Enhanced ALMA

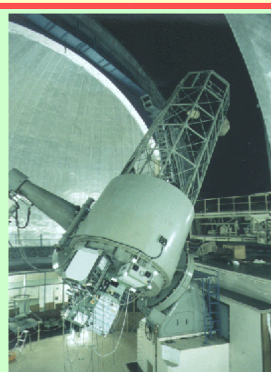
Masato Ishiguro
National Astronomical Observatory of Japan
Access Nova Forum, May 2, 2004

Ground based large telescopes in Japan

It takes 30 ~ 40 years to have a next generation telescope.

optical/IR telescope

Okayama 1960



SUBARU 2000

1960 1970 1980 1990 2000 2010

radio telescope

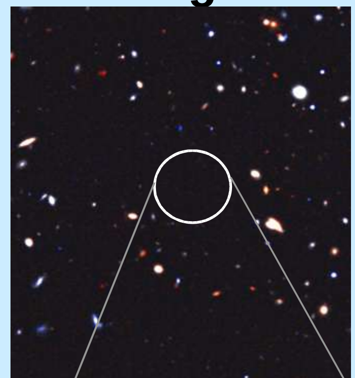
Nobeyama 1982

ALMA 2011

SUBARU and ALMA

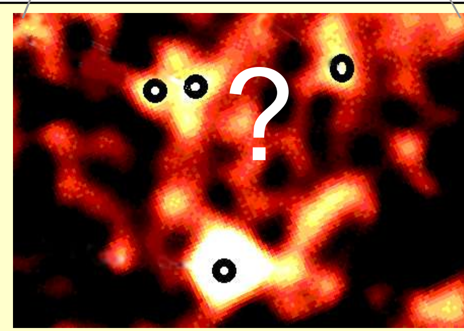
SUBARU (Optical/IR)

Distant galaxies

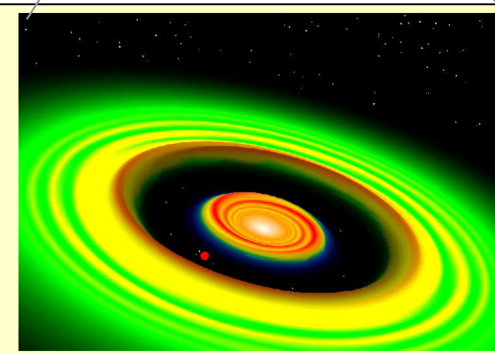


Star forming regions

ALMA (mm- & submm)



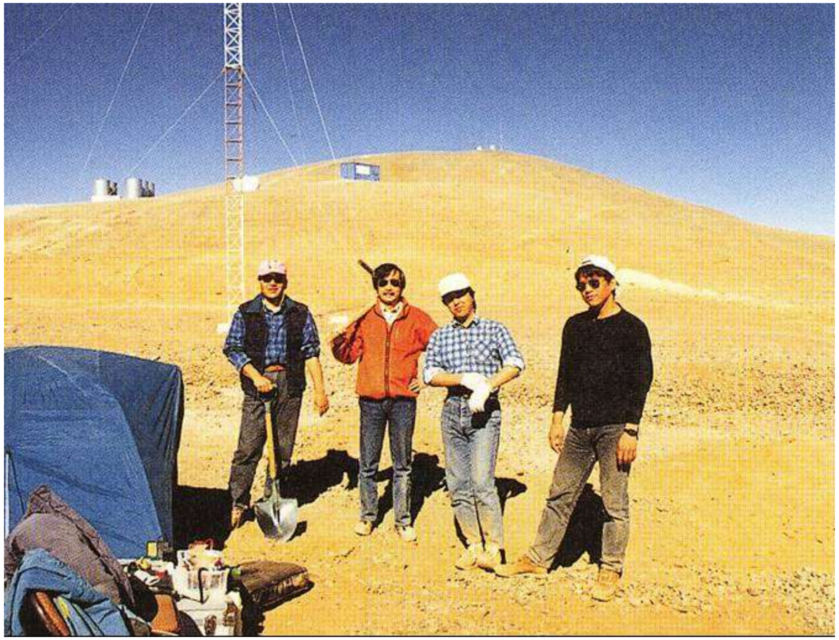
Invisible objects
proto galaxies?



Proto planetary disk

Site survey in Northern Chile by Japanese Team

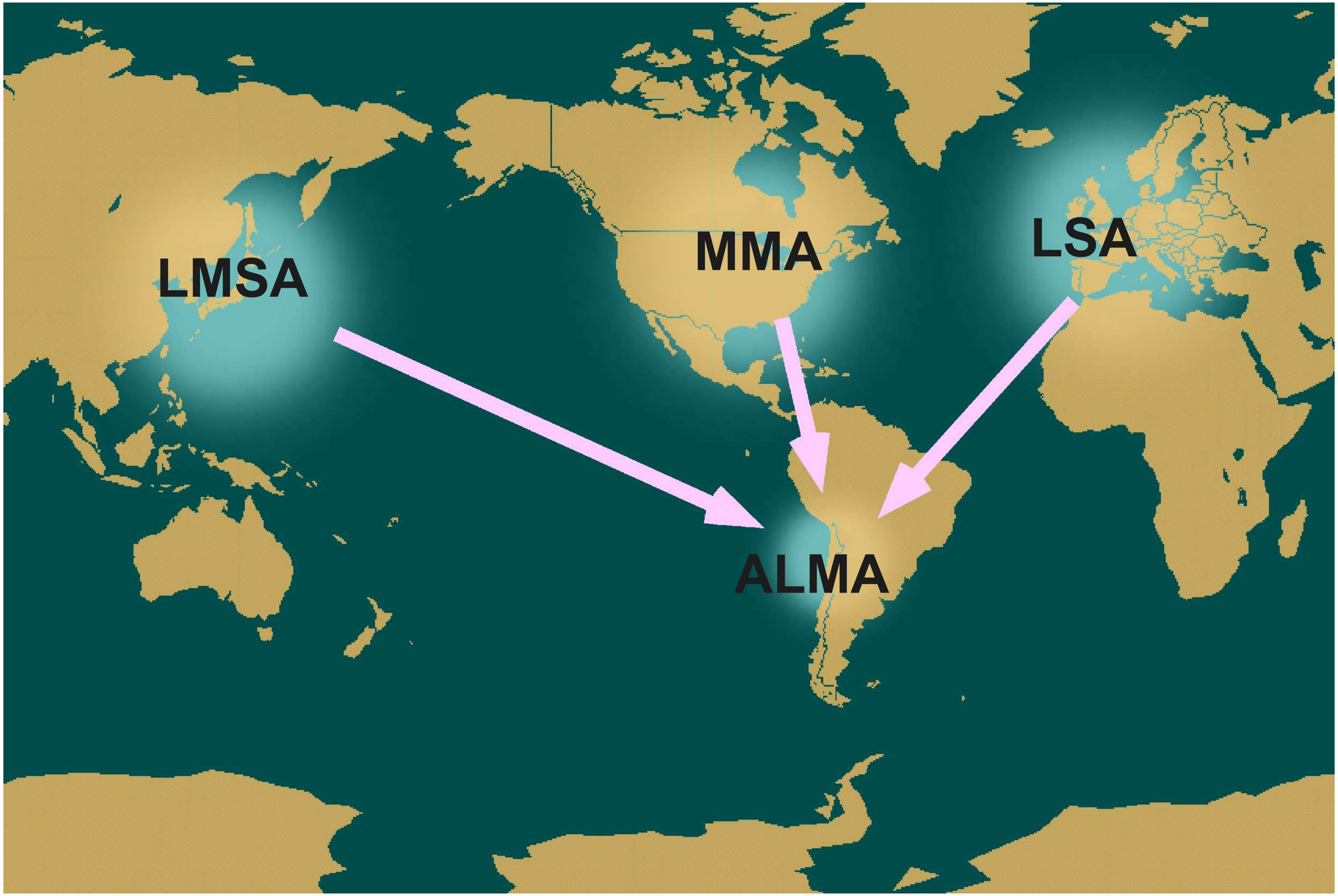
- **Started in 1992**
- **Visited 20 candidate sites**
- **Proposed Chilean site**



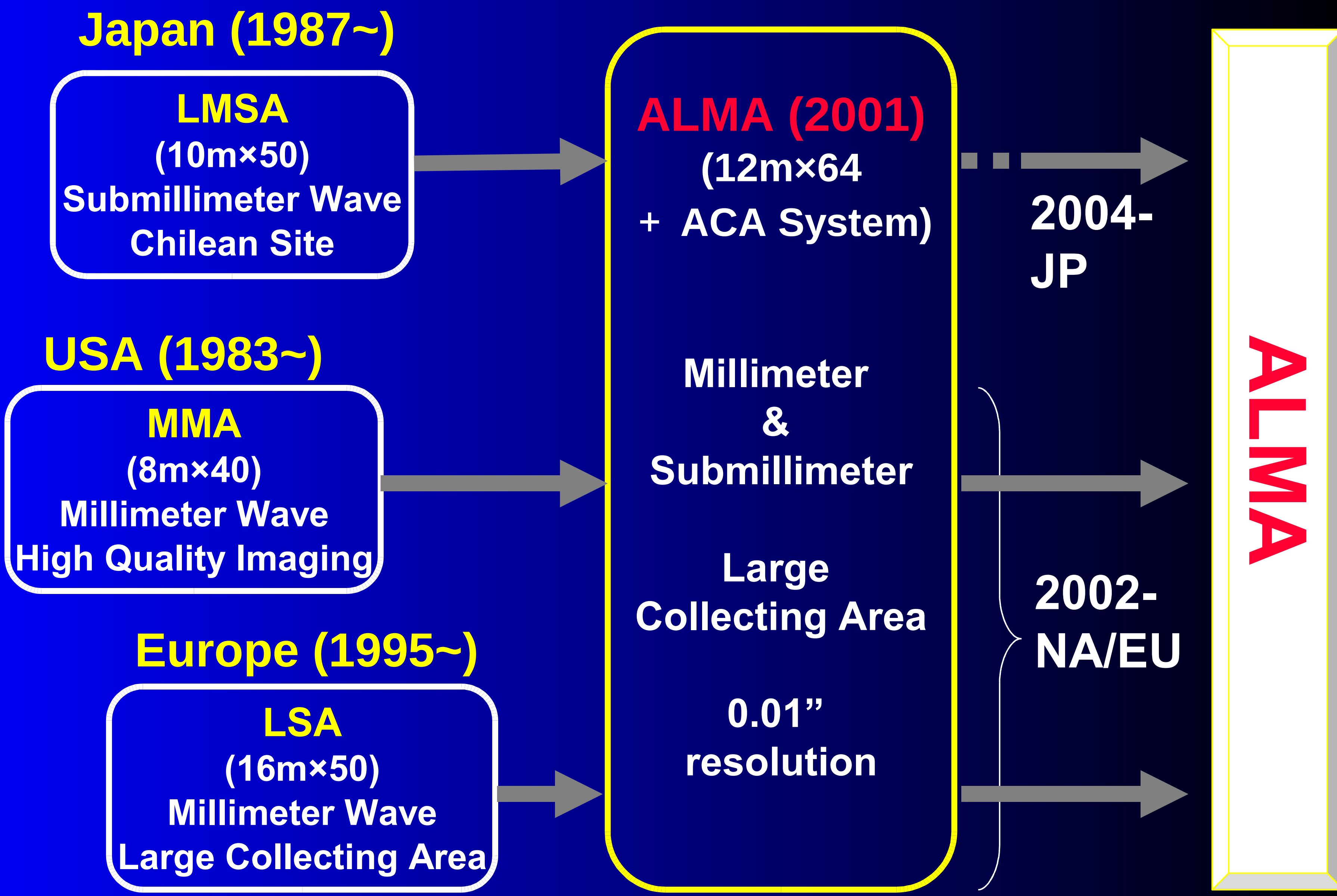
Site testing since 1995

Merge three projects into a single global project

Site selection was one of strong motivation of the merging



History of ALMA



ALMA Enhanced by Japanese Participation

Atacama Large Millimeter Array (**ALMA**)

↓ Japanese Participation

Atacama Large Millimeter/submillimeter Array (**ALMA**)

What's new?

- Atacama Compact Array (ACA) System with 4 12-meter diameter antennas and 12 7-m diameter antennas
- 3 new frequency bands

Major Milestones for ALMA

- 2002 Begin construction of the baseline part of ALMA by NA/EU
- 2003 NA/EU Bilateral agreement signed Feb. 25

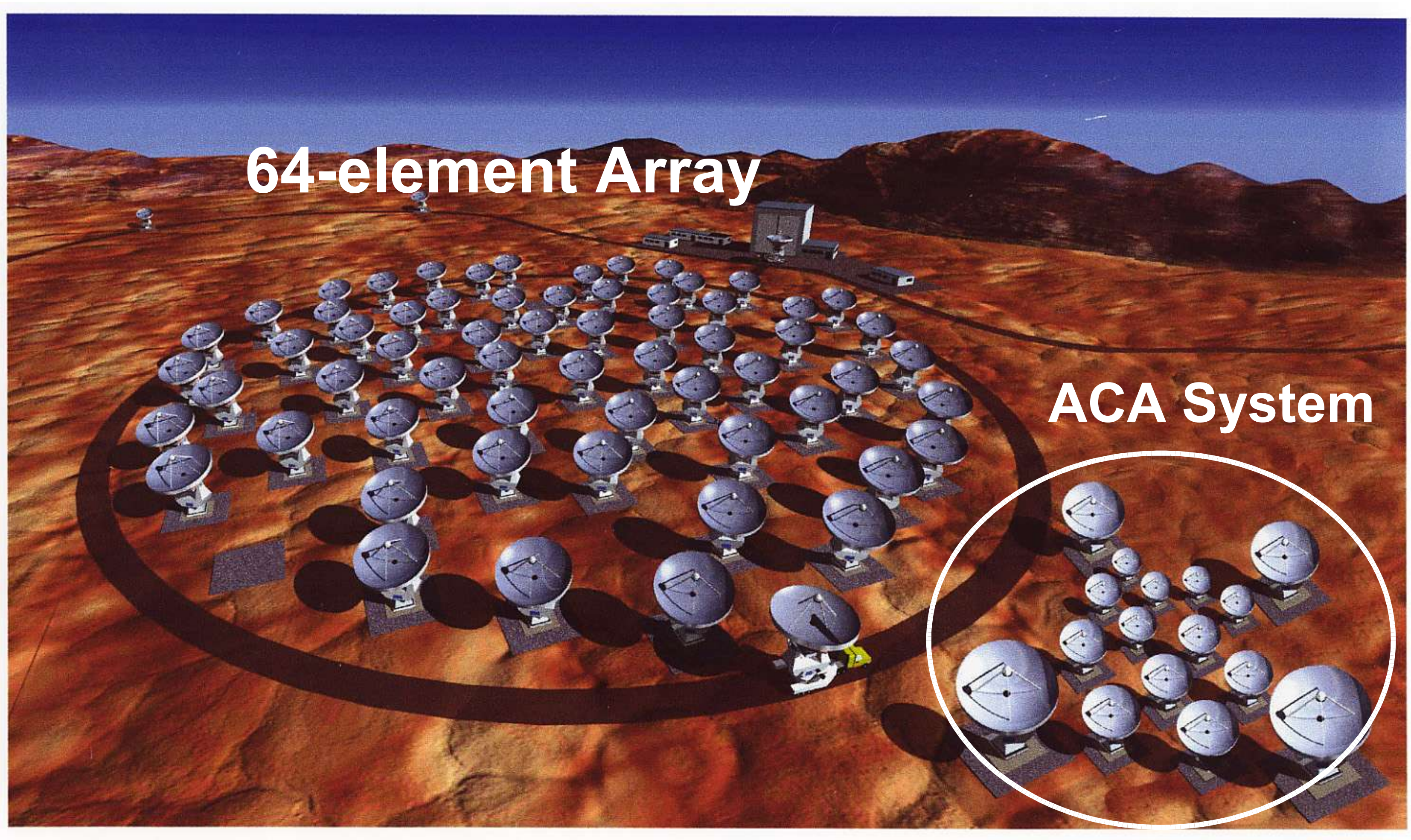
Japanese ALMA budget has been approved in the FY2004 Budget as an 8-year project!

- 2004 Trilateral agreement will be signed in June.
  Japan will join the construction officially
- 2007 Start interim science operations
- 2012 Full science operations

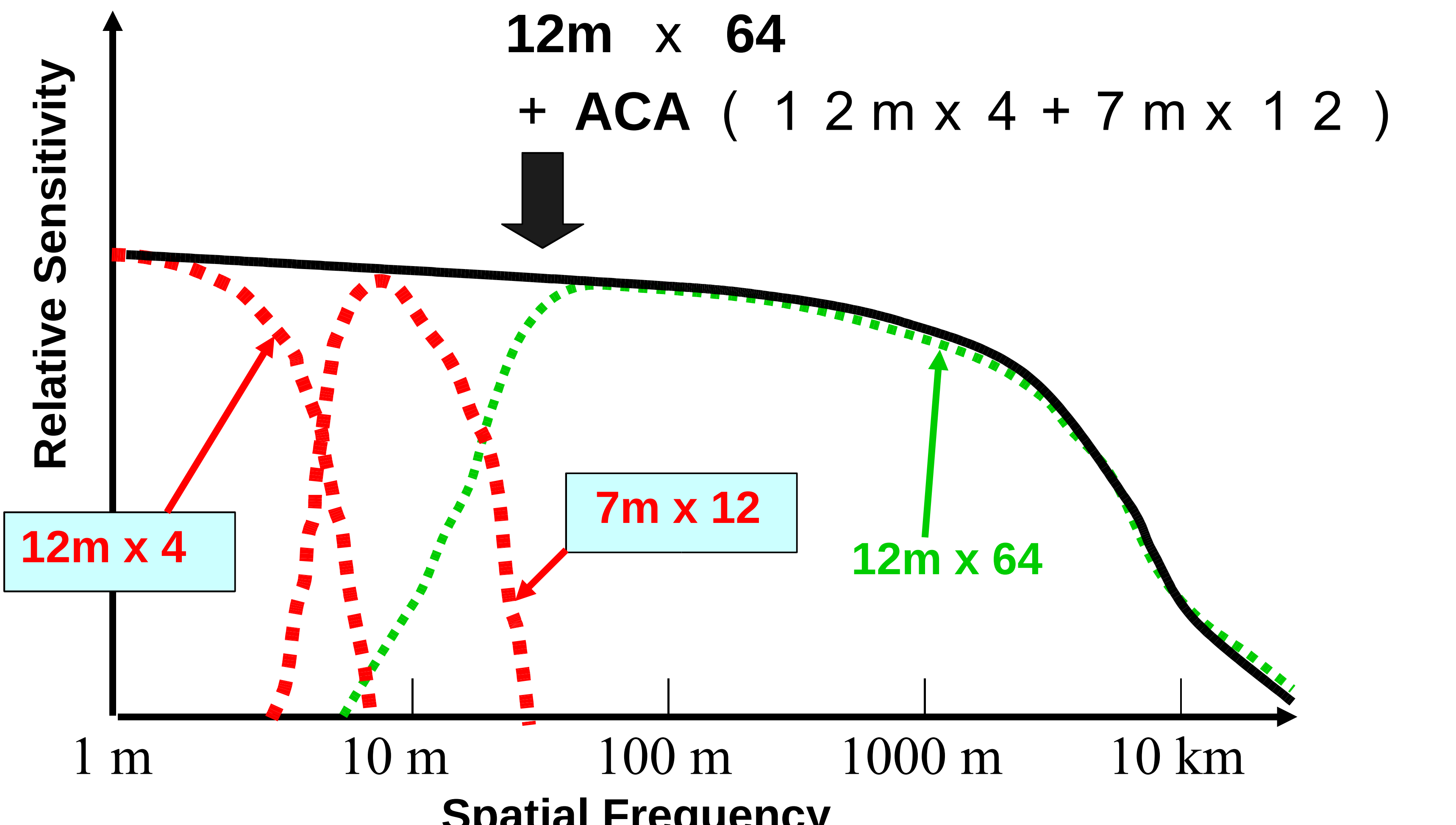
Japanese Contribution Plan

- **Atacama Compact Array (ACA) System**
  - **Twelve 7-m antennas + four 12-m antennas**
  - Higher photometric accuracy by a combination of
    - u-v data with 64-element array
    - On-the-fly single dish mapping
    - short baseline u-v data with ACA
  - **ACA Correlator** (higher sensitivity, simultaneous realiza
- **New frequency bands**
  - Add **Band 10 , Band 8, and Band 4**
- **Contribution to infrastructure & operation**

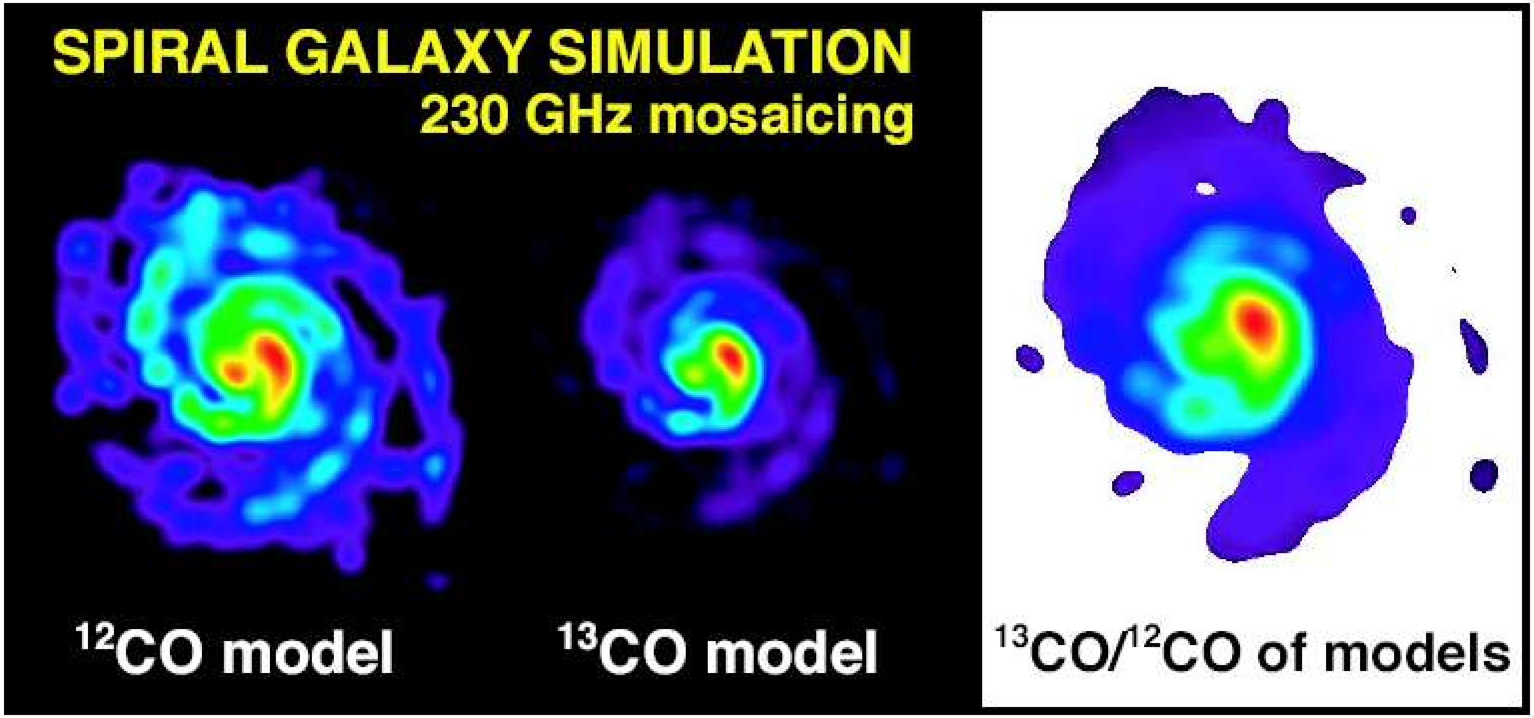
Array Configuration of ALMA



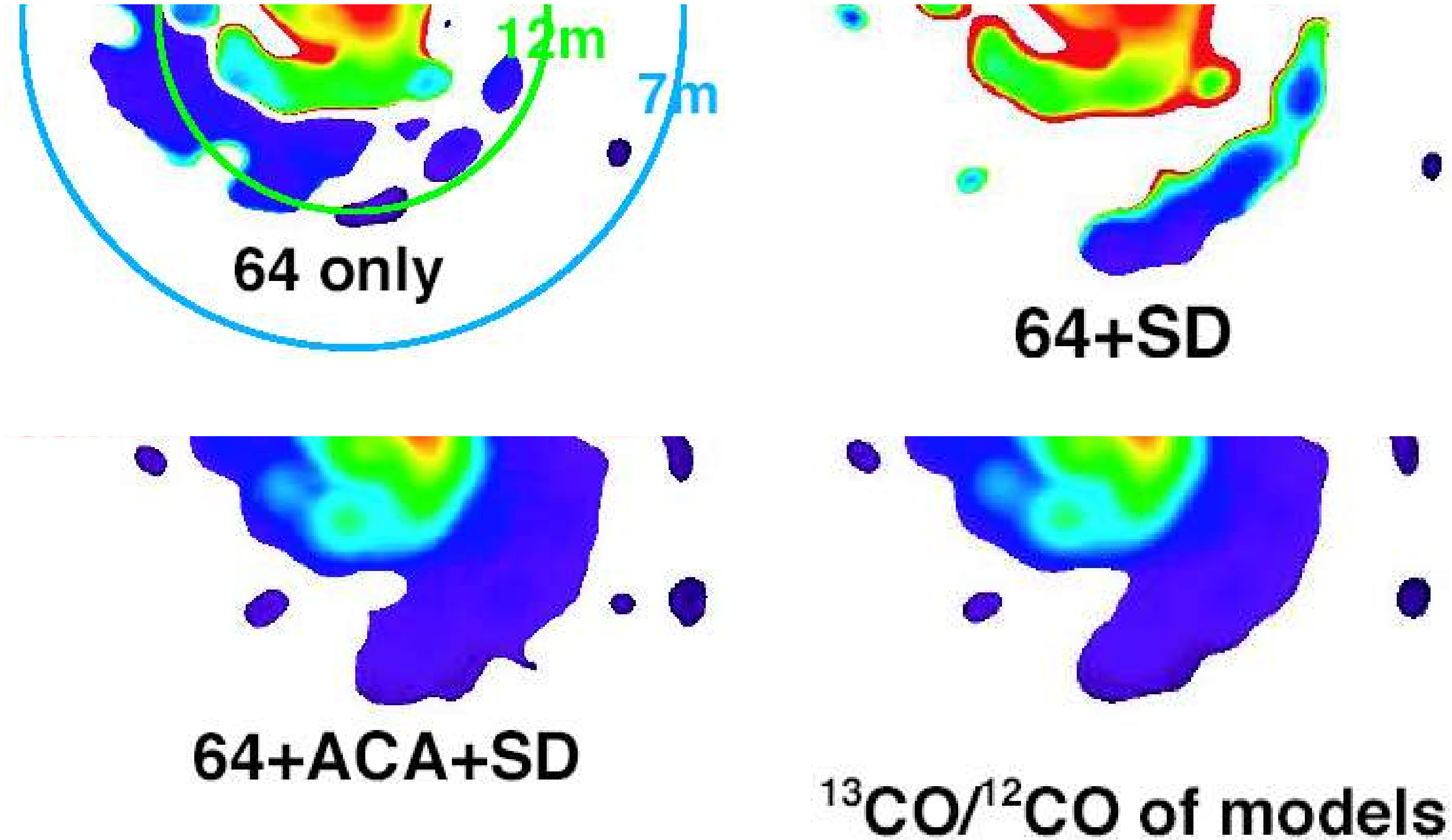
Spatial Frequency Coverage of ALMA



Why we need ACA ?



ACA improves image fidelity



Operation of the ACA System

- **ACA operation**
  - Dynamic scheduling normally independent from the 64-element array
  - Two configurations (source declination)
- **Single-dish operation**
  - Harmonized with ACA observation/calibration (same freq, same source)
  - There are exceptions

ALMA Frequency Bands

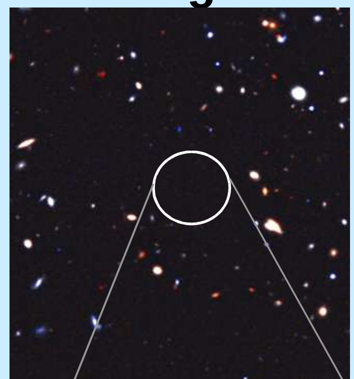
- **Initial Priority Bands in NA/EU Baseline Project**
- **3** (84-116GHz) CO 1-0, high-z CO, SiO
- **6** (211-275GHz) CO 2-1, [CII] z=6-8, dust SED
- **7** (275-370GHz) CO 3-2, [CII] z=4-6, dust SED, Pol.
- **9** (602-720GHz) CO 6-5, [CII] z=1.0-1.4, dust SED

- **Addition of New Bands by Japanese Participation**
- **4** (125-163GHz) CO z~1, [CII] z=10-14, dust SED
- **8** (385-500 GHz) [CI] 492GHz, HDO 464GHz, CO 4-3, [CII] z=3-4
- **10** (767-950GHz) [CI] 810GHz, CO 7-6, dust SED, [CII] z~1

SUBARU and ALMA

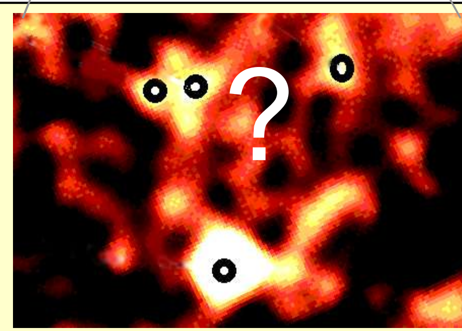
SUBARU (Optical/IR)

Distant galaxies

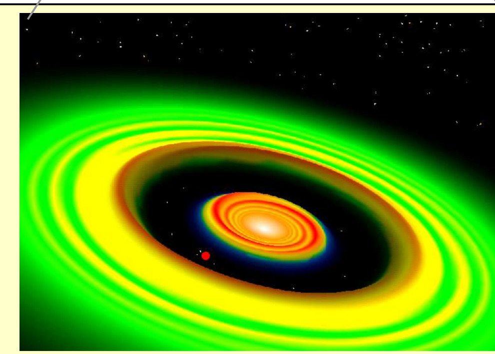


Star forming regions

ALMA (mm- & submm)



Invisible objects proto galaxies?

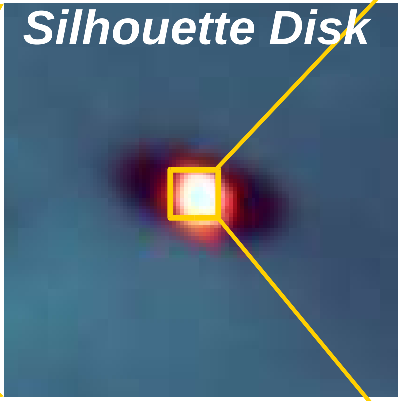


Proto planetary disk

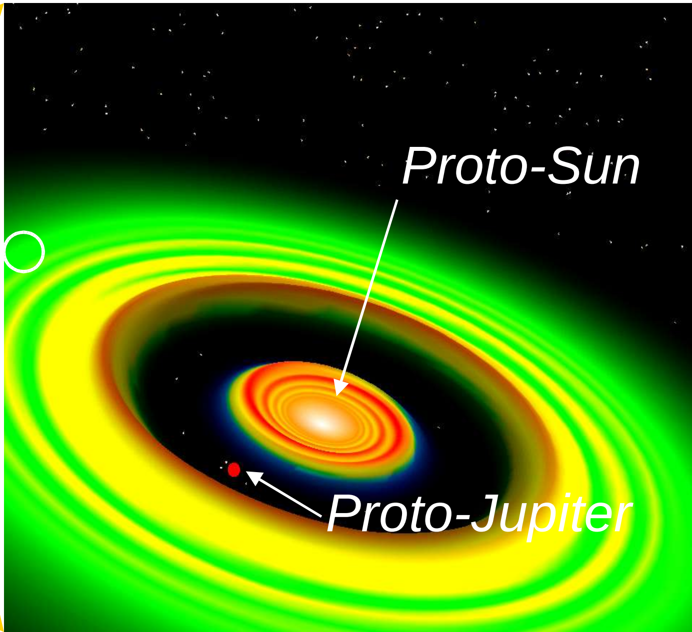
Extra-Solar Planetary System with ALMA

- *ALMA will observe the structure of Proto-Planetary Disks around young stellar objects with 0.01 arcsec resolution (10 times better resolution compared with current big optical telescopes)*

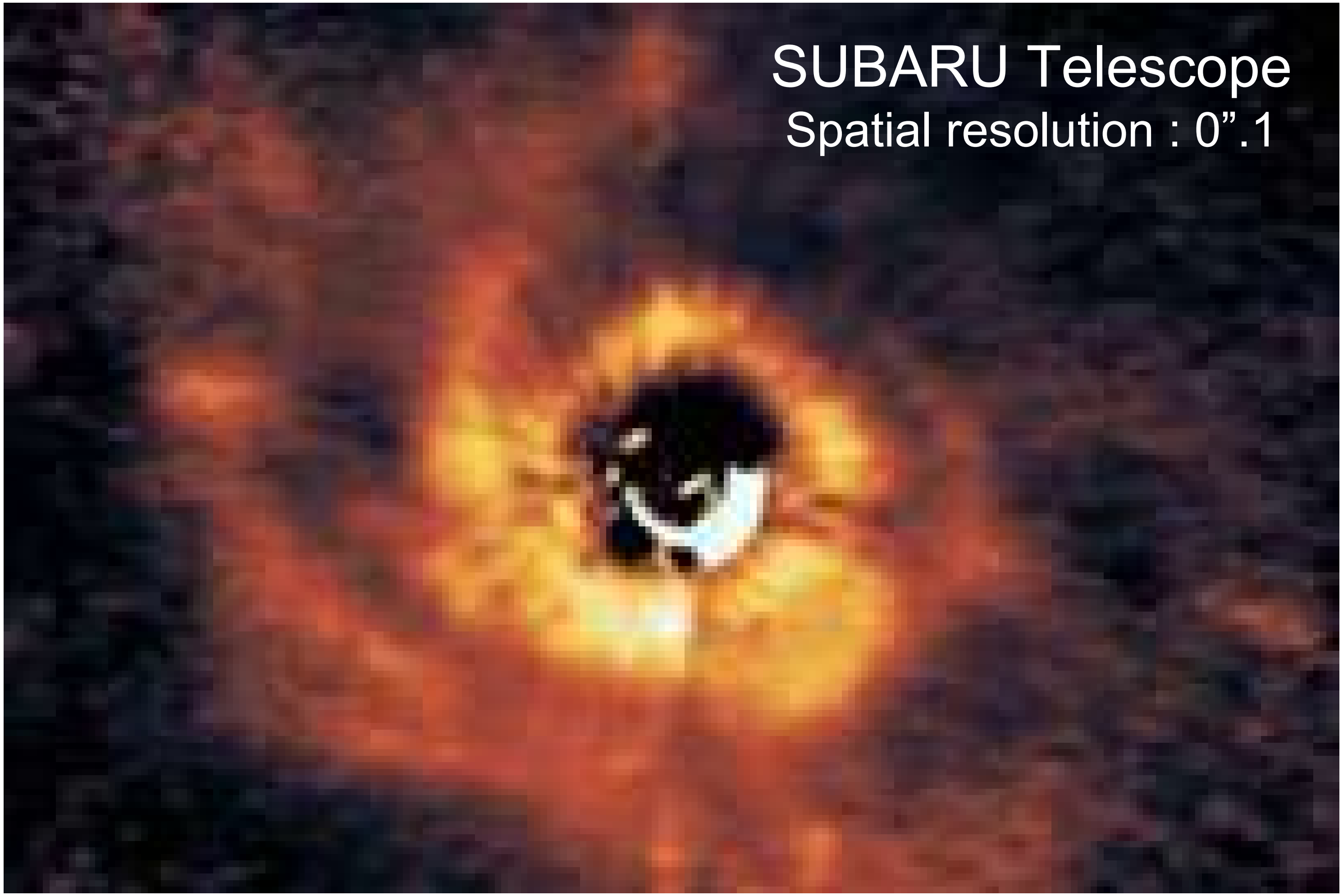
Subaru 、 HST



Proto-Planetary Disk
with ALMA



Circumstellar Disk around AB Aurigae



Coronagraphic Imager with Adaptive Optics at 1.6μm
(Fukagawa, M et al., 2004)

Spiral Structure in the Disk

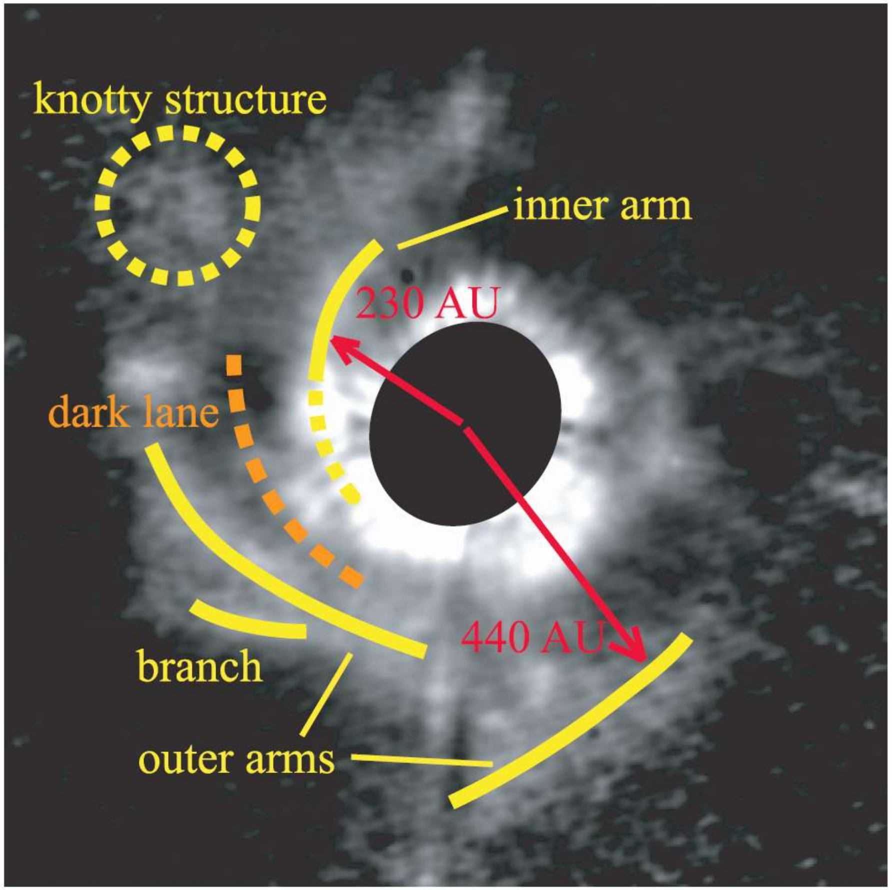
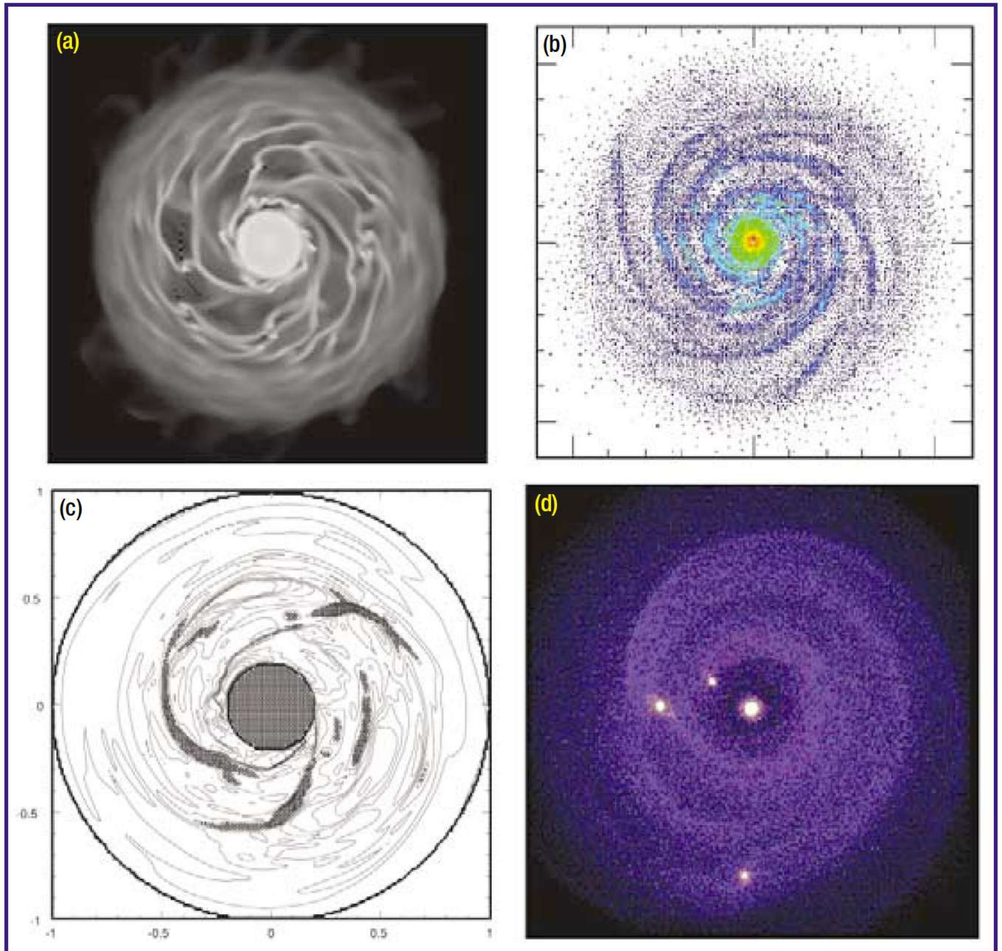


FIG. 3.—Same as Fig. 1, but the image is deprojected with an assumed inclination of 30° to show the "face-on" view of the AB Aur disk. Some of the major features are identified.

Question : ring or spiral?

Theoretical Simulations of Solar Nebula

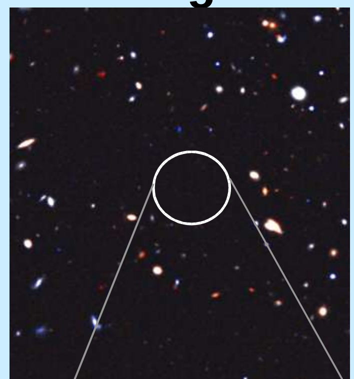


4: Representations of midplane density for simulations of four different solar nebula models. (a) High-resolution locally isothermal simulation of the massive, cold star/disk system studied in Pickett *et al.* (2000a). (b) Surface mass density for the locally isothermal SPH simulation of a protostellar disk model from Nelson *et al.* (2000). (c) Equatorial mass density for the high-resolution solar nebula simulation with radiative physics in Boss (2002). The cross-hatched regions are areas of high over-density (clumps). (d) Surface mass density of the locally isothermal SPH simulation in Mayer *et al.* (2002).

SUBARU and ALMA

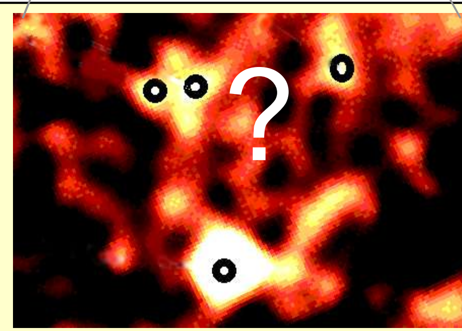
SUBARU (Optical/IR)

Distant galaxies

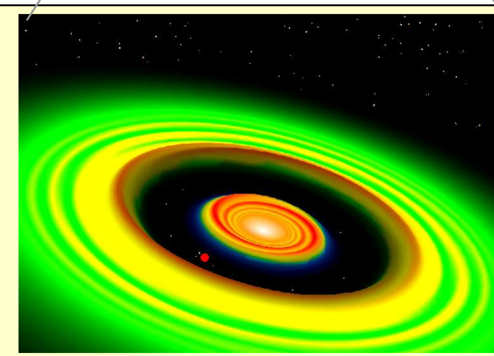


Star forming regions

ALMA (mm- & submm)

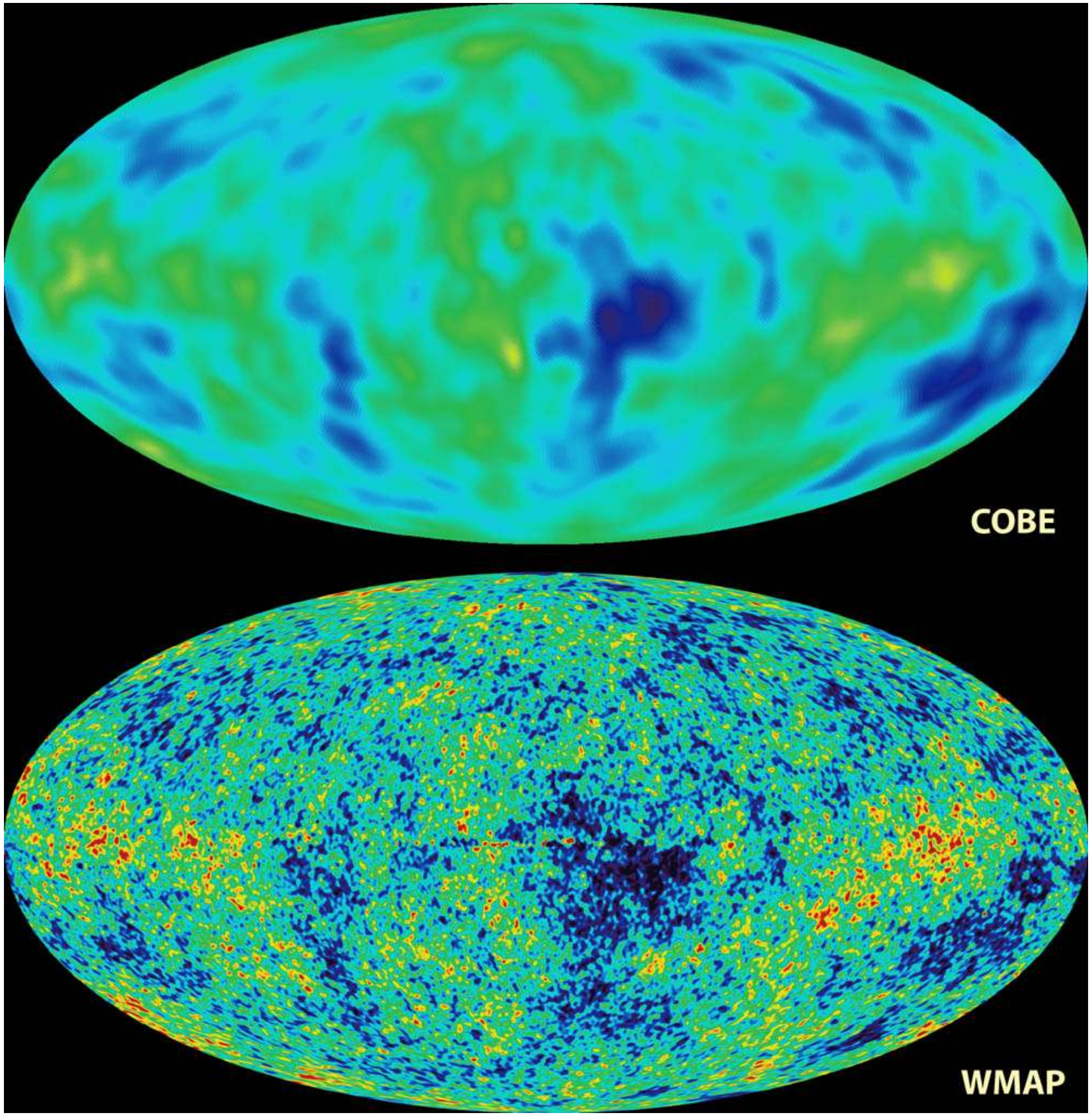


Invisible objects
proto galaxies?



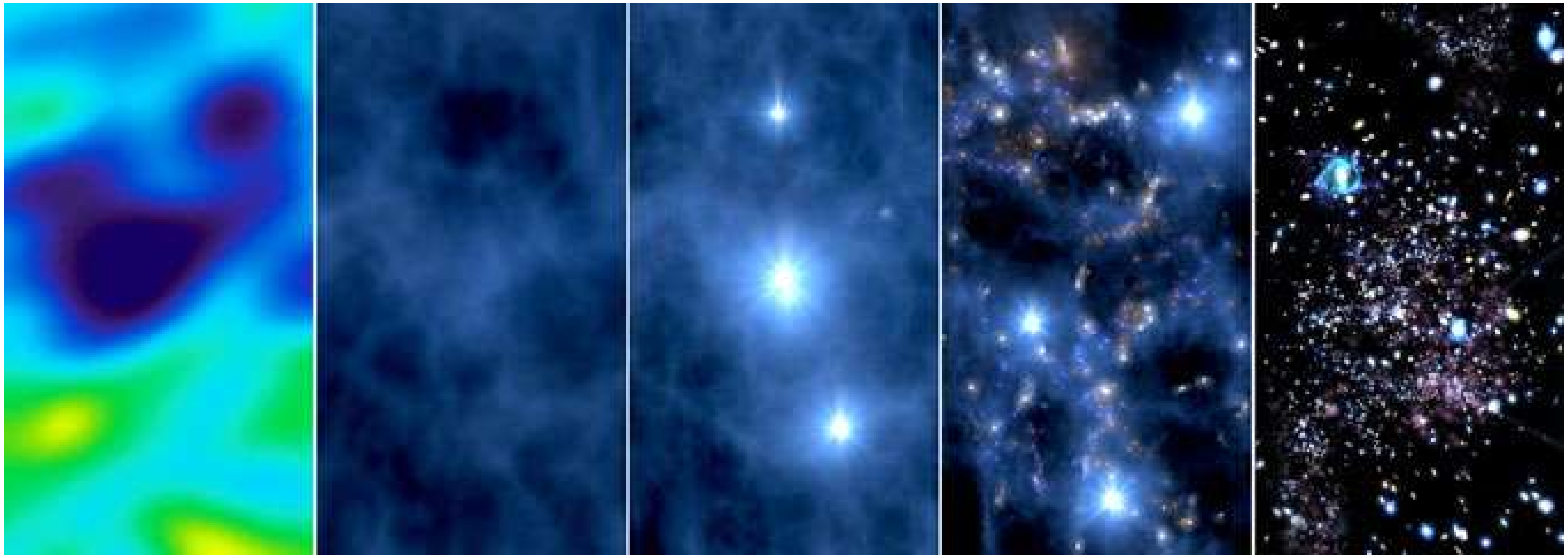
Proto planetary disk

From COBE（1992） to WMAP（2003）



（ http://map.gsfc.nasa.gov/ ）

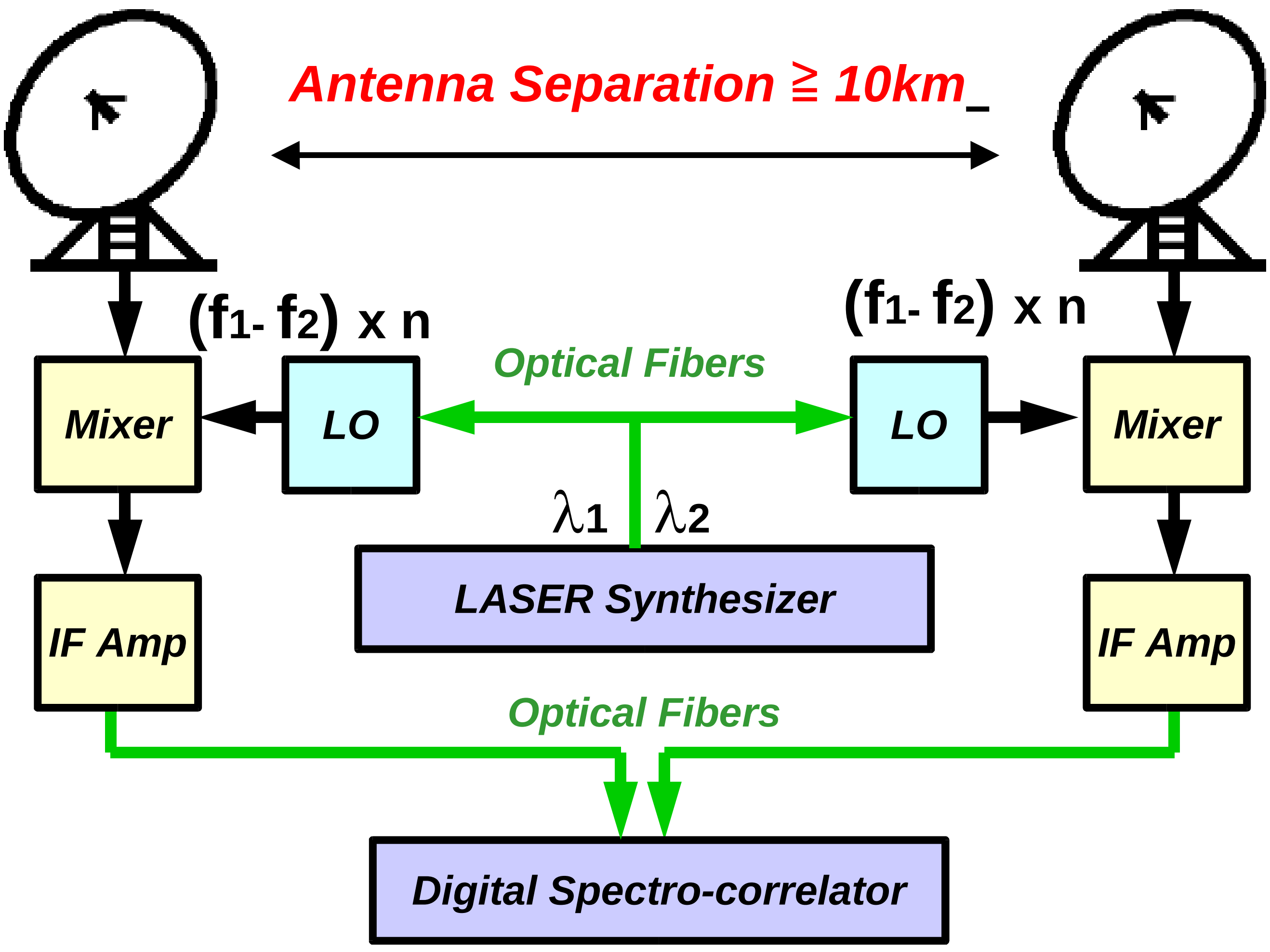
Creation of Stars and Galaxies from Primordial fluctuations



380 Kyr **200 Myr** **13.7 Gyr**

（ http://map.gsfc.nasa.gov/ より

Radio Interferometer System



Key Components in ALMA System

- High precision antennas
- Low noise receivers
- Phase stabilized LO (local oscillators) system including long distance (~20km) transmission lines
- Wide band correlator system
- Calibration system
- Control &Imaging software system

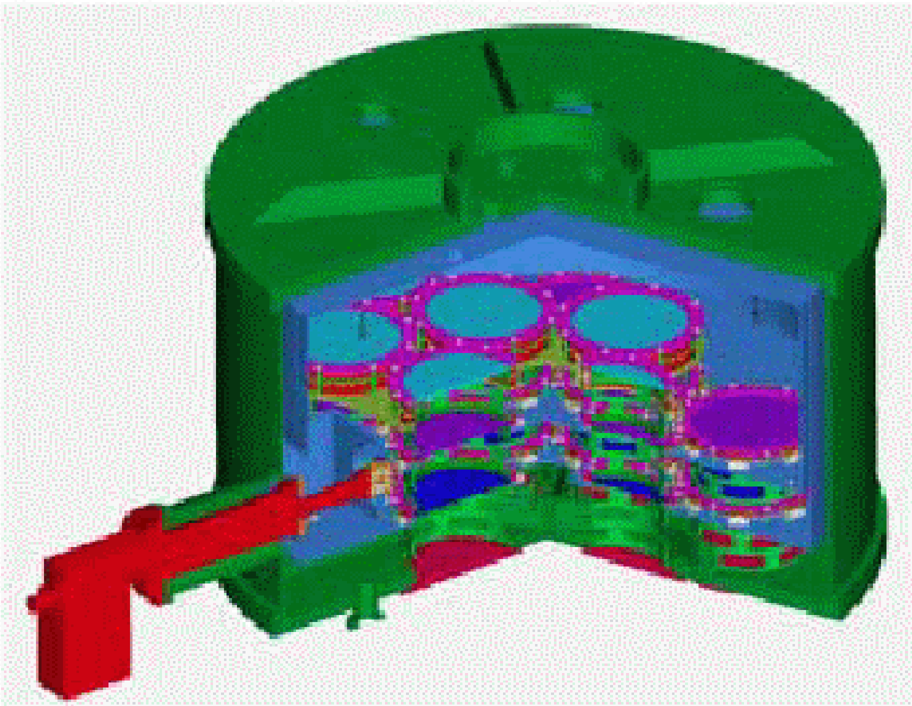
Japanese *12-m Prototype Antenna*

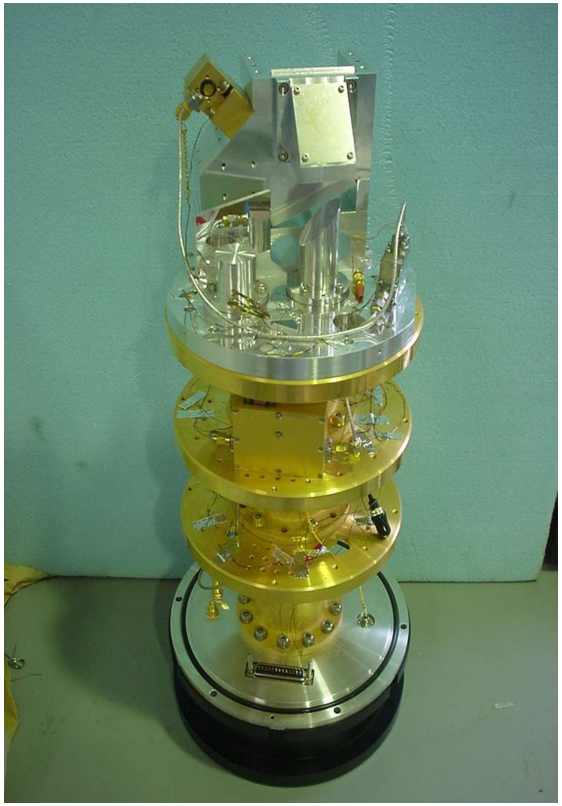
Performance testing

- Photogrametry
- Holography
- Optical pointing
- Radiometric tests

Achievements:
Surface accuracy ~15-20μm
Pointing accuracy ~ 1”

ALMA Front End System





- Cryogenic system (~1m diameter)
- Up to 10 cartridges

Engineering Models for ALMA FE Cartridges

- Engineering models of frontend cartridges
  - Band 8 &10 EM being tested on ASTE

ALMA Frequency Bands

Band	Min. Freq. (GHz)	Max. Freq. (GHz)	Manuf.
1	31.3	45	—
2	67	90	—
3	89	116	NA
4	125	163	JP
5	163	211	—
6	211	275	NA
7	275	370	EU
8	385	500	JP
9	602	720	EU
10	787	950	JP

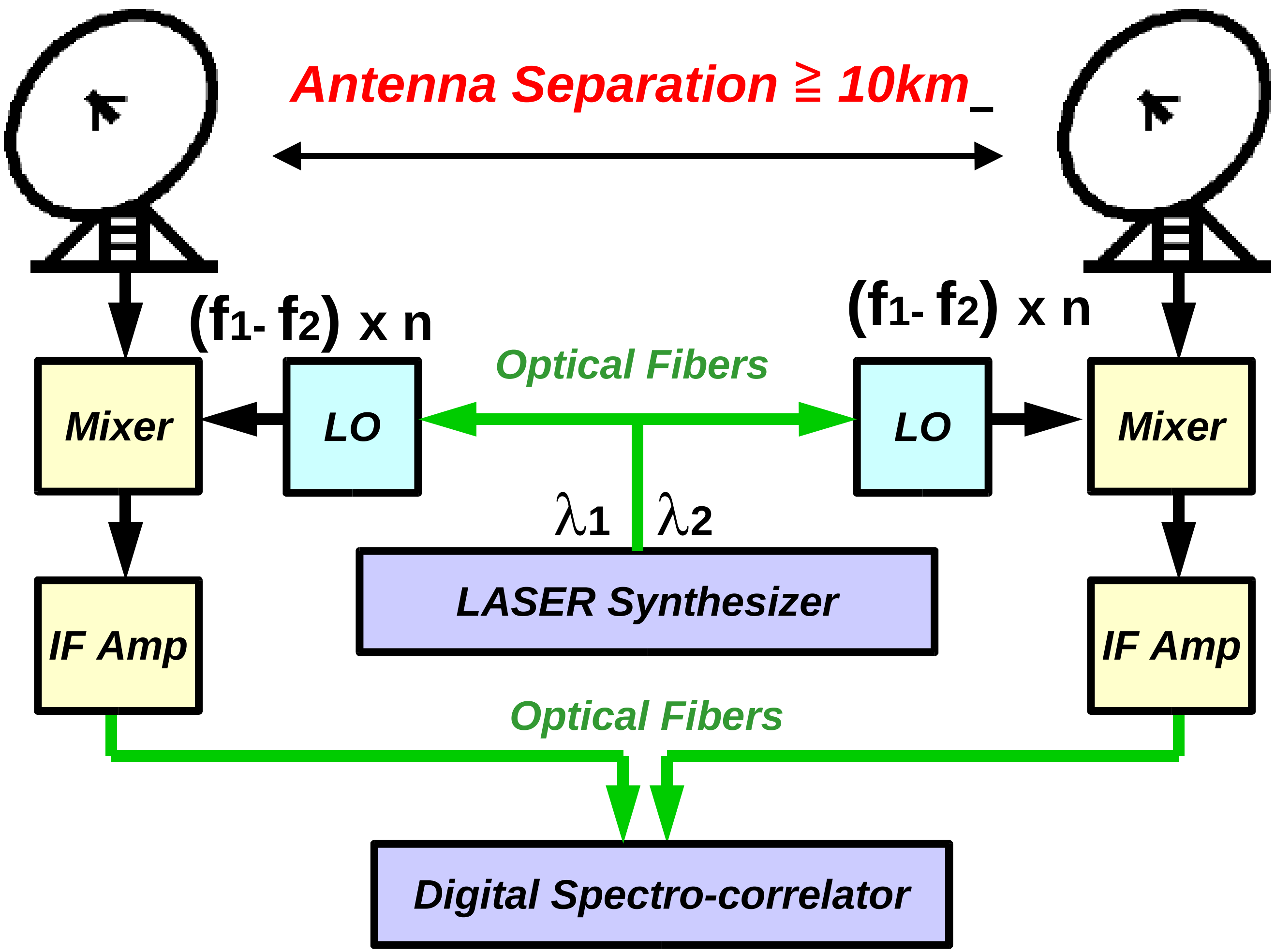
mm wave (Bands 1–6)

sub-mm (Bands 7–10)

Development for SIS junctions for submm

New clean room at NAOJ Mitaka

Radio Interferometer System



Advantages of Photonic LO

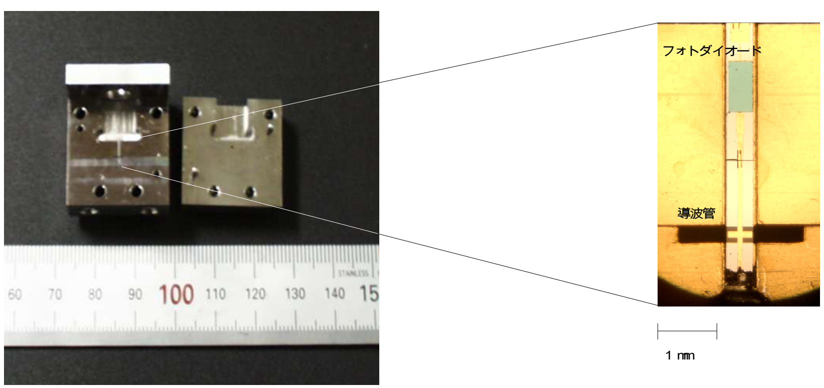
- ***No Mechanical Tuning***
  - ***Simple***
  - ***Reliable***
  - ***Cryogenic Opertaion?***

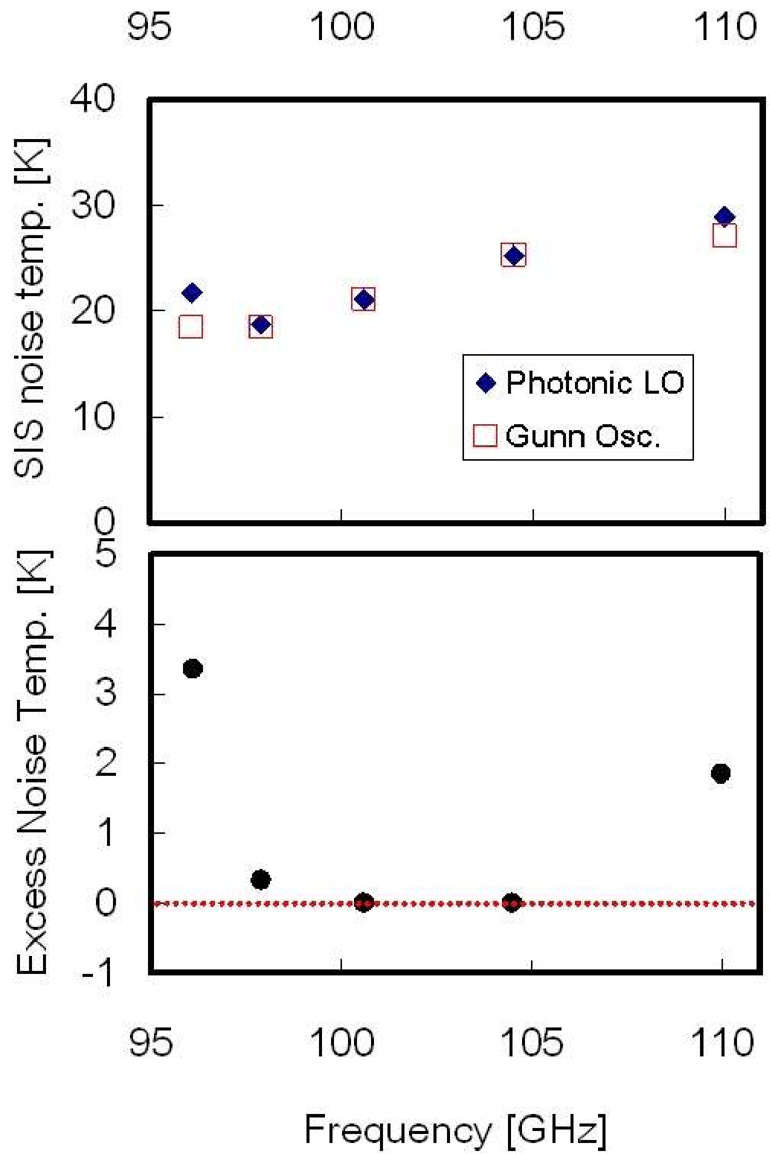
- λ***1.55***μ***m Wavelengths***
  - ***Commercially Available Parts***
  - ***Low Transmission Loss***

⇨
- ***Suitable for transmitting coherent LO signal over a long distance in a large interferometer array***
- ***Suitable for a space mission***

W-Band Low Noise Photonic LO

- *100 GHz WG-type Photomixer using* ***UTC-PD developed by NTT***
- *Wide band design for* ***full WG band (75-120GHz)***
- *High output power ~* ***2mW*** *with* ***low excess noise*** *over Gunn LO*





ACA Correlator

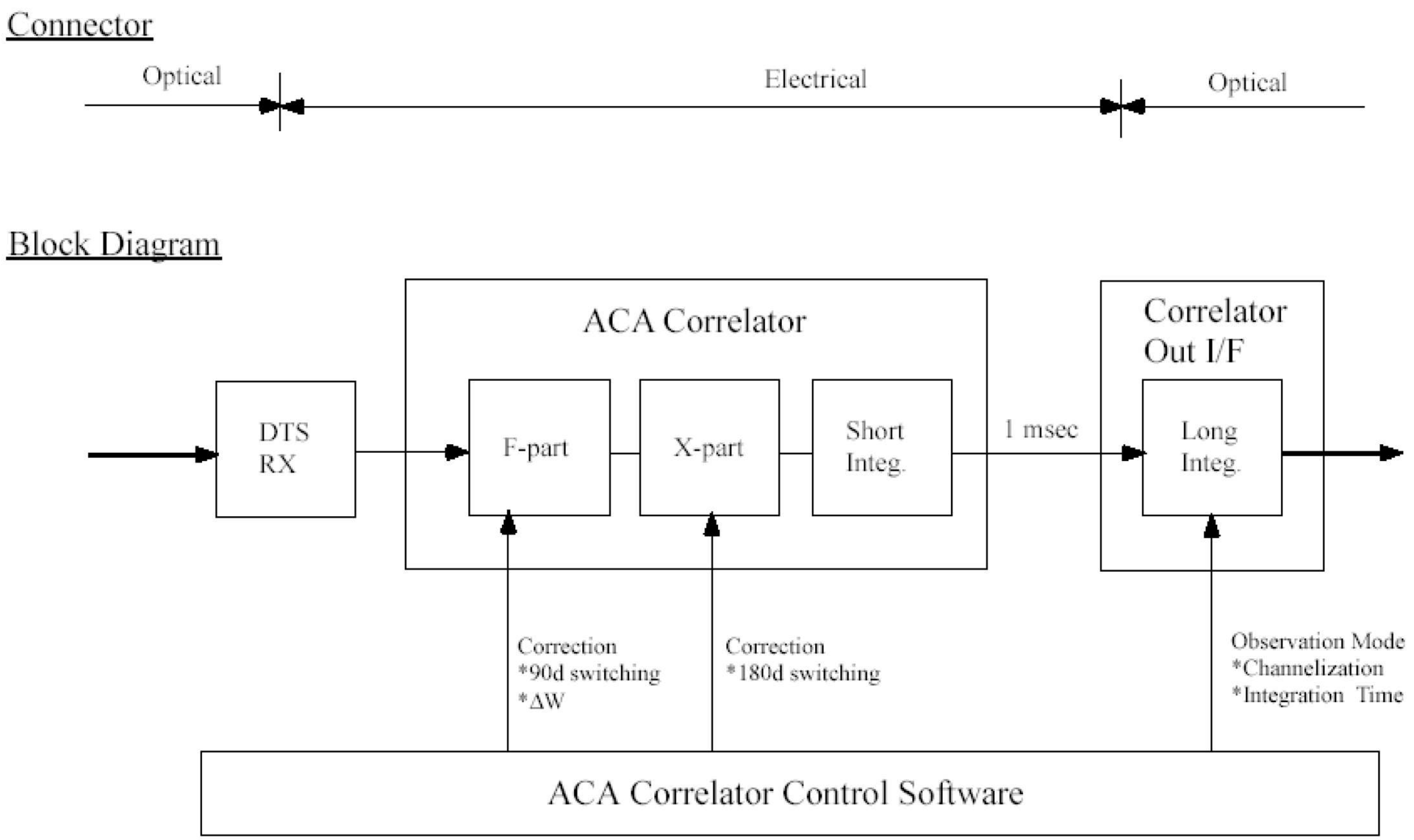
- **12 element interferometry + 4 total power**
- **16 element interferometry**
- **Visibility data rate**

  average 0.12 M visibility/sec

  peak 1.20 M visibility/sec

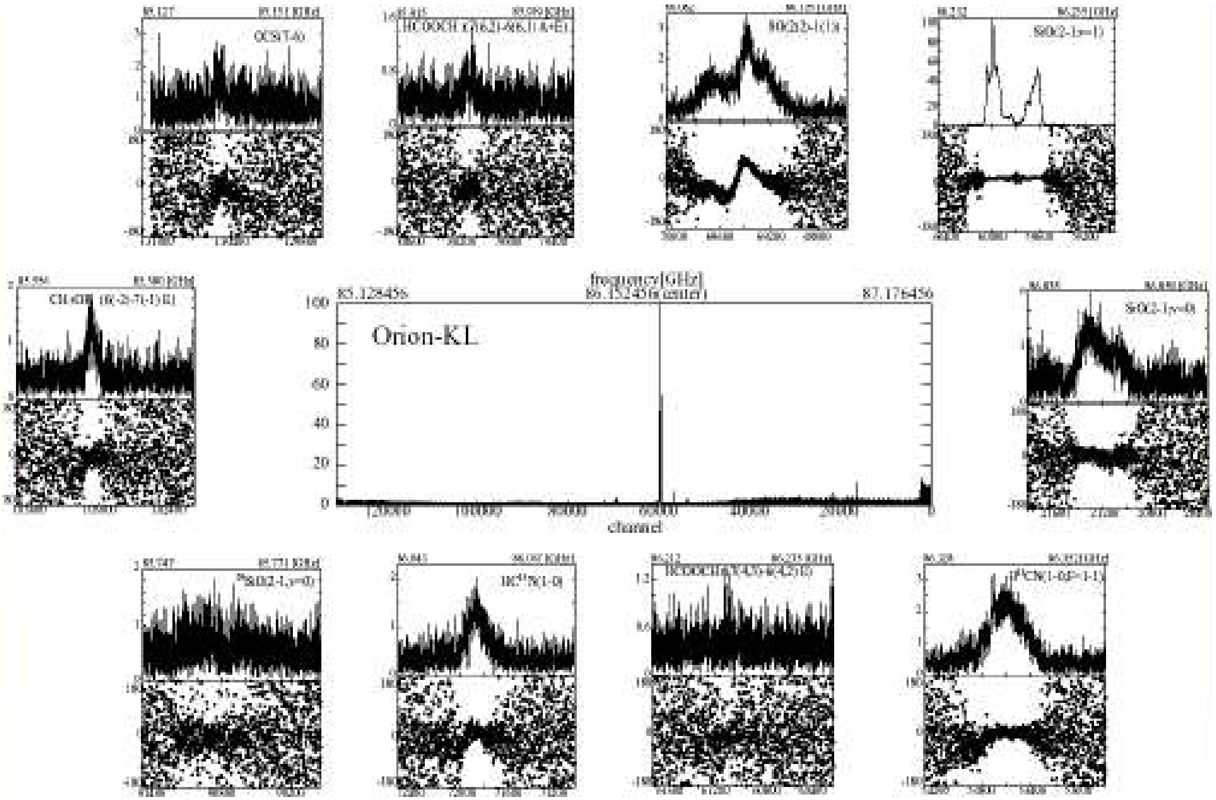
  (6 % of the 64-element array)

ACA Correlator Design



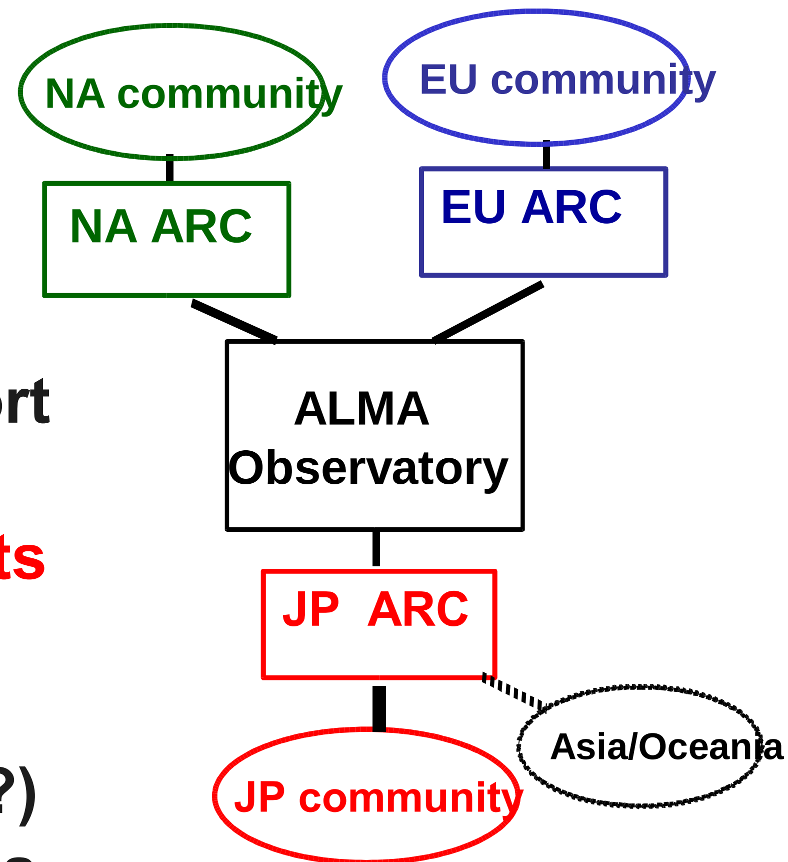
2GHz Spectrum of Orion-KL with the Pre-prototype FX Correlator

- Ori-KL@86GHz NMA with 131000 ch over 2GHz bandwidths
- The performance demonstrated with detecting 20 line features by 1.5-hour integration !



ALMA Regional Centers (ARCs)

- Science Support Services
  - Proposal & observation
  - Preparation user support
  - Data quality assurance
  - Data analysis user support
  - ALMA archive node
  - Astronomer-on-Duty shifts in Chile
- Technical Support Services
  - Remote repair facilities (?)
- Development Support Services
  - Computing system
  - maintenance & development



Collaborations with Univ. Chile and NTT

- Site survey in Northern Chile (Univ. Chile)
- Site testing at Pampa la Bola and Rio Frio (Univ. Chile)
- Access Nova Forum (Univ. Chile, NTT)
- Remote control of ASTE Telescope (Univ. Chile, NTT)
- Joint developments for photonic local oscillators (NTT)

Collaborations are expected to be expanded!


The End

Picture of Hosteria Las Torres