

Synergy between JVN & HE-astrophysics

in the Era of Multi-Messenger Astronomy

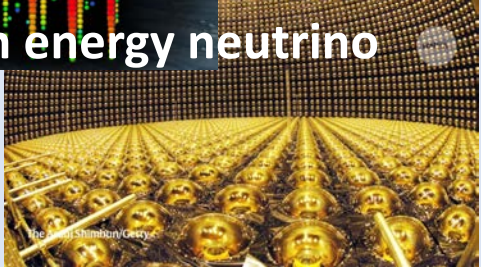
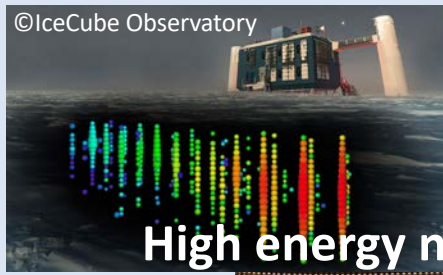
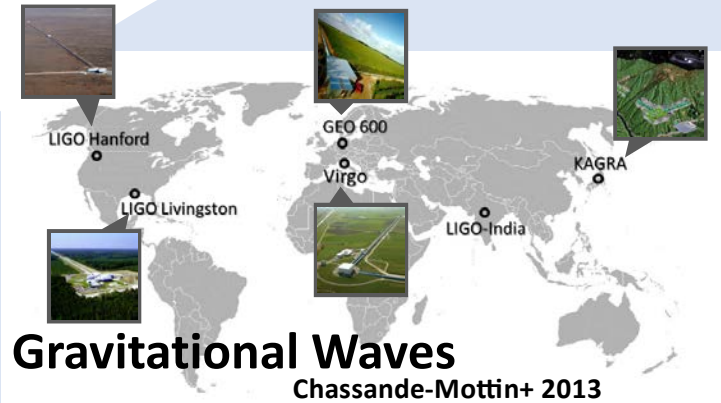
The extreme Universe viewed
in very-high-energy gamma rays 2021

(Feb 21-22, 2021 @ Zoom)

Kotaro Niinuma (Yamaguchi University)

Multi-Messenger Astronomy

Importance of time-domain: Time Domain Astronomy



Extreme object
Extreme phenomena



EM observation →
Counterpart / Emission mechanism

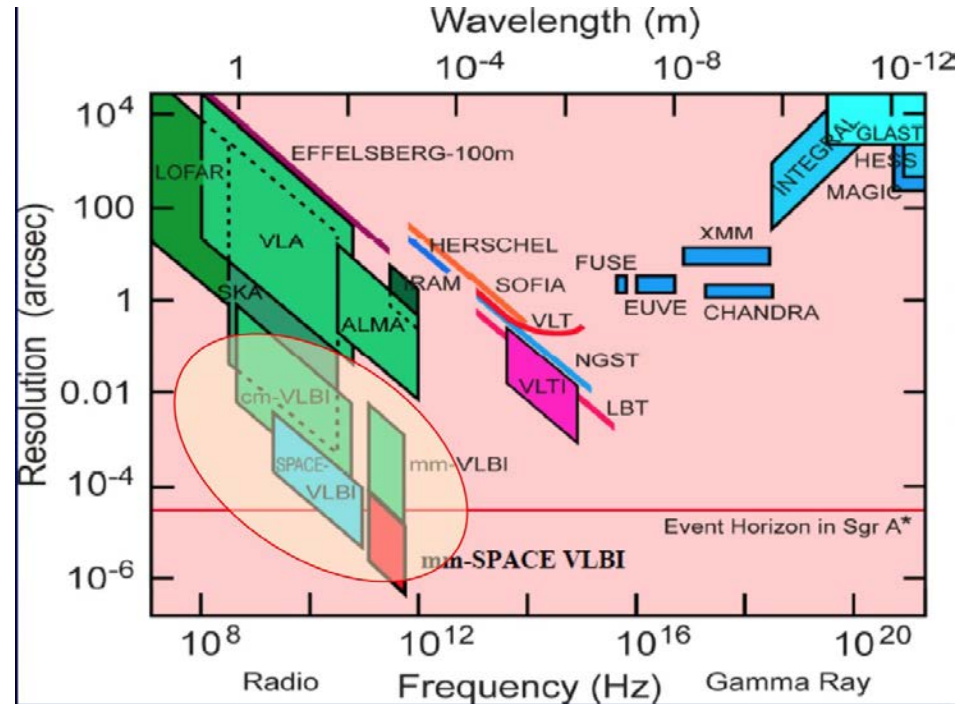
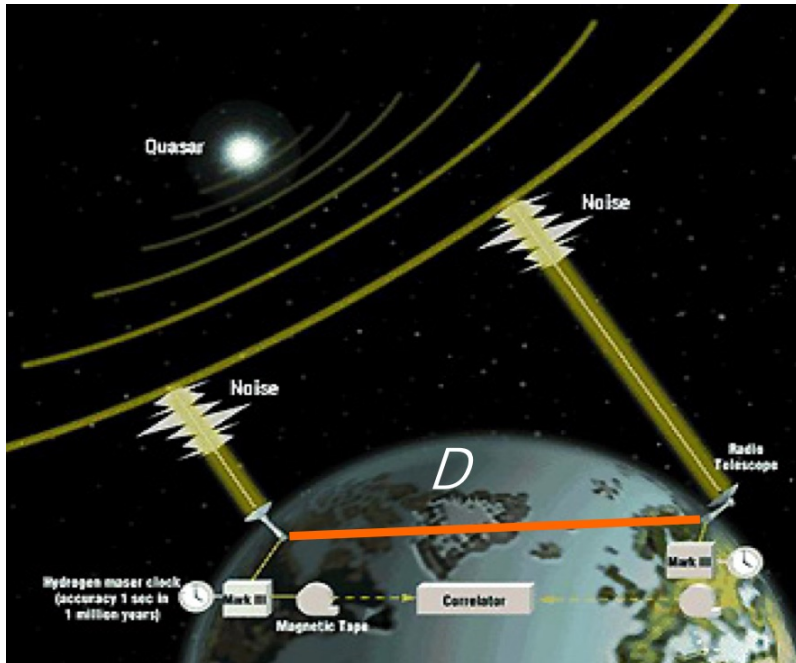


Contents

- Very Long Baseline Interferometry: VLBI
 - Synergy between radio (VLBI) and HE
- Japanese VLBI Network
 - MM/MWL astronomy with JVN
- Polarization capability of JVN
- Summary

Radio Interferometer

Very long baseline Interferometry (VLBI)



Angular resolution (typical):
 $\theta \sim 1$ milli-arcsec (mas)
 (= $1/3600000$ degree or “視力 ~ 60000 ”)

- $D \sim 2000$ km
- $\lambda \sim 1$ cm ($\nu = 30$ GHz)

VLBI is sensitive to compact object with
“high brightness temperature”

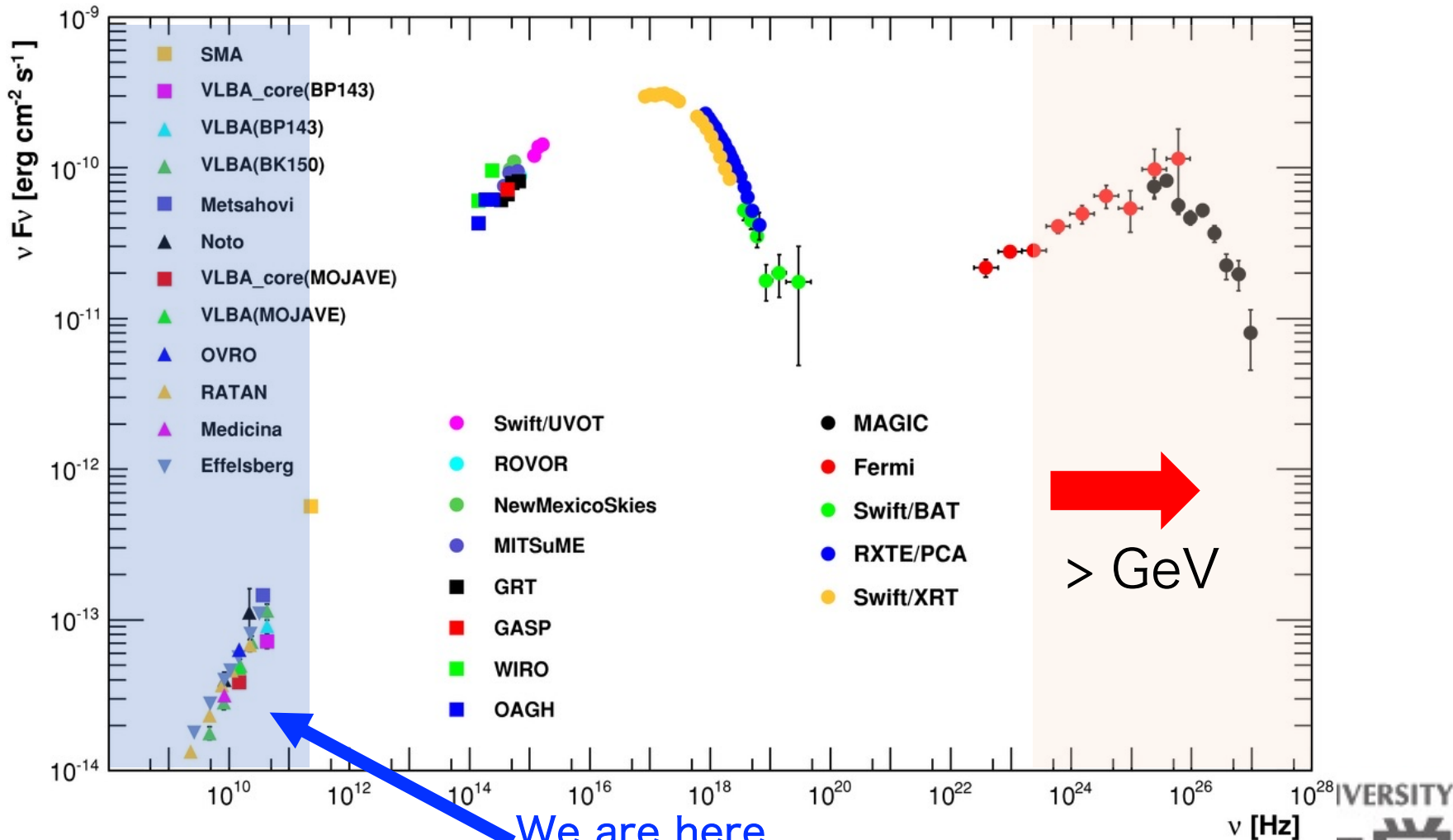
$$T_B \propto S_\nu \theta^{-2} \nu^{-2} (1+z)$$

(e.g., 1mas, 0.1Jy, 10GHz $\rightarrow T_B \sim 10^9$ K)

* 1Jy = 10^{-26} Wm $^{-2}$ Hz $^{-1}$

Synergy with future VHE γ -ray astronomy

Collaboration between the LOWEST energy & the HIGHEST energy

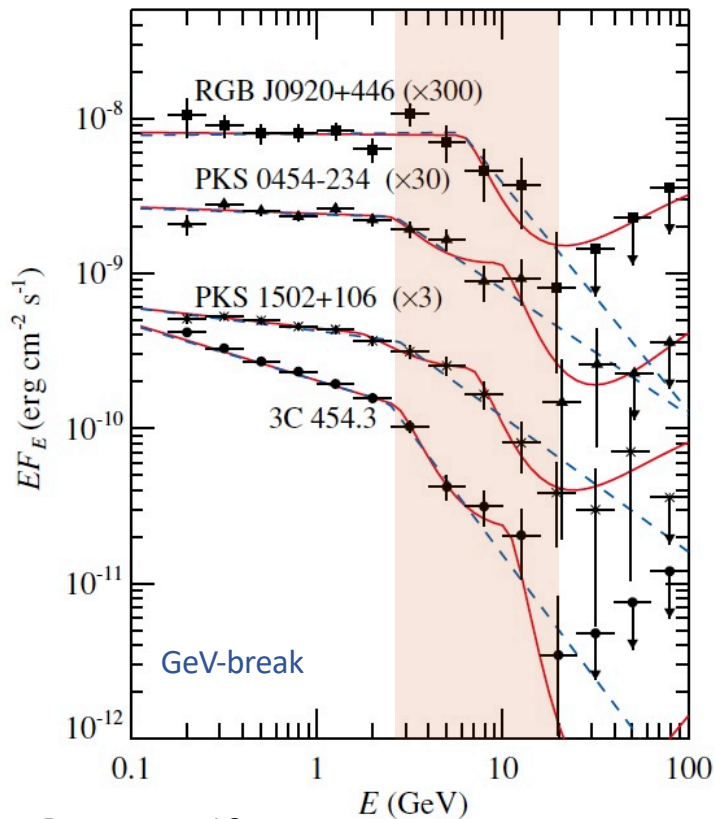


Open Question

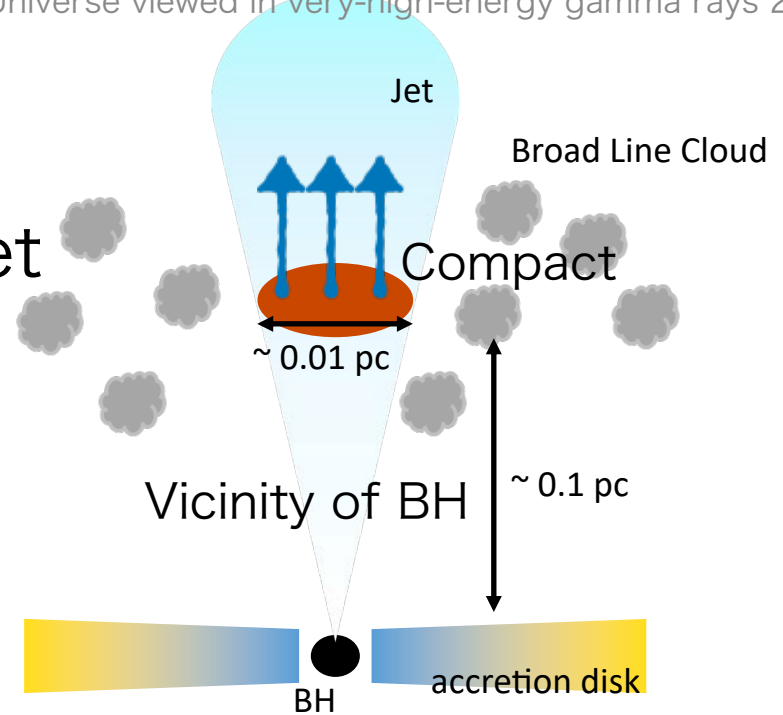
HE-emission region of AGN jet

Absorption of GeV photons ($\sigma_{\gamma\gamma}$)

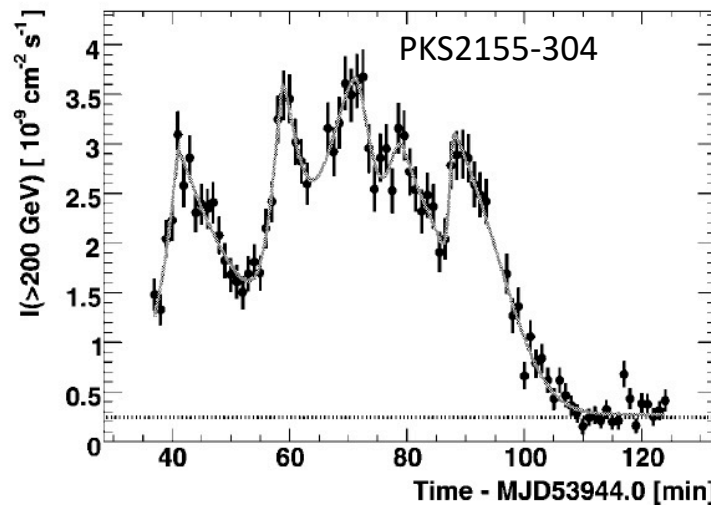
Pair creation: GeV-photon & Ly-continuum photon in BLR



Poutanen+10



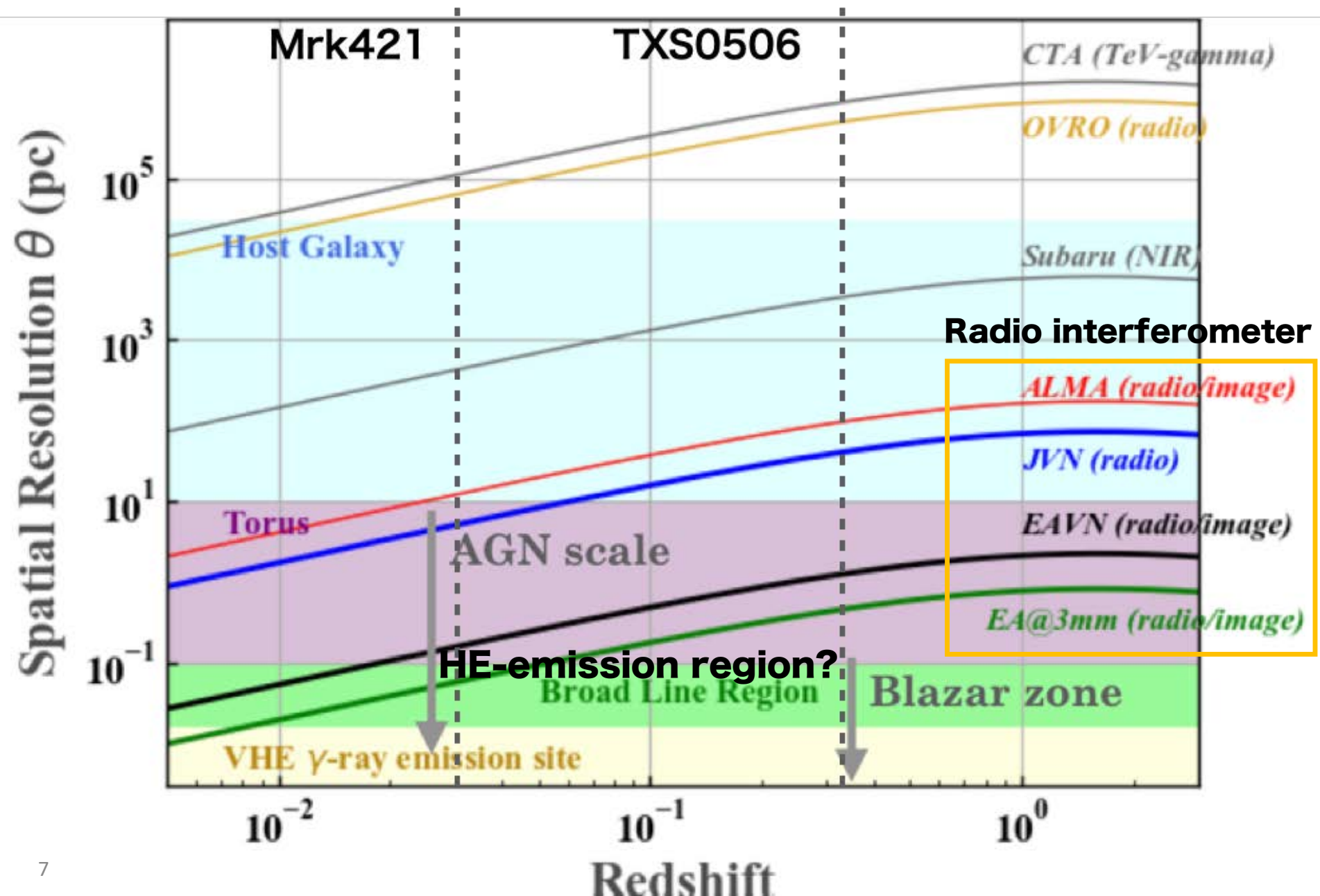
Rapid time variation



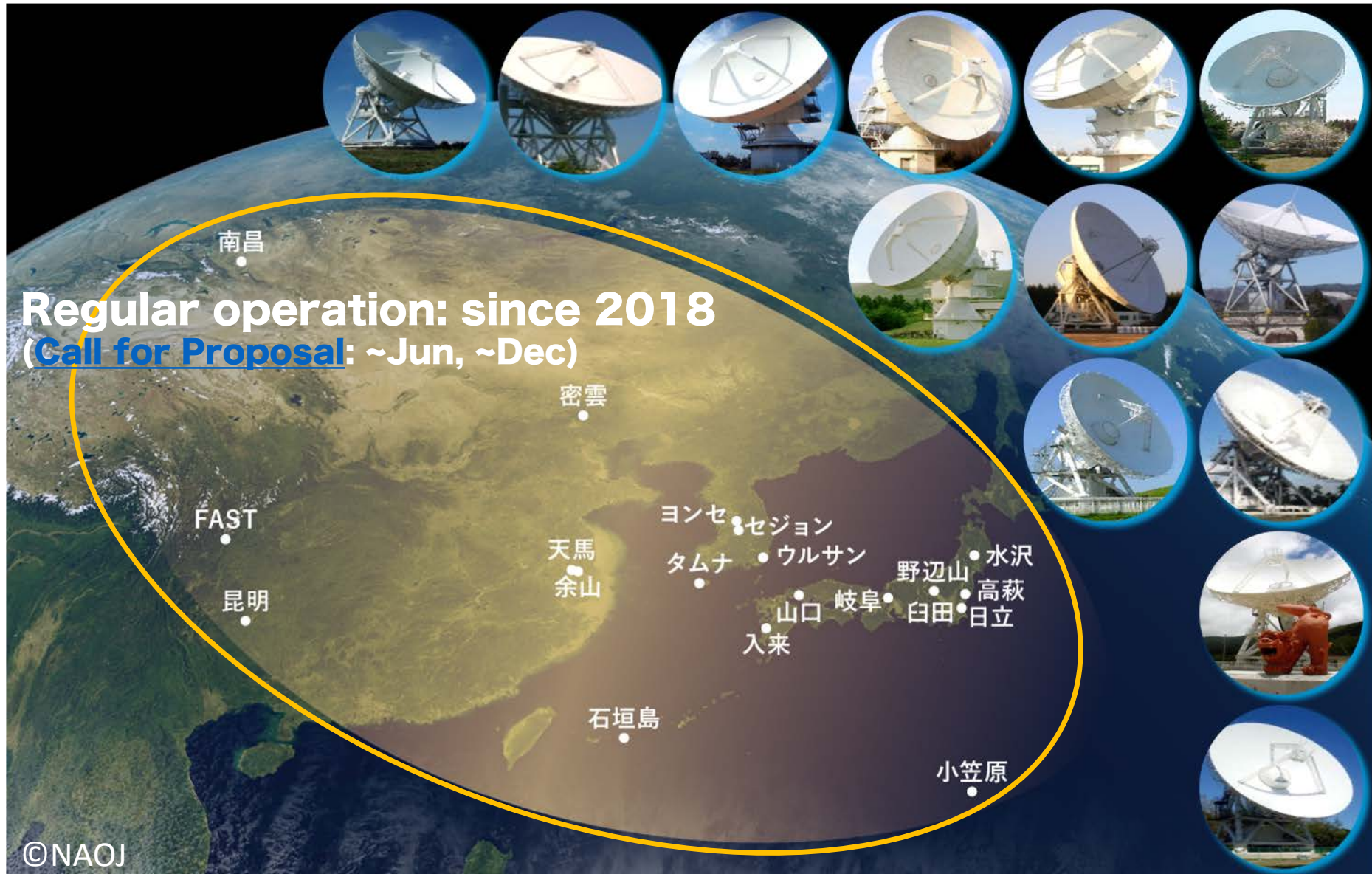
Aharonian+07

➔ Size of emission region

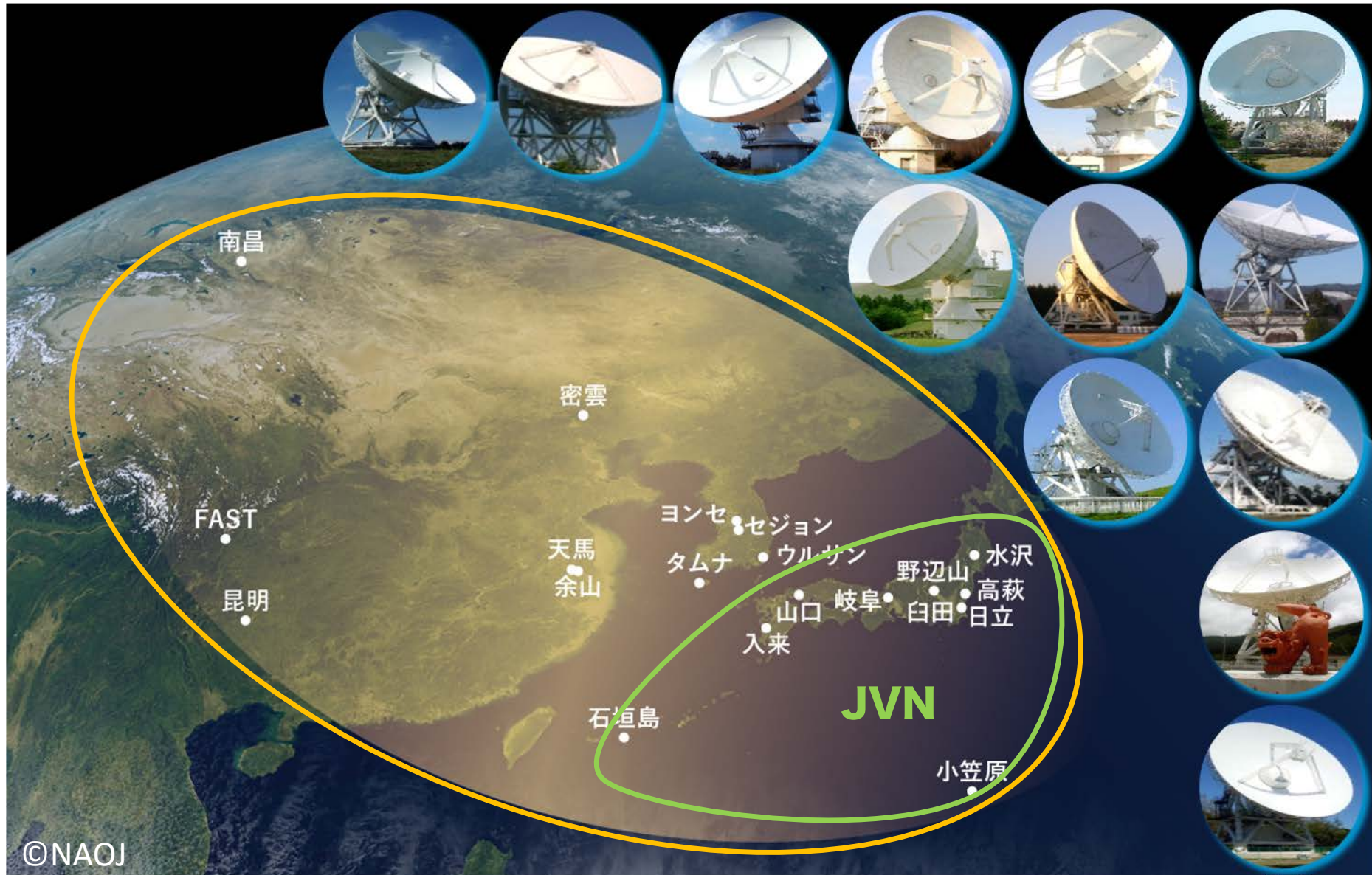
$$R_{\gamma} \sim \frac{c\tau_{\text{var}}\delta}{1+z} \sim 0.01 \text{ pc}$$

$M_{\text{BH}} = 10^8 M_{\odot}$ を仮定


East Asia VLBI Network: EAVN

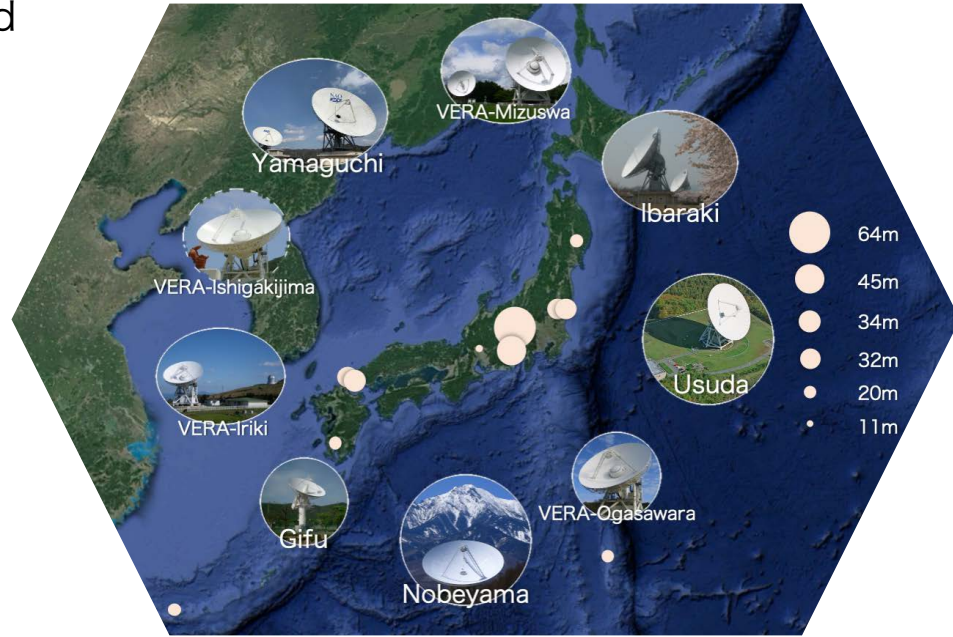


Japanese VLBI Network: JVN



Japanese VLBI Network (current status)

- Collaboration Network of 6 Universities and Research Institutes
 - NAOJ (VERA)
 - Ibaraki, Tsukuba, Gifu, Osaka-pref., Yamaguchi, Kagoshima Universities
 - JAXA, NICT
- Network
 - 9 telescopes (11m ~ 64m)
 - Usually 6 telescopes for imaging observation
 - Baseline length: 200 - 2300 km
 - Frequency 6/8/22 GHz
 - Detection sensitivity: 3 mJy (6/8 GHz, Ibaraki-Yamaguchi) achieved in a few min
- Status
 - 200hr/yr, 30 observations/yr in 2020
 - Imaging observation (~6 telescopes)
 - **Detection observation (Ibaraki-Yamaguchi)**



Japanese VLBI Network (JVN)

Call-for-Proposal: Mar, Jul, Nov
(Collaboration with at least one of the JVJN members is required)

<http://astro.sci.yamaguchi-u.ac.jp/jvn/index.html>

Recent Activities

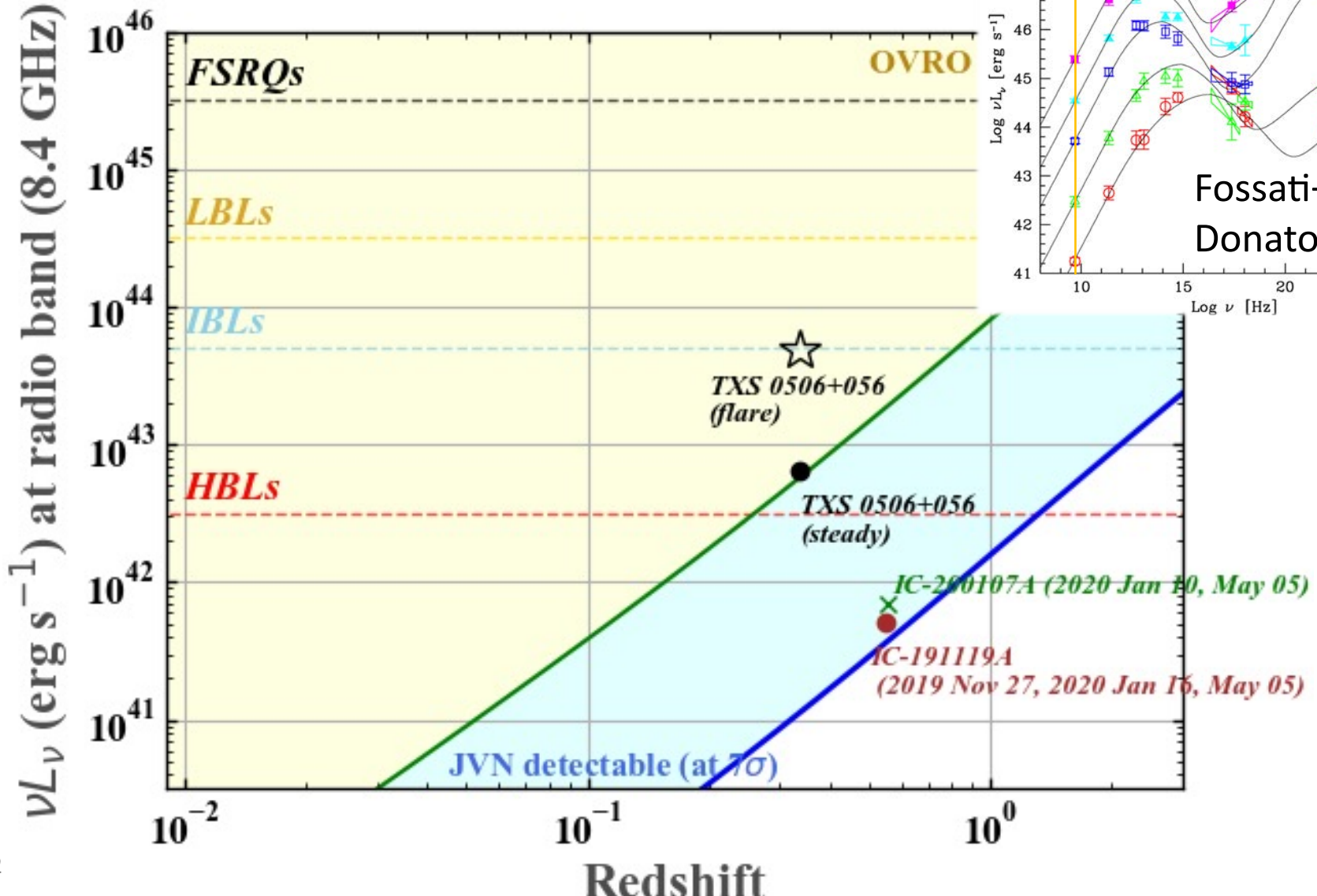
- Participation to EAVN (Ibaraki & Yamaguchi)
 - Takahagi 32m (Ibaraki) @ 22 GHz (2020A~)
 - Hitachi 32m (Ibaraki) & Yamaguchi* 32m or 34m @ 6 GHz (2021A~)
- **Ibaraki-Yamaguchi single baseline** observation
 - **High sensitivity** (~3 mJy), fringe-detection observation (**non-imaging**)
 - Surveys of various categories of astronomical objects
 - First results to be published soon
- Future plan
 - Working group of future VLBI astronomy of Japan (in VLBI consortium of Japan)
 - White paper was published in 2021 Jun (written in Japanese, [here](#))

* Serious system trouble was occurred in Yamaguchi station and cancelled the participation in EAVN session in FY2021



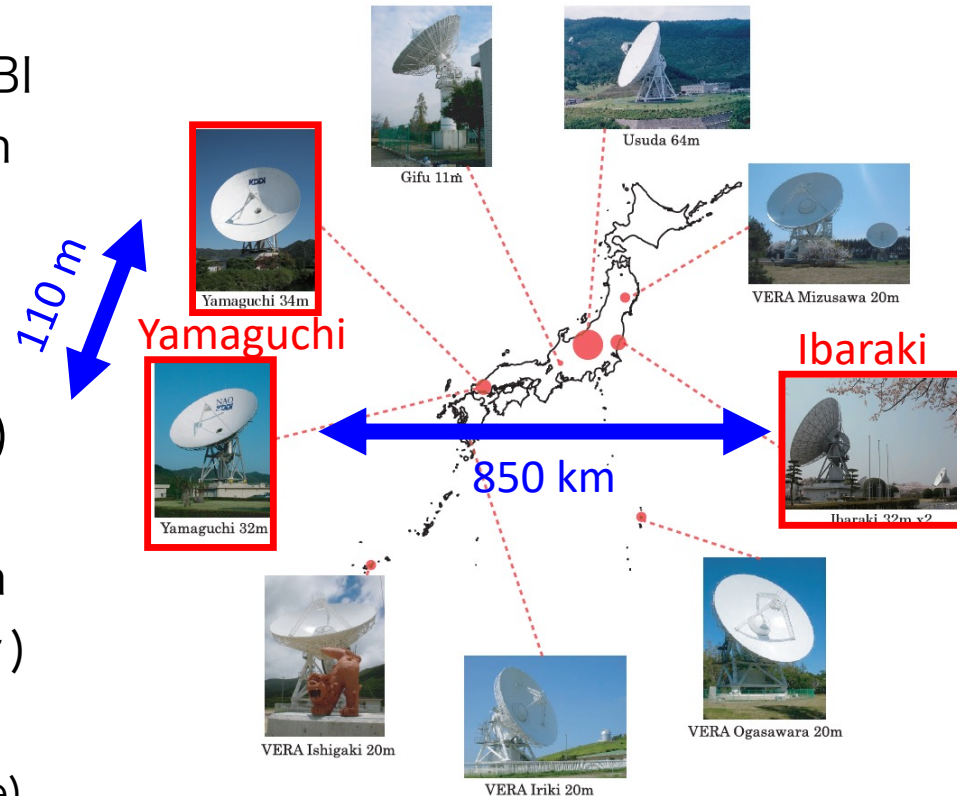
Sensitivity of JVN

Non-imaging mode (= flux measurement)



Ibaraki-Yamaguchi single baseline observation & Yamaguchi Interferometer (YI)

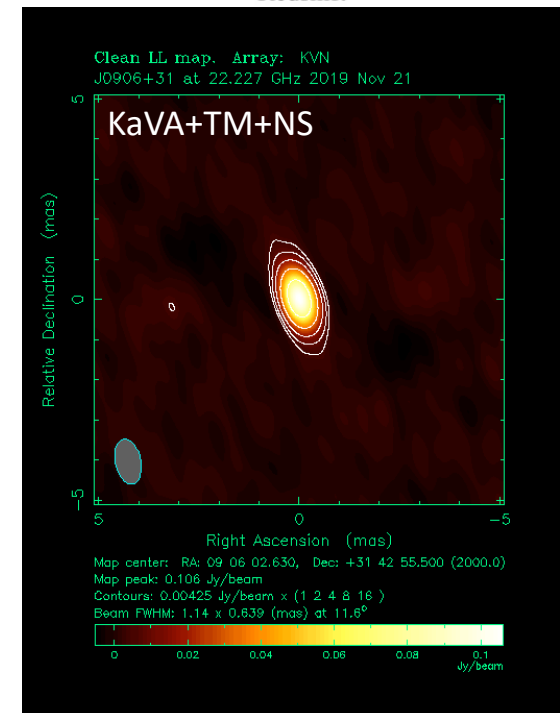
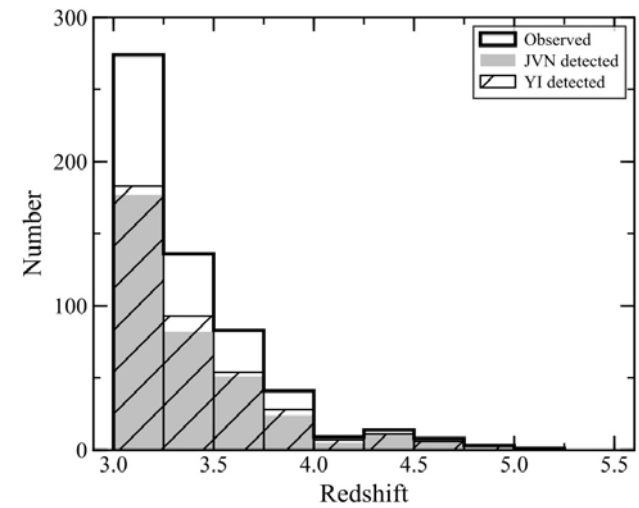
- Ibaraki-Yamaguchi
 - Fringe detection oriented VLBI
 - Non-imaging, fringe detection
 - High sensitivity with 32/34m
 - ~ 3 mJy (7σ) @ 6/8 GHz
 - $T_{\text{bmin}} \sim 10^7$ K
- Yamaguchi Interferometer (YI)
 - Regular operation: 2019~
 - Total flux density observation
 - High sensitivity of ~ 3 mJy (7σ)
 - Long available time
(>1000 hr/yr in future)
- Status: Steady Operation



Survey of various categories of astronomical objects to create “VLBI source” catalogs

Survey and Imaging Observation of High-z AGNs (Furuya)

- Radio properties of high-z AGN jets
 - Structure and spectrum
 - Blazar (Large Doppler)
 - CSS/GPS/HFP (Young jet)
 - Luminosity function
 - Evolution in the cosmological time
- JVN Survey
 - Large and uniform sample survey
 - Selected from SDSS/FIRST survey
 - 570 AGNs with $z > 3$ were observed
 - 363 detected by JVN (Ibaraki-Yamaguchi)
 - ~80% of them show flat spectrum
- EAVN Imaging
 - Imaging by EAVN at 22 GHz for 8 sources
 - An example (J0906+31) ->



MWL/MM astronomy with JVN

- Target
 - Extreme objects
 - Transients: e.g., EHE-neutrino blazar candidates
 - (very) faint blazars such as HBLs/UHBLs or extreme blazars
 - Targets from flare program / long term monitoring (“*Science with the Cherenkov Telescope Array*”)
- ➔ Taking advantage of the high sensitivity of JVN
- Combination of non-imaging and imaging
 - Non-imaging **BUT** high cadence (Ibaraki-Yamaguchi array)
 - Difficulty in discussion on “structure”
 - Monitor of radio flux extracted from very compact region
 - Imaging: pc-scale structure **BUT** time consuming
 - JVN, EAVN (high-quality image)

Multi-Messenger astronomy

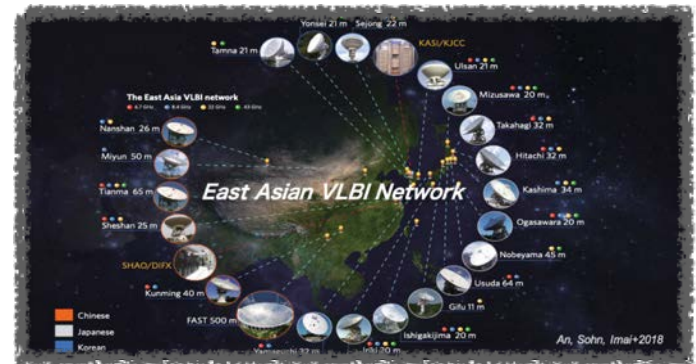
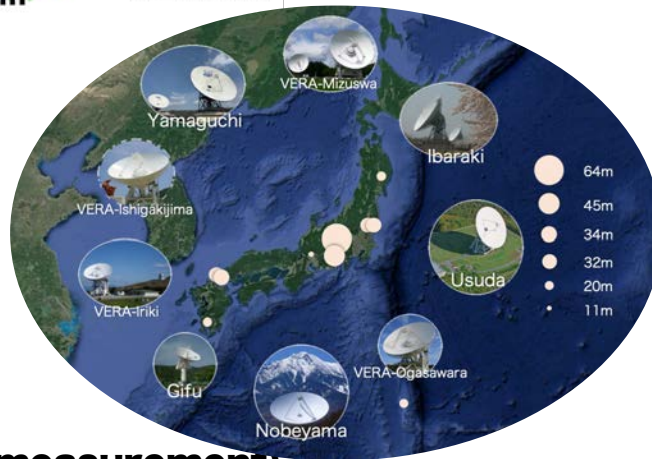
with high temporal/spatial resolution observation

High sensitivity VLBI Network for time-domain research

Yamaguchi Interferometer (32m+34m)



Ibaraki Interferometer (32m x 2)



cm-VLBI (Flux measurement)

- Higher spatial resolution
- High sensitivity
 - snapshot -> High-cadence
 - “my” telescope -> flexible operation

mm-VLBI (imaging)

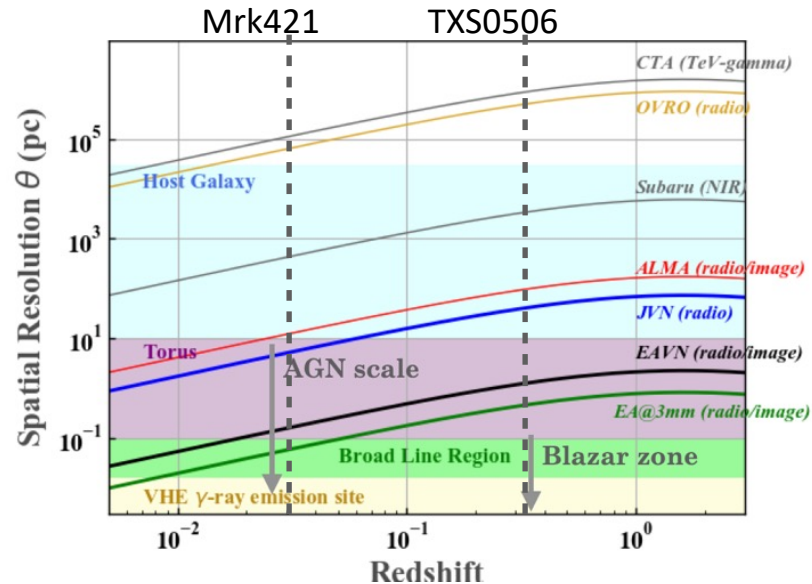
- Higher spatial resolution
- Structural variation
- Transparent to sync. emission

Synergy with future VHE γ -ray astronomy

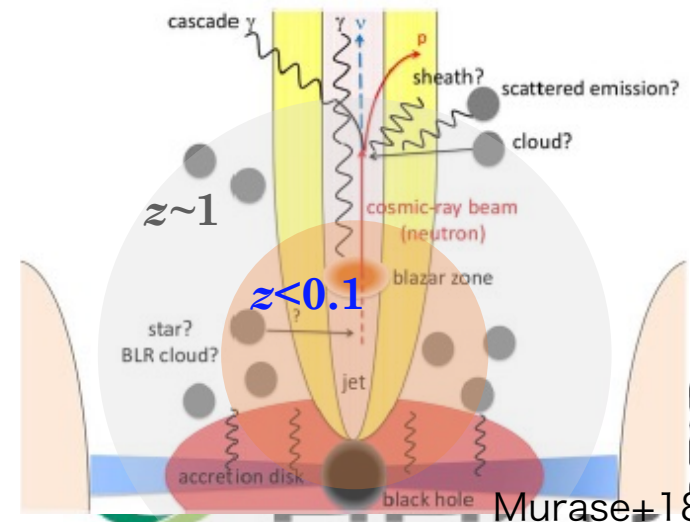
Toward the era of Cherenkov Telescope Array

- Preparatory study with JVN
 - JVN survey to search for further (e)HBL candidates from unidentified gamma-ray sources

E.g., Snapshot of all radio sources located within the positional error of each gamma-ray object



- Developing new EA-3mm-VLBI
 - Approaching to the size of HE-emission region (For nearby TeV γ -ray blazars, scale of BLR will be spatially resolved)



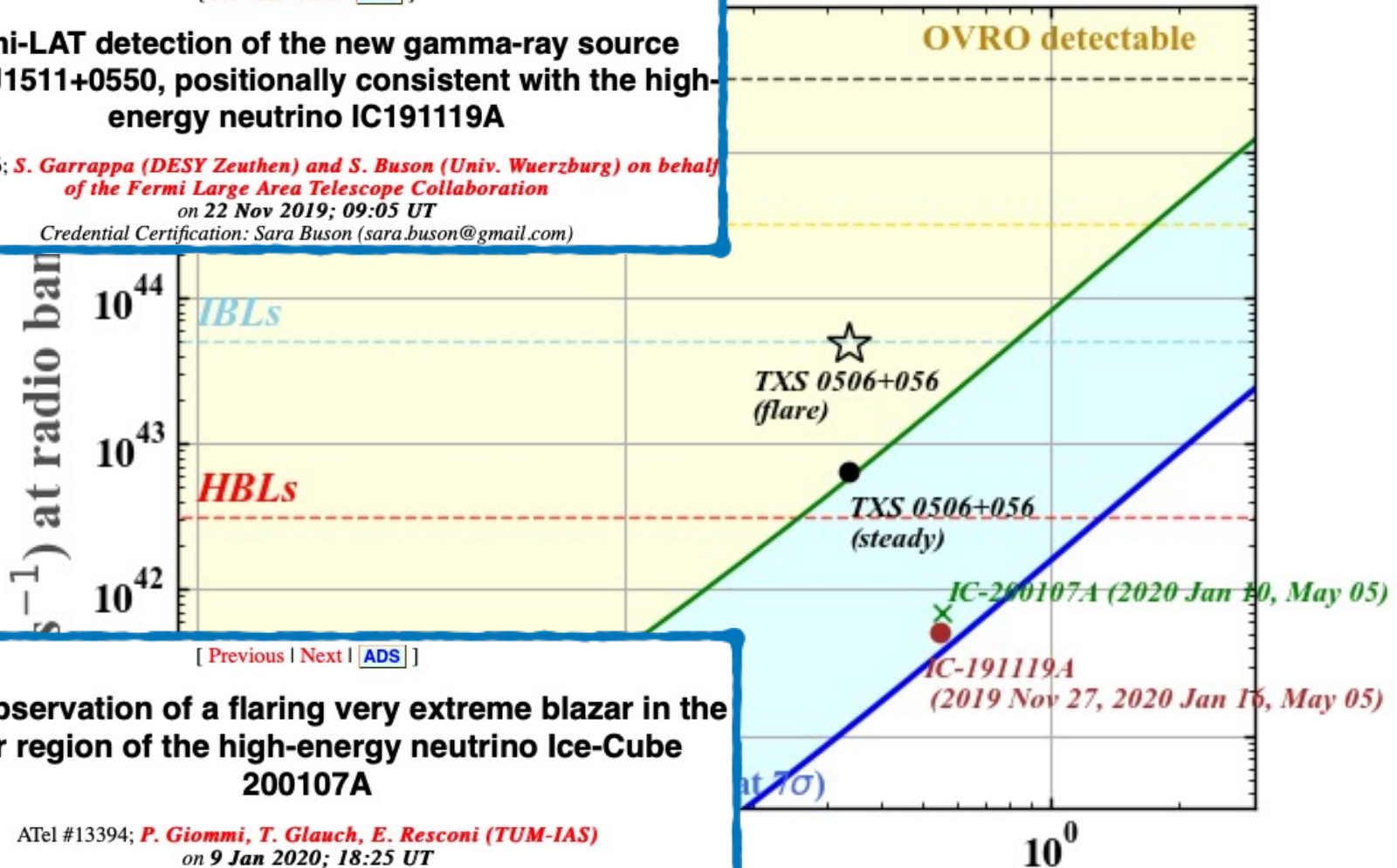
HE- ν blazar

Search for the 2nd, 3rd TXS 0506

[Previous | Next | ADS]

Fermi-LAT detection of the new gamma-ray source Fermi J1511+0550, positionally consistent with the high-energy neutrino IC191119A

ATel #13306; *S. Garrappa (DESY Zeuthen) and S. Buson (Univ. Wuerzburg) on behalf of the Fermi Large Area Telescope Collaboration*
 on 22 Nov 2019; 09:05 UT
 Credential Certification: Sara Buson (sara.buson@gmail.com)



[Previous | Next | ADS]

Swift observation of a flaring very extreme blazar in the error region of the high-energy neutrino Ice-Cube 200107A

ATel #13394; *P. Giommi, T. Glauch, E. Resconi (TUM-IAS)*
 on 9 Jan 2020; 18:25 UT
 Credential Certification: Paolo Giommi (paolo.giommi@asi.it)



JVN

Capability of polarization observation

- Yamaguchi – Ibaraki VLBI array
- VERA array

Yamaguchi-Ibaraki array

- VLBI observation
 - 6GHz / 8GHz, $\Delta S_{\min} \sim 0.5 \text{ mJy}$ in 5min
 - Circular polarizations (RHCP/LHCP)
- Polarization capability
 - Both RHCP/LHCP are available
 - **BUT** performance evaluation is yet to be done (especially as a VLBI)
 - Current status:
 - Total intensity (i.e., Stokes I) observation is available as a VLBI use
 - Stokes I / V observation are available as a single dish use for each telescope

High sensitivity VLBI Network for time-domain research

Yamaguchi Interferometer (32m+34m)



Ibaraki Interferometer (32m x 2)

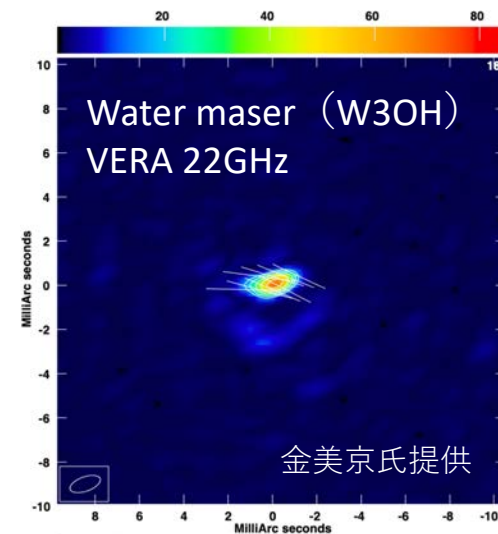
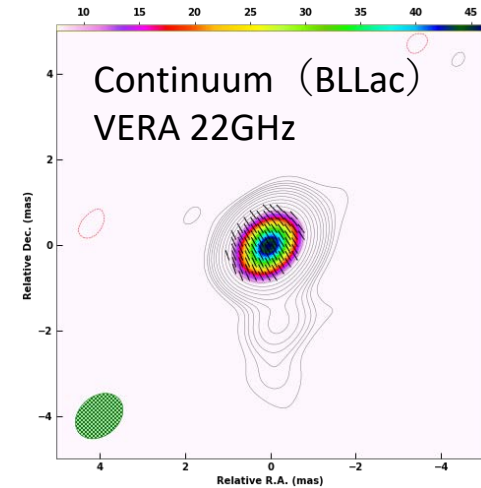


VERA

- 2015: VERA has single polarization capability at 22/43GHz
- 2015: Start development of dual-pol. system at 22/43GHz
based on KAKENHI project (PI: Hagiwara (Toyo Univ.) and Hada (NAOJ))
- 2019: dual-pol system was installed onto all 4-VERA telescopes
- 2020: Dual-Pol commissioning observation together with EAVN
- 2021: Dual-Pol wide-band (16Gbps/band) commissioning for only VERA

Other VLBI networks in the world

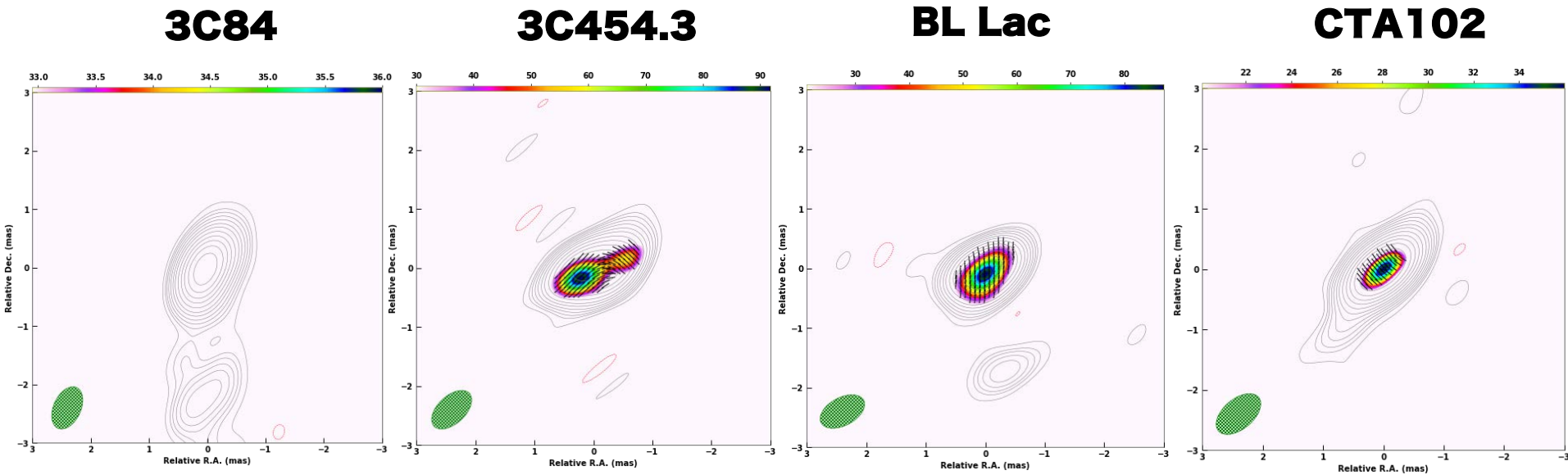
- VLBA 4Gbps, EVN 2Gbps
- KVN 16Gbps (4Gbps/frequency band)
- EHT 32-64Gbps (only one session per year)



Hada-san's talk
Japanese VLBI consortium symposium in 2021

VERA 43GHz polarization images

Contour : Stokes I ($3\sigma_I$ から表示)
 Color : $\sqrt{Q^2+U^2}$ ($3\sigma_p$ から表示)
 Bar : EVPA



- 3C84: No polarized emission was found (typical polarization calibrator)
- 3C454, BLLac, CTA102: A few % of of polarization fluxes are detected by VERA

Hada-san's talk
 Japanese VLBI consortium symposium in 2021

Summary

- VLBI possibly gives a clue to HE-emission site (location/size) in the AGN jet
 - Complementary to VHE-gamma-ray observation
 - High cadence observation with the high spatial resolution for MWL/MM astronomy
- Japanese VLBI Network
 - Unique VLBI array in the world (Universities' Collaboration VLBI)
 - High cadence flux measurement with the spatial resolution of $\sim 10\text{pc}$ is available
 - Combination of non-imaging and imaging are important for MWL/MM
 - Accurate flux measurement by Ibaraki-Yamaguchi array will be available by redundant VLBI mode (uniqueness of JVN)
- Capability of VLBI polarization observation
 - Not established yet for Ibaraki-Yamaguchi baseline
 - VERA: under the wideband test observation (almost ready)