

Stuart Clark

Halfway to space

In ten years time, the European Southern Observatory will have turned the barren Chajnantor Plateau in Chile into one of the most important astronomical observatories in the world. Stuart Clark visited the world's highest construction site.

It is hard to believe that this arid, airless place will be so important to astronomers in the future. At the moment there is just one lonely radio dish and some half finished buildings but the excitement of the astronomers and engineers that work here is infectious. At just over 5,000 metres altitude, there is about half the oxygen as at sea level. "I often say that up here, you are halfway to space," says John Richer, University of Cambridge.

The high-altitude plateau of Chajnantor (pronounced chuck-nan-torr) is in Chile, near the borders with Argentina and Bolivia. The European Southern Observatory (ESO) is building ALMA, the Atacama Large Millimetre Array here, in collaboration with the Americans and Japanese. When finished in 2012, sixty-four 12-metre-diameter dish antennas will be sited here, working in perfect synchrony in a process called interferometry. This will allow them to simulate a single, much larger radio telescope. Apertures of between 50 metres and 15 kilometres will be possible once the array is fully operational.

To achieve this, most interferometers run their individual telescopes on railway tracks so that the distances between them can be varied. Here on the plateau, the undulating terrain and the occasional canyons make laying flat railway lines a prohibitively expensive proposition. Instead, a giant truck will lift each 110-tonne antenna and move it to a different foundation plate. There will be 150 foundations spread across the plateau. "The array will begin in its most compact configuration. It will grow to its largest size over a period of months and then back again," says Richer, who is the UK's ALMA project scientist. Each telescope move will take between two and five hours. Meanwhile, the rest of the array will carry on working. Because these are radio telescopes, they can observe not just during the night but in the daytime as well.

The cool Universe

ALMA is designed to collect radiation from the cool Universe, a realm that has yet to be fully explored. It consists of objects that are enshrouded with dust. “It turns out that half the stars that form in the Universe are obscured by dust,” says Richer. That makes them impossible to see with optical telescopes but easy pickings for ALMA. Apart from bringing these into view, the new array will also capture whole galaxies, containing billions of stars that are blotted out at visible wavelengths because of the dust surrounding them. ALMA is expected to discover one of these galaxies every three minutes of operation.

At present, the James Clerk Maxwell Telescope (JCMT) on Mauna Kea, Hawaii, explores this region of the Universe. Going from this single dish to ALMA is almost the equivalent of going from Galileo’s spyglass to the VLT in one move. “Alma will open a new view of the Universe by looking at wavelengths 1,000 times longer than optical light,” says Richer.

ALMA will not only see through dust, it will reveal the rich chemistry of the Universe as well. The chemical constituents of the Universe are gaining increasing importance in the study of astronomy. The more people look, the more they realise that chemistry charts the evolution of celestial objects such as stars and galaxies. This is because each generation of stars enriches space with different chemical elements, over and above the Universe’s original quota of hydrogen and helium gas.

The larger the fraction of heavier elements, the more interesting the chemistry that can take place. Ultimately, that chemical complexity leads to life, on Earth at least. So ALMA will help astronomers pin down the chemistry of the Universe by looking for more and more complex molecules.

The project is fiercely ambitious. Nothing truly like it has ever been tried before. The 64 antennas have curved surfaces that must be accurate to within the width of a human hair; otherwise they will not focus the elusive sub-millimetre radiation. “When we began this project, we didn’t know whether it was possible to make antennas with the specifications we needed,” says Massimo Tarenghi, director of the ALMA project.

To increase the chances of success, three separate contracts were awarded to produce prototypes: one to Europe, one to America and one to Japan. All produced

workable antennas and so now the final array will contain all three versions manufactured in all three regions.

All are being produced to the most exacting of specifications so that they work together, in a number of ever increasing configurations. If ALMA is going to work in the largest configuration, the makers must confront something that most radio astronomers never have to worry about: turbulence in the atmosphere. “In traditional radio astronomy, working at low frequencies, the atmosphere is pretty much transparent,” says Richer.

In the case of submillimetre signals, however, the amount of water vapour is crucial as it both absorbs some of the signals and distorts those that remain. At most places on the Earth, the effect is so severe that millimetre observations are all but impossible. At Chajnantor, however, the atmosphere is extraordinarily dry.

“Imagine compressing all of the water vapour in the column of atmosphere above the plateau. At Jodrell Bank, you would get perhaps 20mm of water. At Chajnantor, the figure you can rely on is one millimetre of water. That’s a magic number because it allows submillimetre waves through,” says Richer. Three or four nights of the year, that number falls to just 0.1mm.

But the troubles aren’t over just yet. Even though signals get through, the tiny amount of water vapour in the atmosphere acts like turbulence, making the sources twinkle. So ALMA needs a system to correct for this. When correcting for the twinkling of stars at optical wavelengths, astronomers point a special camera towards a guide star. They monitor this star to compute the distortions of the atmosphere and then they use special deformable mirrors to compensate for twinkling – and they have to do it every few milliseconds. Luckily for ALMA, the correction only needs to be made every second or so. Unluckily, stars emit very few submillimetre rays so astronomers turn instead to quasars. Each is powered by gas falling into a gigantic black hole at its centre and is bright at submillimetre wavelengths. Once every minute or so, all sixty-four antennas will turn from the target to a nearby quasar, measure the quasar light and turn back to the source, all in a matter of ten seconds or so.

Richer and colleagues are working on a new system that will automatically monitor the amount of water vapour above each antenna and compute a correction factor to be applied before the signals are combined inside a computer. This will reduce the amount of offsets needed and make ALMA more efficient.

The plateau is currently home to just one test antenna, the Antenna Pathfinder Experiment (APEX). It will be joined next year by the first ALMA antennas. The first science is expected to be performed in 2008 and the whole array will be complete four years later.

ESO's collaboration with Chile has turned the country into the beating heart of world astrophysics. One can only await with relish the discoveries that will flow from the country once ALMA joins the VLT in operation.

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The ALMA visitors centre

The ALMA Operations Support Facility (OSF) will not just be a place for astronomers and engineers. Included in the design is a visitors centre with a viewing gallery that looks into a hangar-sized maintenance area.

“We will announce when we are bringing a telescope down from the summit so that local people and tourists can come and watch. It will be a spectacular sight,” says Massimo Tarenghi, director of the ALMA project.

The truck that lifts and carries the antennas about is like something out of Thunderbirds. The current design has twenty-eight wheels, is ten metres wide, weighs 130 tonnes and can carry a 110-tonne radio telescope along the 20-kilometre dirt road from the summit to the OSF for maintenance. It will also be used to reconfigure the array.

Already on the ALMA site is a small reconstruction of the temporary habitations used by the Andean shepherds until just fifty years ago, as they drove their animals across the mountains following water and grazing. The changing climate finally claimed this way of life but now its memory lives on, thanks to the recreation aided by two aged brothers in the vicinity who lived like this as young men.

High ambition, high altitude

The Chajnantor plateau is breathtaking, metaphorically and literally. At 5,000 metres altitude, I am standing at half the cruising height of a Jumbo Jet with half the oxygen as at sea level. To the east, a range of mountain peaks reach up another 2000 metres

and mark the boundary between Chile, Argentina and Bolivia. To the south, a plume of smokes rises from the volcanic peak of Lascar, a reminder that Chajnantor is geologically active. Lascar last erupted in April 2006 and the prevailing winds carried the ash away from the ALMA site. Meteorological studies show that the prevailing winds are seldom directed towards Chajnantor, so the astronomers feel safe.

To the west, the landscape spreads into an expansive plain that itself remains at 2,300 metres above sea level. It is mostly exposed rocks and scrubby grasses. Everything is painted in ruddy shades.

On the long drive up to the plateau, I was advised on arrival to climb out of the jeep slowly and take three deep breaths from an oxygen canister before moving. I followed the advice and then quickly learnt that walking at normal pace is not advisable. I rapidly became breathless and my head swam. I adopted a lugubrious slow motion gait and concentrated on taking deep breaths of the shallow air.

I was with a group of British science journalists. One member of the party made a mistake, comparing the debilitating effects of the high altitude with what he can do “on Earth.” He laughed nervously at his slip but we all realised what an easy mistake it was to make. High up on the plateau surrounded by Martian-red rocks, the eerie quiet of the low-pressure air definitely promotes an unearthly feeling.

“Safety is everything up here,” Massimo Tarenghi, director of the ALMA project said time and time again. To highlight this, a fully equipped ambulance followed us everywhere on the plateau.

After an hour, I felt myself getting confused. I stopped taking notes and pictures because the effort didn't seem worth it any more. Others in the group felt the same. My driver made to drive away without one of the passengers. I pointed this out and the driver agreed; yet he started driving anyway. Seconds later we both came to our senses and stopped the jeep to make sure that our missing friend was in one of the other jeeps. There was never any danger in this particular situation but it highlights the peculiarly slow way your brain works at high altitude.

That evening, in the soupy oxygen of San Pedro de Atacama, the group celebrated having been to the plateau and toasted the scientific marvels to come from ESO.