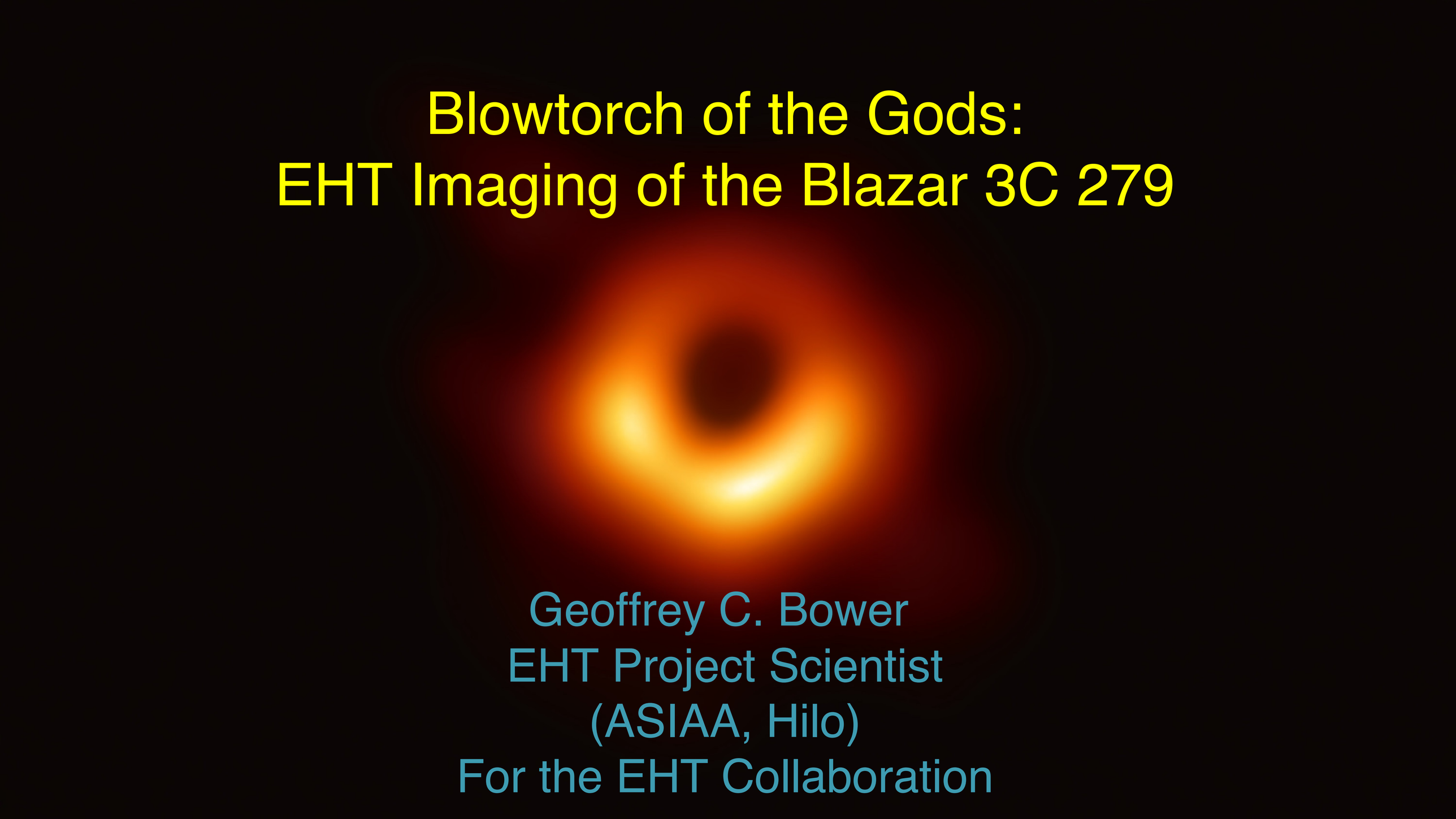
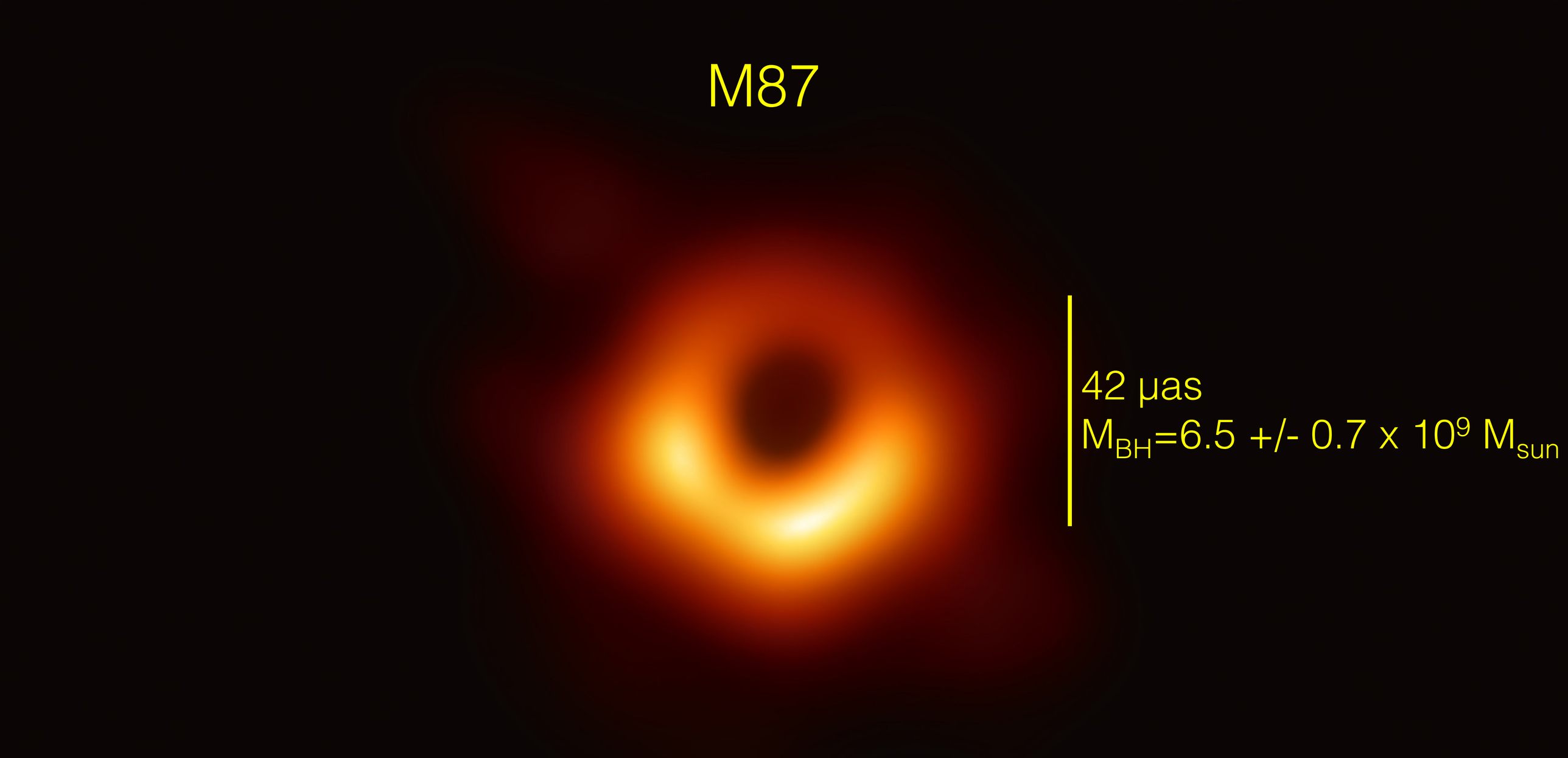
Blowtorch of the Gods:
EHT Imaging of the Blazar 3C 279



Geoffrey C. Bower
EHT Project Scientist
(ASIAA, Hilo)
For the EHT Collaboration

M87



First Image of a Black Hole


Global Team at the EHT 2019 Conference

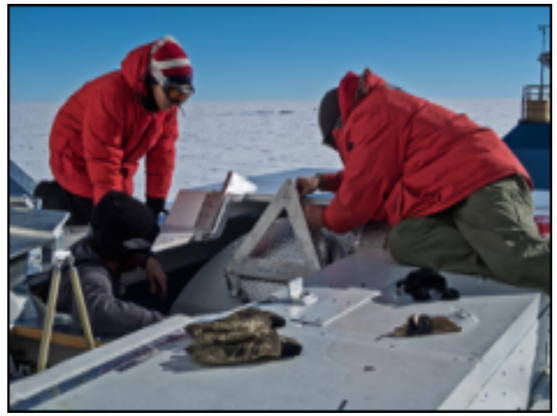

VMIC
Hilo
HAT CREEK

The Submillimeter Array

The JCMT

William Montgomery

Members of the EHT team at Telescopes



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Event Horizon Telescope imaging of the archetypal blazar 3C 279 at an extreme 20 microarcsecond resolution

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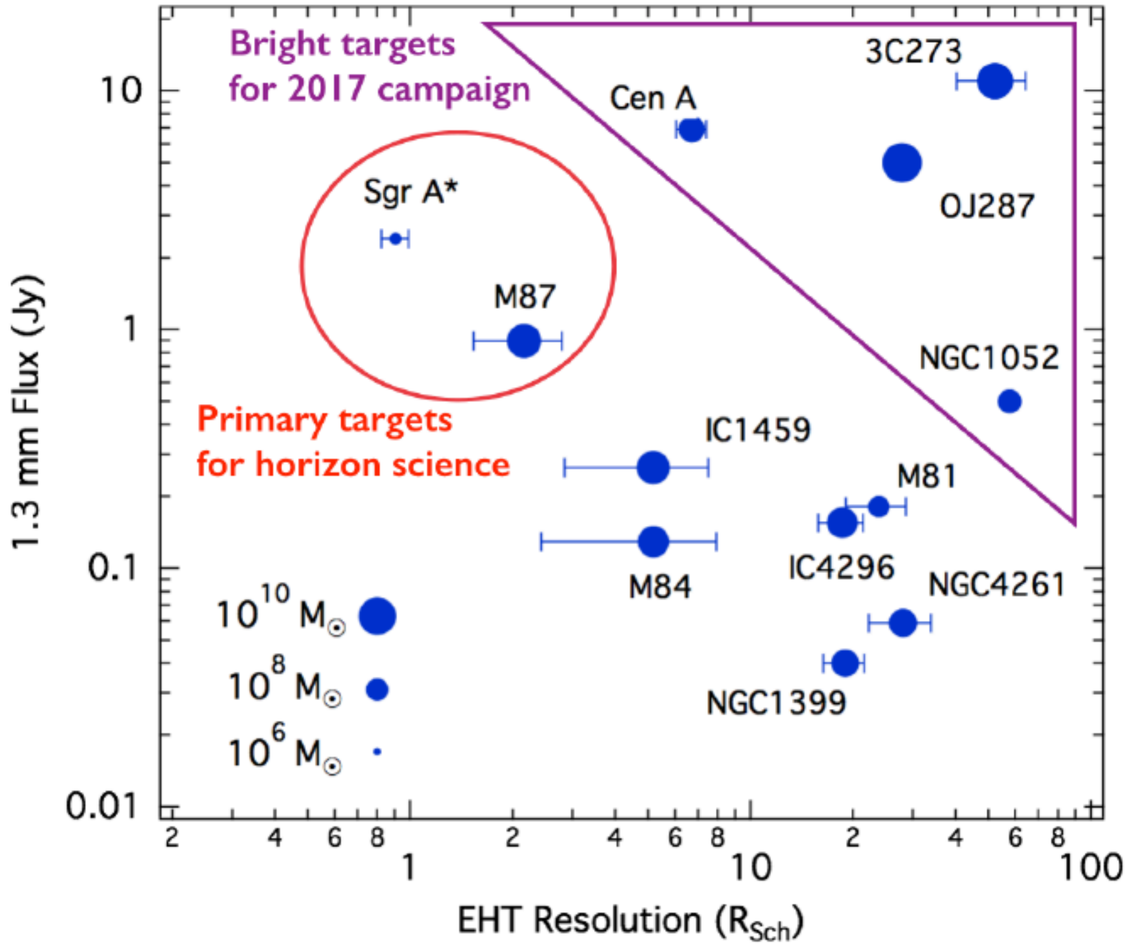
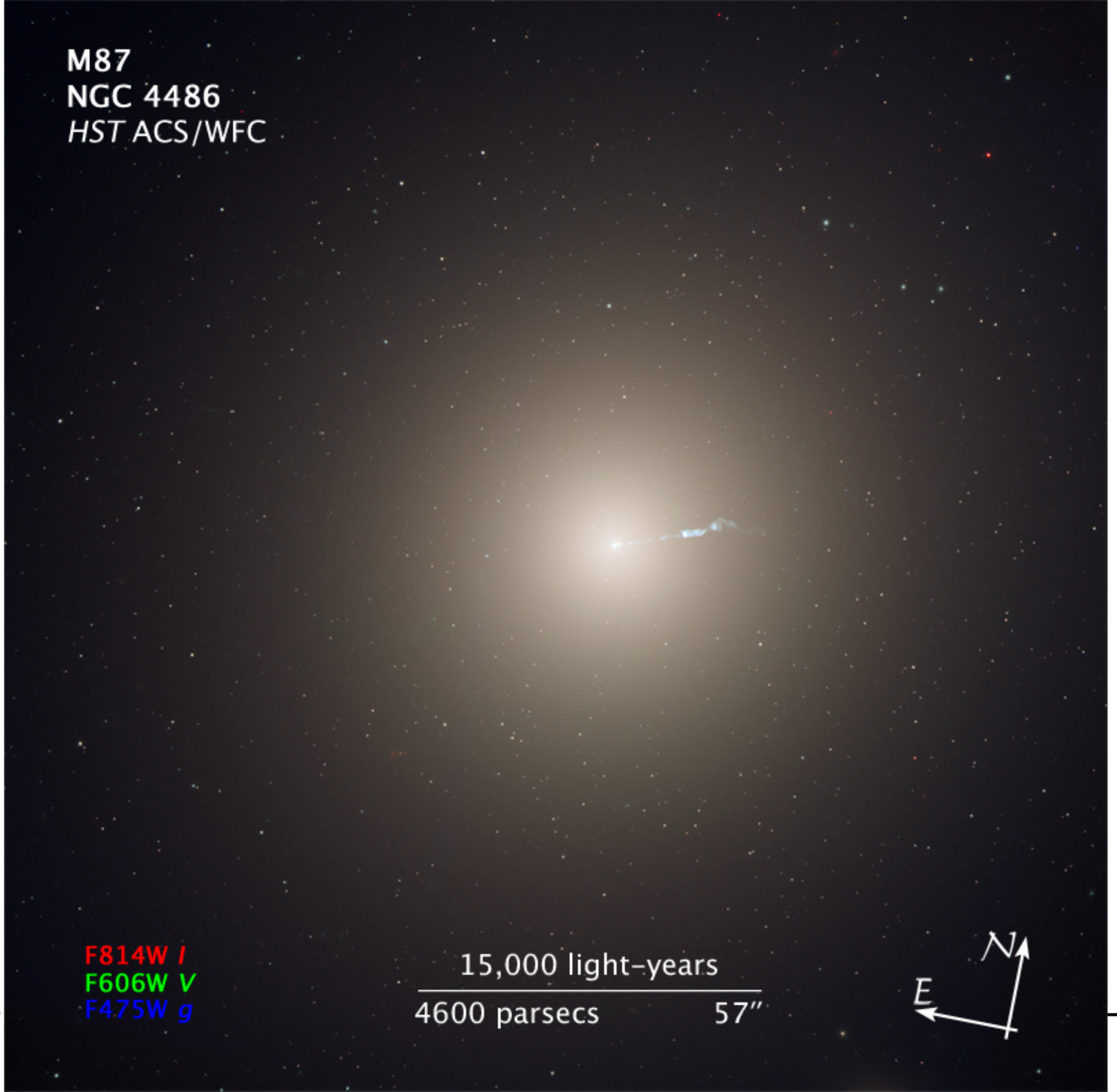
The Largest Black Holes on the Sky



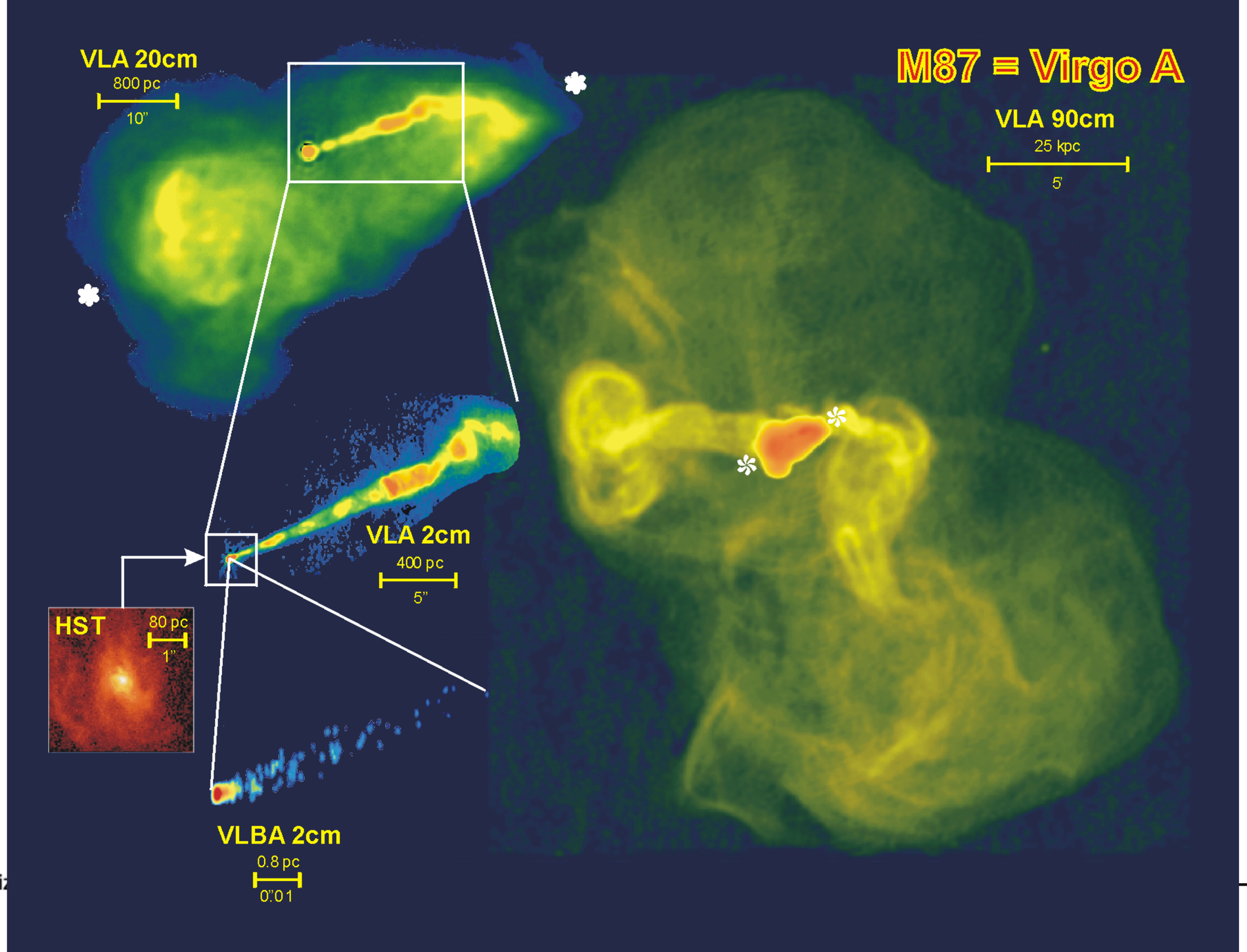
3C 279
1700 R_S

Event Horizon Telescope

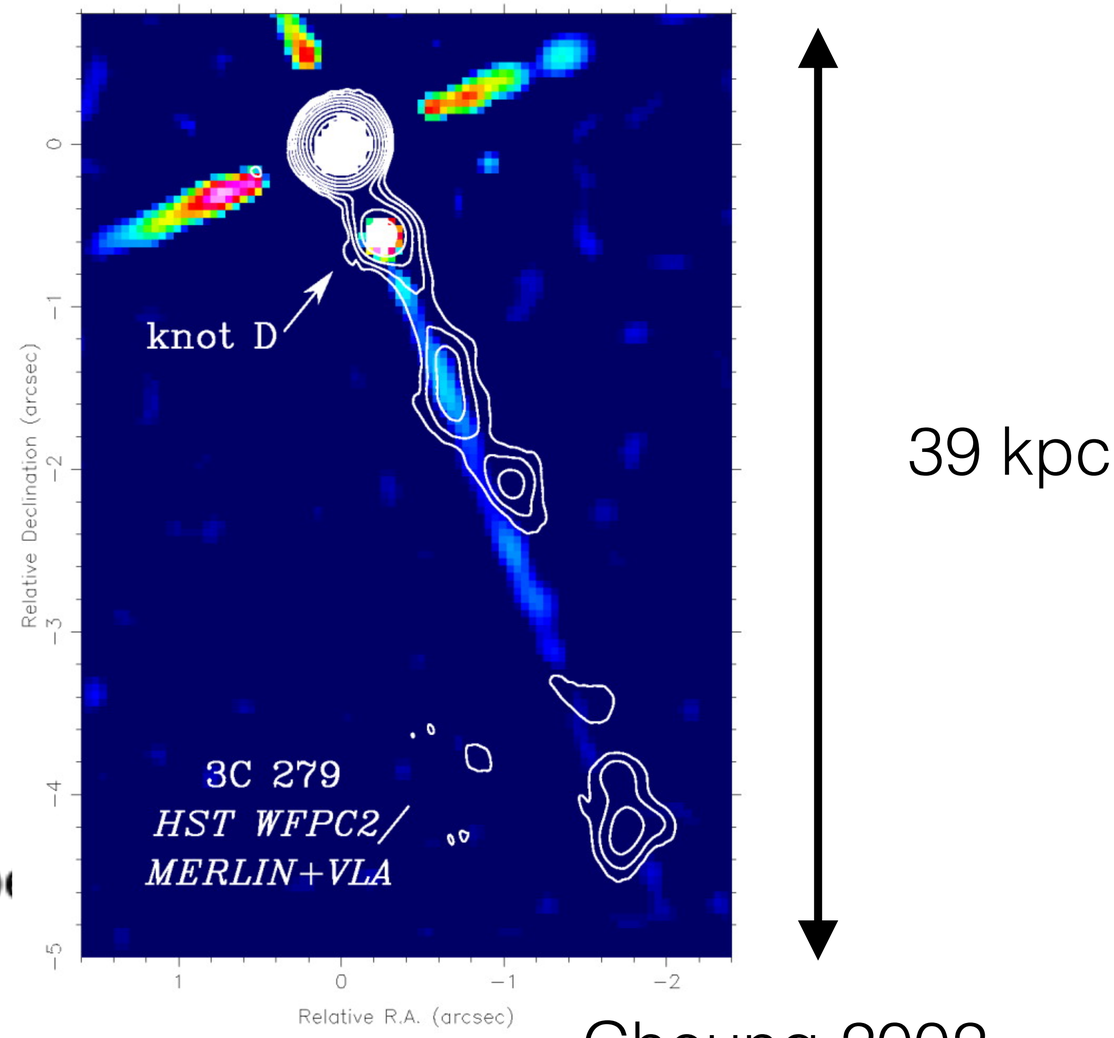


Curtis 1918

Event Horizon Telescope


M87 = Virgo A
VLA 90cm
25 kpc
5'
VLA 20cm
800 pc
10"
VLA 2cm
400 pc
5"
HST
80 pc
1"
VLBA 2cm
0.8 pc
0".01

Jet in 3C 279



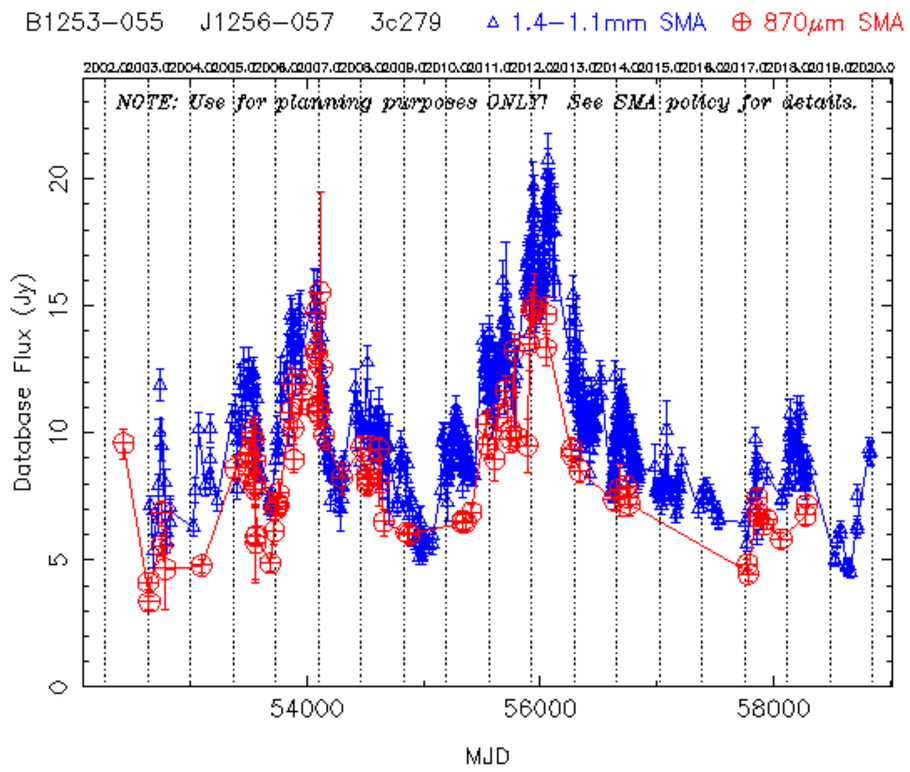
39 kpc

Event Horizon Telescop

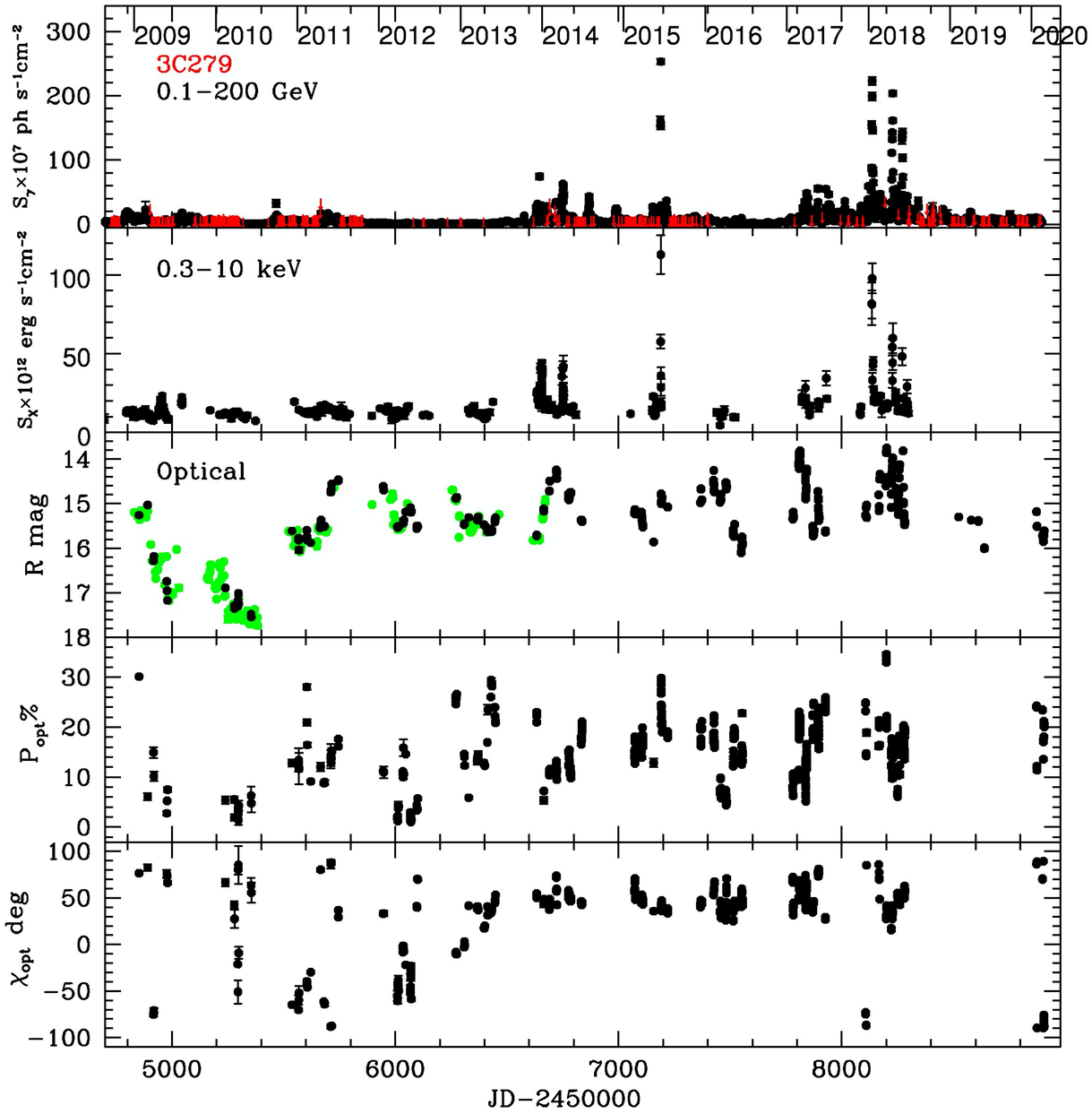
Cheung 2002

	Sgr A*	M87	3C279
Black Hole Mass (M_{sun})	4.1 x 10^6	6.5 x 10^9	8 x 10^8
Redshift		0.00428	0.536
Distance (Angular diameter)	8.0 kpc	17 Mpc	1.4 Gpc
Length Scale at 20 μas	0.2 AU ~2 R_S	0.0017 pc ~2 R_S	0.13 pc ~1700 R_S
X-ray Luminosity (erg s^{-1})	10^{35}	4 x 10^{40}	10^{46}
Jet Inclination Angle	?	17 deg	~2 deg

A Highly Variable Source



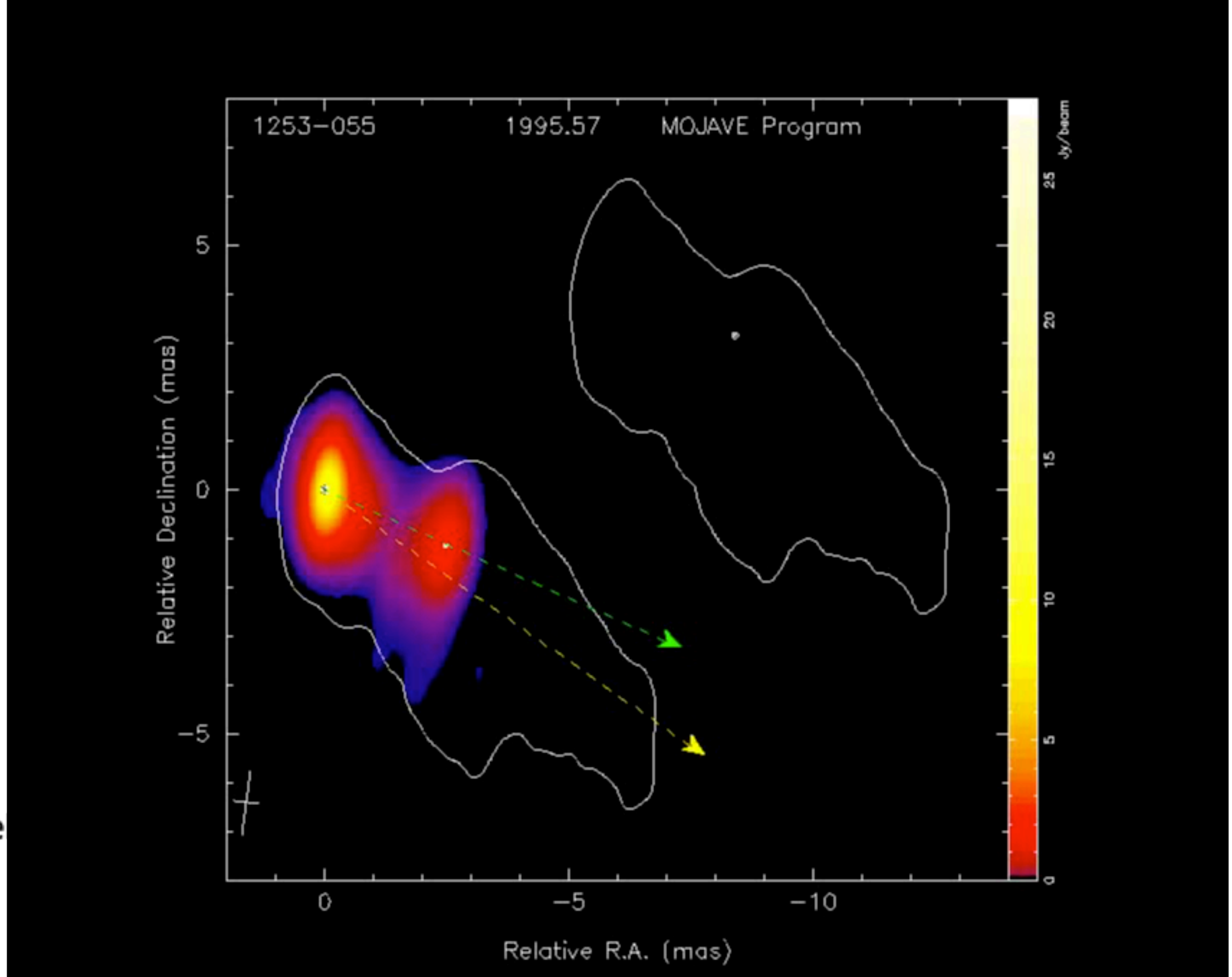
SMA: Gurwell et al



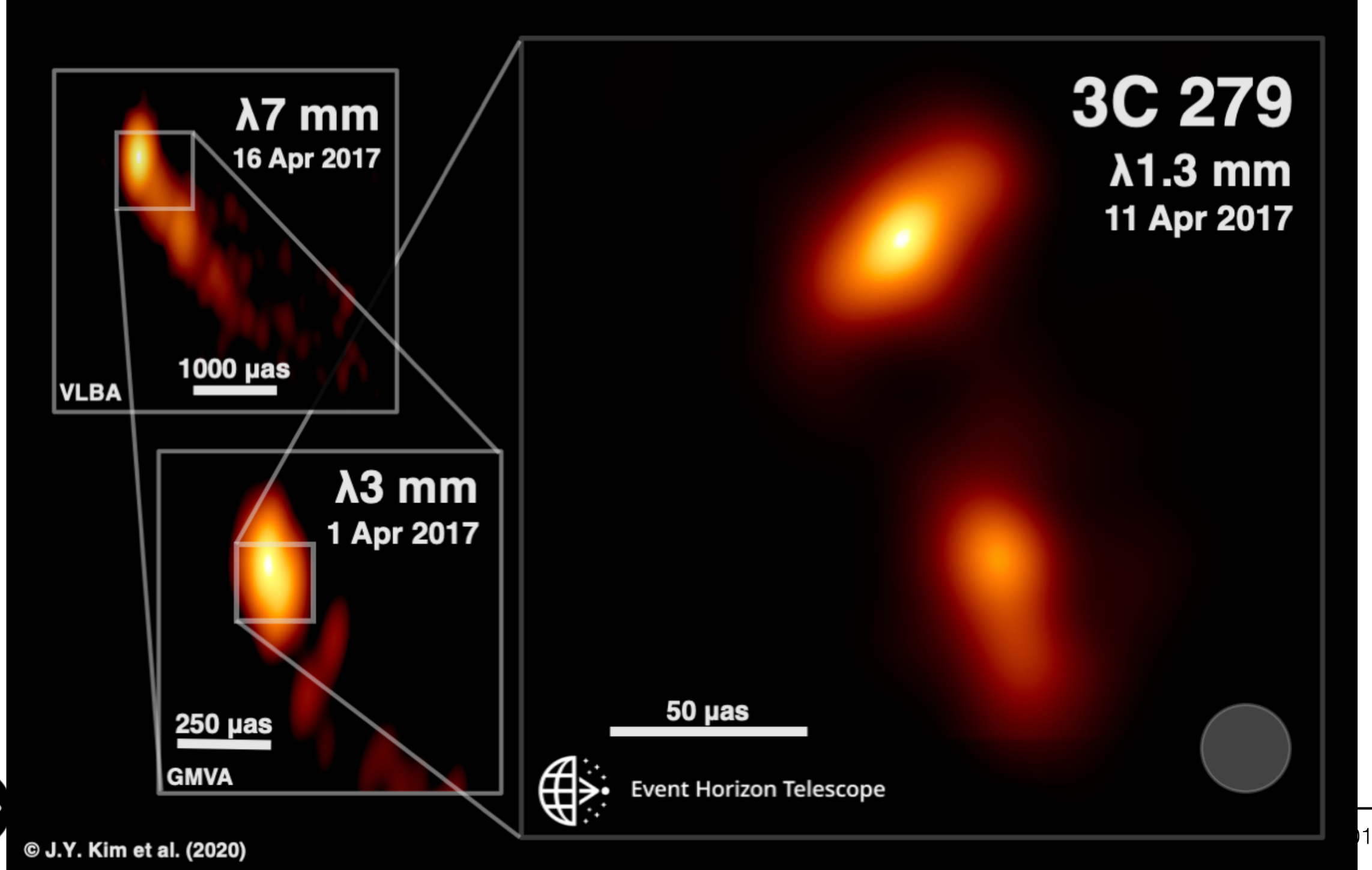
BU Blazar Group: Marscher et al

A Dynamic Jet

15 GHz
VLBA
MOJAVE Program
Lister et al



Event Horizon Te


λ7 mm
16 Apr 2017
1000 μas
VLBA
λ3 mm
1 Apr 2017
250 μas
GMVA
3C 279
λ1.3 mm
11 Apr 2017
50 μas
Event Horizon Telescope
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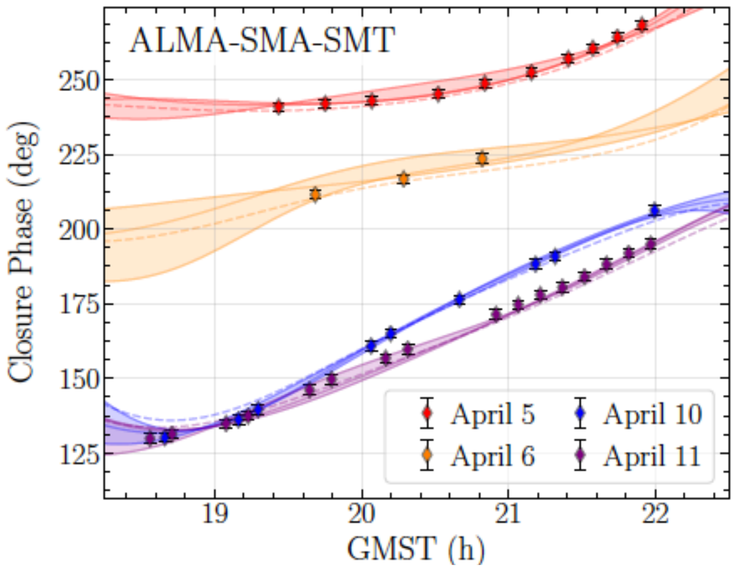
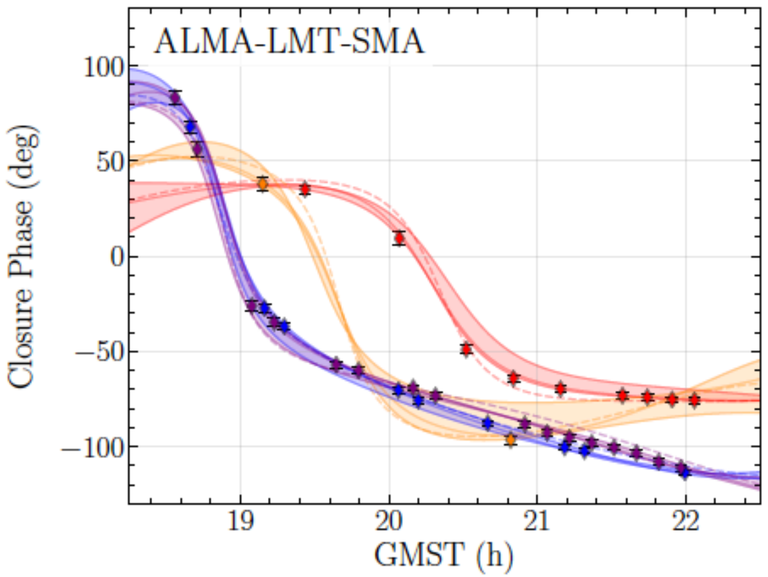
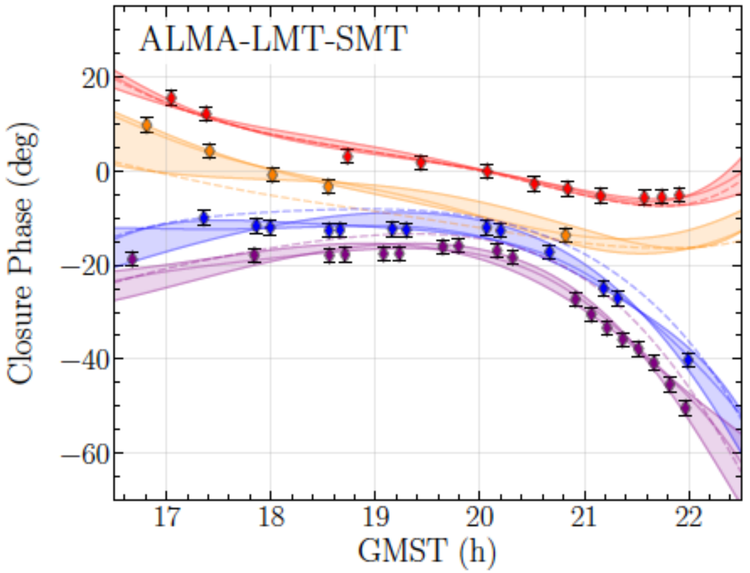
Time Variable Structure

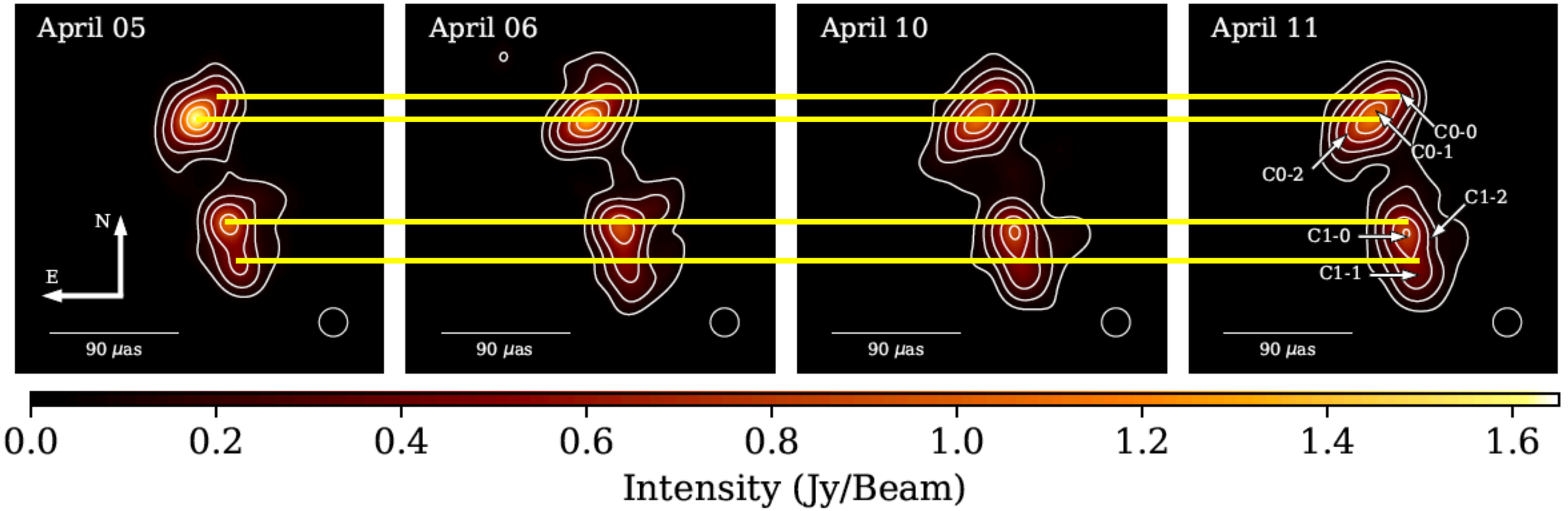






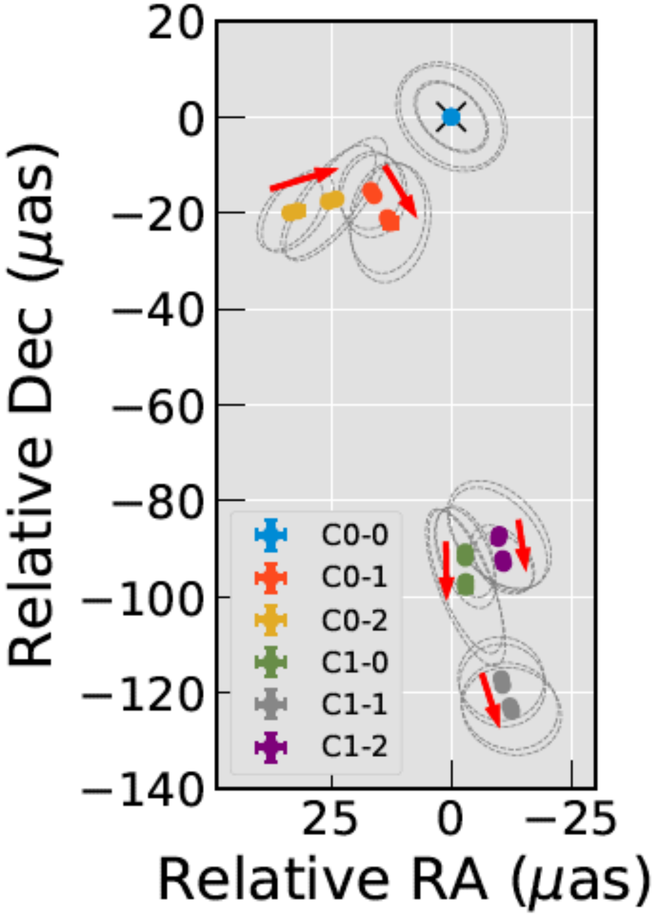
Event Horizon Telescope

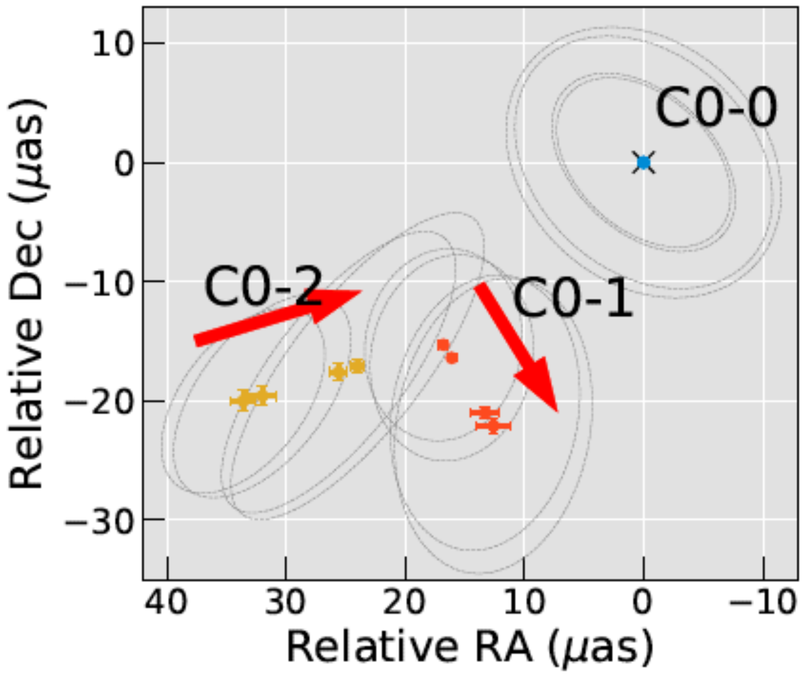
Daily Images

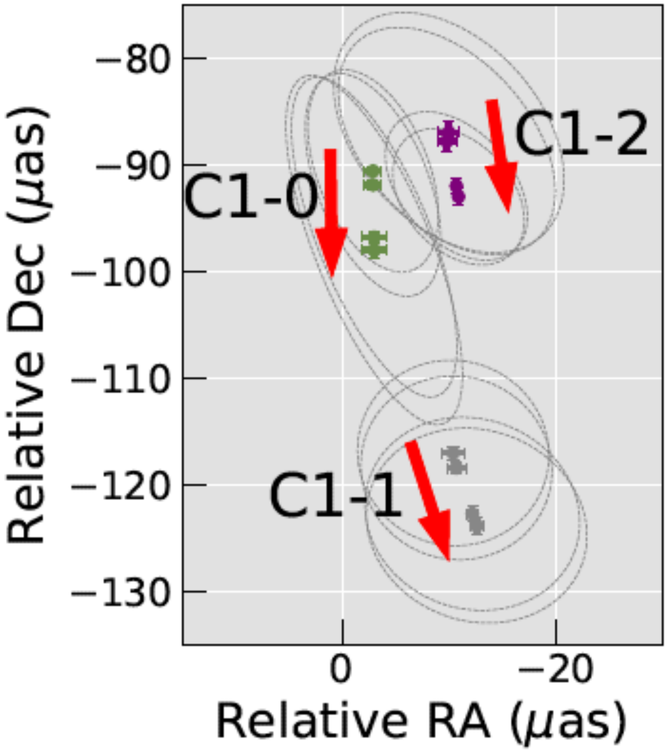


Event Horizon Telescope

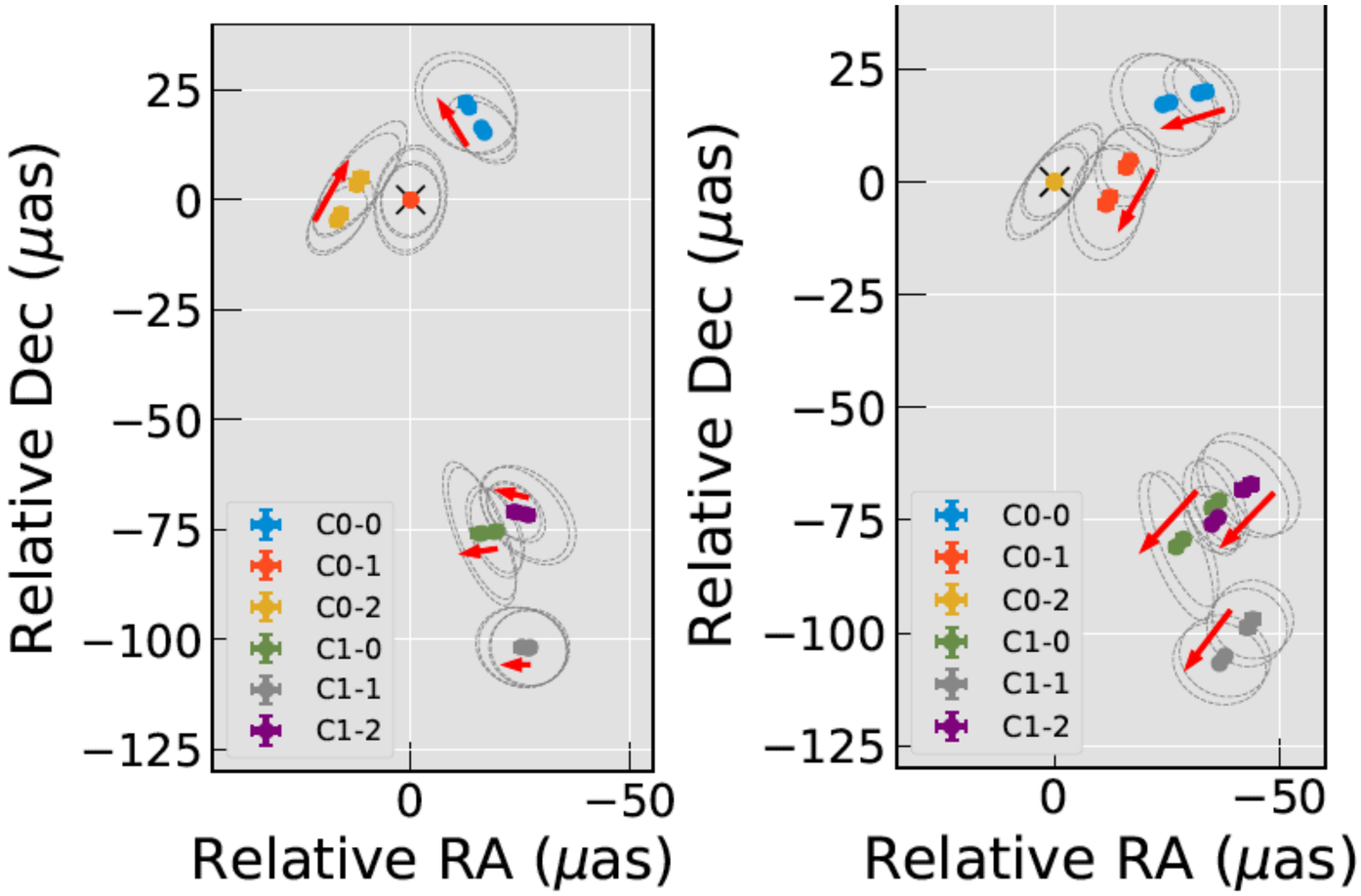
Relative Motions







Alternate Models of Motion



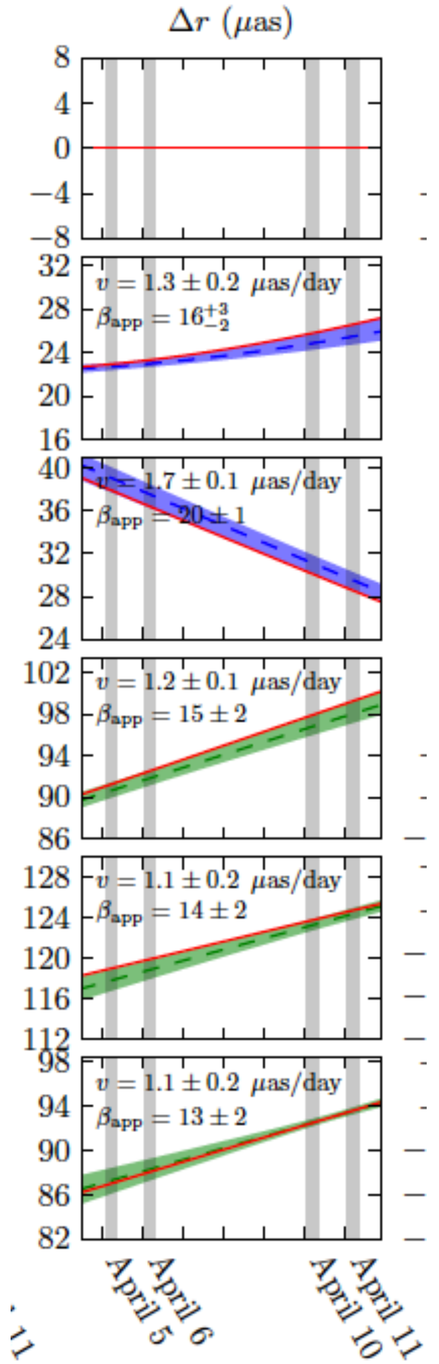
Event H

Superluminal Motion

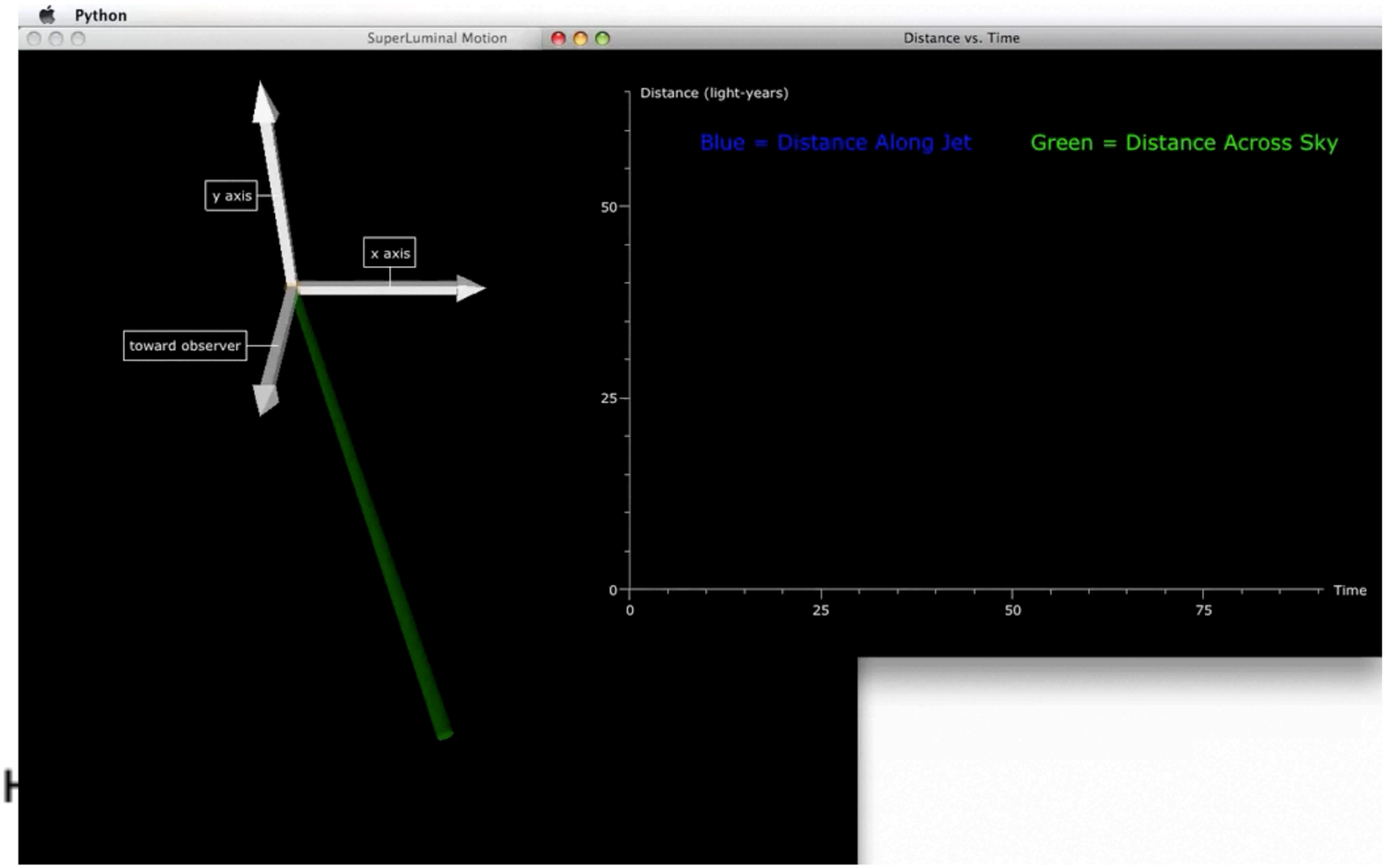
ID	β_{app} (c)	θ (°)	Γ	δ
Curved jet case[a]				
C0-1	16^{+3}_{-2}	≤ 1.5	≥ 20	≥ 32
C0-2	20 ± 1	≤ 2.9	≥ 20	≥ 20
C1-0/1/2	$(13-15) \pm 2$	$\geq 6-8$	≥ 20	$\leq 5-7$
Straight jet case[b]				
C1-0/1/2	$(13-15) \pm 2$	2	$16-17$	$24-25$

$\Gamma>20 \rightarrow v > 0.998\ c$

Event Horizon Telescope



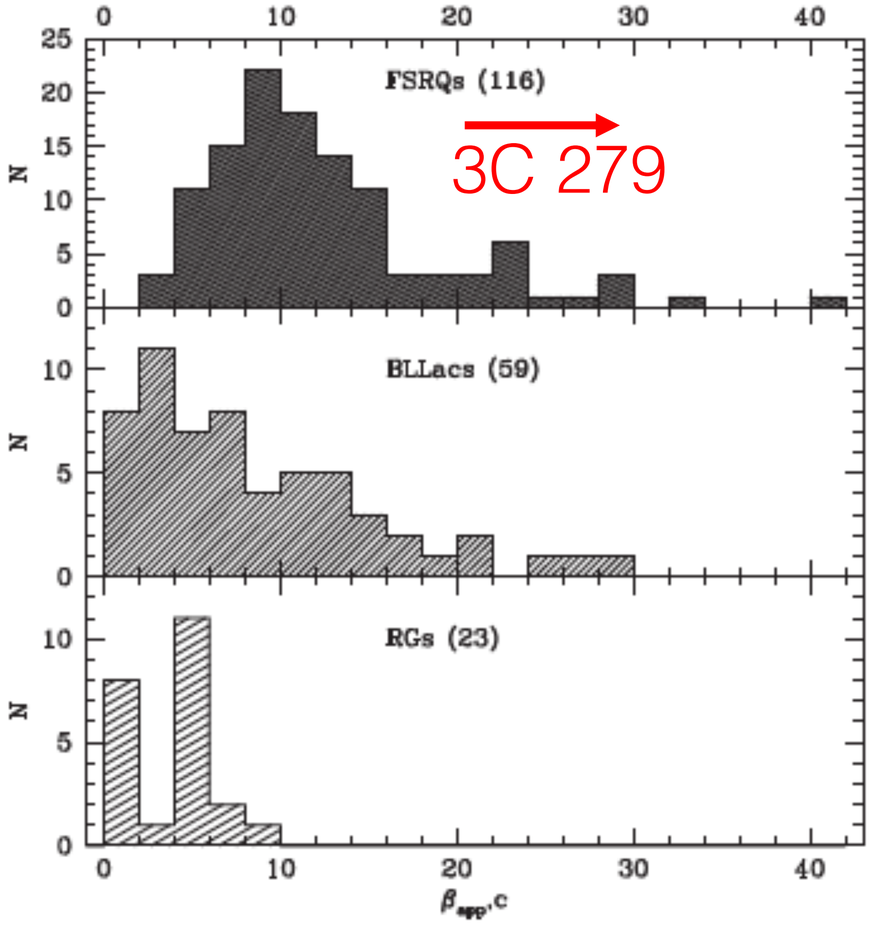
Superluminal Motion Demo



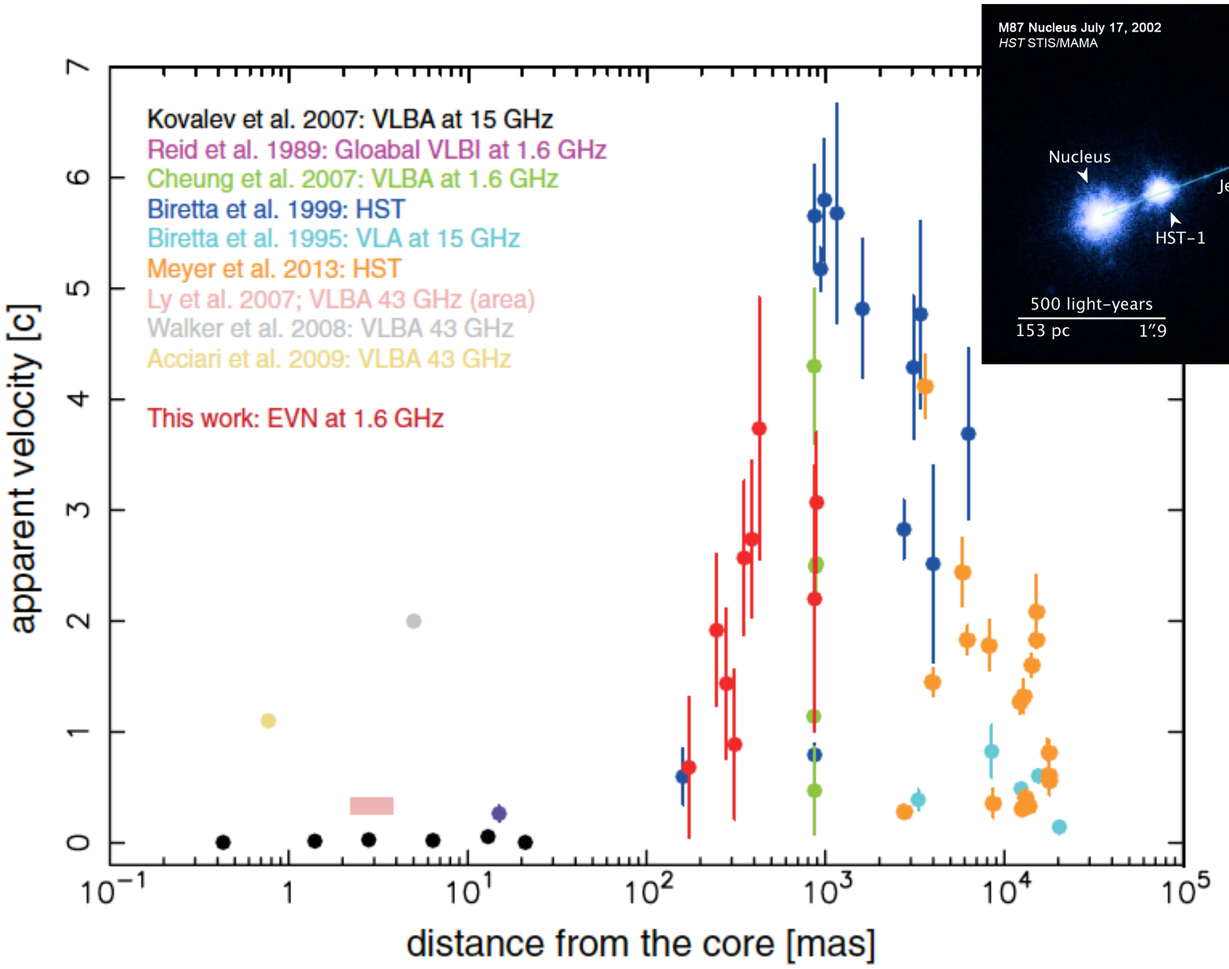
Event H

Dan Homan

Superluminal Motion Distribution

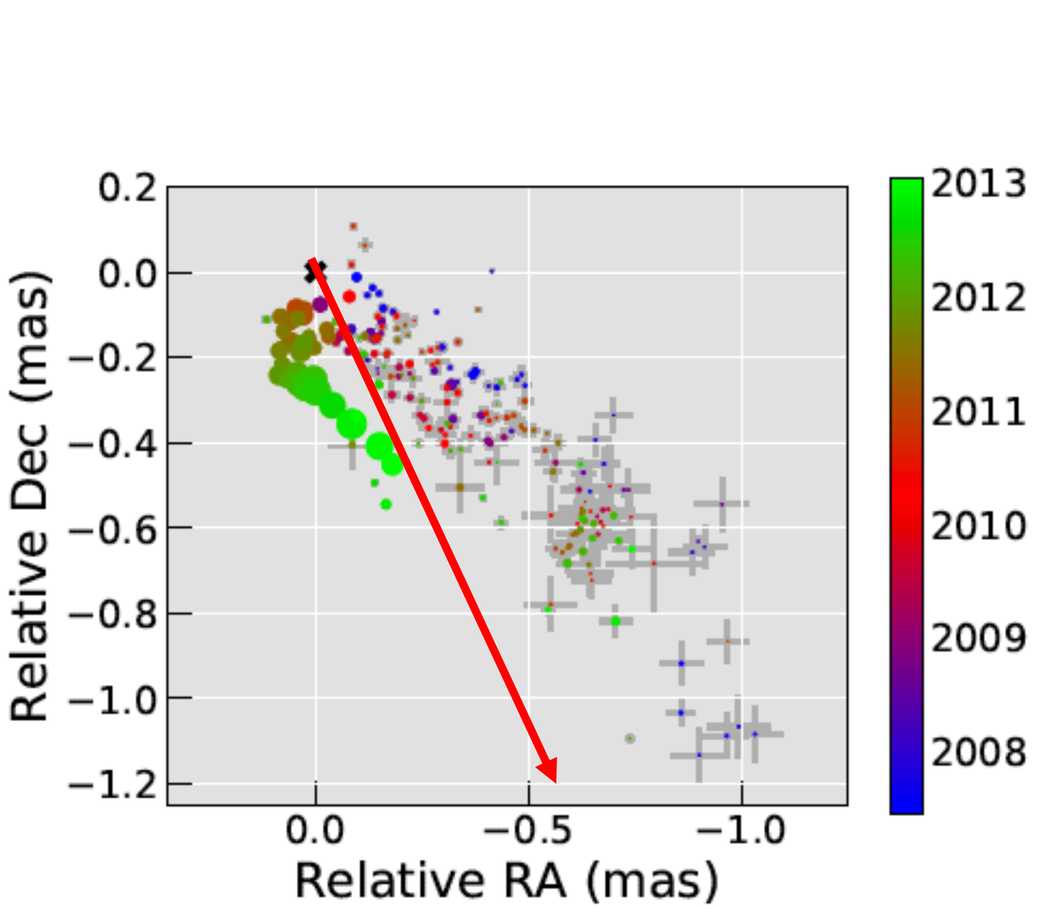


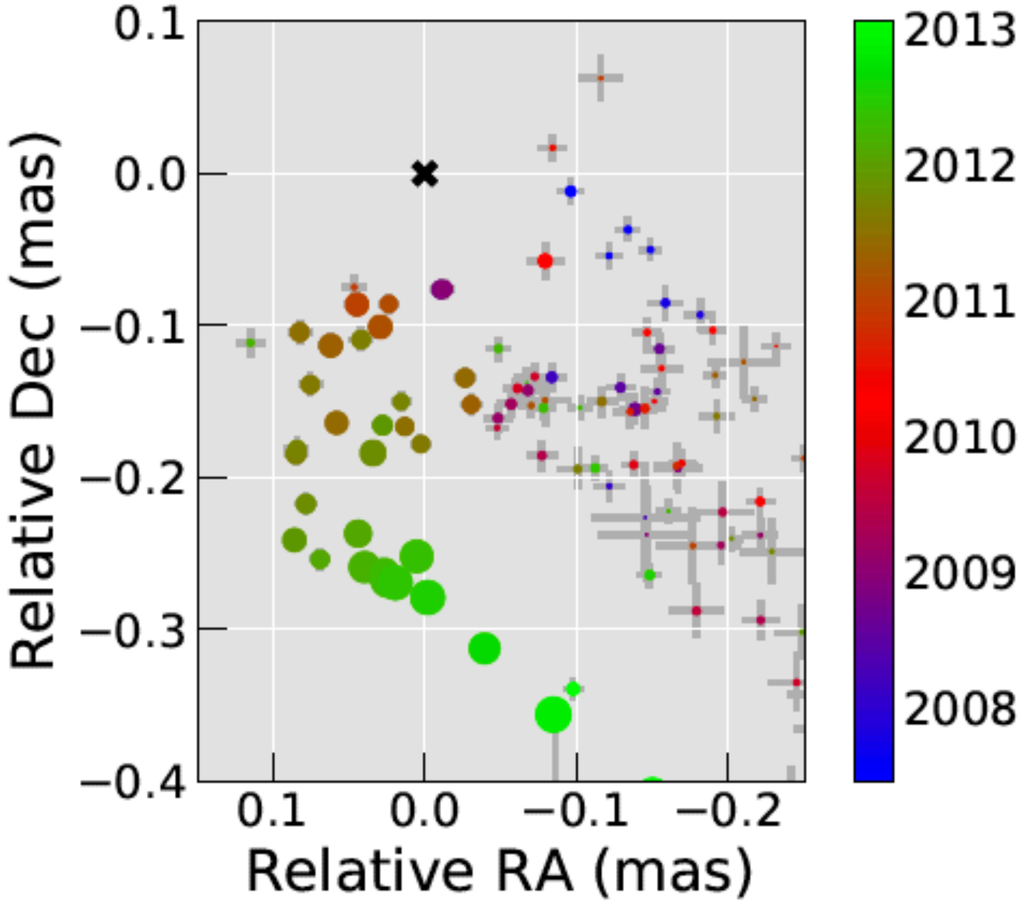
43 GHz VLBA: Jorstad et al 2017



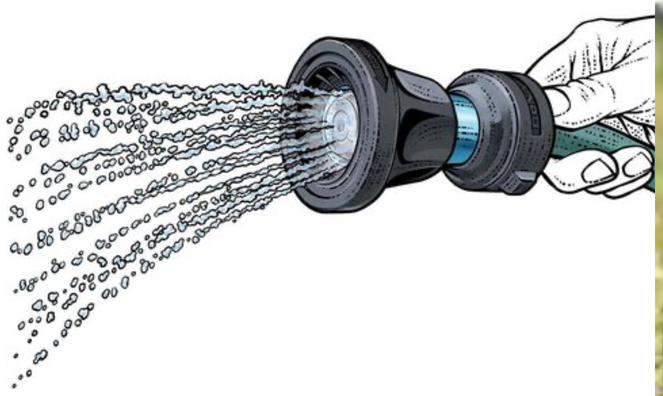
M87: Asada et al 2013

Historical Jet Bending



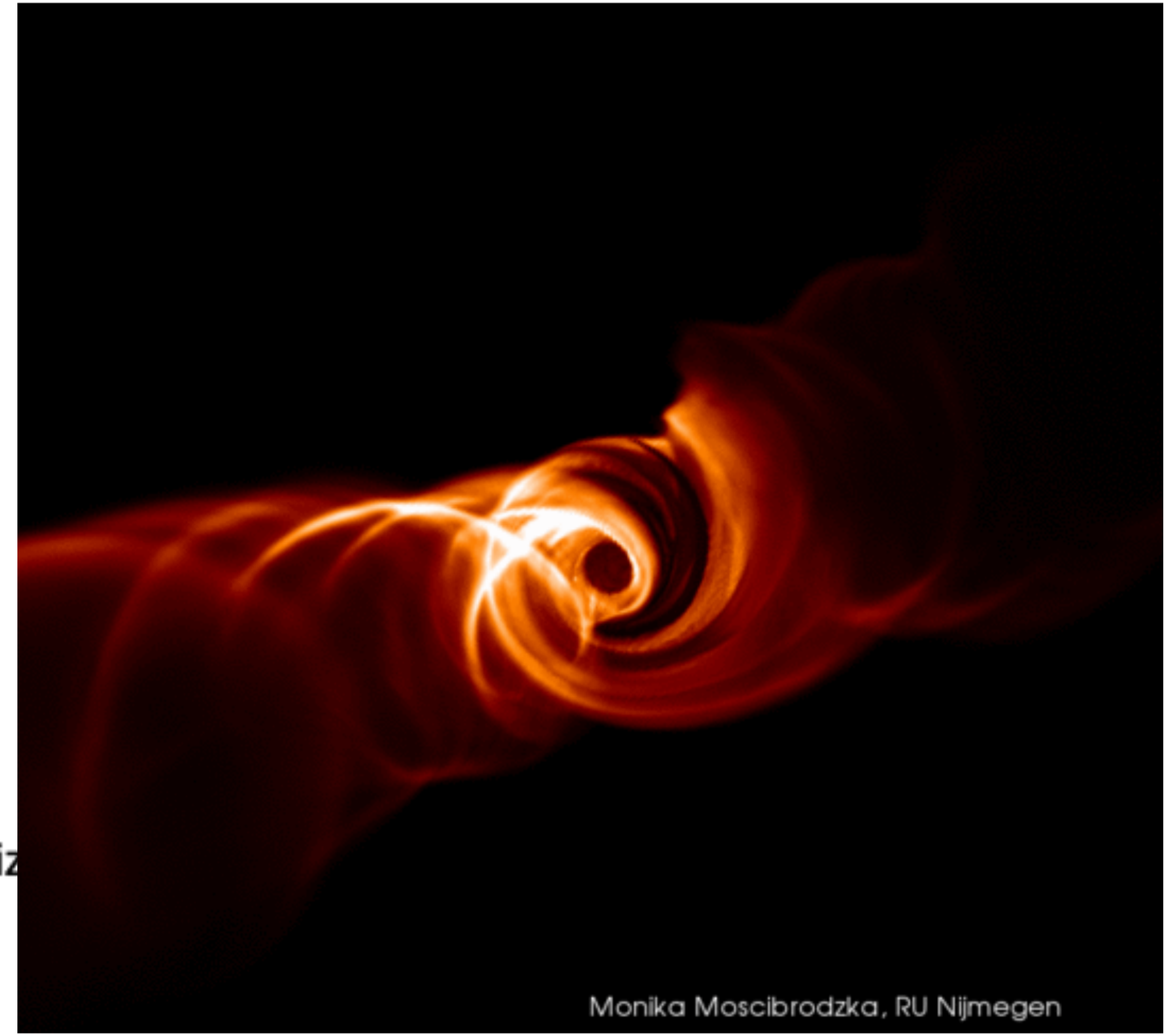


Models for the Bend



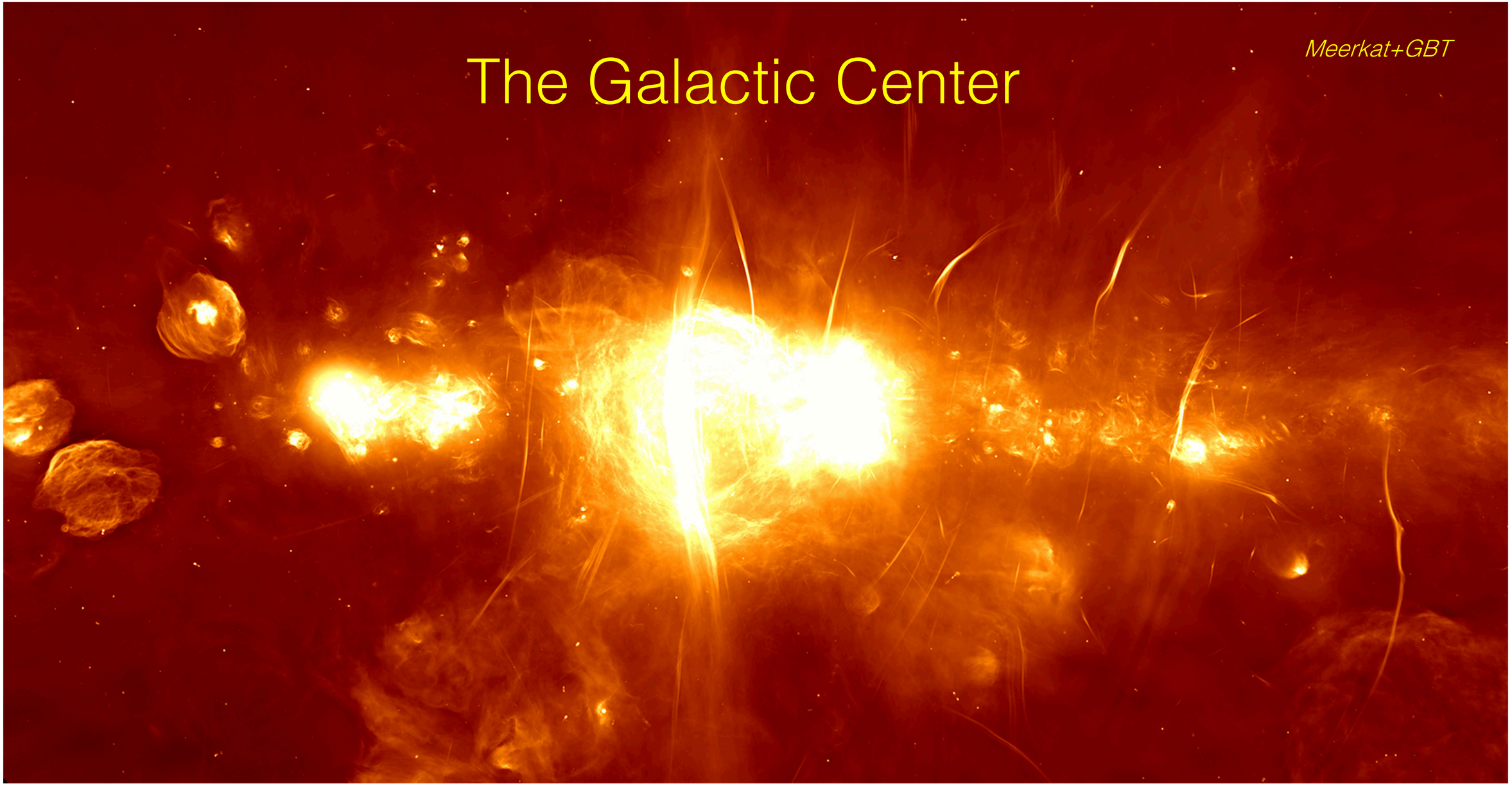
Event Horizon Telescope

Jet Simulation

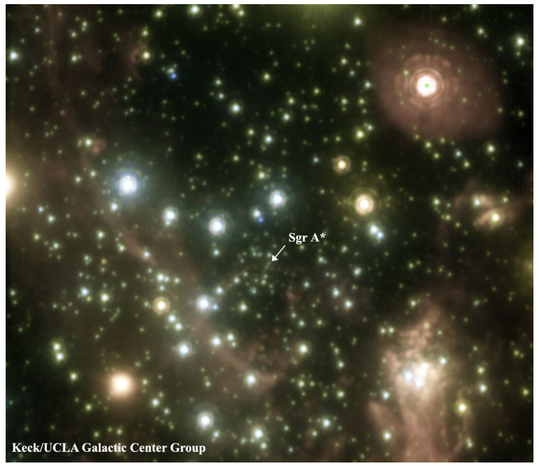


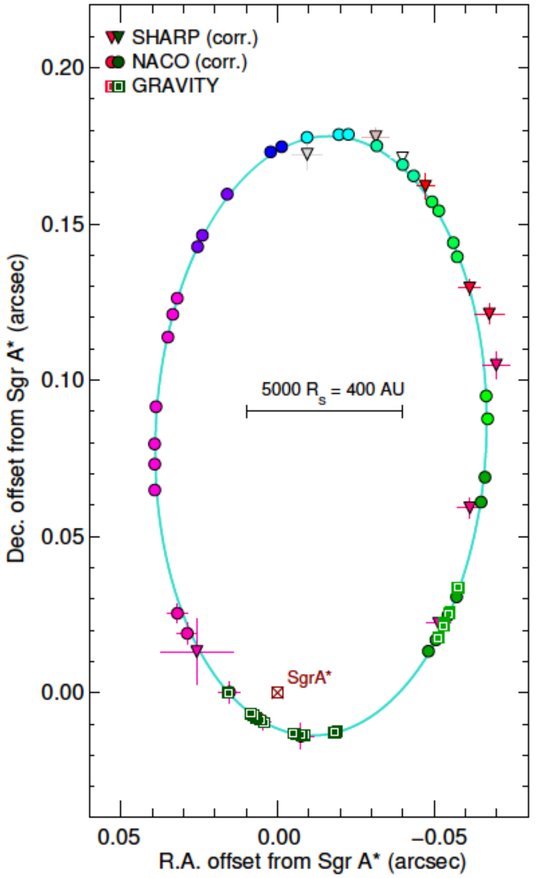
Event Horiz

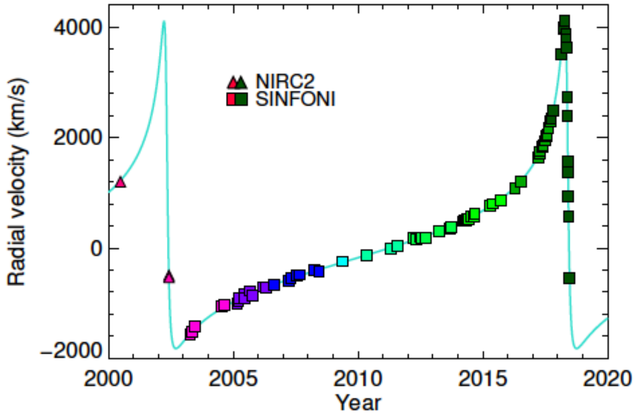
The Galactic Center

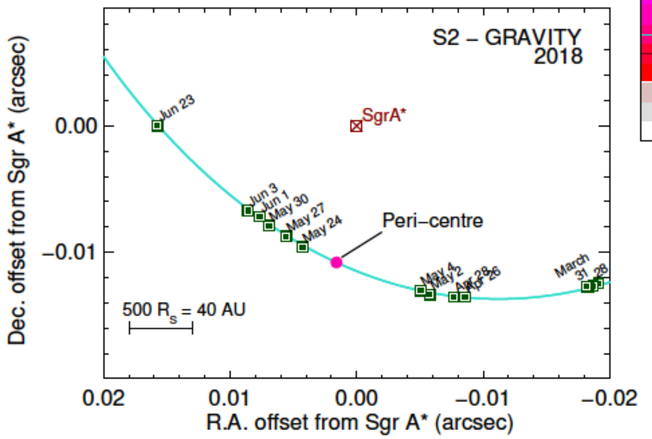


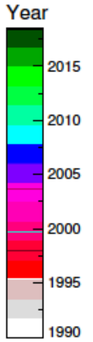
Strong Evidence for a Black Hole

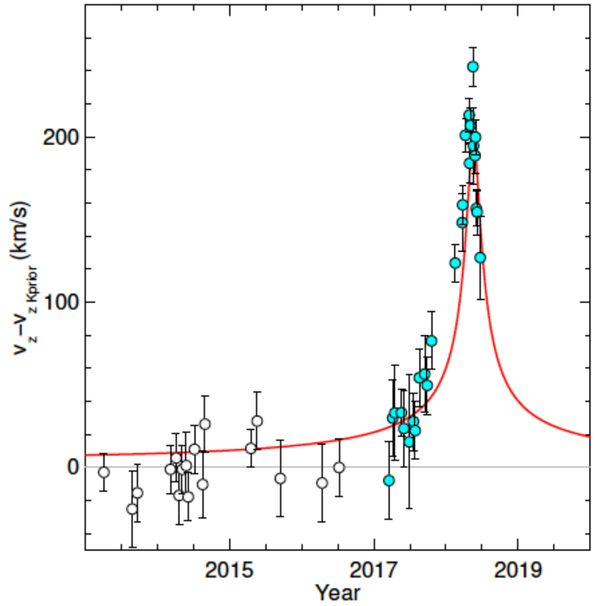


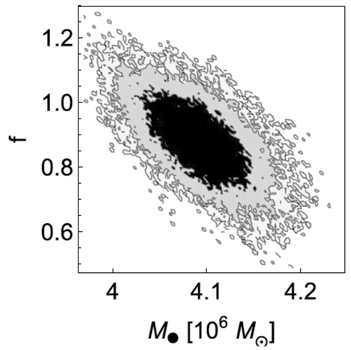


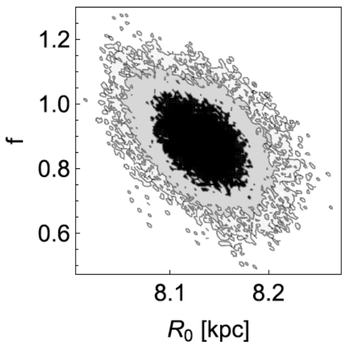








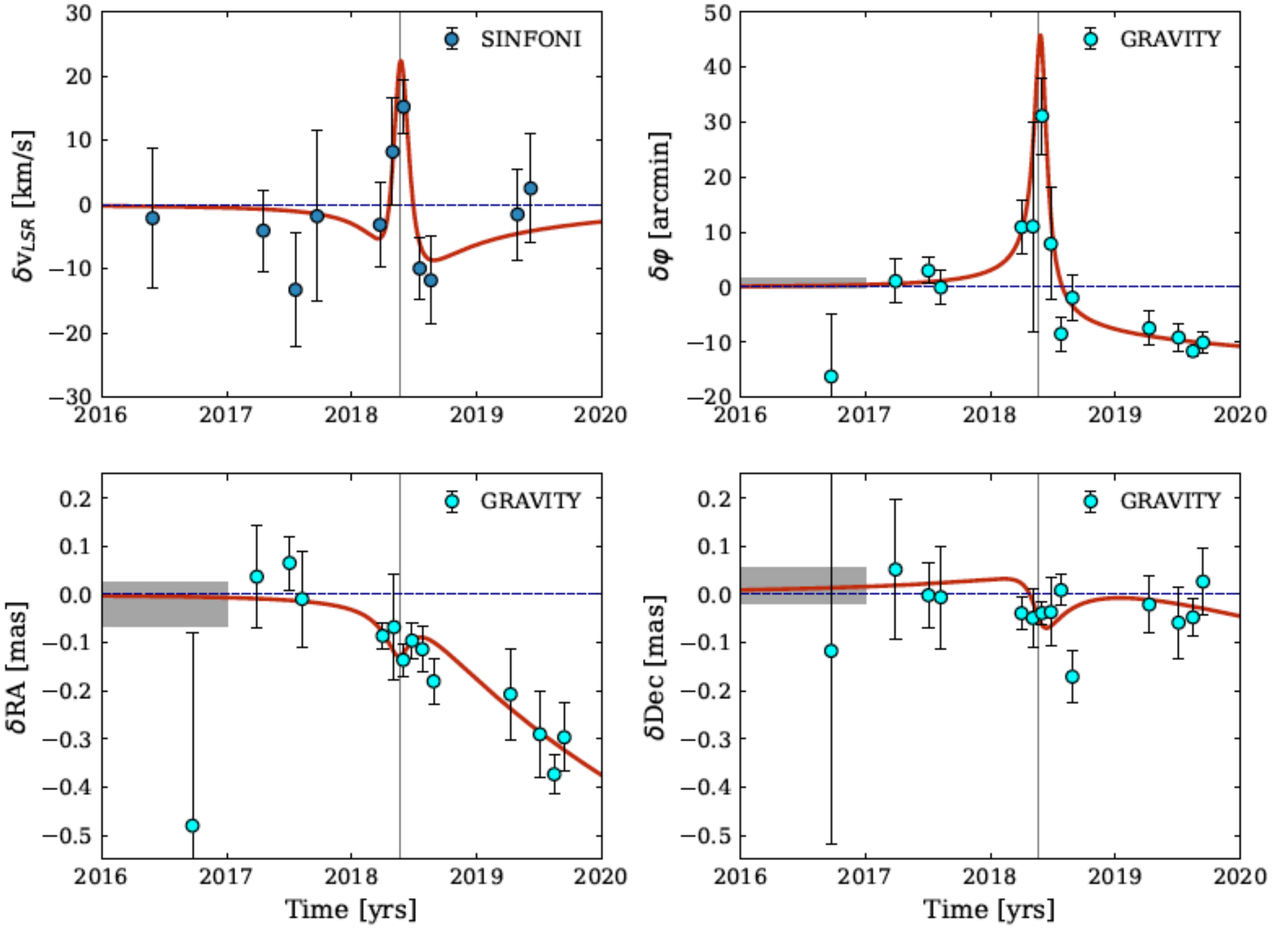


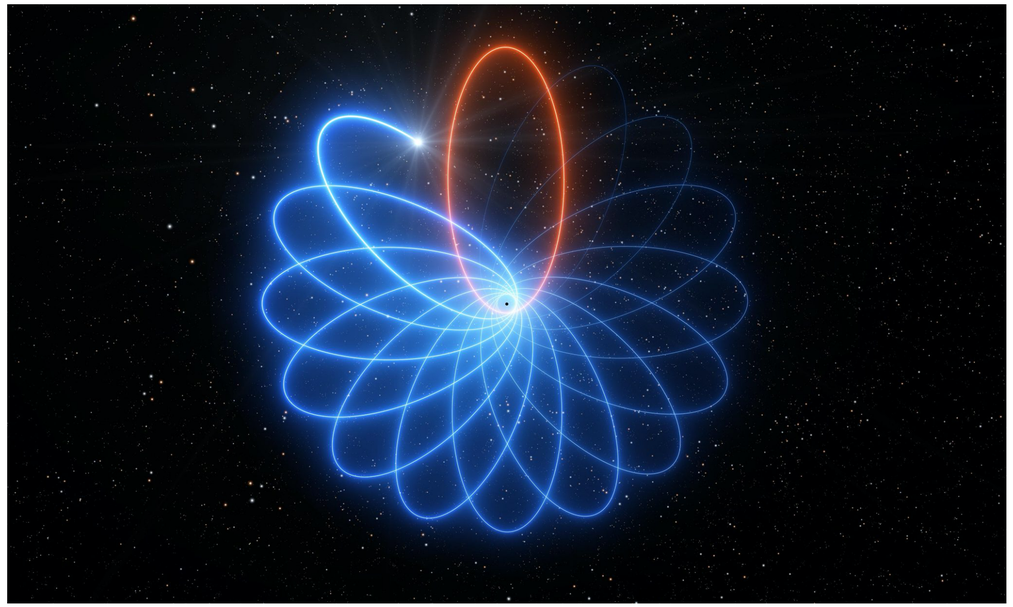


GRAVITY Collaboration 2018

Event Horizon Telescope

Schwarzschild Precession

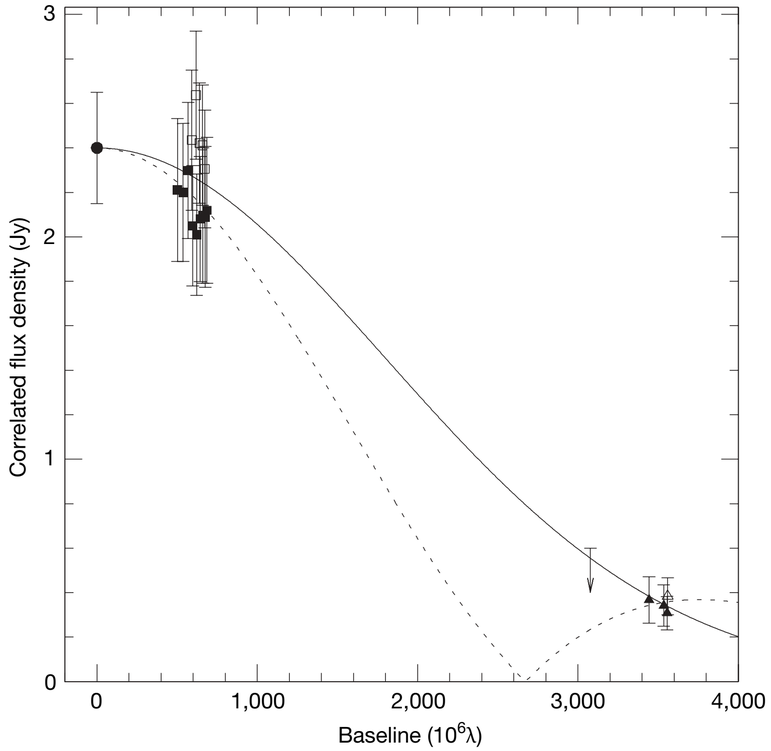


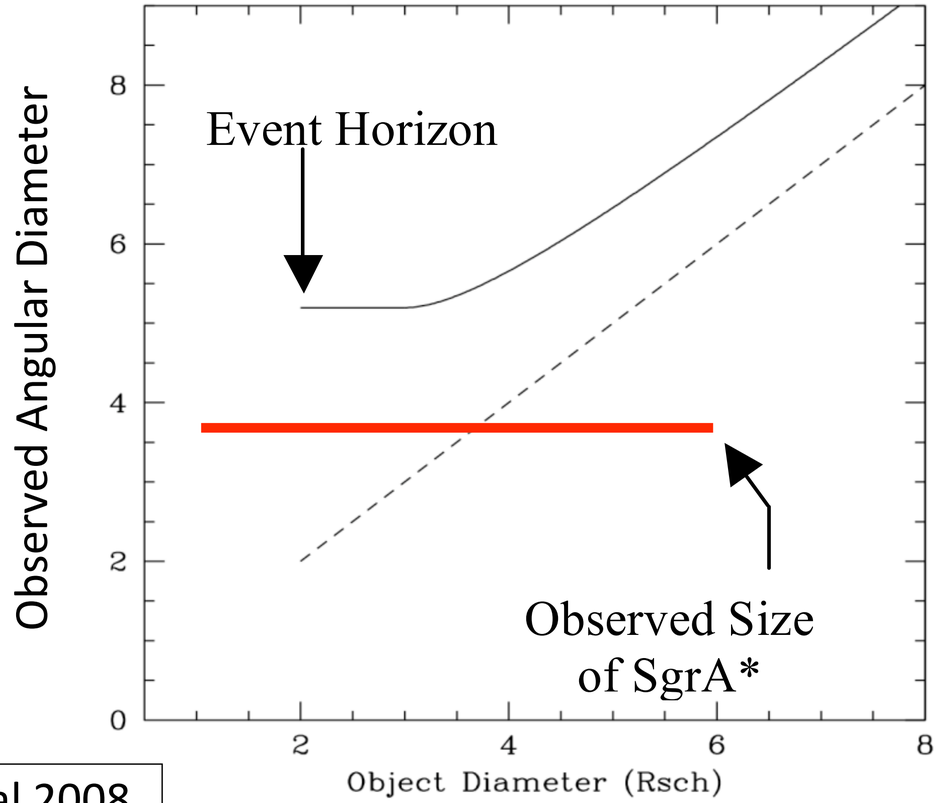


S2: 12’/orbit
Mercury: 43”/century

GRAVITY Collaboration 2020

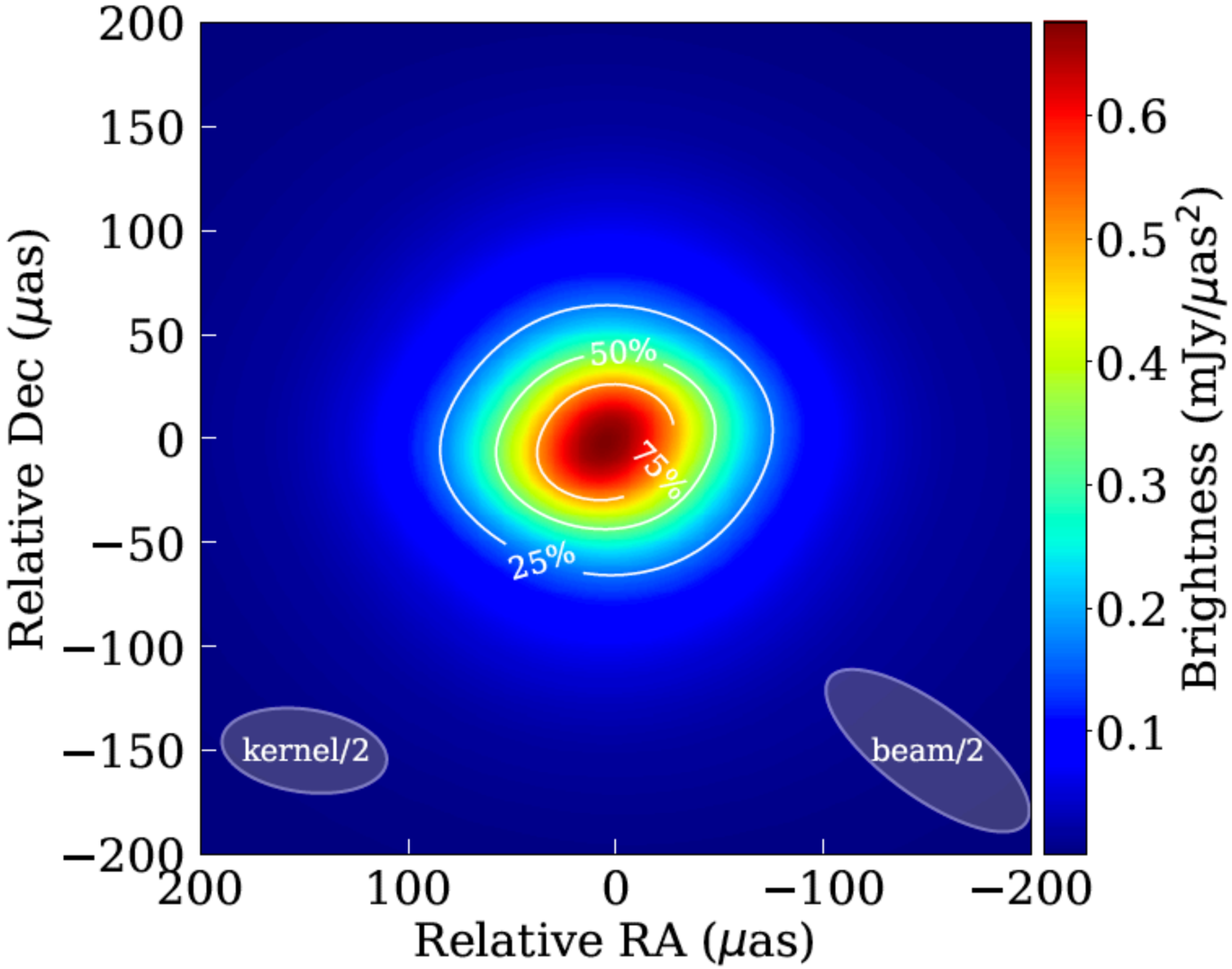
MM VLBI Imaging of Sgr A*





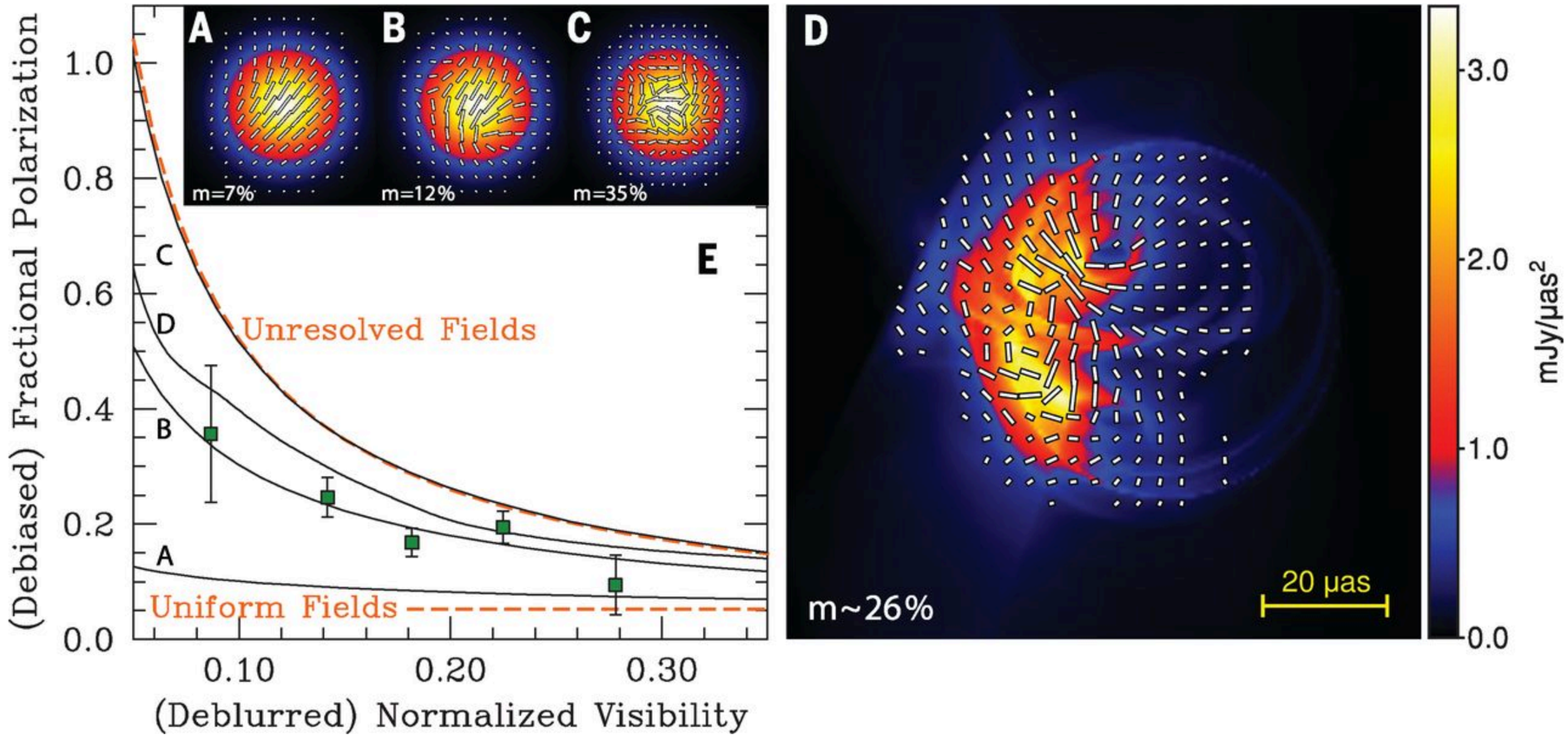
Doeleman et al 2008

The Current State of the Art



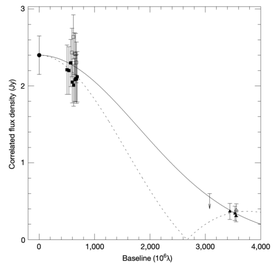
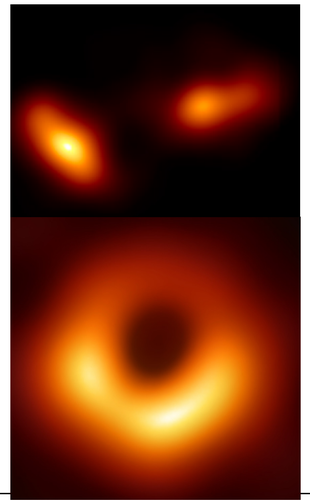
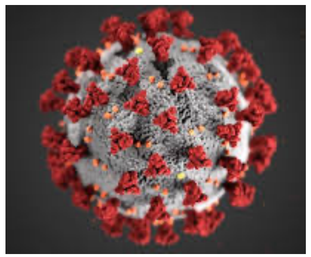
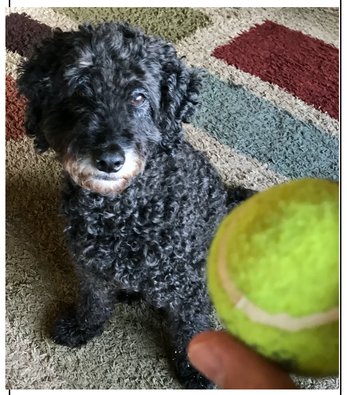
Issaoun et al 2019

EHT Polarization of Sgr A*



Johnson et al 2015

EHT Campaigns

	<2017	2017	2018	2019	2020	2021
Stations	SMT, CARMA, SMA, JCMT APEX	SPT, ALMA, APEX, SMA, JCMT, LMT, SMT, PV	SPT, ALMA, APEX, SMA, JCMT, LMT, SMT, PV, GLT	SPT, ALMA, APEX, SMA, JCMT, LMT, SMT, PV, GLT	SPT, ALMA, APEX, SMA, JCMT, LMT, SMT, PV, GLT, KP, NOEMA	SPT, ALMA, APEX, SMA, JCMT, LMT, SMT, PV, GLT, KP, NOEMA
Bandwidth		32 Gbps	64 Gbps	64 Gbps	64 Gbps	64 Gbps
Results						

EHT Future

- Sgr A*!
- Polarimetry
- AGN, Pulsars
- 2018 & 2021 Epochs
- Multi-wavelength Data
- Movies
- Higher image fidelity
- More sources