Nobeyama Millimeter Array

URSI General Assembly, Montreal Canada
August 25, 2017

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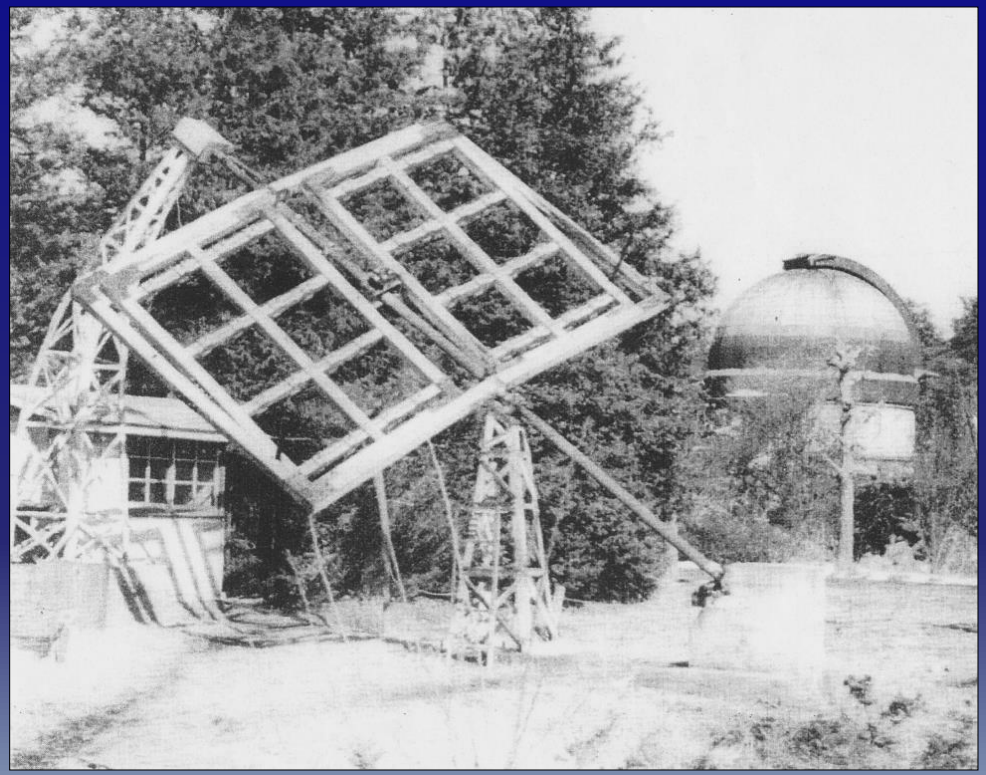
Japanese radio astronomy started with solar radio observations（1949～）

The 3.3 GHz horn antenna
at Osaka University
(Minoru Oda and TatsuoTakakura)



The 200MHz broadside array at
Tokyo Astronomical Observatory
(Takeo Hatanaka)

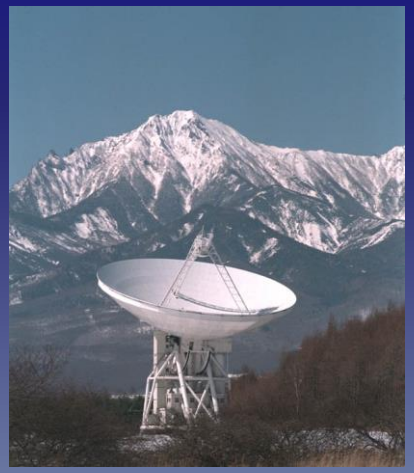
The largest interferometer before NMA（1967）

The radio interferometer at Toyokawa Observatory of Nagoya University used to observe the Sun at 8cm with 34 3-m antennas in the E-W direction. The system was expanded to T-shaped array by adding 17 3-m antennas in the N-S direction in 1974.

Japanese Large Radio Telescope Project

- Discussions of plans started in early 1960s.
  - 200m spherical reflector
  - Interferometer with two 50-m antennas
- 1964~1967
  - 60-m telescope mainly for HI observations
    + 30-m telescope for shorter wavelengths
  - 45-m telescope + Interferometer with two 20-m antennas
- 1970 ~1971: Final Plan decided
  45-m telescope + Interferometer with five 10-m antennas, Nobeyama site
  ⇒ Nobeyama Millimeter Array (NMA)
- 1974 λmin 1cm → 3mm
- 1978 Construction started

Construction of the Nobeyama Radio Observatory started in 1978 and completed in 1982



45-m Radio Telescope

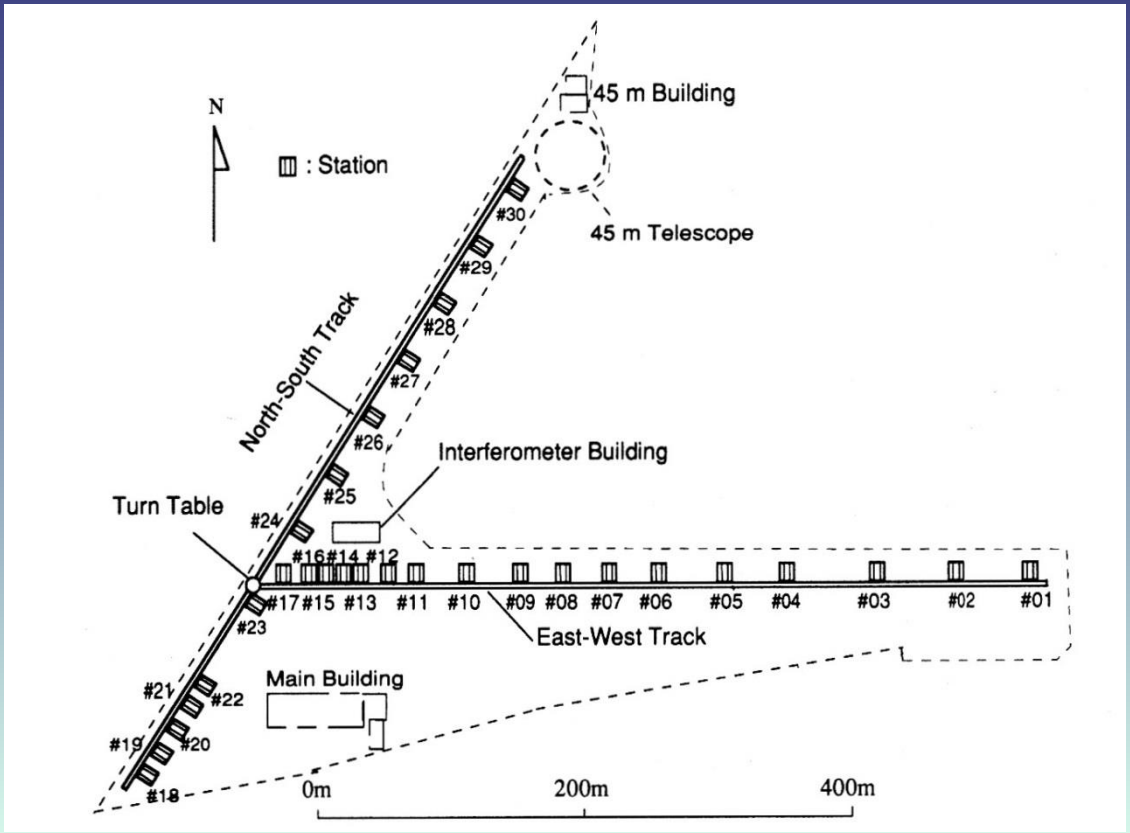
Nobeyama Millimeter Array

Nobeyama : 1350m altitude

30 antenna pads with the maximum baseline of about 600m

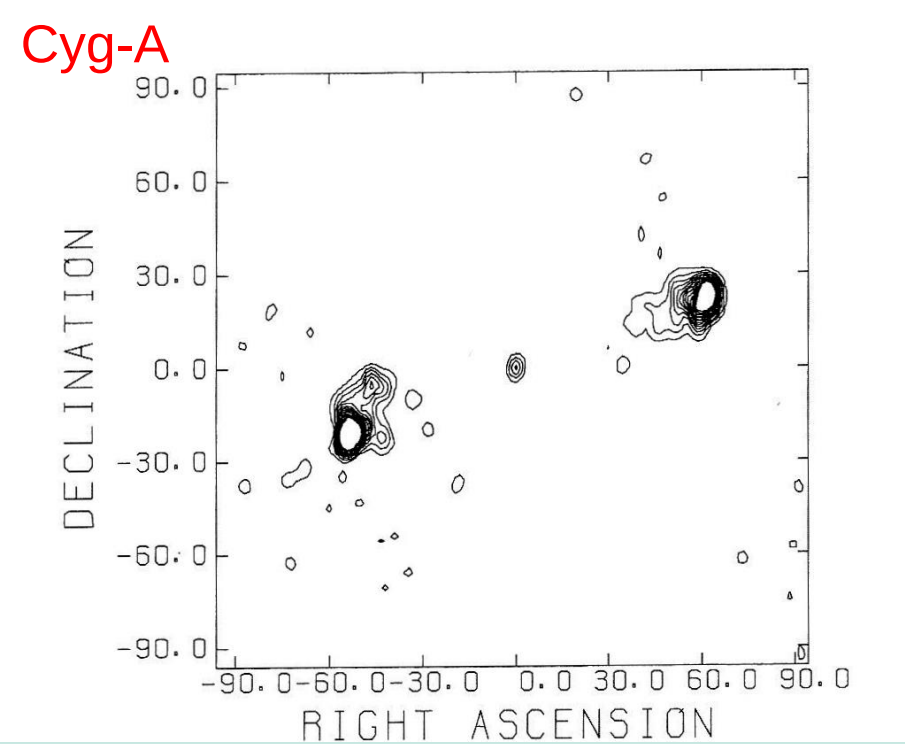
Array configuration of NMA

- 17 pads in E-W (560m) and 13 pads in N-W (520m)
  The configuration was restricted by the land available
- In the “Rainbow” mode, the 45-m antenna was used as an element of the interferometer

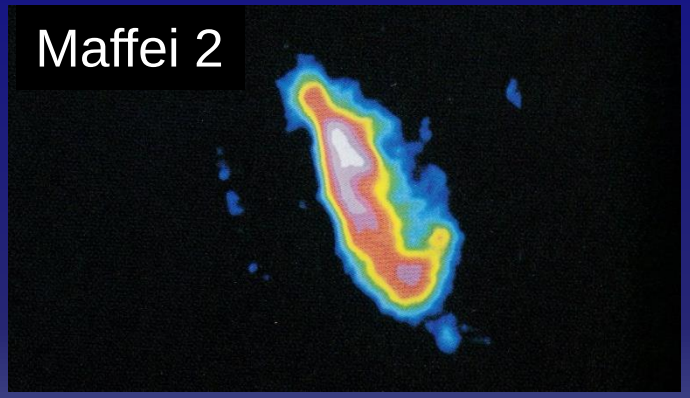


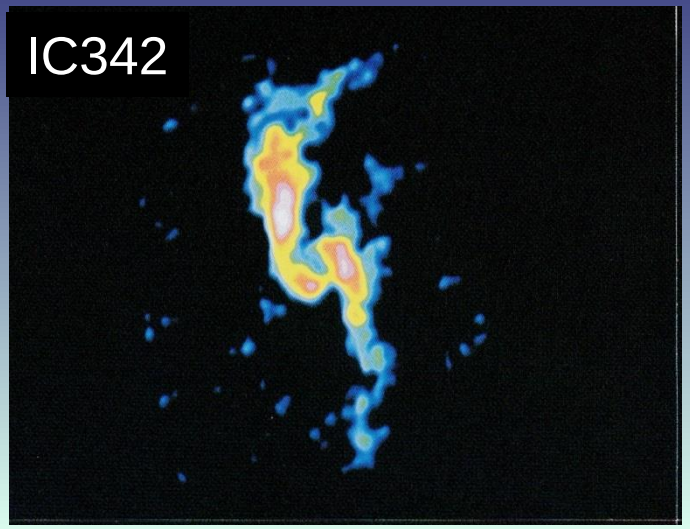
Aperture synthesis mappings with NMA

In 1984, the first aperture synthesis observation was made at 22GHz with 3 configurations and the maximum baseline of 450m.



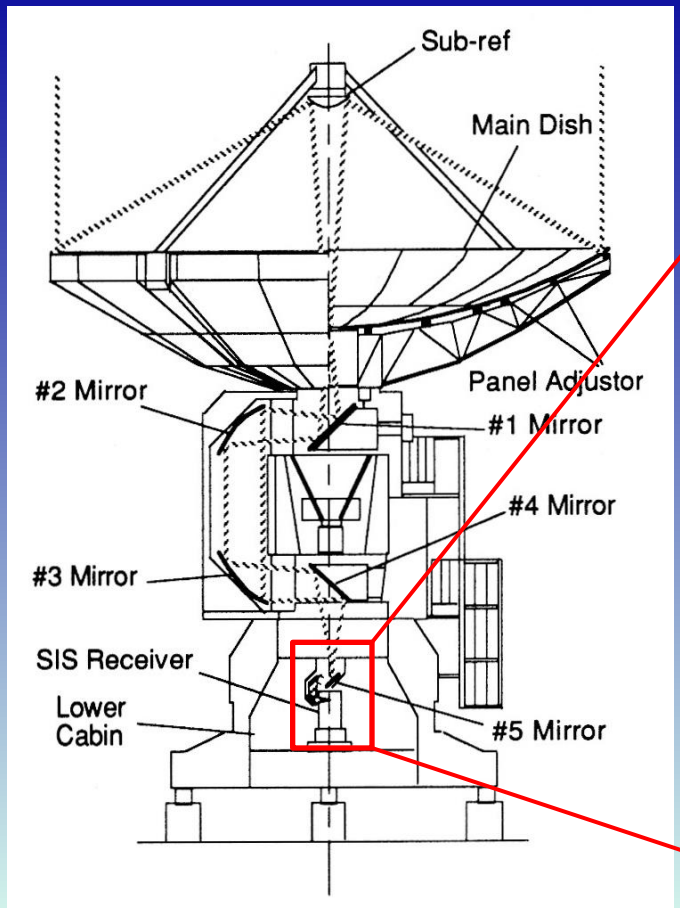
In 1988, the first mm-wave observations were made at 115GHz.

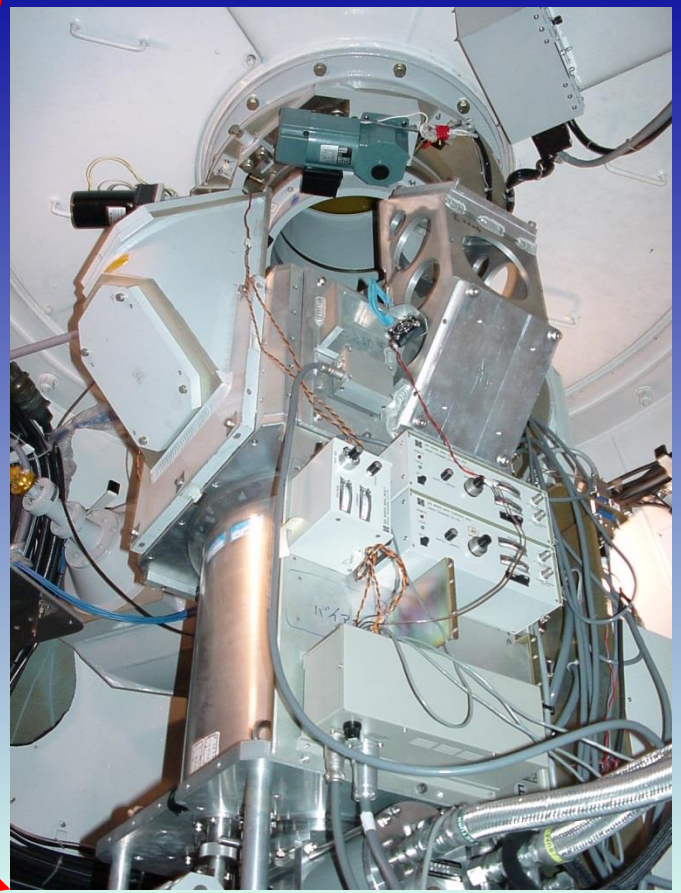




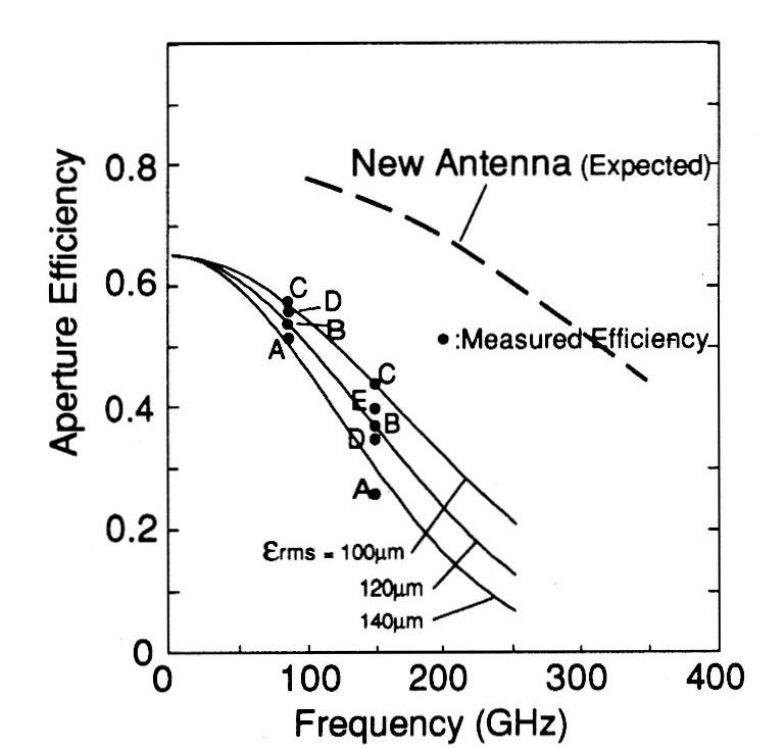
Antenna optics and receiver system

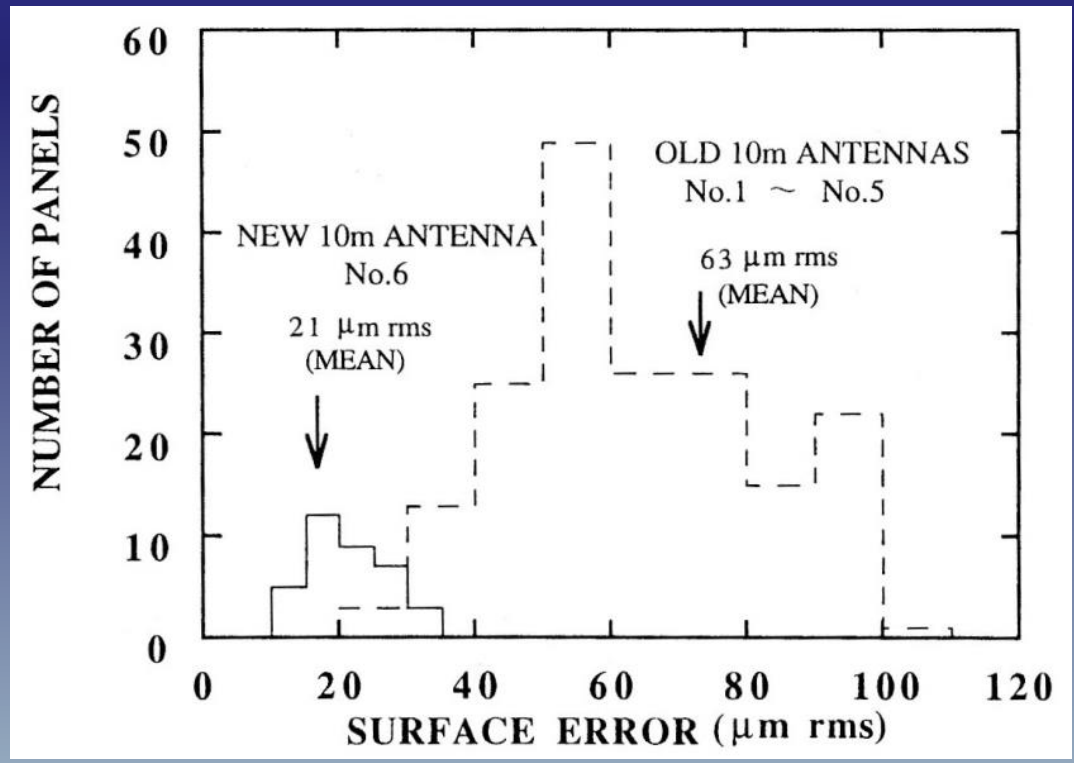
The receiver system was installed inside the cabin fixed on the ground and the radio wave was received through Coude optics..





Surface accuracy and aperture efficiency





Aperture efficiencies of 10-m antennas (A-E)

Histogram of panel accuracies

Lessons: The Coude optics was good for easier operation and lower instrumental polarization but not good for the antenna efficiency.

Summary of the improvements of NMA system

- Antenna:
  - five 10m(1982) ▸ six 10m(1994)
  - ▸ six 10m + ASTE10m (or 45m) (2000,“Rainbow”)
- Receiver:
  - 22GHz/115GHz(1982)
  - ▸ 22GHz/43GHz/115GHz(1987)
  - ▸ 115GHz/150GHz/230GHz(1998)
  - ▸ 100~150GHz/230GHz/350GHz(3 antennas)(2000)
- Correlator:
  - 320MHz/6 antennas(1983) ▸ 1GHz/6 antennas(1997)
  - ▸ 1GHz/7 antennas(2000) (for “Rainbow” mode)

NMA stopped the open use in 2007 and was decommissioned in 2011.

Evolution of antenna technologies

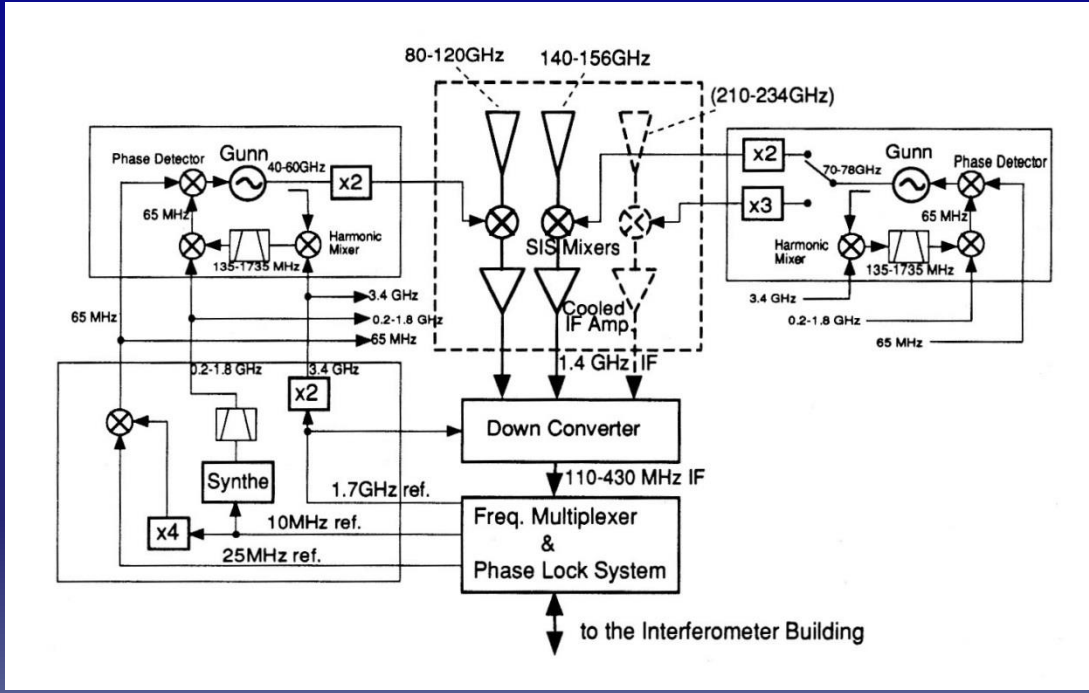
NMA 6-element

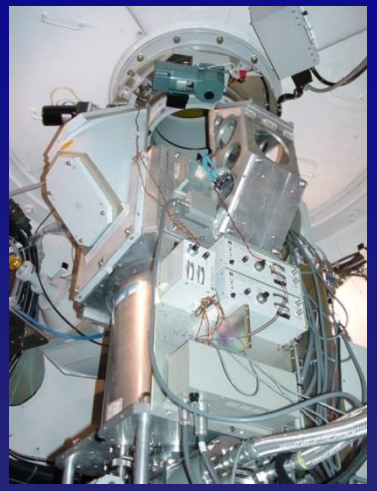
ASTE 10-m
(20 μm rms)

ALMA 12-m(25 μm rms)

ASTE at Atacama site

Front ends and developments for ALMA



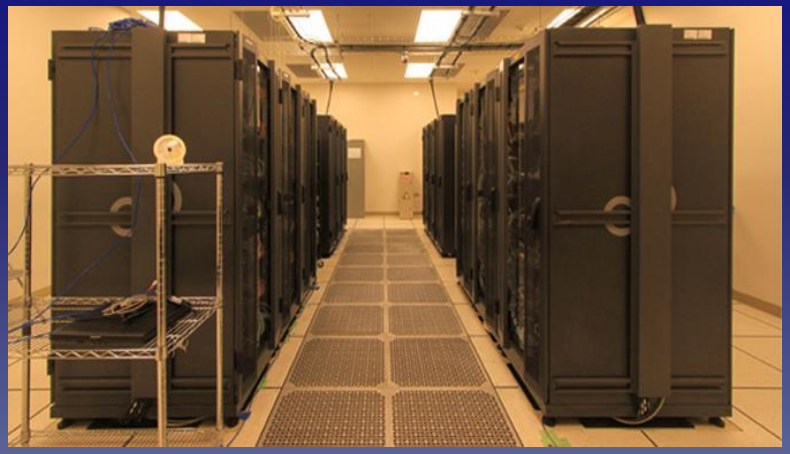


SIS Mixers were switched by rotating a mirror

NMA Correlators and developments for ALMA

1982~1997

- FX: 320MHz maximum bandwidth
  1024 chs for 6 antennas
- WBC: analog correlator with 250MHz Bandwidth

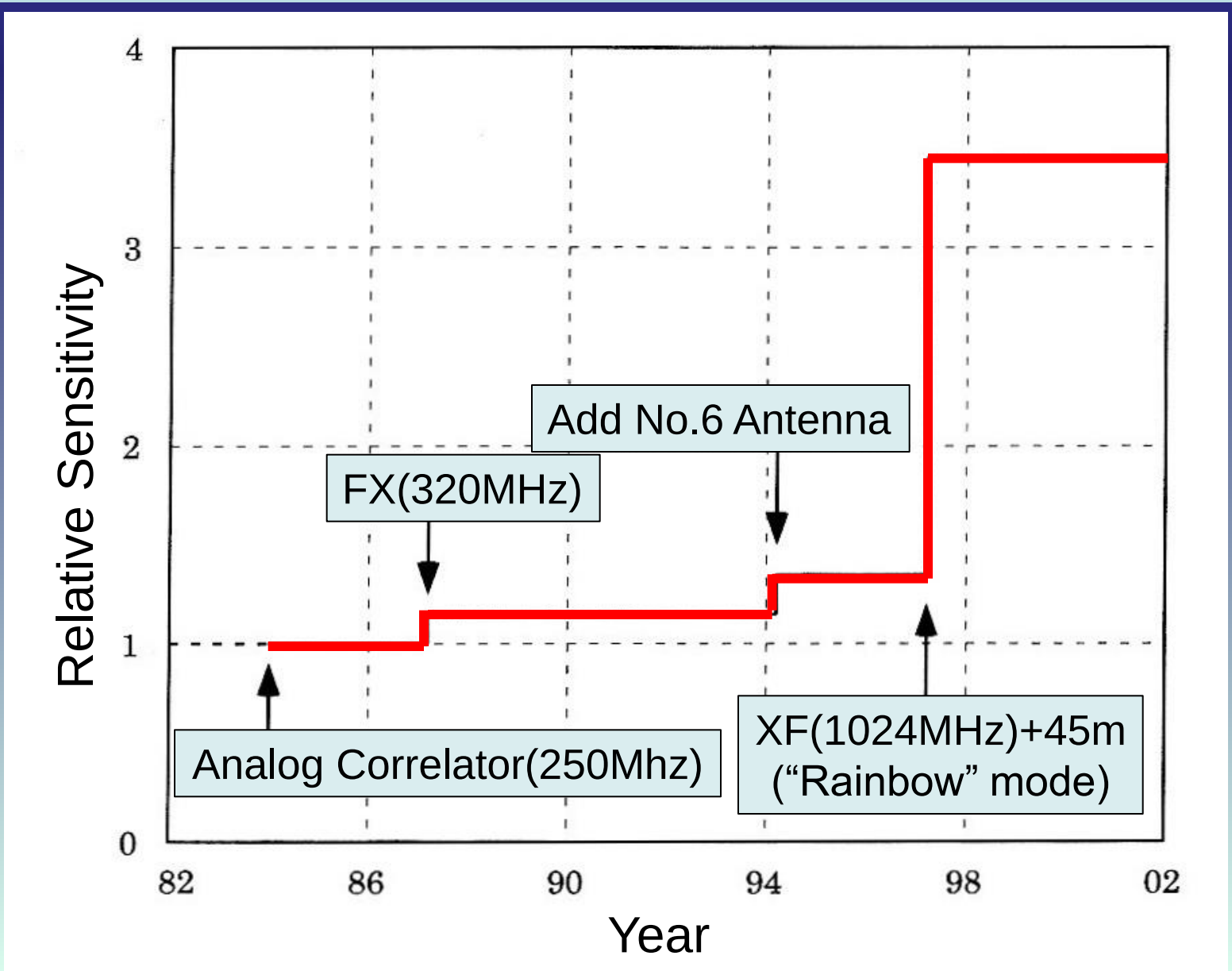


ALMA ACA Correlator

1997~2011

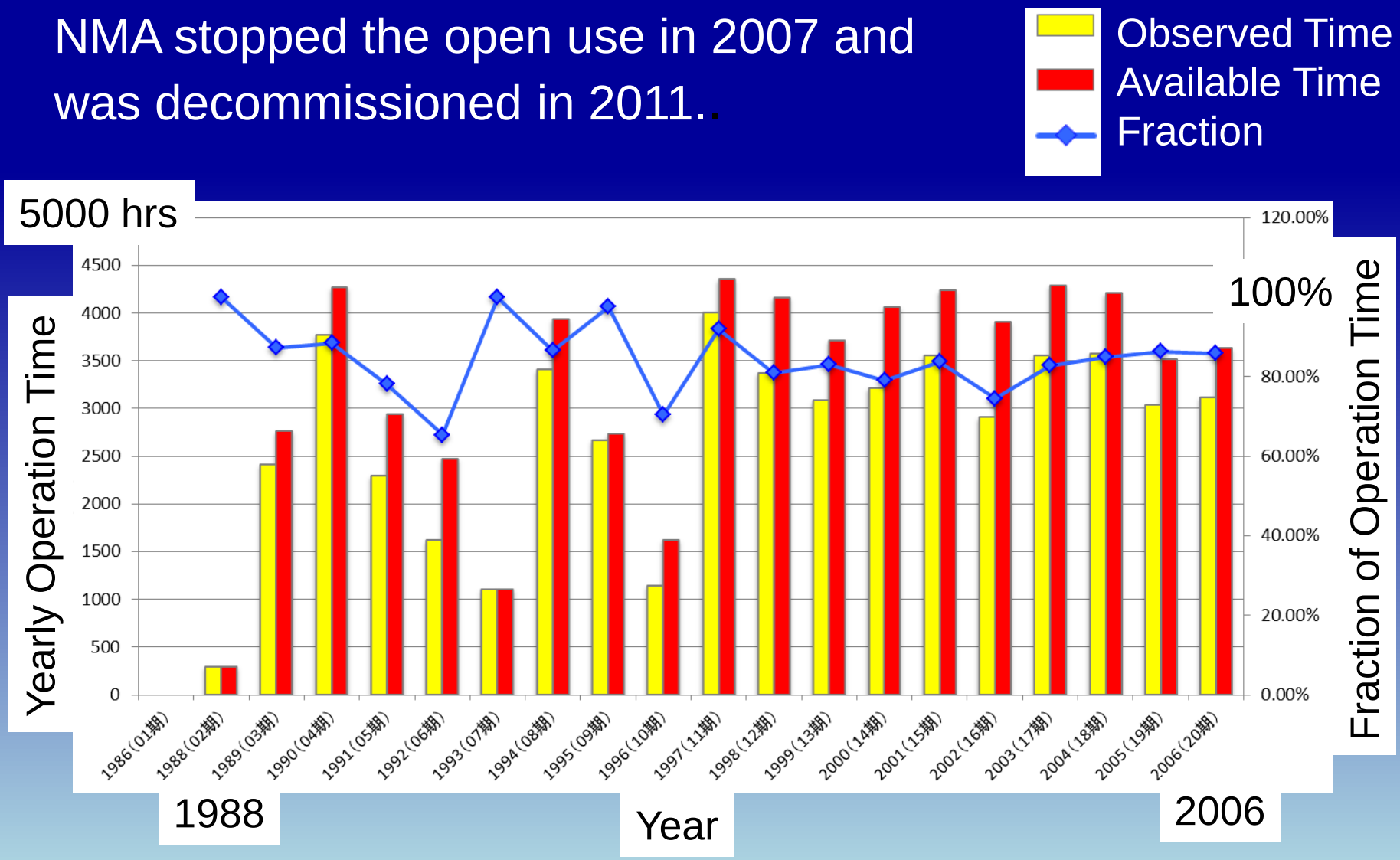
- UWBC : digital XFcorrelator
  1GHz maximum bandwidth
  128/256 chs for 6 antennas
- Expanded to 7 antennas for the "Rainbow" observing mode

The History of the improvement of sensitivity

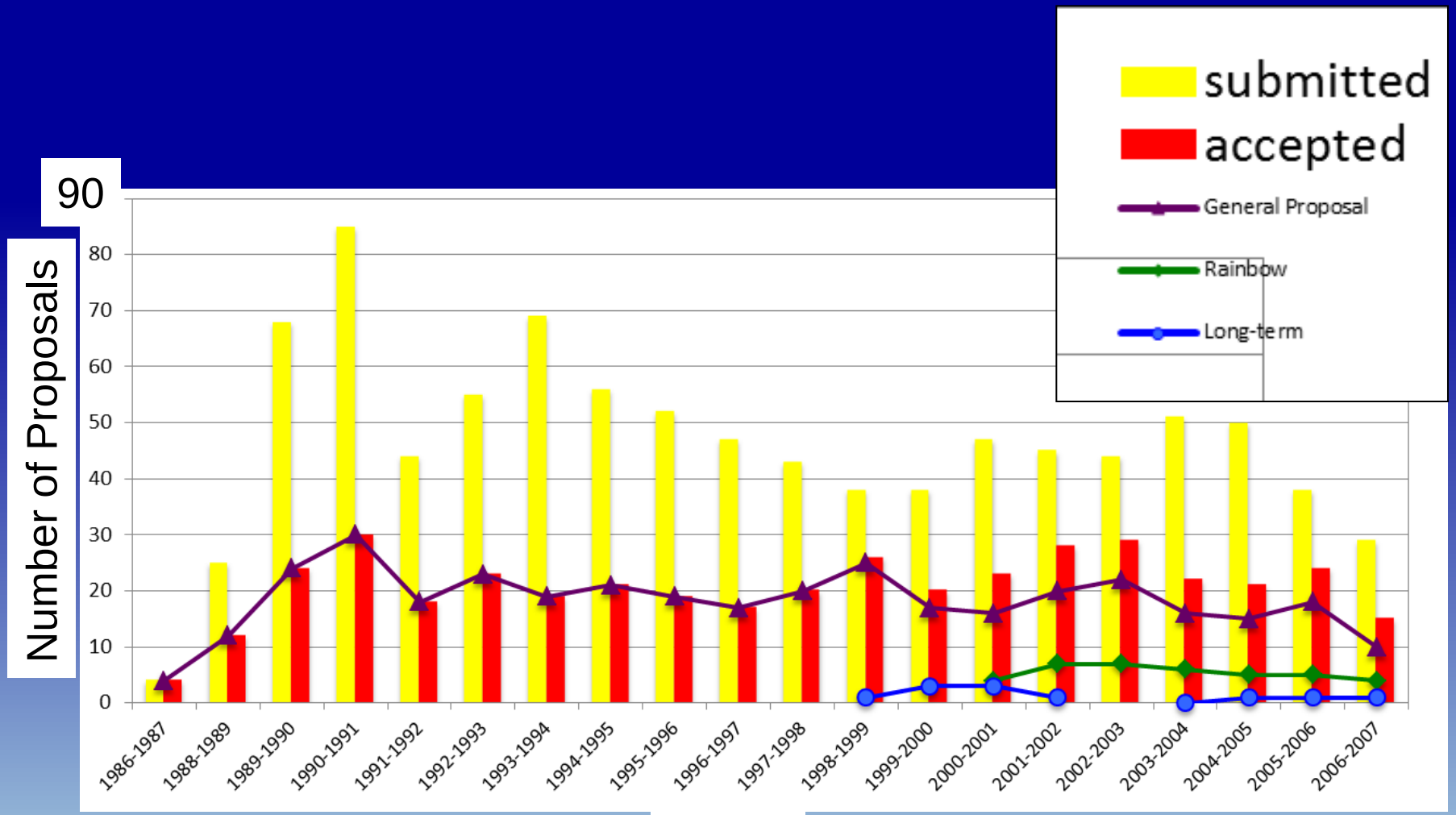


Yearly Operation Time (1988~2006)

NMA stopped the open use in 2007 and was decommissioned in 2011..



Number of Proposals (submitted & accepted)

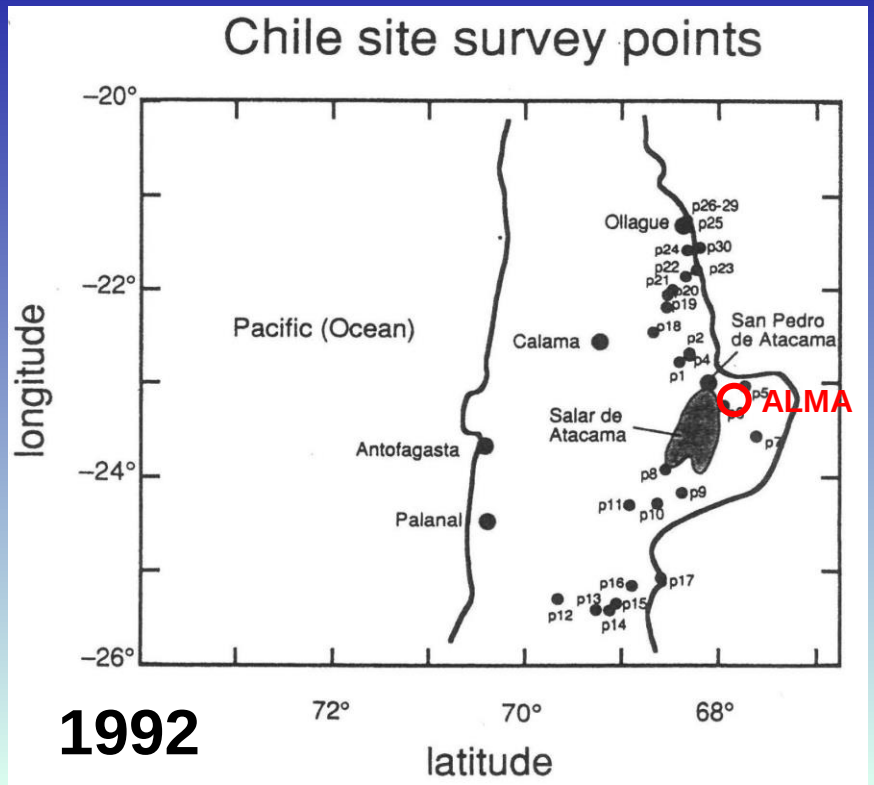


NMA stopped the open use in 2007 and was decommissioned in 2011.

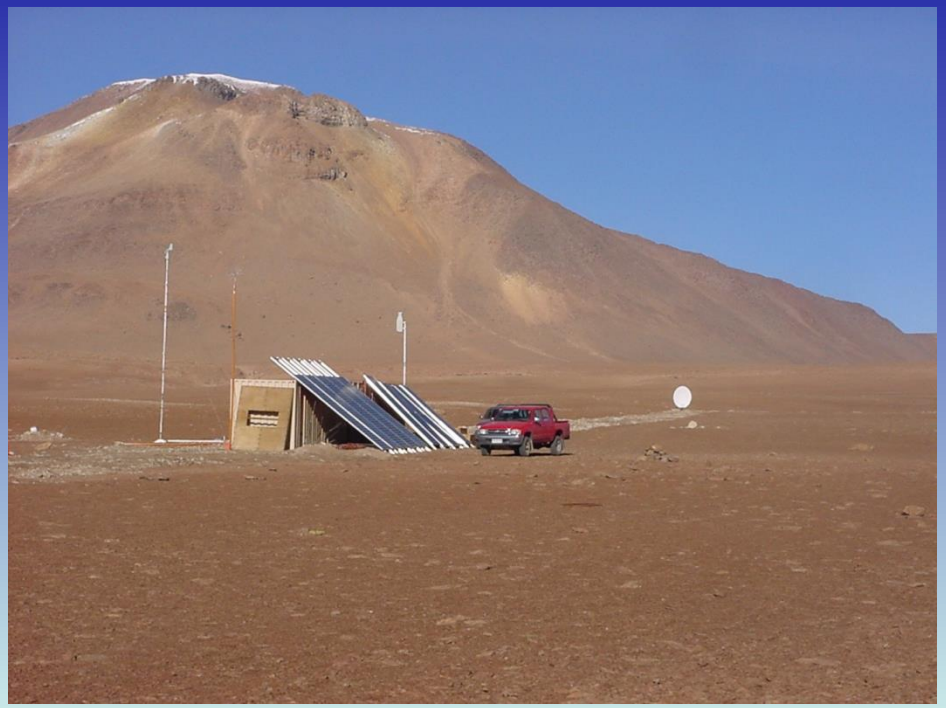
Discussions on Large Millimeter Array started in 1983 and the site surveys in Northern Chile started in 1992

In 1987, the Japanese large array project changed its target to include the capabilities at submm wavelengths.
The project name changed from LMA(Large Millimeter Array) to LMSA(Large Millimeter and Submillimeter Array).

⇒ Selection of the site was crucial for the submm performance



1992

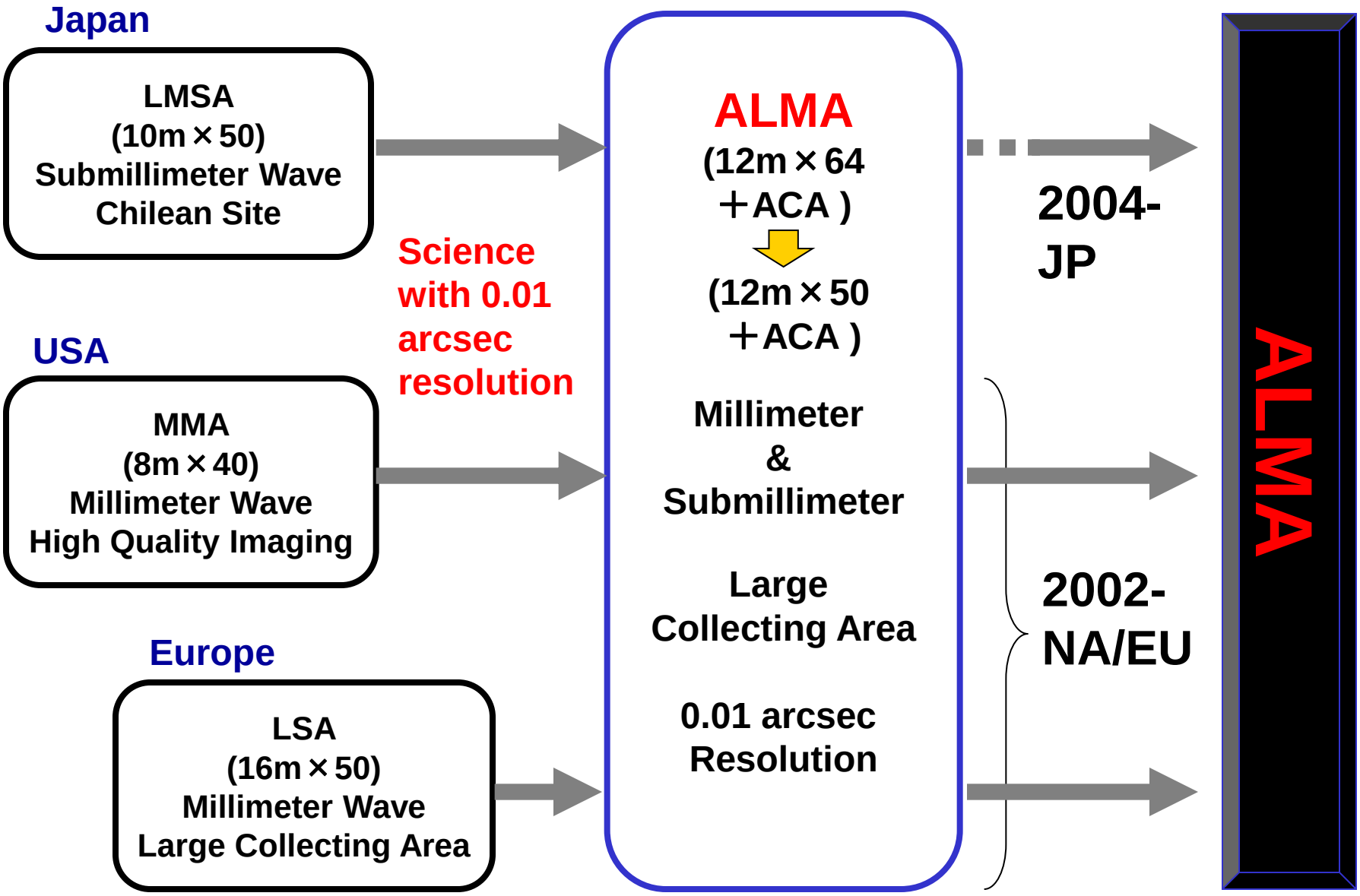


June 1995

IAU Colloquium 140 at Hakone, Japan (1992)

The meeting provided a good opportunity to discuss the Importance of mm and submm astronomy at high angular resolution and to think about plans for international collaboration.

The road to the 3-way ALMA was not straightforward

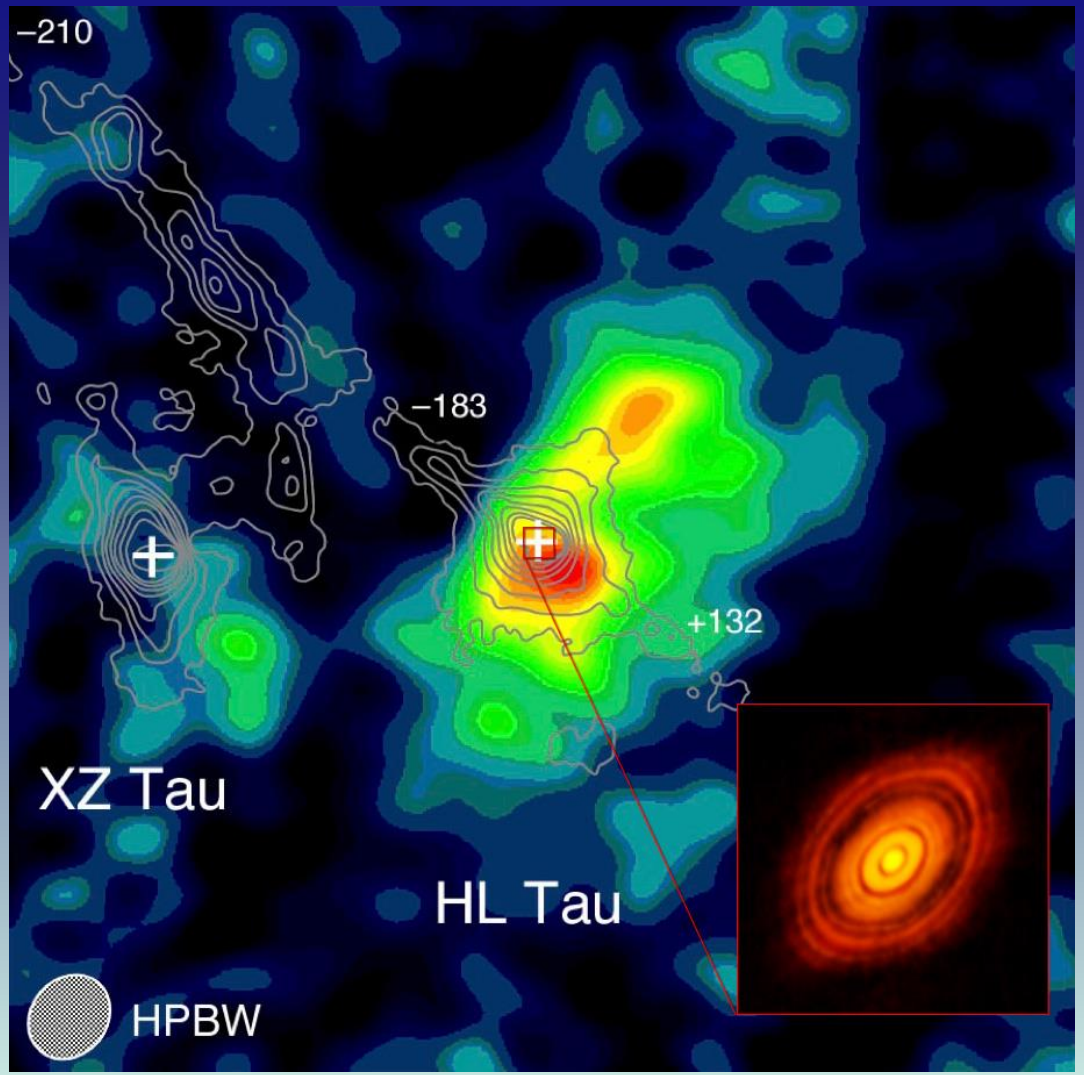


ALMA Dedication (Mar 13, 2013)

ALMA started to produce exciting science!

ALMA Map vs NMA Map(1993) of HL-Tau (ALMA achieved 140 times better resolution!)

Color Map: NMA CO observation with 5 arcsec resolution (ALMA: 0.035 arcsec resolution!)
Contour Map: Jets observed with visible light



Credit: NAOJ/ALMA (ESO/NAOJ/NRAO)

Conclusion

Toyokawa Solar Radio Interferometer (1967)

Nobeyama Millimeter Array (1984)

ALMA (2013)

- NMA contributed to Japanese radio astronomy, publishing 222 refereed papers and 267 papers in the proceedings.
- Due to the lack of experience not only in aperture synthesis but also in millimeter wave interferometry in Japan, the construction of NMA was quite a challenging task.
- Without NMA it would have been very difficult for Japan to be a major partner of the ALMA project.