Report on the ESO Workshop

Science with ALMA Band 5

held at INAF–Osservatorio Astronomico di Roma, 24–25 May 2010

Robert Laing[1]
Roberto Maiolino[2]
Hans Rykaczewski[1]
Leonardo Testi[1]

[1] ESO
[2] INAF–Osservatorio Astronomico di Roma, Italy

A small complement of receivers for the ALMA Band 5 (163–211 GHz) is under construction. This workshop was devoted to the scientific potential and goals of a full set of Band 5 receivers for ALMA, with emphasis on the detection of water in the local Universe and the 158 μm emission line of C^+ from high redshift galaxies.

The Atacama Large Millimeter/submillimeter Array (ALMA) observatory is currently in the commissioning phase on Chajnantor, with expected release of the first call for proposals for Early Science in a few months. ALMA will be initially equipped with a subset of the receiver bands that are finally envisaged. The initial receiver bands selected were those deemed to be both feasible and of the highest scientific interest when construction was approved. ALMA Band 5 (163–211 GHz), although always considered to be scientifically important, was placed at lower priority, primarily because of the difficulty of observing close to the strong atmospheric water line at 183 GHz.

Following the accumulation of statistics showing that the transparency of the Chajnantor site around the water line is better than expected and the development of improved phase-correction techniques, a proposal to support the construction of six Band 5 receivers for ALMA was supported by the European Commission (EC) under the Framework Programme 6 (FP6). The main scientific motivation was the synergy between ALMA Band 5 and the HIFI instrument on the Herschel satellite, which is currently in full operation. ALMA Band 5 will allow us to resolve and image emission from water and its isotopes, which are being detected by Herschel at other (typically shorter) wavelengths invisible from the ground. The small complement of Band 5 receivers will be installed at the ALMA Observatory by 2012.

Since the initial proposal to the EC, the scientific case for Band 5 has strengthened and initial tests of the first receivers are very promising. In order to take full advantage of the development work already undertaken as part of the EC–FP6 project, it is timely to consider the production of a full set of Band 5 receivers. A necessary preliminary step is the re-evaluation of the scientific potential and goals of an ALMA fully equipped with Band 5: this was the primary aim of the workshop.

Over the last decade, and especially in the last few years, there has been an increasing interest in observations at the frequencies offered by the ALMA Band 5, for both Galactic and extragalactic science. Water is, of course, of intense interest because of its role in the origin of life. A key application for Band 5 is therefore high resolution imaging of the water line at 183 GHz in our own Solar System, Galactic and nearby extragalactic sources. In addition, the 158 μm line of C^+ from objects at redshifts between 8.0 and 10.65 will appear in the band, opening up the possibility of probing the earliest epoch of galaxy formation.

Workshop themes

The workshop was attended by representatives from the ALMA project, technical groups developing the ALMA Band 5 receivers for the EC–FP6 programme and by astronomers with a broad range of scientific backgrounds. The status, timeline and plans for the ALMA projects were presented together with the expected schedule for the ALMA Development Plan, from which the full production of ALMA Band 5 cartridges could potentially be funded. The science goals of the EC–FP6 project were also presented, highlighting the opportunities and limitations of the small complement of Band 5 receivers. The science sessions explored in detail the scientific potential of the ALMA observatory with a full complement of Band 5 receivers: this would provide a giant leap in sensitivity and image fidelity as compared to the initial system. The sessions were divided into: Solar System, Late-type Stars, Star and Planet Formation, Nearby Galaxies and the High-redshift Universe. Keynote speakers reviewed the science in each area and were followed by contributed talks and extended discussion sessions.

It became clear that the study of water and its isotopes, including deuterated species, in the Solar System is a major possibility offered by ALMA with Band 5 (H_2S, SO and SO_2 also have transitions in the band). Comets provide unique information on the physics and chemistry of the early Solar System and it will be possible to image them in the water lines and to constrain their water abundances. Seasonal variations of the water content of Mars, Venus and the atmospheres of the giant planets and their larger moons will also be extremely interesting.

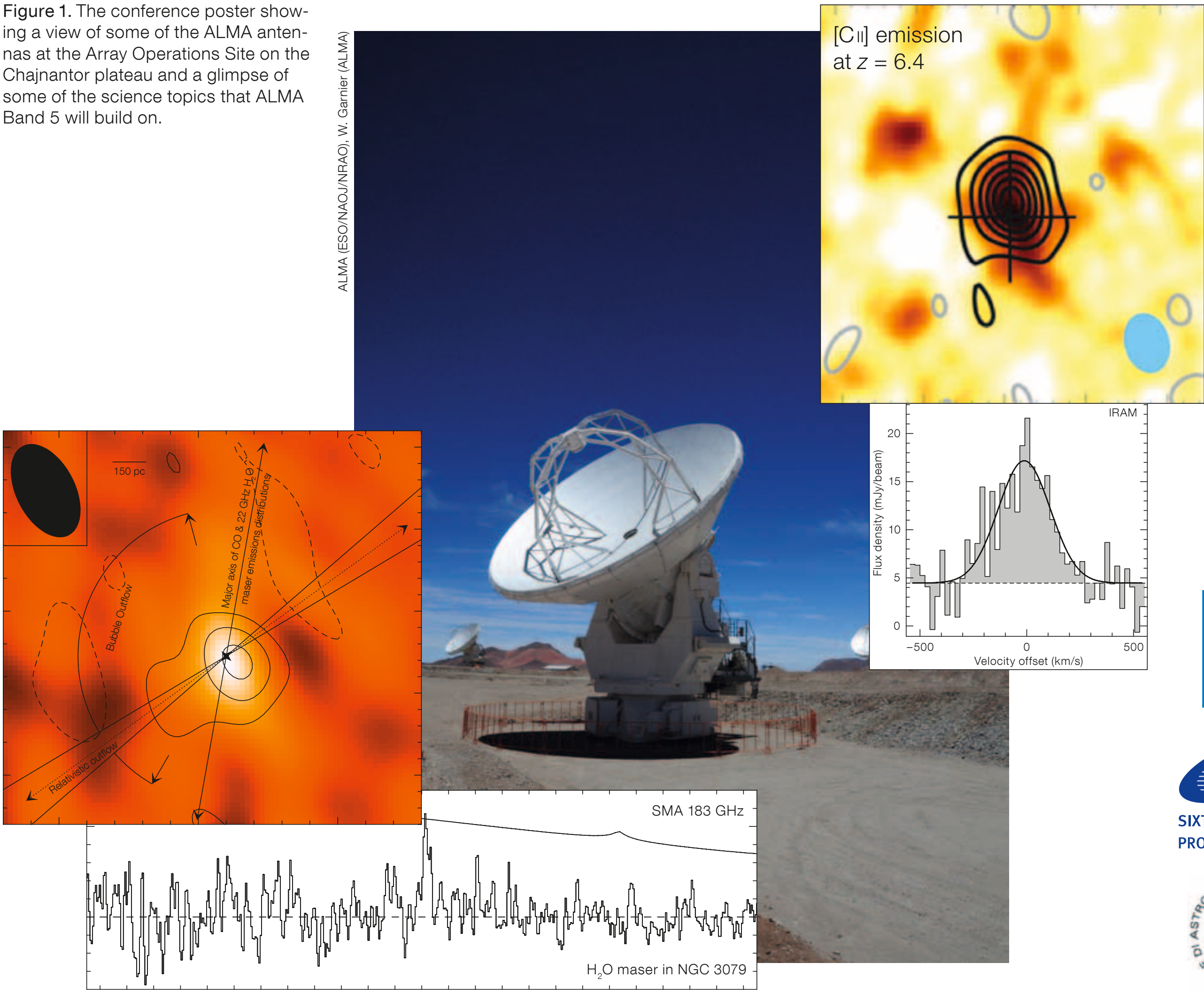
Water is also a key molecule in star formation: its abundance is low in cold, quiescent regions, but increases at shocks, therefore acting as a tracer of energetic phenomena. It is also a principal constituent of grain ice mantles and the main reservoir of oxygen. Studies of $H_2{}^{16}O$ and $H_2{}^{18}O$ in star-forming regions with Herschel are producing extremely interesting results which hint at complex spatial and spectral structure which can only be resolved using ALMA Band 5. As well as water (which is also important to an understanding of oxygen chemistry) many other molecules have transitions in Band 5, particularly relevant to deuteration and chemistry at shocks. Herschel has found surprisingly little cold water vapour in some protoplanetary discs, suggesting that the water may be mostly locked up on the surfaces of dust grains. ALMA's full sensitivity will therefore be needed to deepen our understanding of water in star-forming regions.

One of the main reasons to study late-type stars is their key role in the formation of dust. Models suggest that 183 GHz maser emission may overlap the SiO and H_20 22 GHz maser shells, which in turn straddle the dust formation zone.

The second main theme of the workshop was the observation of C^+ from the first galaxies. This line, observed for the first time by Alan Moorwood, is the main cooling line of the Milky Way and is expected

Figure 1. The conference poster showing a view of some of the ALMA antennas at the Array Operations Site on the Chajnantor plateau and a glimpse of some of the science topics that ALMA Band 5 will build on.

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



SIXTH FRAMEWORK PROGRAMME

also to be the brightest line emitted by the first galaxies. It has so far been detected in quasars out to a redshift of 6.4 (corresponding to ALMA Band 6). The redshift range from 8.0 to 10.65, corresponding to Band 5, is a critical one: observations of the Gunn–Peterson effect show that the epoch of reionisation ends at around a redshift of 6. Detection of C^+ at higher redshifts would allow measurement of gas masses and also constrain the star formation rate in the first galaxies. ALMA is likely to be the only instrument capable of resolving these primordial galaxies and hence of measuring dynamical masses as well as other kinematical properties (e.g., outflows). Although ALMA will not be able to survey large areas at Band 5, blind searches are expected to discover significant numbers of high-redshift galaxies through their C^+ emission. New results from Herschel suggest that the C^+/CO ratio is likely to be very large, making ALMA Band 5 extremely competitive with observations of low-order CO transitions at cm wavelengths (the high-order CO transitions which can be observed at other ALMA bands are probably not excited).

Finally, the current status of the first ALMA Band 5 receiver cartridge, developed at Chalmers University, was presented. The design overcame a number of technical challenges, for example in the cold optics. The mixer noise performance already met ALMA specifications at the time of the meeting, and the combination of the cold cartridge and local oscillator (provided by the Rutherford Appleton Laboratory in the UK) was tested successfully shortly thereafter.

The detailed programme of the workshop and electronic versions of all the presentations are available on the workshop webpage[1].

Acknowledgements

We thank Giuliana Giobbi from INAF–OAR for her support that made the organisation of this workshop possible. The workshop was sponsored by the EC–FP6 project.

Links

[1] Workshop web page: http://web.oa-roma.inaf.it/meetings/AlmaBand5/Home.html