

The Italian ALMA Regional Centre: status and perspectives in the ALMA WSU framework.

Marcella Massardi, Elisabetta Liuzzo and Jan Brand

INAF - Istituto di Radioastronomia and
Italian node of the European ALMA Regional Centre Network

<http://arc.ira.inaf.it>

Oct 2024

Summary

ALMA was officially inaugurated in March 2013. Our previous reports, “Five years of Early Science and the Activities of the Italian ARC”, in October 2015, and “Ten years of ALMA - The Italian ALMA Regional Centre”, in May 2023, presented the details of activities of the Italian node of the European ALMA Regional Centre during first decade of observations of ALMA. Since then, the telescope has entered in a stage of major upgrade that is called “Wideband Sensitivity Upgrade” (WSU), that aims at maintaining the transformational level of science achieved by ALMA in its first ten years for the next decades.

In this document we summarize the achievement of the Italian node towards supporting, expanding and educating the astronomical community, as well as towards the ALMA project, updating the previous documents, and draft the expectations for operations and community growing activities for the next few years during the WSU. We will also foreseen some operational perspectives offered by the synergies of ALMA WSU with other new facilities for the Italian astronomical community.

Contents

1	ALMA and ARC basics	3
2	Italian ARC	3
3	The Italian ALMA community	4
4	Resources and (wo)manpower	6
5	The Italian ARC nodes activity in the WSU framework	7

1 ALMA and ARC basics

The Atacama Large Millimeter/submillimeter Array (ALMA) is a partnership of Europe, North America and East Asia, in cooperation with the Republic of Chile. ALMA is operated by the Joint ALMA Observatory (ESO, AUI/NRAO and NAOJ). ALMA started operations in 2011 with so-called *Early Science* observations. Full operational/science status was reached in 2016 (Cycle 4) and more than 40 antennas in the main array, 10 7-m antennas in the Atacama Compact Array (ACA) and three 12-m dishes in the Total Power (TP) Array, have been offered to observers ever since.

Observing proposals can be submitted (typically) once per year in Spring, in so-called Cycles and observing time is assigned on geographical basis according to the quotes reserved to the Partners. Over the years the number of hours offered for observations has increased from 500-700 in Cycle 0 to 4300 hrs (on each of the arrays) in Cycle 10. Maximum baselines went from 400 m to 16 km, and VLBI observations are also possible, as well as joint proposals with JWST, VLA and VLT. The Telescope can observe in 9 spectral bands from band 1, starting at 35 GHz, to band 10, ending at 950 GHz. A 10th band (namely “band 2”) is being realized, also with INAF involvement: it is currently under review and will soon start the commissioning stage. Spectral resolution to date is a compromise with spectral coverage, with extremes as high as 0.03MHz over 58.6 MHz bandwidth or as low as 15.6MHz over 1857MHz bandwidth.

The interface between ALMA and the astronomical community during the lifetime of the projects and for the archival legacy is provided by the three Partners through the ALMA Regional Centers (ARCs). In Europe the ARC is located at ESO in Garching, Germany, and a Memorandum of Understanding (MoU) established the roles, duties and area of operations of a network of 7 local ARC nodes (Czech, Dutch, German, IRAM, Italian, Nordic, UK; Hatziminaoglou et al. 2015) coordinated by the central node at ESO. The Italian node is located in Bologna, hosted by the INAF-Istituto di Radioastronomia, and financed yearly by the INAF Scientific Directorate.

2 Italian ARC

The Italian ARC node provides support to the Italian community of potential novice and expert users of ALMA, and to the ALMA project itself through several areas of intervention (see fig.1).

According to the MoU, for each ALMA approved project with Italian Principal Investigators (PI) we act as Contact Scientist, i.e. the point of contact between PI and the ESO-ARC for the entire lifetime of a project. We also see it as our duty to bring together the existing community of astronomers working in (or making use of observations in) the (sub)mm-field, to facilitate collaborations and to make this community grow organizing ALMA Proposal Days and bi-yearly Italian mm-conferences, and organise tutorials on various topics (visit our website for a complete list <https://arc.ira.inaf.it/events>). An important aspect of increasing the size of the community is to ignite interest in new generations of astronomers. We address this in two ways: direct education through involvement in University courses, lectures and seminars, and supervision of students for their Master and PhD theses; we have also participated in, or co-organised, Scuole Nazionali di Astrofisica, lecture series on subjects requested by doctoral students and Training Network Schools.

We contribute to the functioning and development of ALMA user tools and facilities. Our activities towards the ALMA project itself are variegated, but always aimed towards an improved operability of the array, assurance of fast delivery of reliable data to the PIs, and creating new opportunities for

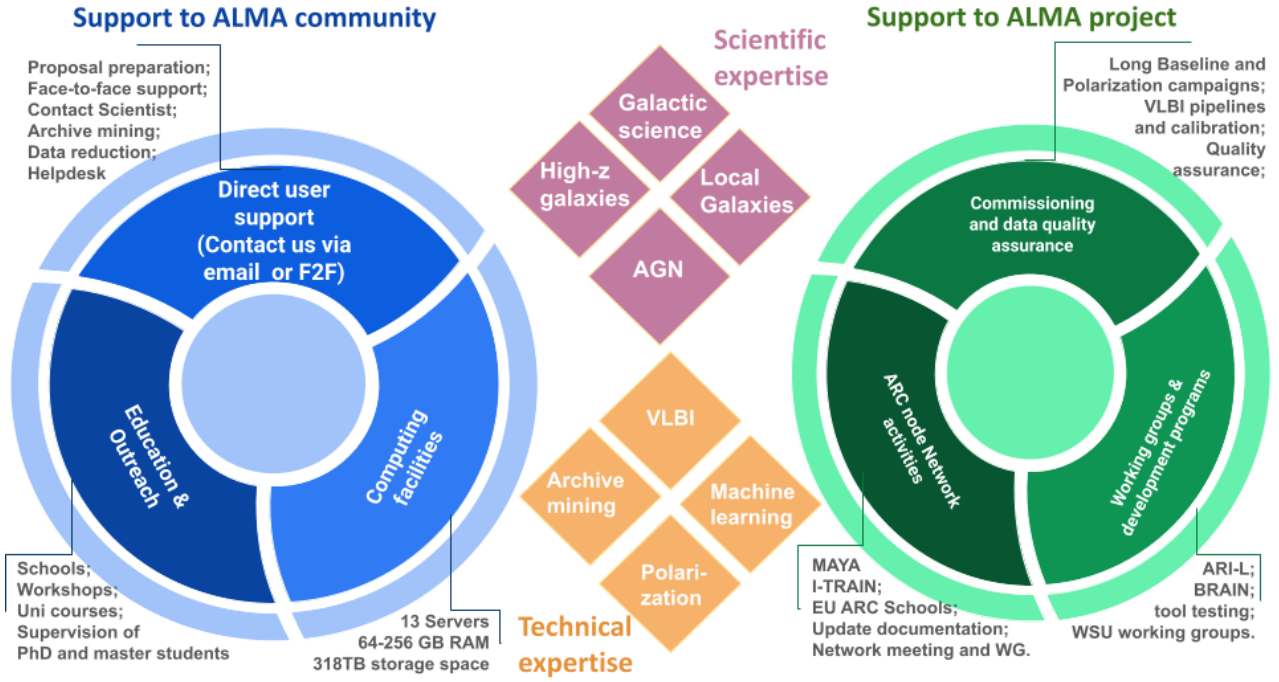


Figure 1: The main areas of activities of the Italian ARC-node in a nutshell.

users to make scientific use of ALMA. We thus participated in: science verification observations and data reduction campaigns; improving the calibration of polarisation data, and in reviewing and testing new polarisation capabilities offered; ALMA Science Archive (ASA) exploitation (such as ARI-L, an independently financed ALMA Development Plan to re-image a large number of projects from Cycles 2-4, led by our node; Massardi et al. 2021); testing tools and editing ALMA official documentation (e.g. the ALMA Archive Primer is edited yearly by our node). We furthermore contribute to the functioning of ALMA, by taking shifts as Astronomer on Duty on-site, and performing quality assurance of the data before they are made available to the PIs (the so-called QA2, and weblog review, in particular for projects in VLBI and full-Stokes polarization observing modes).

Detailed description of our activities is included in the past reports, “Five years of Early Science and the Activities of the Italian ARC”¹, in October 2015, and “Ten years of ALMA - The Italian ALMA Regional Centre”², in May 2023, and on the ARC’s website at <http://arc.ira.inaf.it>.

3 The Italian ALMA community

Figure 2 recollects some statistics on submitted and accepted proposals with Italian PIs. We compare the trends with the behaviour of global submitted and accepted proposals for ALMA. The Italian community grow-up in the first 3 cycles to the global trend and remained aligned along the years. The oversubscription rate (i.e. the ratio between submitted and accepted proposals, the inverse of the success rate) in Italy is 4.1 combining all the cycles, and was 4.6 in the last cycle. That is comparable with the value of 3.0 of the global oversubscription rate (3.3 in the last cycle) and among the best (i.e.

¹<http://www.alma.inaf.it/images/ItalianARCnode-stats-220616.pdf>

²<https://arc.ira.inaf.it/wp-content/uploads/2024/02/Italian-ARC-status-2023.pdf>

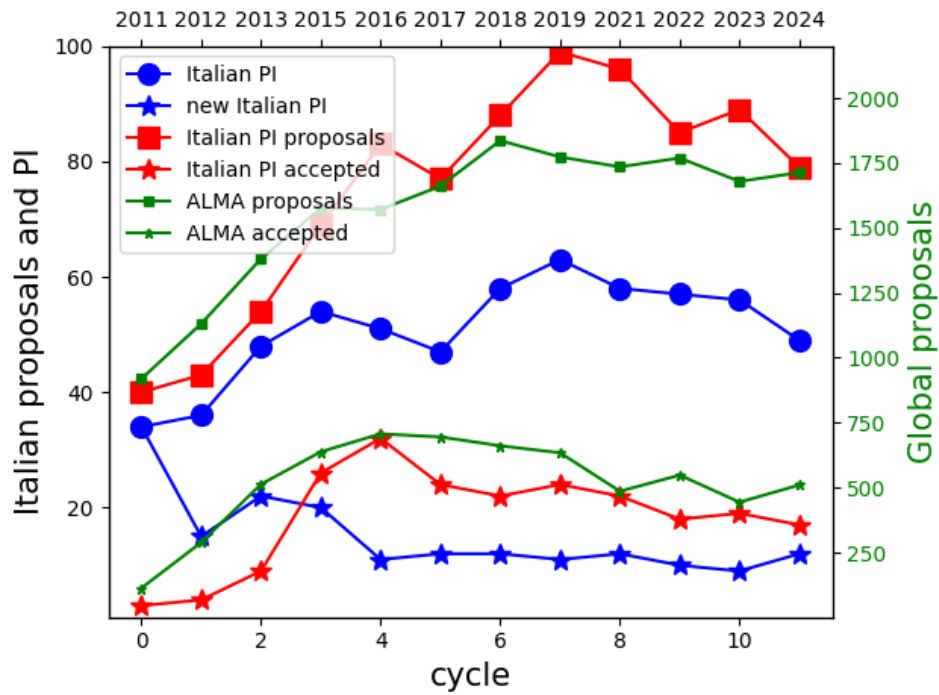


Figure 2: Statistics on submitted and accepted proposals (red squares and stars, respectively) with Italian PIs (blue dots). For comparison we show the trends of submitted and accepted proposals for ALMA (green dots and stars), and the numbers of PIs that for each cycle submitted a for the first time in their life an ALMA proposal (i.e. novice users, blue stars). .

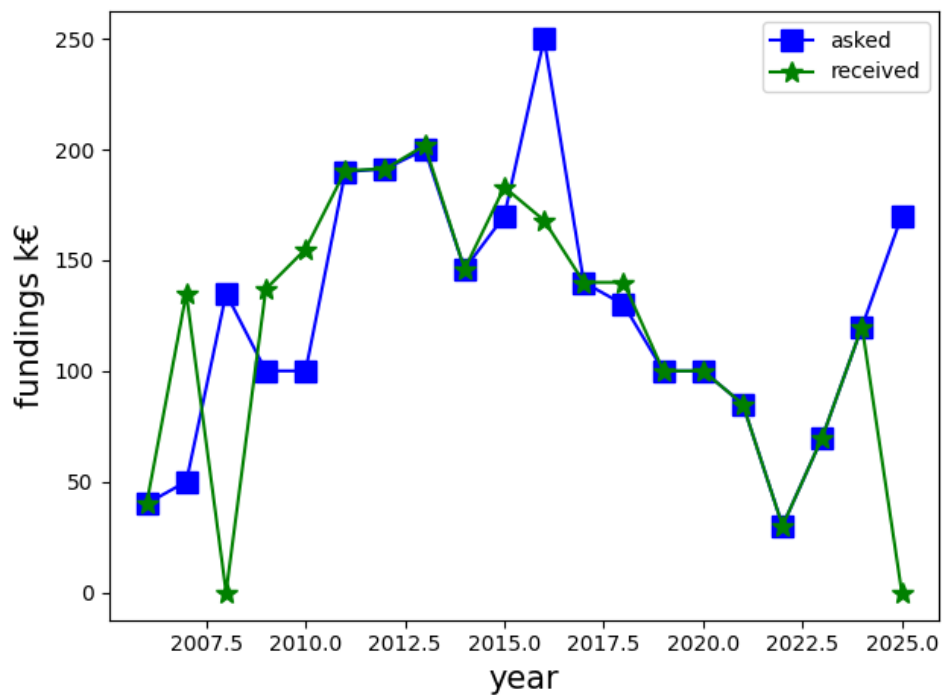


Figure 3: Comparison of requested and received fundings at the Italian ARC along the years.

most successful) in Europe where the average oversubscription is 6.3 on average over the years, and was 8.3 in the last cycle.

The number of PIs that submitted an ALMA proposal for the first time amounts to about 20% of the overall number of Italian PI since cycle 3: this is a confirmation that the Italian community is an evolving and always growing system. These trends are results of the Italian ARC activities for the Italian community. We also report the fundings received by INAF that paid the Italian ARC activities. Our involvement in other funding request and projects in particular AENEAS, EHT, and ARI-L provided additional resources. Details about them are reported in our past reports cited above.

4 Resources and (wo)manpower

More than 20 people have been among the past members of the ARC-IT. Most of them got permanent positions in INAF, in some cases leaving the ARC-IT. Currently the ARC-IT is maintained by five permanent staff members and two post-doctoral fellows. Long-term stability for the staff members guarantees to preserve and enhance the experience thus far developed addressing ALMA and community issues. The team is organised as follows:

Marcella Massardi : since Oct 2023 coordinator for the finances and personnel, and the principal contact with ESO; expert in archive mining (From 2011 to 2023 ARC-IT manager, Primo Ricercatore since 2024);

Elisabetta Liuzzo : since Oct 2023 manager for the day-to-day running of the ARC-IT; expert on mm-VLBI (member of the ARC-IT since 2013, Ricercatore III livello since 2018);

Rosita Paladino : expert on polarisation and ALMA calibration (member of the ARC-IT since 2011, Ricercatore III livello since 2016);

Kazi Rygl : expert on mm-VLBI (member of the ARC-IT since 2015, Ricercatore III livello since 2020);

Nicola Marchili : expert on pipelines (member of the ARC-IT since 2017, Ricercatore III livello since 2022);

Matteo Bonato : expert on synergies with other telescopes (member of the ARC-IT since 2017, TD since 2021);

Ivano Baronchelli : expert on imaging and machine learning techniques (member of the ARC-IT since 2022, TD since 2023);

Jan Brand : former responsible of the ARC (between 2005 and 2023), currently quiescent, emeritus member.

The typical size of an ALMA dataset is ~ 1 TB. Calibration is nowadays mostly performed with a dedicated pipeline. Imaging is performed to certify the data quality to guarantee that they could achieve the scientific goals estimated by the PI and to provide previews for the ALMA Science Archive. Users usually reprocess the data and refine the imaging for their scientific purposes. To allow for this activity we maintain a dedicated computer cluster (13 servers with 64–256 GB RAM and ca. 160 TB local work disk storage [typically 10-15 TB per server], and 318 TB of external storage space).

5 The Italian ARC nodes activity in the WSU framework

The “ALMA Development Program: Roadmap to 2030” (Carpenter et al. 2020) describes the main areas to drive the development over the next decade.’ The new driving goals aim at investigating origins of planets, chemical complexity, and galaxies that requires the expansion of the instantaneous bandwidth to achieve higher sensitivity in shorter time, also at the highest spectral resolution, over broad spectral ranges. This requires the refurbishment of the correlator and of the receivers. All the subsystems (from cables to data management and archive) will be upgraded in the framework of the so-called “Wideband Sensitivity Upgrade” (WSU, Carpenter et al. 2022).

The current correlator allows a maximum bandwidth of 8 GHz and a fixed number of channels, so that a higher spectral resolution translates in a narrower bandwidth. By 2029, in the first stage of upgrade, the new correlator will increase the instantaneous bandwidth to 16 GHz whatever is the resolution, with an increasing number of channels as the resolution increases. The new receivers will allow up to 32 GHz of instantaneous bandwidth that is the final goal both for the receivers and the correlator in the second stage of the upgrade, after 2030. In addition, an improved digitalization will increase the instantaneous sensitivity per channel by factors of at least 3. It is estimated that all the datasets will increase their size reaching a typical size $\sim 1 - 10$ TB. For up to 10% the increasing size factor will be as high as 100 with some projects reaching the size of some PB. For comparison, the current volume of the whole ALMA archive after 11 years of activity is 2 PB. This requires new pipelines, with HPC capabilities. The data management scheme, at least in the early stages will remain the same, with the telescope delivering quality assured raw data and a pipeline for processing, but the calibration and imaging will fall to the users, supported by the ARC network facilities.

The Italian ARC is involved in the WSU working groups that are working

- to the definition of the new pipeline;
- to the analysis of the user needs and planning of future interfaces;
- to foresee the new archive properties and architecture.

New skills will become relevant, including big data management techniques, machine learning and statistical approaches. Our staff is already involved in BRAIN, an ESO-lead development project (PI: Fabrizia Guglielmetti) that is exploiting Bayesian approach and machine learning techniques to improve the cleaning of images in shorter times with respect to what is currently typically used.

In order to provide support to the Italian community we are also already investigating upgrades of our computing and storage resources to anticipate the telescope upgrade and offer the right resources to the community in due time.

The current capabilities of the Italian ARC cluster will soon be enough only for the smallest projects, while more efficient structures are needed for the largest ones. It appears reasonable to consider the ongoing development of INAF capabilities at the Bologna Tecnopolo: it is not only logistically favourable, but also, given its goals for SKA data management, it is expected to be able to address tasks similar to those needed by ALMA, and even on larger data volumes. ALMA WSU resources needs, even if larger than the current ones, will certainly be orders of magnitude smaller than those necessary for SKA. However, the WSU implementation is expected on timescales shorter than SKA ones, and for a mature facility, so that it will be a perfect testbench for the development of INAF resources on simple and well defined science cases, with immediate feedback.

The experience of the Italian ARC node staff in training the ALMA community could easily be exploited to reach and prepare both the Italian ALMA and SKA communities and maximize the efficient exploitation of the Tecnopolo resources.

The new data sizes require about 1PB of warm storage to share among our community for periods as long as 1 year and up to 2 PB of long/term storage to distribute upon request. Computing requests are under evaluation, also in collaboration with the responsables of the INAF Tecnopolo resources deployment.

The Italian ARC guarantees support with all new features and capabilities and is therefore itself also adjusting and acquiring new expertises. We are thus evaluating that the current Italian ARC staff skills must be enforced by hiring new personnel with expertises in data management, advanced HPC techniques and multi-wavelength research.

By the end of the WSU in 2030 ALMA will be a brand new telescope that will serve the scientific community for the following 10-15 years guaranteeing new transformational discoveries. The ARC network, and the Italian ARC within it, will retain its role of supporting the community, and preparing the new generations of researchers to face the technical and instrumental challenges and stimulate the scientific exploitation of this powerful instrument.

References

- Carpenter J., Iono D., Kemper F., & Wootten A. 2020, Mon. Newslett. Internat. URSI Commission J - Radio Astronomy, January 2020
- Carpenter J., Brogan C., Iono D., & Mroczkowski T. 2022, ALMA Memo 621 (arxiv: 2211.00195)
- Hatziminaoglou E., Zwaan M., Andreani P., et al. 2015, The Messenger 162, 24
- Massardi M., Stoehr F., Bendo G.J., et al. 2021, PASP 133, 085001