

East Asian VLBI Network observations of nearby supermassive black holes



East Asia AGN Workshop 2017, Dec/4-6/2017, Kagoshima

Kazuhiro Hada

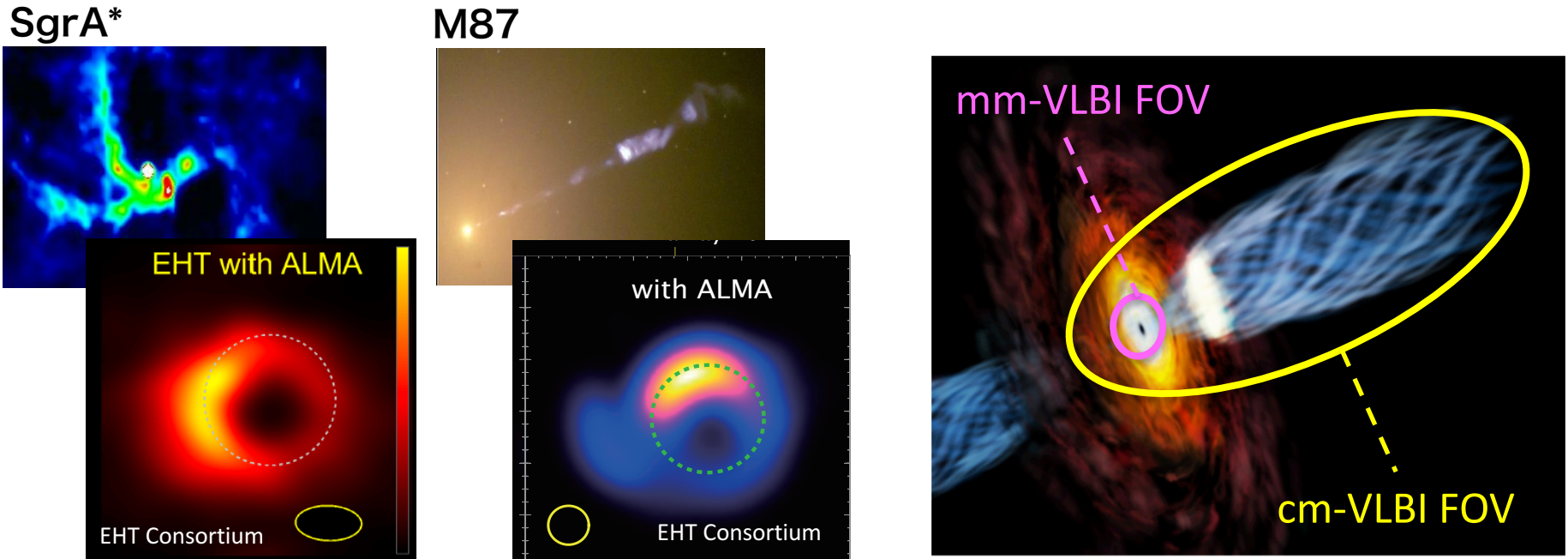
(Mizusawa VLBI Observatory, NAOJ)

On behalf of

EAVN commissioning team ("Tiger Team") and

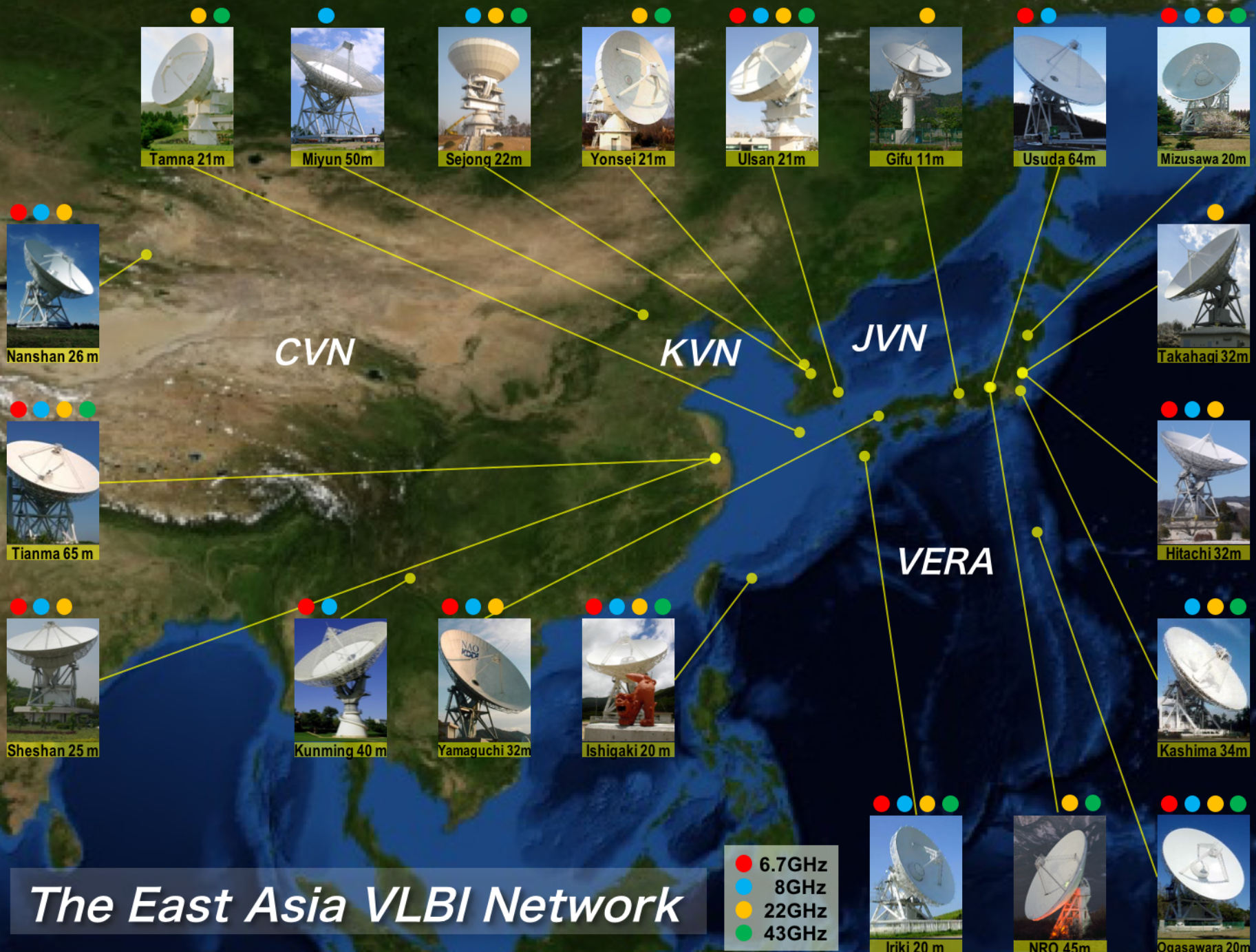
EAVN-AGN Science Working Group

Role of *cm-VLBI* in the era of *mm-VLBI*

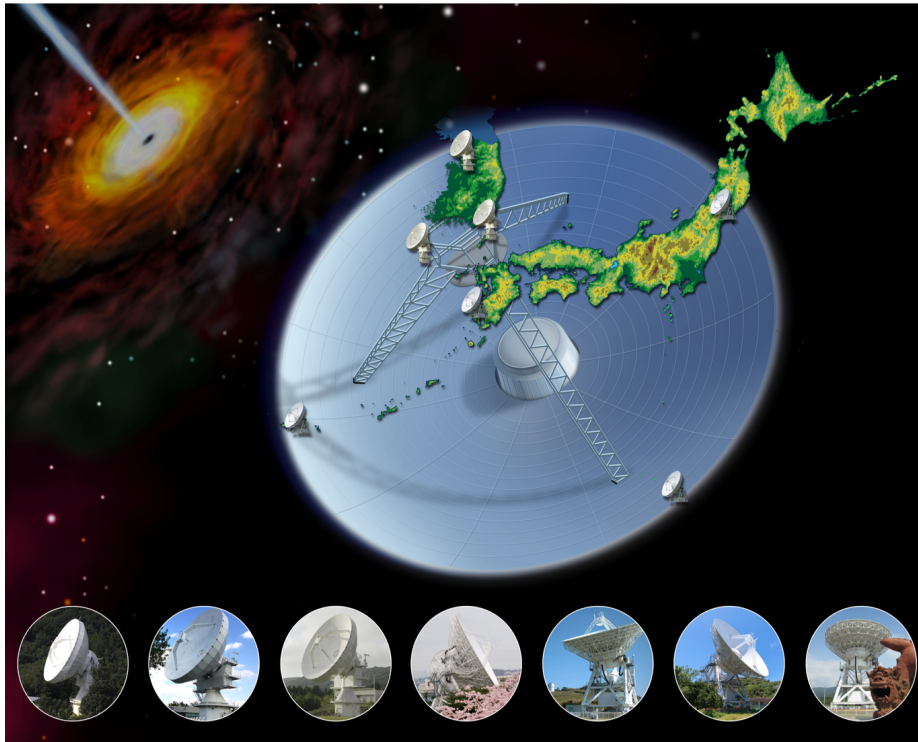


- Millimeter VLBI
 - Image BH shadow, test GR
- Centimeter VLBI
 - Connect horizon-scale images to the global structures (jets, accretion flows)
 - Broad range of science targets (LLAGN, high-*z* quasars, extended structures, transit sources)
 - Connection to SKA



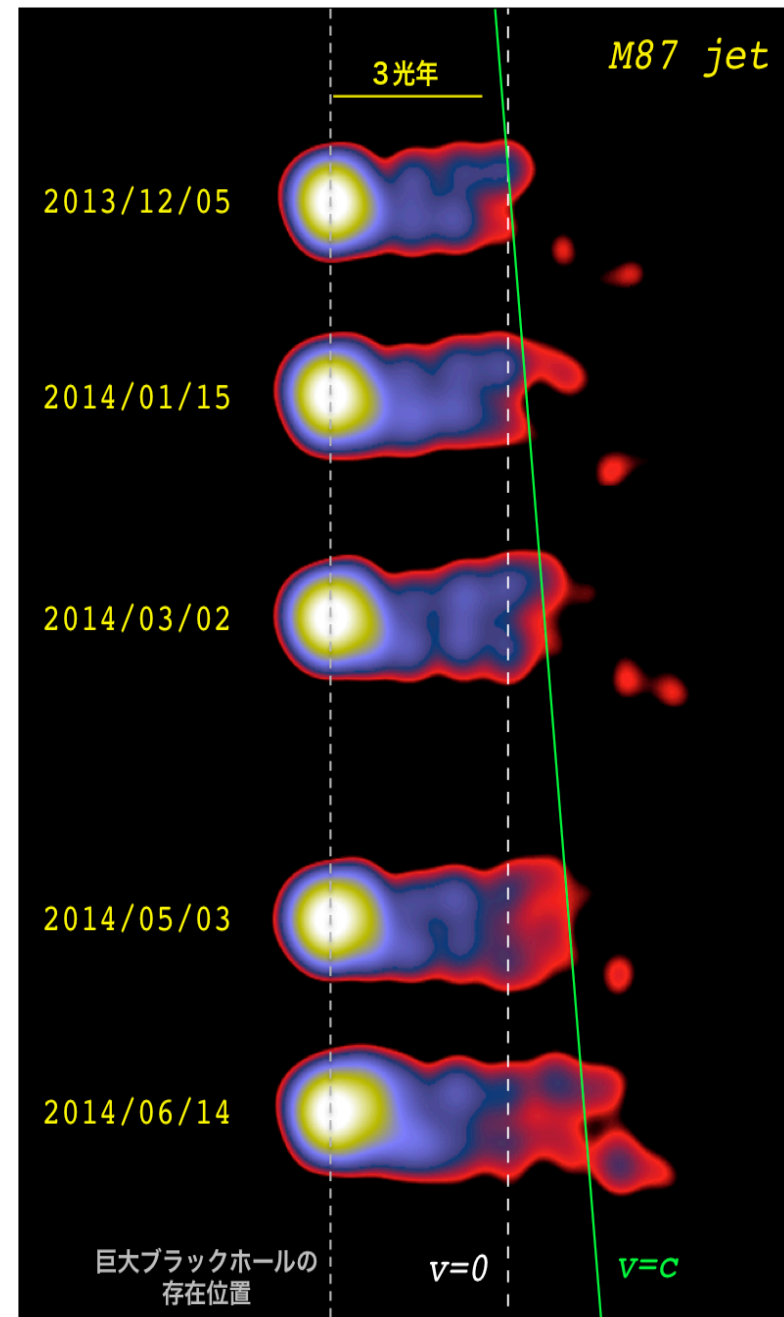


KaVA: precursor of EAVN



- First regularly operating international VLBI array in EA (2014-)
- Jet acceleration, propagation, collimation, γ -ray blazars (see poster by Lee T. P3-03)
- Resolution, sensitivity: still not as good as other cmVLBI facilities (e.g., VLBA)
 - Need more stations particularly from China!

Hada, Park et al. 2017 PASJ



“EAVN-AGN campaign” spring 2017



- Largest-ever East Asian joint VLBI campaign
- **Two key stations from China (Tianma65, Urumqi)**
- Promote EAVN commissioning towards future regular operation
- M87/SgrA* to demo a good EAVN science case. Complement EHT

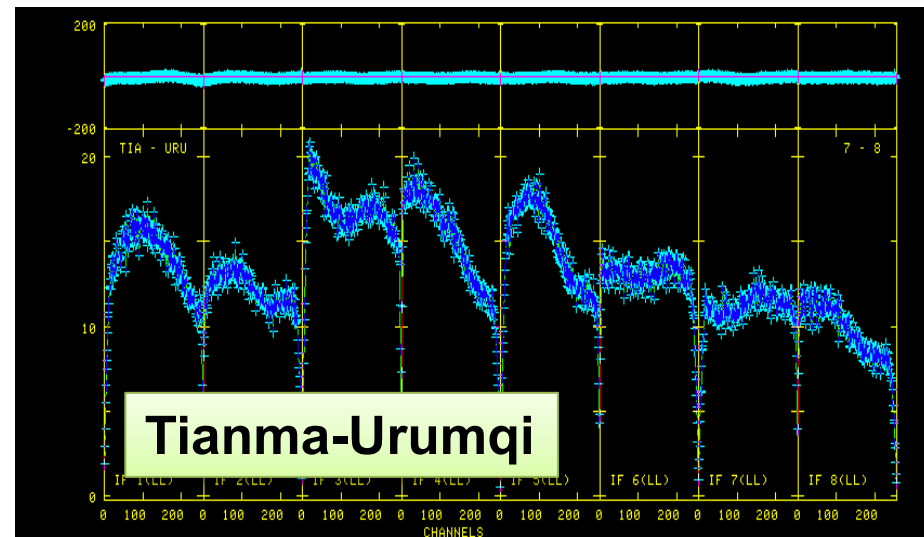
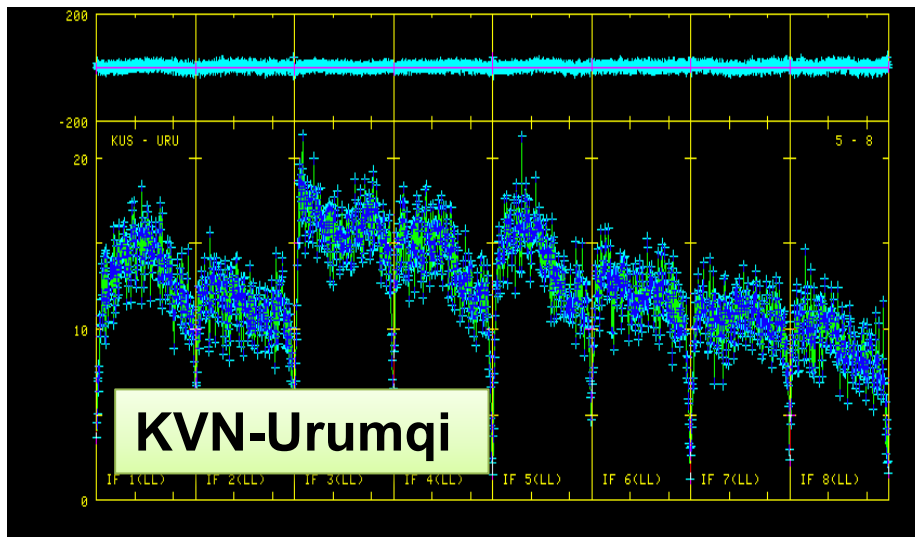
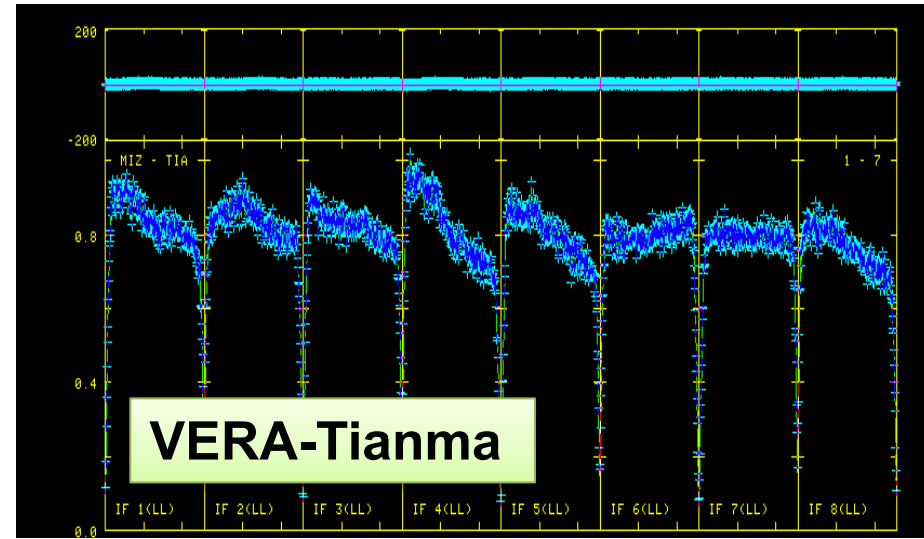
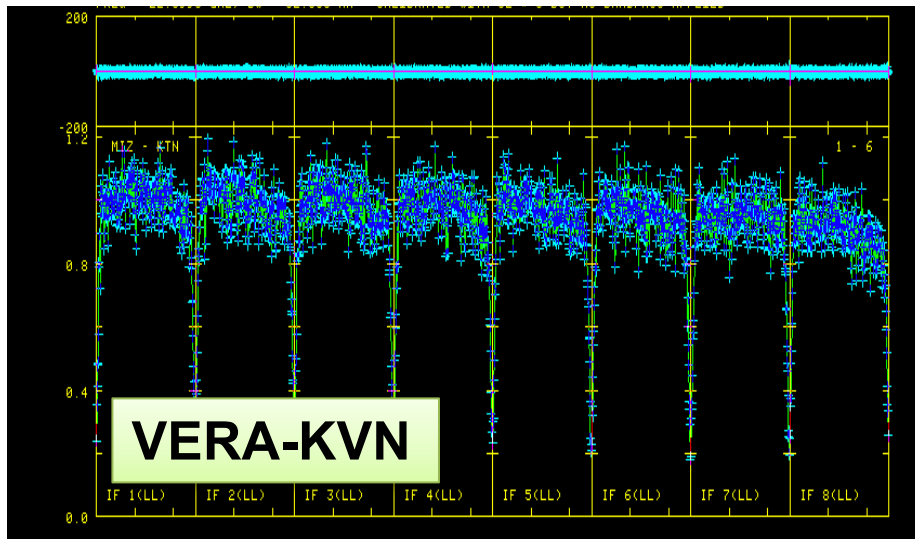
EHT period

	Date	UT time	Target	Freq.	Stations
1	3/12	18:55 – 00:55 (6hr)	SgrA	43GHz	KaVA7, TM
2	3/18	12:45 – 19:45 (7hr)	M87	22GHz	KaVA7, TM, UR, HT, KS
3	3/19	11:40 – 18:40 (7hr)	M87	43GHz	KaVA7, TM
4	3/27	13:10 – 23:10 (10hr)	M87+SgrA	43GHz	KaVA7, TM
5	4/3	13:20 – 23:20 (10hr)	M87+SgrA	22GHz	KaVA7, TM, UR, HT, KS, MC
6	4/4	12:35 – 22:40 (10hr)	M87+SgrA	43GHz	KaVA7, TM
7	4/9	12:20 – 22:20 (10hr)	M87+SgrA	43GHz	KaVA7, TM, NY
8	4/14	12:00 – 22:00 (10hr)	M87+SgrA	43GHz	KaVA7, TM
9	4/17	11:45 – 18:45 (10hr)	M87	22GHz	KaVA7, TM, UR, HT, KS, SJ, MC, NT
10	4/18	11:40 – 21:45 (10hr)	M87+SgrA	43GHz	KaVA7, TM
11	4/24	09:20 – 16:20 (7hr)	M87	22GHz	KaVA7, TM
12	4/25	09:15 – 16:15 (7hr)	M87	43GHz	KaVA7, TM
13	4/26	15:55 – 21:55 (6hr)	SgrA	43GHz	KaVA7, TM, SJ
14	5/10	08:20 – 17:20 (7hr)	M87	22GHz	KaVA7, TM, MC
15	5/11	08:15 – 17:15 (7hr)	M87	43GHz	KaVA7, TM
16	5/25	14:00 – 20:00 (6hr)	SgrA	43GHz	KaVA7, TM
17	5/26	07:15 – 16:15 (7hr)	M87	43GHz	KaVA7, TM

- 17 epochs (5 @ 22GHz, 12 @ 43GHz)
- KaVA+Tianma65 for all the epochs
- Urumqi before/middle/after EHT period

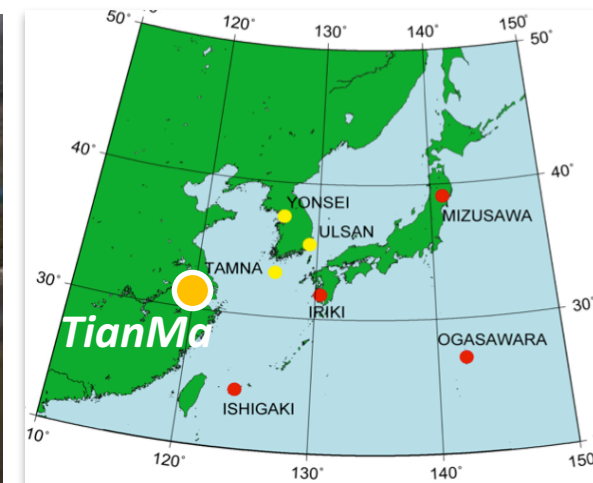
TM: Tianma, UR: Urumqi,
 SJ: Sejong, HT: Hitachi,
 KS: Kashima, NY: NRO45,
 MC: Medicina, NT: Noto

Milestone (March 18 2017 @ 22GHz)

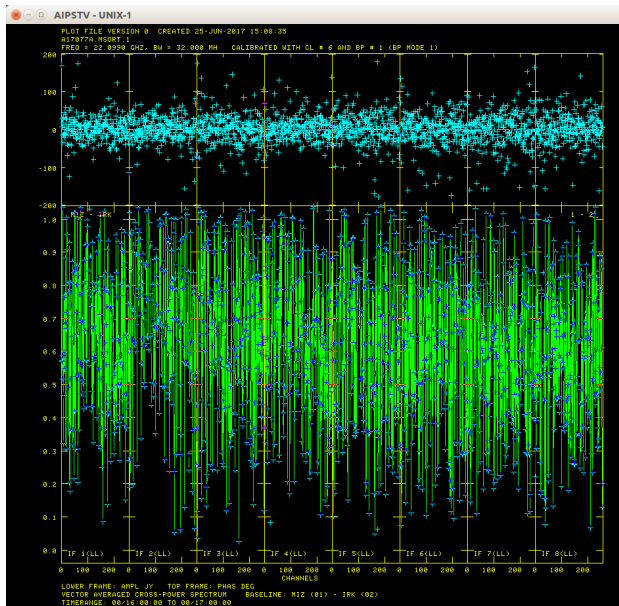


First complete EAVN fringes among China-Korea-Japan!

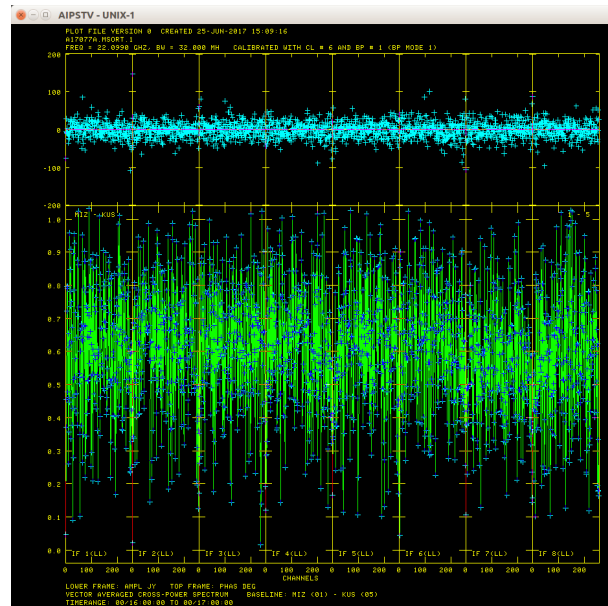
Power of Tianma65



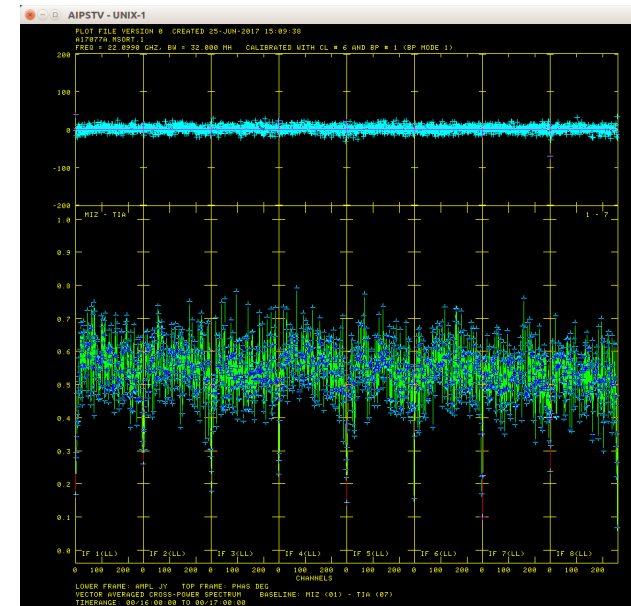
VERA-VERA (MIZ-IRK)



VERA-KVN (MIZ-KUS)



VERA-TIA (MIZ-TIA)

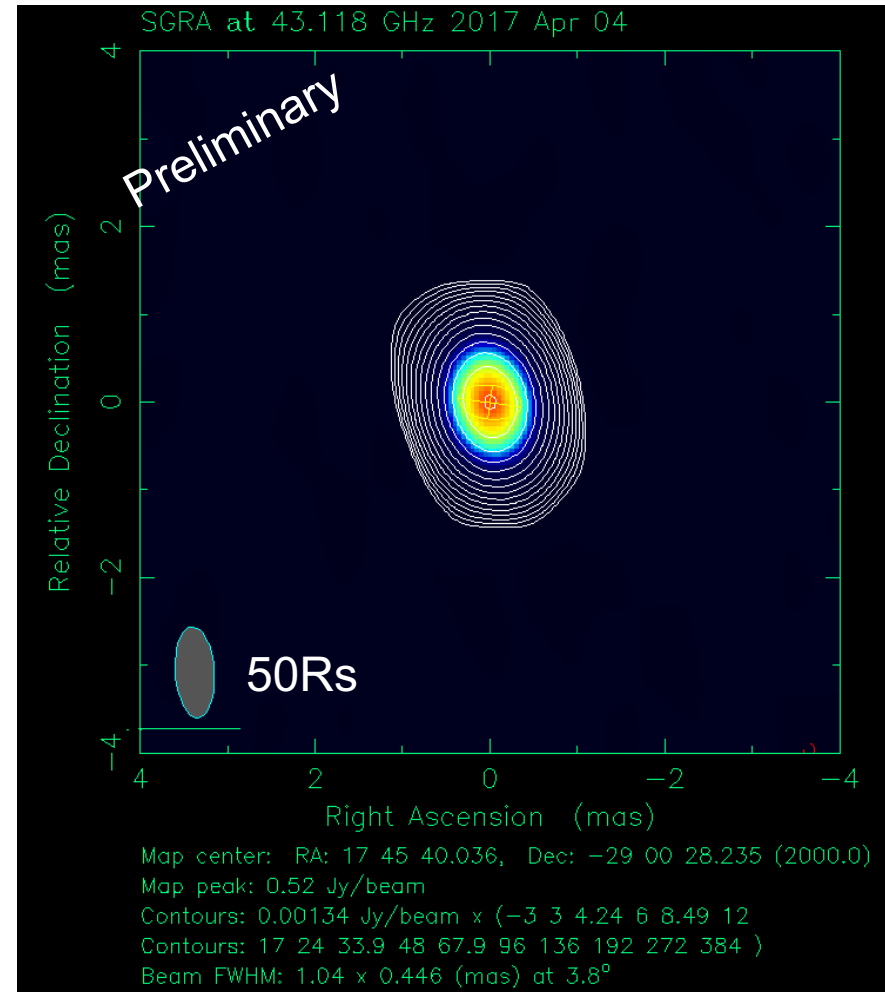
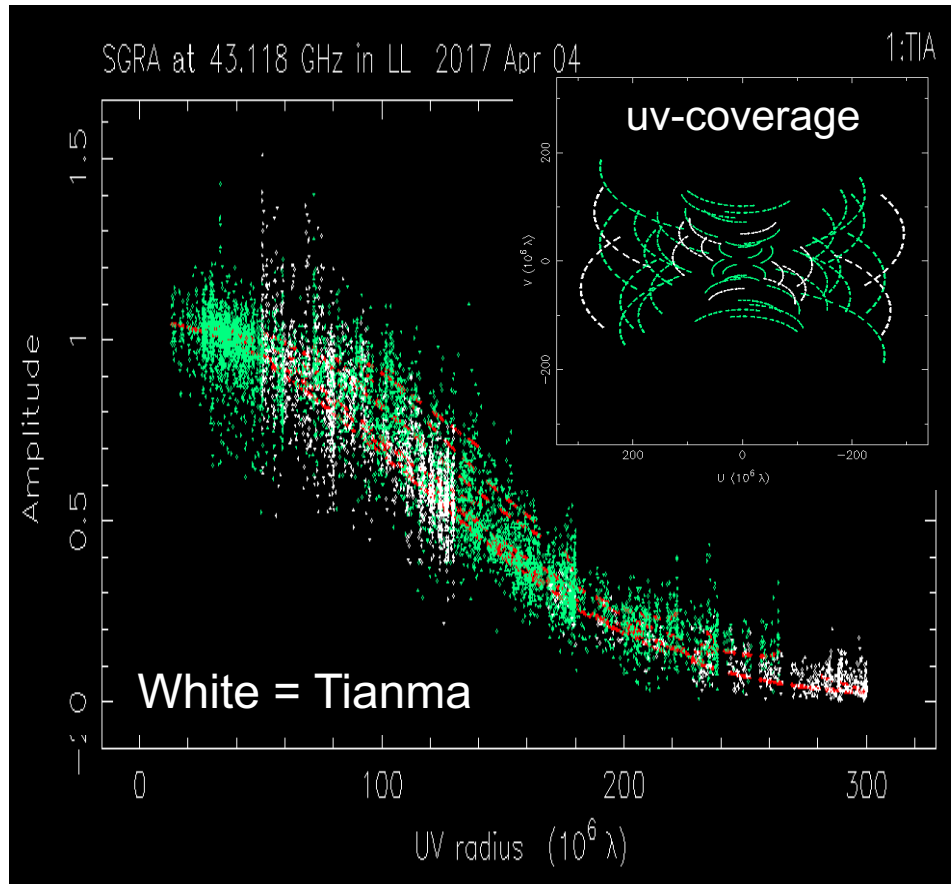


Fringe sensitivity with Tianma: >3 times better than KaVA
 ($1\sigma_{\text{TM}} \sim 2\text{mJy}@22\text{GHz}, 1\text{Gbps}$)

SgrA*

(Guang-Yao Zhao (KASI) et al.)

KaVA+Tianma @ 43GHz

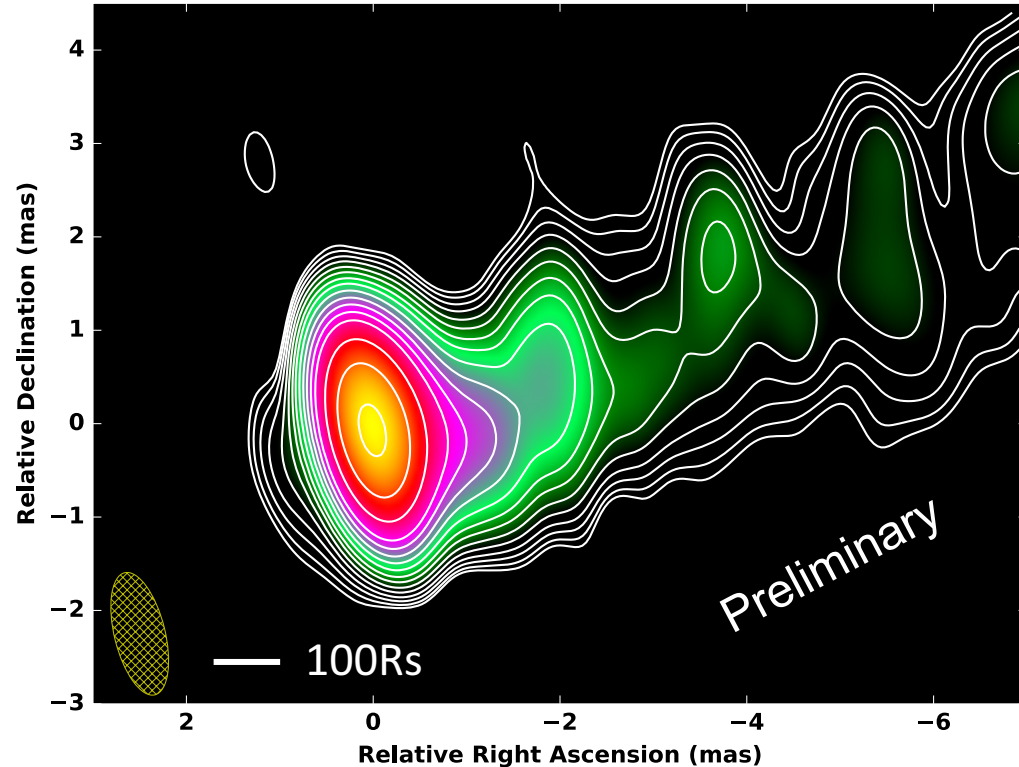


- First KaVA+Tianma image on SgrA*
- Weak signals, uv-coverage, image dynamic range
 - Resolved structures, scattering screen

Power of Urumqi



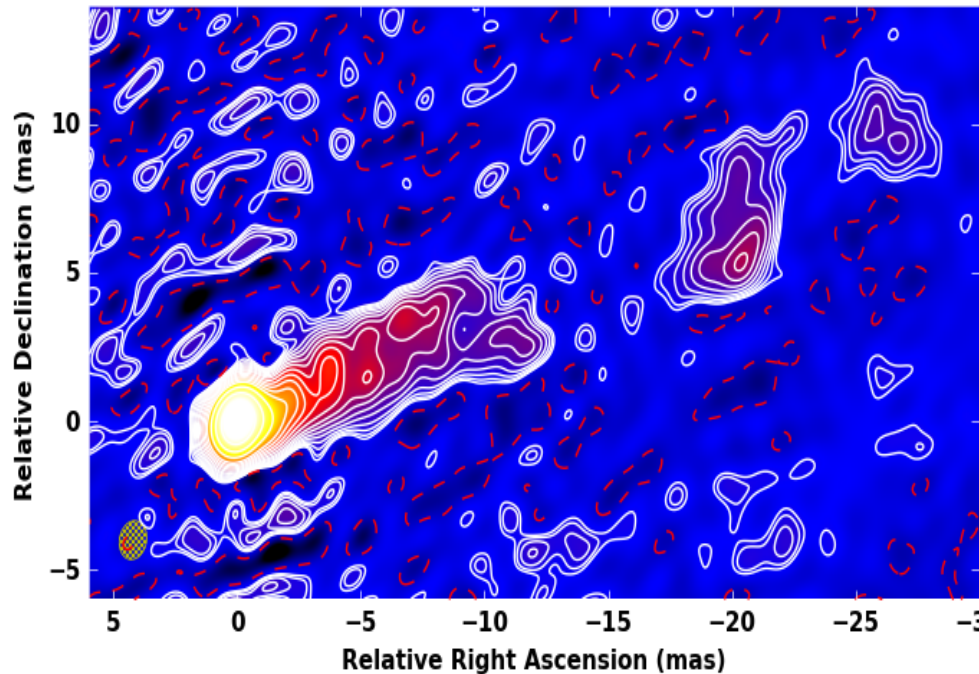
M87 KaVA+Urumqi @ 22GHz



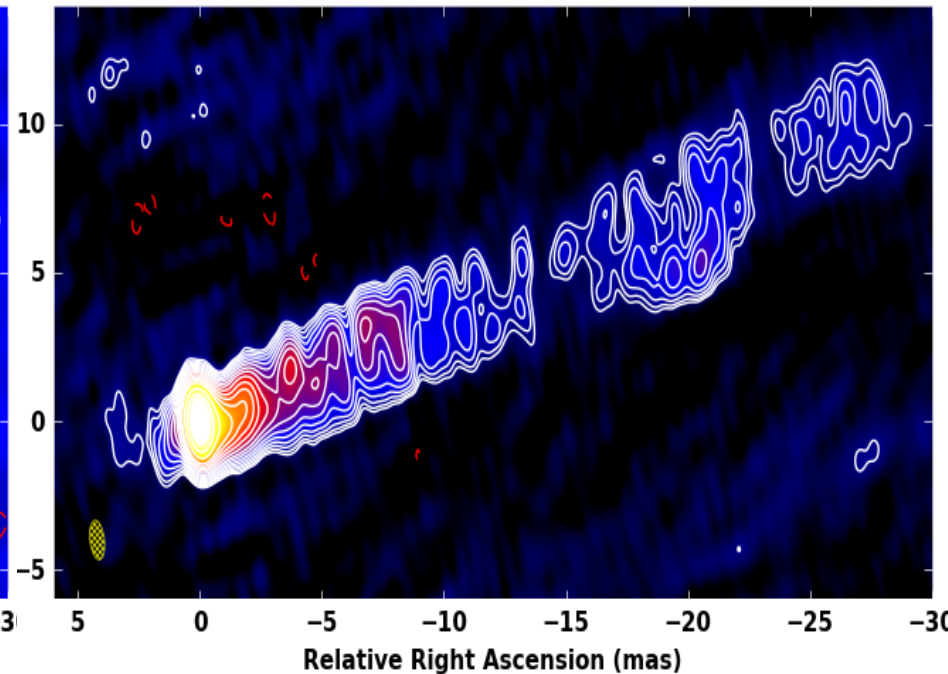
- Urumqi is a critical station to enhance EAVN resolution
- Jet base of M87 resolved down to $\sim 70R_s$ ($\sim 0.5\text{mas}$ at 22GHz)
- With the forthcoming 43GHz receiver at Urumqi, EAVN can further double resolution

KaVA – EAVN image comparison

KaVA



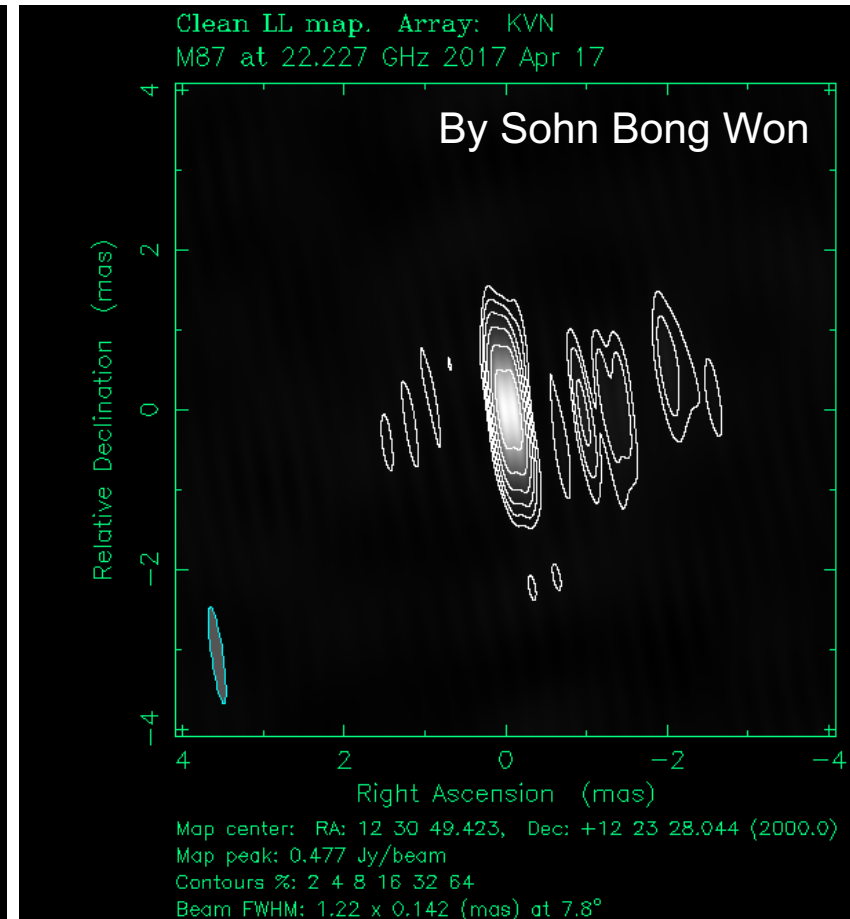
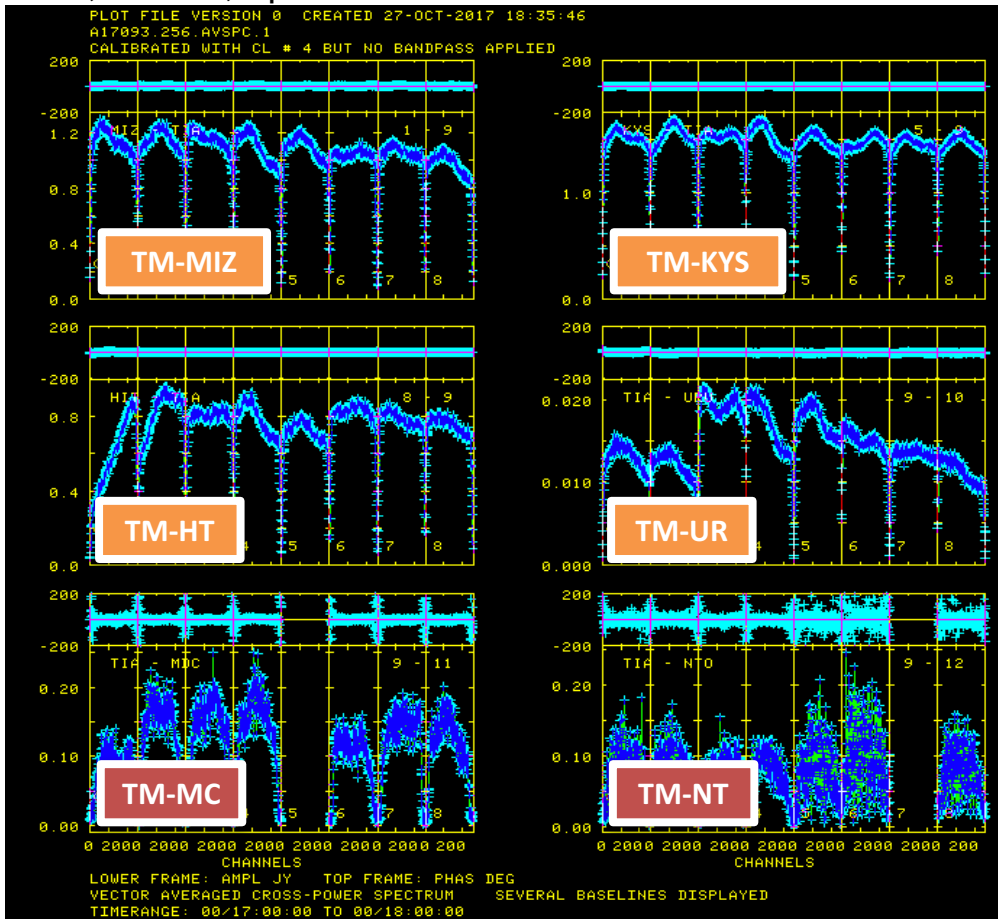
KaVA+Tianma+Urumqi+Hitachi



- Compared to KaVA
 - ~2-2.5 times higher angular resolution ($\sim 0.5\text{mas}$ at 22GHz)
 - ~2-3 times lower image rms noise ($\sim 100\mu\text{Jy}$ at 22GHz)
- Almost equivalent imaging performance to VLBA

EAVN+Italy

M87, 22GHz, Apr/3/2017



- M87 KaVA+MC+NT at 22GHz
- E-W resolution 0.14mas (19Rs) !

Current status

- The highest priority is the technical validation of EAVN array
- Already some milestones through this campaign
 - KaVA+Tianma(+Urumqi): quasi-regular operation successful
 - High-resolution, high-sensitivity imaging comparable to VLBA
- Deeper studies on SgrA/M87 promising!
- We hope to start “EAVN open use” from 2018
- Late 2018: KaVA+Tianma65 (22/43GHz)
- Early 2019: KaVA+Tianma+Urumqi

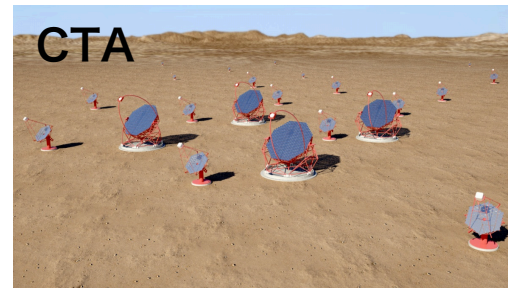
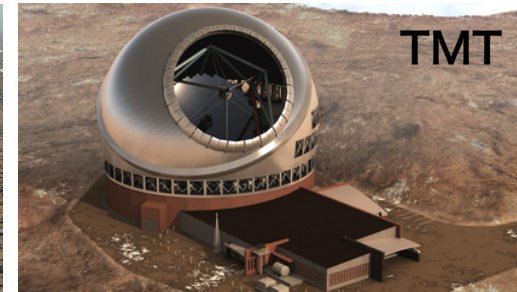
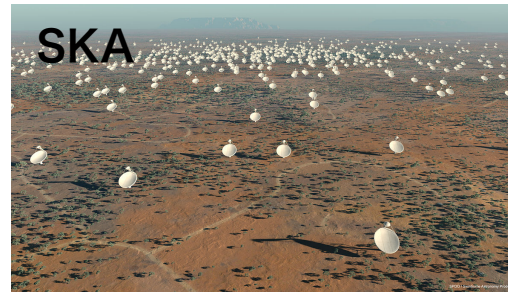
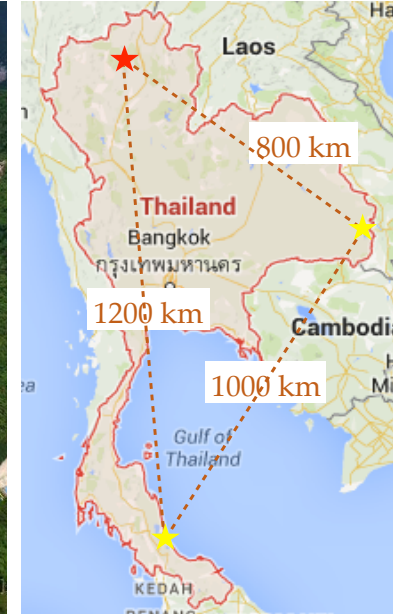
More to come in East Asia

- EAVN will rapidly expand in the next few years
 - FAST 500m
 - Thailand VLBI Network
 - A few more 100m-class radio telescopes in China
 - Wideband recording
- Towards “micro-Jy VLBI”
- Much broader range of science targets
 - Much weaker AGNs, much more distant AGNs
- Synergy with ALMA, SKA, TMT, CTA, LIGO/KAGRA

FAST 500m (China)



TVN (Thai)



Summary

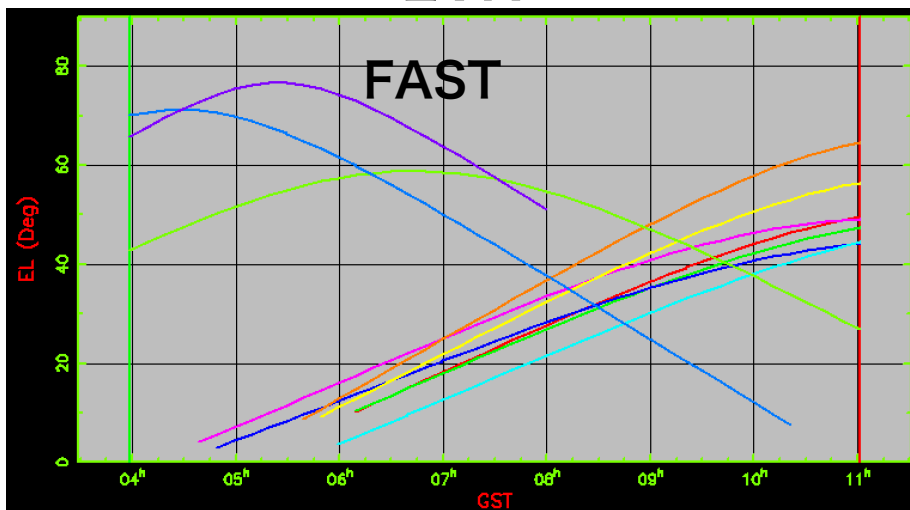
- VLBI collaboration in East Asia is rapidly growing
- EAVN campaign observations of SgrA*/M87 in concert with EHT
 - Complement EHT (jet propagation, accretion flow, scattering)
 - Accelerate EAVN commissioning
- Data analysis still ongoing, but some preliminary results/images already demonstrated powerful performance of EAVN array
 - First science results will come out soon, stay tuned!
- EAVN will further expand in the next few years!
- EAVN is a large telescope for East Asian community
- If you are interested in, please feel free to contact us. We are happy to support your science!

Appendix

VLBI with FAST (S-band, M87)

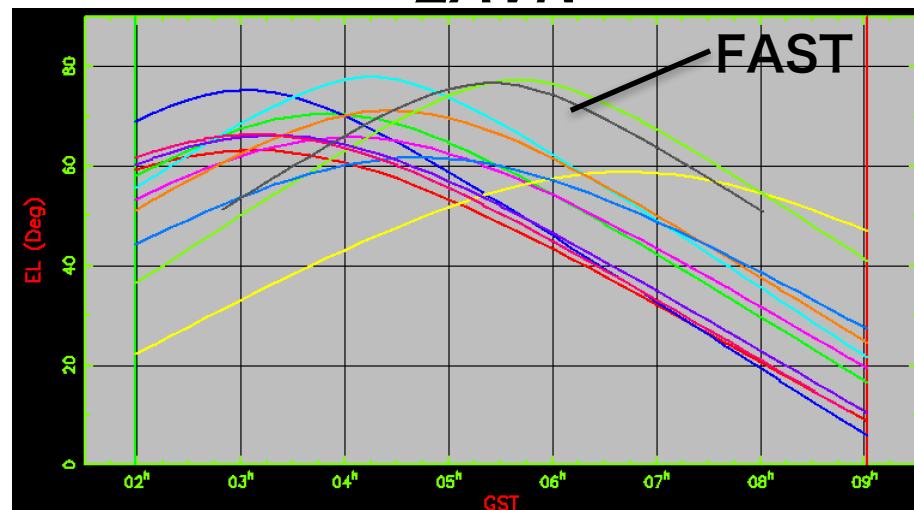
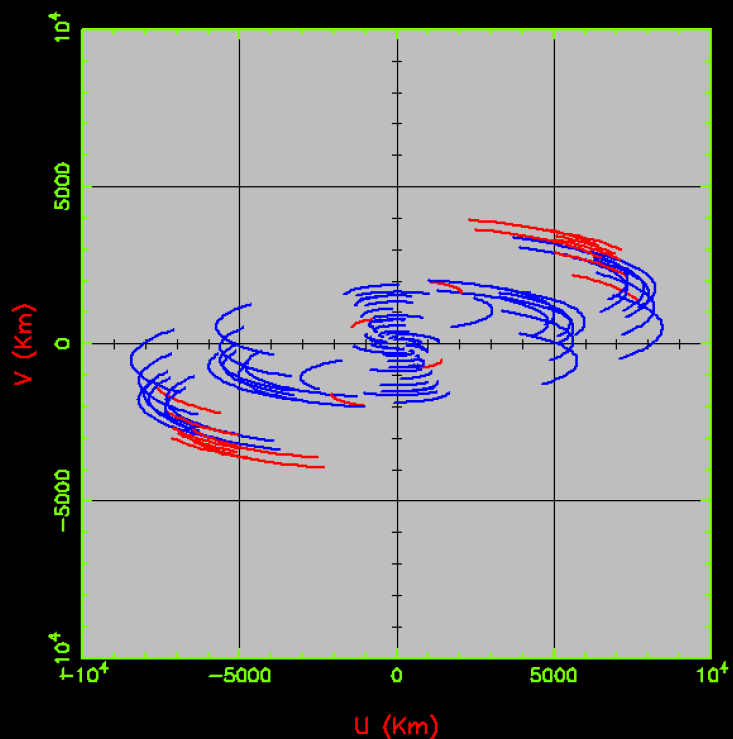
EVN

EAVN



EFLSBERG
WSTRBORK
ONSALA85
JODRELL1
TORUN
MEDICINA
NOTO
URUMQI
TIANMA65
FAST500

M87



VERAMZSW
VERAIRIK
VERAOGSW
VERAISGK
KVNSJ
URUMQI
TIANMA65
KUNMING
NIYUNSO
USUDAVL
KASHIMA
FAST500

M87

