East Asian VLBI Network (EAVN) observations of M87 along with EHT campaign in 2017

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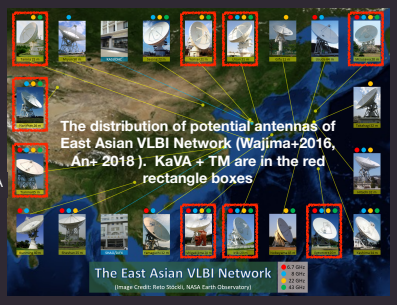
1. Introduction: EAVN campaign 2017



The radio galaxy M87 offers a privileged opportunity to probe the jet launching and formation scales thanks to the proximity and large mass of the central black hole. This makes M87 a prime target for the Event Horizon Telescope (EHT) along with SgrA*. In April 2017, M87 was for the first time observed by EHT+ALMA. This may allow the first imaging of the black hole shadow and jet-launching regions at scales of a few Schwarzschild radii. However, due to the sparse uv-coverage of the EHT, a proper interpretation of the EHT image may require contemporaneous complementary observations at the lower frequencies that provides the higher fidelity jet images.

2. Motivation ——EAVN's Uniqueness

- **EAVN observations was preformed near-in-time with EHT**

Session	Obs. Code	Date	Time	Band	Band width	Target	Stations
1	a17071a	Mar 12	18:55 - 00:55	K	16	SgrA	KaVA, TM
2	a17077a	Mar 12	12:45 - 19:45	K	32	M87	KaVA, TM, UR, HT, KS
3	a17078a	Mar 19	11:40 - 18:40	Q	32	M87	KaVA, TM
4	a17086a	Mar 27	13:10 - 23:10	Q	32	M87 + SgrA	KaVA, TM
5	a17093a	Apr 03	13:20 - 23:20	K	32	M87 + SgrA	KaVA, TM, UR, HT, KS, MC, NT
6	a17094a	Apr 04	12:40 - 22:20	Q	32	M87 + SgrA	KaVA, TM
7	a17099a	Apr 09	12:20 - 22:20	Q	32	M87 + SgrA	KaVA, TM
8	a17104a	Apr 14	12:00 - 22:00	Q	32	M87 + SgrA	KaVA, TM
9	a17107a	Apr 17	11:50 - 18:50	K	32	M87	KaVA, TM, UR, HT, KS, SJ, MC, NT
10	a17108a	Apr 18	11:45 - 21:45	Q	32	M87	KaVA, TM
11	a17114a	Apr 24	09:20 -16:20	K	32	M87	KaVA, TM
12	a17115a	Apr 25	09:15 - 16:15	Q	32	M87	KaVA, TM
13	a17116a	Apr 26	15:55 - 21:55	Q	16	SgrA	KaVA, TM
14	BG251	May 05	23:16 - 10:15	Q	32	M87	SC, HN, NL, FD, LA, KP, PT, OV, BR,
15	a17130a	May 10	08:20 - 17:20	K	32	M87	KaVA, TM, MC
16	a17131a	May 11	08:15 - 17:15	Q	32	M87	KaVA, TM
17	a17145a	May 25	14:00 - 20:00	Q	16	SgrA	KaVA, TM
18	a17146a	May 26	07:15 - 16:15	Q	32	M87	KaVA, TM

High Cadence!

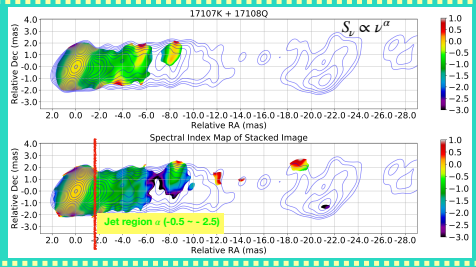
EHT Period

Contemporaneous!

- **Field of View comparison (EAVN & EHT)**

M87: $M_{BH} = 6 \times 10^9 M_{sun}$,
Rs = 8 μas; D = 16 Mpc

3.1 Spectral Index Property



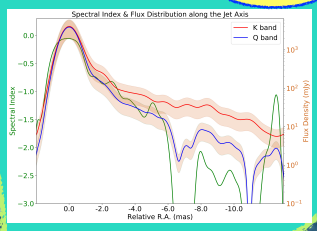
We adopted the self-referencing method (*Croke+2008*) to calculated the core shift between K and Q band. The actual offset is around 20 ~60 μas which is also consistent with phase-referencing method (*Hada+2011*).

We know that $S_{core,43GHz} = 586mJy@VLBA$, from the stacked spectral index map we can get the the spectral index for optically thin region is $\alpha = -1.5$.

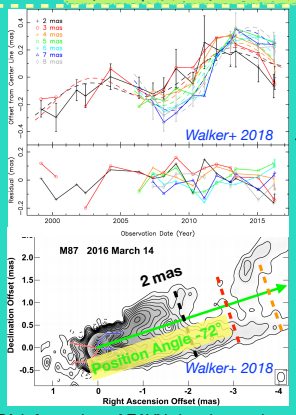
We can calculate the expected integrated flux density around BH:

$$S_{total,230GHz} = S_{core,43GHz} \times (\frac{\nu_{230GHz}}{\nu_{43GHz}})^\alpha = 47mJy@EHT$$

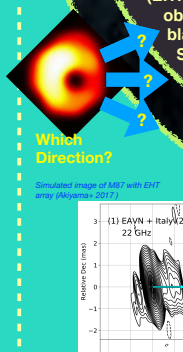
Detectable?

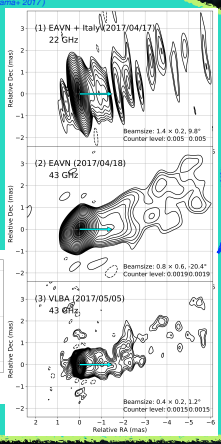


3.2 Jet Direction

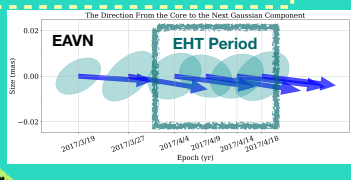


PA information of EAVN data is consistent with the significantly periodic jet position changing with a timescale around 8-10 yr reported by *Walker + 2018*.



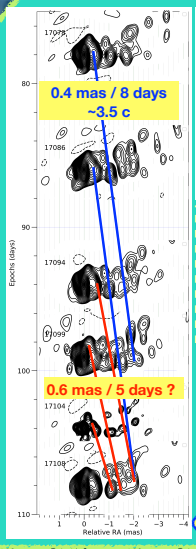


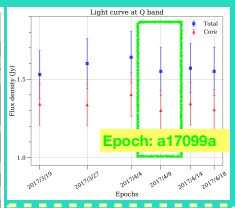
Around BH, Jet is also Horizontal ?



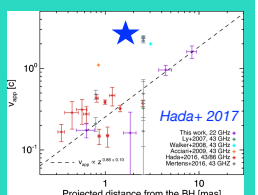
3.3 Velocity Profile

High cadence: the time interval between nearby epochs is 4 ~ 8 days. It may provide a chance to detect very high proper motion. We started with simply visual check of super-resolved images. The knots may have over 3.5 c velocity.

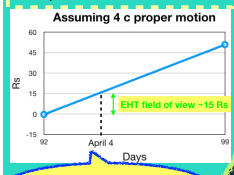




We could determine the possible new component which can be resolved by EAVN. Then the time of producing this component would be figured out, take epoch a17099a as an example.



This is a brief summary of the measured proper motion of M87 inner jet. The highest velocity is 2 c. Most of the velocity is showed lower than 1 c. But the observation cadence is different.



New component?

4. Future Work

Our work is still in progress, in addition to make a more accurate summary of current preliminary results, we will investigate more aspects of EAVN 2017 campaign data:

(1) Possible cause and model for M87 position angle changing;
(2) Try traditional and new method to detect high proper motion;
(3) Comparison of the measured jet collimation and acceleration with theoretical model
(4) Investigations of other sources: we also observed other sources in our observation, like 3C273.

5. Reference

- An et al. 2018, NatAs, 2, 118
- Akiyamaet al. 2017, ApJ, 838, 1
- Croke & Gabuzda, 2008, MNRAS, 386, 619
- Hada et al. 2011, Nature, 477, 185
- Hada et al. 2017, PASJ, 69, 71
- Niinuma et al. 2014, PASJ, 66, 103
- Walker et al. 2018, ApJ, 855,128
- Wajima et al 2016, ASPC, 502, 81