Il Colle di Galileo

INAF Progetto Premiale iALMA and the ALMA Band 2+3 project

Villa il Gioiello, Arcetri, Florence
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Organizer: Leonardo Testi
INAF-Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, I-50125 Firenze, Italy
ESO, Karl Schwarzschild str. 2, D-85748 Garching, Germany
Excellence Cluster Universe, Boltzmann str. 2, D-85748 Garching, Germany

Abstract. On March 25 and 26, 2014, the kick-off of the INAF Progetto Premiale 2012 iALMA took place in the beautiful and historic location of the Villa Il Gioiello. iALMA workpackage leaders from several Italian institutes gathered together to carefully plan the first year activities for the project and to discuss the detailed project implementation with the iALMA External Advisory Board. The iALMA kick-off meeting was followed by an international workshop attended by participants from all ALMA partners in Chile, Europe, Japan and North America, and focused on developing the foundations of an upgrade of the ALMA Observatory aimed at equipping all 66 antennas with the a new receiver: the so-called Band 2+3. Here I provide a brief account of the goals of the iALMA project and of the ALMA Band 2+3 project.

Keywords. ALMA, Complex and Pre-Biotic Organic Molecules in Space, Star Formation in the Universe, Laboratory Astrophysics

The ALMA observatory and the Italian contribution

The Atacama Large Millimeter/submillimeter Array (ALMA, Figure 1), an international astronomy facility, is a partnership of Europe, North America and East Asia in cooperation with the Republic of Chile. ALMA construction and operation in Europe are led by the European Southern Observatory (ESO), on behalf of its Member States (including Italy), and is carried out in collaboration with national scientific institutions and industries throughout Europe. The Istituto Nazionale di Astrofisica (INAF) and several Italian industries have contributed significantly to the development and construction of the ALMA antennas, as well as components for the ALMA software, receivers and digital correlator. ALMA Science Operations is supported in Europe by a network of ALMA Regional Centre nodes, one of which is located at the INAF-Istituto di Radioastronomia in Bologna. Italian astronomers are leading a significant fraction of science projects that are being

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Figure 1. The ALMA Observatory on the Chajnantor Plateau (5000m altitude) in northern Chile (credit: ESO/S. Guisard)

carried out with ALMA since the start of the Early Science phase in 2011. Italian astronomers are mostly focused on using ALMA to study the evolution of galaxies, the effects of supermassive black holes at the hearth of active galaxies, the formation of stars in our Galaxy and the Local Universe, and the evolution of solids and molecular gas towards the formation of (possibly life-hosting) extrasolar planetary systems. As ALMA is coming into Full Science Operations, it is critical to consolidate and streghten the Italian involvement in harvesting the transformational science produced by the observatory. This includes not only the astronomical observations, but also the synergies with theoretical models and laboratory experiments, the definition of the science goals and technical development for the ALMA upgrades, the enhancement of the user support services in Italy, the training of young scientists and the dissemination of the scientific results of ALMA in the public at large. These concepts and goals are at the foundation of the INAF Progetto Premiale iALMA.

The INAF Progetto Premiale iALMA

INAF proposed the iALMA project in response to the call for Progetti Premiali 2012, the project was selected for funding by the Italian Goverment and the kick-off meeting for the activities was held at the Villa il Gioiello on March 24-25, 2014. The four-year program will allow us to develop experiments and observations to study the formation of pre-biotic molecules in young Solar System analogs, and to study feedback and star formation through cosmic time. To achieve these goals, we will develop an innovative receiver band to observe in the frequency range from 67 through 116 GHz, and the tools to use two of the most advanced capabilities of the ALMA observatory: the high accuracy polarization and Very Long Baseline Interferometry modes. An essential component of the iALMA program will be the advanced training in a tight collaboration between INAF and Universitites, to deploy dedicated PhD fellowships, schools and lecture series.

One of the main scientific goals of iALMA is to understand the chemistry related to Complex Organic Molecules (COMs) in space, and especially their role as building blocks of pre-biotic molecules in exoplanetary systems. There is strong evidence that water on Earth has been delivered after formation of the planet. The currently favoured scenario involves a bombardment of the inner Solar System of icy bodies from the outer regions, induced by the rearrangement of the orbits of the four major planets (Jupiter, Saturn, Uranus and Neptune). These small icy bodies are supposed to have delivered water and other volatiles on the inner rocky planets. As part of this process, complex organic species locked in the ices may have been delivered to Earth as "impurities", together with water. Indeed, complex molecules are known to be present in Comets and meteorites, well mixed with water and carbon monoxide ice. In fact, also the simplest of the amminoacids, Glycine, has been detected in non-negligible quantities in these small Solar System bodies. COMs are thought to form in the interstellar ices around young stars as a consequence of solid-state chemistry induced by energetic radiation from the forming stars. Laboratory experiments of ice irradiation have confirmed the production of complex molecules, but the detection in irradiated laboratory ices of very complex and heavy molecules is difficult using conventional spectroscopic techniques. One of the primary goals of iALMA is to upgrade the facilities of the INAF-Osservatorio Astrofisico di Catania to allow a very significant step in the sensitivity of the measurements, allowing the detection with a time of flight spectrometer of very rare and heavy molecules produced in irradiated ices.

The direct detection of COMs in space is also difficult: when frozen on the ices they are mostly unaccessible to traditional microwave spectroscopy techniques. Under certain conditions, part of the COMs are released in the gas phase, through the sublimation of icy mantles, and become observable. As part of iALMA, we will develop predictions for the observability of COMs with ALMA and we will carry out direct searches in various astrophysical environments. Initial results seem to suggest that molecules as complex, and with low abundance as Glycine may be observable in young solar analogs with ALMA, if equipped with a new receiver, the so-called Band 2+3 receiver that will allow to extend the frequency coverage of ALMA down to 67 GHz (see Figure 2). Searches for possible precursors, such as Glycolaldehyde, a simple sugar critical also for RNA chemistry, are already showing the first successes with ALMA. Ultimately, the ALMA observations, compared with the results of laboratory experiments will allow us to trace the origin of prebiotic molecules in space.

To fully achieve these ambitious goals the ALMA Observatory needs to be upgraded with a next generation instrument capable of obtaining sensitive and broad band measurements in the frequency range from 67 to 116 GHz (these limits are set by the atmospheric transparency cutoffs set by two broad O_2 absorption lines centered at 60 and 119 GHz). The lower part of this atmospheric transparency region (67-84 GHz) is currently not accessible with ALMA, and is the most relevant

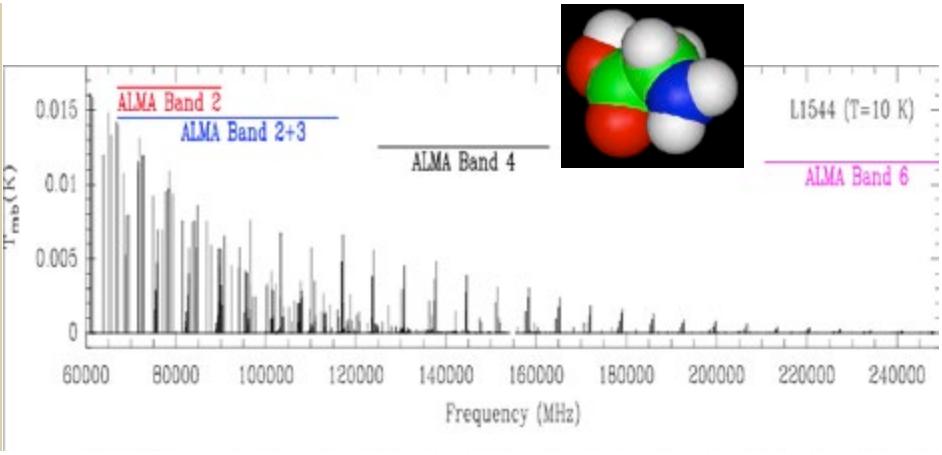

Figure 2. Predicted brightness temperature for the Glycine lines in the low mass pre-stellar core L1544, existing and planned ALMA Bands are shown for reference (adapted from Jimenez-Serra et al. 2014, ApJ 787, L33).

for the study of the COMs in the cold star and planet forming environments. An important aspect of the iALMA program is thus to develop, test and assemble components for a prototype ALMA Band 2+3 receiver to be developed as part of an international collaboration. During the first year of the iALMA project, we will focus on the refurbishment of the laboratories in Arcetri and Bologna, the system design of the overall receiver, the detailed design and prototyping of some of the critical passive components, and on exploring options for the production of a sensitive low noise amplifier as one of the options for the active component.

This new ALMA receiver will not only allow us to study the origin of COMs and pre-biotic molecules in star forming regions, but also in the bodies of our own Solar System, and will allow astronomers to attack also very diverse goals ranging from the study the evolution of galaxies across the Universe, the molecular gas and star formation in the Local Universe, and the evolution of interstellar medium dust particles into larger aggregates and planetesimals. The new ALMA Band 2+3 will also improve the ability to measure accurately polarized signal and probe the effect of magnetic fields in astrophysical environments. In combination with the ongoing ALMA Phasing Project, it will also be possible to use this new receiver in phased array mode for stand-alone or mmVLBI experiments. A phased ALMA at these frequencies will allow to study at high sensitivity the emission from pulsars in regions that are difficult to access with traditional longer wavelengths radio telescopes, like the Galactic Centre. Intercontinental mmVLBI, combining ALMA observations with millimetre-wave observatories in Australia, East Asia, Europe, and North America, will enable to reach microarcsecond agnular resolution, essential to study in detail the relationship between accretion and ejection in supermassive black holes at the centre of active galaxies (and the dormant one at the centre of our own Milky Way) and to probe the

small scale structure of stellar envelopes and star forming regions using maser molecular line emission. To gear up to support these new exciting ALMA capabilities the Italian ARC node will develop, as part of iALMA, specific expertise in the areas of polarization and mmVLBI observing.

iALMA will also collaborate with the national industry to investigate the options for green energy production for the observaotry. At the moment, power for the whole ALMA observatory is provided by burning fossil fuels at the ALMA Operations Support Facility. In the long term, the use of renewable energy will allow to evolve to a more sustainable observatory.

Finally, iALMA is also committed to an outreach program aimed at raising the public awareness on the Italian involvement in ALMA and the scientific results of the observatory.

Six INAF institutes in Arcetri, Bologna, Catania and Roma, and the three Universities of Bologna, Catania and Firenze are involved in the iALMA project. In the Table I show the structure of the iALMA management team. To provide external expert advice, the iALMA project has appointed an External Advisory Board (EAB), composed by four experts in the fields covered by the iALMA activities: Prof. Cecilia Ceccarelli (IPAG, Grenoble, France), Prof. Gary Fuller (University of Manchester, UK), Dr. Robert Laing (ESO, Germany), and Dr. Alessandro Navarrini (IRAM, Grenoble, France). The EAB attended the kick-off meeting in Arcetri on March 26, 2014, and provided a detailed report on the planned activities for the first year. Quoting the EAB report: "The EAB thinks that iALMA will have a great impact on the Italian ALMA community, helping it to grow and to ensure the best possible scientific return."

iALMA Work Packages	Responsible	Institute
WP0 - Management	Dr. L. Testi	INAF-Osservatorio Astrofisico di Arcetri
WP1 - Science	Dr. M. Beltran	INAF-Osservatorio Astrofisico di Arcetri
WP2 - Advanced Training	Prof. L. Gregorini	Alma Mater Studiorum Università di Bologna
WP3 - Italian ARC node	Dr. M. Massardi	INAF-Istituto di Radioastronomia
WP4 - Band 2/3 Passive Components	Dr. R. Nesti	INAF-Osservatorio Astrofisico di Arcetri
WP5 - Band 2/3 Cartridge	Dr. F. Villa	INAF-Istituto di Astrofisica Spaziale di Bologna
WP6 - Laboratory Astrophysics	Dr. M.E. Palumbo	INAF-Osservatorio Astrofisico di Catania
WP7 – Green Energy	Dr. L. Testi	INAF-Osservatorio Astrofisico di Arcetri
WP8 – iALMA Outreach	Dr. F. Rea	INAF-Sede Centrale
WP9 - Control Electronics	Dr. S. Molinari	INAF-Istituto di Astrofisica e Planetologia Spaziali

The international ALMA Band 2+3 project

Following the iALMA kick-off meeting and connected to it, the Villa il Gioiello also hosted an international workshop on the ALMA Band 2 ad 2+3 development with delegates from the Joint ALMA Observatory and all the ALMA Executives (European Southern Observatory - ESO, the USA National Radio Astronomical Observatory - NRAO, and the National Astronomical Observatories of Japan - NAOJ), as well as other collaborating institutes (California Institute of Technology, INAF, Institut de Radioastronomie Millimetrique, Rutherford Appleton Laboratory and University of Manchester). The plans to equip ALMA with this new receiver were discussed focusing on the technical challenges to develop a next generation receiver. The final agreement was to advance the development of two prototype receiver concepts that would test the different technological options for the active component: one based on InP integrated circuit Low Noise Amplifier based and the other on Superconductor-Insulator-Superconductor devices. The trade-offs between the two options are different and it was felt that more research and prototyping has to be performed before taking a final decision.

The Italian groups involved in the iALMA project will design develop and test components for the prototype that will be built by an European consortium of institutes including also IRAM, University of Manchester and RAL. The agreed goal of the programmes is to demonstrate and compare the prototype receivers over a 2-3 years timescale and take a final decision on the technologies to implement for the full scale production in 2017/2018 with a goal of equipping the full ALMA array with Band 2+3 receivers in the early 2020s.