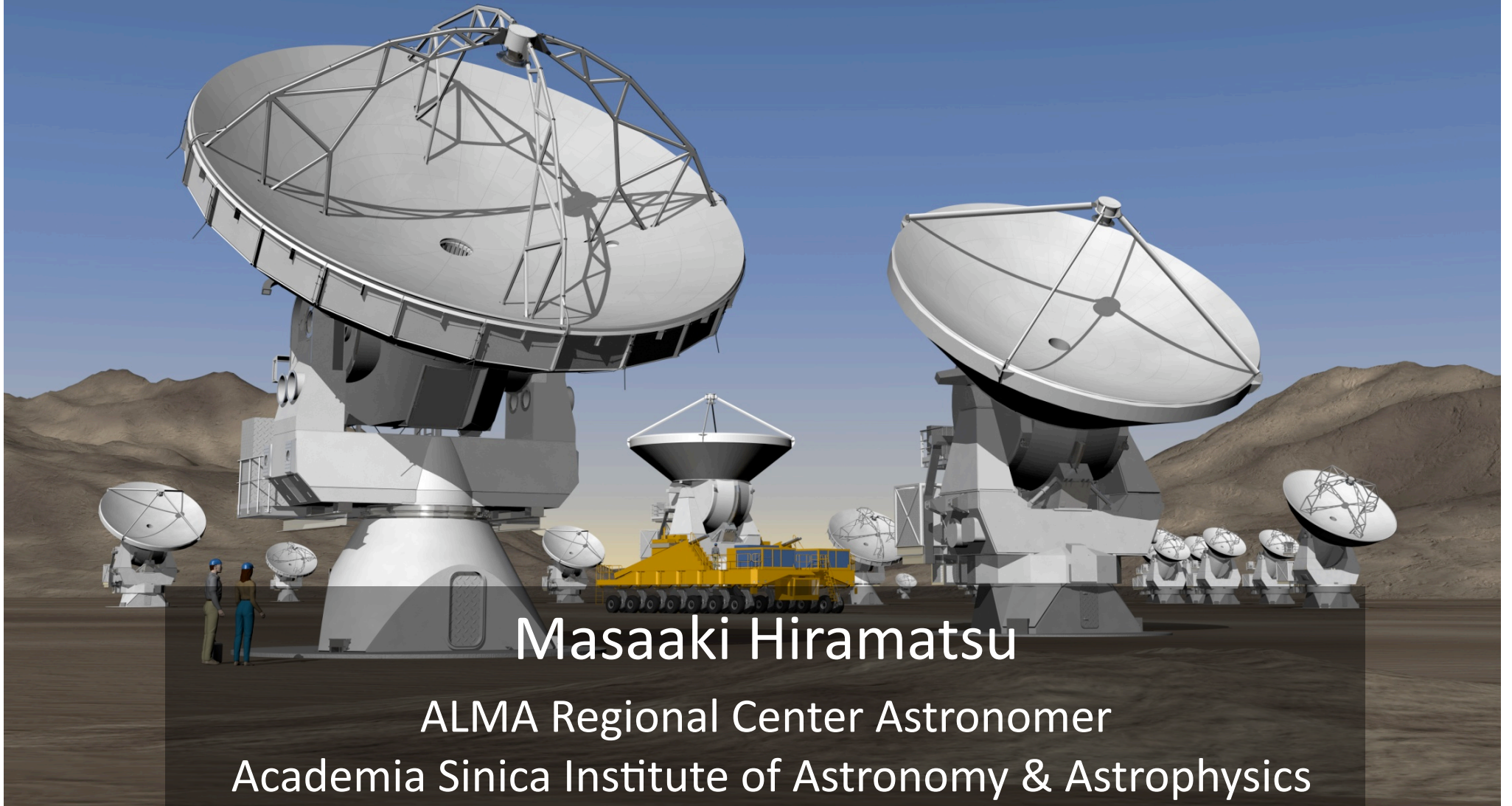


Introduction to Observations using ALMA Telescope

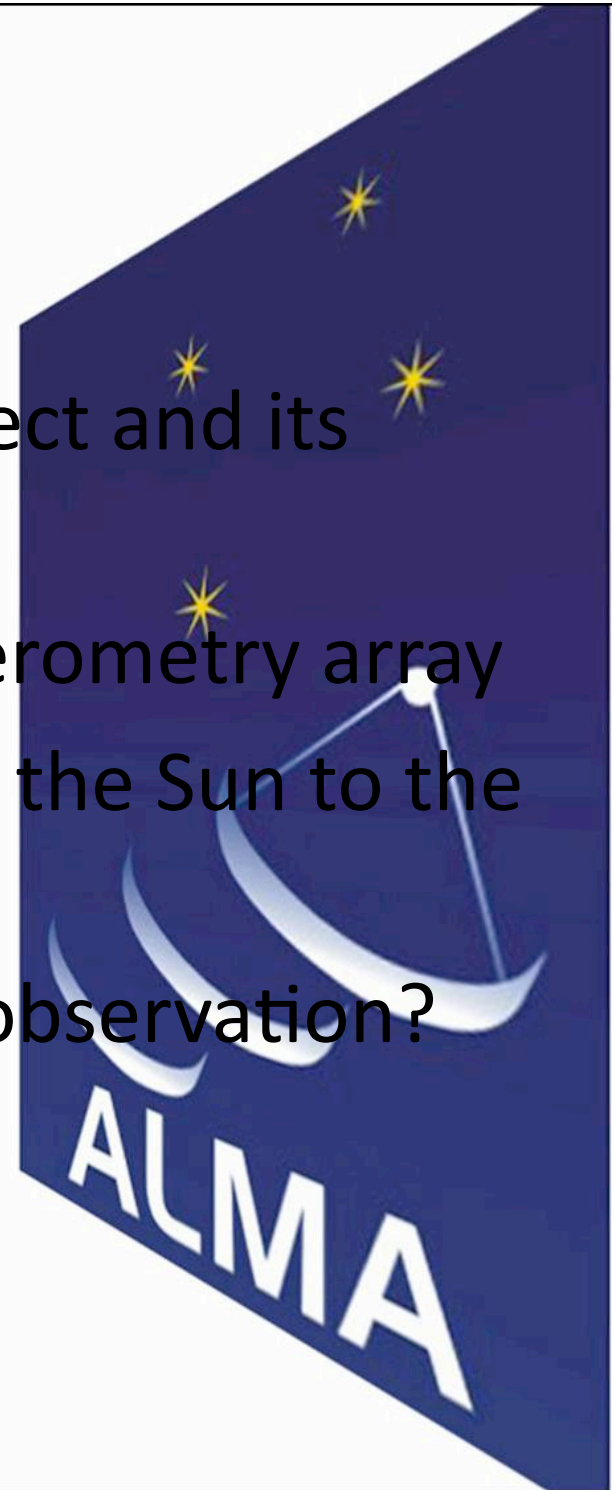


Masaaki Hiramatsu

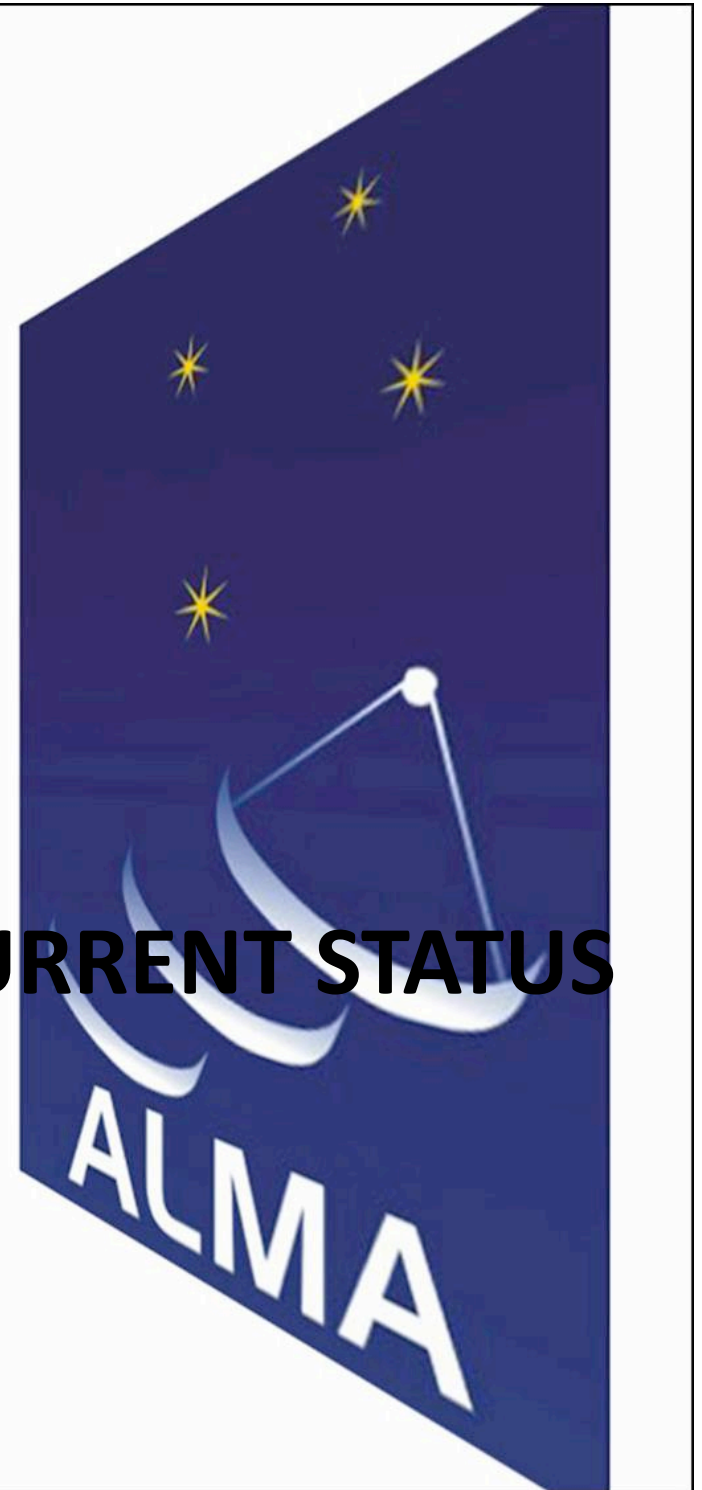
ALMA Regional Center Astronomer
Academia Sinica Institute of Astronomy & Astrophysics

Outline

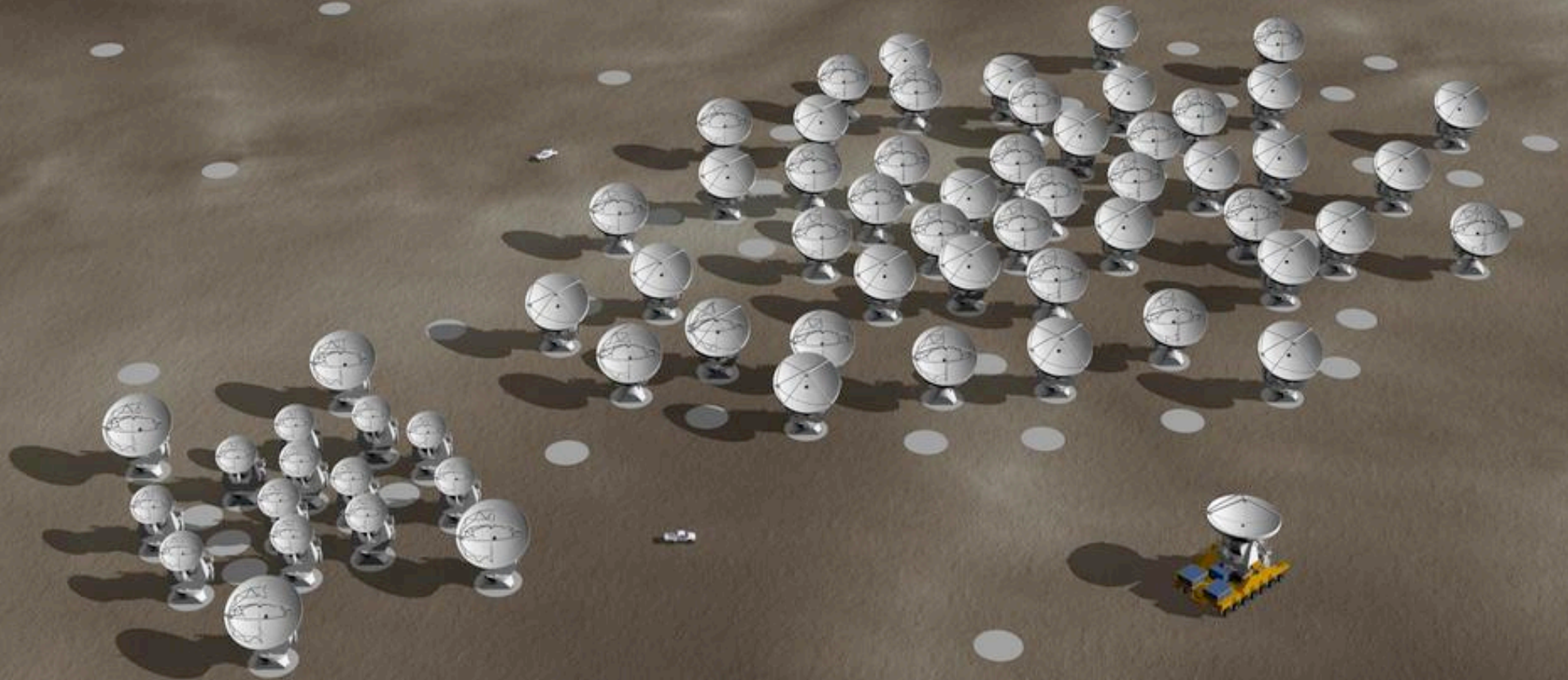
- Introduction to the ALMA project and its current status
- Observation using radio interferometry array
- ALMA Science Showcase: from the Sun to the most distant universe
- How to access ALMA for your observation?



1. INTRODUCTION TO THE ALMA PROJECT & ITS CURRENT STATUS



ALMA: the ultimate radio telescope



66 high-precision antennas

Global Collaboration between East Asia, Europe & North America

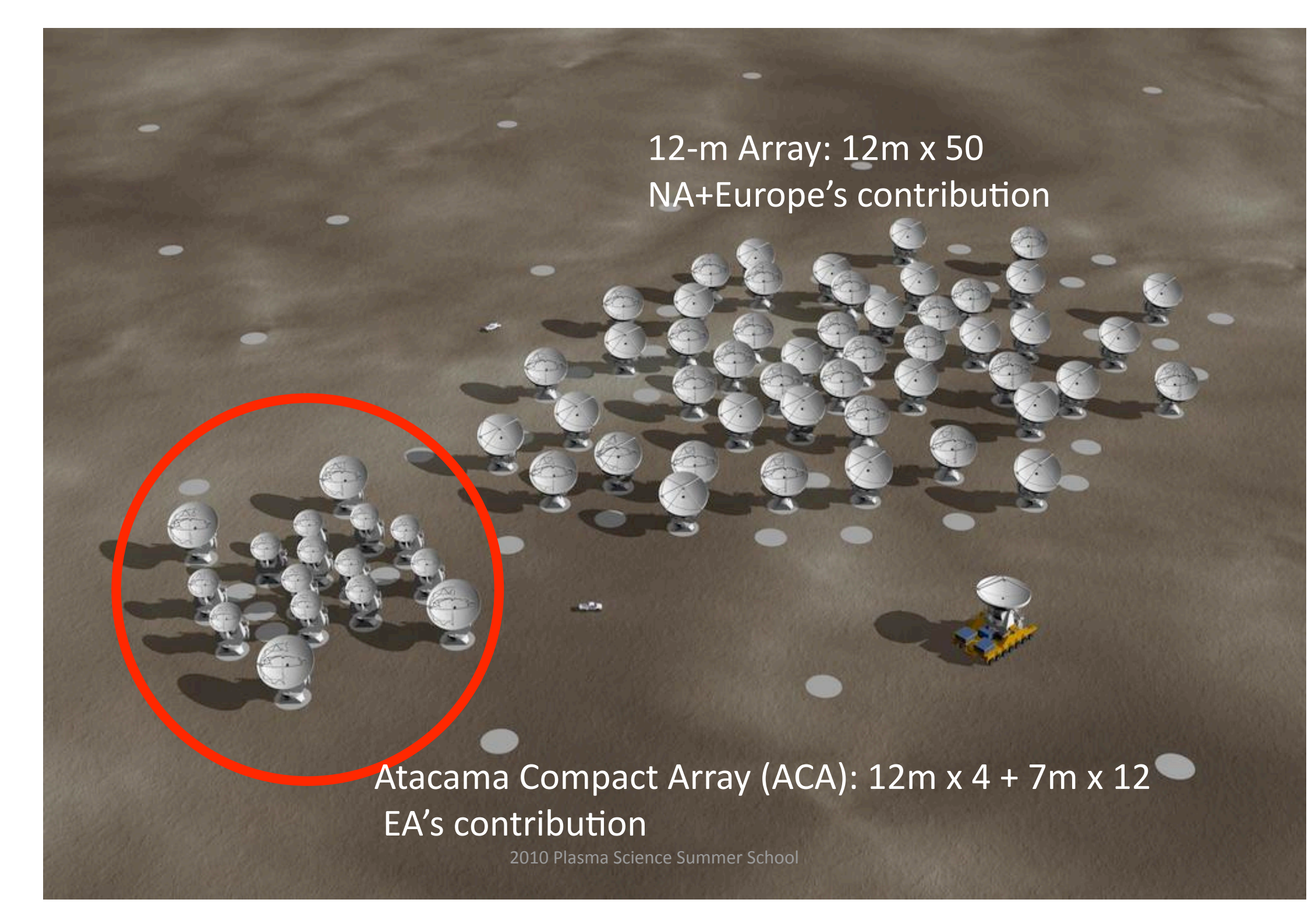
x10-100 sensitive, x10-100 higher resolution

2010 Plasma Science Summer School

ALMA: Basics

- Atacama Large Millimeter/submillimeter Array
- Largest ground-based telescope ever built
- Under construction at Atacama Desert, northern Chile
- 12m x 54 + 7m x 12 antennas
- 10 frequency bands (30 – 950 GHz)
- Highest angular resolution: 0.01 arcsec
- Great tool for all fields in astronomy/planetary science
- Observations start from **2011** !





12-m Array: 12m x 50
NA+Europe's contribution

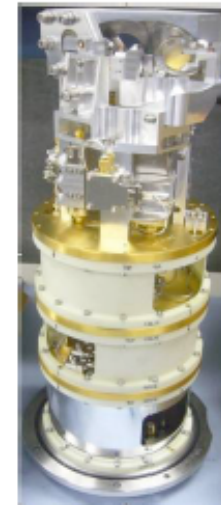
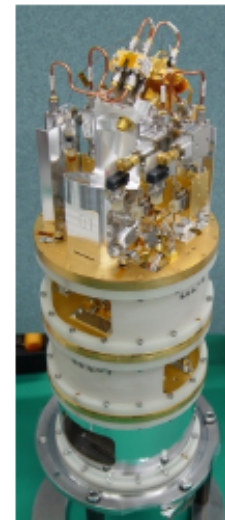
Atacama Compact Array (ACA): 12m x 4 + 7m x 12
EA's contribution

An aerial photograph of a radio telescope array in a desert landscape. The array consists of numerous white, circular dish antennas of varying sizes scattered across a flat, brownish-grey plain. In the background, there are several large, rounded hills under a clear blue sky. The text "Maximum baseline: 16 km" and "Works like a zoom lens" is overlaid in white on the left side of the image.

Maximum baseline: 16 km
Works like a zoom lens

Receiver Bands

| | Freq. (GHz) | Noise Temp. | Type | Who |
|--------|-------------|-------------|------|-----|
| Band 1 | 31.3 – 45.0 | 17 K | SSB | -- |



Band 3

Band 4

Band 6

Band 7

Band 8

Band 9

Band 10

| | | | | |
|---------|-----------|-------|-----|------|
| Band 8 | 385 – 500 | 196 K | 2SB | NAOJ |
| Band 9 | 602 – 720 | 175 K | DSB | SRON |
| Band 10 | 787 – 950 | 230 K | DSB | NAOJ |

The ALMA site



Array Operation Site (AOS)

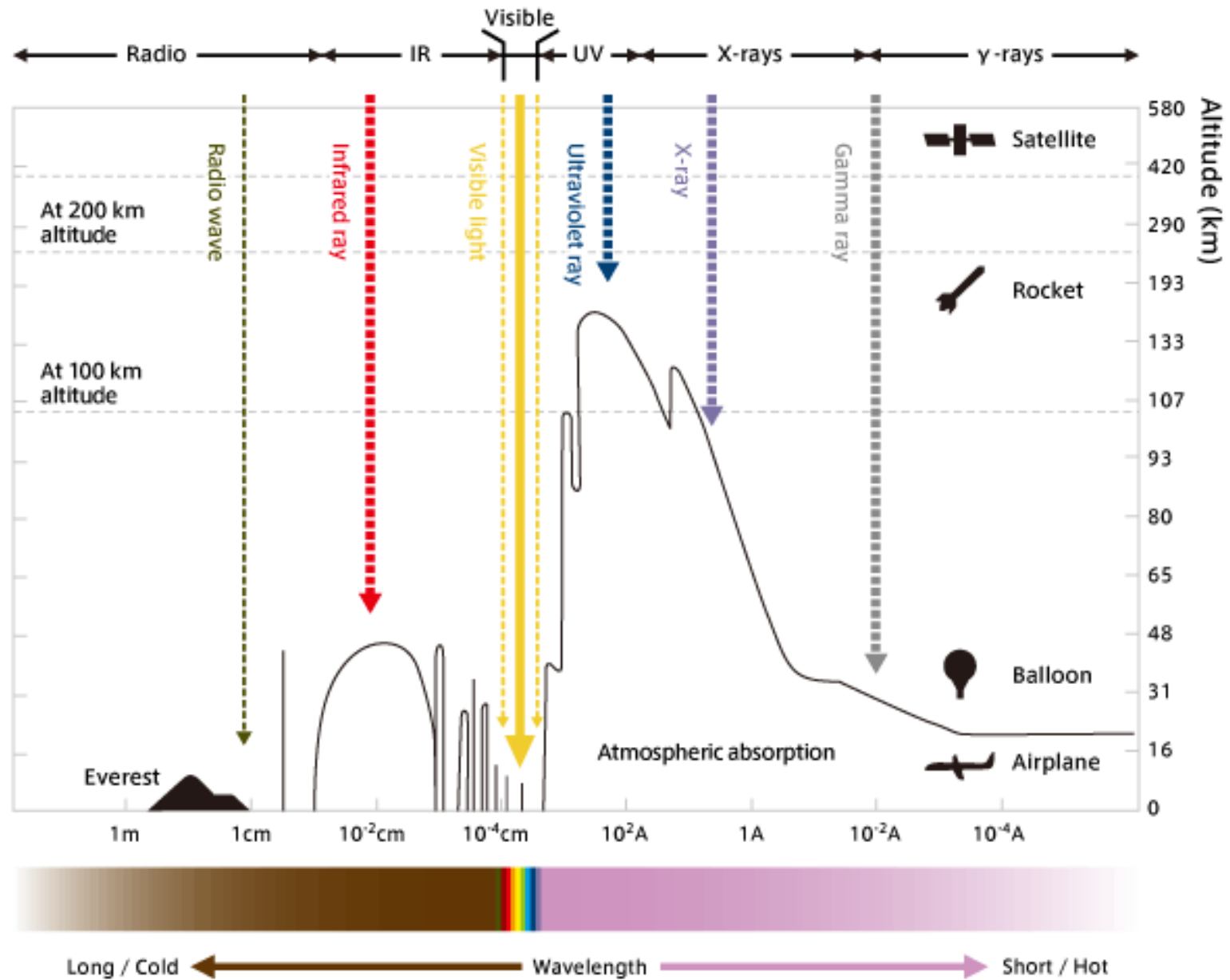


Current Status of ALMA

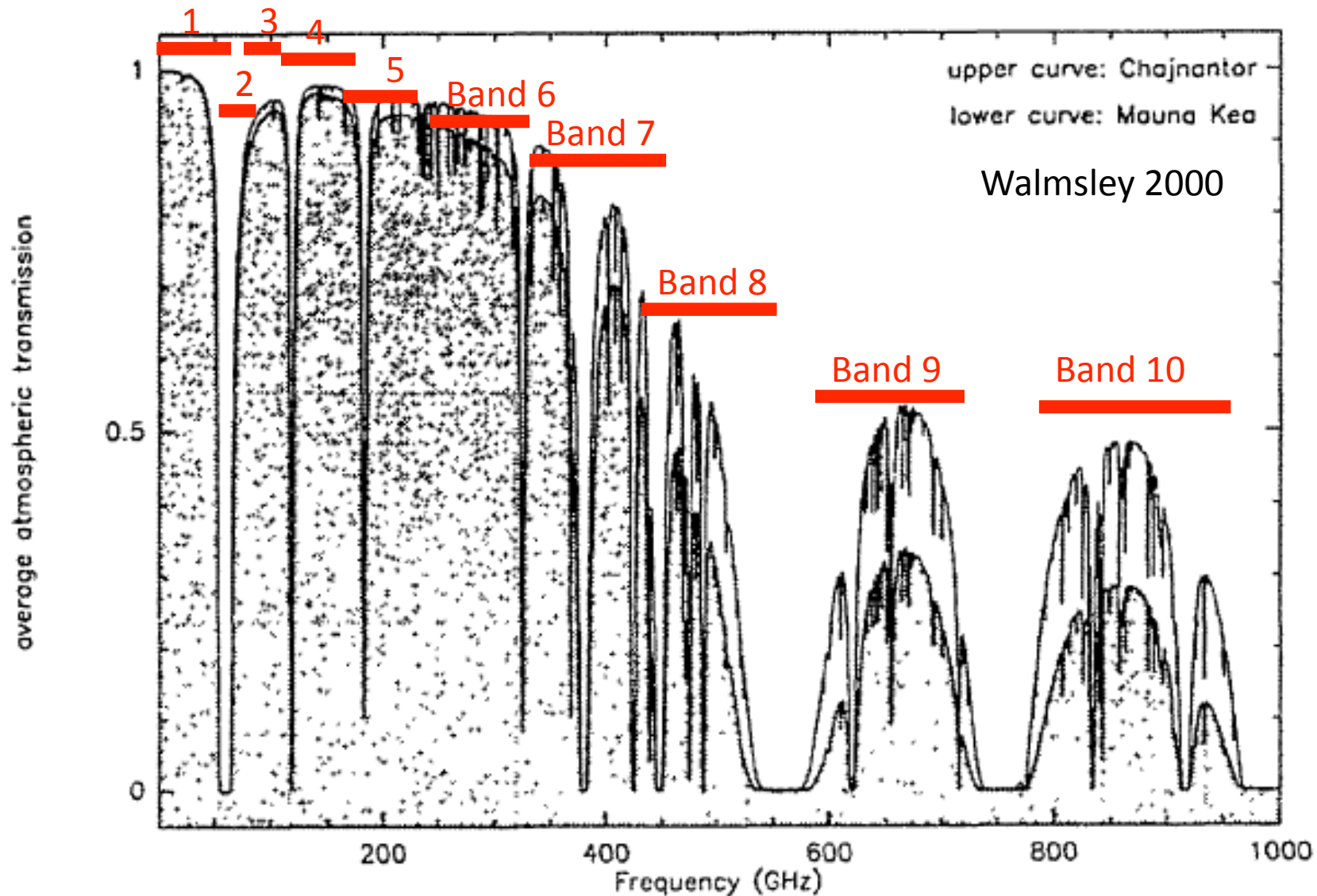
- 5 antennas at AOS
- >10 antennas at OSF under test/construction
- 10 receiver systems will be ready in 2010.
- Software: Under testing



Atmospheric transmission



Why Chilean Andes?



Before ALMA

Submillimeter Array (SMA)



Combined Array for Research in Millimeter-wave Astronomy (CARMA)



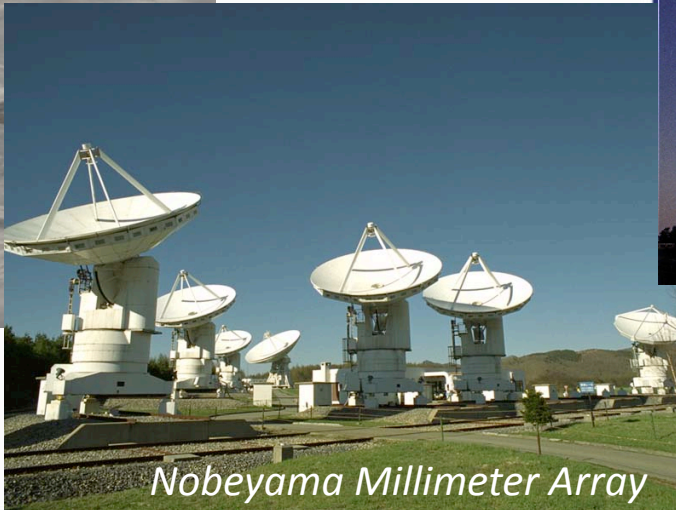
Plateau de Bure Interferometer (PdBI)



Australia Telescope Compact Array (ATCA)



Nobeyama Millimeter Array

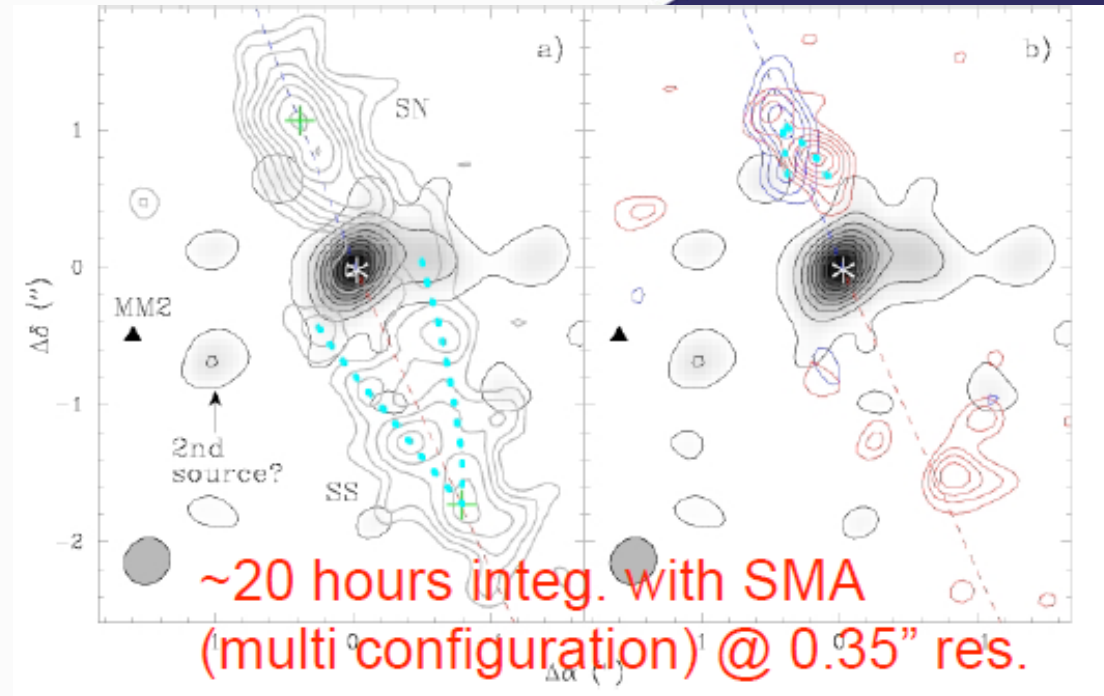
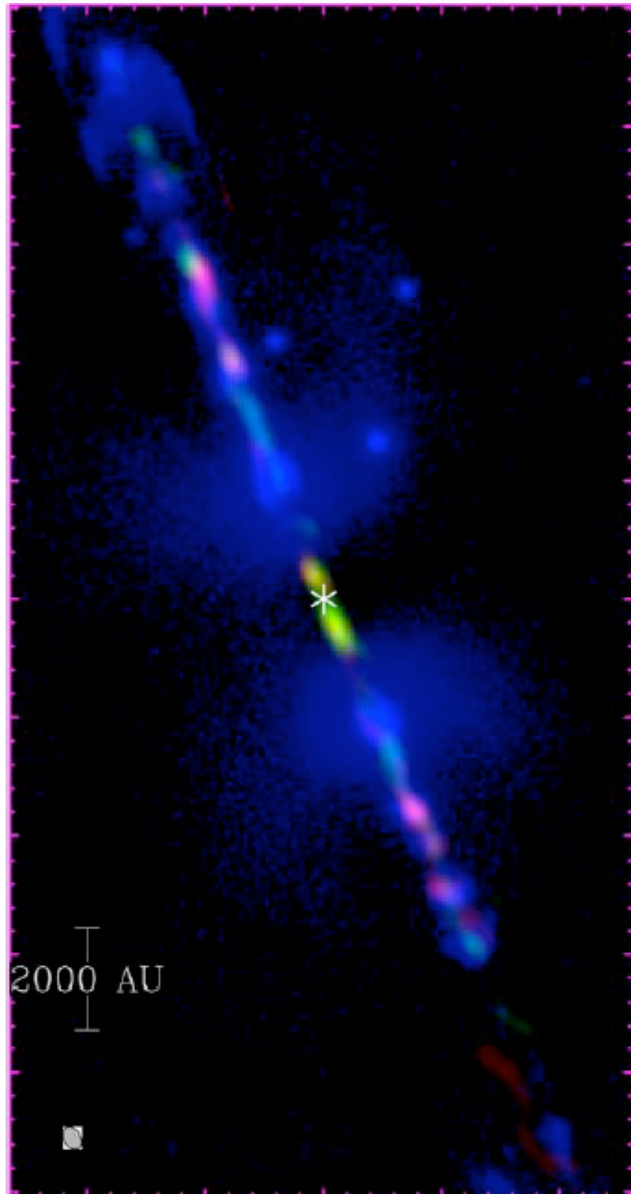


ALMA: How powerful?

| | SMA | CARMA | PdBI | ATCA | ALMA ES | ALMA full |
|-----------------------------------|----------------------|-----------------------|----------|-----------|-----------------------|-----------------------|
| Antenna | 6m x 8 | 10.4m x 6 6.1m x 9 | 15m x 6 | 22m x 6 | 12m x 16 | 12m x 54 + 7m x 12 |
| Collecting Area (m ²) | 230 | 770 | 1060 | 2280 | > 1800 | 6500 |
| Frequency (GHz) | 230, 350 400, 690 | 100, 230 | 100, 230 | 1.2 - 100 | 100, 230, 350, 650 | + 150, 450, 800 |
| resolution | 0.15" | 0.4" | 0.5" | 0.4" | 0.15" | 0.01" |

More than 10 times powerful!

ALMA: How powerful?



ALMA needs only **10 sec** on-source time to achieve same sensitivity and same resolution.

2. OBSERVATION USING RADIO INTERFEROMETRY ARRAY



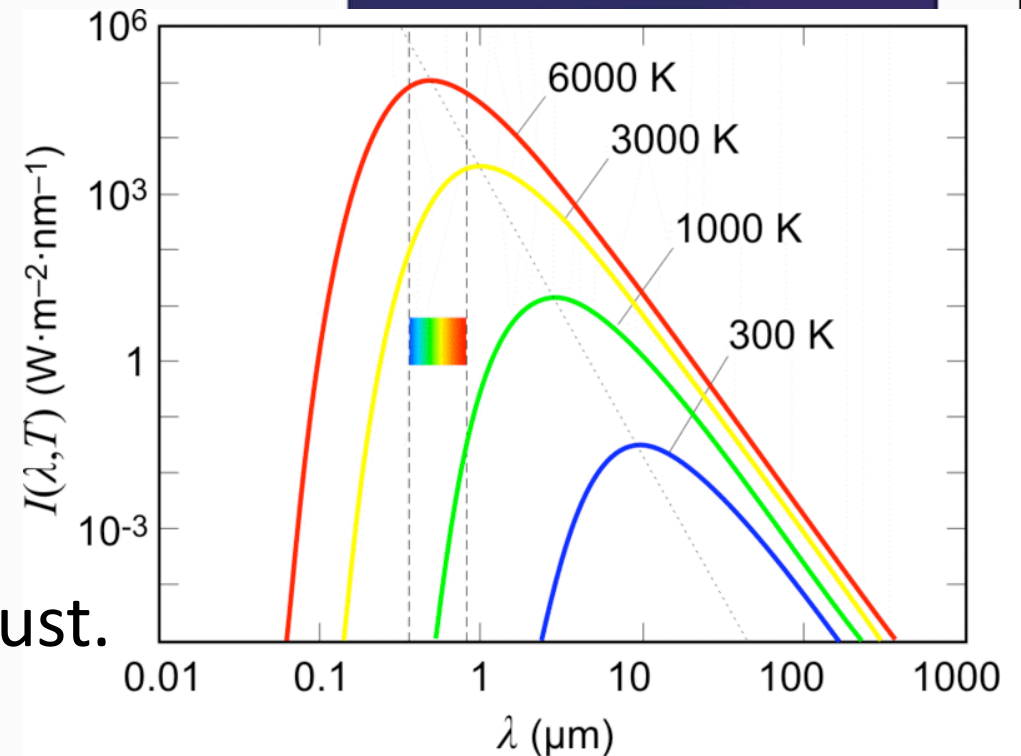
What can we see in mm/submm wave?

- Blackbody radiation from the cool universe

Wien's displacement law

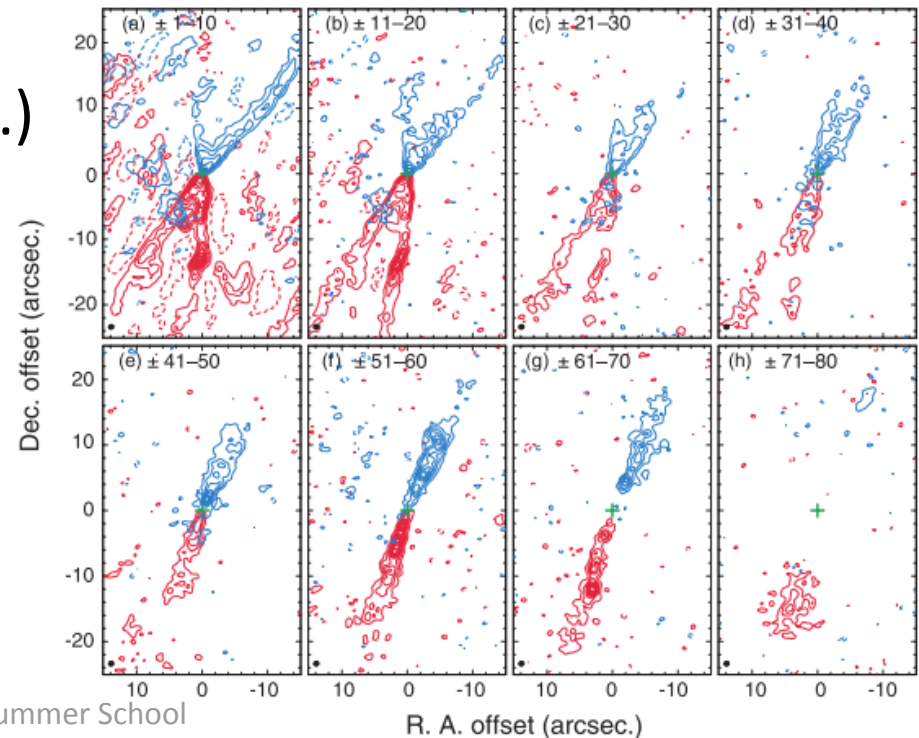
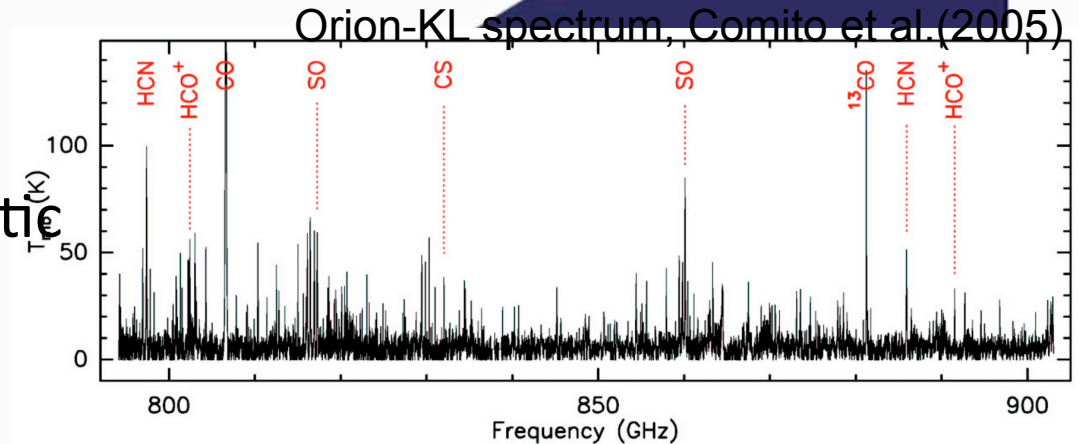
$$\begin{aligned}\lambda_{\max} &= \frac{2.9 \times 10^{-3}}{T} \text{ m} \cdot \text{K} \\ &= 290 \mu\text{m} \quad (T=10 \text{ K}) \\ &\approx 1000 \text{ GHz}\end{aligned}$$

- Efficient in detecting emissions from cosmic dust.



What can we see in mm/submm wave?

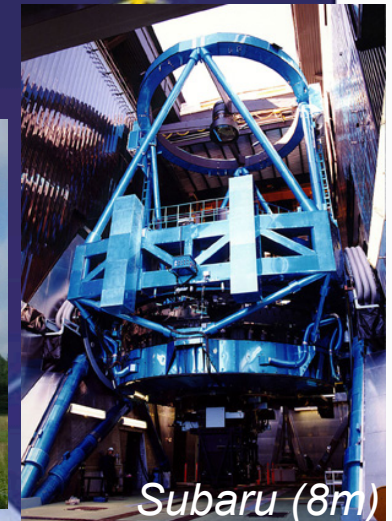
- Molecular line forest:
physical/chemical diagnostic
- Excitation
-> temperature, density
- Doppler broadening
-> kinematics (jet, rotating disk...)
- Molecule species
-> chemistry, timescale, shock...



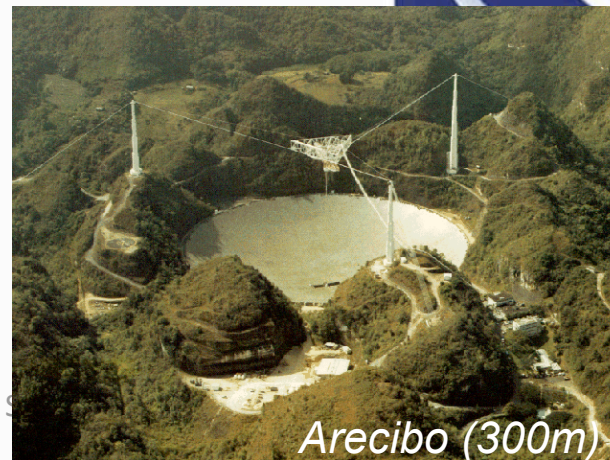
Why need 66 antennas?: Interferometer

- Angular resolution: $R \propto \frac{\lambda}{D}$ Wavelength
Telescope diameter

- Optical telescope:
2 um / 8m -> 0.06 arcsec
- Radio telescope:
3 mm / 45m -> 15 arcsec

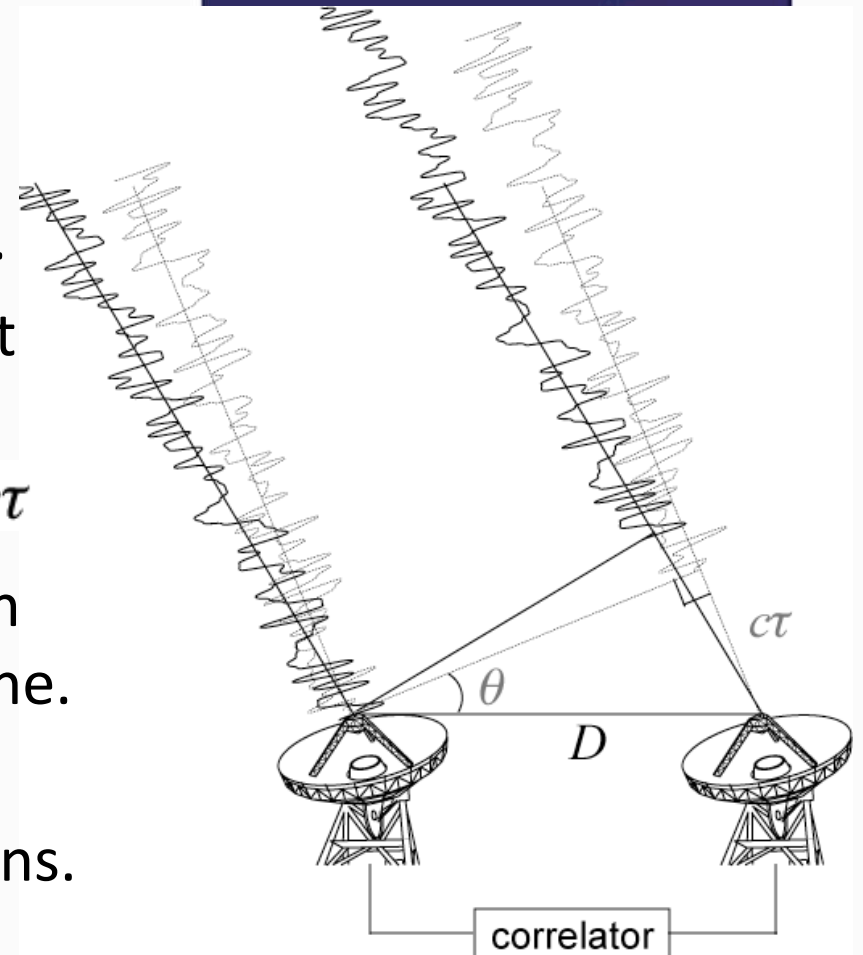


- A **10 km** telescope can achieve 0.06arcsec resolution.
- Technically very difficult to build a huge telescope.
- Divide to smaller pieces!*



Interferometer Basics

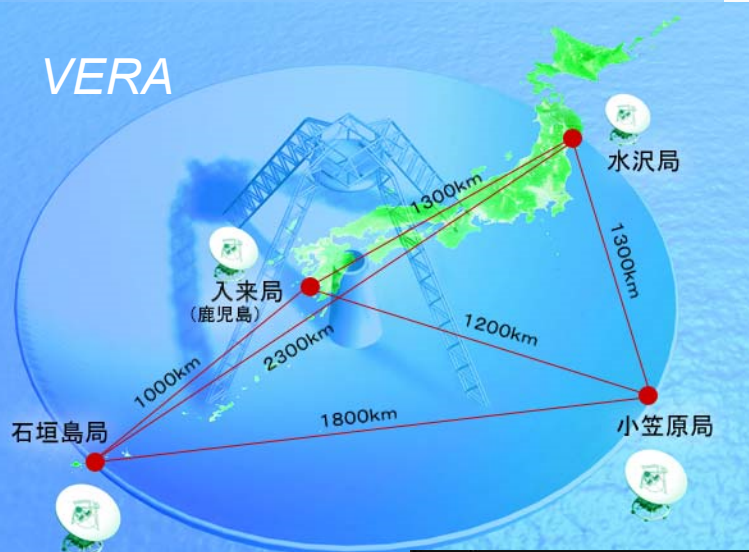
- Coherent signal from the target source
- Difference in the path length: $c\tau$
- Correlator seeks the delay τ , then you get θ : position of the source.
- The other source (or, different part of a source) has different τ .
- Large D : easy to measure small $\Delta c\tau$
- Interferometer has its resolution in the direction parallel to the baseline.
- Earth rotation + multiple antenna provide baselines in many directions.



Interferometers

Submillimeter Array (SMA)

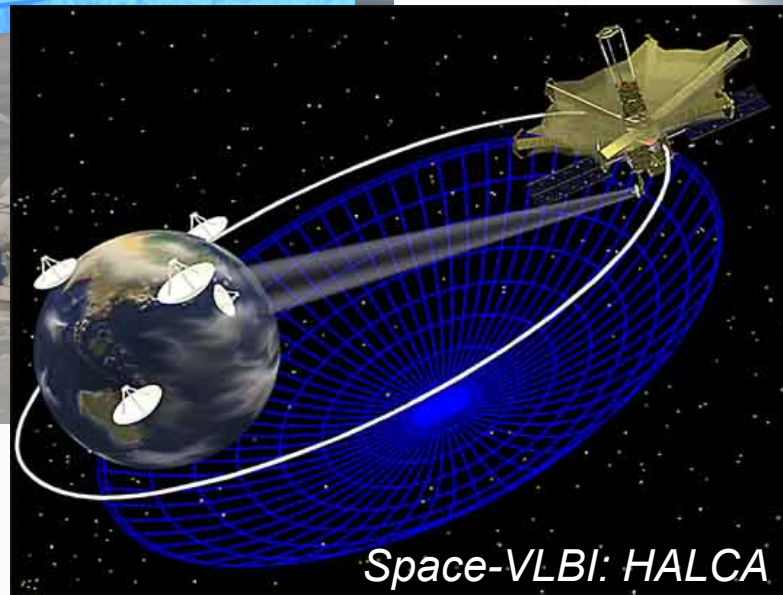
VERA



Combined Array (CARMA)



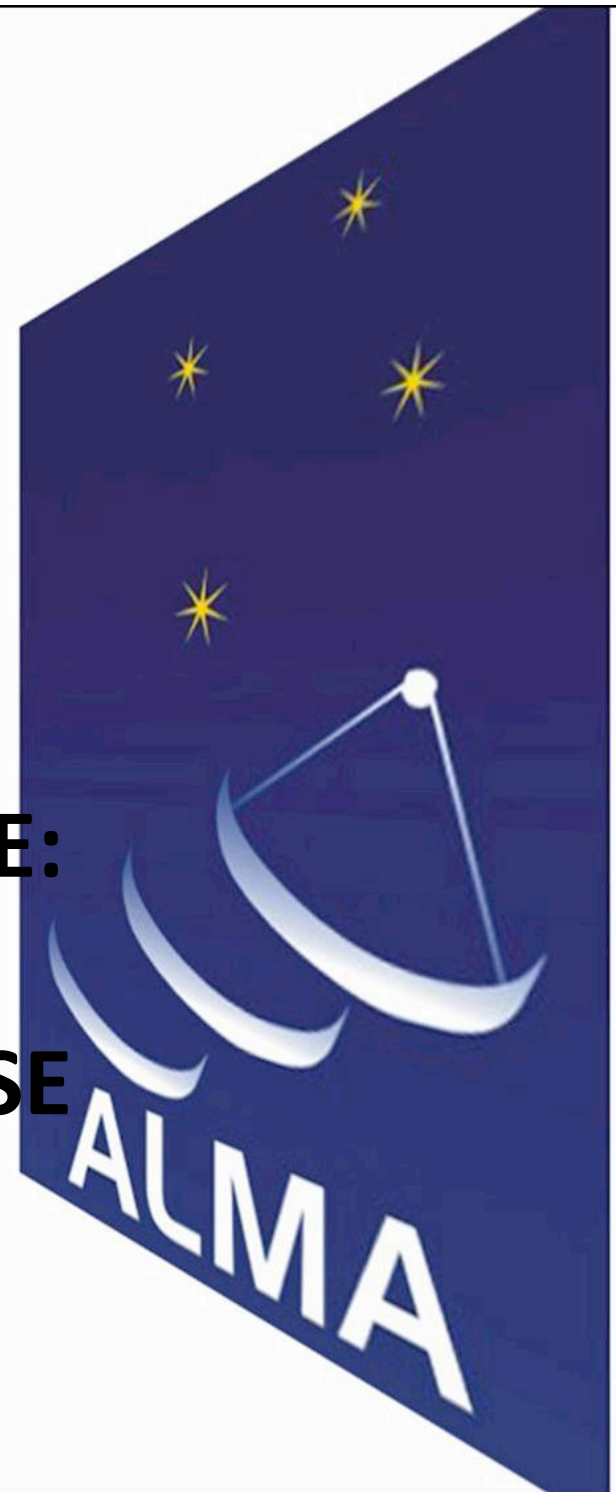
VLBA



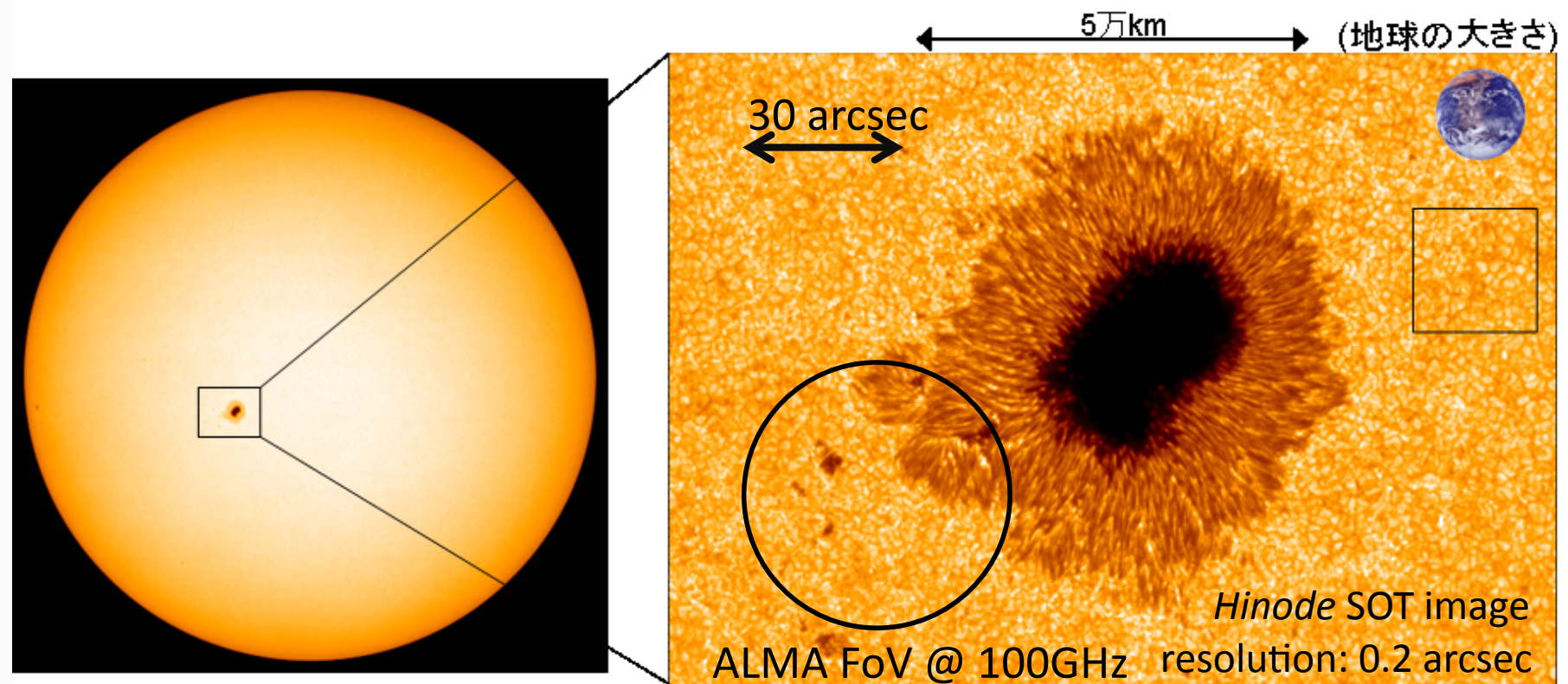
Space-VLBI: HALCA



**3. ALMA SCIENCE SHOWCASE:
FROM THE SUN TO
THE MOST DISTANT UNIVERSE**



ALMA Science: The Sun

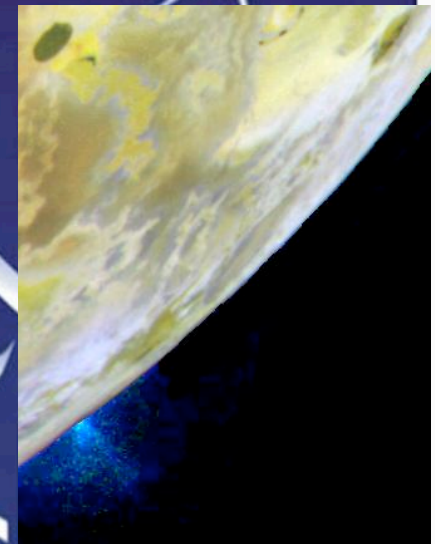
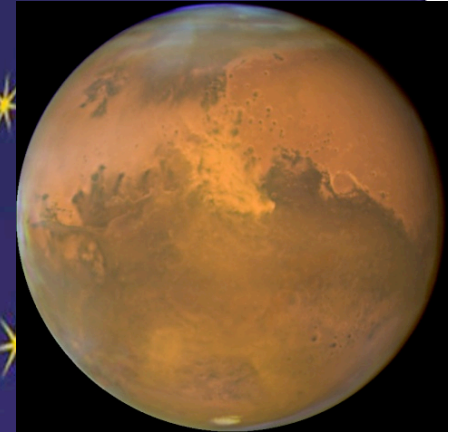


Imaging Flares, Filaments, dynamic processes in the chromosphere.
Recombination lines(?), Zeeman effect..

- 0.2" resolution with 3km baseline @ 100 GHz
- temporal resolution < 1 second

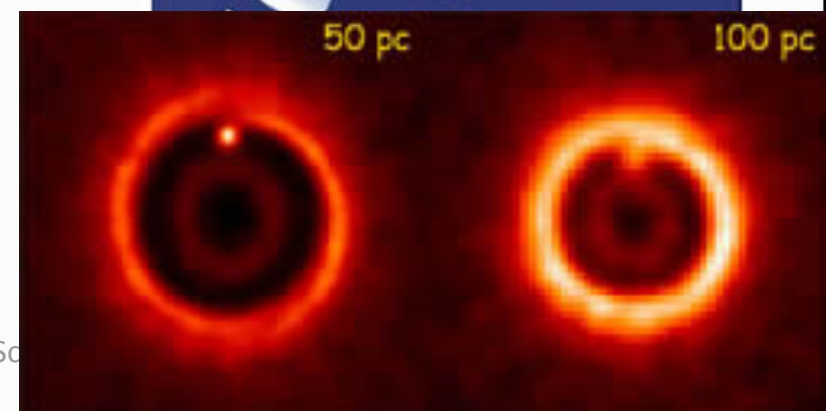
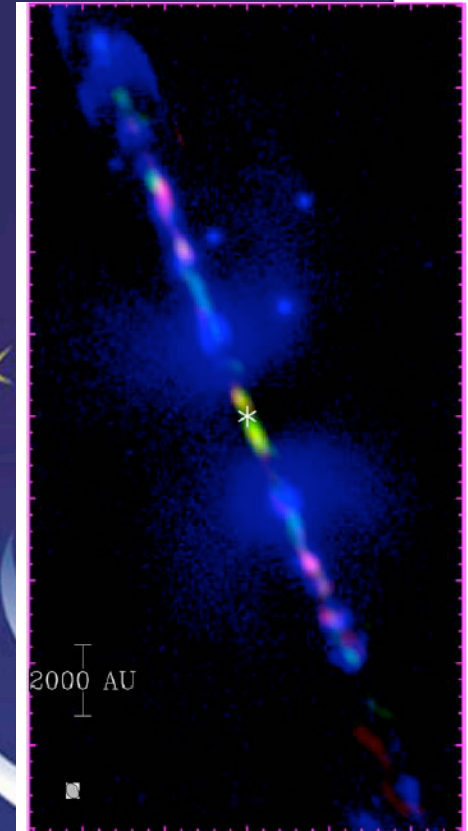
ALMA Science: Solar System

- Dynamics of Mars/Venus atmosphere
 - Local CO abundance, thermal field, wind
- Io's volcano
 - Map the spatial/temporal variation
 - Interaction with plasma torus
- Size/albedo determination of transneptunian objects
 - Records of the ancient solar system



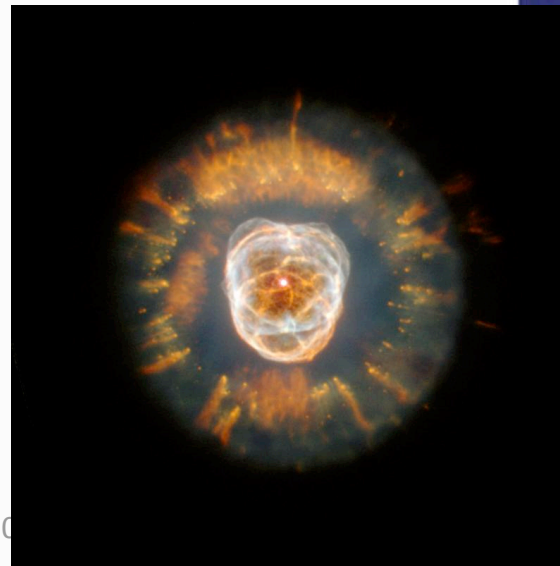
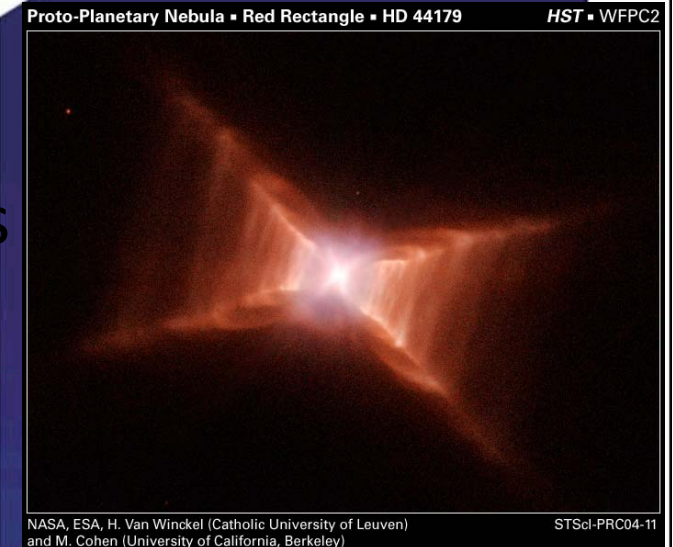
ALMA Science: Star/planet formation

- Kinematics at the most inner part of protostellar cores: When do disks form?
- Exploring the launching point of the jets.
- Direct imaging of the planet formation.
 - When & how are the disks cleared up?
 - What kind of planetary systems are forming?
 - Earth-like planets: how common?



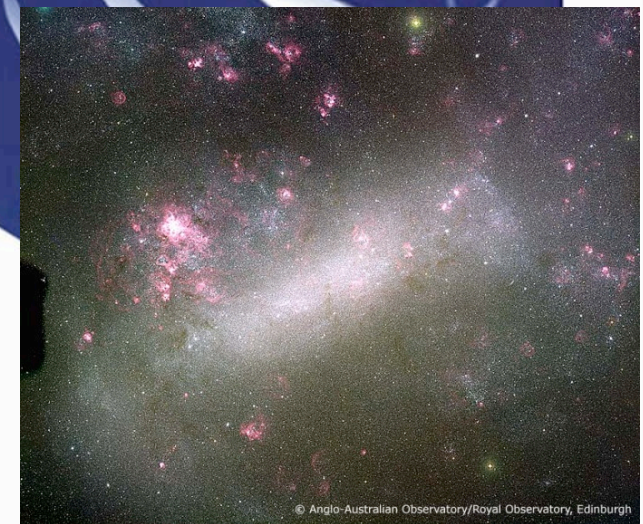
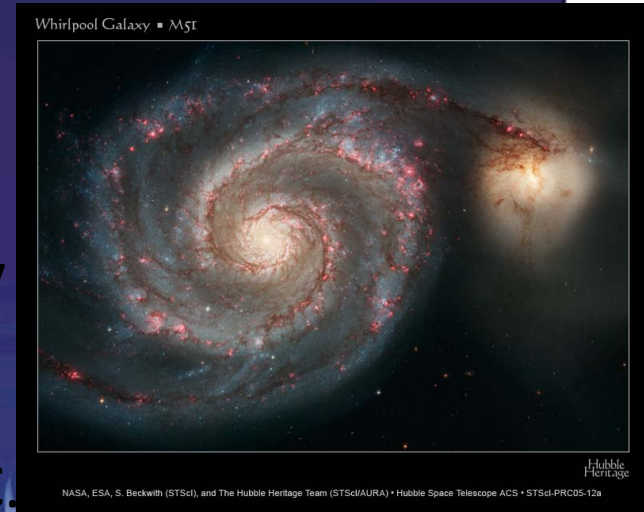
ALMA Science: Dying stars[★]

- What makes asymmetric nebula?
- Probe the high velocity stellar winds & investigate the mass-loss process.
- Physical/chemical condition of tiny structures in planetary nebulae



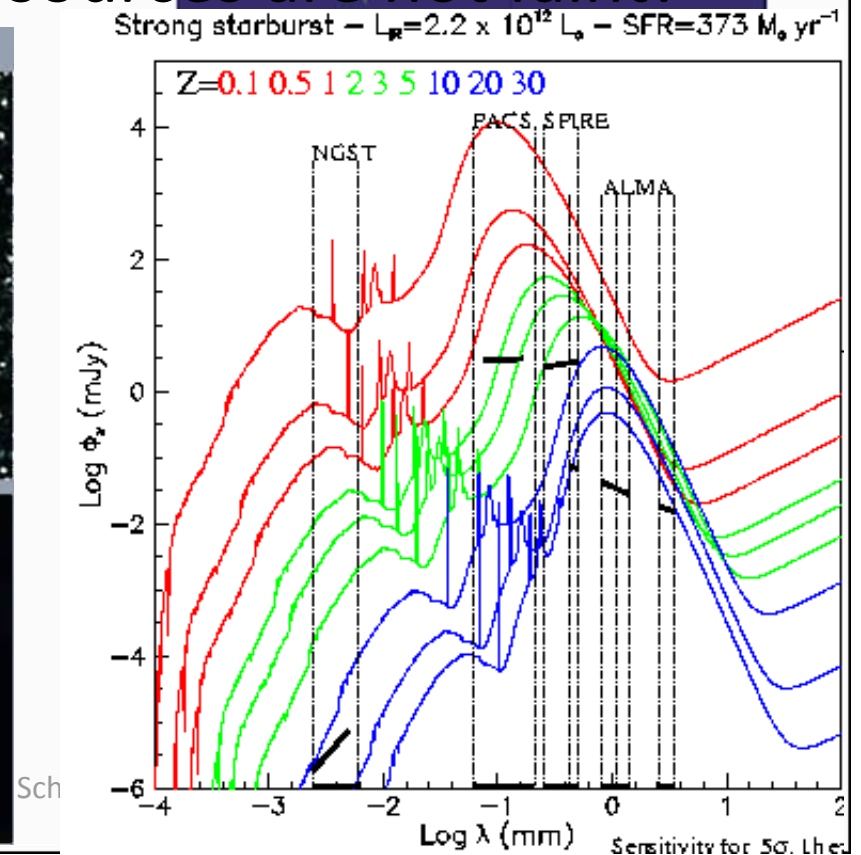
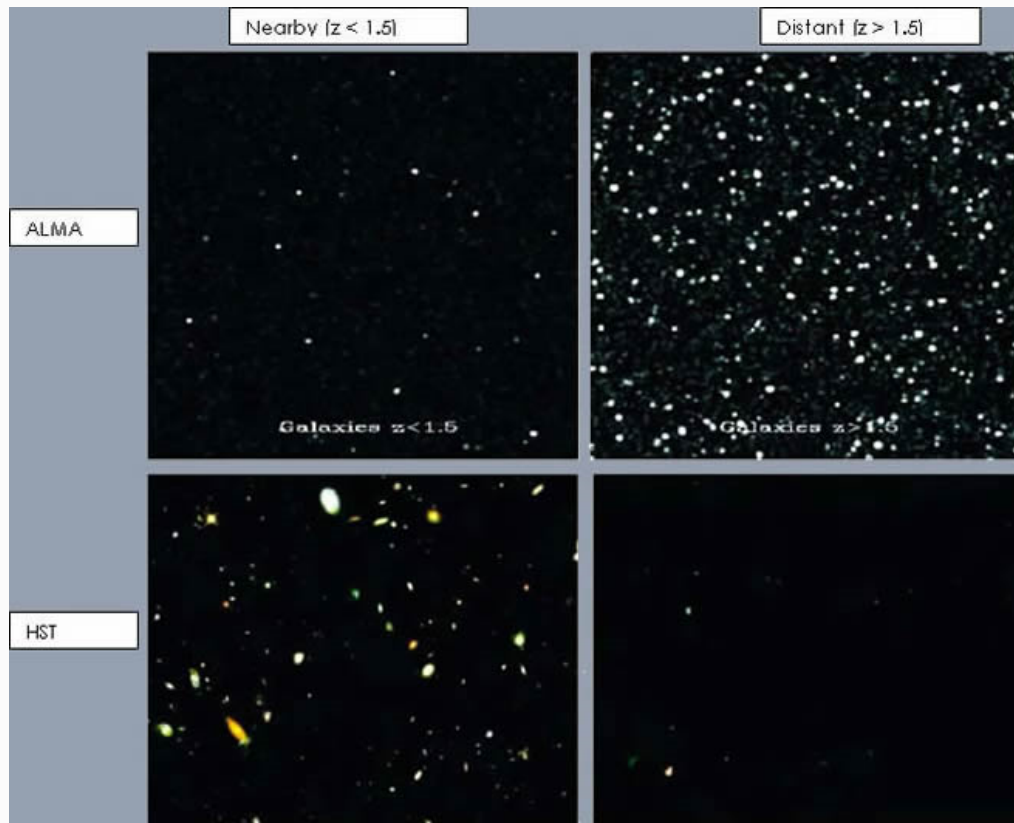
ALMA Science: Galaxies

- Galactic-scale chemistry:
 - Ionization fraction variation?
 - Shocks and galactic dynamics?
- Gas mass & Star formation efficiency
- Magellanic Cloud
 - Structure & star-formation in LMC/SMC
 - Low metallicity than Milky Way
Early universe analogous



ALMA Science: Deepest universe

- Unbiased survey of submm galaxies to investigate the formation and evolution of galaxies
- Negative K -correction: distant sources are not faint!

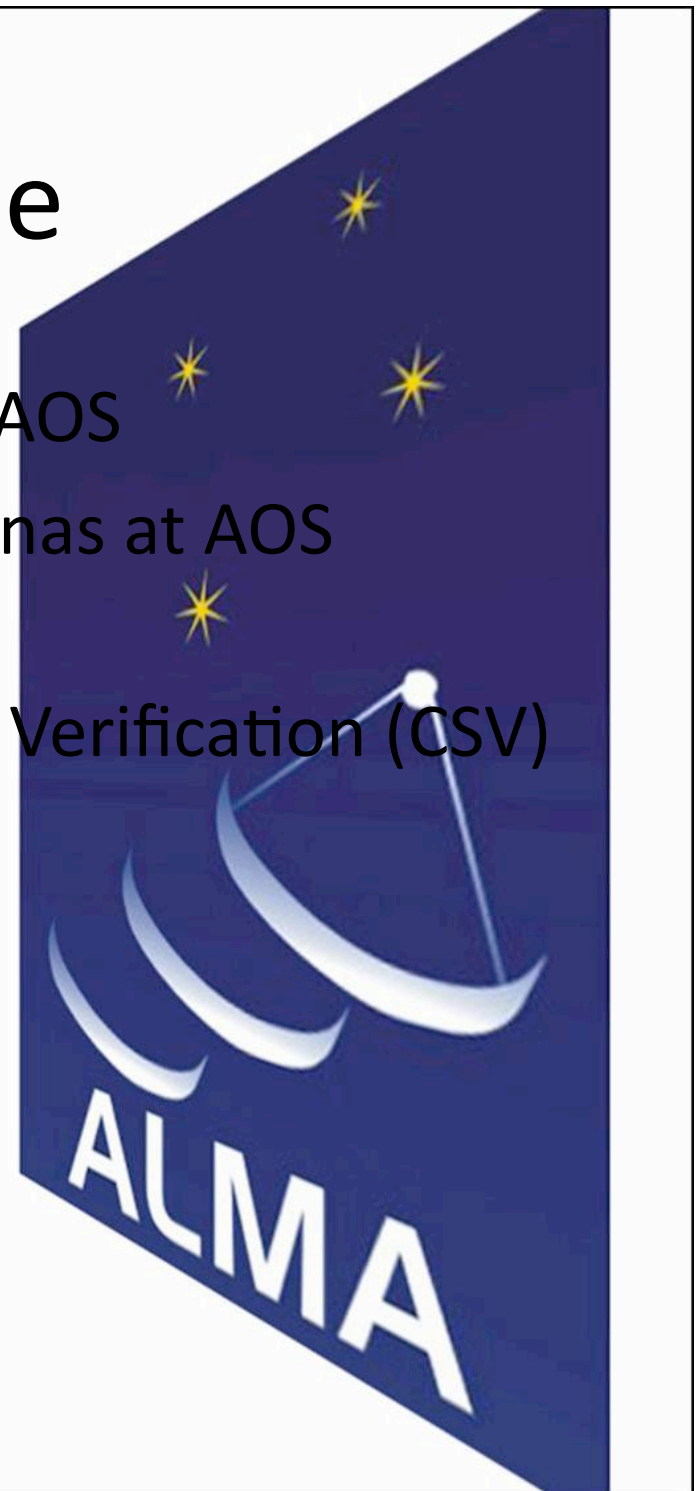


4. HOW TO ACCESS ALMA FOR YOUR OBSERVATIONS?



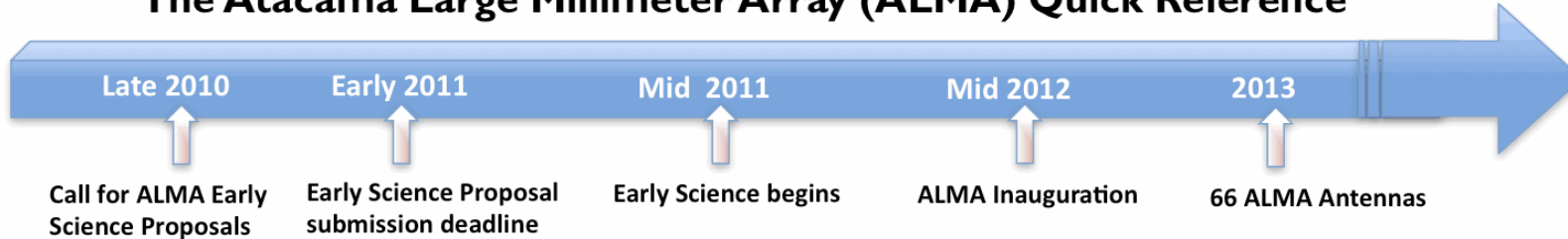
ALMA timeline

- Sep. 2009: First antenna moved to AOS
- Nov. 2009: First fringe with 3 antennas at AOS
- Jan. 2010:
Start the Commissioning & Science Verification (CSV)
- Jan. 2011: ***First Call for Proposal***
- Sep. 2011: Start “Early Science”
- Sep. 2012: Inauguration
- Apr. 2013: 66 antennas in service



ALMA Early Science

The Atacama Large Millimeter Array (ALMA) Quick Reference



| Bands: | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|-----------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Frequency (GHz) | 84-116 | 125-163 | 163-211 | 211-275 | 275-373 | 385-500 | 602-720 | 787-950 |
| Wavelength (mm) | 3.57-2.59 | 2.40-1.84 | 1.84-1.42 | 1.42-1.09 | 1.09-0.80 | 0.78-0.60 | 0.50-0.42 | 0.38-0.32 |

| | Early Science | ALMA Inauguration |
|--|---|--|
| Antennas | ≥ 16 x 12m | ≥ 50 (12m & 7m) |
| Bands | ≥ 3 bands (Bands 3,6,7,9 likely) | Bands 3,6,7,9 (+ 4,8 & 10 on some) |
| Maximum Bandwidth | 16 GHz (2 polarizations × 8 GHz) | |
| Correlator Configurations | ≥ 5 | 0.01 - 40 km/sec, 71 configurations |
| Maximum Angular Resolution | 0.02" $\left(\frac{\lambda}{1 \text{ mm}} \right)$ | $\left(\frac{10 \text{ km}}{\text{max baseline}} \right)$ |
| Maximum Baseline | At least 250m (may reach 1km) | 15.3 km |
| Continuum Sensitivity (60 sec, Bands 3–9) | ~0.2 — 4.2 mJy | ~0.05 — 1 mJy |
| Spectral Line Sensitivity (60 sec, 1 km/sec, Bands 3–9) | ~30 — 250 mJy | ~ 7 — 62 mJy |

Sensitivity Calculator: <http://science.nrao.edu/alma/tools.shtml>



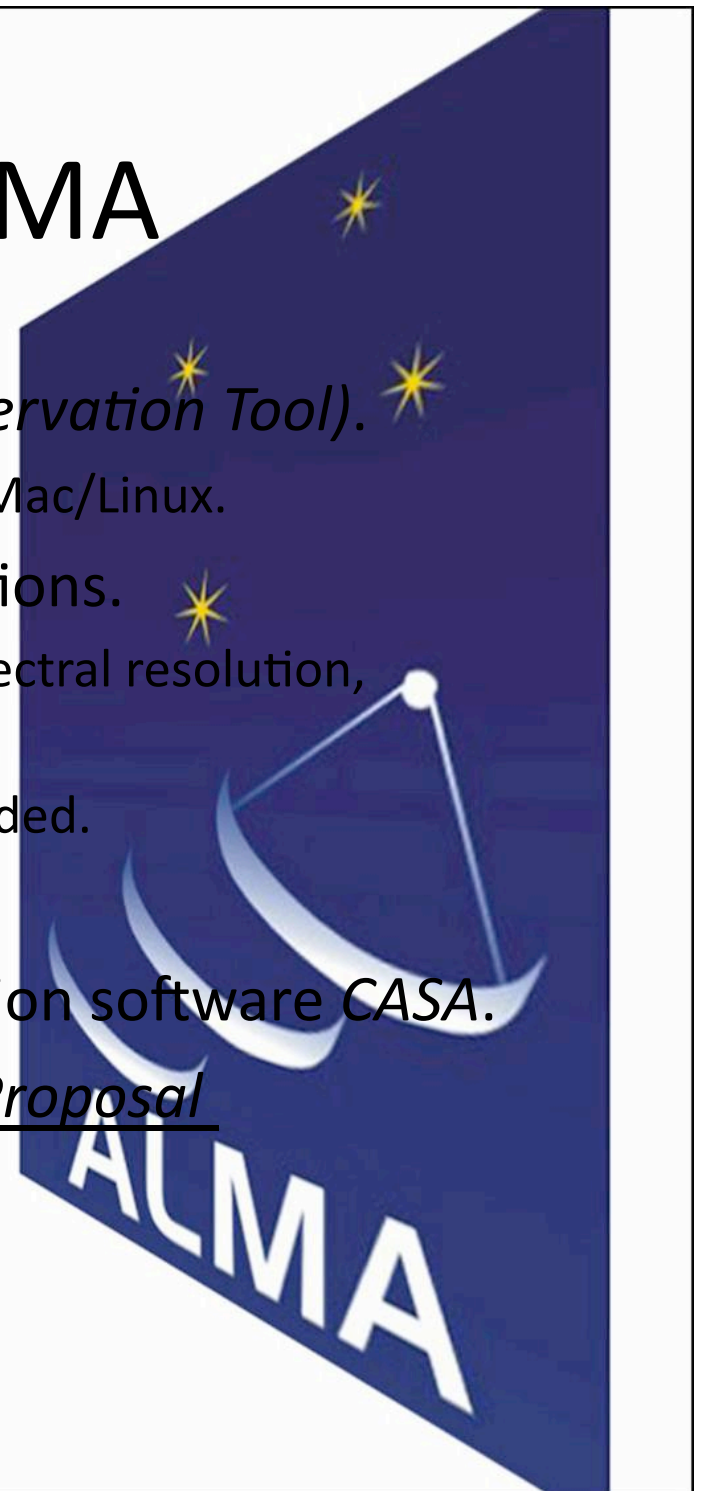
ALMA Specifications

ALMA Sensitivities, FOV, and Resolutions

| Band | Frequency Range (GHz) | Wavelength Range (mm) | angular resolution (") | line sensitivity (mJy) | Continuum sensitivity (mJy) | Field of View (") | Largest scale (") |
|---------|-----------------------|-----------------------|------------------------|------------------------|-----------------------------|-------------------|-------------------|
| Band 1 | 31.3 - 45 | | | | | | |
| Band 2 | 67 - 90 | | | | | | |
| Band 3 | 84 - 116 | 3.6 - 2.6 | 3.18 - 0.038 | 8.9 | 0.05 | 56 | 37 |
| Band 4 | 125 - 163 | 2.4 - 1.8 | 2.5 - 0.03 | 9.1 | 0.06 | 48 | 32 |
| Band 5 | 163 - 211 | 1.8 - 1.4 | | | | 35 | 23 |
| Band 6 | 211 - 275 | 1.4 - 1.1 | 1.52 - 0.018 | 13 | 0.10 | 27 | 18 |
| Band 7 | 275 - 373 | 1.1 - 0.8 | 1.01 - 0.012 | 21 | 0.20 | 18 | 12 |
| Band 8 | 385 - 500 | 0.8 - 0.6 | 0.86 - 0.01 | 63 | 0.40 | 12 | 9 |
| Band 9 | 602 - 720 | 0.5 - 0.4 | 0.52 - 0.006 | 80 | 0.69 | 9 | 6 |
| Band 10 | 787 - 950 | 0.4 - 0.3 | 0.38 - 0.005 | | 1.1 | 7 | 5 |

Proposal for ALMA

- Make proposals with a software *OT (Observation Tool)*.
 - Java-based program. Available on Windows/Mac/Linux.
- Set various parameters for your observations.
 - names of Co.I., target position, frequency, spectral resolution, desired spatial resolution, desired noise level
 - Molecular line list/Sensitivity Calculator included.
- Submit (upload) proposals with *OT*
- Simulation can be done with data reduction software *CASA*.
- *Tutorial for OT will be held after Call for Proposal*



Observation with ALMA

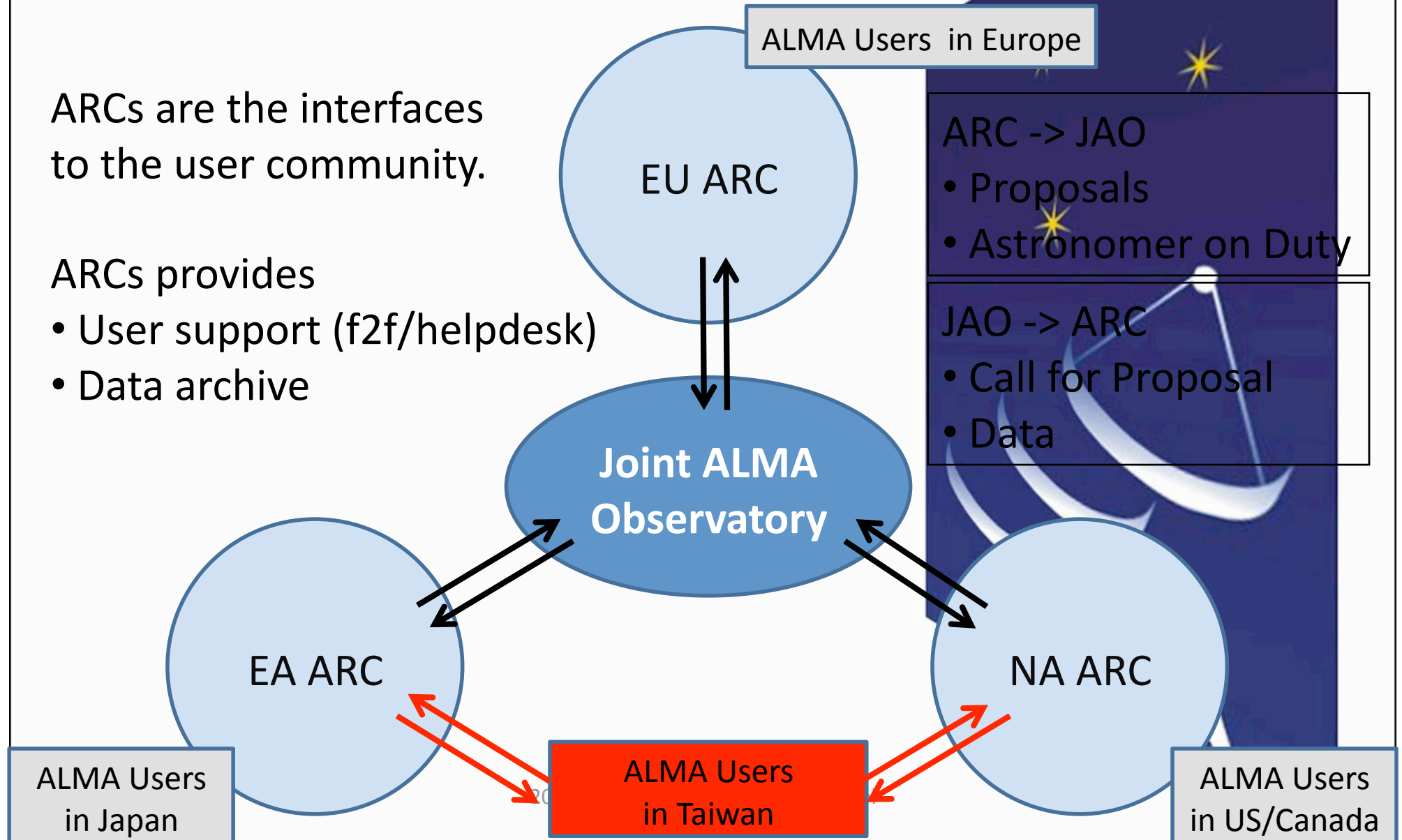
- *Dynamic scheduling* based on the array configuration and the weather condition
 - You don't need to go to the harsh, O₂-deficit site.
 - After the observation, Observatory checks the data quality.
 - Then, data will be stored in ALMA Archive and a notification is sent to the P.I..
- *Data reduction pipeline* will produce the maps.
 - You don't need to reduce your data by yourself.
 - NOT ready in the Early Science
- Raw data also provided. Can be reduced with CASA.

User Support: ALMA Regional Centers

ARCs are the interfaces to the user community.

ARCs provides

- User support (f2f/helpdesk)
- Data archive



EA-ARC Taiwan node

- Manager: Dr. Chin-Fei Lee
- Member: Dr. Yu-Nung Su, Dr. Shige Takakuwa & myself
- Missions
 - Provide user support (f2f, email, website..)
 - Organize tutorials (Proposal preparation, data reduction..)
 - Promote ALMA science in Taiwan
 - Send people to ALMA as Astronomer on Duty.
- Facilities
 - Computers (Data reduction computer/ Data archive)



ALMA-T website

The screenshot displays the ALMA-T website interface. At the top right, there are links for "Webmail" and "ASIAA Login". The main header features the ALMA logo and the title "Atacama Large Millimeter/Submillimeter Array - Taiwan" in both English and Chinese. Below the header, there are two main navigation tabs: "General Information" and "Taiwan-ARC & Observing with ALMA". The "General Information" tab is active, showing an "Introduction" page. The left sidebar contains a menu with categories like "Internal Documents" and "Early Science", with sub-items such as "TW-ARC Node", "Introduction", "Staff", "Facility", "User Support", "Observing Support in Chile", "Tutorials and Workshops", "Observing with ALMA", "Overall introduction", "Phase I: Proposal Preparation", and "Phase II: Observing". The main content area under "Introduction" explains the role of the ALMA Regional Center (ARC) and the specific functions of the Taiwanese ARC node.

阿塔卡瑪大型毫米及次毫米波陣列計畫

Atacama Large Millimeter/Submillimeter Array - Taiwan

Internal Documents

Old ALMA Website

TW-ARC Node

[Introduction](#)

[Staff](#)

[Facility](#)

[User Support](#)

[Observing Support in Chile](#)

[Tutorials and Workshops](#)

Early Science

Observing with ALMA

[Overall introduction](#)

[Phase I: Proposal Preparation](#)

[Phase II: Observing](#)

General Information

Taiwan-ARC & Observing with ALMA

Introduction

The ALMA Regional Center (ARC) provides an interface between the [ALMA Observatory](#) and the user community in each region from the stage of proposal preparation to actual data distribution and analyses. All the ALMA users are required to access ALMA through the ARC at their relevant region. There are three main ARCs in the world; [North American ARC \(NA-ARC\)](#), [European ARC \(EU-ARC\)](#), and [East Asian ARC \(EA-ARC\)](#). In [ASIAA](#), we have established the Taiwanese ARC node on November 4, 2009, as a branch of the NA and EA-ARCs. The role of ARCs is classified into two categories, "core functions" and "enhanced functions", and the Taiwanese ARC node will collaborate with EA-ARC for the core functions and with NA-ARC for the enhanced functions. Our Taiwanese ARC node serves all the ALMA user community in Taiwan, and offers supports for the ALMA proposal and observational preparation, data reduction and data analyses. These include;

Speaker: Dr. Mei-Yin Chou (ASIAA)

News

Summary

- ALMA is the very powerful telescope for all fields in astrophysics, astrochemistry, planetary science, and maybe astrobiology.
- First Call for Proposal will be issued in Jan.2011.
- Please consider what you can do with ALMA.
- Any comments/questions about ALMA
- send e-mail to arc@asiaa.sinica.edu.tw

