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Scope

The scope of this document is to provide a brief description of the [Atacama Millimetre/submillimetre Array \(ALMA\)](#) and the [Very Large Telescope Interferometer \(VLT\)](#) user support structure and procedures. ALMA user support here refers specifically to the support of the European ALMA users, although similar services are offered to the ALMA users in the other ALMA regions, i.e. North America and East Asia.

1 Support to European ALMA users via the European ARC network

1.1 The European ALMA Regional Centre

The [European ALMA Regional Centre \(European ARC\)](#) is the interface between ALMA and the user community in the ESO Member States. It is set up as a network of seven ARC nodes and the Central ARC at ESO, together providing ALMA user support in the ESO Member States and general ALMA operations support. The seven nodes are located in [Bonn-Cologne \(DE\)](#), [Bologna \(IT\)](#), [Onsala \(SE\)](#), [IRAM-Grenoble \(FR\)](#), [Leiden \(NL\)](#), [Manchester \(UK\)](#) and [Ondrejov \(CZ\)](#), and the Central ARC is located at the ESO headquarters in Garching (DE). This Central ARC is a department within the ESO ALMA Support Centre (EASC) division.

The European ARC is the point of contact for ALMA users in the ESO Member States throughout the life-cycle of ALMA observing projects: from the moment of proposal preparation through to the data delivery and analysis. The Central ARC is responsible for the delivery of data to principal investigators (PIs), the maintenance and development of the ALMA data archive, and the provision of feedback on the software relevant for ALMA science operations.

Important decisions within the ARC network (used as an alternative definition to ‘European ARC’ to emphasise its network character) are taken by the ARC Coordinating Committee (ACC) based on consensus. The ACC consists of the representatives of each node, the ARC department head and deputy head and the ARC network coordinator. A number of interfaces between the ARC at ESO and the ARC nodes are in place such as web and confluence pages, telecons, mailing lists and face-to-face meetings, and they are the basis for intense and regular communications within the network.

1.2 The European ALMA user community

The European ALMA user community has been growing steadily ever since the announcement of Cycle 0 ALMA observations in 2011. The evolution of the number of European ALMA users (defined as the users with the European ARC defined as their “preferred ARC” in their ALMA user profile in the ALMA [Science Portal](#)) is seen in Fig. 1. The steady growth is in large part due to the user support services offered to the ALMA users, that renders the facility accessible not only to the traditional European (sub)mm community but to astronomers from other wavelengths, as well.

At any given ALMA cycle, a fraction of the registered ALMA users is engaging in proposal preparation. Since 2018 (the period encompasses three ALMA observing Cycles as well as two Supplemental Calls for the stand-alone use of the Atacama Compact Array) 4019 unique PIs and co-Investigators (CoIs) supported by the European ARC submitted ALMA proposals. Of those, 1877 were unique PIs and CoIs of approved ALMA proposals in the same period of time.

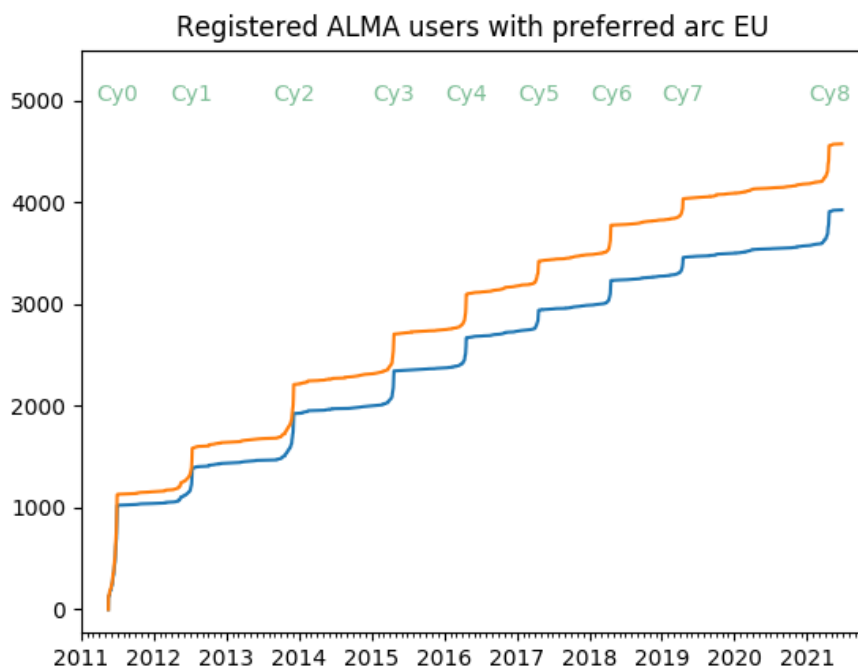


Figure 1: The growth of the European ALMA community since ALMA Cycle 0. The blue line traces users with a European affiliation as recorded in the ALMA User Registry, the orange line includes users from Chile and regions that do not belong to any of the ALMA executives but have selected Europe as their preferred ARC for support.

1.3 Functions provided by the European ARC network

The European ARC is responsible for the provision of a number of functions towards the community in the ESO Member States. Most of these functions are jointly carried out at the Central ARC and at the nodes. Some of them, however, are the responsibility of the Central ARC, while some others have been explicitly delegated by ESO to the ARC nodes.

1.3.1 Support functions provided primarily by the Central ARC

- **Phase 1:** Preparation of end-user documentation (call for proposals, proposers guide, etc) and assistance in coordinating the proposal review process.
- **Phase 2:** Preparation of the Scheduling Blocks (SBs) for non-standard observing modes and checking of SBs for standard observing modes.
- **Data delivery:** Delivery of the final raw and pipeline-reduced data to the PIs.
- **Archive operations:** The Central ARC hosts a complete synchronised copy of the ALMA archive and ensures its seamless operation.

- **Science Portal:** Participation in the ALMA Science Portal development and maintenance.
- **Helpdesk:** Handling of Helpdesk queries of all ALMA users of the ESO community on all user support matters including distribution of the user requests for face-to-face meetings in the ARC nodes.

1.3.2 Support functions provided primarily by the ARC nodes

- **Personalised user support** for proposal preparation and data reduction is one of the cornerstones of the ARC node structure and it is explicitly delegated to the ARC nodes by ESO. Face-to-face data reduction support can range from basic assistance in the usage of data reduction tools to advanced support in understanding ALMA data to archival mining. For standard observing modes, ALMA users can obtain the same level of high-quality user support from every node but every ARC node commits to providing face-to-face support to their local community or “catchment area”;
- **Phase 2 participation:** Contact Scientist assignments for every approved ALMA project with a PI with a European affiliation (including Large Programs) are also explicitly included in the functions of the ARC nodes.
- **Scientific community development:** Organisation of workshops and schools and any other support and/or educational initiatives for users.

1.3.3 Observatory support provided by the ARC network at large

- **Quality assurance (QA2) of science data sets** consists of verifying that the frequency setup, spatial resolution and continuum and line detection sensitivity requested by the PI have been achieved. In times of very high ALMA operations workload at the Joint ALMA Observatory (JAO) in Chile, QA2 can be carried out in the ARCs. When necessary, ARC nodes work (on a best effort basis) in close collaboration with the Central ARC on data reduction and quality assurance of datasets of primarily PIs from the ESO community.

1.3.4 Enhanced user support functions provided jointly by the ARC network

ARC nodes voluntarily and on a best-efforts basis provide further services from among those listed below.

- **Additional Phase 1 tasks:** Contributing to periodical updates of technical user documentation and the review of other documents related to the Calls for Proposals.
- **Science Verification (SV) data reduction:** SV data reduction is done collaboratively between JAO and the three ARCs in Europe, North America and East Asia.
- **Advanced data reduction:** Support of large and/or complex datasets requiring non-standard analysis techniques and the utilisation of the advanced algorithms and software developed by the nodes.
- **Pre-release testing of end-user software subsystems,** namely the Observing Tool (OT), the offline system (data reduction), the pipeline (automatic data reduction), the archive, the Snooping Project Interface (SnooPI) and the Helpdesk.

- **QA3 process of PI data:** Problems that are found by the users after data delivery are resolved in collaboration with JAO.
- **Development and maintenance of new software and techniques** and update of the other ARC nodes and the Central ARC on the related progress.
- **Archive mining support:** Supporting users from the ESO Member States with the exploitation of the ALMA science archive.
- **Community outreach:** In coordination with the ESO Education and Public Outreach Department, whenever necessary.

1.4 Funding and Resources

Funding for the ARC nodes is sought from their own local funding agencies. Additional funding proposals involving multiple ARC nodes plus the Central ARC (for instance for European Commission funding for networks) are coordinated by the ACC. The ACC also seeks funding to support travel of ALMA users to the ARC nodes. If required, funding applications are supported by ESO by providing statistics, documents or letters of support.

The Central ARC and the ARC nodes employ staff members with contracts with varying fractions of ALMA duties. Currently there are of the order of 63 people employed throughout the network (including the ARC at ESO and the nodes), with a total allocation dedicated to the observatory and user support, as described above, of about 25 full time equivalent (FTE). A rough estimate of the amount of FTE allocated to user support tasks is about 2/3s of that. A substantial fraction of user support FTE allocation goes into face-to-face support. In the pre-pandemic era an average of 60 face-to-face visits were recorded every year, 80% of which was dedicated to data reduction and analysis, the remaining to proposal preparation and archive mining. The real number of these visits was higher and included more informal interactions of node staff with members of their local communities or host institutes.

Part of these visits were funded by Network Activity MARCUs (Mobility for ALMA Regional Centre Users) of the RadioNet project – Advanced Radio Astronomy in Europe – Horizon 2020 (2017-2020, grant agreement No 730562) and RadioNet 3 FP7 (2012-2016, grant agreement No 283393).

1.5 The effect of the pandemic on ALMA user support in Europe

During the pandemic, all ARC nodes as well as the ESO ARC reverted to work-from-home. Each of the nodes rapidly adopted virtual ways of interacting between the staff; ARC-node network wide, monthly videoconferences continued as before, but now also the yearly manager meetings and all-hands meetings adopted a virtual format. Continued interaction with the ALMA community in Europe was ensured through virtual community meetings, where interested users were updated on the situation at ALMA and the ways in which user support continued. To continue the user support that often was done face-to-face before, many nodes set up virtual environments employing different platforms, to collaboratively work on a single data set (VNC sessions, sharing desktops, etc), all with an acceptable outcome. It is expected that some level of virtual support will continue in the future, since it lowers the threshold for information sharing and user support. The ARC node network had an added advantage during

the pandemic, that each node could adapt the *mechanics* of their support to the needs of the individual community, which differed because of different pandemic restrictions between countries.

2 Support to VLTI users via the Eii

2.1 The Eii

The [European Interferometry Initiative \(Eii\)](#) is an open association of Institutes and Laboratories willing to collaborate in the exploitation and development of optical long baseline interferometry in optical/infrared astronomy. The Eii confederates the activities included in the European Commission instruments of the 6th, 7th and H2020 R&D program, including the most recent ORP. The current Eii activities are:

- The establishment of a network of VLTI expertise centres across Europe.
- A joint activity enabling access to new VLTI capabilities
- The Fizeau staff exchange programme.
- The organisation of VLTI training summer schools and VLTI open days.

The Eii operates in close articulation with ESO (cf. Section 2.3.3), the organization providing the VLTI infrastructure.

2.1.1 The VLTI Expertise Centres

Structured development of optical interferometry requires leaping towards a European network of VLTI Expertise Centres (VECs) in close articulation with ESO. These centres are the backbone of dissemination activities to new VLTI users, by organising observing preparation and [data reduction schools](#), by co-organising with ESO VLTI open days, and being the end-points of the [Fizeau staff exchange programme](#).

The leap aims at bringing the impact and return of the programme in spreading know-how in Europe to a new level. It follows at a smaller scale the successful experience of the ALMA Regional Centres, where researchers travel to the expertise centres to reduce their data. The centres will be the visible first contact point for astronomers interested in using VLTI.

The present network of VECs includes three partners from the OPTICON Horizon 2020 networking activity:

- [Jean-Marie Mariotti Centre \(JMMC\) - Service aux Utilisateurs du VLTI](#), (SUV) France - a structure that aggregates manpower from different observatories, namely: The [Observatoire des Sciences de l'Univers de Grenoble](#) (OSUG), the [Observatoire des Sciences de l'Univers de Lyon](#) (OSUL), [Observatoire de Paris-Meudon](#) (OPM) and the [Observatoire de la Côte d'Azur](#) (OCA);

- The [Portuguese VLTI Expertise Centre](#) in Portugal and
- The [University of Exeter](#) in the UK;

one interferometry JA (Joint Activities; WP8) lead partner, namely the [KU Leuven](#) in Belgium; and two new nodes from the [OPTICON/RadioNet Pilot](#) (ORP) program, namely the [Leiden Observatory](#) in The Netherlands and the [Konkoly Observatory](#) in Hungary.

Visitors wishing to travel to the above centres to reduce their VLTI data or prepare observations are encouraged to use the Fizeau Programme.

2.2 The VLTI user community

For the past 15 years, about 350 unique PIs applied for VLTI time. In the past 4 years, ~150 unique PIs and ~550 unique CoIs have applied for time, which represent about 700 astronomers. Regarding accepted proposals, there have been 86 unique PIs and 385 unique CoIs (non-PIs) over the past 2 years, hence 471 unique people. The number of astronomers who will directly deal with VLTI time application and data is closer to the number of PIs than the total number of PI+CoI. These figures can be compared with the ALMA community:

One can track the fraction of PIs who authored a proposal for Guaranteed Time Observation (GTO), or track those that were a CoI on a GTO proposal, as a metric for the expertise of the community. Compared to other VLT instruments, VLTI shows the clear trend that the community of early users of instruments are dominated by the GTO team (i.e. the people who build the instrument and who are experts).

As seen on Figure 2, VLTI instruments tend to have a smaller community of users with a larger fraction of the GTO team, compared to other VLT instruments. In other words, the VLTI community does not grow outside the core GTO members as much as other VLT instruments do.

Various polls in the past years have shown that even if VLTI users represent only a fraction of the total number of VLT users (10 to 20%), the number of astronomers interested in the VLTI for their research is much larger. The most cited reason not to apply for time is the complexity of the technique and the lack of expertise. Roughly doubling the community of users, by adding non-GTO members, would bring the VLTI community on par with VLT instruments in both terms of size and fraction of non-experts. This potentially represents a large number of new users (of the order of 100) to welcome and support.

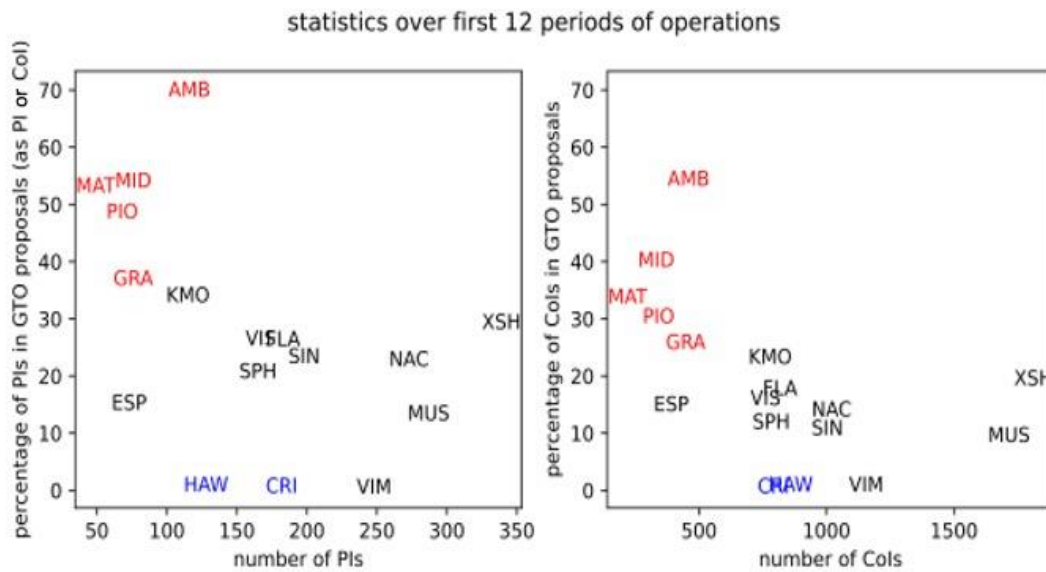


Figure 2: Fraction of GTO team members as PIs (left) and CoIs (right) of accepted proposals as function of the total number in the first 6 years of operations. VLT and VLTI instruments are represented by their first three letters. In red are 1st generation (MIDI, AMBER) and 2nd generation (PIONIER, GRAVITY and MATISSE) VLTI instruments. In Blue are instruments built by ESO (no GTO). It should be noted that MATISSE and GRAVITY (as well as ESPRESSO) have not been in operation for 6 years, at the time this plot was made (2021).

2.3 Functions provided by the VECs

The VECs are responsible for the provision of VLTI support towards the VLTI community in Europe in close articulation with ESO. In particular the VEC provide support to non-ESO Member States, and one of the VECs is located in a non-ESO member state (Hungary). Most of the support is jointly carried out at the VECs. However, several centres have gathered strong expertise in one or more instruments, techniques and/or astronomical sources.

2.3.1 Transversal Support/Dissemination functions provided by the VECs

- **Helpdesk:** Handling of Helpdesk queries (JMMC-based) of all users of the VLTI community on all user support matters including distribution of the user requests for face-to-face meetings in the VECs.
- **Personalised user support:** Provided for proposal and observation preparation and data reduction. Face-to-face data reduction support can range from basic assistance in the usage of data reduction tools to advanced support in understanding VLTI data.
- **Dissemination** by delivering presentations at international (e.g. EAS, EWASS) and national meetings, where VLTI capabilities and available support (through the VECs) are advertised, both to the general astronomer audience, as well as to key science audiences (e. g. radio community).
- **Training** by organizing specific training actions (e. g. VLTI Schools) and special sessions in meetings with a training component (e. g. EAS 22 SS29) in proposal and observation preparation and data reduction, including hands-on experience.

- **Knowledge Transfer** by organizing expertise exchange with complementary interferometry communities (e.g. Sharpest Eyes on the Sky).
- **Outreach** by organizing special sessions (e. g. VLTI Open Days) and participating in local, national and international public forums (e. g. Researcher's Night), where interesting VLTI information about the instrument and science results are brought to the general public.
- **Synergies** by organizing special sessions (e. g. VLTI Open Days), bringing together the academic (scientific, technological) and non-academic sectors to foment mutually beneficial synergies, foment networking and procure new opportunities within the VLTI.

2.3.2 Specific Support functions provided by the VECs

The user support offered by the VECs, all of which have the ESO pipelines installed on dedicated hardware, includes proposal and observation preparation, data reduction, model fitting and image reconstruction for the instruments PIONIER, MATISSE and GRAVITY, along with space for data storage. In addition to the above, several VECs have unique expertise in certain areas. More specifically, the JMMC, the largest among the VECs, also develops and maintains public software for the preparation of observations and data analysis (e.g. Aspro2, LITpro, OImaging, OITools), as well as databases (e.g. catalogues JSDC, JMDC, OIDB). Finally, it manages and maintains the OLBIN publication database. As of March 2021, and thanks to the ORP Program, the Portuguese VEC offers reduction of GRAVITY archive data in coordination with ESO, on top of the full user support for this instrument. The University of Exeter provides advice on coordinated observations with US interferometers (e.g. CHARA), while KU Leuven has a unique expertise in high-contrast signal extraction.

2.3.3 ESO support

The User Support Department (USD) of the ESO Data Management and Operations Division (DMO) is based in Garching, Germany. Its main activities consist in providing support to users of ESO facilities at the time of writing observing proposals, during the preparation of Phase 2 material, and during post-Phase 2 activities (follow-up and troubleshooting of observations, observations progress information, help with retrieval and handling of data). The ESO USD operates a helpdesk system (<https://support.eso.org>) where users can address questions and request assistance on all aspects of ESO telescope Service Mode operations¹. The support relies on collaboration with other operational units that are in charge of (i) call for new observing programmes and scheduling of observations (Observing Programmes Office), (ii) visitor mode observations support and both visitor and service mode execution and quality control (Paranal Science Operations), (iii) data reduction processing of data for selected instruments, science oversight of pipelines, archive management for raw and processed data (Back-end Operations Department). The Instrument Operations Teams monitor and maintain performance of instruments, as well as keep up to date their documentation (web pages, manuals, etc). These teams are composed of ESO staff from Chile and Germany.

¹ Since early 2021 ALMA and USD are using the same Helpdesk Vendor (Deskpro), providing thus a more uniform experience across observatories to all ESO member-state users.

2.3.3.1 Support functions provided primarily by ESO

The VLTI instruments are fully integrated into the general support of ESO facilities. Scientific oversight of the VLTI facility at ESO is led by the VLTI Programme Scientist.

- **Phase 1:** Documentation (call for proposals, user manuals, etc), Exposure Time Calculators, Phase 1 portal.
- **Phase 2:** Documentation, Phase 2 portal to submit Observing Blocks (OBs).
- **Quality Control:** real time Quality Control (QC0) at the telescope, as well as health check for instruments.
- **Archive:** hosting of the raw data and calibration files, which can be accessed by PIs (within property period) and also general users (after property period has expired).
- **Pipeline:** data pipelines are maintained by ESO, with documentation and cookbook. Pipelines are deliverable of consortia when instruments are built.
- **User Support Department:** single point of entry for users' requests, which can be dispatched to other groups within ESO.

2.4 Funding and Resources

The VECs networking activities function under funding from the EU-funded OPTICON RadioNet Pilot (ORP) project. Funding for the individual VECs is also sought from their own local funding agencies. The total FTE allocation for VLTI user support is of 4.56 spread among the ECs – members of Eii.

In the past, funding for the activities was obtained through [OPTICON](#) - the Optical Infrared Co-ordination Network for astronomy - Horizon 2020 (2017-2020, grant agreement 730890), OPTICON FP7 II (2013-2016, grant agreement 312430), OPTICON FP7 (2009-2012, grant agreement 226604), [ONTHEFRINGE](#) (2006-2008: grant MSCF-CT-2005-029954) and OPTICON FP6 (2002-2006, RII3-Ct-2004-001566). Most of the VEC activities were funded as networking activities in H2020.

2.5 Relations between ESO and the VECs

ESO and the VECs operate independently in terms of funding and management. However, there are regular meetings between ESO and the VECs to update each party on their respective activities, in the spirit of offering full support to users, via complementary services. ESO is also represented in the Eii Bureau, the top-level executive body of the Eii.

3 Roadmap towards the final deliverable on knowledge transfer, synergies and lessons

Despite the seemingly similar structure, the ALMA and VLTI user support in Europe have inherent differences, as indicated by the number of users, the provision and scope of user support and the support procedures that are currently in place but also their respective funding models. The aim of JA2.4 is to explore possible synergies in practices and workflows of expert support provision to the

respective communities, with the possibility to expand towards future, emerging user communities. Task distribution, shared responsibilities, reporting systems, communications and information dissemination practices are looked at, under the prism of the diversity between the ARC network and the Eii. This will be detailed in the deliverable D3.6 (Report on knowledge transfer activities, synergies, lessons, month 36). In this section we provide an initial roadmap towards this deliverable.

ALMA's aim from its inception was to make the facility accessible to all users, regardless of their level of expertise in interferometry or submillimetre/radio astronomy. The three ARCs in Europe, North America and East Asia were tasked with the support of their respective communities. In Europe, and thanks to the pre-existing expertise in interferometry, an extensive user support structure was put in place, that has been providing user support of the highest standards from the very start of the ALMA operations. The immediate result of this effort is the ever-growing European ALMA user community (see Figure 1) as well as the number of publications lead by European PIs and making use of ALMA data, that account for more than 40% of the 2690 ALMA publications at the time of writing. The adverse effect is, however, the oversubscription in Europe, that in the latest Cycle (Cycle 8 proposal deadline) exceeded a rate of 7 for the European fraction of ALMA time.

Since its onset, the VLTI has demonstrated a preponderance of GTO team members involved in most of the VLTI proposals. The lack of engagement of the general astronomical community in the VLTI has stemmed from a lack of expertise and from the complexity of the interferometric technique. The creation of the VECs has come into play precisely to provide that liaison between the astronomer (be it expert or non-expert) and the VLTI. The main goal of the VECs is to provide user support at all levels, from basic interferometry concepts to proposal and observation preparation, to data reduction, model fitting and image reconstruction. The VECs target the general astronomical audience, from experts, to early-stage researchers, to more senior researchers with interest in complementing their expertise with interferometry. Specific resources include a helpdesk, personalized user support, dissemination and knowledge transfer through conferences/workshops, and training through schools, all aimed to increase the diversity of VLTI PI/CoIs. In addition, the VECs promote synergies with the non-academic sector, through the organization of special sessions, aimed at stimulating technological, economical and societal impacts of the VLTI. Notwithstanding, the VECs also have a commitment to engage with the general community, through outreach actions, promoting the VLTI and its science, stimulating STEM careers, and fostering gender equality.

The funding schemes of the European ARC network and the Eii are quite different. The ARC nodes are seeking individually their funding, each employing a number of staff corresponding to their funding, with different funding horizons and often different mandates from their local communities and funding agencies. The ARC network is then trying to homogenise the user support provided throughout Europe, taking into account the individualities of each node. All but one VECs, on the other hand, are fully funded by European funds (OPTICON and now the ORP), that only allows for a substantially lower FTE investment in VLTI user support.

The new user support practices employed during the pandemic by the ARC nodes might be a good way forward for both the ARC network and the VECs in addition to the in-person face-to-face. For instance, online user community events and virtual support settings (VNC etc) might allow for a wider attendance. While nothing can ever replace the value of in-person interactions and face-to-face visits, virtual support means can reduce the costs, facilitate the logistics, save time and add flexibility to the user support practices. In the spirit of shared practices, common user support request

distribution systems and workflow or repositories of training and educational material will be looked into. Furthermore, joint schools or training events might not only benefit the user support structures but also allow for the respective user communities to expand towards each other's direction. Finally, joint community events, interferometry schools, image reconstruction techniques or even scientific events on science with ALMA and the VLTI are interesting paths to look toward.

4 Acronyms

ALMA - Atacama Large Millimetre/submillimetre Array

AMBER – Astronomical Mult-BEam combineR

ARC - ALMA Regional Centre. There is one ARC at each of the Executives of the ALMA partnership

ACC - ARC Coordinating Committee consisting of representatives of each node, as well as the ARC Department head and deputy head and the ARC network coordinator

CHARA – Centre for High Angular Resolution Astronomy

CoI - Co-Investigator

DMO – Data Management and Operations division

EAS - European Astronomical Society

ESPRESSO – Echelle Spectrograph for Rocky Exoplanets and Stable Spectroscopic Observations

EWASS - European Week of Astronomy and Space Science

Eii - European Interferometry Initiative

FTE – Full Time Equivalent

GTO - Guaranteed Time Observations

GRAVITY - K-band (wavelength 1.9 to 2.5 microns) 4-beam combiner of VLTI

JAO – Joint ALMA Observatory

JMMC: Jean-Marie Mariotti Centre, France

JRA - Joint Research Activity

MATISSE - L-, M- and N-bands (wavelength 3.5 to 12 microns) 4-beam combiner of VLTI

MIDI – MID-Infrared instrument for the VLTI

PI – Principal Investigator

PIONIER - H-band (wavelength 1.4 to 1.7 microns) 4-beam combiner of VLTI

OBs – Observing Blocks

ORP- OPTICON/RadioNet Pilot

OSUG - Observatoire des Sciences de l'Univers de Grenoble

OSUL - Observatoire des Sciences de l'Univers de Lyon

OCA - Observatoire de la Côte d'Azur

OPM- Observatoire Paris-Meudon

OPTICON - OPTical Infrared Co-Ordination Network

OT – Observing Tool

QA2 – Quality Assurance level 2

QC – Quality Control

SBs – Scheduling Blocks

SnooPI – Snooping Project Interface

STEM – Science, Technology, Engineering and Mathematics

SUV – Service aux Utilisateurs du VLTI

SV – Science Verification

USD – User Support Department

VECs – VLTI Expertise Centers

VLTI - Very Large Telescope Interferometer

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