SPANET –São Paulo Astronomy NetworK (LLAMA, CTA. GMT)

LLAMA

Large Latin American Array

www.llamaobservatory.org

Jacques Lepine; Marcelo E. Arnal; Thijs de Graauw;
Zulema Abraham; Guillermo Gimenez de Castro; Cristina Cappa;
Elisabete de Gouveia Dal Pino; Ricardo Morras; Juan Larrarte;
José Viramontes; Ricardo Finger; Jacob Kooi; Rodrigo Reeves; Pedro Beaklini

Installation of a 12 m radiotelescope in the Andes in Argentina at 4800 m altitude for mm/sub-mm astronomy

ISWA 2016 June 2016

Objectives of the LLAMA project

- develop frontier science in Astronomy, to answer fundamental questions (examples Astrochemistry, Black Holes and Solar physics)

- achieve high-level internacional competitiveness (to be able do observations that others cannot do)

- have constant development of instrumentation to keep the border competitiveness and have technological consequences for the country

- develop strong international presence and collaboration within Argentina and Brazil, and with many other countries

Context

ALMA is the most important project in astronomy of recent years
US, Europe, Japan In North of Chile, 5000 m altitude

66 radiotelescopes 12m diameter, frequency range from 100 GHz to 800 GHz
(Teraherz region of spectrum = 0.1 to 10 THz)

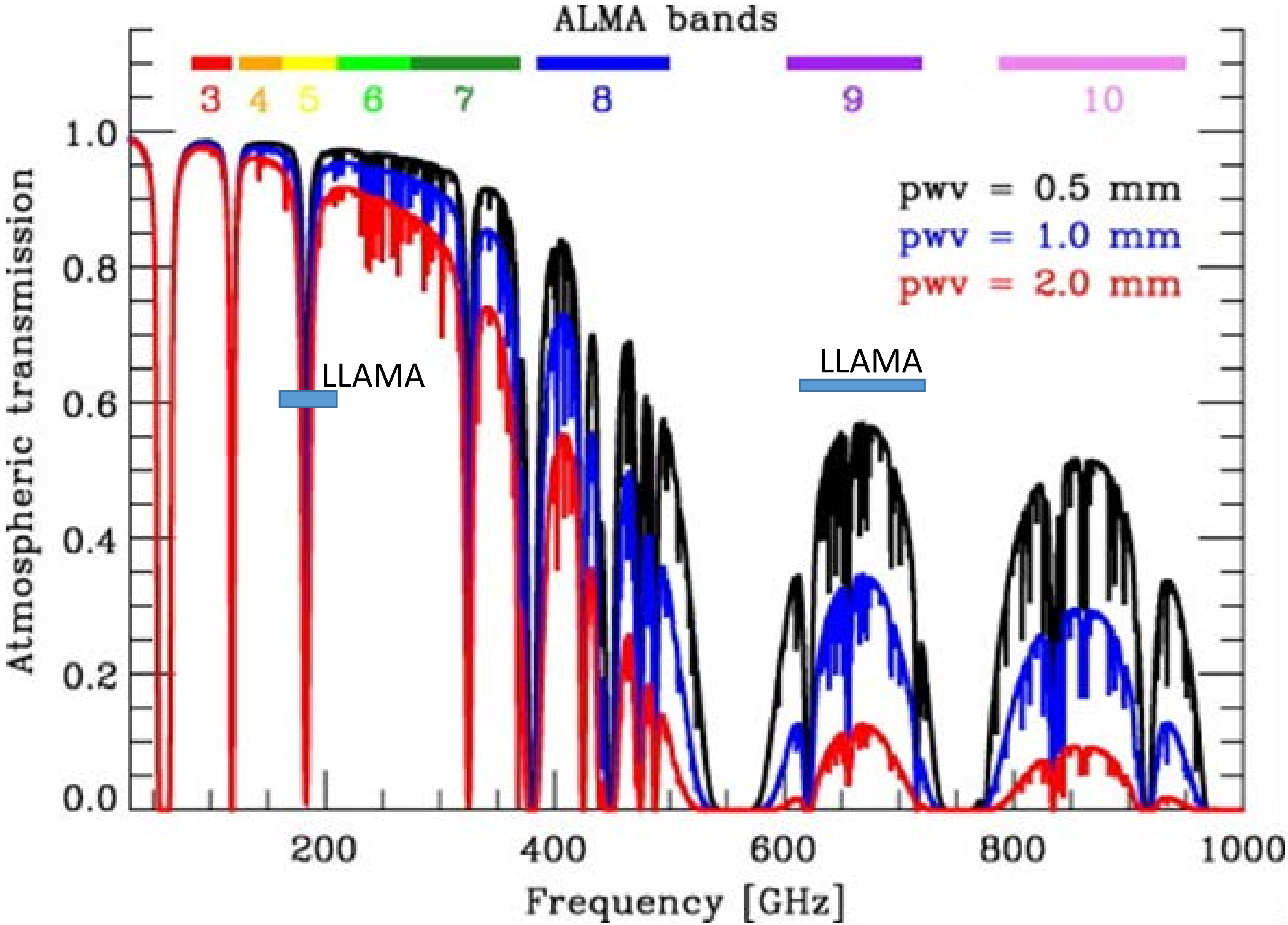
Astronomy is a strong driver of THz technology

Thijs de Graauw was the director during the last 5 years of construction –now working with us

Radiotelescopes above 4000 m

ALMA 66 x 12m antennas	Chajnantor	5000 m	Chile	USA, ESO, Japan/Taiwan
APEX 12m	Chajnantor	5000 m	Chile	Sweden, Germany, ESO
ASTE 10 m	Pampa la Bola	4800 m	Chile	Japan
JMCT + SMA 15 m + 8 x 6m	Mauna Kea	4100 m	USA	East Asian Observatory
LLAMA 12m	Chorillos	4800 m	Argentina	Argentina+ Brazil
		The only single dish able to observe the Sun		
LMT 50 m	Sierra Nevada	4600 m	Mexico	Mexico, USA
NANTEN 2 4m	Chajnantor	4865 m	Chile	Japan, Korea

Why altitude is important?




Sicaya
ALMA
LLAMA
SEST
CART
Itapetinga
Mato Grosso
Plateau
BOLIVIA
PARAGUAY
CHILE
Atacama Desert
Alvorada
Cuiaba
Brasilia
Goiania
Puno
La Paz
Arequipa
Arica
Sucre
Santa Cruz
Campo Grande
Belo Horiz
Fortin Madrejon
Tarija
Boa Vis
Rio De Janeiro
Cruzeiro Do Sul
San Salvador De Jujuy
Concepcion
Sao Paulo
Salta
Coronel Oviedo
Curitiba
Asuncion
Foz Do Iguacu
San Miguel De Tucuman
Rio Parana
Florianopolis
Resistencia
Rio Uruguay
Porto Alegre
Cordoba
Tacuarembo

First results: in less than 2 years we developed active collaborations with 15 international research institutions

Institutions

Argentina
IAR La Plata
IAFE Buenos Aires
Universidad de Cordoba

Chile
ALMA
Universidad de Chile
Universidad de Concepción
Universidad de La Frontera

Netherlands
NOVA Groningen
Sweden
Chalmers University Gothenburg
France and Germany
IRAM Grenoble (post-doc :Pedro Beaklini)
FRANCE
IPAG Grenoble (post-doc: Edgar Mendoza)
IAP Paris (QUBICS)
LAM Marseille (CONCERTO)
USA
NRAO
Japan
NAOJ

Individuals

Thijs de Graauw (mentor)

Technical advisers

Jacob Kooi (Caltech, JPL)
Juan Pablo Garcia
Jorge Ibsen (ALMA)
Jacob Baars

Science External Adviser Committee

Catherine Cesarsky (France)
Lars-Ake Nyman (ALMA)
Riccardo Giovannelli (Cornell)

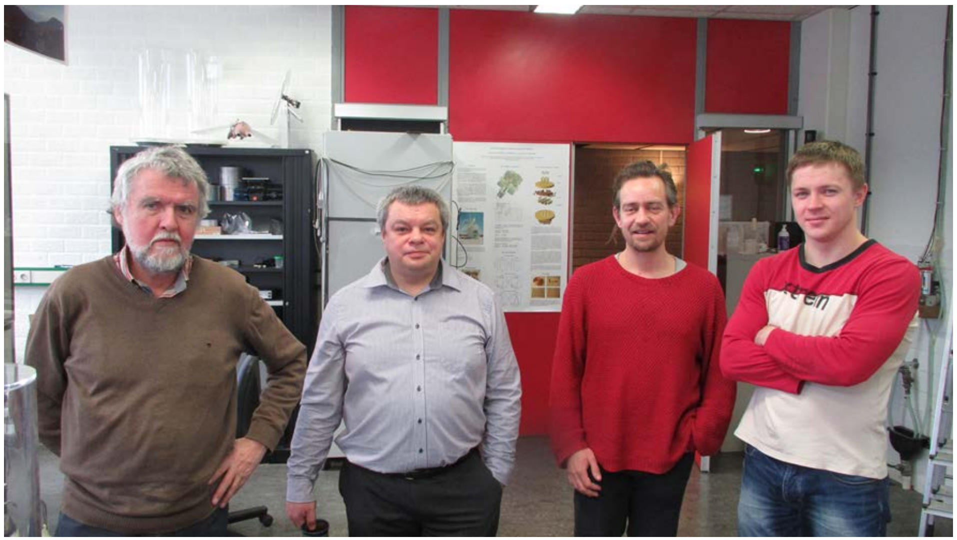
Pedro Beaklini (FAPESP fellowship) is at IRAM (Grenoble) working on commissioning of an antenna at Plateau de Bures

We will send two engineers from Escola Politécnica –USP to NOVA Groningen

Bertrand Lefloch from IPAG visited IAG for 3 months and received our post-doc Edgar Mendoza for 5 months.

NOVA

THE NETHERLANDS RESEARCH SCHOOL FOR ASTRONOMY
(Nederlandse Onderzoekschool Voor Astronomie)
A collaboration between the Universities of Amsterdam, Groningen, Leiden and Nijmegen

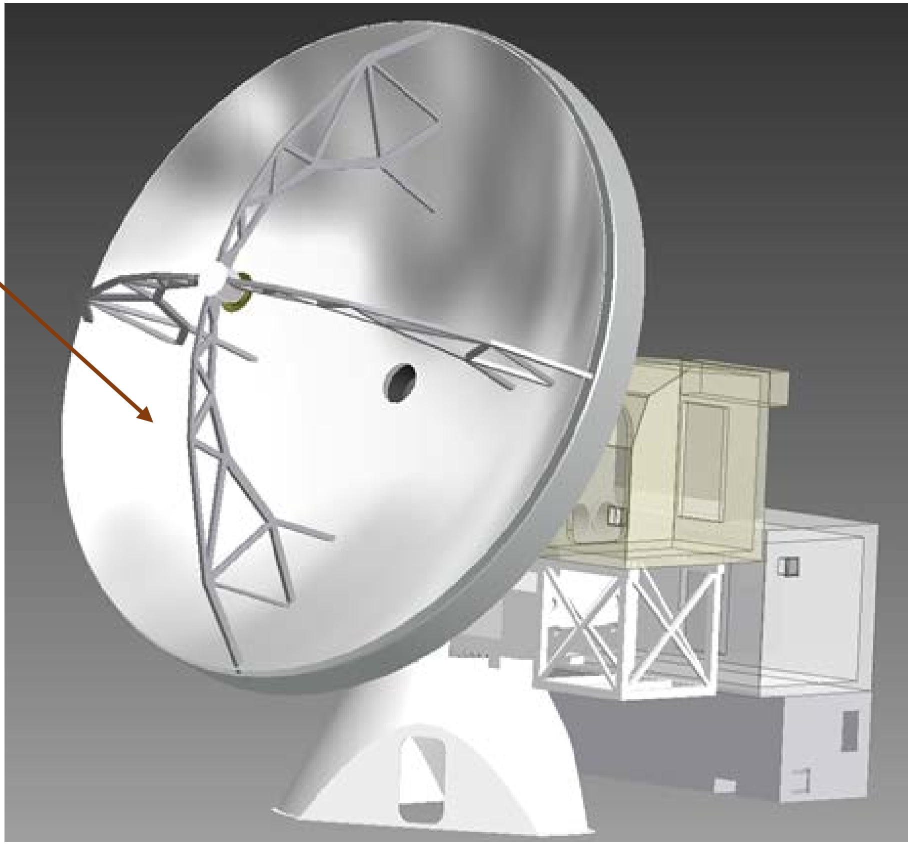


Wilfried Boland, Andrey Baryshev, Jan Barkhof,
Andrey Khudchenko

- **NOVA was responsible for the construction of the 66 Band 9 receivers for ALMA**
- **Nova offered us a Band 9 receiver for LLAMA**
- **NOVA offered to integrate and test not only the band 9, but also the band 5 receiver in the cryostat that we are going to use**
- **Working on a side-band separating 'band 9' receiver for LLAMA**
- **Funds have been allocated by NWO and FAPESP for this collaboration, which includes training of engineers, visits of scientists, and more**

The antenna

Excellent surface accuracy = good efficiency at high frequencies



Unique capability of observing the sun

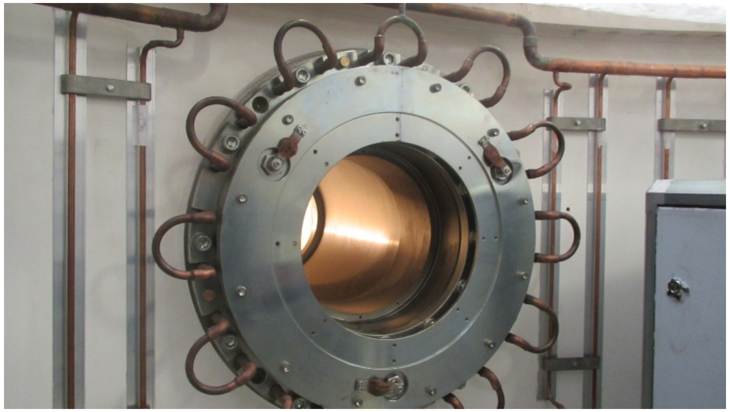
Error budget

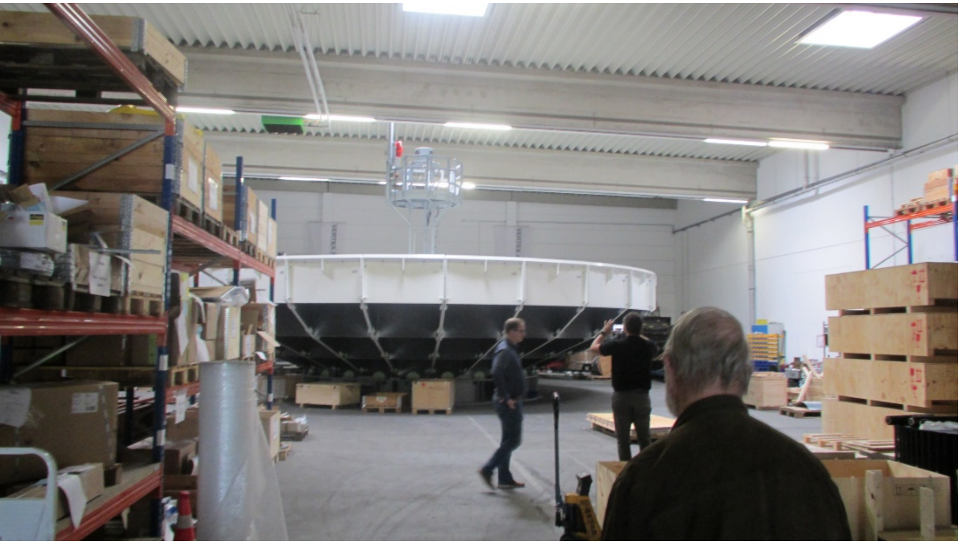
Error Source	RMS Error [µm]
Total Panel (RSS)	9.6
Total Backing Structure (RSS)	14.6
Total Panel Mounting (RSS)	5.3
Total Secondary Mirror (RSS)	6.3
Total Holography	10.0
Other Errors Not Included Above	2.0
Total RSS	21.9
Guaranteed (RSS)	25.0

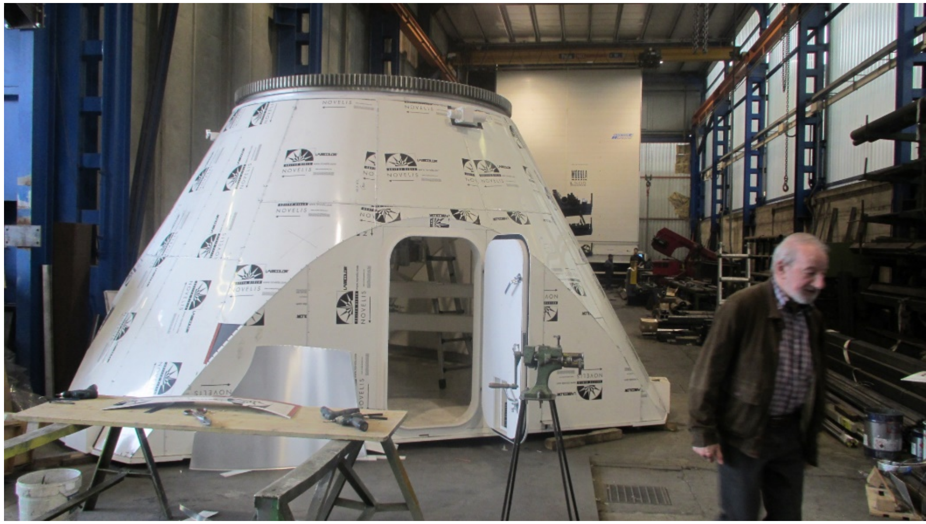
Antenna construction is progressing fast

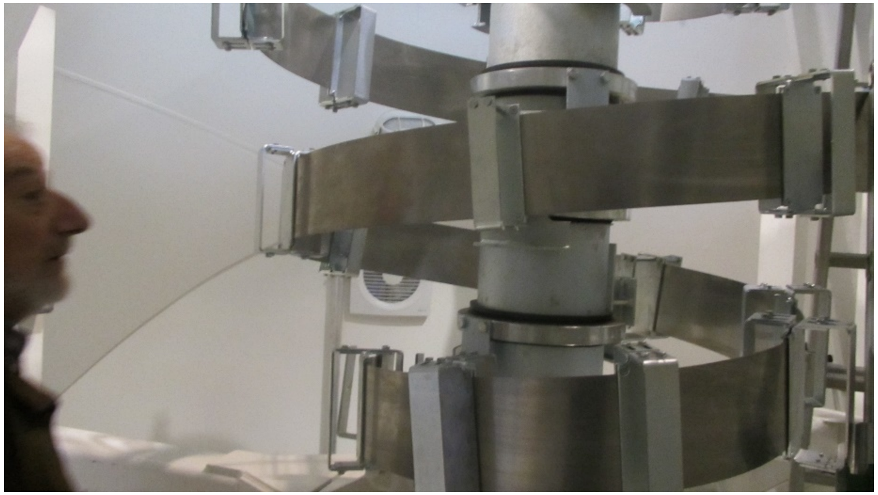
In 2 months from now will be ready to be shipped

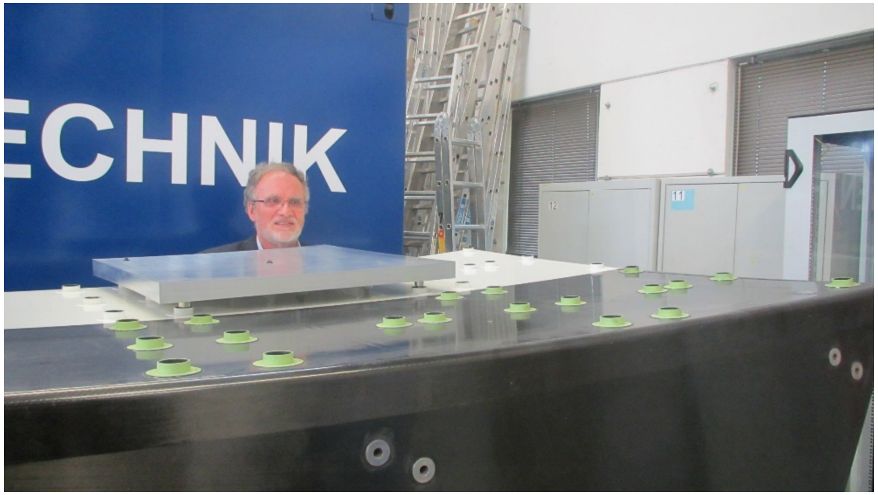
We performed a Factory Acceptance Test
in Duisburg (Germany) and Colombo (Italy)
during last week.

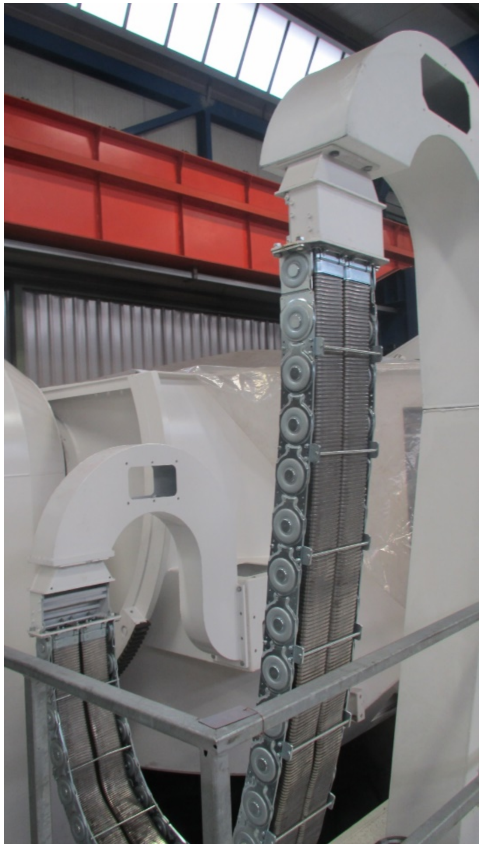









ECHNIK



Cooled receivers – state of the art

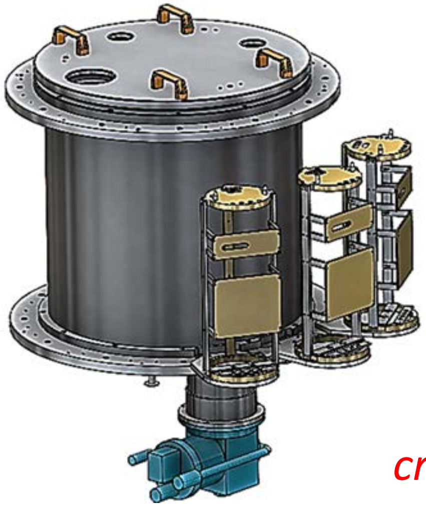
- First 2 receivers + first cryostat will be provided by international collaborations NAOJ (Japan) NOVA (Netherlands) and Chalmers Univ. (Sweden)

Receivers

- Integration and test of the 2 receivers to be available in 2016 (band 5 and band 9) will be made at NOVA Groningen. Training of 2 engineers (Escola Politécnica) start in September

spectrometer

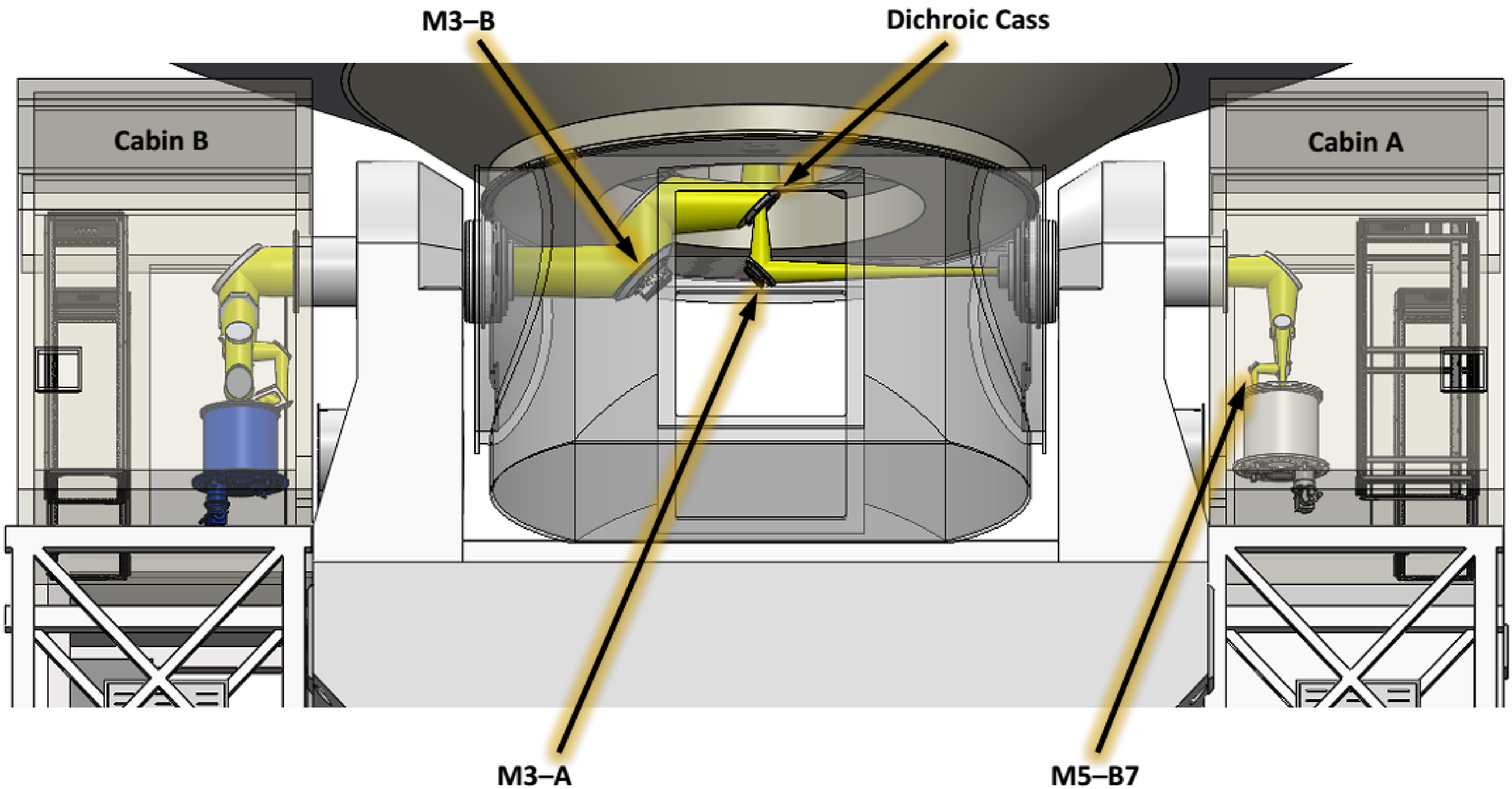
ALMA band	Frequency Range GHz	Construction
1	31-45	Univ. Chile
3	84-116	Univ. Chile
5	162-211	GARD Sweden
6	211-275	NRAO
9	602-720	NOVA Holland



cryostats

competitiveness

Antenna with excellent availability of space for instruments and experiments for new developments

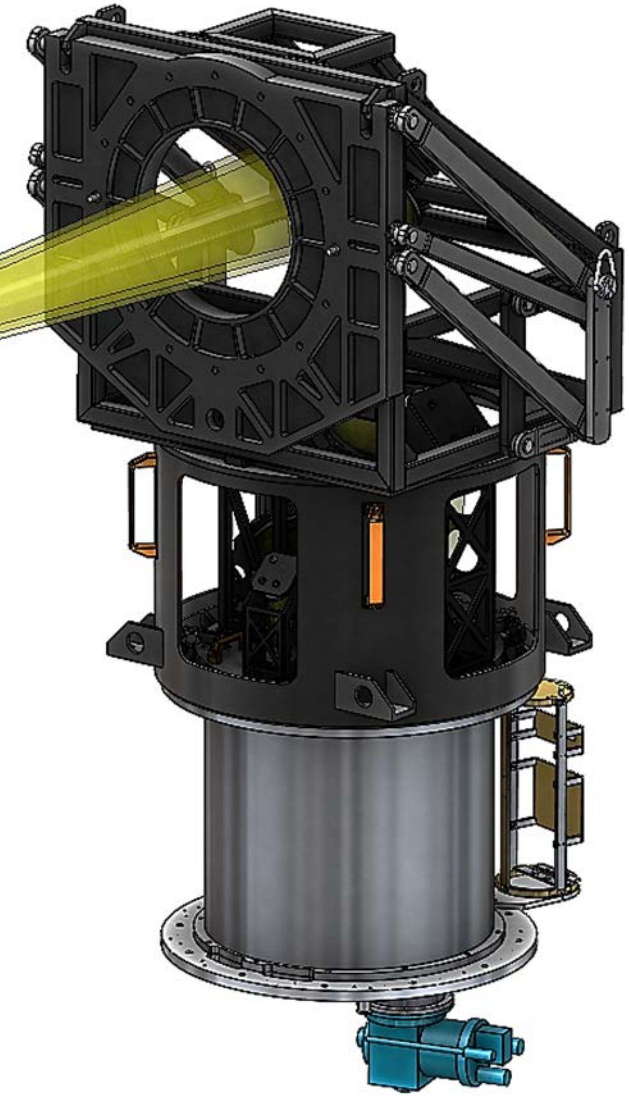


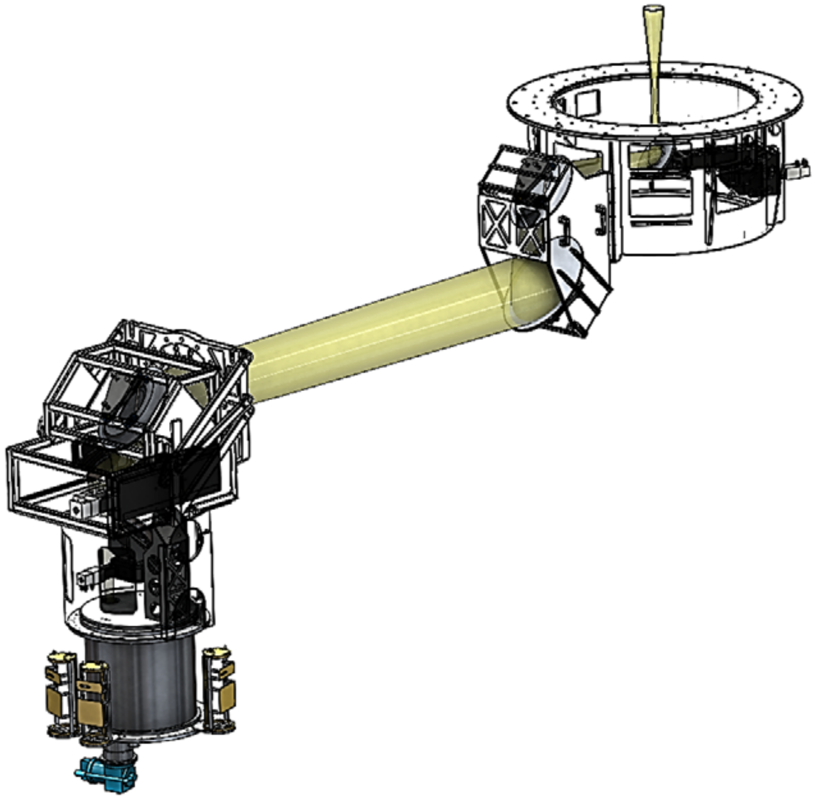
The “optical” path, set of mirrors to bring the beam to the receivers

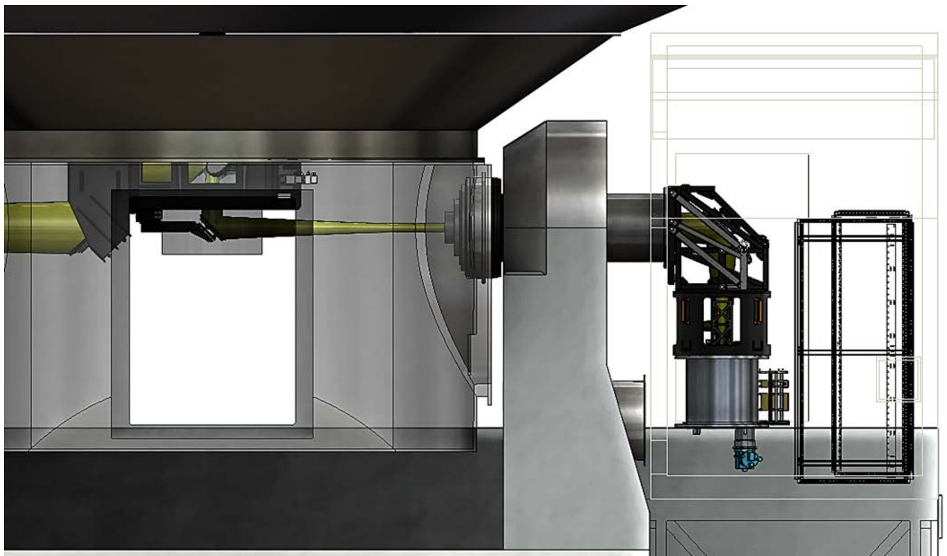
The antenna will be able to observe simultaneously at different frequencies

FIlling the cabins of the antenna: a lot of instrumentation being designed Fernando Santoro - USA

Conceptual design of system of mirror
Support of cryostat going on



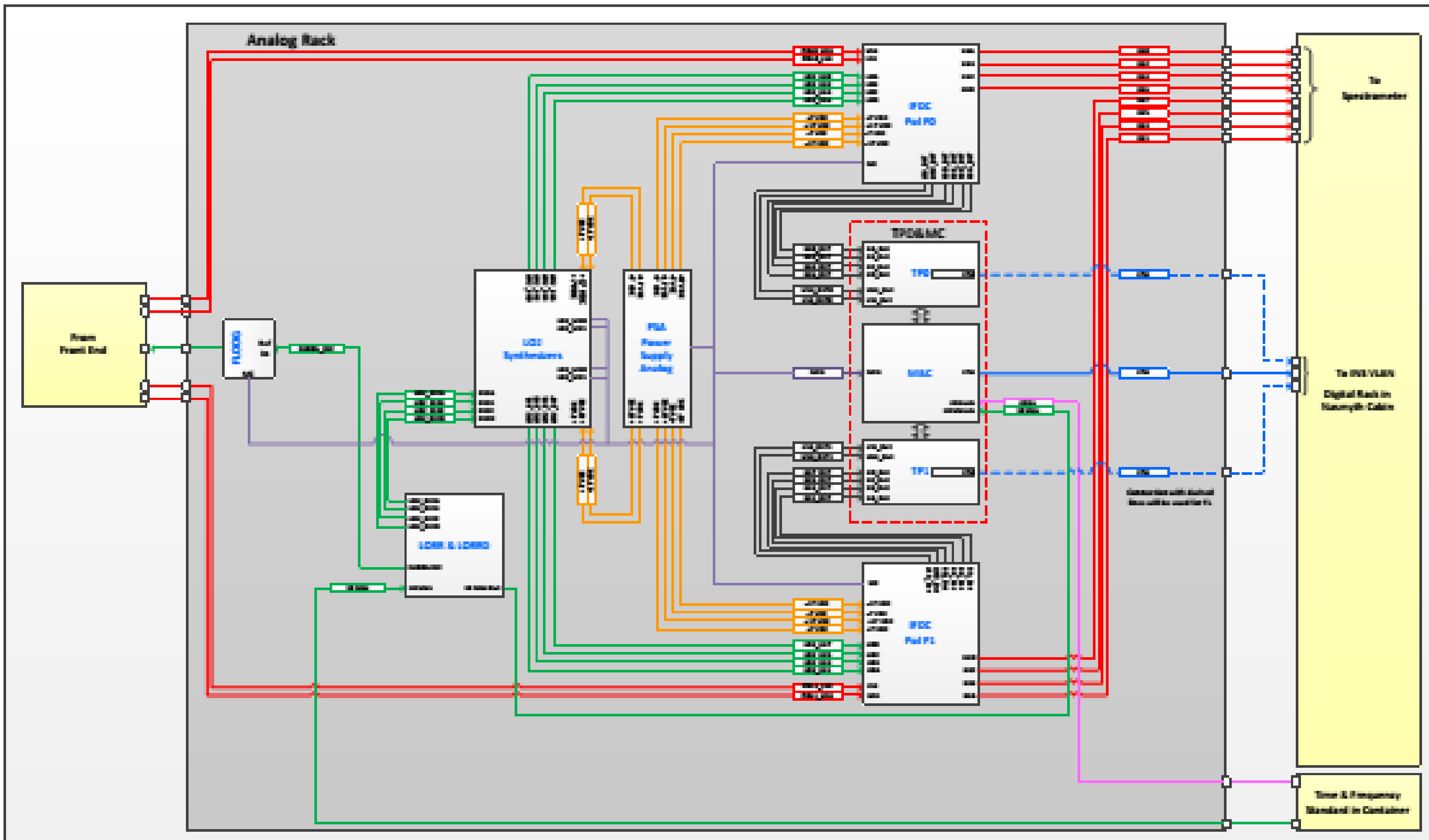




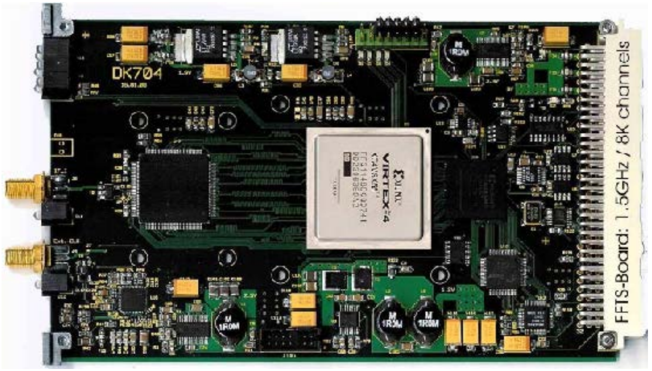
Conceptual project of back-end , if processor, etc, all electronics needed To prepare the signal to feed the spectrometer - going on

Analogue Rack Design Proposal

Juan Jose Larrarte + 2



Fast Fourier Transform Spectrometer (RPG)



- **Signal Input: DC - 1.5 GHz**
- **ADC: 8 bit**
- **DSPL Polyphase filter bank (FFT)**
- **Resolution: 212 KHz @1.5 GHz BW**
- **Channel spacing 183 KHz**
- **Spectral Channels: 8192 (8K) @1.5 GHz BW**

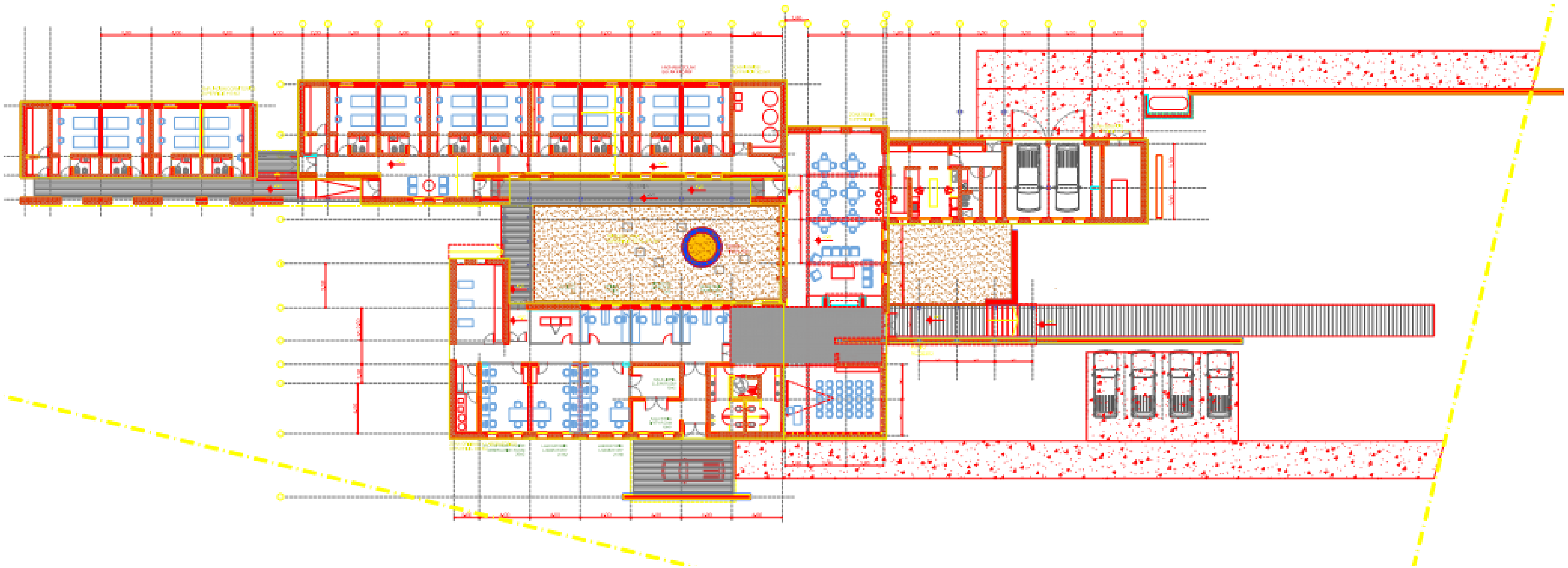
Computation

- Control of antenna position or tracking
- Reading all sensors, receiver parameters
- Setting position of mirrors, switches to put observation at a given frequency
- Data acquisition
- Preparation for remote observations

Makes use of ACS software system of ALMA

Going on (Guillermo G. de Castro, Cesar Strauss, Danilo Zanella, Fernando Hauscarriaga e Federico Bareilles- both from Argentina)

Building at San Antonio de los Cobres



At the beginning, remote observations fron san Antonio 3800 m

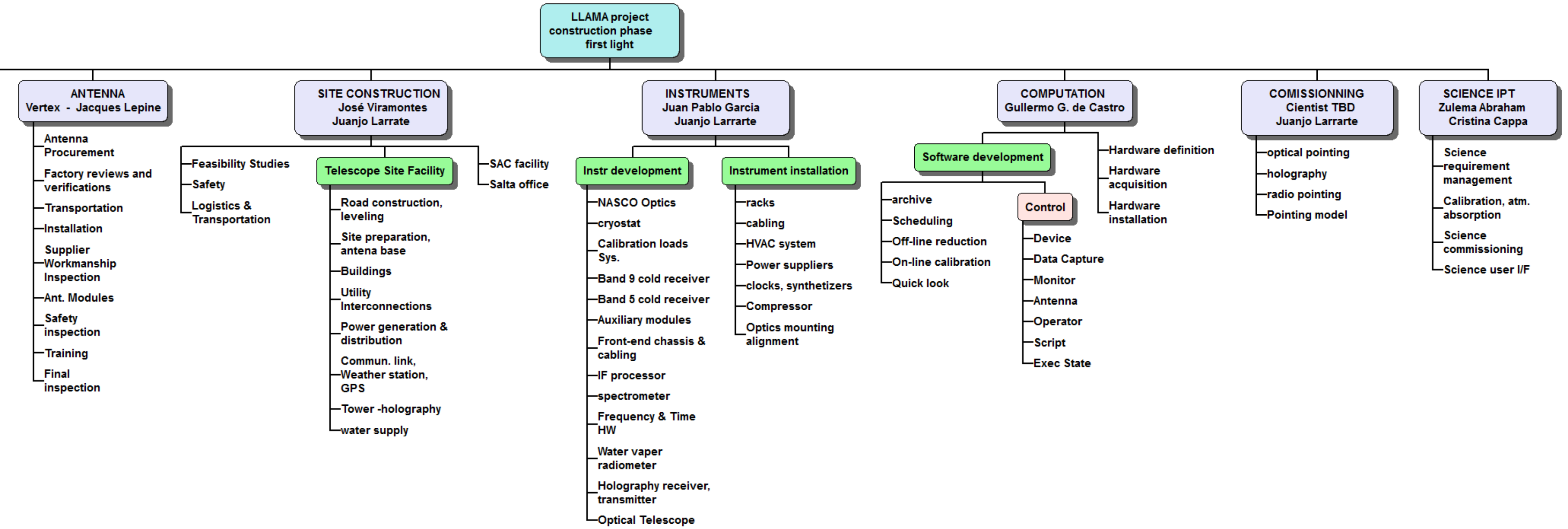
Software team at work

At VERTEX (Duisburg, Germany, testing Commands of antenna May 25, 2016

At IAG- São Paulo, May 2016, With participation of 3 Chileans

Organization of the activities in order to reach first light

Part of the WBS



LLAMA scientific objectives

- VLBI images of regions a few times the horizon size of super-massive black holes (e.g. Sgr A*, Cen A, etc.).

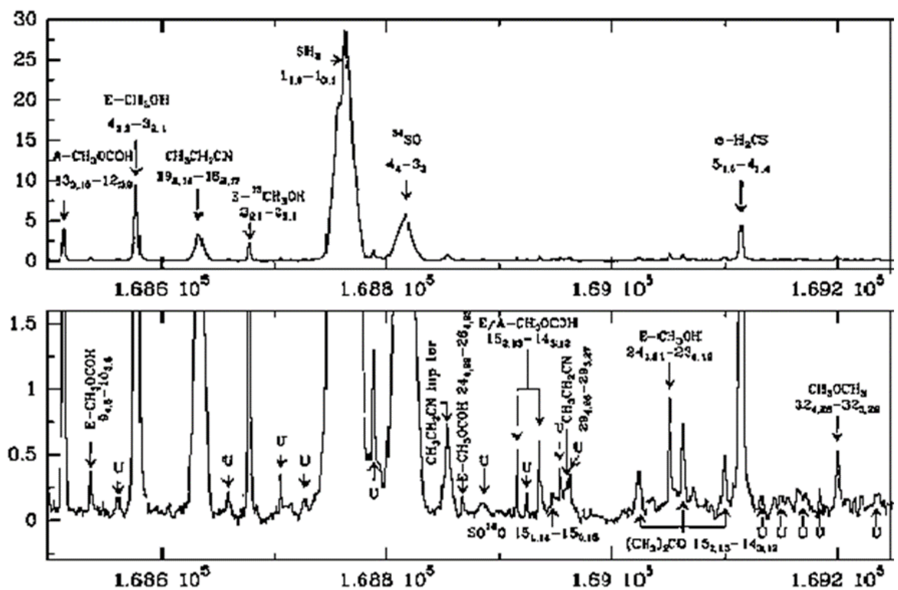
  Event Horizon Telescope Several mm radiotelescopes with Thousand km separations to observe the Black Hole of our Galaxy

- Galaxy Formation in the Early Universe
- Extragalactic megamasers of water molecules
- Masers of recombination lines of the hydrogen atom.
- Astrochemistry: molecular evolution of interstellar clouds
- Spiral structure of the Galaxy and other galaxies
- Molecular absorption in front of quasars at very high Zs
- Non-thermal processes in stellar magneto-spheres
- Extra-solar planets and proto-planetary disks
- Polarimetry of radio sources and of the Interstellar Medium
- Solar Physics

Astrochemistry: evolution of molecular complexity in space

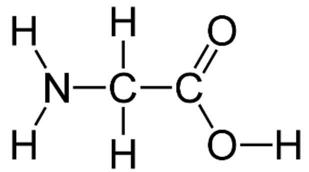
The basic questions of how, why and what molecular complexity is reached are still unanswered.

- The way forward is to collect high resolution unbiased spectra covering the largest possible frequency range, in order to have the most complete census of the present species, towards the largest possible sample of sources representing the various phases the Solar System passed through.

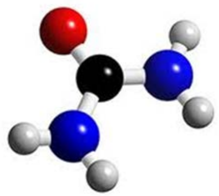


Radio spectrum of Orion molecular cloud

Glycine

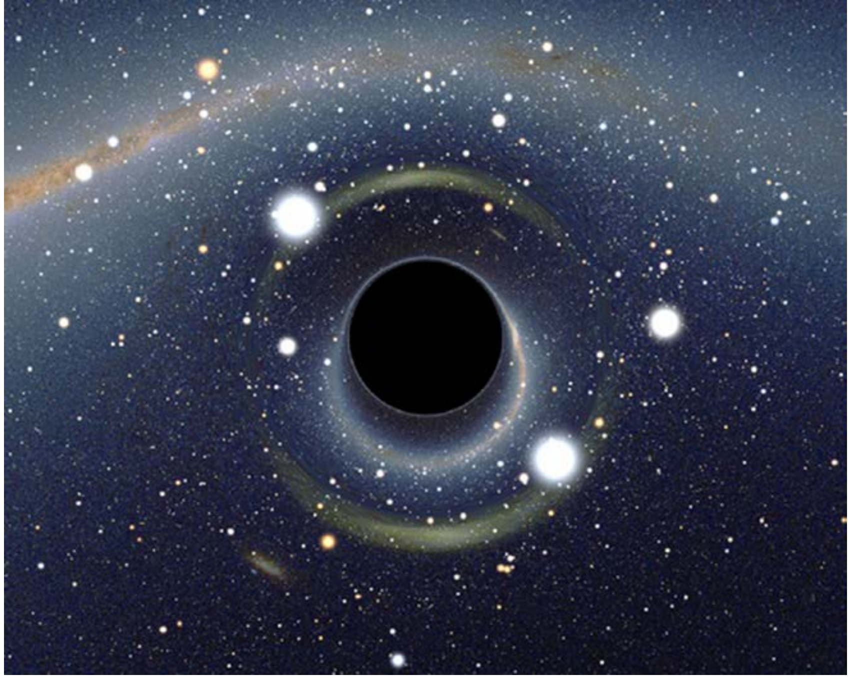


Urea-clearly detected



VLBI images

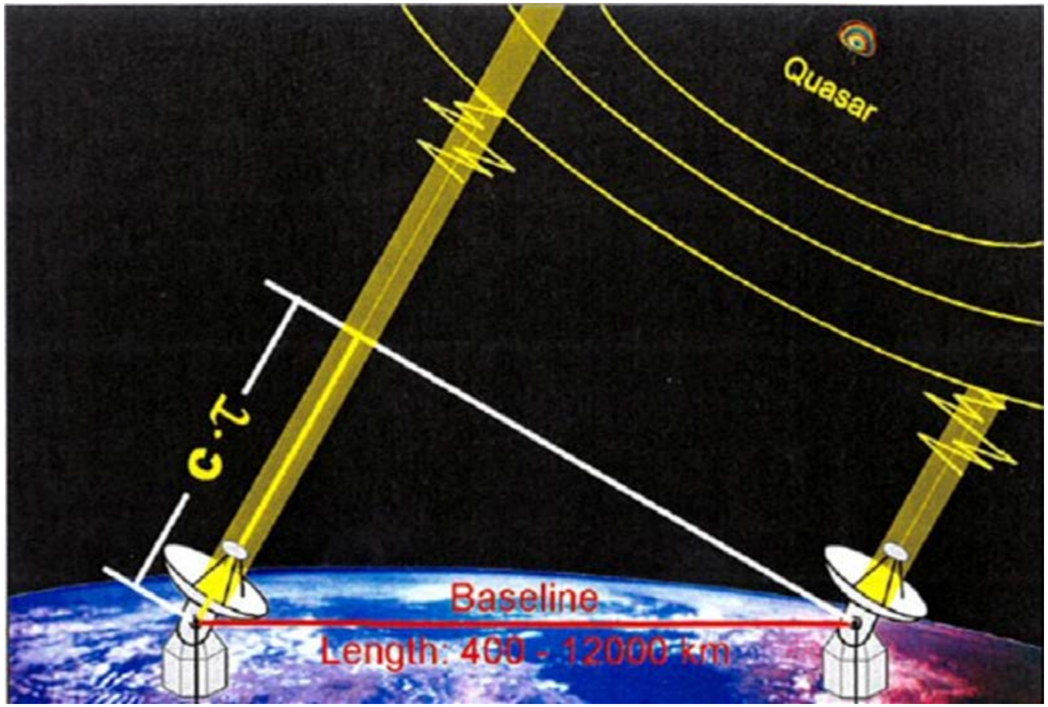
Black hole in the center of our Galaxy is the nearest One. In principle with image resolution 0.03 mas We could see the Event Horizon



Telescope separation 12000 km= $12x10^9$mm
Observation at 1 mm –resolution = 1rd/$12x10^9$ = 0.017 mas   Sgr A^*

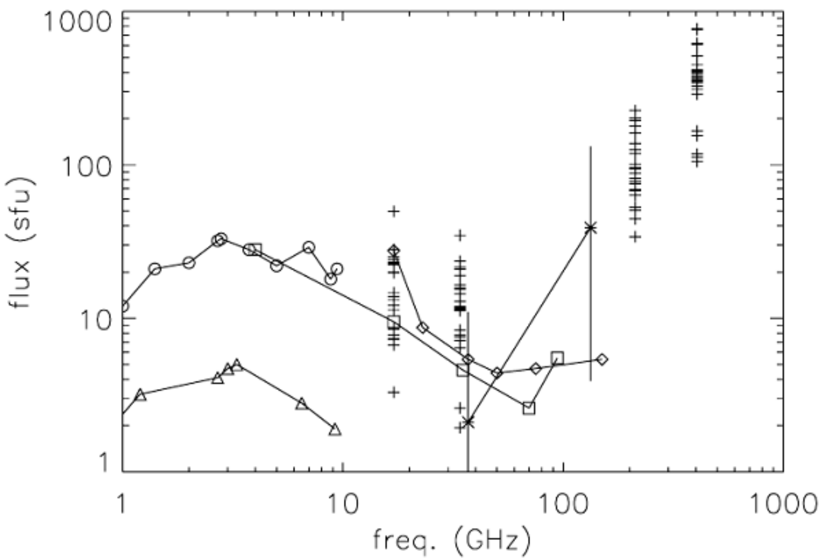
Einstein's theory of general relativity predicts that there will be a roughly circular "shadow" around a **black hole**.

We intend to be part of the EHV
Event Horizon Telescope



Solar Physics

- LLAMA can extend the frequency coverage up to 1000 GHz with the addition of polarization information. Joint observations with SST (mostly 212 GHz), and the other patrol telescopes from 1 to 90 GHz will complete a spectrum with almost three orders in frequency
- Simultaneous observations at different frequencies will be a plus of LLAMA for the observation of flares. We will be able to measure the delay between the maximum of a flare between frequencies, which is due to the propagation of radiation in the plasma



Comparison of submillimeter active region Flux density spectra with previously published data. From Silva et al. (2005)

Antenna Time schedule

• Construction of the road	July 2016 – December2016
• Construction of antenna concrete base	December 2016
• Installation of electricity generators	Feb 2017 – May 2017
• Arrival of the containers at the site:	March 2017
• End of antenna mounting (3 months)	June 2017
• Holography	June-August 2017
• Pointing tests with optical telescope	June- August 2017
• Installation of receivers, back-ends	June- August 2017

Construction of Receivers, cryostats, optics

• Complete optics design and drafting	end September 2016
• construction	November 2016 January 2017
• Fabrication of first cryostat at NAOJ	June 2016 –November 2016
• Arrival of cryostat at Groningen	end November 2016
• Integration of bands 5,9 (6?)	December 2016 –February 2017
• IF processor (IAR)	February 2017

First observation: November 2017

Difficulties?

- Difficult to plan – almost 1 year delay

- We postponed acquisition of some equipment due to financial and/or manpower problems:

Wobbler

Band 6 receiver

Band 1 and band 3 receivers (to be made in Chile)

VLBI equipment

Multi-frequency observations

Spare parts


LHAMA
VERDE
.15