ALMA Newsletter

January 2011

Dear readers of our ALMA Newsletter,

At the time of writing this Newsletter we can clearly see the path to the start of ALMA Early Science. There are nine antennas operating at the Array Operations Site, first test images and spectra have been released, and the timeline and approach that will be adopted for Early Science Cycle 0 has just been announced.

This marks a tremendous achievement for all those people from around the world who have worked so hard to deliver the challenge that is ALMA. I encourage everyone who has played a part in ALMA to date, and everyone who is working hard to continue to deliver the project, to pause and reflect on those achievements. As the ALMA Board said in its public statement regarding Early Science after its Santiago meeting in November 2010:

> *While many challenges remain, it is already clear that ALMA "works"*

In the coming months the ALMA Science Team will conduct Science Verification observations to test and demonstrate the performance of the array. Data from these observations will be released publicly so that astronomers outside the project can start to work directly with ALMA data. Suggestions for Science Verification targets and observations to complement the plans of the ALMA Science Team are encouraged, and more information about how to contribute is included in the body of this Newsletter.

The leadup to Early Science marks a time of great activity across the entire ALMA effort. In particular, the efforts of the ALMA Regional Centres (ARCs) operated by the Executives in East Asia, Europe and North America, the NAOJ, ESO and NRAO, are working extremely hard together with the JAO's Department of Science Operations to ensure that the astronomers who will apply to use ALMA and those who are successful in being awarded time are all supported efficiently and effectively. It is the ARCs that will provide the interface between ALMA and the astronomers that will use it and so their role in Early Science – and of course in ongoing Science Operations – is paramount. A great deal of energy is being devoted to preparing and providing information about how to apply for ALMA time and how to use ALMA and its data products. A number of workshops being offered by the ARCs are noted in this Newsletter, and we invite everybody interested in using ALMA to participate in these events.

At the start of 2011 the scene at the Operations Support Facility is also quite remarkable. On any given day there are 500-600 people at the site working to deliver ALMA, and there are more than 20 antennas in various stages of assemble in the site erection facilities of the three vendors and on the pads behind the OSF Technical Facility. At around the same time as the ALMA project starts Early Science it will also reach the peak rate of delivery and integration of antennas and other subsystems into the array. Early Science will therefore require a delicate balancing act, with the clear intention being to deliver exciting science while not unduly delaying completion of the full array. At the start of Cycle 0 ALMA will offer capabilities that rival the best millimeter/submillimeter arrays available today, and we are all focussed on delivering the full ALMA capabilities as soon as we can.

Here's to an exciting, prosperous, and scientifically rewarding 2011.

Enjoy ALMA's universe!

Lewis Ball, ALMA Deputy Director

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of Europe, North America and East Asia in cooperation with the Republic of Chile. ALMA is funded in Europe by the European Organization for Astronomical Research in the Southern Hemisphere (ESO), in North America by the U.S. National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC) and the National Science Council of Taiwan (NSC) and in East Asia by the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Academia Sinica (AS) in Taiwan. ALMA construction and operations are led on behalf of Europe by ESO, on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI) and on behalf of East Asia by the National Astronomical Observatory of Japan (NAOJ). The Joint ALMA Observatory (JAO) provides the unified leadership and management of the construction, commissioning and operation of ALMA.

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Credit: ALMA (ESO / NAOJ / NRAO) , J. Guarda

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(Above). The working interferometer of eight ALMA antennas at the high site in September 2010

Plan for ALMA Early Science Cycle 0

The Joint ALMA Observatory (JAO) expects to start Early Science observations (Cycle 0) on a best effort basis late in 2011 and a call for proposals will be issued at the end of the first quarter of 2011. The purpose of Early Science will be to deliver scientifically useful results to the astronomy community and to facilitate the ongoing characterization of ALMA systems and instrumentation as the capability of the array continues to grow. Early Science will not be allowed to delay unduly the construction of the full 66-antenna array, but nonetheless provides an important opportunity for first science from this cutting edge facility. Early Science will continue through Cycle 1 and until construction of the ALMA array is complete.

The first release of ALMA test data to the astronomy community will be through the Science Verification program. Science Verification will involve observations of objects designed to test ALMA systems and confirm their performance. The first data from these tests will be available by the time of the ALMA Early Science Cycle 0 Call for Proposals.

The ALMA Early Science Cycle 0 capabilities will comprise sixteen 12-m antennas, receiver bands 3, 6, 7 & 9 (wavelengths of about 3, 1.3, 0.8 and 0.45 mm), baselines up to 250m, single field imaging, and a restricted set of spectral modes chosen to meet a reasonable range of scientific goals. Additional capabilities including somewhat longer baselines, limited mosaic imaging, and some polarization capabilities, may be announced in the Call for Proposals.

ALMA Early Science Cycle 0 is expected to span 9 months. It is anticipated that 500-700 hours of array time will be available for Early Science projects. Any astronomer may submit a proposal in response to the ALMA Early Science Cycle 0 Call for Proposals. Proposals that best demonstrate and exploit the advertised ALMA Early Science Cycle 0 capabilities, producing scientifically worthwhile results from relatively short observations (averaging a few

Credit: ALMA (ESO / NAOJ / NRAO), J. Guarda

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hours), will be given preference. Proposals will be assessed by peer review, and ranked strictly on the basis of scientific quality and feasibility with respect to the (fixed) scientific capabilities offered in the formal Call for Proposals. Projects will not be carried over from Cycle 0 to later cycles (even if they have not been completed in Cycle 0), and will not establish proprietary rights beyond those provided by the ALMA data policy. Moreover, data rights of these projects cannot block later observations with enhanced capabilities.

The key dates in the current plans for Cycle 0 are given below. It is still possible that changes in circumstances may make it necessary to alter them.

- 31 March 2011: CfP for ALMA Early Science Cycle 0 and release of offline Observing Tool.
- 1 June 2011: Opening of archive for proposal submission.
- 30 June 2011: Proposal Deadline.
- Mid-September 2011: Latest date for feedback to proposers on the results from the proposal review process.
- 30 September 2011: Start of ALMA Cycle 0 observing.
- February 2012: One month engineering shutdown.
- 30 June 2012: End of ALMA Cycle 0.

Successful proposers for Early Science Cycle 0 will share risk with ALMA. ALMA staff will conduct quality assurance on ALMA data, and will provide reduced data products through the respective ALMA Regional Centers (ARCs). However, it cannot be guaranteed that projects will be completed or that the characterization and quality of the data and data reduction will meet the standards expected when ALMA is in full scientific operations. Proposers should anticipate that significant experience in radio (in particular, millimeter) interferometry will be an advantage in working with the data products during ALMA Early Science. PIs and observing teams should anticipate the need to invest their own time and expertise in the analysis of ALMA Early Science data products, including the possible need to visit the relevant ARC to assist with quality assurance and data reduction. Collaboration with ALMA staff members at the ARCs or JAO can be arranged for interested PIs who are concerned that they may not have the requisite experience to make full use of their ALMA data during this period.

ALMA's Proposal Review Committee

ALMA's Proposal Review Committee, responsible for the overall ranking of all ALMA proposals, will be Chaired by Professor Neal Evans of the University of Texas. Professor Evans is a renowned expert in star formation and molecular clouds with an impressive track record in mm, submm and IR observational astronomy. He is a past member of the National Research Council's Committee on Astronomy and Astrophysics, Past Chair of the National Radio Astronomy Observatory's Program Advisory Committee, and Past Chair of the ALMA Scientific Advisory Committee. Professor Evans has accepted the appointment as APRC Chair for three years, effectively covering Cycles 0, 1 and 2 of ALMA Science Operations.

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Credit: ALMA (ESO / NAOJ / NRAO), W. Garnier (ALMA)

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ALMA Science Verification

As many of you are aware, ALMA has reached a very exciting point in the construction phase. After a year of testing the basic functionality of antennas and small arrays at the Chajnantor site at 5000m, we are now able to run full observations of scientific targets using at least 8 antennas and 4 receiver bands. We recently had a series of reviews of all aspects of the ALMA Project, resulting in a consensus that we will be ready to issue a Call for Proposals for Early Science projects at the end of the first quarter of 2011, with an expectation of starting these Early Science observations toward the end of 2011.

ALMA (ESO/NAOJ/NRAO), Elisabeth Stenvers

ALMA Science Verification is the process by which we will demonstrate that the data that will be produced by ALMA during Early Science is valid. This is done by running full "end to end" tests of ALMA as a telescope. We will observe objects for which similar data are already available for other telescopes. This allows us to make direct quantitative comparisons of all aspects of the data cubes, in order to determine whether the ALMA instrumentation or software is introducing any artifacts.

This process is getting underway now (January 2011) as we set about testing the validity of data produced with the basic capabilities that have been commissioned so far. To start with, we will be using about 8 antennas on baselines of ~20 to 100 meters with receiver bands 3, 6, 7 and 9. Scientific Verification will continue in stages for the next several years as additional capabilities are brought into operation. When we have data sets that we consider to be valid, we will release them to the community - i.e. make them available for download - both in processed form (calibrated images and data cubes) and as raw data (measured visibilities together with the calibration observations). This will illustrate the capabilities of ALMA and provide prospective users with example data sets for learning how to process ALMA data using CASA. It will also provide opportunities for astronomers to understand the strategies for successful interferometric submillimeter observations with ALMA.

Credit: ALMA (ESO/NAOJ/NRAO), Elisabeth Stenvers

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These are the requirements that we plan to test in the current phase:

- Continuum Sensitivity: demonstrate that the noise level is as expected, given the system temperatures and collecting area, that we do detect known faint sources and that the system does not generate spurious sources, even with long integration times. At this stage the 5-sigma limits in one hour should be around 0.25mJy at 100GHz, 1.5mJy at 340 GHz and 5mJy at 675GHz.
- Line Sensitivity and Resolution: as for continuum, but now demonstrating that faint known lines are detected and that spurious features are not a limitation. We also need to demonstrate that the spectral resolution is as expected (channel spacing between about 30 kHz and 15 MHz can be selected and the spectral response should have a predictable form) and that the bandpass calibration is accurate.
- Imaging Fidelity and Dynamic Range: with the limited UV coverage available at present, we expect the "fidelity" of the images to be modest but we need to confirm that the limitation is indeed set by the UV coverage and not by instabilities in the system or inaccuracies in the measurements. High dynamic range (even as high as 1000:1 at 100 GHz and 100:1 at 675 GHz) should be possible on maps of objects that are bright enough and have suitable structure to do self-calibration, and we need to confirm that.
- Amplitude Calibration Accuracy: demonstrate that we find the correct fluxes for both continuum and spectral line objects. At this stage our goal is 5% accuracy at 100GHz, relaxing to 15% at 675GHz.
- Positional Accuracy: demonstrate that we are measuring the positions of known object correctly (including moving sources - e.g. solar system bodies). Errors should be (much) less than 1/10th of the synthesized beam width.

Other topics that we will be moving on to a little later include polarization, small mosaics and zero-spacing (single-dish) data.

Note that we need to check the performance over the whole frequency range (84GHz to 720GHz at this stage) and in general we will need to use different objects in different bands.

We are in the process of drawing up the matrix of observations and objects that will be used to perform the Science Verification. A draft of this is given in Table 1.

We invite the community to send us suggestions for sources to be added to this list. The main criteria are that there are existing good data (ideally in numerical form, but this is not essential) in at least one of the frequency bands we are using and that the object has properties that will enable us to make quantitative tests of one or more of the above requirements. Targets suitable for Science Verification at this point should be matched to the current compact array (baselines

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Credit: ALMA (ESO/NAOJ/NRAO), Elisabeth Stenvers

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of ~20 to 100 meters). It will be possible to use ALMA Bands 3, 6, 7 and 9 or a combination of those. Single field imaging will be available with tracks long enough to provide sufficient u,v coverage for satisfactory imaging, and a range of correlator modes can be used with spectral resolution from about 15 MHz down to 30 kHz.

Obviously the objects need to be visible from the ALMA site (latitude -23 degrees); for the present phase it would be best if they transit at night during the coming months (LST ~ 5 to 15 hrs). Since the data will be released publicly, making suggestions will not give you any special rights nor advanced access to the data, but we will make sure that credit for the suggestion is given on our web page when the data are released. We will be glad to involve you in the discussion of issues like the quality of the existing data.

Suggestions should include a couple of paragraphs explaining why the proposed target is appropriate and what pre-existing data can be made available for comparison. The ALMA Project Scientist will review the incoming suggestions and will inform contributors of the outcome. If an object is added to the Science Verification matrix, the decision to actually implement it will be made by the JAO science team.

Please send your suggestions to sciverif@alma.cl

Type of Object	Requirements	Example Sources (Bands)
Extragalactic		
High Redshift Continuum	Continuum sensitivity	Submillimeter galaxies (B7,9)
	Positional Accuracy	Quasars (B3,6)
High Redshift Lines	Line Sensitivity	BRI0958, BR1202 (B3,6,7)
	Bandpass Calibration Accuracy	
Nearby Star-forming Galaxies	Imaging fidelity	NGC253 (B3,6,7,9)
	Continuum sensitivity	
	Line Sensitivity	
	Bandpass Calibration Accuracy	
AGN (with circum-nuclear disks - chemistry, masers)	Imaging dynamic range	NGC4945 (B3,6)
	Spectral dynamic range	
	Line Sensitivity	

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Credit: ALMA (ESO / NAOJ / NRAO), J. Guarda

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Galactic		
Protoplanetary disks	Continuum sensitivity	Beta Pictoris (B6,7)
	Image fidelity	
High mass star formation (chemistry)	Imaging dynamic range	Serpens (B3,6,7,9)
	Spectral dynamic range	
	Amp Calibration Accuracy	
Outflows and jets	Continuum sensitivity	NGC1333 IRS4 (B3,6)
	Line Sensitivity	
	Image fidelity	
	Imaging dynamic range	
Line surveys		
	Spectral dynamic range	Orion, G34 (B3,6,7,9)
	Line Sensitivity	
	Bandpass Calibration Accuracy	
Flux monitoring		
	Amp Calibration Accuracy	SgrA*
		MWC349 (B3,6)
Solar System		
Planets and Asteroids	Image fidelity	Uranus (B3,6,7,9)
	Amp Calibration Accuracy	Ceres (B3,6,7,9)
	Bandpass Calibration Accuracy	
	Imaging dynamic range	
	Positional Accuracy	
Comets	Ephemeris tracking	Comets as available (B3-9)
	Continuum sensitivity	
	Line Sensitivity	
Sun	(Not in current phase - solar filters not yet available)	

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Credit: ALMA (ESO/NAOJ/NRAO), Elisabeth Stenvers

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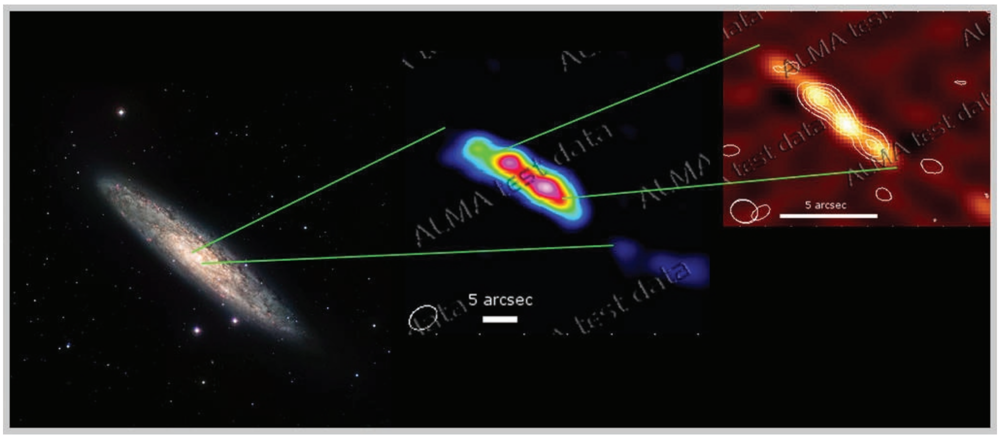
First Test Images made with ALMA

By the ALMA Science Team.

In this issue we are presenting the first test images taken with up to eight of the ALMA antennas. These images were just the byproduct of a series of vigorous tests of the hardware and software components of the whole system made during the second half of 2010. No special effort has been made to obtain the best possible UV coverage or calibration. Some of the images were made with all eight antennas available at that time, others just with a subset. Therefore the images should not be used to draw scientific conclusions on the observed objects or to question existing observations. The purpose of this series of pictures is to, hopefully, convince readers of this newsletter that ALMA is going to be reality very soon.



This shows the well-known spiral NGC253, with an optical image of the whole galaxy on the left (credit: ESO). The ALMA test images show dense clouds of gas in the central regions of the galaxy: (middle) the CO J = 2-1 line at 230 GHz and (right) the continuum and CO J = 6-5 line at 690 GHz.

Let us recall what had to come together to make this possible. The pace in which things happened at ALMA during the last few years has been breathtaking. Many members of the ALMA Board and Scientific Advisory Committee who visited the ALMA site in November 2010 also had visited Chajnantor, the “High Site”, almost exactly a year before. Then we had three antennas at the site, now eight antennas were forming an array. Then we could perform measurements with single antennas or with pairs of them, which demonstrated that the system was working. Now we show images taken with receivers sensitive from wavelengths of 3 mm down to 0.43 mm: these are real images, not just “fringes” (which tell you something about the quality of a telescope but not everything). Two years ago, we were testing single antennas at the Operations Support Facility (OSF), the “Low Site”. At that time we could not yet combine the signals of two antennas to produce even a fringe. And three and a half years ago, the first antennas had just arrived at the Low Site in order to be assembled and tested.

The antennas are the most visible part of our observatory. The images shown were made using seven antennas delivered by the North American vendor Vertex and one antenna delivered by the East Asian vendor MELCO . At the time of writing there are six assembled antennas from the European antenna vendor at the OSF and the first of these is expected to be added to the array around the middle of 2011 . These antennas were prefabricated in Japan, the USA

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Credit: ALMA (ESO/NAOJ/NRAO), Elisabeth Stenvers

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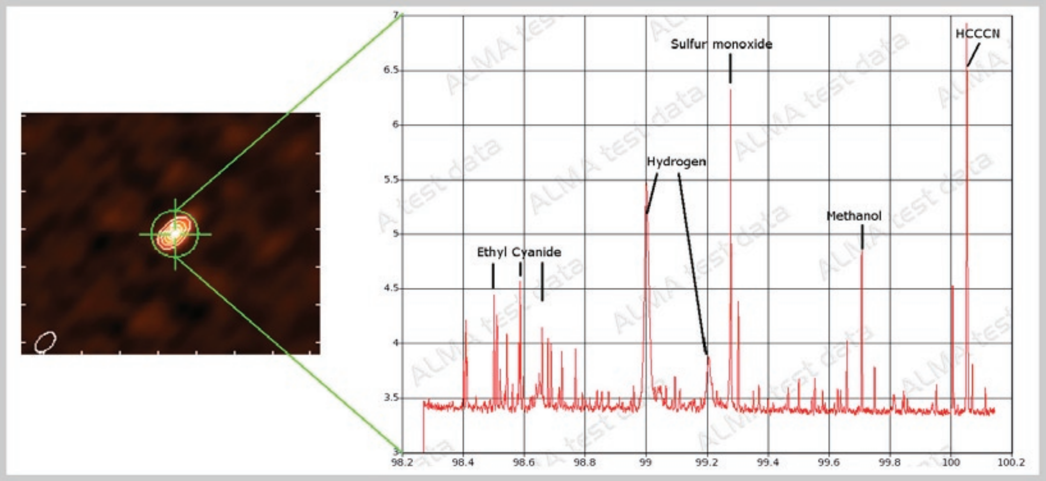
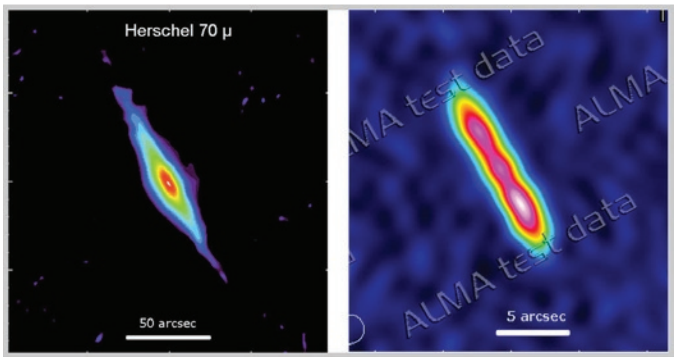


An example of ALMA's potential as a spectroscopic instrument: on the left is the map of the molecular "hot core" G34.26+0.15, which is unresolved with the short baselines that we are presently using, so the "image" is not very interesting whereas a section of the spectrum near 100 GHz shows a "forest" of molecular lines. A few of the chemical species that are responsible for the emission lines are identified on the plot.

or different European countries and assembled by the vendors in the vendors' camps. The manufacturers not only assembled the antennas but also performed first tests to check that they actually could meet the very stringent specifications needed for ALMA.

As soon as an antenna left the manufacturer's camp, it was tested by a team of astronomers and engineers from the "Assembly, Integration and Verification" (AIV) group. In fact, there has always been a very close and genuine collaboration between staff from AIV, from the Commissioning and Science Verification Team, from the Operations group and also from the various Integrated Project Teams (IPT), such as Computing or Antenna IPTs. During the AIV phase, we went through the list of specifications for each of the antennas that were involved in the pictures shown, and also tested other components of the system in order to prove for example that they can track any source in the sky with sufficient accuracy. We also checked that the surface of the antennas matched its ideal parabolic form within less than 20 microns. Sometimes the specifications for the antennas were so stringent that it was a challenge to devise a test to check that these are met. Of course, the different steps of this process are (and will have to be) undertaken for all the remaining antennas that we



This shows the emission from the disk of dust surrounding the star Beta Pictoris. On the left is an image at 70 microns wavelength made with Herschel, (Olofsson et al., SDP Presentations, Madrid, Dec 2009) and on the right is the ALMA test data at 870 microns showing the denser material in the central region of the disk. At this distance 5 arcseconds corresponds to 100 times the radius of the Earth's orbit around the Sun, or about twice the radius of the "Kuiper belt" surrounding the Solar System, which contains many dwarf planets and also some dust, but much less than in the disk around Beta-Pic. The disk is very thin and we are viewing it edge on – in both observations the apparent thickness is a reflection of the angular resolution of the instrument.

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Credit: ALMA (ESO / NAOJ / NRAO), J. Guarda

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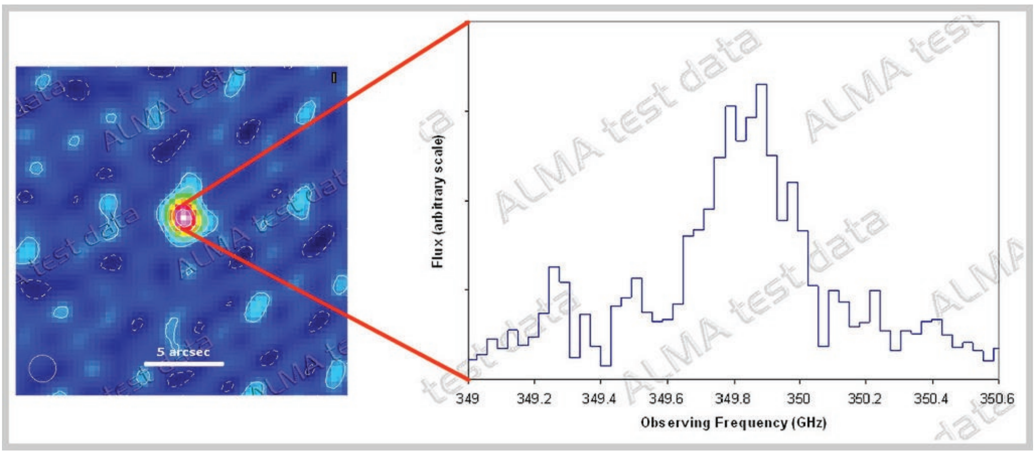
will receive from the manufacturers till the end of the construction. These antennas represent certainly the state of the art, thanks to the expert knowledge and dedication of very skilled engineers and technicians (at the manufacturers but also among JAO staff and the IPTs).



As a test of ALMA's ability to observe broad spectral lines, we observed the quasar BRI 0952-0115, which is at a redshift of z = 4.43. The object is again unresolved on short baselines, but the 158 micron line from ionized carbon is clearly detected in the spectrum, which is impressive given that this observation took only one hour in total.

The antennas are only one part of the system that makes images as the ones shown possible. The antennas used to take the sample images were equipped with four different receiver systems sensitive at some main atmospheric windows, namely around wavelengths of 3mm (band 3, frequency ~100 GHz), 1.3mm (band 6, 230 GHz), 0.9mm (band 7, 345 GHz) and 0.45 mm (band 9, 690 GHz). These four bands do not represent the final state of ALMA's wavelength coverage but a large part of it. The ALMA receivers stand out because of their low noise performance and because of the large wavelength range that can be observed simultaneously. In fact, in each antenna there was a fifth auxiliary receiver, the "water vapor radiometer" (WVR), that is used to measure the amount of water vapor present in the atmosphere at each instant and thus can correct for the blurring effects of the atmosphere. We were amazed that this method to improve the image quality worked almost straightaway. In fact, without this WVR, especially the image in band 9 toward NGC 253 would lack much of its detail. (see more details about this in the #6 ALMA Science Newsletter).

To make interferometry work, one has to combine the incoming signals in such a way that the difference in the length of the signal path is a small fraction of the shortest wavelengths used. To ensure that the positions of the massive antenna pads are always known better than a few hundredths of a millimeter or to measure the tiny changes in the lengths of the cables used is not a trivial task. Time signals that control the data have to be in phase and very exact. The images are a compliment to the mechanical and electronic engineers and technicians who helped to achieve such an incredible precision.

The brain of our observatory is the correlator, where the incoming signals from the antennas are related to each other to produce the so-called visibilities. This correlator is one of the most powerful and complex computers on Earth, and it was specially designed for ALMA. There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Credit: ALMA (ESO / NAOJ / NRAO), J. Guarda

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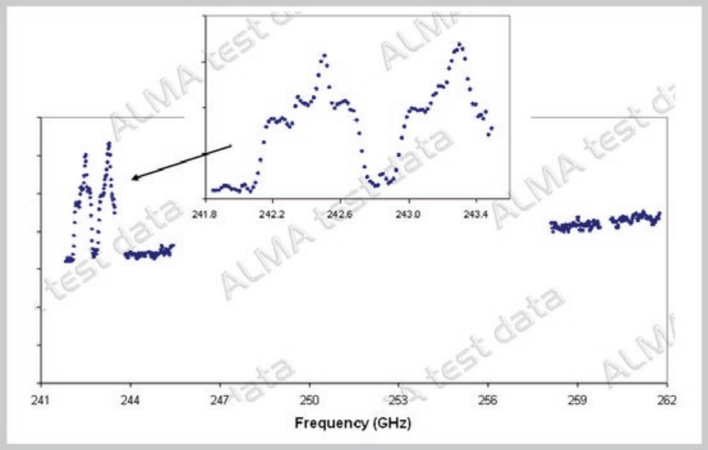
were many ways to do it wrong and just one way to produce the images shown. (see the in-depth article of this newsletter to read more details about the correlator).

Finally, there is the incredible amount of work that went into the software to ensure that the antenna is pointing in the right direction of the sky, to control the correlators and other electronics and to convert the "visibilities" into nice images. There are millions of lines of code involved in making this all work.

A lot had to come together at the same time to produce our images. Let us remind that ALMA is not only technologically and scientifically one of the most advanced projects in astronomy. It is also at a very remote place of this planet at one of the highest sites where people work. That makes construction, infrastructure, maintenance, logistics, communications and safety so important, and at the same time such a challenge for our project. And do not forget the fact that people from many nationalities and cultural background work together to achieve our ambitious goals. Astronomers, technicians, engineers and also administrators have been working hard for more than 20 years to make images like the ones shown possible.



This is the spectrum of a distant galaxy (at a red-shift of $z = 2.3$) which has been nicknamed the Cosmic Eyelash. The signals from this galaxy would be very weak were it not for the fact that it lies behind a massive galaxy cluster and is magnified by the "lensing" effect of its gravity. ALMA takes spectra simultaneously in four sections each about 1.8 GHz wide. The main plot shows the full data set, with two sections on the left and two on the right. In the left-hand section there are two emission lines – these are the $J = 7$- 6 line of carbon monoxide and the fine-structure line of atomic carbon – and the insert shows these in greater detail. The other three sections show that there is a continuum of emission that is rising towards higher frequencies which indicates that it is due to dust in the galaxy.

The pictures presented are, as the ALMA Board stated in its November 2010 meeting, a proof that "ALMA works", but the Board also reminds us that there still remain challenges. The images indicate that ALMA in its present state already would play in the same league as the world's best millimeter and sub-millimeter observatories. But still many things are missing until ALMA reaches its full capabilities.

First of all, there will be more antennas. The more antennas, the more combinations between antenna pairs ("the baselines"). The more baselines, the crisper the images. With 8 antennas, we now have 28 baselines; with 16 antennas we will have 120 baselines. Think of the baselines as pixels in an image (although it is not the whole truth) and you can imagine how much our images will have improved in a year from now.

Credit: ALMA (ESO/NAOJ/NRAO), Elisabeth Stenvers

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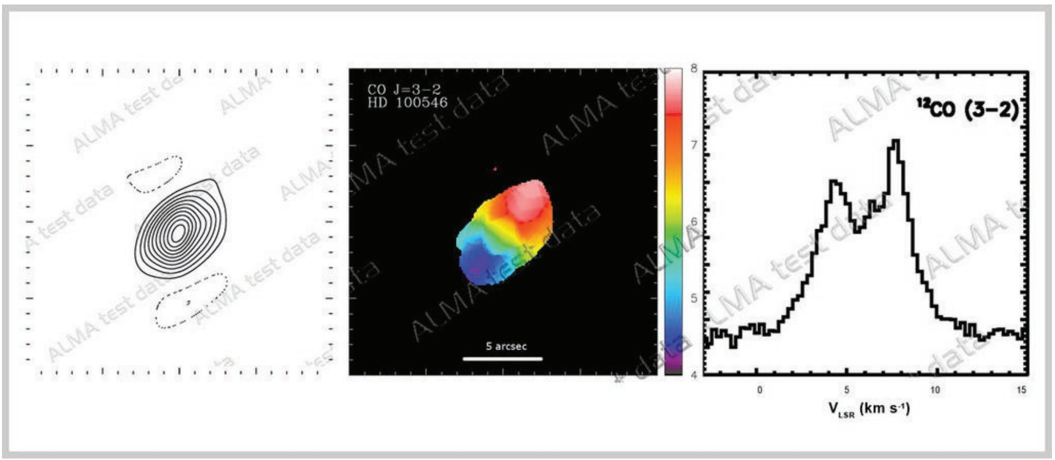
Of course we will integrate European antennas into the array. There is little doubt that also these antennas will perform well. The maximum distance between antennas defines the finest angular resolution of an image. Now all antennas are packed within a very compact array of about 100 m. Soon we will have them spread out in an area measuring several kilometers across. Think of it as a zoom lens with 30 or 100 times magnification. That will add even more details to our images. It will also be the next big challenge, since with increasing distance between the antennas also increase the difficulties to control the lengths of the signal paths within a fraction of a wavelength, and also the adverse effects of the atmosphere. So far we reproduced what has been achieved at several observatories. What now comes will be combinations of baselines and wavelengths that are still unexplored.

What, however, seems almost inevitable is that in a few years from now, ALMA will revolutionize earth bound astronomy and that new and unexpected discoveries will be owed to this instrument.

Some more explanations about the first ALMA test images

ALMA's motto "In search of our Cosmic Origins" will describe much of its scientific program. The Greek astronomers saw the Universe as something static, non evolving. The motion of stars was not related to our existence and our lives. At most, astronomers used the stars to tell the time of the day or the year, or to orient themselves when traveling. This static view of the Universe changed at the beginning of the 20th century when physicists realized that stars cannot live for ever: they are still forming and dying. Likewise larger structures in the Universe, such as the galaxies have their life cycles, and finally, the universe as a whole had its beginning. The material out of which our Sun, the Earth and the other planets formed was not just plain hydrogen and helium, but it contained heavier atoms such as carbon, oxygen or iron which formed molecules that, in a process that we still not understand, make life on Earth possible.



This is an object in our own galaxy. It is a young star which is still surrounded by a disc of gas. Here we are observing the carbon monoxide J = 3-2 line at 345 GHz in the disc. (The star itself is not visible here.) The integrated flux is shown as contours on the left, while the spectrum at the peak of the emission is on the right, showing, via the Doppler effect, that the gas is moving at different speeds. In the middle is the average velocity of the gas at each point in the image, indicated by the colour. This shows a characteristic pattern created by the rotation of the disc around the star.

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Credit: ALMA (ESO/NAOJ/NRAO)

Progress at the ALMA site

Here is a short synopsis regarding the recent progress of the site construction work:

Antennas

As has been the pattern for the last few months as far as ALMA antennas are concerned, we have been working on two main areas – investigating the outstanding technical issues and carrying out end-to-end tests, in which we create scheduling blocks, execute them and process the data (some examples of data from the end-to-end testing are displayed in the "Focus on" section of this newsletter).

The system has generally been performing well with the antenna availability, for the eight antennas, again running at over 90% on average and the software being in a reasonably stable condition and looking promising.

Since a ninth antenna joined the other eight at Chajnantor plateau on December 12, 2010, testing of the system on ~600m baselines was started and so far no unexpected problems have been found. We are trying to collect as much data as possible on atmospheric effects and on the validity of our phase correction techniques while the antennas are in this configuration.

We are now pursuing polarization measurements seriously and the initial results are promising. Here is a plot of the combined "cross-hands" correlations (essentially Stokes' U in the antenna frame) on the quasar J1922 − 293, which is known to have a relatively high degree of linear polarization and passes close to the zenith at the ALMA site.

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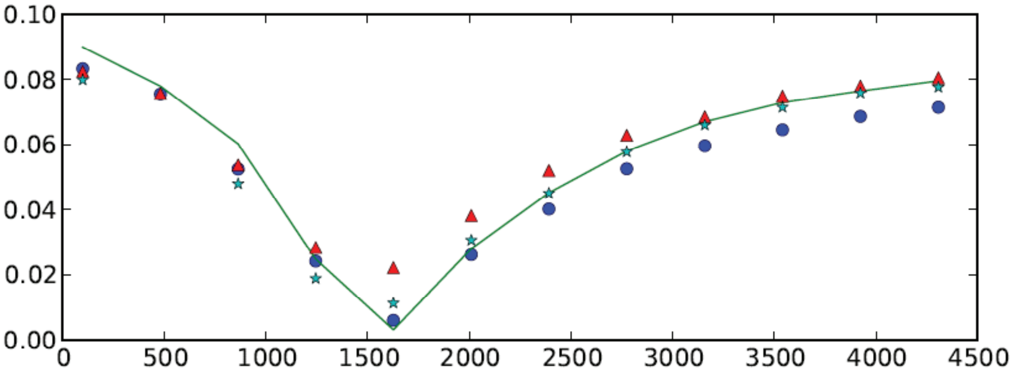
Credit: ALMA (ESO / NAOJ / NRAO), J. Guarda

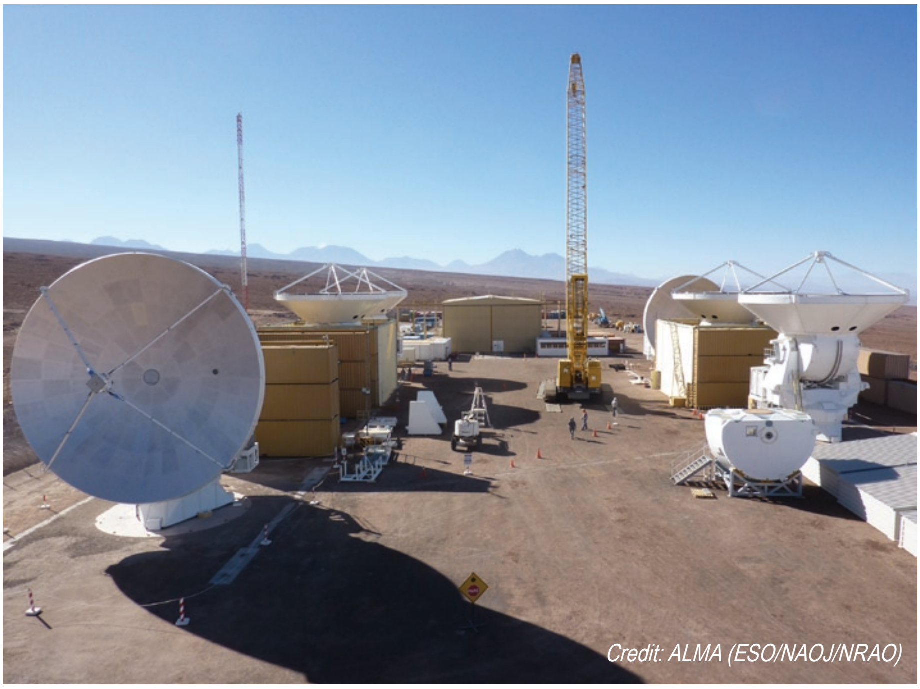
Progress at the ALMA site



Polarisation measurements of a source as it goes through transit .The horizontal scale is time in seconds, the different symbols represent different baselines and the green curve is a model for the expected behaviour due to the change in the parallactic angle as the source transits, assuming a source with 9% linear polarization. Clearly this looks good !

We had a very useful visit from Masumi Shimojo, a solar radio astronomy expert from Nobeyama, who is going to start working with us on establishing the solar observing capabilities of ALMA. An outline plan to enable us to offer solar observing in the Cycle 1 call was drawn up but this is critically dependent on the delivery of the solar filters.

General view of the European antennas assembly site.



Credit: ALMA (ESO/NAOJ/NRAO)

At the **European Antennas assembly site,** there are presently 7 antennas. Antennas 1 and 2 are in formal acceptance testing, with the first one in advanced verification of the pointing performance and having started the holography verification work of the primary reflector surface. In terms of absolute pointing the obtained performances are at a level of 1 arc second or better and presently the stability of the pointing model is being verified, in parallel with the commissioning of the thermal metrology system. Offset pointing verification was started in December and the first results are promising. Fast switching verification also started and based on the results obtained so far it is expected that the specified performance will be obtained, although the full blown test program has not started yet. Presently the surface of the primary reflector of antenna 1 is set at around 13 micrometer RMS. Science related performance testing of the 2nd antenna started in December and covered only all-sky pointing tests with results very similar to those obtained on antenna #1.

Credit: ALMA (ESO / NAOJ / NRAO), J. Guarda

Progress at the ALMA site

Beyond the science related performance, a number of engineering verifications are on-going on both the first and the 2nd antennas. The test program foresees to verify all design related performances on the first two units except for the aspects of maintainability which will be verified on antenna number 3 as soon as it becomes formally available for testing.

Antenna 3 and 4 are under power and are being commissioned. The antenna number 3 is planned to undergo formal review for start of testing in a few weeks. Antennas 5 and 6 are mechanically assembled and work has started on antenna 7 and on the reflector of antenna number 8. The 8th and the 9th antennas are due to arrive at the OSF before the end of January.

An additional integration and testing pad (7 are presently available) is being constructed at the assembly area to allow parallel work on 8 antennas, and obtain a risk reduction on the overall antenna project duration.

At the **North American Assembly site,** six Vertex antennas are in different stages of construction. Just like every antenna to eventually join the ALMA array, these are submitted to more than 200 tests before going through the whole acceptance process, critical step before being moved to the OSF for further testing and integration, and finally to the Chajnantor plateau.

Credit: ALMA (ESO/NAOJ/NRAO), C. Padilla

Arrival of the North American antenna number 15 at the OSF. When high technology meets with ancestral traditions...

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Credit: ALMA (ESO / NAOJ / NRAO), J. Guarda

Progress at the ALMA site

At the **East Asian antennas assembly site,** some final acceptance tests on the fourth 12m MELCO (Mitsubishi Electrical Company) antenna are being conducted aiming at accepting this antenna in the coming weeks. In addition, the first four 7-m antennas arrived in Chile in September and went through assembly and initial testing. The test activities aiming at acceptance of the first 7m antenna are starting this month.

Credit: ALMA (ESO / NAOJ / NRAO)

One 12-m antenna (at far right) and five 7-m antennas (in a row to the left) in the MELCO/NAOJ assembly area at the OSF in December 2010.

At the same time, the Assembly, Integration and Verification team is busy working on several antennas at the OSF.

Operations Support Facility

People working at ALMA (both staff and contractors) are currently hosted in comfortable dormitories, full equipped with television, Internet and individual bathroom. Eventually, when the construction is complete, ALMA staff will be accommodated in a definitive Residence. The design of the Residence was completed last November and the release of the call for tenders should happen very soon.

Array Operations Site

The installation of power and signal connections to the central cluster antenna stations resumed beginning of January. The completion of the work is expected by end of March. Furthermore, the AOS road network construction has been also resumed.

Credit: ALMA (ESO / NAOJ / NRAO), J. Guarda

Progress at the ALMA site

AOS-OSF

The new fiber link connecting OSF and AOS computers became available on Dec.15. Since then it has been in use with the ALMA software with a bandwidth of 1 Gb/s (Gigabit/sec). The expected reliability is higher than with the previous temporary link, which included two microwave segments. The new link allows also to transmit at much higher data rates from the correlator, which is important in view of the increasing number of antennas. Eventually the new link will include also two more fiber pairs at 10 Gb/s, while the old temporary link will remain as a back-up

Credit: ALMA (ESO / NAOJ / NRAO)

Panoramic view of the ALMA OSF, taken from the top of one of the holographic tower. To the left of the picture, from the bottom to the top, one can distinguish the 3 antennas assembly sites, starting with the European site, the East Asian site and the North American one. To the right, one can see the contractor camp, the ALMA base camp and the OSF Technical Facility which hosts the control room, offices and labs. In the background, the Atacama salar.

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Credit: ALMA (ESO/NAOJ/NRAO),

ALMA In-depth

The ALMA Correlators

Technical details, Performance and Status of the Main Array Correlator

by **Alain Baudry**, University of Bordeaux, LAB and European ALMA Project Office, ESO.

Two Correlator sub-systems have been constructed for the ALMA project, one for the Main Array of 12-m antennas and one for the ALMA Compact Array (ACA). Both sub-systems combine the astronomical signals captured by the ALMA antennas to form the images which will be interpreted and modeled by the astronomers. These Correlators also have the ability to analyze the spectral content of the incoming radiation ; in particular, they allow us to identify or discover the molecular and atomic species present in the nearby or distant cold Universe where new generations of stars are being formed. The ALMA Correlators can be seen as highly specialized 'super-computing' machines operated with no hard disks at the highest site ever used for astronomical programs. The 17 peta-operations per second performed by the Main Array Correlator may be compared with the fastest and latest generation of super computers operating in the petaflop domain. In this article we briefly introduce the basic principles of correlation and outline some of the architectural differences between the Main Array and ACA Correlators. We present the main technical characteristics of the Main Array Correlator and give some details on its observing modes and performance. Finally, we summarize the present status of these two powerful Correlator sub-systems and recall that several groups across the world were involved in their construction.

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Credit: ALMA (ESO / NAOJ / NRAO)

ALMA In-depth

ALMA is a highly sensitive and flexible imaging array, which combines the millimetre/submillimetre signals captured by all antennas deployed on the Chajnantor plateau in two correlator sub-systems. The ALMA correlators are powerful digital machines whose flexibility make them key elements of all future ALMA science programs, including Early Science projects. They process a total bandwidth of 8 GHz in each of two different senses of polarization and combine the signals from up to NA antennas (where $N_A = 64$ or 16) movable across the ALMA site within a diameter of about 18 km to 150 m (or even less for the most compact array, the ALMA Compact Array or ACA). Once the input signal voltages have been digitized in specific analog-to-digital converter circuits and combined in the ALMA correlators we obtain: (*a*) the amplitude and phase information contained in the interferometric fringe pattern of $N_A(N_A\text{-}1)/2$ independent antenna pairs, and (*b*) the received power for all N_A antennas. These data are first appropriately calibrated then processed further to produce the ALMA astronomical images in several spectral channels of the input bandwidth. The spectral images represent the ultimate products required by the astronomers to understand the structure and physical processes at work in the observed sources.

A first ALMA correlator, the main array or baseline correlator, was constructed by an NRAO/European team to process up to $N_A = 64$ antennas. (50 12-m antennas are being constructed for the main array but 64 antennas was the initial number in the ALMA project.) The main array correlator combines data from 64x63/2 = 2016 independent antenna pairs. A second correlator, the ALMA Compact Array (ACA) correlator was constructed by a Japanese consortium to process 16 antennas and produce interferometric patterns for 120 antenna pair combinations. (The ACA consists of twelve 7-m diameter dishes to which four other 12-m diameter dishes -the ACA total power sub-array- have been added.)

These two correlators are run as stand-alone machines, but the calibrated images produced at the post-correlation stage for similar frequency profiles will be merged in several projects to deliver a complete picture of the extended and compact spatial structure present in many astronomical sources. In addition, to maximize sensitivity we expect that for a number of projects the main array correlator will process the data collected by both the main array and several antennas of the ACA. This is feasible because all ALMA antennas have identical data formats and because the patch-panel sub-system connecting with optic fibers the antennas to the main array correlator room can be configured in several different ways.

To understand the basic principles of signal correlation it is useful to derive the interferometer response of a single antenna pair, the basic element of any array of antennas. The wave signals from a celestial source, or voltage signals, collected by the antennas are first converted to a frequency range that allows to amplify these input signals. This operation, named heterodyne detection, is performed in the Front-End receivers except for ALMA bands 1 and 2 for which the signal is directly amplified. The amplified signals are later combined in a multiplier and

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Credit: ALMA (ESO/NAOJ/NRAO), Elisabeth Stenvers

ALMA In-depth

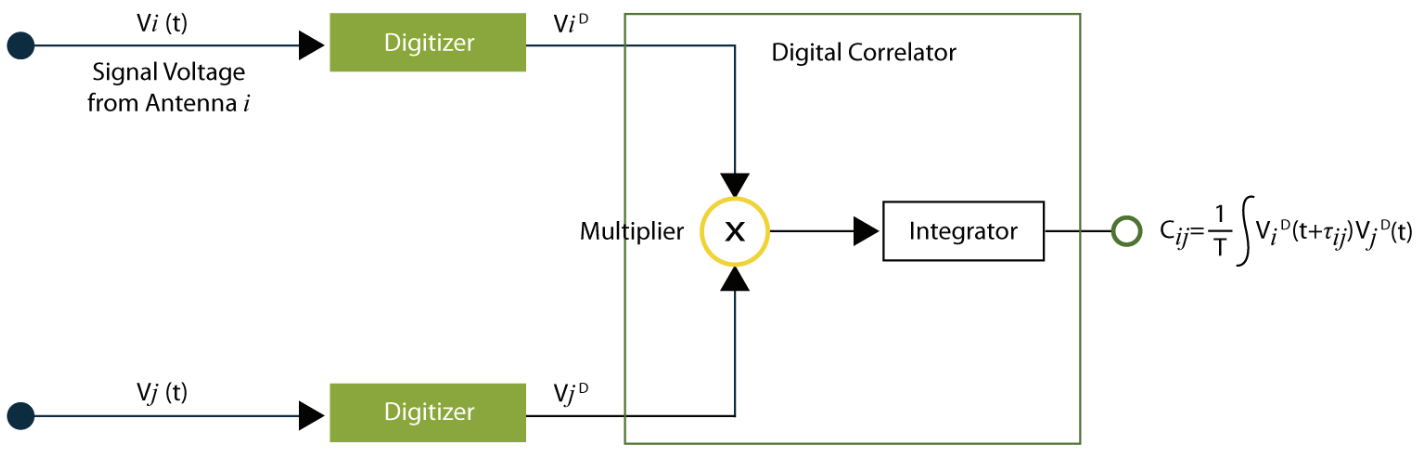

Fig. 1: Generic diagram of a digital correlator. The multiplier and integrator provide the cross correlation, C_{ij}, of the digitized input voltages for the antenna pair (i,j). Multiplication and integration is implemented in the MAC (multiplication and accumulation) cells shown in Fig. 2. Digitization is performed in a specific circuit, the analog-to-digital converter (ADC), which samples and quantizes the input analog signal. Digitization recovers the input signal (i.e. $V_{i,j}^D = V_{i,j}$) if the Nyquist sampling rate condition is met and for a large number of quantization levels. A simplified analysis shows that the correlator output is proportional to $\cos(2\pi\,\nu\tau_{ij})$ where ν is the observing frequency and τ_{ij} is the differential geometrical delay between the two interferometer arms. The delay varies slowly with the source hour angle as the Earth rotates and is equal to zero when the source crosses the meridian plane of the (i,j) interferometer baseline.

integrated over short periods of time. Signal multiplication and time averaging form the core of the correlation process. This is schematically shown in Fig. 1 where, as usual in all modern correlators, the anlaog signal is converted into a limited number of digits (signal digitization) prior to multiplication.

The high frequency component resulting from multiplication of the two signal voltages is filtered out whereas the low frequency product is the 2-antenna interferometer response at the correlator output. This response shows a sinusoidal pattern, the interferometer fringes, whose frequency depends on the observing frequency and the scalar product of the 2-antenna baseline vector with the unit vector to the source direction; the fringe frequency varies slowly with the source hour angle and the response is not distorted by short integrations. The interferometer amplitude is proportional to the power received by the two antennas. In the 2-dimension treatment of the basic 2-element interferometer response the amplitude and phase of the fringe pattern at the correlator output allow to derive the complex source visibility and hence to know the source brigthness distribution on the sky[1].

The above description of an interferometer is valid for a given frequency and for a narrow bandwidth. If this assumption is not fulfilled, i.e. if the passband of each antenna Front-End receiver is broad, it can be divided into independent narrow band channels providing as many independent interferometers. Broad band or multi-channel analysis is required to understand the physics at the origin of the radiation mechanisms of many astronomical sources, and also to provide better sensitivity. In the case of the molecular or atomic radiation emitted by interstellar or circumstellar clouds in very specific frequency ranges, interferometry is required in several

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[1] *More exactly, the visibility function is defined as the Fourier transform in the space frequency domain of the source brightness modified by the antenna power pattern. The visibility amplitude is directly related to the source extent with respect to the fringe spacing. For a point like source the phase information contains the source position once the array baselines have been calibrated (i.e. once the baseline extents and the baseline orientations with respect to the exact positions of distant quasars are known).*

relatively narrow frequency channels to image these clouds and understand their kinematics. As explained later, spectral capability is relatively easy to implement in digital correlators and we do not have to build as many independent interferometers as we wish to have spectral channels.

In the early days of radio astronomy, combination of the signals from an antenna pair was achieved by summing the two signals in a square law detector. The 'adding interferometer' is the equivalent in the radio domain of the Michelson interferometer. The low frequency output of the square law detector contains the interferometer fringe pattern whose frequency varies slowly with time while the fringe amplitude is related to the source size. The major drawback of the adding interferometer is the presence of a constant term or response offset which drifts with time and cannot be easily eliminated. Instead of adding and detecting the captured signals, all modern radio interferometers provide the cross correlation i.e. multiplication of the input signals, thus eliminating all incoherent sources of noise along the two arms of each 2-antenna interferometer (electronics noise) and above each antenna (sky noise).

Spectral correlation and XF-FX architectures

Cross correlation is accomplished in a digital multiplier and integrator as schematically shown in Fig. 1 after the voltages collected at all antennas have been digitized. Formally, cross correlation for an antenna pair (i,j) providing the signal voltages $V_i\ (k\ t_S)$ and $V_j\ (k\ t_S)$ sampled at time $t = k\ t_S$ over a large number of samples, varies as the sum:

$$P_{ij}(p\ t_S) = \Sigma_k\ V_i\ (k\ t_S)\ V_j\ (k\ t_S+p\ t_S)$$

where t_S is the discrete time interval between samples and k and p are integers. The integer p which varies in discrete steps up to an adopted maximum value p_{Max} (where p_{Max} remains always very small compared to the total number of processed samples) is introduced to define a time offset $p\ t_S$ (or time lag) and its associated Fourier transform to the frequency domain a frequency 'channel'. There are as many values of P_{ij} as we have values of the time offsets and, in the associated Fourier space, the frequency separation between channels can be specified once p_{Max} and t_S are known (see below). The summed products P_{ij} when they have been properly normalized and calibrated in terms of the broad band noise standard deviation are also called the cross correlation coefficients[2].

The time interval between two digitized signal samples, t_S, is derived from the sampling frequency which is directly related to the ALMA basic frequency interval, or ALMA baseband B= 2 GHz. (The ALMA baseband is defined as the fourth of the total instantaneous bandwidth, 8 GHz, in each of two polarizations.) In the Nyquist sampling case t_S = 1/2B which implies a high data rate of 4 10^9 samples per second in the ALMA case (t_S = 250 psec). If the cross correlation measurements are made for $2p_{Max}$ time offsets, i.e. $-p_{Max}\ t_S$, …, 0, … $(p_{Max} – 1)\ t_S$, then the Fourier transform of the discretized cross correlation function provides the cross

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[2] *The input signals are both sampled and quantized in the digitizers, and the actual cross correlation coefficient is slightly different from the formal or 'true' cross correlation defined above. In practice the products* $V_i\ (k\ t_S)\ V_j\ (k\ t_S+p\ t_S)$ *are obtained from a look-up table (Read-Only Memory or ROM) whose values correspond to the expected cross correlation products; in this process the input digitized signals are used to determine the address of the products stored in ROMs. The multiplication table is implemented in the correlator circuit.*

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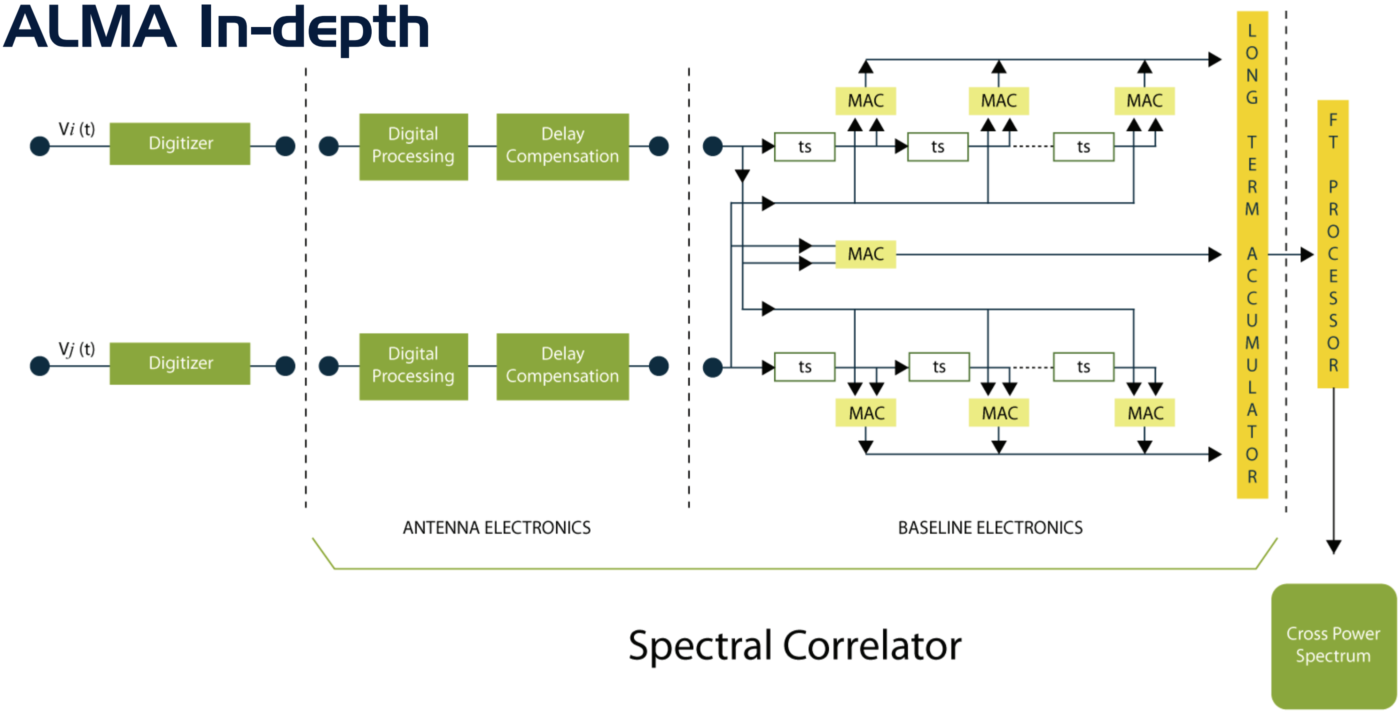

Fig. 2: Schematic diagram of a digital spectral correlator for the antenna pair (i,j). The Antenna Electronics include two essential blocks: 'Digital Processing' which performs digital filtering of the input bandwidth (and other functions in the ALMA case, see TFB card functions in text), and 'Delay Compensation' for geometrical delay compensation at each antenna so that all antennas in the array are processed simultaneously by the correlator. Baseline Electronics provide the cross products of the digitized signals for zero delay and for 1 t_S, 2 t_S, etc. delays inserted in each arm of the interferometer with respect to the other one (t_S is the time interval between samples). Data multiplication and accumulation are performed in a specific correlator 'chip' shown as a MAC cell in the figure. All products are sent to the 'Long Term Accumulator' and Fourier transformed ('FT Processor') to provide the cross power spectrum. Further details on the Antenna and Baseline Electronics for the ALMA main array correlator are given in Fig. 3.

power spectrum at the discrete spectral intervals $1/(2p_{Max}\, t_S)$. Therefore, for Nyquist sampling, the spectral interval or frequency channel separation is B/p_{Max}.[3]

The cross correlation measurements are performed in the 'baseline electronics' part of the spectral correlator schematically represented in Fig. 2. The correlation products are derived in multipliers and accumulators, the MAC cells, where MAC stands for data multiplication and accumulation. Each arm of the 2-element interferometer processing the input signals for the (i,j) antenna pair is delayed with respect to the other one by 1 t_S, 2 t_S, etc. (see Fig. 2). All cross products are then sent to a Long Term Accumulator (LTA) which accumulates the correlation functions. Finally, the cross power spectrum which contains the spectral information of interest to the atsronomer is obtained in the Fourier Transform (FT) processor which performs a discrete Fourier transform of the correlation functions. The 'antenna electronics' and 'baseline electronics' together with the FT processor form the digital spectral correlator system. The final outputs of this large system are the source visibilty functions for several narrow frequency channels across the input bandwidth and for all antenna pairs in the array. They allow the astronomers to build the 2-dimension spectral images of the observed sources as especially required for spectral line observations. If the astronomical sources do not exhibit rapid variations with frequency the astronomers can select a digital correlator configuration with less spectral channels which is then better suited to 'continuum' observations (as opposed to spectral line observations), and eventually measure the average cross correlation product across the entire signal bandwidth.

The digital spectral or continuum cross correlators used to image astronomical sources with relatively narrow or broad band spectra are designated as XF correlators, or lag correlators, where X represents the cross-correlation part of the signal processing and F stands for the Fourier transform. In terms of signal processing it is fully equivalent to construct correlators based on the XF or FX architecture. In the latter case conversion to the frequency domain

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[3] *The total number of time offsets $2p_{Max}$ used to derive $Pij(p\, t_S)$ is very small compared to the number of samples processed in the cross correlator; this limitation degrades the spectral resolution to about 1.2 times the spectral interval between channels.*

(F-part) is performed in a real time fast Fourier transform (FFT) circuit whose outputs are multiplied (X-part) to provide the cross power spectrum[4].

With the XF architecture much complexity is embedded in the correlation part and increases in proportion with $N_A(N_A-1)/2$ (or roughly with the square of the number of antennas) whereas for the FX architecture, Fourier transformation is performed in proportion with the number of antennas. Both architectures have been adopted for the ALMA project. The FX correlator built by the Japanese team processes the signals captured by 16 antennas of the ACA. The main array correlator constructed by the NRAO/European team to process up to 64 antennas is not exactly an XF design but incorporates the European concept of Second Generation Correlator in which the input baseband is digitally split into several frequency-mobile subbands (this is performed in the Digital Processing box of Fig. 2 and, more precisely, in the Tunable Filter Bank Card box of Fig. 3) ; higher flexibility and higher spectral resolution are thus implemented in the main array correlator as described later (see sub-sections on Filtering and Modes). The main array correlator architecture is in fact a digital hybrid XF design or FXF. However, when frequency division of the input baseband is bypassed, then the main array correlator behaves as a pure XF system ; both operating modes are offered to the users (see FDM and TDM modes below).

ALMA main array correlator : technical details and performance

The top level specifications of the main array correlator are gathered in Table 1. (Most of these specifications, baseband inputs/antenna, input sample format, 2-bit 4-level output sample format and number of polarization products are also common to the ACA correlator.) Among the difficulties met by the designers of the main array correlator one may highlight processing a very broad bandwidth (16 GHz in total) for each of 64 antennas and implementing spectral flexibility to provide high or low resolution and selectable spectral windows across the input baseband.

Table1: Top level specifications of the ALMA main array correlator

Item	Specification
Antennas	≤64
Baseband inputs per antenna	8 x 2 GHz
Input sample format	3-bit, 8-level at 4 Gsample/s
Output correlation sample format	2-bit, 4-level or 4-bit, 16-level
Processing rate	125 MHz
Baseline delay range	30 km
Spectral points per baseband (Frequency Division Mode)	≤8192 per correlator quadrant
Spectral points per baseband (Time Division Mode)	64, 128 or 256
Polarization products	1, 2 or 4

The main parts of the main array correlator are shown in Fig. 3 and briefly described below.

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[4] One way to implement the FX correlator consists in sending input data streams of $2n_S$ samples to the FFT circuit of each antenna which then provides ns complex signal amplitudes (cosine and sine outputs). The sample length, $2n_S$, is chosen to optimize the FFT algorithm. The FFT complex amplitudes are later multiplied with the amplitudes from all other antennas in the array to form ns values of cross power spectrum. After FFT transformation the discrete frequency interval is given by $1/2n_S t_S$ or B/n_S in the Nyquist sampling case.

ALMA In-depth

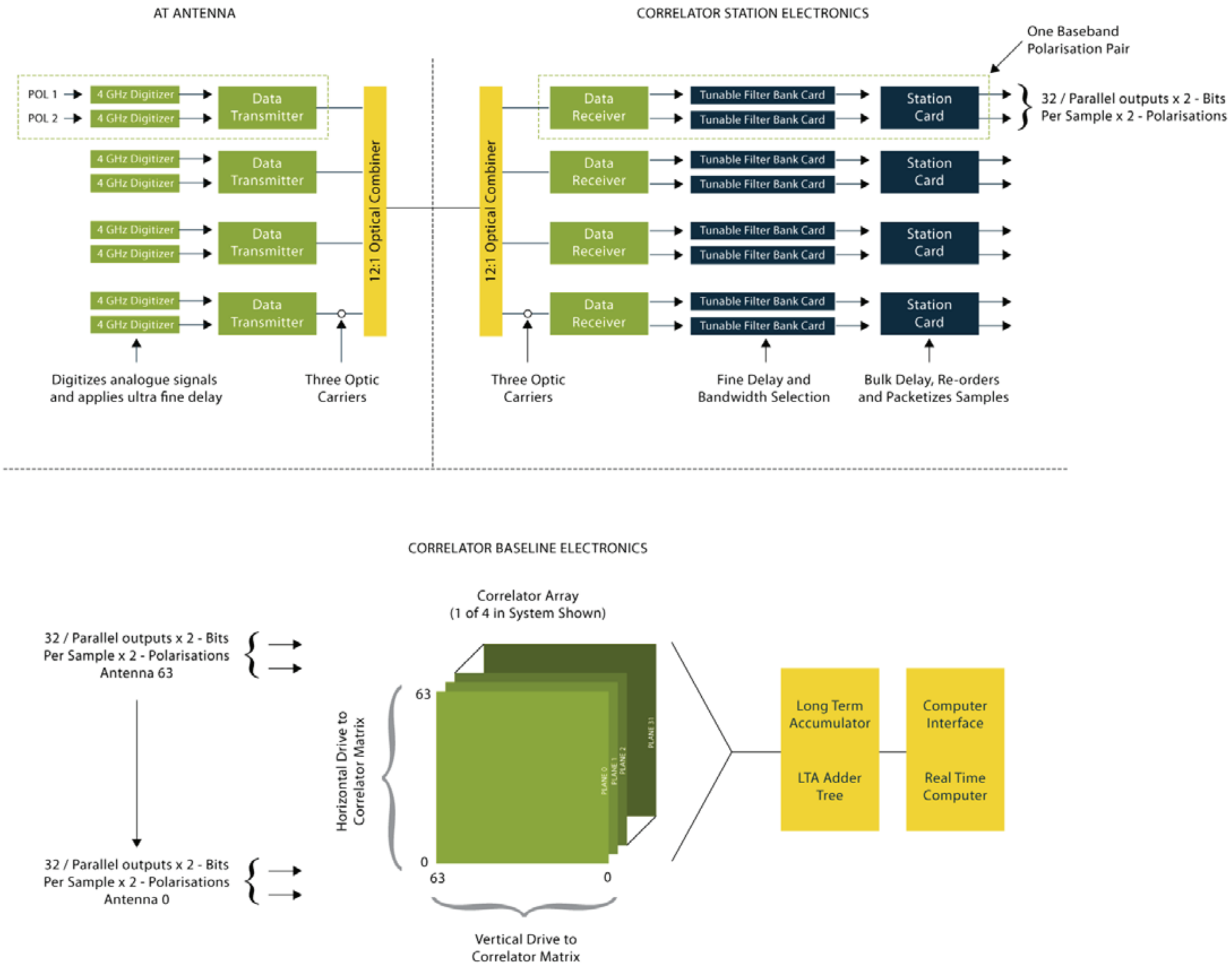

*Fig. 3. Block diagram of the ALMA main array correlator (reproduced from **The Messenger**, vol 135, March 2009 and adapted from ALMA-60.00.00.00-001-C-SPE document). The upper part of the figure shows the electronics required to process all 8 basebands of a single antenna. The Tunable Filter Bank (TFB) card extracts narrow channels from the input baseband and can move these subbands across the 2 GHz input baseband. 512 TFB cards are required for the full 64-antenna system. Delays are controlled in different parts of the ALMA system ; bulk delay compensation is implemented and controlled in the Station Card box shown in this figure, while finer delay adjustments are made in the TFB. The lower part of the figure schematically shows the Correlator Baseline Electronics required to process all 64 antennas and 2 polarizations. The correlator chips are assembled on 512 correlator cards to proces up to 64x63/2 independent baselines.*

Digitization and Filtering

Digitization, that is to say sampling and quantization of the input signal to convert the analog voltage into a digital data flow is a critical step in the ALMA processing chain because it is performed at the antennas soon after the Front-End receivers and for a broad bandwidth (2 to 4 GHz). Digitization of the ALMA baseband requires 4 Gsamples/second digitizers and, according to the ALMA specification, each sample is 3-bit encoded (8 quantization levels). Correlation cannot be performed at the 4 GHz clock rate of the ALMA digitizers, therefore the data flow is demultiplexed to provide much lower frequency signals allowing to ultimately process the data at 250/125 MHz clock rates ; this is achieved in a specific 1:16 demultiplexing stage provided in the digitizer assemblies. The resulting lower frequency parallel bit stream is transmitted from each antenna to the correlator room through optical fibers.

Baseband frequency division is accomplished in the Tunable Filter Bank (TFB) cards which divide the 2 GHz input bandwidth into 32 frequency-agile subbands of 62.5 MHz. Subband extraction is the result of a digital 3-stage digital filter design implemented in a programmable logic device (a Field Programmable Gate Array or FPGA). The last stage of the digital filter strongly determines the filter properties (passband ripple, stopband rejection, use or not of pre-calculated digital weights to narrow the subband further). A commercial large FPGA device using 90 nanometer technology (i.e. the smallest circuit prints in the FPGA are around 90 nanometers) has been selected for the TFB cards. 16 FPGA's are required to implement all 32 subbands in a single card. There are as many as 8 TFB cards per antenna (see Station Electronics TFB blocks in Fig. 3), and 512 cards are required for the full 64-antenna system. It is important to stress that digital filtering offers many advantages in terms of flexibilty or performance reproducibility (e.g. stability with respect to thermal drifts).

Correlation

All cross products for the full array of 64 antennas are derived in 32 correlator 'planes' shown in the 'Correlator Array' of Fig. 3. A correlator plane is a 64x64 matrix in which a total of 256 specific integrated circuits (the correlator chips) are used to multiply the signal by its time shifted version (time lag) for all independent antenna pairs in the array. One correlator plane processes one baseband in two different polarizations and places the 64x64 matrix in four correlator printed circuit cards. These four cards are the 'lags' and 'leads' cards (each providing 64x63/2 cross correlation products) and two other cards providing the auto-correlation coefficients for all 64 antennas. There are 64 correlator chips per correlator card in order to keep a reasonable physical size for the correlator card and also to facilitate power dissipation and thus the cooling. The basic element in one correlator chip is a 256-lag block in which one lag corresponds to the MAC cell shown in Fig. 2. Each 256-lag block can be configured to support single or double polarization observations or to produce all 4 cross products for full Stokes parameters analysis[5].

Each of the 32 digital subbands extracted in the TFB cards is assigned to one of the 32 correlator planes for signal correlation in the widest bandwidth mode. The resulting spectra are stitched together at a later stage to reconstruct a global spectrum with now 32 times more spectral channels across the baseband. To further enhance the spectral resolution one can assign all correlator plane resources to fewer than 32 subbands. In that case the total input bandwidth is less than the original 2 GHz baseband and can be narrowed in powers of two down to 62.5 MHz (or even to 31.25 MHz with special digital weights but with some restrictions).

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[5] *One MAC cell or lag circuit includes a 2-bit x 2-bit multiplier, a multi-bits accumulator and an output register. The basic element being a 256-lag block, there are 16 x 256-lag blocks in one correlator chip for a total of 4096 lags per chip. When the elemental 256-lag block is configured to produce all four cross products for full polarization analysis there are only 64 lags available per cross product ; there are twice more lags for double polarization without cross products.*

ALMA In-depth

Data transmission and rack architecture

Communication of antenna-based electronics with baseline-based electronics is a very difficult problem. The whole system with 64 possible antennas, 8 basebands per antenna and 32 demultiplexed signals (at 125 MHz clock rate) per baseband requires a total of 32768 rack-to-rack interfaces for 2-bit correlation per sample. In the ALMA correlator we multiplex the digital filter card outputs and use twice less cables,16384, carrying 250 MHz signals. The output phase of each cable is remotely controlled and adjusted for error-free data transmission.

The main array correlator is organised by quadrants each quadrant processing one baseband pair for the two different polarizations captured by each antenna. There are 8 racks per quadrant (4 Station Electronics and 4 Baseline Electronics racks) and a total of 32 racks for all 4 quadrants to which one must add the power supply racks, the Correlator Data Processor (where Fourier transformation to the frequency domain is performed) and the Correlator Control Computer racks. All racks are installed in the correlator room at the AOS (ALMA Operations Support) technical building (Fig. 4). One of the main concerns to operate the full system is power dissipation which directly impacts long term reliability. Because the air density at the AOS is about half that at sea level air circulation is forced under the correlator room floor. In addition, several fans are installed at the top of the station racks to improve heat dissipation at the level of the printed circuit cards and components. Temperature is remotely controlled throughout the racks and in the correlator room ; correlator shutdown is programmed in case of emergency. The full system including all computers dissipates around 130 kW ; air circulation in the correlator room is thus a critical question.

Fig. 4. Image of all 8 racks in one quadrant of the main array correlator in the correlator room at AOS Technical Building. It shows 2 first station racks (with green lights) followed by 4 correlator racks (with green lights and red light reflection) and, at the bottom of the room, 2 other station racks (with green lights and red light reflection). The full system includes 4 identical quadrants for a total of 32 main racks. All racks, adding the power and computer racks, dissipate around 130 kW.

Credit: ALMA (ESO/NAOJ/NRAO), S. Argandoña

ALMA In-depth

The builders of the 64-antenna correlator have faced several technical challenges and new firmware or hardware development was required throughout the system. We mention below 3 particular aspects:

a- A digital multiplier and local oscillator are implemented in the TFB card design. This original feature allows us to move all 62.5 MHz subbands anywhere within the 2 GHz baseband thus offering high spectral flexibility to the users as well as the ability to reconstruct spectral 'windows' with different bandwidths. Among all TFB card specifications low dissipation was especially difficult to meet because each TFB card must implement various functions and is inserted in relatively crowded racks in which air circulation is slowed down. Low dissipation was achieved primarily by implementing a new type of digital filter (comb-type filters without multiplications) and by firmware optimization. TFB card dissipation is now below 60 W while the engineering goal was 100 W for all filters active across one baseband. This result lowers the junction temperature inside the FPGA's thus improving the TFB card lifetime.

b- One of the most original hardware development in the correlator system concerns the ALMA correlator chip whose main blocks and sub-blocks have been briefly described earlier. Each chip incorporates 4096 lags which is an impressive number. A total of 32768 chips have been assembled to operate the full 4 quadrants correlator system. With 4096 lags (multipliers) per chip working at 125 MHz the number of 2-bit operations performed per second by the full system is 1.7 x 10^{16}. It is also interesting to note that the number of multi-bits operations performed per second in the full matrix of 4x4 FPGA's on a single TFB card is about 10^{12} operations. These numbers clearly make the ALMA main array correlator the highest (5000-m elevation) and fastest computer ever used at an astronomical site.

c- Another major difficulty was to obtain high quality and reliability of all components in the system including high quality and homogeneous properties for a large production of complex multi-layers cards. This was achieved thanks to high quality industrial production rules and to many controls performed at various levels of the production. In addition, functionality of the individual most complex cards was checked with specially developed card test fixtures. The most complex cards in terms of printed circuit card fabrication and components assembly are the TFB and correlator cards. (512 cards have been fabricated for each type of card and several spare cards have also been produced in view of long term maintenance.)

Observing Modes

Broadly speaking the ALMA main array correlator supports two categories of observing modes the Time Division Modes (TDM) and the Frequency Division Modes (FDM). In the first case the correlator behaves as a pure XF system. 32 'time bins' are first sent from the 'Station Card' (see Fig. 3) to the 32 correlator planes (each processing 1/32 of the digitizer samples). Then all time packet outputs from all 32 planes are summed at a later stage to keep up with the 4 Gsample rate of the antenna digitizers. TDM modes are adequate for relatively low spectral resolution (less lags availbale) and fast dump times (16 msec for cross correlation). In the FDM operation mode each of the 32 TFB card outputs (there are 32 subbands each 62.5 MHz for the 2 GHz input baseband) is processed in one of the 32 correlator planes. Narrower total bandwidths are obtained if not all subband outputs are processed. Higher spectral resolutions are then possible by sending the active filter outputs to all correlator lag resources; this is activated by appropriate addressing of the microcontroller in the 'Station Card' shown in Fig. 3. FDM modes are best suited to high spectral resolution and spectroscopic observations. A large number of FDM modes is offered to the user when one includes the 'higher sensitivity' double Nyquist and 4-bit x 4-bit correlation modes for which digitization efficiency is increased to 94% and 99%, respectively. The latter modes require more lag resources per input bandwidth and the spectral resolution is lowered. The 64-antenna correlator supports a total of 63 FDM and 4 TDM modes including the polarization options (one single polarization baseband and 2 basebands per quadrant with or without cross products). The highest spectral resolution, 3.8 kHz, is obtained for one baseband processed with specific digital weights downloaded in the last stage of the digital filter.

Examples of bandwidths and channel separation are given in Table 2 for two basebands (both polarizations) and 2-bit correlation.

Table 2 : Effective bandwidth per baseband and spacing of spectral points for 2-bit correlation in frequency division mode (FDM) with 2 basebands processed (both polarizations). Spectral resolution is twice less for double Nyquist sampling but sensitivity is improved by 7%.

Effective bandwidth* (MHz)	Channel separation (kHz) Nyquist sampling	Channel separation (kHz) Double Nyquist
1800	488	-
938	244	488
469	122	244
234	61	122
117	30.5	61
62.5	15.3	30.5
31.25**	-	7.6

** The effective bandwidth is determined by the properties of the anti-aliasing analog bandpass filter placed in front of the digitizers and by the slight subband channel overlap required for optimum subband stitching when 2 or more subbands are used.*

*** Available with specific digital weigths downloaded in last stage of the digital filter and for double Nyquist sampling only (3.8 kHz resolution requires the processing of only one baseband)*

The bandwidth and resolution examples given in Table 2 are well suited to spectral line observations in a broad variety of astrophysical environments. The effective bandwidths cover most interesting cases for sources in our Galaxy and for nearby galaxies. This is illustrated in Table 3 in which we give (*a*) the typical velocity coverage observed in a number of sources and (*b*) the total bandwidth required to perform observations around for instance 89 and 602 GHz ; the spectral lines of abundant molecular species (HCO^+ or HCN and methanol) are present near these two frequencies.

Table 3: Examples of total velocity coverage and total bandwidth required for line observations of galactic or extragalactic sources.

Source	Typical total velocity coverage (km/s)	Total bandwidth required (MHz)	
		89 GHz (Band 3)	602 GHz (Band 9)
Galaxy			
Energetic Outflows	300 – 600	90 – 180	600 – 1200
Orion & Galactic Center star forming regions	80 – 160	24 – 48	161 – 321
Compact HII regions	40	12	80
Interstellar Molecular Clouds	5 – 40	1.5 – 12	10 – 80
Extragalactic Sources			
Nearby galaxies (≤ 200 Mpc)	≤ 2000	≤ 600	≤ 4000

Supposing we need two polarizations, examples in Table 2 can be used to help select the total bandwidth and spectral resolution most appropriate to a given astrophysics environment. High resolution, say around 10 to 100 kHz, is well suited to the study of molecular line emission in protostellar discs, interstellar molecular clouds or Galactic masers. On the other hand, 1 MHz resolution is well adapted to the analysis for instance of the widespread CO lines emission observed in nearby galaxies or in Galactic outflows. Tables 2 and 3 suggest that this can achieved with effective bandwidths of 1.8 or 0.9 GHz and by binning spectral channels.

Coarser spectral resolution than shown in Table 2 is best suited to the observation of : (i) broad band continuum emission sources in the Galaxy or external galaxies, and (ii) spectral line sources in distant galaxies for which the total bandwidth must be broad. This is better achieved with the TDM operation mode. There are 3 TDM modes for 2-bit correlation providing 7.8, 15.6 or 31.3 MHz channel separation across 2 GHz (1.8 GHz effective bandwidth) if 1, 2 or 4 polarization products are selected, respectively. There is a fourth, higher sensitivity 3-bit correlation TDM mode, providing 31.25 MHz channel separation across 2 GHz ; it is available if only one 2 GHz baseband polarization channel is processed.

The basic modes described above apply to a single region, 2 GHz in the TDM case and, in the FDM case, to a single region selected from 2 GHz to 62.5 MHz (or 31.25 MHz). But the main array correlator architecture and firmware allow us to support other FDM and correlator planes combinations which we briefly describe below. All of them require, however, new software development from Computing Integrated Product Team in order to offer adequate users interfaces. In addition, some possibilities may just be limited by too high data rates –and these limitations have not yet been fully explored.

- Because FDM allows us to move the 62.5 MHz subbands anywhere within one 2 GHz baseband it is possible to ‘break’ the total bandwidth associated with a selected mode into multiple disjoint spectral regions (up to 4 ‘windows’ are implemented in practice). We can thus anlayze various spectral lines spread across the input bandwidth provided that all regions are multiples of 62.5 MHz and fit within 2 GHz.

- Multi-spectral resolution across different bandwidths is another option allowing to zoom on some complex spectral features. Each quadrant can be split into sub-units and each sub-unit can be operated with a different observing mode (e.g. different resolutions or polarization modes are selectable). The correlator resources available in all sub-units are limited of course by those available in the full 32 planes. (Note that with a single quadrant configured to support 4 basebands it is also possible to select FDM modes with different bandwidths and spectral resolutions in order to achieve multi-resolution.)

Even more configurations are possible. For instance, one can broaden the total bandwidth beyond 2 GHz by combining basebands within a quadrant or by combining quadrants. 1, 2 or 4 basebands are available for each polarization and the agregate maximum bandwidth is 8 GHz per polarization. One can also select FDM and TDM modes for simultaneous spectral line and continuum observations with two independent overlapping quadrants.

Finally, it is important to mention three other correlator configuration modes which will become available soon or in the near future : (a) Sideband separaration mode in which the correlator, in conjunction with 0-90° phase switching, separates the Front-End receiver mixer sidebands. This is required for the double sideband receivers in ALMA bands 9 and 10 and in other ALMA bands when sideband rejection is thought to be inadequate. (b) Subarraying which is the ability to operate in different observing modes independent subsets of antennas. Each correlator quadrant can support 2 or more subarrays. (c) Very Long Baseline Interferometry (VLBI) observations involving the ALMA phased array (or a subset of the ALMA antennas) are possible with the main array correlator design because each correlator card can provide the summed outputs of up to 64 antennas. VLBI requires development of a a specific phasing and control software and additional hardware, mainly an hydrogen maser to replace the ALMA rubidium master frequency standard and a specific data recorder to which the summed antenna outputs are sent.

Status of the ALMA correlators

To conclude, we give brief indications on the ALMA correlators status and installation schedule. Installation and testing at the AOS of quadrant 1 of the main array correlator were completed in October 2008. Quadrant 1 supports up to 16 antennas and 4 baseband pairs. It is being used routinely by the AIV/CSV teams especially for ALMA science verification. The second and third quadrants have been installed at the AOS in the fall and summer of 2009 and 2010, respectively. In October 2010, the 2-quadrant configuration was commissioned and operated from the Correlator Control Computer and the engineering port. 2-quadrant operation will be available soon in 2011. With 2-quadrant configuration and appropriate control software, up to 32 antennas in the array and up to 4 baseband pairs will be available for ALMA Early Science. Full delivery to the users community, however, still requires some software development from Computing IPT.

The fourth quadrant has been constructed and is being operated at the integration center in Charlottesville. Installation at the AOS has been delayed to the second semester of 2011 in order to continue firmware and software development. All 4 quadrants of the main array correlator are needed to support more than 32 antennas (up to 64) and all 4 baseband pairs.

In parallel with the fabrication and installation of the main array correlator, two scaled down models of the large machine have been fabricated with exactly the same production TFB and correlator boards. These models are for 2-antenna operation ; one has been installed at the Operation Support Facility site since 2008 and is used for antenna equipment testing before newly outfitted antennas are moved to the high site.

ALMA (ESO/NAOJ/NRAO), S. Okumura

Fig. 5: Two quadrants of the ALMA Compact Array (ACA) correlator installed in the ACA correlator room.

The ACA Correlator is also built in quadrants. Two quadrants (Fig. 5) have already been successfully connected to 2 antennas on the ACA pads at the AOS in August, 2010. It is expected that all 4 quadrants will be delivered in 2011. When the two ALMA correlators will be fully delivered to the project it would be useful to compare or cross-calibrate the digital efficiency and spectral properties of these two large machines for a subset of ALMA antennas (up to 16, the maximum processed by the ACA correlator). A first investigation of the expected difference between the frequency profiles of the XF and FX correlators has been made by the Japanese team; it shows that frequency profile compatibility is possible as required to combine the main array and ACA images.

Teams involved in the construction

Several teams and a large number of people were involved in the construction of the two large correlator sub-systems. The 64-antenna correlator has been constructed by a consortium of laboratories within the ALMA Correlator Integrated Product Team organization supported by the North American and European ALMA Executives. The key correlation and filtering cards of the 64-antenna correlator were designed, prototyped and functionally tested in Charlottesville (NRAO) and Université of Bordeaux (LAB), respectively. Production of the ALMA 64-antenna correlator cards involved several industrial partners selected after competitive bidding to manufacture the printed circuit cards or the application specific integrated circuits and to assemble all components on the printed circuit cards. Acceptance of the production key cards was supported by specific card test fixtures and test procedures were designed by the Correlator IPT team.

The correlator quadrants have been first assembled and tested in Charlottesville before delivery to Chile at the AOS. Integrated testing of the 64-antenna correlator hardware and firmware embedded in several correlator cards as well as final acceptance at the correlator quadrant level were made possible thanks to the software developed by the correlator sub-group of the ALMA Computing Integrated Product Team. The frequency division mode concept and frequency-agile TFB design emerged in Europe in the years 2001 to 2003 within the 2nd Generation Correlator team which, in addition to incorporating their design in the initial NRAO correlator design, compared their performance and costs with the Japanese correlator project.

The ACA correlator has been constructed by the ACA Correlator team in Japan. This team comprised astronomers and engineers at NAOJ and engineers at FUJITSU Ltd., the sub-contractor. The FX design of the ACA correlator was initially proposed by NAOJ. All details of the final design are the result of the cooperative work of NAOJ and FUJITSU Ltd.. The sub-contractor is also responsible for fabrication, shipment, and assembly on site. Functional and performance testing for acceptance has been conducted by the ACA Correlator team with support of the ACA Correlator sub-group of the ALMA Computing Integrated Product Team.

ALMA Newsletter

January 2011

Credit: ALMA (ESO / NAOJ / NRAO)

ALMA Events

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ALMA Board Meeting & Statement on Early Science

“At its meeting on November 16th-18th 2010, the ALMA Board noted the tremendous recent progress in construction and commissioning of the array and recorded its thanks to the ALMA and regional Executive staff and contractors for their many contributions. Eight of the 66 antennas have already been deployed at the 5000-m elevation site. The accompanying test images illustrate the potential of the full array for unprecedented scientific discovery in the cold Universe.

In preparation for the commencement of Early Science, with a subset of the ALMA array capabilities, the Board received reports and recommendations from a number of comprehensive reviews of the ALMA project. The Board enthusiastically endorses the conclusions of the reviews, and of the Director, that ALMA is on track to begin Early Science observations late in 2011, as planned. While many challenges remain, it is already clear that ALMA “works”.

It is anticipated that the ALMA Director will issue a Call for Proposals for Early Science in the first quarter of 2011. That announcement will provide more details of the expected timeline and capabilities to be offered.”

Credit: ALMA (ESO / NAOJ / NRAO)

ALMA Events

New ALMA Key Personnel

Dr Lewis Ball joined ALMA in September 2010, as Deputy Director of the Joint ALMA Observatory. He joins us from Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO).

Lewis earned his PhD in Theoretical Physics from the University of Sydney. He spent 12 years as a researcher, first in Sweden and then in Australia, before moving into a research management role in CSIRO's Australia Telescope National Facility (ATNF) in 2001. While at CSIRO, he held positions such as Deputy Officer in Charge of Parkes and Deputy Director of the ATNF, then joined CSIRO's Executive Management Council as Acting Director of ATNF and Acting Chief of CSIRO's new division of Astronomy and Space Science (CASS). Over the past year he successfully integrated the ATNF - operated by CSIRO for use by radio astronomers around the world - and the Canberra Deep Space Communication Complex (CDSCC) - operated by CSIRO for NASA as one of its three deep space tracking stations - to create CASS. The research themes that Lewis was responsible for were: "Astrophysics" which involves astronomical research conducted by in-house CSIRO astronomers; and "Technologies for Radio Astronomy" which involves engineering research and development that delivers cutting edge instrumentation for ATNF's existing facilities, and for external contracts. He has led extensive consultation with the astronomical community and worked closely with the teams that will deliver the next generation radio telescope, the Australian SKA Pathfinder (ASKAP).

Lewis's research background is in the theory of shocks, particle acceleration, synchrotron emission and inverse Compton scattering and their application to supernovae, supernova remnants, pulsar winds and radio/X-ray transients. Lewis pioneered the theory of gamma-ray emission from the winds of binary radio pulsars. His model for the binary pulsar B1259-63 led to the theoretical prediction that this system should be a detectable source of extremely energetic (TeV) gamma rays. His predictions were confirmed early in 2004 by observations made using the German telescope known as HESS (High Energy Stereoscopic System) located in Namibia.

Throughout his career, Lewis has pursued research emphasizing the link between theory and observation, first in magnetospheric physics and later in space physics and astrophysics. Together with his extensive management expertise, Lewis will strengthen the leadership in ALMA.

ALMA Newsletter

January 2011

Credit: ALMA (ESO / NAOJ / NRAO)

ALMA Events

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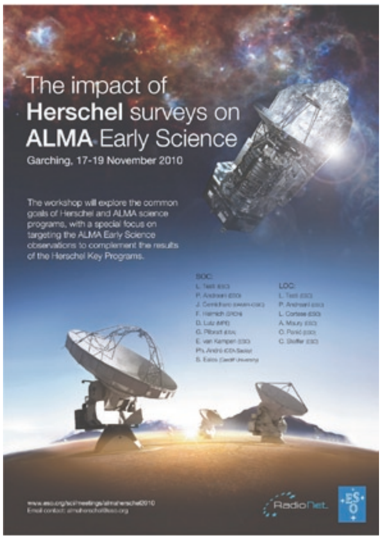
The impact of Herschel surveys on ALMA Early Science



The impact of
Herschel surveys on
ALMA Early Science

Garching, 17-19 November 2010

The workshop will explore the common goals of Herschel and ALMA science programs, with a special focus on targeting the ALMA Early Science observations to complement the results of the Herschel Key Programs.

SOC:

LOC:

The meeting on scientific synergies between Herschel surveys and ALMA Early Science was held in Garching in November 2010.

The participants provided for an exciting discussion and reassured that the Herschel community is fully engaged with the potentials of ALMA coming soon online.

The presentations and posters of the meeting are now available online at the workshop website:

http://www.eso.org/sci/meetings/2010/almaherschel2010.html

ALMA Newsletter

January 2011

Credit: *ALMA (ESO / NAOJ / NRAO)*

Job Opportunities

There are positions for astronomers to be filled in Chile, both as members of the Commissioning Team and in Operations. Commissioning is part of the ALMA construction project and is of course focussed on getting all of the components fully working as a unique telescope and verifying the quality of the data coming out, so we are looking for people with particular interest in and experience of instrumentation and in-depth data analysis. The Science Operations team is now being built up and there are posts to be filled covering a wide range of activities, including instrumentation and data analysis but also planning and scheduling.

Advertisements for these posts will appear in due course on the ALMA website and those of the ALMA partners, but we are always pleased to hear from qualified people who are keen to join the science team in Chile. If you are interested and well-qualified (i.e. with a doctorate and relevant experience) please do contact either Alison Peck (apeck@alma.cl) or Lars Nyman (lnyman@alma.cl), rather than waiting for announcements to appear. In addition, there is a Visitor’s Program in place for people who wish to participate in Chile for periods of about 3 months to a year.

Job Opportunities

The Joint ALMA Observatory (JAO) invites applications for the position of:

Head of the Joint ALMA Observatory Program Management Group (Program Manager) and Deputy Head of the Joint ALMA Observatory Program Management Group (Deputy Program Manager)

The Program Managers lead the PMG and report directly to the Head of Science Operations. The primary purpose of these positions is to provide continuous leadership and management to the Program Management Group.

Main Duties and Responsibilities:

The incumbents have the following major responsibilities:

- Manage the scheduling of ALMA programs and keep track of the time allocation for the ALMA partners. Produce of reports on observing statistics and the status of program execution.
- Manage the quality assurance process and plan calibration observations in coordination with the Head of the Data Management Group.
- Coordinate maintenance and array configuration activities with the JAO Department of Engineering.
- Manage the content of the JAO web pages (including call for proposals, status and technical description of the array, etc.).
- Support the Head of Science Operations in defining policies and procedures for ALMA science operations as well as in planning and coordinating science operations activities.
- Coordinate support to the ALMA Proposal Review Process, including technical assessments of proposals and support to the review process.
- Organize and evaluate tests of the software tools needed for science operations.
- Provide proper infrastructure to support science activities of JAO staff.

Professional Requirements/Qualifications

Applicants for this position shall fulfill the following requirements:

- PhD in Astronomy or Physics.
- At least 6 years of experience after the PhD.
- Ability to lead a multidisciplinary team consisting of astronomers, fellows and data analysts.
- Experience in leading science operations at an observatory (and particularly a radio interferometer or single-dish radio telescope).
- Experience in mm-observations (single dish or interferometry) is an asset.
- Fluency in the English language (oral and written).
- Proven good interpersonal communication skills.
- Proven track record of scientific research.

Due to travel requirements and work at high altitudes, a successful high altitude medical check is a necessary condition of employment for this position.

Deadline for receipt of applications to be considered for the position is 1 March, 2011.

More details available here:

PDF Download Vacancy Notice PDF

Job Opportunities

The Joint ALMA Observatory (JAO) invites applications for the position of:

ALMA Operations Astronomer

Successful candidates will work in the ALMA Program Management Group within the JAO Department of Science Operations. The JAO Department of Science Operations (DSO) is responsible for the ALMA observations. It consists of three groups: the Array Operations Group, the Program Management Group (PMG) and the Data Management Group (DMG).

The Program Management Group is responsible for the day-to-day management of observation execution, tracking of the status of ALMA programs, data quality control and coordination of these activities with the three ALMA Regional Centers (ARCs) located in Europe, North America and East Asia.

Main Duties and Responsibilities:

The responsibilities of the Operations astronomers include:

- Scheduling and execution of observations.
- Executing and developing the ALMA Calibration plan.
- Data quality assurance.
- Tracking the progress of observing programs.
- Supporting array reconfigurations activities.
- Developing documentation needed for science operations as well as the content of the JAO web pages.
- Conducting technical reviews of ALMA proposals.
- Testing of software tools used for Science Operations.

Before ALMA early science operations (2011), the Science Operations astronomers will support the Commissioning and Science Verification team, assisting the Project Scientist in planning and executing the scientific commissioning of ALMA. They will participate in tests and evaluations of the ALMA control software and software tools for science operations, and in the planning of science operations.

Professional Requirements/Qualifications

Applicants for this position shall fulfill the following requirements:

- PhD in Astronomy or Physics.
- At least 3 years of experience in the field after the PhD.
- Experience in mm-observations (single dish or interferometry).
- Previous experience in operating radio interferometers and/or single-dish telescopes and instruments is an asset.
- Experience in data reduction of radio astronomical data (using any of the standard packages GILDAS, AIPS, MIRIAD, CASA, etc) is an asset.
- Fluency in the English language (oral and written).
- Proven good interpersonal communication skills and ability to work in a multidisciplinary team, including operators, astronomers and system/software engineers.
- Proven track record of scientific research.

Due to travel requirements and work at high altitudes, a successful high altitude medical check is a necessary condition of employment for this position.

Deadline for receipt of applications to be considered for the position is 1 March, 2011.

More details available here:

Download Vacancy Notice PDF

Job Opportunities

The Joint ALMA Observatory (JAO) invites applications for the position of:

Deputy Data Manager of the ALMA Data Management Group

The Deputy Data Manager reports directly to the Head of the Data Management Group and is foreseen to be in charge of the daily operations of the archives and the pipeline. The Deputy Data Manager will work closely with the ALMA Regional Centers as well as with the JAO Software Group and System Engineers.

Main Duties and Responsibilities:

The Deputy Data Manager supports the Head of DMG in the management of the group and is in charge of some of the daily operations of DMG. He/she has the following major responsibilities:

- Manage the daily activities of Archive and Pipeline operations.
- Support data quality assurance work conducted by the DSO astronomers.
- ·Act as Head of DMG whenever assigned by the Data Manager.

Before the start of ALMA early science operations (in 2011), participate in tests of the pipeline and software tools used for quality assurance, data delivery and plan pipeline operations, archive operations and also in the setup of the archives.

Professional Requirements/Qualifications

Applicants for this position should fulfill the following requirements:

- University degree (MSc, PhD) in Computing or Engineering.
- At least 5 years of professional experience, preferably in the field of Database Management and/or Archive Installation/ Operations.
- Proven experience in SQL (or variants) query programming and Oracle. Experience in XML and Python programming will be valued as an asset.
- Experience in setting up large data repositories, archive interfaces, data mining tools, or automated data reduction systems, preferably in an astronomical environment, will be regarded as an asset.
- Ability to lead a multidisciplinary team consisting of archive operators/content managers and astronomers.
- Fluency in the English language (oral and written). A basic level of Spanish is regarded as an asset.
- Proven good interpersonal communication skills.

Due to travel requirements and work at high altitudes, a successful high altitude medical check is a necessary condition of employment for this position.

Deadline for receipt of applications to be considered for the position is 31 January, 2011.

More details available here:

Download Vacancy Notice PDF

Job Opportunities

The Joint ALMA Observatory (JAO) invites applications for the position of:

ALMA System Astronomer

ALMA System Astronomers are the experts on the performance of ALMA, and provide advice and assistance to ALMA operations. They work closely with the System Engineers in the ALMA Department of Engineering.

Main Duties and Responsibilities:

When ALMA is in full operations, System Astronomer duties will consist of:

- Overseeing data quality assurance (implementation, assessment and optimization).
- Monitoring and determining the long-term performance of the array based on trend analysis.
- Maintaining, developing, optimizing and executing the ALMA calibration plan.
- Managing the long-term queue of projects.
- Supporting array re-configuration activities (base-line calibration, delay calibration, pointing re-calibration, etc.)

The successful candidates will be expected and encouraged to conduct their own astronomical research. Research in areas directed towards use of ALMA will be strongly encouraged.

Professional Requirements/Qualifications

Applicants for this position should fulfill the following requirements:

- PhD in Astronomy or Physics.
- At least 3 years of experience in the field after the PhD.
- Demonstrated expertise in millimeter/sub-mm observations.
- Experience in commissioning and/or operating radio interferometers and/or single-dish telescopes and instruments is regarded as an asset.
- Programming experience in any procedural and/or object-oriented language. Prior knowledge of Python is regarded as an asset and all successful candidates are expected to master it once hired.
- Experience in data reduction of radio astronomical data (using any of the standard packages GILDAS, AIPS, MIRIAD, CASA, etc). Prior experience in CASA will be considered an asset and all successful candidates are expected to master it once hired.
- Experience in assessing the quality of datasets is considered an asset.
- Fluency in the English language (oral and written). A basic level of Spanish is regarded as an asset
- Proven good interpersonal communication skills and ability to work in a multidisciplinary team, including operators, astronomers and system/software engineers.
- Proven track record of scientific research.

Due to travel requirements and work at high altitudes, a successful high altitude medical check is a necessary condition of employment for this position.

Deadline for receipt of applications to be considered for the position is 31 January, 2011.

More details available here: Download Vacancy Notice PDF

ALMA Newsletter

January 2011

Credit: ALMA (ESO / NAOJ / NRAO)

Upcoming events

EUROPEAN ALMA COMMUNITY DAYS: TOWARDS EARLY SCIENCE

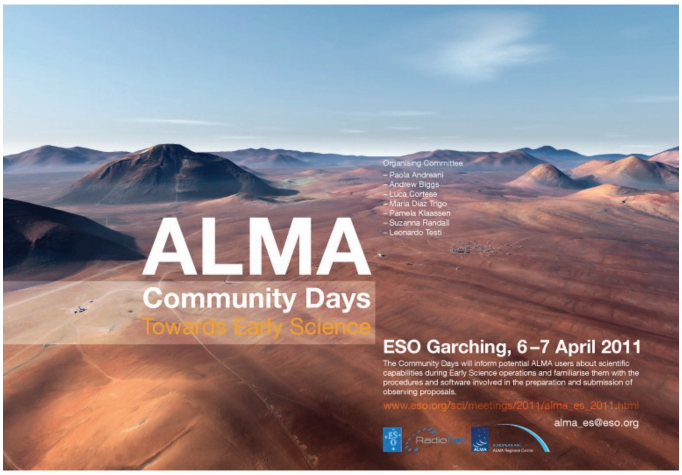
Garching, Germany

2011
- apr -
6/7

While ALMA Full Science Operations are estimated to begin in 2013, the increasing capabilities of the growing array will become available to the astronomical community following the start of Early Science Operations in the second half of 2011. During the first phase of Early Science, an array of 16 antennas will be offered for interferometry with four frequency bands and a limited range of baselines. Early Science observations are currently estimated to be scheduled for at most one third of the available time, the remainder being reserved for continuing commissioning and science verification activities.

Scientific users will interact with the ALMA facility through their local ALMA Regional Centre (ARC), which will provide user support on all aspects related to observing with ALMA and assist observer teams throughout the lifecycle of their project. The European ALMA community is supported by a network of regional ARC nodes that are coordinated by the central European ARC hosted at ESO Headquarters in Garching, Germany.

With the ALMA Community Days, the ESO ARC aims to prepare the European astronomical community for ALMA Early Science operations. The first day will be dedicated to a series of scientific and technical presentations related to ALMA and Early Science capabilities, while the second day will be taken up by interactive tutorials on the preparation of ALMA observing proposals using the ALMA Observing Tool (OT). This should help novice and advanced ALMA users alike to create observing projects that optimally exploit the unique capabilities of ALMA during Early Science operations.



ALMA
Community Days
Towards Early Science

Organising Committee
– Paola Andreani
– Andrew Biggs
– Luca Cortese
– Maria Diaz Trigo
– Pamela Klaassen
– Suzanna Randall
– Leonardo Testi

ESO Garching, 6–7 April 2011

The Community Days will inform potential ALMA users about scientific capabilities during Early Science operations and familiarise them with the procedures and software involved in the preparation and submission of observing proposals.

www.eso.org/sci/meetings/2011/alma_es_2011.html

alma_es@eso.org

Further information can be found at: **www.eso.org/sci/meetings/2011/alma_es_2011.html**
or by emailing: **alma_es@eso.org.**

ALMA Newsletter

January 2011

Credit: ALMA (ESO/NAOJ/NRAO), J. Guarda

If you wish to receive email announcements when new editions become available, please send an email to almanewsletter@alma.cl, with *"subscribe ALMA newsletter"* in the body.

To find out if you are already on the email list, send an email to almanewsletter@alma.cl, with *"which"* in the body.

This newsletter is also available here.

Please send comments on the newsletter or suggestions for articles and announcements to the editors at:

Lewis Ball (lball@alma.cl)
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William Garnier (wgarnier@alma.cl)

More information on ALMA and contact details can be found on the ALMA homepage www.almaobservatory.org

Regional Newsletter ESO

Regional Newsletter NRAO

Regional Newsletter NAOJ