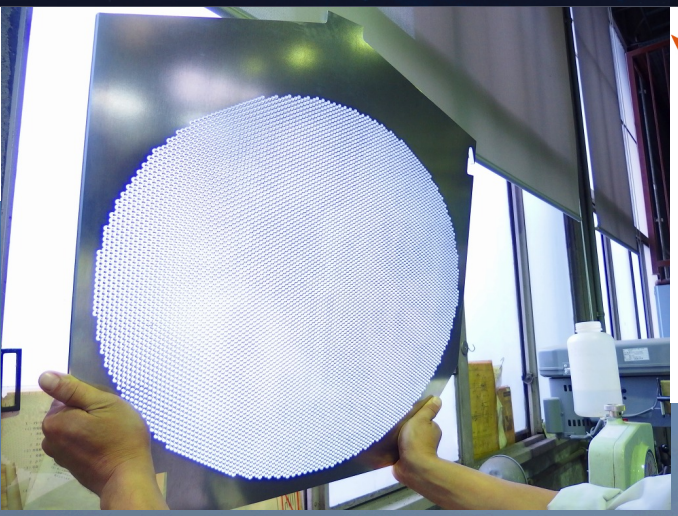
HINOTORI and future 3 mm EAVN capability

Hiroshi Imai

On behalf of HINOTORI team

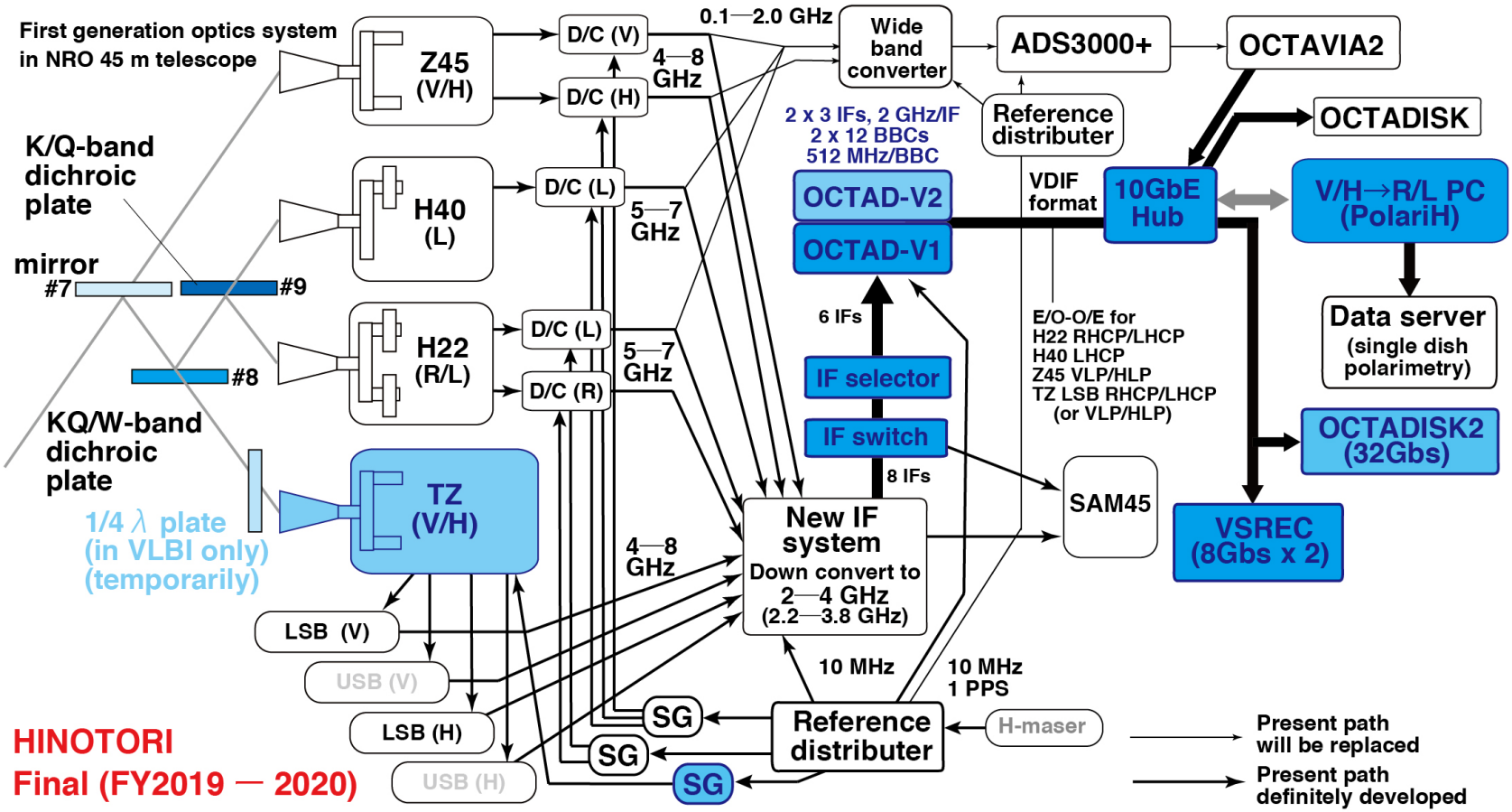


EAO Sub-mm Futures, on 2019 May 20

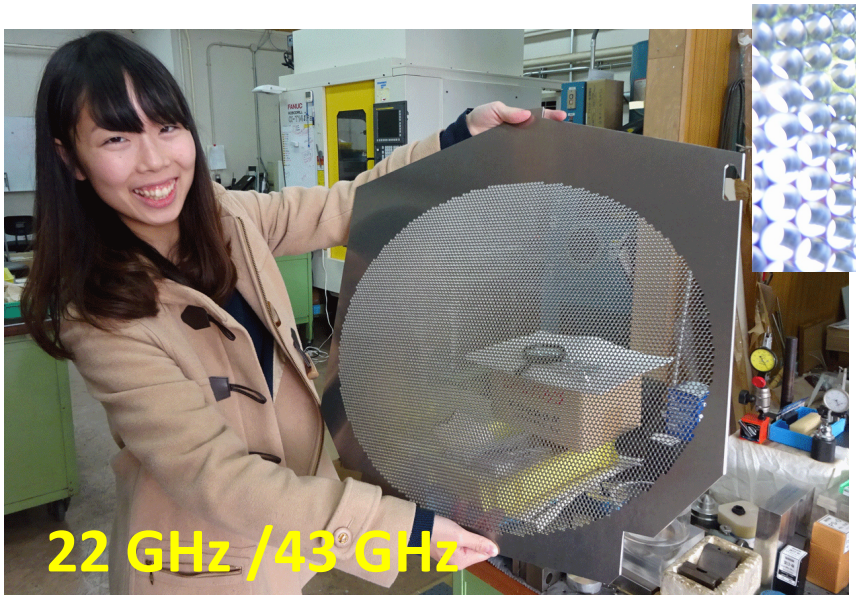
HINOTORI

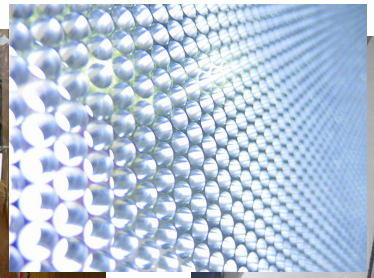
Hybrid Installation Project in Nobeyama, Triple-band Oriented

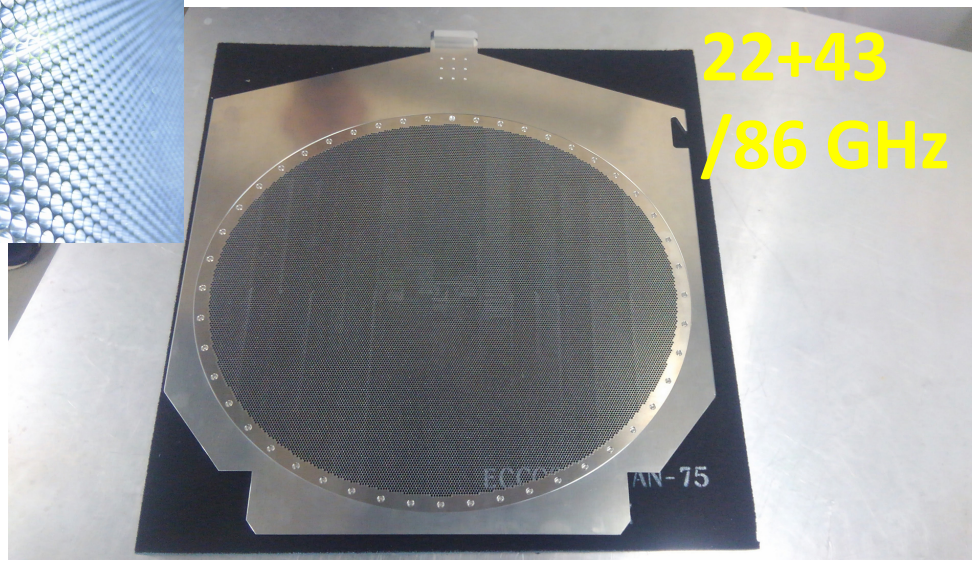
- **Simultaneous triple-band (20—25 GHz/ 42.5—44.5 GHz/ 80—90 GHz) observation system**
- **New VLBI backend with a recording rate of up to 48 Gbps (4 GHz per band at maximum)**

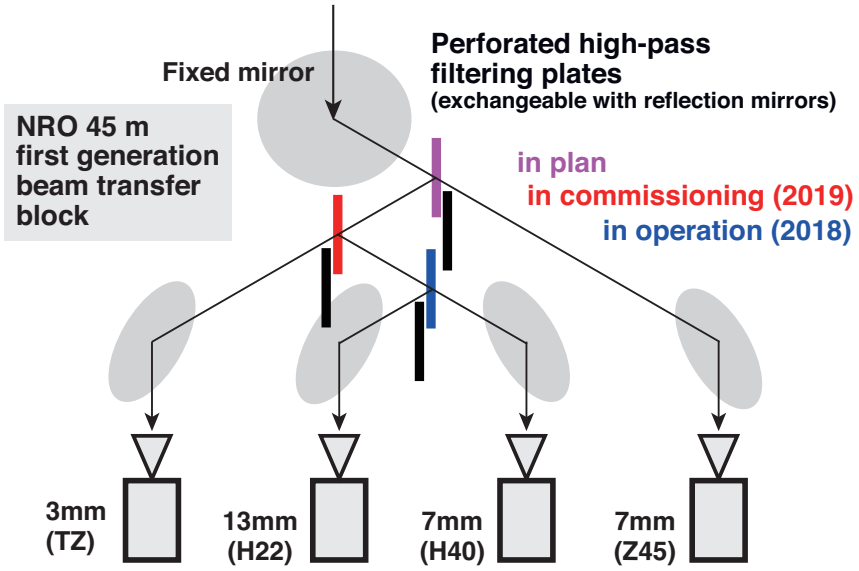


Perforated high-pass band separation plates



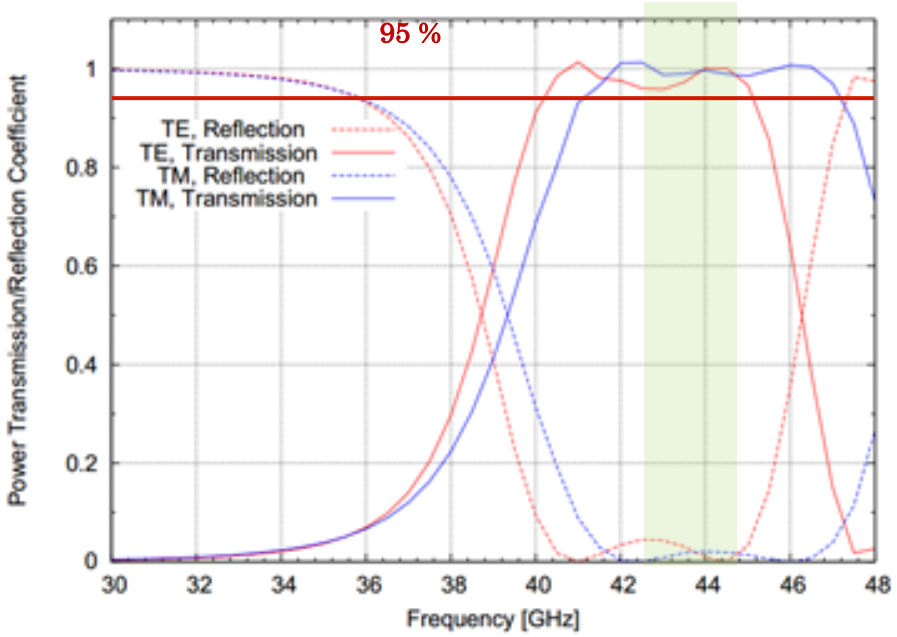


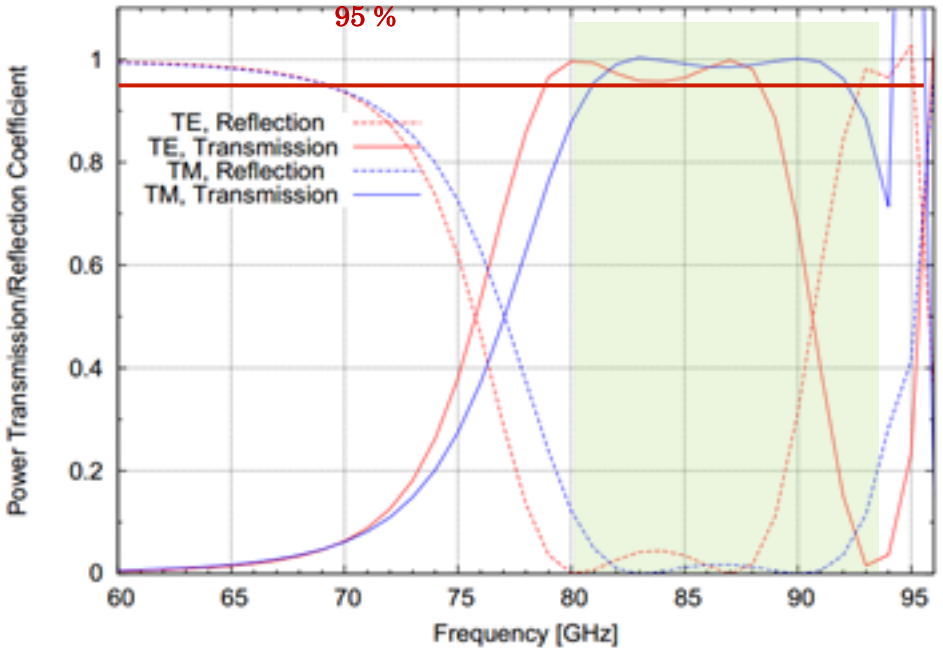




- ✓ **Remote plate changing**
- ✓ **Relative pointing offset ~3″**
  (Okada et al. in prep.)
- ✓ **Used for single-dish open-use in 22 GHz & 43 GHz bands since 2018**
  (Imai et al. in prep.)
- ✓ **Commissioning in VLBI in 22 GHz & 43 GHz bands in 2019**

Transmission and reflection fractions of the band separation plates



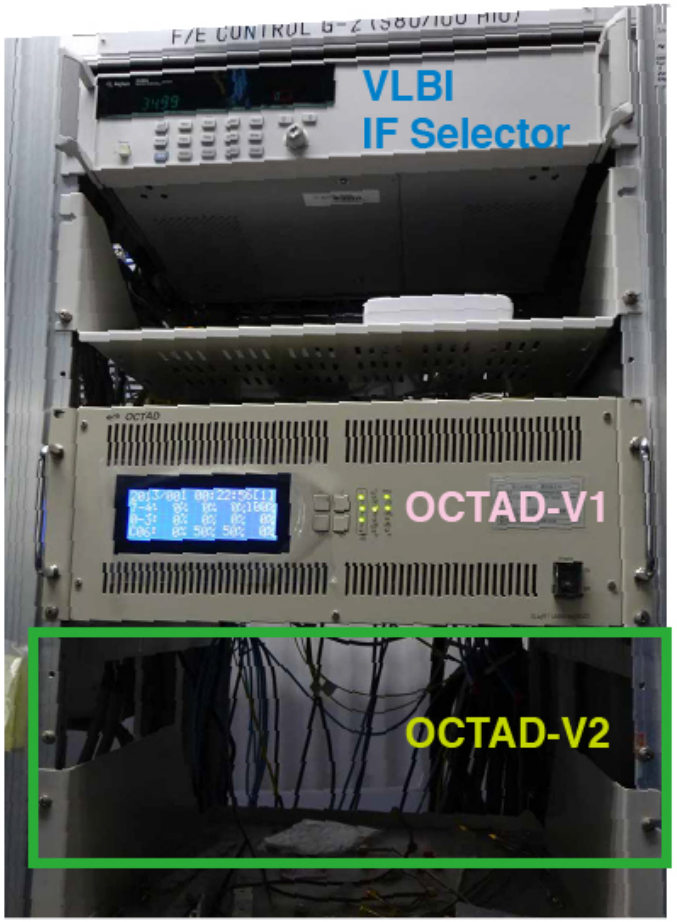


Okada et al. (in prep.)

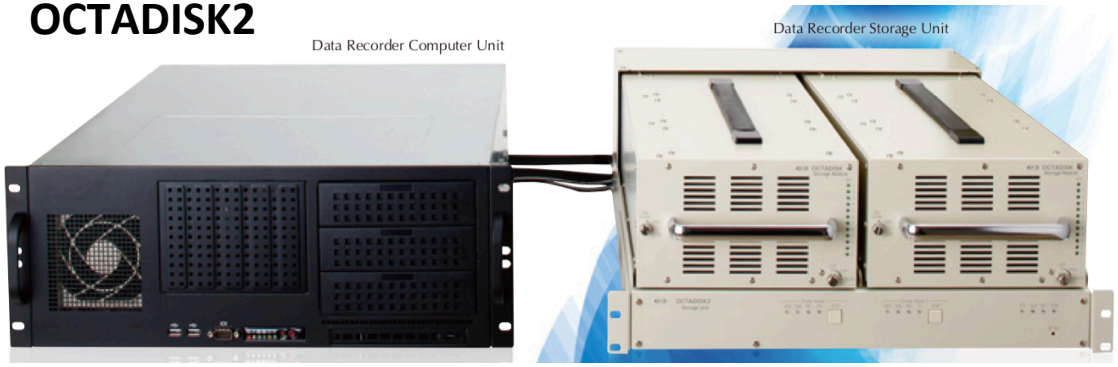
Wide band VLBI signal processing in HINOTORI

- OCTAD-V1&V2 A/D converters
  - 2 GHz/IF x 3 IFs/set x 2 sets
  - 48 Gbps in total
- OCTADISK2 + VSREC (2 sets) recorders
  - 32 Gbps in OCTADISK2
  - 8 Gbps x 2 in 2 VSRECs
  - VDIF format
  - Internet data transfer

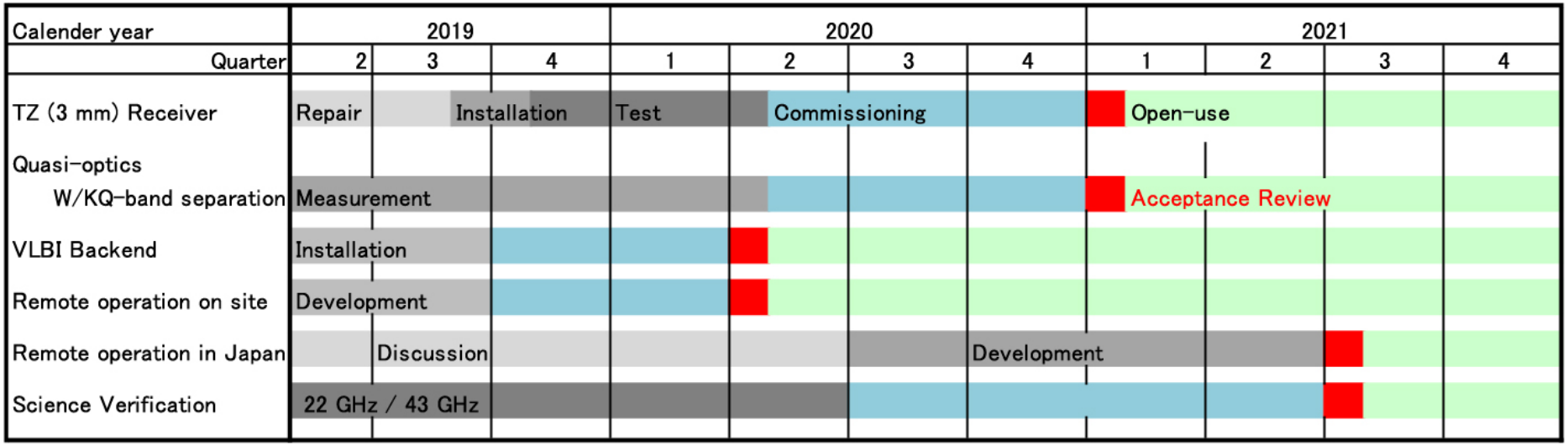
VLBI Rack in the 45 m Lower Cabin



OCTADISK2



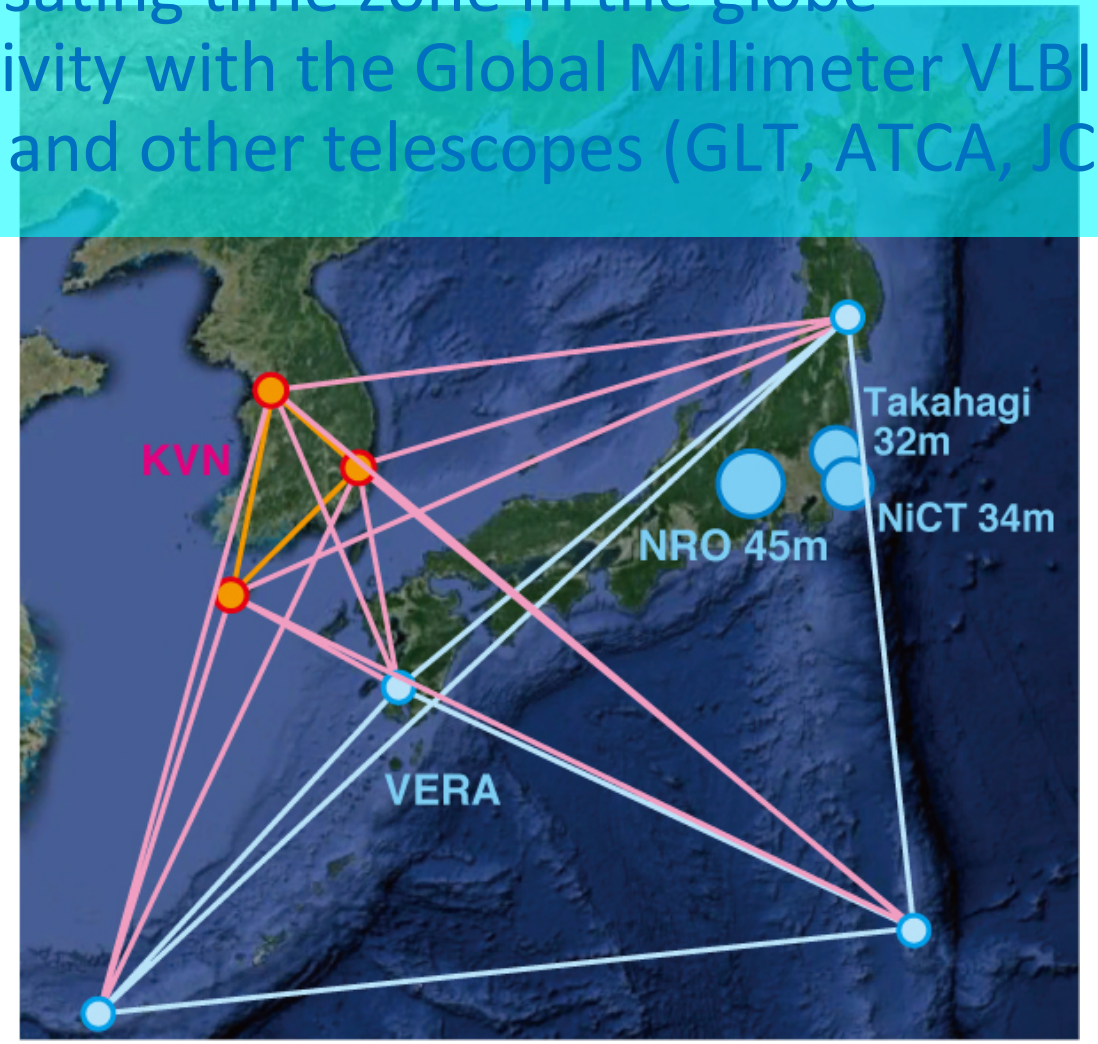
HINOTORI development timeline



- Final completion in 2021 mid
- Open to EAVN
  - 2020A (22 GHz & 43 GHz)
  - 2021B (22 / 43 / 86 GHz)
- Available time?
  - 72 hours /year (general use)
  - 150 hours /year requested by HINOTORI (for Large Projects)

Uniqueness of 3 mm VLBI in East Asia

- Fringe phase calibration with 13 mm / 7 mm data
- Dense network with 4 telescopes within 1000 km
- Compensating time zone in the globe
- Connectivity with the Global Millimeter VLBI Network (GMVA) and other telescopes (GLT, ATCA, JCMT, etc.)



Multiple-band VLBI Network

Italy will join
From others
(GLT, JCMT)?

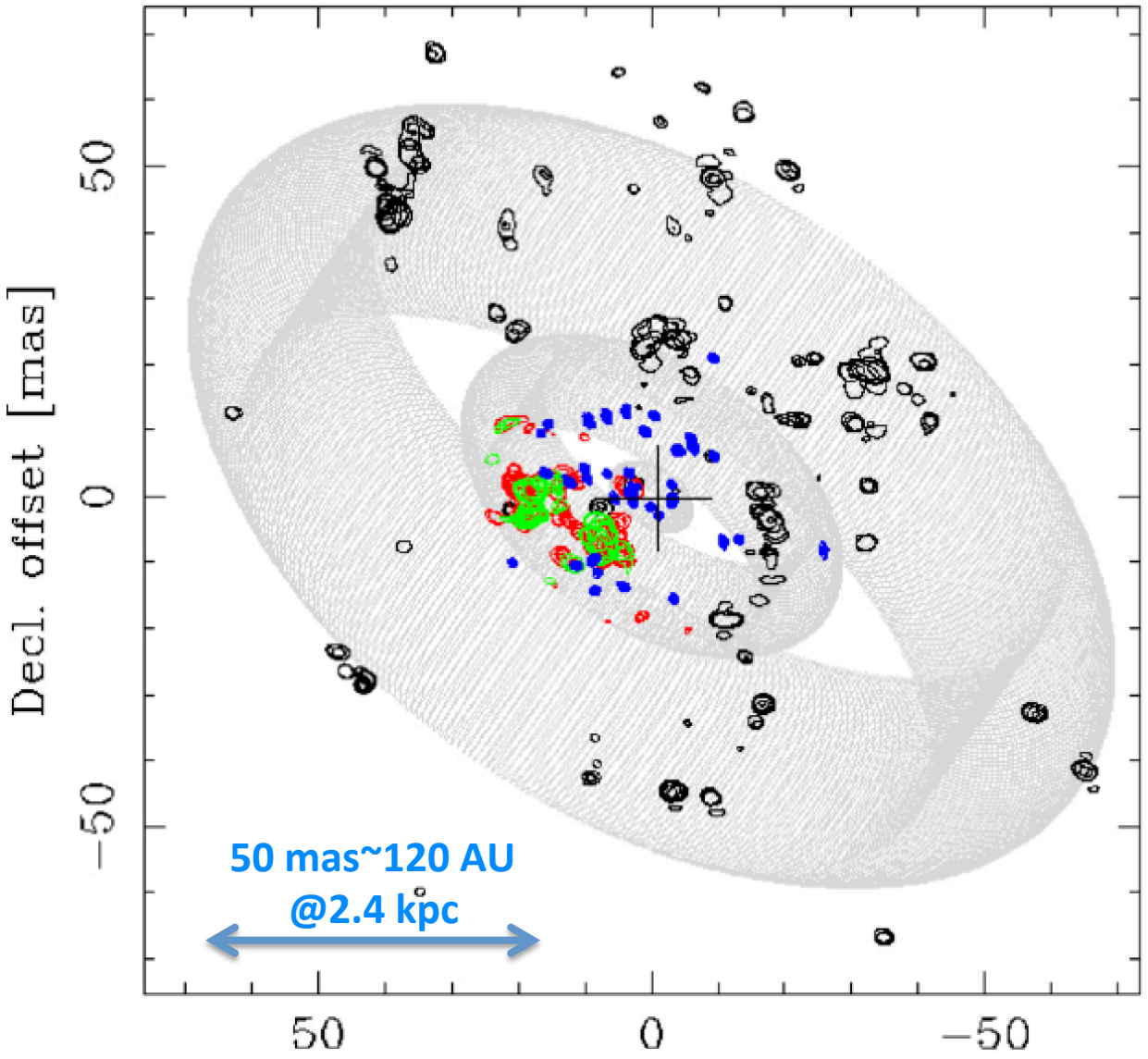
Triple-band VLBI (KaVA @22GHz+KVN @22/43/86GHz)

Red supergiant
S Per
(Asaki et al. in prep.)

Calibration solution transfer from 22 GHz to 43 GHz and 86 GHz

Tracing decadal history of mass loss from stellar surface

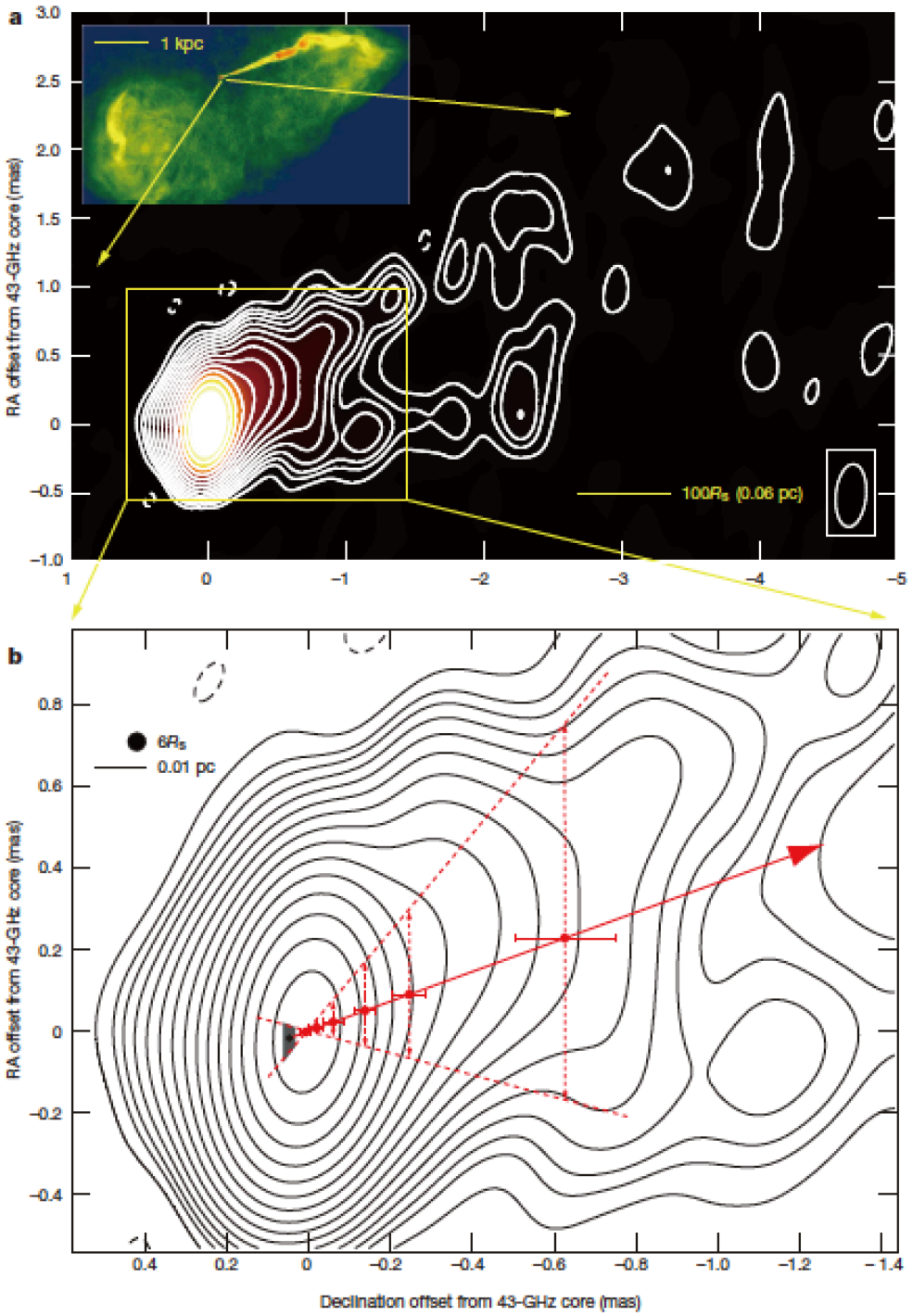
Discontinuous mass ejection uncorrelated with stellar pulsation



H_2O (22GHz) **SiO J=1→0 v=1 (43GHz)** **SiO J=1→0 v=2 (43GHz)**
SiO J=2→1 (86GHz, one KVN baseline)

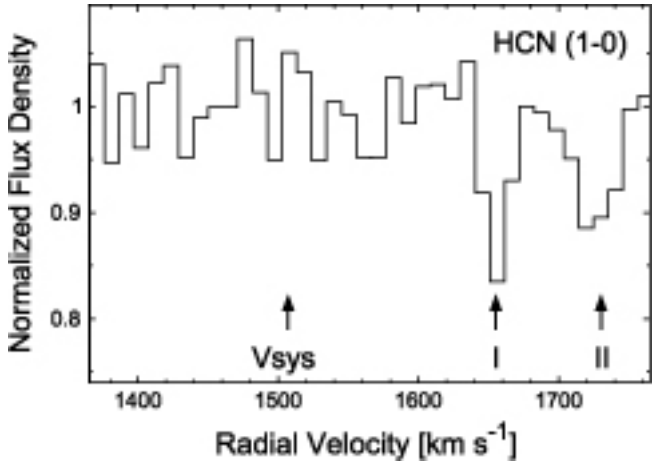
“Core shift” effect

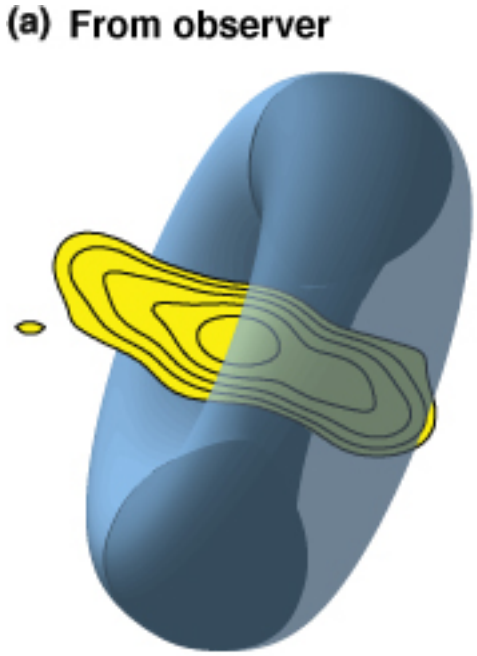
- **Optical thickness dependent on radio frequency**
- **Very close to a high-frequency radio core**
- **Wide opening angle of the jet in M87**
- **Resolving BH accretion torii/disks and roots of jets in 3 mm and higher bands**

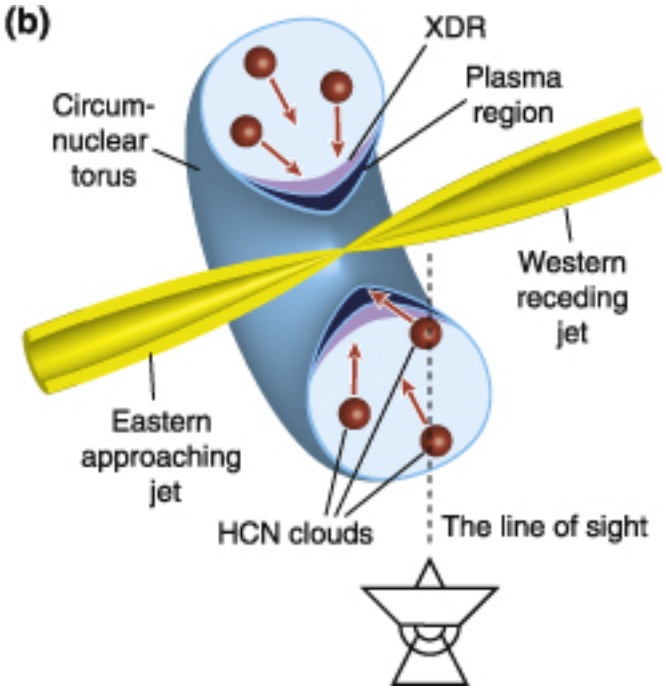


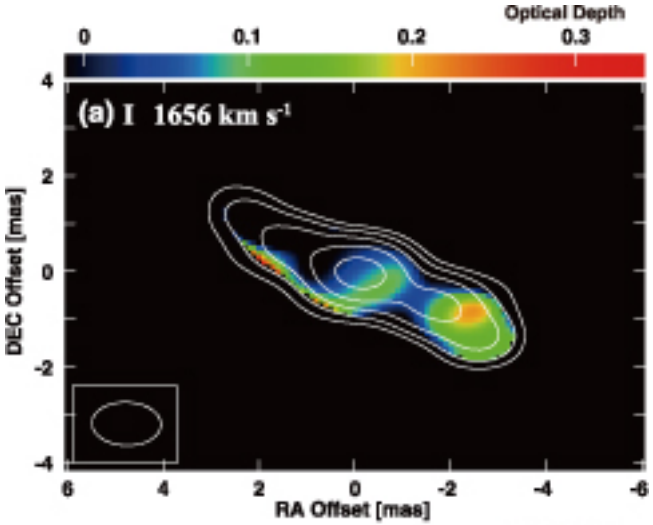
Hada et al. 2011, Nature, 477, 185

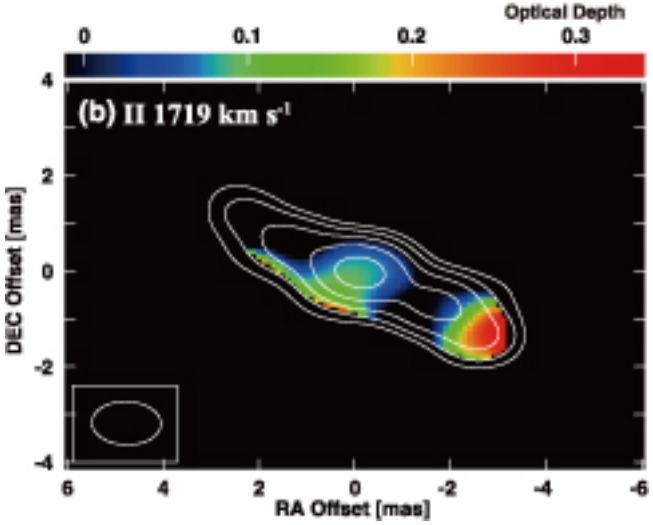
VLBI diagnostics with molecular lines in circumnuclear disks





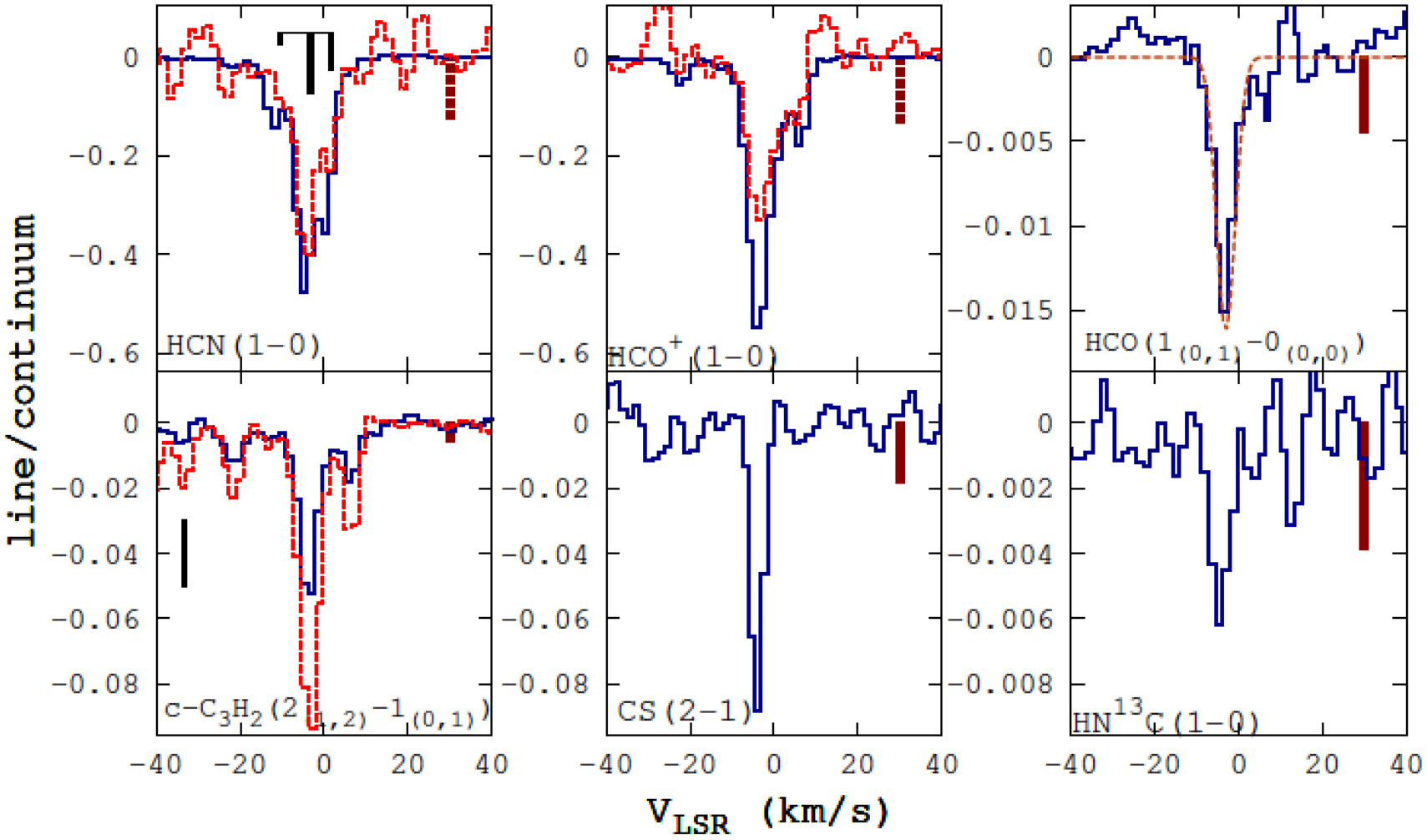






NGC 1052 HCN absorption (with KVN, Sawada-Satoh et al. 2016)

Interstellar tiny-scale structures towards background quasars



^{12}C-bared line **^{13}C-beard line (x30)**

Galactic molecular absorptions detected with ALMA (Band-3) toward J1717-337 (Ando et al. 2015)

Representative Science Use Cases in 3 mm

1. Dynamics of inner circumstellar envelopes probed in multiple maser lines
   - Temporary switching of maser pumping schemes
   - Propagation of pulsation driven-shock waves enhancing stellar mass loss
2. Accelerations of AGN jets
   - Angular momentum transfer from accreting material to jet bullets
3. Kinematical and physical diagnostics of circumnuclear disks
   - Physical phase transfer of materials towards AGNs
4. Galactic interstellar tiny-scale (~1 AU) structures
   - Seeds of molecular gas grown to hierarchical ISM structures?

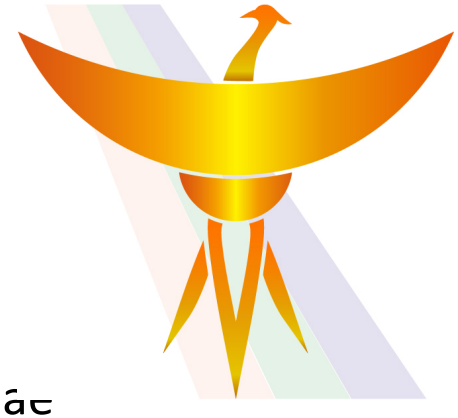
1.3 mm VLBI in East Asia

VLBI signal transfer from SPART 10 m to NRO 45 m telescope via RAINBOW network?

SPART 10 m telescope (Osaka Prefecture University) joining 1.3 mm VLBI (2019 March)
VLBI signal converted and recorded at 8—48 Gbps via NRO 45 m telescope in future?

Networking with SPART+GLT+SNU(+KVN)+JCMT?

Thank you



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