

# ALMA Cycle 8 Proposer's Guide



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ALMA, an international astronomy facility, is a partnership of ESO (representing its member states), NSF (USA) and NINS (Japan), together with NRC (Canada), MOST 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.

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For further information or to comment on this document, please contact your regional Helpdesk through the ALMA User Portal at **[www.almascience.org](http://www.almascience.org)**. Helpdesk tickets will be directed to the appropriate ALMA Regional Center at ESO, NAOJ or NRAO.

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# Cycle 8 Call for Proposals

The ALMA Director, on behalf of the Joint ALMA Observatory (JAO) and the partner organizations in East Asia, Europe, and North America, is pleased to announce the ALMA Cycle 8 Call for Proposals (CfP) for scientific observations to be scheduled from October 2020 to September 2021. The JAO anticipates allocating 4300 hours on the 12-m Array and 3000 hours<sup>1</sup> on the Atacama Compact Array (ACA), also known as the Morita Array, for successful proposals from the main Call in Cycle 8. The ACA allocation includes 3000 hours each on the 7-m Array and the Total Power (TP) Array. Proposals must be prepared and submitted using the ALMA [Observing Tool](#) (OT), which is available for download from the ALMA Science Portal ([www.almascience.org](http://www.almascience.org)). Proposals will be assessed by competitive peer review by a single international review committee. Proposals in Cycle 8 will implement a dual-anonymous process for proposal reviews. While proposers will still enter their names and affiliations in the Observing Tool, their identities will be concealed from the science reviewers. It will be the responsibility of the investigators to write their proposals such that anonymity is preserved.

ALMA Cycle 8 proposal submission will open at **15:00 UT on Tuesday, 17 March 2020**. The Cycle 8 proposal submission deadline is **15:00 UT on Wednesday, 15 April 2020**. Table 1 summarizes these and other important milestones for Cycle 8. PIs are responsible for submitting their proposals successfully by the deadline, and are strongly advised to submit proposals early.

Cycle 8 will include a supplemental CfP for stand-alone ACA observations with the Cycle 8 technical capabilities specified in this document. The observations will be scheduled from January 2021 to September 2021 (Section 1.4). The supplemental call will have some differences compared to the main call, including the priority of the observations. Details will be released with the supplemental CfP. In what follows, this document refers to the characteristics of the Cycle 8 main CfP unless specifically indicated otherwise.

ALMA provides continuum and spectral-line capabilities for wavelengths from 0.32 mm to 3.6 mm, and angular resolutions from 0.012'' to 3.4'' on the 12-m Array. In Cycle 8, the most extended configuration for the 12-m Array will be C-8, providing angular resolutions as fine as 0.028''. The more extended C-9 and C-10 configurations will next be available in Cycle 9. Cycle 8 will bring to ALMA several new observational capabilities, including Solar observations in Band 5, stand-alone 7-m Array observations in Bands 9 and 10, mosaicking of continuum linear polarization observations in Bands 3 to 7 with the 12-m Array, spectral scans with the 7-m Array, VLBI observations of faint science targets using passive phasing, and observations using the 12-m Array operating as a single dish for pulsar science.

This Proposer's Guide provides an overview of significant changes made in both the technical capabilities and observing strategies for Cycle 8 (Section 1), an overview of the ALMA organization (Section 2), the types of proposals offered in Cycle 8 (Section 3), information on proposal planning (Section 4) and submission (Section 5) and post-proposal activities (Section 6), an overview of the offered technical capabilities (Appendix A), and guidelines for writing a Technical Justification (Appendix B).

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<sup>1</sup> The JAO anticipates allocating additional time, the amount to be determined, through the ACA Supplemental Call (Section 1.4).

**Table 1: The ALMA Cycle 8 main call timeline**

Date	Milestone
17 March 2020	Release of Cycle 8 Call for Proposals, Observing Tool & supporting documents and opening of the Archive for proposal submission
15 April 2020 (15:00 UT)	Proposal submission deadline for Cycle 8 Call for Proposals
End of July 2020	Announcement of the outcome of the proposal review process
9 September 2020	Deadline for submission of Phase 2 material for Cycle 8 accepted proposals
October 2020	Start of ALMA Cycle 8 Science Observations
September 2021	End of ALMA Cycle 8

## 1 What's new in Cycle 8

This section summarizes significant changes made for Cycle 8. Additionally, any changes, clarifications, or bugs that are discovered after the publication of this Proposer's Guide will be documented in the Knowledgebase Article:

[\*What Cycle 8 proposal issues and clarifications should I be aware of before submitting my proposal?\*](#)

Proposers should check this article regularly, especially just before submitting their proposals.

### 1.1 Technical and observing capabilities

Observing capabilities are given in Appendix A and fully described in the [ALMA Cycle 8 Technical Handbook](#) (hereafter, the Technical Handbook). New capabilities for Cycle 8 include:

- **Solar observations in Band 5.** The average frequency of the new Band 5 single-continuum setup is 198 GHz and is available in configurations C-1, C-2, and C-3.
- **Observations in Bands 9 and 10 with the stand-alone 7-m Array.**
- **Spectral Scans with the 7-m Array.**
- **Mosaics for continuum linear polarization observations in Bands 3 to 7 with the 12-m Array.** The restriction on being able to observe only a single pointing in full polarization has been lifted for observations of linearly polarized continuum emission. Field setups can be defined using custom mosaics or rectangular areas, in which case there is no restriction on the source size that can be observed.
- **VLBI observations of faint science targets.** Previous to Cycle 8, VLBI targets were limited to those having correlated flux density  $>500$  mJy within an unresolved core on ALMA baselines up to 1 km. Observations of faint targets are now permitted. They will be done in passive phasing mode, where it is recommended to have a bright calibrator within  $5^\circ$  of the science target.
- **Observations of pulsars using the 12-m Array as a single dish.** ALMA is able to operate as part of a VLBI array using special hardware that coherently sums the signals from each

antenna, effectively turning the 12-m array into a large single dish. It is now possible to propose for this mode in a stand-alone (non-VLBI) capability for pulsar science observations. To select this mode the user should create a normal VLBI proposal and select the science keyword 'Pulsars and neutron stars' in the scientific category 'Stellar Evolution and the Sun'. Passive phasing is enforced in this mode.

## **1.2 Proposal format and composition**

### **1.2.1 Dual Anonymous Review**

To help reduce biases, ALMA will implement a dual anonymous review process starting in Cycle 8. In a dual anonymous review, the proposal team does not know the identity of the reviewers and the reviewers do not know the identities of the proposal team. While proposers will still enter their names and affiliations in the ALMA Observing Tool (OT), this information will not appear on the proposal cover sheet, nor in the tools used by the reviewers. It is the responsibility of the proposers to ensure anonymity is preserved when writing their proposals. Guidelines for writing anonymous proposal content are given in Section 5.2.

### **1.2.2 Large Programs proposal format and management plan**

Proposals for Large Programs will now consist of two parts. First is the main proposal, itself, which includes the scientific justification and is to be submitted as usual with the OT. The scientific justification can be up to 6 pages in length. The main proposal must follow the guidelines for dual anonymous review. The second part will be a one-page PDF statement that describes the management plan. This statement is not expected to follow the dual anonymous guidelines, and indeed can include investigator names and affiliations. It should be submitted by email to [pht@alma.cl](mailto:pht@alma.cl) before the April 15 deadline. Section 3.3 gives more information on the proposal format for Large Programs. PIs of Large Programs are also encouraged to contact their corresponding ARC/ARC node to get help with proposal preparations.

## **1.3 Observing Tool features**

For Cycle 8, the Web Start installation is no longer available for the OT. It has been dropped from Java starting with version 11. Instead, a new installer has been created with a modern interface that guides the user through the steps necessary for installation. A separate installer is available for Linux, Mac OS, and Windows and it includes a self-contained distribution of Java 11. It is therefore no longer necessary for users to install Java themselves. The alternative tarball distribution remains available and this will also include Java. All new features are described in more detail in the [OT documentation](#).

## **1.4 Stand-alone ACA supplemental Call for Proposals**

Cycle 8 will include a supplemental CfP for stand-alone ACA observations to be scheduled from January 2021 to September 2021. The supplemental call aims to maximize the scientific output of the ACA by allowing more timely science to be proposed, since it will follow the main CfP by five months. The amount of observing time to be allocated during the ACA Supplemental Call will be determined later. It is anticipated that the supplemental call will be released on **15 September 2020**, with a proposal submission deadline of **15:00 UT on 8 October 2020**.

Proposals may request to use the 7-m Array only or the 7-m Array plus the Total Power Array. The observational capabilities for the stand-alone ACA supplemental call will be the same as those offered for the ACA in the main call (see Appendix A). Supplemental call proposals selected for the observing queue will be given grade C observing priority, while successful proposals from the main call that request the ACA (either in stand-alone mode or in combination with the 12-m Array) may be given grades A, B, or C. Large Programs will not be allowed in the supplemental call. There will be no LST restriction on proposals at the time of submission. Any stand-alone ACA proposal rejected in the main call may be modified to address the comments from the review panels and be submitted to the supplemental call.

In the supplemental call, proposals will be reviewed using a distributed system in which users who submit proposals also commit to reviewing other proposals. At the time of submission, the PI of each proposal must designate a reviewer from their proposal team. Each designated reviewer will be responsible for evaluating ten proposals submitted to the supplemental call. Review assignments will be made based on the scientific keywords and scientific category of the submitted proposal.

Each submitted proposal will be ranked by ten reviewers, and the final ordered list of proposals will be determined by combining all the reviewers' rankings. After the creation of the final ranked list, PIs will be sent their priority grade and reviews, verbatim, from each (anonymous) designated reviewer. If a designated reviewer does not submit the reviews and ranks by the review deadline, the proposal for which they were identified as the reviewer will be rejected.

Any PI and most co-Investigators (co-Is) are eligible to be designated as the reviewer. If the PI does not have a Ph.D. at the time of proposal submission (e.g. a student), the PI can still be the reviewer, but a mentor (who must have a Ph.D.) must be identified at the time of proposal submission through the OT. If the PI designates a co-I as the reviewer, the co-I must have a Ph.D. in astronomy or a closely related field. The PI must designate a reviewer for each submitted proposal.

The Science Portal includes further details on the [supplemental call](#) and the distributed peer review process, with answers to frequently asked questions and up-to-date information. It will also include a link to all the documentation associated with the call when issued and the tools needed to submit and review proposals.

**Table 2: The anticipated stand-alone ACA Cycle 8 supplemental call timeline**

Date	Milestone
15 September 2020	Release of the Cycle 8 stand-alone ACA supplemental CfP, Observing Tool & supporting documents and opening of the Archive for proposal submission
08 October 2020	Supplemental Call proposal submission deadline
December 2020	Announcement of the outcome of the proposal review process and start of Phase 2 for accepted proposals
January 2021	Start of Science Observations
30 September 2021	End of ALMA Cycle 8



## 2 ALMA overview

### 2.1 The ALMA partnership

ALMA, an international astronomy facility, is a partnership of the European Organisation for Astronomical Research in the Southern Hemisphere (ESO), the U.S. National Science Foundation (NSF) and the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Republic of Chile. ALMA construction and operations are led by ESO on behalf of its Member States; by the National Radio Astronomy Observatory (NRAO), managed by Associated Universities, Inc. (AUI), on behalf of North America; and by the National Astronomical Observatory of Japan (NAOJ) on behalf of East Asia. JAO provides the unified leadership and management of the construction, commissioning and operation of ALMA.

### 2.2 The ALMA telescope

ALMA contains 66 high-precision antennas. Fifty of these are 12-meter dishes in the 12-m Array, used for sensitive, high-resolution imaging. The remaining sixteen make up the ACA, used to enhance wide-field imaging: twelve are closely spaced 7-meter antennas (7-m Array), and four are 12-meter antennas for single-dish observations (Total Power, or TP, Array). The wavelengths currently covered by ALMA range from 0.32 mm to 3.6 mm (frequency coverage of 84 GHz to 950 GHz).

The Array is located on the Chajnantor plateau (referred to as the Array Operations Site, AOS) of the Chilean Andes at latitude =  $-23.029^\circ$ , longitude =  $-67.755^\circ$  and an altitude of 5000 m. The site offers the exceptionally dry and clear sky conditions required to operate at millimeter and submillimeter wavelengths. This site is connected via Gigabit fiber links to the Operation Support Facility (OSF), located at an altitude of 2900 m and 40 km from the town of San Pedro de Atacama. Science operations are conducted from the OSF and coordinated from the JAO Santiago Central Office (SCO).

The [Technical Handbook](#) contains a detailed description of the ALMA technical characteristics.

### 2.3 The Joint ALMA Observatory and the ALMA Regional Centers

The JAO is responsible for the overall leadership and management of ALMA operations in Chile. The JAO solicits proposals to observe with ALMA through Calls for Proposals and organizes the peer review of the proposals by science experts. In addition, the JAO schedules all science observations and places the data in the electronically accessible [archive](#).

The three Executives maintain the ALMA Regional Centers (ARCs) within their respective regions. The ARCs provide the interface between the ALMA Observatory and its user communities. The ARCs are responsible for user support, mainly in the areas of proposal preparation, observation preparation, acquisition of data through the Archive, data reduction, data analysis, data delivery, face-to-face visitor support and workshops, tutorials, and schools. Each ARC operates an archive that mirrors the SCO Archive. Browsing and data mining are done through the ARC mirror archives.

The [East Asian ARC](#) (EA ARC) is based at the National Astronomical Observatory of Japan (NAOJ) headquarters in Tokyo. It is operated in collaboration with [Academia Sinica Institute of Astronomy and Astrophysics](#) (ASIAA) in Taiwan and [Korea Astronomy and Space Science Institute](#)

(KASI) in Korea and supports the astronomical communities of Japan, Taiwan<sup>2</sup> and the Republic of Korea.

European researchers are supported by the [European ARC](#) (EU ARC), which is organized as a coordinated network of scientific support nodes distributed across Europe. The EU ARC is located at ESO Headquarters in Garching bei München (Germany), where many of the ARC activities take place. Face-to-face support and additional services are provided by seven regional nodes and one center of expertise. The regional nodes are currently: [Bonn-Cologne](#) (Germany), [Bologna](#) (Italy), [Onsala](#) (Sweden), [IRAM, Grenoble](#) (France), [Allegro, Leiden](#) (The Netherlands), [Manchester](#) (United Kingdom) and [Ondřejov](#) (Czech Republic). The Portuguese ALMA Centre of Expertise (PACE) is located in [Lisbon](#) (Portugal).

The [North American ARC](#) (NA ARC) is contained within the North American ALMA Science Center (NAASC), based at NRAO headquarters in Charlottesville, VA, USA. It is operated in collaboration with the [National Research Council of Canada](#) (Canada) and [Academia Sinica Institute of Astronomy and Astrophysics](#) (Taiwan), and supports the astronomical communities of North America and Taiwan<sup>2</sup>.

## 2.4 The ALMA Science Portal

The ALMA [Science Portal](#) (SP), accessible at <http://www.almascience.org>, is the primary access point to ALMA for science users. It provides a gateway to all ALMA resources, documents and tools relevant to users for proposal preparation, proposal assessment, project tracking, project data access and data retrieval, as well as access to the ALMA Helpdesk.

From the Science Portal, anyone can:

- Register as an ALMA user.
- Access ALMA user documentation and software tools, including the ALMA Sensitivity Calculator, observing simulators, and the ALMA spectral-line database (Splatalogue).
- Download the OT.
- Access Helpdesk “Knowledgebase” articles, which provide answers to common questions.
- Access non-proprietary data from the ALMA Archive.

In addition, registered users may:

- Manage their user profile. For PIs, this includes options to receive automatic email notifications of the progress of their observations, to enable access to proprietary data for other ALMA users, and to delegate the right to submit the Phase 2 material or trigger ToO observations to another selected ALMA user.
- Access SnooPI, the tool for PIs, co-PIs, co-Is and any other user designated by the PIs, to monitor the status of their scheduled observing projects.
- Submit Helpdesk tickets.
- Trigger Target of Opportunity (ToO) observations.
- Access their proprietary data through the ALMA Archive.

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<sup>2</sup> Support of the Taiwanese astronomical community is shared by the EA and NA ARCs.

The Science Portal also includes links to the ARCs webpages from which users can access regional information and specific services of each ARC, such as visitor and student programs, schools, workshops, and outreach materials and activities.

Users must update their ALMA user profile, rather than registering multiple accounts, whenever there is a change in their personal information such as a new email address or a change of affiliation (see Section 2.1 of the [ALMA Users' Policies](#)). Finally, users are encouraged to complete the “Demographics” section of their profile to help ALMA provide adequate user support.

## 2.5 ALMA proposal eligibility

Users of any nationality or affiliation may submit an ALMA proposal. All proposals are evaluated on the basis of scientific merit by a panel-based proposal review system.

Each proposal must have a PI who is the official contact between ALMA and the proposing team for all correspondence related to the proposal. Large Programs and mm-VLBI Proposals may designate co-PIs, who will share the overall responsibility in conducting the proposed science. If co-PIs are identified, the requested observing time will be split among the regions (North America, Europe, East Asia, and Chile) in proportion to the affiliations of the PI and co-PIs (Section 5.6.3).

Regardless of the inclusion of co-PIs, the PI has the responsibility for preparation and approval of the Phase 2 material, has proprietary access to the ALMA data during the proprietary period, and is in charge of the delivery of the data products in the case of Large Programs, in accordance with the [ALMA Users' Policies](#). Any other individuals who are actively involved in any proposal may be designated as co-Is. There is no limit to the number of co-Is or co-PIs who may appear on a proposal.

Additional rules apply for qualification to use the Chilean share of the time and they are described at [http://www.das.uchile.cl/alma\\_crc/das\\_alma\\_crc.html](http://www.das.uchile.cl/alma_crc/das_alma_crc.html).

[ALMA Users' Policies](#) prohibit multiple submissions of the same proposal using different regional affiliations. If such proposals are detected, only the first submitted version will be considered by the ALMA review panels.

## 3 Proposal types

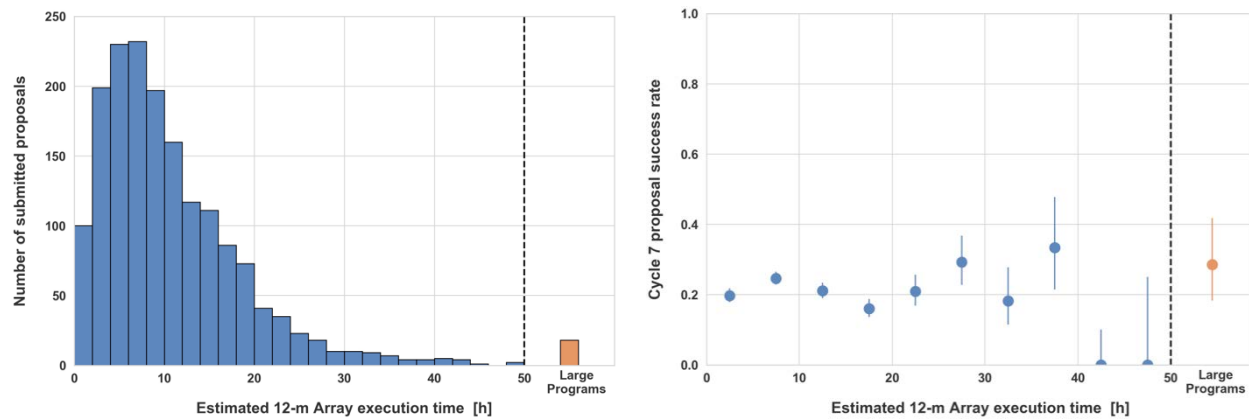
### 3.1 Regular Proposals

Regular Proposals relate to observations that can be fully specified by the regular proposal submission deadline and whose estimated execution time does not exceed 50 hours on the 12-m Array or 150 hours on the 7-m Array in stand-alone mode. Regular Proposals may involve time-critical, multiple-epoch observations, and the monitoring of a target over a fixed time interval.

Figure 1 (left panel) shows that most Cycle 7 proposals requested between 2 and 20 hours of 12-m Array time. However, the success rate of proposals was roughly constant up to 40 hours of requested 12-m Array time (Figure 1, right panel). The JAO aims to have a diverse scientific portfolio by executing a balance of programs with various sizes in terms of observing time, and encourages the community to submit Regular Proposals that request over 20 hours of 12-m Array time.

No restrictions are imposed on the size of the time window specified by PIs for time-critical observations. The scheduling feasibility of any proposal will depend on the total number of

constraints that are imposed (see Section 4.3). Importantly, any time constraint, as with any other type of observational constraint, must be scientifically and technically justified.



**Figure 1:** (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.

### 3.2 Target of Opportunity Proposals

Target of Opportunity (ToO) Proposals should be submitted for observations that can be anticipated but whose targets and/or time of observation are not known in advance. Like Regular Proposals, these proposals must be submitted by the Cycle 8 proposal deadline. As for all other types of proposals, observing modes and sensitivity requests must be specified at the time of submission. In contrast, the target list may be specified at the moment of triggering the proposal. For each triggered Scheduling Block (SB) the proposal should specify the number of triggers needed, what the trigger event will be, and the necessary reaction time for scheduling the observation after it is triggered. Regular Proposals wrongly submitted by the PI as ToO Proposals may be rejected on technical grounds.

The JAO will give priority to observing ToO Proposals during the time period requested by the PI after a trigger request has been submitted provided the appropriate scheduling conditions (mainly weather and antenna configuration, see Section 4.3) are met and the observations do not conflict with critical engineering and development activities or critical observations with a higher grade. ToO observations triggered while the 12-m Array is in one of the most extended configurations are possible but may be subject to longer reaction times. For requests of reaction times under 24 hours, the Observatory recommends that PIs give notice as early as possible about target coordinates or redshift for preparation of the Phase 2 SBs. PIs will trigger observations from accepted ToO Proposals through the Project Trigger Submission Page available at the ALMA Helpdesk. Further instructions on how to trigger a project are available at the [ToO Activation page](#) on the Science Portal. Upon receiving a trigger, the Observatory will communicate with the PI through the Helpdesk ticket to clarify any remaining issues.

### 3.3 Large Programs

Large Programs are proposals with an estimated execution time of greater than 50 hours on the 12-m Array (with or without accompanying ACA time) or 150 hours on the 7-m Array in stand-alone

mode. Large Programs should not involve time-critical or ToO observations, and may not involve full polarization measurements, Solar observations, VLBI, pulsar mode, or Astrometric observations.

A Large Program proposal should address strategic scientific issues that will lead to a major advance or breakthrough in the field, be a coherent science project, not reproducible by a combination of Regular Proposals, lead to high level archival data products, and contain a solid management plan ensuring an efficient utilization of the data, including analysis and organization of the efforts. Consequently, the proposal team for a Large Program should not in parallel submit their Large Program as one or more Regular Proposals, in which case the Regular Proposals will not be considered (further details on this policy are available at the Knowledgebase article “[Are there policies specific to Large Programs?](#)”).

The program teams are expected to deliver their proposed data products and documentation describing the data products to ALMA within one year of the final delivery of calibrated products. The data products and documents will be made available to the community at large. A document describing the standards for product naming, product metadata and product quality will be made available at the Science Portal during Cycle 8.

A maximum of 15% of the Cycle 8 time available for science observations will be dedicated to the execution of Large Programs, corresponding to 645 hours of 12-m Array time and 450 hours of stand-alone ACA time (Section 4.1). Large Programs will not be allowed to exceed 50% of the available time for a given LST range in any of the Cycle 8 configurations.

### **3.4 mm-VLBI and Pulsar Proposals**

ALMA VLBI Proposals are made in concert with either the Global Millimeter VLBI Array (GMVA) at 3 mm (Band 3) or the Event Horizon Telescope Consortium (EHTC) network at 1.3 mm (Band 6). For 3 mm VLBI observations, PIs must have submitted a proposal to the GMVA network by 1 February 2020 in addition to their ALMA VLBI proposal.

ALMA-specific VLBI considerations are given in Section A.12 of this document. Further details on submitting 3 mm VLBI Proposals to the GMVA are available from [the GMVA website](#). Further details on submitting 1 mm VLBI Proposals to EHTC are available from [the EHTC website](#).

Proposals should include a quantitative justification describing why ALMA is essential for the project. VLBI observations cannot be included in Large Programs. VLBI observations that include ALMA will likely occur in March/April 2021.

Given that the outcome of VLBI Cycle 7 proposals, scheduled in March/April 2020, is unlikely to be known before the ALMA Cycle 8 proposal deadline, PIs of such proposals may wish to resubmit their proposals in Cycle 8 in case the Cycle 7 observations are unsuccessful. No resubmission to the GMVA network is needed in such cases. Further details on the handling of resubmitted proposals are available in Section 4.4.2.

Pulsar observing capabilities are given in Section A.13 of this document. Pulsar observations will take place during the VLBI time blocks anticipated to be in March/April 2021.

### **3.5 Director Discretionary Time Proposals**

Director Discretionary Time (DDT) Proposals may be submitted at any time. To qualify for DDT usage, proposals must fulfill the [conditions](#) specified at the Science Portal. Capabilities, time tolerance restriction, and science assessment will be based on the same criteria as for Regular and

ToO Proposals. DDT Proposals will be considered for approval by the ALMA Director based on the advice of a Standing Review Committee, with members from the JAO and the four regions, appointed by the Executive Directors and the ALMA Director. In exceptional cases, the ALMA Director may approve DDT Proposals that would benefit from a very rapid response, and inform the Standing Committee and science operations team of this decision within 24 hours. Further DDT policies are described in the [ALMA Users' Policies](#).

## 4 Proposal planning

### 4.1 Time available in Cycle 8

Cycle 8 will have a duration of 12 months, starting in 2020 October and finishing in 2021 September.

It is anticipated that 4300 hours of the 12-m Array and at least 3000 hours<sup>3</sup> on both the 7-m Array and the TP Array will be available for successful proposals of PI programs and DDT Proposals, including Cycle 7 grade A proposals that are carried over. Large Programs, VLBI and DDT Proposals are limited to a maximum of 15%, 5% and 5% (respectively) of the available time (Sections 3.3, 3.4 and 3.5).

### 4.2 Summary of capabilities offered in Cycle 8

The Cycle 8 capabilities are described in Appendix A. In summary they are:

Number of antennas

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

Receiver bands

- Receiver Bands 3, 4, 5, 6, 7, 8, 9, and 10 (wavelengths of about 3.0, 2.0, 1.6, 1.3, 0.85, 0.65, 0.45, and 0.35 mm, respectively).

12-m Array Configurations

- Cycle 8 includes configurations C-1 through C-8. Configurations C-9 and C-10 will next be available in Cycle 9.
- Maximum baselines between 0.16 km and 8.5 km depending on array configuration and subject to the following restrictions:
  - The maximum possible baseline for Bands 8, 9 and 10 is 3.6 km.
  - The maximum possible baseline for Bands 3, 4, 5, 6 and 7 is 8.5 km.

Configurations with maximum baselines equal or longer than 3.6 km (C-7 to C-10) are considered “long-baseline configurations”. Observations in these configurations include more frequent calibration compared to more compact configurations to ensure the quality of the observations. Files containing [notional 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.

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<sup>3</sup> Additional time, the specific amount to be determined later, will be offered in the stand-alone ACA supplemental call.



### 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.

### Polarization

- Single pointing, on axis, full linear and circular polarization capabilities for continuum and full spectral resolution observations in Bands 3, 4, 5, 6 and 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.
- Mosaics for continuum linear polarization observations for the 12-m Array in Bands 3, 4, 5, 6, and 7. There are no field-of-view restrictions for such mosaics.

## 4.3 Scheduling considerations

Apart from time-constrained observations, various aspects of a proposed observation such as weather conditions or requested angular resolution and Largest Angular Structure (LAS) may affect when an observation is scheduled. This section describes the most important scheduling considerations that investigators should be aware of when preparing their ALMA proposal.

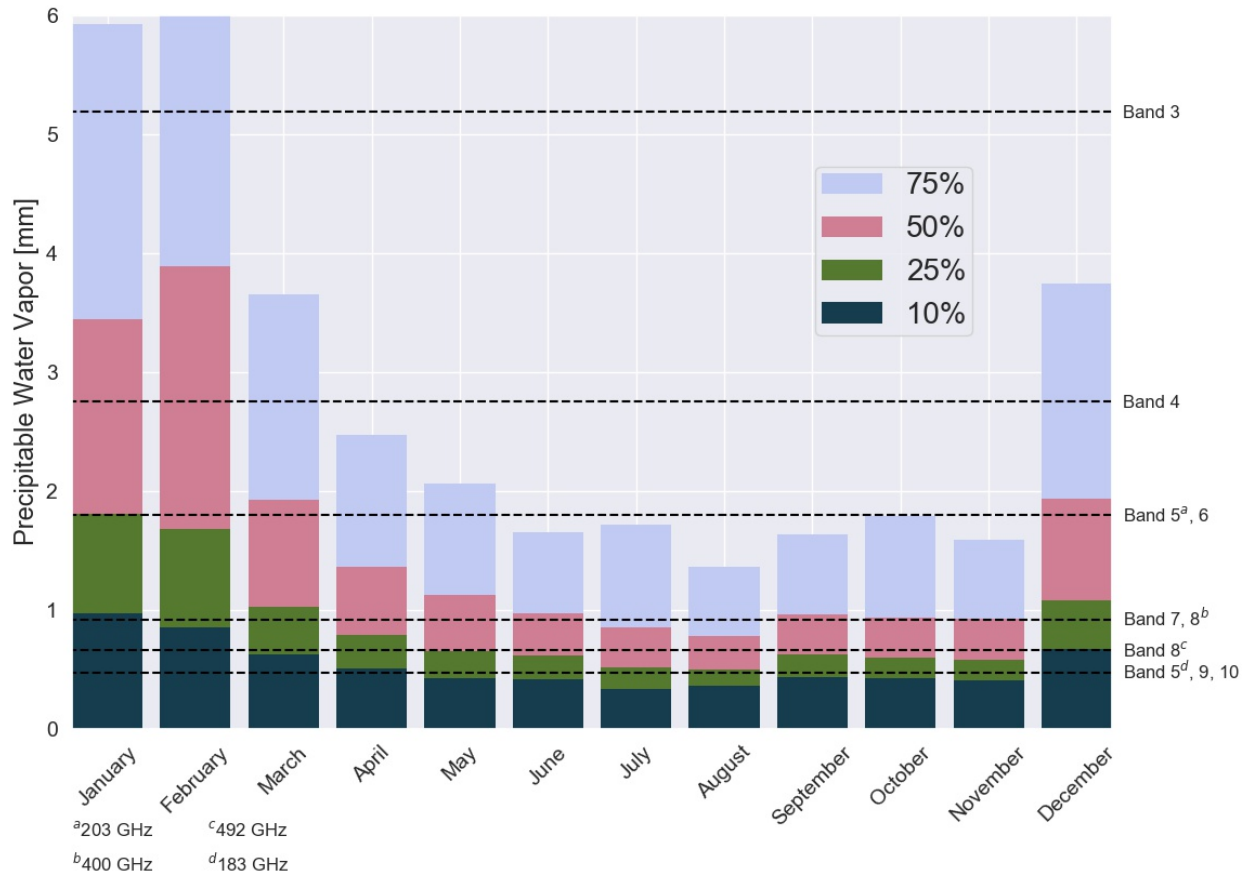
### 4.3.1 Weather

Chajnantor is one of the best sites in the world for ground-based observations at submillimeter wavelengths (Evans et al 2002, ALMA Memo No. 471, available from the [ALMA Memo Series](#)). The opacity (primarily determined by the Precipitable Water Vapor – PWV) and the phase stability of the atmosphere are the two primary factors that dictate when ALMA can observe at certain frequencies, in particular in the higher-frequency bands and at frequencies near water absorption lines. Both transmission and phase stability follow a yearly cycle (late southern winter is best – see Figures 2 and 4 of [Memo 471](#)) and a diurnal cycle (late night and early morning are best – see Figures 3 and 5 of [Memo 471](#)). In addition to the transmission and phase stability criteria, the low wind speeds that typically occur during night and early morning provide optimum observing conditions.

Figure 2 shows the PWV measurements per month, illustrating the yearly cycle. The best months for high-frequency observations are from May to November. Figure 3 shows the percentage of time when the PWV is below the observing thresholds adopted for the various ALMA bands. Such time percentage is shown per month and separately for day and night to highlight the daily and monthly variations. For a given time of the day and a given month, the PWV measurements still show a large scatter due to the differences in weather from year to year. During parts of the year, such as the Altiplanic winter<sup>4</sup> season (December-March), it may be difficult to carry out submillimeter observations. For this reason, an extended maintenance and upgrade period is scheduled each February, during which no science observations are scheduled.

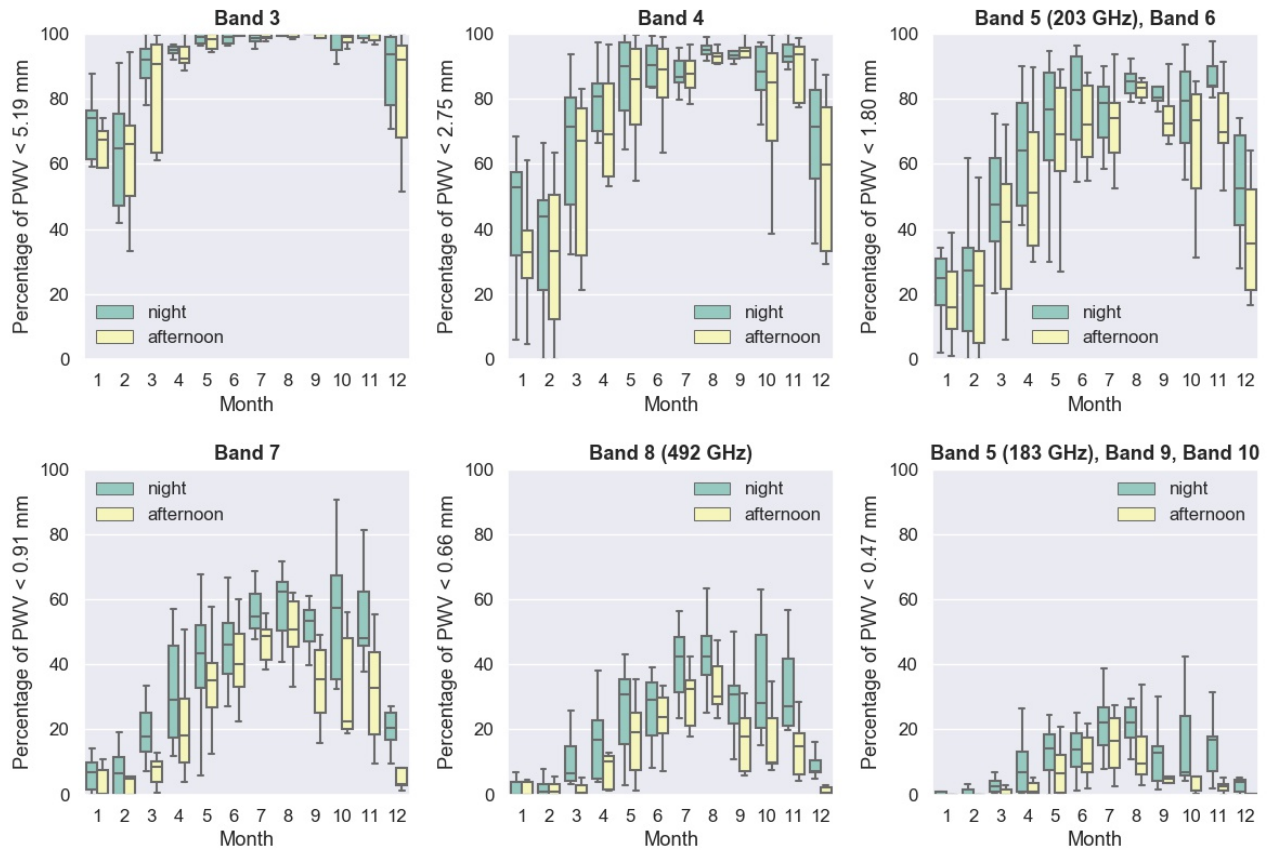
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<sup>4</sup> During southern summer, the high-pressure system over the Pacific Ocean weakens and moves southwards, allowing warm humid air from the Amazons to flow over the Andes into northern Chile, causing rain and occasionally snow to fall on the usually dry Altiplano: this phenomenon is known as Altiplanic winter.



**Figure 2:** 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 with the APEX weather station, ALMA measurements, and weather forecast data 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.





**Figure 3:** 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 25<sup>th</sup>- and 75<sup>th</sup>-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.

The Observatory will schedule the observations during appropriate weather conditions to ensure good data quality. In particular, high-frequency projects will be prioritized when weather conditions are appropriate for them.

### 4.3.2 Angular resolution

PIs can enter a single value or a range when specifying acceptable angular resolutions for a given SG in the OT. Whenever feasible, PIs are encouraged to enter a range spanning more than one configuration. Such a choice will improve chances for having the SB observed, especially for SBs with an intrinsically low probability of execution due to, for example, weather or time constraints.

In practice, the OT will assign to a given SB any number of configurations that fulfill the angular resolution range requested by the PI. For scheduling feasibility and Quality Assurance (QA) purposes, the following will also be considered:

- If the PI selects a single value for the angular resolution or a range narrower than 20% around its center value, a range of  $\pm 20\%$  around the single or center value specified will be enforced.

- If the requested range (after applying the previous rule) does not include the resolution of at least one of the notional configurations, the range will be extended to include the resolution of the closest notional configuration.
- If the requested range includes both long-baseline and more compact configurations, only the latter will be considered. An exception is constituted by ToO observations that can be triggered in any configuration if the angular resolution requested by the PI is ‘any’ (see Section 3.2).

The final range of angular resolutions (i.e. after all the above factors have been considered) that the Observatory will use, and the corresponding set of configurations, are displayed in the Phase 2 SBs in the OT so that they can be reviewed by PIs. Users should note that the synthesized beam shape can be elongated, in particular for sources of high or very low declinations (see Section 7.4 of the [Technical Handbook](#) for details). For reference, the OT will show the expected 2-D beam shape and maximum axial ratio based on observations near transit for a given source. Observations away from transit will result in a higher axial ratio than that shown.

PIs aiming to obtain a specific surface brightness may enter their sensitivity request in temperature units. In this case, if a range of acceptable resolutions is specified by the PI, the time estimate will be determined by the time needed to achieve the surface brightness sensitivity requested at the resolution of the most extended configuration fitting the provided range (i.e. highest resolution). ALMA QA processes are defined in terms of resolution and flux density sensitivity, so the actual surface brightness sensitivity delivered will depend on the resolution achieved by the observations (see Chapter 11 of the [Technical Handbook](#) for more details). Thus, a temperature sensitivity worse than requested could be obtained if the resolution achieved in the delivered images is still within the requested range but higher than that of the most extended configuration assigned to that SB.

### 4.3.3 Configuration schedule for the 12-m Array

The ALMA 12-m array will be configured in 8 different configurations during Cycle 8. **Note that the longest baseline configurations, C-9 and C-10, will not be available in Cycle 8.** While each configuration contains fifty 12-m antennas, only a subset of the 50 antennas will be available for most observations due to maintenance activities, calibration observations, and testing new capabilities. These operational factors impact the actual configuration achieved for a given observation, so the configurations used for simulations and planning are referred to here as “notional configurations.” The OT assumes 43 antennas are available when calculating the time estimates and image characteristics based on these configurations. Cycle 8 configurations are denoted as C-x, with x=1 for the most compact configuration and x=10 for the most extended (see Section A.2 and Chapter 7 of the [Technical Handbook](#) for details). To simulate C-1 through C-8 Cycle 8 observations, users should use the notional configurations C43-1 through C43-8 used in Cycles 6 and 7. Files describing the notional configurations are [available on the SP](#). The planned 12-m Array configuration schedule for Cycle 8 is given in Table 4. This schedule may be modified depending on the results of the proposal review process and the proposal pressure in the different configurations. Changes to the [configuration schedule](#) will be announced on the SP. On average, configurations change once every three weeks. Observations will not be scheduled in February 2021 because of poor weather during the Altiplanic winter.

The first column of Table 4 gives the planned start date for each configuration. These dates are subject to change because of weather conditions. The second column gives the 12-m Array configuration, and the third column lists the longest baseline for the configuration (see Table A-1).

The fourth column lists the LST ranges when the observing conditions are most stable, approximately two hours after sunset to four hours after sunrise (Section 4.3.1). The effective observing time available per configuration for executing PI projects (excluding time spent on observatory calibration, maintenance, reconfigurations, and other activities – see Section 4.3) is shown in Figure 4.

**Table 4: Planned 12-m Array Configuration Schedule for Cycle 8**

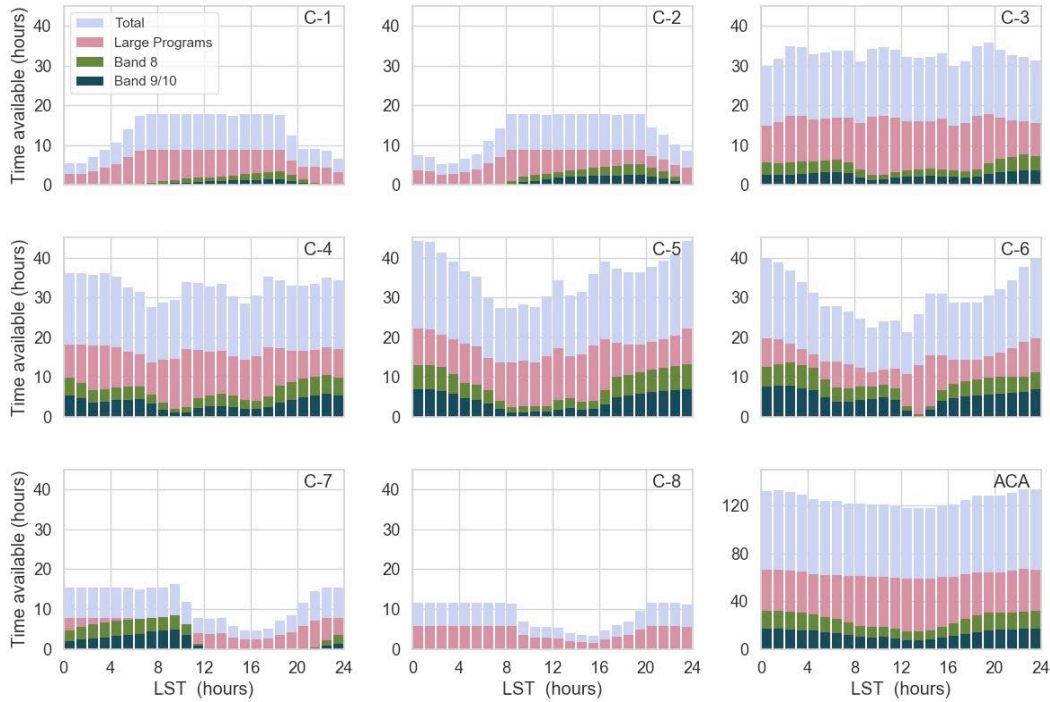
Start date	Configuration	Longest baseline	LST for best observing conditions
<b>2020 October 1</b>	C-8	8.5 km	~ 22—10 h
<b>2020 October 20</b>	C-7	3.6 km	~ 23—11 h
<b>2020 November 20</b>	C-6	2.5 km	~ 1—13 h
<b>2020 December 1</b>	C-5	1.4 km	~ 2—14 h
<b>2020 December 20</b>	C-4	0.78 km	~ 4—15 h
<b>2021 January 10</b>	C-3	0.50 km	~ 5—17 h
<b>2021 February 1</b>	<i>No observations due to maintenance</i>		
<b>2021 March 1</b>	C-1	0.16 km	~ 8—21 h
<b>2021 March 20</b>	C-2	0.31 km	~ 9—23 h
<b>2021 April 20</b>	C-3	0.50 km	~ 11—1 h
<b>2021 May 20</b>	C-4	0.78 km	~ 13—3 h
<b>2021 June 20</b>	C-5	1.4 km	~ 15—5 h
<b>2021 July 11</b>	C-6	2.5 km	~16—6 h
<b>2021 July 30</b>	C-5	1.4 km	~17—7 h
<b>2021 August 20</b>	C-4	0.78 km	~19—8 h
<b>2021 September 10</b>	C-3	0.50 km	~20—9 h

Notes for Table 4:

1. Configuration properties are given in Section A.2

Given the anticipated configuration schedule and weather constraints, the following considerations apply:

- Bands 9 and 10 observations will be scheduled during the LST ranges given in the fourth column of Table 4, corresponding to more stable weather conditions (Section 4.3.1). The amount of time with stable atmospheric conditions suitable for Bands 7 and 8 observations outside of those LST ranges is limited (see Figures 2 and 3). To maximize the completion of high-frequency observations, such projects are given priority in the observing queue when the weather conditions are suitable (Section 4.3.1).
- High-frequency projects (Bands 7, 8, 9, and 10) and Band 5 observations near the atmospheric absorption feature at 183 GHz are not recommended around the Altiplanic winter (December to March) at any LST.
- The probability of an observation being scheduled depends on the over-subscription for the given LST and configuration in addition to the required weather conditions.
- Projects that have imaging requirements (constraining the necessary configuration) and other time constraints (e.g. due to coordination with other observatories) that do not coincide cannot be scheduled.

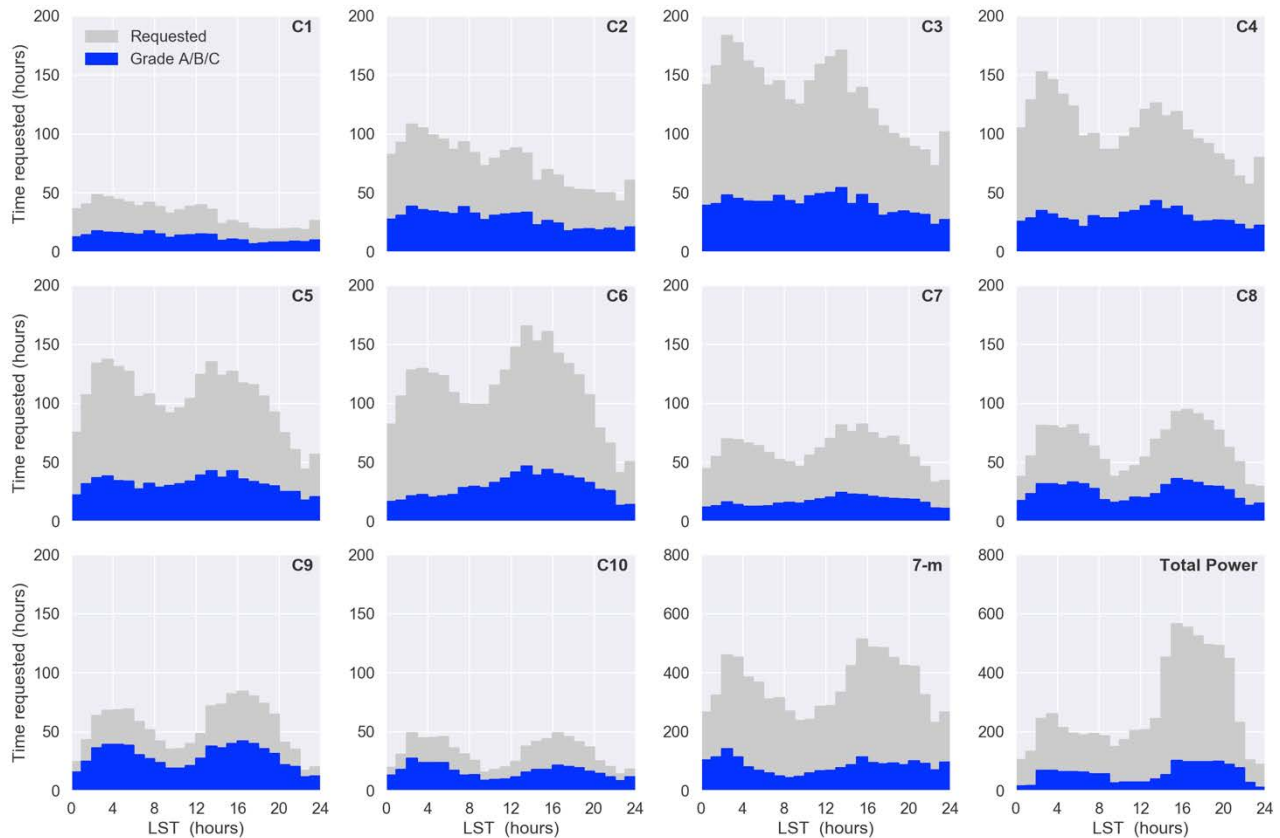


**Figure 4:** Effective observing time available per configuration for executing PI projects. As an example, up to 9 hours may be allocated to Large Programs in configuration C-2 at LST = 10 h. The total number of hours excludes time spent on observatory calibration, maintenance, reconfigurations, and other activities. The fraction of that time available for Large Programs (pink) and high-frequency observations (green and dark blue) is also indicated. The configuration schedule and, consequently, the total number of hours available per configuration may change as a result of proposal pressure (Section 4.3.3).

### 4.3.4 Observing pressure

Figure 5 shows the LST distribution of Cycle 7 submitted proposals and of those awarded grades A, B, or C by configuration and array type. While some LST ranges such as 2-6 h or 12-19 h show over-subscription in several configurations, the degree of over-subscription differs significantly for different configurations. In general, proposals will have a higher probability of acceptance if they request time in less subscribed LST ranges.

The range of angular resolutions provided by PIs (Section 4.3.2) will have a direct impact on the observing pressure per configuration. Proposals that specify a broad range of acceptable angular resolutions (i.e., several acceptable configurations) increase their likelihood of being scheduled and executed. However, PIs should only request the range of angular resolutions that is acceptable for their science goals, as this will be evaluated during the proposal review process.



**Figure 5:** Distribution of estimated execution time in Cycle 7 for all submitted proposals (gray) and proposals assigned Grade A, B, or C (blue). The figure does not include the unfinished Cycle 6 Grade A proposals carried over to Cycle 7.

## 4.4 Duplicate observations and resubmissions

### 4.4.1 Checking for duplications

Duplicate observations of the same location on the sky with similar observing parameters (frequency, angular resolution, coverage, and sensitivity) are not permitted unless scientifically justified. Detailed criteria of what constitutes a duplicated observation are specified in Appendix A of the [Users' Policies](#).

PIs are responsible for checking their proposed observations against the [Archive](#) and the list of

Cycles 5, 6, and 7 programs [provided on the Science Portal](#) to avoid duplicate observations. PIs proposing duplications of previous cycle observations will not have their proposals marked as duplications if they had no way to know about the previous cycle observations, using the resources listed above, by the release of the Call for Proposals. Information on checking for duplications is available on the [Duplicate Observations](#) page on the Science Portal.

The proposal cover sheet contains a section where PIs can justify observations known to be duplicate. PIs may wish to justify their proposed observations in cases where they are similar to previously executed or accepted programs but are not formal duplicates. This will help the reviewers understand why new observations are requested. The ALMA Review Panels (ARPs) will determine if the justification for a duplicate observation is sufficient.

Examples of duplicate observations that may be approved include:

- Observations of time-variable phenomena.
- A large-area survey where cutting out a smaller area to avoid overlap with a previous observation will make the observation inefficient and increase the overall execution time.
- Spectral scan surveys where excluding a frequency range covered by a previous observation will make the observation inefficient and increase the overall execution time.

#### **4.4.2 Resubmission of an unfinished proposal**

Proposal teams that submit a Cycle 8 proposal to observe some or all the SGs of a currently active but unfinished project will have the relevant SGs identified as a “resubmission” by ALMA. A SG is deemed a resubmission if it constitutes a duplication of an active SG following the rules specified in Appendix A of the [Users’ Policies](#) and the PI of the relevant Cycle 7 project is listed as a PI, co-I or co-PI of the corresponding Cycle 8 proposal or the Cycle 8 PI is listed as an investigator on the Cycle 7 proposal.

For such resubmissions, the relevant portion of the Cycle 8 proposal will be cancelled if the observations are successfully completed in Cycle 7. Observations started in a previous cycle and accepted as a resubmission in Cycle 8 will continue to be observed with the setup of the previous cycle.

A scientific justification must be provided if the proposers request one or more additional epochs of observations in Cycle 8 even if the Cycle 7 observations are completed. The APRC will decide if such resubmissions are accepted.

### **4.5 Estimated observing time**

Proposal requests are cast in terms of SGs, each containing a complete observational setup (desired sensitivity, range of angular resolutions and LAS, frequency band, spectral windows and spectral resolutions) to be obtained for one or more targets. The [OT Quickstart Guide](#) and the [OT User Manual](#) provide extensive details and guidance for preparing the SGs. Experienced users who wish to understand how ALMA observations are set up are referred to Chapter 8 of the [Technical Handbook](#).

The observational setup of a given SG is used to estimate a total observing time for that SG (except for Solar or VLBI observations or when overridden by the PI - see Appendix B). This observing time is the sum of the required time-on-source for all science targets, time for all calibrations including overheads, and the time for any additional array configurations needed to meet the specified LAS. The estimated observing time for the proposal is the sum of the times for all SGs. The actual



observing time to reach a given sensitivity, resolution and LAS will depend on the prevailing conditions when the project is observed, the number of antennas available, and the actual array configuration.

The estimated time-on-source is calculated with the [ALMA Sensitivity Calculator](#) (ASC), available within the OT or as a stand-alone web application on the Science Portal. The parameters that affect these time estimates include requested sensitivity, source declination, observing frequency, spectral bandwidth, number of antennas, angular resolution (if the sensitivity is specified in temperature units<sup>5</sup>) and default weather conditions. A description of the ALMA Sensitivity Calculator is given in Chapter 9 of the [Technical Handbook](#).

The estimated time for calibrations and overheads is calculated by the OT and will depend on the frequency, configuration and type of observation (e.g. full polarization requires additional calibrations). Proposals requesting the suppression of some or all calibrations in one or more SGs may be deemed technically unfeasible if the request is not properly justified in the proposal (see Section B.4 for details).

For each SG one or more SBs are generated during Phase 2 depending on the distribution of sources in the sky and the number of configurations needed (Sections A.8.1 and A.4, respectively). Each SB contains all the commands needed to perform the observations and a complete set of calibrations. The minimum duration of the SB is constrained by a minimum time-on-source of 5 minutes for the sum of all the sources in the SB or 50% of the total calibration time (see Section 5.3.5.3 of the [OT User Manual](#)). For SGs that require a combination of arrays but have short time-on-source that is increased to the 5-minute minimum by the OT, the time multipliers given in Table A-2 may not be preserved (see Section A.4). The maximum duration of a SB is around 2 hours (determined by a maximum time-on-source of 50 minutes) and each SB will be re-run as many times as needed to achieve the requested signal-to-noise (S/N) ratio. Consecutive executions of a given SB (if needed) are favored during scheduling to maximize  $uv$ -coverage. However, if  $uv$ -coverage is fundamental for the scientific goals of a proposal, PIs should specify this request as a time constraint and, if necessary, override the OT time estimate with the time needed to achieve such  $uv$ -coverage (see Section B.2 for details). Data from each SB will be processed, assessed, and delivered independently.

The final factor in the time estimate is the possible addition of configurations needed to reach the specified LAS (see Table A-1 in Appendix A). The LAS is compared to the “Maximum Recoverable Scale” (MRS) of the configurations that best match the requested range of angular resolutions (MRS are also listed in Table A-1). If the LAS exceeds the MRS of all matching configurations, then additional configurations, if allowed (Section A.4), are added with a time estimated using the multipliers given in Table A-2. If the array combinations are not allowed (Section A.4), the OT will give a validation error. If the LAS can be achieved with one or more of the best-matching configurations, the remaining configurations meeting the angular resolution but not the LAS request will not be considered.

The PI may include additional SGs for array combinations not allowed in a single SG, but each SG must be separately justified and have its own performance specifications (sensitivity, range of angular resolutions, and LAS).

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<sup>5</sup> Since Cycle 5, the time estimate adopts the configuration that fulfills the highest angular resolution requested if the sensitivity is specified in temperature units (Section 4.3.3).

Observations that require only the ACA are selected by checking a specific box at the OT interface. When calculating the time required for the ACA, for each Science Goal the OT uses the TP Array time if this array is required (based on LAS) or otherwise the 7-m Array time; i.e., it is not the sum of the 7-m and TP Array time. In case of simultaneous observations in the 12-m and 7-m Arrays, the estimated time for the 7-m Array will be set equal to that of the 12-m Array. *Users should note that snapshots with the 7-m Array are strongly discouraged for imaging.* Integrations of at least one hour are necessary for sufficient *uv*-coverage to achieve good image quality. See Chapter 7 of the [Technical Handbook](#) for more information on imaging with ALMA.

Time estimates for each SG are available in the OT by clicking “Time Estimate” in the “Desired performance” box. A summary of the time estimate of each SG can be viewed by clicking the “Time Summary” button on the OT toolbar. The times for the 12-m Array, 7-m Array, and TP Array are tabulated separately on the proposal cover sheet.

## 4.6 Supporting tools and documentation

### 4.6.1 The Observing Tool documentation

The [ALMA OT](#), a Java-based application that resides and runs on the user’s computer, is used to prepare and submit observing proposals (Phase 1) as well as to prepare the observations for execution on the telescope (Phase 2) if the proposal is accepted.

The OT is most conveniently installed using the new installer option, which is available for Linux, Mac OS, and Windows. The installer contains its own version of Java and thus it is not necessary for users to install Java themselves.

The OT documentation suite, which provides all the basic information required to complete the proposal preparation and submission, includes:

- The [OT Phase 1 Quickstart Guide](#): A guide to proposal preparation for the novice ALMA OT user. It provides an overview of the necessary steps to create an ALMA observing proposal.
- The [OT Video Tutorials](#): A visual demonstration of proposal preparation and submission with the OT. Users should note that these videos were produced in Cycle 6 and therefore do not include the changes implemented to the OT in Cycles 7 and 8.
- The [OT User Manual](#): A manual intended for all ALMA users, from novices to experienced users. It provides comprehensive information on creating valid Phase 1 proposals and Phase 2 programs for observing astronomical objects. It is also included as part of the “Help” documentation within the OT itself.
- The [OT Reference Manual](#): A manual providing a concise explanation for all the fields and menu items in the OT. It is also included as part of the “Help” documentation within the OT itself.
- The [OT trouble-shooting page](#): A list of the OT installation requirements and workarounds for common installation problems.
- The [known OT issues page](#): A list of known bugs, their status, and possible workarounds. This page may be updated during the proposal submission period and should be checked first if problems are experienced with the OT.



### 4.6.2 Additional proposal preparation tools

Two tools are available to help users produce simulated images of ALMA observations of simple or user-provided science targets. A guide for simulating ALMA observations with either tool is available at the [CASA guides website](#).

The first simulation tool is integrated into CASA, the offline data reduction and analysis tool for ALMA data. CASA includes the tasks “simobserve” and “simanalyze”, which generate simulated visibility data and make images from these simulated data sets. An additional CASA task, “simalma”, simplifies the process for ALMA data by combining data from multiple arrays, including the TP-array if needed. These CASA tasks require configuration files that specify the layout of ALMA antennas. To simulate observations for Cycle 8, investigators should use the equivalent [Cycle 7 configuration files](#) available on the Science Portal. The CASA simulation tasks are included in the [CASA documentation](#) and detailed examples can be found in the [CASA guides](#). Additional information on CASA, including hardware requirements and download instructions, is available at the [CASA website](#).

The second simulation tool is the ALMA Observation Support Tool (OST). The OST uses a simplified [web interface](#) to help users generate ALMA simulations. Users submit jobs to the OST and are notified by email when the simulations are completed. The OST documentation is available at the [OST website](#).

[Splatalogue](#) is a database containing frequencies of atomic and molecular transitions emitting in the radio through submillimeter wavelength range. This database is used by the ALMA OT for spectral-line selection. More information is available in the [Splatalogue QuickStart Guide](#).

The atmospheric transmission at the ALMA site can be investigated with the [Atmosphere Model tool](#), which allows the user to model the atmospheric transmission as a function of frequency and PWV. The output is a plot of the transmission fraction as a function of frequency. Up to six different water vapor levels can be selected.

### 4.6.3 The ALMA Regional Center Guides

The ARC Guides contain user support details specific to each ALMA regional partner. They are:

- The [East-Asian ARC Guide](#)
- The [European ARC Guide](#)
- The [North American ARC Guide](#)

### 4.6.4 Supplemental documentation

The following documents supplement this Proposer’s Guide for the preparation of Cycle 8 proposals, for either the novice or advanced users. All documents can be accessed via the [ALMA Science Portal](#).

The [Proposing Guidance page](#) from the science portal summarizes the steps involved in the preparation and submission of an ALMA observing proposal. It is designed to help users find the relevant documents and sources of additional information in each step of creating a proposal.

[Observing with ALMA: A Primer](#) is a brief introduction to ALMA observing, submillimeter terminology, and interferometric techniques that should prove useful for those new to radio astronomy. Several example science projects are described.

The [ALMA Users' Policies](#) document contains a complete description of the applicable users' policies. The long-term core policies for usage of ALMA and of ALMA data by the user community are presented.

The [ALMA Cycle 8 Technical Handbook](#) describes the technical details of ALMA during Cycle 8, including but not limited to receiver characteristics, array configurations, available observing modes and correlator setups, and the basis of the OT time estimates.

The [ALMA Memo Series](#) and [ALMA Technical Notes Series](#) include technical reports on various aspects of ALMA project development and construction and from the extension and optimization of capabilities.

## 4.7 The ALMA Helpdesk

The ALMA Helpdesk can be accessed from the [ALMA Science Portal](#) or directly at <http://help.almascience.org>. Submitted tickets are directed to the registered user's ARC, where support staff are available to answer any question related to ALMA, including but not limited to ALMA policies, capabilities, documentation, proposal preparation, the OT, Splatalogue, and CASA. Users may also request information on workshops, tutorials, or about visiting an ARC or ARC node for assistance with data reduction and analysis. The Observatory will create a project ticket for each accepted proposal. On this ticket, investigators are notified about the start of Phase 2 and they can use this ticket for questions and communication on their project throughout its lifetime. Finally, investigators can also trigger ToO observations using the Helpdesk (see Section 3.2 ).

Users must be registered at the ALMA Science Portal to submit a Helpdesk ticket. Replies to an already existing ticket can be sent by the user by logging into the SP or via email (see ["Can I respond to my helpdesk ticket through my email?"](#) for more details). ALMA staff aim to answer Helpdesk tickets within two working days.

The ["Knowledgebase"](#) of the Helpdesk is a database of answered questions or articles on all aspects of ALMA. Users can search the Knowledgebase to find answers to common queries. Knowledgebase articles that match their query are automatically suggested to users as they type. The Knowledgebase query interface also searches all the documentation available on the ALMA Science Portal and provides a direct link to the documentation that may answer a user's question.

# 5 Proposal preparation and submission

The following sections contain guidelines regarding proposal format and preparing the Scientific and Technical Justification. The setup of Science Goals is only briefly explained and users are referred to the extensive suite of OT documentation for details (Section 4.6.1). ALMA novices are encouraged to start with the [OT Quickstart Guide](#) and the [video tutorials](#).

## 5.1 Proposal format

An ALMA proposal consists of basic proposal information that is entered directly into the ALMA OT (Section 4.6.1), a Science Justification uploaded to the OT as a PDF file, and one or more Science Goals.

Science Goals contain the technical details of the proposed observations and must include a Technical Justification. The OT is designed to facilitate proposal preparation and includes a number of tools and checks to ensure submitted proposals conform to the Cycle 8 capabilities.

After entering the basic proposal information and completing the Science Goals in the OT, the PI can generate the PDF of the complete proposal, including Scientific Justification, Science Goals, and Technical Justification that will be distributed to the ALMA Proposal Review Committee (APRC) for evaluation.

The first page of the PDF (the “cover sheet”) includes the title and abstract together with a summary of the SGs. In Cycle 8, ALMA is implementing dual anonymous review so the names of investigators will not be listed on the cover sheet or elsewhere in the PDF reviewed by the panels.

## 5.2 Dual-Anonymous Proposal Review

To ensure that the proposal review process is as fair and unbiased as possible, ALMA is beginning dual-anonymous review in Cycle 8. In a dual-anonymous review, the proposal team does not know the identity of the reviewers and the reviewers do not know the identity of the proposal team. While proposers will still enter their names and affiliations in the ALMA Observing Tool (OT), this information will not appear on the proposal cover sheet, nor in the tools used by the reviewers. It is the responsibility of the proposers to ensure anonymity is preserved when writing their proposals. Proposers should follow the following guidelines when preparing their proposals.

- Do not identify the PI or any of the co-PIs or co-Is in the proposal. This guideline should be followed in the abstract, scientific justification, and technical justification, including all figures, tables, and footnotes.
- Use the third person or neutral wording when referencing any investigator’s work. For example, instead of “In Smith et al. (2018) we demonstrated ...”, write “Smith et al. (2018) demonstrated ...”.
- Do not refer to data from ALMA or any other observatory in an identifying manner. If the data are unpublished, it can be referenced by the project code. For example, instead of “Figure 1 shows the image from our Cycle 7 program (2019.1.02045.S, PI: Smith).”, write “Figure 1 shows the image from the Cycle 7 ALMA program 2019.1.02045.S.”
- Software and datasets that are available in a public repository (e.g., GitHub) or in a public paper can be referenced per normal practices. If the software or data are not public, they can be referenced as “obtained in private communication” or similar language, but a name should not be specified since it could strongly imply who may be an investigator on the proposal.
- Do not include references and links to papers in preparation or submitted that are stored on personal web pages. References to submitted papers on public archives (e.g., arXiv) are acceptable.
- Do not include acknowledgements or the source of any grant funding.
- While proposers may note if they are resubmitting an ongoing Cycle 7 proposal, they should not indicate the proposal code and investigators of the previously accepted proposal. For example, instead of:

“This is a resubmission of our ongoing Cycle 7 program 2019.1.02045.S (PI: Smith). Half of our targets have been observed and we are resubmitting the proposal to obtain the remaining half. “

proposers can write

“This is a resubmission of our ongoing Cycle 7 program. Half of our targets have been observed and we are resubmitting the proposal to observe the remaining half. “

Resubmissions that present unpublished data in a figure may reference the project code using the example presented in the third bullet point, above.

Proposals for Large Programs must consist of two parts:

1. The scientific justification. This must be prepared following the dual-anonymous guidelines above. The scientific justification should motivate the proposed science and observations, describe the data products that will be delivered, and present the publication plan. The scientific justification may be up to 6 pages and is submitted in the usual manner through the ALMA Observing Tool (OT).
2. A one-page PDF document to describe the management plan. This plan should include a schedule of work, a description of the roles of the proposal team, and a plan to disseminate the results, as well as available computing resources and an assessment of scheduling feasibility. This statement must be sent to the ALMA Proposal Handling Team ([pht@alma.cl](mailto:pht@alma.cl)) by email and received before the 15 April proposal deadline. Proposers can include names and affiliations of investigators in this one-page document.

Large Programs will be assessed initially on the scientific justification only. After the scientific evaluation has been completed by the review panels and the APRC, the APRC will review the management plans, computing resources, and scheduling feasibility. The scheduling feasibility will be used to determine which proposals can fit into the observing queue given the scientific rankings of the Large Programs and the time available. After reviewing the management plans and computing resources, the APRC may recommend to the ALMA Director that a proposal be rejected only if they feel the proposal team is not qualified to carry out the program or does not have the necessary computing resources. However, the scientific rankings of the proposals will not change. The ALMA Director will make the final decision on which proposals are accepted.

PIs who do not anonymize their proposals in accordance with these guidelines may have their proposal rejected. In some cases, a proposal may be highly specialized and the identity of the team may seem obvious to the reviewers even after the text is anonymized. As long as these guidelines are followed, such a proposal will not be considered in violation.

Additional details and sample text for dual anonymous text are available on the Science Portal in the news item “[Items for planning Cycle 8 proposals](#)”. Proposers with resubmissions are encouraged to be particularly cognizant of changes needed in their text. All are encouraged to use the Helpdesk for any questions relating to dual anonymous review.

## 5.3 Preparing the Scientific Justification

ALMA Cycle 8 proposals must include a single PDF document that includes a science case written in English. The document may include figures, tables and references. The maximum permitted file size is 20 MB.

### 5.3.1 Page limits and Fonts

**The total length of the PDF document is limited to four pages for Regular, ToO, Solar, mm-VLBI and DDT proposals and six pages for Large Programs (A4 or US Letter format), with a**

**font size no smaller than 12 points.** The OT will check the font size of the PDF and issue an error during proposal validation if more than 15% of the text is smaller than 12 points. To submit the proposal, any problems with small fonts must first be fixed. Note that the OT may issue errors by detecting “hidden text” when figures are cropped from other PDFs. See the [Knowledgebase article on font size problems](#) for further details.

The recommended breakdown is two pages for the science case and two pages for figures, tables, and references, but proposers are free to adjust these numbers within the overall page limit. Large Programs are allotted two additional pages to further present the science case. New for Cycle 8, Large Programs will be required to submit a separate 1-page PDF document by email to the ALMA Proposal Handling Team ([pht@alma.cl](mailto:pht@alma.cl)) by the 15 April deadline to describe the management plan.

Figures and tables may be embedded within the science case so that they appear close to the location where they are referenced in the text. Although the Technical Justification for each Science Goal is entered in the OT, any figure required for it needs to be placed in the Scientific Justification PDF document. Users are encouraged to prepare their Scientific Justifications using the [LaTeX template](#) available on the Science Portal.

Proposals must be self-contained. Reference can be made to published papers (including [arXiv.org](https://arxiv.org) preprints) as per standard practice in the scientific literature. Consultation of those references should not, however, be required for understanding the proposal.

### 5.3.2 Science case

Each proposal must describe the scientific importance of the proposed project and include a clear statement of its immediate observing goals. It is also recommended to provide a brief justification of the requested sensitivity and angular resolution, with full details provided in the Technical Justification (Section 5.3).

Proposers can simulate ALMA observations using different array components and configurations (see Section 4.6.2). Simulations are not required. However, if they are discussed in a proposal to justify any technical aspects of an observation, their results (i.e., images and simulation details) should be included in the Scientific Justification and referenced in the relevant Technical Justification.

Since proposal reviewers are selected with expertise that covers the various topics within a proposal category, the scientific justification should be written for a knowledgeable, but broad-based, audience.

### 5.3.3 Figures, tables, and references

Figures, tables, and references that support the science case and the Technical Justification may be included. **Figure captions, tables and references must use 12-point font** and, together with the science case, they must fit within the overall page length and 20 MB size limit of the PDF proposal.

## 5.4 Preparing the Technical Justification

Each SG within a proposal must contain a Technical Justification (TJ), which is entered directly into the OT in the TJ node of each SG. Any figures associated with the TJ must be included in the Scientific Justification PDF file and clearly referenced in the TJ. Except for the figures, the TJ must be self-contained, and there should be no expectation or requirement that the technical assessor reads the Scientific Justification for details. The TJ must include a quantitative description and justification

of the expected source brightness, the requested sensitivity and S/N ratio, angular resolution and spectral setup. An incomplete TJ may lead to the rejection of the proposal on technical grounds.

Each SG has its own TJ since the technical setup of the observations will often vary substantially from one SG to the next. If a TJ is applicable to more than one SG, the TJ node can be easily copied and pasted (or dragged and dropped) between SGs. The TJ node contains three sections – sensitivity, imaging, and correlator configuration - corresponding to the main aspects that need to be assessed for the technical feasibility of any proposal. Each section includes at least one free-format text box that must be filled in (50 characters minimum), as well as a number of parameters computed from the user input captured in that Science Goal. This information is designed to help with the writing of the TJ, and will also highlight potentially problematic setups (blue text) if applicable. Please see the relevant sections in the [OT Reference Manual](#) (accessible by clicking the “?” symbols within the OT) for details. If the OT detects any technical choices that require an extra justification (e.g. time-constraints), appropriately labelled text boxes will appear in an additional "Choices to be justified" section.

Given that the information and the text boxes displayed in the TJ node are dependent on information provided elsewhere in the SG (including the Expected Source Properties entered in the Field Setup node), the Science Goal should be completed before filling in the TJ. Specific guidelines on filling out the TJ are given in Appendix B.

If a proposal does not conform to the advertised capabilities, it can be declared technically unfeasible either during the proposal review process or during Phase 2 (Section 6.1). The final decision will be made by the Head of Science Operations at the JAO.

The TJ must abide by the guidelines of dual-anonymous review.

## 5.5 Proposal validation, submission and withdrawal

Once the proposal is validated within the OT, it can be submitted to the ALMA Archive. Validation could take up to 5 minutes (or longer!) if the program contains complicated setups or a large number (hundreds) of sources. PIs of such programs should submit their proposals well before the deadline. A Cycle 8 proposal can be updated and submitted again to the ALMA Archive as many times as needed by the PI before the proposal deadline. Each time a proposal is submitted, the previous version of the proposal is overwritten (Section 5.5.1). Submitted proposals cannot be modified after the deadline. DDT proposals are not overwritten when submitted again, so they should only be submitted once.

Regular, ToO, Large, and mm-VLBI Proposals will be accepted starting 15:00 UT on 17 March 2020 and continue until **the proposal deadline at 15:00 UT on 15 April 2020**. No proposal submission or update will be accepted after the deadline. It is the PI's responsibility to submit the proposal successfully before the deadline. PIs are encouraged to submit their proposal early.

In addition, the following considerations apply:

- PIs, co-Is and co-PIs can retrieve proposals from the Archive both before and after the deadline.
- PIs who successfully submit their proposal will receive a confirmation e-mail from ALMA that includes the assigned project code.
- DDT Proposals may be submitted at any time. Like all other proposals, they must include a detailed science case and Technical Justification.

- A Helpdesk ticket should be submitted if the PI needs to withdraw a proposal that has already been assigned a project code.

### **5.5.1 Proposal updates**

PIs that need to update and then resubmit a Cycle 8 proposal should ensure that this is done using the last submitted version either by (i) modifying the proposal saved after submitting it, or (ii) downloading and then modifying the submitted proposal from the Archive. If a PI tries to submit a version of the proposal that had been saved on disk before it was first submitted, it will be rejected by the Archive. An earlier version that was never submitted (and which therefore contains no proposal code) will produce a new (duplicate) submission with a new code.

Users wishing to generate a new proposal starting from a proposal from the current submission period should save the original one to disk before it has been submitted. Otherwise, the second proposal will contain the original proposal's code and will overwrite it when submitted. Alternatively, the OT's "Open Project as New Proposal" (available from the File menu) could be used.

## **5.6 Proposal evaluation and selection**

### **5.6.1 Peer review**

ALMA programs are selected through competitive peer review.

In the main call, reviewers consist of scientists selected from the international astronomical community, and are assigned to individual ALMA Review Panels (ARPs) that are specialized in a scientific category. The APRC consists of the chairs of each ARP and a Chair, who is selected from the international community by the ALMA Director.

The JAO assigns each submitted proposal to a panel based primarily on the science category selected by the PI (see Appendix D for the list of scientific categories), but with care taken to avoid conflicts of interest with the ARP members.

The APRC will review the Large Programs selected by the ARPs and will recommend which to schedule.

After the outcome of the proposal review process is approved by the ALMA Director's Council and a Chilean representative, the results will be communicated to the PIs. The notifications will include the assigned grade and a consensus report from the ALMA review panels that summarizes the strengths and weaknesses of the proposal.

### **5.6.2 Evaluation criteria**

The primary criteria to rank all proposals are the overall scientific merit of the proposed investigations and their potential contribution to the advancement of scientific knowledge. Proposals will also be evaluated for technical feasibility and to ensure they are consistent with Observatory best practices.

Given the significant investment of ALMA resources for Large Programs, the APRC will also consider the following factors for these programs:



- **Scheduling feasibility**  
A Large Program should be designed such that the observations are likely to be completed within Cycle 8 given the antenna configuration schedule and weather constraints (see Sections 3.3 and 4.3).
- **Data products**  
A Large Program should describe the data products that will be produced to achieve their science goals. The program teams will be expected to deliver these data products to the ARCs so that they can be made available to the community at large.
- **Management plan**  
A Large Program must present a separate management plan that describes a schedule of work, a description of the roles of the proposal team, and a plan to disseminate the results. In addition, since Large Programs will acquire a significant amount of data, the plan must describe the computing resources available to the team to reduce and analyze the ALMA data in a timely fashion. The management plan must be sent by email to [pht@alma.cl](mailto:pht@alma.cl) by the April 15 deadline. See Sections 5.2 and 5.3 for additional information on Large Programs.

### 5.6.3 Proposal selection

The JAO will take the recommendations of the APRC and form an observing queue based primarily on the scientific ranking from the APRC<sup>6</sup>, also taking into account the scheduling constraints dictated by the configuration schedule and weather, the share of observing time for each region, and the time constraints on Large Programs and VLBI.

Up to 33% of the nominal time specified in Section 4.1 will be assigned to Grade A proposals and 67% to Grade B proposals. Grade C will be assigned to proposals for filler time to ensure that an adequate number of projects are available for all configurations and LST ranges in case the actual observing efficiency or weather conditions differ from expectations.

The shares of the observing time among the regions are:

- 33.75% for the European Organisation for Astronomical Research in the Southern Hemisphere (ESO).
- 33.75% for the National Science Foundation of the United States (NSF).
- 22.5% for the National Institutes of Natural Sciences of Japan (NINS).
- 10% for the Chilean community, which is administrated jointly by the Comisión Nacional de Investigación Científica y Tecnológica (CONICYT) and the Universidad de Chile.

All regions contribute toward “Open Skies” to enable all eligible Principal Investigators to apply for ALMA time.

## 5.7 Proposal confidentiality

For proposals assigned Grade A or B, the project code, the proposal title and abstract, the name and region of the PI, and the names of co-Is (and Co-PIs, in the case of Large Programs or VLBI Proposals) will be made public soon after PIs are informed of the outcome of the proposal review

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<sup>6</sup> Both ALMA and the GMVA VLBI network review and rank the 3mm VLBI Proposals independently, and both must accept a given proposal for the observations to be scheduled.



process. For proposals assigned Grade C, the corresponding information will be made public as soon as its first data are archived.

Proposal metadata (for example the source positions, observation frequencies, and integration times) for Grade A will become public soon after the proposal review process is completed. For Grade B and C proposals, metadata will be made public as soon as the first data are archived. The metadata for unaccepted proposals or unobserved Grade B or C proposals will remain confidential.

The scientific and technical justifications of all submitted proposals remain confidential, except for proposals for 1 mm VLBI proposals, which will be sent for technical review by the EHTC VLBI network.

## 6 Post-proposal activities

### 6.1 Observations preparation and submission: Phase 2

Once a project has been approved for scheduling, the project passes into Phase 2. PIs of approved projects are responsible for checking and approving the Phase 2 material (see [ALMA Users' Policies](#) for further details). Each approved project will be assigned an ALMA Contact Scientist (CS) at the associated ARC or ARC node and a project Helpdesk ticket will be opened on the behalf of the PI for communication with the CS and others. Necessary minor changes to the project may be implemented during Phase 2 as long as they do not impact the science scope or increase the total execution time. Any significant change may only be made after the approval of a PI-initiated change request through the Helpdesk (Section 6.2). The CS can assist the PI with any questions during Phase 2 review.

Once a PI has reviewed and approved the Phase 2 material, ALMA staff will make sure the Phase 2 SBs will run at the telescope and, in case of problems, will contact the CS and the PI. If no problems are found, the project is approved and submitted to the ALMA observing queue to await execution at the telescope. PIs may track the status of their SBs through the Snooping Project Interface ([SnooPI](#)), accessible from the ALMA Science Portal. PIs who do not submit the Phase 2 material before the due date (see Table 1) will have their projects downgraded in observing priority (from Grade A to B or from B to C). Grade C projects that are downgraded will not be observed.

For approved Solar observations, the ALMA Observatory will coordinate with the PI to get an updated target ephemeris at least 24 hours in advance of the proposed observation. PIs of observations with ephemeris targets other than the Sun are responsible for providing a valid target ephemeris file during the Phase 2 process and any updates during the Cycle if necessary.

### 6.2 Changes to submitted programs

Changes to a submitted proposal will not be permitted prior to the completion of the review process. Therefore, PIs should carefully check source coordinates, frequency and angular resolution settings, and calibration needs before submitting their proposal. PIs are encouraged to use the Helpdesk if they need support.

PIs of proposals assigned a grade of A, B, or C may request changes to their projects subject to the ALMA Change Request policies described in the [Users' Policies](#). Minor changes can usually be made during the Phase 2 process by the PI (see [Phase 2 QuickStart Guide](#)).

Major changes are allowed only if additional information that may seriously affect the scientific case of the project has become available since the time of submission, when there is a demonstrable mistake, or when there is the potential for interesting scientific optimization.

Change requests are made through the ALMA Helpdesk. The request must include a clear description of the proposed change along with a clear, substantive justification for the change. Major change requests are treated case-by-case and evaluated taking into account the increase in science scope, change of observing time, changes in the observing setups, and other factors. Change requests leading to duplications against ALMA proposals in the observing queue or archival observations will not be approved.

### **6.3 Data processing and data delivery**

ALMA staff, assisted by the data reduction pipeline, will conduct quality assurance on ALMA data and will provide processed data products through the respective ARC archives. Quality Assurance Level 2 (QA2) is performed on the data that result from all executions of an SB. In particular, it is checked that data are calibrated to the desired accuracy and contain no significant calibration or imaging artefacts (see [ALMA QA2 Data Products](#) for more details). Data that meet the PI-specified goals within cycle-specific tolerances (see Chapter 11 of the [Technical Handbook](#)) are made available to the PI. Once the products have been identified as suitable for delivery, the PI is notified that the data are available for download through the ALMA Archive. PIs are requested to check the delivered data as soon as practical. For a more complete description of the Quality Assurance process, see Section 6.3 of the ALMA [Users' Policies](#) and Chapter 11 of the [Technical Handbook](#).

If the delivered data have problems other than those caused by a mistake of the PI, PIs must submit a QA3 request to the Helpdesk as soon as possible, since this will have implications for the re-observation of problematic data and its proprietary period. By default, data obtained as part of an ALMA science program are subject to a proprietary period of 12 months (except DDT programs, which have a 6-month proprietary period), starting for each data package when the ARC sends the notification to the PI that the data are available (see Section 8.4 of the [ALMA Users' Policies](#)).

At any time, a PI can request access to raw data for any execution that has passed quality assurance 0 (QA0). This request comes at the expense of the start of the proprietary period. Once the raw data are staged for PI access, the proprietary time starts for that SB. See Section 8.4 of the [ALMA Users' Policies](#) for more details on requesting raw data or contact the ARC for support.

### **6.4 Opportunities for public promotion of ALMA**

If the PI believes their results are newsworthy or of interest to a broader community, the PI should contact the ALMA Education and Public Outreach (EPO) team to develop materials for presentation to the media and the public (e.g. press releases), including support in the preparation of visuals if relevant. EPO may ask for cooperation on the scientific content and for the PI to be available for possible interviews. The e-mail address for the ALMA EPO team is [alma-iepot@alma.cl](mailto:alma-iepot@alma.cl).

## Appendix A ALMA Cycle 8 Capabilities

This appendix describes the characteristics and capabilities of the ALMA Observatory that are offered for the Cycle 8 observing season. All submitted proposals must be compliant with these capabilities or they will be judged as unfeasible. Where possible, the ALMA Observing Tool has validation checks to warn or prevent entering unallowed values.

### A.1 Number of antennas

At least forty-three 12-m antennas in the main array (hereafter the 12-m Array) will be offered. The ACA will have available at least ten 7-m antennas (hereafter the 7-m Array) for short baselines and three 12-m antennas (hereafter the Total Power Array or TP Array) for making single-dish maps. The ACA will be offered both to complement observations with the 12-m Array and as a stand-alone capability. The stand-alone ACA is offered either with the 7-m Array alone or with the 7-m Array and TP Array combined. The OT currently does not permit users to request only the TP Array. However, if a user has existing 7-m Array data through their own program or through archival data, but now realize that TP Array data are needed to obtain short-spacings, they can submit a proposal requesting both the 7-m Array and TP Array. The proposal should indicate that only the TP Array data are needed and that the 7-m Array data should be descope if the proposal is accepted. This option is available only if the 7-m Array data have already been obtained. Proposals requesting stand-alone ACA time are subject to certain restrictions, including no full polarization observations, no bandwidth switching, no Solar observations, no user-specified calibration, and no Astrometric observations. The use of the TP Array is limited to spectral-line observations (not continuum) in Bands 3 to 8.

The number of antennas available may sometimes be fewer than the numbers given above due to unforeseen problems with the equipment, or during array reconfigurations. During these times, ALMA staff aim to schedule observations that will not be seriously affected by having a slightly smaller number of antennas and may increase the integration times or  $uv$ -coverage to compensate whenever this is practical.

### A.2 Array configurations

As detailed in Section 4.5, a Science Goal is defined in terms of a desired range of angular resolutions (ARs) and the Largest Angular Structure (LAS) to be imaged. ALMA will meet these requirements by taking observations in one or more array configurations, which are characterized in terms of their AR and Maximum Recoverable Scale (MRS, the largest smooth angular structure to which a given array is sensitive – see Chapter 7 of the [Technical Handbook](#) for details). The properties of these configurations, and the allowed combinations, therefore define the imaging capabilities of ALMA.

The antennas in the 12-m Array will be staged into configurations that transition from the most compact (with maximum baselines of ~160 m) up to the most extended configuration (maximum baselines of 8.5 km in Cycle 8 and 16.2 km in Cycle 9). Ten 12-m Array configurations have been defined to represent the possible distribution of antennas over this range of maximum baselines. These are denoted as C-x, with x=1 for the most compact configuration and x=10 for the most extended. One 7-m Array configuration has been defined to represent the possible distribution of the ten 7-m antennas. The imaging capabilities of these configurations are given in Table A-1.

**Table A-1: Angular Resolutions (AR) and Maximum Recoverable Scales (MRS) for the Cycle 8 configurations**

Config	Lmax		Band 3	Band 4	Band 5	Band 6	Band 7	Band 8	Band 9	Band 10
	Lmin		100 GHz	150 GHz	185 GHz	230 GHz	345 GHz	460 GHz	650 GHz	870 GHz
7-m	45 m	AR	12.5"	8.4"	6.8"	5.5"	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"
C-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"
C-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"
C-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"
C-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"
C-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"
C-6	2.5 km	AR	0.31"	0.20"	0.17"	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"
C-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"
C-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"			

Notes for Table A-1:

1. See Chapter 7 of the [Technical Handbook](#) for relevant equations and detailed considerations.
2. Values evaluated for source at zenith. For sources transiting at lower elevations, the North-South angular measures will increase proportional to  $1/\sin(\text{ELEVATION})$ .
3. Lmax and Lmin are the maximum and minimum baseline lengths in the array.
4. All angular measures scale inversely with observed sky frequency.
5. Configurations C-9 and C-10, not shown here, will next be available in Cycle 9
6. Angular resolutions assume Briggs weighting with  $robust = 0.5$

### A.3 Total Power Array

The TP Array is used to recover extended emission when mapping angular scales up to the size of the requested map areas. TP Array observations are included only if the LAS cannot be achieved with the 7-m Array, and the TP Array can only be used for spectral-line observations (not continuum) in Bands 3 to 8. No Band 9 or Band 10 TP Array observations are offered for this cycle. Thus angular scales greater than the 7-m Array MRS listed in Table A-1 cannot be recovered for any observations in Bands 9 and 10, or for continuum observations in any band.

## A.4 Allowed array combinations and time multipliers

Except for simultaneous observations of the 12-m Array with the ACA, only certain array combinations are allowed to meet the specifications of a given Science Goal (SG). A SG can use no more than two 12-m Array configurations, and 7-m Array observations are only allowed in conjunction with 12-m Array observations if one of the three most compact 12-m Array configurations is required. TP Array observations are allowed only if 7-m Array observations are also obtained (and subject to the restrictions in the preceding section). The allowed combinations are indicated in Table A-2 (with empty cells indicating combinations that are not allowed), and built into the OT validation.

For the resulting data to be combined based on the sensitivity and weighting between the allowed 12-m, 7-m and TP Array configurations, the different arrays must be observed in the correct proportion, depending on the number of overlapping baselines (see Chapter 7 of the [Technical Handbook](#) for details). These are expressed in terms of multiplicative factors with respect to the time required in the most extended configuration (which in turn is set by the user-requested sensitivity and resolution). The time multipliers adopted are given in Table A-2, and are reported in the OT.

**Table A-2: Allowed Array Combinations and Time Multipliers**

Most Extended configuration	Allowed Compact configuration pairings	Extended 12-m Array Multiplier	Multiplier if compact 12-m Array needed	Multiplier if 7-m Array needed	Multiplier if TP Array needed and allowed
7-m Array	TP			1	1.7
C-1	7-m Array & TP	1		7.0	11.9
C-2	7-m Array & TP	1		4.7	7.9
C-3	7-m Array & TP	1		2.4	4.1
C-4	C-1 & 7-m Array & TP	1	0.34	2.4	4.0
C-5	C-2 & 7-m Array & TP	1	0.26	1.2	2.1
C-6	C-3 & 7-m Array & TP	1	0.25	0.6	1.0
C-7	C-4	1	0.23		
C-8	C-5	1	0.22		

Notes for Table A-2:

1. See Chapter 7 of the [Technical Handbook](#) for relevant equations and detailed considerations.
2. Whether a more compact array configuration is needed is based on the user specified LAS compared to the MRS values corresponding to the more extended configuration, as listed in Table A-1. If the LAS is greater than the MRS of the extended configuration, a more compact configuration is needed. Conversely, if a more compact array configuration is not allowed (e.g. for 12-m Array configurations more extended than C-6), the LAS is not obtainable and will result in a validation error in the OT.
3. C-9 and C-10 are not available in Cycle 8.

If more than one configuration is needed to satisfy the AR and LAS constraints of a given SG, during Phase 2 (Section 6.1), separate Scheduling Blocks (SBs) will be prepared for each required configuration. These will be observed independently, and the data from the different SBs will be calibrated and imaged separately.

## A.5 Receivers

Bands 3, 4, 5, 6, 7, 8, 9 and 10 are available on all antennas. However, observations with Bands 8, 9 and 10 will only be offered for configurations with baselines up to ~3.6 km, and Bands 3, 4, 5, 6 and 7 up to ~8.5 km for Cycle 8 (see Section A.2). In addition, observations with Bands 9 and 10 will not be offered in the TP Array (see below).

There are two types of receivers: dual-sideband (2SB), where the upper and lower sidebands are separated in the receiver and then processed separately, and double-sideband (DSB), where the sidebands are super-imposed coming out of the receiver but are separated in later processing. All bands receive dual linear polarizations (X and Y).

Table A-3 summarizes the properties of the receiver bands offered in Cycle 8. Details can be found in Chapter 4 of the [Technical Handbook](#).

**Table A-3: Properties of ALMA Cycle 8 Receiver Bands**

Band	Frequency range <sup>1</sup> (GHz)	Wavelength range (mm)	IF range (GHz)	Type
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

Notes for Table A-3:

1. These are the nominal frequency ranges for continuum observations. Observations of spectral lines that are within about 0.2 GHz of a band edge are not possible (at present) in Frequency Division Mode (FDM, see Section A.6.1), because of the responses of the spectral edge filters implemented in the correlator. IF is the intermediate frequency.

The capability to rapidly switch between receiver bands within the same SG (except for the purposes of data calibration) is not offered.

Water Vapor Radiometer (WVR) measurements to correct for fluctuations in atmospheric water vapor are available for all 12-m antennas. No WVRs are installed in the ACA 7-m antennas and no WVR corrections will be applied to 7-m Array observations.



## Bands 9 and 10 considerations

For Bands 9 and 10 observations, PIs should take the following considerations into account. Since the sidebands can be separated reliably only in interferometric observations, single-dish Bands 9 and 10 observations with the TP Array will not be offered in Cycle 8. At Bands 9 and 10, a special correlator mode (90-degree Walsh Switching) is available. For every spectral window defined by the user, enabling this feature will produce another spectral window in the other sideband, mirrored around the value of Local Oscillator 1 (LO1). This doubles the bandwidth of continuum setups in these bands to 15 GHz, thus producing a  $\sqrt{2}$  improvement in sensitivity or reducing the time required to achieve a particular sensitivity by a factor of 2. In addition, the greater bandwidth coverage will allow more spectral lines to be observed simultaneously, although aligning the spectral windows such that they cover additional transitions is difficult and thus this mode is currently restricted to the widest-bandwidth spectral windows. In Cycle 8, 90-degree Walsh Switching will be activated by default for continuum and spectral-line setups, although for the latter it will be possible (but not recommended) to deactivate it.

Owing to the complexity of the atmospheric absorption in Bands 9 and 10, calibration will be more problematic (this also applies to Band 8 and the high-frequency end of Band 7). Bands 9 and 10 ACA 7-m Array observations will be more difficult to calibrate than the corresponding 12-m Array observations, since the rapid atmospheric phase correction cannot be applied, and the smaller collecting area will limit the network of usable calibrators; in particular bright calibrators will be sparse at these high frequencies. When possible, the JAO will include 12-meter dishes from the TP Array in the 7-m Array observation to support calibration; no special action or request is required by the PI. All these factors, together with the limited  $uv$ -coverage, will affect imaging at Bands 9 and 10 and will limit the achievable dynamic range with the ACA 7-m Array. Imaging dynamic ranges up to 50 are typical for these bands (see Section A.9.1 for more details).

No mosaics are offered for Band 10 observations.

## A.6 Spectral capabilities

### A.6.1 Spectral windows, bandwidths and resolutions

The ALMA Intermediate Frequency (IF) system provides up to four basebands (per parallel polarization) that can be independently placed within the two receiver sidebands. For 2SB receivers (Bands 3 to 8 – see Table A-3), the number of basebands that can be placed within a sideband is 0, 1, 2, 3, or 4. The placement of the basebands is restricted for these receivers in that it is not possible to place three basebands in one sideband and the fourth baseband in the other (see Chapter 6 of the [Technical Handbook](#) for details). This restriction does not apply for DSB receivers (Bands 9 and 10).

The 12-m Array uses the 64-input Correlator, while the 7-m and TP arrays use the ACA Correlator. Both correlators offer the same spectral setups. The 64-input Correlator operates in two main modes: **Time Division Mode (TDM)** and **Frequency Division Mode (FDM)**. TDM provides modest spectral resolution and produces a relatively small data set. It is used for continuum observations or for spectral-line observations that do not require high spectral resolution. FDM provides high spectral resolution and produces much larger data sets. A total of six correlator setups with different bandwidths and spectral resolutions are available (see Table A-4).

**Table A-4: Properties of ALMA Cycle 8 Correlator Modes, dual-polarization operation <sup>1,2</sup>**

<b>Bandwidth (MHz)</b>	<b>Channel spacing<sup>(3)</sup> (MHz)</b>	<b>Spectral resolution (MHz)</b>	<b>Number of channels</b>	<b>Correlator mode<sup>(4)</sup></b>
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

Notes for Table A-4:

1. These are the values for each spectral window and for each polarization, using the full correlator resources and no on-line spectral binning.
2. Single-polarization modes are also available, giving twice the number of channels per spw, and half the channel spacing of the above table.
3. The “Channel Spacing” is the separation between data points in the output spectrum. The spectral resolution – i.e., the FWHM of the spectral response function – is larger than this by a factor that depends on the “window function” that is applied to the data to control the ringing in the spectrum. For the default function – the “Hanning” window – this factor is 2. See Chapter 5 of the [Technical Handbook](#) for details.
4. Only for the 64-input Correlator

For each baseband, the correlator resources can be divided across a set of “spectral windows” (spw) that can be used simultaneously and positioned independently. Up to four spectral windows per baseband are allowed. The correlator can be set to provide between 120 and 3840 channels within each spw, and the fraction of correlator resources that are assigned to each spw sets the number of channels and the bandwidth available within it. The sum of the fractional correlator resources spread across all spectral windows must be less than or equal to one (120 or 3840 channels in total).

The default correlator setup for FDM modes averages every two channels. This has the advantage of halving the data rate to produce more manageable data cubes, while reducing the spectral resolution by only 15%. However, an additional consideration when selecting the spectral averaging is that data taken over different time periods (e.g., different configurations or multiple observations within the same configuration) are not guaranteed to be precisely aligned in frequency. Therefore, the spectra will need to be interpolated onto a common frequency grid in CASA. If the expected line width is poorly sampled at the resolution of the spectrometer, no channel averaging (i.e. a spectral averaging value of 1) is recommended in order to improve the accuracy of the interpolation (see Chapter 5 of the Technical Handbook for more information). Each correlator has a maximum data rate (70 MB/s for the 64-input Correlator) and the OT will issue a validation error if a given SG exceeds that data rate. For any spectral setup requiring an average data rate of more than 40 MB/s PIs will be contacted during Phase 2 to discuss the possibility to reduce the data rate.

Different correlator modes can be specified for each baseband, but all spws within a given baseband must use the same correlator mode. For example, a high-resolution FDM mode can be used for spectral-line observations in one baseband (with up to four independently placed FDM spectral windows), while the other three basebands can be used for continuum observations using the low-



resolution TDM mode. And while each spw within a baseband must use the same correlator mode, they can each be assigned a different fraction of the correlator resources and each use a different spectral averaging factor, providing a broad range of simultaneously observed spectral resolutions and bandwidths. Spectral windows can overlap in frequency, although the total continuum bandwidth for calculating the sensitivity is set by the total non-overlapped bandwidth.

Users are encouraged to enter the redshift or velocity of the target in the OT when feasible, as opposed to calculating the sky frequency themselves. Entering the expected redshift or velocity will allow automated line searches and identifications in the archive or with external tools.

### A.6.2 Science Goals with more than one tuning

Users can include up to five tunings per group of sources within 10 degrees in a single SG, except for SGs that request long-baseline configurations, for which the grouping of sources into clusters will consider only sources within 1 degree. This enables spectral scans or observations of targets with different radial velocities within the same SB.

The current calibration scheme for ALMA is to make each SB self-contained in terms of calibration. Therefore, multi-tuning SGs result in bandpass, amplitude, and gain calibrators being observed for each tuning in the SB. For SBs that can be completed in a single execution, this is quite efficient. However, for SBs that require multiple executions, the available time for science targets in each execution is reduced, and the resulting SBs can be quite inefficient. Separating each tuning into its own SG can lead to more efficient SBs and lower overall time estimates.

### Spectral scan mode

A special case of the multiple tuning SG is the Spectral Scan mode. This is useful for proposers who wish to carry out spectral surveys or redshift searches. The OT will automatically set up a set of contiguous spectral windows to cover a specified frequency range. The following restrictions apply:

- Angular resolution and LAS are computed for the Representative Frequency of each SG.
- No more than five frequency tunings per target are used, all in the same band.
- Only one pointing per target is used (no mosaics or offsets allowed).
- Full polarization cannot be selected.

## A.7 Polarization

In addition to the dual-polarization (XX, YY) and single-polarization (XX) modes, observations to measure the full intrinsic polarization (XX, XY, YX and YY) of sources are also offered for 12-m Array TDM and FDM observations in Bands 3, 4, 5, 6 and 7. The full-polarization products can be used to measure both the linear and circular polarization emission.

When a **Dual Polarization** setup is used, separate spectra are obtained for the cross-correlated parallel hands (XX and YY). These will give two independent estimates of the source spectrum that can be combined to improve sensitivity.

In **Single Polarization** mode, only a single input polarization (XX) is recorded. For a given resolution, this provides  $O(\sqrt{2})$  worse sensitivity than the Dual Polarization case, but one can use either a factor two more bandwidth for the same spectral resolution (unless the maximum bandwidth was already being used) or a factor of two better spectral resolution for the same bandwidth.

Mosaics are possible for linear polarization, continuum maps. Otherwise, targets must have a user-specified largest angular structure that is less than one-third and one-tenth of the 12-m Array primary

beam at the frequency of the planned observations for linear polarization and circular polarization observations, respectively. The expected minimum detectable degree of linear polarization, defined as three times the systematic calibration uncertainty, is 0.1% of the peak Stokes I (i.e. total unpolarized) flux for on-axis sources for both TDM and FDM observations within 1/3 of the primary beam. This limit does not depend on the source size (i.e. compact or extended). The minimum detectable degree of circular polarization is 1.8% of the peak Stokes I flux for both TDM and FDM observations within 1/10 of the primary beam. **Note that the systematic calibration uncertainty can degrade by a factor of ~2 depending on the quality of the polarization calibrator and observation conditions** (see Chapter 8 of the [Technical Handbook](#) for more details). The frequency settings for continuum polarization measurements can be specified by the user, but the OT supplies default setups as detailed in Table A-5. For FDM mode, polarization observations at any frequency setting within Bands 3, 4, 5, 6 and 7 are allowed, but the spectral setup has to be the same for the polarization calibrator and the science target.

For linear polarization mosaics, the 150-point restriction per SG is maintained. The mosaic pattern can be arbitrary, but ALMA recommends a hexagonal grid when possible. While Nyquist sampling (half a beam overlap) is sufficient, a sampling of less than Nyquist (i.e., a more “loosely packed” mosaic) must be justified. A proposal requesting a mosaic sampling rate of less than Nyquist may be rejected on technical grounds. The average error estimates for linear polarization mosaics are 1 degree in polarization position angle, and 0.1% in polarization fraction in the regions of the mosaic that correspond to the inner 1/3 FWHM of a given pointing. Near the FWHM of a given pointing, the estimated upper limits are 4 degrees and 0.5% (see Chapter 8 of the [Technical Handbook](#) for details).

**Table A-5: Default frequencies for Continuum Polarization Observations<sup>1</sup>**

Band	spw1 (GHz)	spw2 (GHz)	LO1 (GHz)	spw3 (GHz)	spw4 (GHz)
3	90.5	92.5	97.5	102.5	104.5
4	138.0	140.0	145.0	150.0	152.0
5	196.0	198.0	203.0	208.0	210.0
6	224.0	226.0	233.0	240.0	242.0
7	336.5	338.5	343.5	348.5	350.5

Notes for Table A-5:

1. Fixed central frequencies for four TDM spectral windows, each of width 1.875 GHz, and the corresponding LO1 setting. Frequencies were chosen to optimize spectral performance, and they are centered in known low noise and low instrumental polarization tunings of the receivers.

## A.8 Source restrictions

Source positions are designated by: 1) fixed RA and DEC; 2) RA and DEC at epoch 2000.0 with a linear proper motion; or 3) An ephemeris that is specified that gives the RA and DEC as a function of time. All positions should be in ICRS (J2000).

At low elevations, it is possible for foreground array elements to block or “shadow” the signal received by background antennas, compromising the sensitivity and imaging characteristics of an observation (see Section 7.3 of the [Technical Handbook](#) for details). Therefore, observations of

extremely high and low declination targets should be avoided, particularly in compact configurations. For the 12-m Array, this shadowing becomes significant ( $> 5\%$ ) in the most compact configuration for sources with declination lower than  $-65^\circ$  or higher than  $+20^\circ$ . For the ACA, shadowing becomes significant for sources with declination lower than  $-70^\circ$  or higher than  $+25^\circ$ . The adopted upper declination limit for ALMA is  $\sim +47^\circ$  (corresponding to a maximum elevation of 20 degrees at the ALMA site) and the OT gives a warning for objects transiting between 20- and 30-degrees elevation (corresponding to  $\sim +37$ - $47^\circ$  declination). The ALMA Sensitivity Calculator takes shadowing into account when determining time estimates.

### **A.8.1 Source Science Goal restrictions**

A single SG is constrained to include one set of observational parameters that apply to all sources included in that goal. This includes a single angular resolution, sensitivity, LAS, and receiver band. There is no restriction on the number of SGs per proposal.

For sources distributed widely in the sky the SG will be split by the OT into different “clusters”, each grouping all sources within 10 degrees (1 degree for SGs requiring long-baseline configurations). For each grouping within the SG, the total number of pointings must be less than or equal to 150. Pointings with the ACA, if used in concert with 12-m Array observations, do not count against this 150-pointing limit.

The sources in a SG are further subjected to the following restrictions:

- All the sources in a SG must be defined by the same field setup – either all as rectangular fields, or all as individual positions.
- Sources must use the same spectral setup (relative placement and properties of spectral windows).
- For a given group of sources with positions within 10 degrees (1 degree in SGs requesting long-baseline configurations) in the sky the total number of separate tunings cannot exceed 5.

### **A.8.2 Rectangular Field**

A rectangular field (also referred to as a mosaic) is specified by a field center, the length, width and orientation of the field, and a single spacing between the pointing centers. Observations are conducted using the “mosaic” observing mode. This repeatedly cycles through all the pointings in the mosaic so that the imaging characteristics across the map are similar.

The OT will set up a uniform mosaic pattern based on a user-specified pointing separation, and will calculate the time to reach the required sensitivity considering any overlap. Non-Nyquist spatial samplings are allowed but must be justified in the Technical Justification.

If ACA observations are requested as part of a mosaic, then a corresponding 7-m Array mosaic will also be observed. If these include TP observations, the mosaic area(s) will be covered by the TP Array using on-the-fly mapping.

Multiple sources may be included inside a SG, each of which can have a differently sized rectangular field. The collection of mosaics is subject to the source SG restrictions given above.

### **A.8.3 Individual Pointings**

PIs may choose to define a “custom mosaic” by specifying a set of individual, overlapping pointing positions. Gaps in pointings are not allowed. Custom mosaics are subject to all the source SG restrictions given above.

The interferometric data will be combined in post-processing to produce a single image. If ACA observations are requested as part of a 12-m Array SG, then the corresponding 7-m Array observations will be obtained using a Nyquist-sampled mosaic pattern that covers the 12-m Array pointings. If these include TP observations, the mosaic area(s) will be covered by the TP Array using on-the-fly mapping.

Pointings that do not overlap within a given SG must be included as different field sources within the SG.

## **A.9 Calibration**

The ALMA Observatory has adopted a set of strategies to achieve good calibration of the data (see Chapter 10 of the [Technical Handbook](#)). Requests for changes in these strategies will only be granted in exceptional circumstances and must be fully justified. The default option is automatic calibrator selection by the system at observing time, but some flexibility exists in choosing the actual calibrator sources in the OT. If users opt for selecting their own calibrators, justification will be needed. This may result in decreased observing efficiency and/or calibration accuracy.

### **A.9.1 Imaging dynamic range**

The standard ALMA data reduction with nominal phase stability should be sufficient to produce images with dynamic ranges (peak continuum flux to map rms) up to  $\sim 100$  for the ACA and for compact 12-m Array configurations. For configurations more extended than 2 km and at frequency Bands 8, 9 and 10 the imaging dynamic range may be closer to 50.

Images of bright sources may be dynamic-range-limited rather than sensitivity-limited. Their image quality may be improved by using self-calibration. For more information please see the Knowledgebase article [“What is meant by imaging dynamic range?”](#) and Section 10.5.1 of the [Technical Handbook](#).

### **A.9.2 Absolute flux accuracy**

Absolute amplitude calibration will be based on observations of objects of known flux density, including eight Solar System objects and a set of 40 quasars whose flux densities are monitored every 15 days. It is expected that these calibrators provide an absolute flux accuracy better than 5% for Bands 3, 4 and 5; 10% for Bands 6, 7 and 8; and 20% for Bands 9 and 10. The decrease in accuracy at the higher frequencies is caused by variable atmospheric opacity, pointing errors, and coherence loss due to phase fluctuations.

### **A.9.3 Bandpass accuracy**

The amplitude and phase shape of the spectral response for each antenna in the array is measured by observing a bright source, usually a quasar, for the time needed to reach the desired spectral sensitivity for the relevant spectral resolution. The accuracy of this shape particularly affects projects that intend to observe spectral features that cover a significant fraction of a spw, and/or study faint spectral features in the presence of strong continuum. A spectral dynamic range (i.e. the desired signal-to-noise ratio per spectral resolution element) of 1000 has been demonstrated for Bands 3, 4, and 6, and a spectral dynamic range of 400, 250, 170, and 150 has been demonstrated for Bands 7, 8, 9, and 10, respectively. For Band 5, a spectral dynamic range limit similar to Band 6 may be assumed, except for setups at 183 GHz. The achieved spectral dynamic range will depend on the brightness of the bandpass calibrator, the observing frequency, and spectral resolution (see

Section 10.4.6 of the [Technical Handbook](#) for details). Proposals that request higher accuracies need to provide a feasible calibration strategy in the Technical Justification or the proposal may be rejected on technical grounds.

#### **A.9.4 Total Power calibration**

The intensity calibration for single-dish observations with the TP Array is made by using the Amplitude Calibration Device (ACD), which results in an intensity scale in terms of the corrected Rayleigh-Jeans antenna temperature  $T_A^*$  (K). To combine the TP data with the interferometric data, the intensity scale is converted from K to Jy. The conversion factor is a function of the observed frequency, half-power beam width, and aperture efficiency of the TP Array antennas. The latter two are derived from regular single-dish calibration observations. The overall accuracy for the total power calibration is about 5% at Bands 3, 4, 5, 6 and 7, increasing to 15% at Band 8.

#### **A.9.5 Astrometry**

The absolute positional registration of an ALMA image on the sky depends on the angular resolution and the quality of the phase calibration. With a stable atmosphere, calibrator-target separation less than a few degrees, and signal-to-noise ratio of the target image of at least 20, the expected astrometric accuracy (standard deviation of the position determination) is 5% of the synthesized beam for angular resolutions  $>150$  mas. At higher angular resolutions,  $\sim 50$  mas, the astrometric accuracy decreases to  $\sim 10\%$  of the synthesized beam (see Chapter 10 of the [Technical Handbook](#) for details).

When astrometric measurements are a main scientific goal, recommendations for Cycle 8 (that should be justified in the Technical Justification) are:

- Choose a phase calibrator that has an estimated VLBI position error  $<2$  mas and is as close to the target as possible.
- Include a second phase calibrator (“check source”) with a known, accurate position, so its measured position offset, after normal calibration, is an indication of the astrometric accuracy of the science target.
- Choose an integration time on the science target that will give a  $\text{SNR} > 20$  so that the position accuracy will not be signal-to-noise limited.
- If observing over multiple epochs, use the same phase calibrator for all epochs.
- Choose the observing frequency and configuration to maximize the astrometric accuracy based on the angular size and spectral properties of the target, and on the observation time span for multiple epochs.

Further details and guidelines are given in Chapter 10 of the [Technical Handbook](#). Proposers of astrometric experiments are also encouraged to discuss the observations with their local ARC.

#### **A.10 Time-constrained observations**

Monitoring observations and time-constrained projects are offered subject to the following restrictions:

- Observations to be performed with two 12-m Array configurations to satisfy the PI requests of AR and LAS within a SG are not allowed to have time constraints.

- Observations with one 12-m Array configuration and the ACA are allowed to have time constraints only if simultaneous observations with the two arrays have been requested.
- No restrictions will be imposed on the size of the time window specified by PIs for time-critical observations. The scheduling feasibility of any proposal will depend on the total number of constraints that are imposed and on whether the time window takes place during other activities on the array such as engineering or computing time. Whether such observations are technically feasible will be decided on a case-by-case basis. In particular, observations with strict timing constraints but many possible time windows may be feasible.
- Programs that require more than two hours of continuous observations to monitor a source cannot be guaranteed due to variable weather conditions and system interruptions. Proposers may request monitoring observations longer than two hours, but if the observations fail after two hours, the observations will not be repeated. Monitoring observations will be interrupted by regular calibrations.

Stand-alone ACA proposals requesting only observations on the 7-m Array are allowed to have time constraints.

## A.11 Solar observations

Proposals will be accepted for ALMA interferometric and Total Power observations of the Sun with the following capabilities and restrictions:

- Solar observations will be conducted only during the periods when the 12-m Array is in one of the allowed configurations for the requested band, namely C-1 to C-4 for Band 3, C-1 to C-3 for Band 5, C-1 to C-3 for Band 6, and C-1 to C-2 for Band 7 (see configuration schedule in Section 4.3.3).
- The interferometric component of Solar observations will be conducted using a special combined array comprising both 12-m and 7-m antennas (to ensure sufficient short-spacing information is observed), and will be processed with the 64-input Correlator (Section 5.1 of the [Technical Handbook](#)). Observations with only the 12-m Array or only the 7-m Array are not offered.
- To minimize shadowing of 7-m antennas, observations will be carried out between 10:00 and 17:00 CLT (13:00 UT and 20:00 UT).
- PIs may designate a desired range of angular resolutions. This is restricted to the range provided by the 12-m configurations allowed for Bands 3, 5, 6, and 7, as described above.
- The Total Power component of Solar observations consists of fast-scanning mapping observations of the full Sun to recover the largest angular scales for interferometric observations. Proposals requesting only Total Power single-dish observations will not be accepted. The Total Power observations will be taken contemporaneously with the interferometric observation. These observations will not be executed when the Sun is at elevations above 70° because the required fast-scan azimuth slew speeds are too high. The time cadence of full-sun images obtained from Total Power observations is about 10, 13, 15 and 25 minutes for Bands 3, 5, 6, and 7, respectively.
- Proposers will specify their Solar target by providing a target position in Heliocentric coordinates. The ALMA Observatory will coordinate with successful PIs to get an updated target position at least 48 hours in advance of the proposed observation. The interaction will

be done via the Helpdesk. The [ALMA Solar Ephemeris Generator](#) tool is available for PIs to help them generate the ephemeris.

- Only proposals for continuum observations in Bands 3, 5, 6 and 7 will be accepted. For interferometric observations, these will be obtained using the low spectral resolution (TDM) mode (see Section A.6.1). The individual integration times for this mode are fixed to 1 second, and the frequencies are fixed to four 1875 MHz-wide spectral windows centered on the frequencies shown in Table A-6. The high spectral resolution (FDM) observing mode is not offered for Solar observations.
- The observing frequencies of the Total Power observations are as shown in Table A-6, but the Total Power data only include one channel per spw; a correlator will not be used for Total Power observations in Cycle 8 and so autocorrelation measurements will not be available.

**Table A-6: Observing frequencies for Cycle 8 Solar observations**

Band	spw1 (GHz)	spw2 (GHz)	LO1 (GHz)	spw3 (GHz)	spw4 (GHz)
3	93.0	95.0	100.0	105.0	107.0
5	191.0	193.0	198.0	203.0	205.0
6	230.0	232.0	239.0	246.0	248.0
7	339.6	341.6	346.6	351.6	353.6

- Simultaneous observations with Bands 3, 5, 6 and 7 are not offered: each Science Goal can only include one band.
- Observations may be performed using dual linear polarization (XX, YY) or single polarization (XX) correlations; full polarization measurements are not currently offered for Solar observations.
- Because the WVR receivers are saturated when the antennas point at the Sun, WVR corrections for on-source (Solar) data are not possible.
- Absolute calibration of single-dish brightness temperatures is currently no better than ~10% but is more realistically ~15%. While efforts are on-going to improve Solar calibration, Science Goals that require absolute temperatures more accurate than this, and in particular comparisons of absolute temperatures between Bands 3, 5, 6 and 7, will be difficult to carry out successfully.

## A.12 VLBI observations

Proposals will be accepted for ALMA VLBI (phased array) observations, with the following capabilities and restrictions:

- VLBI observations will be conducted using a “campaign mode”, whereby specific dates are reserved for the execution of VLBI programs in coordination with the other facilities in the VLBI network and so that VLBI experts are available to help with program execution. Observing windows will be identified during the periods when the 12-m Array is in one of the three most compact configurations (maximum baselines less than 500 m; see configuration schedule in Section 4.3.3). The actual campaign dates will be set after the proposal review process.



- New to Cycle 8, VLBI observations will be permitted for faint science targets, with correlated flux densities  $< 0.5$  Jy on intra-ALMA baselines out to 1 km. These observations will be done in passive phasing mode, where the user must select a bright ( $>0.5$  Jy) phase calibrator, ideally within 5 degrees of the science target. The user-defined calibrator interface is enforced for passive phasing and the default dynamic phase calibrator should be replaced with a fixed calibrator. The choice of calibrator should be justified in the Technical Justification.
- Only proposals for continuum observations in Bands 3 and 6 will be accepted. These will be obtained in full polarization using the high spectral resolution (FDM) mode (see Section A.6.1) and the 64-input Correlator. Observing frequencies are fixed to four 1875 MHz-wide spectral windows centered on the frequencies shown in Table A-7 below.

**Table A-7: Observing Frequencies for Cycle 8 VLBI Observations**

Band	spw1 (GHz)	spw2 (GHz)	LO1 (GHz)	spw3 (GHz)	spw4 (GHz)
3	86.268	88.268	93.268	98.268	100.268
6	213.1	215.1	222.1	227.1	229.1

- The proposers are required to enter a VLBI total time requested. Here, they should enter the amount of time requested for ALMA (and not the total time requested to the GMVA/EHTC networks, which may be longer). Note that this time must include overheads. For ALMA + GMVA or EHTC the total observing time (including overheads and ALMA calibrations) is a factor of four (25% duty cycle) of the expected time on source.
- A VLBI session will not exceed one week so if multi-epoch observations are requested, they must fit within one week and the total time must be the aggregate time of all observations.
- A minimum of three observing hours is required to make a clean linear to circular transformation of the data.

For 3-mm VLBI, a proposal must have been submitted to the GMVA network by their 1 February 2020 deadline (see the [GMVA website](#) that also provides a [sensitivity calculator](#)). Another sensitivity calculator is available at the [European VLBI Network site](#).

For 1-mm VLBI, the ALMA Observatory will forward the submitted proposals to the EHTC network for technical assessment. Thus, proposers do not need to send their proposal to the EHTC.

### A.13 Phased-array/pulsar observations

In previous cycles the data produced by ALMA in phased-array mode has only been used in combination with data from other VLBI telescopes. Starting with Cycle 8, the phased array can be selected in a stand-alone mode for observations using the 12-m Array operating as a single dish for pulsar science. The proposal should not be sent to any other observatories; these are ALMA-only observations.

- This mode is available as part of the VLBI proposal type and is triggered by selecting the scientific keyword 'Pulsars and neutron stars' in the scientific category 'Stellar Evolution and the Sun'. The proposal code will have the “.V” suffix.

- The capabilities are similar to those currently available for VLBI, i.e. a single source per Science Goal with a maximum-bandwidth, pseudo-single-continuum spectral setup, but only Band 3 is available. The spectral window frequencies are the same as those used for VLBI.
- Since this mode is only for pulsar observations, passive phasing is enforced by the OT as these sources are very weak at mm/sub-mm wavelengths. A fixed phase calibrator will need to be selected and justified.
- The data will be written out in PSRFITS format.
- Observations using this mode will be scheduled during the time periods assigned for VLBI.

## Appendix B Technical Justification guidelines

The Technical Justification must be entered directly into the OT for each Science Goal. Below are guidelines on issues to consider in the different sections. Sections B.5, B.6, and B.7 point to specific items that need justification for Solar, VLBI, and pulsar observations, respectively. In general, PIs should address all the parameters requested in the OT.

### B.1 Sensitivity

At the top of the sensitivity section, the OT will display the sensitivity and S/N ratio achieved for different bandwidths (bandwidth requested for sensitivity, aggregate bandwidth, a third of the line width) as appropriate for the spectral setup and the Expected Source Properties defined. While the justification for the requested sensitivity or S/N ratio should be included in the Scientific Justification (Section 5.3.2), the TJ must explain which sensitivity or S/N ratio are expected for all the parts of the spectrum that are of interest, e.g. for a spectral setup targeting a weak and a strong spectral line as well as the continuum, and the means by which the proposed technical setup will achieve those requests.

The fluxes in the Expected Source Properties must be entered **per synthesized beam**, i.e. proposers may have to correct any available flux measurements for the fact that the requested source is spatially resolved by ALMA and the flux is distributed over several synthesized beams (see Knowledgebase articles [“How can I estimate the Peak Flux Density per synthesised beam using flux measurements in Jy or K from other observatories?”](#) and [“How do I convert flux measurements given in Jy km/s or K km/s into the peak flux density required by the OT?”](#) and this [video](#) for more details on using fluxes/brightness temperatures from other facilities).

Users should be aware that the sensitivity requested may not be achievable in practice if the observations are dynamic-range limited; e.g. when the field of view contains another, very bright, source or the spectrum has very bright lines. S/N values smaller than three trigger a blue informative message and need to be fully justified; they may lead to a rejection of the proposal on technical grounds if no adequate explanation is given. For setups including spectral lines, another value to double-check is the ratio of the line width (entered in the Expected Source Properties) over the bandwidth used for sensitivity (from the Control & Performance editor), which is conveniently displayed by the OT. It is important to understand that the sensitivity requested will be achieved over a frequency bin corresponding to this bandwidth, **not** necessarily over every spectral resolution element. For spectral-line measurements this value should normally be larger than three (or even higher if you want to measure the shape of the line profile). An informative message will appear if this is not the case, and PIs should address this issue in the justification text (e.g. if the sensitivity requirement is driven by the continuum it may be acceptable to have a very low ratio).

The final parameter to be checked for observations measuring both line and continuum emission is the spectral dynamic range, defined as the continuum peak flux divided by the line rms. Limits on the spectral dynamic ranges offered in Cycle 8 for the different ALMA bands are given in Appendix A (Section A.9.3); an informative message will appear in the OT if these are exceeded and the proposal may be rejected on technical grounds. The spectral dynamic range is important especially when trying to detect a weak line on top of a strong continuum, and high spectral dynamic ranges may require a better bandpass accuracy than possible with a standard calibration. If a high spectral dynamic range is required, extra bandpass calibrations may need to be obtained selecting “User-defined calibration”.

## B.2 Imaging

When planning ALMA observations, in addition to the sensitivity goals, the complexity of the emission in the science target field should also be considered. An interferometer's ability to reconstruct complex emission is directly related to the  $uv$ -coverage of the data. This section is used to justify the requested AR and LAS, which for convenience are reported back by the OT. The AR and LAS needed to image complex emission should be carefully justified (if necessary, including simulations), especially if multiple antenna configurations are required. The number of required antenna configurations is listed in the observing time estimate of the project time summary in the OT.

The "snapshot" (i.e. short observation)  $uv$ -coverage is excellent for the compact ALMA configurations C-1 to C-3 and still reasonably good for C-4 to C-6, but for the longer baseline configurations, C-7 to C-10, it is quite sparse even with 50 antennas (see Section 7.5 of the [Technical Handbook](#)). Therefore, more observing time must be spent to "fill in" the missing  $uv$ -coverage, as much as possible. Thus, high fidelity imaging of complex and/or high dynamic range emission may require a longer observing time than implied by sensitivity requirements alone, and this is especially true for the long-baseline configurations. Consecutive executions of a given SB (if needed) are favored during scheduling in order to maximize  $uv$ -coverage. Nonetheless, if more extensive  $uv$ -coverage is required to satisfy the imaging requirements, the OT's sensitivity-based time estimate can be overridden (see below). PIs are strongly encouraged to use the ALMA simulator tools to assess the potential need for extra  $uv$ -coverage. For the 7-m Array, integrations of at least one hour are recommended to achieve good image quality.

For single or non-overlapping pointings the source should fit within the inner one-third of the primary beam (field of view), or the PI should discuss the effects of the sensitivity loss towards the beam edges.

PIs should also pay attention to the expected image dynamic range (see Section A.9.1) if attempting to detect a weak signal that falls in the same pointing as a much brighter source. The OT cannot identify such cases automatically since it has no knowledge of the flux structure of the field to be observed. See the Knowledgebase article ["What is meant by imaging dynamic range?"](#) for details.

## B.3 Correlator configuration

For spectral-line observations, the OT reports the number of (Hanning smoothed) spectral resolution elements per line width, taking into account any spectral averaging, and the width of the representative spectral window. PIs have to make sure to select the correct representative spectral window. If the spectral resolution is larger than one third of the line width from the Expected Source Properties, an informative message will appear, and if not suitably justified this will lead to the rejection of the proposal on technical grounds. Note that the spectral resolution is not necessarily the same as the bandwidth for sensitivity!

The requested correlator setup and the placement of spectral windows should be carefully justified in the free-format text box. In the case of multiple spectral lines and/or narrow spectral windows in particular, PIs should double-check that the line profiles are fully covered by the selected spectral windows.

PIs should also check whether any of the spectral windows are severely impacted by atmospheric absorption, which can affect Bands 5 and 7 to 10 especially. If necessary, the representative frequency should be modified to be at the most restrictive part of the atmosphere where a line needs

to be detected, which will impact the time estimate. Any continuum windows should be moved to avoid areas of bad transmission.

For the double sideband receivers (Bands 9 and 10), the atmospheric transmission in the mirrored spectral window due to the 90-degree Walsh Switching (Section A.5) impacts the sensitivity achieved in the spectral window and therefore the time estimate. PIs may wish to modify the spectral setup accordingly. It is advisable to add continuum spectral windows in any unused basebands, in particular for high-frequency SGs.

For sources with known high line density ( $\sim 1$  spectral feature per 10 MHz), PIs are encouraged to set up all the spectral windows in FDM mode. This will allow a more robust determination of the line-free channels used to form the aggregate continuum during data processing and imaging.

## B.4 Choices to be justified

The OT will automatically catch a number of user choices that must be explicitly justified in a text box. These choices are:

- **Override of OT's sensitivity-based time estimate:** Proposers may wish to override the OT's time estimate to monitor a source over a certain time range or to build up the  $uv$ -coverage for imaging a complex source. When using this option, proposers should keep in mind that programs that require more than two hours of continuous observations cannot be guaranteed due to variable weather conditions and system interruptions (Section A.10). The time entered refers to the 12-m Array time, includes all calibrations, and must be fully justified. Note that the OT assigns the PWV based on the representative frequency of the requested observations and the declination of the source to ensure data quality. Thus, it is not possible to request specific weather conditions for the observations.
- **Time-constrained observations:** the OT allows you to specify two types of time-constrained observing: single visit and multiple visits. In the first case, one or more time windows are specified, but the observations will only be carried out once during any of these time windows. In the second case, the Science Goal is observed in each of the time windows specified. The technical feasibility of time-constrained observations will be decided on a case-by-case basis.
- **User-defined calibration:** the default system-defined calibration option ensures that the proper calibrations for the flux scale, bandpass, and relative antenna gains are obtained. Observations making use of the full polarization capabilities of ALMA will also include the necessary calibrations by default. User-defined calibrations should be necessary only in rare cases, e.g. if a very high spectral dynamic range is required, it may be necessary to perform additional calibrations and/or use specific sources. Such requests must be explained and justified in detail. Programs that cannot be calibrated or that increase significantly the complexity of data reduction will not be allowed and flagged as technically unfeasible and rejected.
- **Low maximum elevation:** sources that transit at a low elevation are difficult to schedule for observation since they suffer from high atmospheric attenuation and require low PWV, especially at high frequencies (see Section A.8). A detailed explanation should be provided as to why these sources need to be observed rather than sources at higher elevation.

- Single polarization: this should only be used when the highest spectral resolution is required, as the sensitivity achieved is lower than when using the default dual polarization. PIs should carefully justify why the high spectral resolution requested is required.
- Sparser sampling than the default  $\lambda/\sqrt{3}D$  (Nyquist sampling) can be more effective at covering large areas more quickly, at the price of less uniform spatial coverage and noise. Deviating from the default mosaic sampling must be justified scientifically, and is to be avoided when imaging extended sources, particularly if image fidelity is an important concern.

## B.5 Solar observations

The sensitivity calculator is not adequate for Solar observations because the antenna temperature greatly exceeds the system temperature and, moreover, depends on the Solar target (e.g., quiet Sun, active region, Solar limb). Therefore, Solar proposers are asked to enter the total time and justify this request to the extent that depends on technical imaging considerations, not on scientific factors. For example, for a mosaic of a target in a given frequency band, PIs should indicate how many repetitions of the sampling pattern are needed and why. For this calculation PIs should take into account that ALMA observations are comprised of one or more executions of a SB. The total execution time of an SB cannot exceed 2 hours, which will include the time overheads for bandpass and flux calibration. These calibration overheads amount to about 25 mins.

## B.6 VLBI observations

The VLBI Technical Justification should be tuned to the overall science goals. As a guideline, the ALMA Technical Justification should include the reasons for using the 1.3- or 3-mm bands, the flux density of the target on a 1 km baseline, correlated flux densities on baselines longer than 5000 km, the total observing time requested (including time for calibration), and potential bandpass, polarization and delay calibrators. If polarimetry is requested, the expected S/N ratio for the polarized emission should be stated. If imaging is requested, imaging considerations should also be mentioned (e.g. dynamic range issues, complex source structure, etc.) as well as any special technical requirements with either the set up or the data processing. Finally, the proposers should specify the EHT or GMVA stations that are requested for VLBI.

New to Cycle 8, faint targets (correlated flux densities  $< 0.5$  Jy on intra-ALMA baselines out to 1 km) may be proposed for observation for both Bands 3 and 6. The suitability of the selected fixed phase calibrator must be justified with regards to its flux density and proximity to the VLBI target.

The following online material is currently available to help justify the requested observing time:

- At 3 mm: the [sensitivity calculator](#) and the [3 mm VLBI page](#).
- At 1 mm: the [1 mm VLBI page](#) and links.

## B.7 Phased-array/pulsar observations

The proposer should first read the pulsar mode sections of the [Technical Handbook](#) for Cycle 8, paying particular attention to the items in the "Technical Justifications" Section at the end.

As passive phasing is enforced for this mode, the choice of fixed phase calibrator must be justified. Additional inputs are also required to construct the Scheduling Block and these should be provided in the observations and post-processing text box:

- Number of observing blocks and the length for each. Each block contains scans on both the science target (up to several minutes each) and the fixed phase calibrator (phaser; typically, 2-3 minutes each), plus telescope slewing time in between (of order seconds).
- Total observing time requested. For a proper parallactic angle change on the polarization calibrator, typically ~3-4 hours are required. However, the proposer should indicate how much time is needed on target for the analysis.
- The pulsar period (if known). This value should be provided so that the cadence of the correlator subscans (multiples of 1.008s) does not interfere with the pulsar signal. The time resolution of the PSRFITS file must be a multiple of 8  $\mu$ s; if lower resolution is adequate, it should be specified to avoid larger than needed PSRFITS files.
- The polarization of the PSRFITS data product. The proposer can select from total intensity, dual polarizations (XX and YY), coherence product, or full Stokes.



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## Appendix C Acronyms and abbreviations

ACA	Atacama Compact Array
ACD	Amplitude Calibration Device
ALMA	Atacama Large Millimeter/submillimeter Array
AOS	Array Operations Site
APEX	ALMA Pathfinder EXperiment
ARC	ALMA Regional Center (for EA and NA) or Centre (for EU)
ARP	ALMA Review Panel
APRC	ALMA Proposal Review Committee
AR	Angular Resolution
ASC	ALMA Sensitivity Calculator
ASIAA	Academia Sinica Institute of Astronomy and Astrophysics
AUI	Associated Universities, Inc.
CASA	Common Astronomy Software Applications
Co-I	Co-Investigator
Co-PI	Co-Principal Investigator
CONICYT	Comisión Nacional de Investigación Científica y Tecnológica
CS	Contact Scientist
DDT	Director's Discretionary Time
EA ARC	East Asian ALMA Regional Center
EHTC	Event Horizon Telescope Consortium
EPO	Education and Public Outreach
ESO	European Organisation for Astronomical Research in the Southern Hemisphere
EU ARC	European ALMA Regional Centre
FDM	Frequency Division Mode
FOV	Field Of View
GMVA	Global Millimeter VLBI Array
IF	Intermediate Frequency
KASI	Korea Astronomy and Space Science Institute
JAO	Joint ALMA Observatory
LAS	Largest Angular Structure
LO1	Local Oscillator 1
LSRK	Kinematic Local Standard of Rest
LST	Local Sidereal Time
MOST	Ministry of Science and Technology in Taiwan
MRS	Maximum Recoverable Scale
NA ARC	North American ALMA Regional Center
NAASC	North American ALMA Science Center
NAOJ	National Astronomical Observatory of Japan
NINS	National Institutes of Natural Sciences
NRAO	National Radio Astronomy Observatory
NRC	National Research Council of Canada
NSC	National Science Council of Taiwan
NSF	National Science Foundation
OSF	Operation Support Facility
OST	Observation Support Tool
OT	Observing Tool
OUS	ObsUnitSet
PDF	Portable Document Format
PI	Principal Investigator
PWV	Precipitable Water Vapor
QA2	Quality Assurance Level 2
SB	Scheduling Block

SCO	Santiago Central Office
SG	Science Goal
S/N	Signal-to-noise
SnoopPI	Snooping Project Interface
SP	Science Portal
spw	Spectral window
TDM	Time Division Mode
TJ	Technical Justification
ToO	Target of Opportunity
TP	Total Power
VLBI	Very Long Baseline Interferometry
WVR	Water Vapor Radiometer

## Appendix D Science categories and keywords

The list below presents the available science categories and the corresponding keywords that can be used in the OT to further specify the scientific area of the proposal. **Proposers must select at least one and at most two keywords.**

### Category 1 – Cosmology and the high redshift universe

- a. Lyman Alpha Emitters/Blobs (LAE/LAB)
- b. Lyman Break Galaxies (LBG)
- c. Starburst galaxies
- d. Sub-mm Galaxies (SMG)
- e. High-z Active Galactic Nuclei (AGN)
- f. Gravitational lenses
- g. Damped Lyman Alpha (DLA) systems
- h. Cosmic Microwave Background (CMB)/Sunyaev-Zel'dovich Effect (SZE)
- i. Galaxy structure & evolution
- j. Gamma Ray Bursts (GRB)
- k. Galaxy Clusters

### Category 2 – Galaxies and galactic nuclei

- a. Starbursts, star formation
- b. Active Galactic Nuclei (AGN)/Quasars (QSO)
- c. Spiral galaxies
- d. Merging and interacting galaxies
- e. Surveys of galaxies
- f. Outflows, jets, feedback
- g. Early-type galaxies
- h. Galaxy groups and clusters
- i. Galaxy chemistry
- j. Galactic Centers/nuclei
- k. Dwarf/metal-poor galaxies
- l. Luminous and Ultra-Luminous Infra-Red Galaxies (LIRG & ULIRG)
- m. Giant Molecular Clouds (GMC) properties

### **Category 3 – ISM, star formation and astrochemistry**

- a. Outflows, jets and ionized winds
- b. High-mass star formation
- c. Intermediate-mass star formation
- d. Low-mass star formation
- e. Pre-stellar cores, Infra-Red Dark Clouds (IRDC)
- f. Astrochemistry
- g. Inter-Stellar Medium (ISM)/Molecular clouds
- h. Photon-Dominated Regions (PDR)/X-Ray Dominated Regions (XDR)
- i. HII regions
- j. Magellanic Clouds

### **Category 4 – Circumstellar disks, exoplanets and the solar system**

- a. Debris disks
- b. Disks around low-mass stars
- c. Disks around high-mass stars
- d. Exoplanets
- e. Solar system: Comets
- f. Solar system: Planetary atmospheres
- g. Solar system: Planetary surfaces
- h. Solar system: Trans-Neptunian Objects (TNOs)
- i. Solar system: Asteroids

### **Category 5 – Stellar evolution and the Sun**

- a. The Sun
- b. Main sequence stars
- c. Asymptotic Giant Branch (AGB) stars
- d. Post-AGB stars
- e. Hypergiants
- f. Evolved stars: Shaping/physical structure
- g. Evolved stars: Chemistry
- h. Cataclysmic stars
- i. Luminous Blue Variables (LBV)
- j. White dwarfs
- k. Brown dwarfs
- l. Supernovae (SN) ejecta
- m. Pulsars and neutron stars
- n. Black holes
- o. Transients



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