Event Horizon Telescope

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06/01/2018

Outline

- Brief review on black holes
- How EHT works
- The scientific goals of EHT
- Current status of EHT survey
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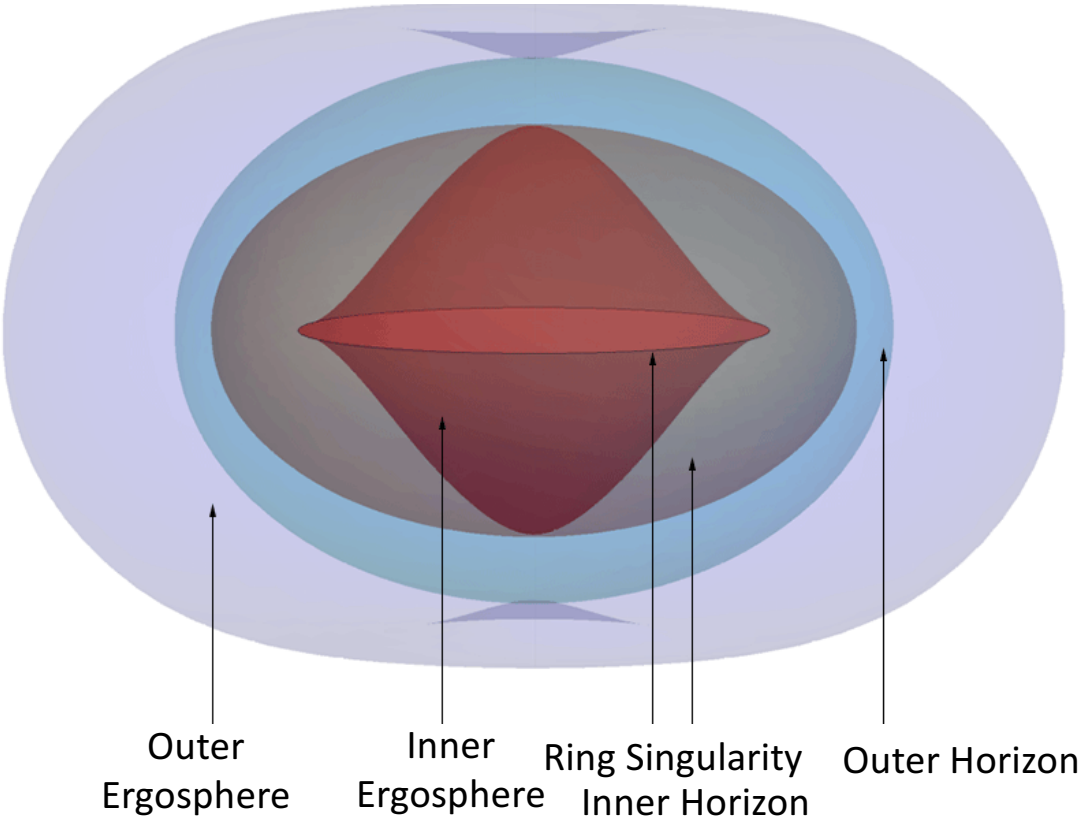
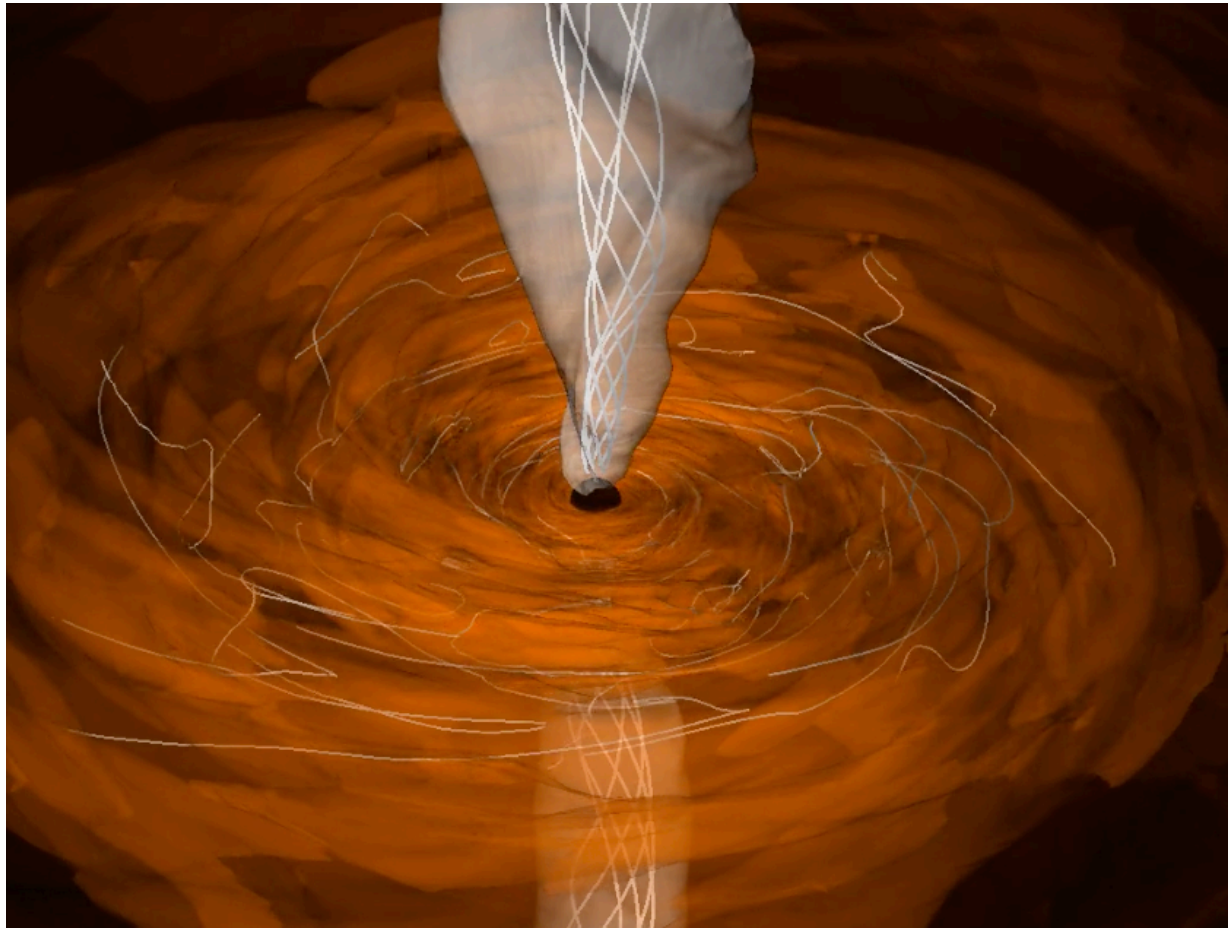
Theoretical structures of a black hole

- Three parameters are enough to describe a classical BH alone (mass, angular momentum and charge)



… with something around it

- Accretion disks, jets …
- Plasmas, magnetic fields …



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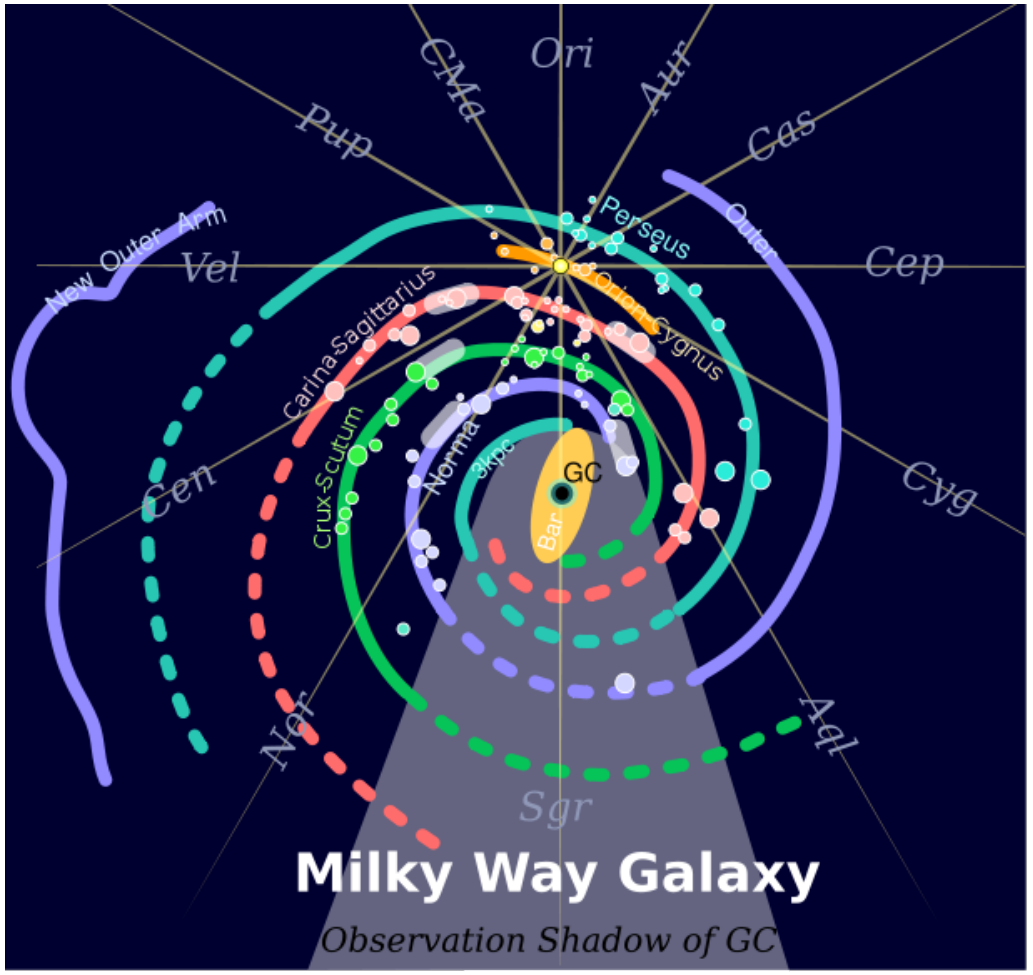
‘See’ the event horizon

- The angular sizes of BHs’ event horizons are small.
- Take Sagittarius A* for example:

$$\delta\theta = \frac{2R_s}{d} \approx 19\mu arcsec \approx$$

$$4\times10^{-4}\ HST's\ resolution$$



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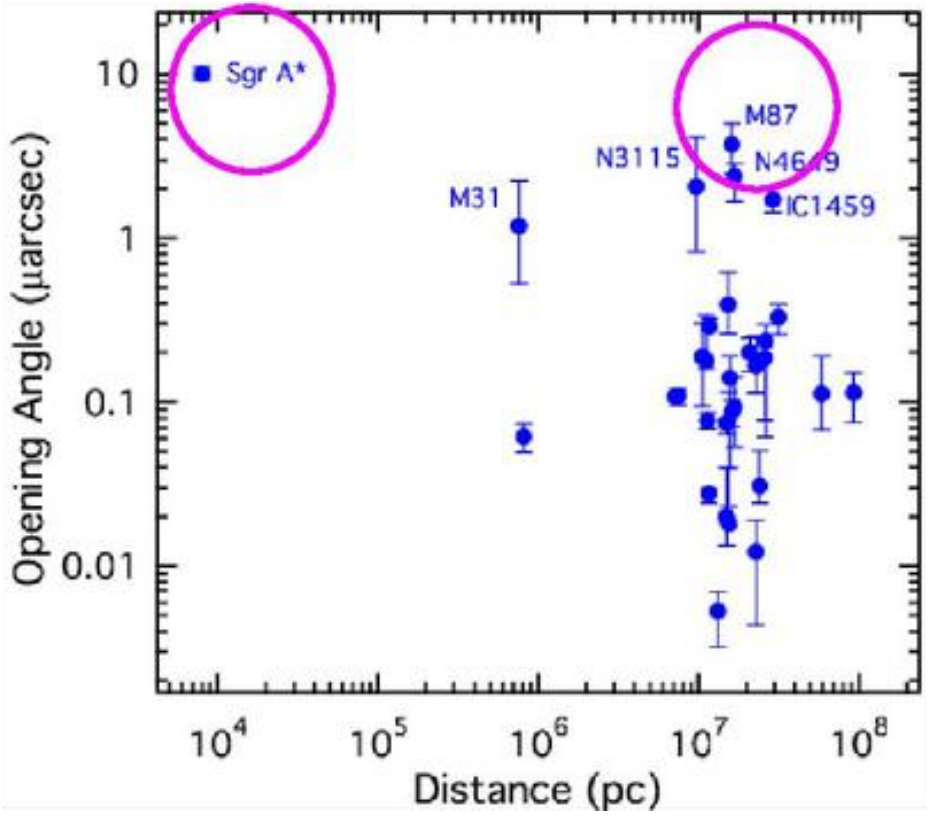
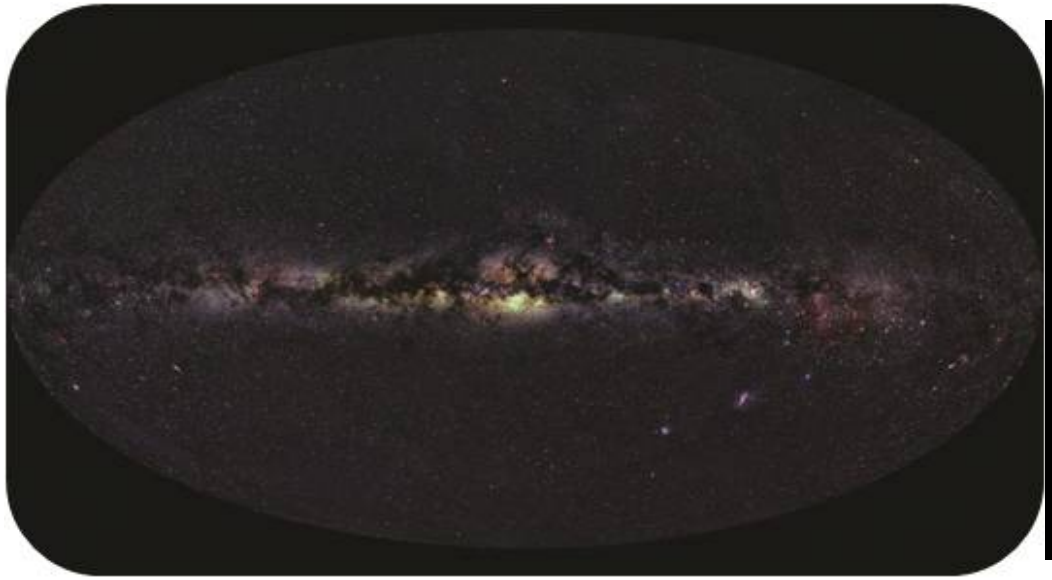
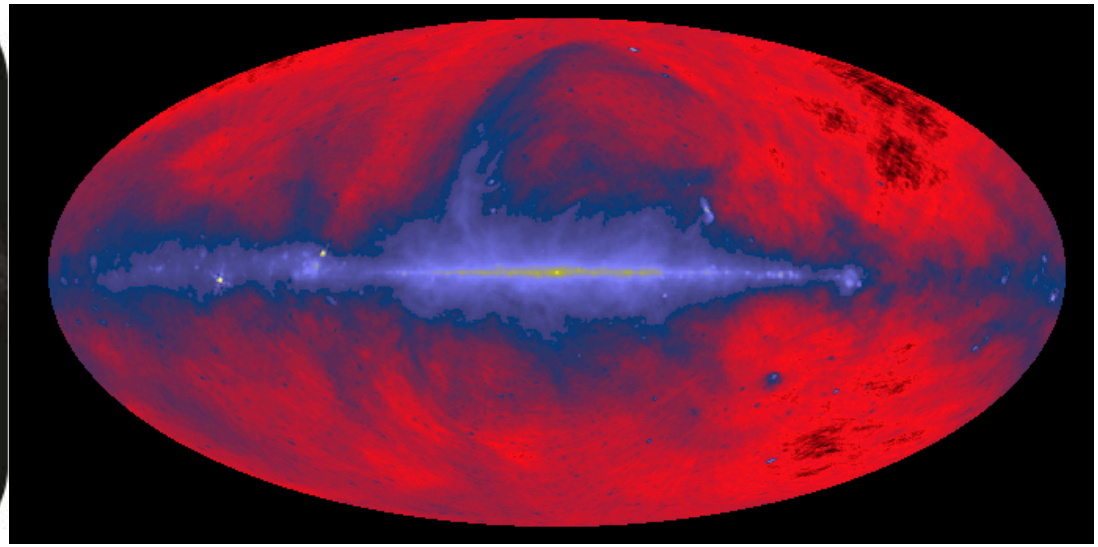


Psaltis et al. 2008

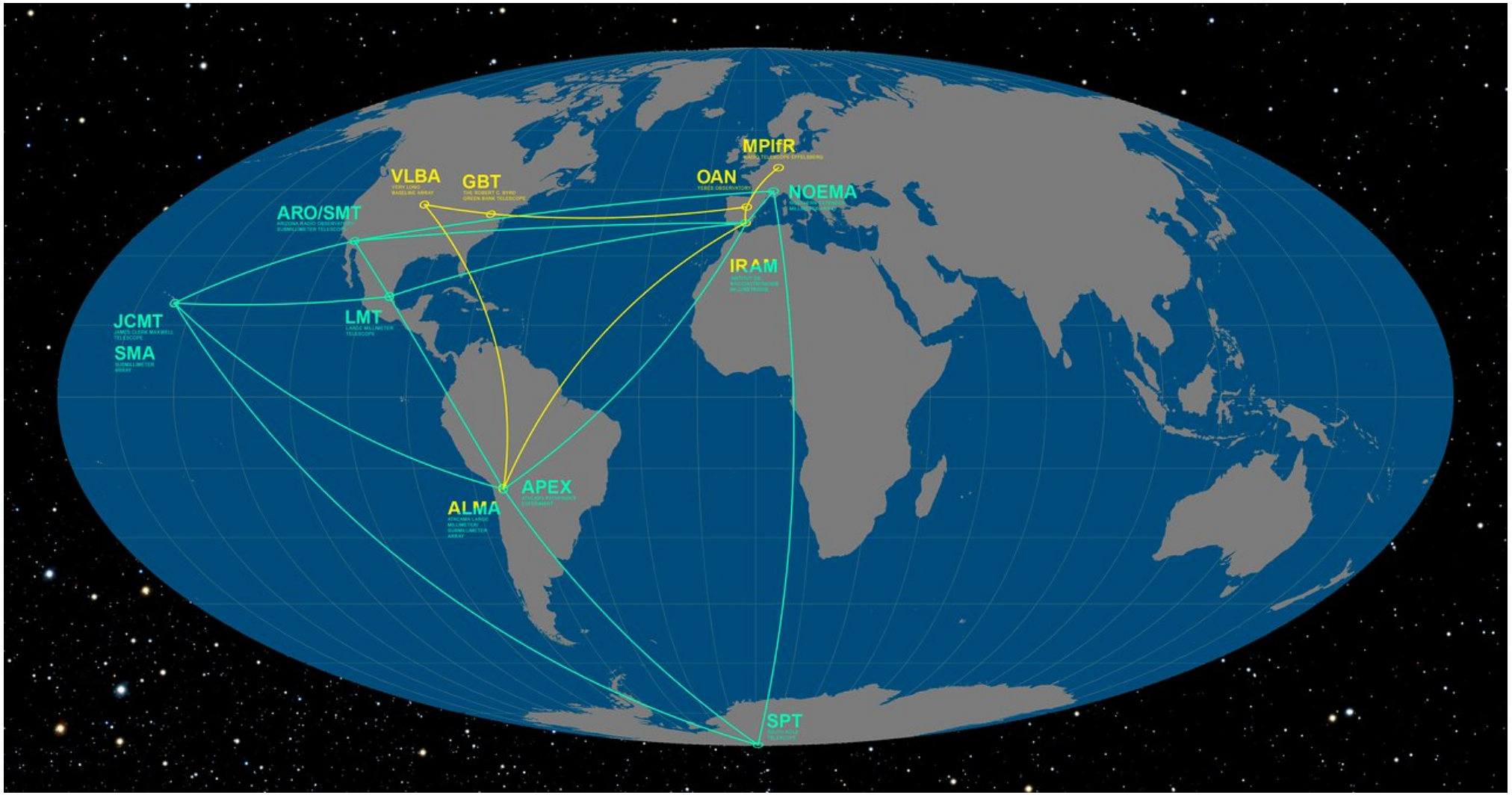
‘See’ the event horizon

- EHT works in sub-millimeter wavelength
- The size of the telescope should be ~ 10000 km ~ 6400 km $\approx R_{earth}$
- Interferometry thus takes place

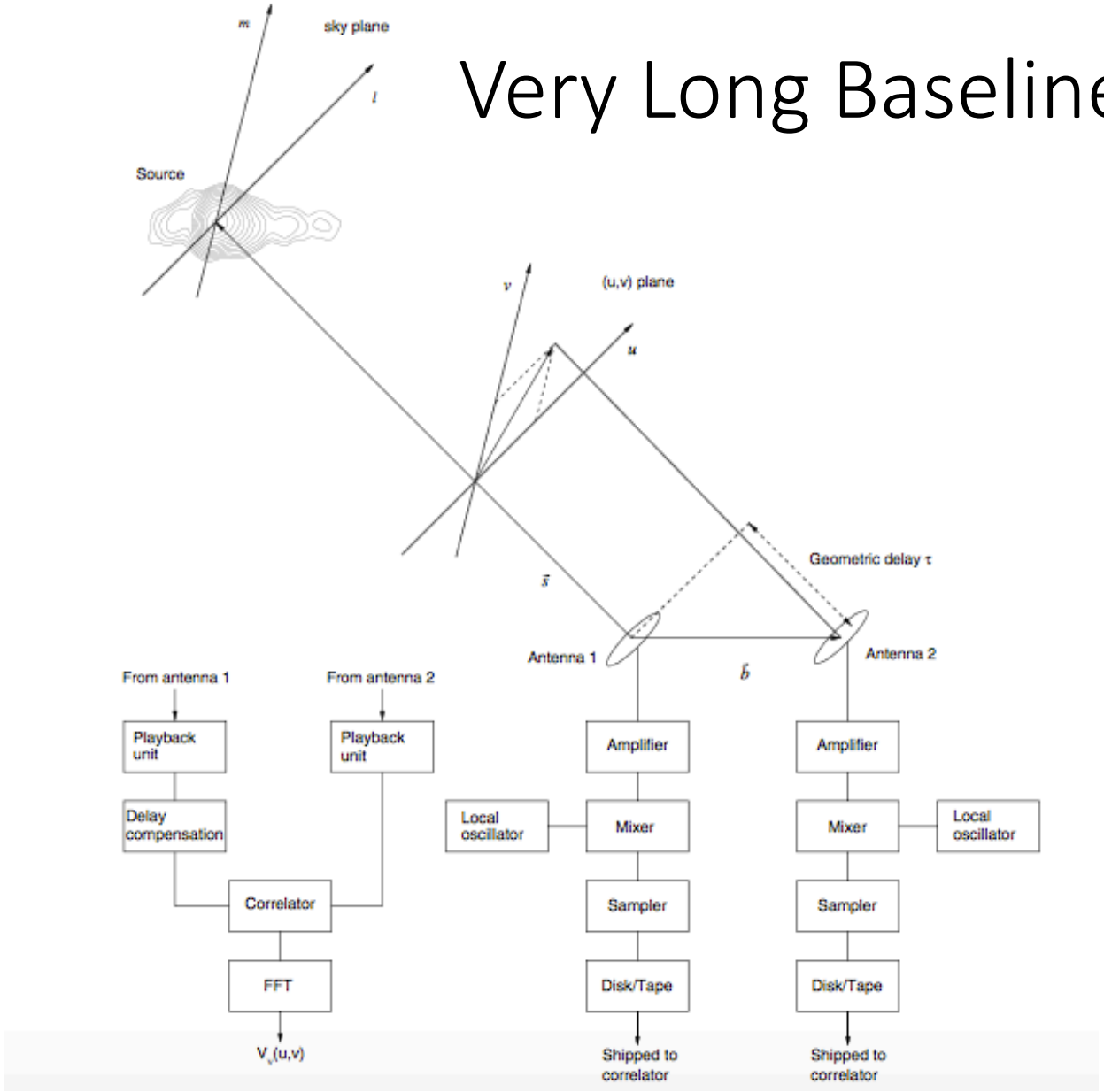




Observatories that constitute the EHT



Very Long Baseline Interferometry (VLBI)



$$V_\nu(u,v) = \int\int I_\nu(l,m) \mathrm{e}^{-2\pi \mathrm{i}(ul+vm)} \,\mathrm{d}l \,\mathrm{d}m$$

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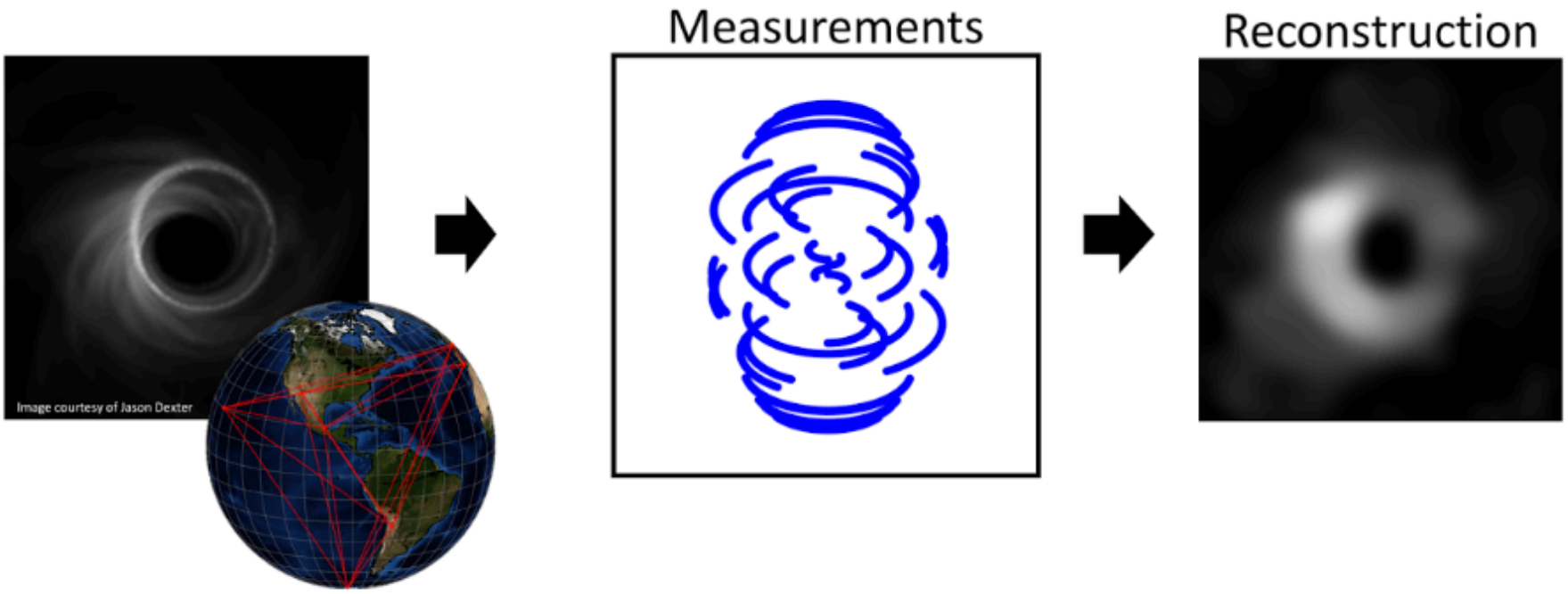
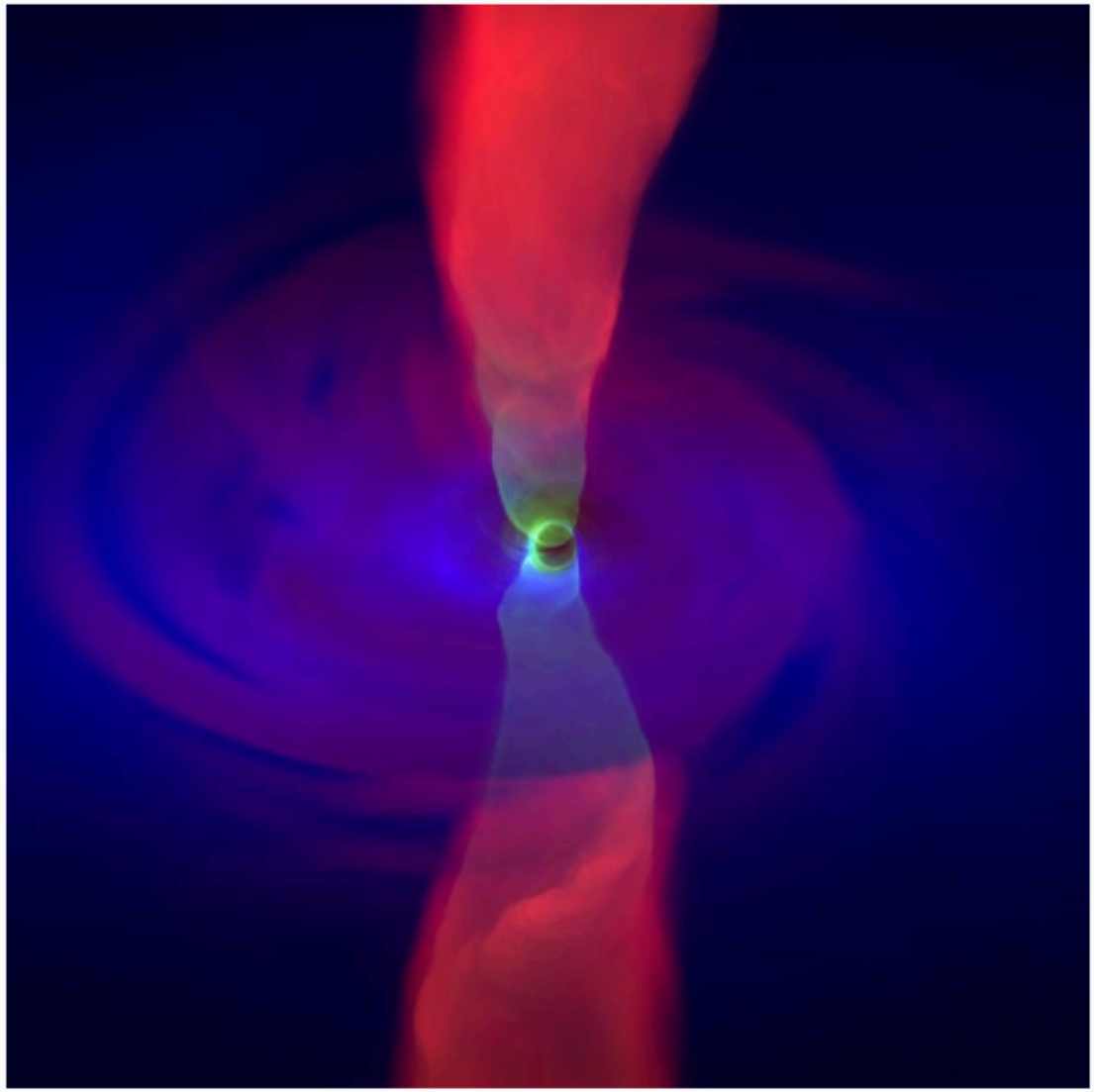


Why sub-millimeter

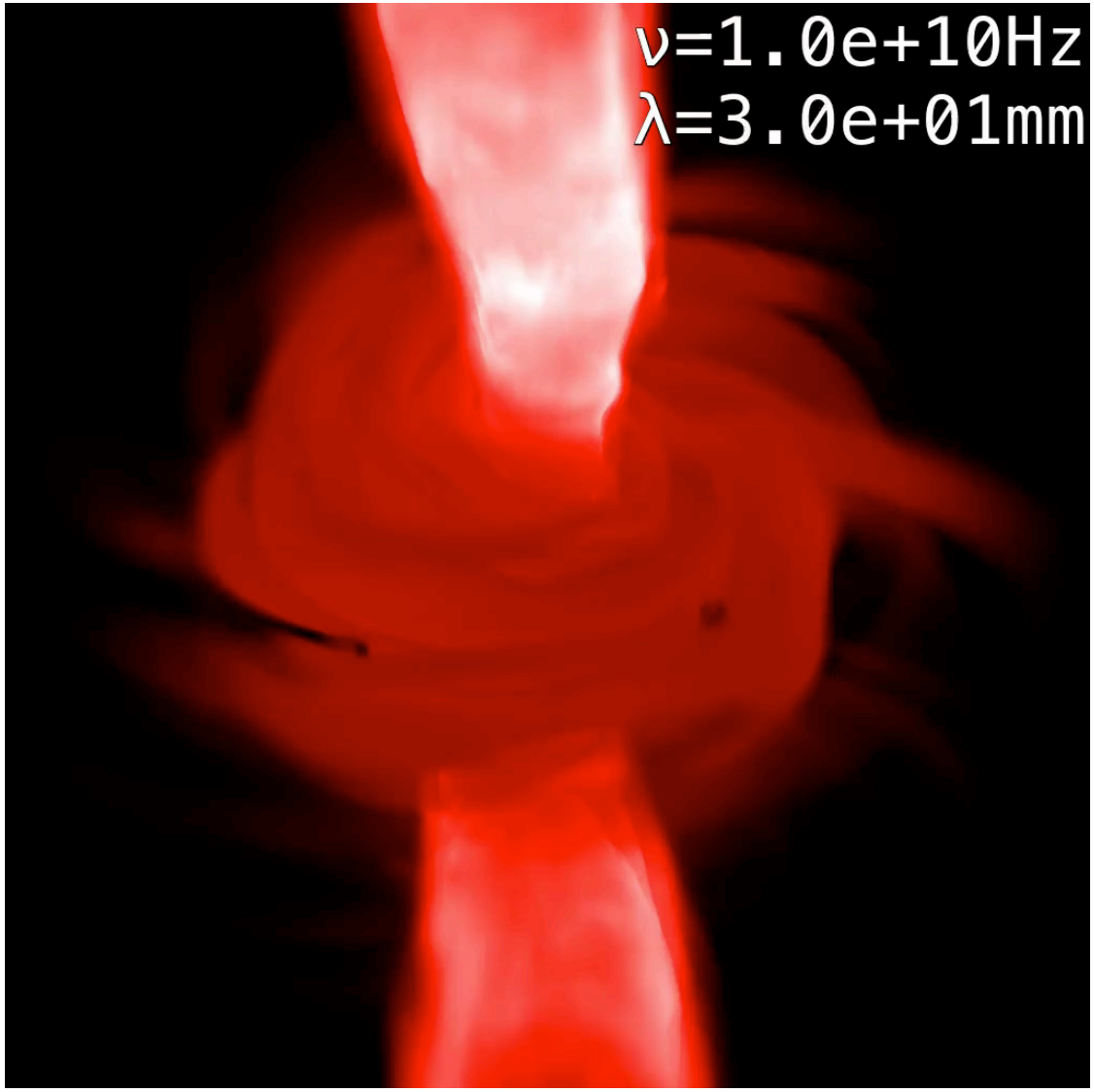
- Red: ~ 1 cm
- Green: ~ 1 mm
- Blue: diffuse X-ray emission



from eventhorizontelescope.org

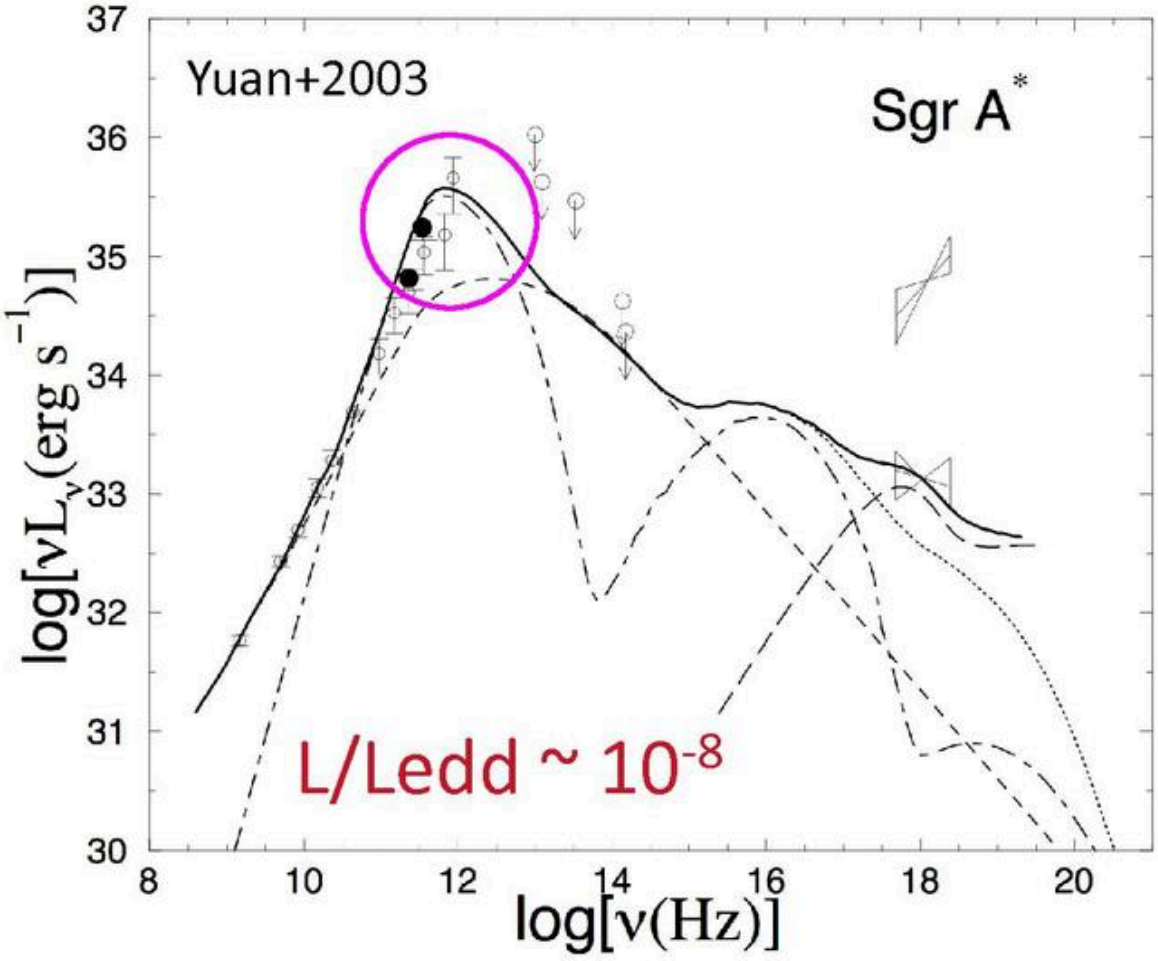
Why sub-millimeter

- Disk become transparent towards ~ 1 mm
- Interstellar scattering (by turbulent electrons) also becomes weaker



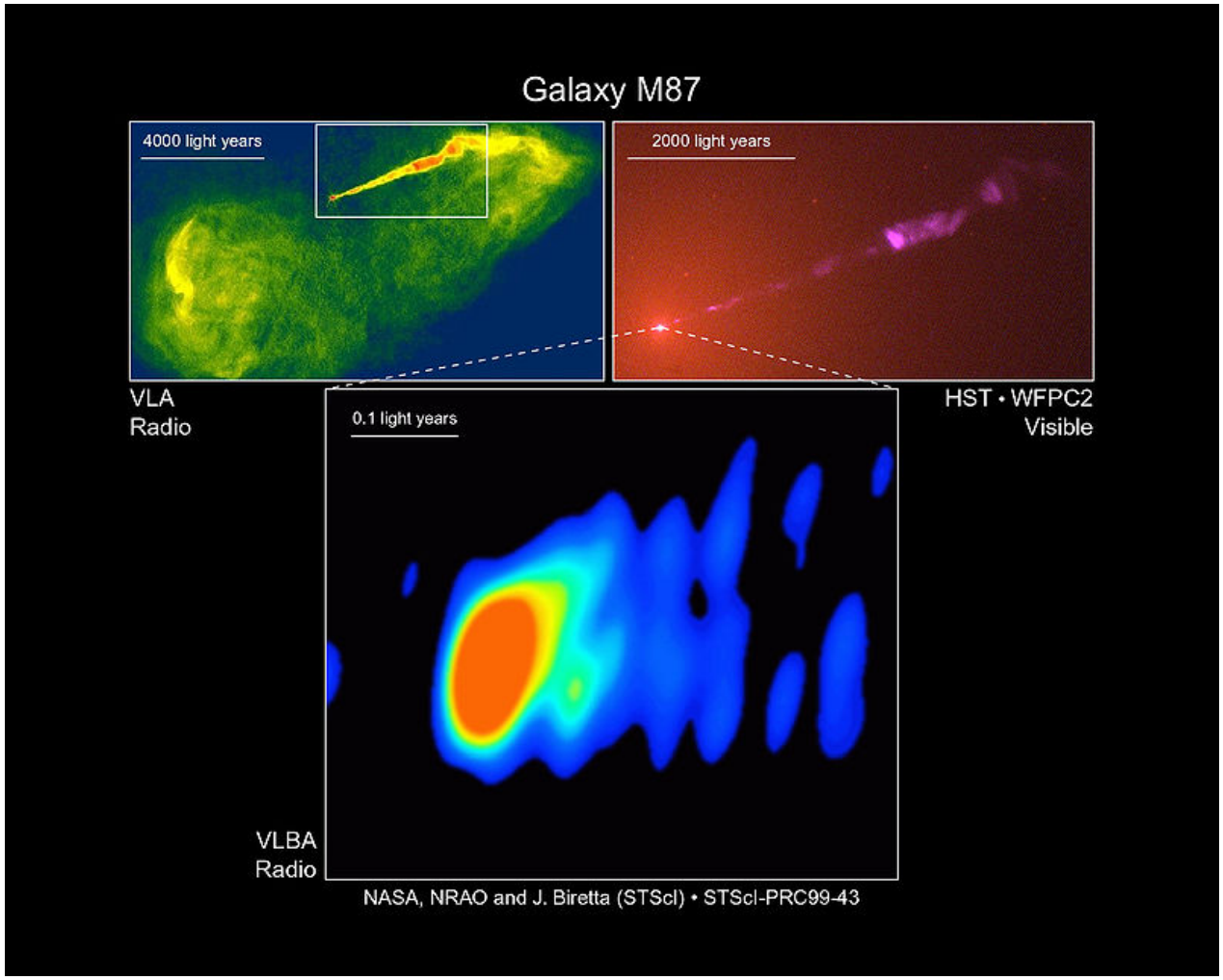
from eventhorizontelescope.org

Sources of interests



- Largest angular size
- Observable in radio spectrum
- Presence of compact radiation component (synchrotron radiation)

Sources of interest

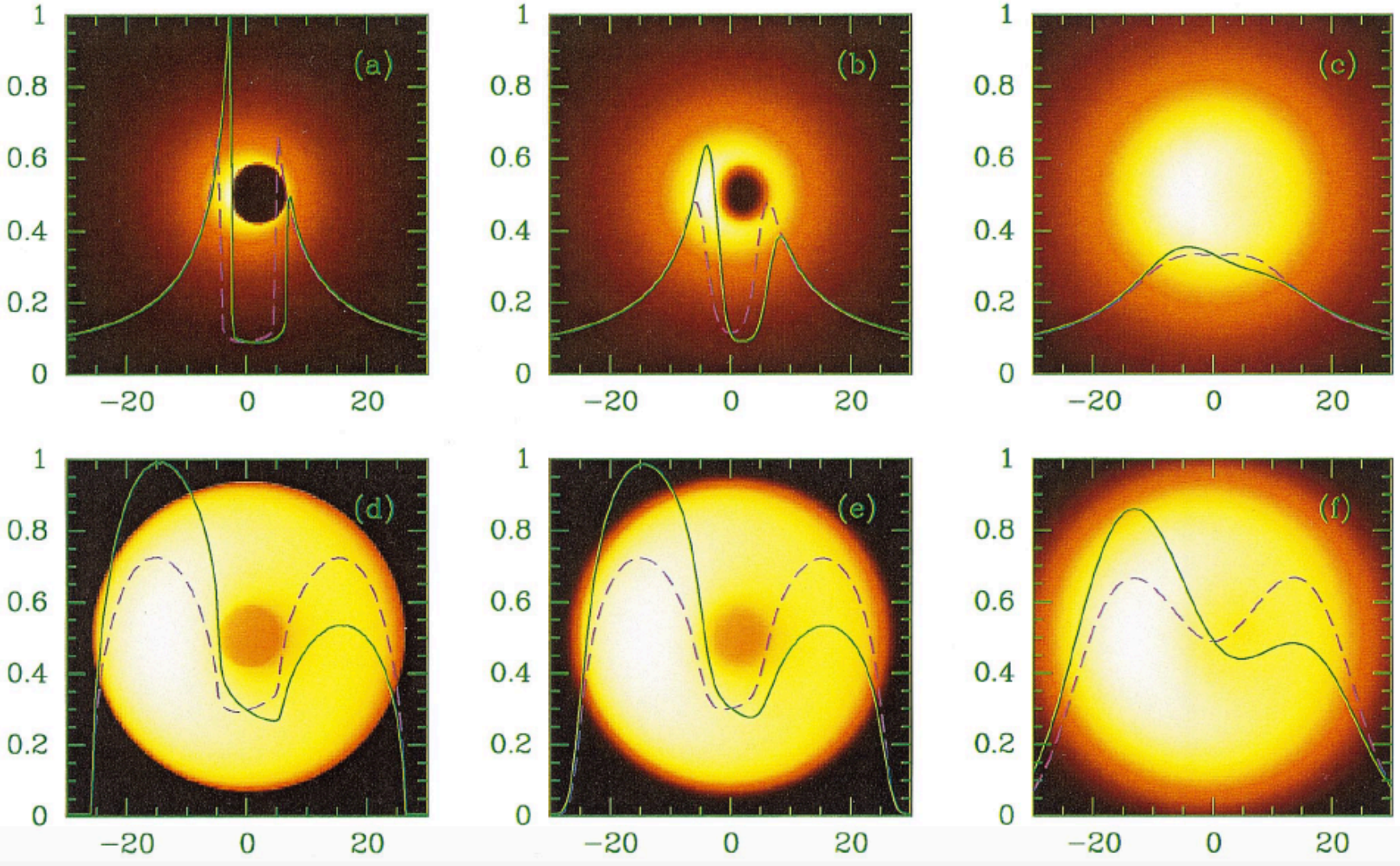


- Second largest angular size
- Prominent jet structure
- Small interstellar scattering

M87

Look into the shadow

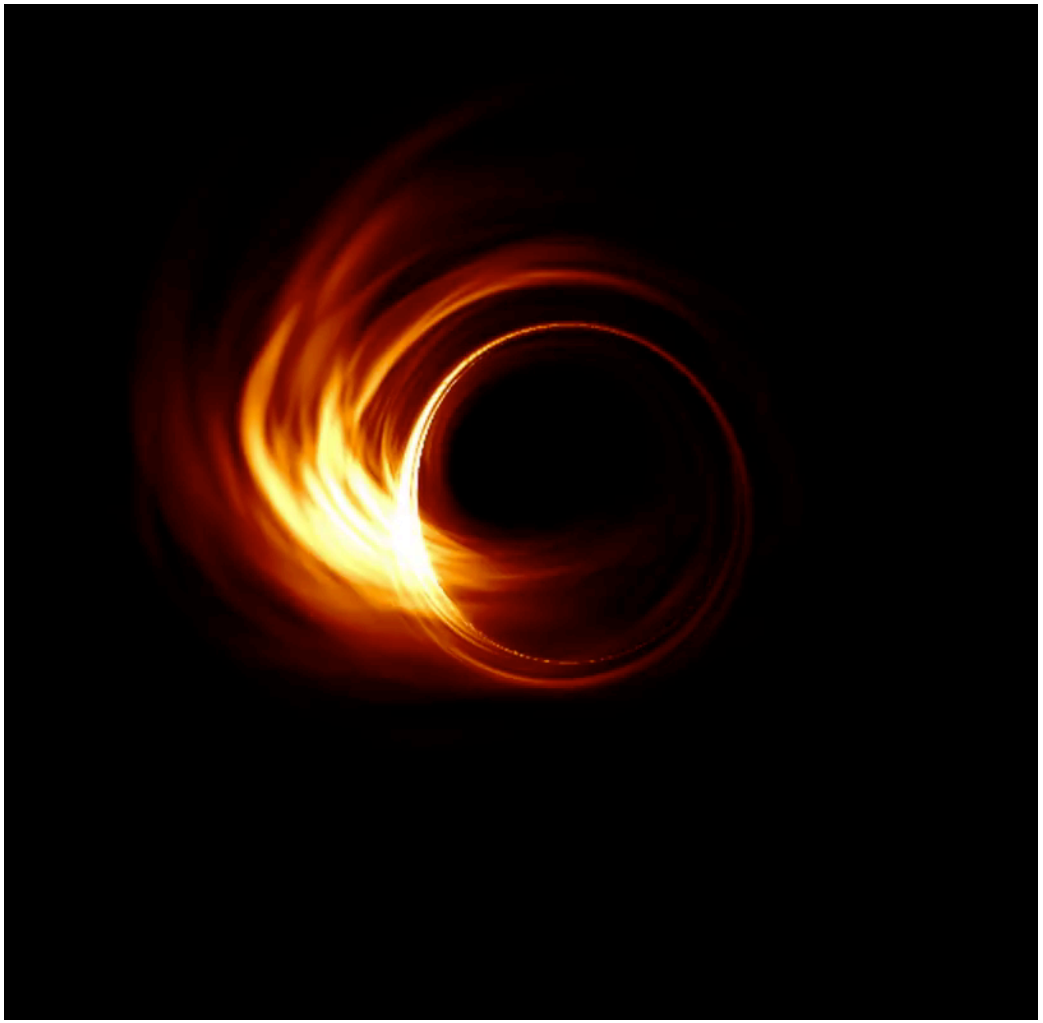
Observable size for Sgr A*: 46 – 52 μas



Magnified shadow + Accretion disk (+ jet)

Falcke et al. 2000

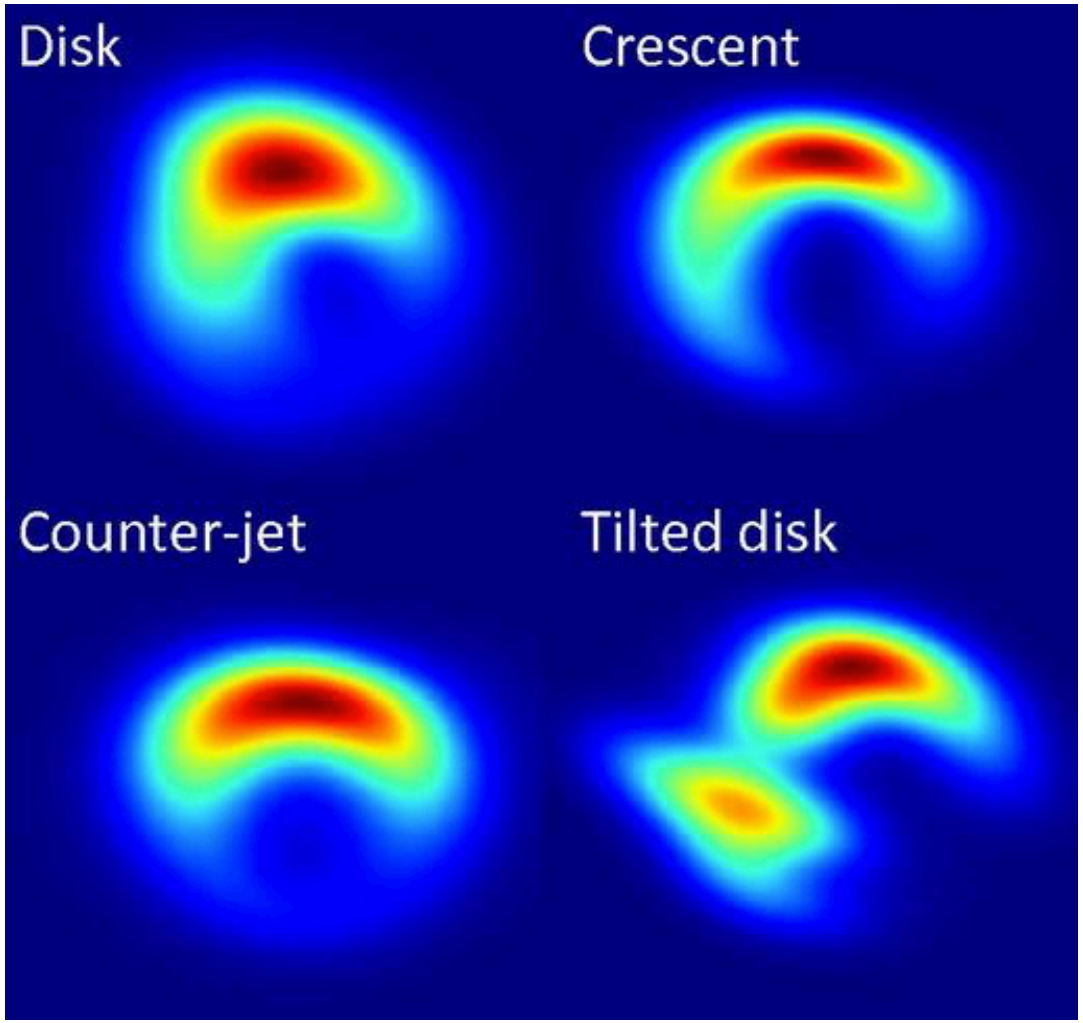
Look into the shadow



- The radiation from a disk (GRMHD simulation)
- Viewing angle: 45 degrees
- Doppler beaming effect can be easily seen

from eventhorizontelescope.org

Different models



- Different models yield different observable shapes
- But they are hard to distinguished!

Dexter et al. 2010, 2012, 2013

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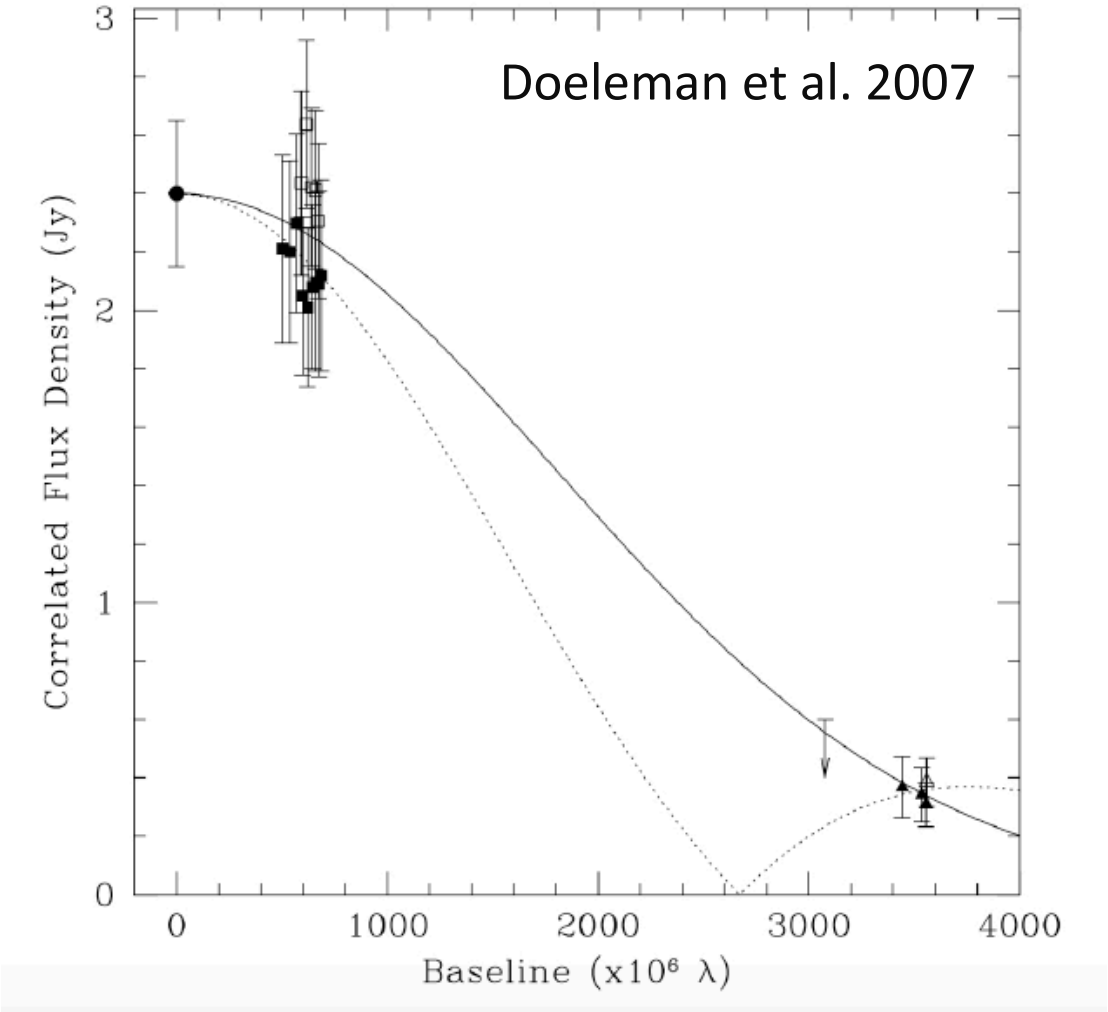
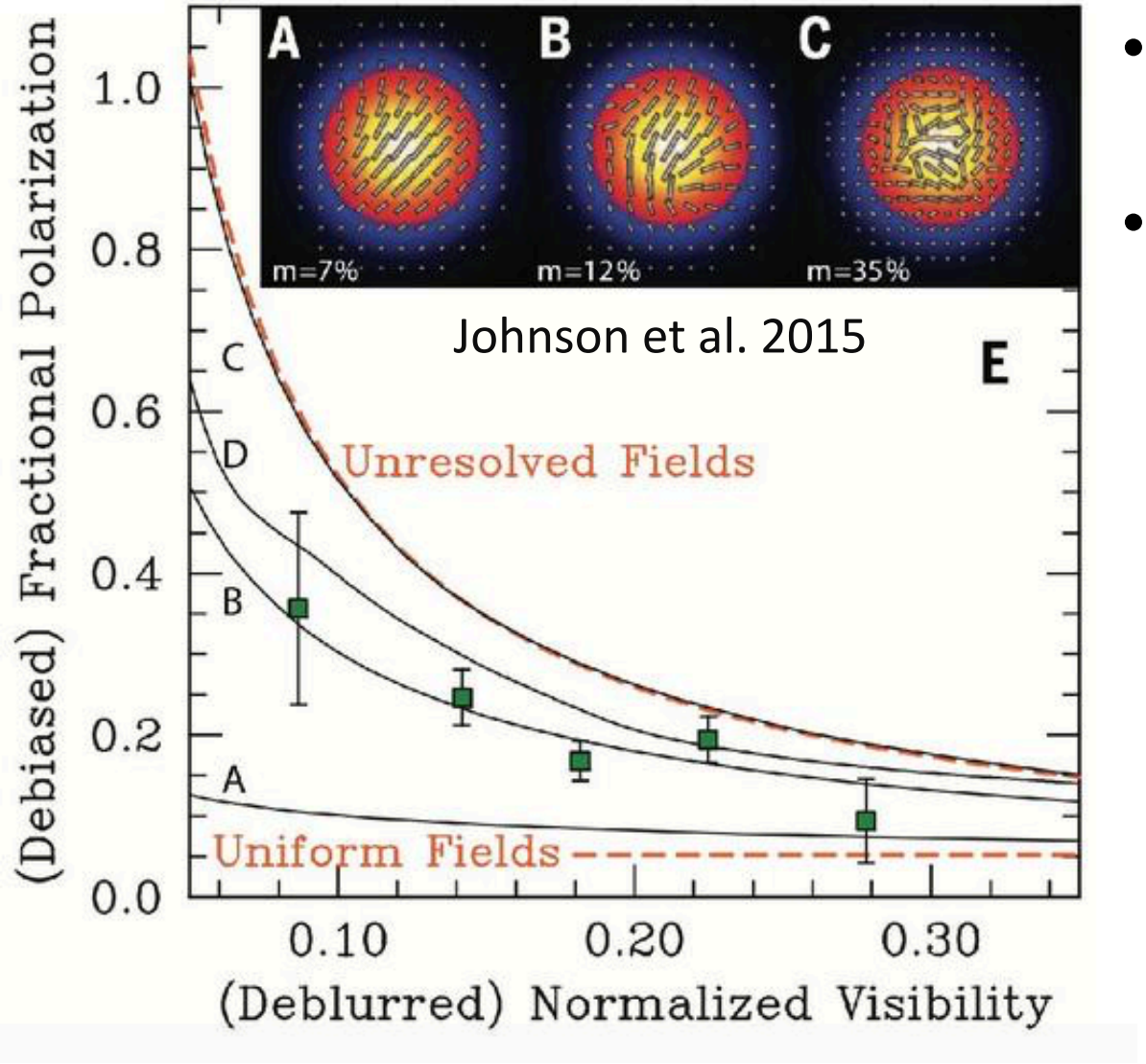
Early EHT work



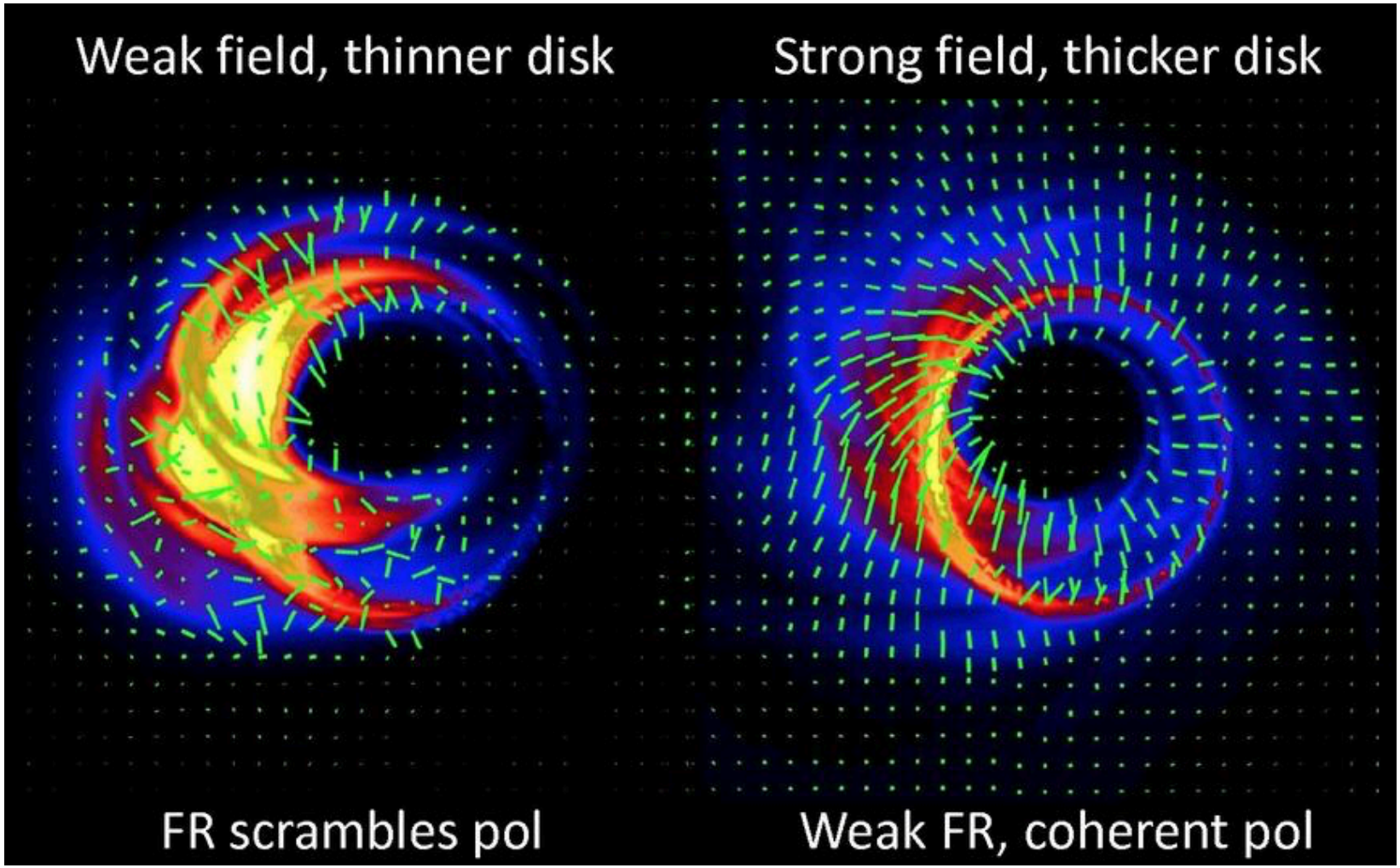
- Observation at 1.3 mm at three sites (ARO/SMT, CARMA and JCMT)
- Longest projected baseline: ~ 4500km
- Too few visibility to form an image
- Fitted size ~ $37\mu as$ (using a single Gaussian)
- This implies that the radiation source might not be spherically symmetric

Polarizations of magnetic fields



- Constraining the coherence of magnetic fields around Sgr A*
- Between totally ordered and totally tangled

Polarizations of magnetic fields

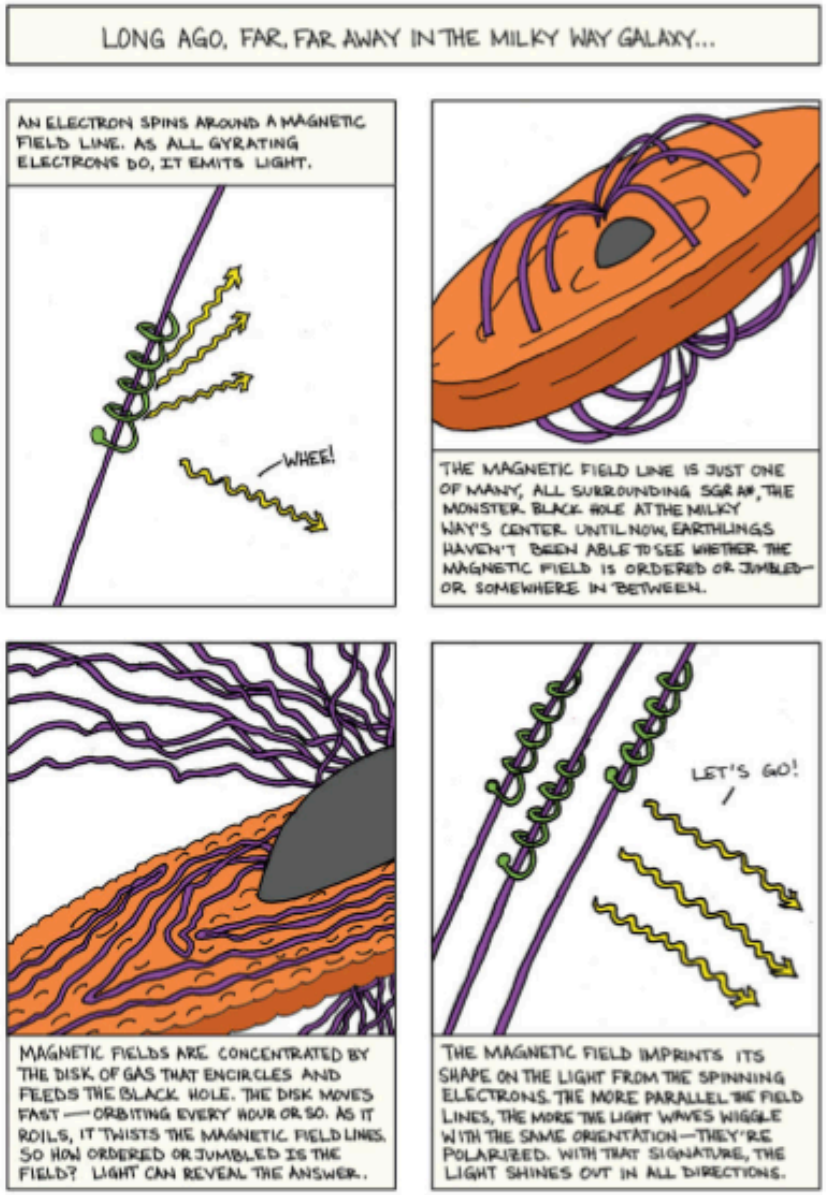


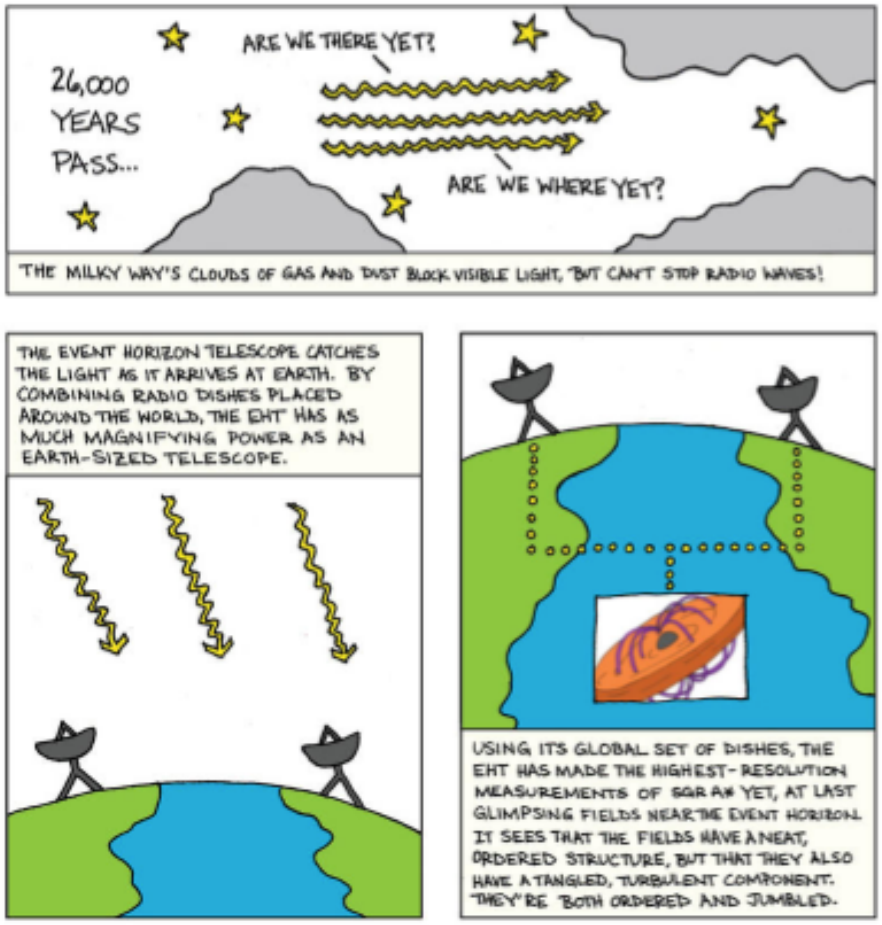
Constraining disk models

Dexter et al. 2016

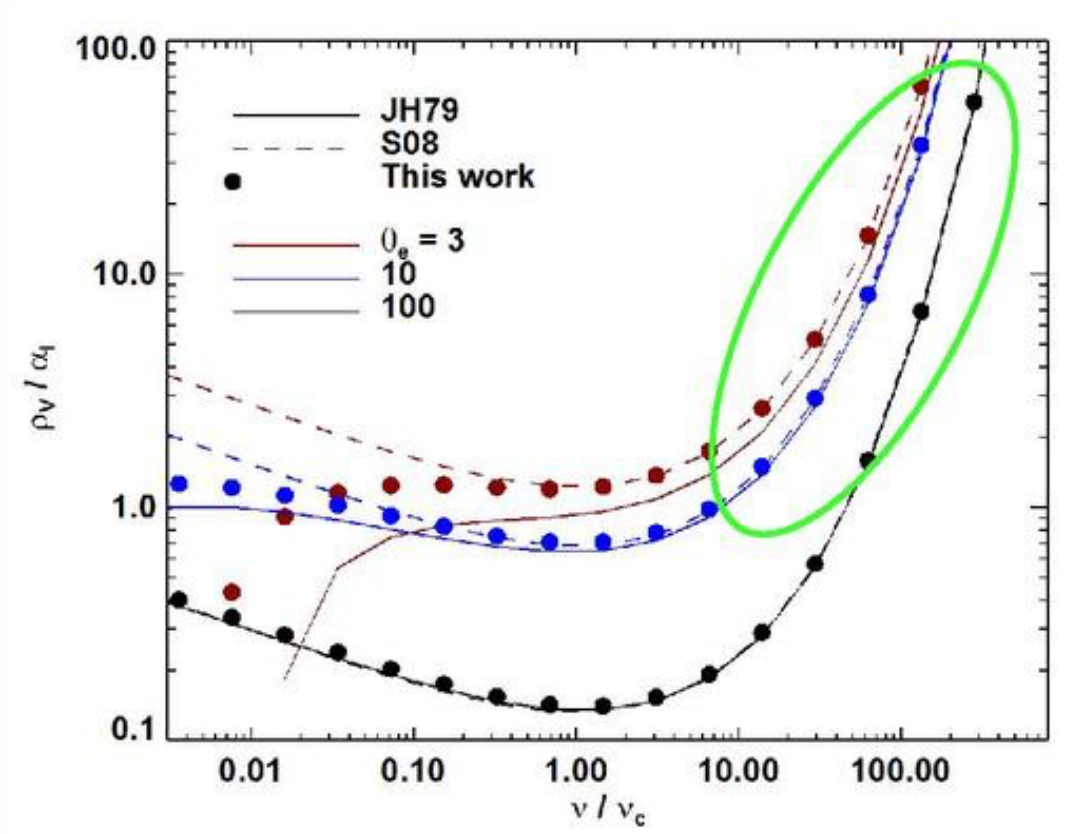
EHT comic: Light's Odyssey

Resolved magnetic fields around Sgr A*





Plasma properties

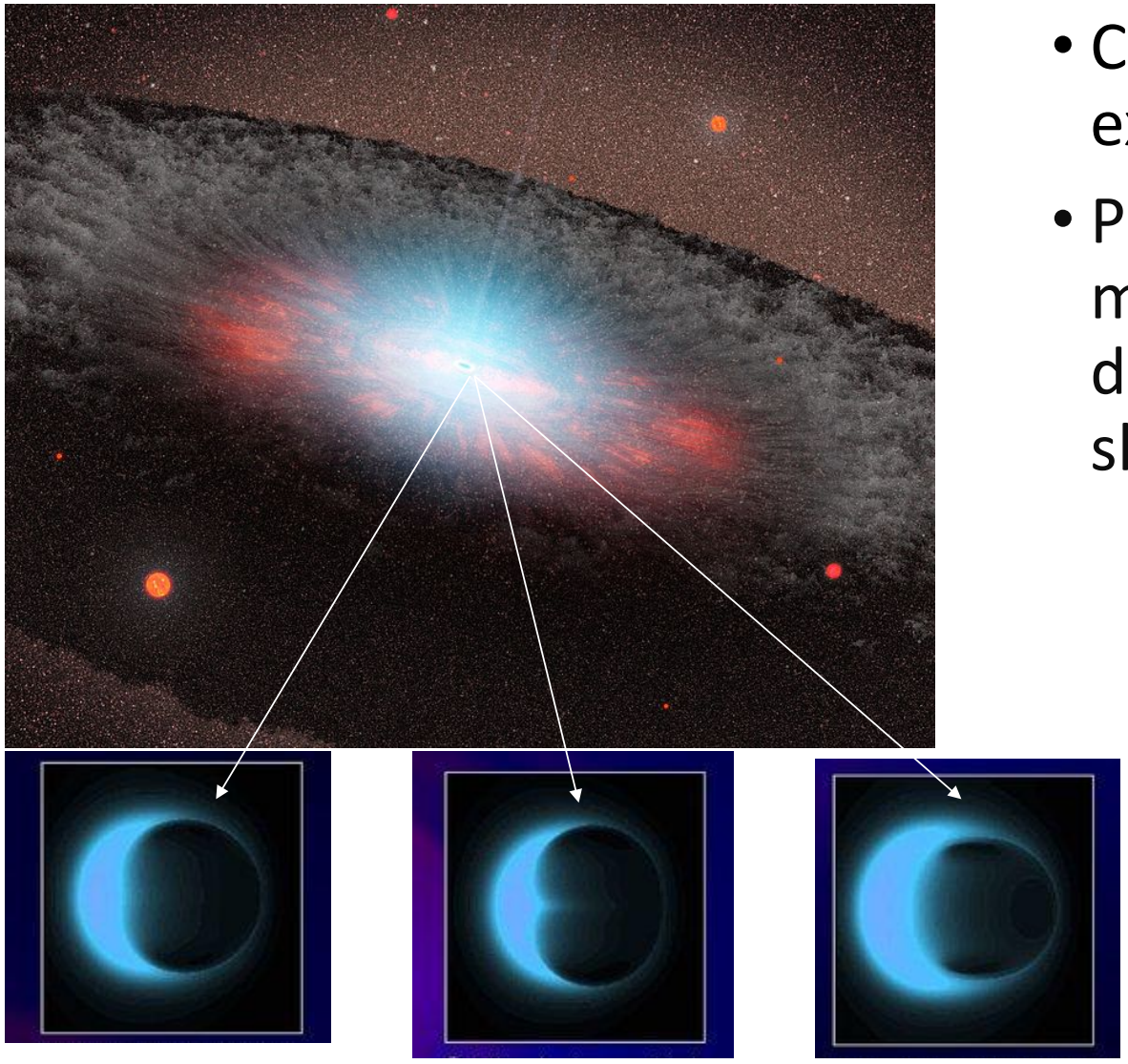


Dexter et al. 2016, Jones & Hardee 1979, Shcherbakov et al. 2008

- At high frequency, FR becomes important
- Constraining the plasma parameters

$$\theta_e = \frac{kT}{mc^2}$$

Testing Einstein's general relativity



- Confirm (or overthrow) the existence of SMBHs
- Provide direct test to GR: modified gravity predicts different shapes of the shadow

from eventhorizontelescope.org

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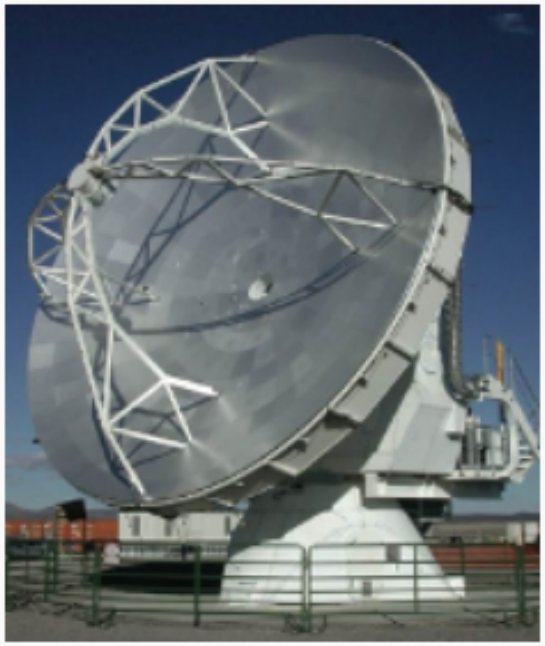
Data processing!

- The data collected from 2017 have just been put together (due to delay of the shipment from the SPT).
- Data calibration (using bright quasars)
- New observation during this April. Collected data tripled.
- Data from 2017 are now being analyzed. Preliminary images of Sgr A* and M87* will emerge (soon?)

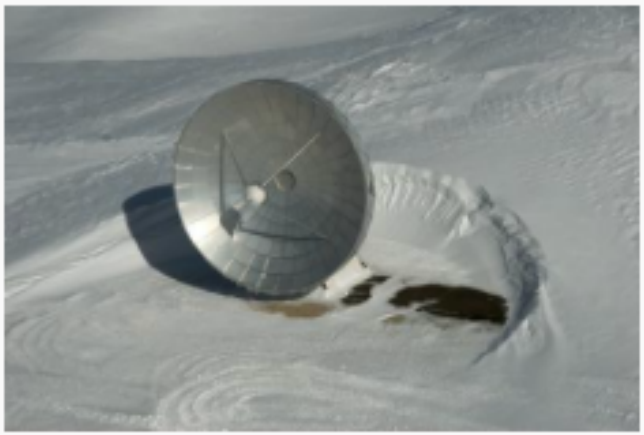
More sites are joining the EHT

Kitt Peak National Observatory (KPNO)

Greenland Telescope Project



- While processing the data, the EHT is planning to have more radio telescope around the world joined in the future observation.



NOrthern Extended Millimeter Array (NOEMA)

Summary

- EHT uses VLBI to image the event horizons and accretion disks of BHs
- Sgr A* and M87 are primary sources
- Various science concerning GR, plasma physics, jet and disk structures can be learned
- Data are under analyzing