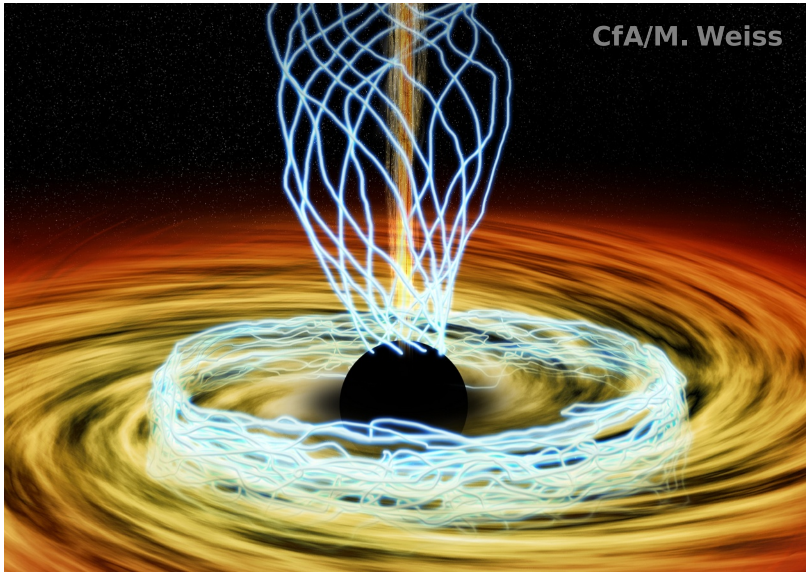
Smithsonian Astrophysical Observatory

Gordon and Betty MOORE FOUNDATION

Imaging Magnetic Fields at the Event Horizon of a Black Hole

Michael Johnson (CfA)

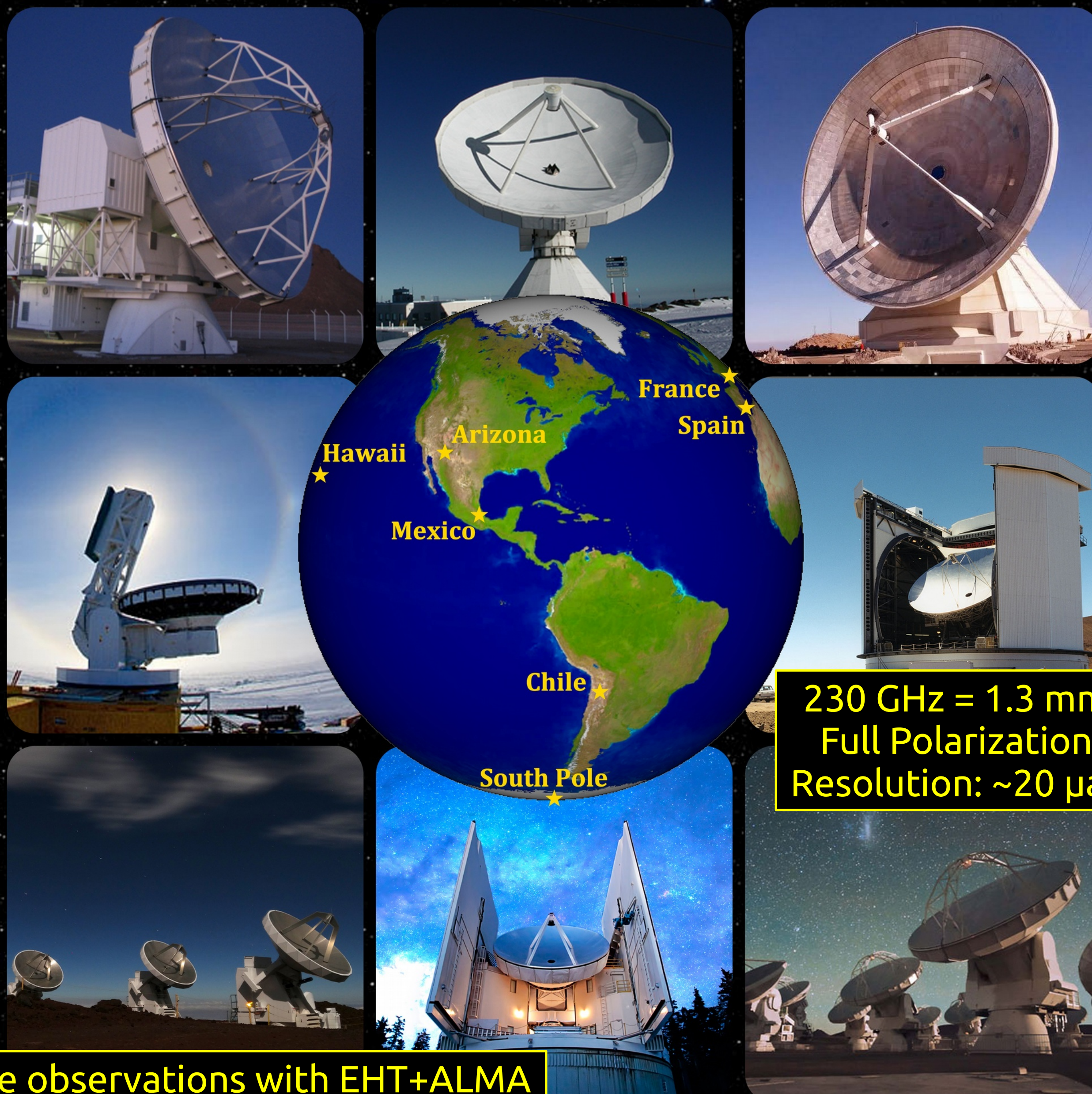


NSF

Polarised Emission from Astrophysical Jets
June 12, 2017

JOHN TEMPLETON FOUNDATION

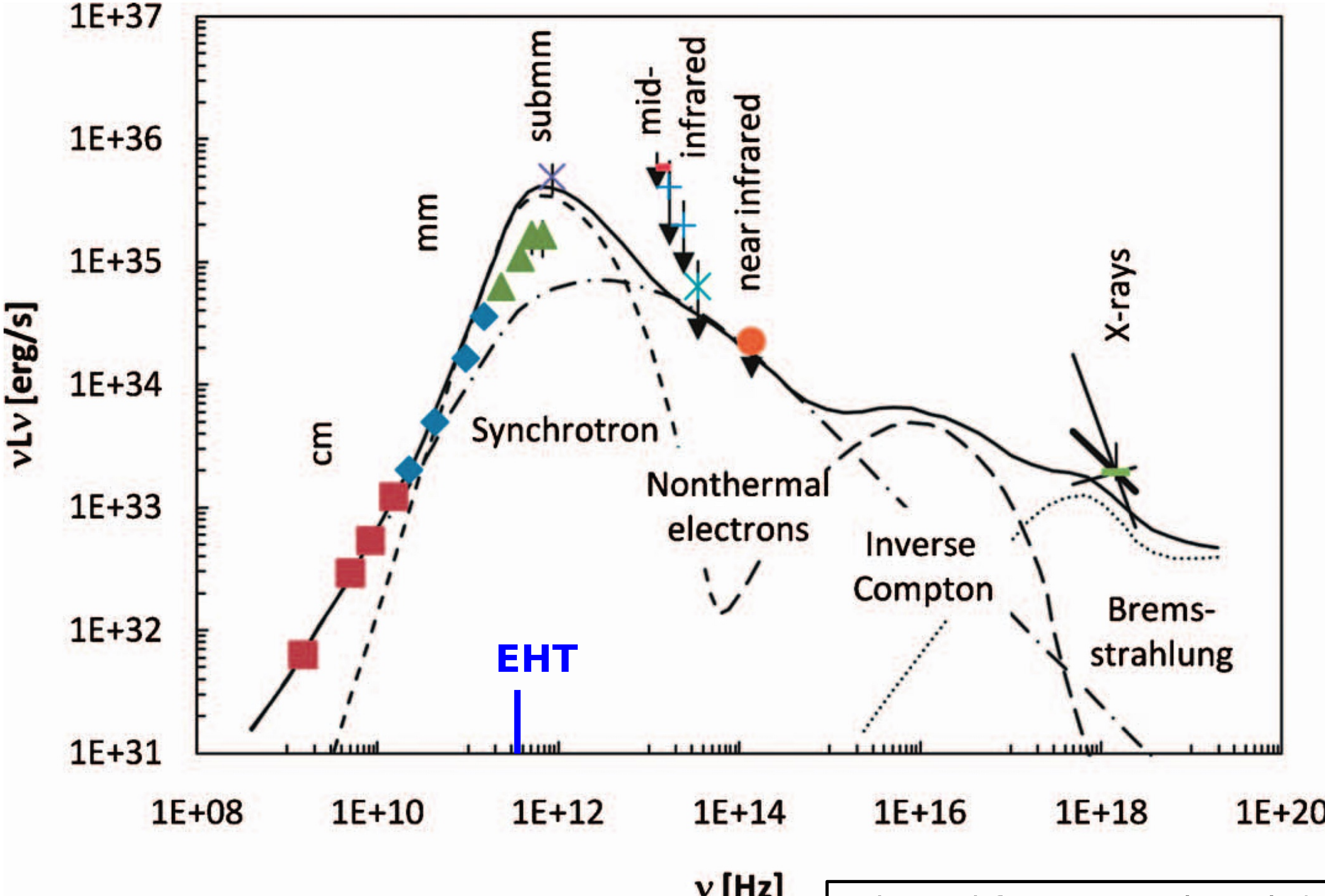
The Event Horizon Telescope



230 GHz = 1.3 mm
Full Polarization
Resolution: ~20 μas

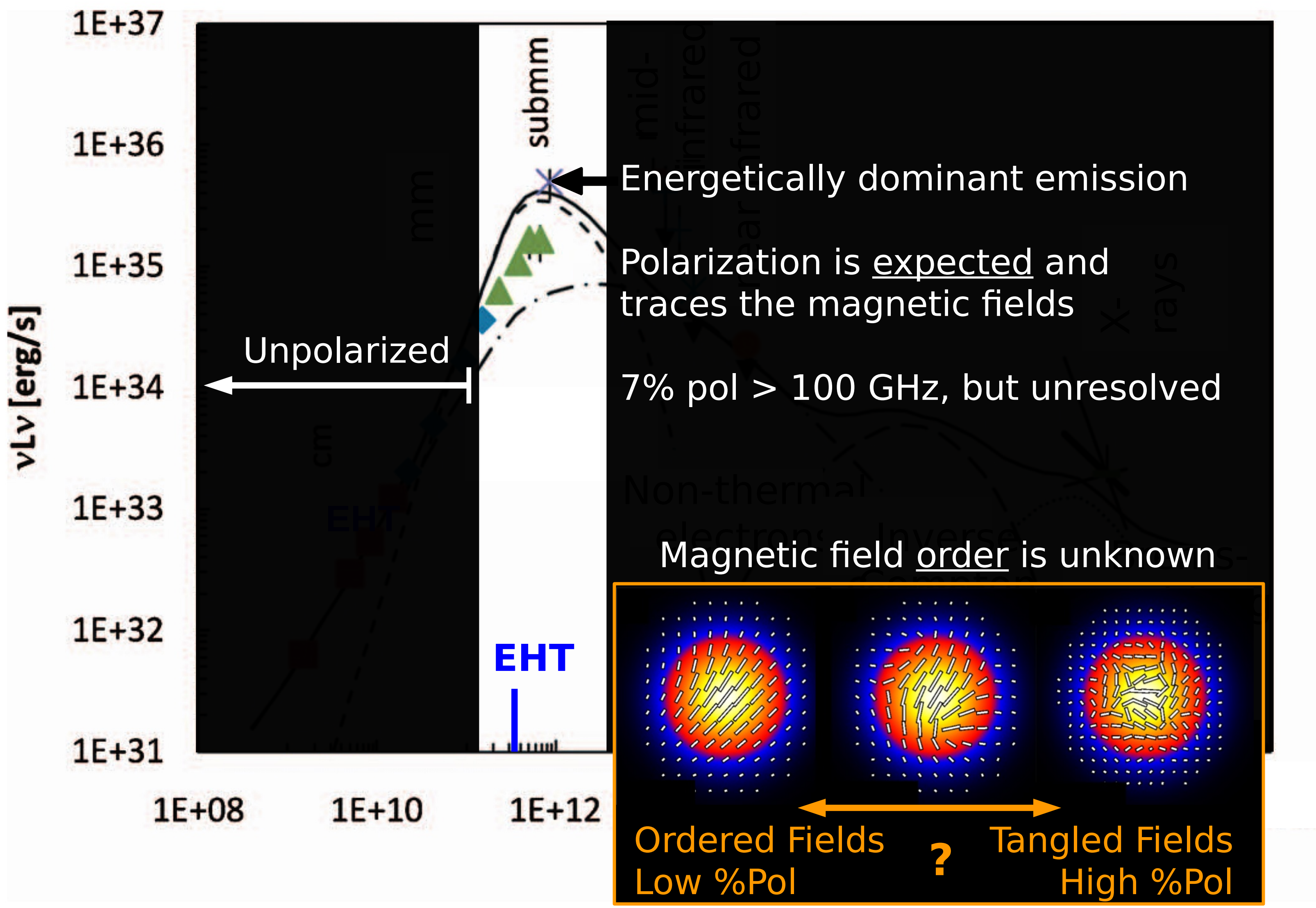
2017: First science observations with EHT+ALMA
2018: 5× Increase in total BW (2× recorded BW)

The Spectrum of Sgr A*

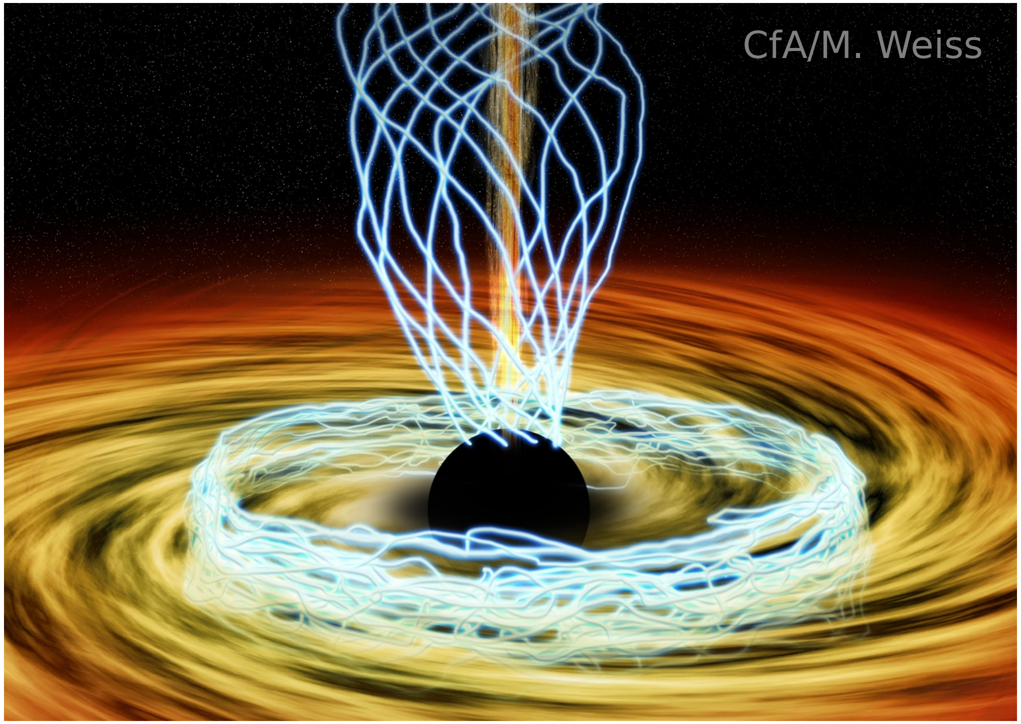


Adapted from Genzel et al. (2010)

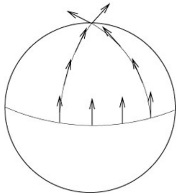
The SED of Sgr A*



Why Study Polarization?

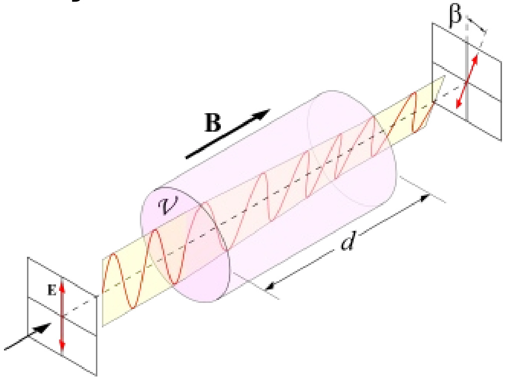


Strong Gravity:
- Parallel Transport
- Relativistic Aberration



BH Accretion and Outflow:
- Field morphology
- Turbulence

Global Accretion:
- Faraday rotation & conversion



The accretion rate of Sgr A* was not determined until submillimeter polarization was detected!

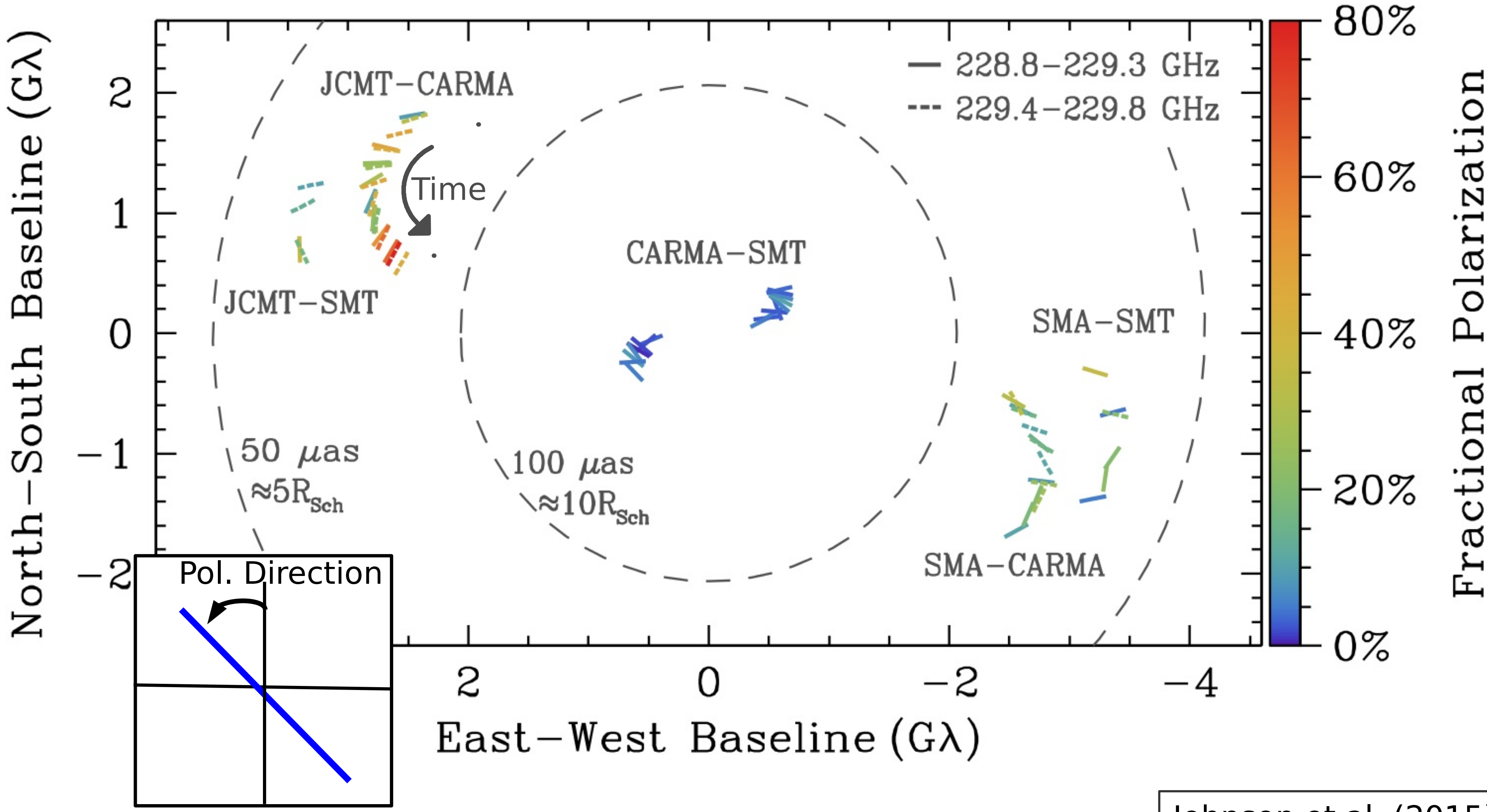
(Aitken et al. 2000; Marrone et al. 2007)

Polarimetry with the EHT

Image Credit: APEX, IRAM, G. Narayanan, J. McMahon, JCMT/JAC, S. Hostler, D. Harvey, ESO/C. Malin

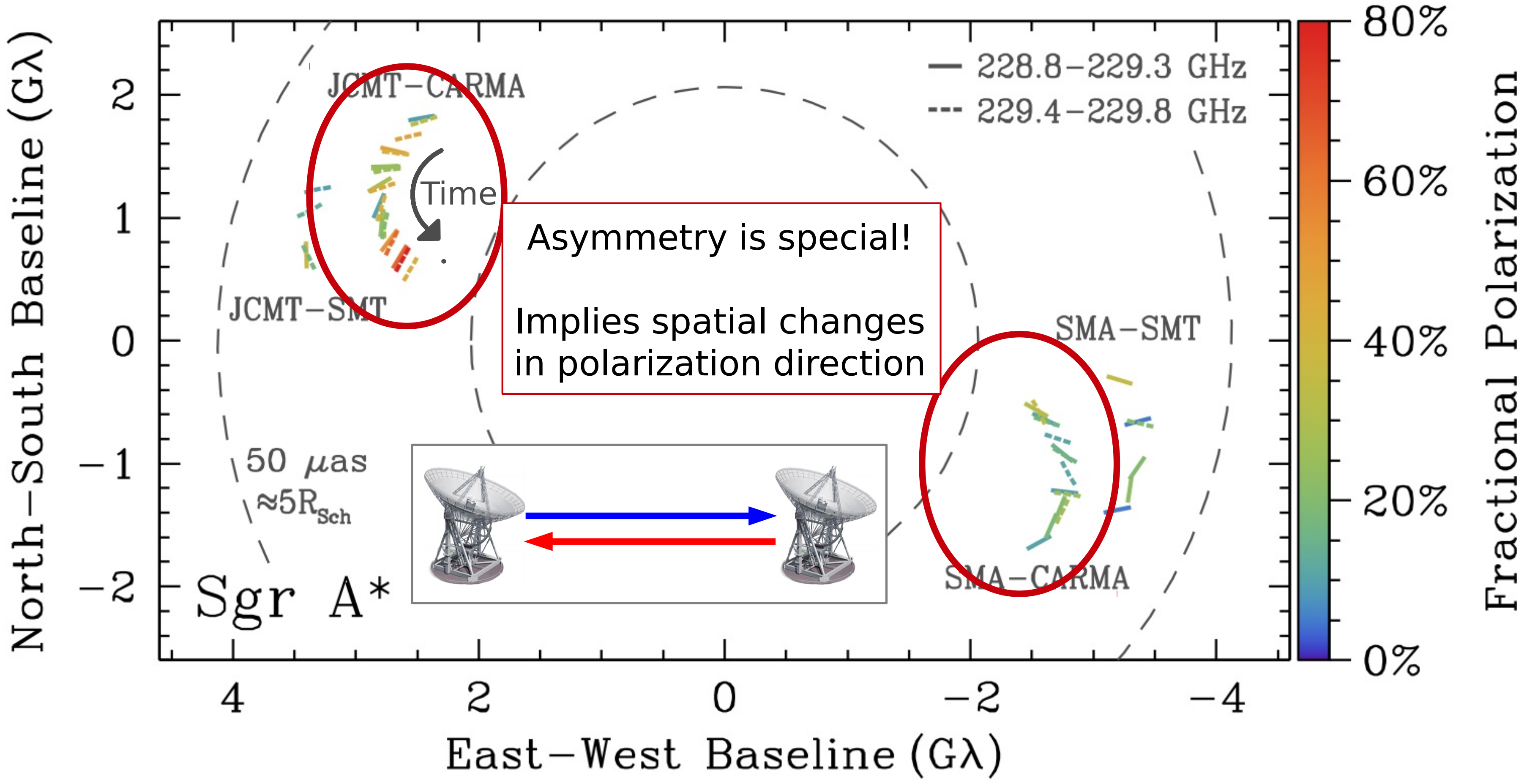
Resolving Sgr A* with the EHT

First polarimetric VLBI at 230 GHz;
First resolved polarization of Sgr A* at <u>any</u> wavelength

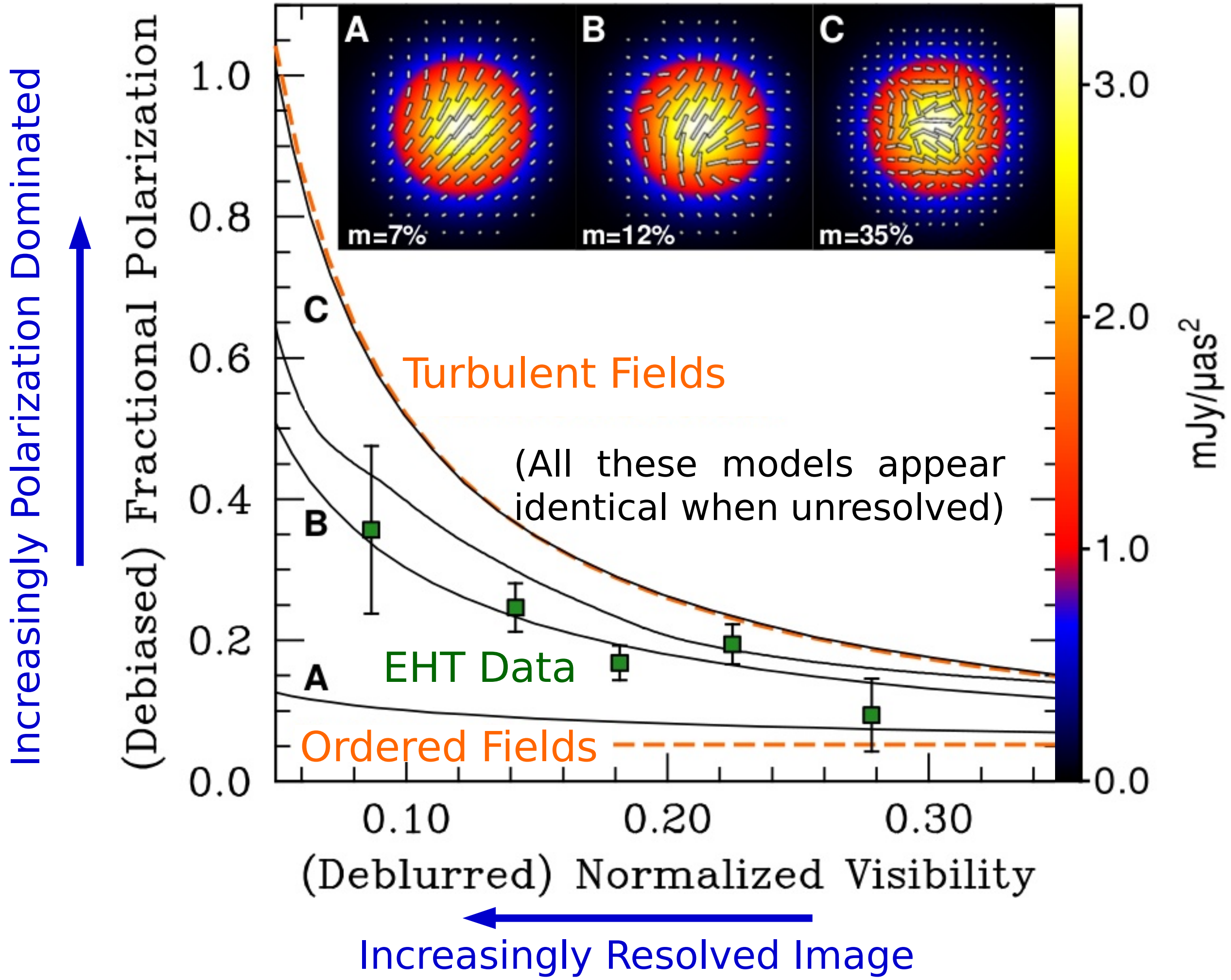


Johnson et al. (2015)

Resolving Sgr A* with the EHT

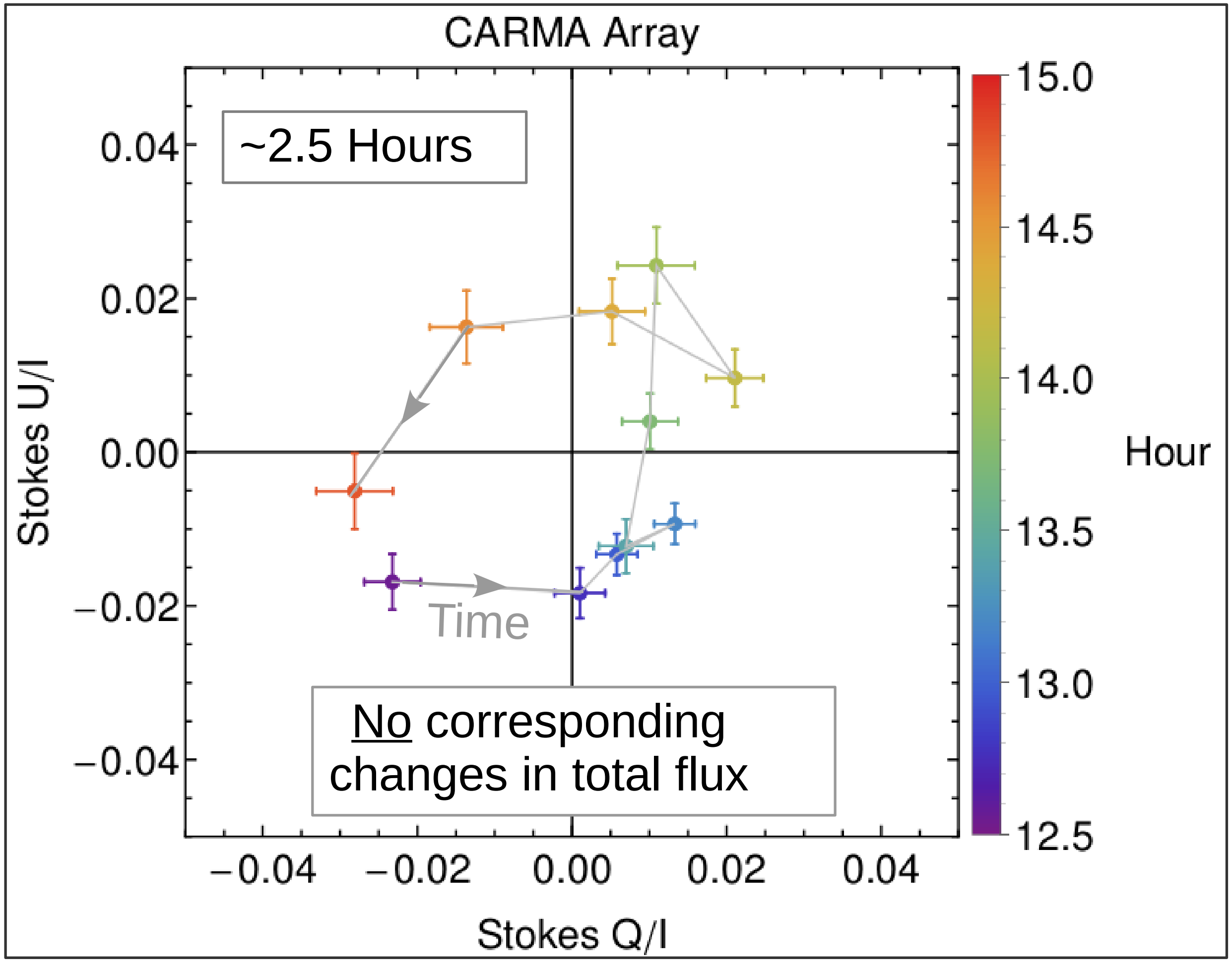


Ordered Fields Near the Horizon



Johnson et al. (2015)

Time Variability of Sgr A*

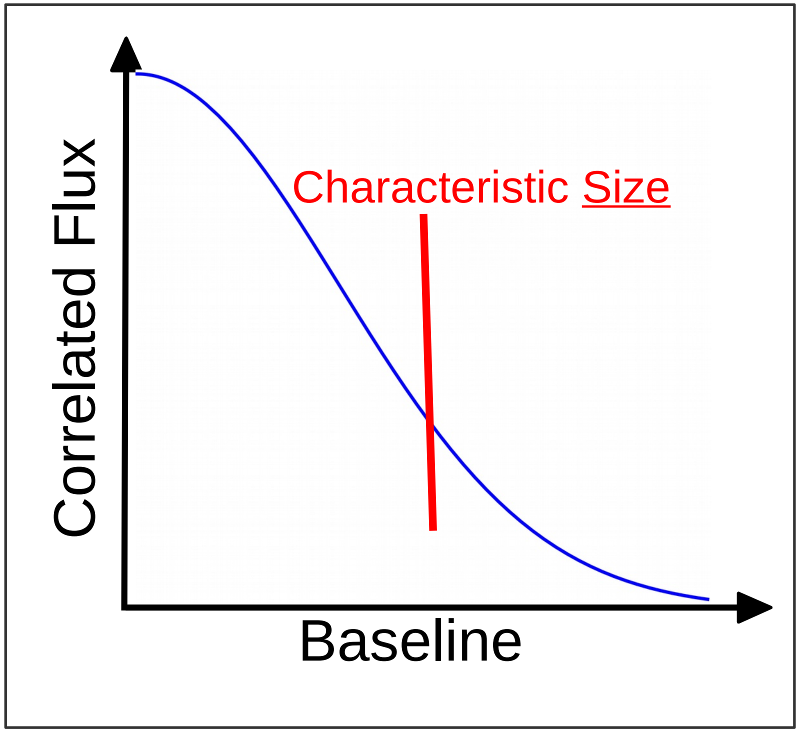


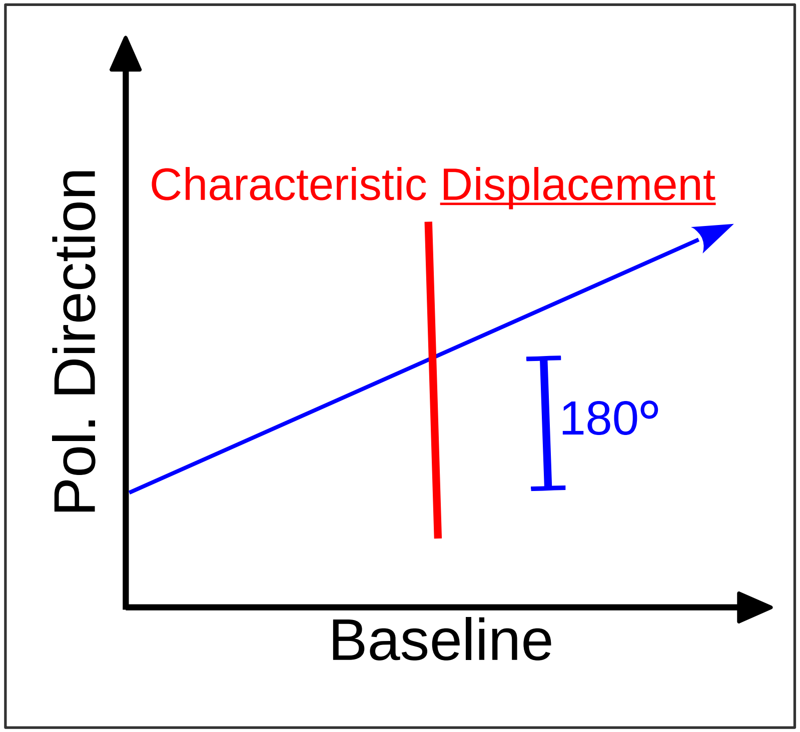
see also: Marrone et al. (2007), Fish et al. (2009)

Relative Offset of the Polarization Centroid

Model-independent morphology constraints via the polarization angle

An Analogy

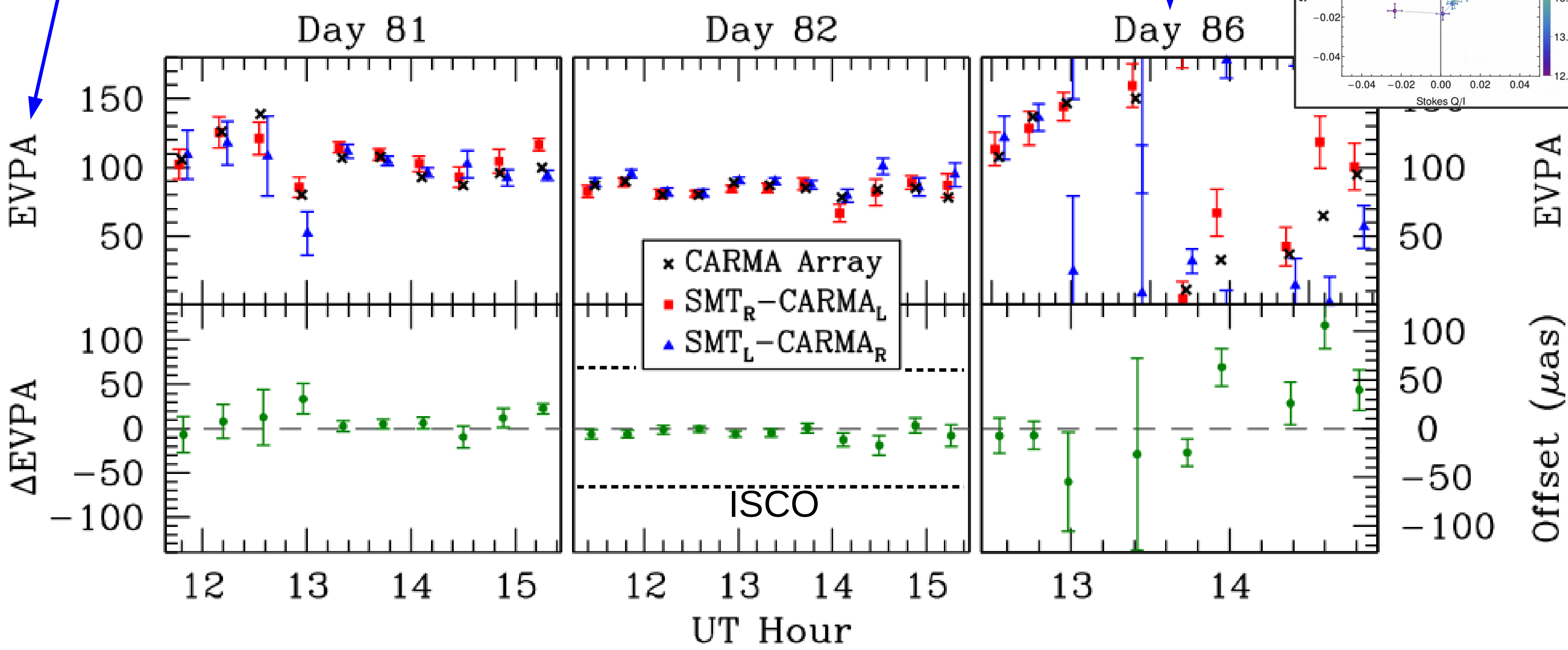


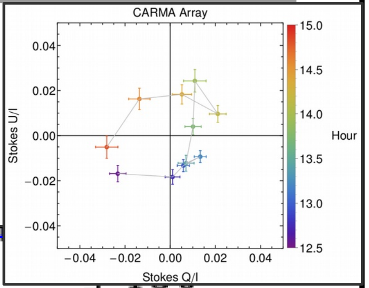


For a California-Arizona Baseline: 1 R_{Sch} offset <=> 10° in polarization direction

Tracking Dynamical Activity of Sgr A*

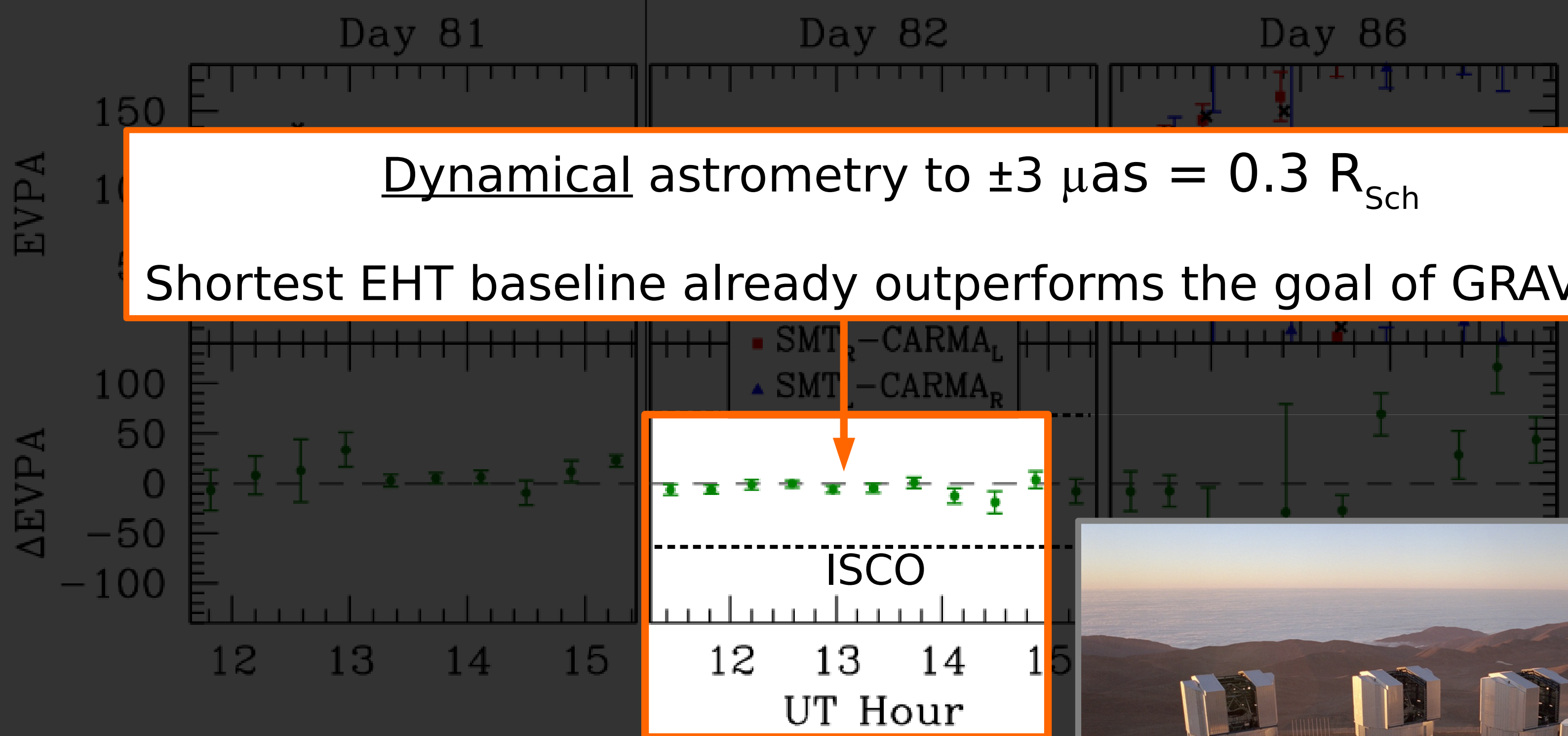
Pol. Angle





Johnson et al. (2015)

Tracking Dynamical Activity of Sgr A*

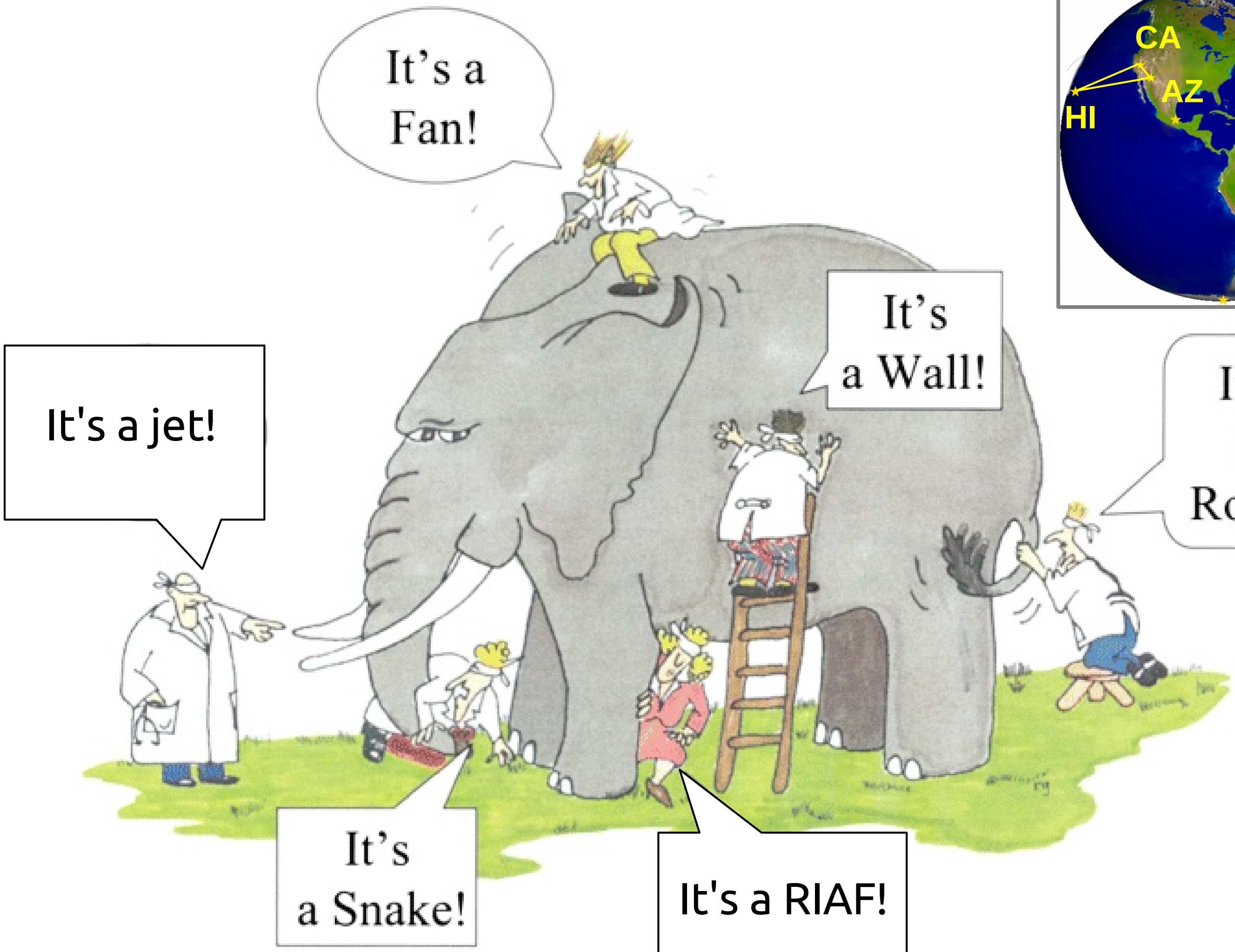


Dynamical astrometry to ±3 μas = 0.3 R_{Sch}

Shortest EHT baseline already outperforms the goal of GRAVITY!

See astro-ph:1705.02345

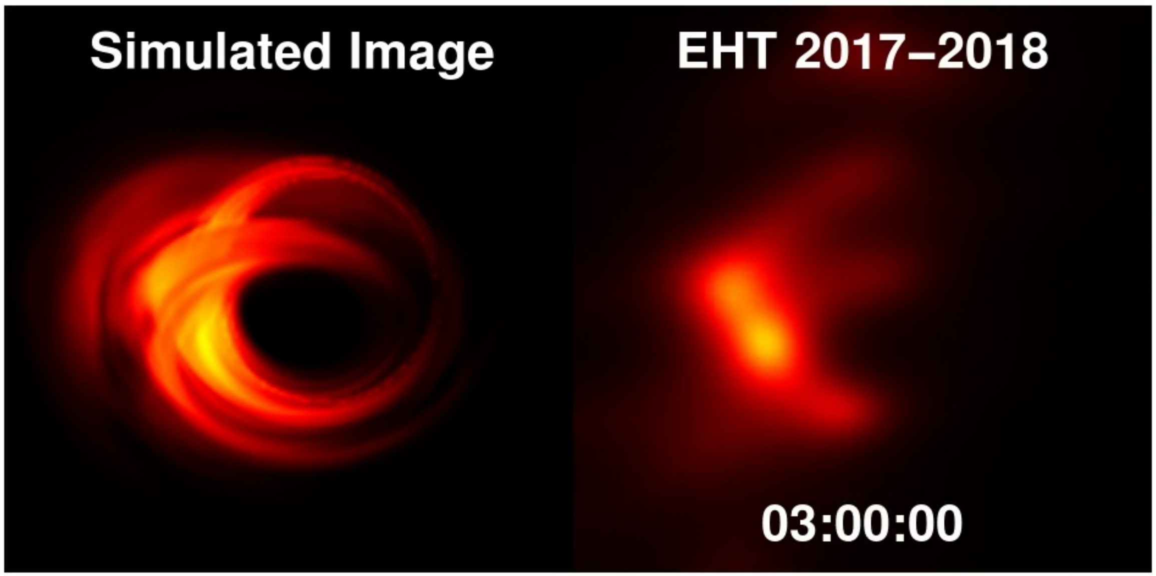
Working with Sparse Information



Source: balajiviswanathan.quora.com

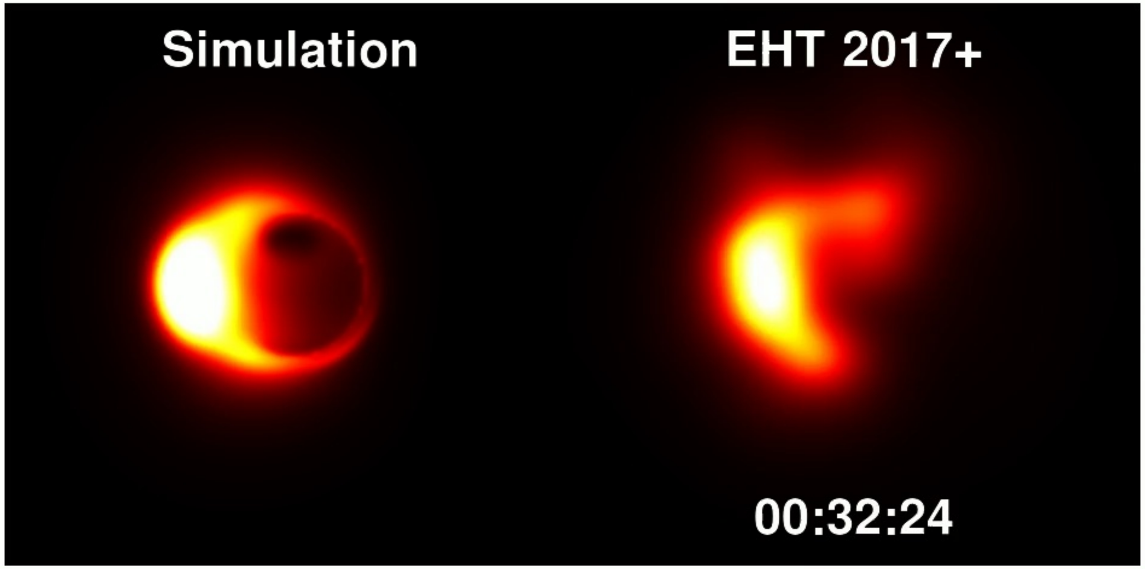
Next Steps (2017-2018): Imaging

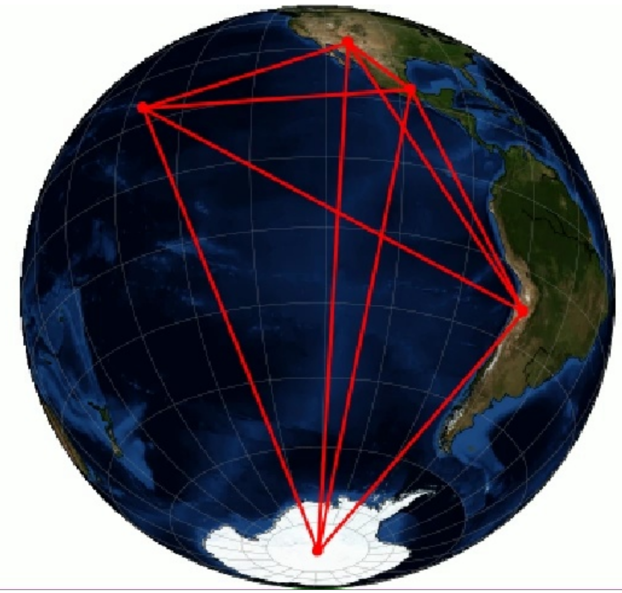
EHT imaging simulations are encouraging:



But, conventional Earth-rotation synthesis imaging is not appropriate for Sgr A*!
(e.g., Lu+ 2016, Gold+ 2016, Roelofs+ 2017, Medeiros+ 2017)

Dynamical Imaging with Interferometry





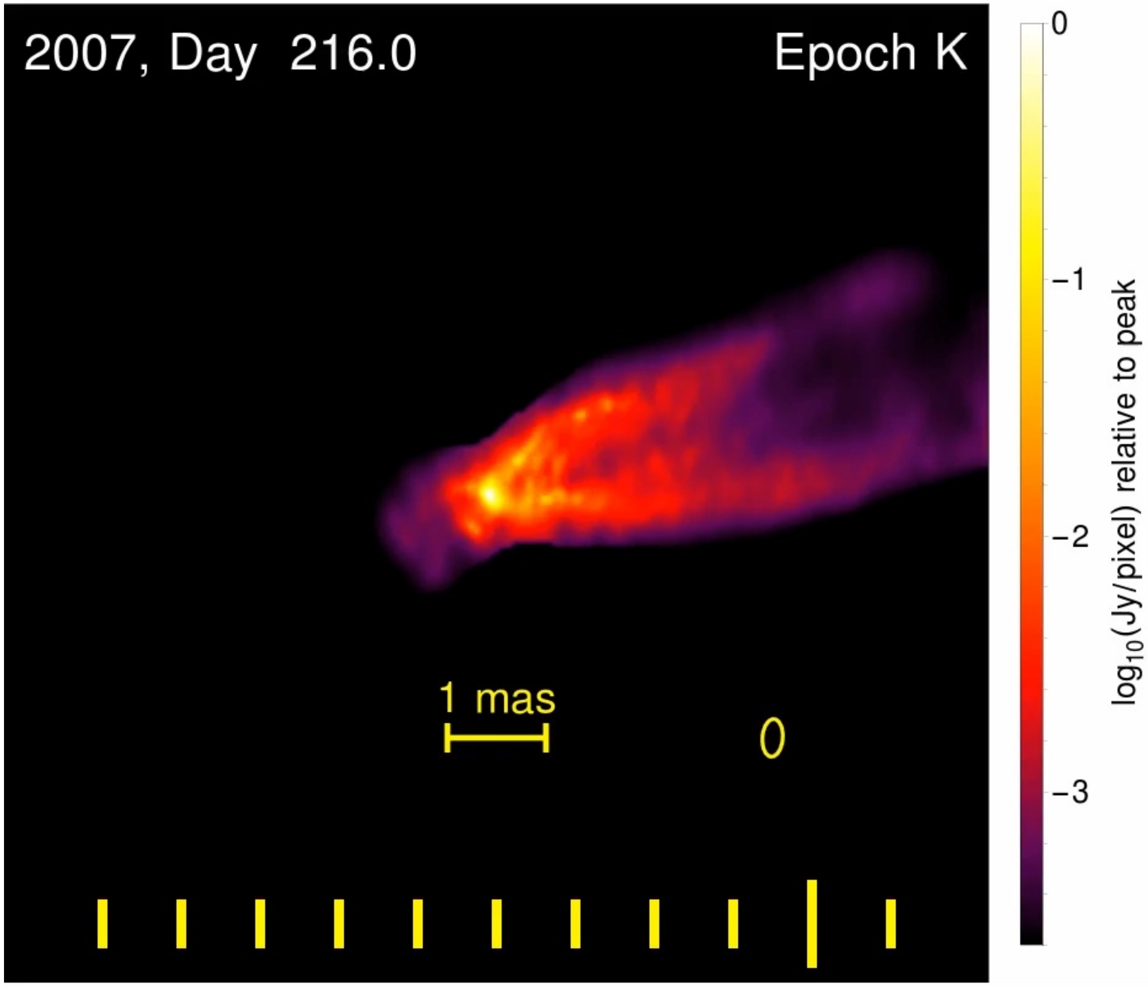
Simulation:

- An orbiting "hot spot" (Broderick & Loeb 2006)
- Earth rotates 7° per hot spot orbit (27 minutes)

Reconstruction:

- Assumes the sites and sensitivities of the expected 2017 EHT
- Snapshot images (~1 minute of data per frame)
- An entire movie is reconstructed, favoring frame-to-frame continuity

7mm VLBA Observations of M87



Computing Time: ~hours

Framework is flexible

- Irregularly spacing
- Inhomogeneous beam

A calibration/imaging framework

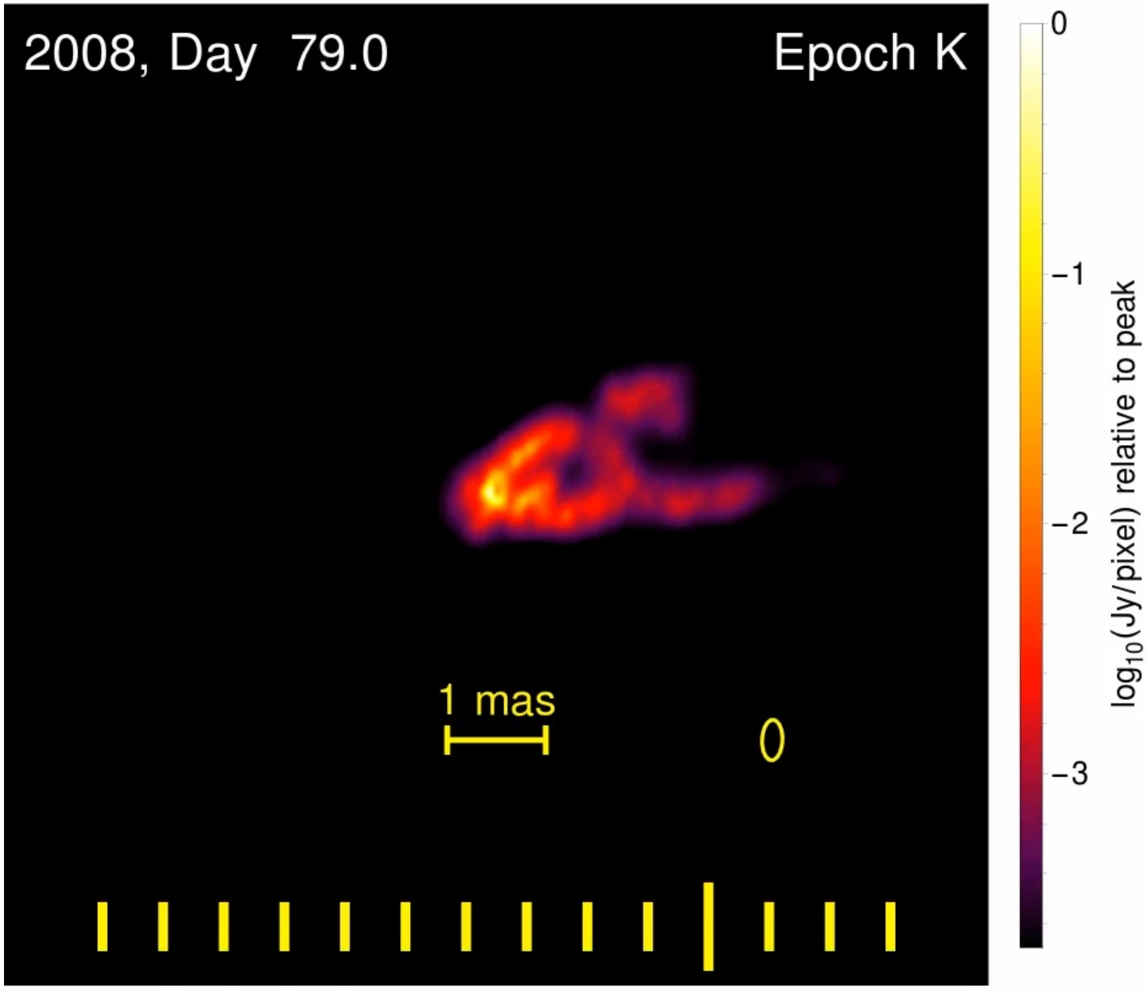
Results can be post-processed; e.g., wavelet analyses (Mertens & Lobanov 2015)

← Equivalent to ~3-hr for Sgr A*

with **Craig Walker**, Andrew Chael, Katie Bouman, Lindy Blackburn, Shep Doeleman

Data: Walker+ (2016, 2017)

7mm VLBA Observations of M87



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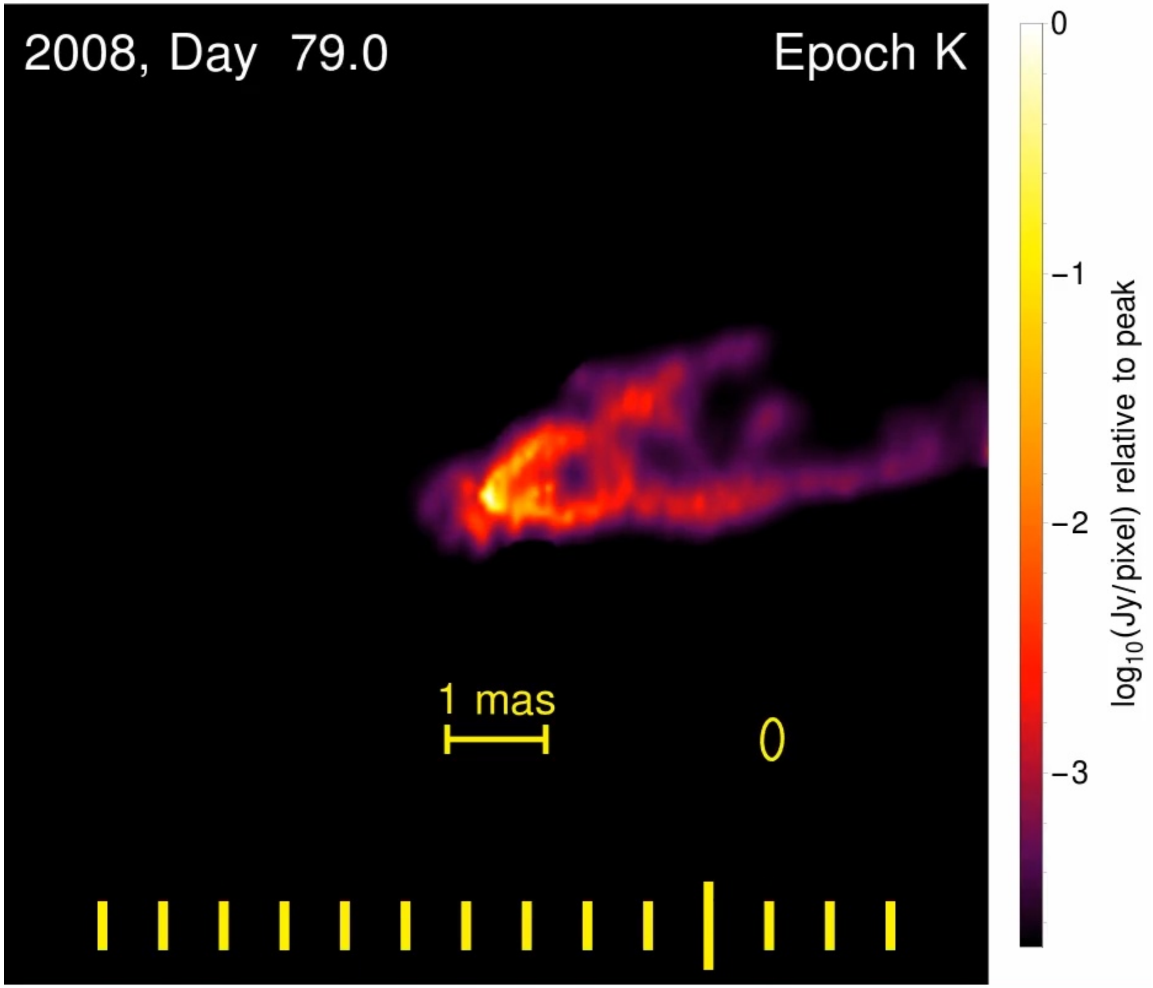

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Polarimetric extension can use regularization methods (Holdaway & Wardle 1990, Chael+ 2016, Coughlan & Gabuzda 2016, Akiyama+ 2017). Still in progress!

Dynamical Imaging with Interferometry

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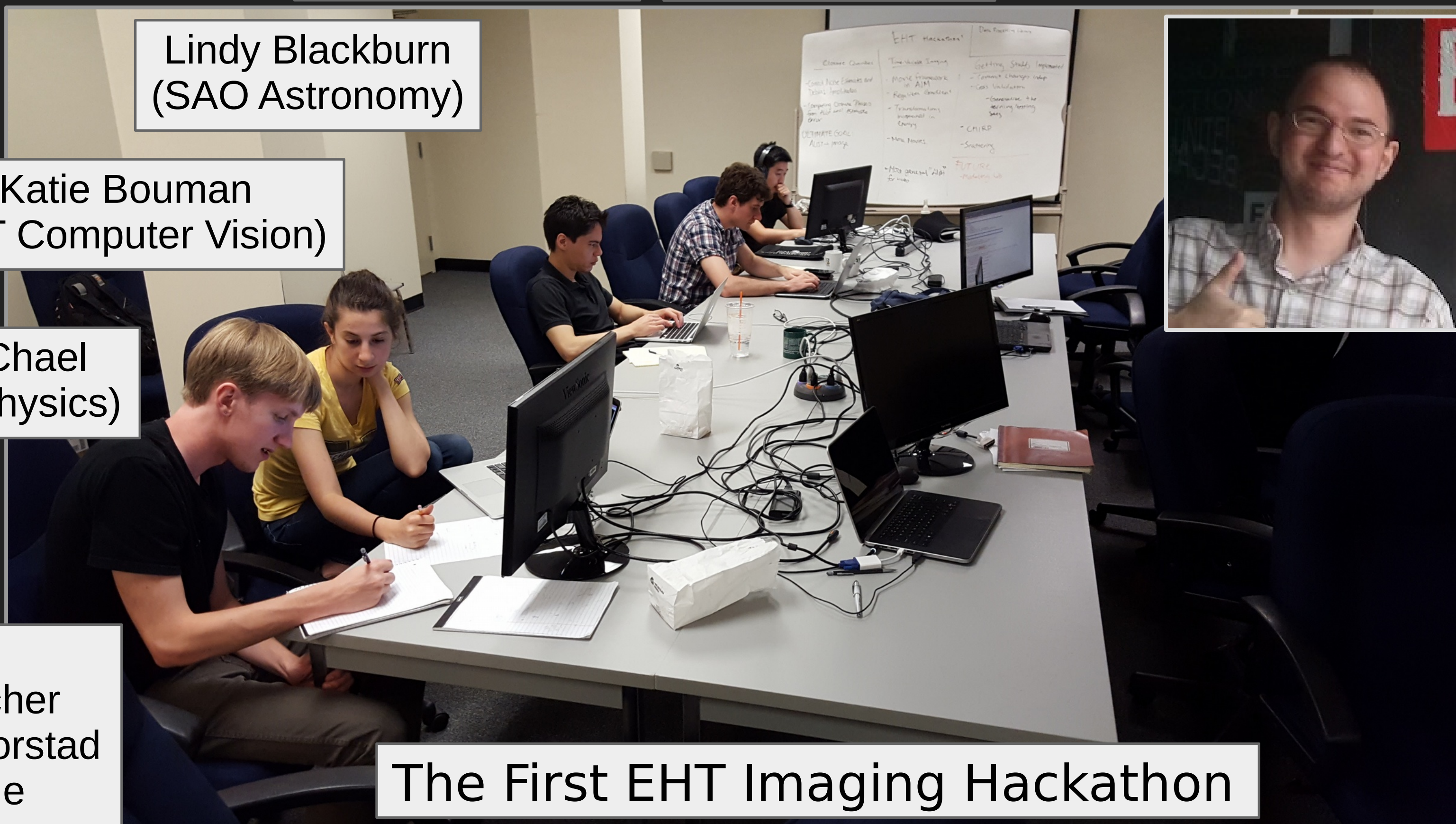
Kazu Akiyama
(MIT Astronomy)

Julian Rosen
(UGA Mathematics)

Lindy Blackburn
(SAO Astronomy)

Katie Bouman
(MIT Computer Vision)

Andrew Chael
(Harvard Physics)



The First EHT Imaging Hackathon

Also:
- Alan Marscher
- Svetlana Jorstad
- John Wardle
- Craig Walker
- Shep Doeleman

Summary

Recent EHT results:

- Compact structure in total flux of Sgr A*, only ~5 Schwarzschild radii in size
- Ordered magnetic fields and strong polarization near the event horizon
- Also a component with small-scale polarization structure
- Intense variability in polarization

In the next few years (7-9 sites):

- Images of the black hole shadow and magnetic fields near Sgr A*
- Movies of dynamical activity, flares, and polarization of Sgr A* and M87
- Faraday rotation images of Sgr A* in 2018+
- Other Targets: OJ287, 3C273, 3C279