ALMA Cycle 6 Proposer's Guide

www.almascience.org

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

User Support:

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Revision History:

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1.0	6 March 2018	Paola Andreani, John Carpenter, Maria Diaz Trigo, Elizabeth Humphreys, Hiroshi Nagai, Anthony Remijan, Martin Zwaan

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Cycle 6 Call for Proposals

The ALMA Director, on behalf of the Joint ALMA Observatory (JAO) and the partner organisations in East Asia, Europe, and North America, is pleased to announce the ALMA Cycle 6 Call for Proposals (CfP) for scientific observations to be scheduled from October 2018 to September 2019. It is anticipated that 4000 hours of the 12-m Array time and 3000 hours of the Atacama Compact Array (ACA) time, also known as the Morita Array, will be available for successful proposals from Principal Investigators (PIs) in Cycle 6. 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*). Proposals will be assessed by competitive peer review by a single international review committee.

ALMA Cycle 6 proposal submission will open at **15:00 UT on Tuesday, 20 March 2018**. The Cycle 6 proposal submission deadline is **15:00 UT on Thursday, 19 April 2018.** Table 1 summarises these and other important milestones for Cycle 6.

ALMA provides continuum and spectral-line capabilities for wavelengths from 0.32 mm to 3.6 mm, and angular resolutions from 0.018” to 3.4” on the 12-m Array. Cycle 6 will bring to ALMA several new observational capabilities, including full circular polarization observations, lifting of some restrictions for simultaneous observations with the 12-m Array and the ACA, Band 8 stand-alone ACA observations and an increase of the Band 6 Intermediate Frequency (IF) bandwidth.

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

Table 1: The ALMA Cycle 6 timeline

Date	Milestone
20 March 2018 (15:00 UT)	Release of Cycle 6 Call for Proposals, Observing Tool & supporting documents and opening of the Archive for proposal submission
19 April 2018 (15:00 UT)	Proposal submission deadline
End of July 2018	Announcement of the outcome of the proposal review process
August - 6 September 2018	Submission of Phase 2 material
October 2018	Start of ALMA Cycle 6 Science Observations
September 2019	End of ALMA Cycle 6

1 What's new in Cycle 6

This section summarises significant changes made in Cycle 6. 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 6 proposal issues and clarifications should I be aware of before submitting my proposal?

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

1.1 Technical and observing capabilities

The new observing modes that will be offered in Cycle 6 are listed below. Details of these observing modes are given in Appendix A, with supplemental technical material given in the ALMA Cycle 6 Technical Handbook (hereafter, the Technical Handbook).

Circular polarization observations

Proposals will be accepted for Bands 3, 4, 5, 6 and 7 in all (including circular) polarization modes for continuum and spectral-line, single-field, on-axis, observations. The minimum detectable degree of circular polarization, defined as three times the systematic calibration uncertainty, is currently 1.8% of the peak flux for both continuum and spectral-line data.

Changes to simultaneous observations with the 12-m Array and the ACA

In Cycle 6, PIs can request simultaneous observations of any 12-m Array configuration (except those defined as "long-baseline configurations", see Section 4.2) with the 7-m Array (and, if required, the TP Array) in which case all observations will have the same duration, namely that of the 12-m Array observation. For simultaneous observations, the restrictions on allowed configuration combinations (except those involving two 12-m Array configurations) and time multipliers specified in Section A.4 do not apply.

Band 8 stand-alone ACA

Band 8 observations will become a standard mode in Cycle 6 (see Section 4.2). Consequently, proposals will be accepted for Band 8 stand-alone ACA observations.

Band 6 IF extension

The Band 6 IF bandwidth has been increased by 0.5 GHz to extend from 4.5 to 10 GHz. This will enable ^{12}CO, ^{13}CO and $C^{18}O$ J=2-1 to be observed simultaneously with broader spectral windows.

1.2 Proposal format

In Cycle 6, the figure captions, tables and references included in the proposal Scientific Justification (SJ) must use a 12-point font (see Section 5.2.3).

1.3 Observing Tool features

The more notable changes for Cycle 6 include:

- The minimum time on source (adding all the sources in a given Scheduling Block or SB) will be the largest of 5 minutes or 50% of the total calibration time (amplitude and bandpass).
- For calculation of the Executive Balance, the affiliation of a user, as well as his/her email, at the time of a proposal's last submission will be considered.
- It is no longer possible to enter a user-defined bandwidth that exceeds the bandwidth of the spectral setup.
- For sources distributed widely in the sky within one Science Goal (SG), the OT splits the SG into different "clusters", each grouping all sources within a radius of 10 degrees (see Section A.8.1). In Cycle 6, for SGs that request "long-baseline configurations" (see Section 4.2 for definition) the grouping of sources into clusters will consider only sources within a radius of 1 degree (see Section A.8.1). For all other baselines, the grouping remains unchanged.
- The LSRK to barycentric correction now works properly for all velocity definitions. This may result in projects from previous cycles not validating. If so, the spectral setup should be modified.
- There is no longer a text box associated with the time-constraint interface. The box on the TJ node should be used instead.
- FITS files in Galactic coordinates are now handled correctly.
- Source coordinates in decimal degrees input in an ASCII format will now be recognised as Galactic.
- The OT will issue a validation error if a given SG exceeds the instantaneous maximum data rate of 70 MB/s.

All new features are described in more detail in the OT documentation.

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 antennas are 12 metre dishes in the 12-m Array, used for sensitive, high-resolution imaging. The remaining sixteen antennas make up the ACA, used to enhance wide-field imaging: twelve of those are closely spaced 7 metre antennas (7-m Array), and four are 12 metre 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°, longitude = –67.755° and an altitude of 5000 m. The site offers the exceptionally dry and clear sky conditions required to operate at millimetre and submillimetre wavelengths. This site is connected via Gigabit fibre links to the Operation Support Facility (OSF), located at an altitude of 2900 m, at 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 Centres

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 organises 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 Centres (ARCs) within their respective region. 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 is a mirror of 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[1] and Republic of Korea.

European researchers are supported by the European ARC (EU ARC), which is organised 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 centre 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[1].

[1] Support of the Taiwanese astronomical community is shared by the EA and NA ARCs.

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 the option to receive automatic email notifications of the progress of their observations, to enable access to proprietary data to other ALMA users or to delegate the right to submit the Phase 2 material to another selected ALMA user.
- Access SnooPI, the tool for PIs, co-PIs, co-Investigators (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.

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 programmes, 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 details such as a new email address or a change of affiliation (see Section 2.1 of the ALMA Users' Policies).

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 and technical feasibility 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 Programmes and mm-VLBI Proposals may designate co-PIs, who will share the overall responsibility in conducting the proposed science. 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 Programmes, 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-PIs or co-Is who may appear on a proposal.

The requested observing time will be split among the regions (North America, Europe, East Asia, and Chile) based on the proportionality of the regional affiliation of the PI and co-PIs (Section 5.5.3).

Additional rules apply for qualification to use the Chilean share of the time and they are described at *http://www.das.uchile.cl/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 refer 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 ACA in stand-alone mode. Regular Proposals may include standard or non-standard modes and may involve time-critical, multiple-epoch observations, and the monitoring of a target over a fixed time interval.

As shown in Figure 1 (left panel), the requested time of the majority of Cycle 5 proposals is between two and ten hours of 12-m Array time. However, the success rate of proposals was roughly constant up to at least 30 hours of requested 12-m Array time (see Figure 1, right panel). ALMA continues to encourage the community to submit Regular Proposals that request over 10 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.

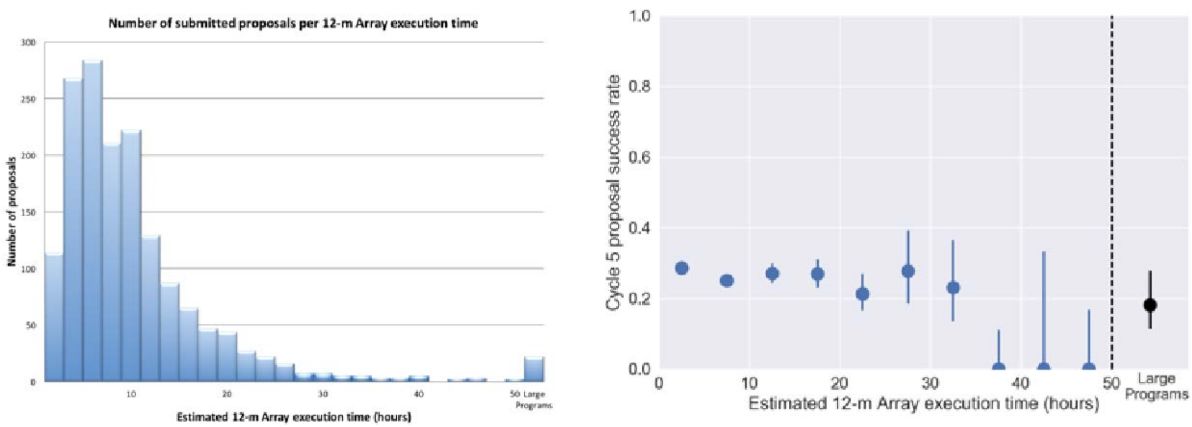

Figure 1: (Left) Number of proposals submitted as a function of the 12-m Array execution time in Cycle 5. (Right) The fraction of proposals (with 1σ confidence intervals) that are assigned priority Grade A or B as a function of the estimated 12-m Array time.

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 6 proposal deadline and may include standard or non-standard modes. 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 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 at the moment of triggering 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 Science Portal). Further communication of the Observatory with the PI to clarify any necessary issues for the ToO observations will proceed via the Helpdesk ticket opened upon trigger receipt.

For ToO observations that require follow up/subsequent observations based on the outcome of the initial observation, the PIs have the possibility to request the release of the raw data to enable a prompt analysis. Requests for these raw data should be submitted through the ALMA Helpdesk. In Cycle 6, the proprietary period for these observations will start when the quality assured data products are delivered to the PI, as for any other observation (Section 6.3).

3.3 Large Programmes

Large Programmes 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 ACA in stand-alone mode. Large Programmes must include only standard modes (as defined in Section 4.2) and should not involve time-critical or ToO observations.

A Large Programme 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 utilisation of the data, including analysis and organisation of the efforts. Consequently, the proposal team for a Large Programme should not in parallel submit their Large Programme 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 KB article "Are there policies specific to Large Programs?").

The programme 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 data. The data products and documents will be made available to the community at large. ALMA will inform the PIs of approved Large Programmes about the standards for product naming, product metadata and product quality.

A maximum of 15% of the time available for science observations will be dedicated to the execution of Large Programmes, corresponding to 600 hours of 12-m Array time and 450 hours of stand-alone ACA time (Section 4.1). To optimise the success in completing the observations within Cycle 6, the following scheduling constraints will be imposed when selecting Large Programmes: (1) the time allocated to Large Programmes shall not exceed 33% of the available time for a given Local Sidereal Time (LST) range on antenna configurations with baselines longer than 12 km (configurations C43-9 and C43-10, see Section 4.3.3); and (2) the time allocated to Large Programmes shall not exceed 50% of the available time for a given LST range on configurations with baselines shorter than 12 km (ACA and C43-1 to C43-8).

3.4 mm-VLBI Proposals

ALMA VLBI Proposals in Bands 3 and 6 are made in concert with the following VLBI networks: the Global Millimetre VLBI Array (GMVA) at 3 mm and the Event Horizon Telescope Consortium (EHTC) network at 1.3 mm. For 3 mm VLBI observations, PIs must have submitted a proposal to the GMVA network by 1 February 2018 in addition to their ALMA VLBI proposal (see 3 mm VLBI announcement).

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 as to why ALMA is essential for the goals of the project. VLBI observations cannot be included in Large Programmes and DDT Proposals.

VLBI observations that include ALMA will likely occur in March/April 2019 while ALMA is in a compact antenna configuration (Section 4.3.3), with up to thirty-nine 12 m antennas in the phased array.

Given that the outcome of VLBI Cycle 5 proposals, scheduled in April 2018, is unlikely to be known before the ALMA Cycle 6 proposal deadline, PIs of such proposals may wish to resubmit their proposals in Cycle 6 in case the Cycle 5 observations are unsuccessful. No resubmission to the GMVA network is needed in such cases. Further details on handling of resubmitted proposals are available in Section 4.4.2.

3.5 Director Discretionary Time Proposals

Director Discretionary Time (DDT) Proposals may be submitted at any time during Cycle 6 for execution during this cycle. To qualify for DDT usage, proposals must fulfil 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 6

Cycle 6 will have a duration of 12 months, starting in 2018 October and finishing in 2019 September.

It is anticipated that 4000 hours of the 12-m Array and 3000 hours of the ACA will be available for successful proposals of PI programmes and DDT Proposals, including Cycle 5 grade A proposals that are carried over. Up to 20% of the available time can be allocated to non-standard observing modes, which are listed in Table 2. Large Programmes, VLBI[2] 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 6

The Cycle 6 capabilities are described in Appendix A. In summary they are:

Number of antennas

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

Receiver bands

- Receiver Bands 3, 4, 5, 6, 7, 8, 9, and 10 (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

- Maximum baselines between 0.16 km and 16 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 Band 7 is 8.5 km.
    - The maximum possible baseline for Bands 3, 4, 5 and 6 is 16 km.

Configurations with maximum baselines equal or longer than 3.6 km (C43-7 to C43-10) 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 representative antenna configurations for the 12-m and 7-m Arrays suitable for Common Astronomy Software Applications (CASA) simulations are available from the ALMA Science portal.

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.

[2] Note that the 5% of time allocated to VLBI Proposals is included in the 20% of the time allocated to non-standard modes (Section 5.2).

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.

Cycle 6 observing modes are classified as standard or non-standard. Standard modes have been well characterised and the observations can be calibrated with the ALMA data reduction pipeline. Non-standard modes, listed in Table 2, are not as well characterised and may require additional Observatory resources to calibrate, image and deliver ALMA data products. Up to 20% of the Cycle 6 observing time will be allocated to proposals requesting non-standard modes.

Table 2: List of non-standard modes

Bands 9 and 10 observations
Band 7 observations with maximum baselines > 5 km
All polarization observations
Spectral scans
Bandwidth switching projects (having less than 937.5 MHz aggregate bandwidths over all spectral windows)
Solar observations (Bands 3 and 6)
VLBI observations
User-specified calibrations
Astrometric observations

Stand-alone ACA observations are available for standard modes only.

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 submillimetre wavelengths (Evans et al 2002, ALMA Memo No. 471, available from the ALMA Memo Series). The opacity (primarily determined by the amount of Precipitable Water Vapour – 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[3] season (January-March), it may be difficult to carry out submillimetre observations. For this reason, an extended maintenance and upgrade period is scheduled each February, during which no science observations are scheduled.

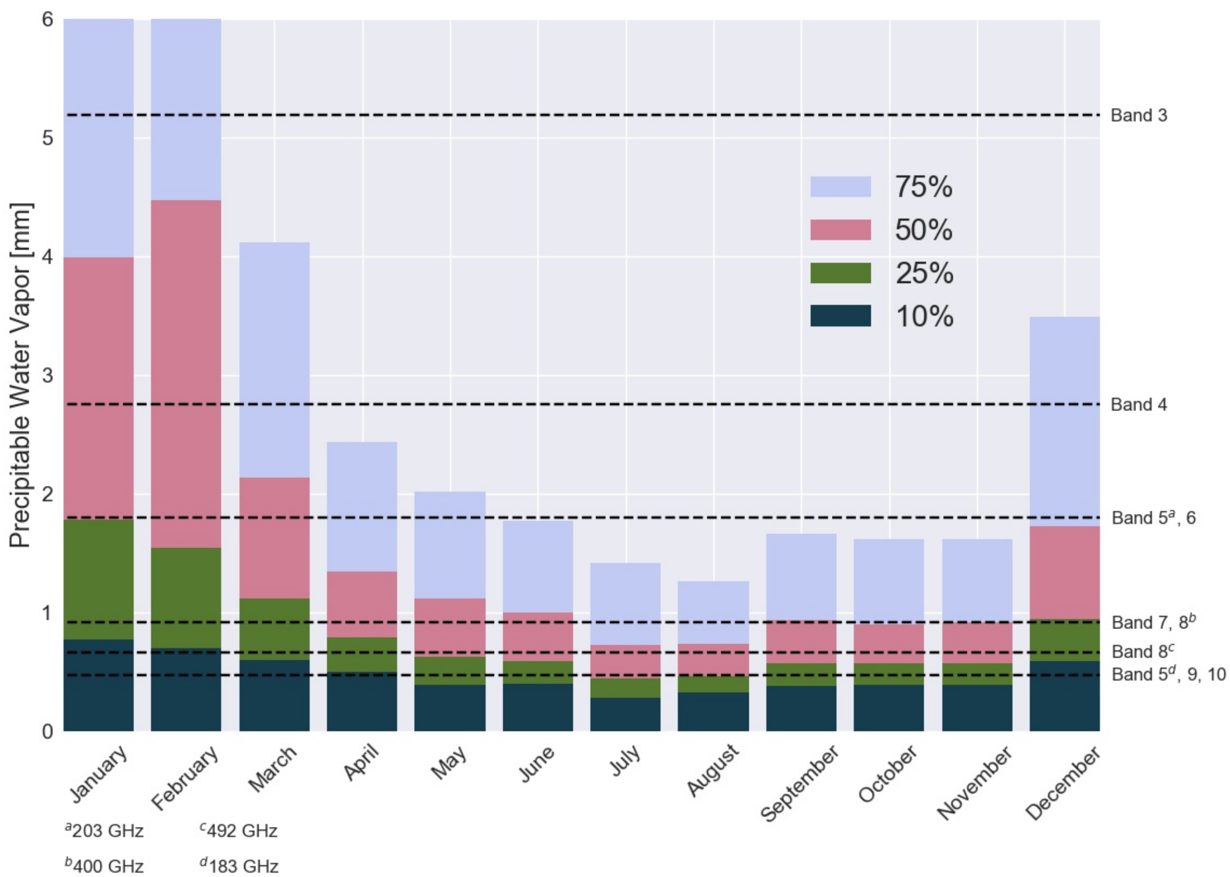

Figure 2: Fraction of time that the PWV falls below a given value along the year. The percentages shown indicate the fraction of time that the PWV is under the PWV value indicated on the y-axis. For example, in March 75% of the PWV measurements are under 4.1 mm, and in June 75% of the PWV measurements fall below 1.8 mm. The data were obtained with the APEX weather station between 2007 and 2017. The horizontal dashed lines show the observing thresholds adopted for the various ALMA bands for an elevation of 60 degrees.

[3] 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.

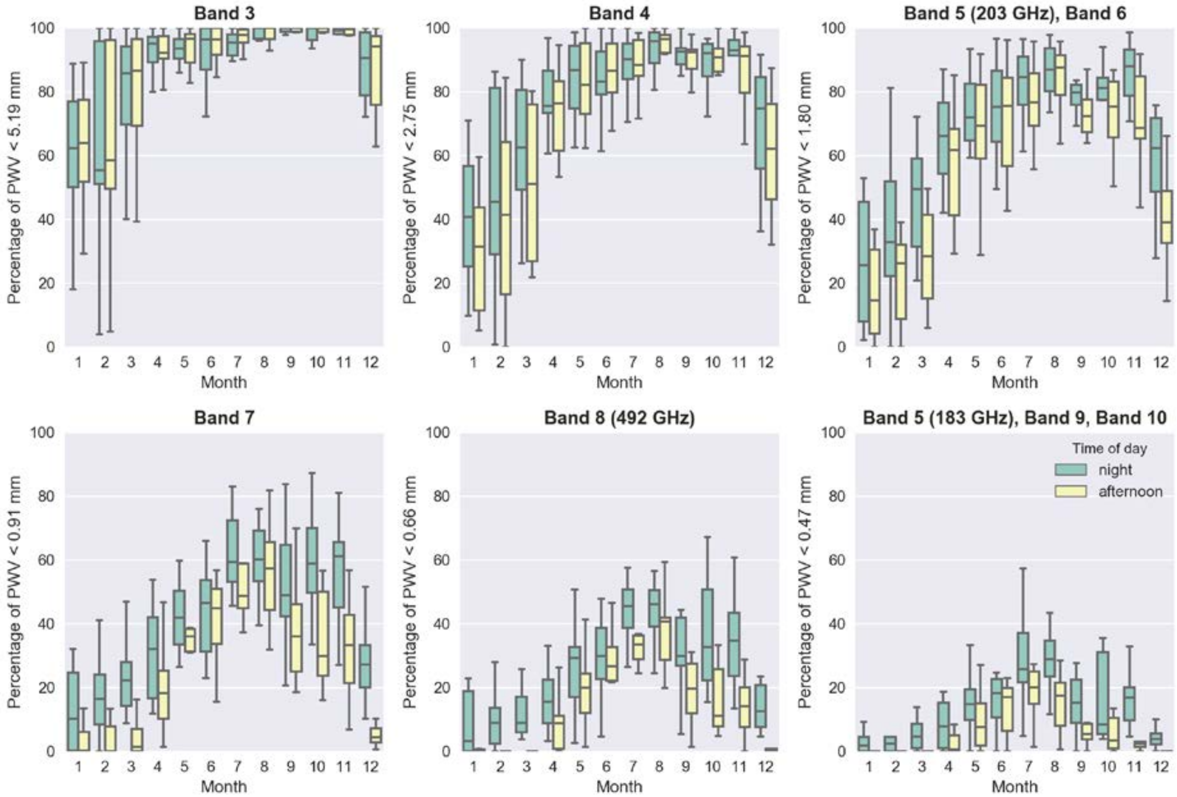

Figure 3: The percentage of time when the PWV is below the observing thresholds adopted for the various ALMA bands for night-time (green) and afternoon (yellow) and for an elevation of 60 degrees. The horizontal line within the box indicates the median. Boundaries of the box indicate the 25th- and 75th- percentile, and the whiskers indicate the highest and lowest values of the results. The data were obtained with the APEX weather station between 2007 and 2017.

The Observatory will schedule the observations during appropriate weather conditions and to ensure good data quality. In particular, this implies that high frequency projects will get priority over other lower frequency projects when the weather conditions are appropriate for the former, thus increasing their probability of execution.

4.3.2 Angular resolution

PIs can enter a range of angular resolutions for a given SG in the OT. An extended range of angular resolutions, spanning more than one configuration, will lead to an increased chance of having the SBs corresponding to a given SG observed, especially for SBs with an intrinsically low probability of execution due to, for example, weather or time constraints. The range should be justified in the proposal and be scientifically meaningful (Section 5.2).

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

- If the PI selects a single value for the angular resolution or a range narrower than 20% around its centre value, a range of ±20% around the single or centre 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 nominal configurations, the range will be extended to include the resolution of the closest nominal configuration.
- If the requested range includes both "long-baseline configurations" and more compact configurations, only the latter subset will be considered.

The final range of angular resolutions (i.e. after all the above factors have been taken into account) 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.

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. finest 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). This implies that a temperature sensitivity worse than requested could be obtained if the resolution achieved in the delivered images is still within the requested range but finer than that of the most extended configuration assigned to that SB.

4.3.3 Configuration schedule for the 12-m Array

During Cycle 6, it is anticipated that the 12-m Array will be reconfigured fourteen times. At the end of each of these reconfigurations, the Array is expected to have imaging properties similar to one of the ten "representative" configurations that are used to characterise the advertised Cycle 6 imaging capabilities and estimate the observing times (denoted as C43-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). The planned 12-m Array configuration schedule for Cycle 6 is given in Table 3. The overall schedule may also 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 made available at the Science Portal. On average, there will be a new configuration every three weeks. As mentioned in Section 4.3.1, observations will not be scheduled in February due to the bad weather conditions during the Altiplanic winter.

The first column of Table 3 gives the planned start date for each configuration. These dates may be subject to change due to 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, which is approximately two hours after sunset to 4 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 3: Planned 12-m Array Configuration Schedule for Cycle 6

Start date	Configuration	Longest baseline	LST for best observing conditions
2018 October 1	C43-6	2.5 km	~ 22h – 10h
2018 October 15	C43-5	1.4 km	~ 0h – 12h
2018 November 25	C43-4	0.78 km	~ 2h – 14h
2018 December 15	C43-3	0.50 km	~ 4h – 15h
2019 January 5	C43-2	0.31 km	~ 5h – 16h
2019 January 20	C43-1	0.16 km	~ 6h – 17h
2019 February 1-28	*No observations due to February shutdown*		
2019 March 1	C43-1	0.16 km	~ 8h – 21h
2019 March 15	C43-2	0.31 km	~ 8h – 22h
2019 April 1	C43-3	0.50 km	~ 9h – 23h
2019 April 15	C43-4	0.78 km	~ 10h – 0h
2019 May 1	*No observations due to major antenna relocation*		
2019 June 1	C43-10	16.2 km	~ 13h – 3h
2019 June 20	C43-9	13.9 km	~ 14h – 5h
2019 July 10	C43-8	8.5 km	~ 16h – 6h
2019 August 1	C43-7	3.6 km	~ 18h – 8h
2019 September 5	C43-6	2.5 km	~ 20h – 9h

Notes for Table 3:

1. Configuration properties are given in Section A.2

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

- Band 9 and 10 observations will be scheduled during the LST ranges given in the fourth column of Table 3, 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 maximise 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 (especially December-March) at any LST.

- The probability that an observation be scheduled depends on the over-subscription for a given LST and configuration besides the required weather conditions. In particular in Cycle 5, projects requesting configurations C43-8, 9, or 10 had a higher success rate than those requesting other configurations. Also, stand-alone ACA observations have a high probability of being scheduled, especially at LST between 20 h and 14 h.

- 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.

The extended, long-baseline, configurations for Cycle 6 will occur from June to August. Long periods suitable for high frequency observing are expected from August to November. In Cycle 7 the array configuration schedule will likely complement this plan.

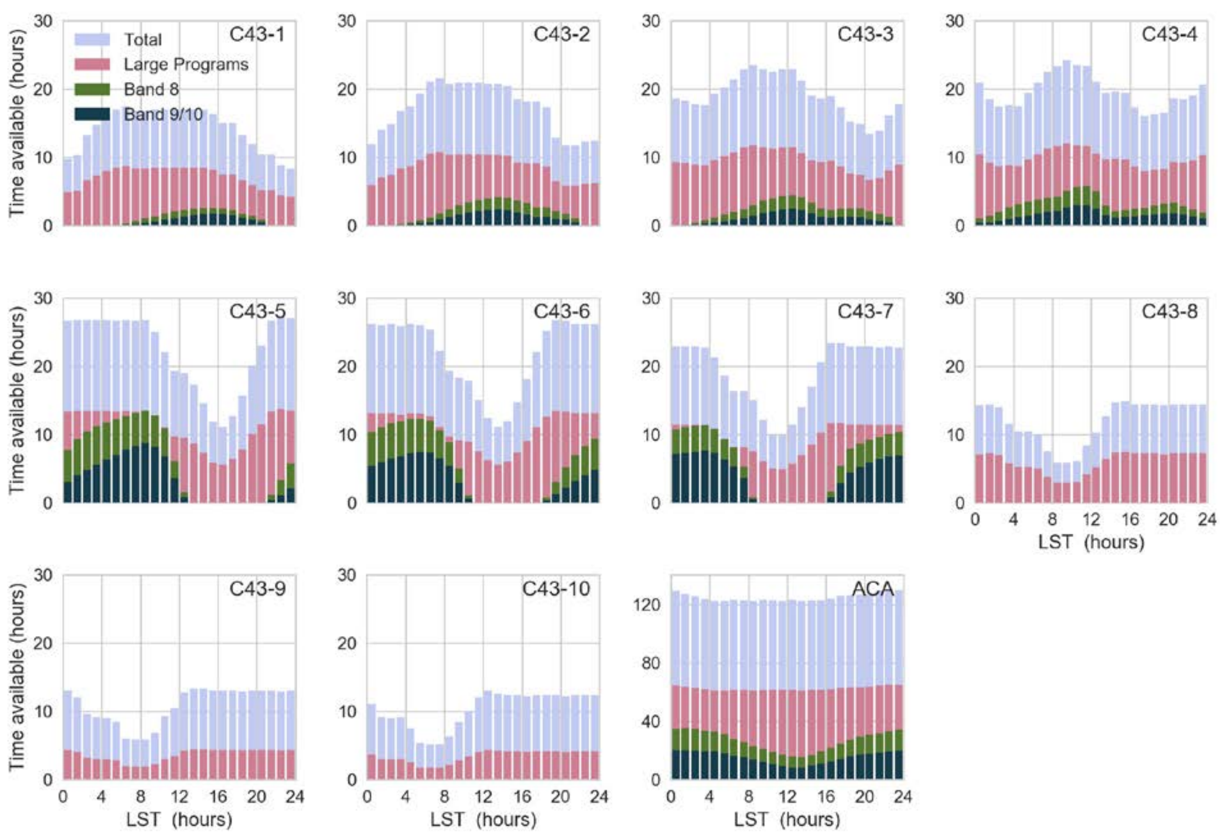

Figure 4: Effective observing time available per configuration for executing PI projects. As an example, up to 10 hours may be allocated to Large Programmes in configuration C43-2 at LST = 10 h. The total number of hours excludes time spent on observatory calibration, maintenance, reconfigurations, and other activities. The fraction of that time available for Large Programmes (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). The data files containing these histograms are available here.

4.3.4 Observing pressure

Figure 5 shows the LST distribution of Cycle 5 submitted proposals and of those awarded grades A-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 in less subscribed LST ranges will have a higher probability of execution.

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.

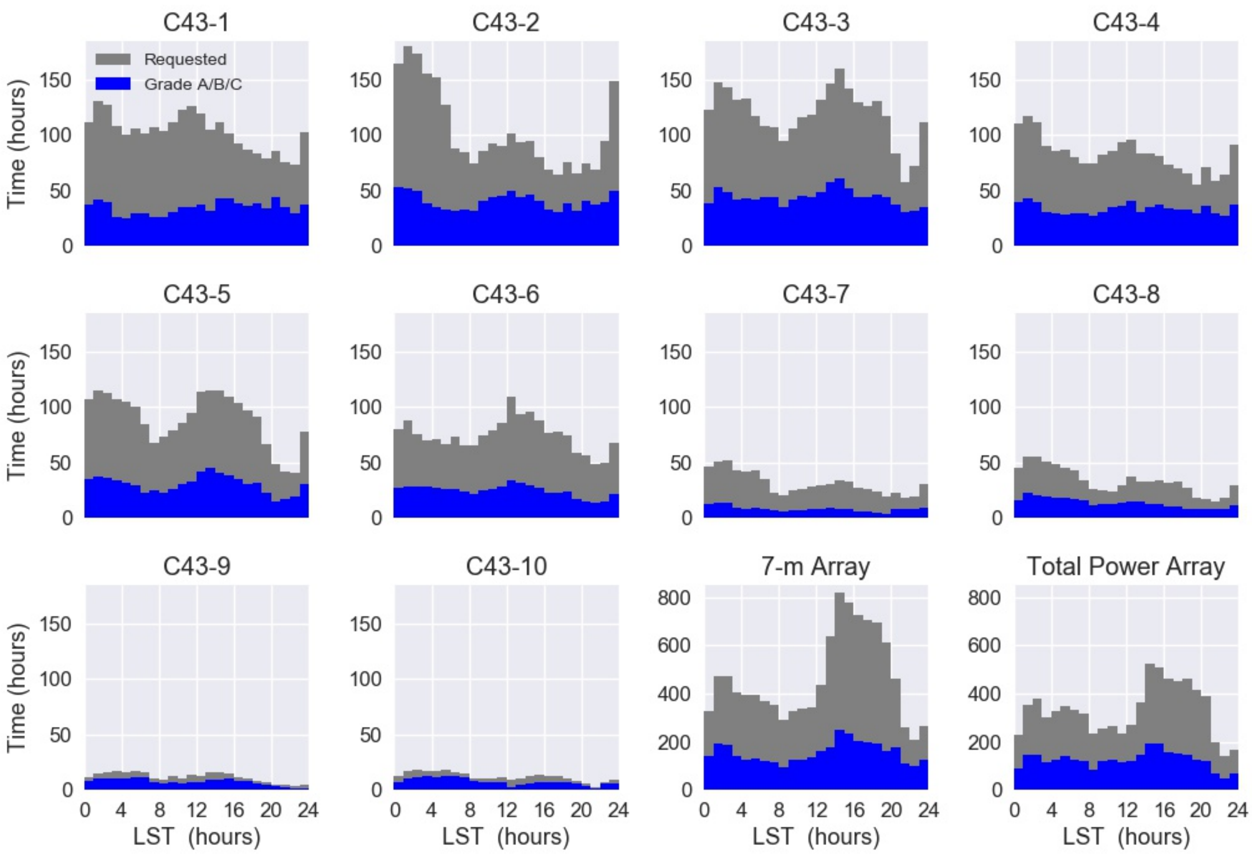

Figure 5: Distribution of estimated execution time in Cycle 5 proposals for all submitted proposals (gray) and proposals assigned Grade A, B, or C (blue). The figure does not include the unfinished Cycle 4 Grade A proposals carried over to Cycle 5.

4.4 Duplicate observations and resubmissions

4.4.1 Checking for duplications

To ensure the most efficient use of ALMA, 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. Archival data should be used whenever possible to accomplish the science goals of a proposed investigation. Observations are considered duplicates if the conditions indicated in Appendix A of the Users' Policies are met.

PIs are responsible for checking their proposed observations against the Archive and the list of Cycles 4 and 5 Grade A programmes provided by ALMA to avoid duplicate observations. PIs will not be penalised for proposing duplications of previous cycle observations if they had no way to know about them, using the resources listed above, by the release of the Call for Proposals. More information on checking for duplications is available at the Science Portal.

The proposal cover sheet contains a section where PIs can justify proposed duplicate observations. PIs are also advised to justify their proposed observations in cases where they are similar to previously executed or accepted programmes 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:

- Synoptic 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 6 proposal to observe some or all 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 5 project is listed as a PI, co-PI or co-I of the corresponding Cycle 6 proposal or the Cycle 6 PI is listed as an investigator on the Cycle 5 proposal.

For such resubmissions, the relevant portion of the Cycle 6 proposal will be cancelled if the observations are successfully completed in Cycle 5. Observations started in a previous cycle and accepted as a resubmission in Cycle 6 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 6 even if the Cycle 5 observations are completed. The APRC will decide if such resubmissions are accepted.

4.5 Estimated observing time

Proposal requests are cast in terms of Science Goals, 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 sources. 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[4]) 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 will be flagged as non-standard and 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 the 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 favoured during scheduling to maximise *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 time for any additional configurations needed to supplement the configurations that best match the requested range of angular resolutions to also 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.

[4] Since Cycle 5, the time estimate adopts the configuration that fulfils the finest angular resolution requested if the sensitivity is specified in temperature units (Section 4.3.3).

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).

Observations that require only the ACA are selected by checking a specific box at the OT interface. When calculating the time required for ACA, 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 set equal to that of the 12-m Array.

The results of all the time estimates are reported in the OT per SG 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 and ACA and total time are tabulated separately on the proposal coversheet.

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. *Oracle has scheduled an update of Java 8 for mid April and users are advised to wait until after the proposal deadline (19 April 2018) before installing this.*

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.
- The **OT User Manual**: A manual intended for all ALMA users, from novices to experienced users. It provides comprehensive information about how to create valid Phase 1 proposals and Phase 2 programmes 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 currently 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 ALMA data and make images from the simulations. An additional CASA task, “simalma”, simplifies the process of combining data from multiple arrays. These CASA tools require configuration files that specify the layout of ALMA antennas. Files for representative Cycle 6 configurations are available at the Science Portal. 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 submillimetre wavelength range. This database is used by the ALMA OT for spectral-line selection. More information is available in the Splatalogue QuickStart Guide on the Science Portal.

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 amount of PWV. The output is a plot of the transmission fraction as a function of frequency. Up to six different water vapour levels can be selected.

4.6.3 The ALMA Regional Centre 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 6 proposals, for either the novice or advanced users. All documents can be accessed via the ALMA Science Portal.

The **Proposing Guidance link** from the science portal summarises the steps involved in the preparation and submission of an ALMA observing proposal. It is designed to help users to find the relevant documents and sources of additional information in each step easily.

Observing with ALMA: A Primer is a brief introduction to ALMA observing, to submillimetre terminology, and to interferometric techniques, that should prove useful for investigators who are new to radio astronomy. Several example science projects illustrating the Cycle 6 capabilities are also provided.

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 6 Technical Handbook** describes the technical details of ALMA during Cycle 6, 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 optimisation of capabilities.

4.7 The ALMA Helpdesk

The ALMA Helpdesk is 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. Users are notified about the start of Phase 2 of their approved projects via the Helpdesk and can use the project ticket to enquire about aspects of their project throughout its lifetime. Finally, they can also trigger their ToO observations via a dedicated department of 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 without submitting a Helpdesk ticket. Knowledgebase articles that match their query are automatically suggested to users as they type. The Knowledgebase query interface also searches all the documentation available off the ALMA Science Portal and provides a direct link to the documentation that may answer a user's question.

5 Proposal preparation and submission

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 6 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 Science Justification, Science Goals and Technical Justification that will be distributed to the ALMA Proposal Review Committee for evaluation.

The following sections contain guidelines for preparing the Science 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.**

5.2 Preparing the Scientific Justification

ALMA Cycle 6 proposals must include a single PDF document that includes a science case written in English. The document may optionally include figures, tables and references. The maximum permitted file size is 20 MB.

5.2.1 Page limits

The total length of the PDF document is limited to four pages for Regular, ToO, Solar and mm-VLBI Proposals and to six pages for Large Programmes (A4 or US Letter format), **with a font size no smaller than 12 points**. 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 Programmes are allotted two additional pages, which can be used to further present the scientific justification and describe the scheduling feasibility, data products, and management plan. It is strongly suggested that Large Programmes devote at least one page to describe the data products and 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 Science Justification PDF document. Users are encouraged to use the LaTeX template developed by ALMA for preparation of their proposals (available at the Science Portal).

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

5.2.2 Science case

Each proposal must describe the astronomical 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 science case 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.

5.2.3 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.

5.3 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 Science 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 Technical Justification may lead to the rejection of the proposal on technical grounds.

Each SG has its own Technical Justification since the technical setup of the observations will often vary substantially from one SG to the next. If a Technical Justification is applicable to more than one SG, the TJ node can be easily copied and pasted between SGs. The TJ node contains three main sections – sensitivity, imaging, and correlator configuration - corresponding to the main aspects that need to be addressed to assess the technical feasibility of any proposal. Each section includes at least one free-format text box that must be filled (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 Technical Justification, 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 rest of the Science Goal should be set up before filling in the Technical Justification. Specific guidelines on filling out the Technical Justification are given in Appendix B. Please also see the ALMA OT video tutorial 4: "The technical justification".

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 ALMA Director based on the advice from a standing committee consisting of senior staff at the JAO.

5.4 Proposal validation, submission and withdrawal

Once the proposal is validated within the OT, it can be submitted to the ALMA Archive. Validation of Large Programmes could take up to 5 minutes (or longer!) if the programme contains very complicated setups or a large number (hundreds) of sources. PIs of such programmes should submit their proposals well before the deadline. A Cycle 6 proposal can be resubmitted as many times as needed by the PI before the proposal deadline. With each resubmission, the previous version of the proposal is overwritten (Section 5.4.1). Submitted proposals cannot be modified after the deadline. For DDT Proposals the first submission is final.

Submission of Regular, ToO, Large and mm-VLBI Proposals will be available starting **15:00 UT on 20 March 2018 and until the proposal deadline of 15:00 UT on 19 April 2018**. No proposal submission or resubmission will be accepted after the deadline.

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.
- Cycle 6 DDT Proposals may be submitted anytime throughout the cycle. 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.

5.4.1 Proposal updates

If a PI needs to update and then resubmit a previously submitted Cycle 6 proposal, he/she should ensure that this is done using the last submitted version. This can be done by either (i) modifying the proposal saved after submitting it, or (ii) downloading and then modifying the submitted proposal from the Archive. If an earlier submitted version saved on disk is 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.

5.5 Proposal evaluation and selection

5.5.1 Peer review

ALMA programmes are selected through competitive peer review. The 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 ALMA Proposal Review Committee (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 Programmes selected by the ARPs and will recommend which ones 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 of submitted proposals. The notifications will include the assigned grade and a consensus report from the ALMA review panels that summarises the strengths and weaknesses of the proposal.

5.5.2 Evaluation criteria

The primary criteria to rank all proposals are the overall scientific merit of the proposed investigation and their potential contribution to the advancement of scientific knowledge. The proposals will also be evaluated to ensure that they are technically feasible and consistent with the Observatory best practices, unless justified in the proposal.

Given the significant investment of ALMA resources for Large Programmes, the APRC rank will also consider the following factors for these programmes:

- Scheduling feasibility

  A Large Programme should be designed such that the observations are likely to be completed within Cycle 6 given the antenna configuration schedule and weather constraints (see Sections 3.3 and 4.3).
- Data products

  A Large Programme should describe the data products that will be produced to achieve their science goals. The programme 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 Programme should present a management plan that describes a schedule of work, a description of the roles of the proposal team, and a plan to disseminate the results.

5.5.3 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[5], but taking also into account the scheduling constraints dictated by the configuration schedule and weather, the share of observing time for each region and the time available for non-standard modes.

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. The total time assigned to Grade A and B proposals will correspond to the nominal number of hours indicated in Section 4.1, Grade C will be assigned to proposals up to an additional 50% of the nominal available time, to ensure that an adequate number of projects are available for all configurations and LST 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).

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[5] 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. The ALMA VLBI Coordinating Committee (AVCC) oversees the merging of the ALMA and VLBI network reviews.

- 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.

5.6 Proposal confidentiality

For proposals assigned Grade A or B, the project code, the proposal title and abstract, the name and region of the PI, as well as the names of co-Is (and Co-PIs, in the case of Large Programmes or VLBI Proposals) will be made public soon after PIs are informed of the outcome of the proposal review 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 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). Any changes resulting from the proposal review process or necessitated by technical considerations will be implemented by the ALMA staff and reviewed by the PI for approval before the SBs are submitted to the scheduling queue. The PI may request the help of an ALMA Contact Scientist (CS) at the associated ARC or ARC node by replying to the Helpdesk ticket that will be opened on his/her behalf.

Necessary minor changes to the project may also be implemented at this stage as long as they do not impact the science scope or increase the total execution time. Any change that is more significant must be requested through the Helpdesk (see Section 6.2).

Once a PI has prepared 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.

For successful 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.

6.2 Changes to submitted programmes

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 and use 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 optimisation.

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, change from a standard to a non-standard mode, 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 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 programme are subject to a proprietary period of 12 months (except DDT programmes, 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 Sections 8.4.3 and 8.4.4 of the ALMA Users' Policies).

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.

Appendix A ALMA Cycle 6 Capabilities

This appendix describes the characteristics and capabilities of the ALMA Observatory that are offered for the Cycle 6 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 un-allowed 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 as well as a stand-alone capability. The stand-alone ACA is offered either for standard-mode observations only with the 7-m Array or with the 7-m Array and TP Array combined, but not with the TP Array alone. The use of the TP Array is limited to spectral-line observations (not continuum) in Bands 3, 4, 5, 6, 7 and 8. Bands 9 and 10 are not available for any TP observations.

The number of antennas available may sometimes be less than the numbers given above due to unforeseen problems with the equipment, or during array reconfigurations. ALMA support staff will endeavour to schedule observations that will not be seriously affected by having a slightly smaller number of antennas. The integration times or *uv*-coverage might also be increased 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 characterised 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 ~16 km). Ten 12-m Array configurations have been defined to represent the possible distribution of 43 antennas over this range of maximum baselines. These are denoted as C43-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 dishes. 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 6 Array configurations

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

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(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. Bold blue text indicates non-standard modes (see Table 2).

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 3–8. No Band 9 or Band 10 TP Array observations are offered for this cycle. This means that 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 (Section 1.1), 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	Multiplier if 7-m Array needed	Multiplier if TP Array needed and
7-m Array	TP			1	1.7
C43-1	7-m Array & TP	1		7.0	11.9
C43-2	7-m Array & TP	1		4.7	8.0
C43-3	7-m Array & TP	1		2.4	4.1
C43-4	C43-1 & 7-m Array & TP	1	0.34	2.4	4.0
C43-5	C43-2 & 7-m Array & TP	1	0.26	1.2	2.1
C43-6	C43-3 & 7-m Array & TP	1	0.25	0.6	1.0
C43-7	C43-4	1	0.23		
C43-8	C43-5	1	0.22		
C43-9	C43-6	1	0.21		
C43-10	-	1			

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 C43-6), the LAS is not obtainable and will result in a validation error in the OT.

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, Band 7 up to ~ 8.5 km, and Bands 3, 4, 5 and 6 up to ~ 16 km (see Section A.2).

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 may be separated in later processing. All bands receive dual linear polarizations (X and Y).

Table A-3 summarises the properties of the receiver bands offered in Cycle 6. Details can be found in Chapter 4 of the Technical Handbook.

Table A-3: Properties of ALMA Cycle 6 Receiver Bands

Band	Frequency range[1] (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 Vapour Radiometer (WVR) measurements to correct for fluctuations in atmospheric water vapour 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.

Band 9 and 10 considerations

For Bands 9 and 10 observations, additional uncertainties will affect the data. 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 6. 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 16 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.

Owing to the complexity of the atmospheric absorption in Bands 9 and 10, calibration will be compromised (this also applies to Band 8 and the high frequency end of Band 7). Bands 9 and 10 ACA 7-m Array observations are more compromised 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. 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 3–8 – 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 16-input 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 compact 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 6 Correlator Modes, dual-polarization operation [1,2]

Bandwidth (MHz)	Channel spacing[(3)] (MHz)	Spectral resolution (MHz)	Number of channels	Correlator mode[(4)]
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). The instantaneous maximum data rate is 70 MB/s. 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 4 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.

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 5 frequency tunings per target are used, all in the same band.
- Only one pointing per target is used (no mosaics or offsets allowed).
- Only 12-m Array observations can be requested (the ACA is not offered for this mode).
- Full polarization cannot be selected.

Spectral scans are categorized as a non-standard mode, limiting the total time available for such observations.

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.

When a **Dual Polarization** setup is used, separate spectra are obtained for the cross-correlated parallel hands (XX and YY). These will give two largely 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 √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.

Full Polarization measurements are non-standard, limiting the total time available for such observations. Sources 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%(1%) for compact sources and 0.3%(3%) for extended sources for TDM(FDM) observations, respectively. The minimum detectable degree of circular polarization is 1.8% of the peak flux for both TDM and FDM observations. **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).** Full polarization is not offered for spectral scans or mosaics. 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 any frequency setting within Bands 3, 4, 5, 6 and 7 is allowed, and the spectral setup has to be the same for the polarization calibrator and the science target.

It should be noted that Full polarization observations require about three hours of parallactic angle coverage for proper calibration. SGs with properties that lead to a total observing time estimate that is less than three hours will have the time estimate set to three hours to ensure sufficient parallactic angle coverage.

Table A-5: Default frequencies for Continuum Polarization Observations[1]

Band	spw1 (GHz)	spw2 (GHz)	LO1 (GHz)	spw3 (GHz)	spw4 (GHz)
3	90.5	92.5	97.5	102.5	104.5
4	127.0	129.0	134.0	139.0	141.0
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 optimise spectral performance, and they are centred 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 high 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° or higher than +20°. The adopted upper declination limit for ALMA is ~+47° (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 ~+37-47° declination).

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 centre, the length, width and orientation of the field, and a single spacing between the pointing centres. 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. Individual mosaics will not be combined during post-processing.

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

For each field source one or more pointings can be defined at a position of PI's choice and all must overlap i.e. they must form a single mosaic without gaps. These are often referred to as "custom mosaics" and are subject to 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. These changes will make the proposal non-standard (see Section 4.2). 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 ~100 for the ACA and the 12-m Array compact 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?".

A.9.2 Flux accuracy

Absolute amplitude calibration will be based on observations of objects of the known flux density of eight Solar system objects and a set of 40 quasars whose flux density are monitored every 15 days. It is expected that the accuracy of the absolute amplitude calibration relative to these objects will be 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. 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. Proposals that request higher accuracies may be rejected on technical grounds. For Band 5, a spectral dynamic range limit of 500 may be assumed, but users should note that this has not yet been verified.

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. For the standard calibration with average phase conditions, the typical image registration accuracy is ~ (angular resolution)/20.0 but with a minimum of 0.003", without special calibrations. This assumes that the S/N ratio of the target image is at least 20:1 to reach this accuracy. For projects for which measuring the position of an object or its motion over a period of time is a main goal, recommendations for Cycle 6 are:

- Choose a calibrator with a VLBI position as close to the target as possible, using spw and polarization averaging for weaker calibrators.
- Confirm the observations contain a secondary calibrator of known position (and justify it in the Technical Justification), so its measured position after normal calibration is an indication of the astrometric accuracy of the observations.
- Choose the observing frequency and configuration to maximise the astrometric precision of the target, based on its angular size and spectral properties.
- If the desired astrometric precision is better than about 0.003" rms, then multiple calibrators should be observed. Further details and guidelines are given in Chapter 10 of the Technical Handbook. Proposers are also encouraged to discuss the experiment with their local ARC.

A.10 Time-constrained observations

Observations of monitoring 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.
- Programmes 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 three most compact configurations (maximum baselines less than 500 m; see configuration schedule in Section 4.3.3). There will be no dedicated "solar campaign" during those configurations, but the observations may be executed at any time.
- 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 minimise 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 one of the three most compact 12 m configurations (see Section A.2).
- 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^{o} 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 7 minutes for Band 3 and 10 minutes for Band 6.
- 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 and 6 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 centred 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 6 and so autocorrelation measurements will not be available.

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

Band	spw1 (GHz)	spw2 (GHz)	LO1 (GHz)	spw3 (GHz)	spw4 (GHz)
3	93.0	95.0	100.0	105.0	107.0
6	230.0	232.0	239.0	246.0	248.0

- Simultaneous observations with Bands 3 and 6 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, the on-line WVR phase correction will not be applied and the off-line WVR correction for on-source (Solar) data is 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 and 6, 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 programmes in coordination with the other facilities in the VLBI network and so that VLBI experts are available to help with programme 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.
- Due to the need to phase up on the target source, only targets with 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.

- 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 centred on the frequencies shown in Table A-7 below.

Table A-7: Observing Frequencies for Cycle 6 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. Therefore, 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 2018 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 1 mm VLBI proposals to the EHTC network for technical assessment. Thus, proposers do not need to send their proposal to the EHTC.

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 and B.6 point to specific items that need justification for Solar and VLBI 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 5.2.2), 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 synthesised 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 6 for the different ALMA bands are given in Appendix A (Section A.9.3); an informative message will appear 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 of the more compact ALMA configurations (C43-1 to C43-3) is excellent (see Section 7.5 of the Technical Handbook), it is still reasonably good for C43-4 to C43-6, but for the longer baseline configurations (C43-7 to C43-10) the *uv*-coverage is quite sparse even with 50 antennas. As such, more observing time must be spent to "fill in" as much as possible the missing *uv*-coverage. 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 favoured during scheduling in order to maximise *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 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 7-10 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 (~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 programmes 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 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. Programmes 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 taking into account the phased ALMA array.

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.

Due to the need to phase up on the target source, only targets with 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 following on-line 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.

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 Millimetre 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
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 Vapour
QA2	Quality Assurance Level 2
SB	Scheduling Block
SCO	Santiago Central Office
SG	Science Goal
S/N	Signal-to-noise
SnooPI	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 Vapour 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 Centres/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

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of the European Organization 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 is funded by ESO on behalf of its Member States, by NSF in cooperation with the National Research Council of Canada (NRC) and the National Science Council of Taiwan (NSC) and by NINS in cooperation with the Academia Sinica (AS) in Taiwan and the Korea Astronomy and Space Science Institute (KASI).

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