LLAMA radiotelescope update

Jacques Lepine - University of São Paulo 14/12/2021

Reuven Opher Workshop on Challenges of New Physics in Space

WE are constructing a radiotelescope which looks like this one (APEX, installed in Atacama, Chile) no Atacama, Chile)

APEX is saturated (by a factor 3 in Observing time) Ours is different In many aspects.

LLAMA

12 m diâmetro
4800 m altitude

Context

ALMA is the most important radio observatory of the world (USA + Europe + Japan) North of Chile at 5000 m altitude
66 antennas 12 m diameter

Frequency bands covering from about 100 GHz to 800 GHx
We call this the Teraherz region (from 0.1 to 10 THZ)

Spectacular results are being obtained every day

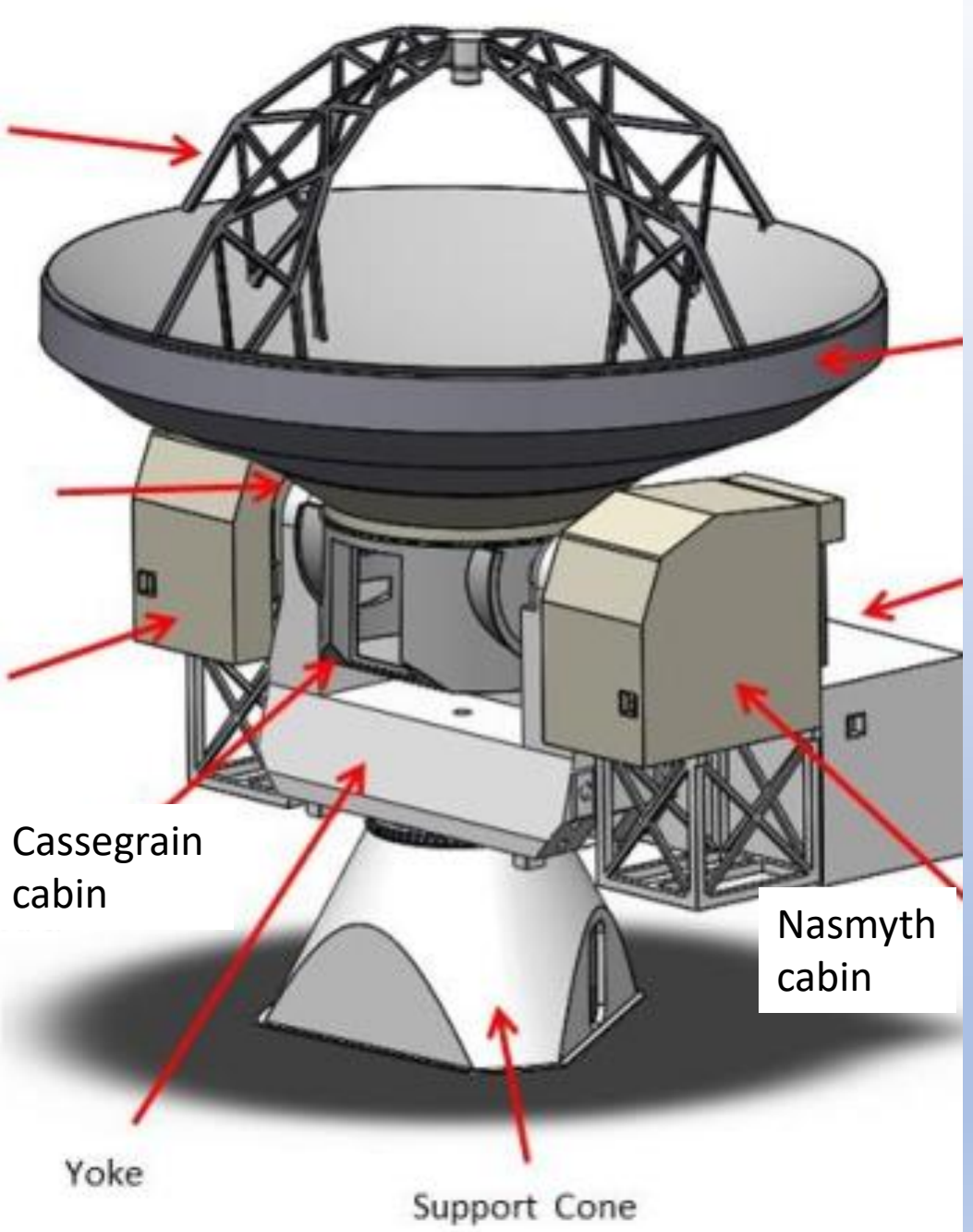
The radio telescope is based on the same design of the antennas manufactured by the German company VERTEX AntenenTechnik GmbH for the ALMA (Atacama Large Millimeter/submillimeter Array).

the antena will have a Cassegrain focus and two Nasmyth cabins thus offering the possibility to receive a wide variety of peripheral instruments.

Once assembled, and at the time of acceptance to start the phase of commissioning and science verification, the antenna surface should have rms accuracy 25 µm rms, with the precision of pointing expected of about 2 seconds of arc.

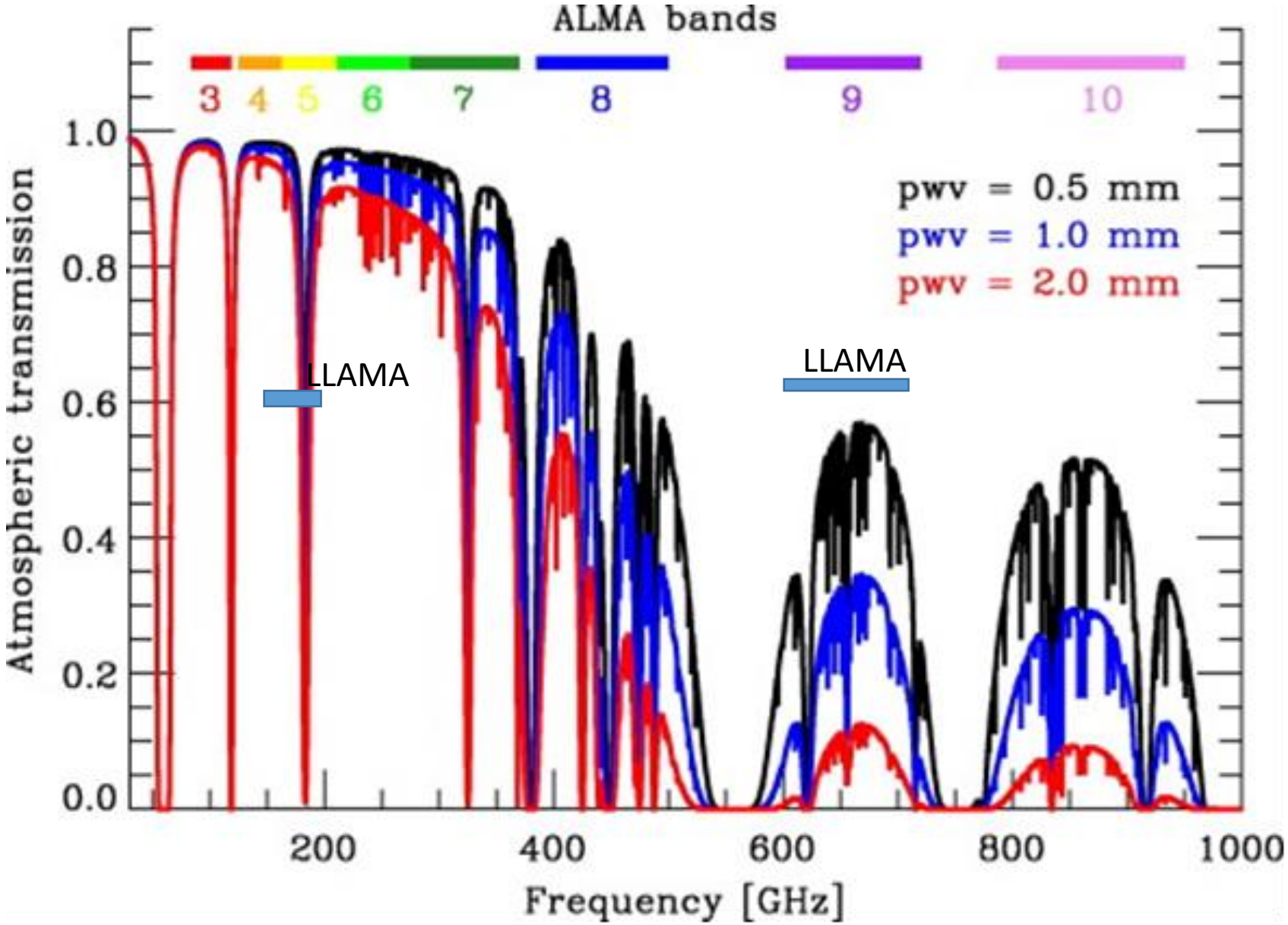
A subsequent adjustment of the pannels using holographic technique will in principle bring the surface accuracy around 15 µm rms. Good to observe at frequencies (or wavelength) of the order of 300 µm

=1 THz




Sicaya
ALMA
LLAMA
Itapetinga
CART
SEST
Mato Grosso
Alvorada
BOLIVIA
Plateau
Puno
La Paz
Cuiaba
Brasilia
Goiania
Arequipa
Santa Cruz
Arica
Sucre
Campo Grande
PARAGUAY
Fortin Madrejon
Tarija
Cruzeiro Do Sul
San Salvador De Jujuy
Concepcion
Sao Paulo
Salta
Coronel Oviedo
Curitiba
Asuncion
San Miguel De Tucuman
Florianopolis
Resistencia
Porto Alegre
ARGENTINA
Cordoba
Tacuarembo

Why altitude is so important?



Competitive !!!

Radio telescopes > 4500 m altitude and D>10 m

ALMA 66 x 12m antennas Japan/Taiwan		Chajnantor	5000 m	Chile	USA, ESO,
APEX	12m	Chajnantor	5000 m	Chile	Sweden, Germany, ESO
ASTE	10 m	Pampa la Bola	4800 m	Chile	Japan
LLAMA	12m	Chorillos	4800 m	Argentina	Argentina+ Brazil
LMT	50 m	Sierra Nevada	4600 m	Mexico	Mexico, USA
NANTEN 2	4m	Chajnantor	4865 m	Chile	Japan, Korea

The only single dish able to observe the Sun

A double sad story

- The transportation of the antenna from the harbour (Zarate) to the peak occurred in 2019 During the transportation, there was an accident with one truck, and an important piece (the Yoke structure)

- Another one was constructed by VERTEX, and paid by the insurance company

- Since then the antenna is kept In containers on the site, waiting to be mounted. A concrete base has to be constructed to mount it.

Evaluation of the LLAMA Project by an external team of high level scientists

- It was a decision of Mincyt to have this evaluation The members of the panel were Matias Zaldarriag (Princeton, Usa), Gabriela Gonzalez (Lico Collaboration, USA) Hugo Loffler (INVAP, Argentina), Lars Nymam (APEX, Chile), Rodrigo Reeves (Universidad de Concepción Chile). Thijs de Graauw (ALMA former director). They started working during the first semester of 2020

- Final document in August 2020

Recommendations of the external scientist team

- LLAMA presents a unique opportunity for the astronomical community of Argentina and Brazil. The $20M project involves a single-dish radio observatory in Salta, with the potential to make important contributions to astronomy and astrophysics, as well as enabling the associated technology development. **The scientific case was very strong when approved in 2014, and is still just as strong**

- **The project is not currently organized nor has the necessary detailed plans to guarantee a successful completion of the first light phase or to estimate a realistic budget.**

Mincyt then decided to have a contract with the public-private company INVAP high technological level, high management level, to take responsibility of LLAMA until first light is reached.

Science

- In principle, it is a multi-purpose radiotelescope, not a dedicated one.

However, a number of applications brings up to the top level in world competitivity:

1)- VLBI applications Extended ALMA, EHT, even Millimetron

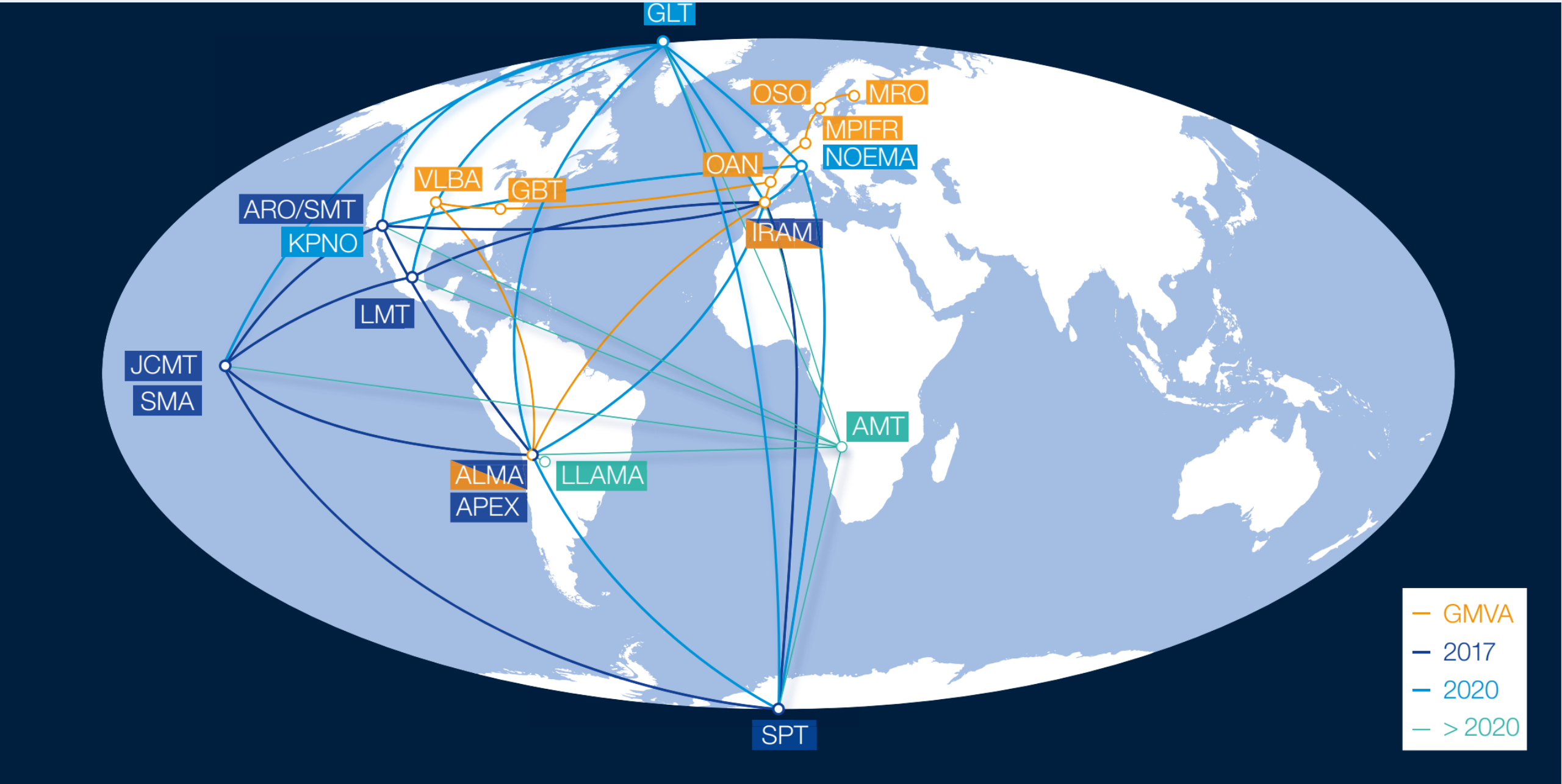
Related science : black holes, jets, quasars

2)-Astrochemistry- identification of new molecules, understanding the appearance of life, interstellar medium, star formation

3) Solar Physics – understanding the physics of solar activity, solar spots cycles, why the solar spots disappear at some epochs with important consequence for the climate on Earth

VLBI and EHT

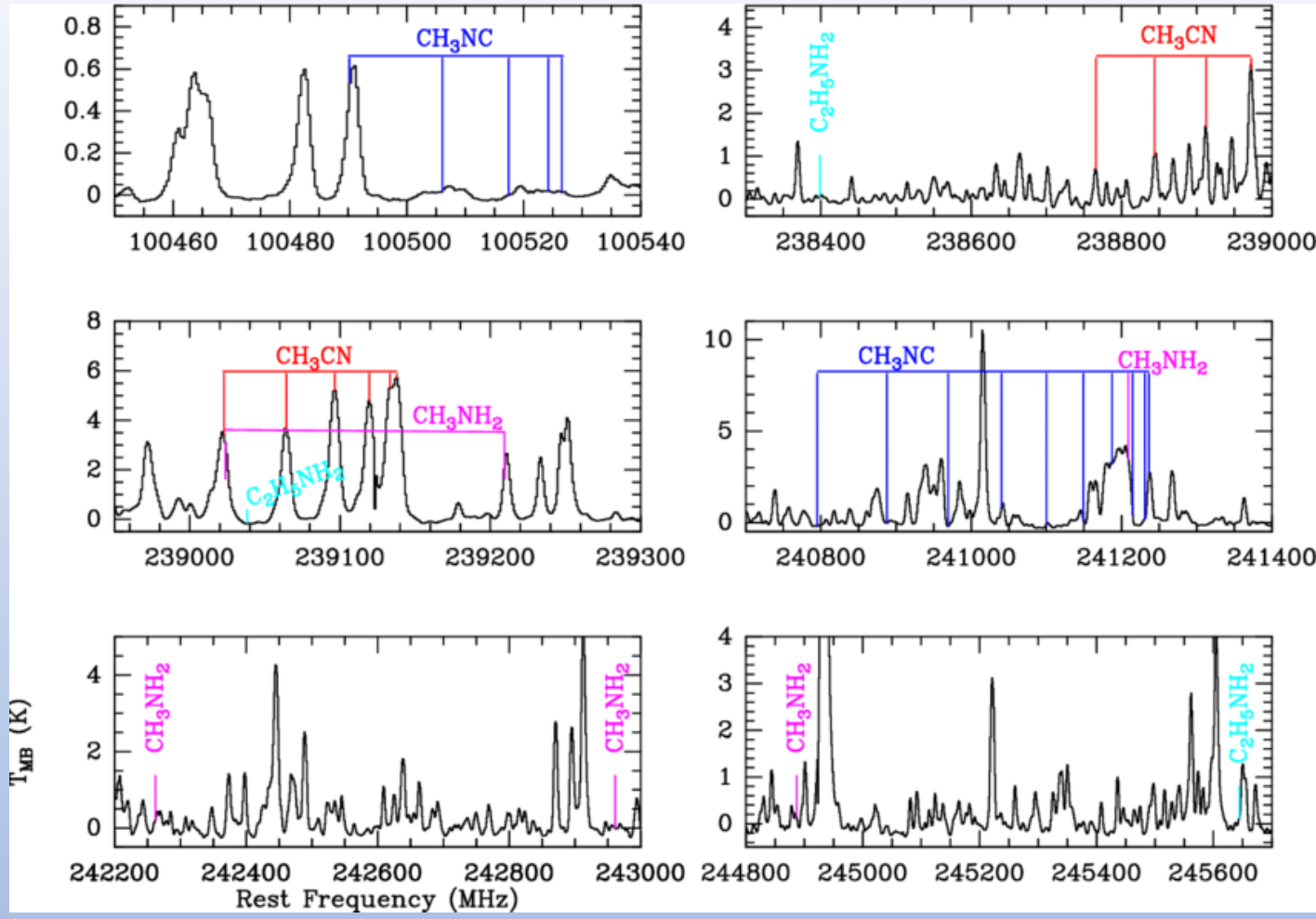
ALMA Extended Array is also a dream



In the Millimetron website, the LLAMA radiotelescope is not mentioned in the list of ground counterparts or VLBI partners. This is because stopped to believe that LLAMA will exist. However, we are coming back, and our contacts with Millimetron are possitive although other similar radiotelescopes are listed (example : the Greenland radiotelescope)

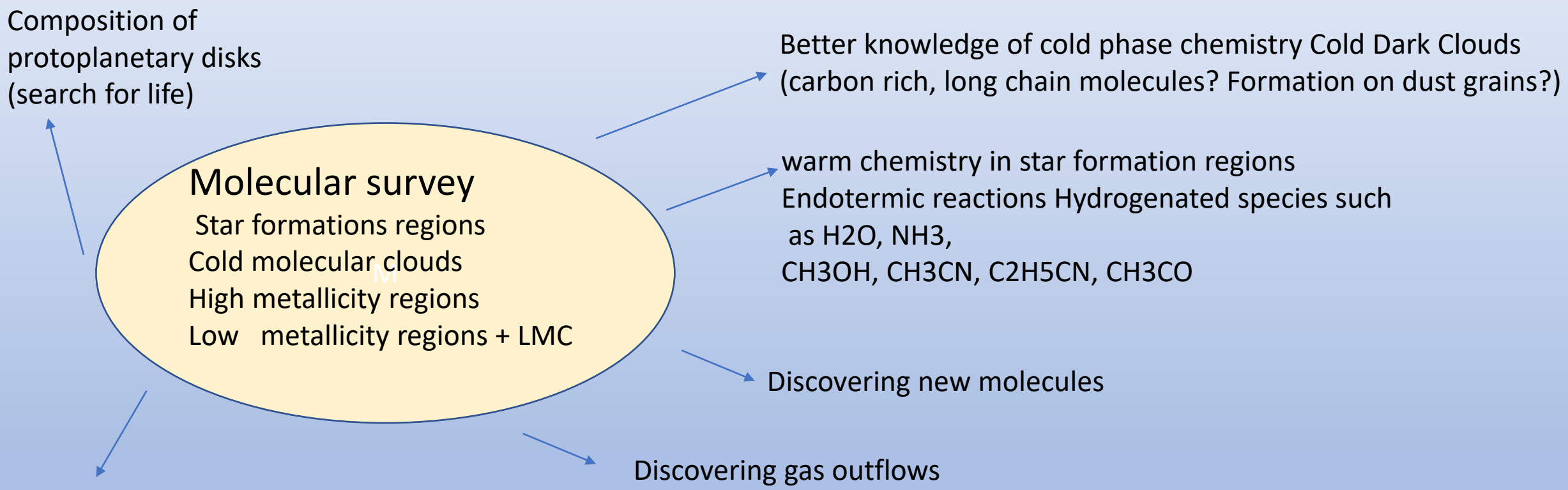
- Molecular complexity became more complex

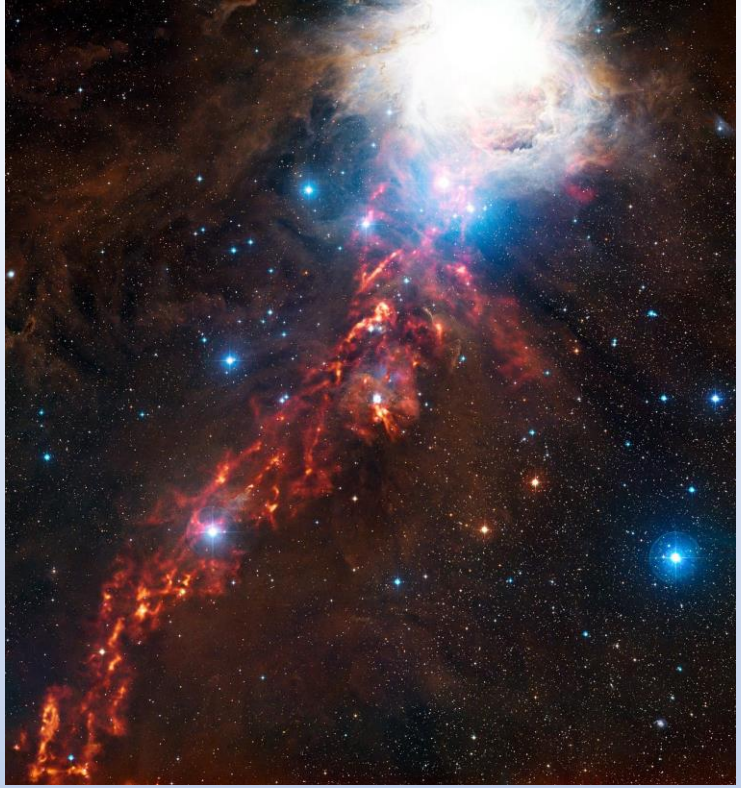
Portion of the W51/e2 spectra as observed at 1 and 3 mm with the IRAM 30 m telescope. Line assignmentd of CH 3 CN (red), CH 3 NC (blue), C 2 H 5 NH 2 (cyan), and CH 3 NH 2 (magenta) are indicated on top of the spectra. (= ALMA band 6)



How to identify an unkown line in your spectrum? 1) Find this same line in spectra coming from diferent places in the Galaxy. 2) correlate the intensity of the unknown line with that of a well identified line, in the group of observations 3) if the correlation iss good, the two molecules belong to a same "Family" 4) keep trying with other well known molecules

A wide molecular survey, covering all tipes of interstelar clouds, will bring broader understanding of astrochemical processes, gas dynamics, time-scales os chemical evolution, etc

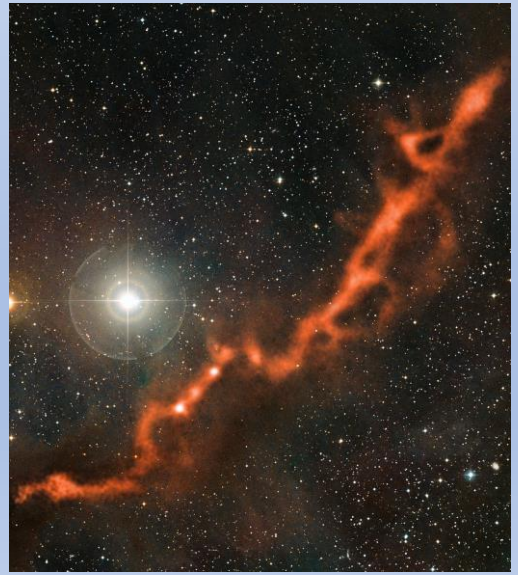




The submillimeter-wavelength glow arising from the cold dust clouds is seen in orange in this image and is overlaid on a view of the region taken in the more familiar visible light.

Above: Orion Nebula

Right botom: Taurus Molecular claoud



• Exoplanets and Search for life

- With the KEPLER mission, specially K2, which became operational in 2014, a large number of exoplanets were discovered, one came to the conclusion that there **are at least one planet per star**, that is, a huge amount. This encourages NASA to go on with its program “Search for life”. We could investigate the composition of protoplanetary disks, by means of the molecular content of the interstellar matter were the star was born.
- Weakly related to this, it woud be inertesting to have a better knowlege of the content and distribution of H_2O and H_2 in the Galaxy.

H_2 is not detectable at sub-mm, since it has no dipole moment, but can be obtained ...indirectly.

Solar observations

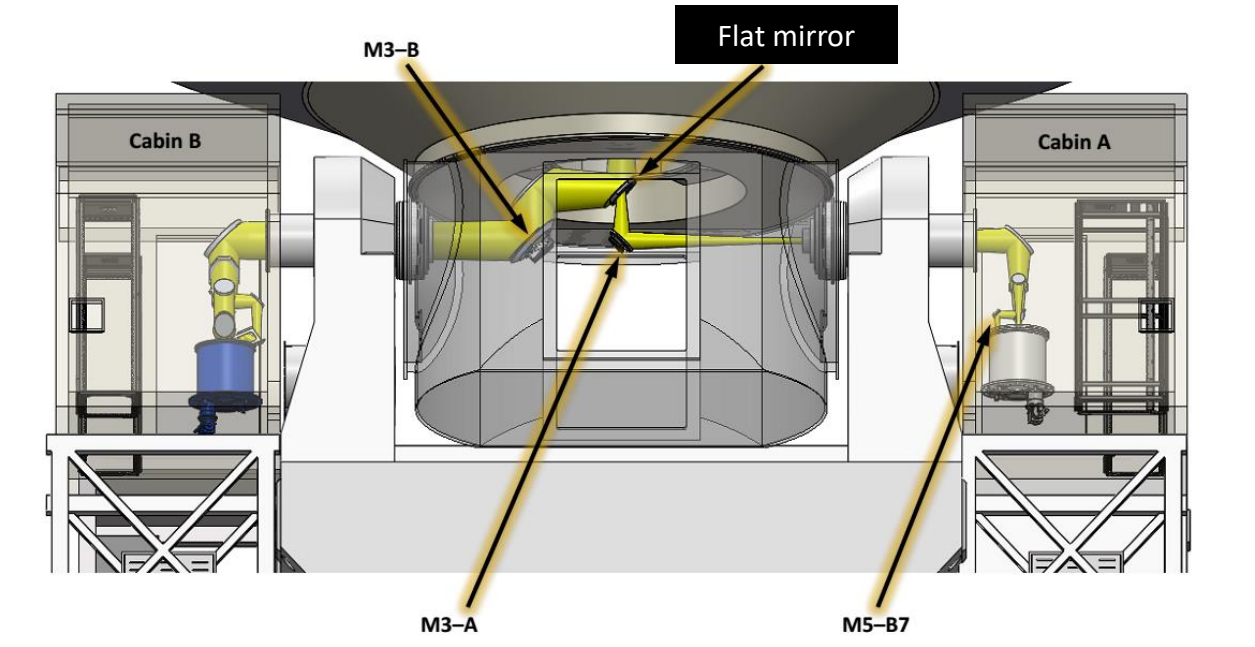
The antenna is specially designed to be able to point towards the Sun, because the visible and infrared energy will be scattered by the de-polished surface of the dish and will not concentrate on the secondary reflector, which would damage it. This surface treatment in not usual in mm radio telescopes. Furthermore, in a latter stage, a dichroic mirror will be installed in the optical system, which will permit to observe with two receivers simultaneously (one in each Nasmyth cabin). This will allow to determine phase differences of Solar burst-like peaks at different frequencies and spectral hardnessof the particle´acceleration. Mapping the full disk in total power is extremely valuable for the analysis of the chromosphere temperature structure (https://arxiv.org/abs/1812.07293) Fast mapping of active regions during transient emission will contribute to the comprehension of the energy transport at lower atmosphere levels.

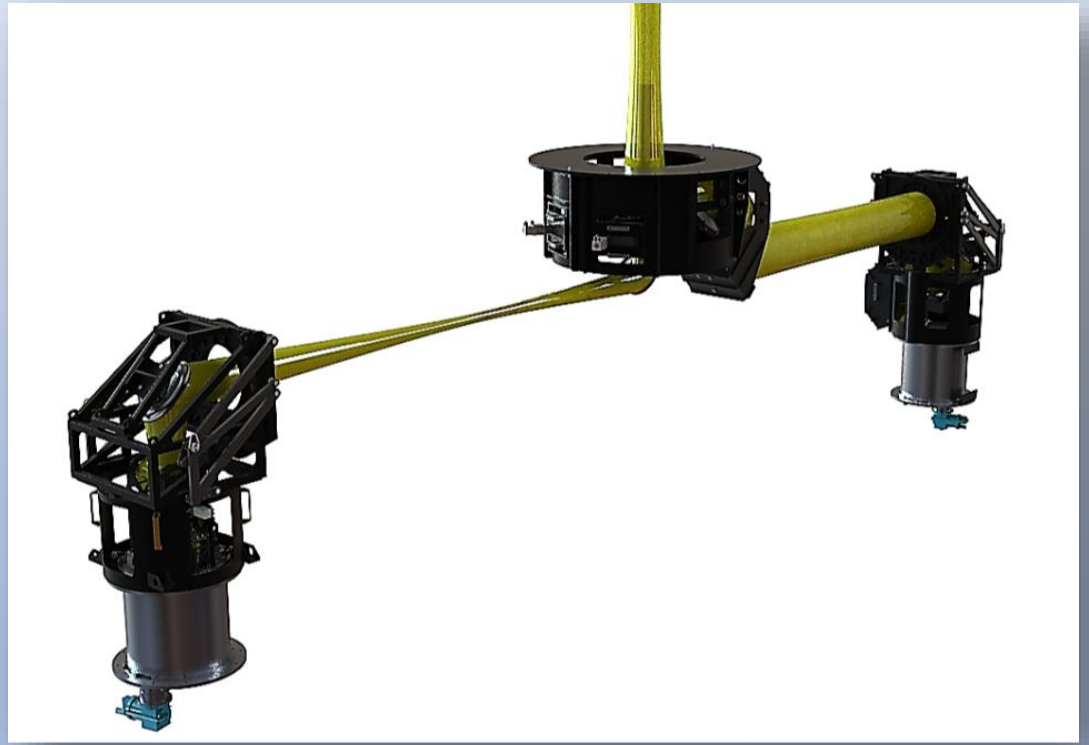
Technical aspects of the project, Brazilian responsibilities and Technological research

Subsystem

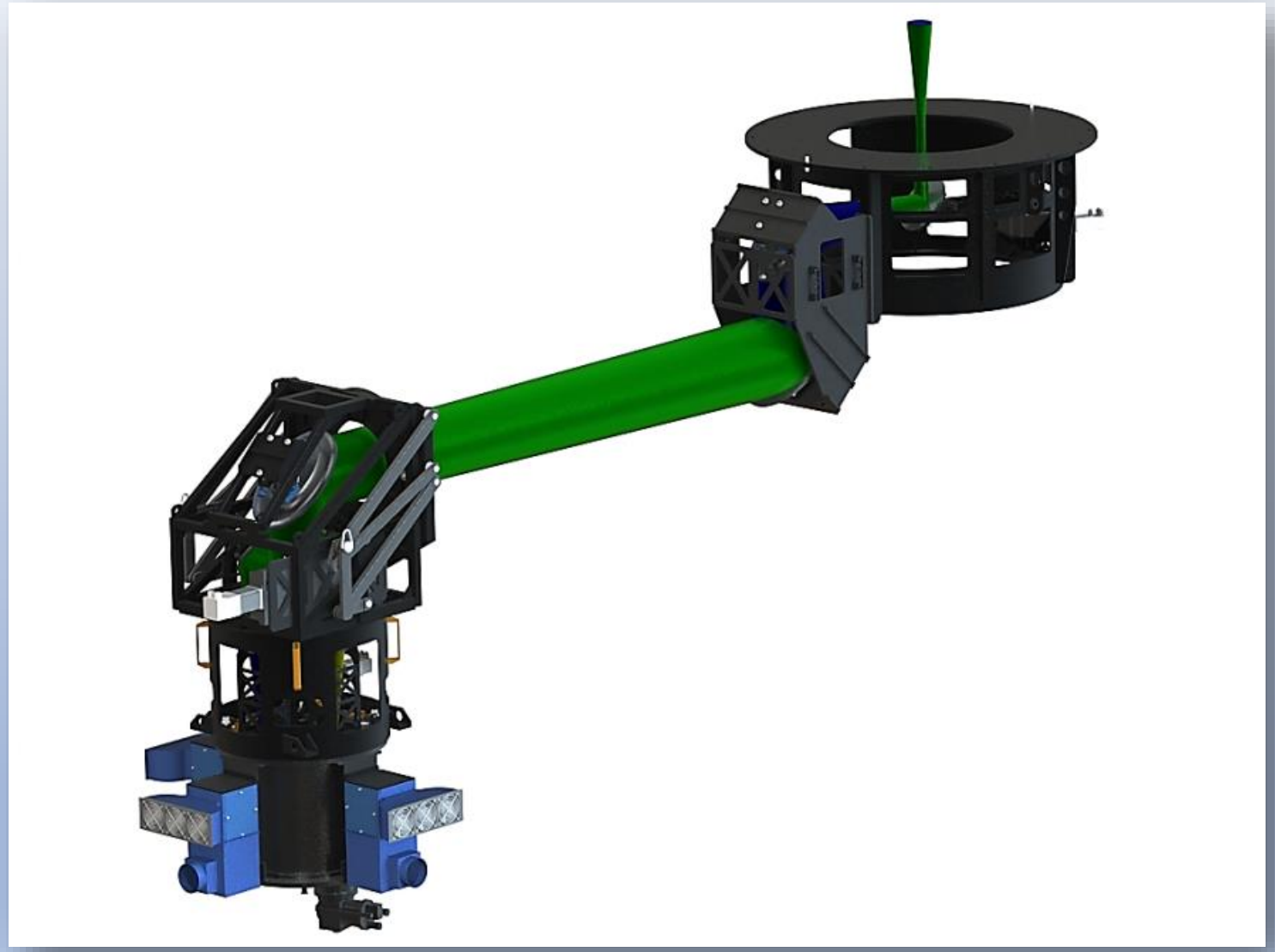
NACOS (NAsmyth Cabin Optical System)

Opto-electrical-mechanical solution to guide the light for different cabins and receptors.





NACOS development team: Jacob Kooi, Emiliano Rasztocky, Jacques Lépine, Carlos Fermino, Fernando Santoro, Danilo Zanella, ALFA Ferramentaria.



Considering that we have two receptors (and one cryostat with three spots), it was decided to populate only Cabin B for the start of operations.

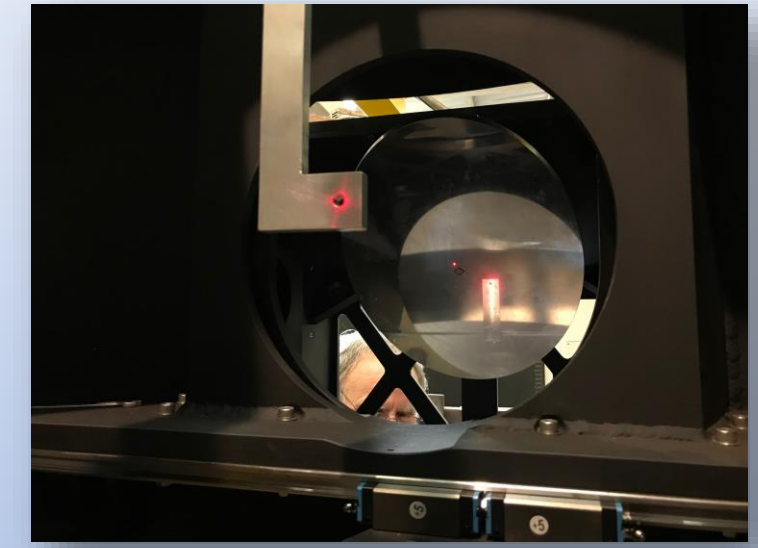
Machining, integration and alignment of NACOS at ALFA Ferramentaria (Araraquara, SP).

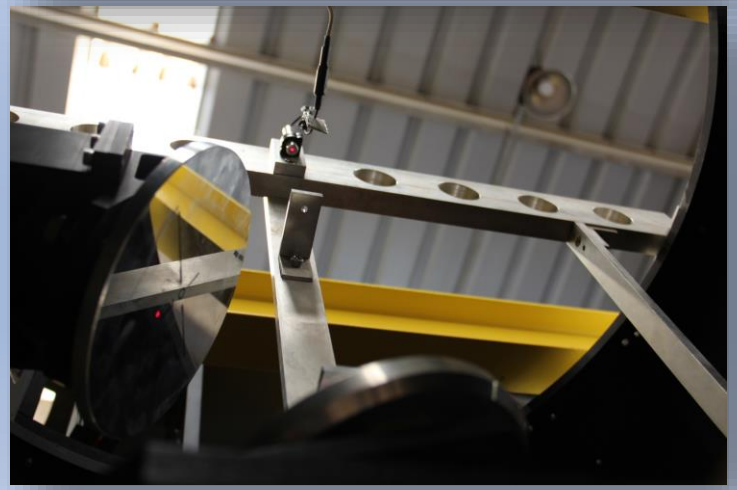
CASS

NASS

Handling/installation carts were designed and machined.

Start of the optical alignment work.





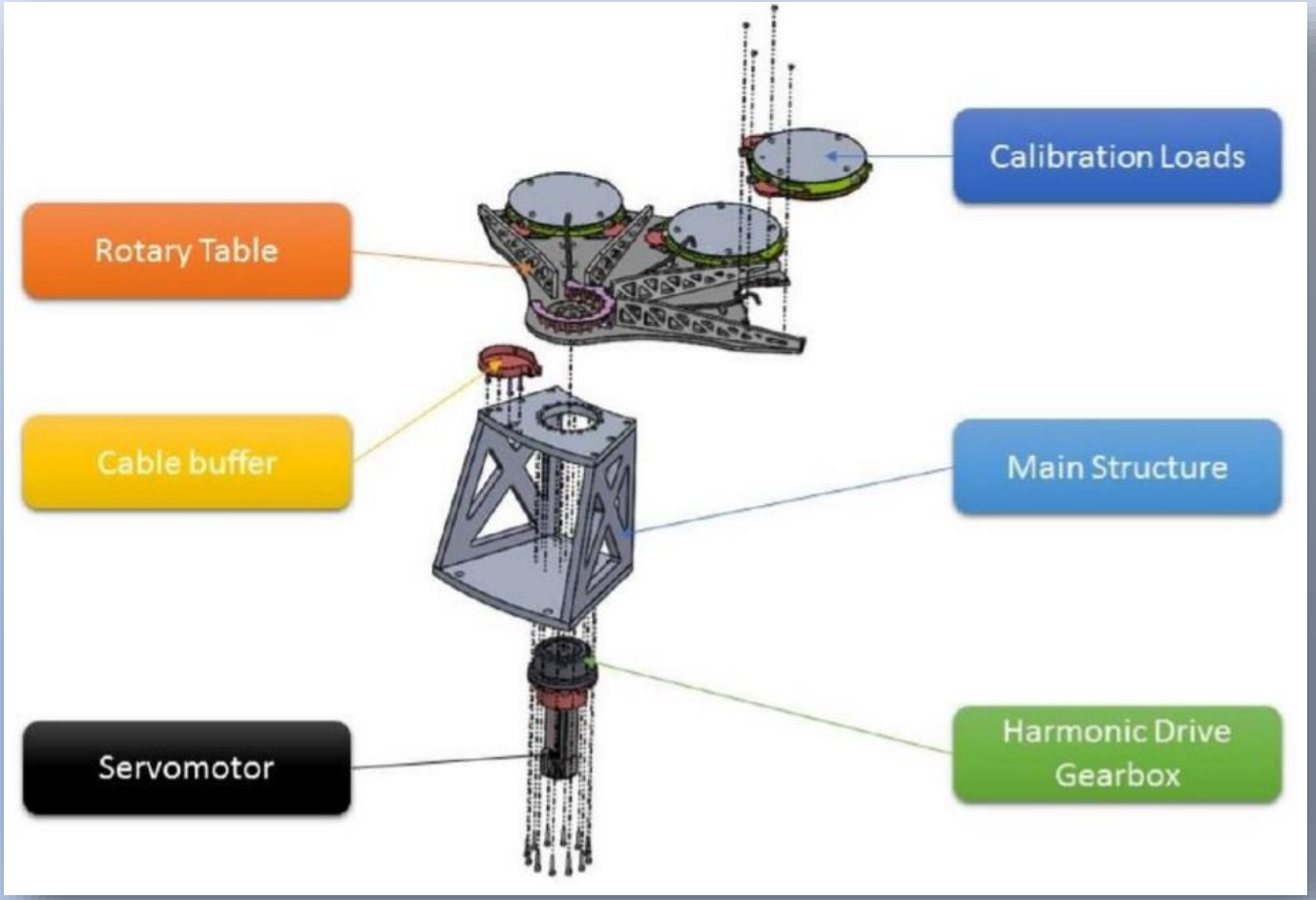

The Alfa engenharia team in Araraquara
QD-01

Subsystem

Calibration loads

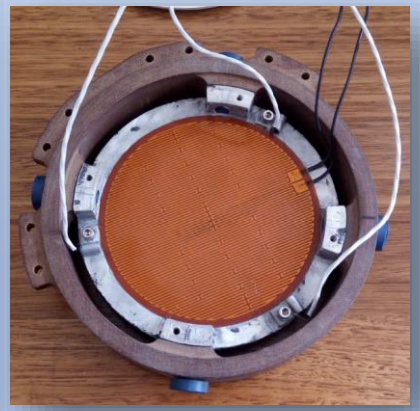
Development team: R. Reeves et al.

Universidad de Concepción

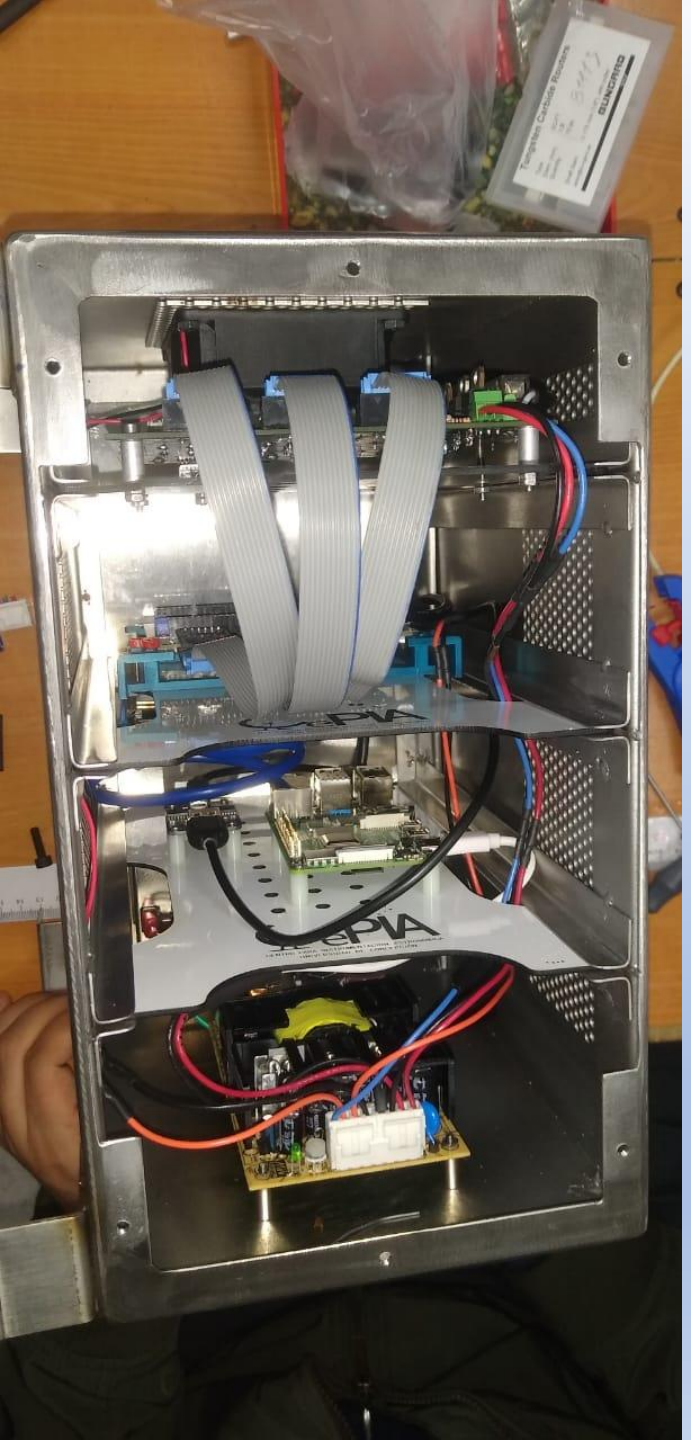


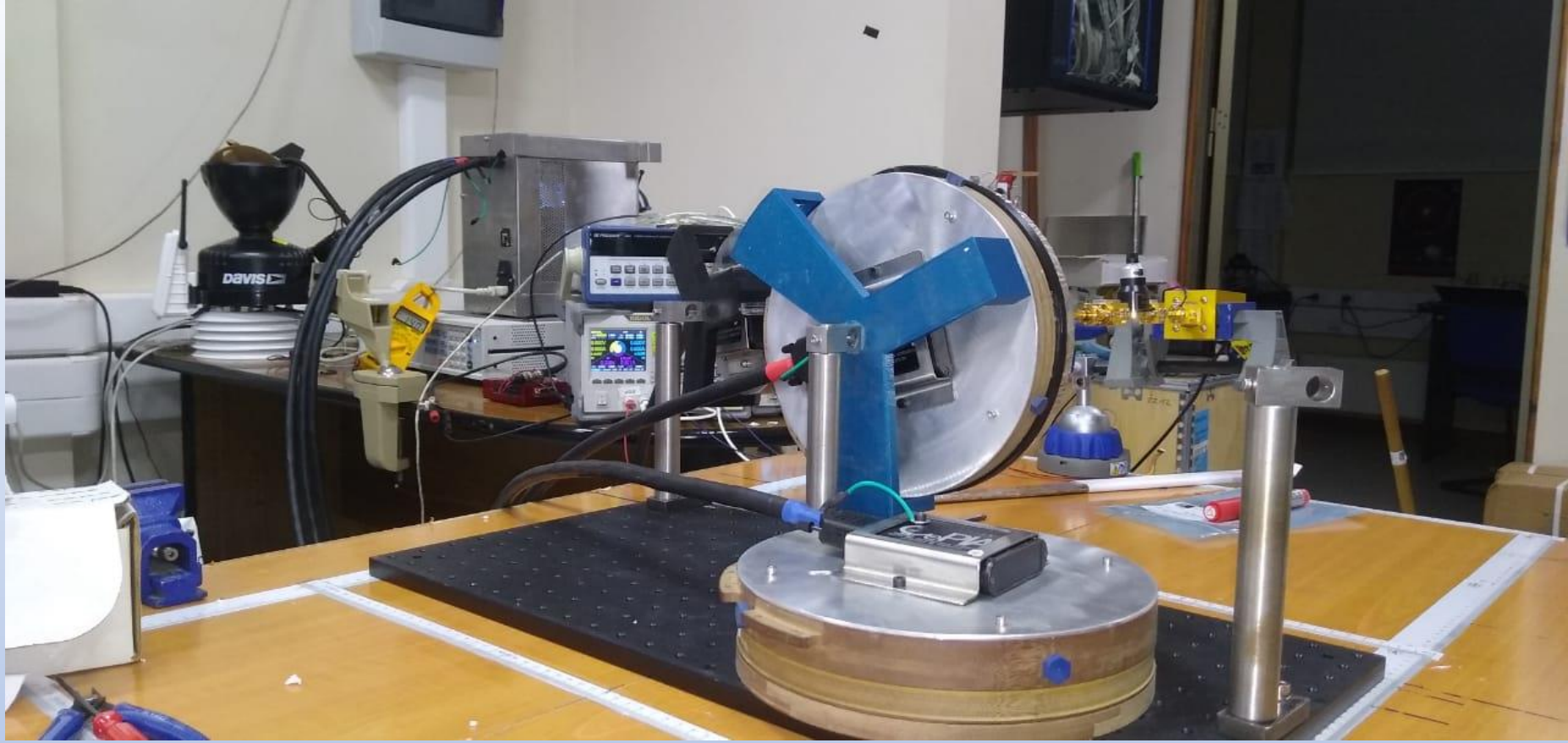
Three calibration loads:

- Two hot (>150 GHz higher temp.; > 38 GHz lower temp.);
- One at ambient temperature.



Development of electronic and software to control the temperature

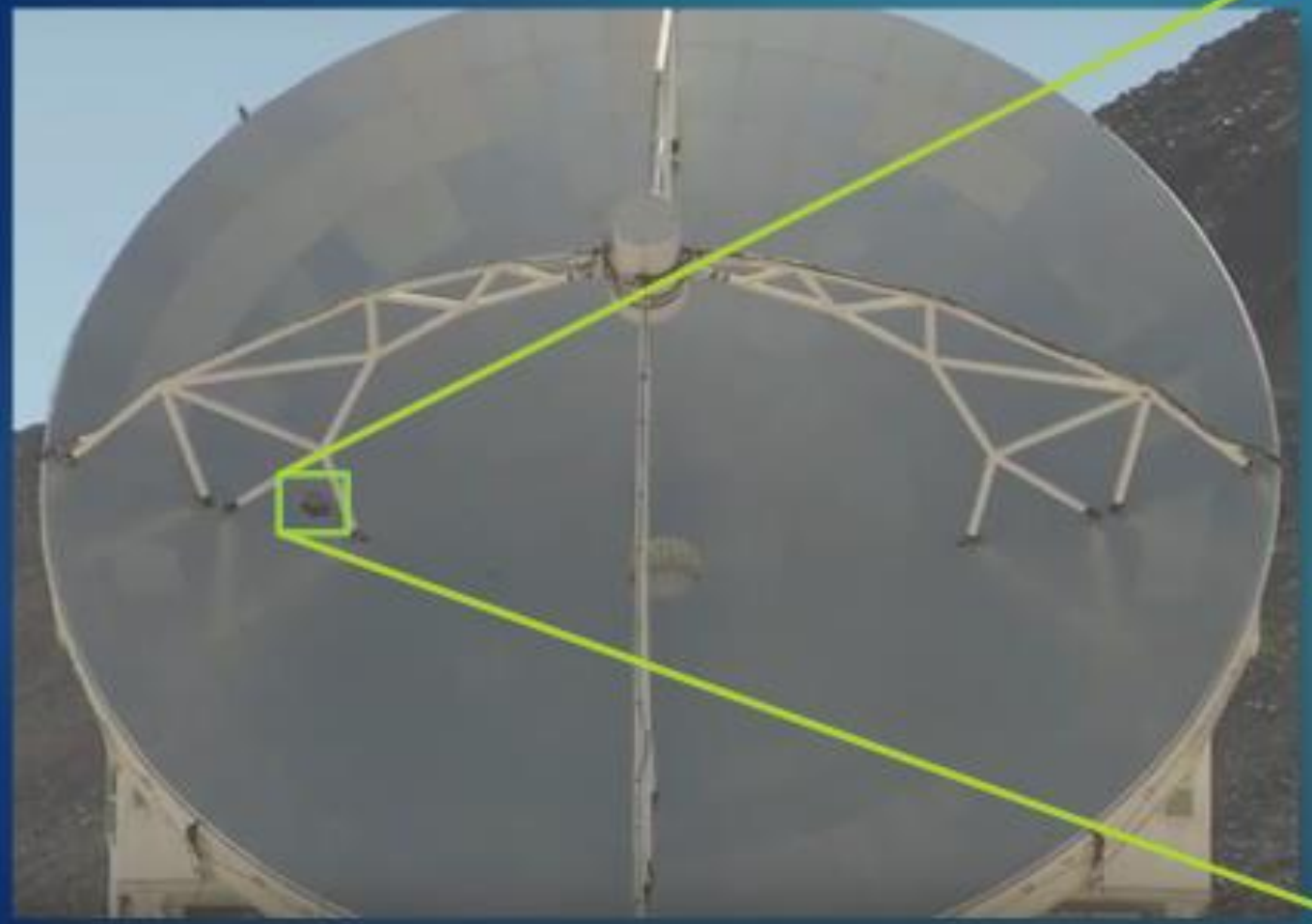


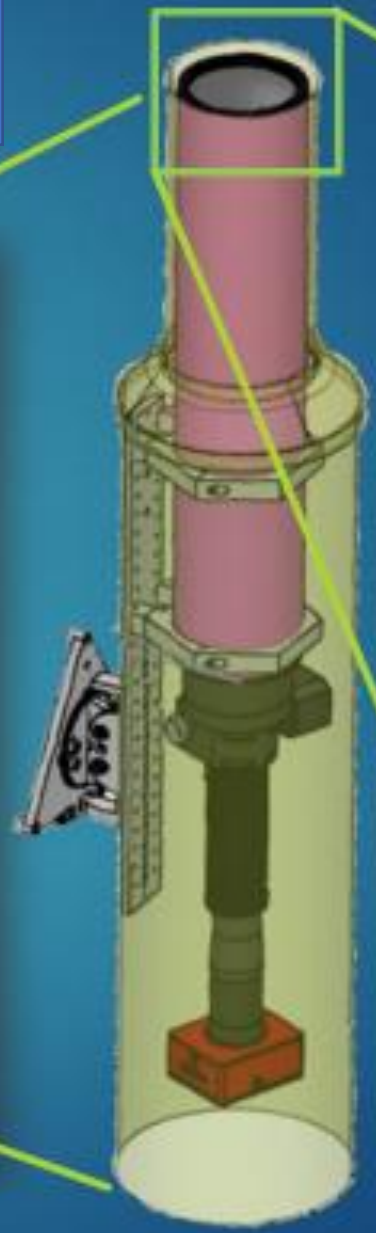


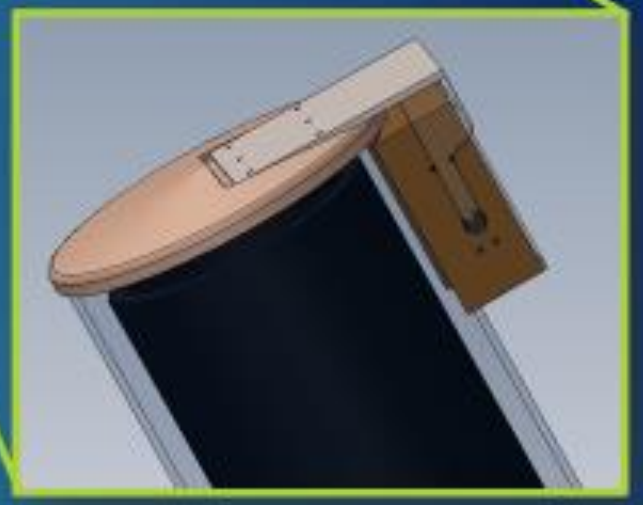
The temperature control system of Calibration Loads

Rodrigo Reeves, Concepción, Chile

Optical telescope used to initially set precisely the constantsof the tracking program, by observing visible standard stars







Optical telescope team: Tânia Dominici, Danilo Zanela, Sjoerd Timmer, Jacques Lepine, Zulema Abraham, Pedro Beaklini

Subsystem

Holography

Technique for measuring and improving antenna surface quality.

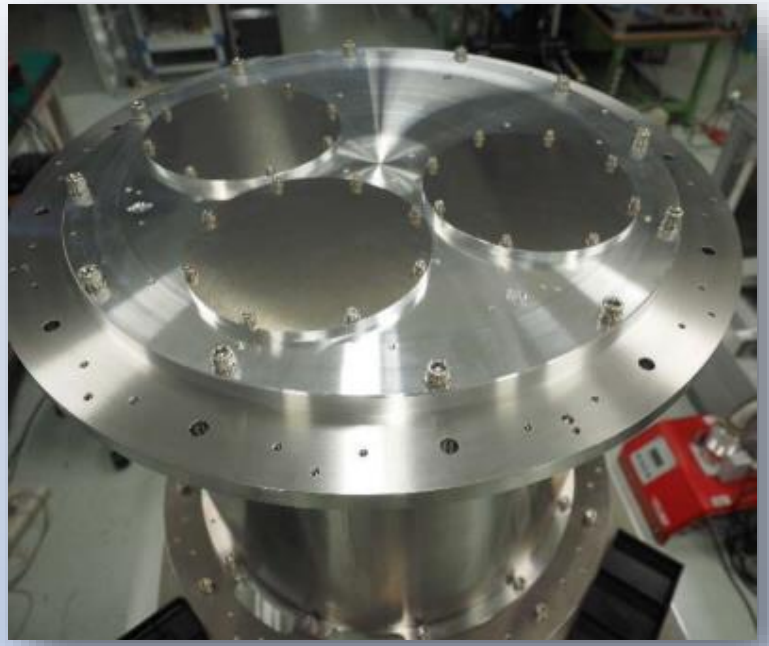
→ See talks by Fatima Correra and Pedro Beaklini.

Baars et al. (2007)

Holography team: Fatima Correra, Sandro Verri, Marcos Luqueze, Wesley Beccaro, Jacques Lépine, Zulema Abraham, Pedro P.B. Beaklini, Daniele Ronsó, Danilo Zanella, Luiz Reitano, Tânia Dominici.

Band 5, (OSO; NOVA)

Band 9 (NOVA)



Cryostat (NAOJ; NOVA)

Front-End

Integration

Receivers: extraodinary help from NOVA (Groningen)

IF Processor (IAR; NOVA)

Spectometer

Backend

Subsystem

Software

Last but not least

"The alma of LLAMA" -> see the contribution by Danilo Zanella.

- **Team (October 2019): Guillermo G. de Castro, Cesar Strauss, Sjoerd Themba Timmer & Danilo Zanella.**

- **Development based on ALMA Common Software (ACS).**

Examples of tasks:

- **Control of antenna position, pointing and tracking;**
- **Reading of sensors;**
- **Adjustment of receiver parameters;**
- **Setting position of mirrors (NACOS) and calibration loads (robotic arms);**
- **Data acquisition;**
- **Archiving.**

Perspectives

- With the arrival of INVAP company to take care of the construction of the antenna and of the radio observatory site construction, we are in a new era, in which the time schedules start to make sense, We believe that indeed, we will have a fist light in 2023,

- We are working at full steam, in Brasil too, to make this happen

- The help that we are getting from NOVA, Gronigen is extraordinary, concerning the receivers band 5, band 9, and now band 6
  We are very grateful to Nova

- A collaboration with Ricardo Finger and Universidad de Chile has been renewed, and will bring a receiver for band 2+3. It is just beginning

- We plan to have more outreach activity and involvement of young people in near future