Large Latin American Millimeter Array (LLAMA)

White Paper - collaboration Argentina

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Revised version: S. Paron (IAFE) – November 2019

1. Overview

The Large Latin American Millimeter Array (LLAMA) is a joint project of Argentina and Brazil aimed at the installation, operation, and maintenance of a 12m-diameter antenna in the northwest of Argentina to explore the southern sky. This telescope, located at about 4800 meters above sea level, will work in the 35–700 GHz frequency range (millimeter and submillimeter wavelengths). Although initially the instrument will be used as a single dish telescope, in a near future it could be part of a very large baseline interferometry (VLBI) network in Latin America with telescopes such as the Atacama Large Millimeter/submillimeter Array (ALMA), which will allow us to increase about 10 times the angular resolution achieved by this interferometer. This can place our countries in an auspicious position in the global radio astronomy community.

As a single dish radiotelescope, this instrument will be suitable for continuum and atomic/molecular lines observations towards astronomical objects located in a broad distance range, from the solar neighborhood to high-redshift galaxies, which can contribute to find answers to several astrophysical open questions. In this context, extended surveys of continuum emission and molecular lines of the southern sky can contribute to the study of many astrophysical and astrochemical processes, and can be used as a first step to perform further detailed interferometric observations.

In the next sections we briefly focus on the key projects and the main scientific goals to be achieved with the telescope working as a single dish facility, along with the characteristics of the site where it will be installed, and a brief summary of its technical specifications.

2. Scientific goals

A variety of astronomical studies can be carried out with a 12-m telescope operating as a single dish instrument. Most of the ALMA bands will be available in LLAMA. This region of the electromagnetic spectrum contains a large amount of rotational transitions of many molecular species present in the interstellar and intergalactic medium, as well as in our solar system.

2.1. Extragalactic studies

Firstly, it is important to note that LLAMA will reach galaxies with declinations lower than +30 deg, which enables us to complete northern-sky surveys at the southern sky.

Molecular studies in nearby galaxies, mainly using CO lines, give insights on how stars are formed in regions of low molecular gas surface density and low metallicity. Knowing how the conversion of atomic to molecular gas relates to the global properties of a galaxy, e.g., mass, morphology, and metallicity, is important to predict the fraction of dense gas, and hence the star formation rate. Abundance estimates of other quite simple molecules, such as CH, CH^+, H_2CO, etc., including high density tracers, and atoms, such as [CI], are also important to carry out this kind of studies, which are useful to test the Schmidt law relation between mass of gas and star formation rate.

Observations of red-shifted CO can be used as a proxy of star formation rate studies of an early epoch. The star-formation history of the Universe, when galaxies were young, can be envisaged by probing the nature of protogalaxies in the first billion years of the Universe through the red-shifted emission from lines and continuum, peaking in the submillimeter regime.

The instrument will be crucial to measure ripples in the cosmic microwave background radiation emanating from the era when hydrogen was first formed, 300,000 years after the Big Bang, because that thermal spectrum today peaks in the millimeter regime. It will also help to provide distances to far-away clusters of galaxies, by measuring the radio emission produced by the Sunyaev-Zeldovich effect on them. The search for counterparts to gamma-ray sources detected with the future array of Cherenkov telescopes (Cherenkov Telescope Array) can be successfully carried out.

2.2. Galactic studies

2.2.1. Molecular gas in our Galaxy

The interstellar medium (ISM) plays a central role in the evolution of the Galaxy. Large molecular clouds are the most extended structures in the ISM and harbor the sites of active star formation. The molecular clouds have spatial structure on all scales that can be studied through rotational transitions of a variety of molecular and atomic species. This kind of observations allows us to study in detail the physical and chemical properties of the ISM.

Most of molecular line surveys were done with telescopes in the Northern hemisphere. For example, the Milky Way Galactic Ring Survey, performed with the FCRAO 14 m Telescope, and surveys such as CHIMPS and COHRS done with the 15 m James Clerk Maxwell Telescope (JCMT). Using LLAMA, we will be able to survey the southern sky in the ^{12}CO and its isotopes at different transitions towards large regions in the Galaxy not covered by existing surveys.

Additionally, LLAMA will allow us to survey specific Galactic regions in many molecular species, which will be very useful to perform astrochemistry studies and to estimate molecular (relative) abundances. The study of the behaviour of relative abundances in relation to the interstellar radiation UV field is an important tool to understand the interplay between the massive stars and the ISM.

In summary, given that extended areas of the Southern sky lack molecular data with intermediate angular resolution, LLAMA can be used to perform large surveys of these regions in several molecular lines, opening interesting opportunities to discover and investigate in deep the dense gas counterparts of objects detected in other wavelengths. Such studies will also serve to identify particular areas to be investigated with higher angular resolution using interferometers.

2.2.2. Star formation

Stars are born in dense molecular clouds within the Galaxy. The gas and dust of these clouds obscure the early stages of star formation from optical telescopes. However, the dusty cocoons around the newly born stars emit efficiently at submillimeter and infrared wavelengths, allowing us to peer inside the clouds and gain a greater understanding of the processes involved in starbirth. In particular, massive stars form in regions inside the giant molecular clouds, which contain large amounts of matter, from 10^5 to some 10^6 solar masses and are very cold, typically only from 10 to 30 K. Their main constituent is molecular hydrogen gas, but other molecules such as carbon monoxide, ammonia, and methanol, among other molecular species, are also present.

With the sensitivity and angular resolution of LLAMA, it will be possible to carry out systematic physical and chemical characterizations of molecular clumps in star forming regions through the observation of several molecular transitions, which complemented with infrared data, will help us to contrast the predictions from theoretical models and numerical simulations, shedding light to the still open questions in the star formation field. Besides, other major facilities in the timeframe of LLAMA operations will include VLBI observations using the ALMA array, allowing us to build baselines of more than 150 km. In this sense, LLAMA will become a key instrument to explore the physics and chemistry associated with star and planet formation at exquisite detail.

2.2.3. Astrochemistry

The study of organic molecules can provide a powerful tool to better understand the evolution of the ISM, specially of star forming regions, where stars and planets form along with the development of a very rich chemistry. Briefly, the chemistry that occurs during the formation of stars evolves through three stages: *cold core phase, collapse/warm-up phase, and hot core phase.*

The first stage is characterized by low temperatures and a chemistry governed by exothermic reactions that form large (5-6 carbon atoms) unsaturated molecules. In the second stage the density and temperatures increase leading to the formation of more complex molecules (such as NH_3, CH_4, CH_3OH, CH_3CH_2OH, H_2CO, etc.) via grain-surface reactions. During the last stage, temperature and density can rise significantly. Icy mantles are sublimated and the chemistry is dominated by gas-phase reactions with high energy barriers which originate a new generation of heavy complex organic molecules (e.g. CH_3COOH, CH_3OCHO, CH_3OCH_3, $CH_2(OH)CHO$), including complex molecules like amino acids, sugars and aldehydes, from which life in Earth may have originally evolved. These molecules will remain in the vicinity of the pre-stellar core for some time until they are destroyed by the intense ultraviolet radiation of the newly born star. This kind of molecules can be also formed by the action of molecular flows impinging upon the molecular parental cloud. In summary, organic molecules in cold cores tend to be unsaturated and exotic (in comparison with terrestrial chemistry). On the other hand, organic molecules in hot cores tend to be saturated, terrestrial in nature (many of these molecules are even of great importance in terrestrial biological processes), and their appearance reflects the presence of a central heating source such as a protostar. Thus, identifying and studying complex organic molecules towards molecular clouds, particularly towards molecular clumps, can help not only to better understand the physical and chemical properties of the ISM, but also to identify the different evolutionary phases of the molecular gas during the star forming processes.

LLAMA will be an extraordinary tool to look for complex organic molecules in the Galaxy, and in particular in star forming regions, namely: 1) the spatial resolution range achieved is suitable to observe typical Galactic star forming regions, where complex chemistry might be occurring, 2) the sensitivity allows a positive detection of weak emission lines like those produced by rare organic molecules, 3) the frequency coverage and bandwidth (~ 35 to 700 GHz, and 4 to 8 GHz, respectively) will offer an excellent outreach to unambiguously identify rotational lines of complex organic molecules, 4) the velocity resolution will be adequate to deblend rotational lines of different molecules that are close in frequency. Long observing programmes towards star forming regions, in which a large variety of molecular species can be observed, will be extremely useful to advance in the knowledge of the chemistry produced in such regions and to test theoretical chemical models.

2.2.4 Supernova Remnants (SNRs) and Pulsar Wind Nebulae (PWNe)

The supernova explosions that mark the death of massive stars usually occur near the giant molecular clouds. Such a physical proximity often leads to mutual interactions that can strongly modify the physical processes taking place at the SNR shocks, as well as the physical and chemical conditions of the shocked clouds. The SNR shock waves propagating in molecular environments can compress, heat, excite, ionize and even dissociate molecules. Besides, shocks in SNRs have been proved to be efficient accelerators of cosmic rays and studies of gamma-ray emission from numerous SNRs demonstrate that those interacting with molecular clouds show strong evidence of relativistic protons. Additionally, the gravitational collapse of massive stars usually leave neutron stars which, through their relativistic particles and strong magnetic fields, drive the pulsar wind nebulae (PWNe) in the interior of the expanding remnants. The PWNe are other potential sources of cosmic rays. In this research area, there are several topics where LLAMA, with its extremely sensitive receivers, can have a large impact operating both as single-dish radiotelescope and as part of an interferometer.

At radio frequencies, PWNe have typically flat spectra (spectral index α varying between 0 and -0.3, with $S_\nu \propto \nu^\alpha$), but in X-rays the behavior changes and becomes $\alpha < -1$. It is therefore presumed that PWNe have at least one spectral break at intermediate wavelengths. Such breaks are theoretically predicted, and result from a combination of synchrotron losses and the time-evolution of the pulsar's changing energy output. Locating these breaks provides a key insight into the physical conditions of the pulsar wind, and can be used to directly infer the nebular magnetic field. These observations are fundamental to improve our understanding of the diffusion and lifetimes of the highly energetic electrons supplied by the PWN. In order to identify the break frequencies it is essential to measure flux densities at frequencies near the spectral break, i.e. at millimeter and infrared wavelengths. Also, the spatial variations in the break energy can be used to identify and map out the processes of particle diffusion and radiative losses within the flow, helping to understand the physics of PWNe and their coupling with the surrounding plasma. Furthermore, LLAMA can be used to conduct surveys searching for new PWNe and to investigate the radio counterparts to the new PWNe expected to be discovered by their emission in the X-ray and gamma-ray regimes with the forthcoming instruments.

It is known that SNRs interacting with molecular clouds can generate gamma-rays through neutral pion decay after proton-proton collision. LLAMA will serve to uncover the presence of dense molecular clumps located immediately adjacent to the SNR and farther, where accelerated hadrons can diffuse out and power TeV emission.

Observations of continuum emission towards SNRs in the submillimeter range are important to answer two key issues. First, an increasing number of SNRs are detected in gamma-rays, and many efforts are being carried out to identify the origin of such emission. The main competing mechanisms are inverse Compton effect, bremsstrahlung and neutral pion decay in hadronic interactions. Spectra constructed from high energy data and radio emission usually represent ambiguous results when trying to decide which mechanism is predominant. Completing the spectrum with the flux density in the submillimeter domain will be crucial to disentangle which theoretical model more accurately describes the energy distribution along the whole electromagnetic range. Second, the role of SNRs as dust factories is still under debate. Although an important fraction of the dust formed in stellar atmospheres is destroyed by the passage of the shock wave after the explosion, the observed excess indicates that there must be an extra source of dust. There is evidence that a significant quantity of dust is produced in SNe. Data from *Spitzer* in the mm range (up to 160 mm) show warm, freshly-formed dust in SNRs. LLAMA will contribute to the detection of cold dust, whose emission peaks at wavelengths of a few hundred mm.

Additionally, the detailed study of molecular transitions across an ample spectral range, including maser emissions, allows us to trace widely different density regimes in the shocked molecular clouds and helps to provide accurate diagnostics of the nature of the SNR shocks (whether they are dissociative, radiative, etc.). In particular, high line transitions such as ^{12}CO J=6-5, emitting at 691 GHz, and several maser lines of OH, H_2O and CH_3OH at different bands are especially useful because they unambiguously trace shocked-heated gas, providing valuable information on physical conditions, such as temperature and density in shock waves.

2.2.5 Sun and Solar systems

The Sun provides a laboratory for the study of magnetic activity and associated plasma effects that no other available situation provides. This ordinary, middle-age star is our only experimental window into the vast and varied activities that other stars and galaxies also undergo, but are too distant to be resolved. Solar radio physics has a particularly important role to play in the study of energy release in explosive phenomena in the universe, from solar flares to AGNs, by combining space observations in X-rays and gamma-rays, and ground-based radio and optical data with theoretical studies.

Solar radio bursts and associated phenomena, such as coronal mass ejections (CMEs), are the most dynamic aspects of the solar corona that involve the fast and large scale desestabilization of the coronal magnetic field. The available magnetic free energy goes into particle acceleration, radiation, thermal energy, and plasma flows that have effects in space weather and, eventually, affect the terrestrial atmosphere through geomagnetic storms and connected phenomena. Therefore, the study of flares and CMEs, besides its scientific interest, is relevant in the prevention of potential harmful effects that they could generate to our highly technology-dependent society.

Systematic submillimeter solar observations began in this century with the installation of the Solar Submillimeter Telescope (SST), which operates between 212 and 405 GHz. A striking discovery, at frequencies above 100 GHz during flares, was the existence of the so-called "THz component", a spectral component with a positive (increasing) slope at the highest observable frequencies (up to 405 GHz) towards the THz domain that is hard to explain as gyrosynchrotron or free-free emission. The use of LLAMA to observe the sun will allow us to obtain the best spatial resolution ever registered for solar radio observations and will bring data in an unexplored spectral range (>400 GHz), improving by orders of magnitude the sensitivity of solar submillimeter observations. The specific objective is to create an observational data set of statistical significance for solar events emitting at submillimeter wavelengths.

Observations focused on quiet sun phenomena are also included in the planned topics for LLAMA. We expect that LLAMA will bring more information on the chromosphere thermal structure and dynamics, including waves, shocks, and heating, which will impose new constraints to atmospheric models. On the other hand, the chromospheric structure is of special interest as an input to the theories of coronal heating. Measures of the degree of circular polarization averaged over the beam will permit to infer estimates of the magnetic field strength at different coronal heights where the radiation originates. Furthermore, the solar radius determination at different frequencies is an unavoidable input for atmospheric models. The mean radius during Solar Cycle 24 has decreased respect to that of Cycle 23, which opens many questions about the microwave quiet emission. An extension of these studies to higher frequencies will provide new insights into this area.

3. Technical Overview

3.1. The site

Water vapor in the atmosphere is the main obstacle in astronomical observations at millimeter and submillimeter wavelengths, degrading the sensitivity of the telescopes. Because the water vapor is largely confined to the lower atmosphere, very dry air can be found at sites of high altitude. The Puna of Atacama region with altitudes above 4000 meters meet, a priori, the conditions favorable for this kind of astronomical observations. Along several years the Instituto Argentino de Radioastronomía (IAR) has been carrying out a series of almost uninterrupted monitoring campaigns to measure the transparency of the atmosphere in several locations in the northwestern region of Argentina, in the Salta and Jujuy provinces. The instrument used for the measurements of transparency is a radiometer that operates at a frequency of 210 GHz ("tipper") provided by the Universidad Autónoma de México (UNAM). Based on these measurements and on temperature and wind conditions, the site selected to install LLAMA is the region of Alto Chorrillo (Longitude: 66º 28´ 29".4 ; Latitude: -24º 11´ 31".4), about 4820 meters above sea level and 16 km away from the town of San Antonio de los Cobres (see Figure 1).

Figure 2 shows the distribution function of the sky opacity for autumn and winter for Alto Chorrillo. The percentage as a function of the sky opacity is indicated on the right scale (blue lines), while the cumulative distribution function, in red, is shown on the left scale. The diagram indicates that the sky opacity is lower than 0.2 during 85% of the time as measured in the period 2003-2007.

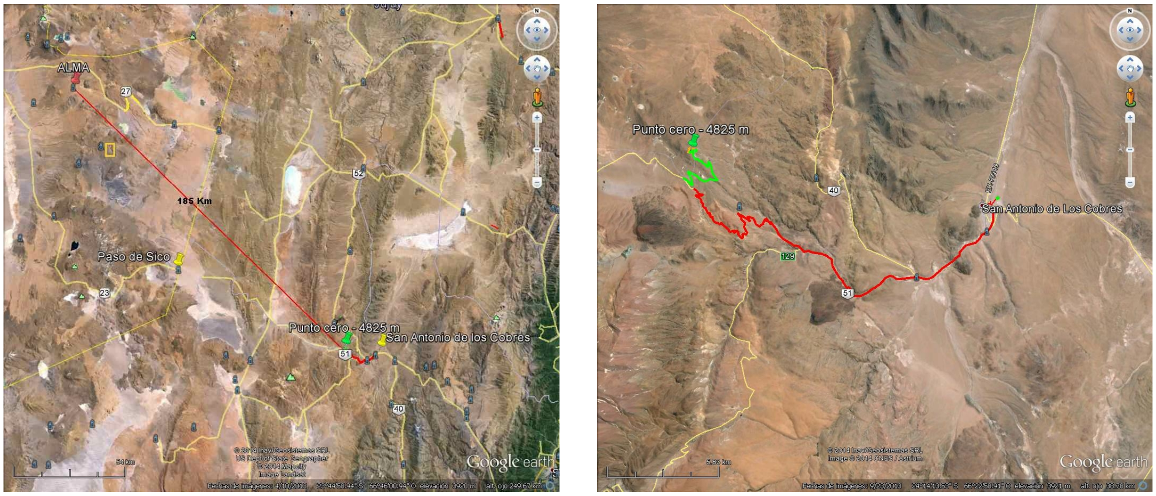

Figure 1: *Left*: Google image showing the northwestern part of Argentina. LLAMA ("Punto cero") and ALMA sites are indicated, besides San Antonio de los Cobres town. The distance to the ALMA site is indicated with a red line, while the yellow line mark the limit between Argentina and Chile, particularly the border crossing named Paso de Sico. The light cream color line indicates the trace of the National Route RN 51. *Right*: Zoom of the right image, indicating the LLAMA site ("Punto cero") and San Antonio de los Cobres town, connected by the National Route RN 51 (red line).

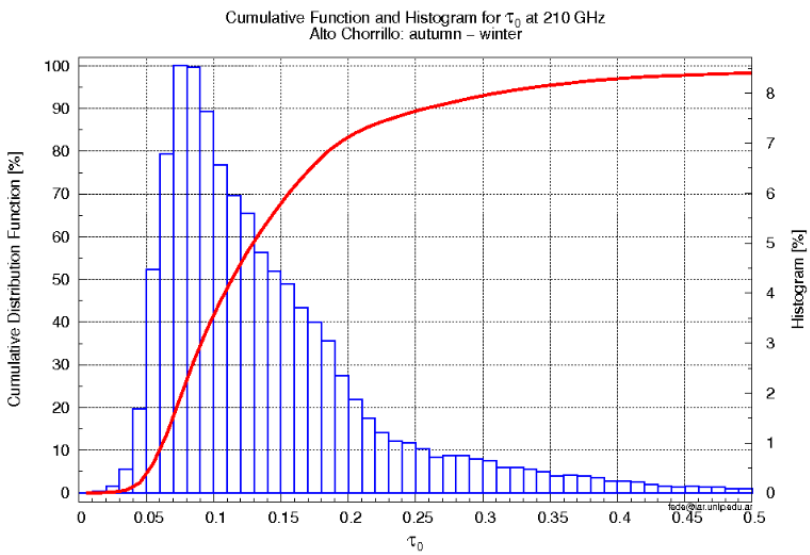

Figure 2: *Opacity distribution function for autumn and winter obtained for Alto Chorrillo*.

The selected site experiences seasonal changes, especially during summer, when atmospheric opacity degrades because of the influence of the so called "Bolivian winter", which translates into an increase in the frequency of rainfall. This phenomenon affects the entire region, including the region of Chajnantor, site of the ALMA telescopes. However, even in that period, our site remains adequate for observation in the millimeter range of the spectrum.

Variations in ambient temperature for the period 2003-2007 were in the range from -16 to +17°C, while temperature changes in ten minutes have been found to be below 0.6°C. Wind conditions show seasonal variations, with 80% of the days with wind velocities below 10 m/s, 99.65% of the days below 20 m/s, and only 0.35% showing wind velocities higher than 20 m/s. Clearly, ambient temperatures, wind velocities, and atmospheric opacity indicate that Alto Chorrillo is suitable for the installation of an instrument for observation in the millimeter/submillimeter bands. It is worth mentioning that these characteristics are similar to those in the ALMA site. The high altitude needed for this kind of astronomical observations, has its drawback in the lower Oxigen volume density in the atmosphere. For this reason, staff authorized to perform tasks on the site shall do so under strict security rules in order to prevent health consequences typical of high altitude sites. For the same reason, dormitories, laboratories and offices shall be installed at a lower altitude in San Antonio de los Cobres, and the operation of the telescope should be remotely operated.

3.2. Instrument Description

The telescope will work in the 35 - 700 GHz frequency band (ALMA bands 1 to 9) and will be equipped with superconducting receivers having sensitivities a few times the quantum noise limit. Although initially the instruments will work as a single dish telescope, in the mid-term LLAMA may become one of a series of antennas that would make up the first interferometry VLBI network in Latin America.

3.2.1. The Antenna

The telescope will be an APEX-like instrument (see Figure 3) having a Cassegrain focus; two Nasmyth cabins to accommodate heterodyne receivers, and two large containers for supplementary equipment. The antenna has an operating range from 30 GHz to 950 GHz and has a symmetric paraboloidal reflector with a diameter of 12m, mounted on an elevation over azimuth mount. The overall characteristics of the Cassegrain configuration are given in Table 1.

Table 1. Optical parameters of LLAMA telescope

Name		
Parameter	Symbol	Value
D	Primary Apperture	12.0 m
f_p	Focal Length of Primary	4.8 m
D_s	Secondary Aperture	0.75 m
M	Magnification Factor	20.0
θ_p	Primary Angle of Illumination	128.02°
θ_s	Secondary Angle of Illumination	7.16°
$2c$	Distance between Primary and Secondary Focus	6.177 m
H	Depth of Primary	1.875 m
V	Primary Vertex Hole Clear Aperture	0.75 m
W	Total Weight	125 tons

The main dish consists of 264 aluminium panels in 8 rings fixed on a carbon fiber reinforced plastic (CFRP) backup structure of 24 sandwich shell segments. Each panel is supported by five vertical (four corners and center) and three horizontal adjustment elements. The panels, which have been chemically etched to scatter visible and IR radiation and thus allow daytime observations, have been manufactured to an average surface accuracy of 8 µm rms. The backup structure (BUS) is supported by an INVAR cone, which is attached to the top of the Cassegrain cabin. The total mass of the modified antenna is roughly 125 tons. The scientific specifications require a surface accuracy of the main reflector better than 20 µm rms, a tracking accuracy of 0.6'' (within 2 degrees to calibrator) and an absolute pointing accuracy of 2'' rms for primary observing conditions

Figure 3: APEX antenna. APEX: Atacama Pathfinder Experiment, is a collaboration between Max Planck Institut für Radioastronomie (MPIfR), Onsala Space Observatory (OSO), and the European Southern Observatory (ESO). This antenna essentially has the same design as LLAMA. Image Credit: ESO.

Table 2. Single pixel instruments.

Band	Frequency (GHz)	Average Noise Performance (SSB) (in K)	Receiver Typpe / Technology	IF Band (GHz)	Nasmyth Cabin
1	30–50	17	SSB / HEMT	4–12	B
3	84–116	35	2SB / SIS	4–8	B
5	163–211	45	2SB / SIS	4–8	B
6	211–275	55	2SB / SIS	6–10	A
7	275–373	70	2SB / SIS	4–8	A
9	602–720	160	2SB / SIS	2–8	A

The physical location of the slightly modified ASTE-like cryostats and ALMA receiver cartridges will be in the telescope’s Nasmyth foci. Intensity calibration loads, pick-up mirrors, and control devices (both electronic and mechanical), and some of the required data processing systems will also be installed into the main (Cassegrain) receiver cabin. In addition, future bolometric cameras and/or heterodyne imaging arrays will also share the main Cassegrain focus area, to take advantage of the available field of view (~10').

3.2.2. General Optical Design

The single pixel receivers will reside in the Nasmyth cabins. All high frequency receivers (Band 6, Band 8, and Band 9) will be located in the cryostat located closer to the altitude encoder side, while low frequency receivers (Band 1, Band 3, and Band 5) will be located on the other Nasmyth cabin. Dual polarization capabilities will be available in dual band simultaneous observations.

Observations with receivers located in different cryostat and within receivers located in the same cryostat, will be possible. In this way a maximum of four different receivers could be simultaneously used. However, to keep the complexity to a manageable level, this flexibility has a limitation: on different cryostats only a maximum of two receiver combinations will be possible. For example, in the cryostat housing Band 1, Band 3, and Band 5 receivers, the only possible combinations will be the following: a) Band 5 and Band 1; or b) Band 5 and Band 3). In the other cryostat only the following combinations will be available: a) Band 9 and Band 6; or b) Band 9 and Band 8.

Though the optical design of the telescope will not allow Cassegrain/Nasmyth simultaneous observation to be carried out, the system will have the capability of making a hot swap (in the lapse of a few minutes) between instruments located at the Cassegrain focus (e.g. a MKID camera or an heterodyne array at a given frequency) and those located at the Nasmyth foci.

It will be possible for the system to carry out solar observations. Unlike ALMA, for this observing mode, no solar filter will be employed. Instead, the working points of the amplifiers or the mixers, depending on the receiver being chosen, will be modified. The system will also count with an uncooled Water Vapor Radiometer. Table 2 shows the bands for heterodyne receivers, their noise performance, technology, Intermediate Frequency-IF band and the distribution in the telescope.

3.2.3. Front End - Bolometric Camera

The Cassegrain focus area (also known as Receiver Cabin) with its ~10' of FOV, is ideally suited to house bolometric and/or heterodyne arrays. At present, the most promising bolometric camera technology employs 300 mK cooled microwave kinetic inductance detectors (MKIDs). These devices work on the principle that superconducting electron (Cooper) pairs may be broken by suitably energetic photons (in this case far IR photons) leaving quasi-particles or unbound single electrons. When employed in a resonant LC circuit this breaking of Cooper pairs results in a resonant frequency shift and circuit loss (reduced Q). The advantage of MKIDs is that up to 400 pixels maybe frequency division multiplexed on a single coaxial line. To make, for example, a 10,000 pixel camera, it will require on the order of 25 read out lines, something that is manageable with today technology.

3.3. Infrastructure and operations

The funds required for the construction, commissioning, and science phases of LLAMA will be provided by Argentina and Brazil on the basis of an equal share contribution. For the initial construction phase of the Observatory, Argentina's funds will be provided by Secretaría de Articulación Científico Tecnológica of MINCyT (Ministerio de Ciencia, Tecnología e Innovación Productiva). On the Brazilian side, FAPESP (Foundation for Research Support of the State of Sao Paulo) will be the funding source for the construction phase. In Brazil the project is led by NARA (Support Nucleus of Research in Radio Astronomy of the University of São Paulo).

The project includes an initial phase, consisting of the installation of a single-dish antenna. In addition to its scientific value, its installation will allow us to learn more about the logistical problems in the operation of such kind of observatory at high altitude, and generate a fruitful collaboration between astronomers and engineers of both countries. In a second phase of the project, it is expected to proceed with the acquisition of equipments for VLBI.

By November 2019 the Headquarters in San Antonio de los Cobres that will house laboratories, dormitories and the remote operation of LLAMA are almost done (Figure 4), and the antenna components are already located at the site in Alto Chorrillos (Figure 5).

There are few places in the world with instruments located in a site like the one proposed in this project. This fact promotes that astronomers around the world compete for access to these instruments. Because of this, observational projects/programs that require many hours of observation are less likely to be carried out. Thus, LLAMA will allow the astronomical communities in Argentina and Brazil to have access to the tool to develop their scientific projects.

Figure 4: Headquarters in San Antonio de los Cobres that will house laboratories, dormitories and the remote operation of LLAMA.

Figure 5: The arriving of different components of LLAMA antenna in Alto Chorrillos. Credit: Fundación CAPACIT-AR and Instituto Geonorte, INENCO (CONICET).