ALMA Newsletter

April 2010

ALMA

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Introduction

Dear ALMA newsletter recipients,

By far the most dramatic event that happened in Chile since the last newsletter was of course the big earthquake on 27th February. This affected everybody's lives in one way or another but we feel extremely lucky that none of the ALMA staff were injured. While the property damage in the Santiago area is limited, further south the disruption was much more severe and several families of our staff suffered significant material damage and were deprived for some time from food and water. In response to this critical situation, we arranged three emergency shipments of supplies, and ALMA staff volunteers transported these to Regions VII and VIII, the regions most affected by the catastrophe. Also, we set up a relief fund to collect and channel donations from employees. The ALMA site is far enough from the epicenter that there was no direct effect but it was necessary to put the activities there into a standby mode so that the staff members who needed to, could return home to be with their families. Operations resumed on the 8th of March.

However, there have been plenty of positive things happening within the Project as well. January saw the formal start of Commissioning and Science Verification (CSV). This is the process which is intended to take the whole instrument from the stage where it is a collection of very complex parts which have been integrated together and make it into an instrument capable of producing images and making measurements with the exquisite sensitivity and precision which is the goal of the project. The work started with the three antennas in the "Phase I" locations somewhat to the west of the site. At the end of March the antennas were moved to a new location at the center of the site, using the antenna stations that will eventually form the Atacama Compact Array. This enables us to put the antennas close together, which is essential for some of the critical tests of the antenna performance and the stability of the system. You can find more details about these exciting developments in this newsletter. And as usual, you will also find a list of upcoming events, seminars and workshops related to ALMA and radio astronomy that we strongly recommend as well as the latest job opportunities to join the exciting and challenging ALMA adventure.

I cannot finish this introduction without drawing your attention to the emerging results of the Herschel satellite and its instruments, HIFI, PACS and SPIRE (More Info). The images and spectra are truly stunning and very exciting and of great interest for future ALMA observing programs.

Enjoy ALMA's universe!

Thijs de Graauw, ALMA 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), Sergio Cabezón (NRAO).

Focus on...

ALMA on the move by Richard Hills, ALMA Project Scientist.

Credit: ALMA (ESO / NAOJ / NRAO), Richard Hills (ALMA).

Thus far we have been carrying out the commissioning with the antennas in the “Phase I” configuration. The three antennas were located somewhat to the west of the center of the array on foundations which were separated by 100 to 200 meters. This was fine for doing the initial testing and checking out of the system, but to proceed with the next phase of commissioning we need to have the antennas closer together. This will make it possible for us to observe planets which (apart from the Sun and the Moon) are the strongest sources of (sub-) millimeter wave signals in the sky. It also reduces the effects of fluctuations in the atmosphere which would otherwise mask any small variations in the antennas or the electronics which are the things that we now need to investigate. To bring the antennas close together they have been moved to foundations that will eventually form part of the Atacama Compact Array (ACA) which is to the south of the technical building.

Before we could make the transition to this “Phase II” configuration, much preparatory work had to be completed. First, the concrete foundations had to be ready with their “inserts” in place. The inserts are the pieces of steel which the antennas actually stand on – these have to be accurately aligned and level. The

Credit: ALMA (ESO / NAOJ / NRAO), Richard Hills (ALMA).

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wide and smooth roads needed for the transporter had to be prepared and the ground around the foundations made smooth. Finally the optical fibers for communications and the cables, transformers and switch-gear to provide power had to be installed, tested and put into operation. The power system was particularly challenging because the distribution is done at 23,000 volts and this is the first time that ALMA has brought such a system into operation.

All this work was completed by the middle of March and on the 21st and 22nd of March two of the antennas were moved to their new locations. By the evening of the 22nd those two antennas were put back into operation as an interferometer and on the 23rd we were able to establish the connection with the third antenna which was still at its original location nearly 600 meters away. This last step was an important test that all the basic functions do operate correctly with this relatively long baseline. Once we had detected the fringes using the strong maser emission line in Orion, we were able to refine the settings of the system (in particular the compensation for the delay of the signals coming through the optical fibers). We were particularly impressed that Robert Lucas's program for automatically finding the relative locations of the antennas was able to come up with the right solution to better than one millimeter accuracy even though (due to an unfortunate blunder with reference positions used for the coordinates) the position we originally assumed was in error by nearly 15 meters!

This relatively long baseline also enabled us to test another critical aspect of ALMA which is the correction for the effects of water vapour in the atmosphere. Even though ALMA is such a dry site there is still some water in the atmosphere the variation in the amount of water along the line of sight of each antenna causes minute changes in the time of arrivals of the signals. If these changes are not corrected the images that ALMA produces will be badly distorted. Each antenna is therefore equipped with a sensitive "radiometer" – a specialized millimeter-wave receiver specially designed to measure the amount of water in front of each antenna. These measurements can then be

These photos show the process of moving ALMA 12 meter antennas on the 5 km high site from the initial set of locations to locations in the ACA (Atacama Compact Array). The process consists of preparing antennas for the pickup on the ALMA antenna transporter, the move and then setting down of antennas at the ACA.

Credit: ALMA (ESO / NAOJ / NRAO), Sergio Cabezón (NRAO).

Focus on...

Credit: ALMA (ESO / NAOJ / NRAO), Sergio Cabezón (NRAO).

used to apply a correction to the astronomical signals. The initial trials that we were able to carry out with the antennas in this intermediate configuration were very encouraging.

Finally on 1st of April the third antenna was moved to the ACA and the three of them were linked up to form our first "close-packed" array. We are now busy with the second phase of the commissioning using this configuration. This will continue for the next few months with antennas being added as they complete their assembly and test procedures at the Operations Support Facility (OSF). Later in the year we will start to move the antennas out to larger configurations again as we explore the astronomical capabilities of the system.

Credit: ALMA (ESO / NAOJ / NRAO), Sergio Cabezón (NRAO).

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

Progress at the ALMA site

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

Operations Support Facility

European antenna is placed on its base. The 12-meter diameter reflecting dish is attached to the base, with the whole structure weighing over 100 tons. When complete, the reflecting surface of the dish will be accurate to less than the thickness of a sheet of paper, and the antenna will be able to point precisely enough to pick out a golf ball at a distance of 15 kilometers. This is the second European antenna to be assembled at the OSF. Credit: ALMA (ESO/NAOJ/NRAO).

At the Operations Support Facility (OSF), four ALMA antennas are being tested. Two of these are nearly through the complete Assembly/Integration/Verification procedures and will join those at the ALMA high-site. The two antennas accepted several weeks ago are undergoing pointing and holography tests preparatory to being outfitted with the full retinue of ALMA electronics. Another front end has arrived from the European Front End Integration Center (FEIC) in the U. K. and is undergoing its acceptance tests before being installed into one of these antennas. Yet another complete front end is expected from the East Asian FEIC in Taiwan in early April. Additional highlights were the successful installation of two backup structures assembled at the AEM ((Alcatel Alenia Space France, Alcatel Alenia Space Italy, European Industrial Engineering S.r.L., MT Aerospace) contractor's facility onto their mounts structures.

In addition, the documentation for the architectural and engineering design of the Residence is still under review and revision. To augment the staff working on the design of the Residencia, a cooperative student from Drexel University is working with the ALMA team for 6 months. The purpose of this effort was to assist with definition of

Progress at the ALMA site

sustainability requirements for the design of the Residencia, as well as to analyze alternative energy sources and energy storage for the Observatory. This group has presented the results of their study to the JAO on 23 March.

Array Operations Site

The pouring and curing of cement for the 192 antenna foundations has been completed by the contractor, and documentation hand over is in progress. Since there are two types of foundations, depending on the soil conditions, there had been some modifications from the initial plan, so the documentation handover of the actual state of the foundations is crucial.

All of the on-site contractors suffered one-to-two week delays at the beginning of March due to the difficulty of transporting staff to the site in the wake of the earthquake. The contractor for AOS road networks continued to make good progress. Installation of the power and fiber optic networks needed to connect the Atacama Compact Array (ACA) antenna stations to the AOS temporary power substation and the AOS Technical Building was completed, but commissioning of the high voltage transformers and switchgear was delayed by more than two weeks due to the unavailability on-site of specialists from the equipment supplier. The installation of inserts and power and signal vaults in ACA antenna stations was completed by mid-March. The ACA antenna stations, which are on the critical path for Commissioning and Science Verification (CSV), were ready to receive antennas as of 19 March. This allowed movement of two antennas (DV01 and PM03) to the ACA area on 21-22 March and another movement of a third antenna on 1 April. The continuation of the antenna station design review was held on 18-19 March and successfully completed, pending closure of several action items. In total 32 AOS antenna stations have been completed so far. Further installation of inserts to the antenna foundations will occur later this year.

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

Progress at the ALMA site

Site Power

The initial plan for permanent site power was modified to account for changing conditions in northern Chile. The first plan was to make use of natural gas that was transported south of the ALMA site. This is no longer available, so the next solution was an overhead power line from Calama. This proved to be unworkable, so the present solution has had to be “island mode” power generation. That is, fuel will be delivered to the OSF, and electricity will be generated by ALMA at OSF and brought to AOS. This will be a dual fuel system. Before the permanent power is installed, there has had to be temporary power for construction at OSF and initial operation at AOS. Power for the first stage of antenna operations at AOS are already in place. The power transmission from OSF to AOS is forecast for January 2011. This transmission line includes the laying of optic fiber for data transfer.


Credit: ALMA (ESO / NAOJ / NRAO), Sergio Cabezón (NRAO).

For the CSV work, a temporary power generation station is installed while the permanent power line and AOS substation are being built. This temporary power station will provide for the needs of the CSV antennas when these are moved to the Atacama Compact Array foundations and also the AOS Technical Building. The connections to the ACA pads are ready and have been tested. These will begin operation as soon as the antennas are moved to the ACA foundations.

The power transmission from this arrangement will then be extended to the Central Cluster and to other antenna locations until the permanent power supply (PPS) is operational.

The implementation of the AOS temporary power system (TPS) was completed on 19 March as was the commissioning of the 23 kV equipment.

Progress at the ALMA site

Santiago Central Office

The construction is progressing according to plan, and the building should be completed by mid-2010. The installation of climatization and electrical subsystems, as well as finishing work on interior walls and ceilings continues. The contractor hosted a celebration to mark completion of the structure at the facility on 26 March. Everything remains on schedule for completion of the construction before mid-2010, and occupancy by September 2010.

In the background is the shell of the soon to be completed ALMA Santiago Central Office. The structures in the foreground are a part of the underground parking garage.

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Technology

ALMA Measures Calama Earthquake

By Rodrigo Brito, ALMA Photonic Engineer & Bill Shillue, Head of Photonic LO Group

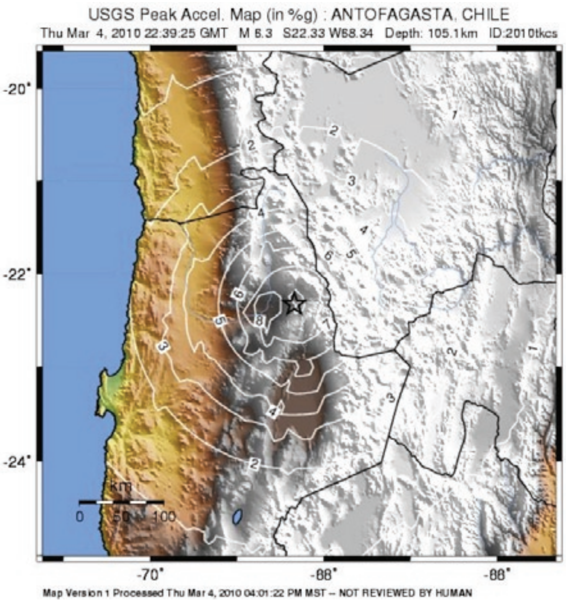


fig 1. Magnitude of earthquake's peak acceleration around the epicenter (data from the U.S. Geological Survey for the region near Calama, Chile, on 4 March 2010). The ALMA site is marked by the black star.

On 4 March 2010, the ALMA system response to an extraordinarily large disturbance was measured when a magnitude 6.3 earthquake struck near Calama, Chile, relatively close to the ALMA site. Figures 1 through 4 demonstrate the remarkable performance of the ALMA system to a huge disturbance that was more than 100 times the specification for correction accuracy.

The ALMA telescope includes a Photonic Local Oscillator distribution system, in which each antenna is connected to a central building by optical fiber. The optical fiber is buried 1-m deep in the earth on the Chajnantor plateau in northern Chile. Due to the unprecedented combination of high observing frequencies (up to 950 GHz) and baselines up to 15 km, ALMA requires state-of-the-art precision in all of its instrumentation.

To provide the most accurate oscillator timing signals to the antennas, the approach adopted by ALMA uses a very accurate yardstick to probe the small changes in the fiber optic delay to each antenna. This is done via an ultra-stable "Master Laser" used in combination with an optoelectronic fiber optic line stretcher that continuously adjusts the overall fiber length to each antenna. This system corrects the timing for ALMA so that temperature changes and antenna motion effects are removed.

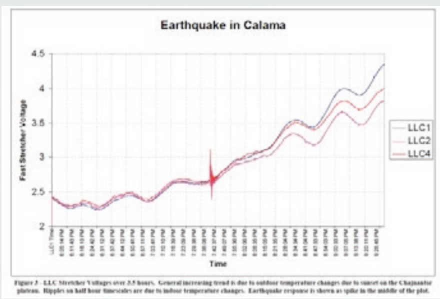


fig 2. The ALMA Line Length Correction (LLC) Stretcher Voltages over the 3.5 hours centered on the earthquake. The generally increasing trend is due to outdoor temperature changes at sunset on the Chajnantor plateau. The fast stretcher voltage ripples on half hour timescales are due to indoor temperature changes. The system's earthquake response is the spike at center.

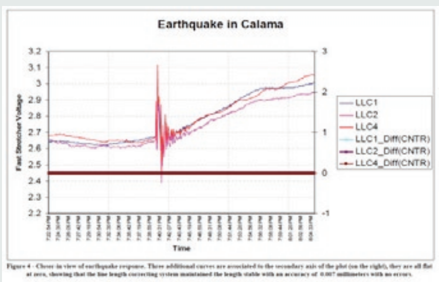


fig 3. A closer view of the ALMA system's earthquake response. Three additional curves are associated with the plot's secondary axis (right). These are all flat at zero, demonstrating that the line length correcting system maintained the length stable to an accuracy of 0.007 millimeters.

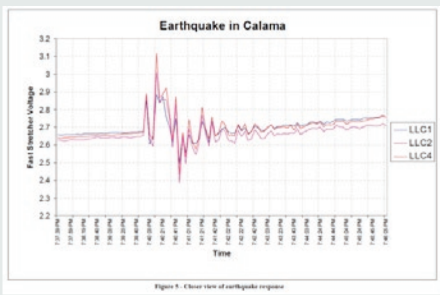


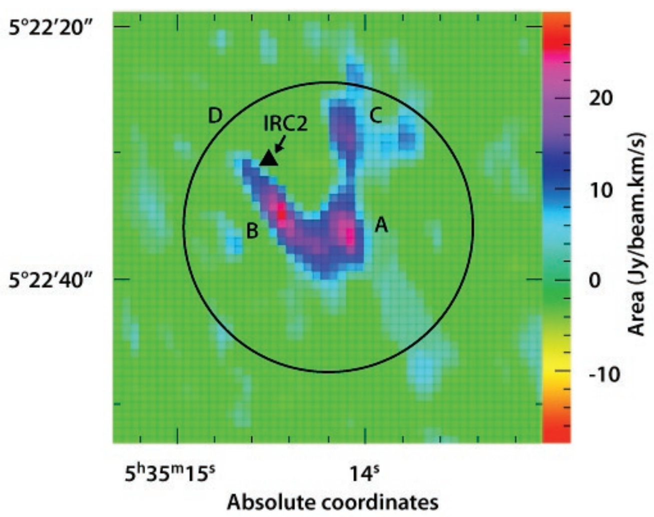
fig 4. A detailed view of the ALMA system's earthquake response.

Credit: ALMA (ESO / NAOJ / NRAO), Cynthia Collao (ALMA).

ALMA In-depth

How Will ALMA Make Images?

The invention of the optical telescope by Galileo 400 years ago marked the beginning of modern astronomy. Galileo used glass lenses mounted in a tube to construct his telescope. This allowed him to collect more light and to distinguish details that could not be seen with the unaided eye. The same principle applies to any single aperture optical telescopes such as the ten meter diameter Keck telescope, the 8 meter Subaru telescope on Mauna Kea, or the four 8-m units of the Very Large Telescope on Paranal: they allow us to investigate very faint optical phenomena whose details cannot be studied with the unaided eye. The evolution of optical instruments also includes detector systems: first the unaided eye, then photographic plates, and today Charge Coupled Devices (CCDs) or detectors that are sensitive to "invisible light", such as X-rays, UV and Infrared Radiation, and radio waves. Fluctuations in the earth's atmosphere smear images, but astronomers have learned to improve image quality by techniques such as adaptive optics or speckle interferometry.



The circle marks the angular resolution of the IRAM 30-m radio telescope at this frequency (101.5 GHz). The detail seen is because the interferometer has a much higher angular resolution since the maximum distance between antennas is of order 1 km, giving a beamsize of 3.3" by 1.7" as compared to the 23" beam of the IRAM 30-m single dish. The letters mark the locations of maxima found in ammonia emission.

However, even if one could control all the effects of the atmosphere, the ultimate limit of all optical (this includes the "invisible light" mentioned above) instruments is determined by the ratio of wavelength to diameter of the instrument. For example, the highest angular resolution in the visible light with a single aperture is achieved with the Hubble Space Telescope (HST), which operates above the atmosphere: it is 0.04 arcseconds, which corresponds to two objects separated by 80m at the distance of the Moon. The ability to distinguish between two sources is referred to as the *"angular resolution"*.

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

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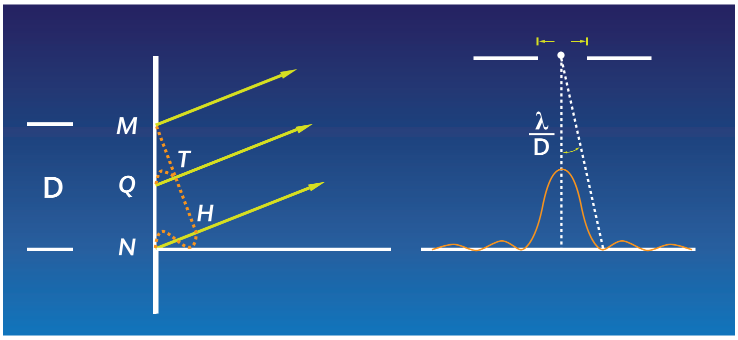

Fig. 1. A sketch designed to illustrate the concept of angular resolution. The size of the aperture in mm is D, and the wavelength of the wave, also in mm, is λ. There are two distant sources. The first is on axis, and is not shown for clarity. Waves from this source reinforce to produce the maximum as shown on the right. Waves from a second source pass through the aperture at an angle θ so have the same phase on the line MTH. At this angle θ, the waves at HN and QT have opposite phase, since QT is going negative whereas NH is going positive. This argument can be applied to pairs of waves. If we choose these at equal distances above the positions of HN and QT, the sum of the pairs is zero. The result is that the response is zero at an angle (measured in arcseconds) θ=206000λ/D where λ and D have the same units. This so-called diffraction pattern is shown on the right. Such a pattern will smear the fine details of any image; the amount of smearing depends on the ratio of wavelength, λ, to aperture, D. In addition to this response, there are smaller secondary maxima, the sidelobes, as shown in the diagram on the right.

To understand this fundamental limit, we assume that the first source is located exactly along the axis of the telescope tube, while the second is slightly offset from this axis. The angular resolution is determined by summing the light (visible or invisible) waves from these two sources as these reach the detector (see Fig. 1).

Any telescope, and our eye as well, works according to the same principle: A light wave that reaches the telescope along the axis of its tube is shaped by a lens, or a mirror, so that it reaches a certain point in the telescope, so called focus, in such a way that regardless of the way the light takes within the telescope, the waves add up. The best example is a burning glass. Radiation also arrives at other points near the focus (the focal plane), but here the light travelling through different parts of the telescope does not completely add up, and in the worst case, wave minima and maxima cancel each other out to produce a zero signal. The larger the telescope mirror or lens (the "aperture") is, the smaller is the image of a very compact light source on a CCD or photographic plate.

A second point like source in the sky that is displaced from the axis of the telescope tube by a small angle will be focused at a slightly different location on the CCD or photographic plate. We can distinguish it only from the on-axis source if this difference in locations is larger than the size of the diffraction pattern of the two sources. In the opposite case, the two diffraction patterns will smear out in single blob. The minimum separation angle that two sources must have in order to be separated by a telescope only depends on one quantity: the ratio between the wavelength of the observed radiation λ and the diameter of the telescope's lens or mirror D. The so called angular resolution in arcseconds is given by approximately θ=206000λ/D, where both λ and D are in mm.

Thus, a 12 meter diameter radio telescope, such as an ALMA antenna, receiving radiation at λ=3mm has about the same ability to distinguish two sources in the visible with the human eye, namely about 50 arc seconds (this angle would allow us to recognize features on the face of a human at 100 meters). The angular resolution is the same because the wavelength of light is about sixteen thousand times smaller than the 3 mm wavelength, but the aperture of the radio telescope is sixteen thousand times larger. This comparison highlights a problem of radio astronomy: since radio waves are much longer than visible light, the telescope diameter must be correspondingly larger to obtain the same angular resolution. Nevertheless, measurements

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

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in the mm/sub-mm wavelength region are essential for investigating the coolest components of outer space such as cold and dusty molecular clouds, where star formation is occurring. Only longer waves can escape from such regions, since visible light is absorbed and scattered by dust.

ALMA can operate at a wavelength as short as 0.3 mm. However, to resolve features in a planet-forming disk around a star like the Sun, one finds that ALMA must have a total extent, D, of 16 km. The angular resolution of ALMA is then 0.004 arc seconds (this is the apparent size of a truck at the distance of the Moon). This even exceeds the resolution of the Hubble Space Telescope. Over the 16 km distance, the intensities must be combined with an error of less than two hundredths of a millimeter (1/16 of a wavelength) to produce accurate images. To reach this accuracy with a single mechanical structure on earth is beyond the limits of technology. There is another approach, illustrated in Fig. 2. Now parts of a single aperture are covered with non-reflecting material, except for two regions.

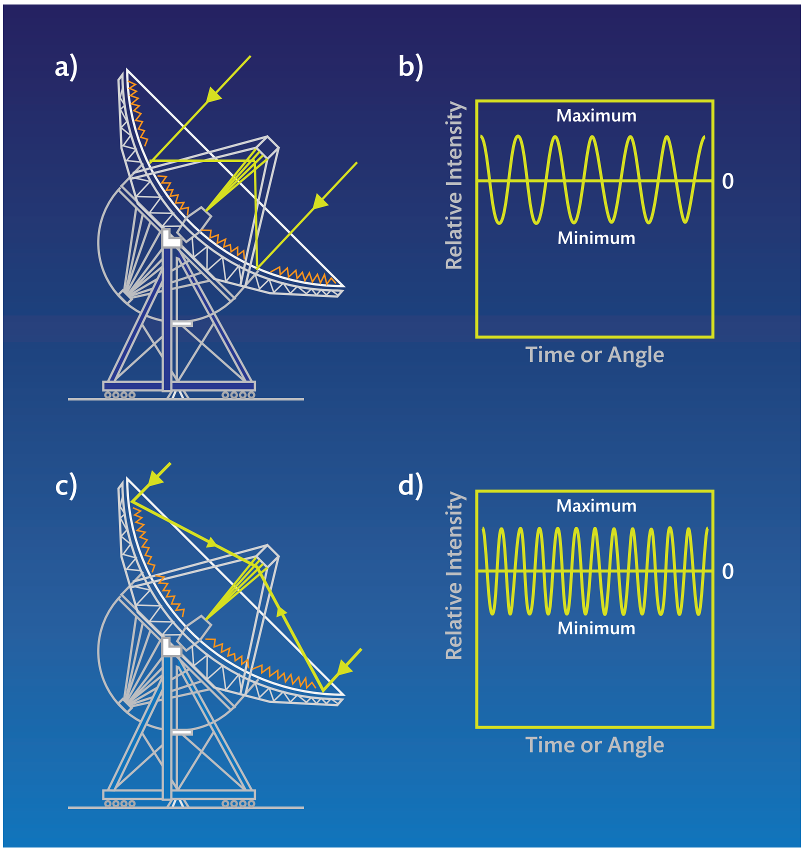

Fig. 2(a). The diagram on the upper left shows the filled aperture instrument with most of the main reflector surface, M1, covered with absorbing material. In this illustration, two regions are not covered. Then the power from a radio source is reflected only from these two regions, and then combined at the receiver. As shown in (b) in the upper right, the response is a series of maxima and minima with the same intensity, referred to as "fringes". The outputs of the two elements are arranged so that the maxima and minima are symmetric about the zero level. This is the usual measurement method with interferometers. In part (c) the two uncovered regions are more widely spaced. The result is a set of more finely spaced fringes, as shown in (d), which gives a finer angular spacing between maxima or minima.

The waves reflected by the two apertures have a small time delay due to the speed of light. When these are combined, the angular resolution is given by the ratio of wavelength to the *separation* of the two reflecting regions. The result is that: (1) the width of the maxima depends on the separation, and (2) since the two uncovered regions are small compared to the total size of the antenna, the sidelobes (Fig. 1) are as large as the main lobe. In this example, the maxima and minima are referred to as "fringes". In other words, constructive or destructive interference depends on small changes in source positions with respect the axis of the antenna.

As shown in Fig. 2(c) and (d), when the distance between the two uncovered regions is larger, the fringe spacing is finer in angle. Deviations from the calculated response can be used to determine source positions to a small fraction of a fringe. The waves reflected from the uncovered regions must be aligned to produce these fringes.

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

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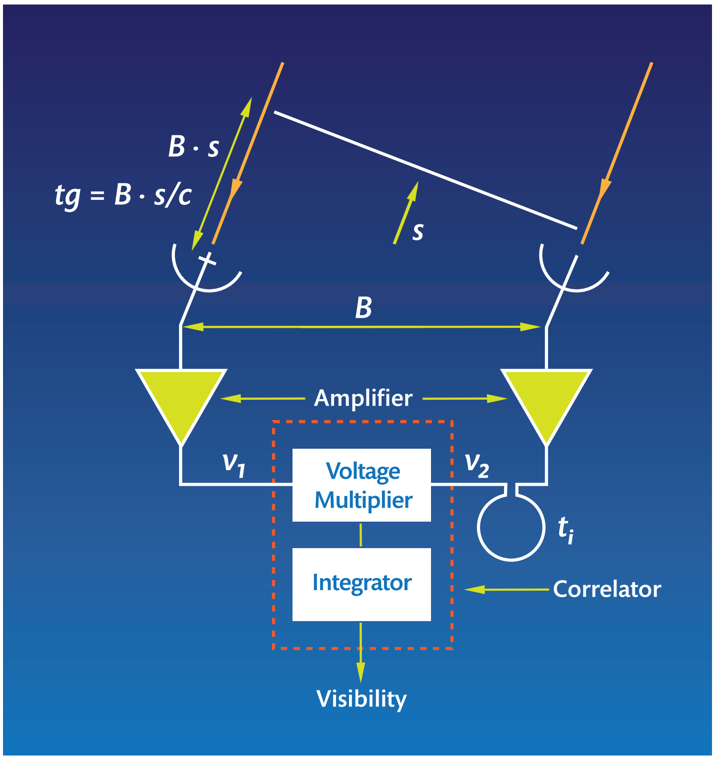

Fig. 3. Shown is the schematic of a two element interferometer. This consists of individual antennas whose size is small compared to their separation or "baseline", B, projected in the direction of the source (this is analogous to the distance D in Fig. 2 but B changes as the source moves across the sky). In this illustration, the inputs are amplified at each element then combined in the Voltage Multiplier. The result is the visibility, that is, the response of the instrument, as a function of the baseline. The output is summed over a short time in the Integrator. It is usual to adjust the time delay, τ_i, electronically so that the waves reaching the voltage multiplier are aligned, that is, in phase; thus the mechanical alignment of a reflector is replaced by an electronic alignment. As the source rises and sets the projected baseline changes. Thus the measurement of a source at different times is made with different projected baseline spacings, so additional measurements of source structure and position are possible.

Slightly changing this scheme, we can replace the single large aperture of diameter D by two small antennas (each with its own receiver) of size d<<D, separated by a distance D. Such an arrangement is simpler to achieve than one large mechanical structure. Then one obtains the angular resolution of a single aperture with a diameter D. By varying the separation, one can obtain an estimate of the source size and position that is more accurate than a filled aperture of diameter D, since the positional accuracy depends on timing which can be very accurate, rather than mechanical stability which is subject to external conditions such as wind and temperature. In the following, we change notation, replacing the separation of the regions "D" by the baseline "B".

The outputs of the small antennas are aligned by electronic means, which is easier to control than the mechanical alignment of a single large antenna that would have the size of the separation B. The usual practice is for these small antennas (each of diameter d << B) to track a source as it moves across the sky. By varying the antenna separation B, one finds that for some sources the response changes. That is, the difference of maximum and minimum divided by the sum of these (*the source visibility*) will change with antenna spacing.

So far in this presentation we have shown how one can determine the position and size of a radio source with a two element interferometer. One could imagine moving the antennas, so the source is measured with different baselines, and in addition, one could measure the source from rising to setting, thus allowing for a number of different projected baselines. In the early days of radio astronomy, this approach only allowed one to distinguish between some very simple possibilities such as a single source, a double source, or extended doubles but it was *not* possible to obtain images. With multi-antenna arrays, the approach can be different, and the models more complete. In the following we indicate how mathematics can be used produce images, like those produced by optical telescopes, as shown in Fig. 4. This requires a more elaborate framework. To prepare this, we first present a number of details that are needed.

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

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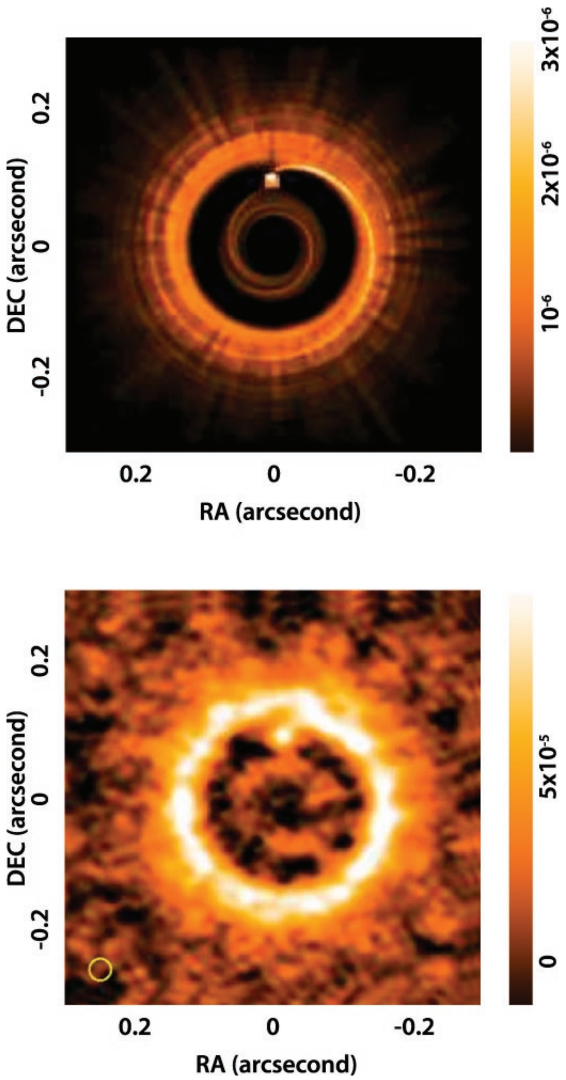

Fig. 4. Here we show a simulation to illustrate the imaging quality of ALMA. On the left is a model image of a proto-Jupiter embedded in a proto-planetary disk. On the right, we show the result of imaging this region with ALMA in an extended configuration after 8 hours. The measurement is carried out at a wavelength of 0.8 mm, so the angular resolution is 0.02 arc seconds (the beamsize is the small circle in the lower left). At this resolution, the disk is clearly imaged, but the details of the ring structure are smeared. Measurements made in a shorter time or with fewer antennas will be worse.

Geometry plays a large role in interferometry. The baseline, that is, the distance projected in the direction of the source in Fig. 3, changes as the source moves a function of time. For two antennas arranged on an East-West line, when the source rises or sets, the baseline projected in the direction of the source is small. When the source is higher in the sky, this baseline length is larger. A sketch of the projected baselines, as a function of time, for a two element interferometer is shown in Fig. 5.

For radio interferometers, it is possible to divide the amplified output of each antenna without seriously degrading performance, so the output of a given antenna can be combined with the outputs of many other antennas. This pair-wise combination allows simultaneous measurements of a source. This is much faster than changing the separation of two antennas. In the ALMA 12-m array, such a pair-wise combination is done by a specially designed computer, the correlator (which is used for a complex comparison of outputs), which can combine the outputs of 1225 antenna pairs.

The data arranged on a rectangular grid in the (u,v) plane are shown in Fig. 5. These results were taken with a three element interferometer. The baseline for A-C is larger than for the baseline A-B, so the visibilities are at a larger distance from the origin of the (u,v) plane. With 3 antennas, one can measure three independent sets of positions in the (u,v) plane: A-B, A-C, B-C. In Fig. 6, we show filled squares to represent the three sets of data.

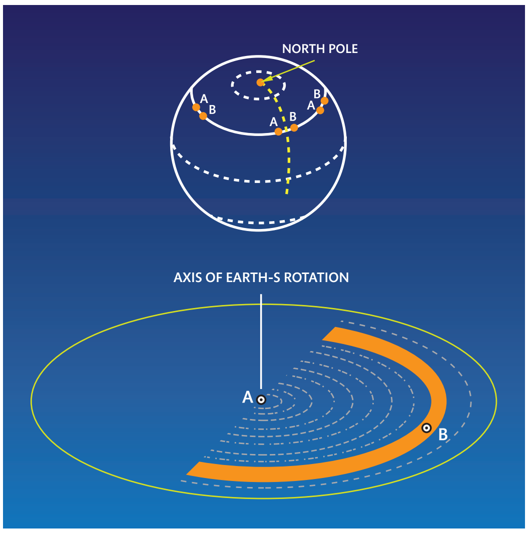

Fig. 5. In this example, the two elements of the interferometer are arranged on an East-West baseline on earth. We assume that the separation of the interferometer elements is small compared to the size of the earth, so the geometry can be two dimensional, that is, flat. For clarity, the radio source is assumed to be in the direction of the north celestial pole. The baseline length (divided by wavelength, and projected in the direction of the source) can be separated into two orthogonal directions, referred to as "u" and "v". Placing measurements in the (u,v) plane is the standard method used to arrange the response of the interferometer.

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Credit: ALMA (ESO / NAOJ / NRAO), William Garnier (ALMA)

ALMA In-depth

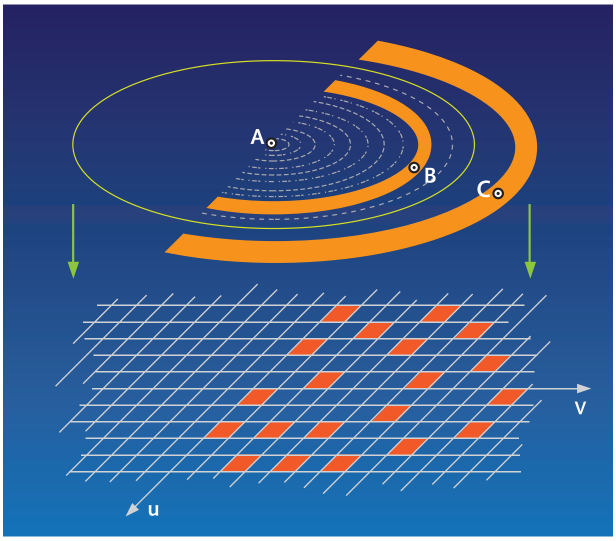
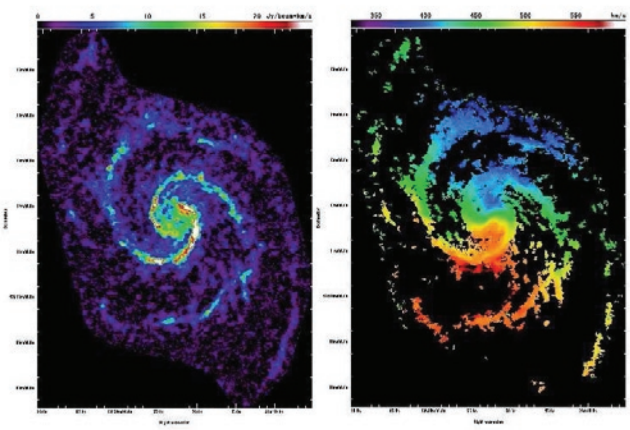


Fig. 6. In this two part plot, the upper part is the spatial location of three elements of an interferometer with antennas labeled A, B and C. As in Fig. 6, as the source moves across the sky, the response of the interferometer traces a path in the (u,v) plane. Shown below is a rectangular grid where the visibility data, shown as black squares. This is the (u, v) plane. The units of (u,v) are antenna spacings in wavelengths. Closer to the origin, (u, v)=(0, 0), are from B-C, while those further are from A-B and are furthest from the origin are those from A-C. There are gaps in the center of the (u, v) plane since the spacing of the antennas is larger than the size of each antenna.

In the mm/sub-mm wavelength region, atmospheric effects, especially changes in the water vapor content, can smear images. This is similar to the apparent motion of stars in the visible (so-called "seeing"). In addition, there may be changes in the instrument during a measurement. Corrections for such effects are possible. With three antennas, it is possible to find improvements in the phases of astronomical signals since the relative phase of antennas A and B minus the relative phase of antennas A and C must equal the relative phase of antennas B and C. This is referred to as "phase closure." With four antennas, similar corrections can be found for amplitudes; this is referred to as "amplitude closure". With ALMA, there are many more than 4 antennas, so these procedures are even more effective.

In the case of ALMA, corrections for the time delays relative to an assumed position for a source are continuously applied. These are referred to as "phase tracking." Thus, although one speaks of "fringes", this is only a historical term leftover from the early days of interferometry. At ALMA, measurements using the two element interferometer system at the Operations Support Facility (OSF) results in a pair of plots of source amplitude and phase. For these tests, unresolved sources are used. If the time delays are correct, the amplitude response and phase response should be constant. These measurements are meant to test the performance of the system, including stability, sensitivity and behavior of time delays. At the ALMA Array Operations Site (AOS) at 5 km elevation, the outputs of more than 50 antennas will be combined pair wise, to give more than 1225 products simultaneously. Then the analysis becomes less simple, but still understandable on the basis of the previous examples.

If all of the (u,v) plane can be filled with data, one can, after some mathematics, obtain almost the same detail as that measured with a filled aperture of the same size.



This is a false color plot of the integrated emission of the carbon monoxide rotational transition between the first level and the ground state of the molecule from Messier 51 (=NGC5194). The carbon monoxide is thought to represent the distribution of the molecular hydrogen, which cannot emit at low temperatures. These results show the positions of Giant Molecular Cloud Associations where stars will be formed. These data are a combination of the single dish data from the Nobeyama 45 meter telescope combined with the interferometer data from the Combined Array for Research in Millimeter Astronomy (CARMA). The CARMA data consist of data from 151 individual positional measurements covering a 6 by 8.4 arc minute region. The angular resolution of the image is 2.2 arc seconds.

Credit: J. Koda et al. (2009 ApJ 700, L132)

ALMA In-depth

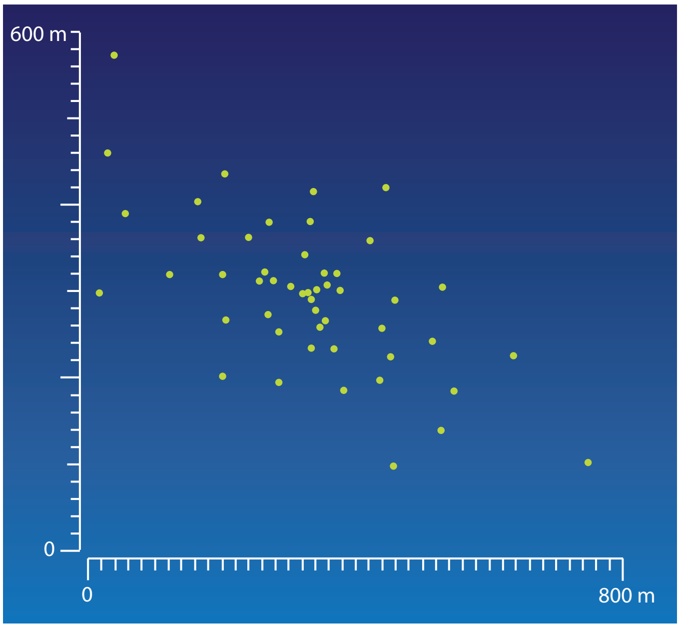


Fig. 7. The locations of the antennas in the ALMA 12 meter array at the AOS are shown as small circles, for so-called "configuration 10". The extent of the vertical and horizontal coordinates is shown in the plot. For the formation of images, the data are taken by correlating (a complex comparison) signals between pairs of these antennas. When the interferometer is used to measure a source from rising to setting, a larger region in the (u,v) plane is filled (see the lower part of Fig. 6). Because more of the (u,v) plane is filled, the image quality will be better. However, not all of the locations in the (u,v) plane will be filled, so the uncorrected image, even for 50 antennas in the 12-m array, is affected by instrumental effects.

In Fig. 7 we show a plot of the antenna positions for ALMA in a typical configuration as dots. The (u,v) data from this are the products of the outputs of pairs of antennas. These are arranged on coordinates in the (u,v) plane that are the spacings (i.e. relative positions) of the antennas. Thus, the antennas at the center of Fig. 7 are closely spaced, so the (u,v) data are near the origin, while the products of all antennas with those at the top and to the extreme right of this plot are further from the origin.

In many cases, the astronomical source is measured from rising to setting. Then in the (u,v) plane, the positions of the individual ALMA elements will appear to rotate, so more of the (u,v) plane is filled. The ideal is to fill the entire (u,v) plane with data, so that this sampling reproduces that which one could obtain with a filled aperture. However, even tracking a source from rising to setting and measuring a source in many configurations, there will still be gaps in the sampling. More typical are the beams produced by short integrations (in this case 5 minutes) as shown in Fig. 8. Compared to a single dish beam, this has much larger instrumental effects, but to some extent, images can be corrected further for the missing data.

It is expected that there will be some degradation of images caused by atmospheric effects or instabilities in the instrument. To reduce such degradations the ALMA antennas will rapidly measure an astronomical calibrator followed by a longer measurement of the target source. In addition, there will be sensors to measure the atmospheric water vapor content above the antennas. These will be used to correct for phase shifts caused by small pockets of water vapor, which affect incoming astronomical signal. Taken together all of these corrections will allow ALMA to produce the best possible images. For the shortest wavelengths to be used at ALMA, this is equivalent to a length of 20 micrometers. However the diffraction effects shown in the right side of Fig. 4 will be the ultimate limit on the detail that one can measure.

Even if all of the corrections for instrumental and atmospheric effects are made, the ALMA beam will be as shown in Fig. 8 upper panel. The somewhat large sidelobes, caused by an incomplete coverage of the (u,v) plane, will give rise to inferior images. Post-data-taking corrections can be applied to improve the images.

From the preceeding, one can understand that an interferometer that consists of many identical elements can image details of a source down to angular scales determined by the largest spacing of the individual antennas. However, there is also a limit determined by the closest spacing between antennas. Since these may not touch, this spacing is 15 meters for the ALMA 12-m array. At a wavelength of 3 mm, this corresponds to an angular scale of 50

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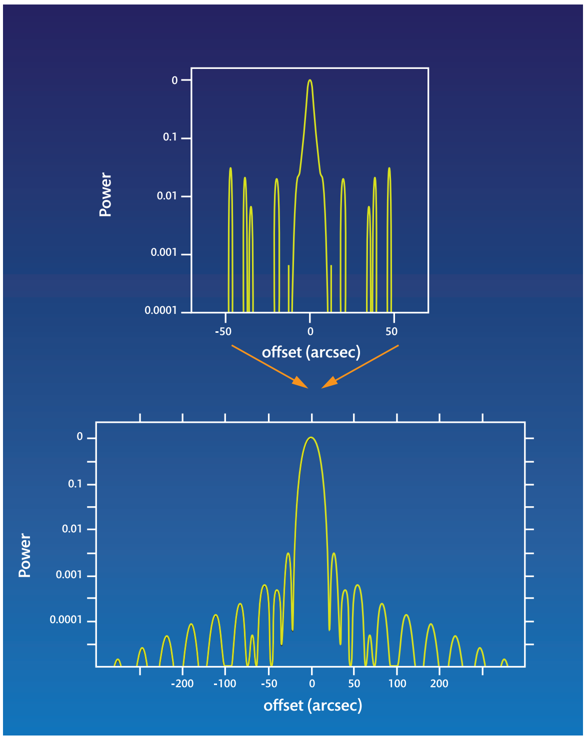
Credit: ALMA (ESO / NAOJ / NRAO), William Garnier (ALMA).

ALMA In-depth



arc seconds. Source structures larger than this will not be recorded. Since one of the high level ALMA science goals is to produce excellent images, this is a severe restriction. To overcome this limitation, the ALMA project has been extended to include the "Atacama Compact Array" or ACA. The ACA consists of an interferometer consisting of 7 meter diameter antennas (the "ACA 7-m array") together with single 12 meter antennas for total power (ACA TP Array). Use of this combination of smaller antennas and interferometry provides the response to extended emission. Simulations of the response of the ACA allow an estimate of the performance. The result is the response of the combination of the ACA with the 12 meter interferometer array as shown in Fig. 9.

From Fig. 9, the response of the ACA four 12 meter Total Power antennas (in the TP Array) is about a factor of two below the response of other parts of the system. In part this is caused by the smaller number of antennas in the TP Array. To equalize the responses, the ACA must spend four times as much time on a specific source. Thus, the ACA must be scheduled independently of the 12m Array.

Fig. 8. Shown above is the cross section of a simulated ALMA beam produced after a 5 minute integration with the antenna positions shown in Fig. 10. The beam can be thought of as the image of a very compact source. This determines the detail that one can image. This plot was made for a wavelength of 1 mm. The vertical scale is in powers of ten to accommodate the large range in intensity. This causes some distortion in the width of the sidelobes. The full width of the main beam is 0.3 arc seconds. The peaks beside the main beam are sidelobes; these are caused by the incomplete sampling of the (u,v) plane. The peak power in the highest sidelobe is about 1/40 of the power in the main beam. This beam is produced by the fifty 12 meter antennas of ALMA. In addition, the Atacama Compact Array (ACA), consisting of four 12 meter and twelve 7 meter antennas will improve the shape of this beam by lowering the sidelobes and recording all of the source flux density. That is, use of the ACA will improve the shape of the ALMA beam but will not improve the angular resolution of ALMA. Shown below is the cross section of the beam of a single 12 meter filled aperture at a wavelength of 1 mm. The main beam has a full width to half power of 20 arc seconds, that is, 66 times larger than the beam produced by ALMA at 1 mm. However, the power received in highest sidelobe is 1/400th of that in the main lobe. Thus, the unfilled ALMA array produces a higher angular resolution, but with the drawback of larger instrumental effects. The lines connecting the upper and lower panels show the relation of the angular scales. That is, the single dish telescope has a much worse angular resolution than ALMA, but the instrumental effects present in an ALMA beam are larger than those in a single dish beam.

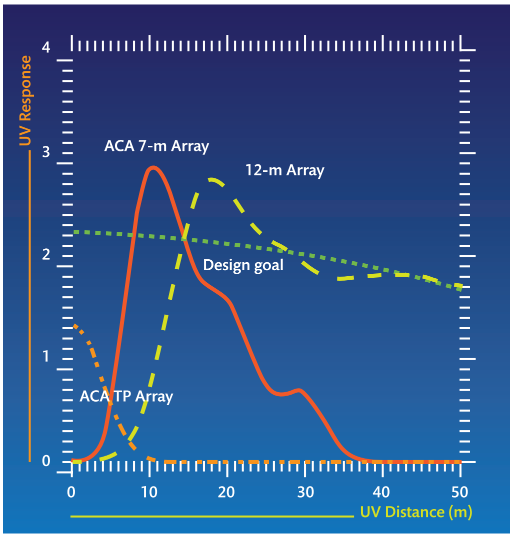


Fig. 9. This shows the response of the ALMA instrument to sources of extended source emission. There are three components: the ACA 12m Array which consists of the antennas in the interferometer array (response is shown as a dashed line), the four ACA 12 m antennas used for total power measurements (their response is shown as a dash-dotted line), and the twelve 7m antennas (their response is shown as a solid line).

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Who's who:

The ALMA Commissioning and Science Verification Team

By Antonio Hales, Kartik Sheth and Tom Wilson, commissioning scientists.

Credit: ALMA (ESO / NAOJ / NRAO), Cynthia Collao (ALMA).

ALMA will provide an unprecedented combination of sensitivity, angular resolution, spectral resolution and imaging fidelity at the shortest radio wavelengths for which the Earth's atmosphere is transparent.

ALMA will make extremely important contributions in a variety of subjects:

1. It will be a premier tool for studying the first stars and galaxies that emerged from the cosmic "dark ages" billions of years ago. These objects now are seen at great cosmic distances, with most of their light stretched out to millimeter and submillimeter wavelengths by the expansion of the Universe.

2. In the more nearby Universe, ALMA will provide an unprecedented ability to study the processes of star and planet formation. Unimpeded by the dust that obscures visible-light observations, ALMA will be able to reveal the details of young, still-forming stars, and is expected to show young planets still in the process of developing.

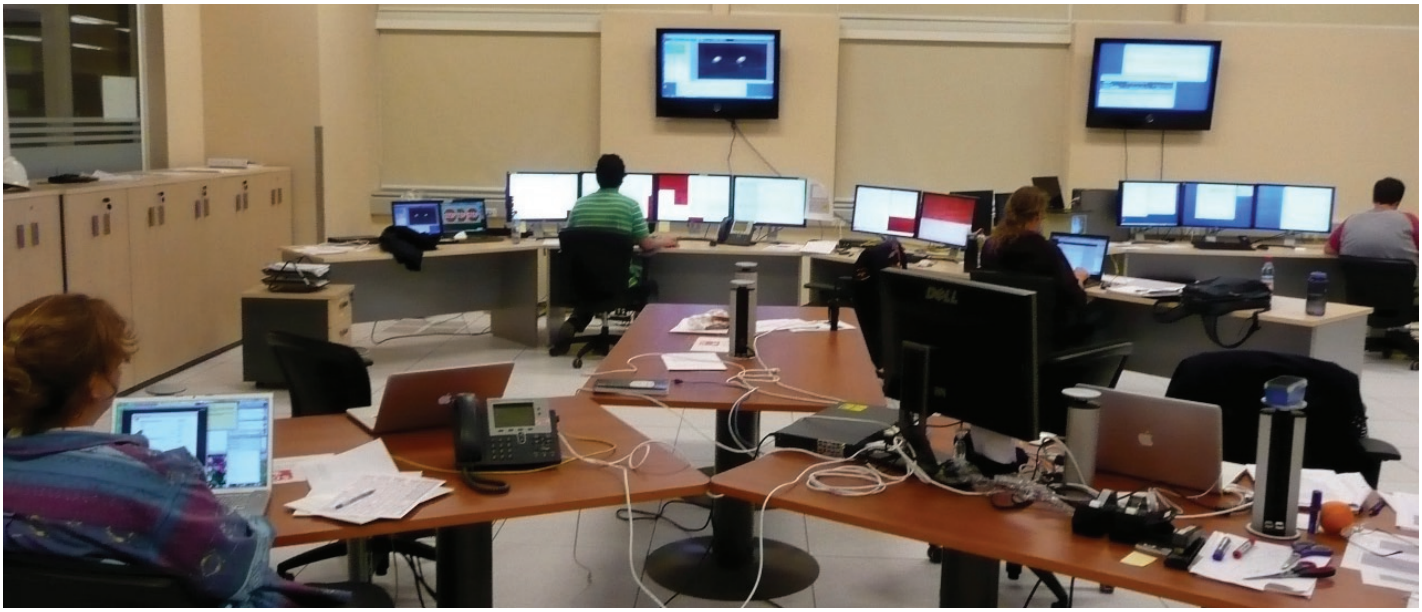
3. In addition, ALMA will allow scientists to learn in detail about the complex chemistry of the giant clouds of gas and dust that spawn stars and planetary systems.

Credit: ALMA (ESO / NAOJ / NRAO), Victor Ruiz Caballero.

Who's who:

In order to bring ALMA from the construction to science phase, the project has been divided into several distinct phases. We are currently in the Commissioning and Science Verification (CSV) stage, which follows the Antenna Integration and Verification (AIV) stage.

Before we discuss the CSV stage in detail, we note that the components for ALMA are produced in a number of manufacturing facilities, laboratories and observatories around the world. These undergo limited tests before shipment to ALMA, but the ultimate tests of the entire system are successful astronomical measurements. ALMA consists of state of the art soft- and hardware and is an extremely complex instrument. In addition, observations with ALMA are expected to be very flexible and easy to use for the non-expert, so the user interface must be simple and transparent. These requirements impose stringent demands on the Commissioning and Science Verification (CSV) team.



A set of ALMA Science Specifications has been prepared and is available as an ALMA report accepted by the ALMA Board. These specifications consist of a few high-level science requirements and a longer, more specific list of technical requirements.

The goal of **Commissioning** is to take ALMA from the stage reached at the end of AIV, that is, a system that functions at an engineering level to an instrument that meets the science / astronomy requirements. **Science Verification** is the quantitative confirmation that the data produced by the instrument is valid and has the required characteristics in terms of sensitivity, image quality and accuracy.

The vast majority of the effort during Commissioning is aimed at finding those characteristics that are not within the specifications. In this stage, the CSV team will devise tests, identify

Who's who

and solve problems in close collaboration with the computing, engineering and AIV teams. The CSV/AIV/DSO (DSO stands for Department of Science Operations) team has grown from about 10 scientists one year ago to 32 scientists. This team is actively working in the commissioning and science verification of the system (most of the team are based at the Joint ALMA Observatory, together with few visitors from the ALMA Regional Centers (ARCs) in North America, Europe and East Asia). The final goal for this team is to have an array that meets the stated ALMA specifications. In addition to close interaction with the other teams, there must be an efficient communication system to track bugs and to report and communicate the information, i.e., proper, detailed but transparent documentation to the ALMA technical staff and to the staff in the executives.

The start of CSV phase began on January 22, 2010 with the delivery of 3 fully equipped, fully functioning antennas to the AOS. The following requirements had to be met by the AIV stage for handover to the CSV team:

- Three antennas operating at the AOS with:
  (1) Front-ends containing at least Receiver Bands 3 (1.3 mm), 6 (1.3 mm), 7 (0.8 mm) & 9 (0.6 mm)
  (2) Calibration units with hot and ambient loads
  (3) Complete Back End and stable LO system
- Correlator capable of processing three inputs
- Demonstration of fringes and phase closure (Nov 2009)
- Software for basic operation and data reduction (R7.0, deployed in Jan 2010)

The ALMA Project Scientist Richard Hills decided that these requirements were met on Jan 18, 2010. The CSV stage officially began a few days later.

These antennas were integrated into the `CSV Array'. This array will grow continuously as AIV delivers newly assembled, integrated and verified antennas to the AOS. This process will continue until the end of construction. As new antennas are added to the initial CSV Array, the goal of the CSV testing will be to ensure that the sensitivity and image quality of ALMA meets specification. Members of the CSV Team lead small groups that carry out one or more specific commissioning tasks. These will evolve as the project proceeds, i.e. starting with measuring the properties of individual antennas, then testing and calibrating the various interferometric observing modes and then progressing to the verification of the quality of the data that ALMA produces.

The CSV process must also produce operational procedures and documentation for operation of ALMA as a science facility, including end-to-end data management and reports documenting as-built performance, exceptions, recommendations for improvement and test data, including a verification matrix showing the performance of ALMA as measured against the science

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Credit: ALMA (ESO / NAOJ / NRAO), Victor Ruiz Caballero.

Who's who

Celebration for the official launch of CSV on 22 January.

requirements. The end of CSV will be marked by a handover to the DSO for regular array operations.

Until the start of the CSV phase, all ALMA scientists were involved, to some extent, in the support of AIV activities. With the CSV array in place, the AIV and CSV teams work together on two distinct tasks. AIV activities are still focused on accepting and verifying newly delivered individual systems (that is the combination of antennas, front ends, etc) so that these can be integrated into the CSV array. These efforts are concentrated on the antennas at the OSF. CSV activities are focused primarily on ensuring that all components of the CSV Array at the Array Operations Site (AOS) at 5 km elevation, so that these function as a complete instrument. Currently, scientists from the DSO team work closely with the rest of the CSV and AIV team, assisting them with ongoing tests. A primary goal of the DSO is to ensure that all observing modes are operational, which in turn involves stringent testing of ALMA software such as the ALMA Observing Tool (OT), ALMA Control Software (ACS) and the data reduction package, CASA. So, working together in this way ensures that the telescope performs to the standards expected by DSO, and also provides training in all of the ALMA subsystems for the DSO staff.

The Early Science period is defined to be the first operational phase of ALMA for observations proposed by the worldwide astronomy community, in response to an open call for proposals which is expected to be issued late 2010. Early Science begins when at least sixteen 12m antennas, equipped with at least 3 receiver bands, are fully commissioned. In addition, the main observing and data processing capabilities must have been verified for scientific use. Early Science is scheduled to begin by the second semester of 2011.

Credit: ALMA (ESO / NAOJ / NRAO), Victor Ruiz Caballero.

Who's who

Some of the main goals of the CSV process prior to Early Science are listed below:

- At least three of the receiver bands 3, 6, 7, and 9 available on all antennas plus bands 4 and 8 on as many antennas as possible.
- Synthesis mapping of extended fields using pointed mosaic mode.
- Configurations extending to baselines of 1km.
- Linear and circular polarization measurements of compact sources.
- Single-dish mapping of extended objects in both continuum and spectral line modes, including on-the-fly observing.
- The quality of calibration exceeds that of existing mm-wave arrays.

The CSV process will end when a 50 antenna array is accepted by Science Operations. This will mark the Inauguration of ALMA and is scheduled at the end of 2012. The end of CSV and the start of normal operations have the following goals:

- Regular operations with ≥ 50 fully-equipped antennas. (This includes both 12m and 7m antennas.)
- All antenna stations complete, providing synthesis mapping with high fidelity using the full set of array configurations.
- Simultaneous operation of ≥ 4 sub-arrays is possible.
- Capability for combining data from the 12m array with data from the ACA including "zero-spacing" data, and multi-configuration images
- Linear and circular polarization measurements, including mosaicing of sources that are larger than the primary beam.
- Fast time-resolution observations, e.g. of solar flares.
- Major software systems available and working in a way that allows astronomers who are not synthesis experts to use ALMA.
- Accurate calibration of all the procedures listed above.

Who's who

In a nutshell

AIV - The primary Assembly, Integration and Verification (AIV) tasks are to assemble and integrate the major ALMA sub-systems into a working system, establish its initial atechnical performance and ensure it meets stated technical requirements. AIV will continue until all antennas are accepted from the suppliers, outfitted with electronics and integrated into the array. AIV includes single-antenna activities such as pointing, tracking and surface accuracy determinations, two element interferometry, and system-wide activities. **More info about AIV at** http://www.almaobservatory.org/newsroom/newsletter/166-newsletter-no-2#whoswho

CSV - The purpose of the Commissioning and Science Verification activities is to test and optimize the components of the ALMA system (e.g. antennas, correlator modes, receiver or software components). These include astronomical measurements to ensure that the sub-system in question meets the scientific requirements outlined. CSV is a construction activity led by the JAO Project Scientist, Richard Hills and Deputy Project Scientist, Alison Peck. The CSV phase is defined to begin with the handover from AIV to CSV of a verified 3-element interferometer at the Array Operations Site (AOS). This marks the transfer of responsibility from Project Engineer to Project Scientist for this equipment. However, there will be continual and significant overlap in personnel and techniques before and after this transfer. Where applicable, the CSV phase for individual components of the array is considered to start when the mode or device is handed over by AIV (following Acceptance Tests in which AIV and CSV personnel participate) and ends with acceptance on behalf of the Department of Science Operations (see below). As members of the CSV team, ALMA Commissioning Scientists assist the Project Scientist and the Deputy Project Scientist in planning and executing the scientific commissioning of ALMA. This mainly consists on preparing specific test procedures and carrying out measurements, processing the data and producing reports. If the procedures should fail, the CSV team will follow up the test process to locate the source of error.

ES – Early Science is defined to be the first operation of the array for observations proposed by users in response to a full, open call for proposals. The capabilities of the array will be restricted at this stage. The call for proposals will be issued well in advance of the start of Early Science. Early Science is scheduled to start in the second semester of 2011.

DSO – The Department of Science Operations will be responsible for carrying out all the scientific functions of the observatory during the operational phase, including the processing of observing proposals, scheduling and performing the observations, and archiving the data and monitoring its quality. These roles begin with Early Science but preparations for them have been underway for some time. The scientists on the staff of the DSO are participating in the test activities needed for AIV and CSV, although the emphasis of their work remains in preparation for Early Science.

DTS – The Department of Technical Services provides the necessary support across a wide range of activities that are needed for CSV to proceed. A few examples are software and IT support, as well as support needed for the use of technical buildings, power and the operation of the transporter to move the antennas. **More info at:** http://www.almaobservatory.org/newsroom/newsletter/179-newsletter-4#whos_who

Job Opportunities

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

Head of Technical Services

The Head of the Department of Technical Services of the Joint ALMA Observatory reports directly to the ALMA Director. As a member of ALMA's core management team, the Head of Technical Services will contribute to strategic planning, policy development, implementation, as well as overall decision-making.

Main Duties and Responsibilities:

The Head of Technical Services has the following major responsibilities:

• Preventive and corrective maintenance for the array sub-systems, including antennas, instrumentation packages, local oscillator, correlator, electricity supply and site monitoring equipment.

• Performance trend analysis, problem reporting and tracking of the array sub-systems.

• Antenna transportation and array re-configuration.

• Monitoring and management of the system configuration status.

• Training and certification of technical staff.

• Leadership of the technology-coordination team of the ALMA partnership.

The Technical Services Department has approximately 130 people in its team, considering staff and contractors. During the construction phase, the Head of Technical Services will work in close cooperation with the ALMA AIV/Systems-Integration Lead.

Deadline for receipt of applications to be considered for the position is 1st of May 2010.

More details available here:

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Job Opportunities

The JAO invites applications for the position of:

Head of the Joint ALMA Observatory Data Management Group

The Data Management Group:

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), which is responsible for scheduling and tracking of projects as well as data quality assurance during the observations, and the Data Management Group (DMG). The DMG is responsible for the final data quality assurance and operations of the JAO archives and the data reduction pipeline. The two JAO archives are located at the ALMA Operations Support Facility near San Pedro de Atacama and at the ALMA offices in Santiago, where also pipeline operations activities take place. The DMG works closely with the three ALMA Regional Centers (ARCs) located in Europe, North America and Japan. The ARCs are the interfaces to the ALMA astronomical community, and each of them operates a mirror archive (a copy of the Santiago archive).

Main Duties and Responsibilities:

The Data Manager leads the DMG and reports directly to the Head of Science Operations. He/she has the following major responsibilities for:

- Archive operations.
- Pipeline operations.
- Data quality assurance.
- Trend analysis of the array performance.
- Maintenance, development and execution of the ALMA calibration plan.
- Management of the long-term queue of projects.

The DMG will consist of the Data Manager, a Deputy Data Manager, 4 System Astronomers and 12 Archive operators/content managers. The Deputy Data Manager is foreseen to be in charge of the daily operations of the archives and the pipeline. The Data Manager will work closely with the ALMA Regional Centers as well as with the JAO Software Group and System Engineers.

Before the start of ALMA early science operations (in 2011), the Data Manager will participate in tests and development of the pipeline and software tools used for quality assurance, data delivery and scheduling as well as plan science operations, pipeline operations, archive operations and participate in the setup of the archives.

Deadline for receipt of applications to be considered for the position is May 15, 2010.

More details available here:

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Job Opportunities

The JAO invites applications for the position of:

System Engineer

The successful candidate will work in the JAO System Engineering team, which is responsible for the definition and execution of system engineering activities across the project. This position reports directly to the ALMA Lead System Engineer.

Main Duties and Responsibilities:

• Participate in equipment acceptance in Chile and/or at the supplier's site.

• Plan the system requirements verification, prepare the verification procedures and execute the verification activities.

• Maintain the ALMA System Budgets and Allocations.

• Contribute to the development of the ALMA System Performance Analysis Tool.

• Review test results and populate budgets accordingly.

• Contribute to the configuration control process and ensure compliance of deliverables to the ALMA requirements.

• Maintain and update the ALMA System Block Diagram.

• Organize and participate in product reviews.

• Support product assurance activities.

• Support the preparation of operation and maintenance plans that ensure a smooth transition from Construction to Operations.

• Participate together with AIV and CSV staff in problem diagnostics.

Deadline for receipt of applications to be considered for the position is 1st of May 2010.

More details available here:

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Job Opportunities

For its ALMA Regional Centre (ARC) Department within the Data Management and Operations Division (DMO) at the Headquarters in Garching near Munich, Germany, ESO, the European partner of ALMA, is opening the position of a:

ALMA Regional Centre (ARC) Scientist (European ARC)

The European ARC shall be the primary interface between the Joint ALMA Observatory (JAO) in Chile and the European user community. The European ARC consists of a main centre located in the DMO Division at ESO and several local nodes located in institutes of different European countries.

Main Duties and Responsibilities:

The duties of the ARC Scientist include:

• Integrating multiple web-based systems to support the diverse needs of the European ALMA user community through a User Portal that is consistent in look, feel and message with the ESO and ALMA User Portals.

• Configuring and customizing forms for the ALMA helpdesk; maintaining helpdesk implementation.

• Answering queries from external users, interacting with users, as needed, to assure that user needs are met by the User Portal implementation and its underlying applications.

• Maintaining the ALMA Regional Centre web-site and contributing to maintain the ALMA science web-site.

• Participating in testing the ALMA operations-related software, providing requirements and feedback to the software developers and reporting bugs, in particular the applications related to the ALMA archive.

• Taking part in the ARC activities at ESO, in particular in checking the quality of the final data before delivery to users.

• Contributing to the development of operations documentation.

The successful applicant will be expected and encouraged to use 20% of the time to actively conduct astronomical research. Research in areas directed towards using the ALMA facilities will be particularly supported.

Closing date for applications is April 18th 2010.

More details available here:

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Upcoming events

COMETARY RADIO ASTRONOMY

2010
- may -
17/19

In the next few years there will be an explosive growth in instrumental capabilities for cometary radio astronomy. These include the start of operations of the EVLA and ALMA, the first focal plane cameras on the Green Bank Telescope and the Large Millimeter Telescope, and other facilities worldwide.

For these reasons we are organizing a workshop on cometary radio astronomy to be held on 17-19 May 2010 at the Green Bank Observatory of the NRAO. The workshop will bring together researchers to consider what might be done with these new capabilities, and to provide input into the development and operation of radio telescopes for the benefit of cometary science. In addition, it will offer a forum for promoting the importance of cometary research in the scientific portfolio.

Dates: May 17-19, 2010. **Location:** NRAO Observatory, Green Bank, West Virginia.
More information: http://www.nrao.edu/meetings/comets10/index.shtml

PREPARING FOR ALMA:
AAS MIAMI SPECIAL SESSION INFORMATION AND DISCUSSION

2010
- may -
24

The Atacama Large Millimeter/submillimeter Array (ALMA) will provide an unprecedented combination of sensitivity, angular resolution, spectral resolution, and image fidelity at millimeter and submillimeter wavelengths, enabling a wide range of transformative research. ALMA will provide observing opportunities at wavelengths from 0.3 mm to 9.6 mm (950 GHz – 31 GHz), a key part of the electromagnetic spectrum, for example, for probing the first stars and galaxies, directly imaging planetary formation, and studying the energy output from supermassive black holes in starburst galaxies.

The first call for ALMA observing proposals is expected in late 2010, while construction continues. This Special Session will describe this Early Science opportunity and the ALMA tools and support available through the North American ALMA Science Center (NAASC). Located at the NRAO headquarters in Charlottesville, Virginia, the NAASC staff will provide accurate

Upcoming events

and timely information on ALMA observing modes and capabilities to the community, support users creating proposals with the ALMA Observing Tool, staff an electronic Help Desk, validate observers' scheduling blocks, and provide post-observation user support.

The special session will include an introduction to the major tools that users will to prepare their observations and analyze their data, including the ALMA Observing Tool (OT) for proposal preparation and submission, the Common Astronomy Software Applications (CASA) package that will be used to reduce ALMA science data and includes an "observing simulator" task, and Splatalogue, an on-line VO-queriable spectral line database.

During Early Science, ALMA is expected to include at least 16 antennas, 4 receiver bands, baselines to .25 km, and single field interferometry. A goal is to offer baselines to 1km and single dish mapping of extended objects in continuum and spectral line modes. While Early Science will coexist with array commissioning, a portion of the available time will be allocated for science observations.

Potential Speakers:

Peck – Status of ALMA.
Wootten – ALMA: The March to Early Science and Beyond.
Lonsdale – Community Programs and Support from the North American ALMA.
Science Center (NAASC).
Kelsey Johnson (U. Va.) – ALMA from the Users Perspective.
Remijan – Preparing for ALMA: User Tools.

Dates: Monday 24 May, 6 - 8pm. **Location:** Miami, Florida.
More information: http://science.nrao.edu/events/preparingforalma.shtml

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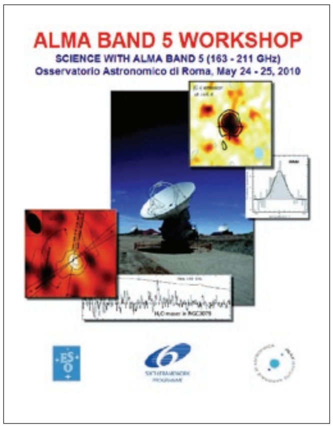
April 2010

Upcoming events

WORKSHOP: SCIENCE WITH ALMA BAND 5 (163 - 211 GHZ)



2010
- may -
24/25

There is increasing interest in observations at frequencies between 163 and 211 GHz (ALMA Band 5) for both Galactic and extragalactic science. A key application is high-resolution imaging of the water line at 183 GHz in Galactic and nearby extragalactic sources. In addition, the 158 micron line of C+ from objects at redshifts between 8.0 and 10.6 will appear in the band, opening up the possibility of probing the earliest epoch of galaxy formation.

The recent launch of Herschel and the imminent commissioning of ALMA offer complementary approaches: Herschel will allow spectroscopy free from absorption by water in the Earth's atmosphere but at low spatial resolution, whereas ALMA observations will provide very high spatial resolution.

The European Union is funding the production of six Band 5 receivers for ALMA through the FP6 Enhancement Programme, together with the development of advanced phase-correction and mapping techniques to support these challenging observations. The receivers will be delivered to ALMA in 2010-2011. The ALMA Project will be seeking proposals for enhancement of the instrument in the near future. These are likely to include the development of a full set of Band 5 receivers (66 + spares).

The aims of the workshop are:

- to assess the potential of ALMA Band 5 for both Galactic and extragalactic applications.
- to inform the community of the opportunities for observing with the initial set of Band 5 receivers.
- to develop synergies with the Herschel mission.
- to discuss technical approaches to production of a full set of receivers.
- to evaluate approaches to calibration and data reduction for the band.

The primary output will be a science case for a full set of Band 5 receivers on ALMA, to be submitted to arXiv.

The workshop will take place at the Osservatorio Astronomico di Roma on May 24 and 25 2010. There will be a small number of invited reviews, together with ample time for contributed papers and discussion. We anticipate a small, focused meeting with approximately 50 participants.

Limited financial support (primarily for young researchers from EU institutions) will be available from the EU ALMA Enhancement Programme. There will be no registration fee.

Dates: May 24-25, 2010. **Location:** Osservatorio Astronomico di Roma. Italy.
More information: http://web.oa-roma.inaf.it/meetings/AlmaBand5/Home.html

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COMPUTATIONAL STAR FORMATION SYMPOSIUM

2010
- may/jun -
31/04

Computational Astronomy is a relatively new branch of research that spans a wide range of skills, including the theory of gaseous and stellar dynamics, computational and algorithmic science, and visualization. It is also usually accompanied by serious comparisons with observations. Simulations of star formation and young cluster evolution have now reached a level of sophistication where they can reproduce the initial stellar mass function, the binary distribution as a function of stellar mass and period, the spatial distribution of stars in young clusters, the evolution of clusters, and the structure and evolution of galaxies. At the same time, there are large differences in techniques, algorithms, and computer hardware, and equally large differences in the assumptions about initial and boundary conditions and what physical processes to include.

This Symposium will be the forum to discuss simulations and observations of star formation in 2010. The result of this Symposium will be a better understanding of the similarities and differences between computational techniques, and a recognition of the successes and shortcomings in matching the simulation results to detailed observations of star formation.

Dates: 31 May to 4 June 2010. **Location:** Barcelona, Spain.
More information: http://www.iaus270.org/

TWELFTH SYNTHESIS IMAGING WORKSHOP

2010
- Jun -
8/15

The Twelfth Synthesis Imaging Workshop will take place on June 8-15, 2010 in Socorro, NM. The school will comprise a week of lectures on aperture synthesis theory and techniques at a level appropriate for graduate students in astrophysics. Basic lectures on synthesis imaging, and advanced lectures on more specialized techniques, will be included. There will be two days of practical tutorials demonstrating data collection, calibration and imaging of both EVLA and VLBA. There will be a $200 registration fee, which will cover the cost of the meeting and a copy of ASP Vol. 180, “Synthesis Imaging in Radio Astronomy II”, from the 1998 summer school.

Dates: 8-15 June 2010. **Location:** Socorro, New Mexico, USA.
More information: http://www.aoc.nrao.edu/events/synthesis/2010/

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Upcoming events

MOLECULES IN GALAXIES

2010
- Jul -
26/30

The conference "Molecules in Galaxies", to be held in Oxford, UK, 26-30 July 2010, will tackle many of the contemporary questions surrounding the molecular gas content of galaxies. In particular, it will allow to review the state of the field as the Atacama Large Millimeter/Sub-Millimeter Array (ALMA) starts operation, and thus carefully plan its exploitation.

Dates: 26 to 30 July 2010. **Location:** Oxford, UK.
More information: http://www.physics.ox.ac.uk/mmconf/

2010 ASIA-PACIFIC RADIO SCIENCE CONFERENCE

2010
- sep -
22/26

The "2010 Asia-Pacific Radio Science Conference" (AP-RASC'10) will be held at Toyama International Conference Center, Toyama, Japan on September 22-26, 2010. The AP-RASC is the Asia-Pacific regional URSI conference held between the URSI General Assemblies. The objective of the AP-RASC is to review current research trends, present new discoveries, and make plans for future research and special projects in all areas of radio science, especially where international cooperation is desirable, and a particular emphasis is placed on promoting various research activities in the Asia-Pacific area. Scientific sessions composed of oral and poster papers will be organized at this conference in order to cover all scientific activities by URSI Commissions A-K:

A: Electromagnetic metrology.
B: Fields and waves, electromagnetic theory and applications.
C: Radiocommunication systems and signal processing.
D: Electronics and photonics.
E: Electromagnetic environment and interference.
F: Wave propagation and remote sensing.
G: Ionospheric radio and propagation.
H: Waves in plasmas.
J: Radio astronomy.
K: Electromagnetics in biology and medicine.

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Further details and a registration form are at:

Commission J: Radio Astronomy
J2: Millimeter- and sub-millimeter-wave telescope and array
http://www.ap-rasc10.jp/pdf/AP-RASC10_SecondCFP.pdf
Convener: Satoru Iguchi (NAOJ, Japan) and Nagayoshi Ohashi (ASIAA, Taiwan)

Dates: September 22-26, 2010. **Location:** Toyama International Conference Center, Japan.
More information: http://www.nrao.edu/meetings/comets10/index.shtml

7TH IRAM INTERFEROMETRY SCHOOL 2010

2010
- oct -
4/8

The 7th IRAM millimeter-interferometry school will take place from October 4th to 8th; it is intended for PhD students, post-docs and scientists who want to acquire a good knowledge of interferometry and data reduction techniques at millimeter wavelengths.

Dates: 4 to 8th October 2010. **Location:** IRAM headquarters. Grenoble, France.
More information: http://www.iram-institute.org/EN/news-astronomers/2010/24.html

OBSERVING WITH ALMA - EARLY SCIENCE

2010
- nov -
29

The European ARC node at IRAM will be organizing a workshop on the ALMA Early Science, from Nov. 29th to Dec 1st. The goal of the workshop is to provide astronomers with the practical information needed to plan ALMA Early Science observations and answer the first Call for Proposals: status and performances of the instrument, preparing and submitting a proposal with the Observing Tool, etc.

Dates: 29 November to 1st December 2010. **Location:** IRAM headquarters. Grenoble, France.
More information: http://www.iram-institute.org/EN/news-astronomers/2010/25.html

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Space Station View of the Operations Support Facility. Credit: Soichi Noguchi, Astronaut, International Space Station (ISS). Excerpt from Twitter (http://www.twitpic.com/1c4wpj/)

ALMA

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

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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

Tom Wilson, former ALMA commissioning Scientist and one of the editors of this newsletter, decided to leave the project for new horizons and challenges and accepted the position of Head of the Radio, Infrared and Optical Sensors Branch at the U.S. Naval Research Laboratory in Washington, D.C.

We are very grateful for his valuable contribution to the success of this newsletter and wish him a lot of success in his new appointment.