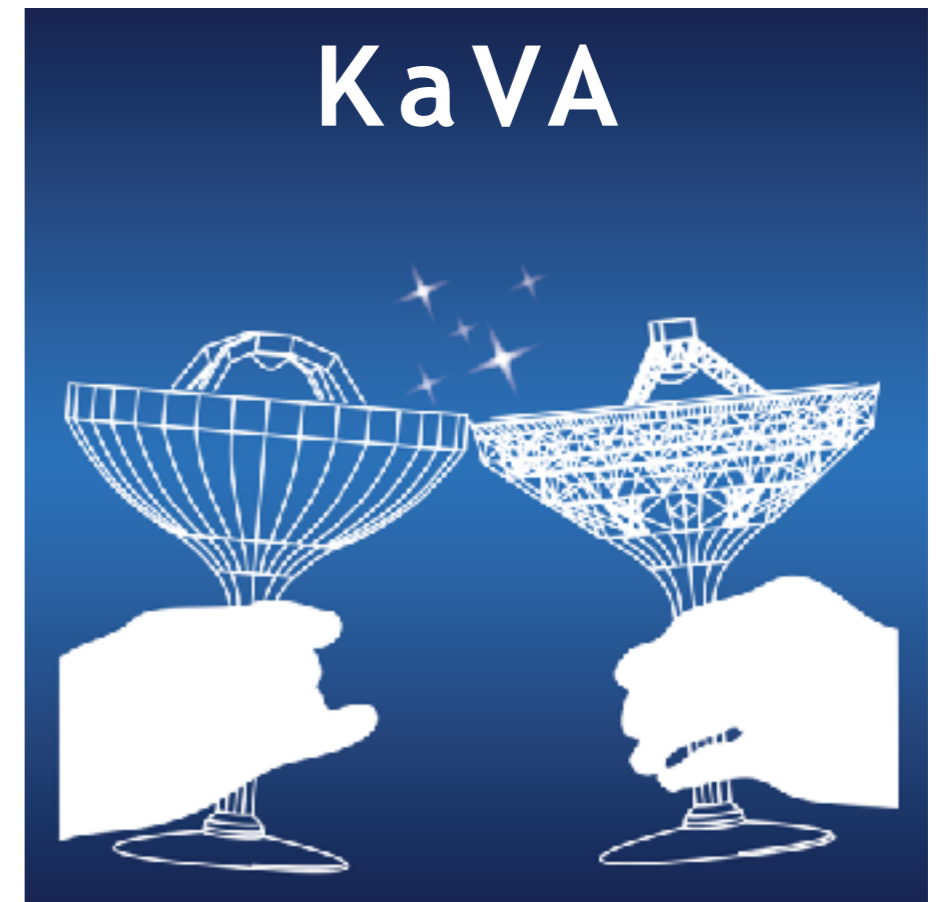
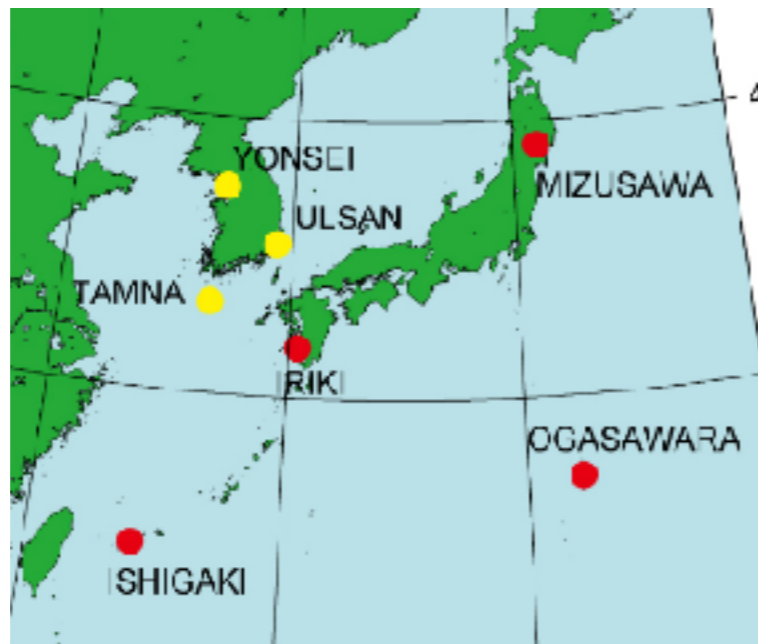


# KaVA (KVN and VERA Array) Updates



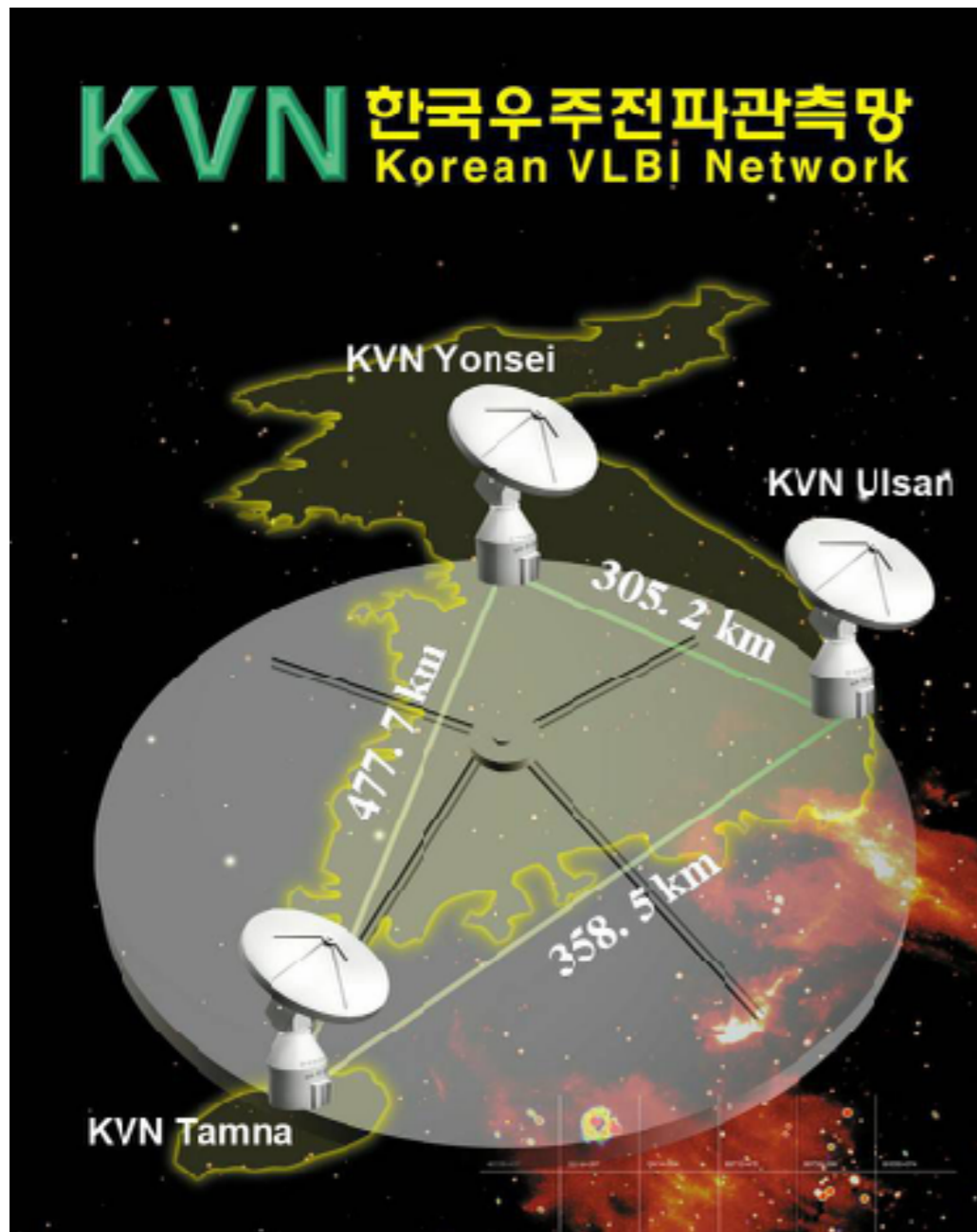
**Do-Young Byun (KASI)**  
on behalf of KaVA operation team  
APRIM 2017@Taiwan



# Outline

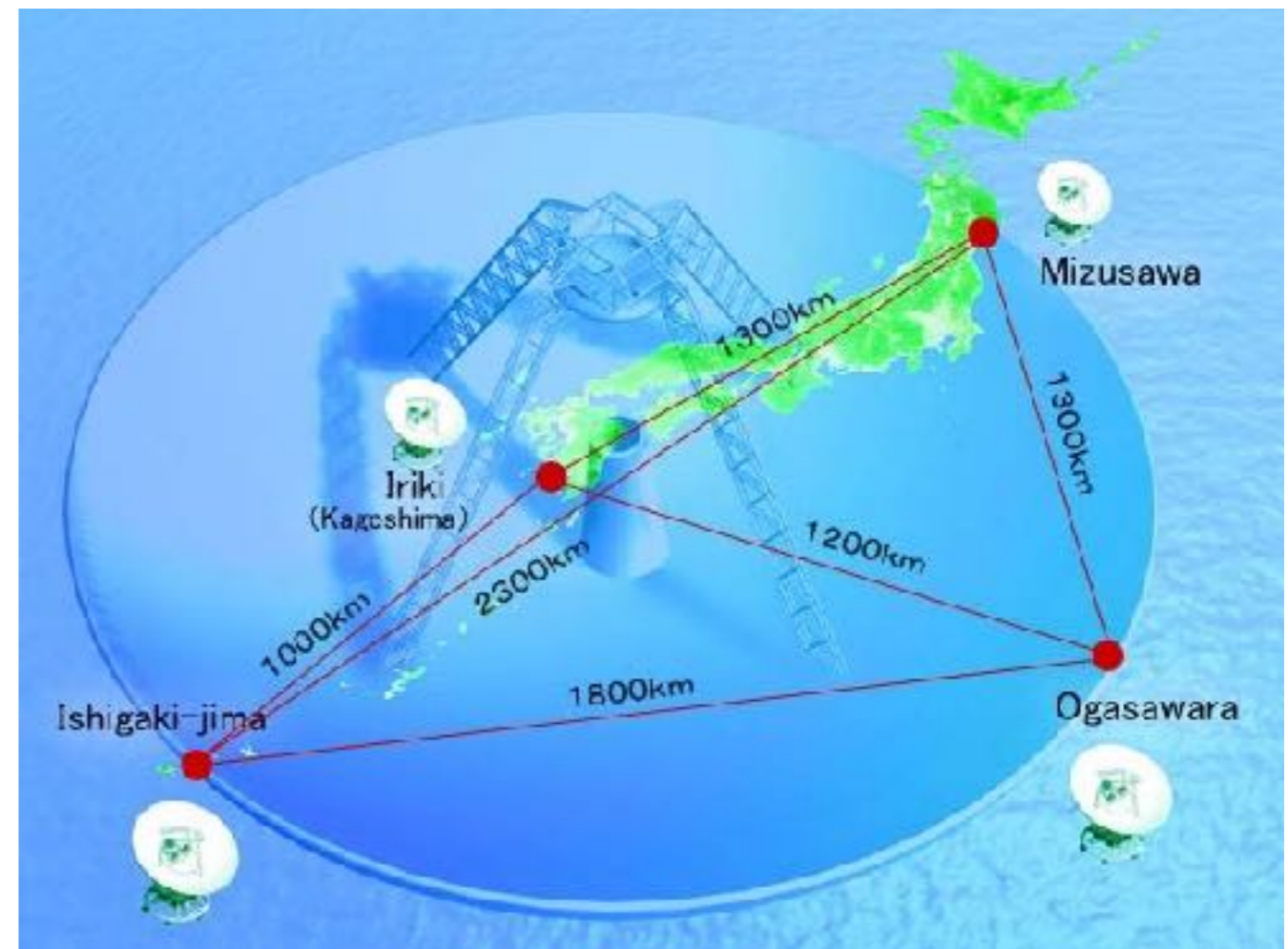
- KaVA
- Recent Operational Results
- Large Programs
- Upgrade Activities

# KaVA (KVN and VERA Array)



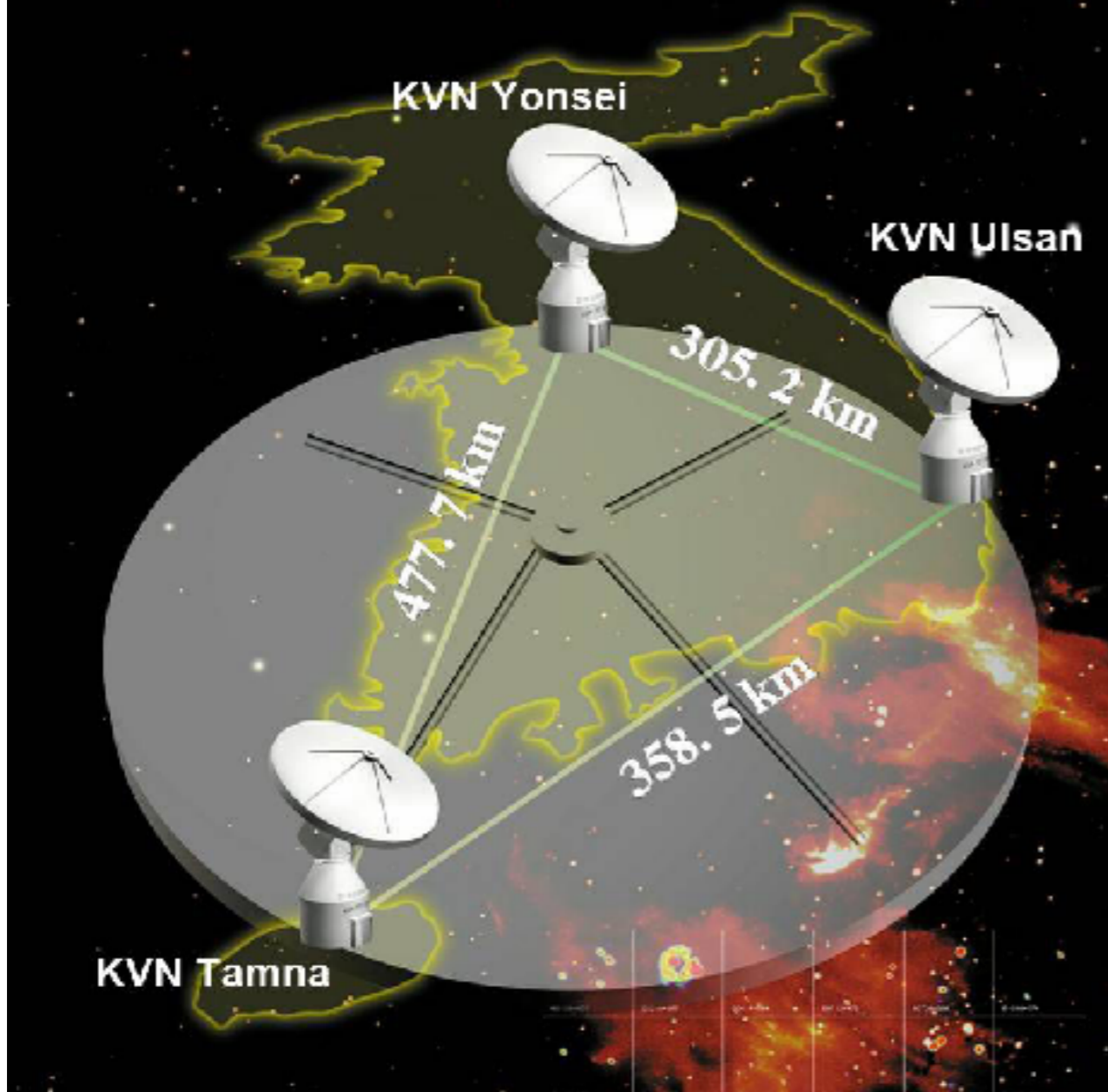
+

## VERA VLBI Exploration of Radio Astrometry

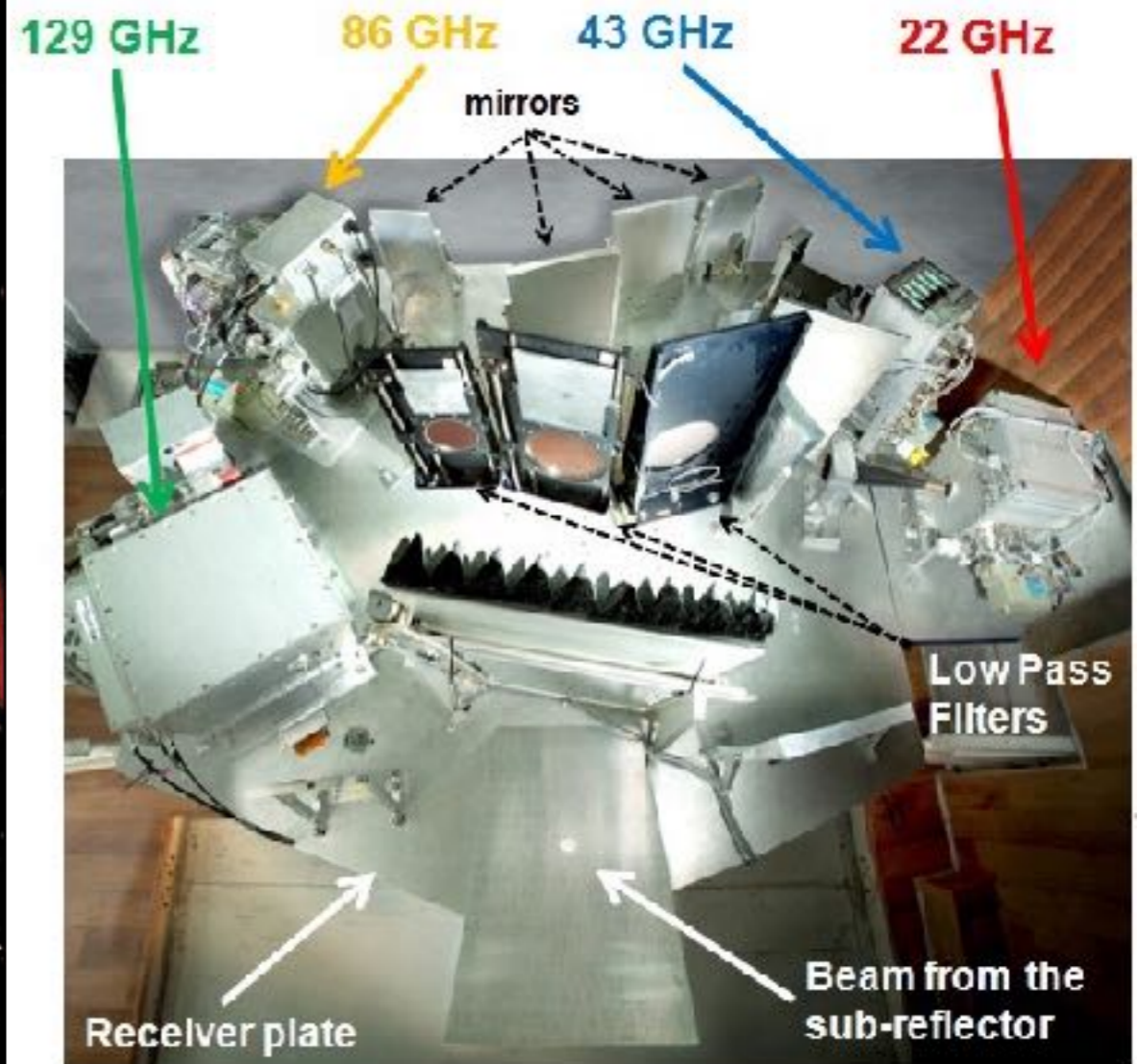




# KVN 한국우주전파관측망 Korean VLBI Network

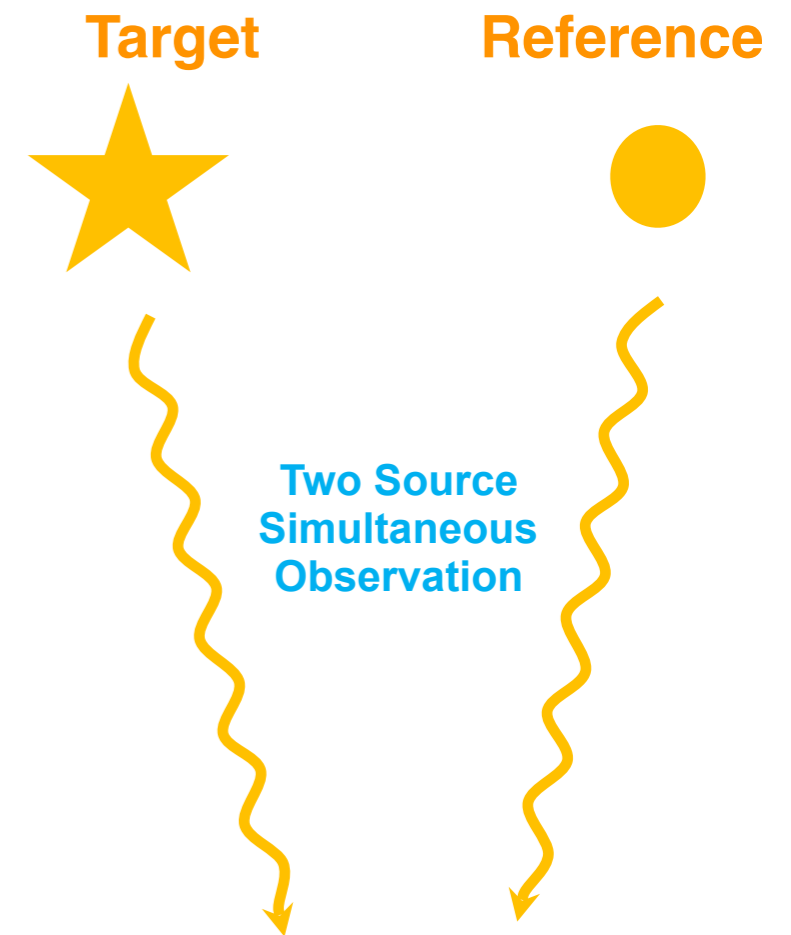
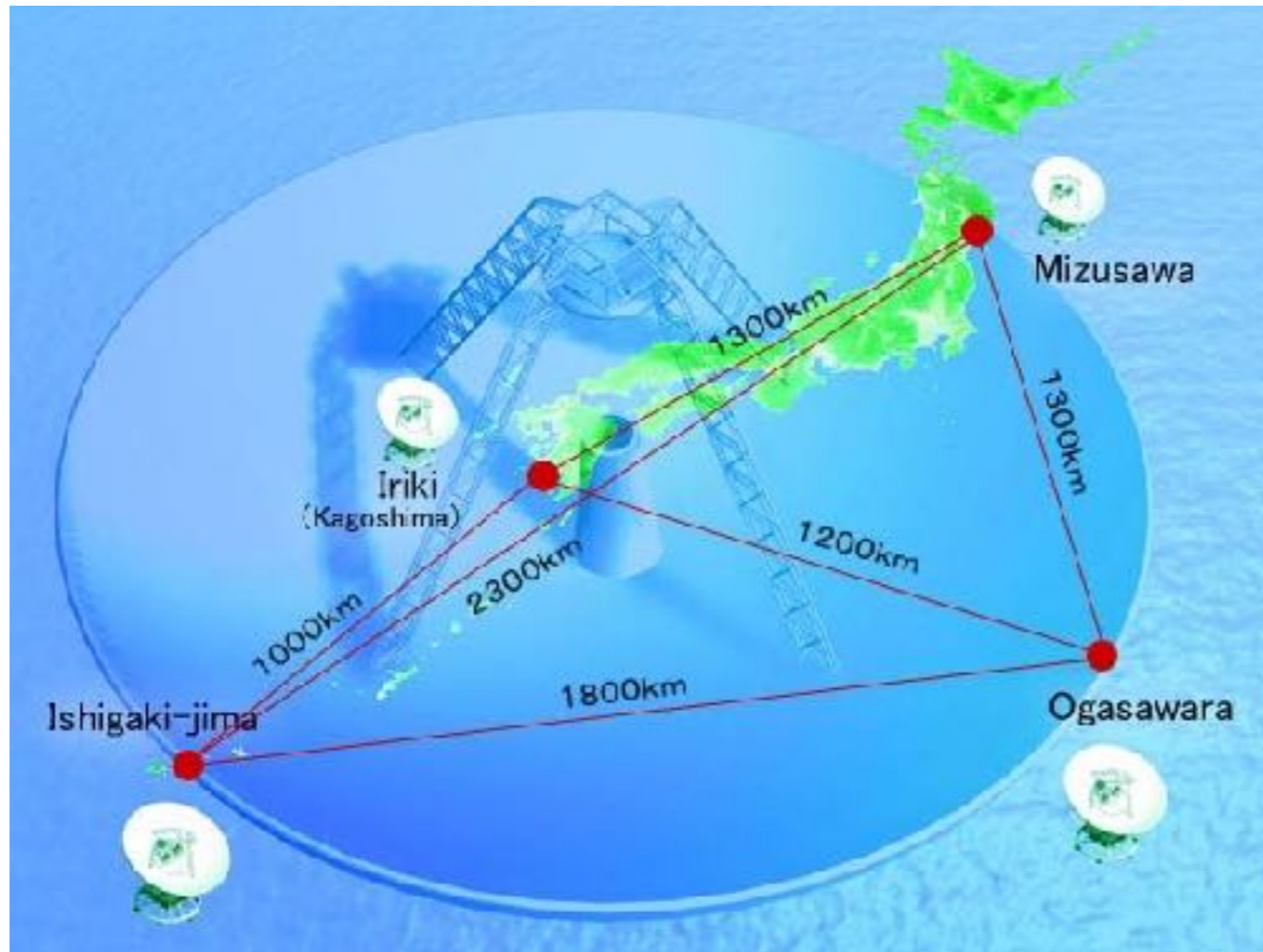


- Three 21m antennas
- Baseline length 300 - 500km
- Simultaneous Multi-frequency @ [22/43/86/129GHz](#)



# VERA: VLBI Exploration of Radio Astrometry

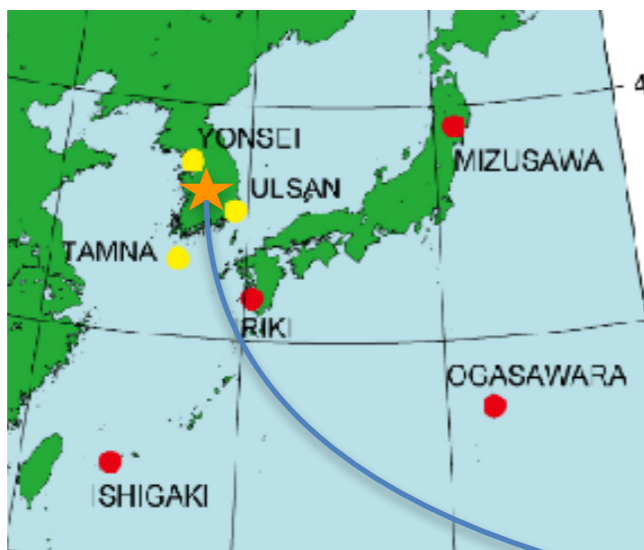
- Four 20m antennas
- Baseline length 1000- 2300 km
- Frequency : 2/8/22/43GHz
- Dual Beam System for high precision astrometry





# KaVA

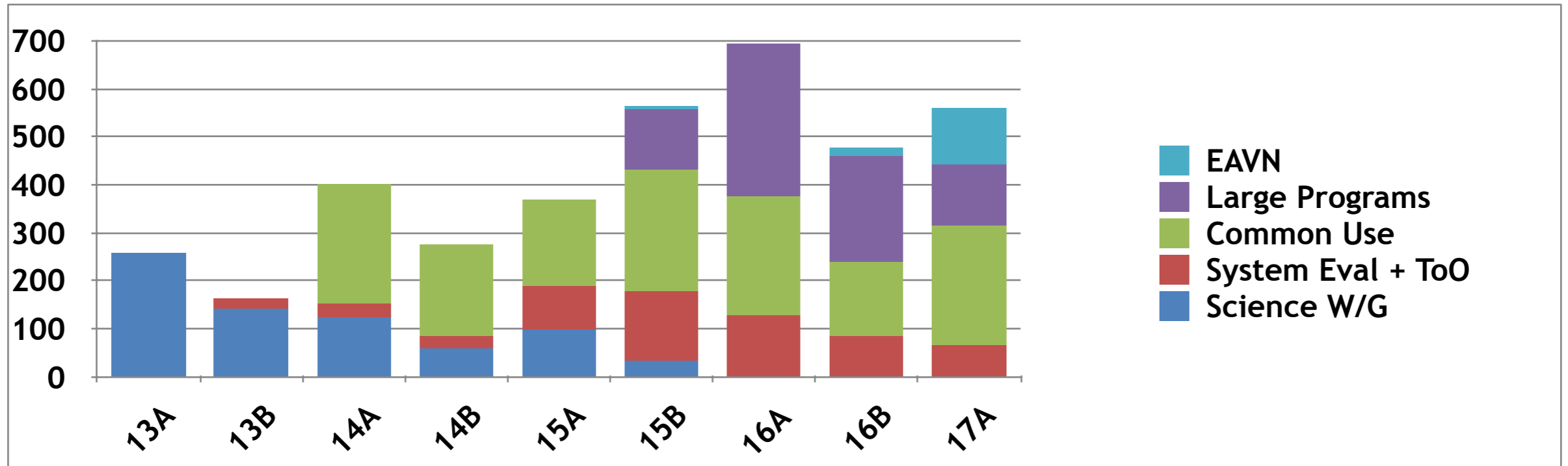
- 7 antennas (D ~ 20m)
- Baseline length 300 - 2300 km
- Frequency : 22/43 (/86/129)GHz
- Beam Size : 1.2/0.6 (/1.5/1.0) mas
- Baseline Sensitivity : 10/20 mJy



Daejeon Correlator  
@Korea-Japan Correlation Center

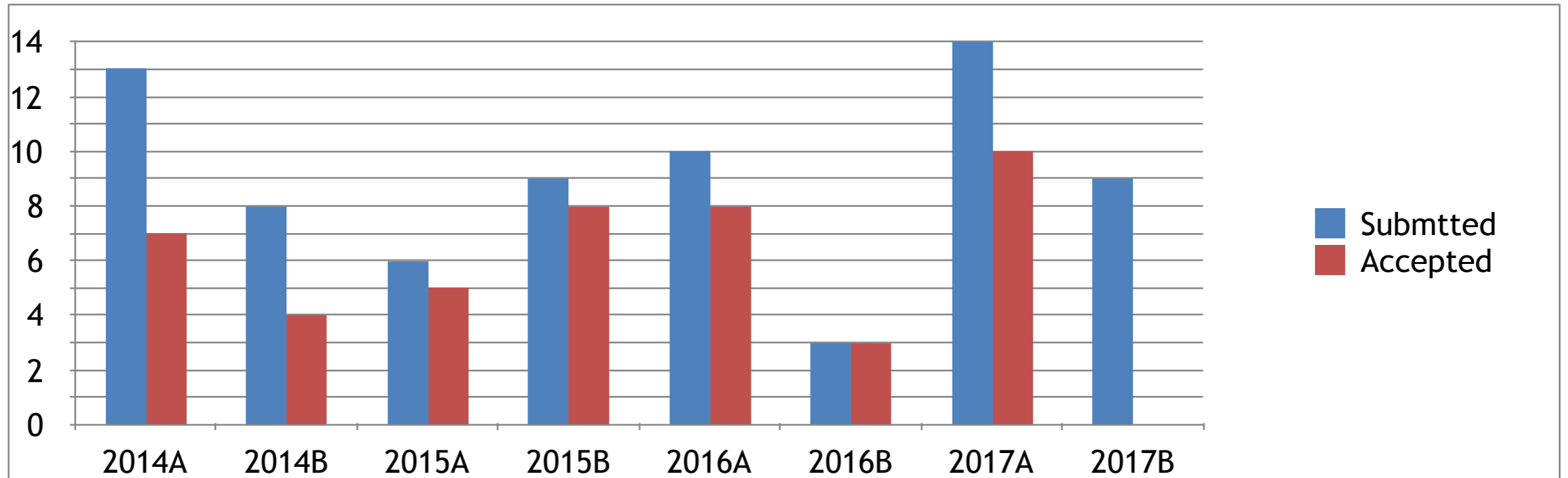
S6-4-6 by Se-Jin Oh

# Operation Times



- ~1000 hours /yr
  - $\leq 500$  h/yr for common use, 500 h/yr for LPs
- 85% have data from 7 stations. 15% have one missing station due to system trouble.
- 5 day KaVA sessions with 2-week interval
- Target of Opportunity Observations

# Common Use Observation



- **14 proposals in 2017A**
  - Requested Time : 450h (Allocated : 250h)
  - Korea (6) / Japan (4) / **China (2) / Others (2)**
  - **AGN (12) / SF (1) / Evolved Star(1)**
- Proposal Submission Deadlines : June 1 (B) and Nov 1 (A)



# Publications with KaVA

1. The First VLBI Image of a 44GHz Methanol Masers with KaVA, N. Matsumoto+, 2014, ApJL (SFR)
2. VLBI observations of bright AGN jets: Evaluation of Imaging Capability, K. Niinuma+, 2014, PASJ (AGN)
3. PaGAN II: The Evolution of AGN Jets of sub-parsec Scales, J. Oh+, 2015, JKAS (AGN / [Common Use](#))

– 2016

4. Identifying High Frequency Peakers using the Korean VLBI Network , Y. Jeong +, 2016, AN (AGN / [Common Use](#))
5. SiO Masers around WX Psc Mapped with the KVN and VERA Array, Y. Yun +, 2016, ApJ (Evolved Star)
6. VLBI observations of flared optical quasar CGRaBS J0809+5341, T. An +, 2016, PASJ (AGN / [Common Use](#))

– 2017

7. J0906+6930: a radio-loud quasar in the early Universe, Y. Zhang +, 2017, PASJ (AGN / [Common Use](#))
8. Pilot KaVA monitoring on the M87 jet: confirming the inner jet structure and superluminal motions at sub-pc scales, K. Hada +, 2017, PASJ in press (AGN)
9. Fossil shell in 3C 84 as TeV gamma-ray emitter and cosmic-ray accelerator, M. Kino + , 2017, ApJ in press (AGN / [Common Use](#))

# KaVA Science WGs & Large Programs

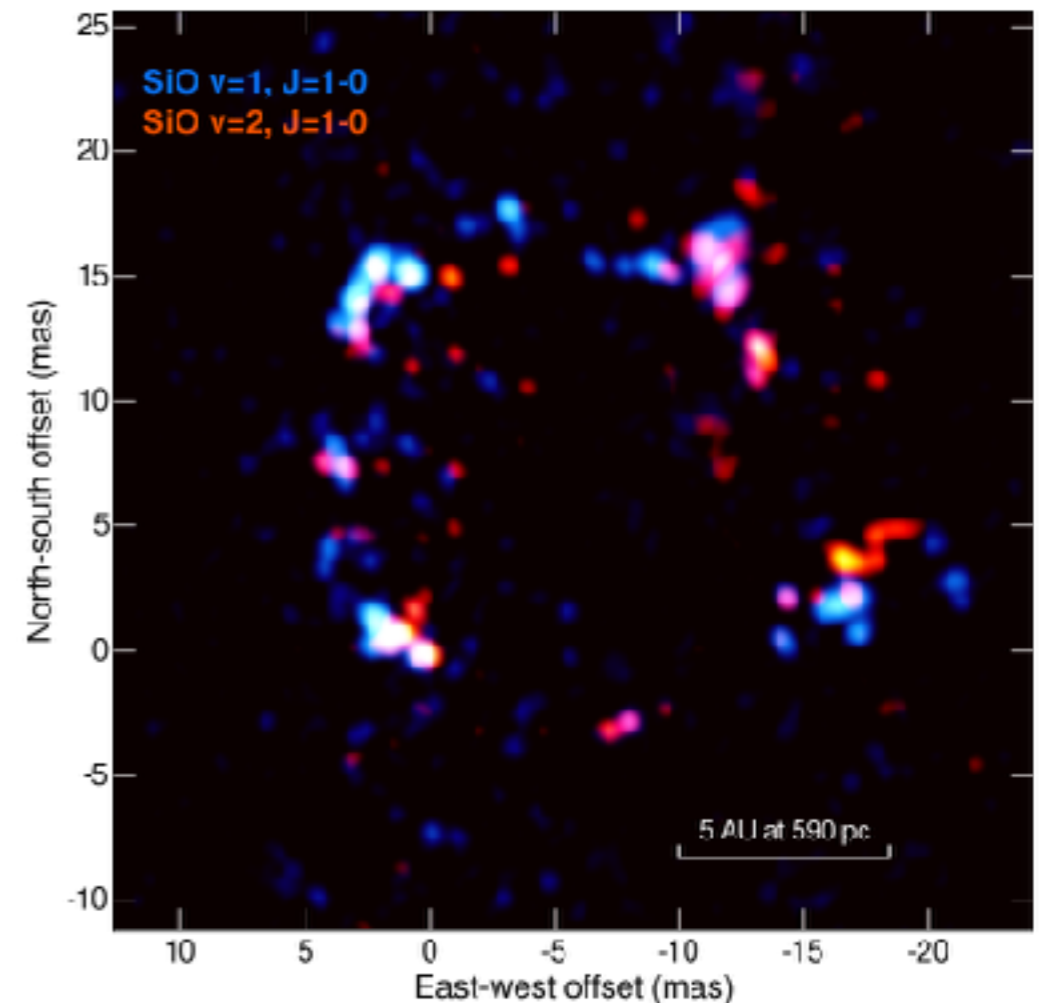
- 4 K-J Science Working Group for KaVA (2010~)
  - Evolved Star/Star Formation/ AGN /Galactic Astrometry
  - f-f Meeting twice in a year & monthly telecon
- 3 KaVA LPs started in 2015 - 2016
  - Evolved Star / Star Formation / AGN

# Evolved Star Large Program

- Expanded Study on Stellar Masers

H.Imai(Kagoshima Univ.), S.-H.Cho (KASI)

- 1st yr (2015-2017): Snapshot imaging of 80 H<sub>2</sub>O (22GHz) and SiO (43/86/129GHz) maser sources
  - spatial distribution on ~100 AU scale
  - size distribution on ~0.1 AU scale
  - maser pumping mechanism
- 2nd yr (2018 - ): Maser movie of ~20 targets
  - Mass loss
  - Evolution of asymmetric structure

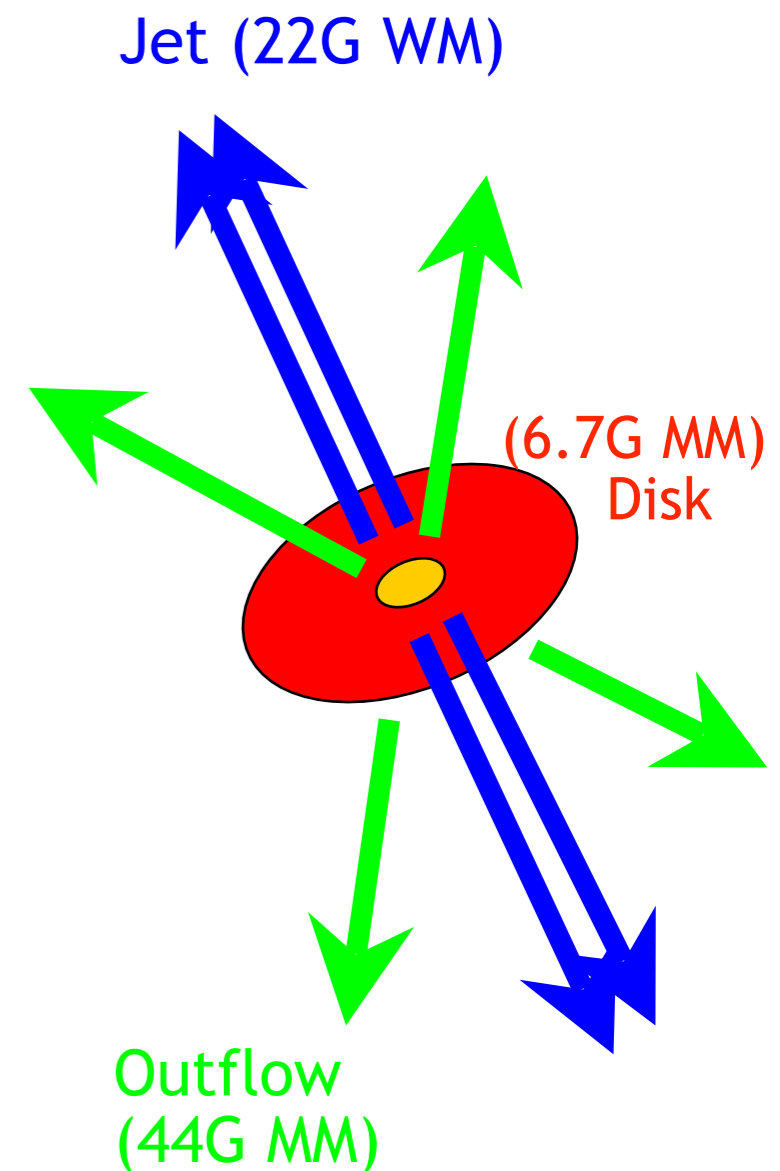


SiO v=1 and 2, J=1-0 maps toward WX Pcs w/ KaVA (Yun et al. 2016 ApJ)



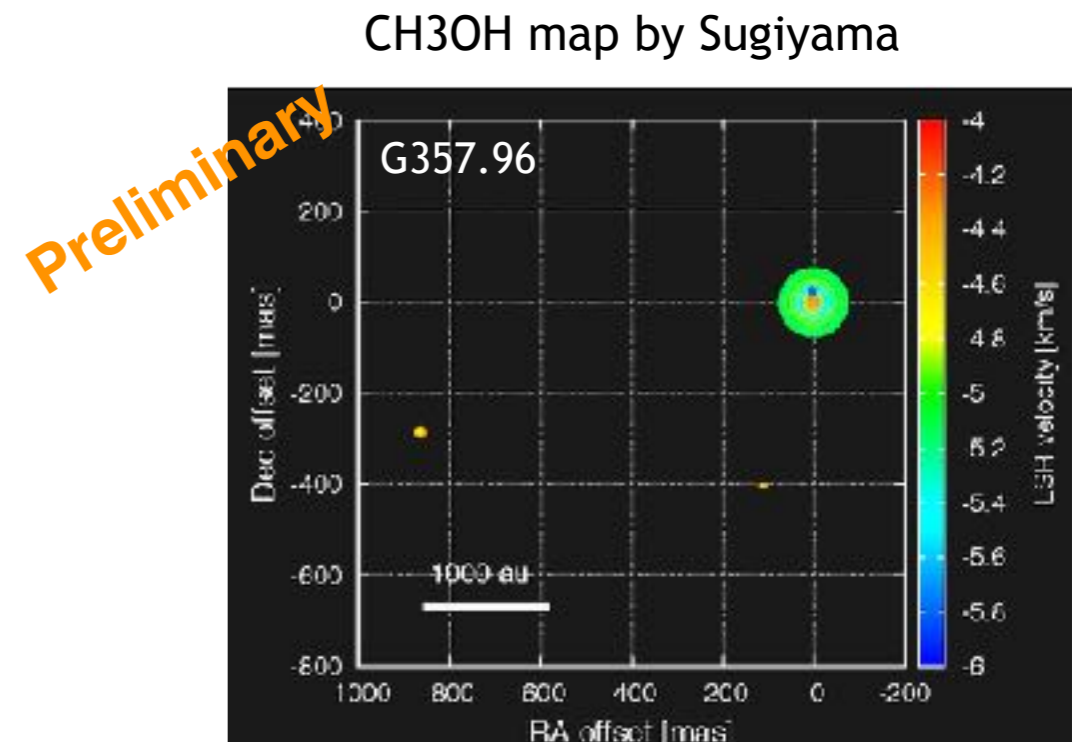
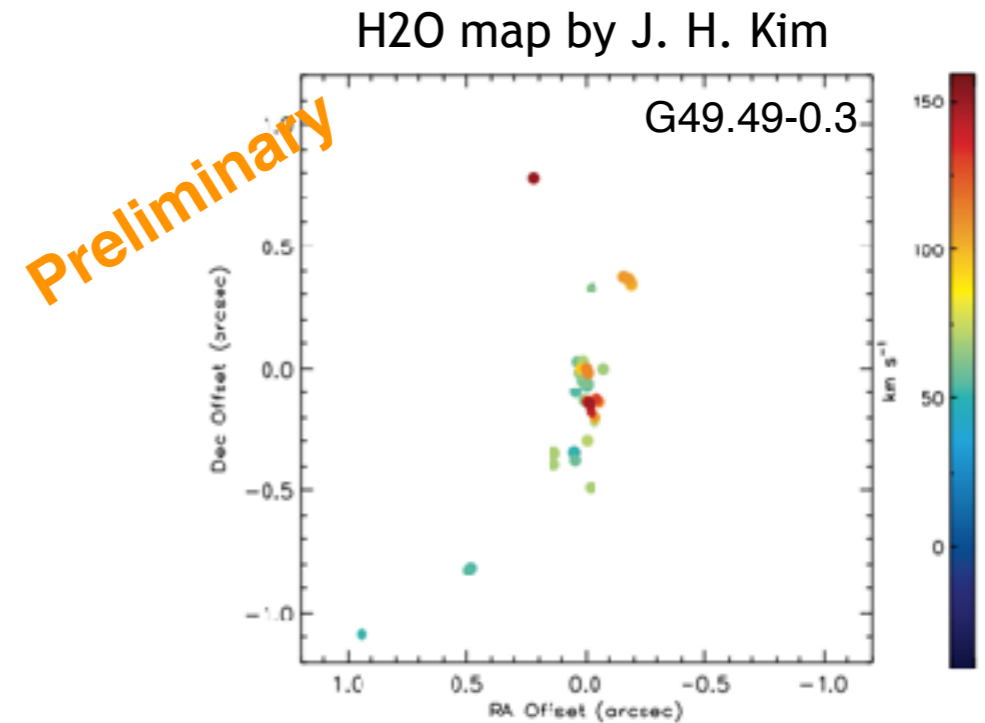
# SF Large Program

- Understanding high-mass star formation through KaVA observations of water and methanol masers
  - T. Hirota (NAOJ), K.-T. Kim (KASI)
  - VLBI monitoring/survey to reveal **3D velocity and spatial structures** in **87 high-mass YSOs** (HM-YSOs)
    - Physical and dynamical properties of **disk-outflow systems** of HM-YSOs
    - Evolution of disk-outflow systems of HM-YSOs and **maser evolutionary sequence**
    - Testing **formation scenarios** of HM-YSOs
  - follow up with JVN 6.7GHz Methanol, ALMA, VERA, ..



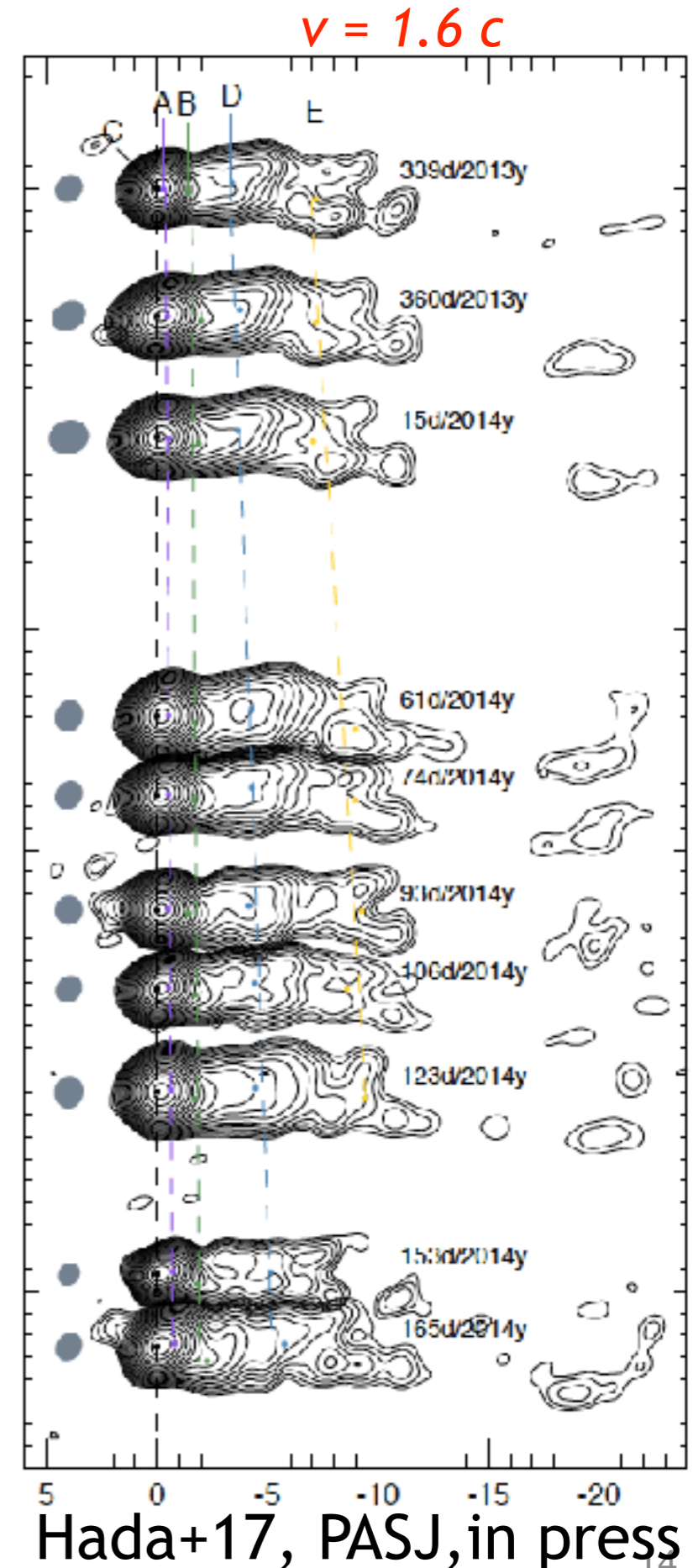
# SF LP: Current status (cont.)

- First year (~2017)
  - Snap-shot imaging survey of 25 H<sub>2</sub>O masers and 18 CH<sub>3</sub>OH masers (44 GHz)
  - Selected mainly from KVN single-dish survey (K.-T. Kim et al.) but without previous VLBI data
- Second year (2018~)
  - Monitoring of selected targets from the first year samples and archive data



# AGN Large Program

- Exploring the vicinity of super-massive black hole with KaVA
  - Motoki Kino, B. W. Sohn (KASI)
- **M87**: biweekly at 22/43GHz
  - Velocity field of M87 Jet
  - KaVA's densely-sampled (bi-weekly) monitoring find the components with  $\beta_{\text{app}} > 1$ !
- **SgrA\***: monthly at 43GHz
  - G2 encounter event in 2011
  - Gas accretion process
- complementary with EHT-ALMA



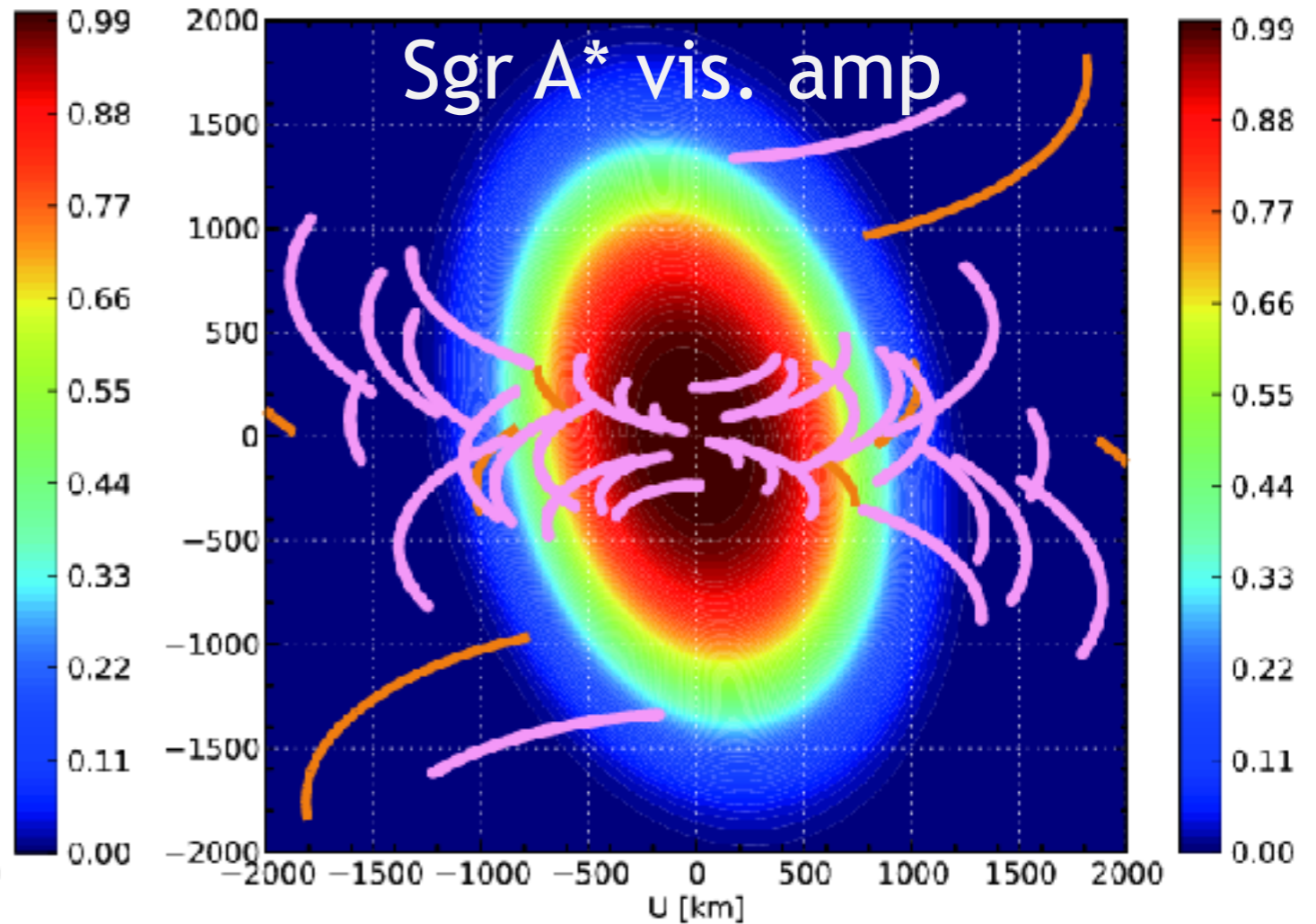
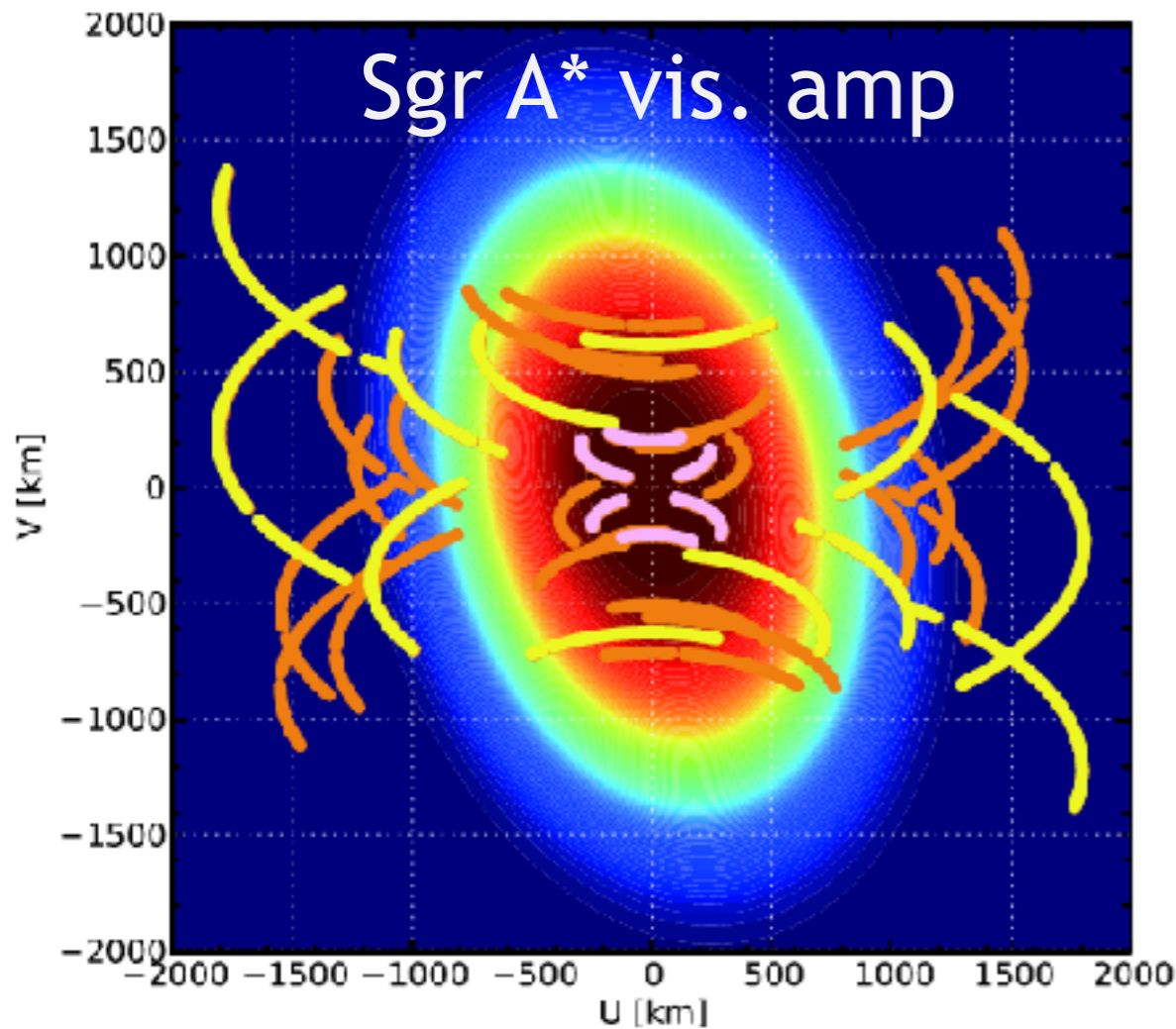


# AGN LP SgrA\* : KaVA array has best $(u,v)$ coverage for short-baselines!

See P4-04 by Zhao

## KaVA

## VLBA+GBT



Pink: KVN only  
Orange: KaVA  
Yellow: VERA only

Pink: VLBA+GBT  
Orange: VLBA only

# Bower+14 vs. Zhao+ *in prep*

the best quality data among KaVA 2014 Sgr A\* data was used.

	Bower et al. (2014) Closure-Amp	Zhao+ KaVA SWG <i>in prep</i> Closure-Amp	Zhao+ KaVA SWG <i>in prep</i> Self-Cal
Major axis ( $\mu\text{as}$ )	722 +/- 3	734.2 +/- 2.7	726.7 +/- 1.9
Minor axis ( $\mu\text{as}$ )	345 +/- ~30	427.0 +/- 21.8	426.0 +/- 7.0
Pos. angle (degrees)	82.4 +/- ~1.0	81.79 +/- 2.74	82.96 +/- 0.56

Size of scatter broadening is crucial for proper reconstruction of EHT image

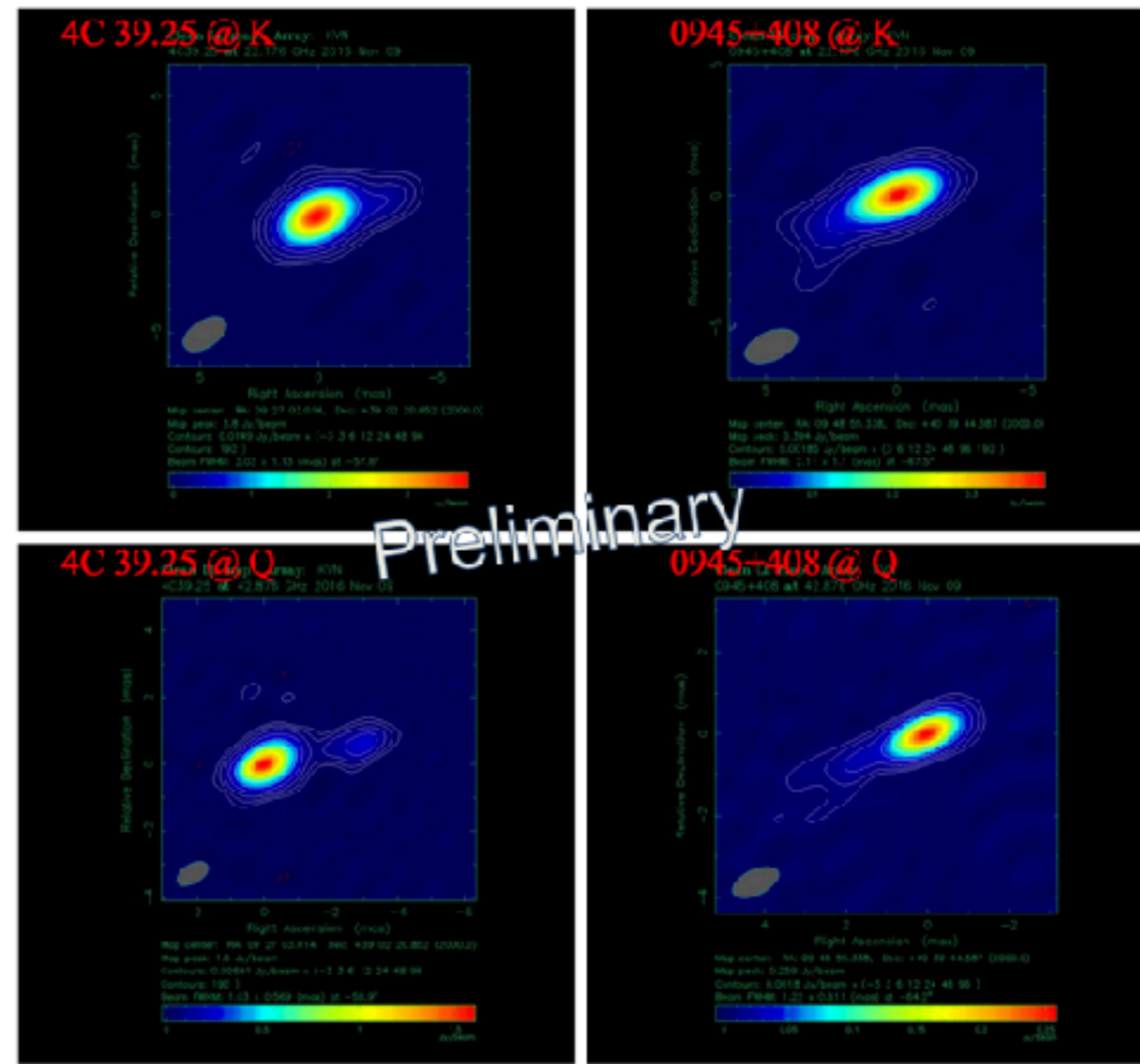
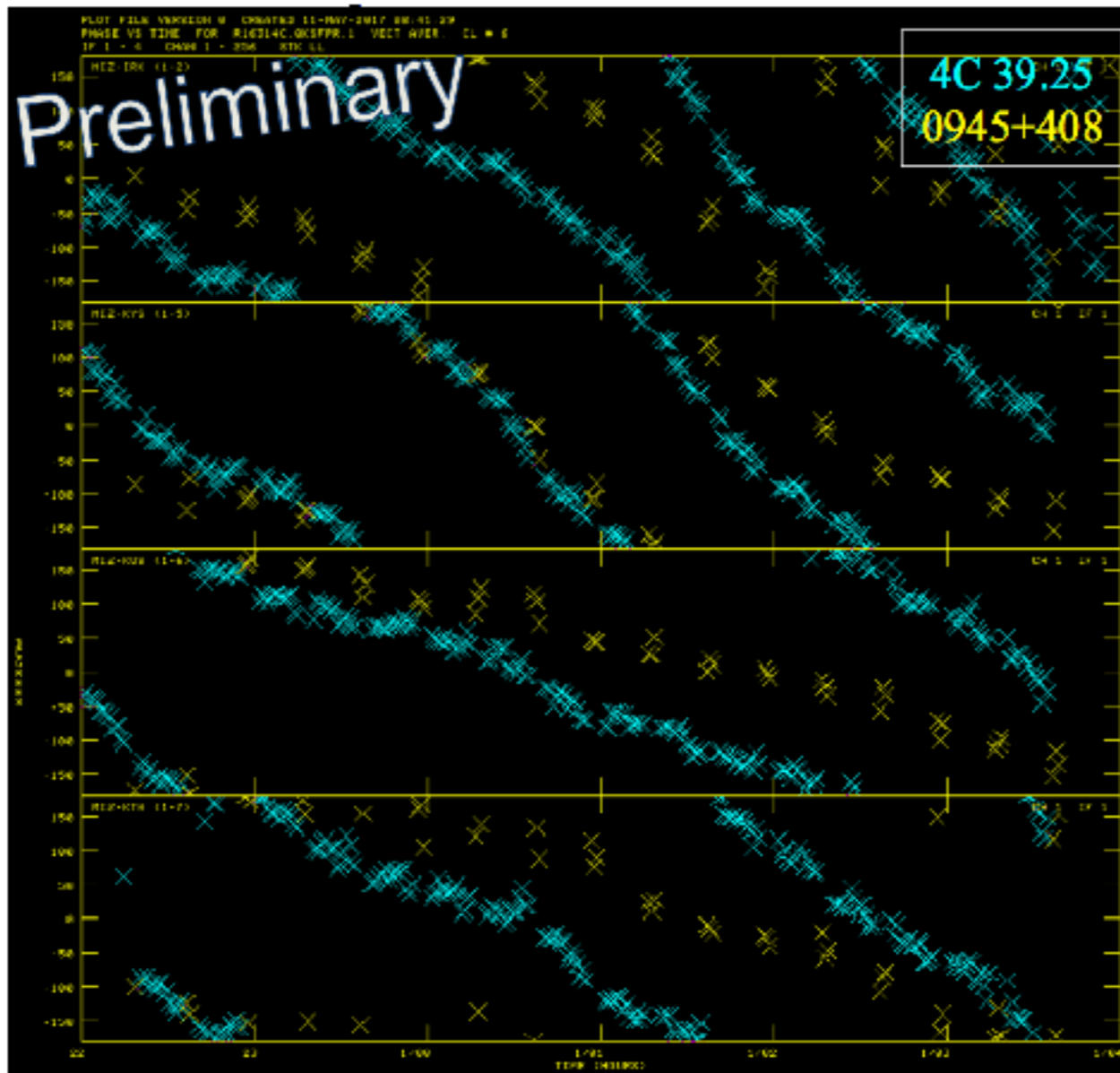
# Upgrade Activities

- Phase Referencing for high precision Astrometry
  - VERA Dual Beam + KVN Antenna Nodding
  - under evaluation and will be available in 2018
- Simultaneous 22/43GHz Observation
  - KVN 3 + VERA 2 Stations (MIZ and IRK) : 2016
  - KVN 3 + VERA 4 Stations : 2017B
- Wideband recording mode
  - 1Gbps mode (Current) : 256MHz BW (16MHz x 16 IF, ..)
  - 2Gbps mode (New) : 512MHz BW x 1 IF
- Polarization Observation
  - 22GHz Dual-Pol Receivers at VERA MIZ and IRK



# Simultaneous 22/43GHz Result : First Successful FPT in 1000km baselines !

- KaVA 5 Stations (KVN3+VERA2) in 2017 Nov



43GHz FPTed Phase

See P6-12 by Taehyun Jung

# Upgrade Activities

- Phase Referencing for high precision Astrometry
  - VERA Dual Beam + KVN Antenna Nodding
  - under evaluation and will be available in 2018
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# Summary

- KaVA continues steady and stable operation
- KaVA large programs
  - 1yr observations were finished in 2017 and 2-yr will start in 2018
  - begin to produce preliminary results
  - new members and collaborators are welcome
- Astrometry, multi-frequency, polarization will be available within 1-2 yrs.
- Please visit <http://kava.kasi.re.kr>