

A Guide to ALMA Operations and Interactions with the Community

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A primary goal of the Atacama Large Millimeter/submillimeter Array (ALMA) has always been to be a facility accessible to astronomers, radio-interferometry experts and non-experts alike. As a project, it is strongly committed to listening to its users and to utilising this input in decision making and priority setting. Feedback from the community often highlights the perceived complexity of ALMA's organisational structure and, by extension, a diffuse uncertainty around how to make users' voices heard. The aim of this article is to provide insight into the functioning of ALMA as an integrated observatory, with an emphasis on science and science operations. We present information on the ways the observatory communicates with the broader community, with a focus on the mechanisms by which the community can provide feedback to the project.

ALMA organisational structure

To set the scene, below we provide a very brief overview of ALMA's organisational structure. ALMA is a worldwide

partnership^a spread over four continents, in which the European partner is ESO, representing its Member States. The three executives that jointly operate ALMA are ESO, the AUI/National Radio Astronomy Observatory (NRAO) and the National Astronomical Observatory of Japan (NAOJ). On-site operations are executed by a shared team based in Chile headed by the Joint ALMA Observatory (JAO) Director and Deputy Director and jointly supported by the executives. In contrast, all off-site activities (related to science operations, maintenance, and development) are conducted regionally, with each executive providing services and support tailored to the needs of its regional community and following the regional processes.

As one of ESO's primary facilities, off-site ALMA operations are embedded in ESO's organisational structure, within the ESO ALMA Support Centre, a Division of the ESO Directorate of Operations, working closely with the ESO Directorates of Science and Engineering. The ALMA Support Centres in the three regions provide all interactions between the regional communities and ALMA and are responsible for the execution of the ensemble of regional activities related to ALMA operations. These activities are related to science operations, computing, engineering, development, and public outreach. The heads of the three regional ALMA Support Centres, together with the JAO Deputy Director, form the ALMA Management Team (AMT). The AMT is the forum in which any issues relating to the planning and management of ALMA operations are shared, discussed, coordinated and resolved. The ultimate authority over ALMA high-level principles and policies is the ALMA Board. As the overall ALMA governing body, it is the primary forum for interactions amongst, and decisions of, the three ALMA contracting parties.

The integrated teams

One of the main challenges to the smooth functioning of ALMA is the coordination between the JAO and the regions such that effective support of operations, maintenance, and development is ensured. To this end, for each major area an Integrated Team (IXT¹) was created and tasked with executing this coordination.

Currently, there are four global IXTs: Engineering, Computing, Science, and Science Operations. An IXT dedicated to the coordination of the major ALMA system upgrades, the Integrated Development Team, is in the process of being set up. Staff in the regions and in Chile are responsible for the full distributed effort towards the goals and tasks within each IXT.

Here we focus in particular on two IXTs. The first, the Integrated Science Operations Team, or ISOpT, is tasked with defining and optimising the end-to-end workflow of science operations, from proposal preparation to data reduction and user support. The team develops and implements policies governing global science operations and is responsible for delivering the full package of science operations tasks. The ultimate goal is to provide an effective, efficient and homogeneous global user experience in order to maximise high-quality and transformational science. The team also acts on issues that are raised through various channels, including ALMA staff from the ALMA Regional Centres (ARCs) and the JAO.

The management of each IXT within ALMA is composed of one member from the JAO and three from the regions. In the case of ISOpT, this means the head of the ALMA Department of Science Operations (DSO) at the JAO and the managers of the three ARCs. In the decision making process, ISOpT usually invites input from experts and aims to reach a unanimous decision amongst the members.

Practices related to proposal preparation/submission (Phase 1), programme preparation/execution (Phase 2), project tracking, data reduction, data delivery and user support at each of these steps are all explicitly under the remit of ISOpT. It also deals with innovative improvements to observing strategies, increased pipeline reliability, data processing issues and improvements. An optimal information flow to the science community regarding science operations is another priority, as is supporting the user community through the Helpdesk, face-to-face consultations, training events and community days. Staff across the three ARCs (and related ARC nodes) and the DSO jointly carry out these tasks.

The Integrated Science Team (IST) is formed of the three regional programme scientists and the observatory scientist. Responsibilities of the IST include advising ALMA on the scientific priorities for the ALMA Development Program and providing scientific support for this programme. The IST also monitors the scientific productivity of ALMA and proposes ways to improve it. It also organises the triennial international ALMA science conference, and supports the organisation of topical or regional scientific and development meetings.

ALMA Subsystems

A primary responsibility of ISOpT is to set requirements for science software subsystems used by the scientific community and ALMA staff, and to verify that this software meets the design specifications and scientific requirements. To this end, ISOpT interacts closely with the Integrated Computing Team (ICT) in the area of software development priorities, testing, and deployment. ISOpT also oversees the testing of these subsystems and preparation of end-user documentation.

For each software subsystem, a subsystem scientist, who is an expert on that subsystem at one of the ARCs or at the JAO, leads the formulation of the scientific requirements and priorities. It is of course essential that these priorities are aligned with the overall ALMA observatory priorities. To ensure that all ALMA regions are represented in the collection and prioritisation of requirements, the subsystem scientists are supported by working groups with members from all four regions. In general, consensus must be reached in the working groups before improvements or new feature requests are raised to the implementation phase.

Amongst the numerous subsystems, some are relatively invisible to the user community, such as internal tools to track observing projects and quality assurance or scheduling, and their requirements are defined through well-established procedures within the project. Others, such as the ALMA Observing Tool, the Snooping Project Interface (SnooPI), the Science Archive, the Science Portal and the Helpdesk, interact directly with the user com-

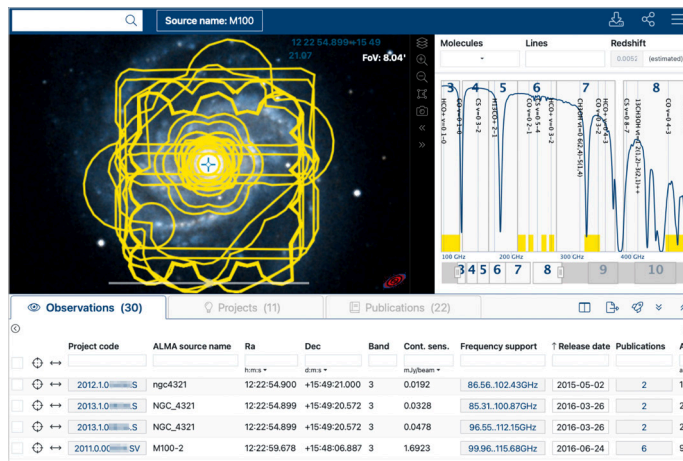


Figure 1. The redesigned ALMA Science Archive query interface provides access to all proprietary and public ALMA data.

munity and welcome user feedback as an essential facet of setting requirements. The subsystem scientist and their working group weigh the relative importance of all new feature requests and improvements and discuss solutions with the computing team, who are then tasked with their timely and robust implementation.

Three of the subsystems listed as examples above are led from the ESO ARC. SnooPI is now a very mature system and is one of the main interfaces between the user community and the observatory. Principal Investigators (PIs) and Co-Investigators (Co-Is) can log into the tool to follow their ALMA projects from the moment of proposal submission all the way to data delivery, and they can download quality assurance reports. The ALMA Science Archive is developing very fast to meet user requirements. Some recent highlights include a completely redesigned query interface, the Cube Analysis and

Rendering Tool for Astronomy (CARTA) remote visualisation and the new ALMA virtual observatory (VO) services. Finally, the ALMA Observing Tool is being upgraded to a web-based application. The current desktop tool began development nearly twenty years ago and so the upgrade will also bring it up to date in terms of the technologies used, introducing both user enhancements and easier maintainability. It should be noted that the Observing Tool upgrade, upcoming ALMA Science Archive enhancements, and the Additional Representative Images for Legacy (ARI-L²) project, which produces homogeneous imaging products for Cycles 2 to 4, are all possible thanks to the ALMA Development Program³.

Department of Science Operations

Although ISOpT is overseeing the overall global ALMA science operations, it is

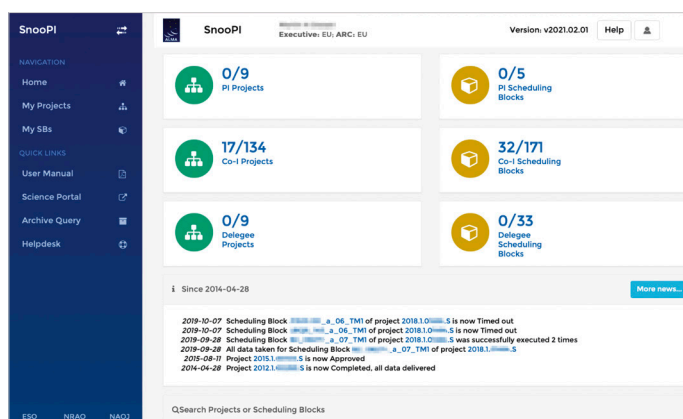


Figure 2. SnooPI allows PIs, Co-Is and Deleees to track the observational and processing status of their ALMA science projects.

important to clarify that many of the tasks within science operations are the explicit responsibility of the DSO at the JAO. This department is directly responsible for the day-to-day science operations at the telescope, including the execution of the science projects, but also troubleshoots issues with the ALMA array, acquires and processes test data, performs trend analysis of the array performance, and coordinates quality assurance. Issues related to antenna availability, configuration details (pad availability, the relocation schedule) are also within the purview of the DSO. Staff within the DSO are responsible for most of the astronomer-on-duty shifts, augmented by visits from ARC astronomers. The yearly process that makes new observing capabilities possible — known as ObsMode — is also led and coordinated by the DSO (Takahashi et al., 2021).

ALMA Regional Centres

Within the regions, ALMA science operations are organised at the ARCs. In addition to hosting a subset of the subsystem scientists, the ARCs are responsible for user support in their regions and work closely together with their colleagues in Chile and the other ARCs to deliver the science operations programme.

The ARCs also host complete mirrored copies of the ALMA Science Archive, one additional copy of which is located in Chile. It contains all raw science target and calibration data, all data products produced by the ALMA Pipeline or by manual data reduction, and quality assurance parameters. Externally contributed products (for example, from Large Programmes) will also be available in the near future. The ARCs contribute to documentation, deliver call-for-proposal and observation preparation support, and assist with enabling new capabilities (see Maud et al., 2021). Data processing and quality assurance (see Petry et al., 2020) constitute a major task as well, in addition to Helpdesk staffing.

In Europe, the ARC is uniquely organised as a distributed structure, where, in addition to the ARC department at the ESO headquarters, seven nodes throughout Europe provide enhanced services to

ALMA users. The face-to-face user support, one of the backbones of ALMA's user support structure, is fully delegated to the nodes in the ARC network. European users can receive face-to-face or virtual help from ALMA experts at each of the seven nodes. The functioning of this network is explained in detail by Hatziminaoglou et al. (2015).

One particular priority of the ESO ARC is to identify synergies with departments responsible for user support and science operations at ESO's other facilities. For example, the ALMA Helpdesk has migrated to the new service provider Deskpro. This same tool is now also employed for La Silla Paranal, which means that all ESO users will have a uniform user experience when creating tickets and interacting with support staff.

As another example, ALMA data products have now been integrated into the ESO Archive Science Portal along with data products from the ESO's other facilities. Millions of datasets can be browsed jointly through a uniform set of query items, providing a unique integrated panchromatic view of the southern hemisphere, extending from the near-ultraviolet to millimetre wavelengths. The selected data can then be downloaded from the respective portals for ALMA and ESO.

From the community to the project

ALMA is very much committed to nurturing an optimal two-way communication with its users. News from the observatory is posted on the ALMA Science Portal⁴, and in Europe this information, as well as additional ALMA news relevant to the European community, is disseminated through a newsletter⁵ that is distributed to all European ALMA users. Furthermore, most of the European ARC nodes maintain their own regional newsletters. Everything our users need to be aware of, for example information related to calls for observing proposals, data reduction, community events, and developments in capabilities, is shared through these channels, as well as via the various social media accounts.

Equally important though, is that ISO_{pT} is fully aware of its users' needs and wishes and is in touch with what the community considers important to reach their scientific goals (see Figure 3). The front-line channel for all feedback to ALMA is the Helpdesk, although in reality most information that comes to ALMA through this channel is directly related to observing programmes, for example status of observations, requests for help with data reduction. Another very important channel is provided by advisory committees, through which the community can make its voice heard on topics

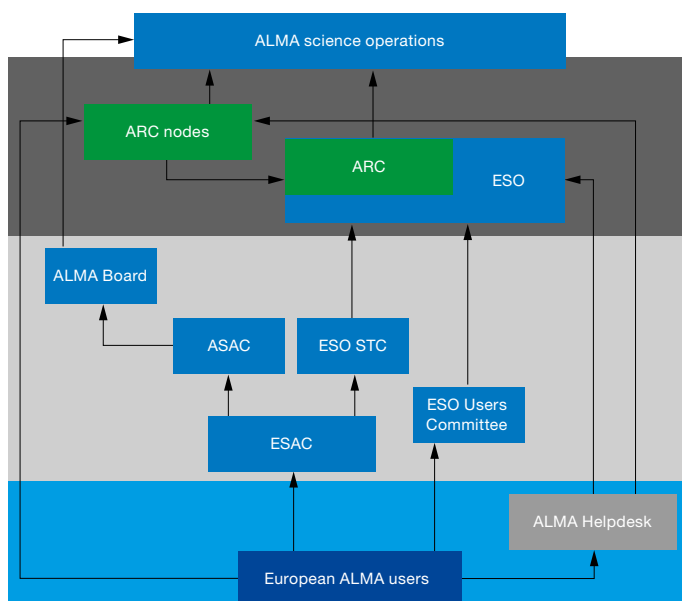


Figure 3. An illustration of how community input can reach ALMA science operations. European ALMA users can submit Helpdesk tickets, contact their ESAC or UC representatives, or communicate directly with the ARC nodes.

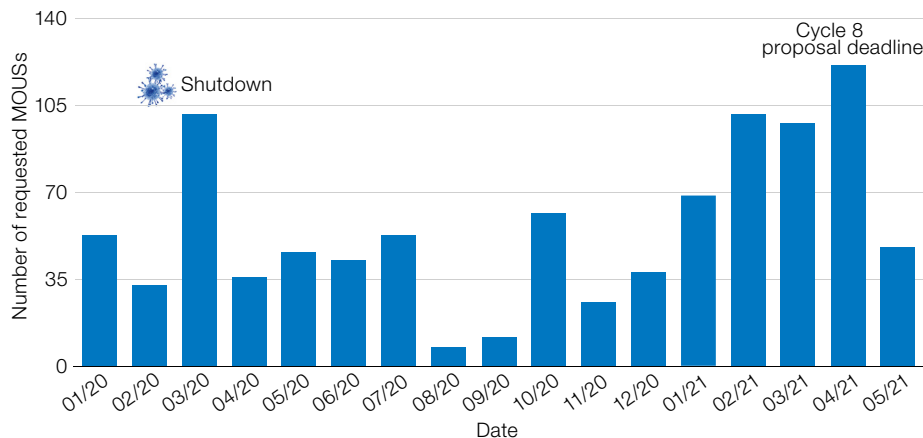


Figure 4. The number of member observing unit sets (MOUSs) that the ESO ARC delivers through its calibrated data set service, as a function of time.

related to operations, science priorities, enhancements and future development.

The European Science Advisory Committee (ESAC), a subcommittee of the Scientific Technical Committee (STC), is tasked with advising ESO on all technical and scientific matters related to ALMA. The ESAC members, all of whom are representatives of the European ALMA science community, are appointed by ESO, typically for a period of three years. The ESAC is coordinated by the European ALMA Programme Scientist, who interfaces between the committee and the ALMA activities at ESO. Counterparts of the ESAC exist also in North America and East Asia, and representatives of all these three regional committees have seats on the ALMA Science Advisory Committee (ASAC⁶), which, in turn, advises the ALMA Board. The ALMA observatory scientist coordinates the ASAC and interfaces between the ASAC and the JAO. Each of the members of the ESAC⁷, as well as the European ALMA Programme Scientist, can be contacted at any time in relation to ALMA development and science matters.

European ALMA users have yet another channel through which to have their say in ALMA priorities and directions. The ESO Users Committee (UC⁸; see also Cioni, 2019) is an advisory body that represents active European users of the La Silla Paranal Observatory, including the Atacama Pathfinder EXperiment (APEX), and ALMA. Its members are appointed for a three-year term and encompass a

broad range of scientific competences. As an example of the recommendations that are formulated, following signals from the community, the UC made a strong recommendation to ESO to implement a service that provides access to ALMA calibrated measurement sets for archive users and PIs. The ESO ARC followed up on this recommendation and implemented this service, which is now a very popular and welcome addition to the suite of services it offers (see Figure 4).

ALMA is constantly seeking out new ways of receiving feedback from, and engaging with, its user community. The latest such effort is the ongoing Re-defining the User eXperience (RedUX), a series of interviews with individual ALMA users that expressed their interest in participating, following a call for volunteers in the autumn of 2020 sent to ALMA users world-wide. The aim of this exercise is to take a holistic view of the ALMA user experience, identify issues and implement innovative solutions, in an effort to further enable high-impact science with ALMA.

Concluding remarks

ALMA is a unique project in the astronomical landscape, a large collaboration of diverse institutes and cultures, all bringing together the best of their worlds. In order to achieve one of its primary goals, i.e. the accessibility of the facility to all astronomers, regardless of their expertise, ALMA is committed to engag-

ing with its user community. This article has given an overview of ALMA's organisational structure, its functioning as an integrated observatory and the different channels available to the European ALMA users to provide their feedback and make themselves heard, helping to keep ALMA at the forefront of astronomical research.

References

- Cioni, M. et al. 2019, *The Messenger*, 176, 8
- Hatziminaoglou, E. et al. 2015, *The Messenger*, 162, 24
- Maud, L. et al. 2021, *The Messenger*, 183, 13
- Petry, D. et al. 2020, *The Messenger*, 181, 16
- Takahashi, S. et al. 2021, *ALMA Memo*, 618

Links

- ¹ The ALMA management structure: <https://www.almaobservatory.org/en/about-almathe-people/alma-management/>
- ² The ARI-L project: <https://almascience.eso.org/alma-data/aril>
- ³ The ALMA Development Program: <https://www.almaobservatory.org/wp-content/uploads/2018/07/20180712-almadevelopment-roadmap.pdf>
- ⁴ The ALMA Science Portal: <http://almascience.org>
- ⁵ The European ARC newsletter: <https://www.eso.org/sci/facilities/alm/news/arc-newsletter.html>
- ⁶ ASAC members: <https://www.almaobservatory.org/en/about-almathe-people/the-almacommittees/asac-members-list/>
- ⁷ ESAC members: <https://www.eso.org/public/about-eso/committees/stc-esac/stc-esac2021.html>
- ⁸ ESO Users Committee: <https://www.eso.org/public/about-eso/committees/uc/uc2021.html>

Notes

- ^a ALMA is a partnership of ESO (representing its Member States), the National Science Foundation in the USA and the National Institutes of Natural Sciences in Japan, together with the National Research Council (Canada), the Ministry of Science and Technology and the Academia Sinica Institute of Astronomy and Astrophysics (Taiwan) and the Korea Astronomy and Space Science Institute (Republic of Korea), in cooperation with the Republic of Chile.