First EHT Result of M87

Fumie Tazaki

Mizusawa VLBI Observatory, National Astronomical Observatory of Japan

On Behalf of the EHT Collaboration

Event Horizon Telescope

Event Horizon Telescope (EHT)

Event Horizon Telescope Collaboration

EHT Collaboration consists of more than 200 scientists in 18 countries and regions.

EHT Observation in 2017

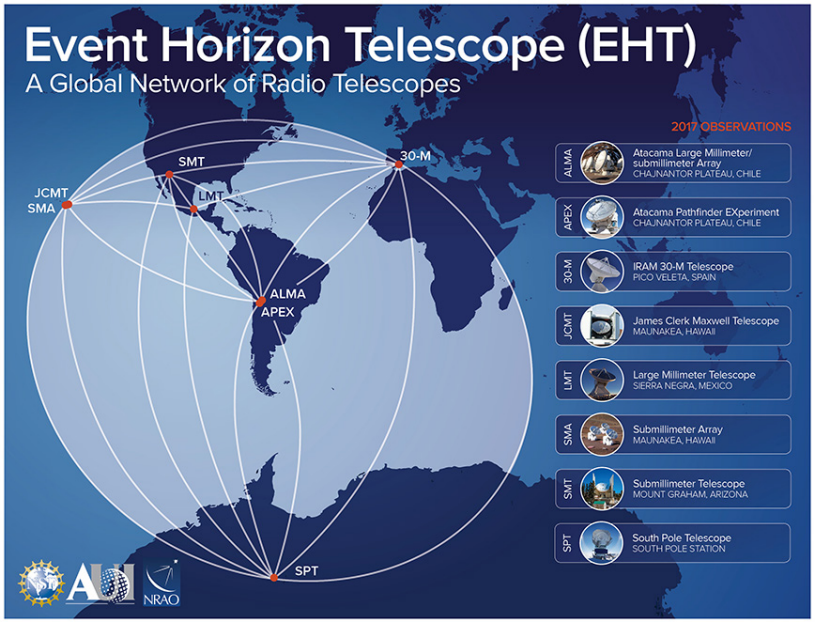
4 epochs in April 5-11th, 2017

8 telescopes at 6 places

longest baseline: ~10,000 km

wavelength: 1.3 mm

beam size: 25 μas



Correlation site: MIT, MPIfR

Calibration tools: HOPS, CASA, AIPS

Tools for EHT imaging

RML Method

CLEAN + Selfcalibration (traditional)

- eht-imaging (Chael+2016,2018)
- DIFMAP (Sheperd+1997,1998)
- SMILI (Akiyama+2017a,b)

3 software tools are used for whole imaging processes.

Blind imaging with 4 teams

Kazu's slide

Team 1

Americas

US & Chile

(SAO, U. Arizona, U. Conception)

Leader: K. Bouman & A. Chael

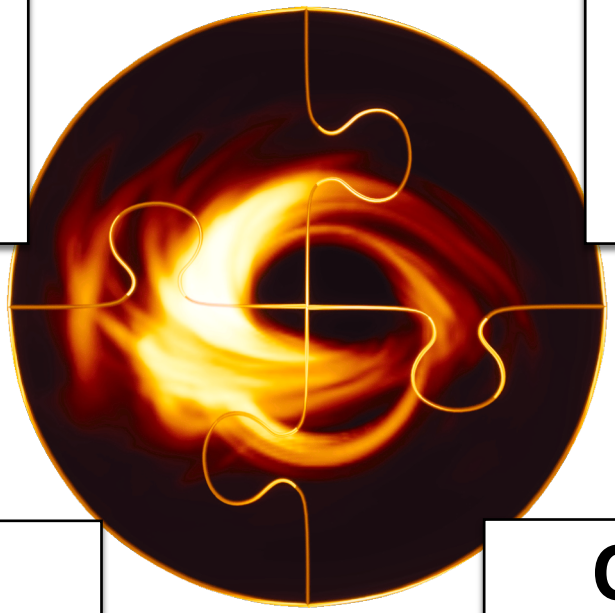
Team 4

East Asians

Korea, Japan & Taiwan

(ASIAA, KASI, NAOJ)

Leader: S. Koyama



Team 2

Global

US, Japan, Netherland

(MIT, NAOJ, Hiroshima U., Radboud U.)

Leader: K. Akiyama & S. Issaoun

Team 3

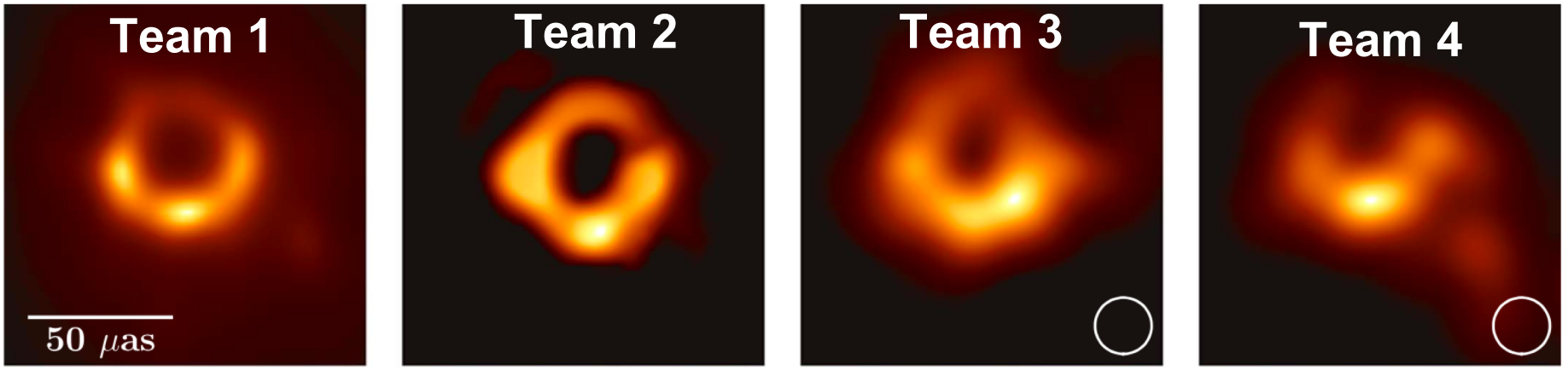
Cross Atlantic

US, Spain, Germany, Finland

(Boston U, MPIfR, IAA, Aalto)

Leader: A. Marscher

Blind imaging with 4 teams



- 4 teams successfully reconstructed asymmetric ring structure independently.

- Slightly different appearance between each image.

➡ Parameter sets we choose affect to the result?
Which parameter space brings plausible images?

Simulation data for imaging parameter test

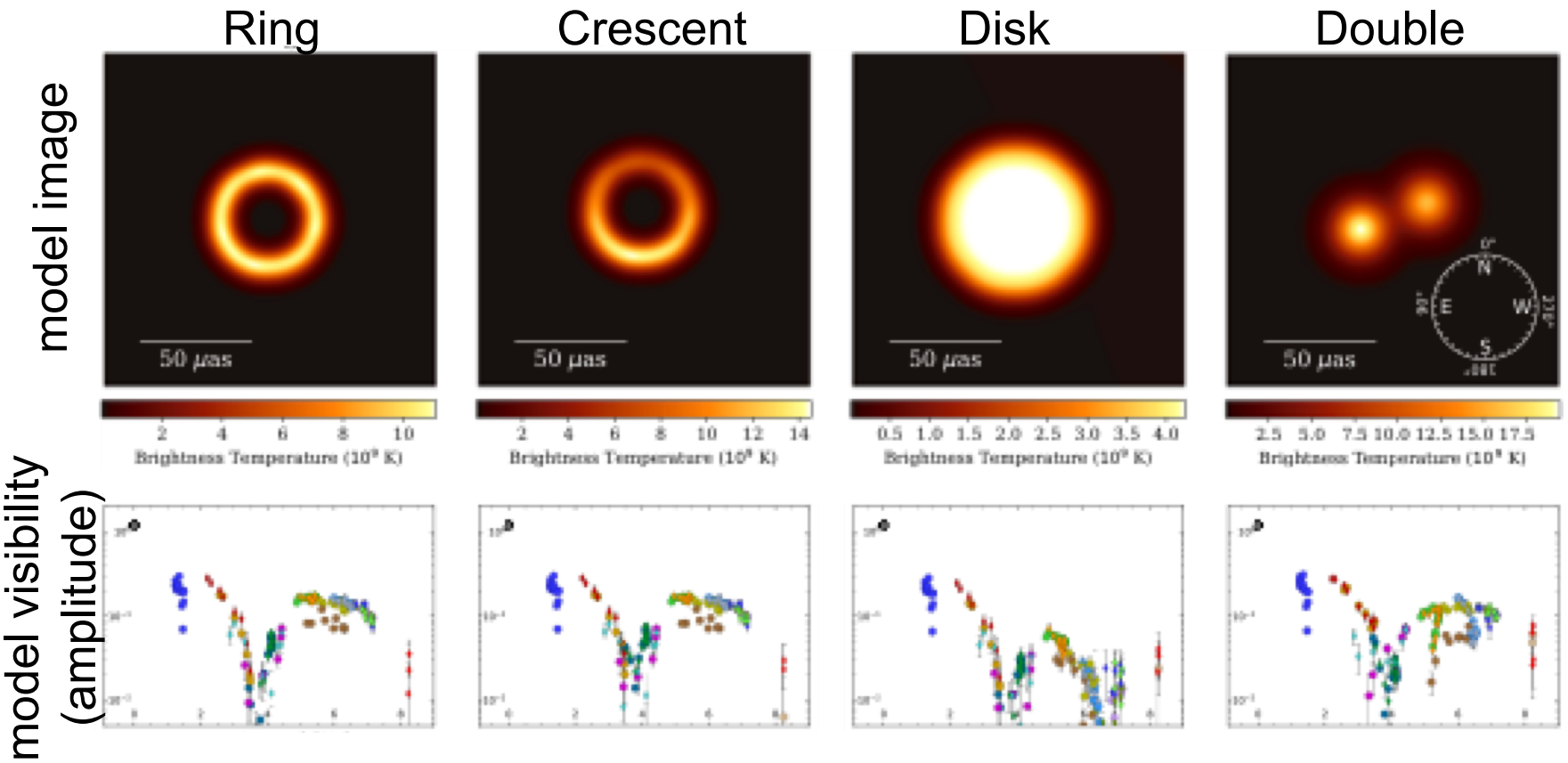
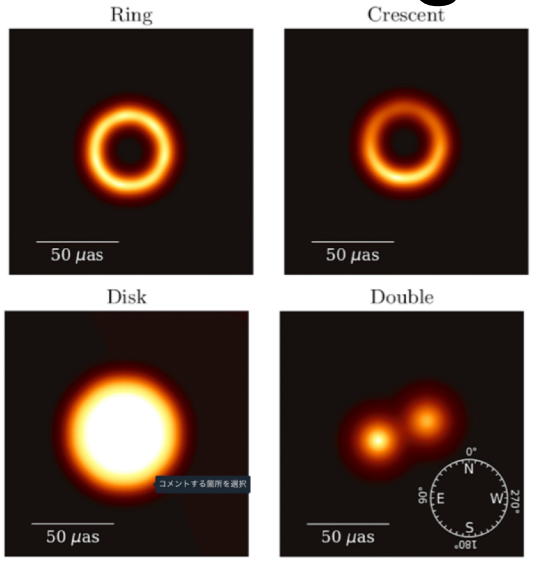


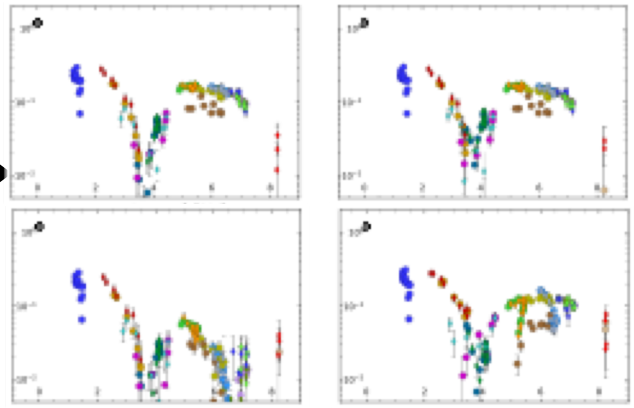
Image domain: respective different structure
Visibility domain: same feature as M87*

Evaluation of imaging parameters

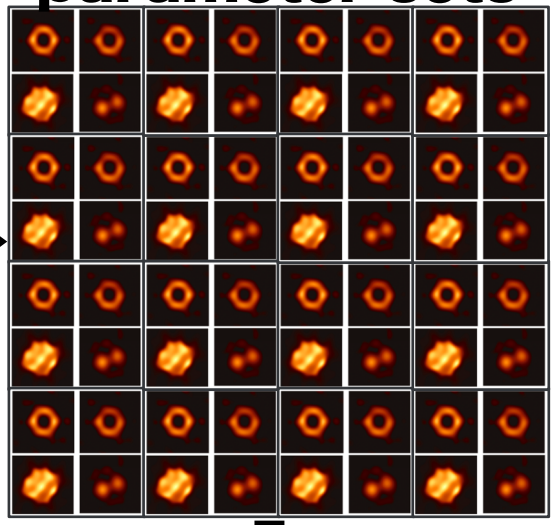
model image



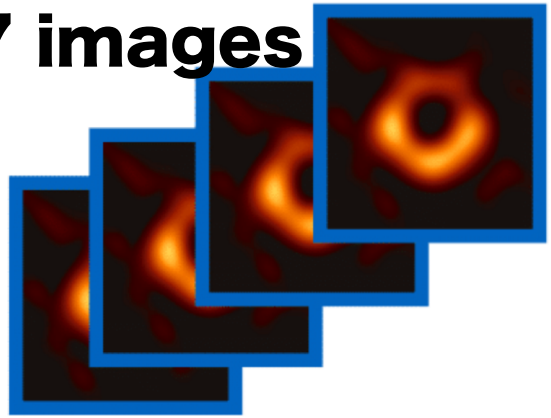
model visibility



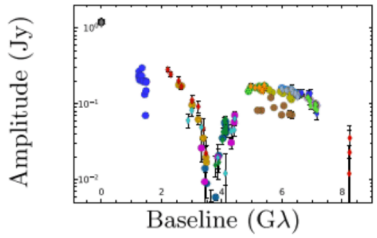
5x10⁴ parameter sets



2000 M87 images



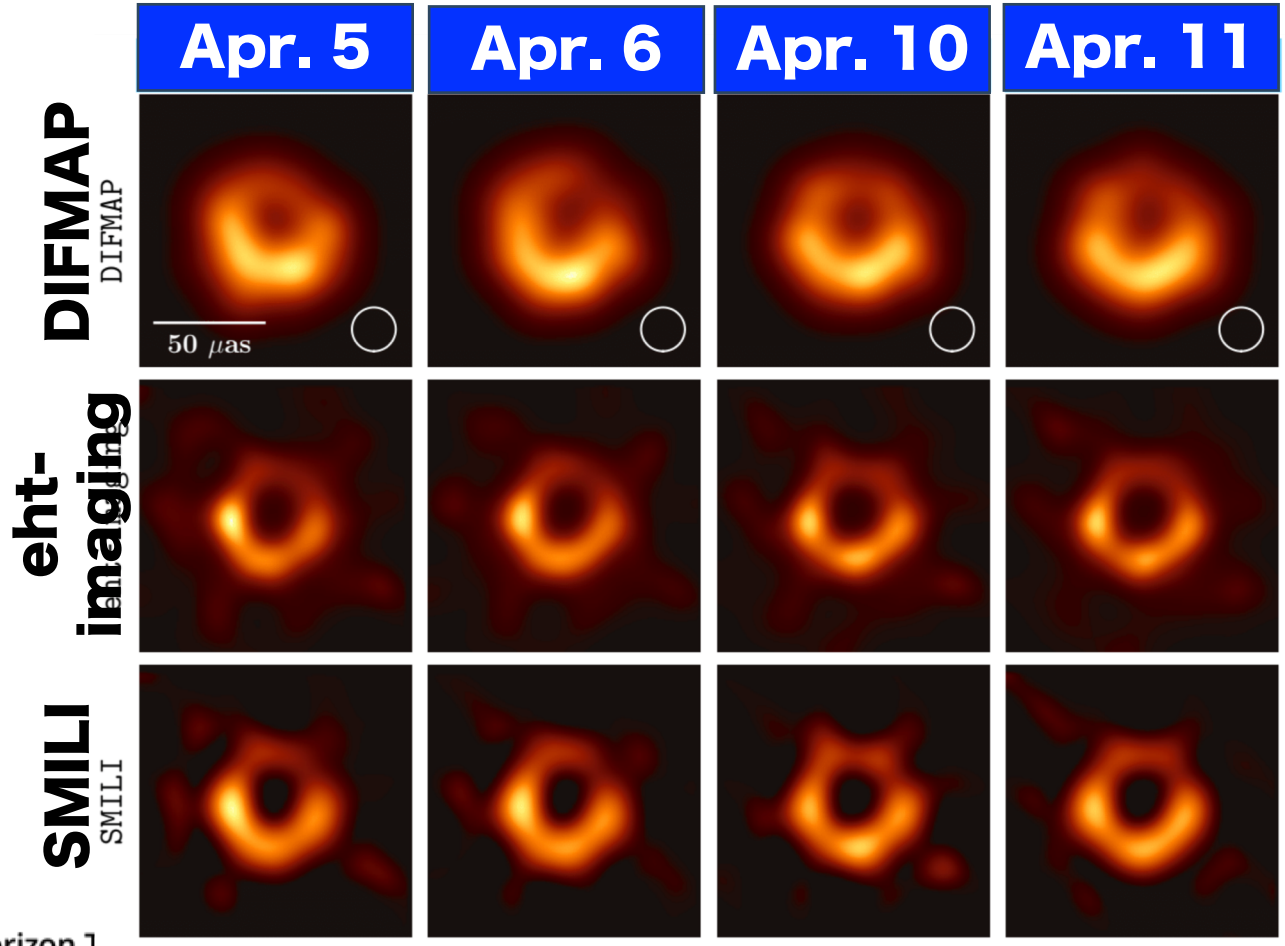
M87 observed data



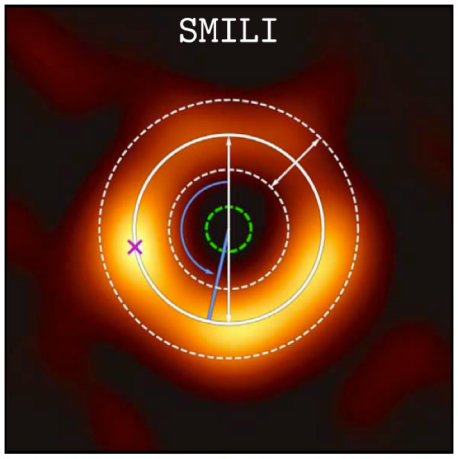
successful parameter sets: 2000

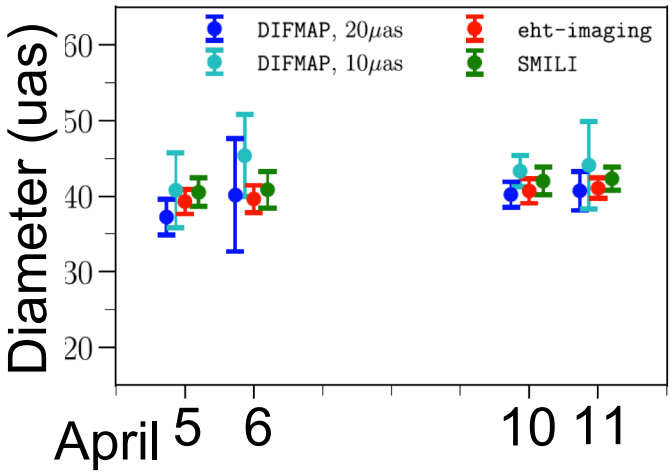
Final images of M87

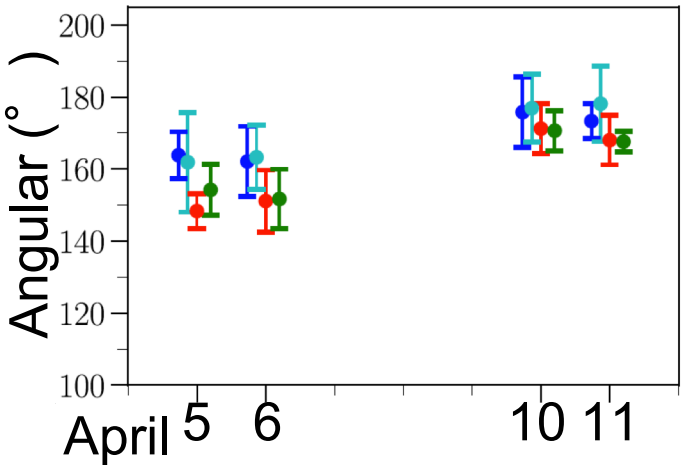
We confirmed the consistent asymmetric ring structure with 2000 images for each observation day.



Ring Parameters







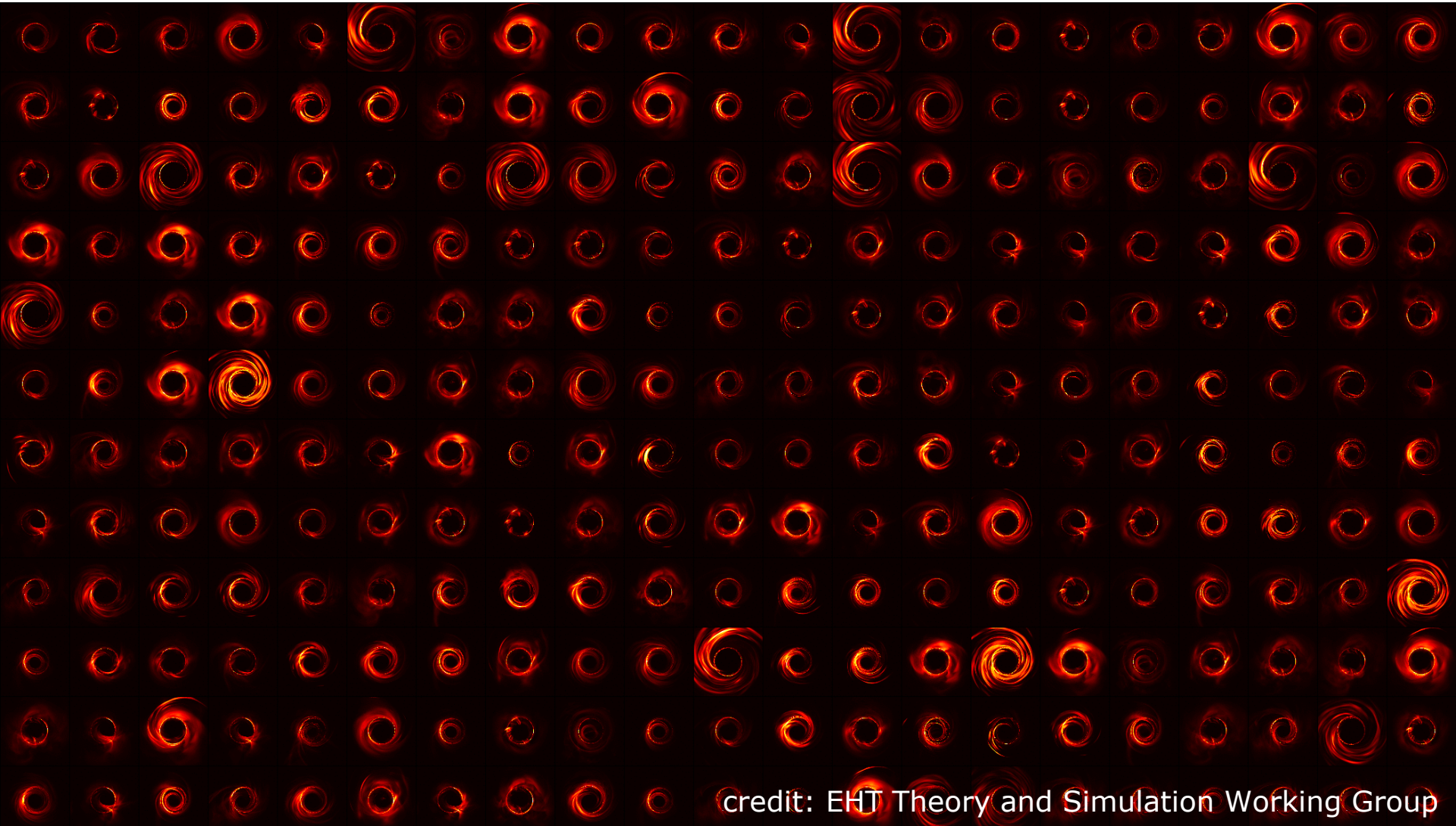
Diameter : Consistent in dates and tools
Angular : Consistent in tools
systematic change (~20°) in a week

➡ **M_{BH} = 6.5 x 10^9 M_{sun}**

➡ **Hotspot position was changed.**

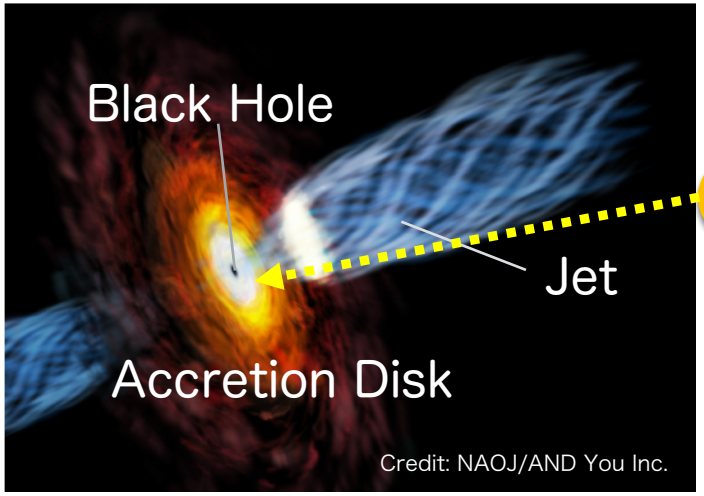
General Relativistic Magnetohydrodynamic (GRMHD) Simulations

Construct a large library of GRMHD models, and compare with observed quantities.

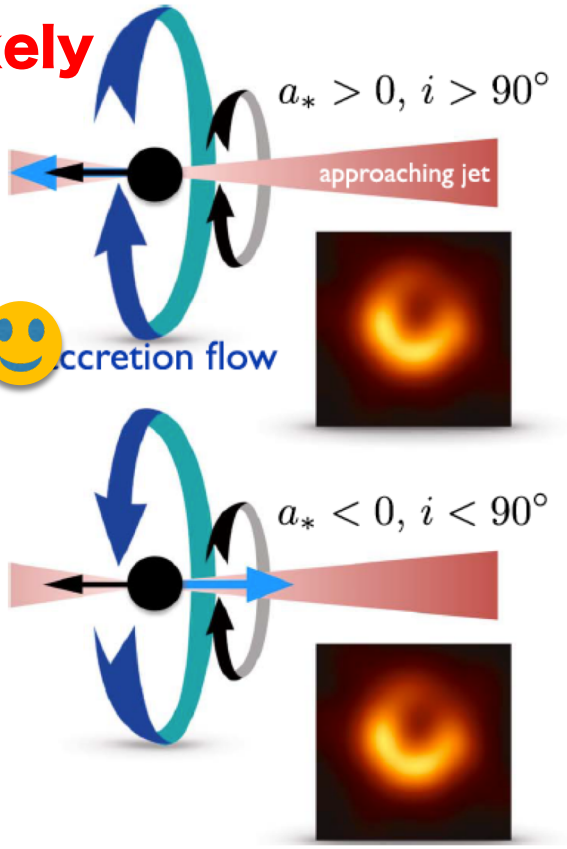


credit: EHT Theory and Simulation Working Group

What Cause Ring Asymmetry?



More likely



Consistent with clockwise black hole spin.

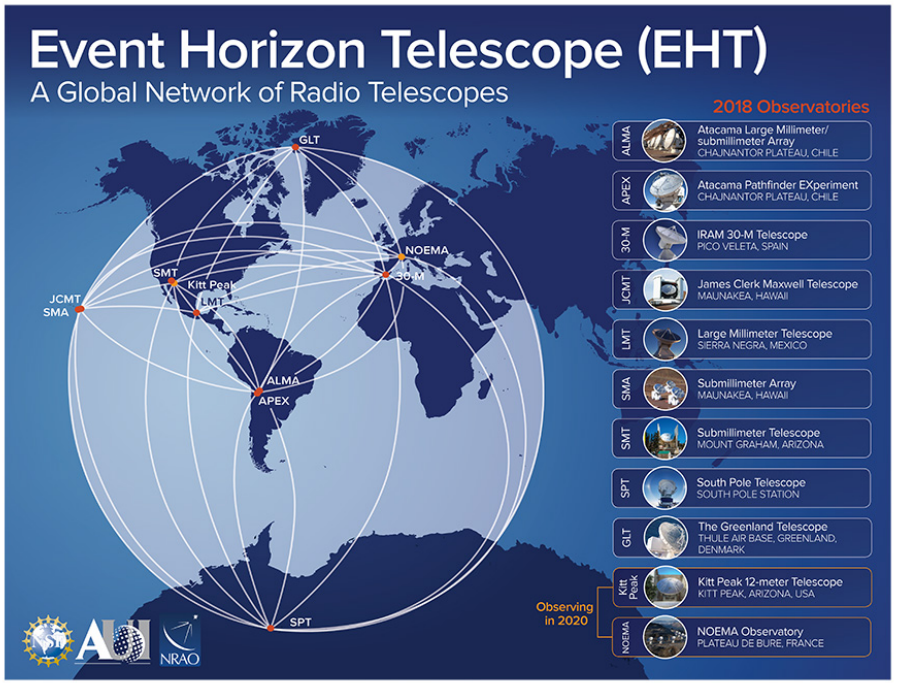
First Papers of EHT

The EHT Collaboration, 2019, ApJL, 875, L1-L6

- Paper I: The Shadow of the Supermassive Black Hole
- Paper II: Array and Instrumentation
- Paper III: Data Processing and Calibration
- Paper IV: Imaging the Central Supermassive Black Hole
- Paper V: Physical Origin of the Asymmetric Ring
- Paper VI: The Shadow and Mass of the Central Black Hole

Next Goal of EHT

- Black hole shadow of Sgr at the center of our galax
- Movie reconstruction
- Polarimetric imaging



Future of EHT array

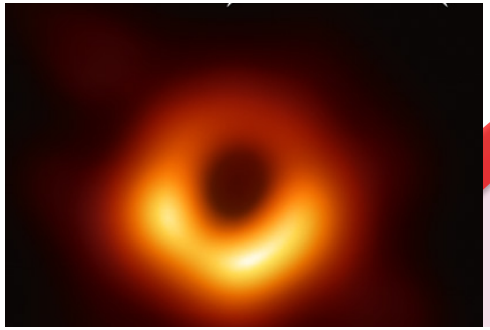
- Increase telescopes
  → higher sensitivity image
- Higher frequency observation (345GHz)
  → higher resolution

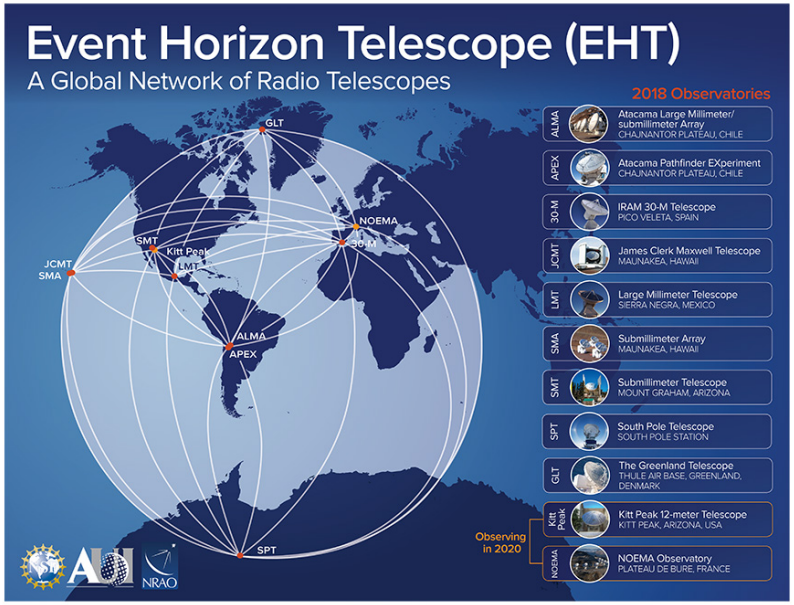
Synergy of EHT and East Asia

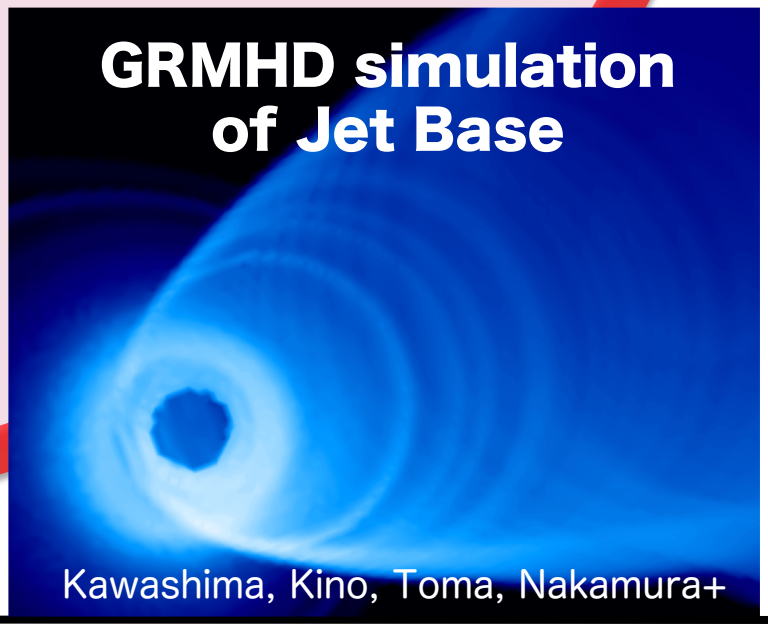
East Asian VLBI Network

Yuzhu's talk

EHT







17th UM, Dec. 13th – 14th, 2019

Summary

- We EHT Collaboration captured the supermassive black hole at the center of M87.
- Observation of M87 core with the global VLBI array (EHT) was performed in April, 2017.
- Careful imaging and large survey of GRMHD simulation were performed with well-calibrated data, to confirm the results.
- The first ever image of black hole shadow is the beginning of a new astrophysics era by “seeing” black hole.

EHT Stakeholder Logos