History of Radio Interferometers in Japan

IAU General Assembly, Busan
Division B; Session 2B
History of Radio Astronomy in East Asia
August 5, 2022

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Outline of the history (classified into 3 phases)

1) Early phase (1950~1970)

- Concept of 5X5 grid array at Osaka Univ. (1950)
- 5-element 4GHz solar interferometer at Toyokwa, Nagoya Univ. (1953)
- 3-element 200MHz solar interferometer at Tokyo Astronomical Observatory (TAO) (1959)

2) Period of rapid growth (1970~1980)

- λ3cm and λ8cm Radioheliographs at Toyokawa (1969, 1975)
- Solar mm-wave interferometer at Nagoya Univ. (1970)
- 160MHz solar interferometers at Nobeyama, TAO (1970)
- 17GHz solar interferometer at Nobeyama, TAO (1970)

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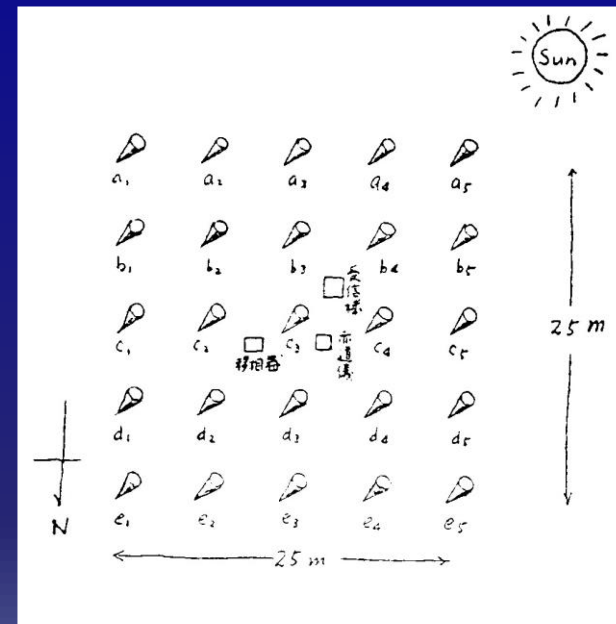
3) Golden Age (1980~)

- Nobeyama Radioheliograph (1992~2020)
- Nobeyama Millimeter Array (1984~2011) ⇒ ALMA (2013~

The first concept of radio Interferometer in Japan by Oda's group (1950)

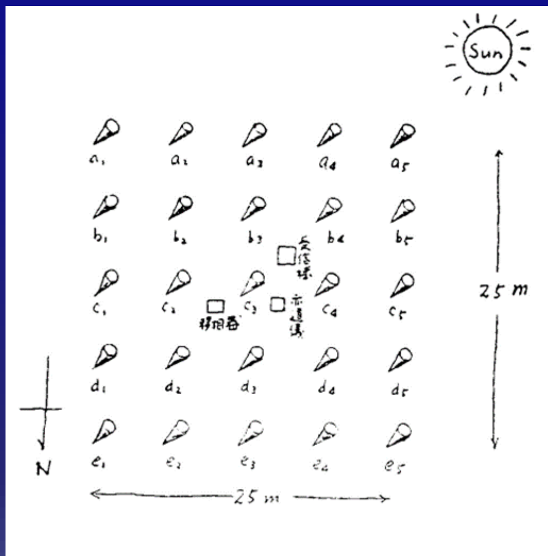
Minoru Oda
(1923-2001)
X-ray
Astronomer

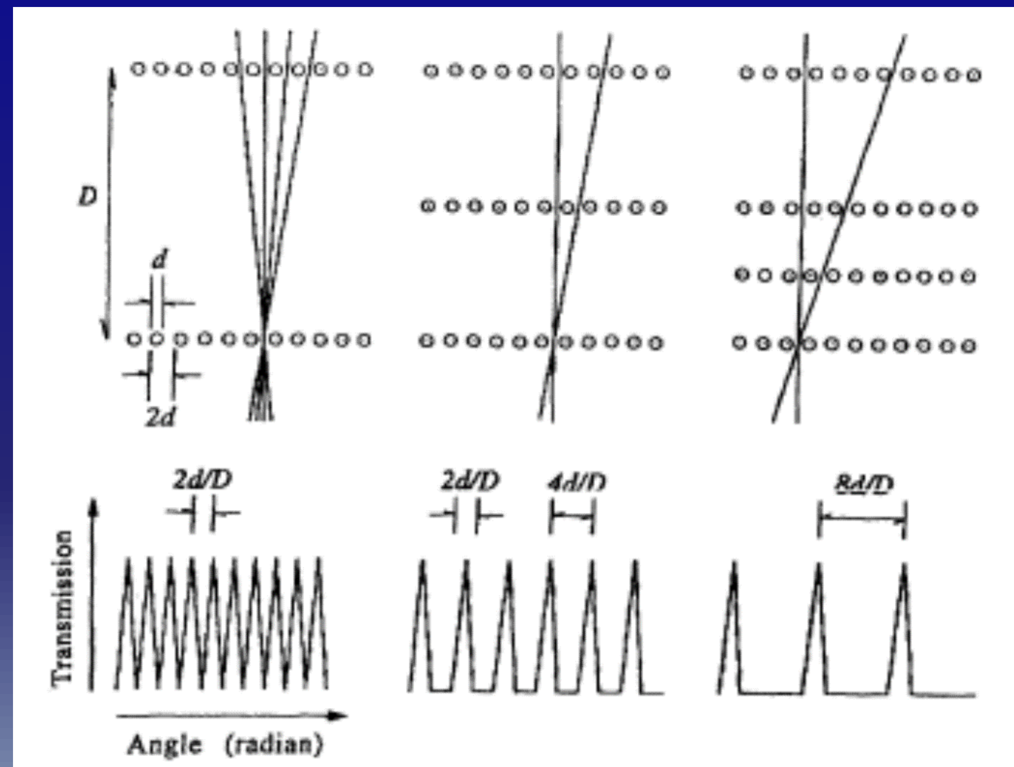
Solar Radio Telescope
at 3.3GHz (Osaka Univ.)
by Oda and Takakura (1949).
Continuous observation
from April 1950 to June 1951.



Oshio, T. et al. (1950)
"A plan for the localization of solar sources on the solar surface by 5-column 5-low electromagnetic horns" ⇒ never actually built

Minoru Oda invented X-ray modulation collimator with a similar response as the solar grating array (1965)



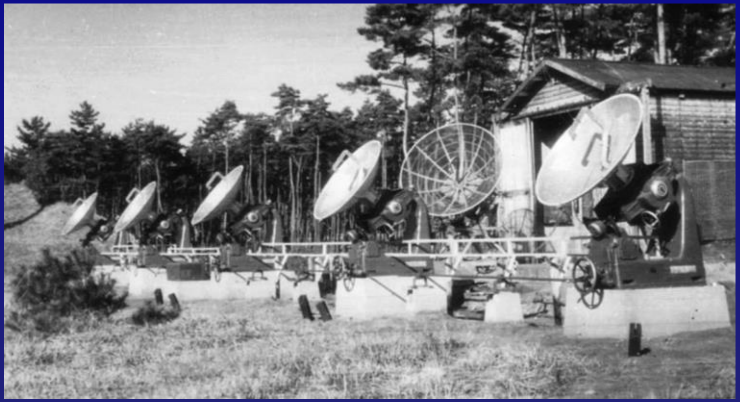


X-ray Satellite “Hakucho” (1979) with Modulation Collimater invented by Oda

Principle of modulation collimater. Layers of the gird produce the Moire fringe pattern. Transmission with respect to the angle is illustrated. (Oda, 1995)

The pioneer of radio interferometer in Japan

Haruo Tanaka
(1922-1985)



5-element 4GHz solar interferometer at Toyokwa, Nagoya Univ. by H. Tanaka & T. Kakinuma (1953).

- The first radio interferometer built in Japan, inspired by the Oda's concept.
- A delay of only about one year after the 32-element interferometer constructed in Australia by W.N. Christiansen for the first time in the world in 1952.

The intereferometer was expanded to 8-elemetnts in 1954

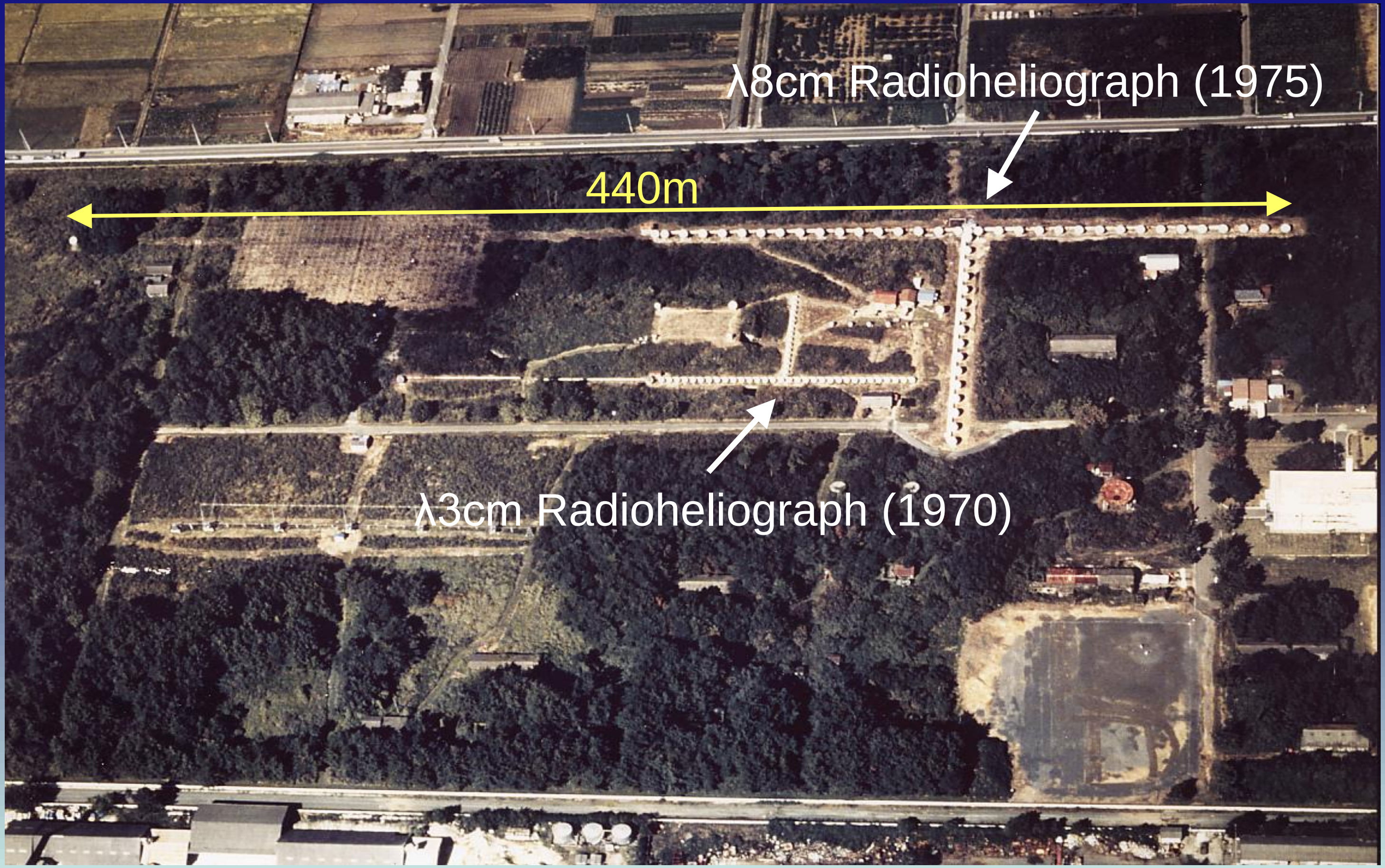
One dimensional array ⇒ Two dimensional array λ3cm and λ8cm radioheliographs at Toyokawa

- λ3cm radioheliograph
  2mx32+3mx2 (EW),
  1.2mx16 (NS
- started with 8 antennas of 1.2m diameter in 1959 and modified to a T-shaped array in 1969

- λ8cm radioheliograph
  3mx32+3mx2(EW),
  3mx17(NS)
- started with 34 antennas of 3m diameter in 1967 and modified to a T-shaped array in 1975

Toyokawa Observatory, Nagoya Univ.

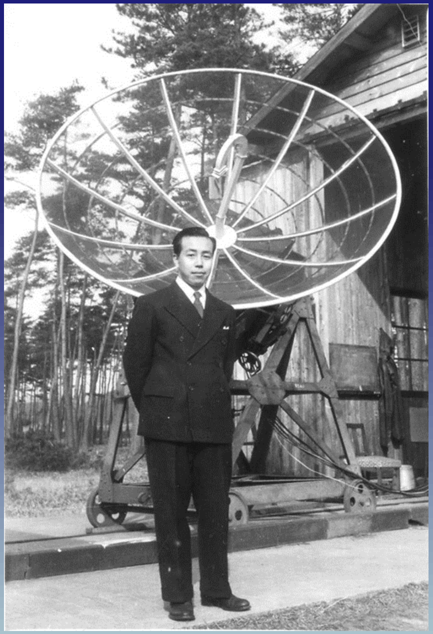
- The site was originally used as a naval arsenal.
- The Research Institute of Atmospherics of Nagoya Univ. was established in 1949



Sojiro Norizuki: a key person who contributed the construction of radio telescopes in Japan.

As president of a small town factory, Norizuki manufactured more than 200 antennas for radio astronomy in Japan in 40 years.

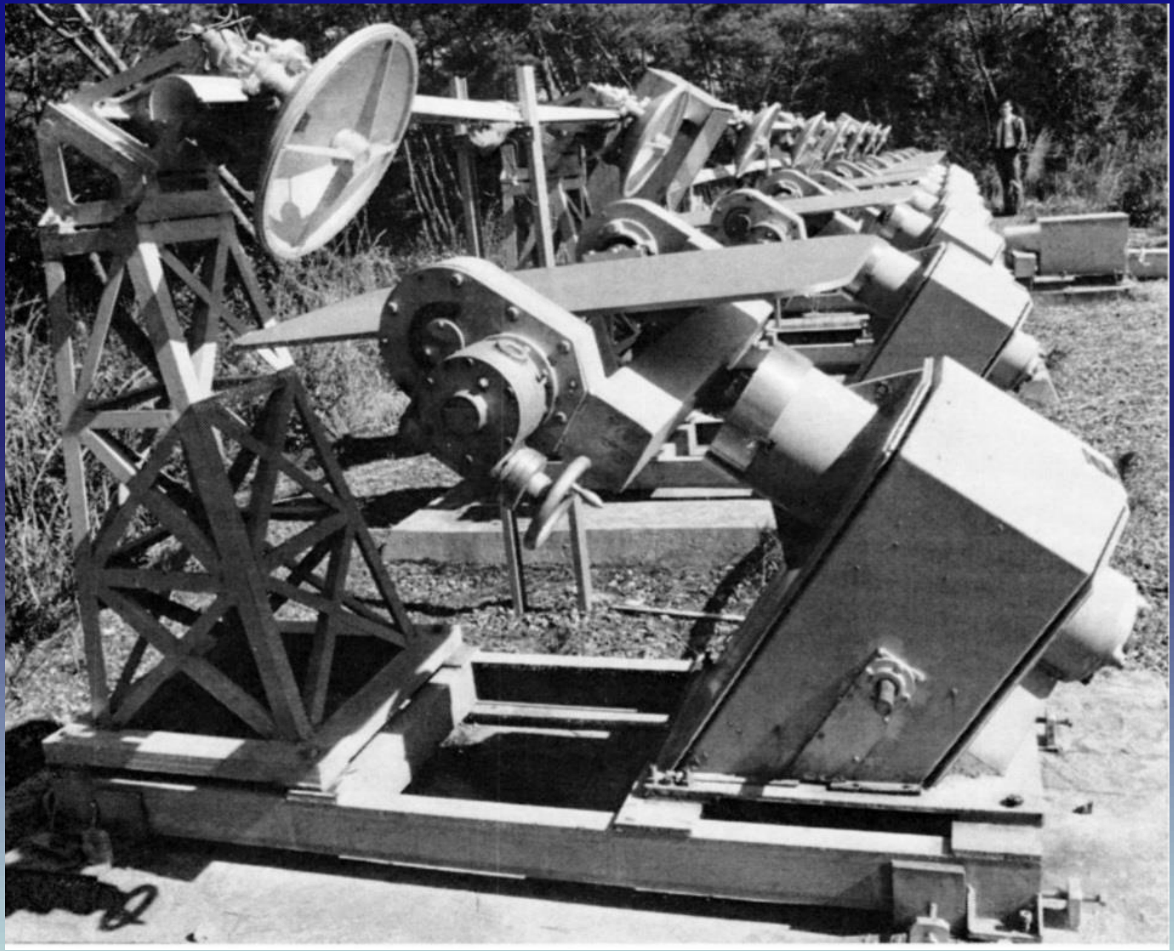
Sojiro Norizuki
(1912-1995)



The first parabolic reflector manufactured by Norizuki (1951)

The solar radio interferometer at the Department of Physics, Nagoya Univ.

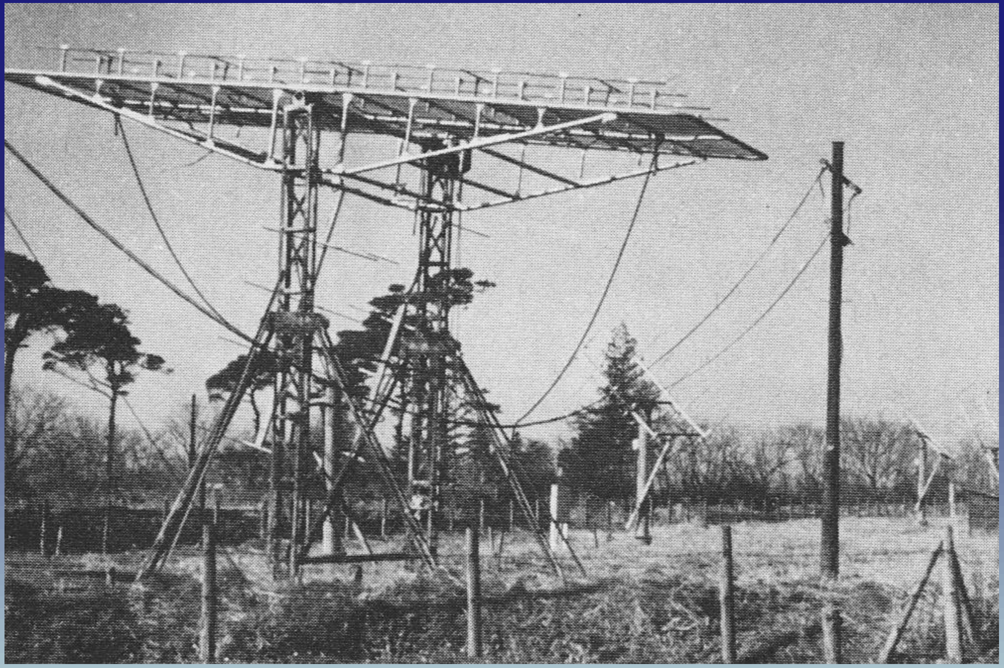
The first mm-wave interferometer in Japan



- 8 antennas 16-m baseline interferometer at 35 GHz in 1970-1975
- 16 antennas and 32-m baseline in 1976.
- observations of the Solar chromospheirc structure and radio bursts.

200MHz solar radio interferometer at Tokyo Astronomical Observatory (1959)

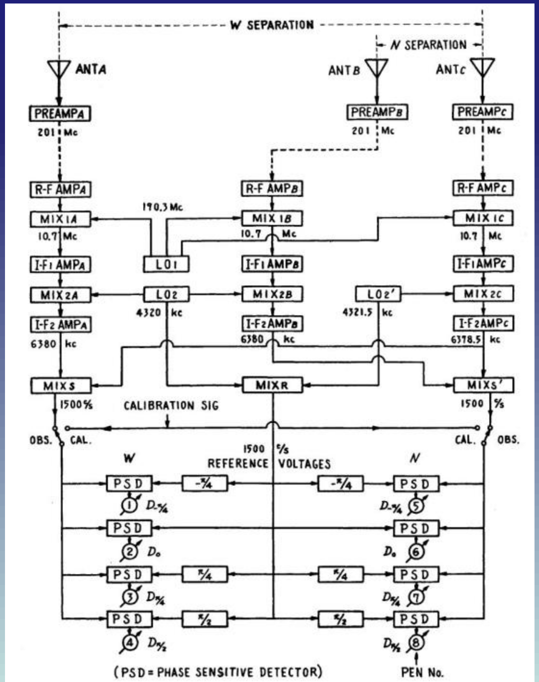
Suzuki, S. developed multiphase radio interferometer for locating the east-west position of radio sources, in order to minimize the position ambiguity.



One of the three broadside antennas used for the E-W position interferometer.

507m

76m



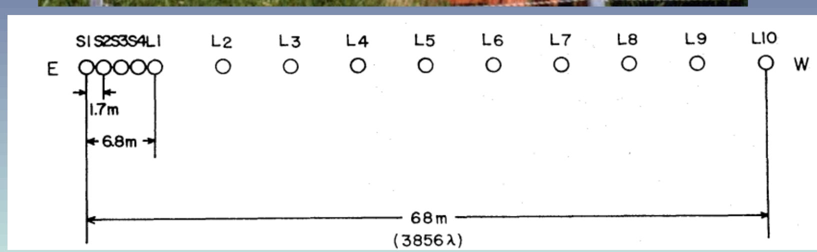
The system block diagram

160MHz solar interferometer at Nobeyama Solar Radio Observatory (TAO)

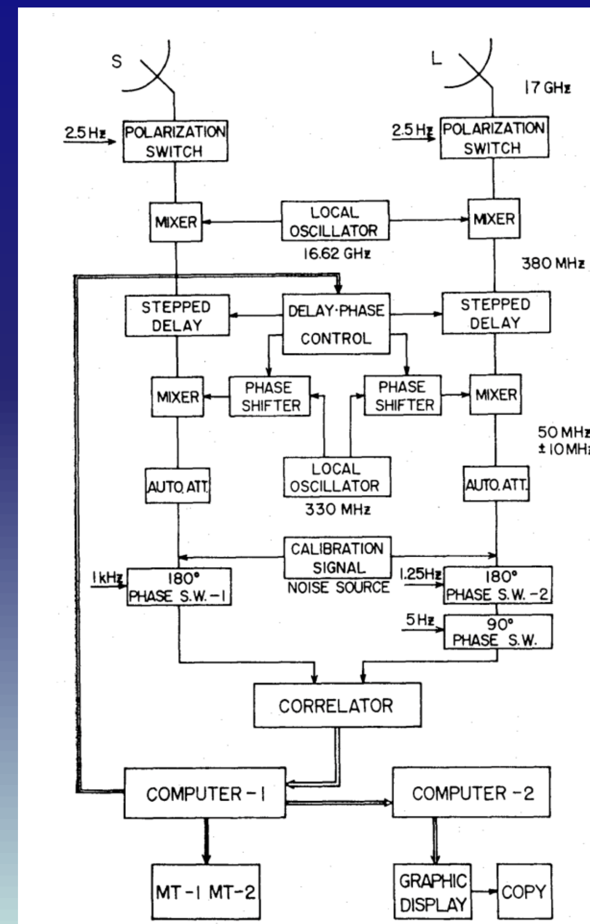
- Two independent interferometers in E-W(11 ant.) and N-S(6 ant.)
- East-West (∼2.3km): nine 6-m antennas + two 8-m antennas
- North-South (∼1.4km): six 6-m antennas
- The longest baseline in Japan
- Operation: 1970 - 1989

17GHz solar interferometer at Nobeyama Solar Radio Observatory（1971 - 1992）

- Initially (1970）: 12 antennas of 1.2-m diameter, drift scan system
- Upgraded (1978): 14 antennas, the first correlator type interferometer in Japan. 49 arcsec resolution with 0.8sec time resolution
- Phase correction with redundancy algorithm (Ishiguro, 1971)
- Prototype for the Nobeyama Radio Heliograph



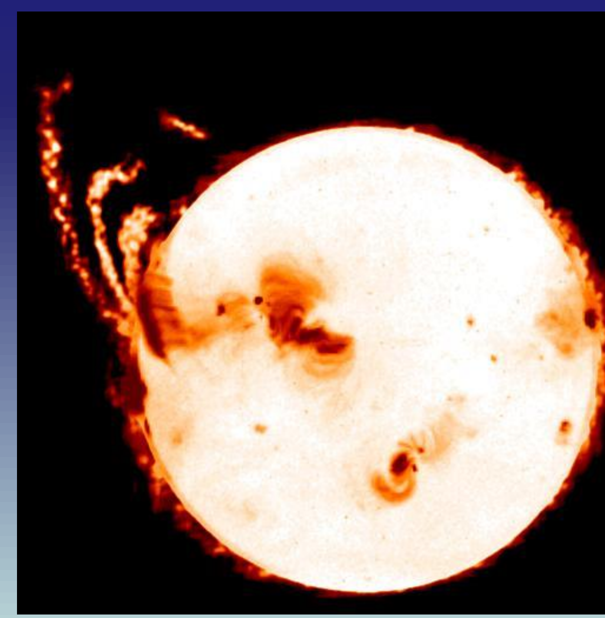
Antenna layout



Receiving system

Nobeyama Radioheliograph(1992- 2020)

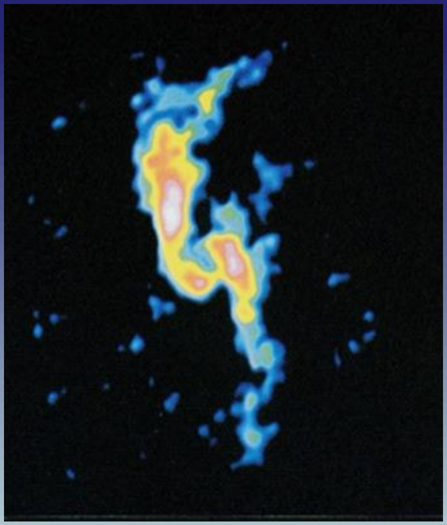
- 84 antennas of 80 cm diameter arranged as T-shaped array of extending 489 m in E-W and 220 m in N-S
- 17 GHz in 1992, and 17/34 GHz after 1995
- High spatial and temporal resolution imaging of the whole Sun (10 arcsec (17GHz) and 5 arcsec (34GHz) with 0.1 sec resolution)
- Real time phase calibration using redundancy



Prominence eruption (July 31,1992)

Nobeyama Millimeter Array (1984-2011)

- The first aperture synthesis telescope in Japan
- five 10-m antennas(1982) ▸ six 10-m antennas(1994)
- Frequency bands: 22GHz/115GHz(1982)
  - ▸ 22GHz/43GHz/115GHz(1987)
  - ▸ 115GHz/150GHz/230GHz(1998)



CO mapping of IC342

Summary

1)The radio interferometers in Japan started for solar observations.

2)The accumulation of technologies for solar radio interferometers developed at Toyokawa and Nobeyama was finally culminated in Nobeyama Radio Heliograph.

3) In the field of cosmic radio astronomy, Nobeyama Millimeter Array (NMA) was the first aperture synthesis telescope in Japan and served as an important step toward ALMA .

Thank you