Atacama Large Millimeter/submillimeter Array (ALMA)

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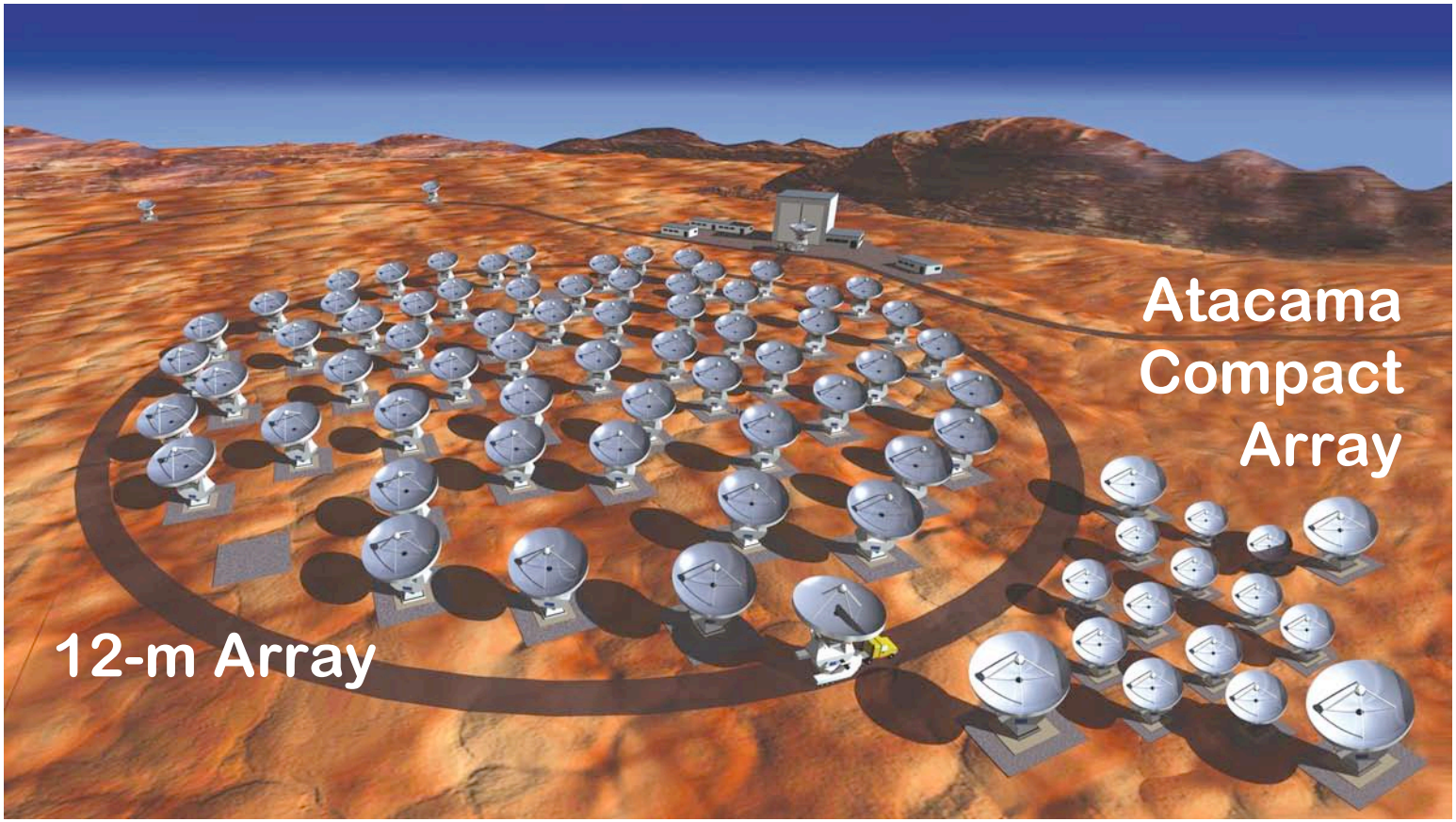
What is ALMA?

Atacama Large Millimeter/submillimeter Array

- **An aperture synthesis radio telescope that consists of**
  - **an array of up to 64 (min 50) 12-m dishes and**
  - **a compact array of 12 7-m dishes + 4 12-m dishes**



What is ALMA?

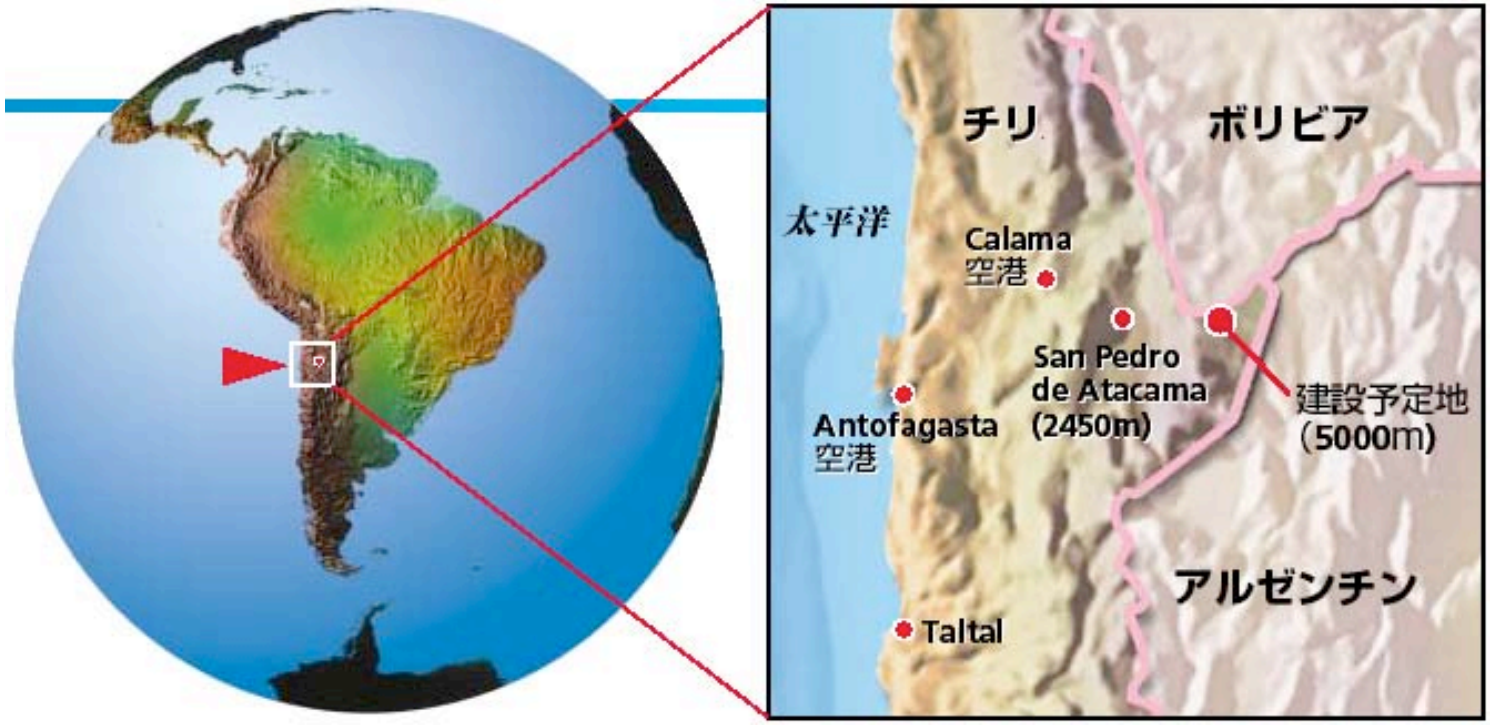
Atacama Large Millimeter/submillimeter Array

- **Observes millimeter and submillimeter waves (31 GHz to 950 GHz)**
- **Excellent sensitivity and imaging capability**
- **The highest spatial resolution of < 0.01” with maximum baseline of 18 km**
- **High fidelity imaging with heterogeneous array (12-m and 7-m antennas)**

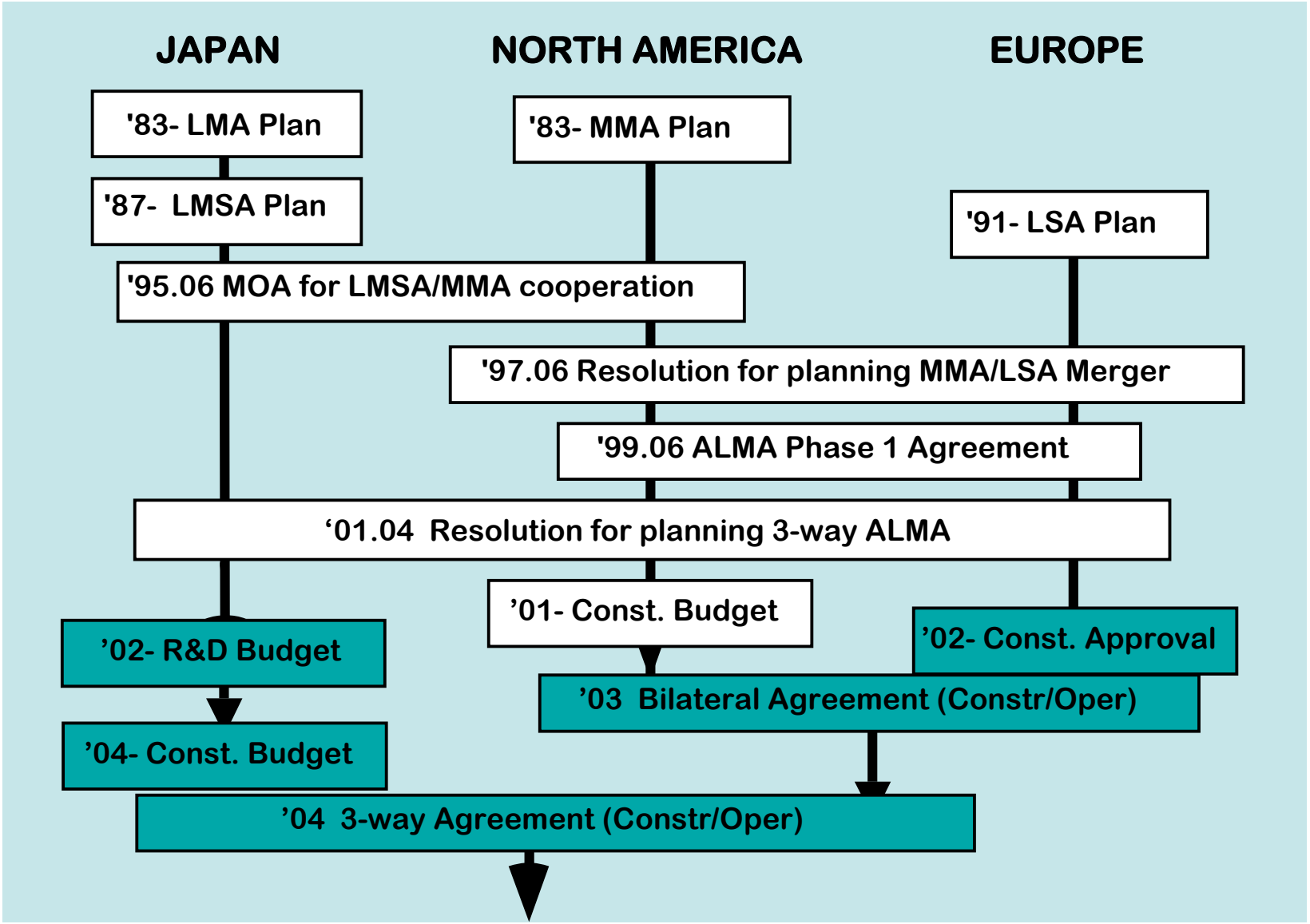
What is ALMA?

Atacama Large Millimeter/submillimeter Array

- **Constructed at the high altitude (5000 m) site in Chilean Andes**
- **International collaboration between North America, Europe, Japan (+Taiwan), and Chile**

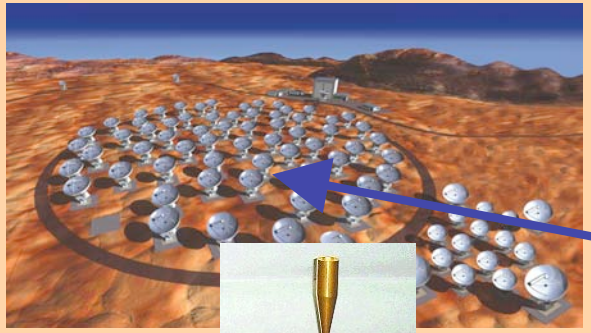


Three roots of ALMA



The ALMA System

Antenna
64-element array (64 12-m dishes)
ACA system (12 7-m + 4 12-m dishes)

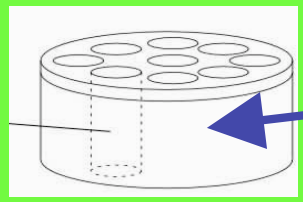


副反射鏡

主反射鏡

Receiver Front End

4K Cryostat



Cartridge

Receiver Cabin

Correlator

Correlation
Spectroscopy

Receiver Back End
LO creation/distribution
IF conversion
Digital sampling
Signal transmission

Receiver Bands

Band	Frequency (GHz)	Development/Production
1	31.3 - 45	
2	67 - 90	
3	84 - 116	NA (HIA, Canada)
4	125 - 163	Japan (NAOJ, Osaka Pref.U.)
5	163 - 211	
6	211 - 275	NA (NRAO, USA)
7	275 - 370	EU (IRAM, France)
8	385 - 500	Japan (NAOJ, PMO)
9	602 - 720	EU (SRON, Netherlands)
10	787 - 950	Japan (NAOJ, NICT, ASIAA)

International task division

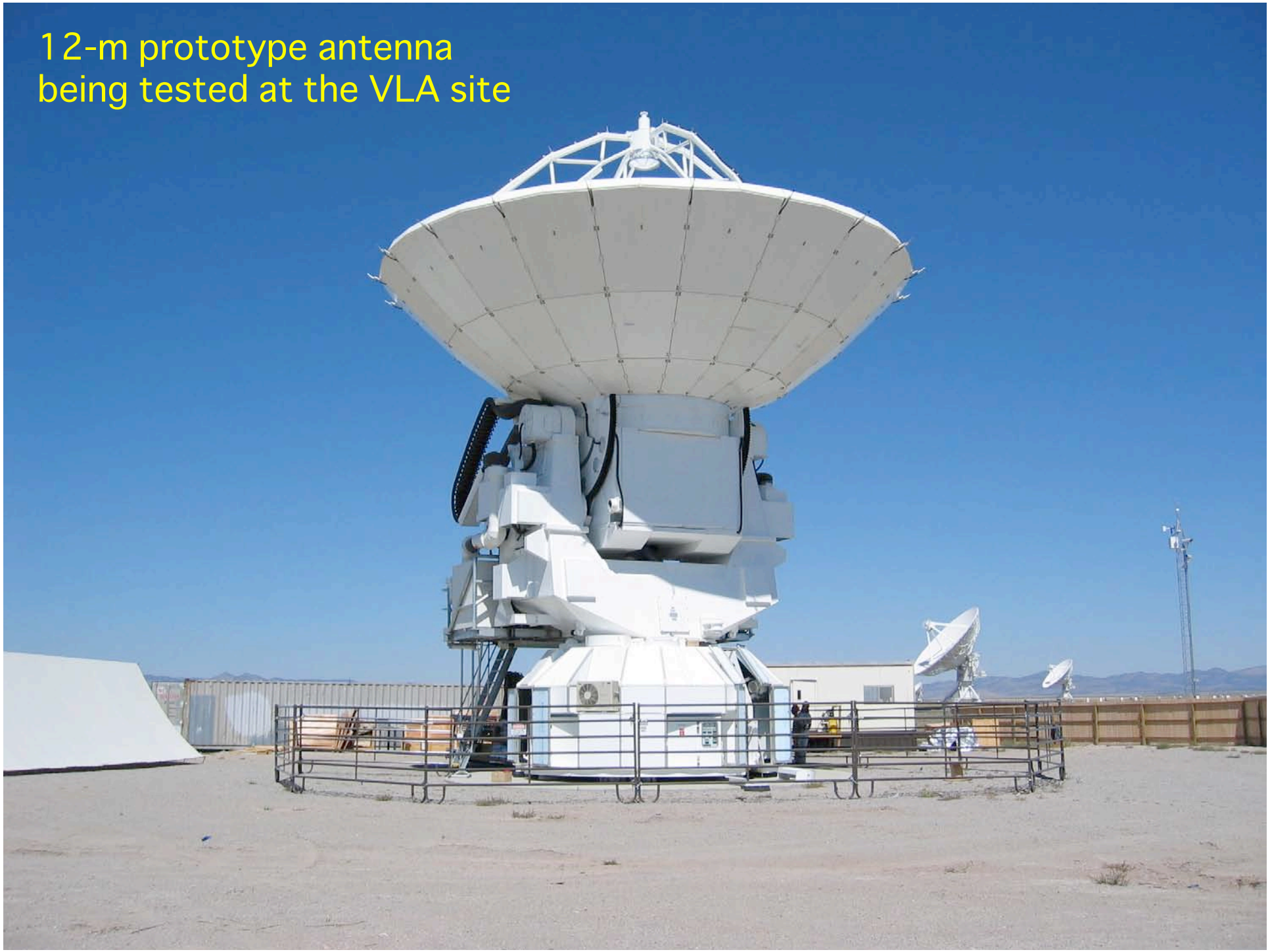
	Europe and North America	Japan (+ Taiwan)	Enhancements
Antennas	64 12-m dishes (50 for the time being)	ACA 12 7-m dishes 4 12-m dishes	High fidelity imaging of extended sources
Receiver bands	Band 3, 6, 7, 9	Band 4, 8, 10	Submillimeter up to 950 GHz
Correlators	Baseline correlator	ACA correlator	Low loss 3-bit correlation

Developments in Japan

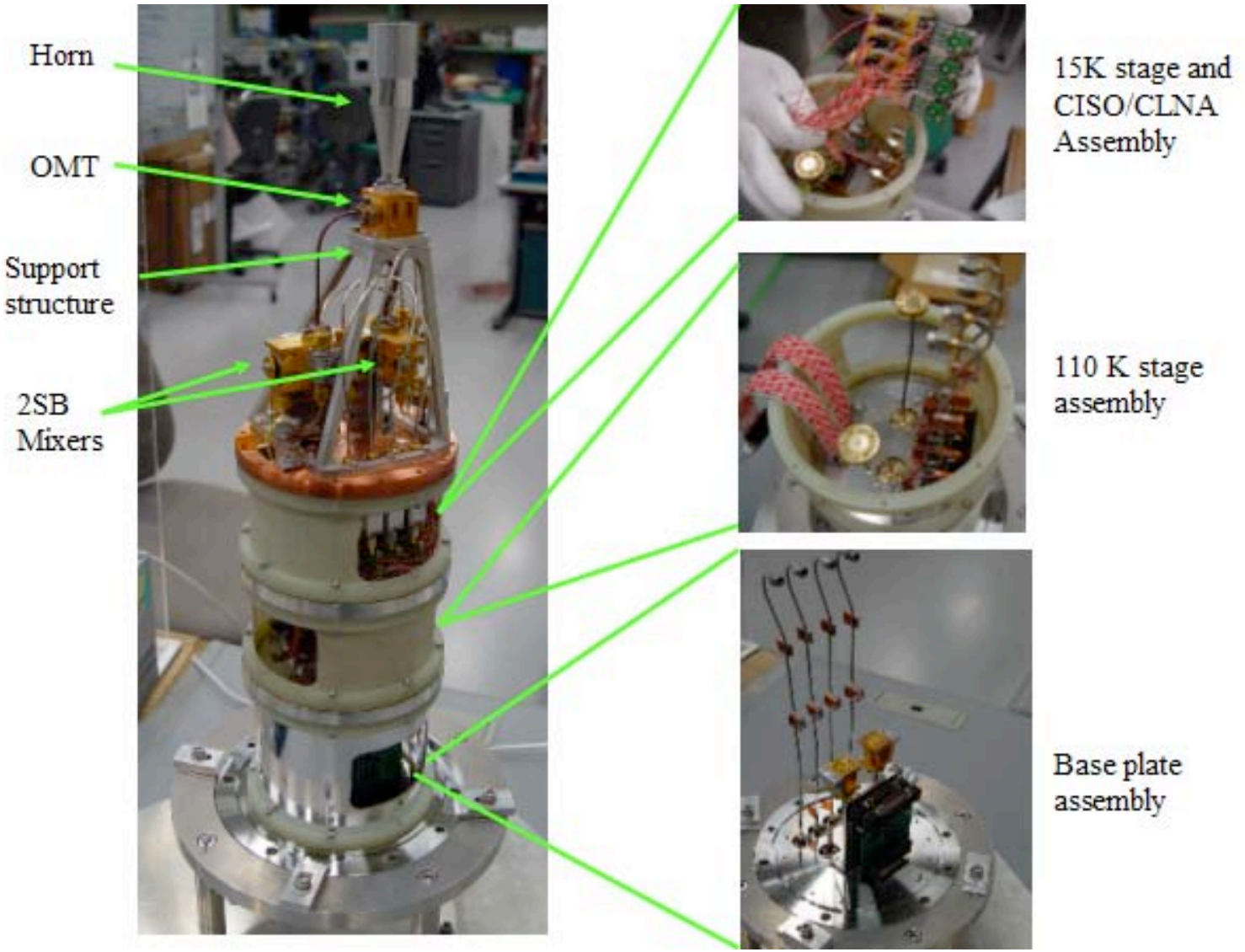
- **Antennas**
  - **A prototype 12-m antenna built and tested in Socorro, USA (2003-2004)**
  - **ACA 12-m antennas being built in Japan**
  - **ACA 7-m antenna production to be contracted**
- **Receivers**
  - **Band 4 and 8 receiver cartridges developed, production starting**
  - **Band 10 receiver being developed (SIS mixer development)**
  - **Photonic local oscillator**

Developments in Japan

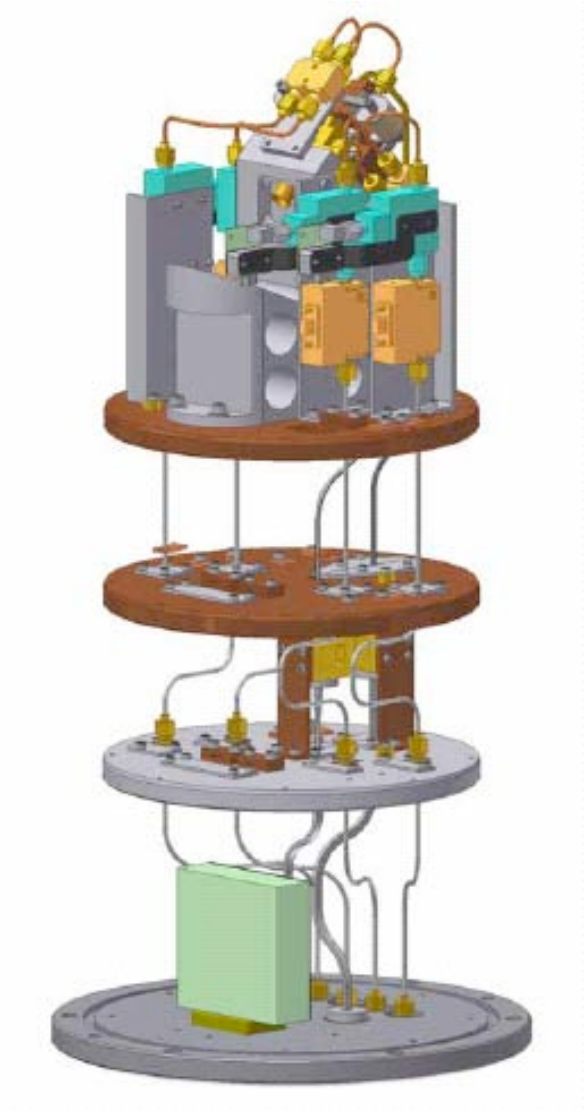
- **Correlator**
  - **A wide-band spectro-correlator with FX architecture**
- **Software**
  - **Participation in the international team of the ALMA software development**

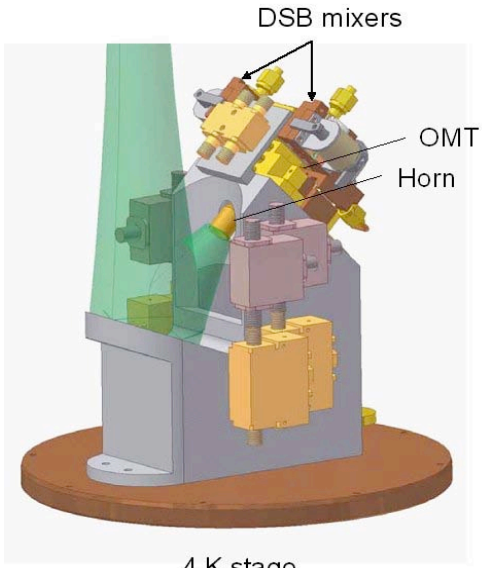

12-m prototype antenna
being tested at the VLA site

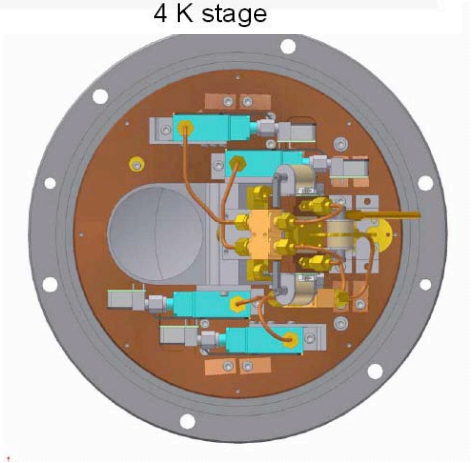
Assembled Band 4 Pre-Production Cartridge



Band 8 Pre-Production Cartridge Design







Band 10 Development

Band 10 LO development

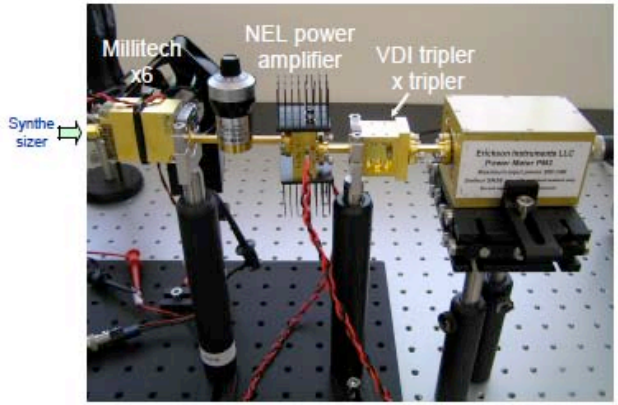


Fig. 1. A photograph of a fixed tuned LO source. A power meter is connected to the source via a WR-10 straight waveguide

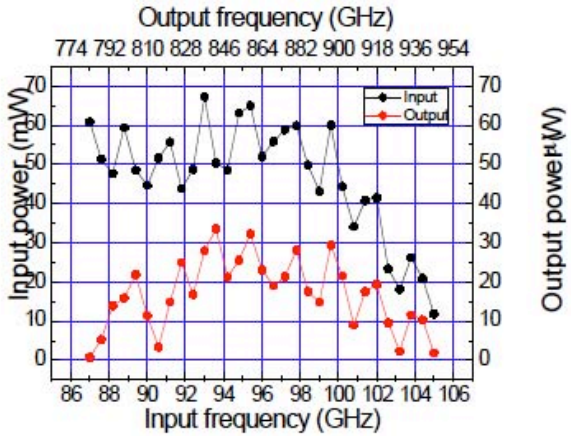
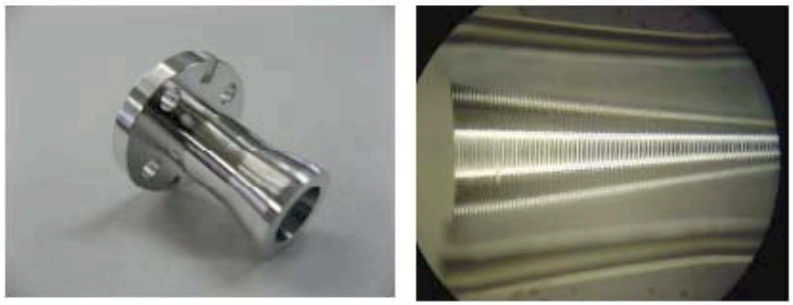


Fig. 2. Performance of the nonuoler (tripler x tripler) at room temperature. The input

Band 10 Corrugated Feedhorn



(a) (b)

Fig. 3. (a) A corrugated horn fabricated by machining. (b) Cross sectional view. The size of the corrugation is 54-μm width and 83-μm height.

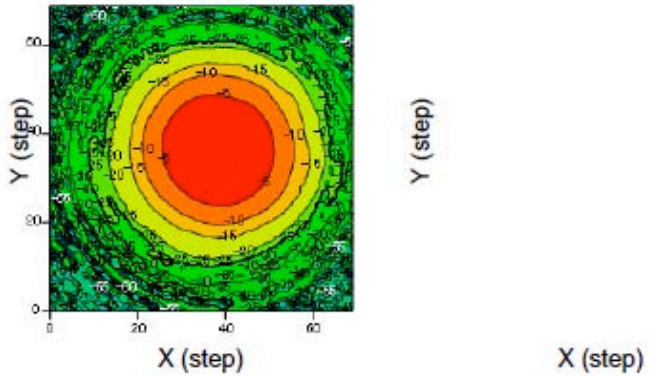
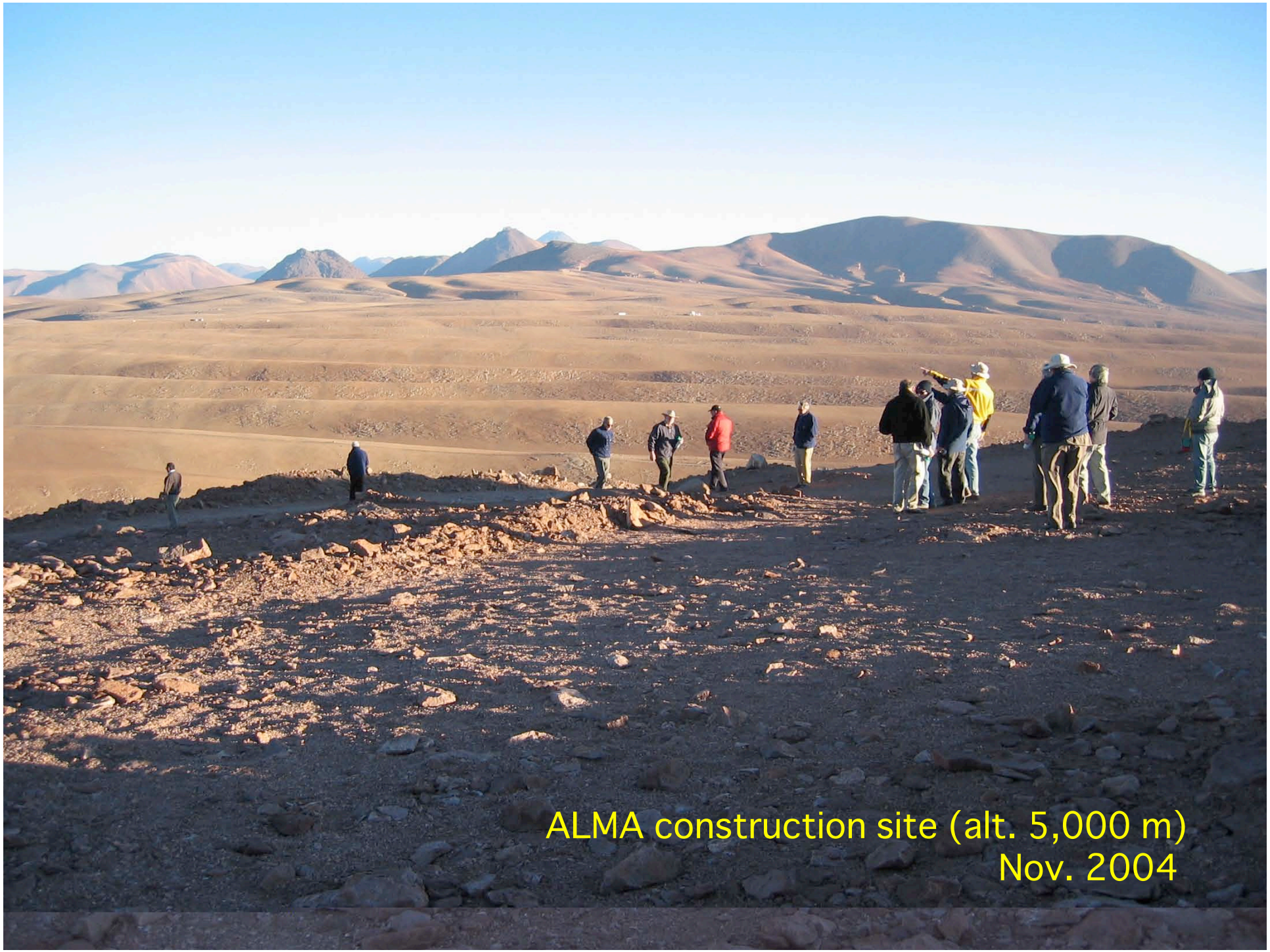


Fig. 4. Two dimensional amplitude (right) and phase (left) beam map of the corrugated horn. The amplitude contours are expressed in dB and the phase contours are shown in every 45 degree. The step size is 0.3 mm.

- ACA Correlator
  - Prototype testing finished
  - CDR on December 6 - 7
  - Delivery to AIV in 2008 April

Figure 6-1 Prototype Correlation and Integration (CIP) Card

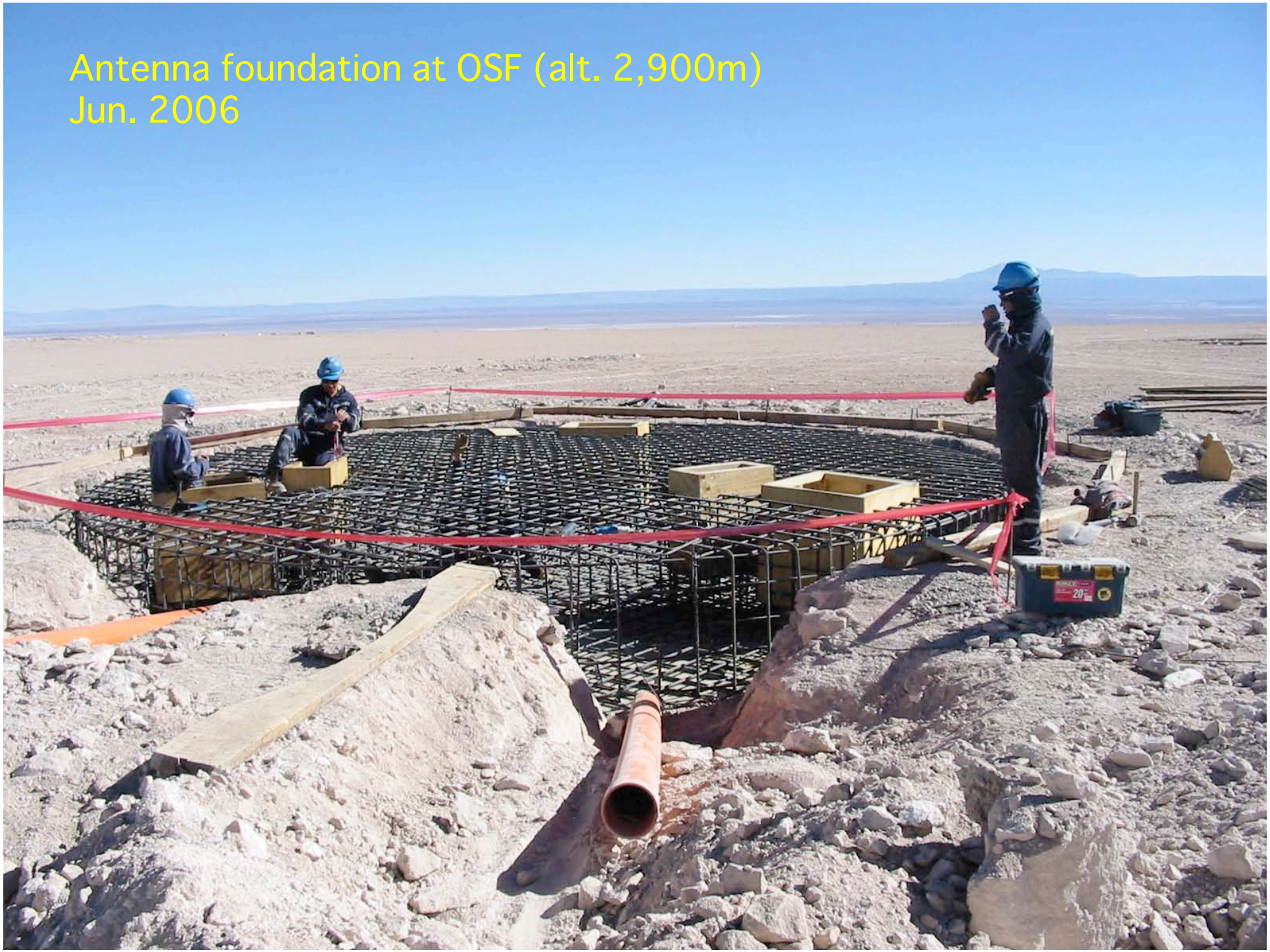

ALMA construction site (alt. 5,000 m)
Nov. 2004


O_2


Array Operation Site (alt. 5,000 m)
Jun. 2006


AOS Technical Building (alt. 5,000 m)
Jun. 2006


Operation Support Facility (alt. 2,900 m)
Nov. 2004


Antenna foundation at OSF (alt. 2,900m)
Jun. 2006

Operation of ALMA

- **ALMA is a single integrated instrument**
  - Researchers in Japan, Taiwan, North America, and Europe can enjoy all the capabilities
  - The share of observing time is proportional to the Value of contribution to the project
- **Dynamic scheduling**
  - Make the full use of the good condition for submillimeter observation
  - Observers will not go to the site
- **Pipeline processing**
  - User-friendly system: open to non-specialists
  - Data archive open to the world researchers

Science with ALMA

- **Compared with existing millimeter arrays:**
  - **Sensitivity** **100 times higher**
  - **Spatial resolution** **100 times higher**

  >>> **ALMA will reveal unknown faces of any object!**

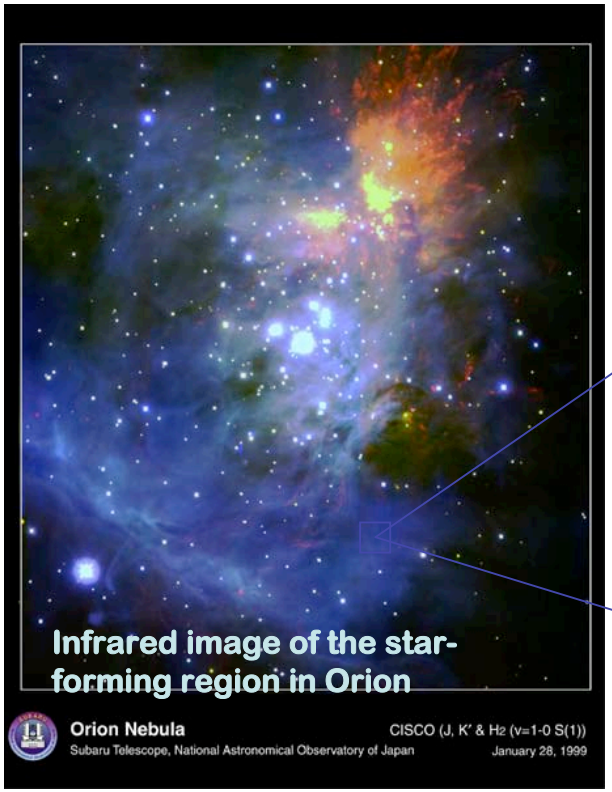
- **Submillimeter astronomy: A new window**
  - **Probe warm and dense interstellar medium (dust and molecular gas)**
  - **Spectral lines from important atoms/ions (C^0, redshifted C^+, redshifted N^+, etc.)**

Science with ALMA

- **Three Key Science Areas:**
  - **Protoplanetary disks:**
    Formation of Planetary Systems
  - **Protogalaxies:**
    Formation of Galaxies
  - **Interstellar chemistry:**
    Origin of life in space

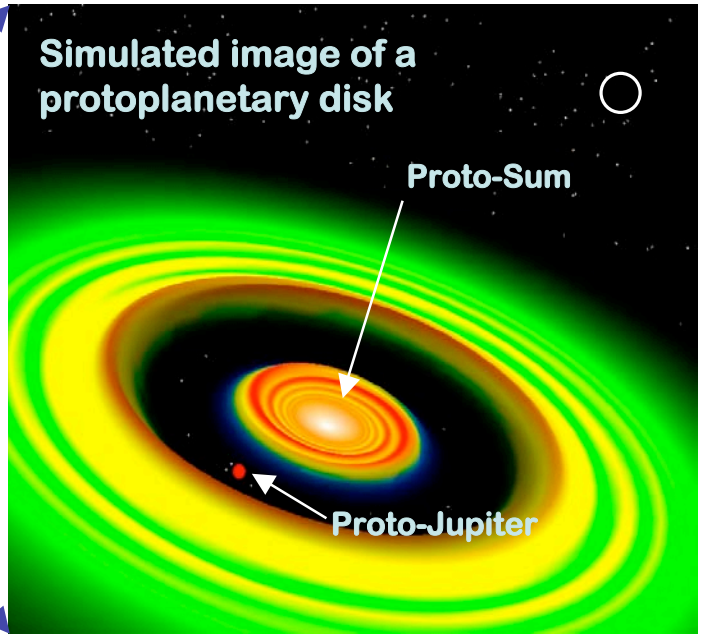
Formation of planetary systems

- Reveal the internal structure of disks forming planets with the highest spatial resolution (0.01”).
- Study the origin of the diversity in planetary systems from a large sample of protoplanetary disks.



Subaru, HST

ALMA

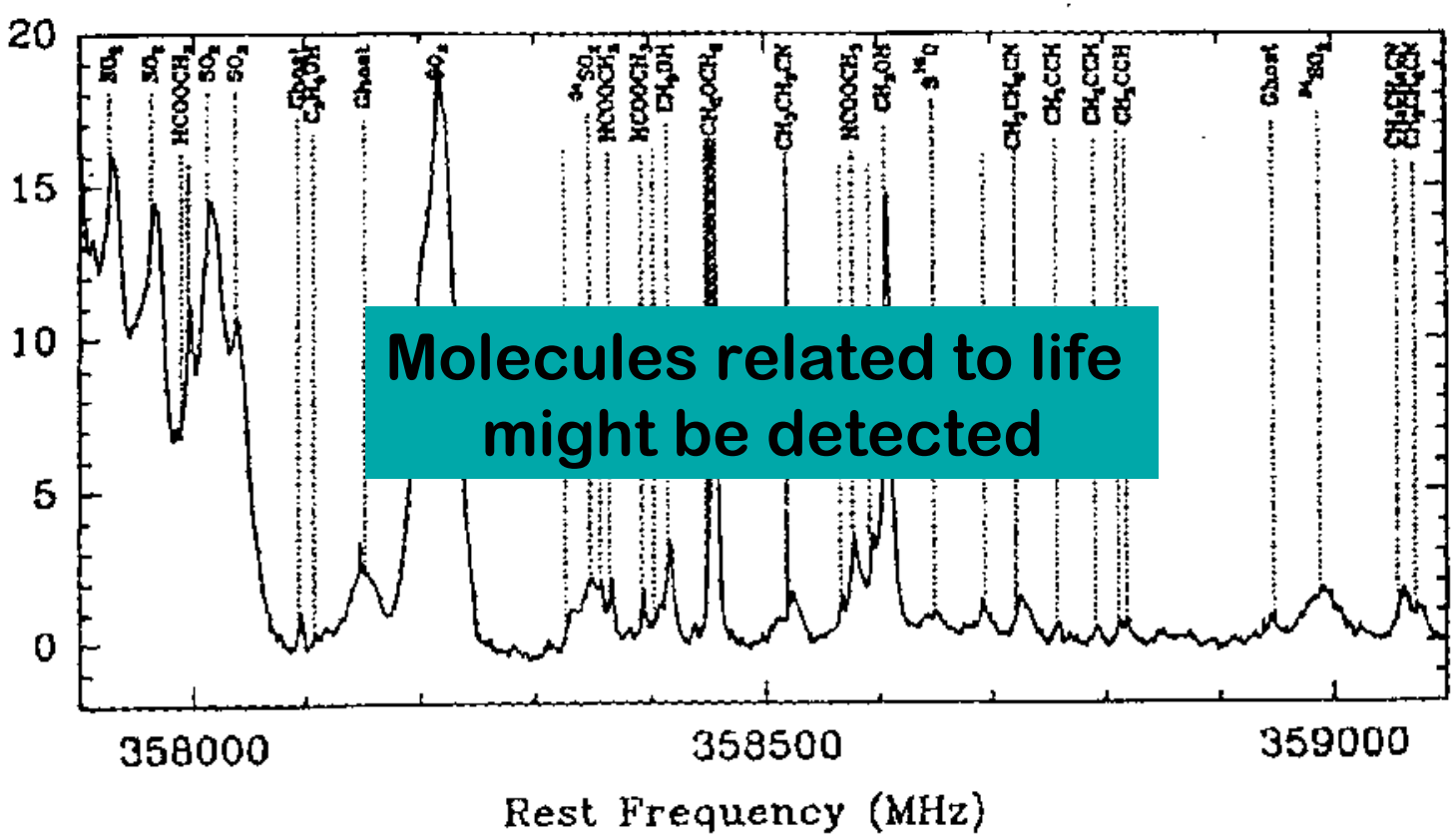


Feasibility

- **Ex.) Young stars in neaby star-forming clouds (distance 450 ly)**
  - **A lunar mass dust concentration can be detected in 10 minutes**
  - **We can see structures larger than 1 AU (Earth-Sun distance) such as gaps and spiral patterns created by protoplanets**
  - **A Jupiter mass protoplanet surrounded by planetesimals (or circum-planet gas disk) can be detected in 10 hours**

Chemical composition

Rapid Spectral Scan



Orion Spectral Line Survey (Schilke et al. 1997)

Milestones

- **2003 Feb.** — **Bilateral Agreement signed (North America & Europe)**
- **2003 Nov.** — **Groundbreaking**
- **2004 Q2** — **Trilateral Agreement signed (Japan participates)**
- **2007 Q3** — **First antenna on site**
- **2010 Q4** — **Start science observations**
- **2012 Q4** — **Start full science operations**

ALMA reveals celestial objects in formation

www.alma.info

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership between Europe, Japan and North America in cooperation with the Republic of Chile. ALMA is funded in Europe by the European Southern Observatory (ESO), in Japan by the National Institutes of Natural Sciences (NINS) in cooperation with the Academia Sinica in Taiwan and in North America by the U.S. National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC). ALMA construction and operations are led on behalf of Europe by ESO, on behalf of Japan by the National Astronomical Observatory of Japan (NAOJ) and on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI).