13.27$

Harikane+21

REBELS, Bouwens+21
ALMA hosts an extensive archive of previous observations!

Filter columns based on target, publication, etc.

List of programs

**Table:**

<table>
<thead>
<tr>
<th>Project code</th>
<th>ALMA source name</th>
<th>RA</th>
<th>Dec</th>
<th>Band</th>
<th>Cont. sens.</th>
<th>Frequency support</th>
<th>Release date</th>
<th>Publications</th>
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<tr>
<td>2018.1.0120.5</td>
<td>IRAS,15398-3359</td>
<td>15:43:02.242</td>
<td>-34:09:06.805</td>
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<td>0.0532</td>
<td>216.08.234,371GHz</td>
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<td>2011.0.0019.5</td>
<td>Fomalhaut b</td>
<td>22:17:38.685</td>
<td>-29:37:12.816</td>
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<td>2011.0.0010.5</td>
<td>GRB021004</td>
<td>00:26:54.680</td>
<td>+18:55:41.600</td>
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<td>0.1136</td>
<td>337.01.353,000GHz</td>
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<td>2011.0.0013.5</td>
<td>R Sco</td>
<td>01:26:58.079</td>
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<td>2011.0.0039.7</td>
<td>J035448.24-33082...</td>
<td>03:54:48.240</td>
<td>-33:08:27.200</td>
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<td>2011.0.0039.7</td>
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<td>04:17:54.100</td>
<td>-28:16:55.900</td>
<td>7</td>
<td>0.4848</td>
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<td>2012-12-20</td>
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<td>J063027.81-212055...</td>
<td>06:30:27.810</td>
<td>-21:20:58.600</td>
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<td>0.5346</td>
<td>337.00.352,990GHz</td>
<td>2012-12-20</td>
<td>3</td>
</tr>
</tbody>
</table>
Often including quick-look images and spectra

Click on links for direct download of files

Hover over for quick look
ALMA in a nutshell...

- Angular resolution down to 0.015” (at 300 GHz)
- Sensitive, precision imaging 84 to 950 GHz (3 mm to 320 µm)
- 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
ALMA is a telescope for all astronomers!

You do not need to be an expert to propose!
### ALMA frequency bands

<table>
<thead>
<tr>
<th>Band</th>
<th>Frequency (wavelength)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>84-116 GHz (2.59-3.57mm)</td>
</tr>
<tr>
<td>4</td>
<td>125-163 GHz (1.84-2.40mm)</td>
</tr>
<tr>
<td>5</td>
<td>158-211 GHz (1.42-1.90mm)</td>
</tr>
<tr>
<td>6</td>
<td>211-275 GHz (1.09-1.42mm)</td>
</tr>
<tr>
<td>7</td>
<td>275-373 GHz (0.80-1.09mm)</td>
</tr>
<tr>
<td>8</td>
<td>385-500 GHz (0.60-0.78mm)</td>
</tr>
<tr>
<td>9</td>
<td>602-720 GHz (0.42-0.50mm)</td>
</tr>
<tr>
<td>10</td>
<td>787-950 GHz (0.32-0.38mm)</td>
</tr>
</tbody>
</table>

![ALMA Bands](chart.png)

**Chart Description:**
- **X-axis:** Frequency (GHz)
- **Y-axis:** Atmospheric Transmission
- **Legend:**
  - Band 3: Blue
  - Band 4: Magenta
  - Band 5: Pink
  - Band 6: Red
  - Band 7: Green
  - Band 8: Orange
  - Band 9: Yellow
  - Band 10: Red

This chart illustrates the atmospheric transmission across different frequency bands for ALMA observations.
ALMA array configurations

Main: 50 x 12m
ACA (Atacama Compact Array): 12 x 7m + 4 x 12m
ALMA array configuration (Cycle 9)

<table>
<thead>
<tr>
<th>Config</th>
<th>Min-max baseline</th>
<th>Angular resolution at l=3mm</th>
<th>Maximum recoverable scale at l=3mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>7m</td>
<td>9-45m</td>
<td>12.5”</td>
<td>66.7”</td>
</tr>
<tr>
<td>C-1</td>
<td>15-161m</td>
<td>3.38”</td>
<td>28.5”</td>
</tr>
<tr>
<td>C-2</td>
<td>15-314m</td>
<td>2.30”</td>
<td>22.6”</td>
</tr>
<tr>
<td>C-3</td>
<td>15-500m</td>
<td>1.42”</td>
<td>16.2”</td>
</tr>
<tr>
<td>C-4</td>
<td>15-784m</td>
<td>0.92”</td>
<td>11.2”</td>
</tr>
<tr>
<td>C-5</td>
<td>15-1400m</td>
<td>0.55”</td>
<td>6.70”</td>
</tr>
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<td>C-6</td>
<td>15-2500m</td>
<td>0.31”</td>
<td>4.11”</td>
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<td>C-7</td>
<td>64-3600m</td>
<td>0.21”</td>
<td>2.58”</td>
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<tr>
<td>C-8</td>
<td>110-8500m</td>
<td>0.096”</td>
<td>1.42”</td>
</tr>
<tr>
<td>C-9</td>
<td>368-13900m</td>
<td>0.057”</td>
<td>0.81”</td>
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<tr>
<td>C-10</td>
<td>244-16200m</td>
<td>0.042”</td>
<td>0.50”</td>
</tr>
</tbody>
</table>

- Maximum baselines in Cycle 9 will be 16.2 km in configuration C-10.

- Configurations C-9 and C-10 with maximum baselines of 13.9 km and 16.2 km, respectively, will NOT again be available until Cycle 11.
## ALMA timelines and milestones

### Cycle 9 Timeline

<table>
<thead>
<tr>
<th>Date</th>
<th>Milestone</th>
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<tbody>
<tr>
<td>24 March 2022</td>
<td>Release of Cycle 9 Call for Proposals, Observing Tool, and supporting documents, and opening of the Archive for proposal submission</td>
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<tr>
<td>21 April 2022 (15:00 UT)</td>
<td>Proposal submission deadline for Cycle 9 Call for Proposals</td>
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<tr>
<td>1 June 2022 (15:00 UT)</td>
<td>Deadline to submit reviews for the distributed peer review system</td>
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<tr>
<td>August 2022</td>
<td>Announcement of the outcome of the proposal review process</td>
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<tr>
<td>1 October 2022</td>
<td>Start of ALMA Cycle 9 Science Observations</td>
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<tr>
<td>30 September 2023</td>
<td>End of ALMA Cycle 9</td>
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</table>
ALMA array configuration schedule (Cycle 9)

NOTE: No PI observing takes place in Feb!

The forward-looking configuration schedule (through Cycle 11) can be found at:

https://almascience.nrao.edu/observing/observing-configuration-schedule/long-term-configuration-schedule

<table>
<thead>
<tr>
<th>Start date</th>
<th>Config</th>
<th>Longest baseline</th>
<th>LST: Best conditions</th>
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<tbody>
<tr>
<td>1-Oct-22</td>
<td>C-3</td>
<td>0.50</td>
<td>22-10</td>
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<td>20-Oct-22</td>
<td>C-2</td>
<td>0.31</td>
<td>23-11</td>
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<td>10-Nov-22</td>
<td>C-1</td>
<td>0.16</td>
<td>1-13</td>
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<td>30-Nov-22</td>
<td>C-2</td>
<td>0.31</td>
<td>2-14</td>
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<td>20-Dec-22</td>
<td>C-3</td>
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<td>4-15</td>
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<td>5-17</td>
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<td>C-4</td>
<td>0.78</td>
<td>8-21</td>
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<td>C-5</td>
<td>1.4</td>
<td>9-23</td>
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<td>20-Apr-23</td>
<td>C-6</td>
<td>2.5</td>
<td>11-1</td>
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<td>20-May-23</td>
<td>C-7</td>
<td>3.6</td>
<td>13-3</td>
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<td>20-Jun-23</td>
<td>C-8</td>
<td>8.5</td>
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<td>11-Jul-23</td>
<td>C-9</td>
<td>13.9</td>
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<td>C-10</td>
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<td>C-9</td>
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<td>10-Sep-23</td>
<td>C-8</td>
<td>8.5</td>
<td>20-9</td>
</tr>
</tbody>
</table>
ALMA capabilities

The Cycle 9 capabilities are fully described in Appendix A of the ALMA Proposers Guide available at https://almascience.nrao.edu/documents-and-tools.

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

- Bands 3, 4, 5, 6, 7, 8, 9, and 10 (wavelengths of about 3.1, 2.1, 1.6, 1.3, 0.87, 0.74, 0.44, and 0.32 mm, respectively)
**ALMA capabilities**

### 12-m Array Configurations

- Cycle 9 includes configurations C-1 through C-10.

- Maximum baselines between 0.16 km and 16.2 km depending on array configuration and subject to the following restrictions:
  - The maximum possible baseline for Bands 3, 4, 5, 6, 7, and 8 is 16.2 km (C-10).
  - The maximum possible baseline for Band 9 is 13.9 km (C-9).
  - The maximum possible baseline for Band 10 is 8.5 km (C-8).

- Files containing representative antenna configurations for the 12-m and 7-m arrays suitable for Common Astronomy Software Applications (CASA) simulations are available from the ALMA Science portal (http://almascience.org/documents-and-tools/cycle9/alma-configuration-files)
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
- Single field interferometry (all bands) and mosaics (Bands 3 to 9) with the 12-m Array and the 7-m Array
- Single-dish spectral line observations in Bands 3 to 8
ALMA Capabilities

Polarization

- Single-pointing, on-axis, full linear and circular polarization for both continuum and full spectral resolution observations in Bands 3 to 7 on the 12-m Array. The field of view of linear and circular polarization observations is limited to the inner one third and the inner one tenth of the primary beam, respectively.

- Mosaicking of continuum linear polarization observations (Bands 3 to 7).
  - Linear polarization near on-axis imaging in continuum and full spectral resolution modes at the 0.1% (3s) fractional polarization level with the very brightest calibrators and 0.2% (3s) level for a typical observation
  - Minimum detectable circular polarization: 1.8% of peak flux for both continuum & full spectral resolution observations
  - Single pointing on-axis linear polarization in Bands 3-7 with the standalone ACA (ACA + 12m pol not available)

- Up to a total of 75 hours of full polarization observations of a single field with the 7-m Array in stand-alone mode at the Main Call only (Bands 3 to 7).
  - Note that combined 7-m Array and 12-m Array polarization observations are not supported this cycle.
ALMA capabilities – NEW!!

In Cycle 9, the following technical capabilities will be available for the first time:

- Fast Regional Mapping (FRM) for Solar Total Power observations. The size of the field of view for Solar Total Power observations can be changed by PI.

- Spectral line Very Long Baseline Interferometry (VLBI). This capability is offered in Band 3 only, in conjunction with the Global Millimeter VLBI Array (GMVA). Need to submit the same proposal to ALMA and GMVA.

- Submillimeter VLBI. A continuum VLBI capability will be offered for the first time in Band 7 (0.87 mm) in conjunction with the Event Horizon Telescope (EHT). No need to submit the same proposal to EHT.

- Longer baseline high-frequency observations: Band 8 up to C-10, Band 9 up to C-9, and Band 10 up to C-8. The band-to-band (B2B) calibration mode may be triggered for long baseline high frequency observations in order to find a suitably close and strong calibrator. Some science targets, particularly at the highest frequencies and longest baselines, may NOT BE POSSIBLE even with B2B (see Appendix 9.6 of the PG).

  - The total time allocated to projects requiring band-to-band calibration techniques may be limited to 45 hours. For more information about band-to-band calibration see Section 4.2 of this document or Section 10.5.3 of the Technical Handbook.
ALMA capabilities – NEW!!

Band-to-Band calibration

- For observations in Band 7 and higher, observations requiring C-8 to C-10 may require Band-to-Band (B2B) calibration in order to find a nearby and sufficiently bright phase calibrator to ensure phase calibration quality. The ALMA Observing Tool will automatically check the availability of suitable phase calibrators during proposal validation and will automatically trigger the B2B mode where required.

- B2B observations are subject to the availability of suitable calibrators as checked by the ALMA-OT. Some science targets, particularly at the highest frequencies and longest baselines, may not be possible even with B2B. See Chapter 10 of the Technical Handbook.

A maximum of 45 hours of Cycle 9 observing time will be available for observations requiring the B2B calibration mode.
ALMA capabilities

Observing Time:

- 4300 hours on the 12-m Array and 4300 hours on the Atacama Compact Array (ACA), also known as the Morita Array, for successful proposals in Cycle 9 (includes DDT, Cycle 8 Carryover and resubmissions)
- Cycle 9 is not expected to include a Supplemental CfP for stand-alone ACA observations. The community is encouraged to submit ACA projects in the LST range of 20h to 10h for the April 2022 deadline.

Observing Time (other notes):

- Proposals requesting more than 25 hours on the 12-m Array, including Large Programs, will have priority to fill at least 10% of the observing queue (see Section 1.4 of the PG).
- There is no longer a cap on the total time that can be allocated to Large Programs.
- However, Large Programs will not be allowed to exceed 50% of the available time for a given LST range in any of the Cycle 9 configurations.
ALMA capabilities

- But ALMA doesn't accept long proposals. I have a better chance of submitting a shorter proposal because it will be accepted, right?!?!?

- WRONG!!!

Left: Number of proposals submitted as a function of the 12-m Array execution time in Cycle 7.
Right: The fraction of proposals (with 1 sigma confidence intervals) that are assigned priority Grade A or B as a function of the estimated 12-m Array time.
ACCSA Supplemental Call:

- In Cycle 8, 2021, ALMA will offer a stand-alone ACA Supplemental Call for Proposals.
- The Supplemental Call will open on 08 September 2021 and the proposal deadline will be on 06 October 2021.
- Observations from the Supplemental Call will be scheduled from January 2022 to September 2022.
- The anticipated amount of time available will be announced in the Call. While stand-alone ACA proposals accepted from the Main Call may be assigned priority "A", "B", or "C", all accepted proposals from the Supplemental Call will be assigned priority "C".
- More information about the supplemental call can be found at: https://almascience.nrao.edu/proposing/7m-array-supplemental-call
ALMA capabilities

Standard vs Non-Standard modes?? (STILL) GONE!

• Unlike in previous cycles, there will no longer be a distinction between standard and non-standard modes so… there is no more 20% cap on the time request for non-standard modes!!
• Proposal types in Cycle 9 will include Regular, Very Long Baseline Interferometry (VLBI), Phased Array, Target of Opportunity, and Large Programs. VLBI proposals work in concert with the Global mm-VLBI Array (GMVA) or the Event Horizon Telescope (EHT).
• GMVA programs must also submit a proposal to the GMVA by its 1 February 2022 deadline. Additional information about proposing with ALMA using the GMVA was made available in the GMVA Call for Proposals in early January 2022.

However, Large Program Observing Modes will STILL be restricted. They CANNOT include:

• Time Critical or ToO, Full Polarization, Solar, VLBI or Phased Array, Astrometric Observations
• Non-standard calibrations (user-defined calibrations selected in the OT) or Band-to-Band calibrations
• Bandwidth switching projects (having less than 1 GHz aggregate bandwidths over all spectral windows)
• NOTE: Contact your local ARC for support NOW to help with preparing your large programs. The ARCs have both proposal preparation and data processing support available for your large programs. Review the documentation off the science portal on how to prepare “value added” data products.
ALMA capabilities in the future

Full ALMA Operations (All Cycle 9 Capabilities plus):

Receiver bands:
  • Include Bands 1 and 2
    • Full ALMA Band 1 Science Case: http://arxiv.org/abs/1310.1604
    • Band 2 summary report from 2019 June - https://zenodo.org/record/3240407

Baselines:
  • All observing bands out to 16 km.

Observing Time:
  • Up to 4500 hours+ for successful proposals of PI programs expected on the 12m Array (includes DDT, Cycle 8+ Carryover and resubmissions)

Observing Modes:
  • Full operations include full Stoke plus circular polarization at all observing bands including mosaics and Total Power
WARNING!!!!

THERE IS NO SUCH THING AS A “LATE” PROPOSAL

“My internet is down…”
“My proposal won’t validate…”
“My power went out…”
“I thought the time was 16UT not 15UT…”
“My dog at my proposal…”

There is no excuse for a late proposal UNLESS the Observatory grants an extension.
ALMA observing strategies (Cycle 9)

The percentage of time when the PWV is below the observing thresholds adopted for the various ALMA bands for night-time (green) and afternoon (yellow) 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 September 2010 and February 2019.
ALMA observing strategies (Cycle 9)

Estimated observing time available per configuration based on precipitable water vapor (PWV) only. The time available for Large Programs is shown in pink and time for high-frequency observations in green and dark blue.
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](https://help.almascience.org).
  - Also can ask for a “NAASC Chat” through the f2f department which is more than a ticket but less than a full virtual f2f visit!

• **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](https://science.nrao.edu/opportunities/student-programs/sos)

• **NAASC Financial Support for Workshop/Conferences:** The NAASC invites scientists to apply for funding in support of upcoming conferences and workshops. - [https://science.nrao.edu/facilities/alma/community1/NAASC-Conference-and-Workshop-Support](https://science.nrao.edu/facilities/alma/community1/NAASC-Conference-and-Workshop-Support)
NAASC sources of support

• **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](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](https://science.nrao.edu/facilities/alma/visitors-shortterm)

• **ALMA Ambassadors**: You too can become an ALMA Ambassador. For program eligibility visit - [https://science.nrao.edu/facilities/alma/ambassadors-program](https://science.nrao.edu/facilities/alma/ambassadors-program)
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