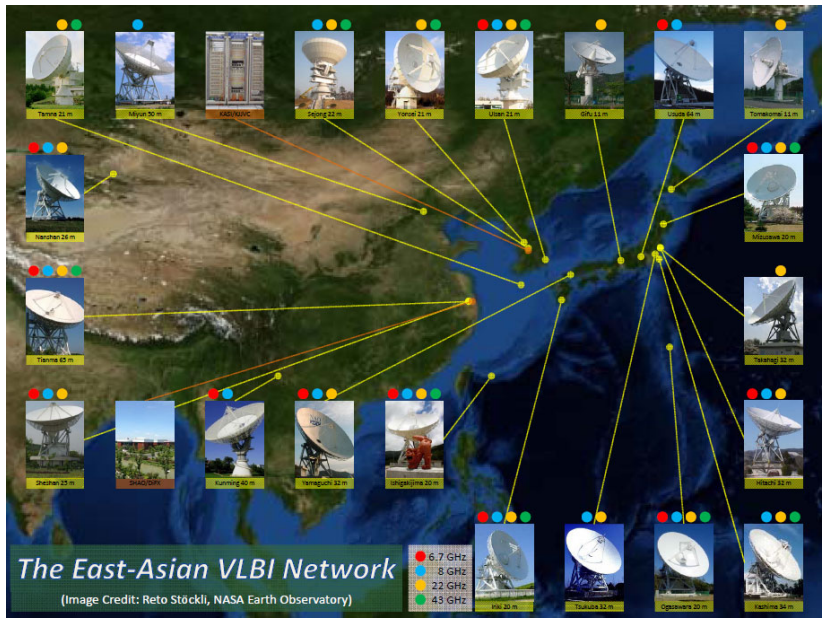
Current status and future developments of receivers at NAOJ's VLBI facilities

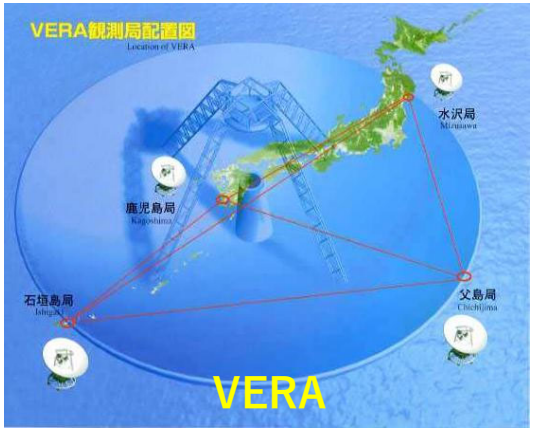
Mareki Honma

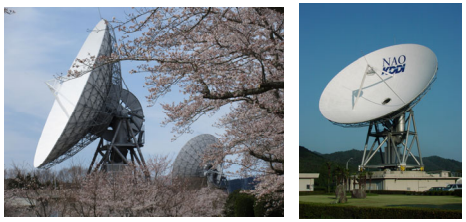
(NAOJ, Mizusawa VLBI Observatory)

VLBI stations in Japan as a part of EAVN

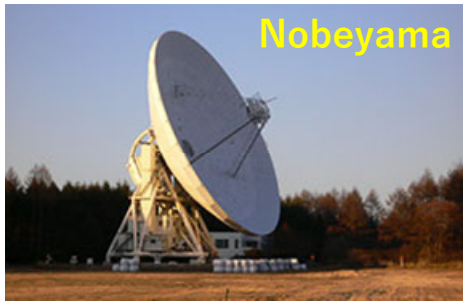


East Asian VLBI Network
(China, Japan, Korea, Thai)





Ibaraki & Yamaguchi stations



EAVN bands
(EAVN status report)

Telescope	Band C	K	Q
KaVA	$\bullet^i$	●	●
TMRT65	●	●	●
SHRT25	●		
NSRT26	●	●	
NRO45		●	●
TAK32		●	
HIT32	●		
YAM32	●		
KSJ		●	●

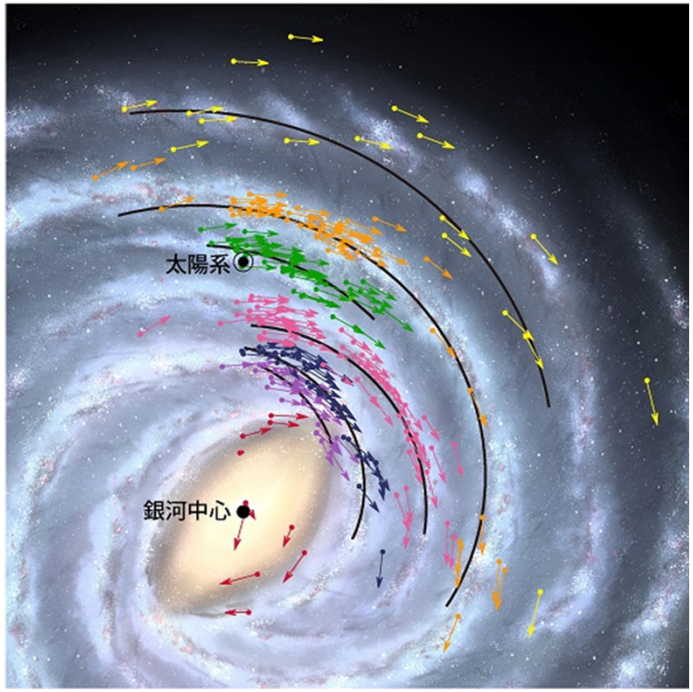
(KaVA: VERA+KVN,
with 8 stations)

VERA (VLBI Exploration of Radio Astrometry)

- 20m dish x 4 stations.
- mainly operating at K, Q bands (H2O/SiO masers)
- target: maser astrometry with dual-beam
- + S/X and C band single-beam receivers

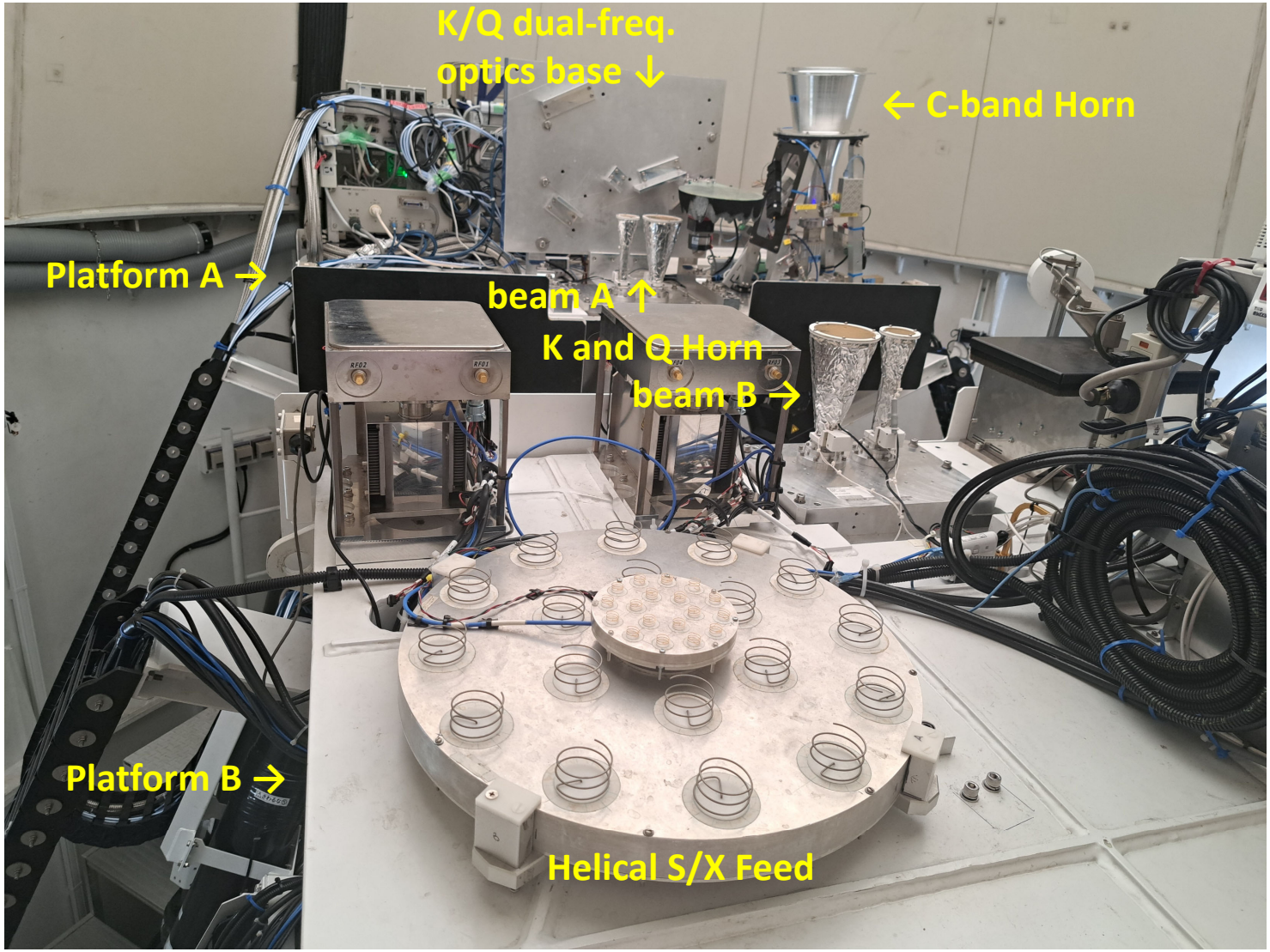
VERA array map

dual-beam RX platform



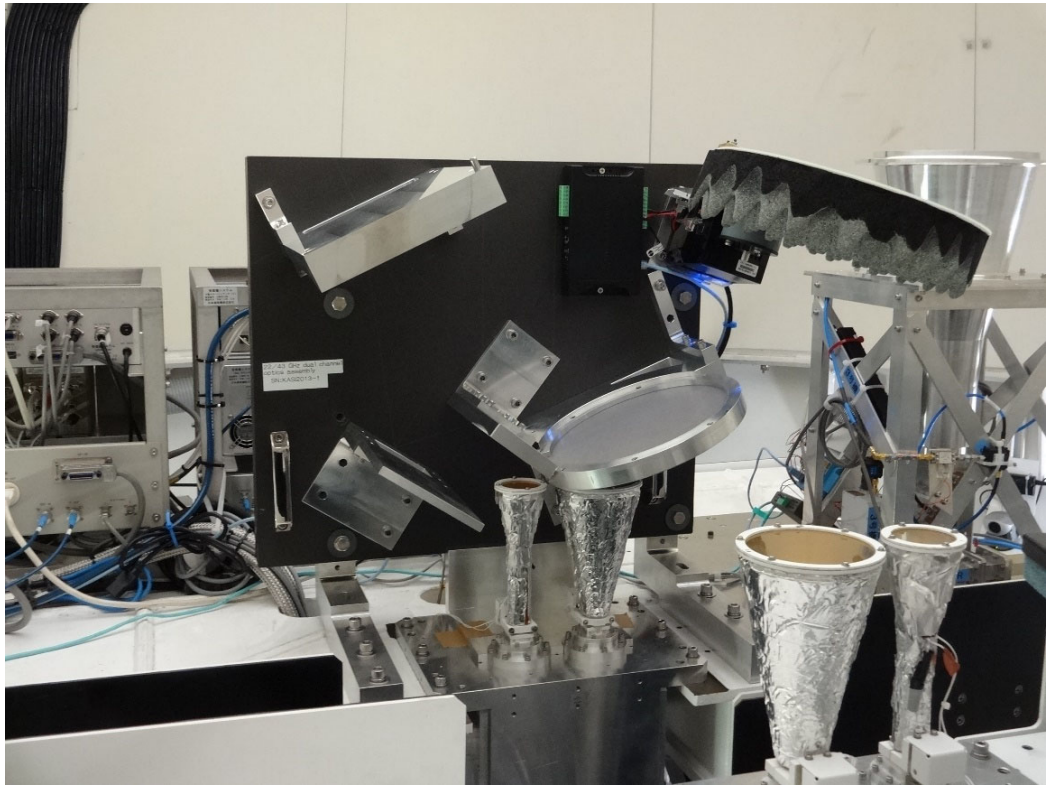
Mily Way Map with maser astrometry (Hirota+2020)

VERA receiver cabin



Dual-band capability at present

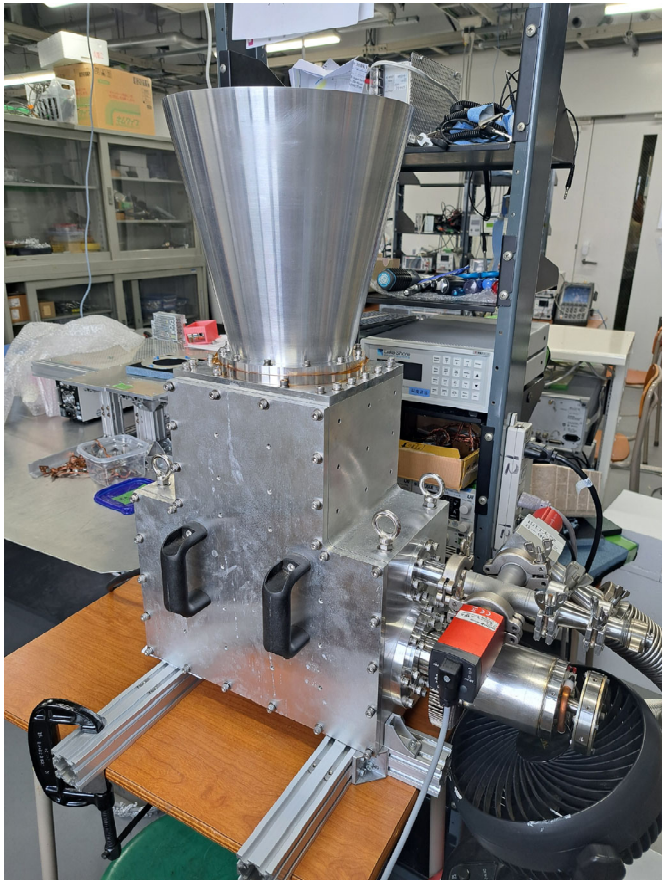
- K-Q dual-frequency receiving optics is available for all the 4 stations of VERA (developed by KASI)
- Optics needs manual setting of mirrors (relatively low agility)
- EAVN's K-Q dual-freq. observing sub-array consists of 9 stations, i.e., **VERA x 4 + KVN x 4 + KSJ**.



VERA K-Q dual-band optics

Development of new RX for 6-18 GHz

- First-prototype of quad ridge horn covering 6-18 GHz, to be installed to VERA Mizusawa station later this year.
- will replace VERA's C-band receivers
- Combination with digital backends will provide multi-frequency capability, e.g., 6.7 GHz, 8 GHz, 12 GHz, 15 GHz ….



Wideband RX at Osaka Metro U. RX lab

Digital backends and correlator for VERA

High-speed digital processing is a key for multi-band capability

OCTAD

2GHz x 4 streams at max.
RF direct sampling up to 26 GHz

OCTADISK

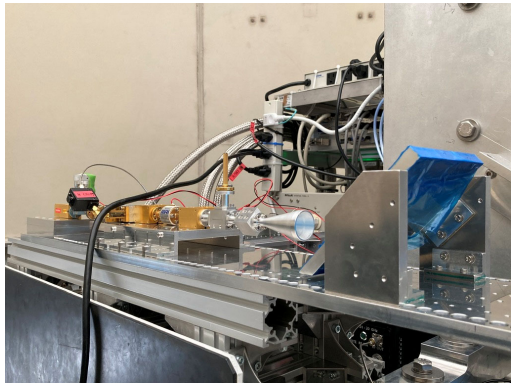
4 Gbps recording per unit

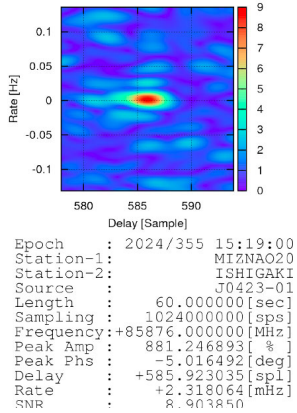
Correlation Center at Mizusawa (CPU/GPU correlator + disk packs)

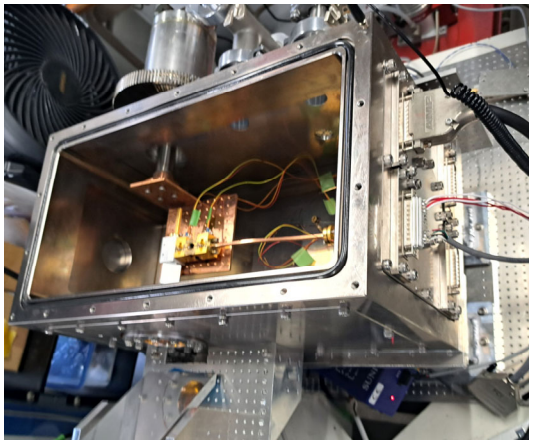
VERA 86GHz RX development

- VERA 86GHz new receiver (led by Kazuhiro Hada etc., with Osaka Metro.U. team)
- Fringe test done successfully with room temperature RX. Antenna efficiency is found to be ~30%.
- Cooled RX to be installed to Mizusawa this fall. For other 3 station, in next 2~3 years
- For K/Q/W receiving, new optics is needed (to be designed).

test RX at VERA Mizusawa (left) and fringe with VERA (right)







86GHz RX dewer under development

JVN Ibaraki & Yamaguchi stations

- 32m dishes (converted from sat-com antennas).
- Observing bands: C & X (and K for one of the two stations at Ibaraki).
- Dual-frequency capability available at C+X (6.7 GHz + 8 GHz)

- New RXs to cover 6-12 GHz band is now in operation (for observations of multiple methanol maser lines at 6.7 & 12.2 GHz)

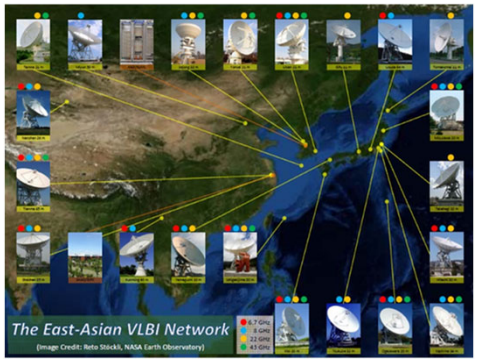
two 32m dishes of Ibaraki U.

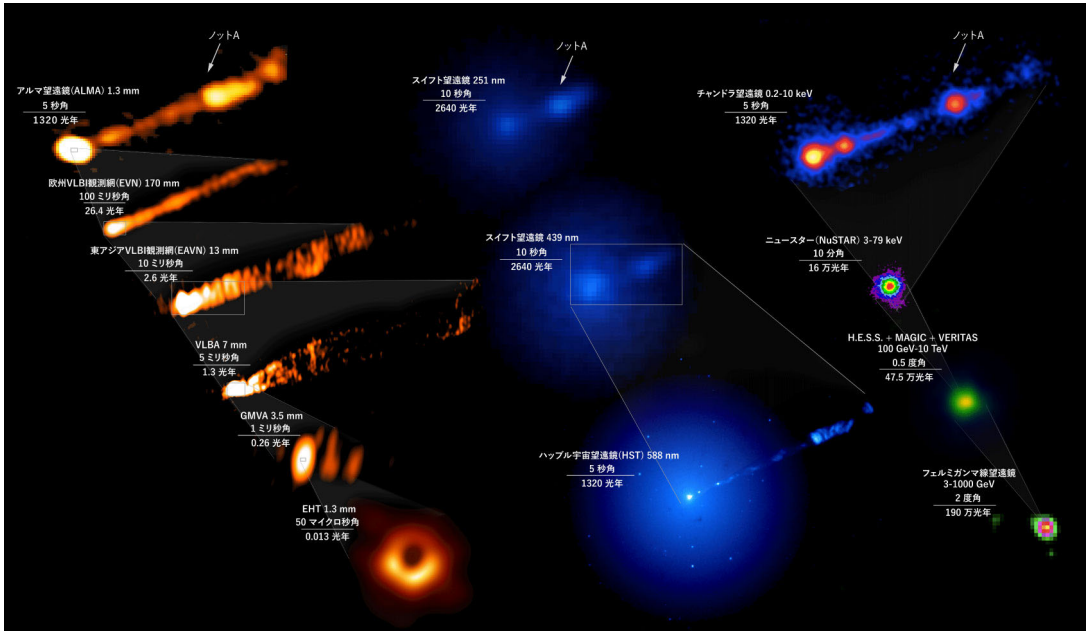
Yamaguchi U. 32m

AGN Science with global multi-band VLBI

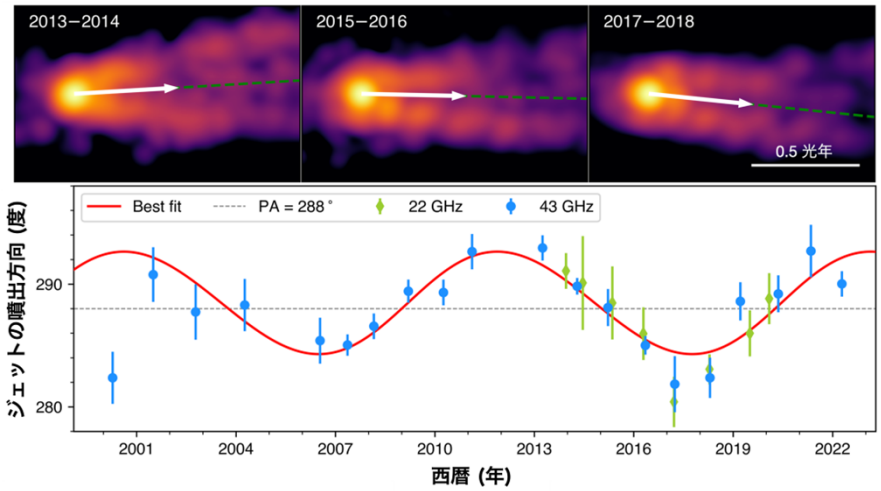
Multi-frequency capability is needed for AGN jet studies.

- Inner region with higher-frequency
- Outer region with low-frequency





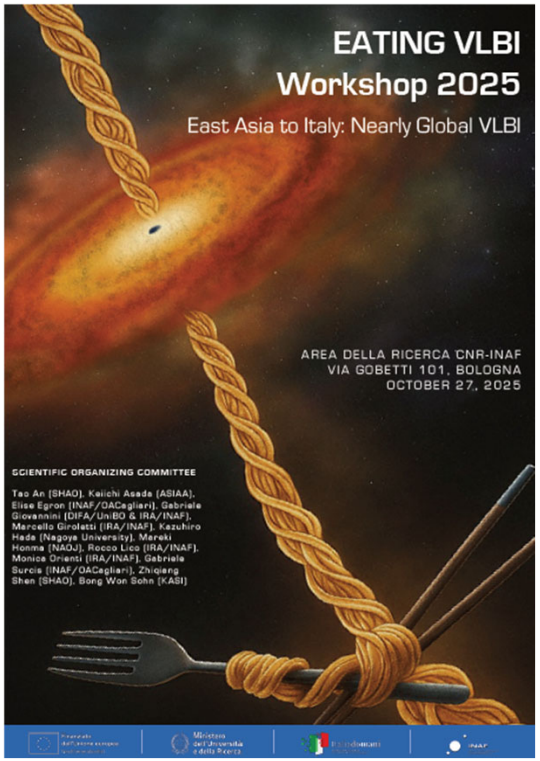
Multi-wavelength view of M87, including EAVN images (EHT+2021)

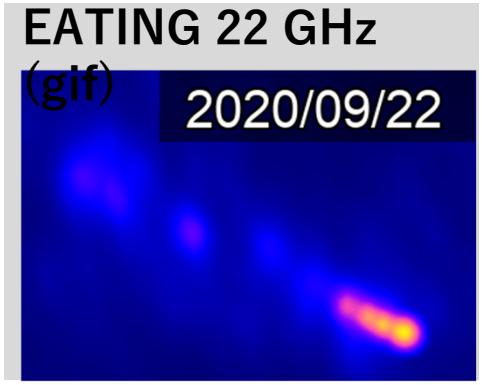


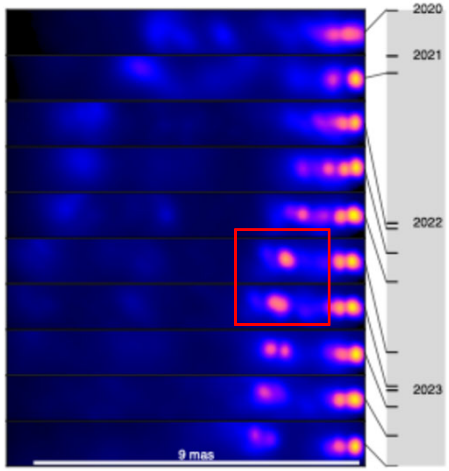
M87 jet precession with a period of ~11 yr, interpreted as Lense-Thirring precession (Cui+2023)

3C111 jet study with EATING VLBI and VLBA (by Kawamura+)

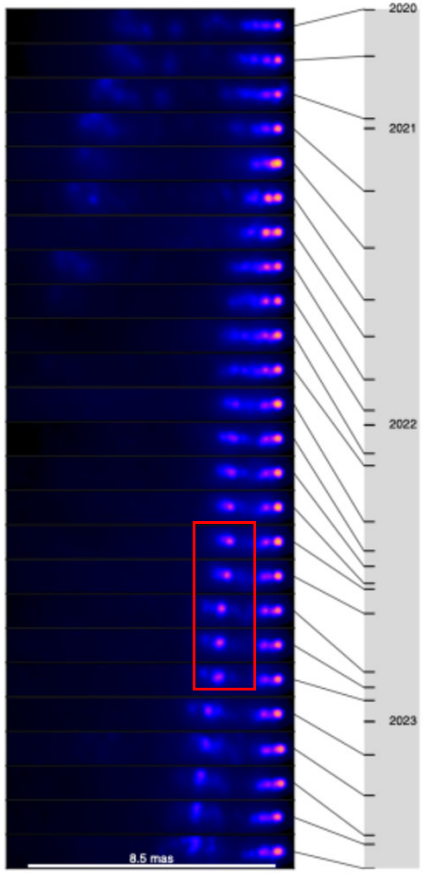
- EATING VLBI:
  "EA-To-Italy Nearly-Global" VLBI
- 3C111 jet with EATING VLBI and VLBA reveals a possible internal shock(?)



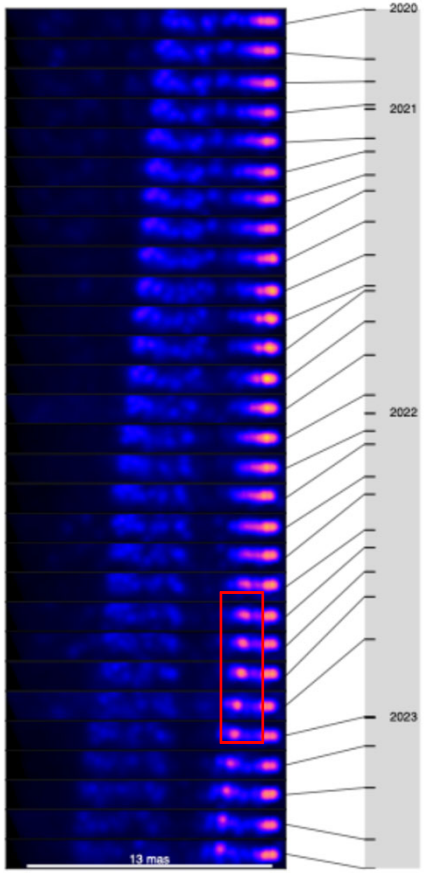




EATING 22 GHz



BU 43 GHz

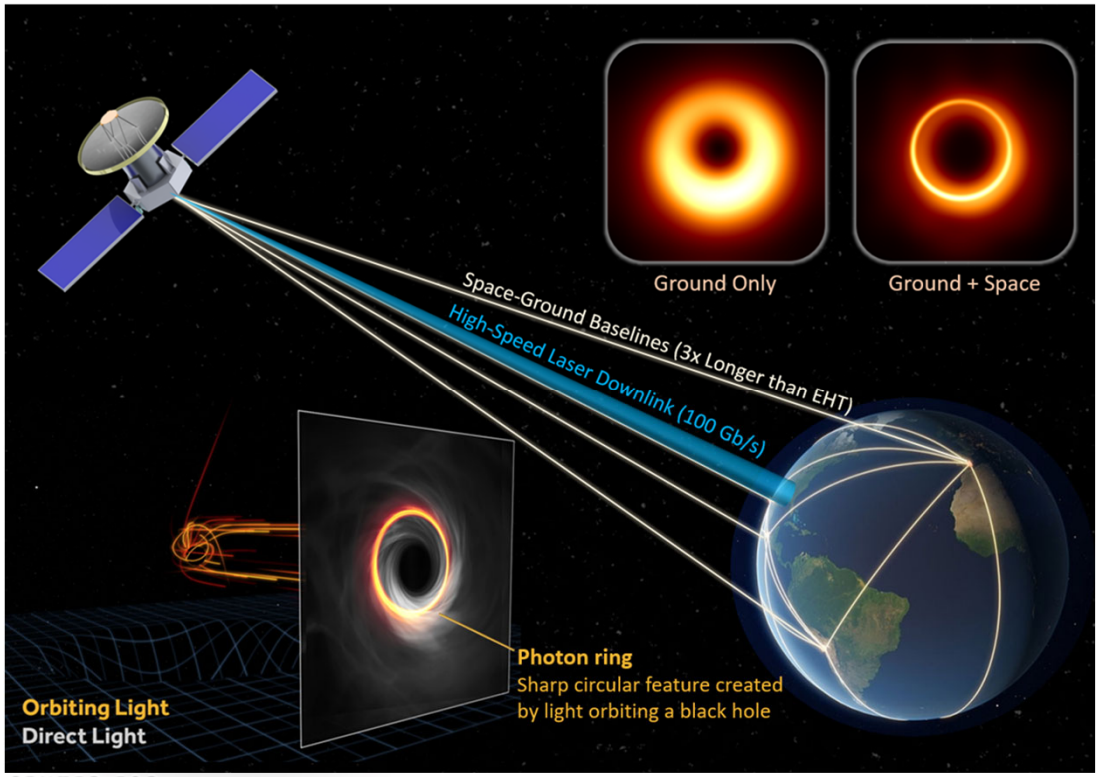


MOJAVE 15 GHz

We look forward to conduct K/Q multi-freq. obs. between Europe and Asia.

Future AGN/BH studies with BHEX

BHEX: space mm-VLBI at 80 GHz + 240-320 GHz
(dual-bands !!)



CENTER FOR ASTROPHYSICS HARVARD & SMITHSONIAN
THE UNIVERSITY OF ARIZONA
LINCOLN LABORATORY MASSACHUSETTS INSTITUTE OF TECHNOLOGY
VANDERBILT UNIVERSITY
LOCKHEED MARTIN
BLACK HOLE INITIATIVE
National Radio Astronomy Observatory
MIT HAYSTACK OBSERVATORY
NAOJ National Astronomical Observatory of Japan
NIST

4K cryocooler development

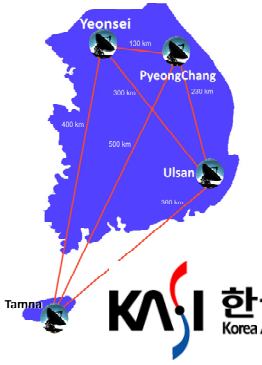
JAXA
Sumitomo Heavy Industries, Ltd.

Cryo-cooler

Development of ground mm-VLBI telescopes

NAOJ

Ground Array, SIS mixer



KASI 한국천문연구원 Korea Astronomy & Space Science Institute

ASIAA

EAObservatory

Ground Array

Nobeyama 45m telescope for 230 GHz?

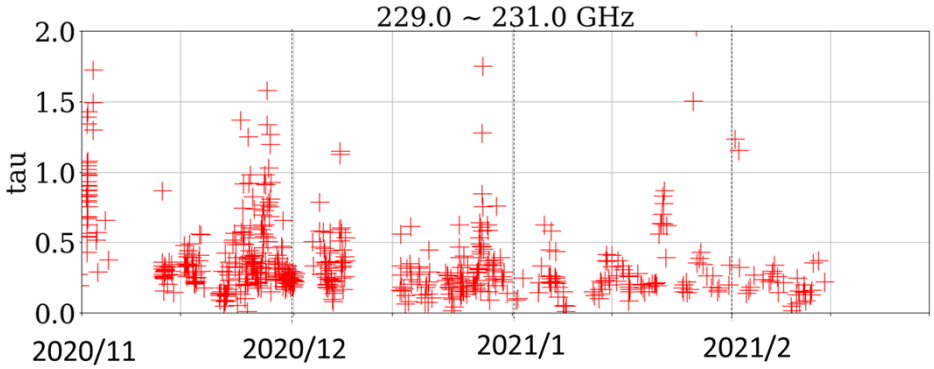
- operation since 1982 (more than 40yr)
- altitude: 1350m
- Main band: 22 – 115 GHz

- Surface accuracy (as of 2015)
  ~49 um RMS within 30m
  ~54 um RMS within 40m
- best-case efficiency would be ~50% for the central 30-40m area.

it could be a powerful 1mm station (!)

For details of Nobeyama RX, please do not miss Imai-san's talk next to me!

Nobeyama 45m telescope



230 GHz optical depth at Nobeyama (measured by Osaka Metro. U.)

Summary

- Multi-band RX system provides great science opportunities for future studies of AGN, maser etc.

- Currently VERA+KVN (KaVA) are fully operation for K-Q dual-frequency observations as 9-station array.

- We hope to collaborate with stations in Europe and the world (i.e., EATING VLBI, EVN, GMVA and beynd)

- Several new RX developments for VLBI are on-going, including 6-18 GHz RX, W band RX etc. for VERA, 6-12 GHz RX for Yamaguchi/Ibaraki, and 240-330 GHz RX for BHEX and potentially Nobeyama 45.

Let’s keep in touch!!