EAVN -hi-
Status and Prospect

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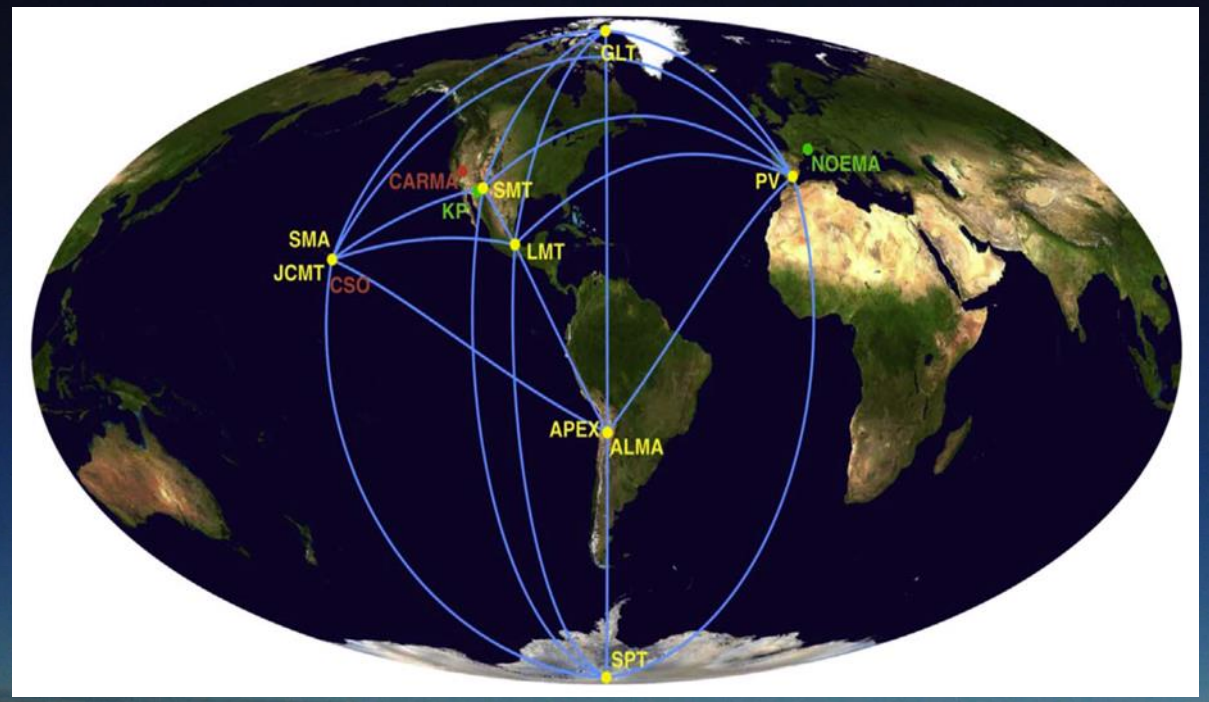
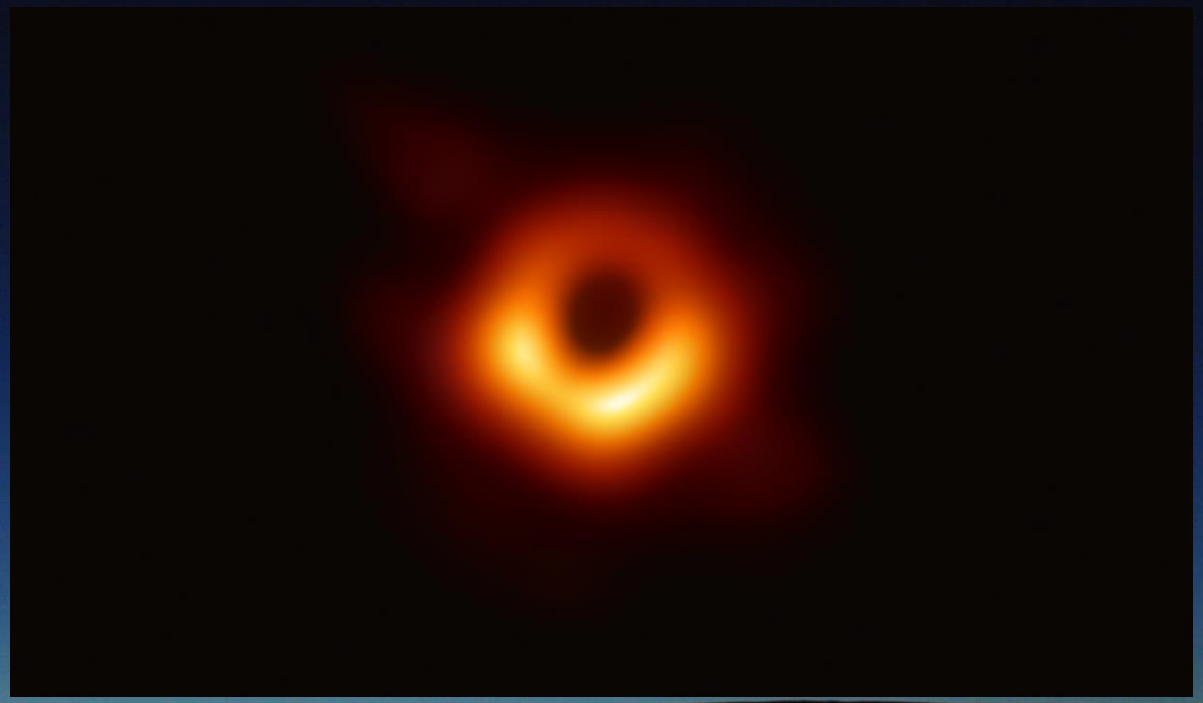
On behalf of the EAVN -hi- Collaboration

Event Horizon Telescope (EHT)

- World-Wide 230 GHz (& 345 GHz) VLBI Network
  - Only once a year (March or April); 5-6 days within 10-16 days window.
  - So far, only 2017 & 2018. No observation on 2019 & 2020.
  - So far, only continuum emission.





What Can We Do at EHT Era?

- Time domain high frequency (86 GHz & 230 GHz) VLBI.
  - High cadence Black Hole / AGN study.

- New trials.
  - 345 GHz (and probably higher freq.) VLBI observations.
  - Emission/absorption line observations.
  - Non-AGN targets.
  - Multi-frequency simultaneous observations (frequency phase transfer [FPT] technique).

EAVN -hi-

- East Asian VLBI Network (EAVN) mainly at 230 GHz.
  - 86 GHz and 345 GHz are also the possibilities.
- Telescopes:
  - Greenland Telescope (GLT): 86 GHz, 230 GHz, & 345 GHz
  - James Clerk Maxwell Telescope (JCMT): (86 GHz), 230 GHz, (& 345 GHz) ASIAA Rx
  - Solar Planetary Atmosphere Research Telescope (SPART): 230 GHz
  - SNU Radio Astronomy Observatory (SRAO): 230 GHz
  - Korean VLBI Network (KVN) Yonsei Observatory:
    23 GHz, 43 GHz, 86 GHz, 129 GHz, (& 230 GHz: ASIAA/OPU Rx)
  - KVN SNU PyeongChang Radio Observatory (available from 2024):
    (23 GHz, 43 GHz, 86 GHz, 150 GHz, & 230 GHz)
- Correlator:
  - Shanghai Astronomical Observatory (SHAO) DiFX software correlator

EAVN -hi-

- System Setup

	GLT	JCMT	KVN Yonsei	SRAO	SPART
Diameter [m]	12	15	21	6	10
SEFD [Jy]	4 900	4 500		78 000	18 000
Start Freq. [GHz]	230.200	230.200	230.200	230.200	230.200
Bandwidth [MHz]	2 048	2 048	2 048	1 024	512
Polarization	Dual circular	Dual circular	Dual circular	Dual circular	Single linear
Recorder	R2DBE Mark6	R2DBE Mark6	OCTAD Mark6	R2DBE Mark6	ADS3000+ OCTAVE

EAVN -hi- Observations (1st Year)

- On 2019 Mar. 18 & 19, we performed the EAVN -hi- 230 GHz VLBI test observations for the first time with the SPART in Japan, the SRAO in Korea, and the GLT in Greenland.
- Data were correlated at the SHAO in China.

No detection…

EAVN -hi- Observations (2nd Year)

- On 2020 Feb. 1 – 5, we performed the second EAVN -hi- 230 GHz VLBI observations with the JCMT in Hawaii, the SRAO in Korea, and the GLT in Greenland.

EAVN -hi- Observations (2nd Year)

- Data were correlated at the SHAO in China.

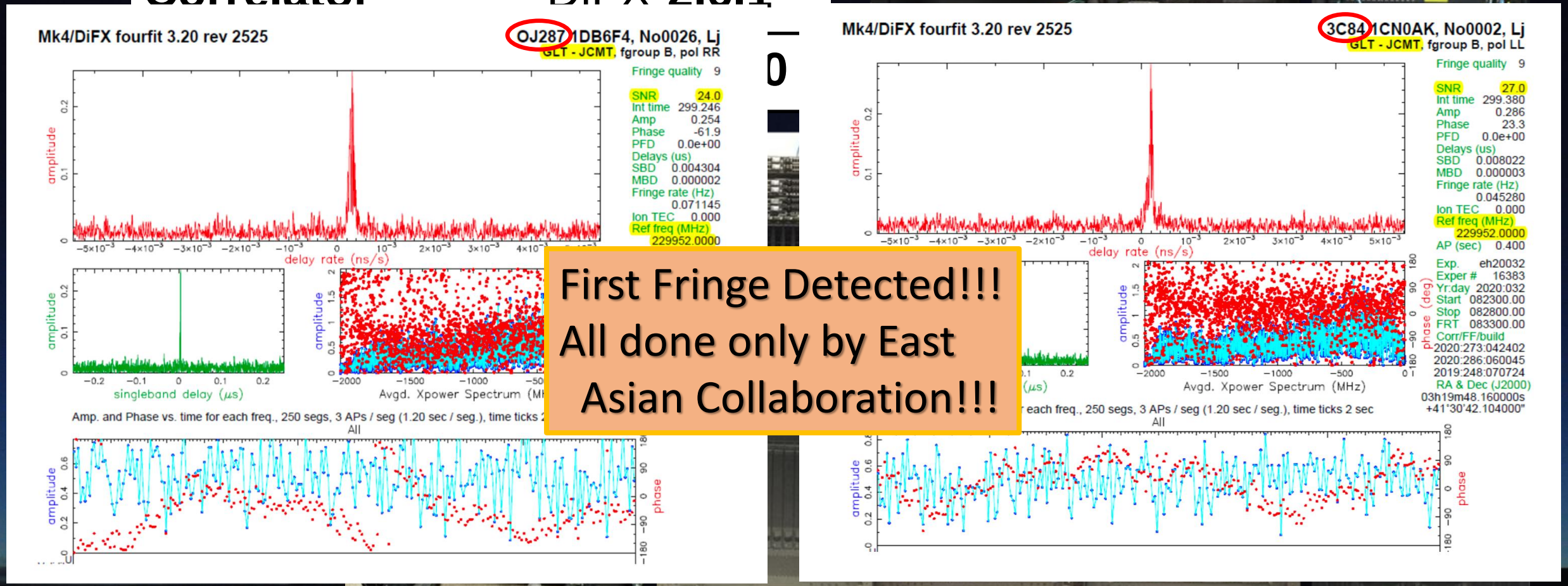
Correlator	DiFX-**2.6.1**
Post processing	HOPS-**3.20**

SHAO DiFX correlator

EAVN -hi- Observations (2nd Year)

- Data were correlated at the SHAO in China.

Correlator DiFX-**2.6.1**



First Fringe Detected!!!
All done only by East Asian Collaboration!!!

EAVN -hi- Observations (3rd Year)

- Late 2021, we may perform the third EAVN -hi- 230 GHz VLBI observations with the JCMT in Hawaii, the KVN Yonsei Observatory in Korea, and the GLT in Greenland.
- Data will be correlated at the SHAO in China.

EAVN -hi- Observations (3rd Year)

- GLT Status
  - Due to the pandemic, we cannot travel to the GLT Thule site.
  - We setup the remote observation room/desk in ASIAA, Taipei, and started operating the GLT remotely. So far, we are operating without any problem.

EAVN -hi- Science

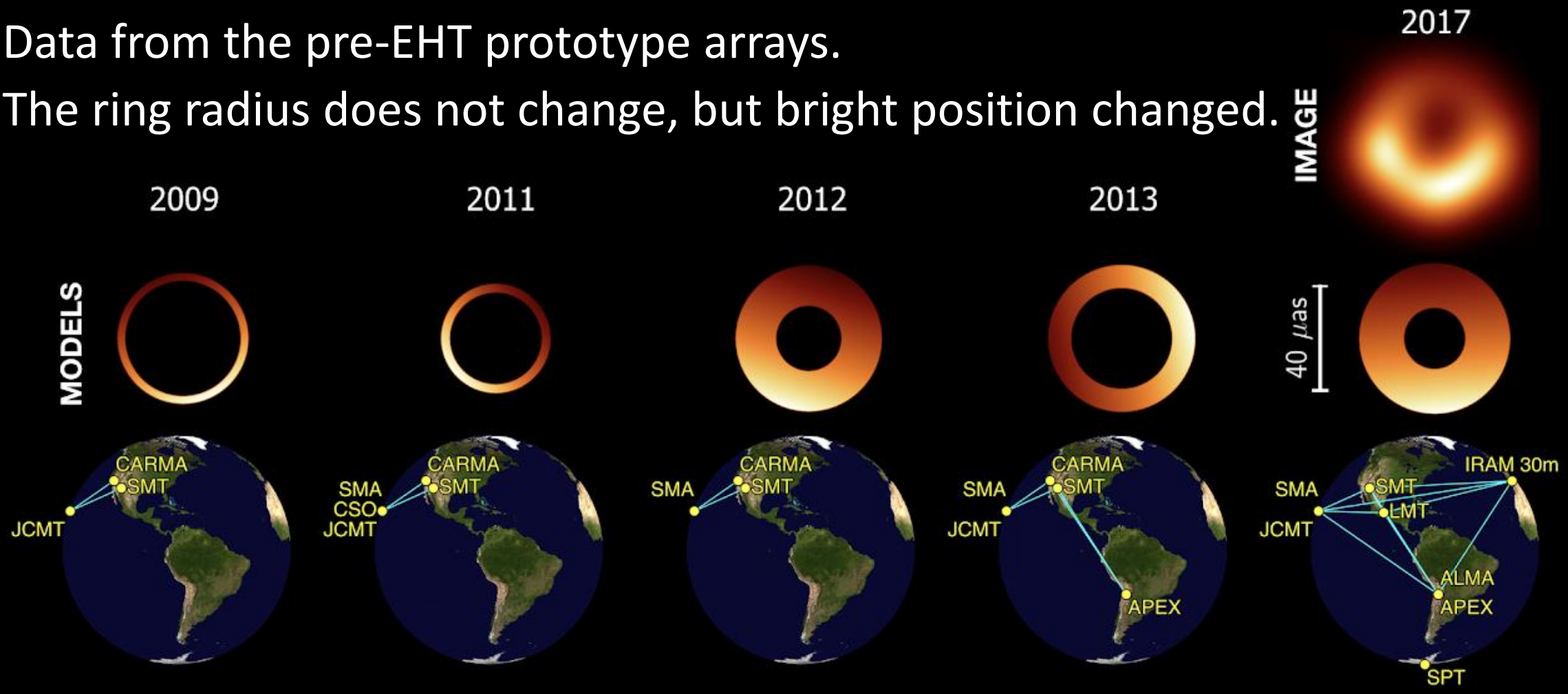
- Science with the EAVN -hi- is getting very realistic.
  - Time domain high frequency (86 GHz & 230 GHz) VLBI.
    - High cadence Black Hole / AGN study.
  - New trials.
    - 345 GHz (and probably higher freq.) VLBI observations.
    - Emission/absorption line observations.
    - Non-AGN targets.
    - Multi-frequency simultaneous observations (frequency phase transfer [FPT] technique).

Wobbling Black Hole Shadow?

- Data from the pre-EHT prototype arrays.
- The ring radius does not change, but bright position changed.

Model Images that are most consistent with observation results.

Observation Arrays



Credit: M. Wielgus, D. Pesce

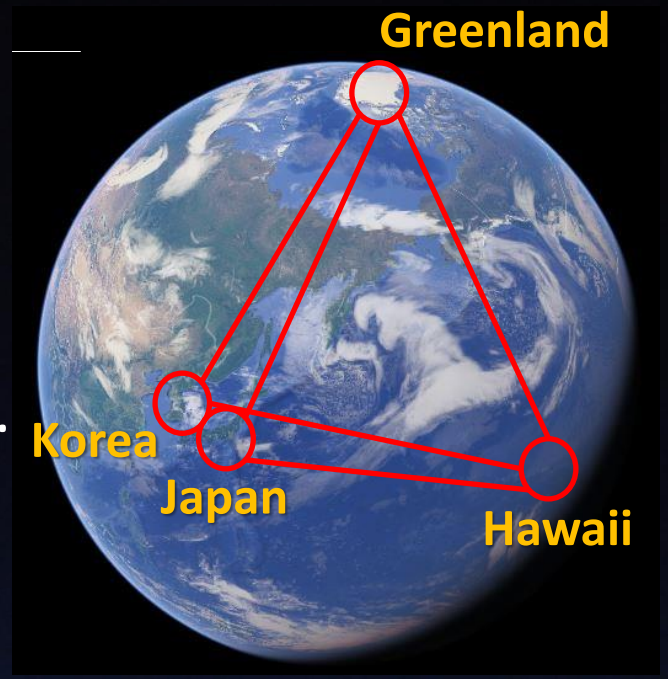
Event Horizon Telescope

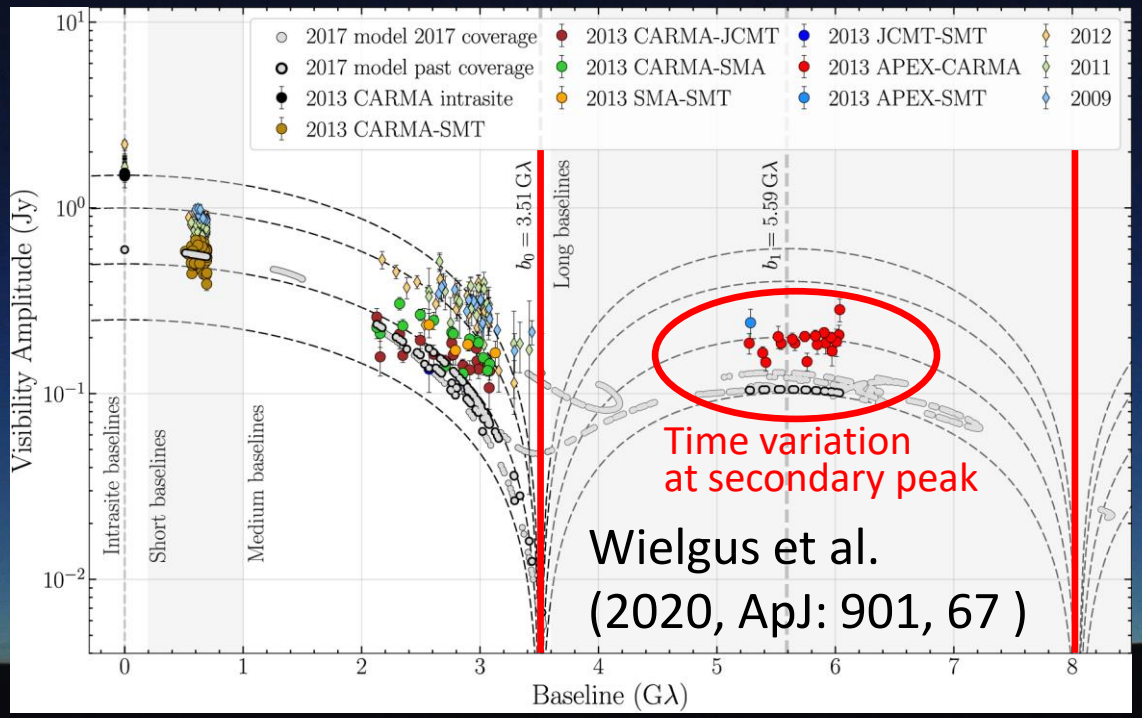
Wielgus et al. (2020, ApJ: 901, 67)

EAVN -hi- Science

- M87 230 GHz Monitoring
  - East Asian baselines tracks the primary peak.
  - East Asia – Hawaii baselines tracks the secondary peak.
  - Greenland – Hawaii baseline track 2nd null.

⇨ Very sensitive to the shadow structure.





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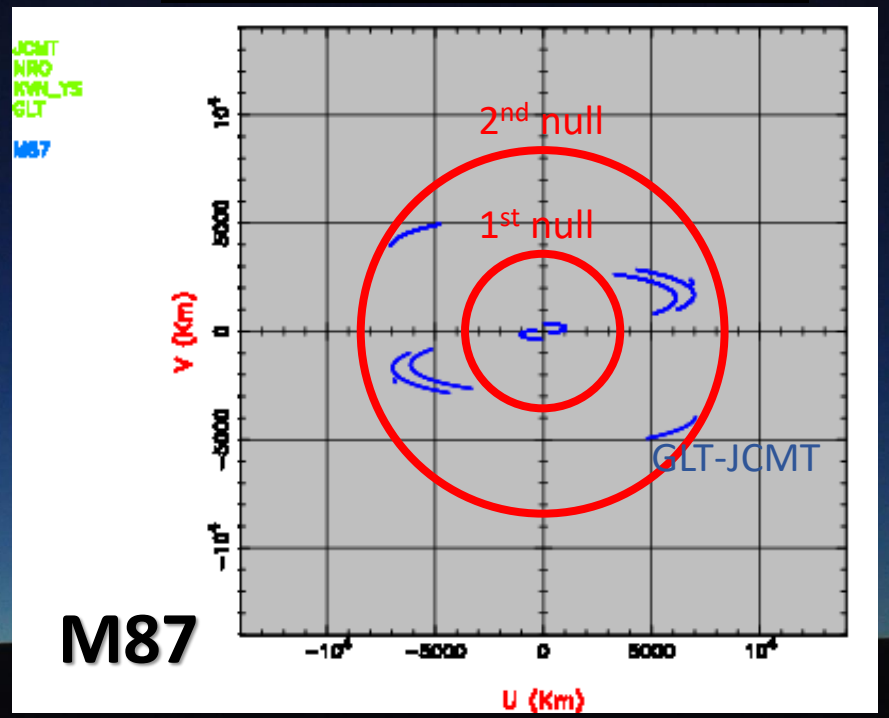
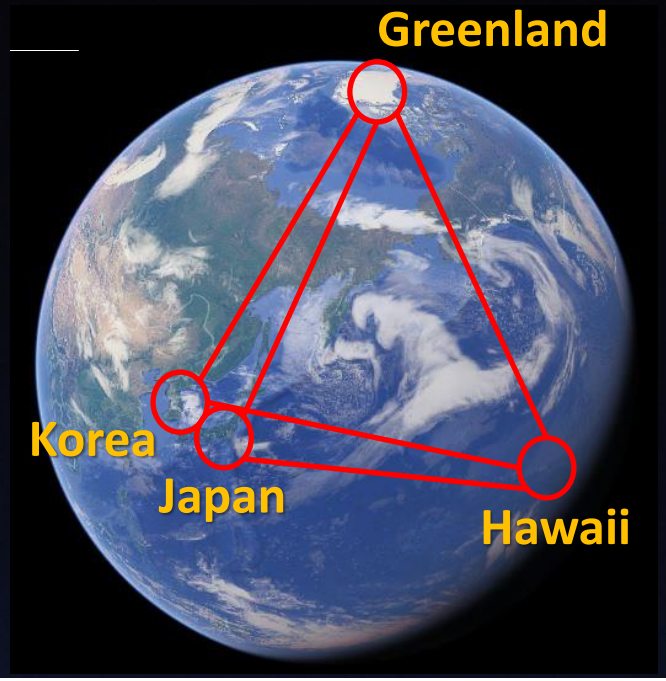
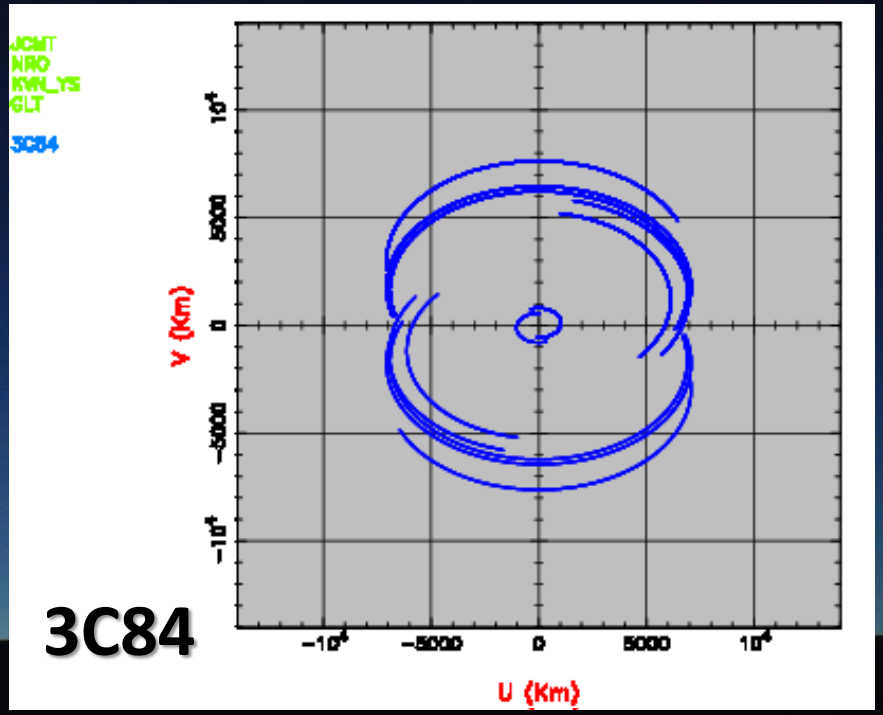


EAVN -hi- Science

- VLBI fringe detection survey for northern sky
  - ~10-30 sources including BL Lac, 3C279/3C273, and 3C454.3.

- 230 GHz AGN Monitoring (especially northern sky sources)
  - 3C84, 3C 120, OJ287, Mrk 421, Mrk 501, etc.





EAVN -hi- Science

- Water maser lines
  - Rx86 (84.0 – 96.5 GHz)
    - 96.261 GHz: H_2O $4_{40} – 5_{33}$ v_2=1, E_u/k = 3065 K
  - Rx230 (213.1 – 245.0 GHz)
    - 232.687 GHz: H_2O $5_{50} – 6_{43}$ v_2=1, E_u/k = 3463 K
  - Rx345 (275.0 – 373.0 GHz)
    - 293.439 GHz: H_2O $6_{61} – 7_{52}$ v_2=1, E_u/k = 3935 K
    - 321.226 GHz: H_2O $10_{29} – 9_{36}$, E_u/k = 1862 K
    - 325.153 GHz: H_2O $5_{15} – 4_{22}$, E_u/k = 470 K
    - 336.228 GHz: H_2O $5_{23} – 6_{16}$ v_2=1, E_u/k = 2956 K
    - 354.885 GHz: H_2O $17_{412} – 16_{710}$, E_u/k = 5782 K

EAVN -hi- Summary

- 230 GHz first fringe detected between GLT and JCMT.
  - Purely the East Asian effort!
- High frequency telescopes/sites are growing and evolving in East Asia.
- Many science observations and technical tests are possible at the EHT era.