MAYOR INSTRUMENTAL PROJECTS FOR ASTROPHYSICS IN ARGENTINA

- **Pierre Auger Observatory:** It is the world's leading science project for the exploration of cosmic rays. **More than 500 scientists from 16 countries** have been working together **since 1998 in the Province of Mendoza, Argentina**, to elucidate the origin and properties of the most energetic particles in the Universe, coming to us from the far reaches of the cosmos. After the detection of those particles presently **is being upgraded to find out the nature of those particles.**

The ANDES Deep Underground Laboratory

PI: Xavier Bertou (CONEA). Collaboration between Argentina, Brazil, Chile and Mexico. Aims at a better understanding of the neutrino. How does it oscillate? What kind of particle is it? What mass does it have? do they really travel faster than light? Dark matter, expected to be 85% of the total matter of the Universe. Will also be a full geophysics underground laboratory, linked to both the Chilean and the Argentine network of seismographs.

Two Tunnels:

Connecting the ports of Coquimbo & Porto Alegre

- more than 1750m of rock overburden
- Of 13,8 km long and 12 m of diameter

LLAMA

“LARGE LATIN AMERICAN MILLIMETER ARRAY”
Argentinian-Brazilian project in astrophysics

MILLIMETER ARRAY OF ANTENNA(E) IN SOUTH AMERICA

ALMA (Atacama Large Millimetre Array)

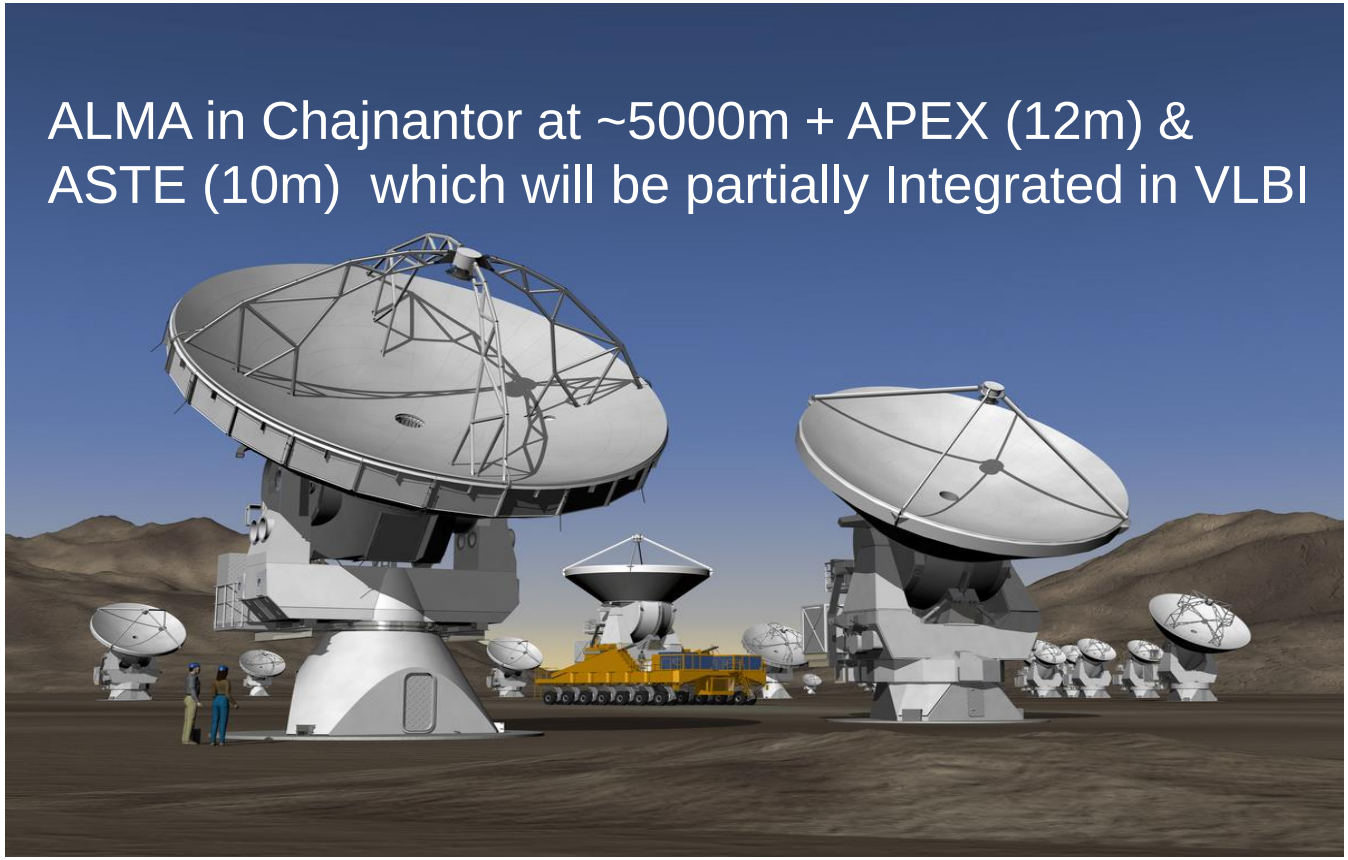
-Estimated total construction cost: US$ 1.4 billons

-50 antennae of 12m +16 antennae of Atacama Compact Array

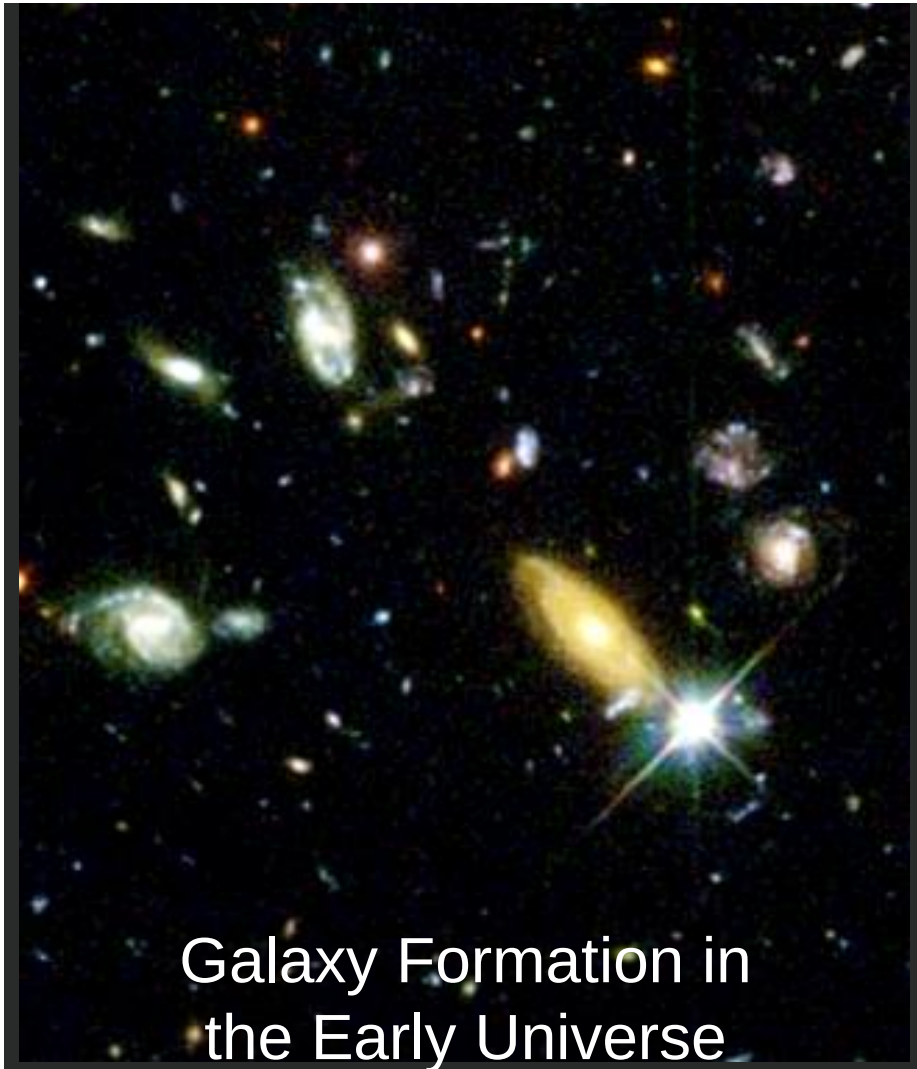
-Angular resolution: 0.2” λ(mm) / baseline(km)

-Frequency range: 84 - 950 GHz (λ = 0.3 - 3mm)

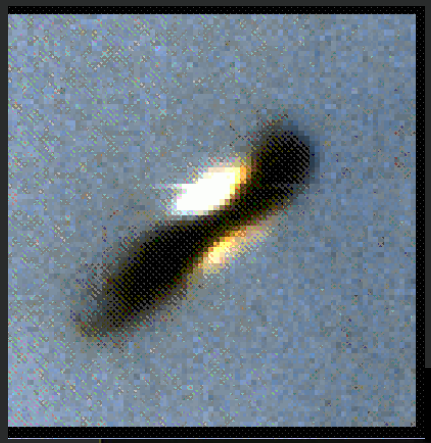
-For max. baseline of 14.5km the resolution at λ1mm is 0.015”



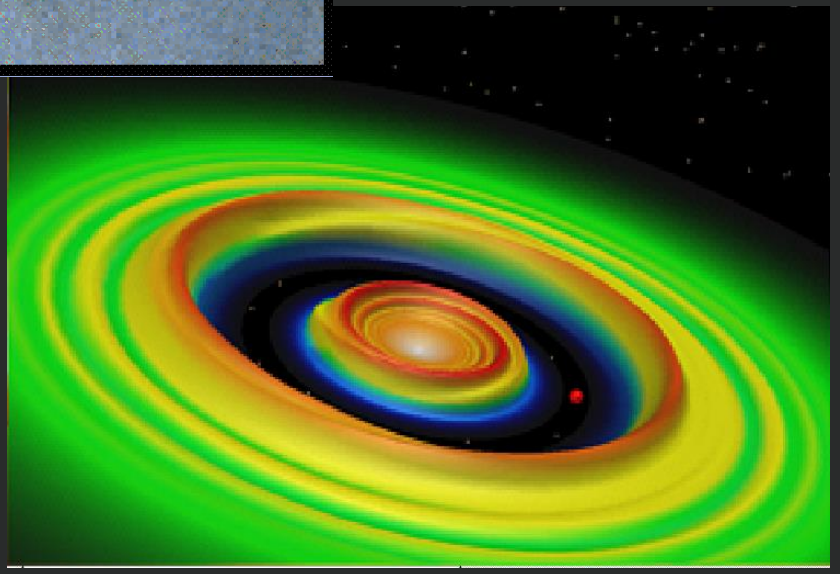
Main Science Drivers of ALMA



Galaxy Formation in the Early Universe

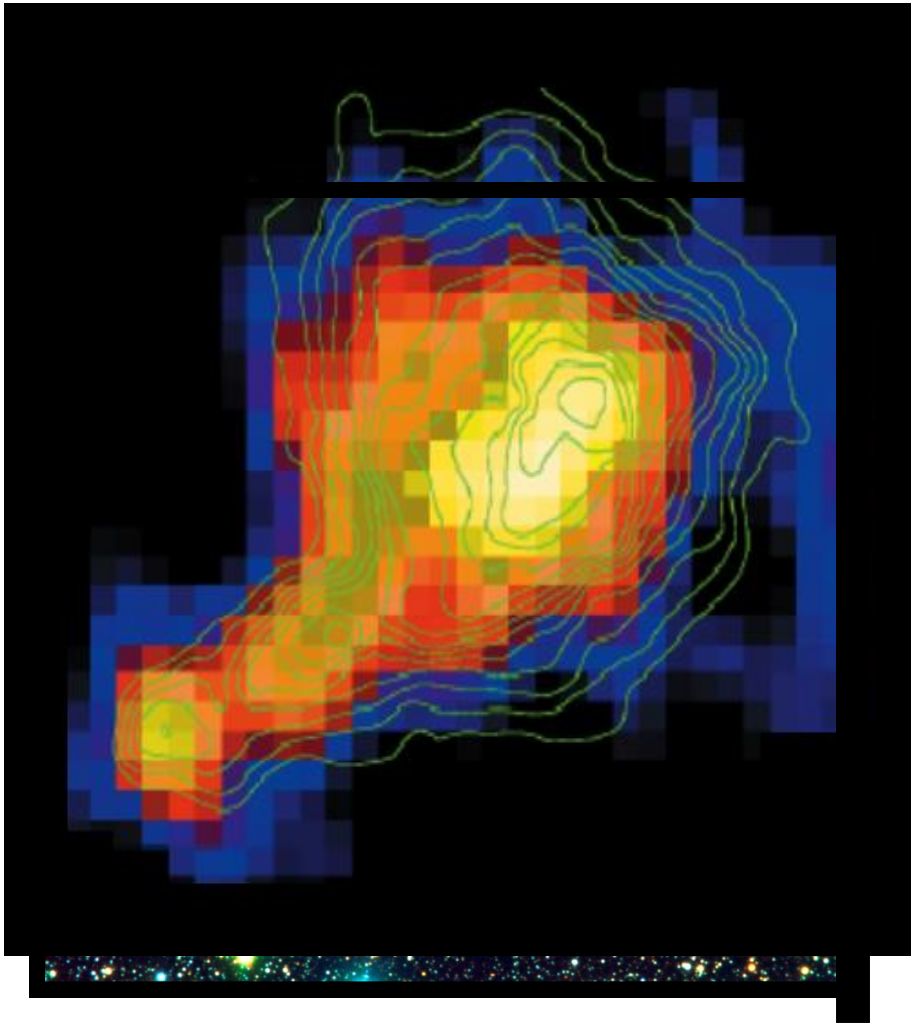


Star & Planet Formation



Millimeter Astronomy

e.g. a "dark" cloud



The *cold* Universe

The formation of galaxies, stars and planets

Emission from dust and molecules

Multi-wave astronomy opens

A rich scientific frontier

Synergy of ALMA with large optical & infrared telescopes

VLBI with ALMA @ Chajnantor

Installing antennae at 150-200 km from Chajnantor at elevations > 4700 m would allow an increase in angular resolution of ~ one order of magnitude:

angular resolution ~ 0.001”

Where ?

on the Argentine side of the Atacama desert called Puna

EARLY HISTORY OF PROJECT LLAMA

- 1986: I search a site for the European LSA project in the NW of Argentina (Salta)
- 2006: I present a manuscript with the idea of LLAMA to the president of CONICET, Minister of Mincyt of Argentina & Director of ALMA
- 2007: I discuss the idea of LLAMA with Brazilian and Argentinian colleagues
- 2008: LLAMA becomes the priority project for astrophysics in the road map of Mincyt
- 2008: The project is presented at the IAU general Assembly in Rio de Janeiro.

A WINDOW OF OPPORTUNITY FOR SOUTH AMERICAN ASTRONOMY

The possibility of installing two radio telescopes for millimeter and sub-millimeter wavelengths, in the Argentinean side of the Atacama desert at distances of 180-210 km from Chajnantor (the site of ALMA), and altitudes greater than 4700 meters, has been discussed among astronomers of Argentina and Brazil.

The support to this idea has been ratified in September 2008 by the Argentinean Astronomical Assembly. In Brazil it 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 informed that in the context of regional integration, funds may be available for original projects on basic sciences, with technology transfer components.

The initial US$ 20 million investment 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 ALMA) with equipment provided by UNAM (México), and further site testing started at other site 180 km SE of Chajnantor (see attached map). A proposal for initial funding to carry on the in depth study of this project will be submitted by December 2009.

We invite you for an open meeting on this project that will take place on Tuesday August 11 at 17:30 in room 2.11.

I.F. MIRABEL, M. ARNAL,
R. MORRAS, G. ROMERO,
J. LEPINE, Z. ABRAHAM,
EL. M. DE GOUVEIRA DAL PINO

LOCATION OF CHAJNANTOR, MACÓN AND CHORRILLOS. THE YELLOW LINE SHOWS THE BORDER BETWEEN ARGENTINA AND CHILE, THE BLACK LINE THE RAILWAY TRACK SALTA-ANTOFAGASTA.

2010: Take the lead of LLAMA

Argentina: IAR (Arnal & Morras, Director & sub-director)

Brasil: Univ. Sao Paulo (Lepine, Gouveia Dal Pino, Abraham)

México: UNAM Rodríguez, Lizano (provided instrumentation fsite tests)

LANDSCAPE OF THE ARGENTINIAN DESERT (‘PUNA’ OF SALTA)

Chajnantor – Macón - Chorrillos

Chorrillos:4800 m
Better infrastructure:
Railway track,
national road
20 km from SAC
3 h from Salta

Macón: 4600 m
was one of the 3 test sites for the E-ELT

tests started in 07/09

Chorrillos: The site at 4850m for the first antenna

Other possible international projects at this site: QUBIC & HAWC

Chorrillos is next to the “Tren de las nubes”

VIEW FROM MACÓN: the site for the second antenna (>5000m)

Millimeter VLBI Science

- **Studies of regions a few times larger than the horizon of super-massive black holes (e.g. Sgr A*, Cen A, etc.).**
- **How relativistic jets are released, accelerated & collimated.**
- **Afterglow spectra of LGRBs**
- **Hiper-starbursts at high redshifts (universe <1 Gyr old)**

- Extra-solar planets and proto-planetary disks
- Megamasers, Masers & stellar envelopes
- Molecular absorption in front of quasars at very high z
- Non-thermal processes in stellar magneto-spheres
- Solar phenomena at unprecedented angular resolution
- Solar system studies: Comets, etc…
- Searches for molecules in circumstellar environments

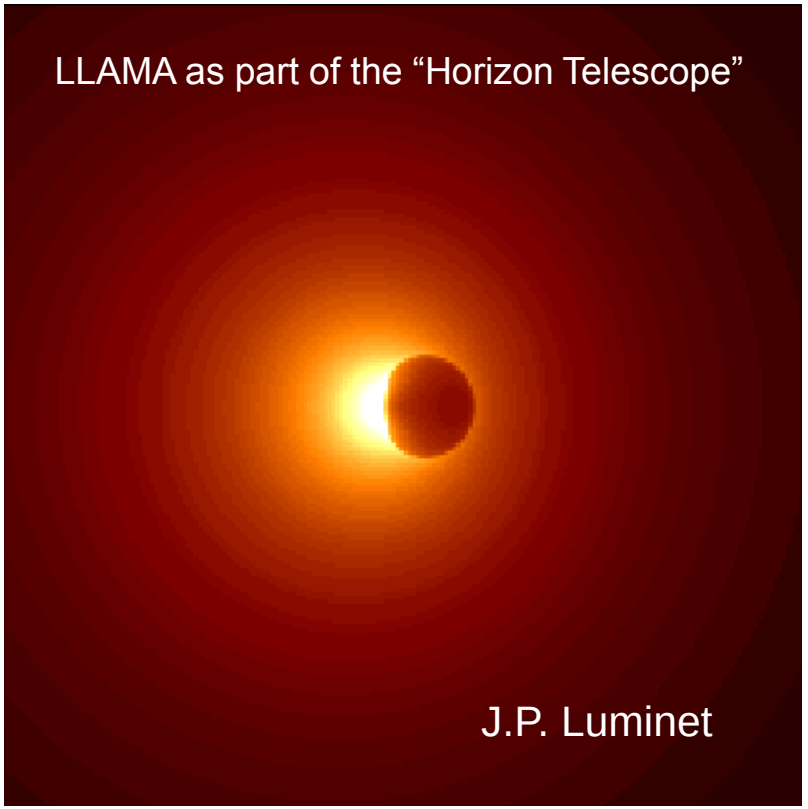
Science in stand alone mode

- Surveys (oversubscription in the ESO time of APEX is large)

GR IMAGE OF THE SMBH IN Sgr A*

- **Dark circle caused by radiation from behind BH being swallowed by the event horizon (R = 10 μas = 0.1 UA)**
- **Bright ring = rays deflected by BH**
- **Shadow is off-centre due to flung of photons in the direction of BHs' spin**

- **VLBI @ 1.3mm with a resolution of 40μas showed that the bulk of the emission is not centered on the BH**
  (Doeleman et al. in Nature Sept. 2008)



- **4 x 10^6 $M_\odot$ confined in a region enclosed by less the orbit of the Earth**
- **R < 10 μarcsec could be imaged with VLBI at sub-millimeter or X-rays**

INTERCONTINENTAL VLBI WITH ALMA…THE FIRST GR IMAGE?

CONCLUSION

LLAMA offers the following advantages:

- Takes an initiative that may allow the countries of the region the possibility to participate in global projects.
- An initial investment of US$ 20 million allows partial integration in a project that costs US$ 1.4 billion.
- It is an original and unique scientific-technological project that will not repeat goals already achieved.
- It will allow to test and correct regional scientific-technological integration, in a step by step process.
- It is an ideal context to train human resources in materials engineering, microwave technologies, with applications in telecommunications, microelectronics and business management, at a national and regional level.