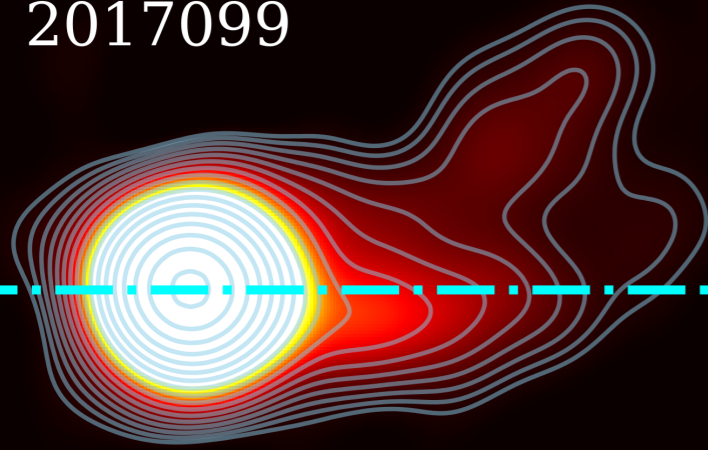
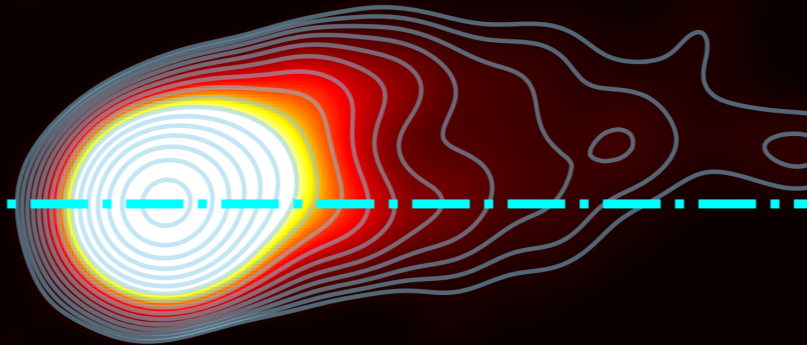


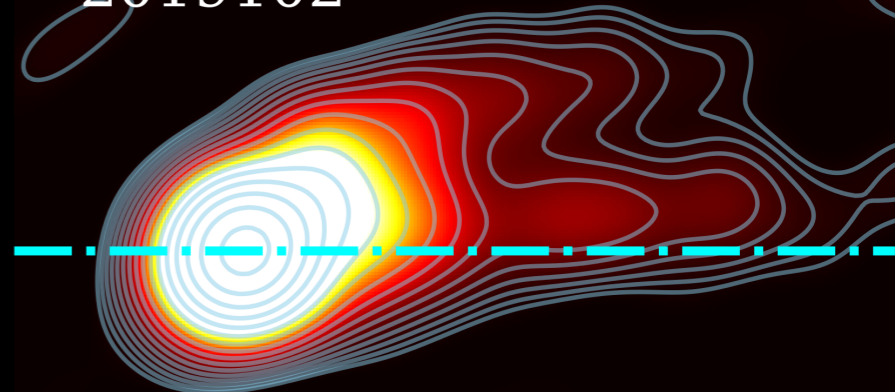
2017099



2018101



2019102



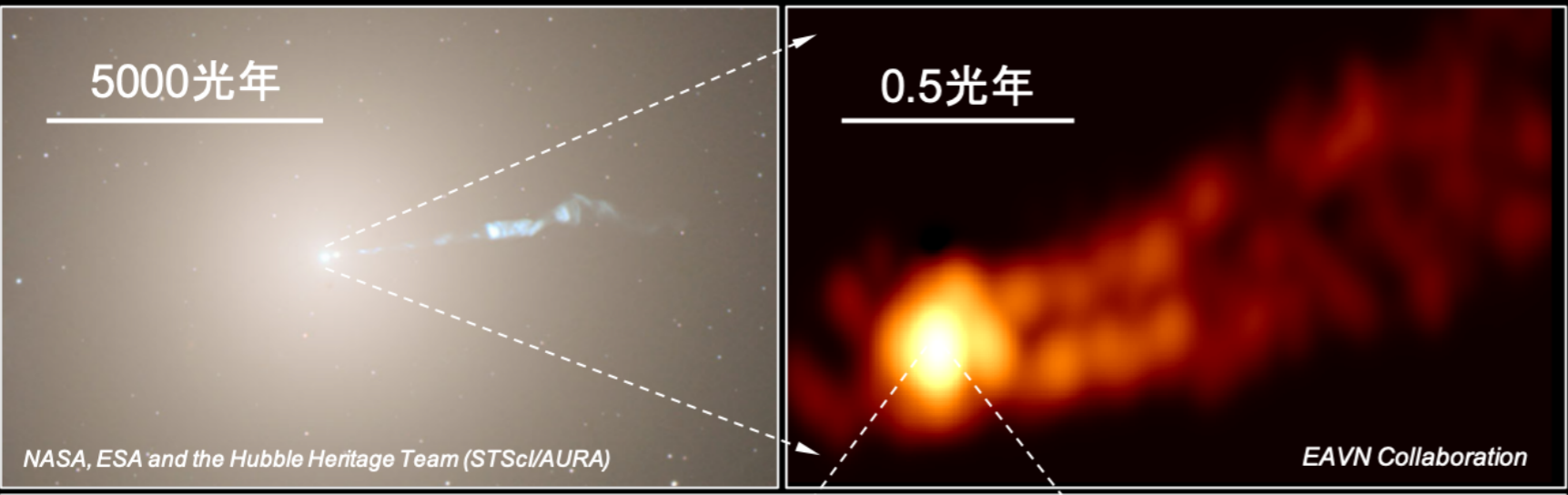
Variation of M87 jet base revealed by EAVN 2017-2019 campaign

Cui Yuzhu, Hada Kazuhiro, Honma Mareki, on behalf
of EAVN AGN Science Working Group

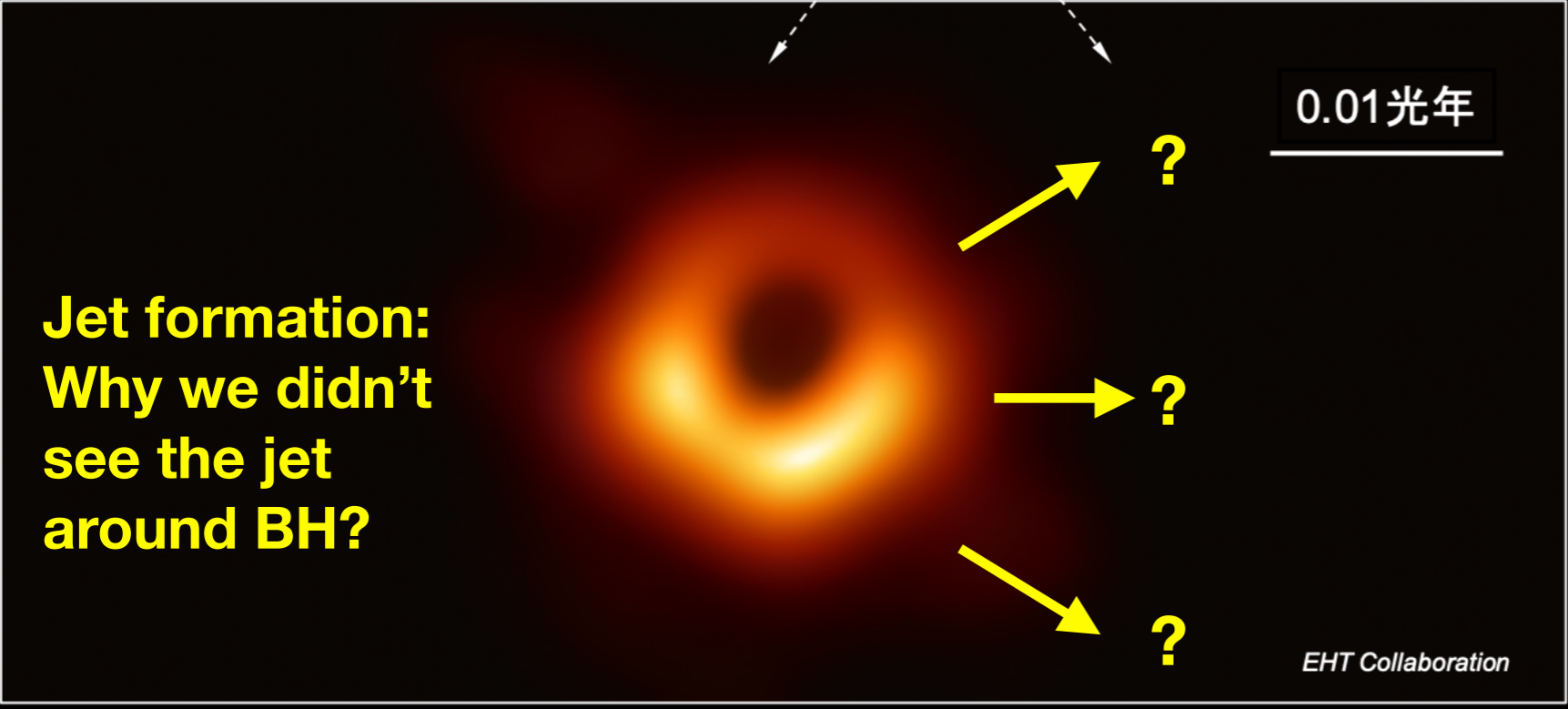
Content

- Background:
 - Previous work on M87 jet and black hole
 - EAVN campaign in 2017, 2018 and 2019
- Results:
 - Light curve
 - Position angle
 - Connection with EHT scale
 - Time variation of position angle, opening angle and jet width
- Discussion
- Summary and future plan

M87: the Best Laboratory To Study the **Jet** and **Black Hole**

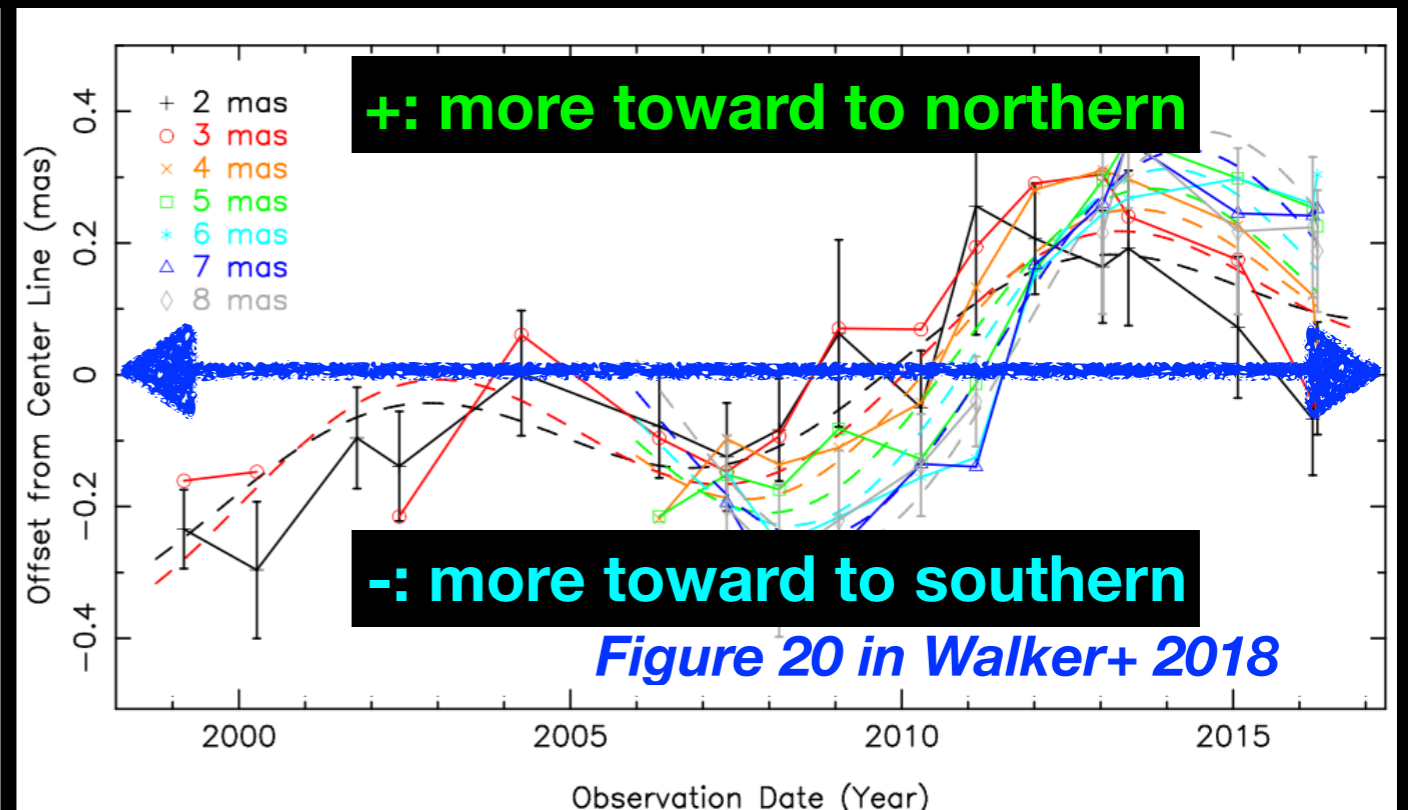
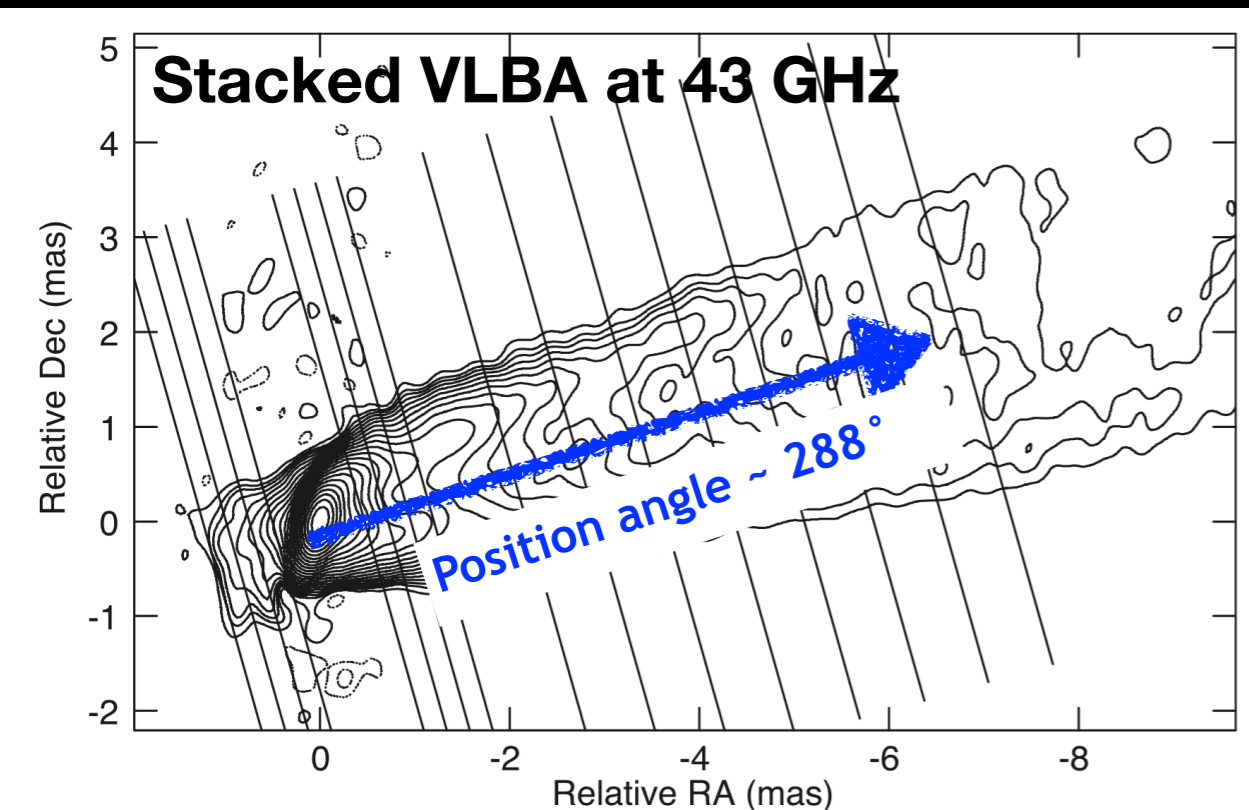


- **Highly collimated jet extended to kpc scale (5000 ly) which is detectable at multi-wavelength.**



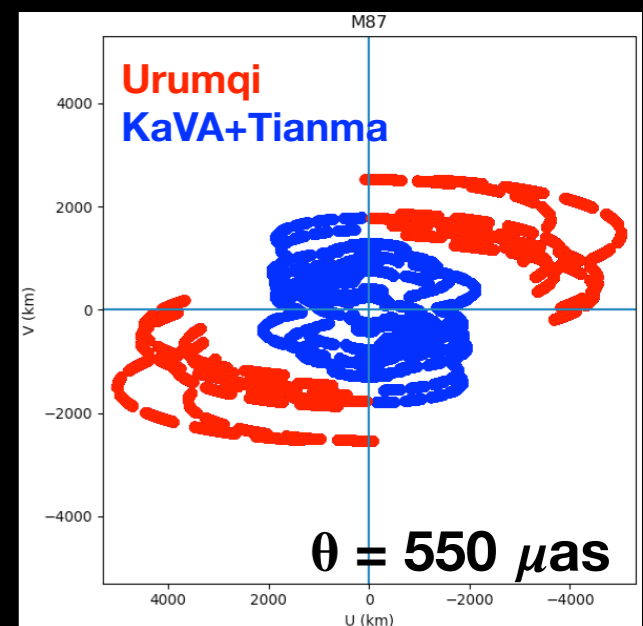
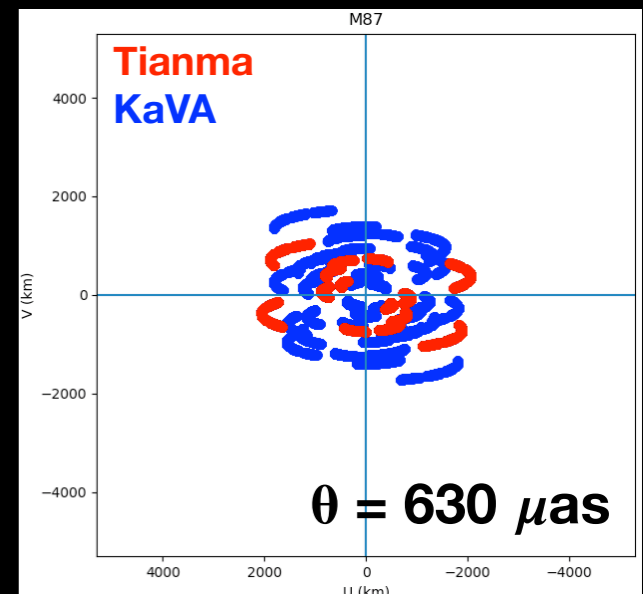
- Nearby radio galaxy: one of the closet AGN, **D=16.7 Mpc (~53 million ly)**;
- Supermassive black hole inside: **$M_{BH}=6.6 \times 10^9 M_{\odot}$**

Position angle at mas scale: variable along 288°



- Position angle of M87 jet can be variable over time;
- Comparison with simultaneous, low-frequency and multi-epoch VLBI images (eg, EAVN/VLBA) is necessary.

East Asian VLBI Network



- Eight antenna joined at Q band;
- Nine and more other antenna joined at K band.

EAVN campaigns during 2017-2019

Obs. Year	Obs. Freq.	Before April	April (EHT)	After April	Sum1	Sum2
2017	22 GHz	5	3	1	9	21
	43 GHz	6	5	1	12	
2018	22 GHz	2	3	2	7	16
	43 GHz	3	3	3	9	
2019	22 GHz	5	2	2	9	19
	43 GHz	6	2	2	10	
Sum	2	27	18	11	56	Pl: Hada

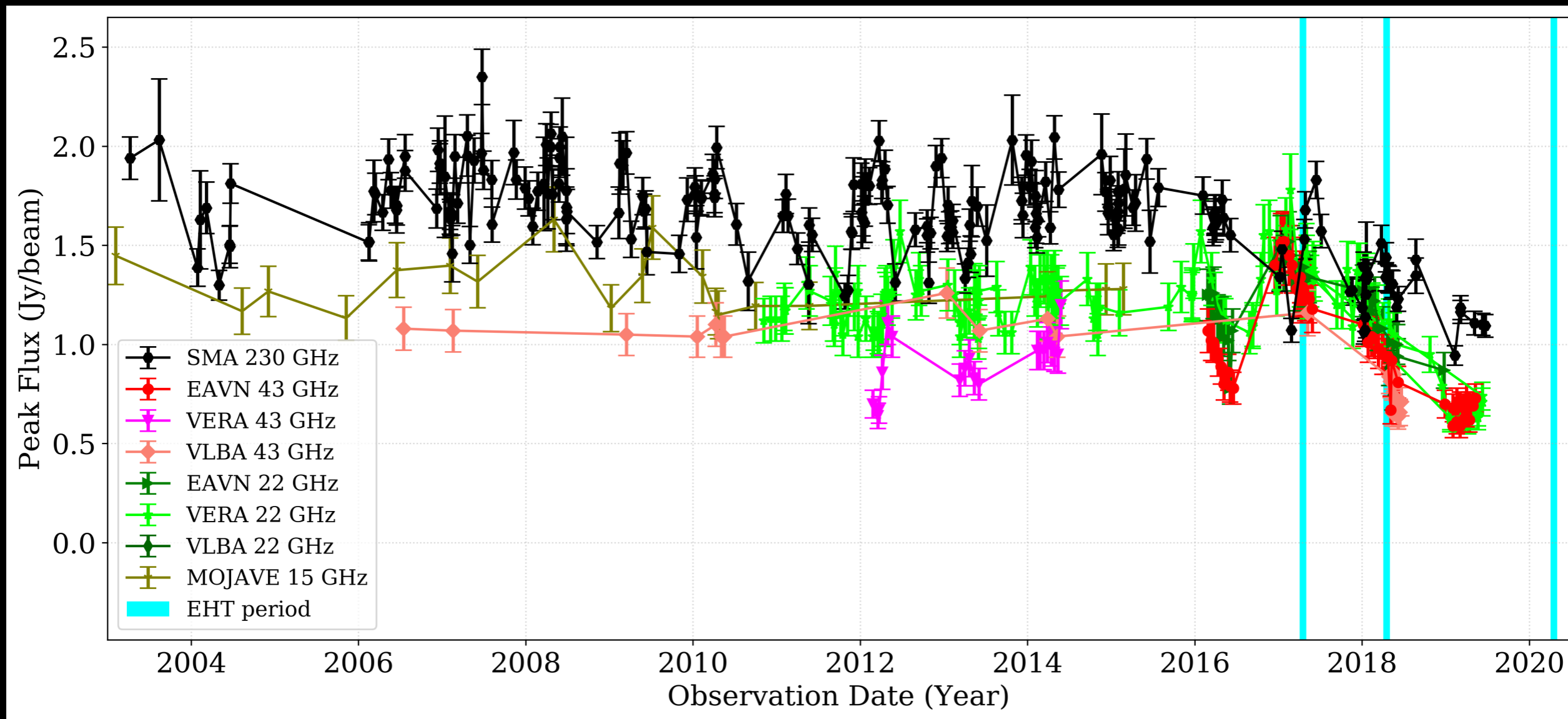
- EAVN total: 56 epochs (25@22 GHz, 31@43 GHz);
- KaVA total: 22 epochs (11@22 GHz, 11@43 GHz)

Uniqueness of our EAVN/KaVA M87 observations:

- **Multiple epochs fully cover EHT window:**
 - Long-term variation (light curve, position angle, collimation, proper motion...)
 - connection between BH and jet
- **Simultaneous K and Q observation:**
 - Reliable spectral index to trace the particle distribution

Q1: What was the status of M87 during EHT-2017/2018 window?

M87: Falling into low status from 2017 to 2019

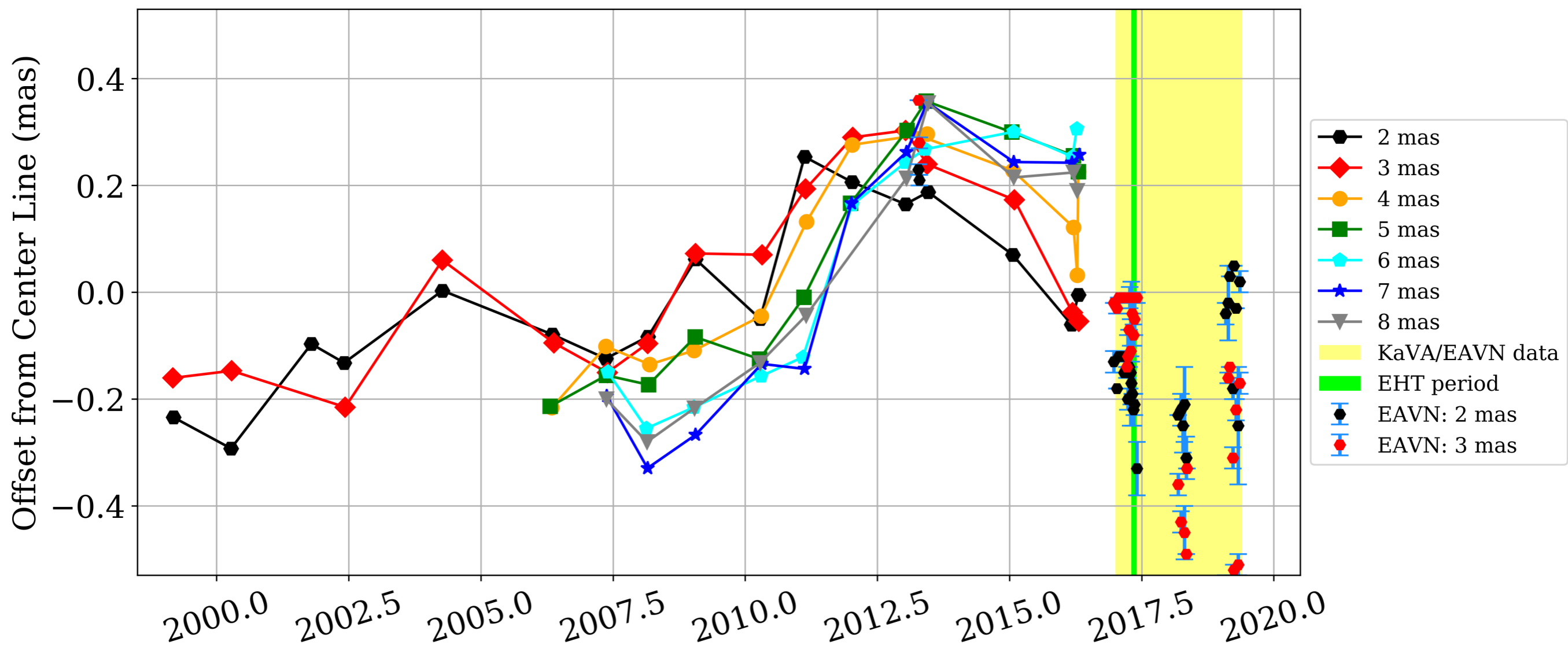


- ✓ VLBA -> Q: 12 epochs
(PI: Hada)
- ✓ Genji -> Q: 19 epochs
K: 133 epochs
(PI: Niinuma)

- Starting from 2017, the flux of M87 keeps decreasing; EAVN: (2.03 ± 0.21) Jy, Genji: (1.83 ± 0.36) Jy, VLBA: (1.23 ± 0.17) Jy, SMA: (1.6 ± 0.23) Jy
- It seems in 2019 the flux is recovering

Q2: Can the long term position angle variation be confirmed?

Position angle of M87 jet (time variation)

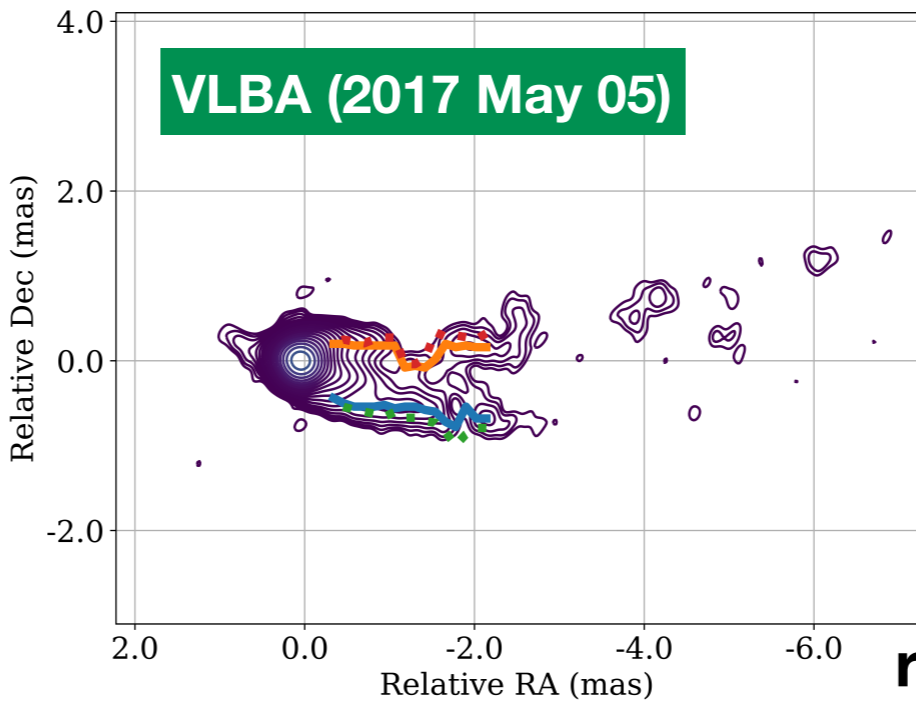
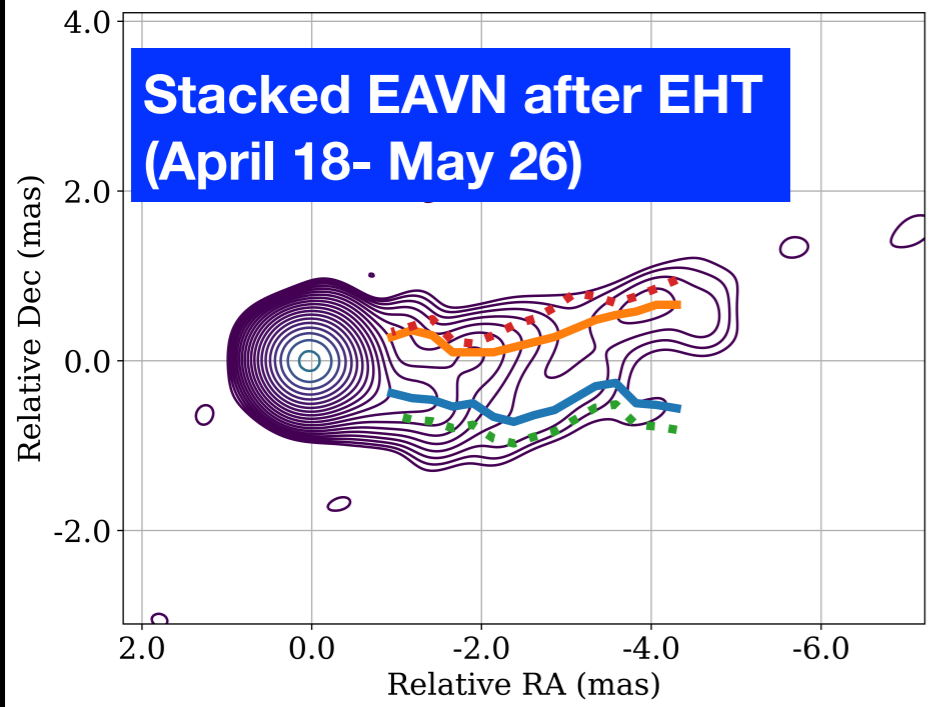
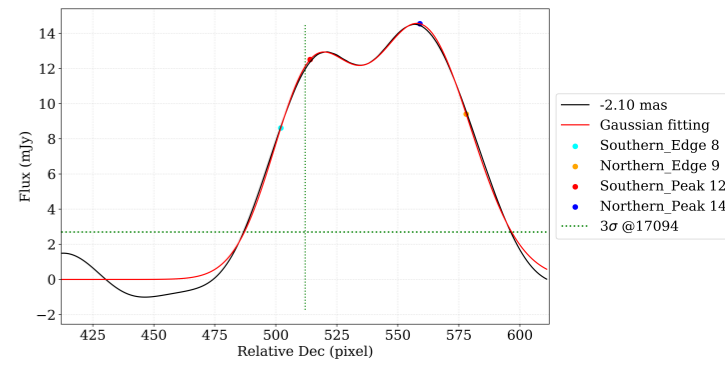
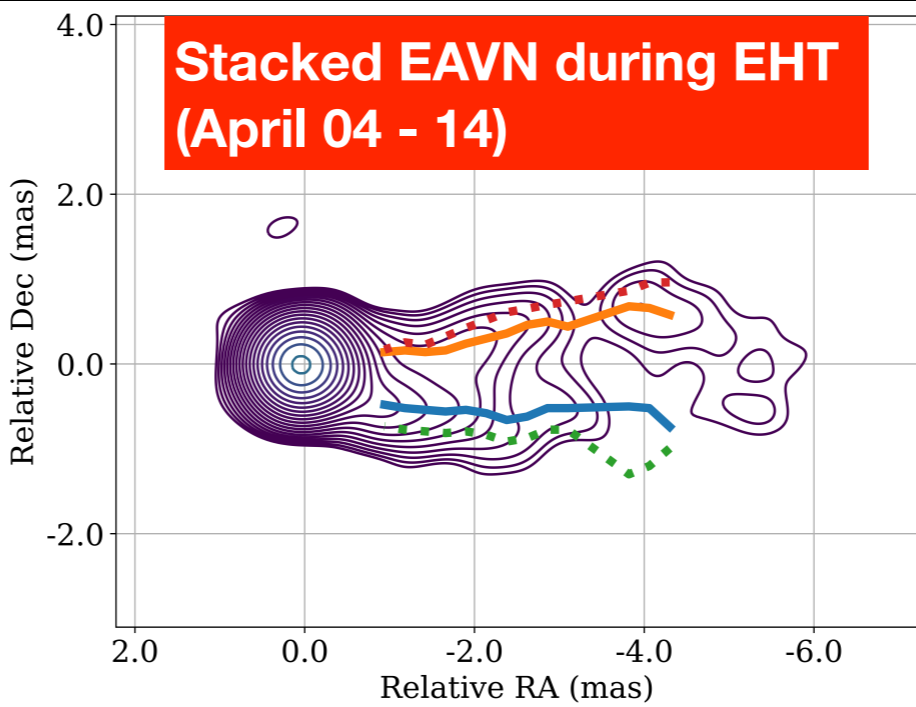
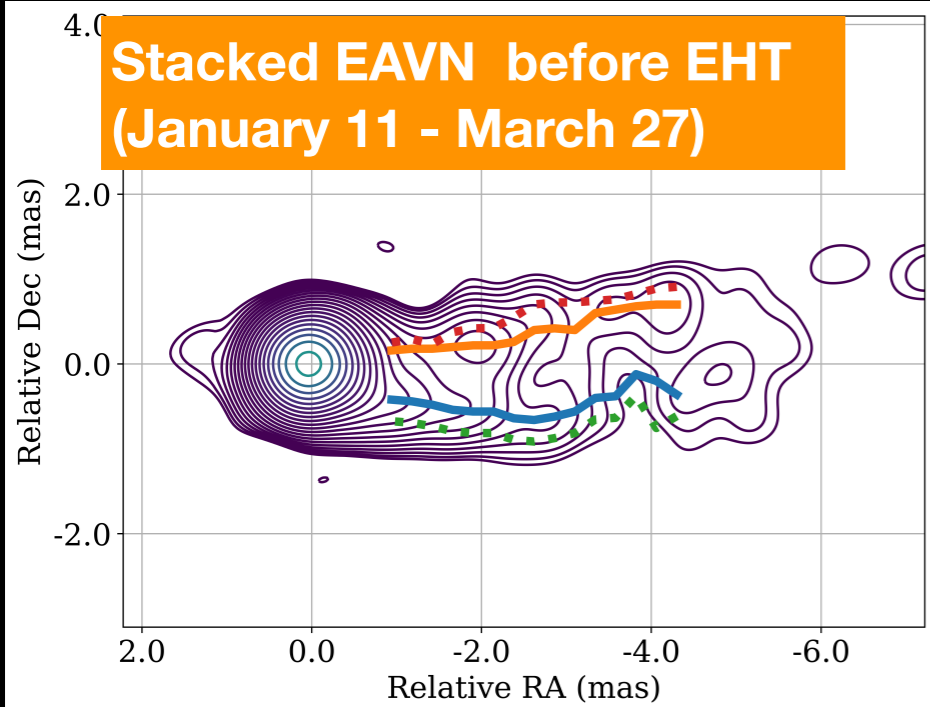


- We confirmed the transverse motion with 2017/2018/2019 EAVN (KaVA) data;
- Around EHT period, the jet center has around 0.18 mas offset which indicates the jet center in this method is toward to ~280 degree.
- The jet seems to reach the south-most point at the end of 2017

Q3: Why we didn't see the jet emission surrounding the BH?

Results

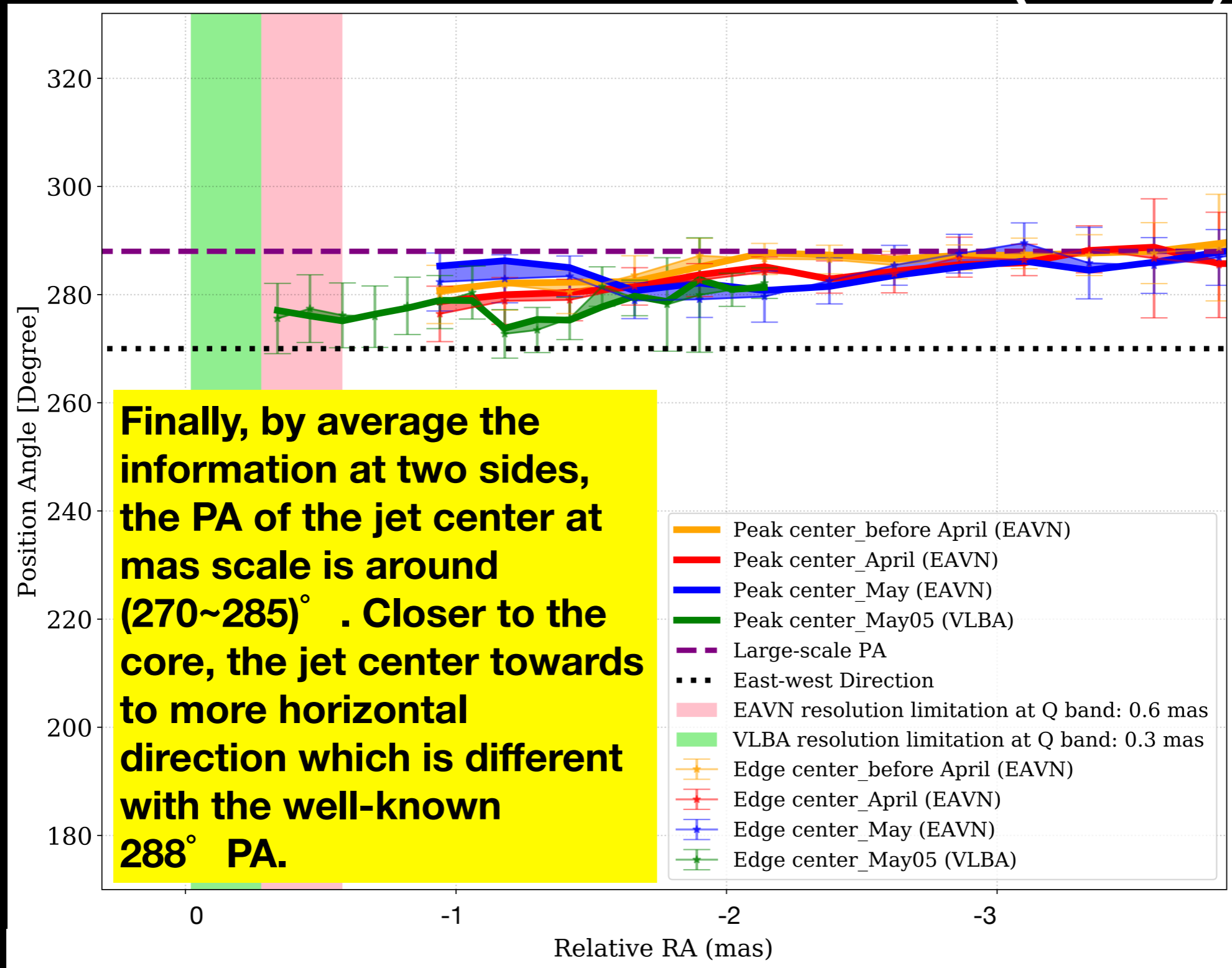
Group our 2017 data into four groups to compare the PA before/during/after EHT period



- Peak_S
- Peak_N
- - - Edge_S
- - - Edge_N

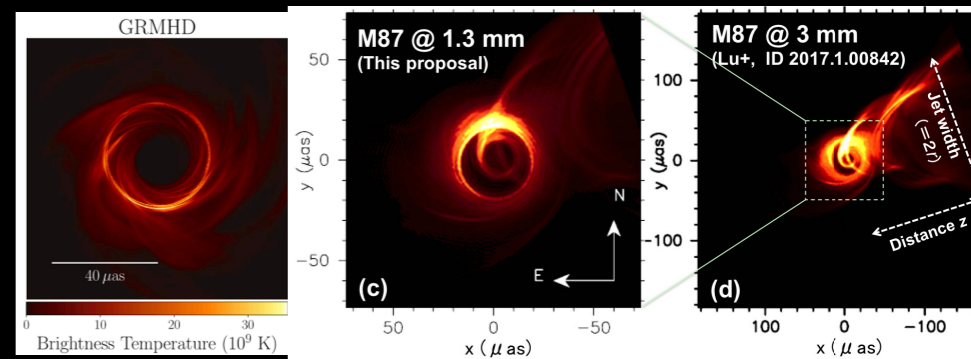
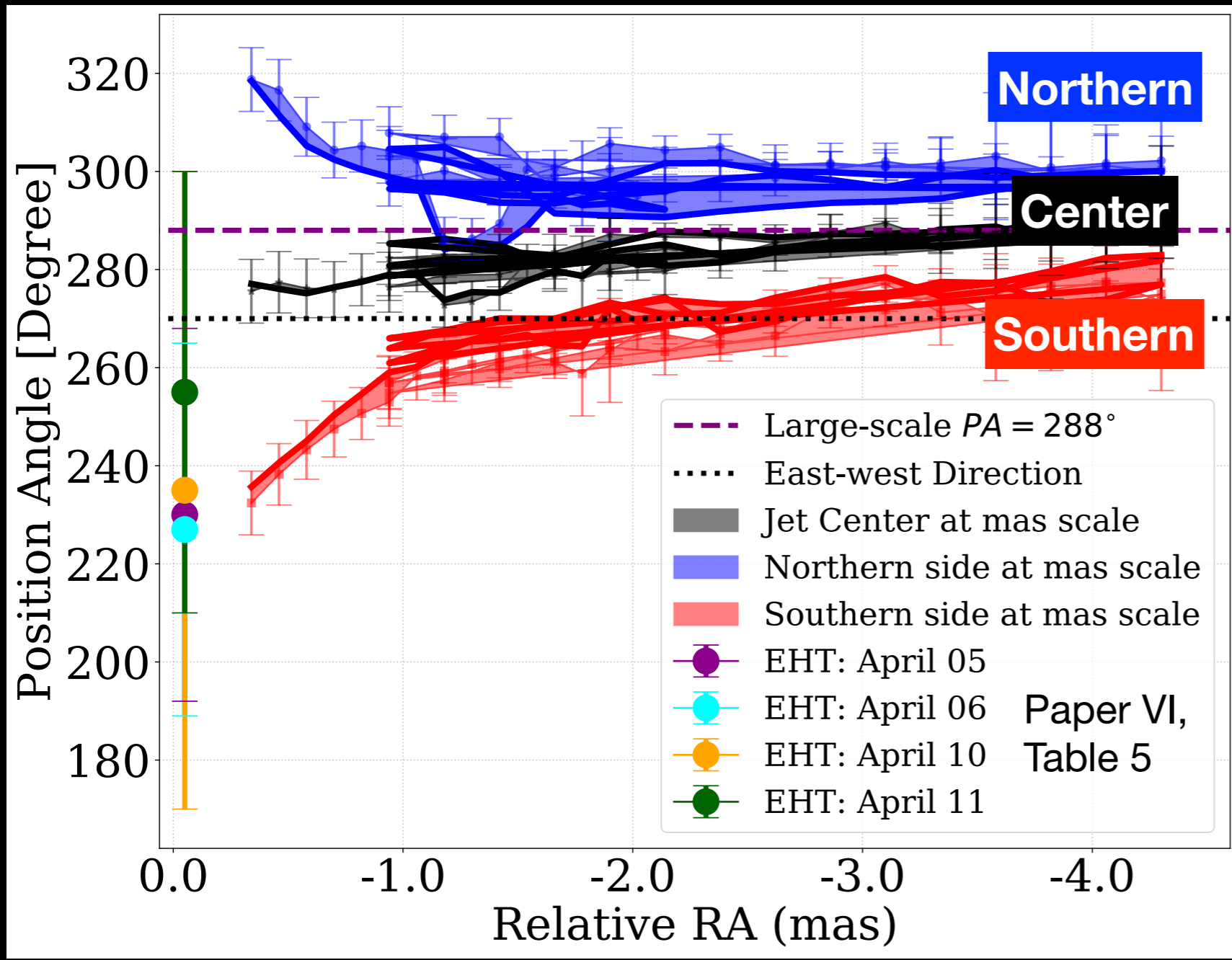
rotated -18°

Position angle of the M87 jet edges and center at mas scale (2017)



Results

The non-detection of the jet at μas scale may be due to the super-extended jet with a wide range of opening angle? (2017)



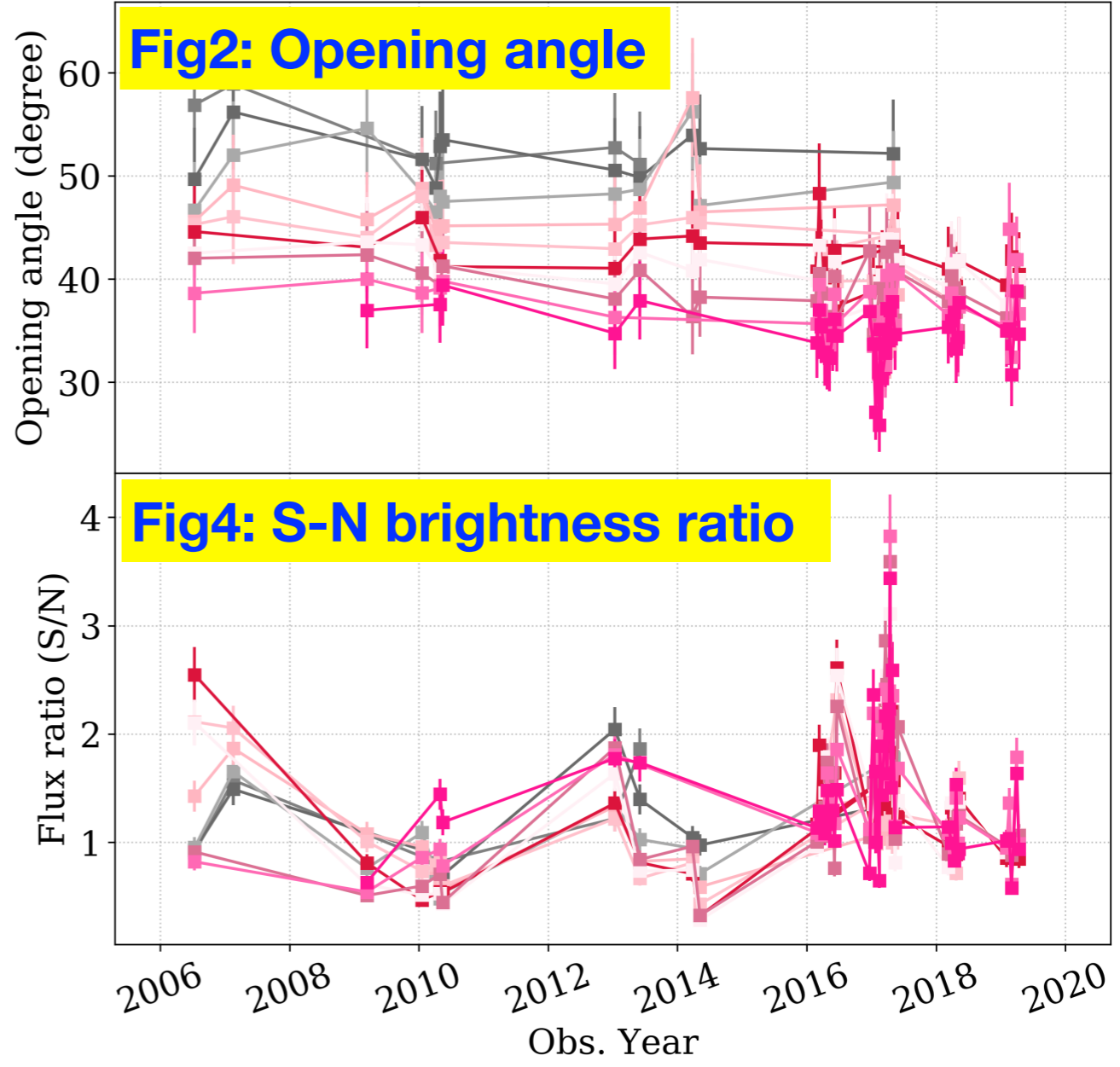
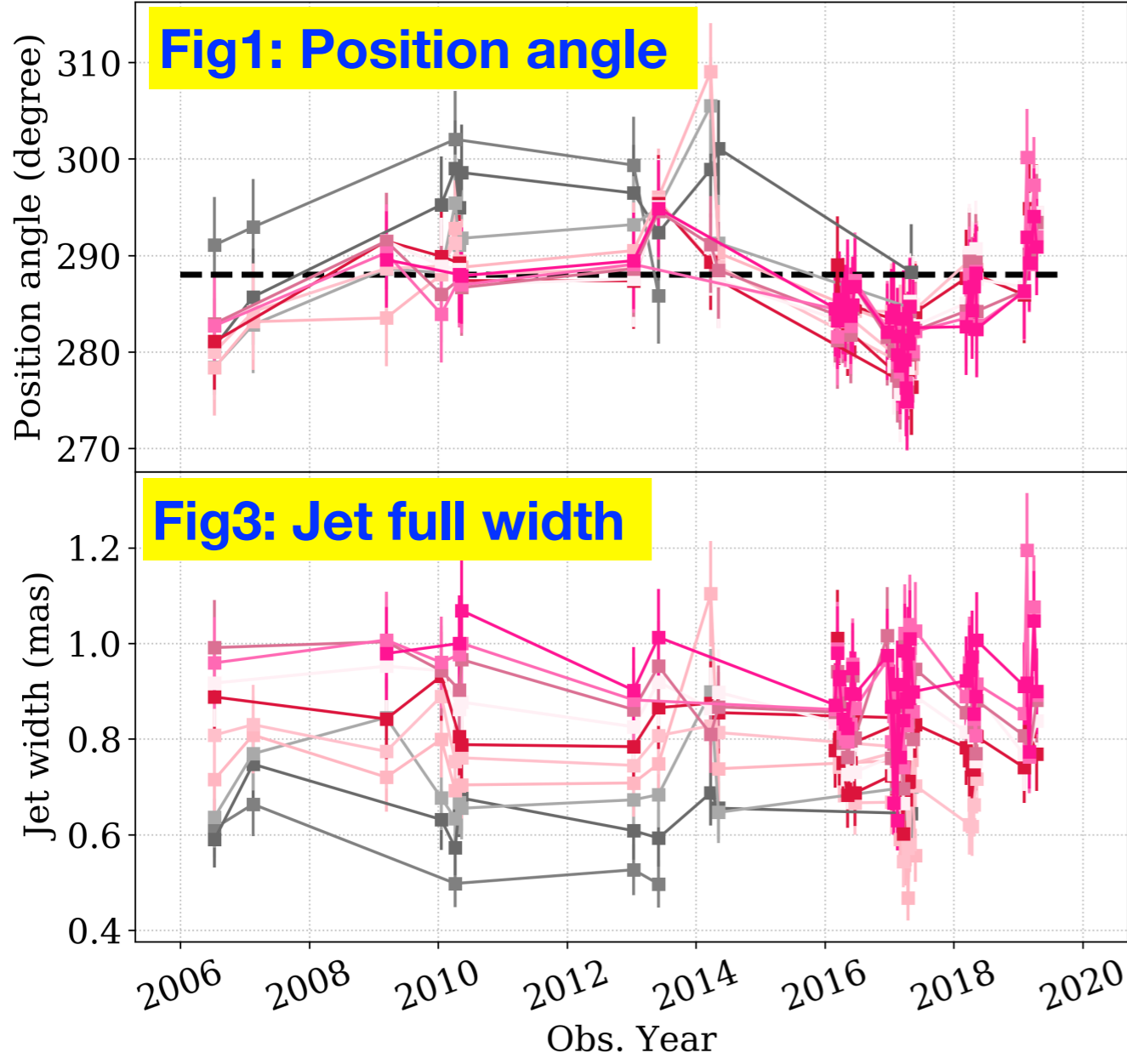
1. The jet PA at μas scale is consistent with that at mas scale, especially at the innermost region close to the core
2. Further joint mm/cm-VLBI monitoring in the following campaign will fill the some gap between μas scale and mas scale and better solve this key question

Q4: What is the long-term variation of the jet width, opening angle and S-N brightness ratio?

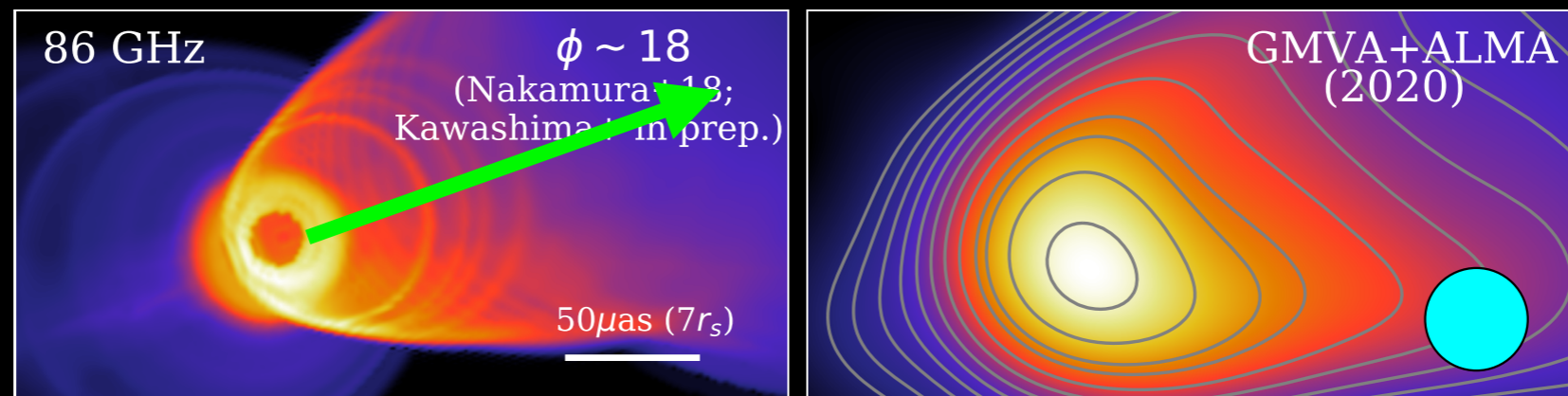


Results

Time variation of PA, OA Jet width, and S-N BR



Well confined jet shape no matter how jet direction changes?

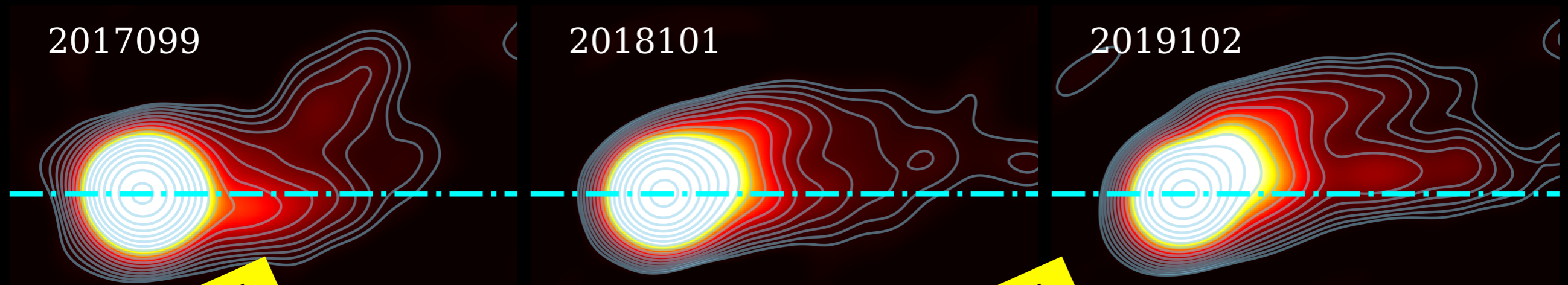


PI: J. Kim+, GMVA+ALMA proposal (Cy. 7)

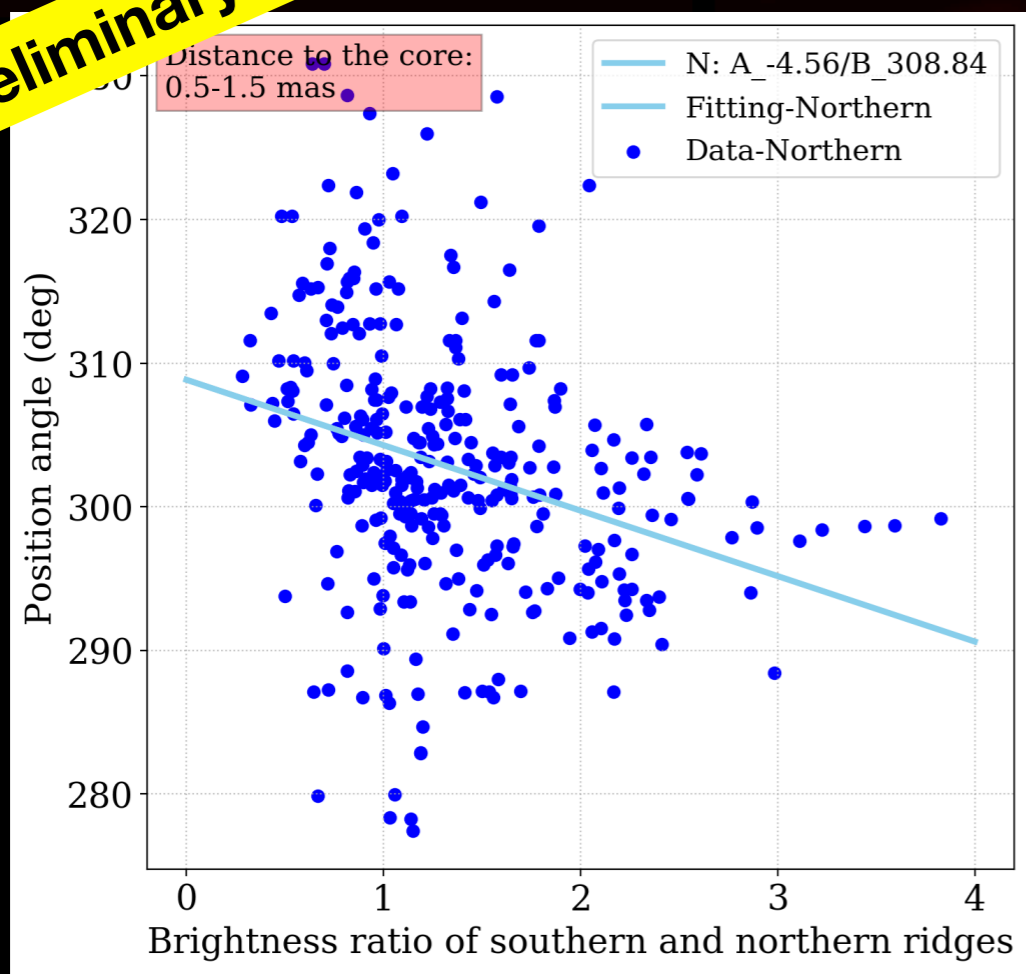
- **Well confined jet shape which is with fixed opening angle and jet width at certain distance to the BH, the jet axis direction is changing with the time**
 1. **2-D oscillation**
 2. **3-D oscillation:** there is a 5 degree error bar of opening angle in the projected plane, that means the possible precession angle is within 11 degree

Discussion

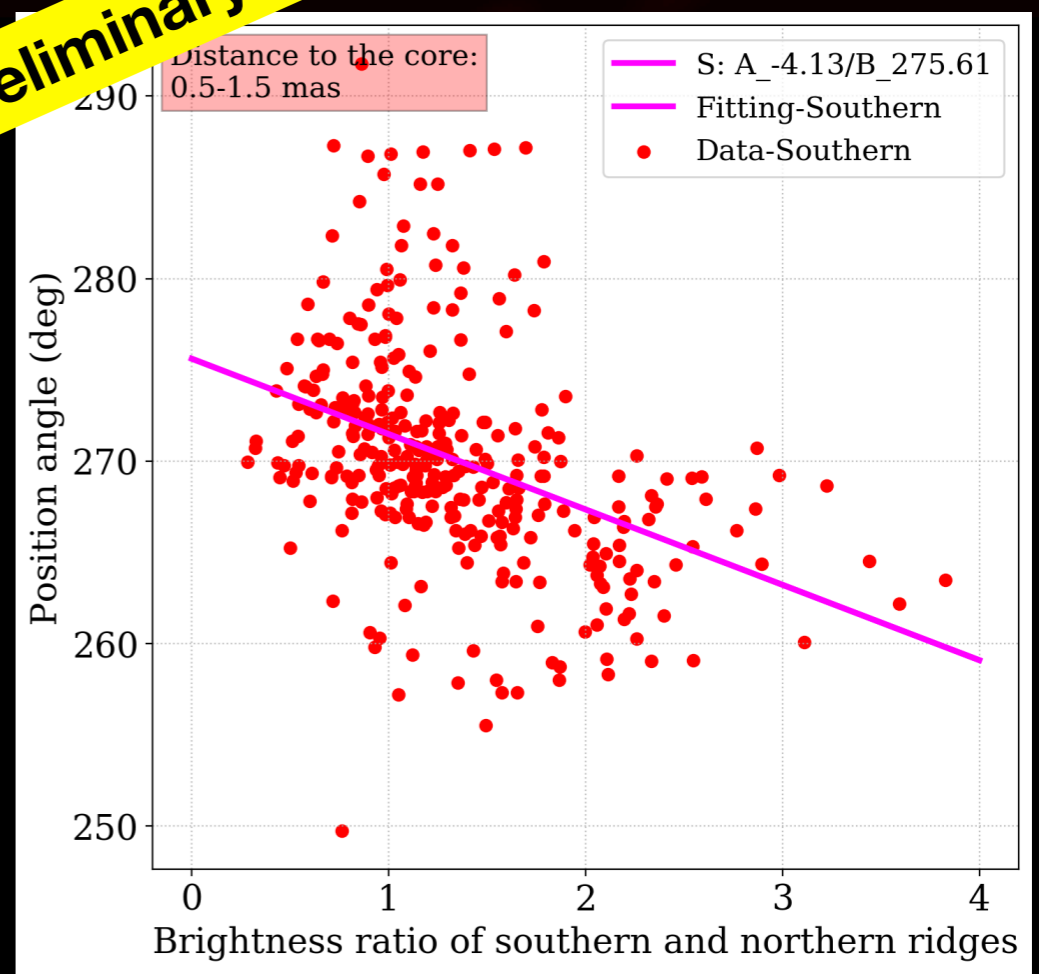
The brightness distribution variation is connected with the jet PA change?



Preliminary!



Preliminary!



Summary and future plan

1. Data analysis:

- Jet collimation profile;
- Jet position angle (north/south/average);
- S-N brightness ratio variation;
- Jet kinematics / motion;
- Spectra profile

2. Theoretical model

3. New proposal of EAVN-EHT campaign in 2020A: submitted

