LLAMA

Long Latin American Millimeter Array

A window of opportunity for South American Astronomy

The possibility of installing radio telescope(s) for millimeter and sub-millimeter wavelengths, in the Argentinean side of the Atacama desert at distances of 150-200 km from ALMA, and altitudes greater than 4600 meters, has been discussed among astronomers of Argentina and Brazil. The support to the idea of a unique Very Long Baseline Interferometer (VLBI) for millimeter/sub-millimeter wavelengths has been ratified in September 2008 by the Argentinean Astronomical Assembly. In Brazil is being studied as one of the possible key science goals of the recently approved Astrophysics National Science Institute by the Brazilian National Council of Research - CNPq. Top authorities of Science and Technology in Argentina and Brazil informed that in the context of regional integration, funds may be available for original projects on basic sciences, with technology transfer components. The initial investment of US$ 20 million of LLAMA would allow Argentine and Brazilian scientists to develop millimeter and sub-millimeter single dish radio astronomy, as well as integration in global experiments with Very Long Baseline Interferometer networks. Of particular interest may be VLBI with already existing radio telescopes in Chajnantor (APEX and ASTE), and in the long run with elements of the ALMA array. Site testing in Argentina has been carried out for three years in Macón (4600m, 180km SE of Chajnantor) with equipment provided by UNAM (México), and further site testing started at other site 180 km SE of ALMA (see attached maps). A proposal for initial funding to carry on the in depth study of this project will be submitted by December 2009.

I. General Context

The Atacama Large Millimeter Array (ALMA), which entails an initial investment, up to the year 2012 of 1.4 billion dollars, is the largest global astronomical project of the central countries (Europe, North America, Japan/Taiwan) on the earth's surface. ALMA will consist of an interferometer of up to 64, 12m antennas, for millimeter and sub-millimeter observations, distributed over an area of ~15 km, at an altitude of 5000m, situated in the Chajnantor Plateau, Atacama Desert (Chile), a few kilometers away from the frontiers with Bolivia and Argentina.

On the other hand, Japan and Taiwan are building a compact array of smaller antennas in Chajnantor, in order to produce exploratory maps of relatively large regions, that will allow the identification of targets to observe with ALMA larger antenna array, with higher angular resolution and sensitivity. Furthermore, the 10m ASTE radio telescope of the National Observatory of Japan, and the European 12m APEX (Atacama Pathfinder Experiment) radio telescope presently in Chajnantor, may in the future, be incorporated into millimeter VLBI networks.

To achieve the higher angular resolution required by certain projects it will be necessary to combine elements of ALMA, and/or ASTE and APEX with other radio-telescopes at dry, high altitude sites over the South American Andes, covering distances of hundreds, or even thousands of kilometers. We propose that the first antenna(s) of this extended array in the Southern Hemisphere might be installed at high altitudes, in the Eastern side of the Andes, in the Argentinean part of the Atacama desert called "Puna".

However, until the end of the construction phase of ALMA in 2013 and probably not before 2015, the central countries may not be able to channel resources for the construction of an array of antennae for the millimeter and sub-millimeter VLBI in South America. In this context, the installation of the first antenna(s), at altitude(s) greater than 4600m in the Provinces of Salta and/or Jujuy, Argentina, would be an opportunity for South American countries that are not presently involved in ALMA, to take the initiative in an original, state-of-the-art project at scientific and technological level, that otherwise would most probably start to be funded by the central countries, but not earlier than in the middle of the next decade.

II.-Scientific Objectives

A millimeter/sub-millimeter radio telescope, at high altitude in the desert of NW Argentina could be used for research in every field area of astronomy, i.e., for studies of the sun, solar system, stellar evolution, interstellar media, extragalactic astronomy. Antennae for millimeter/sub-millimeter wavelengths in the Southern Hemisphere can be used as independent antenna(e) in stand alone mode or in VLBI experiments. It is worthwhile mentioning that, currently, the over-subscription on the ESO observing time for the APEX 12m is large, as large as the time requested for ESO's Very Large Telescope (VLT). **As** single dish it can be used –among others- for the following:

- Large surveys of Galactic and Extragalactic regions for follow up studies with ALMA at high angular resolution and sensitivity.
- Hyper-starbursts at high redshifts.
- Extra-solar planets and proto-planetary discs.
- Molecular outflows in star forming regions.
- Masers of the recombination lines of the hydrogen atom.
- Molecular masers in star forming regions and in stellar envelopes.
- Molecular absorption along sights to quasars.

In VLBI experiments with elements of ALMA, ASTE, APEX and other arrays, LLAMA would be used to carry out follow up studies of sources previously observed with ALMA, with an enhancement of angular resolution of more than one order of magnitude. As part of interferometer networks it could be used, -among others- for the following projects:

- Studies of the environment of super-massive black holes (e.g Sgr A*, Cen A, etc).
- Studies of how astrophysical jets are released, accelerated and collimated.
- Studies of non-thermal processes in stellar magnetospheres.
- Solar activity: flares, wind turbulence, etc.
- Various applications in Geodesy (e.g. movement of tectonic plates).

III.-Technical context

This project may have spin-offs related to the following technology transfer areas:

- Communications: Engineer training in high frequency microwaves.
- Natural Resources: Satellite surveying in high frequency microwaves.
- Materials sciences and engineering: Carbon fiber technologies.
- Electronics: Construction of radiometers and high-frequency receptors.
- Signal Processing and image reconstruction
- Business management at a national and regional level.

IV. –Political Context

Considering the recent international investment in astronomical facilities in the Southern Hemisphere it would be desirable an increase in the level of engagement and participation of South American countries.

The AUGER Project in the Province of Mendoza, Argentina, has shown the capability of Latin American countries to play a protagonist role in global scientific and technological projects. During the years that preceded the recent financial global crises, the countries of the region maintained sustained growth, and there is an explicit will for integration, including scientific and technological developments in state-of-the-art areas.

Besides these aspects, the present project proposal can enhance multli-wavelength astronomy in South America. As remarked by Jay Gallagher, Editor-in-Chief of the Astronomical Journal, “A mm-VLBI array including ALMA will clearly open a new and exciting approach to multi-wavelength astronomy to the world community. Given its location…can add tremendous scientific value and allow the South American community to place their scientific stamp on the wider science fostered by ALMA”.

Antennae at more than 4600m altitude and 150-200 km South-East and East from ALMA, ASTE and APEX, would be the first step to develop an interferometer for VLBI associated with antennae at Chajnantor, with elements distributed in the Andes. Moreover, it’s worthwhile mentioning that Argentina, Brazil, México, Chile (and Colombia in the future) are developing scientific-technical groups in radio-astronomy,

and their integration in global millimeter and sub-millimeter projects would be desirable.

V. –Budgeting context

Antennae:
The following alternatives exist for the first antenna:

- Use one of the ALMA prototype antennae, built by TALES-ALESIA and VERTEX, currently in the State of New Mexico. Refurbishment and transport would cost ~US$ 1.5 million, plus the installation costs. However, it is not clear whether proper documentation and parts for these prototypes will be available.
- Purchase additional 12m antenna(e) such as ALMA's. The construction, transportation and installation cost per antenna is ~US$ 8 millions.

b) VLBI and receivers:

Equipment for VLBI costs ~ US$ 1M, plus receivers for stand alone use US$ 3M.
Total cost of the option buying one ALMA antenna: ~ US$ 12M.

Cost of infrastructure and operations: It depends on the location of the site of the antenna.

VI. Conclusion

The Project offers the following advantages:

- Take the initiative, in a global project that the central countries would not start to fund before 2015. This would provide the countries of the region the possibility to collaborate in projects developed with ALMA, thereby stretching their intellectual and technological roles in growing Southern American astronomy.
- An initial US$ 20 M investment will allow collaborations with teams undergoing research in a global project that entails an investment of US$ 1.4 billion.
- It is an original, scientific-technological project and unique, in the sense that it will not repeat goals already achieved, e.g. the construction of 4m size optical and/or infrared telescopes, installed in Chile since decades ago.
- It will allow to test and correct regional scientific-technological integration, step by step, and in a progressive way, since this project will, in the future, require the installation of antennae in other countries of South America.
- It is an ideal context to train human resources in materials engineering and microwave technologies, with applications in telecommunications, surveying of natural resources, microelectronics and business management, at a national and regional level.

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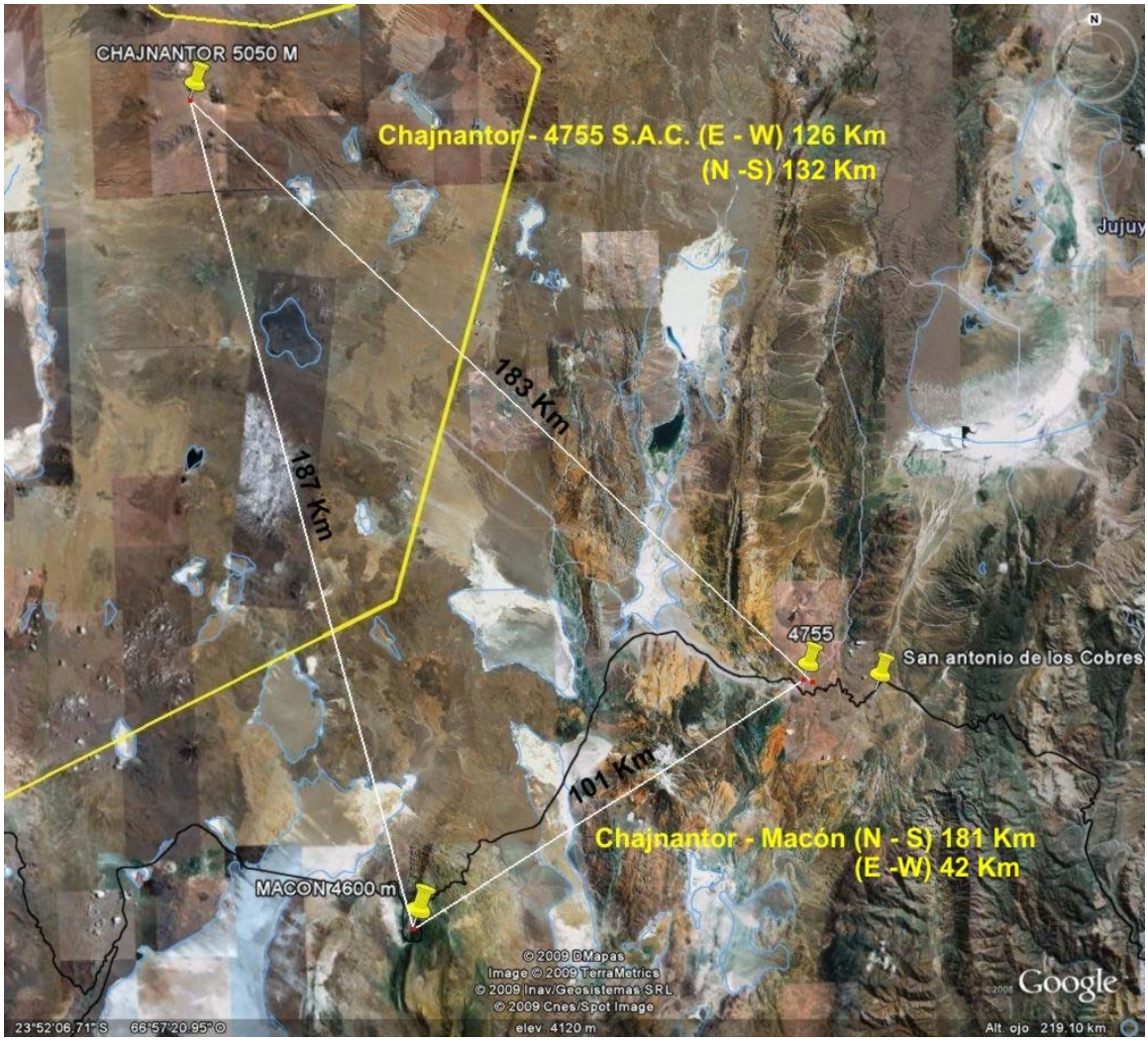

Fig. 1: Locations of Chajnantor, Macón (181 km in straight line from ALMA at 4600m) and Chorrillos (183 km from ALMA at 4755m). The yellow line shows the border between Argentina and Chile, the black line the railway track Salta-Antofagasta. Chorrillos is 1.5 km from the railway track, national route 51, high tension power line and gas pipeline. Besides, Chorrillos it is close to San Antonio de los Cobres (S.A.C., 3000 inhabitants), a tourist town with hotels that is the NW base of “Gendarmeria Nacional”. S.A.C. is 2-3h from Salta, which has an international airport. Site tests have been carried out for 3 years at Macón, and started in Chorrillos (4755m) on July 2009.

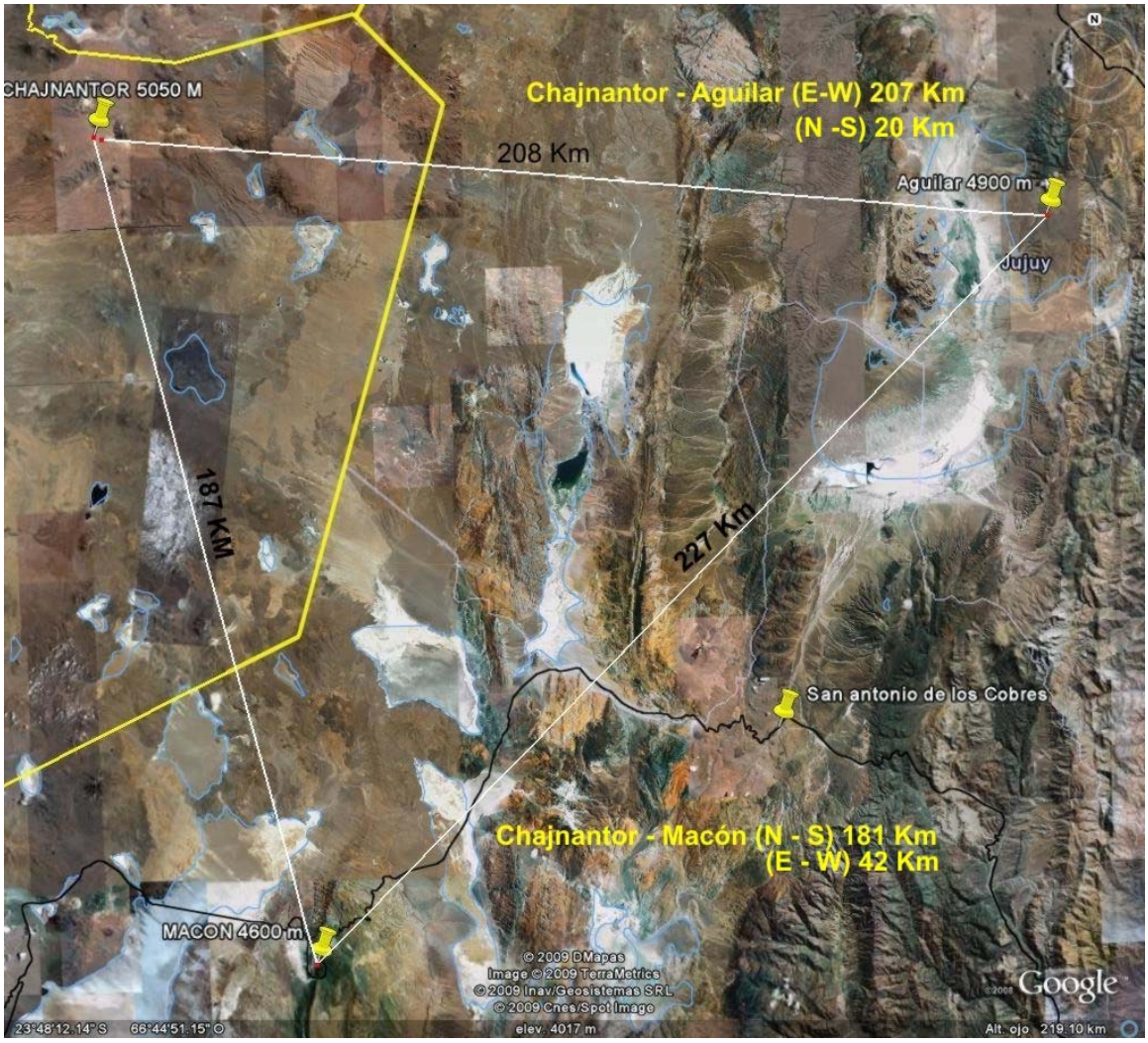

Fig. 2: Locations of Chajnantor, Macón and Mina Aguilar region (208 km from ALMA) in the province of Jujuy. The Aguilar region has good infrastructure (energy, water, roads, etc), but “Mina Aguilar” has mining rights over large areas in this region.