Report on the

ALMA Developers' Workshop

held at Chalmers University, Gothenburg, Sweden, 25–27 May 2016

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A workshop was recently held in Gothenburg to discuss the ALMA Development Programme for the period 2015–2030. The main aims were to inform the European and international communities about progress on current development projects, to solicit new ideas and to discuss priorities for the future. This contribution summarises the outcomes of the workshop.

The Atacama Large Millimeter/Submillimeter Array (ALMA) is already the world's premier facility for astronomical observations from 84 to 950 GHz, and will soon be fully operational in all of its originally planned frequency bands. Since its first observations, ALMA has routinely delivered ground-breaking scientific results in nearly all areas of astrophysics. Looking forward to 2030, the purpose of the ALMA Developers' Workshop was to ask the European and international mm/submm communities "What's next for ALMA?". The specific aims were to review previous and current development studies and projects, to discuss priorities identified by the community and to solicit new ideas for ALMA.

The workshop formed part of the programme on "Origins of Habitable Planets" of the Gothenburg Centre for Advanced Studies in Science and Technology (GoCAS), a joint endeavour between Chalmers University and the University of Gothenburg. It was held on the Chalmers campus in Gothenburg, just before the release of a new ESO Call for ALMA Development Studies. The workshop was chaired by Leonardo Testi.

The ALMA Science Advisory Committee (ASAC) has considered the way forward for ALMA over the next 15 years in its ALMA2030 documents, which cover major science themes, the landscape of major facilities, and pathways to ALMA development, respectively. Following the completion of ALMA2030, a Development Working Group has been established to draft a prioritised and roughly costed plan covering the next 5–15 years for approval by the ALMA Board in 2017. The Working Group is chaired by the ALMA Director, Pierre Cox, who opened the workshop by reporting on its activities. The main development paths recommended in ALMA2030 are:

1. Completion of ALMA as originally specified by restoring functionality deferred on grounds of cost.
2. Improvements to the ALMA Archive: enabling gains in usability and impact.
3. Larger bandwidths and better receiver sensitivity: enabling gains in speed.
4. Longer baselines: enabling qualitatively new science.
5. Increasing the instantaneous field of view and enabling more efficient mapping.

The ALMA Development budget is currently 13.6 M$/year, shared between the three regional executives (Europe, North America and East Asia). It is allocated within the regions to a mix of small studies and larger projects. The current regional development programmes were summarised by the programme scientists: Leonardo Testi (ESO), Al Wootten (National Radio Astronomy Observatory, NRAO) and Daisuke Iono (National Astronomical Observatory of Japan, NAOJ), while Nick Whyborn (Joint ALMA Observatory, JAO) outlined related activities in Chile.

Current developments

Major development projects to date have concentrated on restoring deferred capabilities. These include receiver bands and phasing for millimetre Very Long Baseline Interferometry (VLBI). Band 5 (167–211 GHz) receiver cartridges are currently being delivered by the Nederlandse Onderzoekschool voor Astronomie (NOVA) and the Group for Advanced Receiver Development (GARD), with NRAO providing the warm cartridge assemblies. The cartridges are currently being integrated into the ALMA front ends at the Operations Support Facility (OSF) in Chile. Pavel Yagoubov (ESO) described the progress of Band 5 production: 18 cartridges had been integrated at the time of the workshop and the performance comfortably meets the specification.

Approval for full production of Band 1 (35–50 GHz) was given just before the workshop to a consortium led by Academia Sinica Institute of Astronomy and Astrophysics (ASIAA). The project was described by Ted Huang. Millimetre VLBI and the ALMA Phasing Project were introduced by Eduardo Ros (Max-Planck-Institut für Radioastronomie, MPIfR), with contributions on the software from Ivan Marti-Vidal (Onsala Space Observatory, OSO) and Mark Kettenis (Joint Institute for VLBI in Europe, JIVE). These activities have resulted in VLBI with phased ALMA being offered in Cycle 4, with the first observations scheduled for March 2017.

The final receiver band originally planned for ALMA is Band 2 (67–90 GHz). This was discussed in detail at a specialised meeting held immediately before the workshop, and its conclusions were summarised by Robert Laing. Development is under way both at NRAO (where a prototype cartridge designed to meet the existing Band 2 specification is currently under test) and in Europe/Chile, where a consortium of the University of Manchester, the Science and Technology Facilities Council (STFC) Rutherford Appleton Laboaratory (RAL), Istituto Nazionale di Astrofisica (INAF) Osservatorio Astrofisico di Arcetri (OAA), INAF Istituto di Astrofisica Spaziale e Fisica Cosmica (IASF) Bologna, the University of Chile and ESO has taken the alternative approach of building a receiver designed to cover the wider frequency range between 67 and 116 GHz with an increased instantaneous bandwidth. Promising test results have been obtained by both groups for the optics and passive components and characterisation of optimised Monolithic Microwave Integrated Circuit (MMIC) amplifiers is eagerly anticipated.

New Developments

There were contributions on possible improvements to the higher-frequency receivers, which are based on superconductor-insulator-superconductor (SIS) technology, by Victor Belitsky (OSO/GARD), Andrey Baryshev (Netherlands Institute for Space Research, SRON) and Takafumi Kojima (NAOJ). Sideband separation for the two highest frequency bands (perhaps using digital techniques),

focal-plane arrays, ultra-wide-band receivers and high current density junctions are all promising approaches.

Wider instantaneous bandwidths require enhancements in digital electronics as well as new receivers. Options for faster digitisers and upgrade or replacement of the ALMA correlator were presented by Al Wootten, Benjamin Quertier (Université de Bordeaux) and Lewis Knee (National Research Council Canada, NRC), while Satoru Iguchi (NAOJ) showed plans for a spectrometer to deliver improved sensitivity, linearity and spectral dynamic range for total-power observing.

A wide variety of software upgrades was also presented, including a redesigned Observing Tool (Alan Bridger, UK Astronomy Technology Centre, UKATC), science archive development (Felix Stoehr, ESO; Sandra Burkutean and Marcella Massardi, INAF Istituto di Radioastronomia [IRA]), a new integrated alarm system (Maurizio Chavan, ESO) and high-performance computing for data reduction in CASA (Sandra Castro and Justo Gonzalez, ESO). Potential improvements in phase calibration were described by Remo Tilanus (Leiden University) and Anita Richards (University of Manchester). It was clear that phase correction using the water-vapour radiometers generally works very well, but that better could be done both in poor conditions (for example in the presence of clouds) and in the very best conditions, when the dry component of the atmosphere dominates.

ALMA and development of other facilities

The final part of the meeting concerned development at other millimetre and sub-millimetre facilities and its relevance to ALMA. Progress towards completion of the NOrthern Extended Millimeter Array (NOEMA) — which will be the most powerful mm array in the northern hemisphere — was presented by Frederic Gueth (Institut de Radioastronomie Millimétrique, IRAM). Several presentations discussed developments for single dishes, including the Atacama Submillimeter Telescope Experiment (ASTE), the Nobeyama 45-metre telescope, the descoped Cerro Chajnantor Atacama Telescope (CCAT) project and the Atacama Pathfinder EXplorer (APEX).

There is considerable interest (particularly from the ESO community) in a large survey telescope located either on the ALMA site or nearby at higher altitude. This would complement ALMA, in particular by providing a highly multiplexed survey capability. Leonardo Testi summarised the report of the ESO Single Dish Science Strategy Working Group, which had considered the options, concluding that a 40-metre class dish on the ALMA site with state-of-the-art cameras for line and continuum would be very productive in synergy with ALMA.

Conclusion

The concluding discussion at the workshop led to consensus on a number of general points. Firstly, ALMA needs a new set of top-level science requirements to replace the original version that successfully drove the construction of the array. This can then flow down to a new set of system-level technical requirements. Secondly, we need a rigorous analysis of current performance (including possible optimisations and failure rates) to act as a baseline for new developments: much of the quantitative system verification of ALMA was done when the array was incomplete. Finally, it was clear to everyone that there are far too many exciting technical possibilities to implement at once and that priorities will need to be set very carefully.

All of the presentations from the workshop are available on the workshop webpage[1].

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Links

[1] Workshop webpage: http://www.chalmers.se/en/centres/GoCAS/Events/ALMA-Developers-Workshop/Pages/Programme.aspx

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Some of the 50 ALMA 12-metre antennas in close configuration on the Chajnantor Plateau.