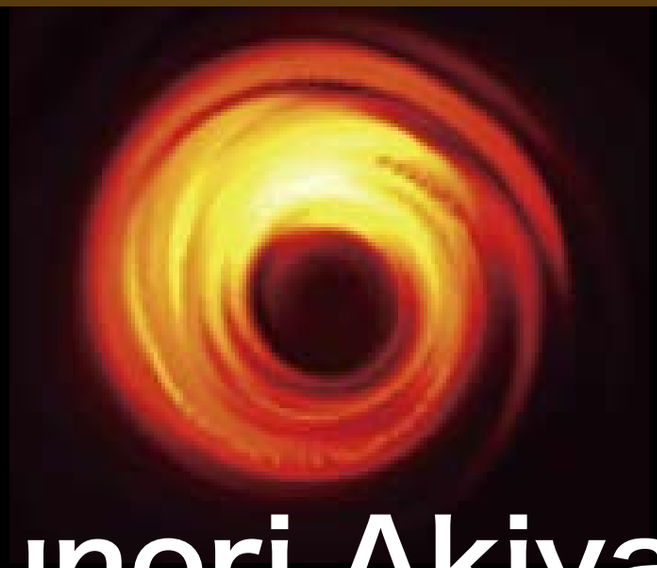
New Event Horizon Telescope Observations of M87 in 2012 (Akiyama et al. 2015, ApJ, 807, 150)

+ Sparse imaging of the event-horizon-scale structure

+ Scientific Impact of Nobeyama Baselines at 1.3 mm



Kazunori Akiyama

NAOJ Mizusawa VLBI Observatory

=> MIT Haystack Observatory (2015. September -)

国立天文台 NAOJ National Astronomical Observatory of Japan → MIT HAYSTACK OBSERVATORY

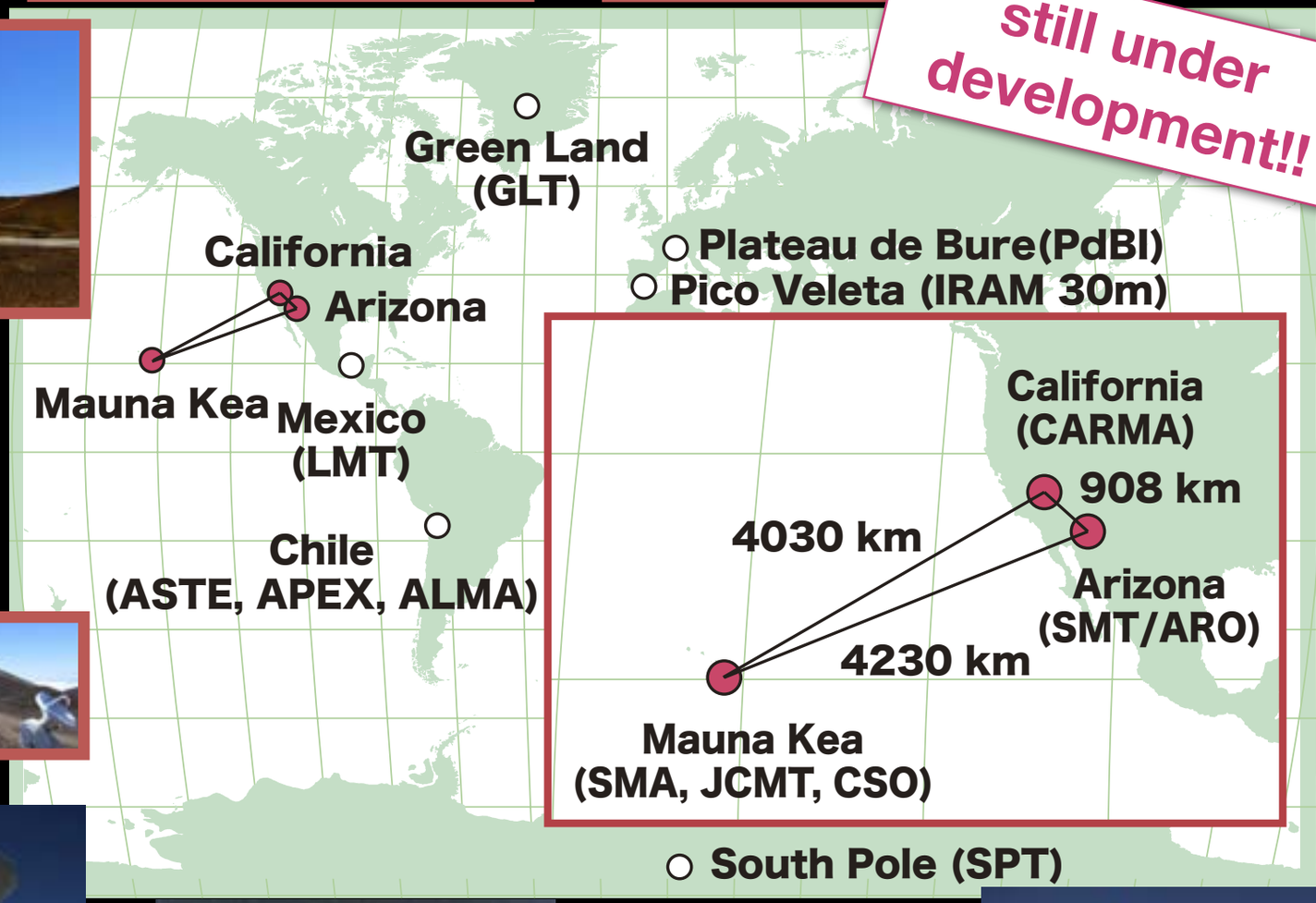
Angular radius of Super Massive Black holes

Source	BH Mass (M_{solar})	Distance (Mpc)	Angular radius of R_s (μas)
Sgr A* (Galactic Center)	4×10^6	0.008	10
M87 (Virgo A)	$3 - 6 \times 10^9$	17.8	3 - 7
M104 (Sombrero Galaxy)	1×10^9	10	2
Cen A	5×10^7	4	0.25

Shadow diameter:
several x Schwarzschild radius

Event Horizon Telescope in Early Phase (~ March 2012)

still under development!!



History of EHT: nostalgic journey to 1970s

Image I(x,y) ⟷ Compex Visibility V(u,v)

Fourier Transformation

$$V(u,v) = A(u,v)\exp(-i\,\phi(u,v))$$

Visibility Amplitude Visibility Phase

Only Amplitude

2007 Obs.

Sgr A*

(Doeleman et al. 2008, Nature)

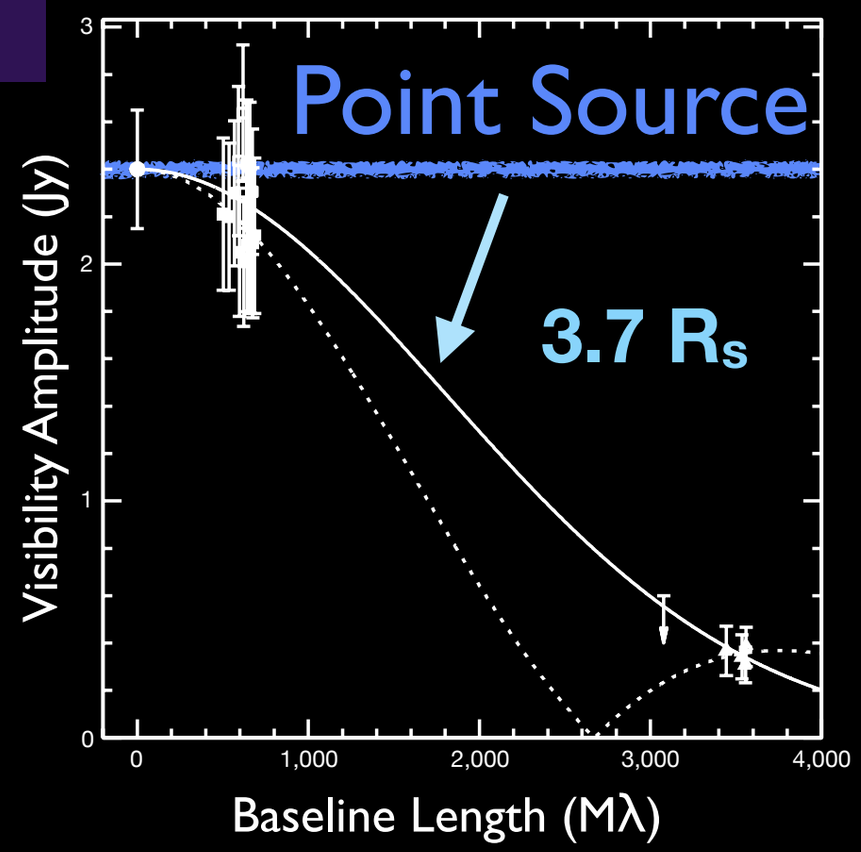
2009 Obs.

Sgr A*

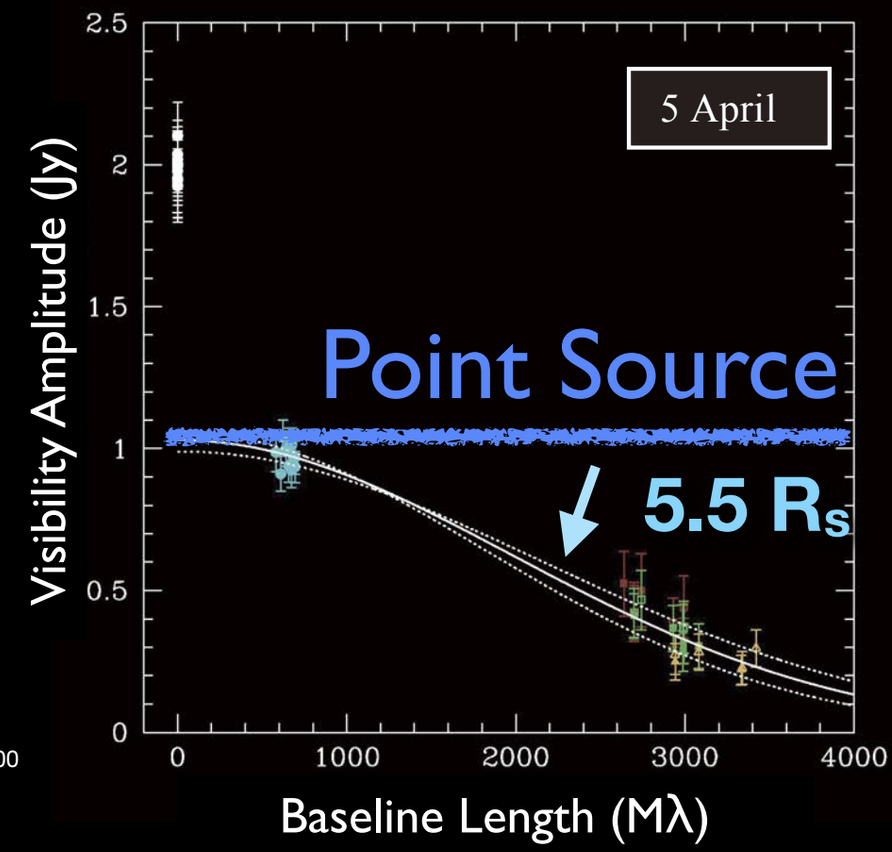
(Fish et al. 2011, ApJL)

M87

(Doeleman et al. 2012, Science)



(Doeleman et al. 2008, Nature)



(Doeleman et al. 2012, Science)

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Visibility Amplitude Visibility Phase

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2007 Obs.
Sgr A*
(Doeleman et al. 2008, Nature)

2009 Obs.
Sgr A*
(Fish et al. 2011, ApJL)

M87
(Doeleman et al. 2012, Science)

Amplitude + Closure Phase

2009 Obs.
1921-293
(Lu et al. 2012, ApJL)

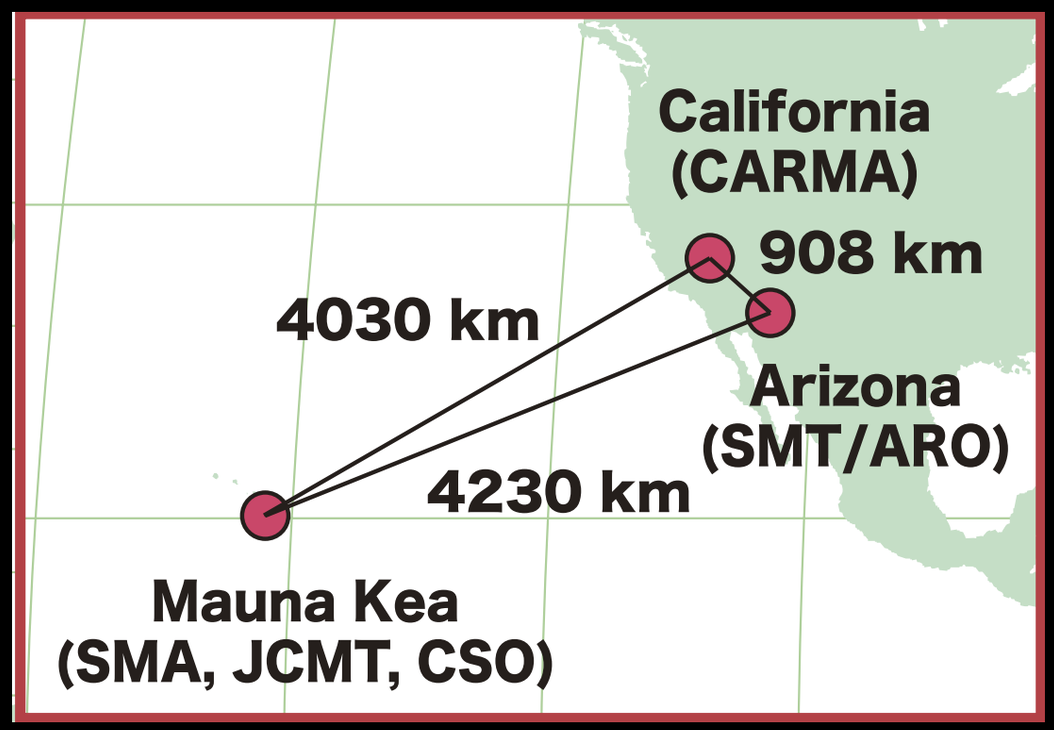
2011 Obs.
3C 279
(Lu, Fish & KA et al. 2013, ApJ)

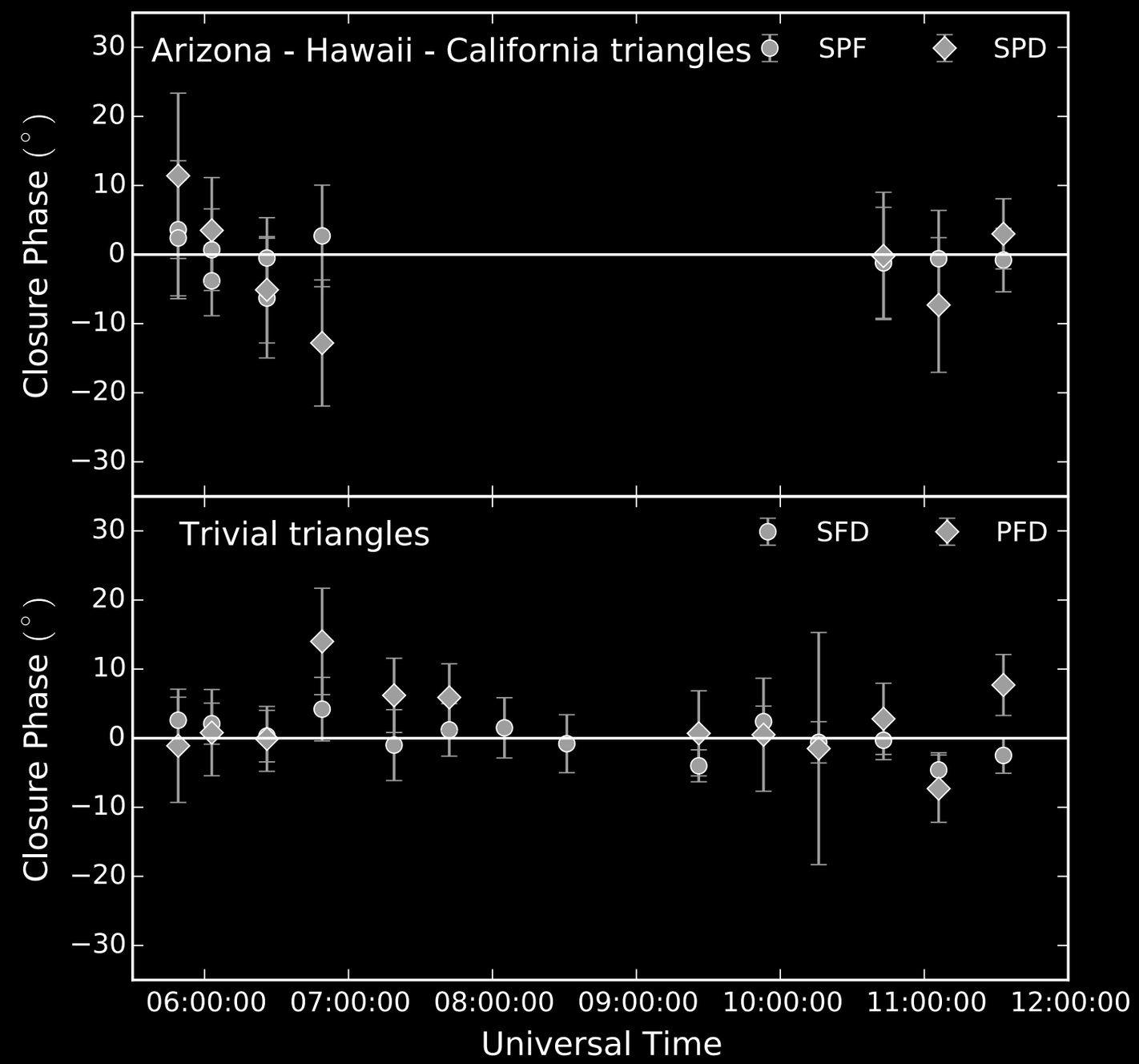
NRAO 530
(KA, Lu & Fish in prep.)

2012 Obs.
M87 (KA, Lu & Fish et al. 2015, ApJ)

3C 279 (Wagner et al. 2015, A&A)

The First Closure Phase detections on M87





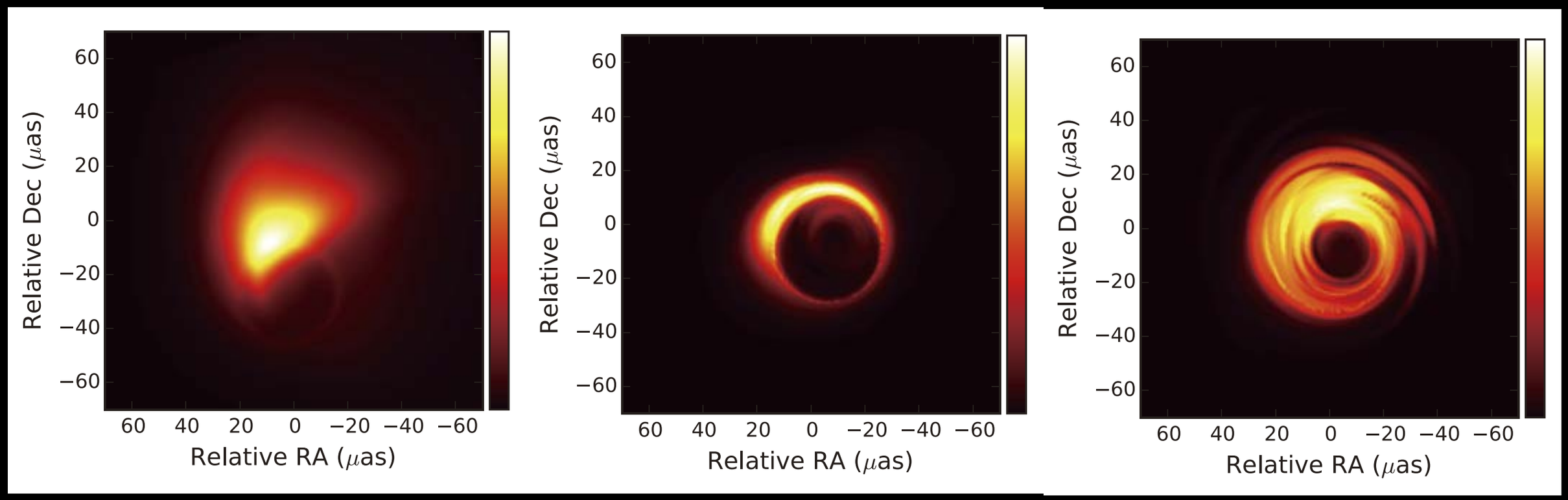
Closure Phase on CARMA-SMT-MK triangles are ~ 0

Physically-motivated models for M87

Approaching jet
(Broderick & Loeb 2009)

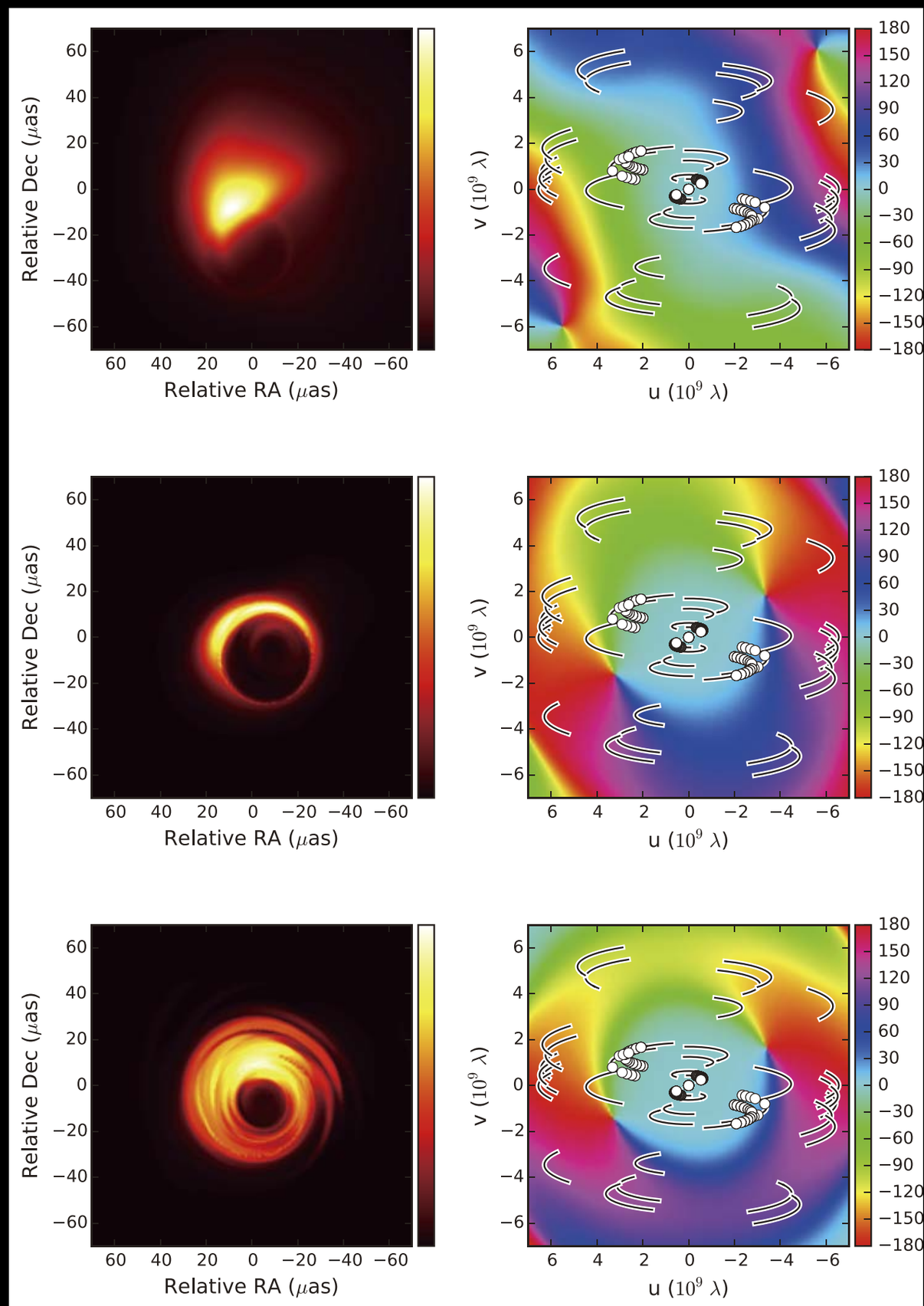
Counter jet
(Dexter et al. 2012)

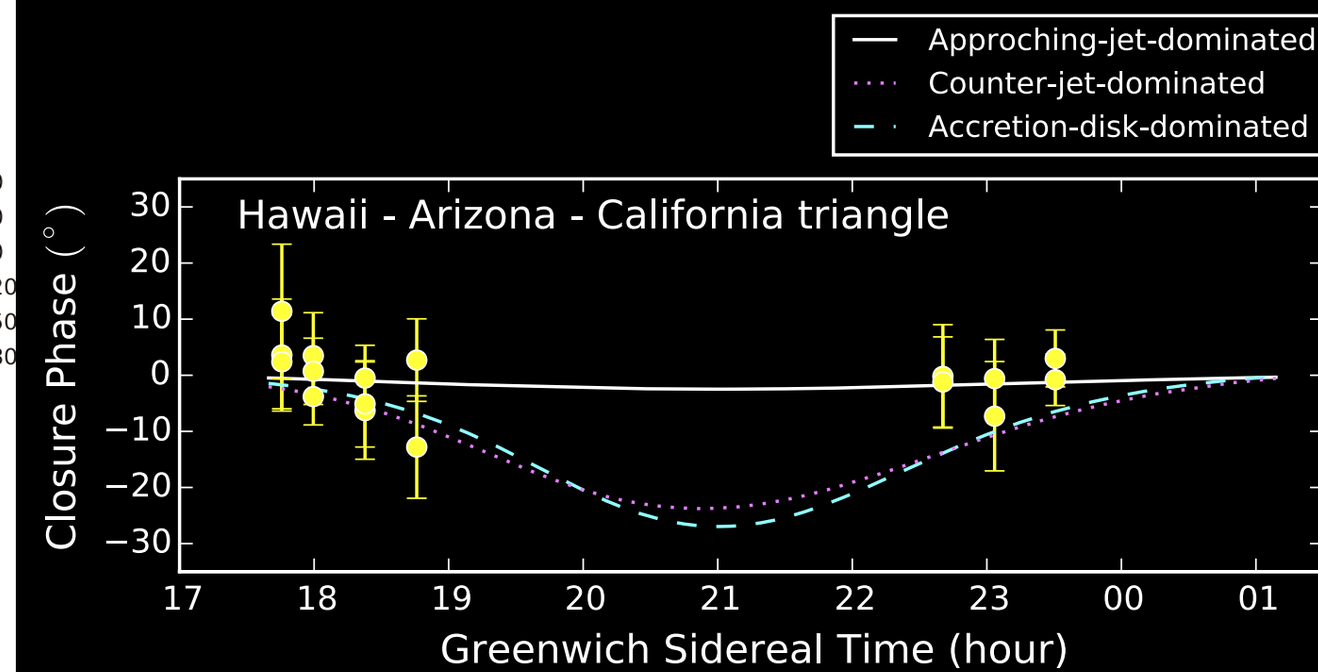
Accretion Disk
(Dexter et al. 2012)



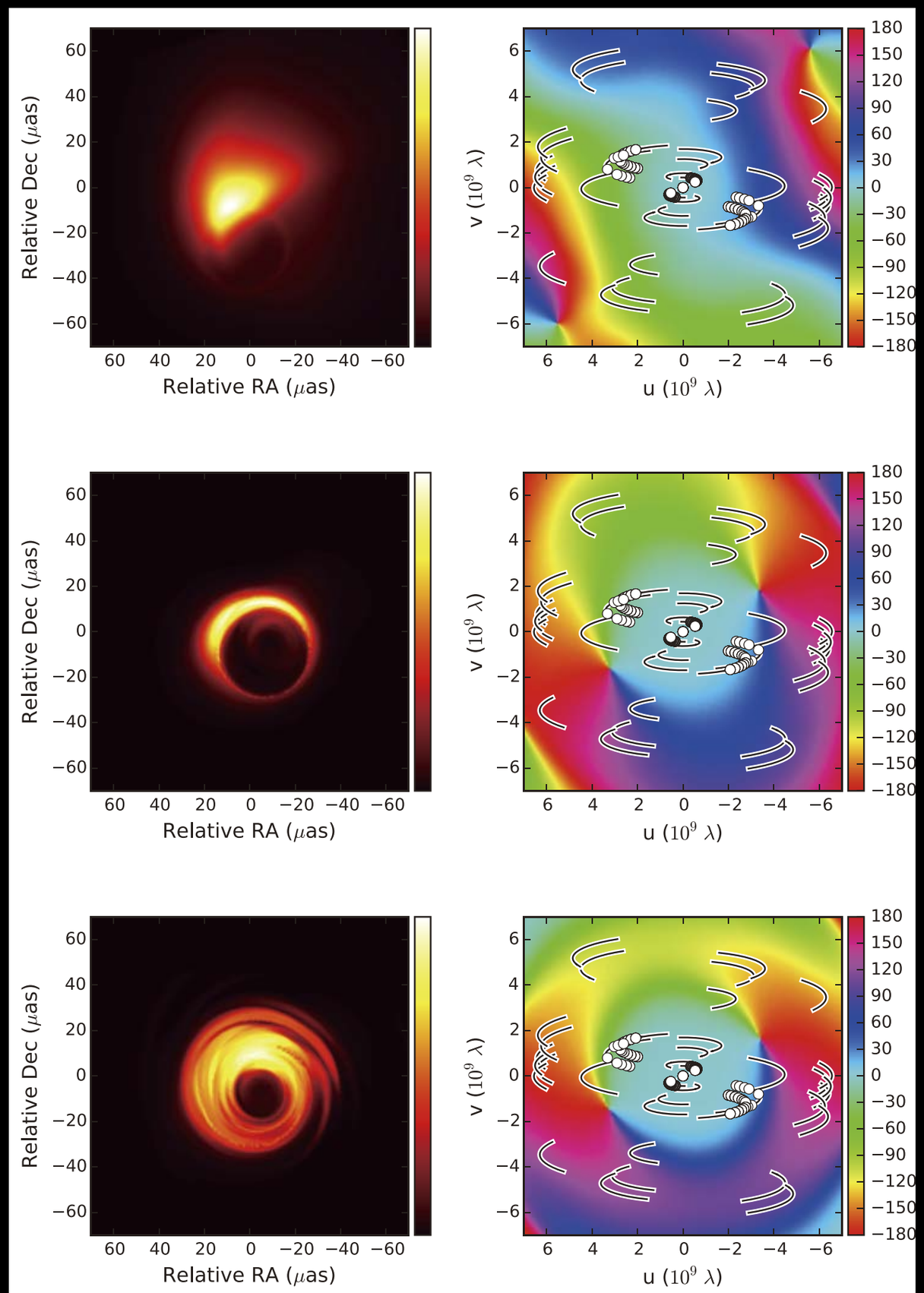
All models are broadly consistent with 2009 data.

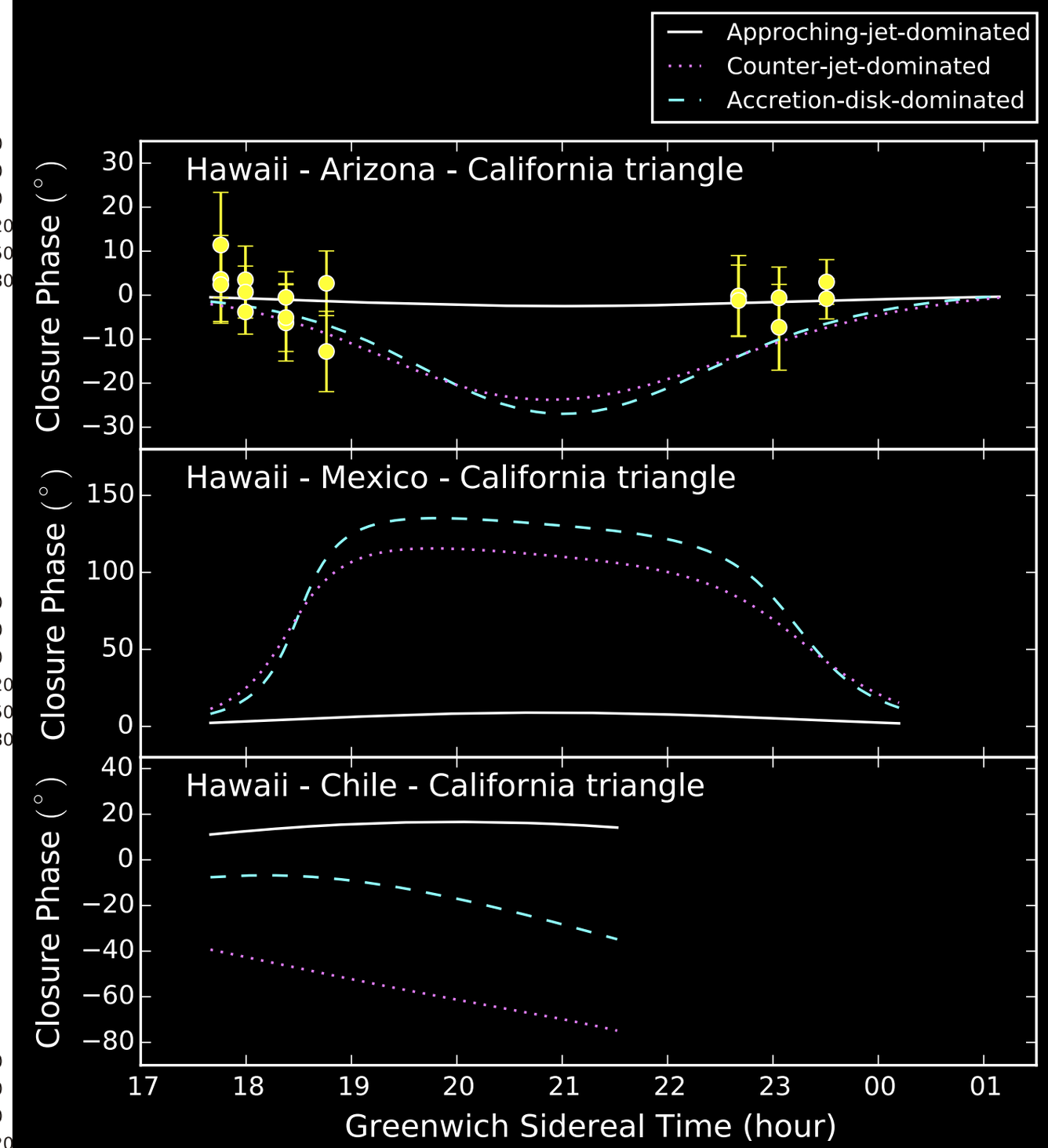
The First Closure Phase detections on M87





The First Closure Phase detections on M87





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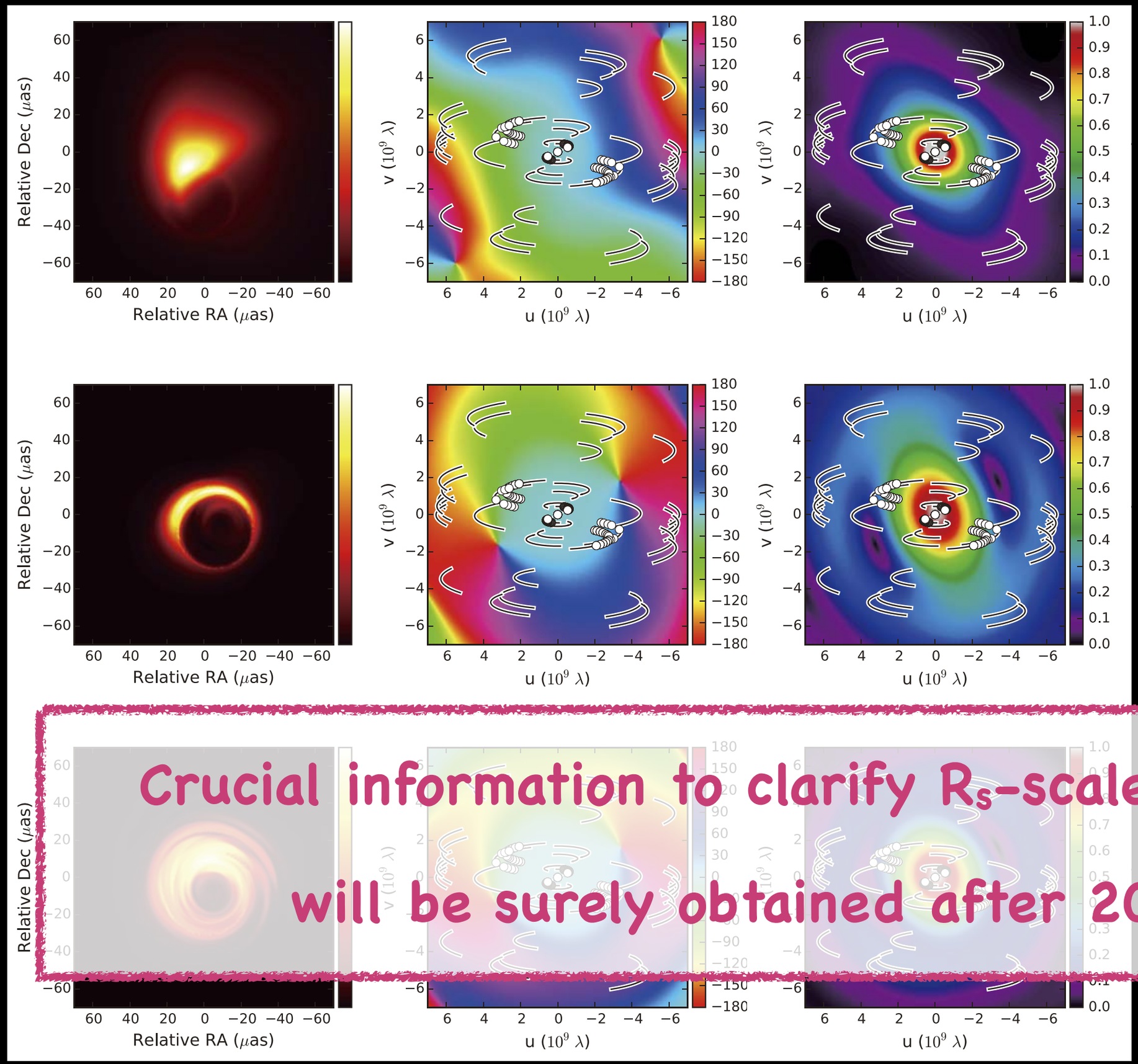
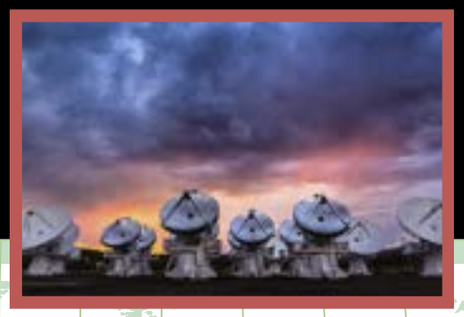


Crucial information to clarify R_s-scale structure

will be surely obtained after 2015 !!

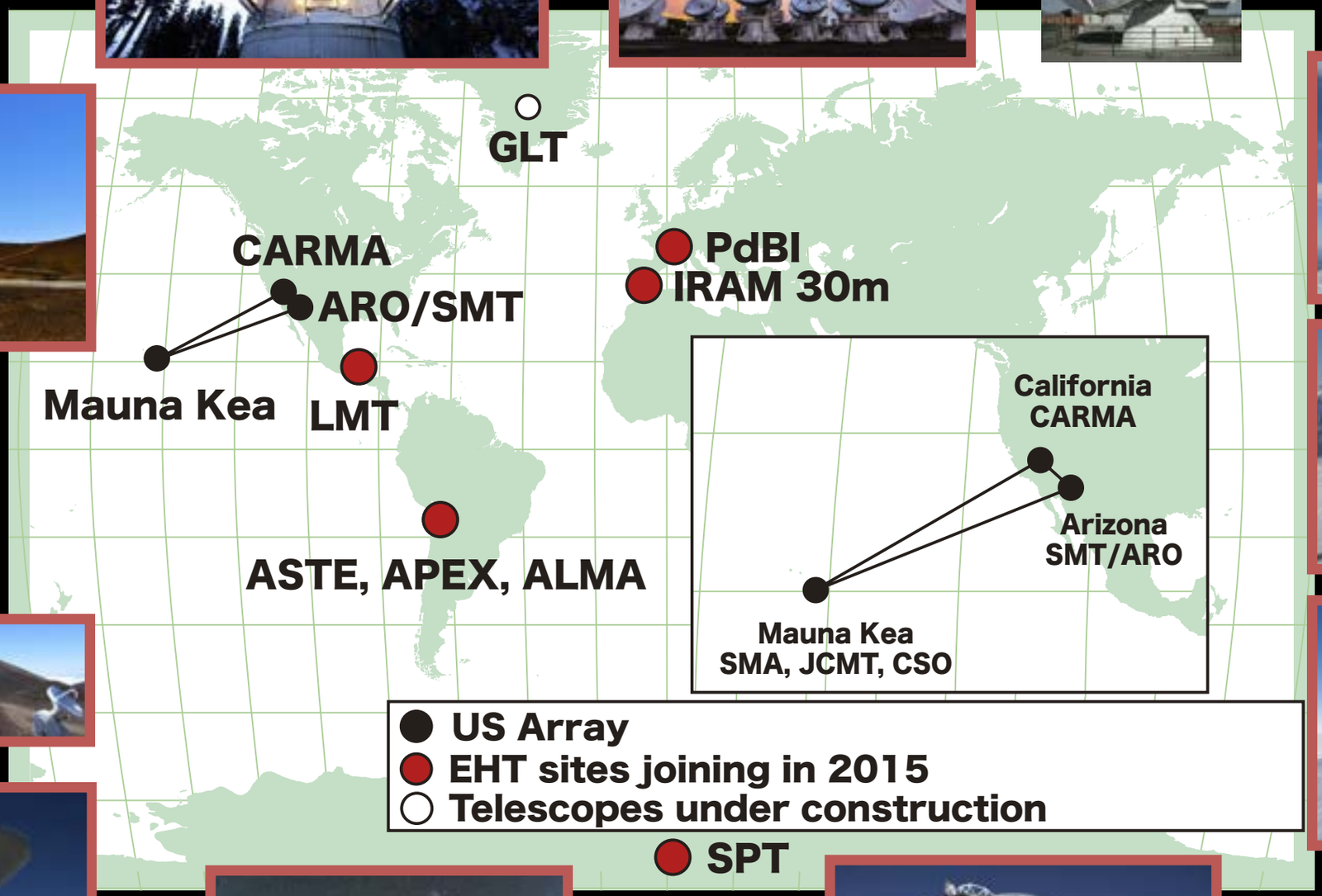
EHT 2015-2016



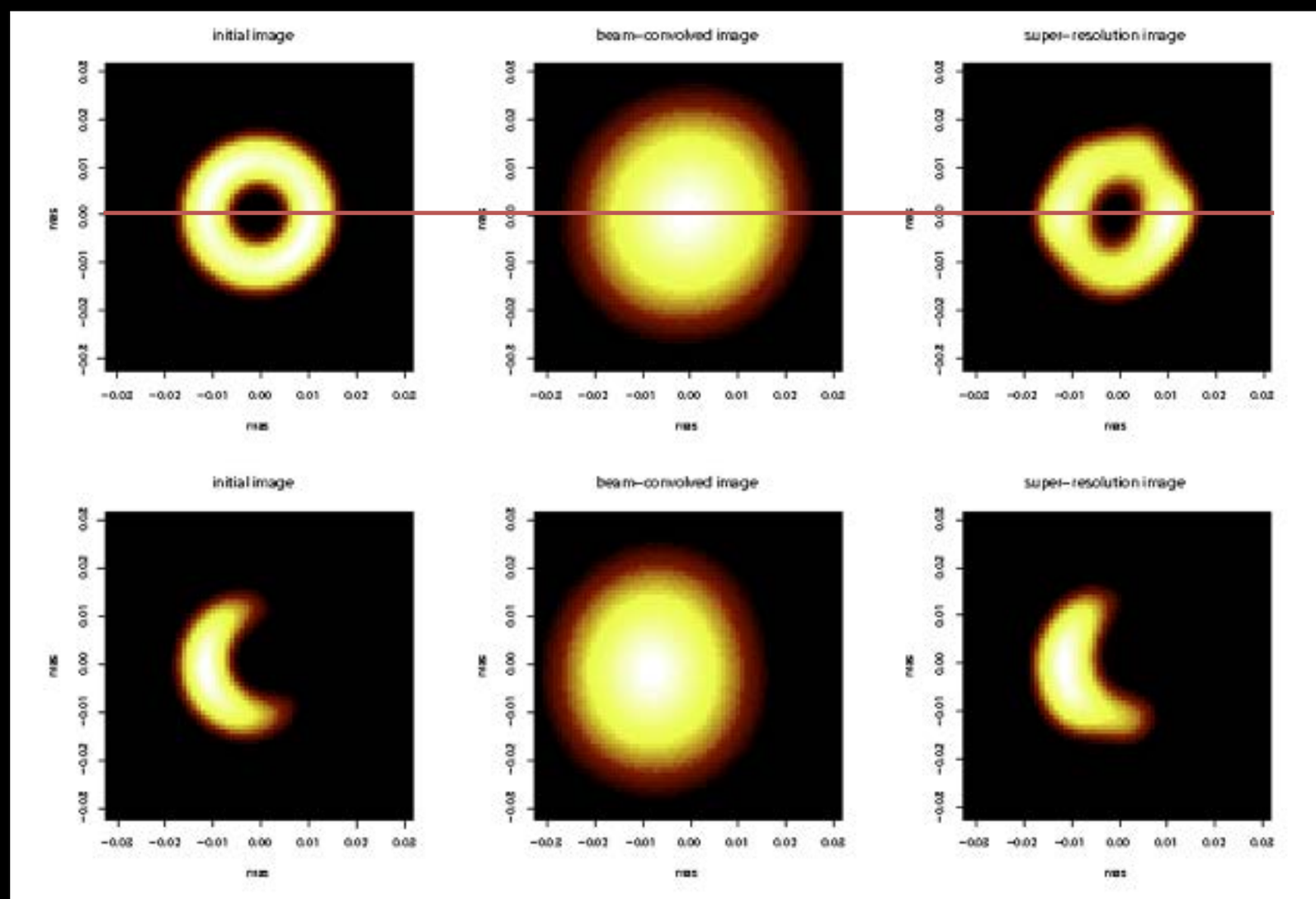




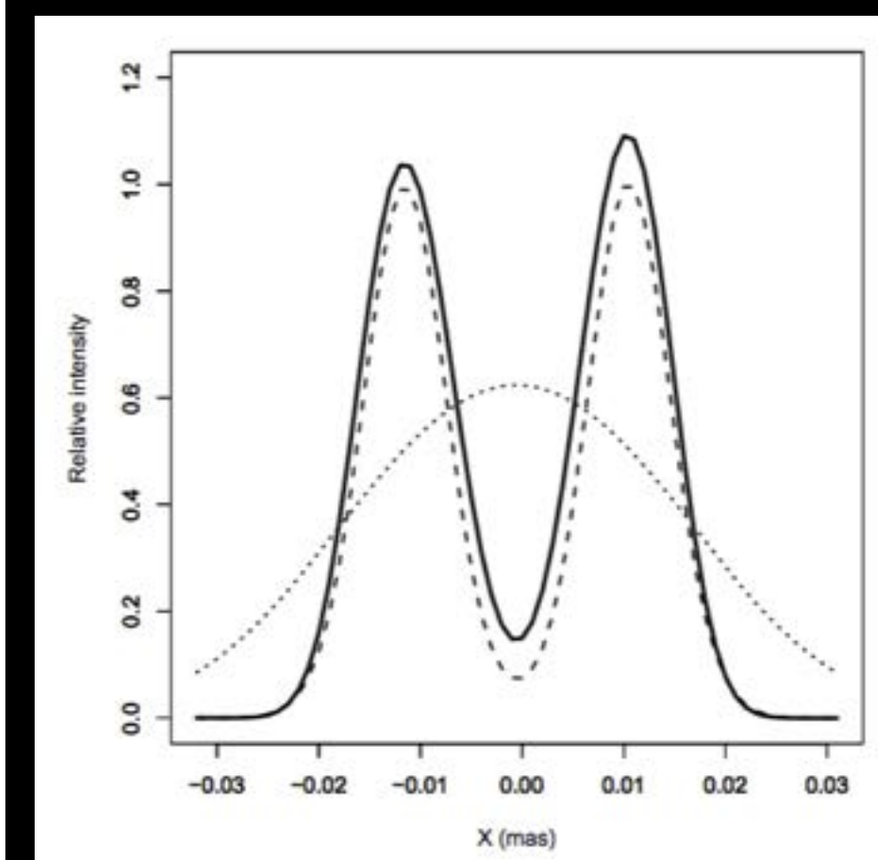



EHT 2015-2016 + Sparse Modeling "LASSO"

Model Diffraction Limit LASSO image



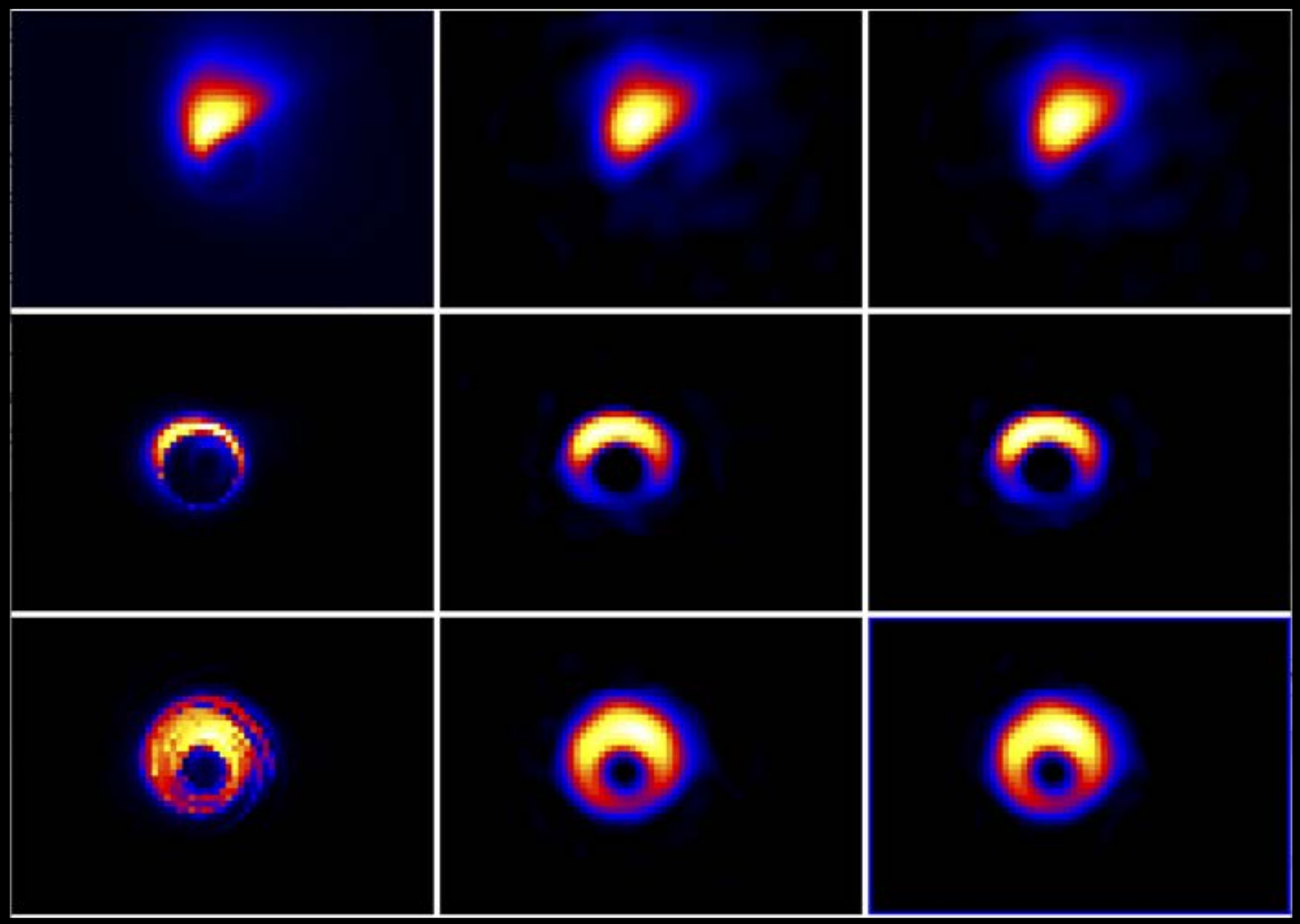
Sliced image



M87, Shadow Diameter ~ 20 uas (for the case of $M_{BH} = 3 \times 10^9\ M_{solar}$)

(Honma, ***KA***, Uemura & Ikeda 2014, PASJ)

EHT 2015-2016 + Sparse Modeling "LASSO"



M87, Shadow Diameter ~ 40 uas (for the case of $M_{BH} = 6 \times 10^9\ M_{solar}$)

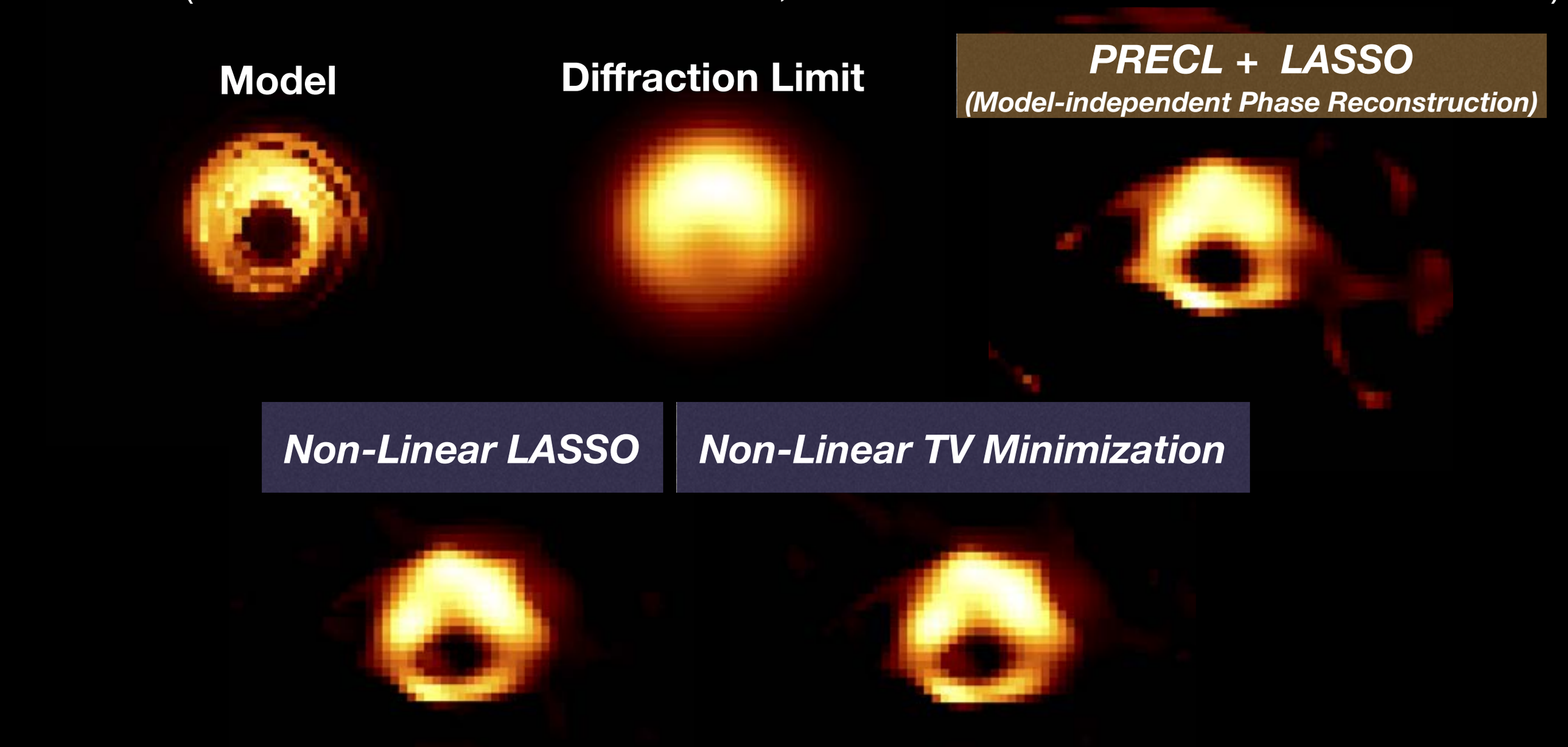
(KA & F. Tazaki+ in prep.)

EHT 2015-2016 + Sparse Modeling

"PRECL+LASSO" or "non-linear LASSO/TV"

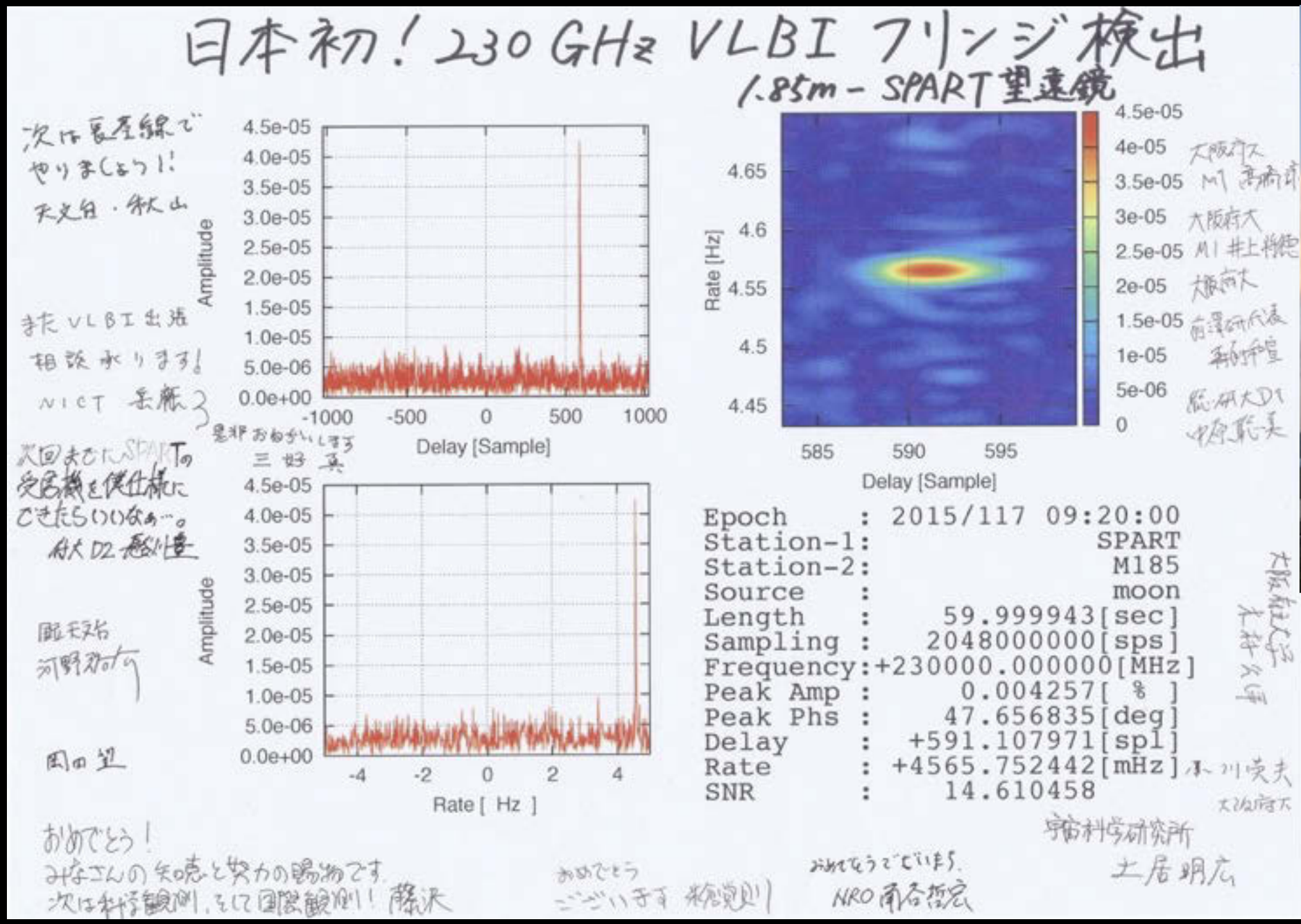
Image Reconstruction from the Visibility Amplitude and Closure Phase

(*PRECL*: Ikeda & *KA*+ to be subm, *Non-linear LASSO & TV minimization*: *KA*+)



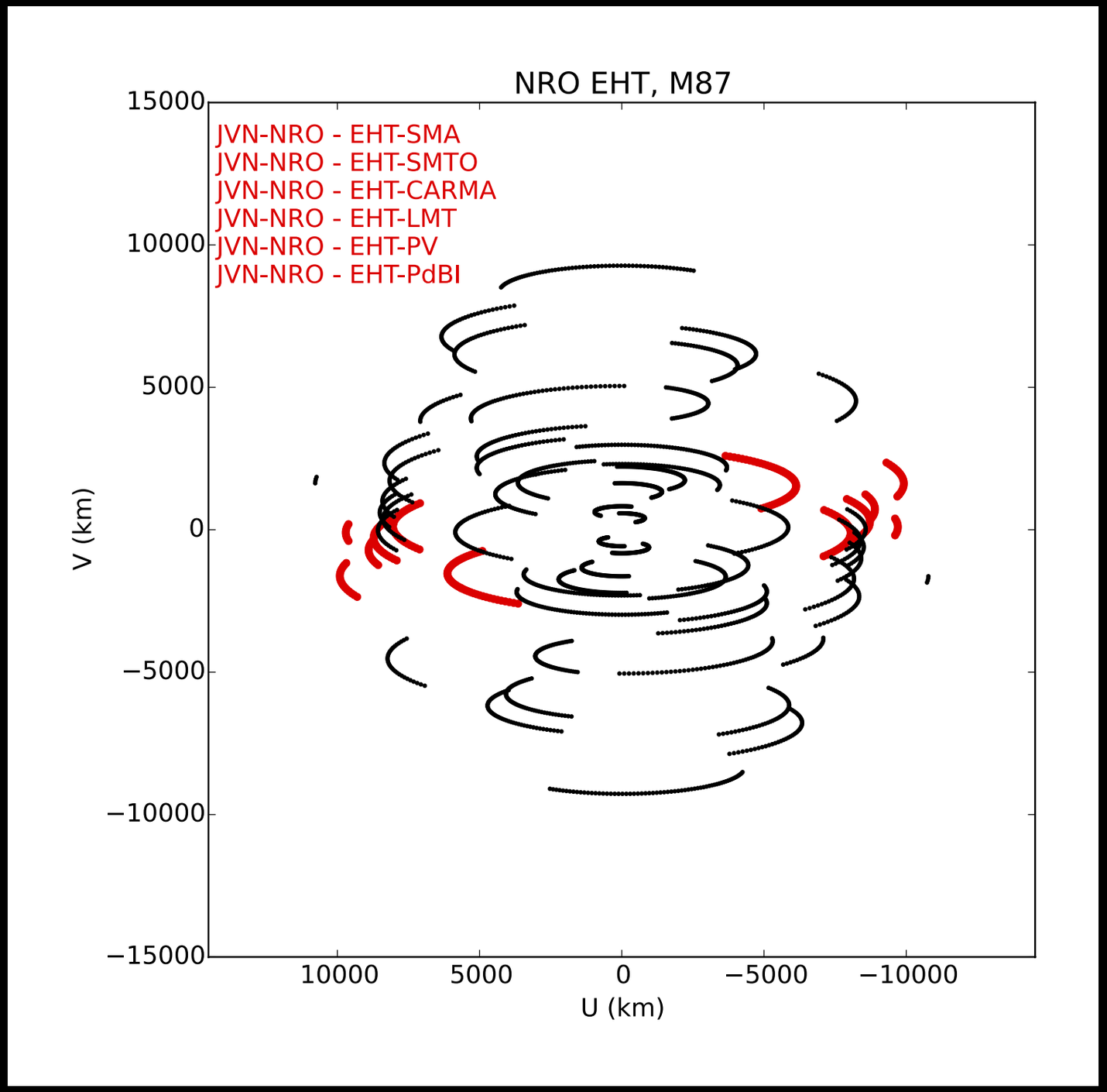
We no longer need the visibility phase and phase self-calibration!!

230 GHz VLBI Experiment at Nobeyama (MICE 2015)



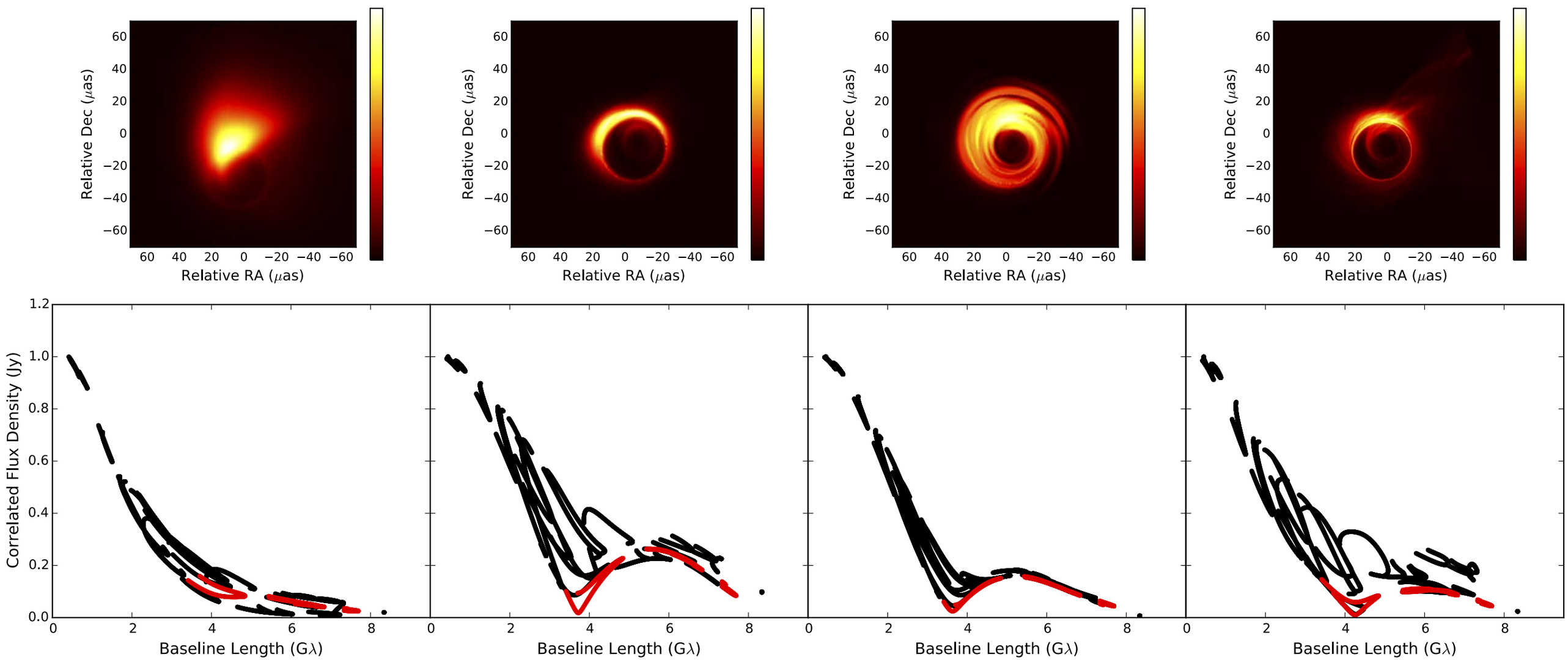
Fujisawa & ALL-Japan Team, April 27, 2015

uv-coverage for M87 (EHT+Nobeyama; EL>20°)



Baseline Length ~ 5000-10000 km

Simulations how Nobeyama works out



NRO baselines are **exactly** located between the first and second null regions
(*uv*-coverage is really effective to study the presence of the shadow)

—> Why not performing 1.3 mm-VLBI observations with Nobeyama (SPART and 45m Telescope)!?