

An Introduction to ALMA

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DA-59

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ALMA (the Atacama Large Millimeter/submillimeter Array) is the world's best millimetre/submillimetre telescope.

The telescope, located in Chile, is designed to observe at 31–950 GHz (0.32–9.5 mm).

The primary emission sources it detects are:

- Thermal (modified blackbody) dust continuum emission
- Molecular spectral line emission
- Free-free continuum emission.

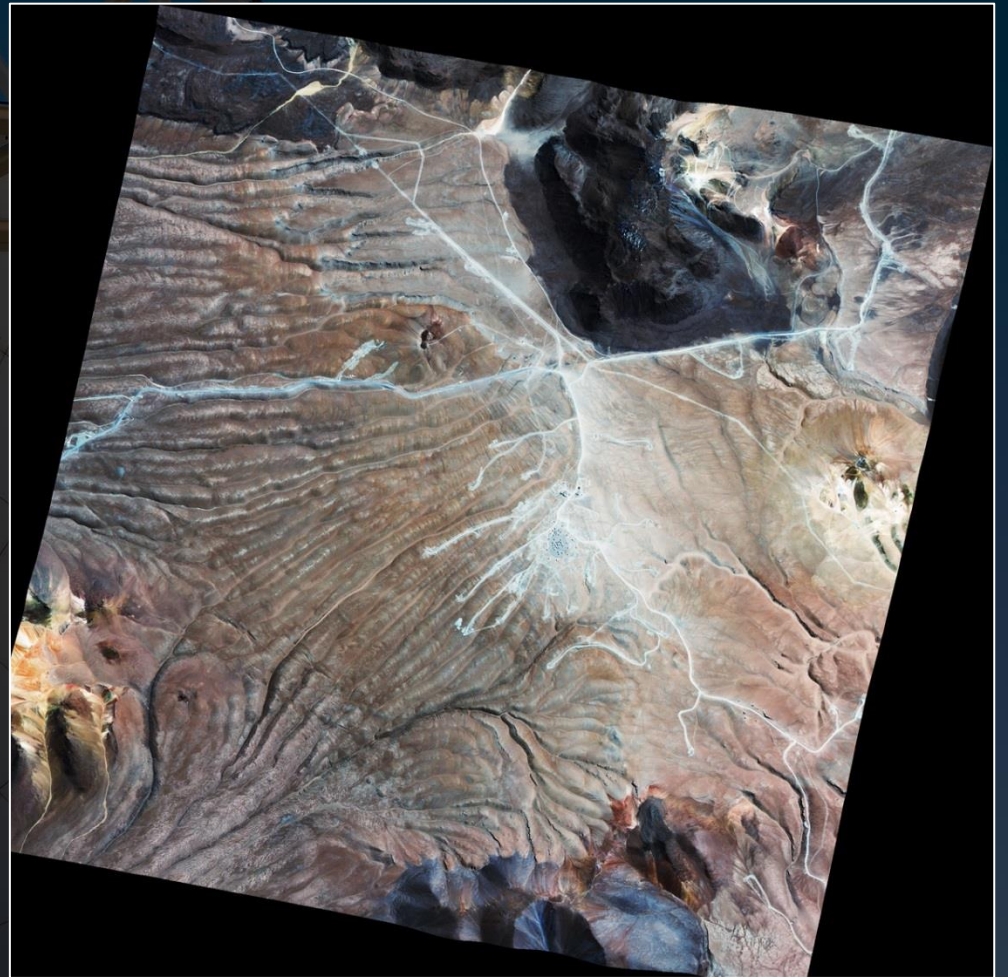
A large, white, segmented radio telescope dish is shown against a dark blue sky. The dish is supported by a complex metal truss structure. The image is slightly dimmed to allow text to be overlaid.

Some of the science performed with ALMA includes:

- Detecting dust emission from high-redshift galaxies (up to $z=10$)
- Using CO to measure redshifts for distant galaxies
- Imaging molecular gas and dust in nearby galaxies
- Examining the formation of protostellar objects in molecular clouds
- Identifying the chemical composition of molecular gas around protostellar objects
- Resolving protoplanetary disks
- Observing the formation of molecules and dust grains around evolved stars and supernovae
- Studying the physics of the Sun

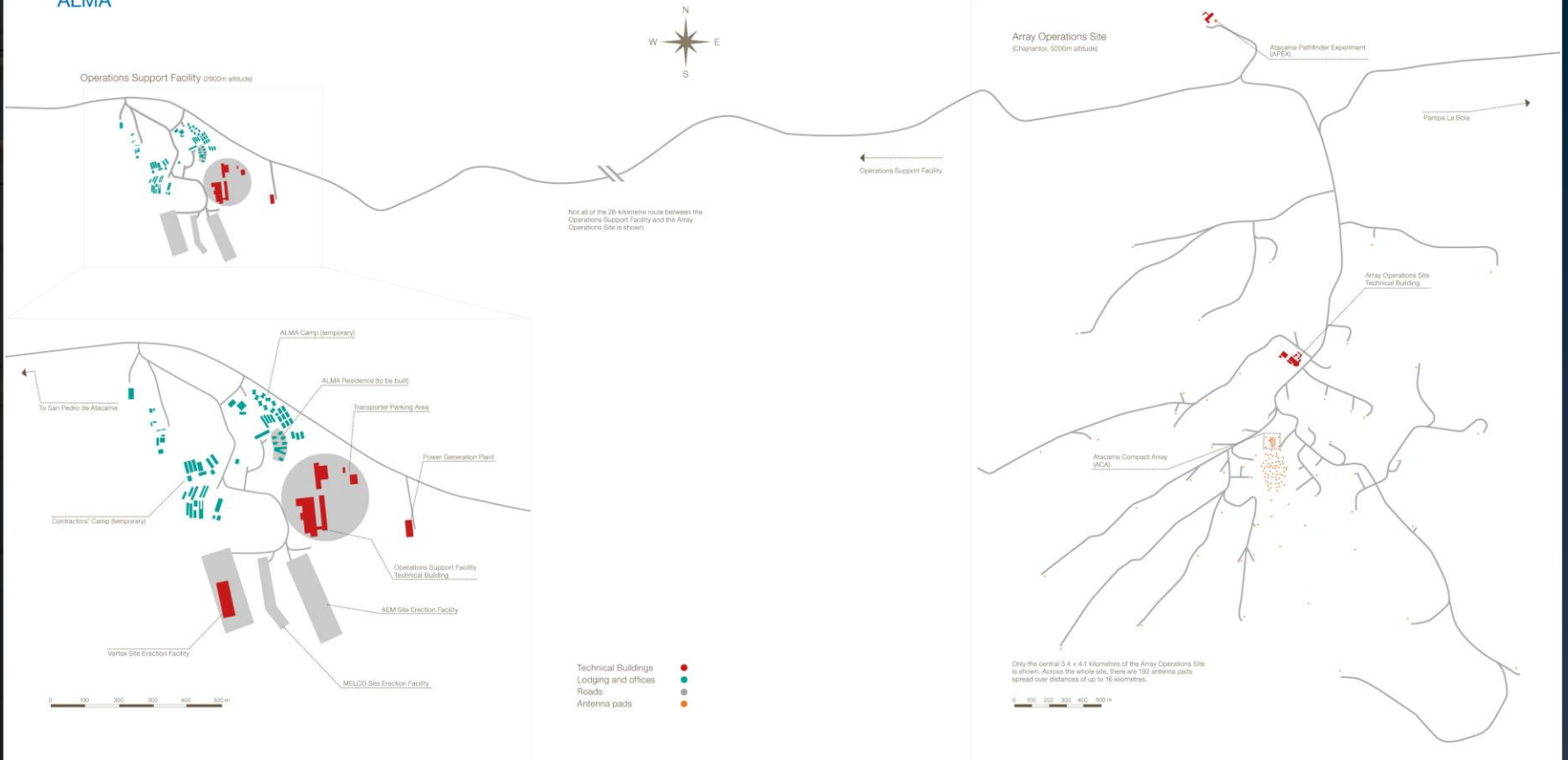
ALMA is located in the Atacama Desert, a high-altitude desert in Chile.

Because the air is cold and dry, the site is ideal for observing in submillimetre and millimetre bands.



(Credit: Aerophotogrammetry Service, Chilean Air Force)

ALMA



(Credit: ESO)

The Array Operations Site (AOS) is located at an elevation of 5000 m.

Access to the site is highly restricted, even for people working with the observatory.



(Credit: ALMA (ESO/NAOJ/NRAO)/A. Caproni (ESO))

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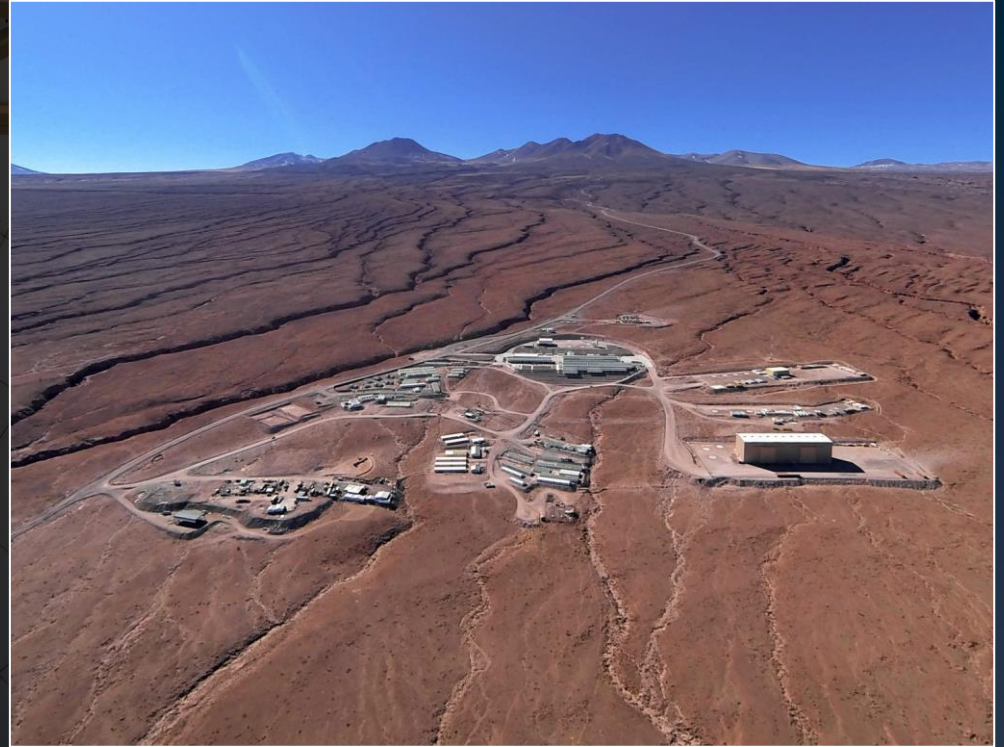
Access to the site is highly restricted, even for people working with the observatory.



(Credit: ESO/S. Fandango)

Workshops for the telescope are located at the Observation Support Facility (OSF) at an elevation of 2900 m.

Public tours of the site are available.



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(Credit: ALMA (ESO/NAOJ/NRAO), W. Garnier (ALMA). Acknowledgment: General Dynamics C4 Systems)

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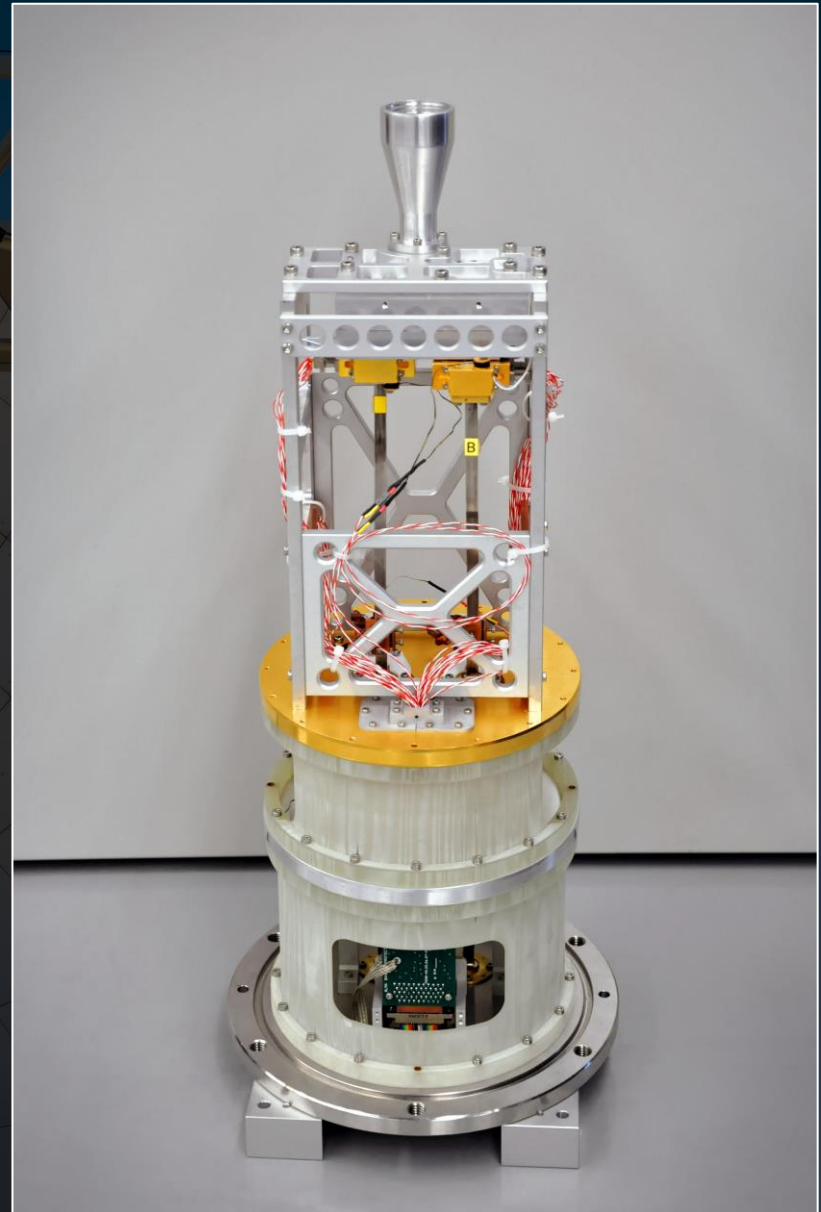
ALMA operations are managed from the Joint ALMA Office on the European Southern Observatory campus in Santiago.



(Credit: ESO & ALMA (ESO/NAOJ/NRAO))

ALMA uses multiple sets of heterodyne receivers.

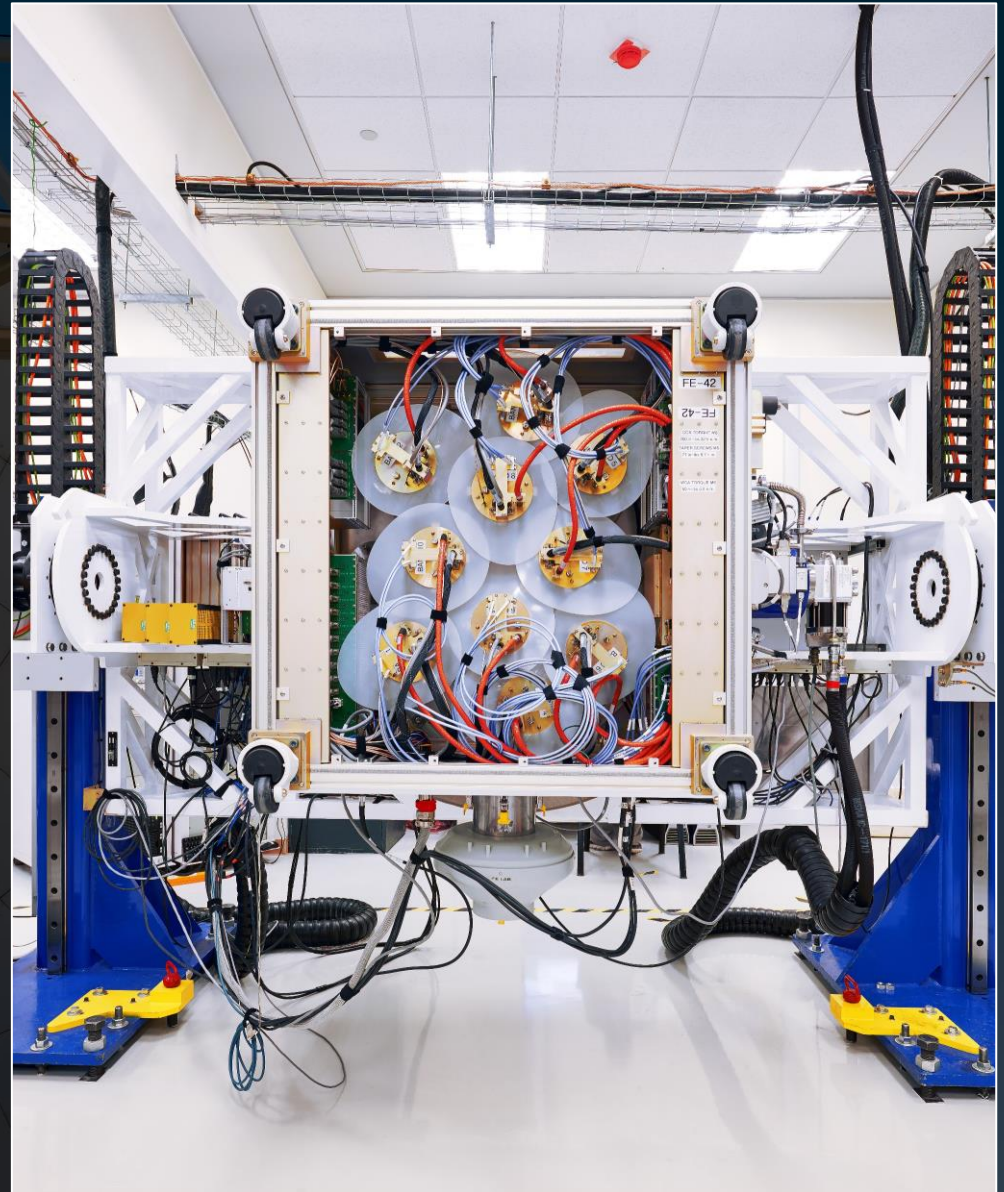
9 bands are available in Cycles 10 and 11.



(Credit: ASIAA/NAOJ/ESO/S. Guisard (www.eso.org/~sguisard))

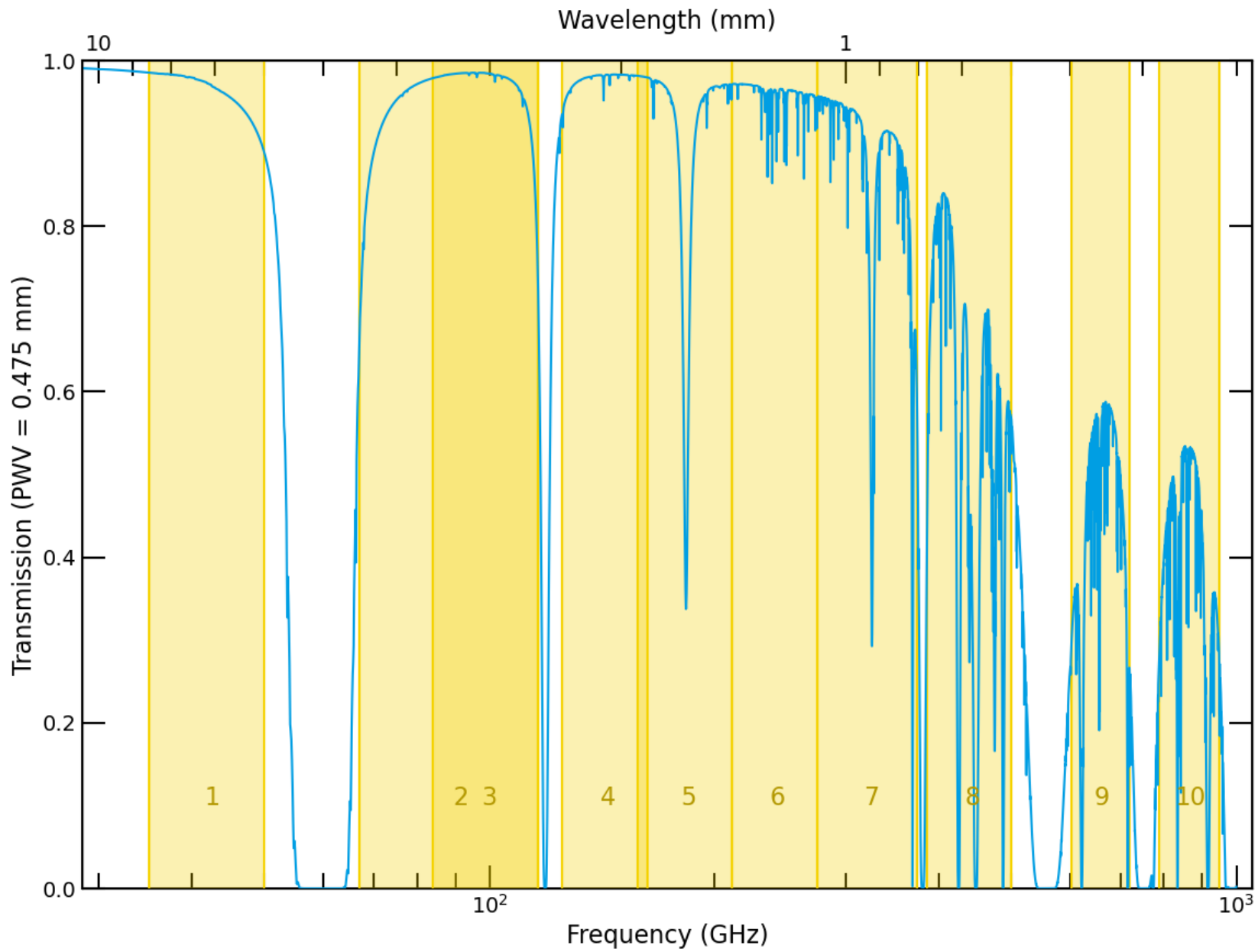
ALMA uses multiple sets of heterodyne receivers.

9 bands are available in Cycle 10.



(Credit: Enrico Sacchetti/ESO)

| Band | Frequency (GHz) | Wavelength (mm) | Primary Beam (arcsec) | Angular Resolution (arcsec) | |
|------|-----------------|-----------------|-----------------------|-----------------------------|------------------------|
| | | | | Compact Configuration | Extended Configuration |
| 1 | 35-50 | 6-8.5 | 142 | 8.6 | 0.230 |
| 2 | 67-116 | 2.6-4.5 | 72 | 4.0 | 0.111 |
| 3 | 84-116 | 2.6-3.6 | 63 | 3.5 | 0.097 |
| 4 | 125-163 | 1.8-2.4 | 43 | 2.4 | 0.067 |
| 5 | 163-211 | 1.4-1.9 | 30 | 1.9 | 0.053 |
| 6 | 211-275 | 1.1-1.4 | 25 | 1.4 | 0.039 |
| 7 | 275-373 | 0.80-1.09 | 19 | 1.1 | 0.029 |
| 8 | 385-500 | 0.60-0.78 | 14 | 0.78 | 0.021 |
| 9 | 602-720 | 0.42-0.50 | 9.2 | 0.52 | 0.014 |
| 10 | 787-950 | 0.32-0.38 | 7.1 | 0.40 | 0.011 |



ALMA has three subarrays that observe different-sized structures:

- The main array (50 antennas with 12m diameters)
- The Atacama Compact Array (12 antennas with 7m diameters)
- The total power antennas (4 antennas with 12m diameters)



(Credit: ESO)

The main (12m) array can be reconfigured in different ways to achieve different angular resolutions.

- Short baseline configurations image extended emission.
- Long baseline configurations resolve small structures.



(Credit: ESO/P.Martinez)

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(Credit: ESO)

The ACA is used to image large-scale structures that are usually resolved out by the 12m array. It can also be used as a stand-alone array when resolving structure is unimportant.

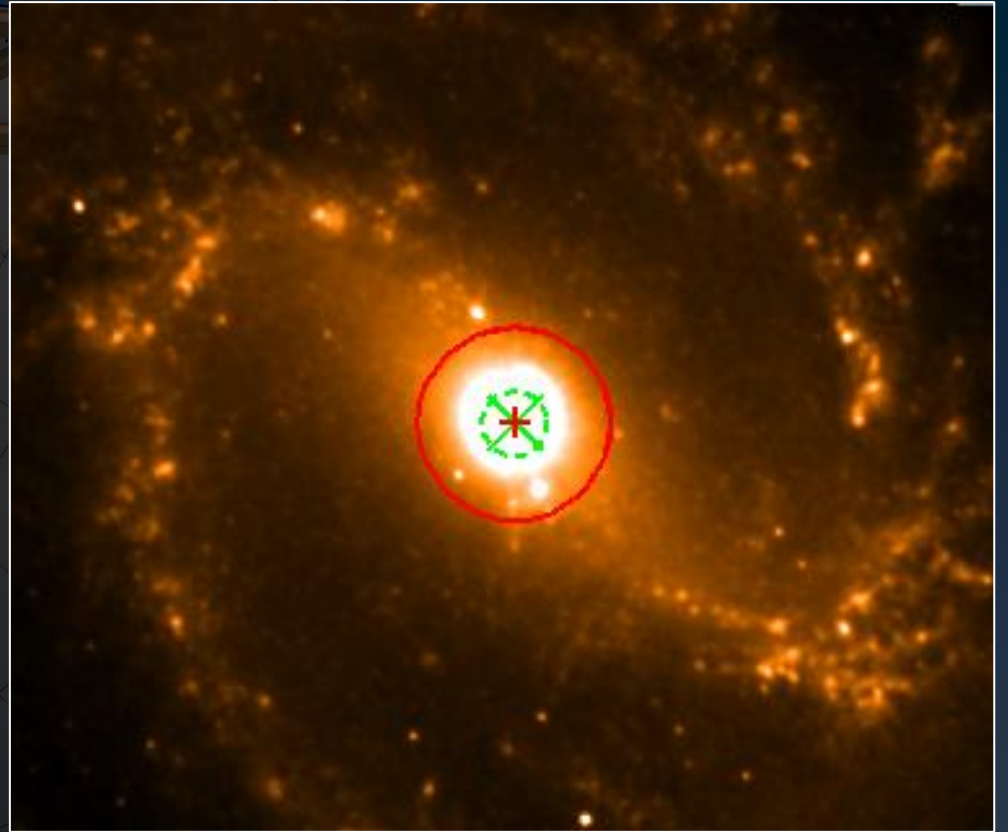


The total power antennas are used to detect large-scale line emission resolved out by both the 12m and ACA arrays. (Continuum-imaging capabilities may be added in the future.)



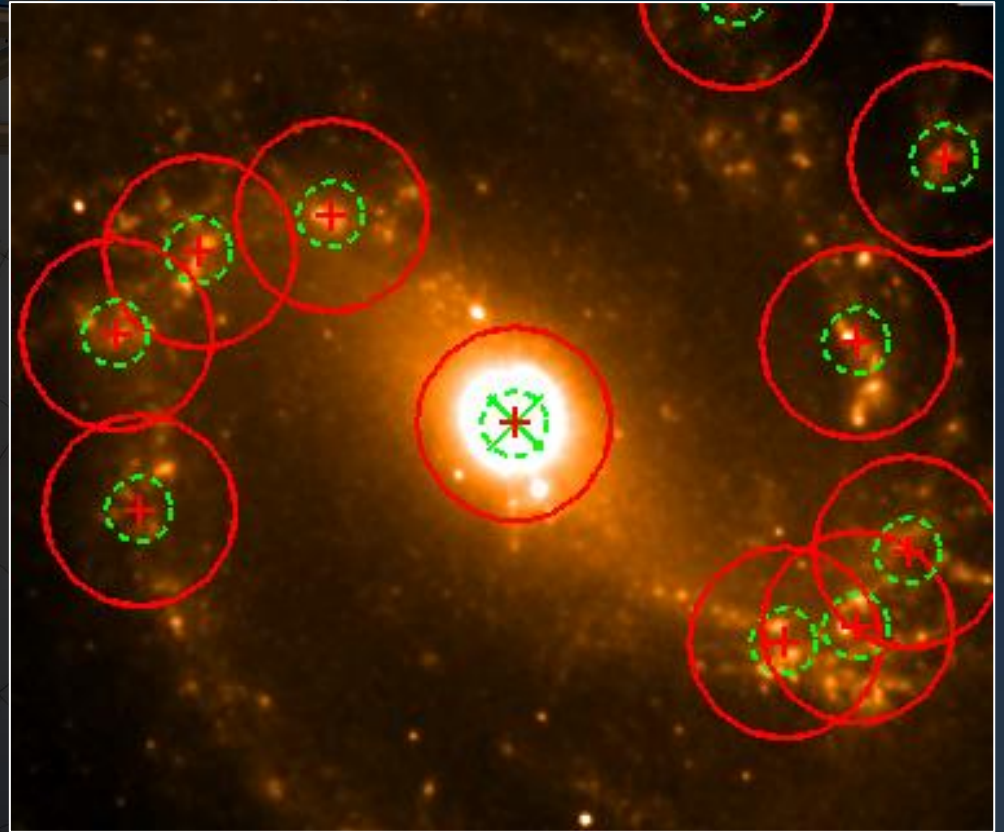
The most basic field that can be imaged by ALMA is a single pointing.

However, ALMA can also image multiple pointings as a set of observations of one target or mosaic a rectangular field.



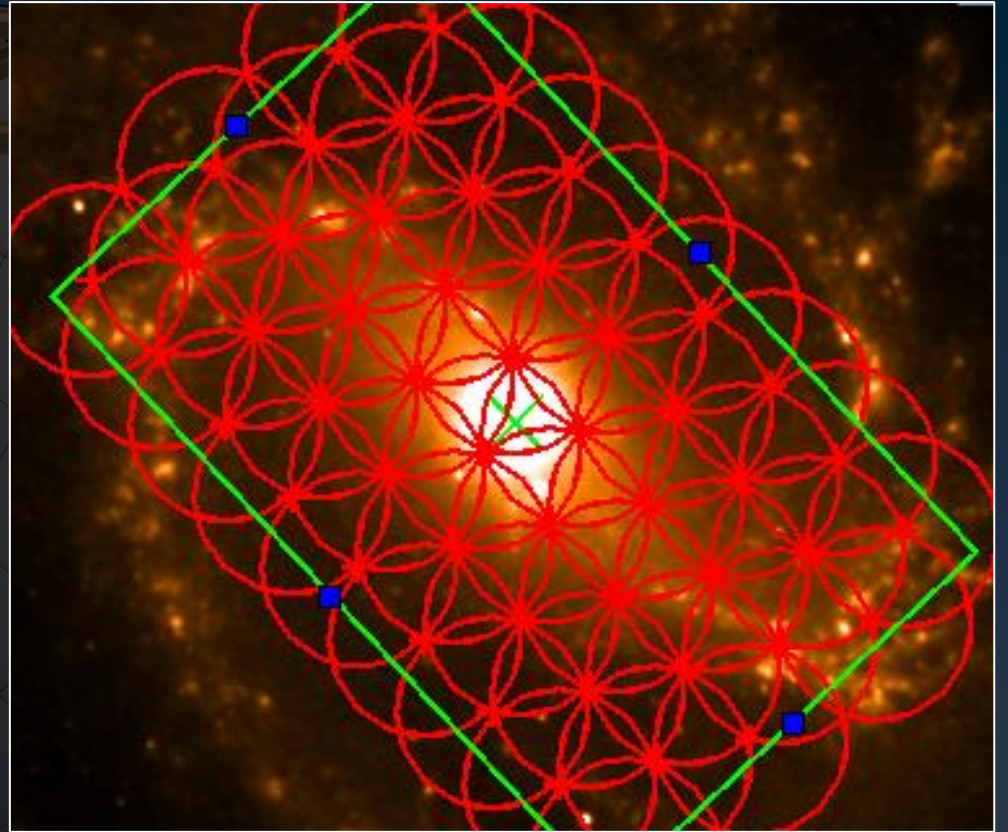
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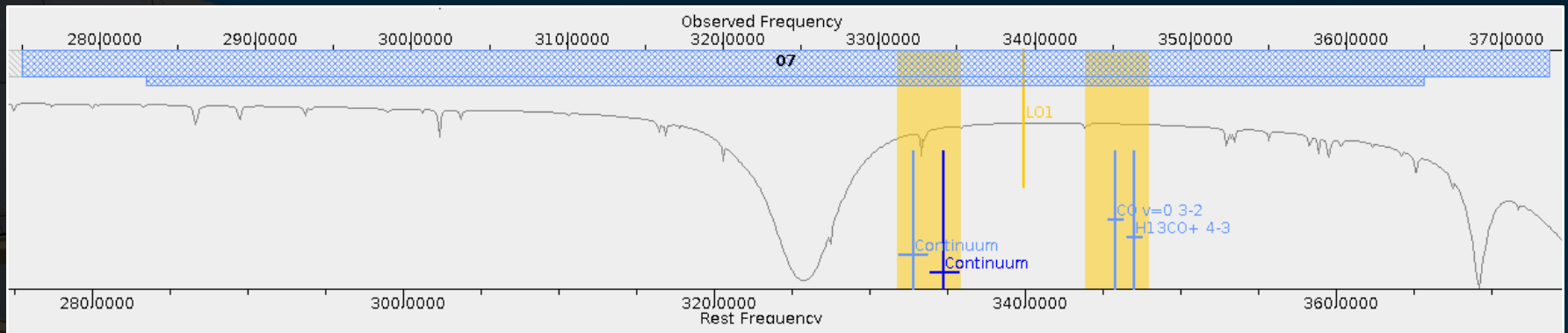
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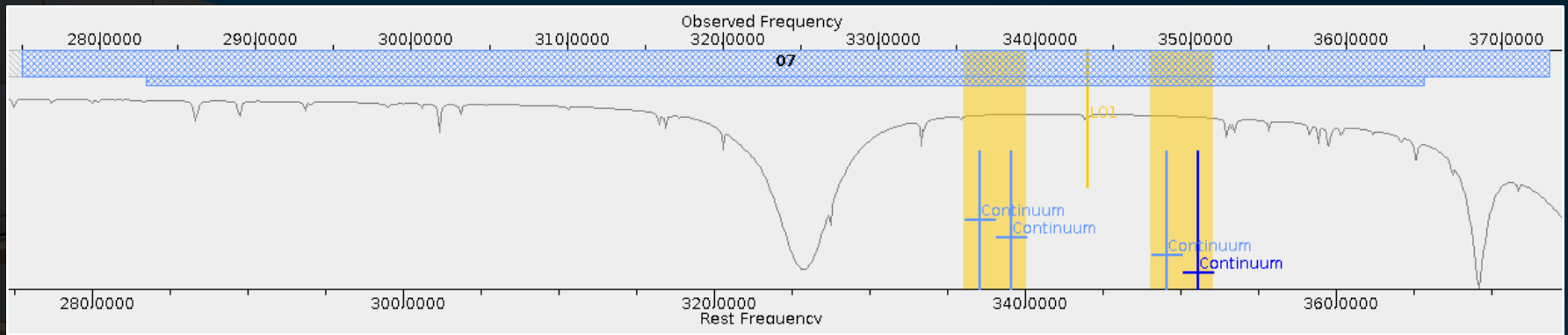


ALMA currently offers three types of spectral set-ups.

- Spectral line imaging mode
- Continuum mode
- Spectral scan mode

In all three modes, each observation is normally performed with 4 or more spectral windows (spws), with two spws on each side of a local oscillator signal (except for bands 9 and 10, where all the spws are on one side of a local oscillator).

Each spw can contain up to 3840 channels (or 4096 for the ACA).

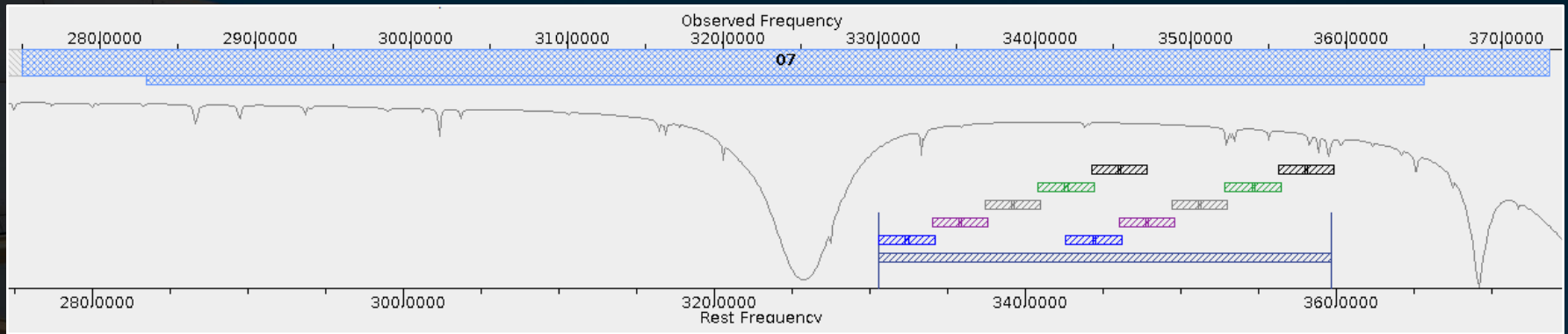


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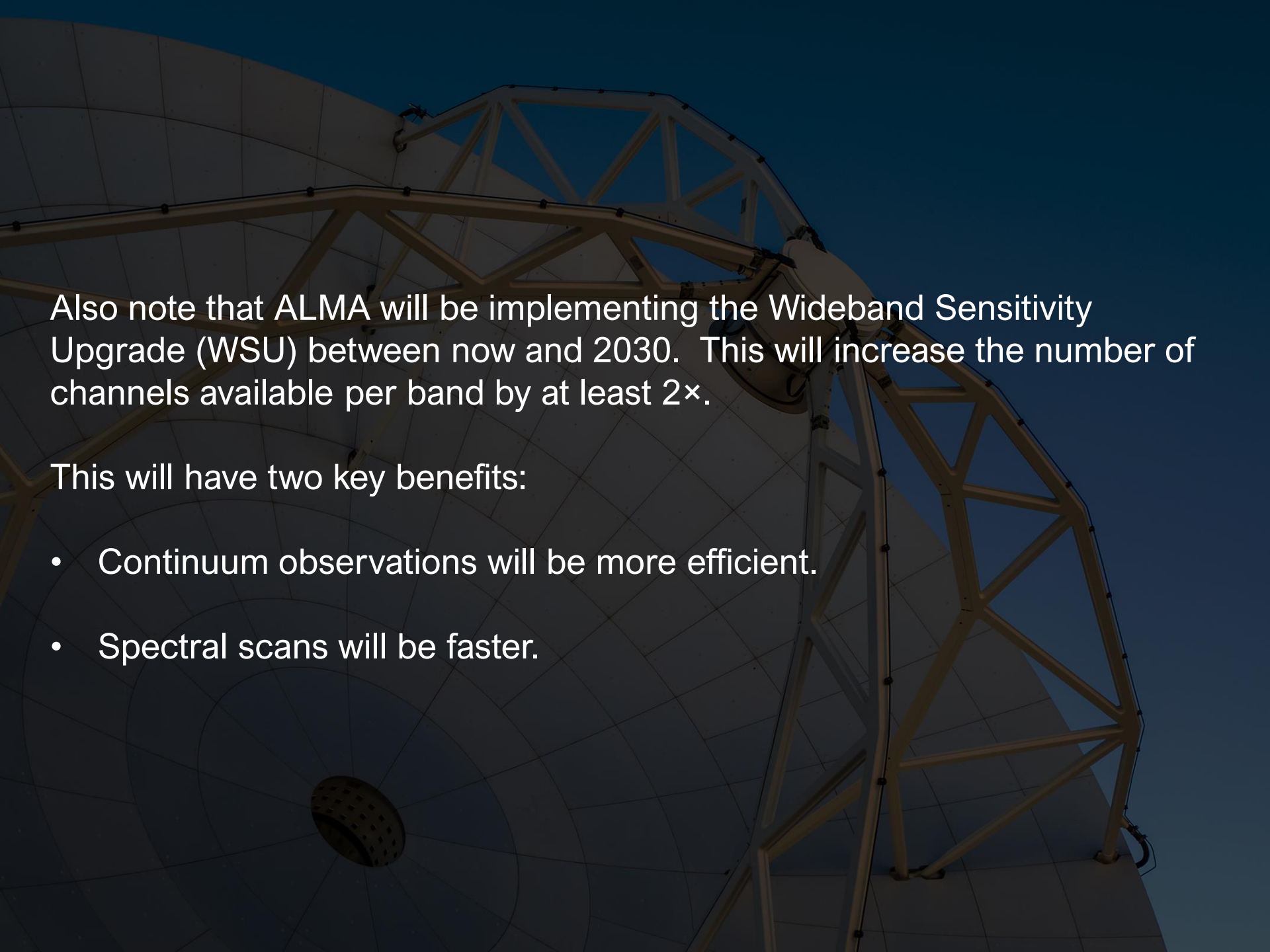


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Also note that ALMA will be implementing the Wideband Sensitivity Upgrade (WSU) between now and 2030. This will increase the number of channels available per band by at least 2×.

This will have two key benefits:

- Continuum observations will be more efficient.
- Spectral scans will be faster.

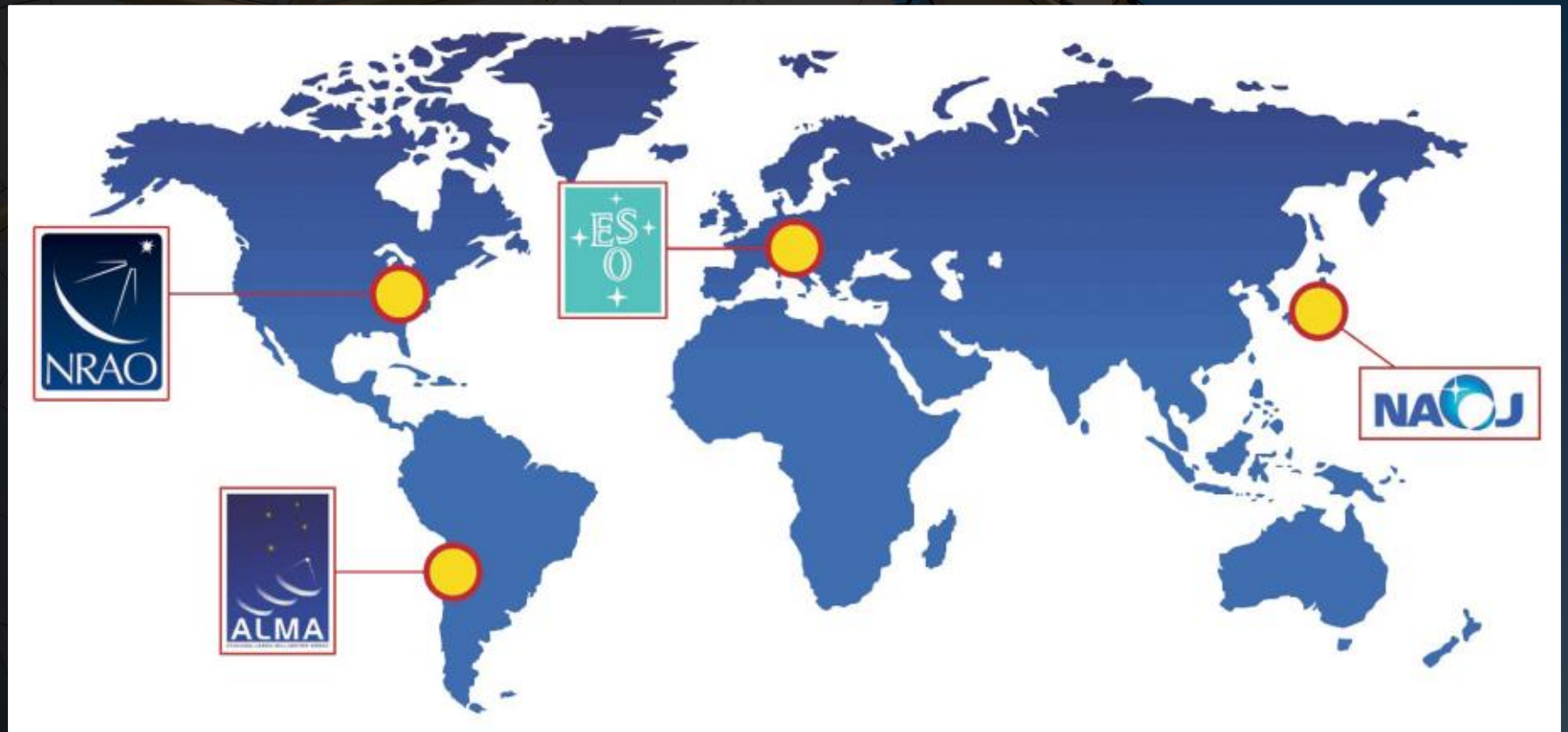


ALMA also has a series of other capabilities, including:

- Polarization observing modes
- VLBI observing modes (involving other telescopes)
- Solar observing modes
- Phased array (pulsar) observing modes

ALMA is operated by a collaboration between North America, Europe, and East Asia. Regional activities are coordinated by ALMA Regional Centres (ARCs).

The Joint ALMA Office (JAO) in Chile coordinates all activities.



The European Southern Observatory coordinates ALMA activities in Europe.

Multiple ARC Nodes provide local user support. Staff at these nodes also participate in other support activities.

The University of Manchester hosts the ARC Node for the United Kingdom.

European ARC Network



The ALMA website for the general public is at <http://www.almaobservatory.org>.

The screenshot shows the ALMA Observatory website homepage. The browser address bar displays <https://www.almaobservatory.org/en/home/>. The page features a dark blue header with the ALMA logo and navigation menu. The main content area is divided into several sections:

- Top Left:** ALMA logo and navigation menu with options for About ALMA, News, Outreach, Multimedia, ALMA for, ALMA at 10 years Conference, Scientists, Schools, and Media.
- Top Right:** A large image of a galaxy with a central bright spot, accompanied by a "Press Releases" section titled "Gas on the run – ALMA spots the shadow of a molecular outflow from a quasar when the Universe was less than one billion years old" dated 1 February, 2024. The text describes quasars as compact regions powered by supermassive black holes.
- Middle Left:** A "Press Releases" section with two images of black hole shadows, dated 18 January, 2024, titled "M87* One Year Later: Proof of a persistent black hole shadow".
- Middle Right:** A "The People" section titled "10 Years Transforming Together our Understanding of the Universe" dated 16 March, 2023, featuring logos for ALMA, NAOJ (National Astronomical Observatory of Japan), and NRAO.
- Bottom:** A row of four small images, each with a "Press Releases" label, showing various astronomical phenomena.

The JAO has a webpage for professional astronomers at <https://almaobservatory.org/en/scientists>.

Scientists | ALMA | ALMA

Atacama Large Millimeter/submillimeter Array

Eng Esp

About ALMA

News

Outreach

Multimedia

ALMA for

ALMA at 10 years Conference

Scientists

Schools

Media

10 years

All Science Highlights
ALMA Conference
5 December, 2023

JAO

The Joint ALMA Observatory (JAO), located in Santiago (Chile), provides the unified leadership and management for ALMA. JAO staff are responsible for maintaining and optimizing the performance of the Radio telescope and conducting observations on behalf of the astronomical community.

JAO Science Team

The Science Team at the JAO is responsible for optimizing the scientific performance of ALMA, calibrating and imaging ALMA data, and conducting scientific research. The Science Team consists of both long-term staff members in the JAO Department of Science Operations and postdoctoral fellows.

Recent JAO Publications

December 31, 2023
BASS. XLII. The Relation between the Covering Factor of Dusty Gas and the Eddington Ratio in Nearby Active Galactic Nuclei

December 27, 2023
What Determines the Physical Size of a H₂O Megamaser Disk?

Each ARC has a professional astronomer page. The ESO ARC webpage is at <https://almascience.eso.org>.

The screenshot displays the ALMA Science Portal website. At the top, the ALMA logo is accompanied by the text "Atacama Large Millimeter/submillimeter Array" and "In search of our Cosmic Origins". A navigation bar includes links for "About", "Science", "Proposing", "Observing", "Data", "Processing", "Tools", "Documentation", and "Help".

The main content area is divided into several sections:

- Science Highlight:** Titled "Protonated acetylene in the z=0.89 absorber toward PKS1830-211", it features two contour plots of the molecule. The left plot is labeled "Diidymos-Dimorphos 345 GHz Continuum" and the right plot is "Diidymos-Dimorphos + Ejecta 345 GHz Continuum". Below the plots is a paragraph describing the detection of a new interstellar molecule, protonated acetylene (C₂H₃⁺), and a "More..." link.
- Observatory News:** Lists several announcements including "Announcement for early proposal planning for Cycle 11" (Dec 20, 2023), "Restart of the Cycle 10 antenna relocations" (Dec 05, 2023), "Announcement from ALMA director on observatory priorities during WSU implementation" (Nov 20, 2023), "Release of Science Verification Data for W51 in Band 1" (Nov 06, 2023), and "Release of Solar Full Polarization ALMA Test Data" (Nov 06, 2023). A "More..." link is provided.
- EU ARC News:** Lists "Upcoming workshop 'The promises and challenges of the ALMA Wideband Sensitivity Upgrade'" (Jan 10, 2024), "Postdoctoral Researcher for an ALMA ADP pipeline" (Dec 22, 2023), "European ALMA school" (Oct 25, 2023), "At the Allegro node: ALMA Data Reduction Training Day on 27 November 2023" (Oct 21, 2023), and "Postdoctoral position(s) at the Allegro ARC node at". A "More..." link is provided.
- ALMA Status:** Includes a "Configuration Schedule" section with "Retired publications: 3641", "Last observed source: NGC_7252E", and "Current configuration: C-3". A "More..." link is provided.

At the bottom, a "Quick Links" table is visible:

| | |
|------------------------------|----------------------------------------|
| ALMA Basics | Configuration Schedule |
| ALMA Science | SnooPI |
| ALMA Primer | DDT Proposals |

The footer contains "Site Map", "Accessibility", "Contact", "Privacy Statement", and "Region: EA EU NA".

The UK ARC Node has a website at <https://www.alma.ac.uk> that provides news and information for UK ALMA users.

The screenshot shows a web browser window displaying the UK ALMA Regional Centre website. The browser's address bar shows the URL <https://www.alma.ac.uk>. The website's main header features the title "UK ALMA Regional Centre" and a banner image of ALMA antennas with the text "EUROPEAN ARC ALMA Regional Centre || UK". Below the banner is a search bar.

The left sidebar contains three main sections:

- Local Information**
 - Home
 - About
 - Directory
 - Contact Information
 - Visitor Information
- Science & Support Information**
 - Meetings
 - Newsletter
 - PI Information
 - Publications
 - Public Outreach
 - Software and Tools
- External Links**
 - ALMA Regional Centres
 - ALMA Observatory
 - ESO
 - NAOJ
 - NRAO
 - Documentation
 - Proposer's Guide
 - Technical Handbook
 - Outreach
 - ESO ALMA Image Archive
 - ESO ALMA Video Archive
 - UK ARC Node Twitter

The main content area features a video player titled "Meet the UK ARC Node" with a play button and a "Watch on YouTube" link. Below the video is a news article titled "ALMA Creates New Images with Unprecedented Angular Resolutions" accompanied by a colorful astronomical image.

Data can be downloaded from the ALMA Science Archive at <https://almascience.eso.org/aq>.

The screenshot displays the ALMA Science Archive interface. On the left, there is a spectral plot showing intensity versus frequency (100 GHz to 900 GHz). The plot features several labeled absorption lines, including CO v=0-0, CS v=0-0, HCO v=0-0, CH3OH v=0-0, HNC v=0-0, 13CH3OH v=0-0, CO v=0-0, HCN v=0-0, and H2O v=0-0. On the right, a table lists various molecules and their corresponding lines, along with their redshifts. Below the plot, a navigation bar shows 'Observations (69434)', 'Projects (4559)', and 'Publications (3604)'. The main content area contains a table of observation data.

| Project code | ALMA source name | RA | Dec | Band | Cont.sens. | mJy/beam | Frequency support | Release date | Publications | Ang.res. | Min.vel.res. | Array | Mosaic | Max.reco.scale |
|----------------|---------------------|--------------|---------------|------|------------|----------|---------------------|--------------|--------------|----------|--------------|-------|--------|----------------|
| 2011.0.00191.5 | Fomalhaut b | 22:57:38.685 | -29:37:12.616 | 7 | 0.1181 | | 343.077-358.839 GHz | 2012-12-06 | 2 | 1.047 | 0.816 | 12m | | 10.640 |
| 2011.0.00131.5 | R Scl | 01:26:58.079 | -32:32:36.424 | 7 | 0.9115 | | 330.246-346.109 GHz | 2012-12-06 | 5 | 1.043 | 0.846 | 12m | mosaic | 11.517 |
| 2011.0.00101.5 | GRB021004 | 00:26:54.680 | +18:55:41.600 | 7 | 0.1136 | | 337.009-353.001 GHz | 2012-12-06 | 2 | 1.107 | 26.541 | 12m | | 9.258 |
| 2011.0.00397.5 | J035448.24-330827.2 | 03:54:48.240 | -33:08:27.200 | 7 | 0.4848 | | 337.026-353.011 GHz | 2012-12-20 | 3 | 1.128 | 26.541 | 12m | | 7.950 |
| 2011.0.00397.5 | J041754.10-281655.9 | 04:17:54.100 | -28:16:55.900 | 7 | 0.4848 | | 337.023-353.008 GHz | 2012-12-20 | 3 | 1.118 | 26.541 | 12m | | 7.842 |
| 2011.0.00397.5 | J063027.81-212058.6 | 06:30:27.810 | -21:20:58.600 | 7 | 0.5346 | | 337.007-352.992 GHz | 2012-12-20 | 3 | 1.183 | 26.541 | 12m | | 8.015 |
| 2011.0.00397.5 | J061200.23-062209.6 | 06:12:00.230 | -06:22:09.600 | 7 | 0.5346 | | 337.005-352.989 GHz | 2012-12-20 | 3 | 1.183 | 26.541 | 12m | | 7.819 |
| 2011.0.00397.5 | J070257.20-280842.3 | 07:02:57.200 | -28:08:42.300 | 7 | 0.5346 | | 337.006-352.991 GHz | 2012-12-20 | 3 | 1.154 | 26.541 | 12m | | 8.053 |
| 2011.0.00397.5 | J054930.06-373940.1 | 05:49:30.060 | -37:39:40.100 | 7 | 0.4848 | | 337.016-353.001 GHz | 2012-12-20 | 3 | 1.156 | 26.541 | 12m | | 7.888 |
| 2011.0.00397.5 | J064228.93-272801.8 | 06:42:28.930 | -27:28:01.800 | 7 | 0.5346 | | 337.008-352.993 GHz | 2012-12-20 | 3 | 1.165 | 26.541 | 12m | | 8.123 |

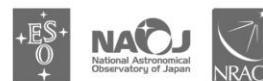
The best way to communicate with ALMA staff (including the UK ARC Node) is to use the ALMA Helpdesk at <https://help.almascience.org>.

The screenshot shows a web browser window with the URL <https://help.almascience.org>. The page header includes the ALMA logo and the text "Atacama Large Millimeter/submillimeter Array Observer Support". Below the header, there is a navigation bar with "ALMA Science" and a "Submit Helpdesk Ticket" button. A search bar with the placeholder text "How can we help you today?" is prominently displayed. Below the search bar, there are four main navigation options: "Knowledgebase" (View all articles), "Submit Helpdesk Ticket" (Get in touch for help), "My Tickets" (View your tickets), and "Face to Face Visit" (Arrange a visit). A welcome message "Welcome to the ALMA Helpdesk" is shown in a white box. At the bottom, there is a "News" section with a notification icon.

Observing with ALMA – A Primer (Cycle 11)

The documentation website (<https://almascience.eso.org/documents-and-tools>) has three documents that are very useful references:

- Observing with ALMA – A Primer
- ALMA Proposer's Guide
- ALMA Technical Handbook



www.almascience.org

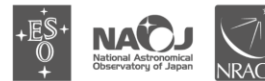
ALMA is a partnership of ESO (representing its member states), NSF (USA) and NINS (Japan), together with NRC (Canada), NSTC and ASIAA (Taiwan), and KASI (Republic of Korea), in cooperation with the Republic of Chile. The Joint ALMA Observatory is operated by ESO, AUI/NRAO and NAOJ.

ALMA Cycle 11 Proposer's Guide



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Doc 11.3, version 1.4 | March 1st, 2024

ALMA Cycle 11 Technical Handbook

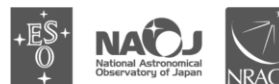


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Using ALMA archival data - A Primer

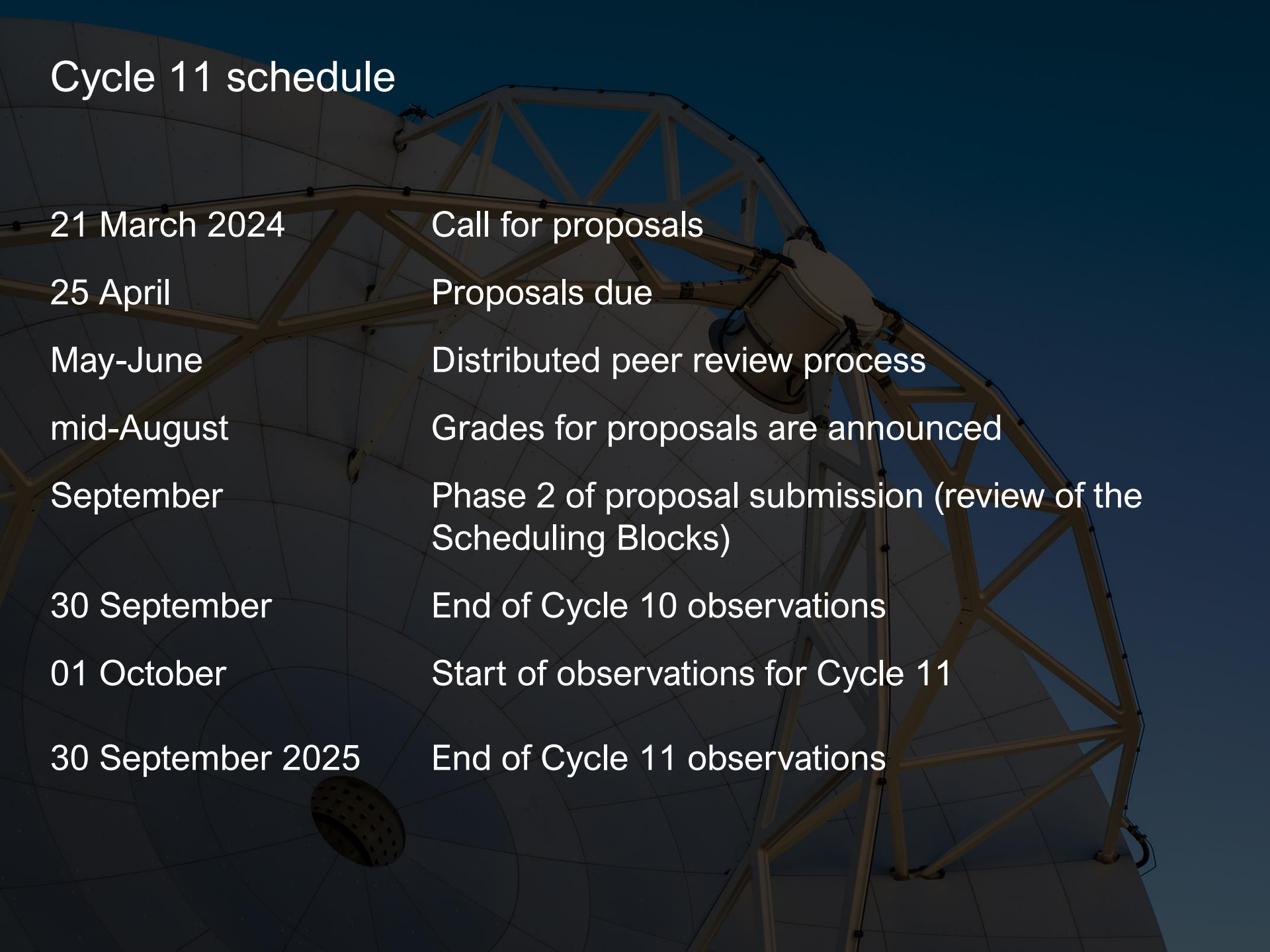
I have also worked on a document on using the ALMA Archive that is also available from <https://almascience.eso.org/documents-and-tools>.



www.almascience.org

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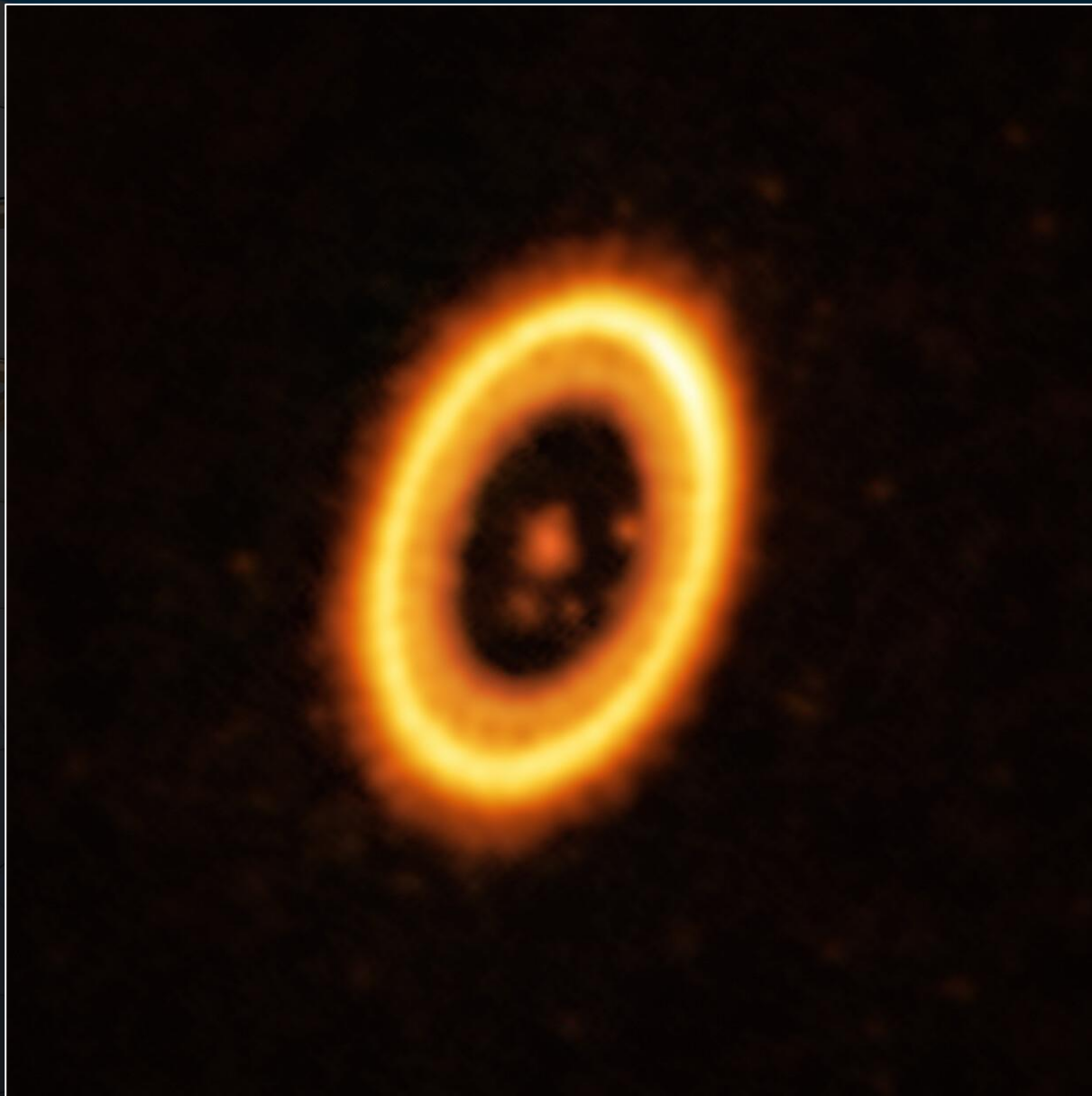
Cycle 11 schedule



| | |
|-------------------|------------------------------------------------------------------|
| 21 March 2024 | Call for proposals |
| 25 April | Proposals due |
| May-June | Distributed peer review process |
| mid-August | Grades for proposals are announced |
| September | Phase 2 of proposal submission (review of the Scheduling Blocks) |
| 30 September | End of Cycle 10 observations |
| 01 October | Start of observations for Cycle 11 |
| 30 September 2025 | End of Cycle 11 observations |



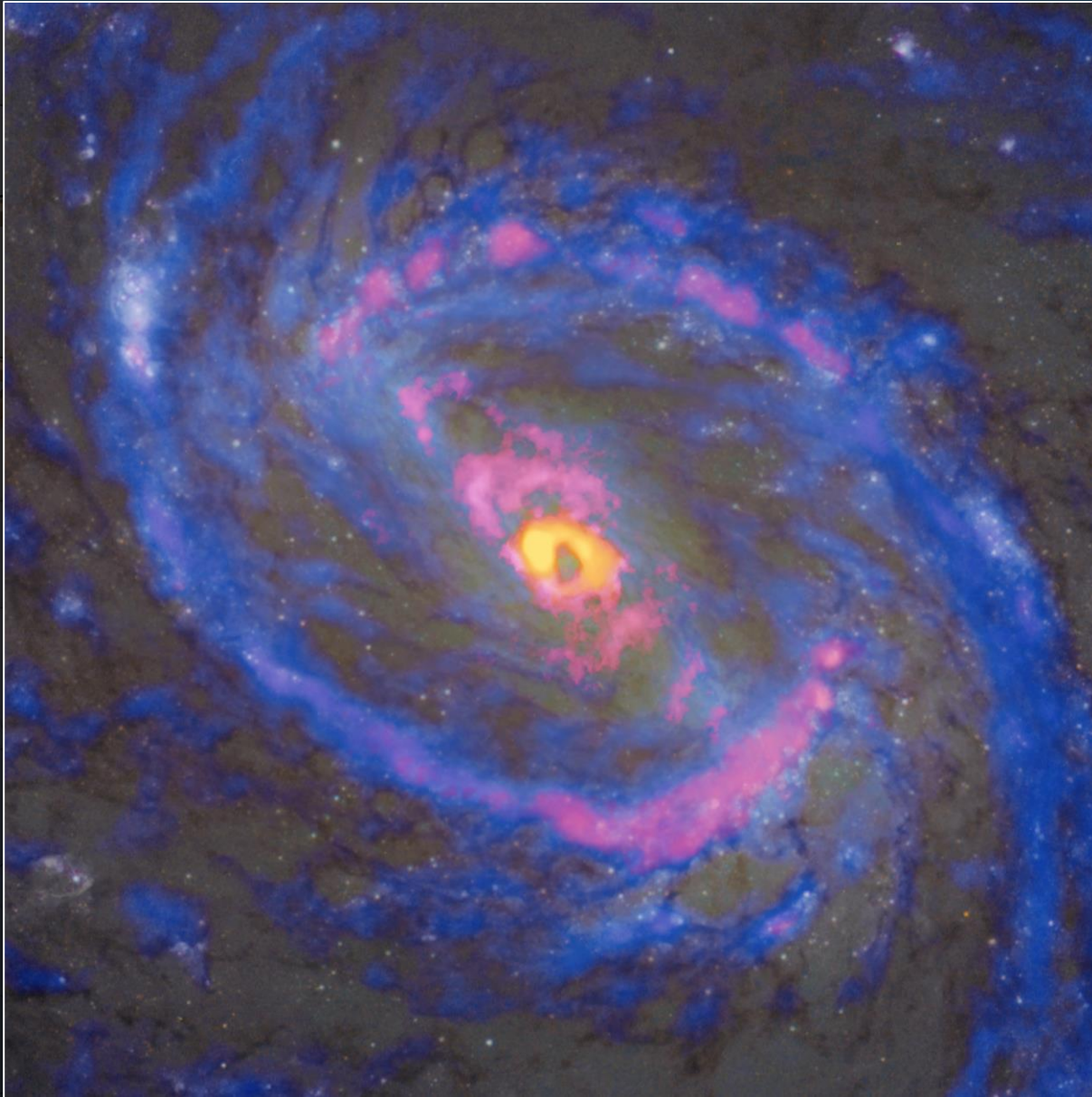
(Credit: Y. Asaki & N. Lira – ALMA (ESO/NAOJ/NRAO))



(Credit: ALMA (ESO/NAOJ/NRAO) / Balsalobre-Ruza et al.)



(Credit: ESO/ALMA (ESO/NAOJ/NRAO)/A. McLeod et al.)



(Credit: ALMA (ESO/NAOJ/NRAO), NASA/ESA Hubble Space Telescope, T. Nakajima et al.)

2017 April 11

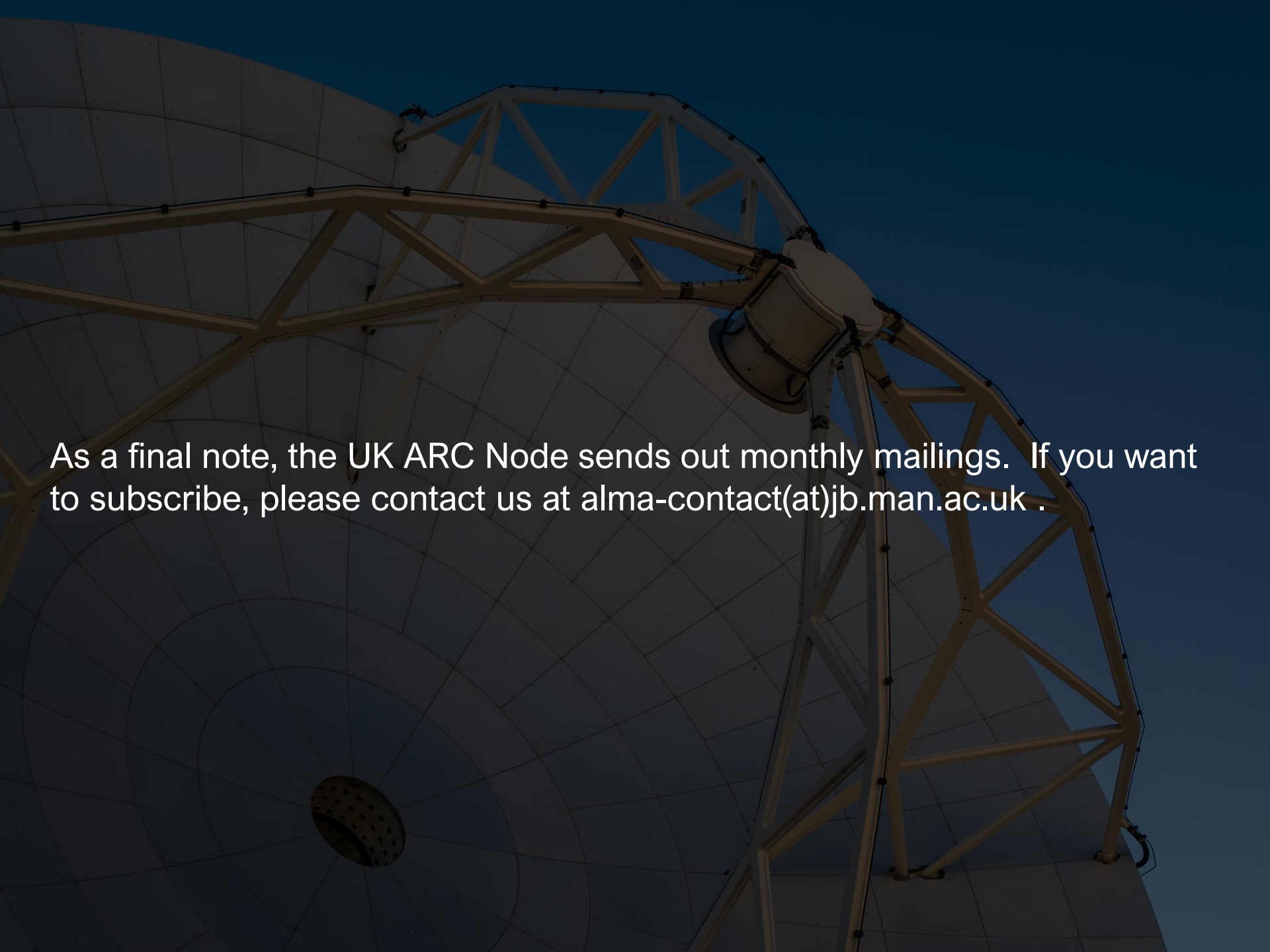
2018 April 21



(Credit: EHT Collaboration)



(Credit: ALMA (ESO/NAOJ/NRAO)/J. Geach et al.)

A large satellite dish antenna structure is shown against a dark blue sky. The dish is composed of a complex metal lattice of beams and supports. A large, circular, perforated horn antenna is mounted on the right side of the structure. The dish surface is visible on the left, showing a grid of panels.

As a final note, the UK ARC Node sends out monthly mailings. If you want to subscribe, please contact us at [alma-contact\(at\)jb.man.ac.uk](mailto:alma-contact(at)jb.man.ac.uk) .