The Inauguration of the Atacama Large Millimeter/submillimeter Array

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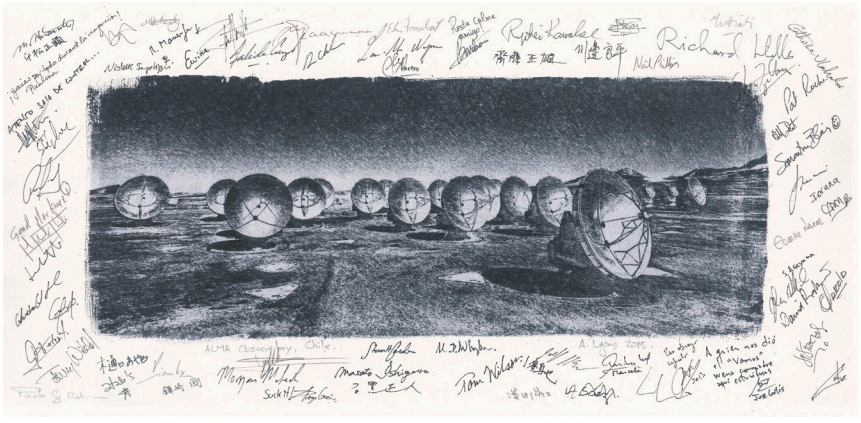
On 13 March 2013 the official inauguration of the Atacama Large Millimeter/submillimeter Array (ALMA) took place at the Operations Support Facility in northern Chile. A report of the event and the preceding press conference is presented and the texts of the speeches by the President of Chile, Sebastián Piñera, and the Director General of ESO, Tim de Zeeuw, are included.

The ALMA project underwent its official opening on 13 March, with a ceremony attended by representatives from all the partner Executives, many who are currently working on the project or were involved in the past, as well as the President of Chile and local representatives from the Atacameño community. Although the array is not yet fully operational, 57 of the 66 antennas were at the ALMA Operations Site (AOS), 5050 metres above sea level on the Chajnantor Plateau in northern Chile, at the time of the inauguration. The inauguration took place at the Operations Support Facility (OSF) at 2900 metres above sea level and was preceded by a press conference on 12 March, also held at the OSF. Dignitaries and attendees also visited the high site on the morning of the 13th and on the 14th. On the evening of the 13th, a private party for ALMA staff was hosted at the OSF by the then ALMA Director, Thijs de Graaw, who also presented everyone with a commemorative canvas depicting the array (Figure 1).

The genesis of the project to construct a large-area millimetre/submillimetre array for astronomy dates back about 30 years to independent initiatives and plans in Europe, the USA and Japan. In the USA the Very Large Array, now called the



Antonio Hales

Figure 1. On the day of the inauguration, Thijs de Graauw presented the ALMA staff with this print on canvas of the ALMA array. ALMA astronomer Antonio Hales collected the signatures from members of the ALMA science team, array operators, engineers and data analysts on his canvas.

Figure 2. Tim de Zeeuw, ESO Director General, the President of Chile, Sebastián Piñera, the Director of the USA's National Science Foundation (NSF) Subra Suresh, the former Director of ALMA, Thijs de Graauw, and the Senior Vice Minister of Japan's MEXT (Ministry of Education, Culture, Sports, Science and Technology) Teru Fukui (shown left to right) aboard one of the ALMA transporters.

Jansky Very Large Array, provided a precedent, but since it operates at radio frequencies, the technology was very different from that needed for a millimetre/submillimetre array. The construction of a large array was endorsed by the US astronomy decadal survey released in 1991. Through the Swedish–ESO submillimetre telescope (SEST) on La Silla, ESO had been participating in millimetre-wave astronomy since the mid-1980s, and then, in 1991, the suggestion to build an array was discussed by the SEST User Group (Madsen, 2012, p. 371ff). At about the same time, Japan, which already had a single-dish millimetre telescope at Nobeyama and a small interferometer array, was also considering a large millimetre/submillimetre array. The size of the undertaking rather naturally led, after much discussion and negotiation, to the three agreeing on a joint project. In 1996 Chajnantor was selected as indisputably the best millimetre/submillimetre site worldwide. The progress of the project has been regularly reported in *The Messenger* and a chapter is devoted to ALMA in Madsen (2012).

Inaugural ceremony

The inauguration was attended by about 500 people, with large representations from the three Executives — ESO, North America (USA and Canada) and East

Asia (Japan and Taiwan). It took place in a large tent that had been erected specially for the occasion. The high level of public interest in ALMA was reflected in the large number of press representatives (120) attending, all of whom also visited the AOS on the Chajnantor Plateau. The logistics of transporting all the attendees to the remote OSF at 2900 metres above sea level were considerable.

Following a short reception, the inauguration began at 12:00 noon after the President of Chile Sebastián Piñera had had an opportunity to visit the AOS and the OSF facilities. The ceremony was introduced and chaired by the ALMA Executive Officer Paulina Bocaz. The proceedings could be viewed remotely by live streaming and are archived[1]. Thijs de Graauw, the ALMA Director at the time of the inauguration, launched the official speeches by introducing ALMA as opening up the cold Universe to high sensitivity and high spatial resolution study. Later in 2013 the full contingent of 66 antennas will be in place and the operation of the array will be developed, with longer baselines, polarisation observations, Solar observations, new bands and observing modes. The Director emphasised the technological aspects of the project — the four types of antennas with 7- and 12-metre apertures and their stringent surface and pointing accuracies, the two correlators for 16 and 64 antennas, and the demand for antenna signal synchronisation that is accurate to a fraction of a picosecond. He also emphasised the strong links with the host nation, Chile, in terms of the educational, scientific, technical and cultural aspects, and displayed some paintings by Chilean children of the antennas and the array. He closed by thanking all the visionary scientists and engineers who have worked to realise the project, and all those currently working (a staff complement composed of 20 nationalities, with 80 % of staff from Chile). He also thanked the previous Director Massimo Tarenghi. Thijs de Graauw retired from his position as ALMA Director on 31 March 2013 and has been replaced by Pierre Cox.

ALMA's Chief Scientist, Ryohei Kawabe then spoke about some of the recent science results from ALMA. Its high angular resolution and wavelength coverage will

Figure 3. Tim de Zeeuw presenting his speech at the ALMA inauguration.

contribute to a wide range of topics from chemistry and planet formation to cosmology. The ability to detect emission from biotic and pre-biotic molecules contributes to study of the origin of human life. Although ALMA is intrinsically a narrow-field telescope, large areas of sky can be efficiently observed using a mosaicking technique, which was admirably demonstrated by the results of wide-field CO imaging, revealing the distribution of molecular clouds in the bar and spiral arms of M83. A study of molecular and atomic gas in lensed high-redshift galaxies, released on the day of the inauguration, demonstrates that the chemistry at early epochs is now within reach of ALMA observations (see also ESO PR 1313). These and other early observations from Science Verification (SV) and Cycle 0 have demonstrated the potential of ALMA and Ryohei Kawabe concluded that ALMA is a dream come true!

The Director of the US National Science Foundation, Subra Suresh, emphasised the NSF's investment in Chile, over a period of more than 60 years, of which the ALMA project was just one component, although the largest in terms of investment. The broad international aspects of ALMA make it a key example for future collaborations in ground-based astronomy. He concluded by introducing a live link from the International Space Station orbiting above the Atacama Desert, where astronauts Tom Marshburn and Chris Hadfield greeted the attendees at the ALMA inauguration and sent their best wishes for future discoveries to the new observatory.

The Japanese government representative, Teru Fukui, described how discussions on a large millimetre/submillimetre array had taken place in Japan as early as 1983 and had eventually led to Japan formally joining the ALMA project with the USA and ESO in 2006. The National Astronomical Observatory of Japan (NAOJ) and the National Institute of Natural Sciences had played key roles in securing funding and promoting the project in Japan. Japanese industry has played key roles in the design and construction of the antennas and the correlators. Fukui looked forward to the many fantastic discoveries to come from ALMA.

Tim de Zeeuw, Director General of ESO, stressed what a momentous occasion the inauguration of ALMA was for science and technology (the full text of his speech is printed on p. 5). The inauguration also occurs in the year that marks 50 years of ESO's presence in Chile, underlining ESO's long-term involvement with Chile. He recalled his first trip to the high northern Atacama Desert region, when he travelled on the Calama railway from Calama to La Paz in Bolivia in 1982. Europe's road to ALMA began with

developments in the infrared, which evolved into millimetre/submillimetre telescopes at the Institut de Radioastronomie Millimétrique (IRAM) and SEST at La Silla, which opened in 1987. In the early 2000s, following the choice of Chajnantor as the future ALMA site and the beginning of construction activities, the Atacama Pathfinder Experiment (APEX), a collaboration between the Max Planck Institute for Radio Astronomy (MPIfR, 50 %), the Onsala Space Observatory (OSO, 23 %), and ESO (27 %), was commissioned in 2005. De Zeeuw recalled the prescient plot of the novel by Fred and Geoffrey Hoyle, *The Inferno*, which laid out the case for building a submillimetre telescope as an international collaboration and siting it at high altitude in Chile — all this written 40 years ago. Now that has become a reality, as a result of ESO's collaboration with its partners from North America and East Asia.

Prior to the final speech given by the President of Chile, Sebastián Piñera, a film of the Atacameño ceremony, which asked for blessings from Mother Earth for the ground on which ALMA is built and for the people who live and work nearby, was relayed (see Figure 4). President Piñera referred to this ceremony and pointed out that the choice of the name of the plateau on which ALMA is built was prescient, as Chajnantor means "place of departure, observation point" in the language of the original people. Although the ALMA Observatory is built to satisfy the curiosity of a few, its discoveries will contribute to the knowledge held by all humanity. He expressed his gratitude to all those countries that have invested in astronomical facilities in Chile, and so making it a world astronomy capital. He closed by looking forward to all the discoveries that will come from ALMA. The text of the speech is presented on p. 6.

Figure 4. The Atacameño sacred ceremony, consisting of an offering to ask for blessings and thanks, was performed on Chajnantor at the AOS.

Finally, a live transmission from the AOS presented by the Chilean ALMA staff astronomer Antonio Hales concluded the official opening ceremony with the ALMA antennas moving to point towards the Galactic Centre (Figure 5).

Following the speeches, lunch was provided for all the attendees, organised by a renowned Chilean chef and featuring regional dishes.

Press conference

The day prior to the inauguration was dedicated to the press, with staff from ALMA and the Executives available to answer questions and tour the laboratories at the OSF. Among the highlights of the day were a press conference at the OSF, a press visit to the AOS and a demonstration of the transporter lifting one of the antennas in the European contractor camp. The press conference, attended in person by 100 journalists from around the world and many more by teleconference, was introduced by the then ALMA Director, Thijs de Graauw. He described the ALMA project: of the 66 ALMA antennas which will constitute the full array, the final nine are in an advanced state and the final antenna is expected to

Figure 5. The President of Chile, Sebastián Piñera, and Thijs de Graauw, the recently retired ALMA Director, closing the ALMA inauguration ceremony with a background projection of the ALMA antennas observing the Galactic Centre.

be delivered by August 2013. Most of the hardware and software is in place and the second year of observations, actually named Early Science Cycle 1, has begun, after the successful Cycle 0 in 2011–2012.

Al Wootten, the ALMA Project Scientist for North America, then spoke about the history of the project. He stressed the large amount of research and development that had to be done to construct the high performance antennas, fitted to the high altitude conditions, the state-of-the art receivers with seven of the ten proposed bands furnished, and the correlator to combine the signals from all the antennas. This was followed by the incoming ALMA Director, Pierre Cox, who reported on some of the extragalactic science results from the science verification data and Cycle 0 Early Science. He emphasised the power of ALMA for the detection of normal galaxies out to high redshift and for its potential to study the earliest stages of galaxy formation. He described ALMA as a renaissance for millimetre/submillimetre observation after the discovery of CO emission from a galaxy at $z > 1$ in 1991.

Ewine van Dishoeck from Leiden Observatory, and a former member of the ALMA Board, then described the science that ALMA is beginning to achieve in the area of star and planet formation. ALMA allows us to probe the initial phases of the growth of the rocky cores of planets (see ESO Release eso1248). The complexity of the astro chemistry just beginning to be explored is clear from the vast numbers of unidentified emission lines in the spectra of nearby star-forming regions such as Orion, and is exemplified by the early discovery of glycolaldehyde in a protostellar binary system (see ESO Release eso1234). But ALMA is also making discoveries in the late stages of stellar evolution, as revealed by the spiral CO outflow from the asymptotic giant branch star R Sculptoris (see ESO Release eso1239).

The final speaker at the press conference was Michael Thorburn, the head of ALMA Engineering, who described some of the engineering and infrastructure that makes ALMA an operational observatory, such as the 192 antenna foundations spread across the Chajnantor Plateau, the two ALMA transporters, named Otto and Lore, and the provision of electrical power to the whole facility. The press conference closed with questions from the members of the press present and online participants.

Acknowledgements

We would like to thank Valeria Foncea and Douglas Pierce-Price, both of whom played key roles in organising this event so successfully, for their input. Antonio Hales kindly provided the image for Figure 1.

References

Madsen, C. 2012, *The Jewel on the Mountaintop – The European Southern Observatory through Fifty Years*, (Weinheim: Wiley-VCH)

Links

[1] ALMA inauguration page: http://www.almaobservatory.org/inauguration/

Texts of Speeches

Tim de Zeeuw, ESO Director General

President Piñera, Doña Cecilia Morel, Excellencies, Minister Fukui, Director Suresh, Ambassadors, former, present and future ALMA Directors, other luminaries, colleagues and friends,

In 1982, Ewine van Dishoeck and I visited Chile for the first time, for an observing trip to the La Silla Observatory. Afterwards we travelled north, and took the legendary narrow-gauge train from Calama to La Paz. We were stunned by the beauty of the terrain, and remember particularly well the magnificent sunset near Ollague on the border between Chile and Bolivia. Little did we realise that 30 years later we would both be attending the inauguration of the world's most powerful radio telescope, so nearby on the similarly stunning Chajnantor Plateau.

It is therefore a great pleasure and a privilege to speak at this momentous occasion for science in general, and astronomy in particular. I represent the European Organisation for Astronomical Research in the Southern Hemisphere, commonly known as the European Southern Observatory. ESO is an intergovernmental organisation with fourteen European Member States and Brazil poised to join as soon as the Accession Agreement has been ratified by the Brazilian Parliament.

ESO was founded in 1962, and came to Chile in 1963, where it built the La Silla Observatory, followed by the Paranal Observatory with the Very Large Telescope, which will be joined in about a decade by the Extremely Large Telescope on nearby Cerro Armazones. All these facilities observe the Universe at visible and near-infrared wavelengths. So why did ESO join ALMA?

The development of infrared detectors made it possible to peer deeper into the dusty and cold regions of the Universe, where stars form, and to study objects at higher redshift, i.e., in the early Universe. The community which was engaged in this research in Europe realised it could do even better by capitalising on the development of submillimetre detector technology, with Thijs de Graauw as one of its pioneers. This led to the creation of Institut de Radioastronomie Millimétrique (IRAM) and the James Clerk Maxwell Telescope (JCMT), and to ESO entering the short-wavelength radio domain with the 15-metre Swedish–ESO Submillimetre Telescope (SEST) on La Silla, a copy of one of the IRAM dishes and operational between 1987 and 2003. SEST was followed by the 12-metre Atacama Pathfinder Experiment (APEX) on Chajnantor in 2005, operated by ESO in partnership with the Max Planck Institute for Radio Astronomy in Bonn and the Onsala Space Observatory. As a result, the European optical and millimetre communities integrated naturally.

The logical next step was to increase resolution and sensitivity by going from a single dish to an interferometer on a really high site, with the best high-frequency receivers that could be built. The power of a radio interferometer goes up with the square of the number of antennas, so by joining the worldwide ALMA partnership it was possible to build a much more powerful facility at an affordable price. Building the array in Chile with the strong support of the Chilean government, was of course also natural for ESO.

ESO's model of operation is to work very closely with institutes and industries in its Member States, for the construction of observatories, telescopes and instruments, all with the goal of enabling scientific discoveries. ESO's contributions to the ALMA project are similarly drawn from all over Europe, in industry (for example, the antennas provided by the AEM consortium and the transporter built by Scheuerle), and in institutes (for example, the high-frequency receivers built by IRAM and the Netherlands Research School for Astronomy [NOVA]). This same distributed model underlies ESO's approach to the science support: this is done in a network of nodes (the ALMA Regional Centres) in the Member States. That this model works is clear: the pressure on observing time for ALMA is highest in the ESO Member States.

This same spirit of collaboration between multiple partners and multiple institutions is now working

at the global level and can serve as an example for other large research infrastructures.

When preparing for today's event I could not help but recall an amusing science fiction book written by Fred Hoyle and his son Geoffrey in 1973, entitled *The Inferno*. Fred Hoyle was the genius who contributed to working out how stars can make carbon through nuclear fusion of lighter elements. One strand of the story concerns the protagonist, a fictional Scottish physicist who was the Director General of the European Organization for Nuclear Research (CERN), working together with the Director of the US National Radio Astronomy Observatory (NRAO) to review plans for a new radio telescope in Australia to be built in partnership with the United Kingdom. At stake were different antenna designs, new solid-state techniques to detect the radiation, selecting the best wavelength range and finding the ideal location. The protagonist comes out strongly in favour of shorter wavelengths to study the gas and molecules in the Universe, allowing smaller antennas and enabling the most promising new science. He furthermore suggests putting the telescope, not in Australia, but in Chile, and to ignore those who do not think this is radio astronomy. All of this sounds extremely familiar! But the remarkable aspect is that this was written forty years ago as part of a novel, at a time when only a few interstellar molecules had been found. Amazing!

Since then the field of submillimetre astronomy has indeed gone from very humble beginnings (which featured a small telescope on top of a building at Columbia University in New York) to the transformational ground-based facility we are inaugurating today in the 50th year of ESO's presence in Chile. The first scientific results that have been obtained with a partial array are already stunning, and I look forward to much more.

Thank you very very much to all who have helped create ALMA!

Sebastián Piñera, President of Chile

Friends of science, astronomy, research, progress and the Universe:

The truth is that mankind, since our origins, has always felt an irresistible drive to learn about, discover, and understand what is beyond the horizon, to expand the frontiers of knowledge.

Newton told us that to achieve that goal, he stood upon the shoulders of giants.

And that's why this afternoon, here in this desert, the driest in the world, the Atacama Desert, it is a great privilege to inaugurate this observatory, a true giant of astronomy and observation.

It is undoubtedly the most powerful radio telescope in the world, and it will enable us to expand the frontiers of knowledge, to go further than our predecessors and probably find out the secrets of the origin of the Universe, as well as its destiny, the origins of life, and the origins of the Galaxy. Because this observatory is not here just to satisfy the curiosity of a few, but will contribute significantly to the knowledge of all of humanity, by enabling us to learn more about the world in which we live, the Universe in which we live, and it may even enable us to find life beyond planet Earth.

It is true, Tim, that 40 years ago a novel called *The Inferno* was published, which in a certain way anticipated this project. For more than 30 years, men and women in Europe, the United States and Japan, not only dreamed about, but planned and worked to make it a reality today. But there were others who knew that this would happen even before then. The Atacameño people always knew that this great observatory would be here, in this land, because the name of this plateau, home to these 66 antennas, is not a coincidence. Chajnantor, in the language of the original people of this land, means "place of departure, observation point".

And so perhaps they knew that it was an exceptional place to look at the stars, the Universe, and through observing, to get to know ourselves better.

The name of this telescope, ALMA, Atacama Large Millimeter/submillimeter Array, is a technical one, but it has a very profound meaning in the Spanish language, which is "soul".

And therefore, we recall from the Book of Genesis that "God created man from dust", but finally, with one breath he introduced life, the soul, and transcendence along with that.

This project, this adventure, this ALMA initiative, is not merely technological, but also has a profound mystical, metaphysical meaning, related to the expansion of our knowledge of ourselves, where we come from, and where we're going.

That's why astronomy has always played an exceptional role in the history of humanity. Since antiquity, astronomers have always been renowned and admired, including Copernicus and Galileo. Because in the end, as so many have said for so long, we are not alone in the Universe. We don't know if there is life as we understand it out there, but we do know that we are part of a Universe that is vastly larger and more extensive than we believed for a long time.

And it is very likely that this remarkable observatory will allow us to learn more about the scope, the nature, the extension of this great Universe in which we live.

And it will enable us to learn about stars that perhaps don't exist today, and to penetrate, with an eye that is much more powerful than the human eye, because the human eye is only capable of perceiving certain colours. But the Universe has many more colours, and it will enable us to look into that cold area of the Universe that requires specialised technologies, not only to see and observe, but also to interpret.

Therefore, I would like to express my sincere gratitude to all who have been part of this major effort. Of course, I am grateful for the efforts made by countries in Europe and North America, and Japan as well, the efforts made by scientists, astronomers, the engineers who have worked on this project, the ALMA array, for so long. I would also like to thank the Chilean workers who built this observatory and made this day possible.

I would like to say to the scientists, to the Chilean astronomers who have joined this project with so much enthusiasm, that Chile is a small country, but when it comes to astronomy, with your support, we hope to become a true giant.

So for Chile it is a great privilege that thanks to your contributions, today Chile has practically become the astronomy capital of the world. And probably, with the projects that are on the way, in addition to existing ones such as La Silla, Tololo, Paranal and ALMA, plus all those to come, Chile will be home to 60 % of mankind's capacity to observe the Universe.

And in that endeavour, I want you to know, all who have that curiosity, that commitment, that interest in investigating, discovering, you will always be able to count on the steady, clear, decisive and enthusiastic support of the Government of Chile.

I would like to conclude by saying that for Chile this is a great privilege. We want Chile to become a world astronomy capital. We also want to take advantage of astronomy to create a real astronomical tourism industry, because every day there are more men and women in the world who want to know more about the stars, the Universe, that perhaps infinite world that surrounds us.

So our commitment is not only to develop astronomical tourism, but also to take advantage of the opportunity to play an exceptional role in the world of astronomy, to make Chile a country in which innovation, science and technology are an essential part of the society we want to build.

That's why this is the year of innovation, because we understand that for a country to be developed, it is not enough to increase *per capita* income. We also have to be a country capable of becoming a full member of this new and modern society, the knowledge society, the information society. And for that, no doubt, projects such as ALMA will be a tremendous stimulus and support.

Finally, I would like to hope that good things come out of this great adventure of mankind that today we are inaugurating at ALMA. Hopefully all that we discover here will not only help us know more, but also help us be better. And I believe that no one should be afraid of knowledge, no one should be afraid of that spirit of awakening, inquisitiveness and curiosity that has moved the world since its origins, and which today is manifested fully in a project with the scope, magnitude and transcendence of ALMA.