Future prospects for constraining black hole space time

Kotaro Moriyama (Goethe University)

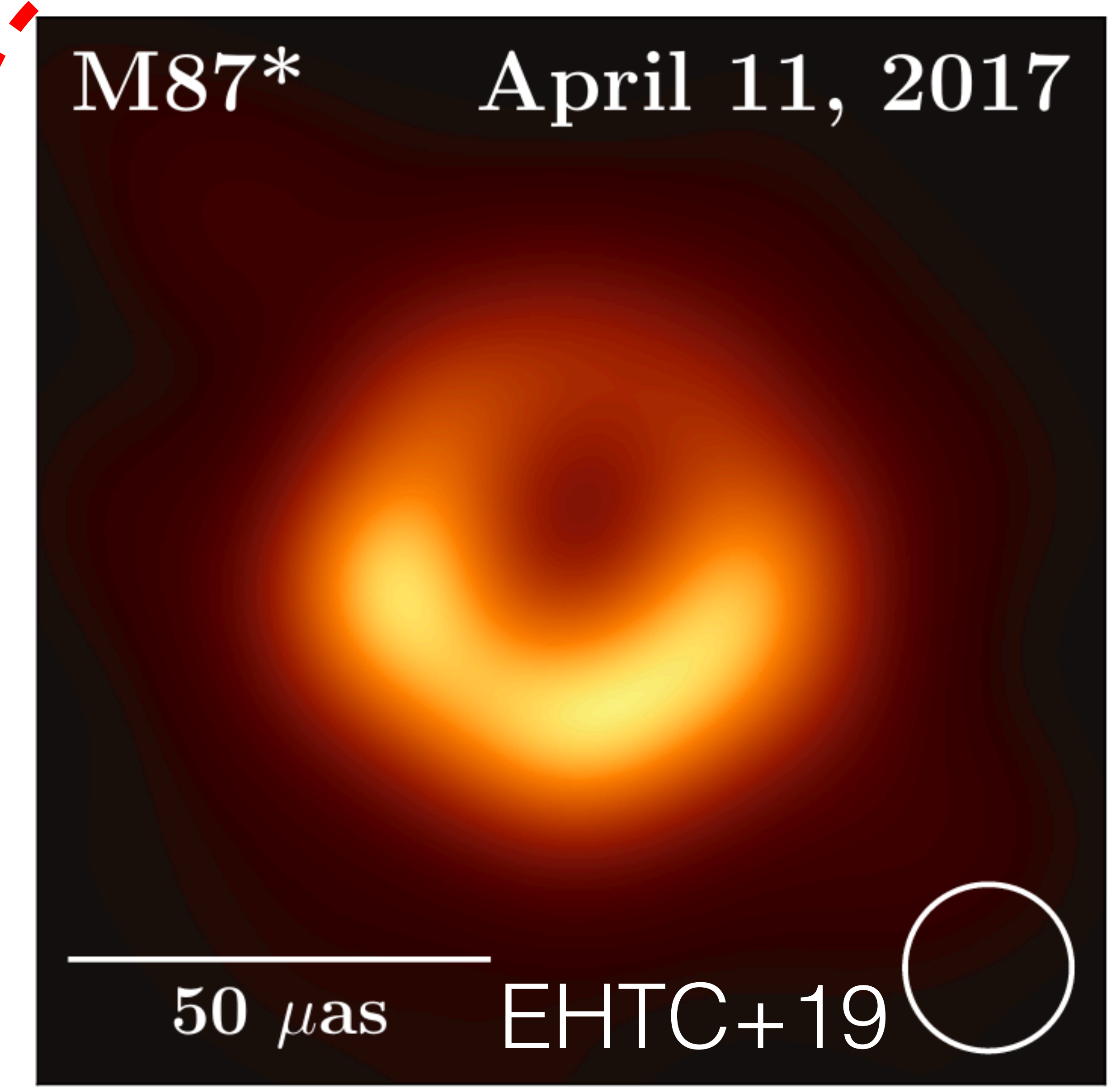
Alejandro Cruz-Osorio, Yosuke Mizuno, Christian M. Fromm, Antonios Nathanail, Luciano Rezzolla

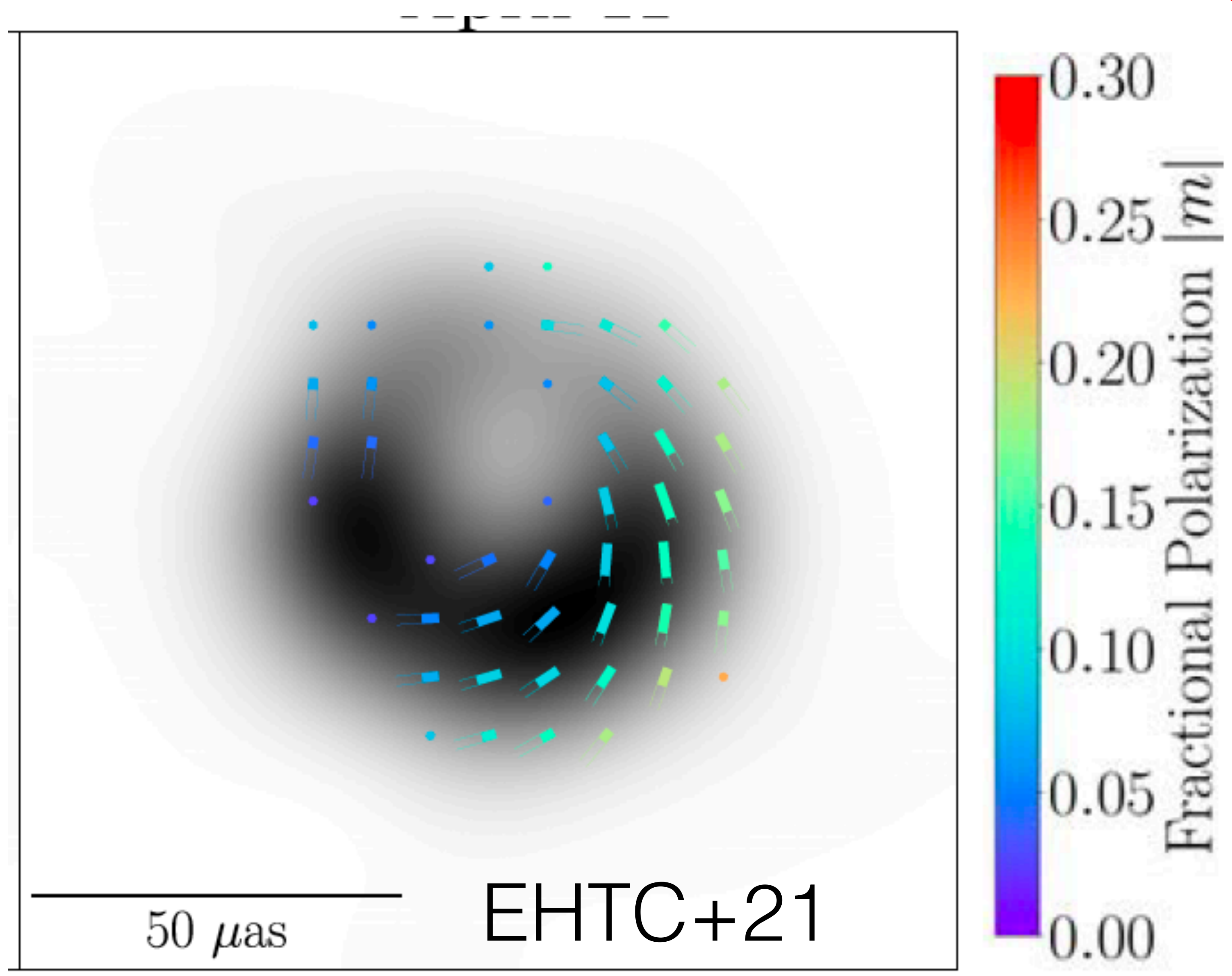
Event Horizon Telescope

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

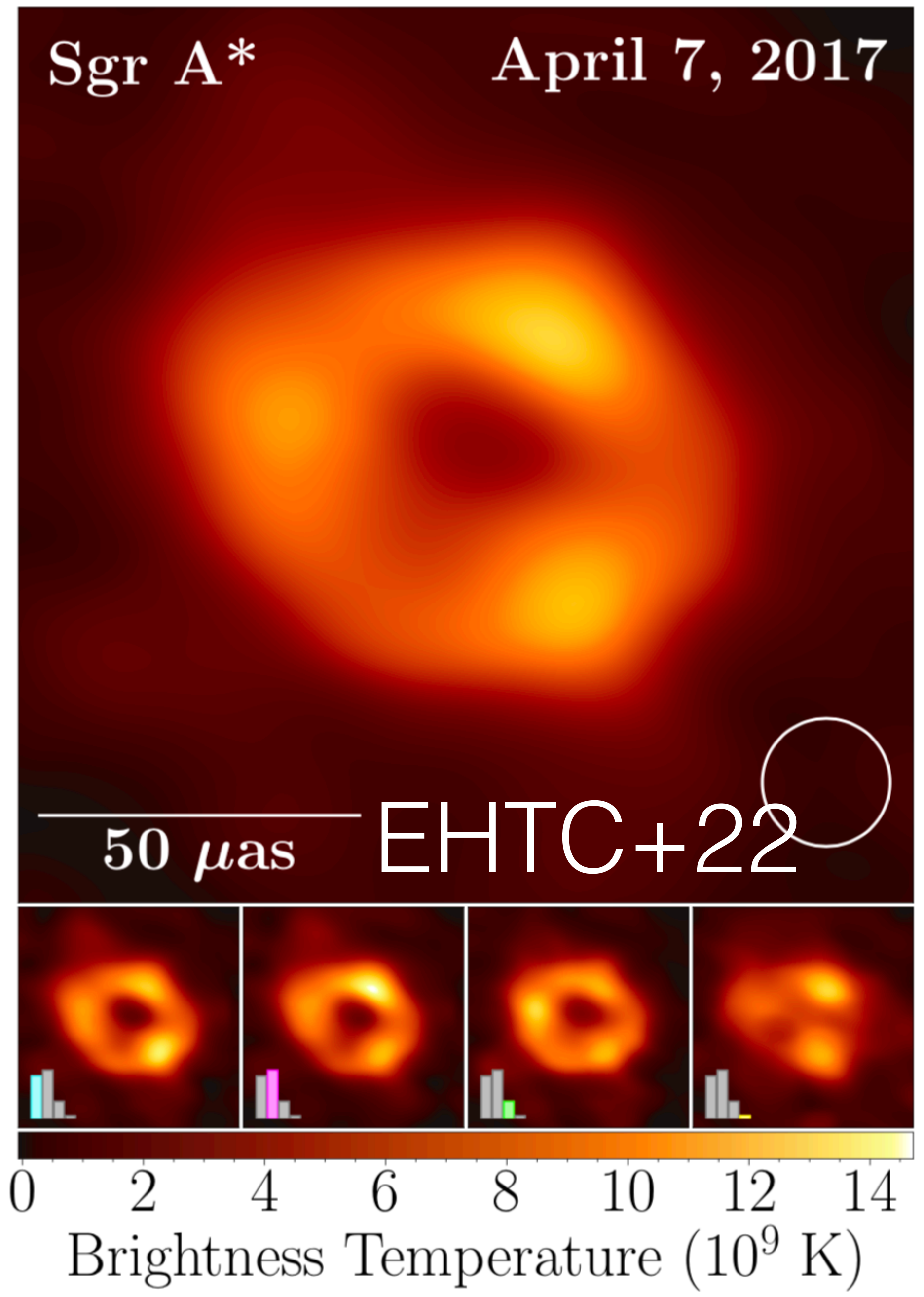
EHT current achievements and next topics

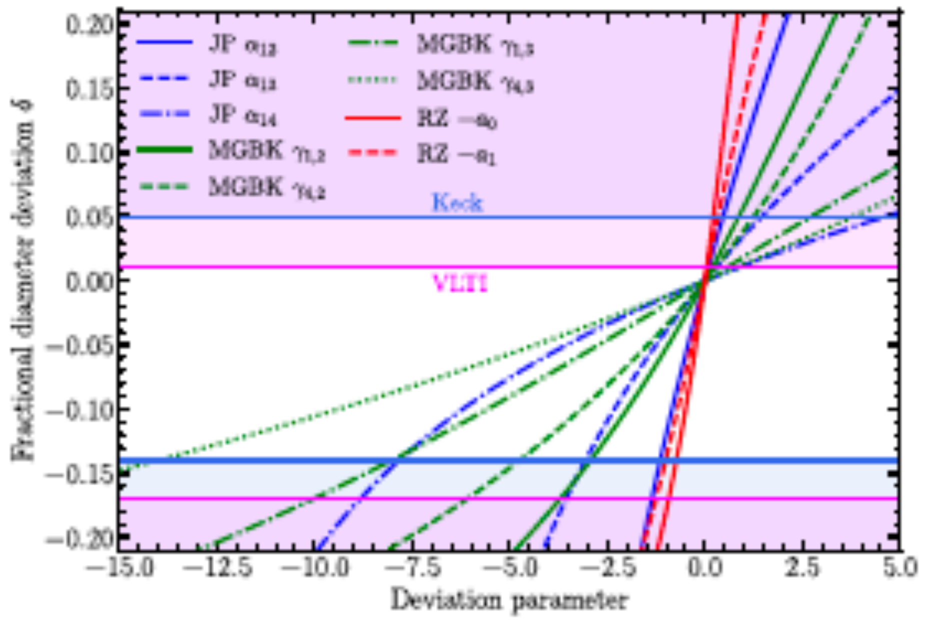
Image consistent with that of the black hole shadow predicted by general relativity

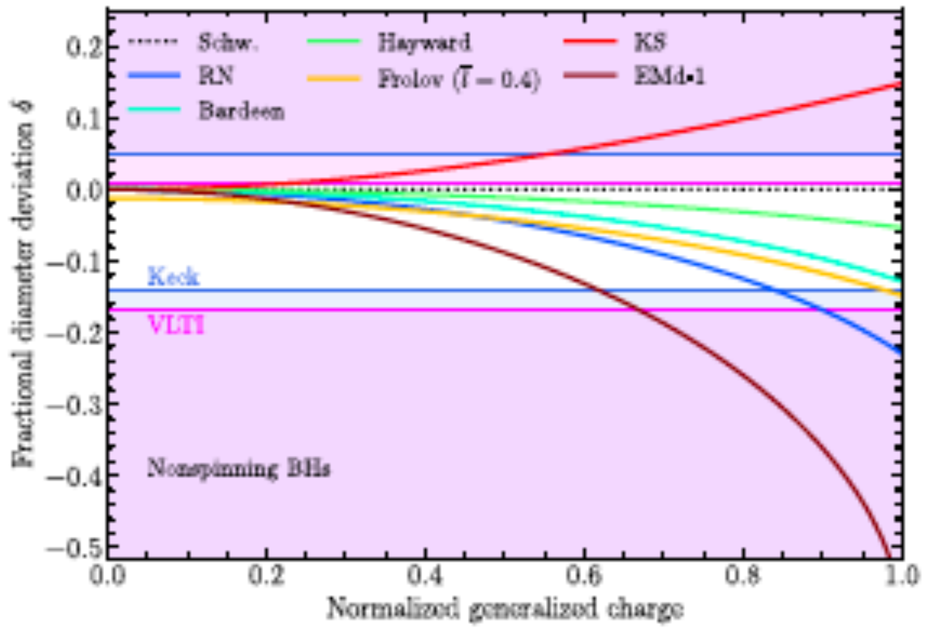




Today's focus







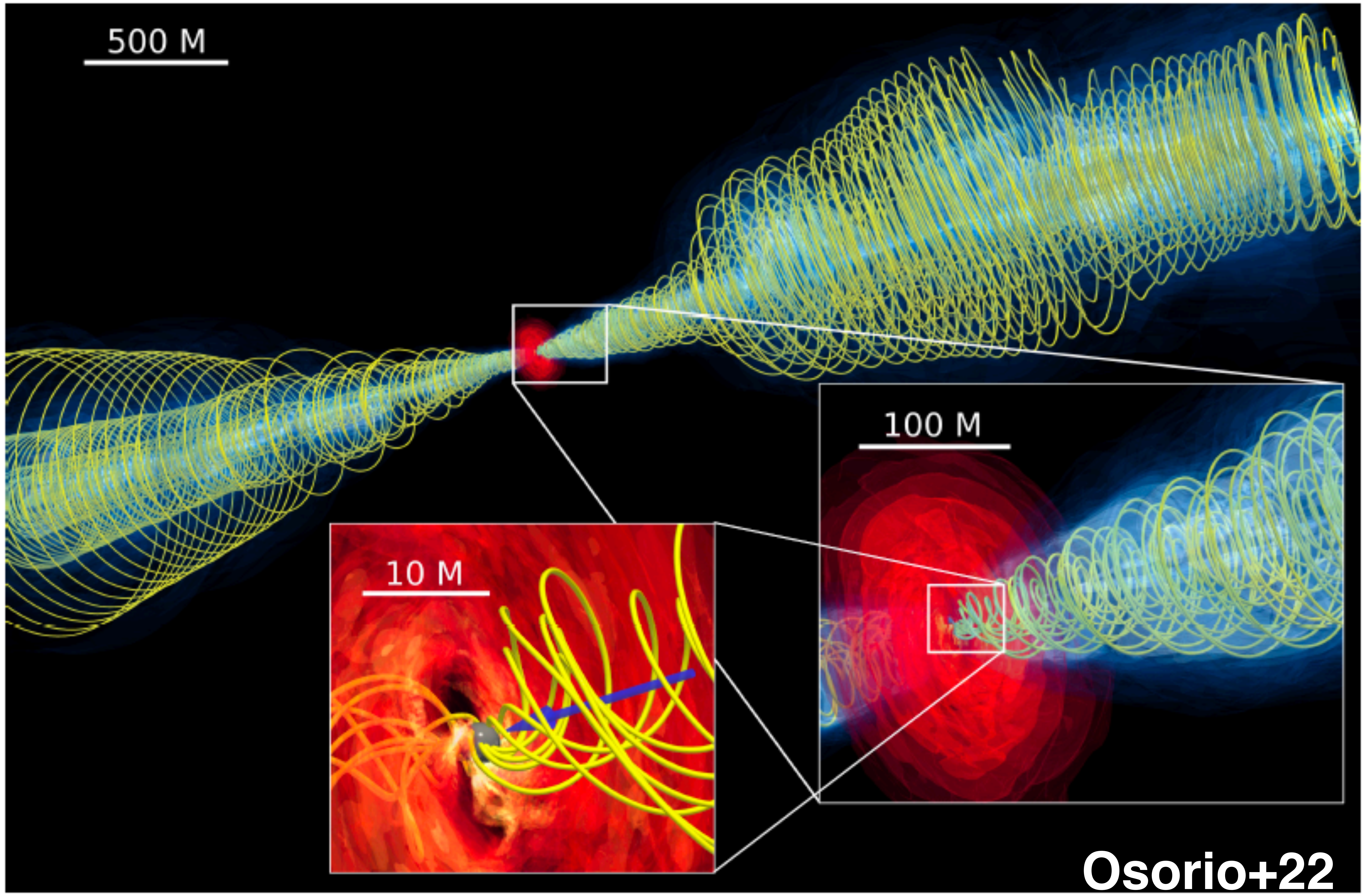
Black hole spacetime= black hole mass and spin

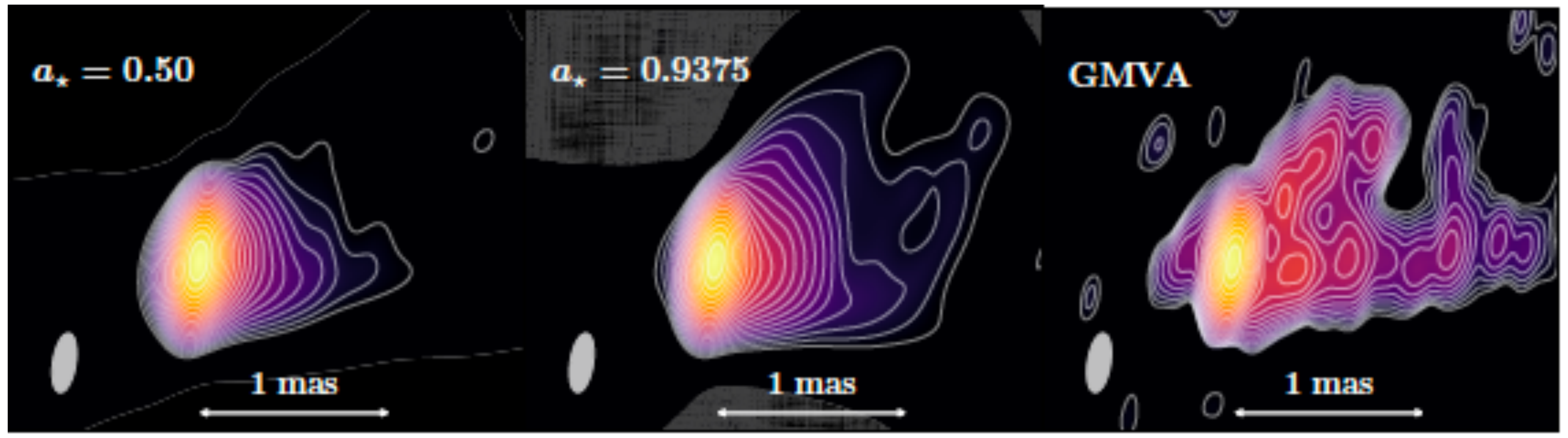
Focus of this presentation: Spin constraint of M87 with the jet/disk dynamics

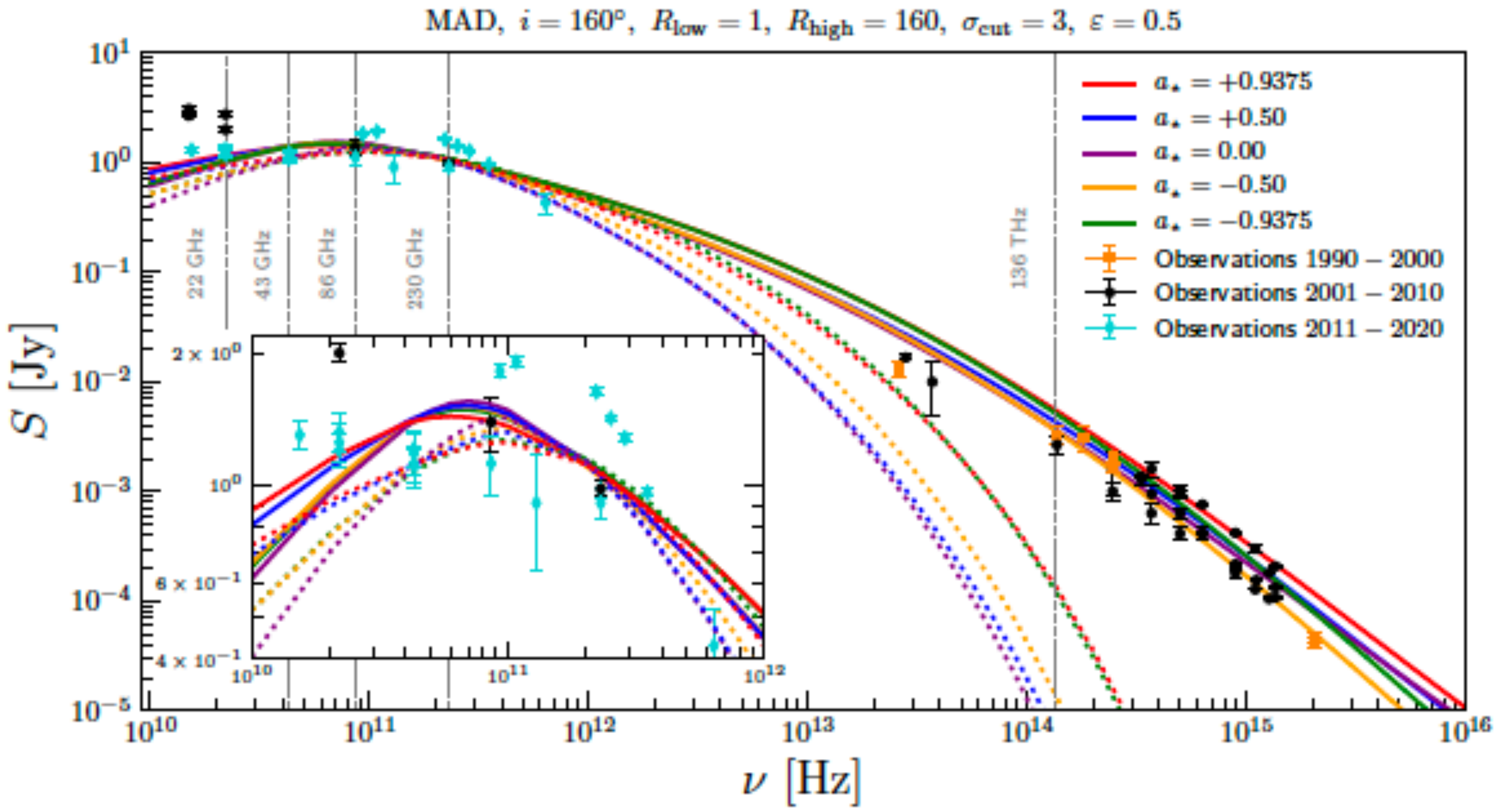
GOETHE UNIVERSITÄT FRANKFURT AM MAIN

EHT

jet/disk simulation with BHAC/BHOSS







GRMHD+GRRT with Non-thermal effects:

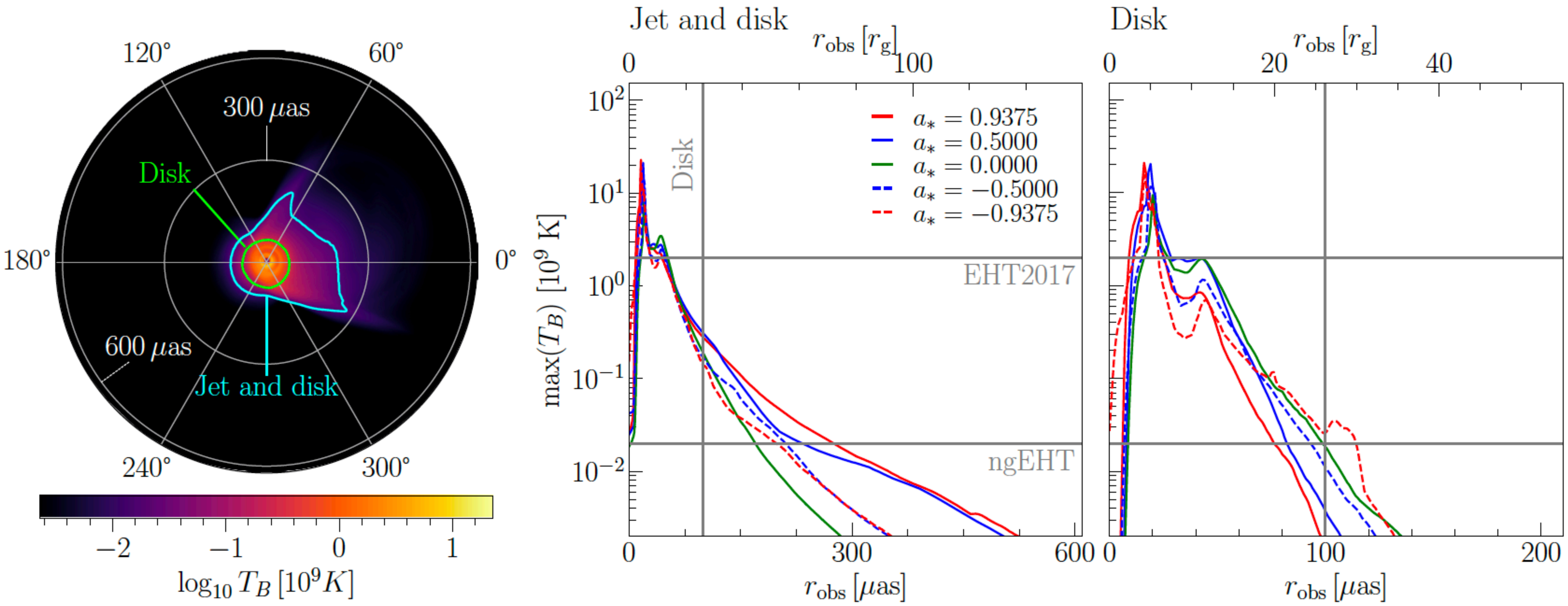
- **Similar jet morphology at 86GHz**
- **Reproduce radio-near IR spectrum**

Parameters: -0.94 < a_*< 0.94, i=160°

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

EHT

Detection of photon ring and extended jet

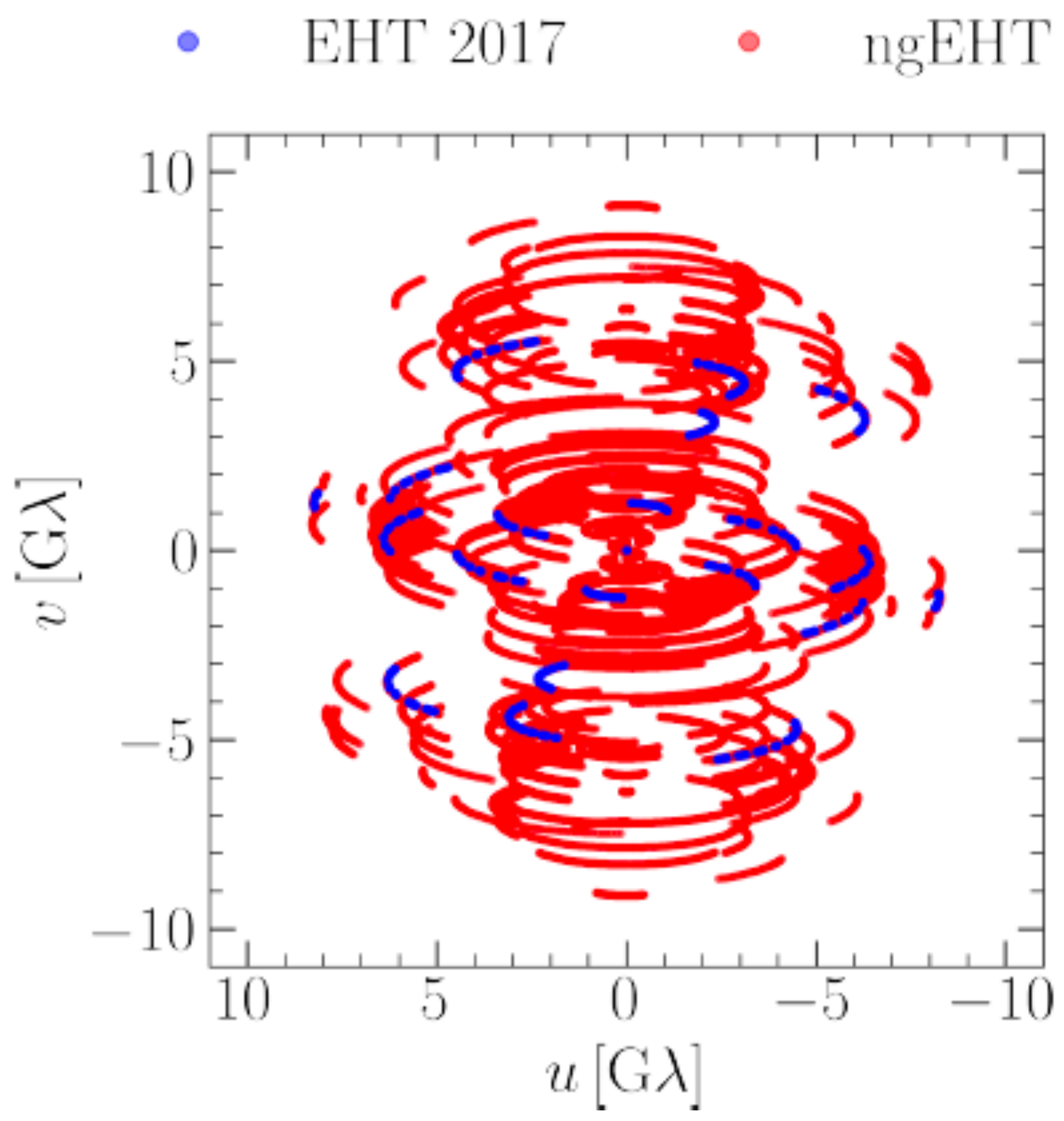


Disk region : 0 uas ≦ robs ≦100 uas
Jet region : 100 uas≦ robs ≦ 300 uas

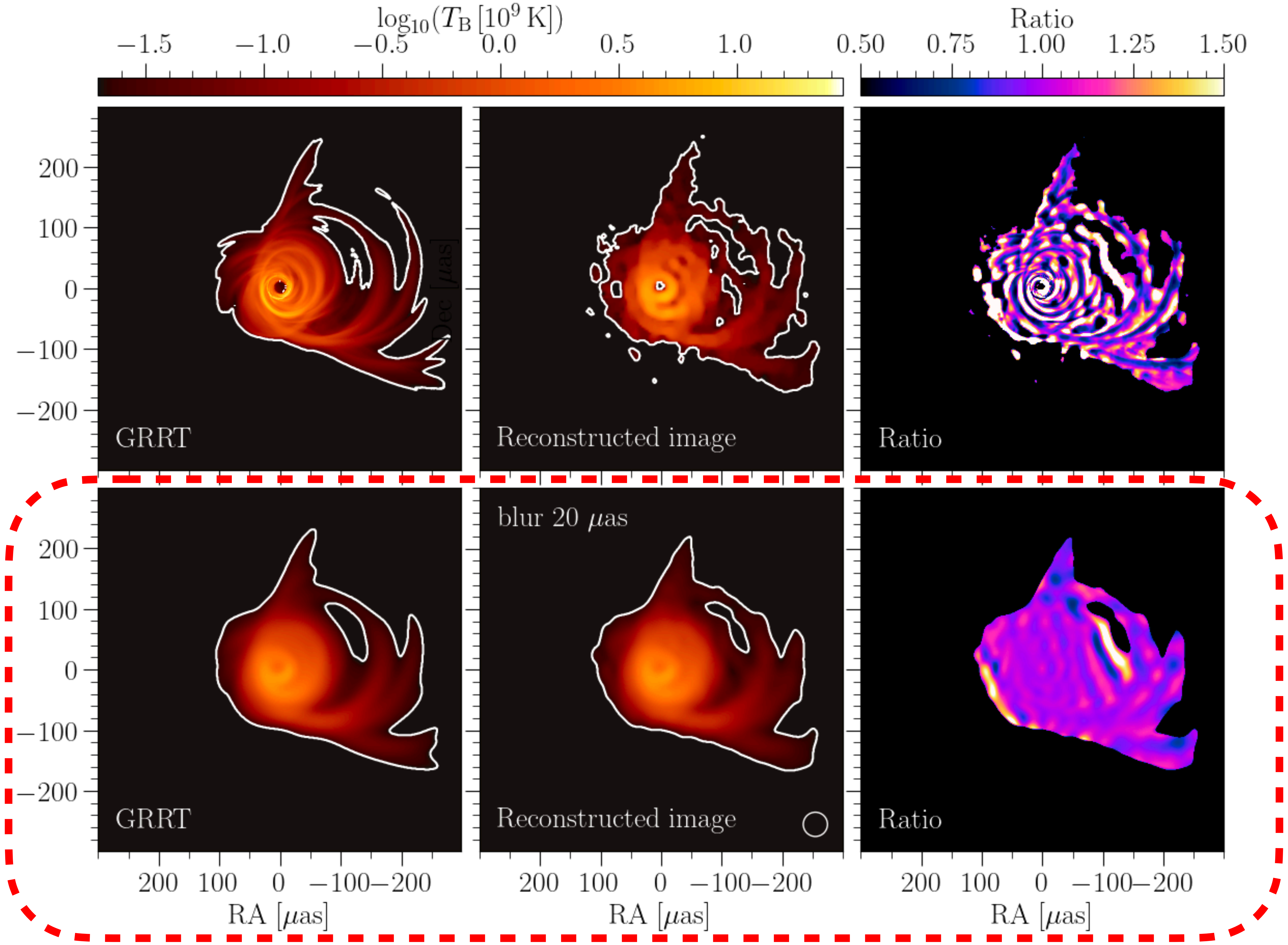
GOETHE UNIVERSITÄT FRANKFURT AM MAIN

EHT

GRRT and expected ngEHT observations



ngEHT: Raymond+21 , Roerof+23,
https://challenge.ngeht.org/



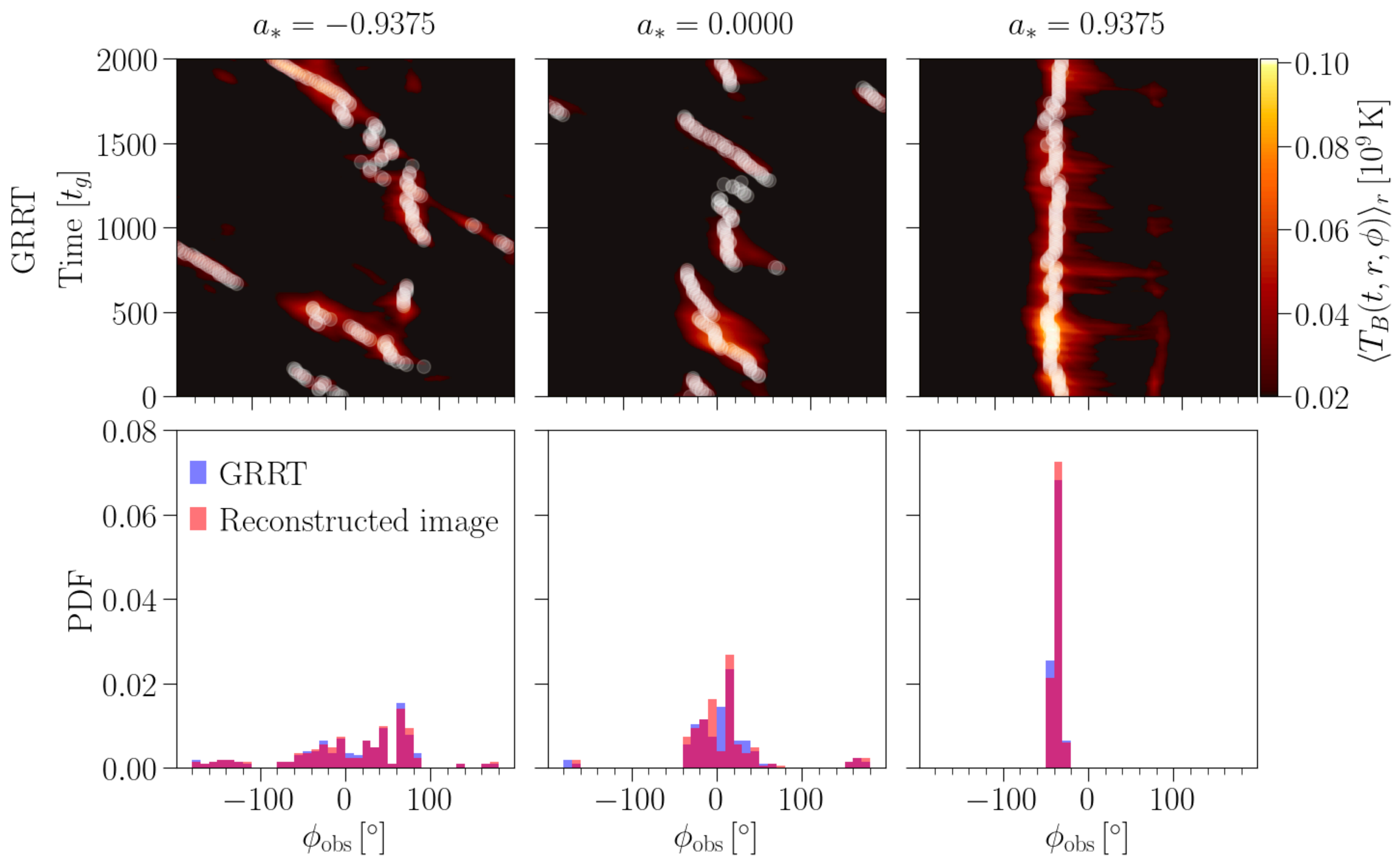
GOETHE UNIVERSITÄT FRANKFURT AM MAIN

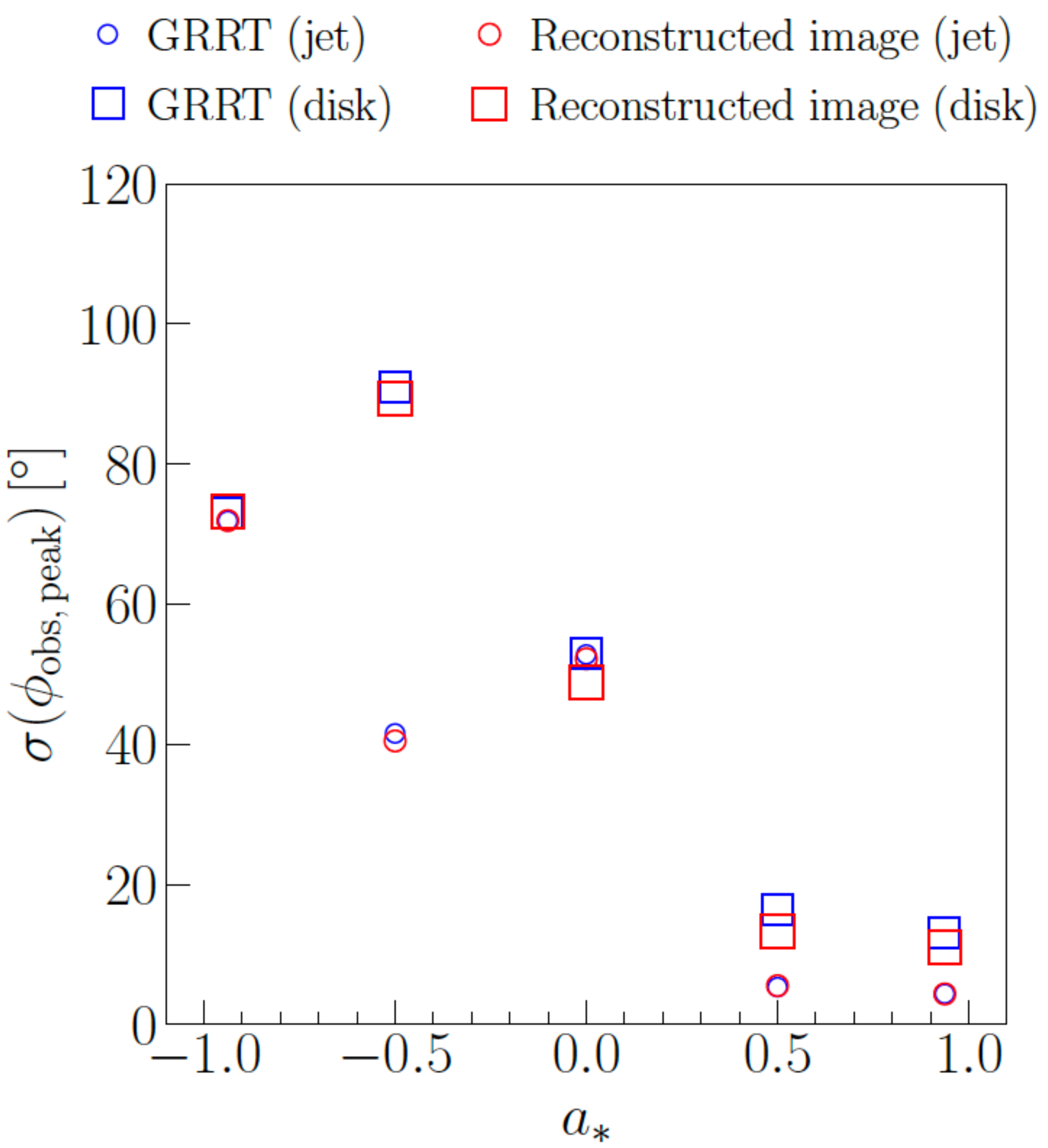
EHT

Focus phenomena: GRRT/imaging with the 20 uas restoring

GRRT images: BHAC+BHOSS, Imaging scheme: SMILI, fcv

Azimuthal angle variation of jet bight region





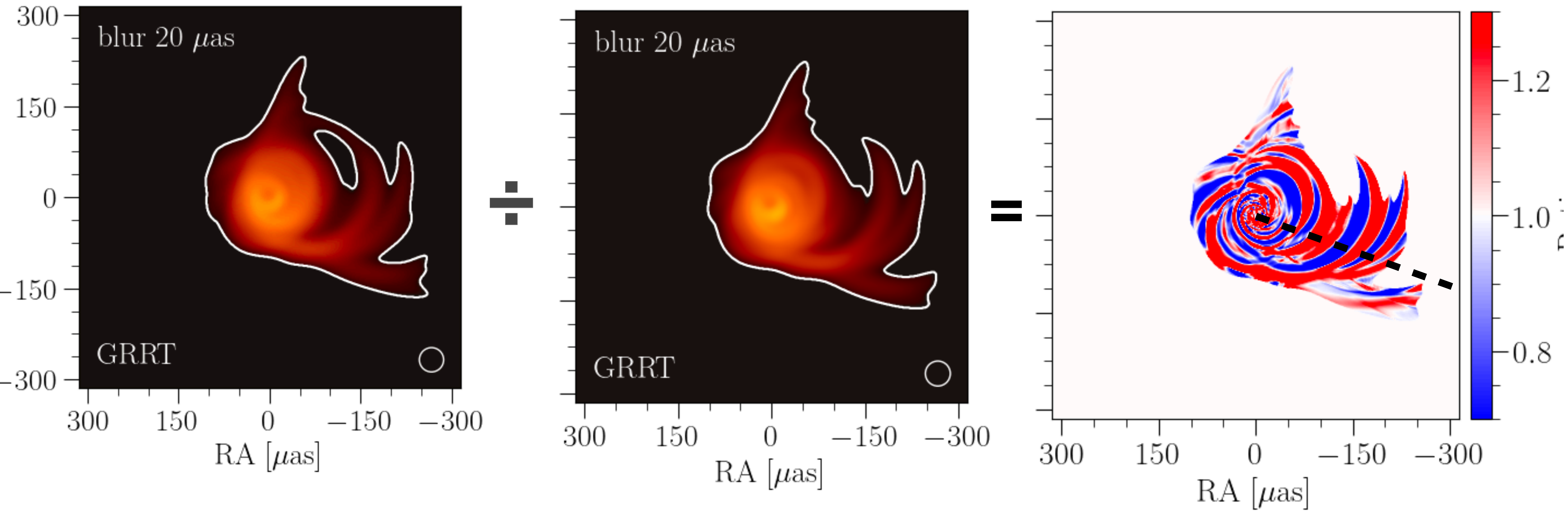
Positive spin jet axis predicts azimuthally stable (~10°)
Similar trend can be seen in the jet/disk

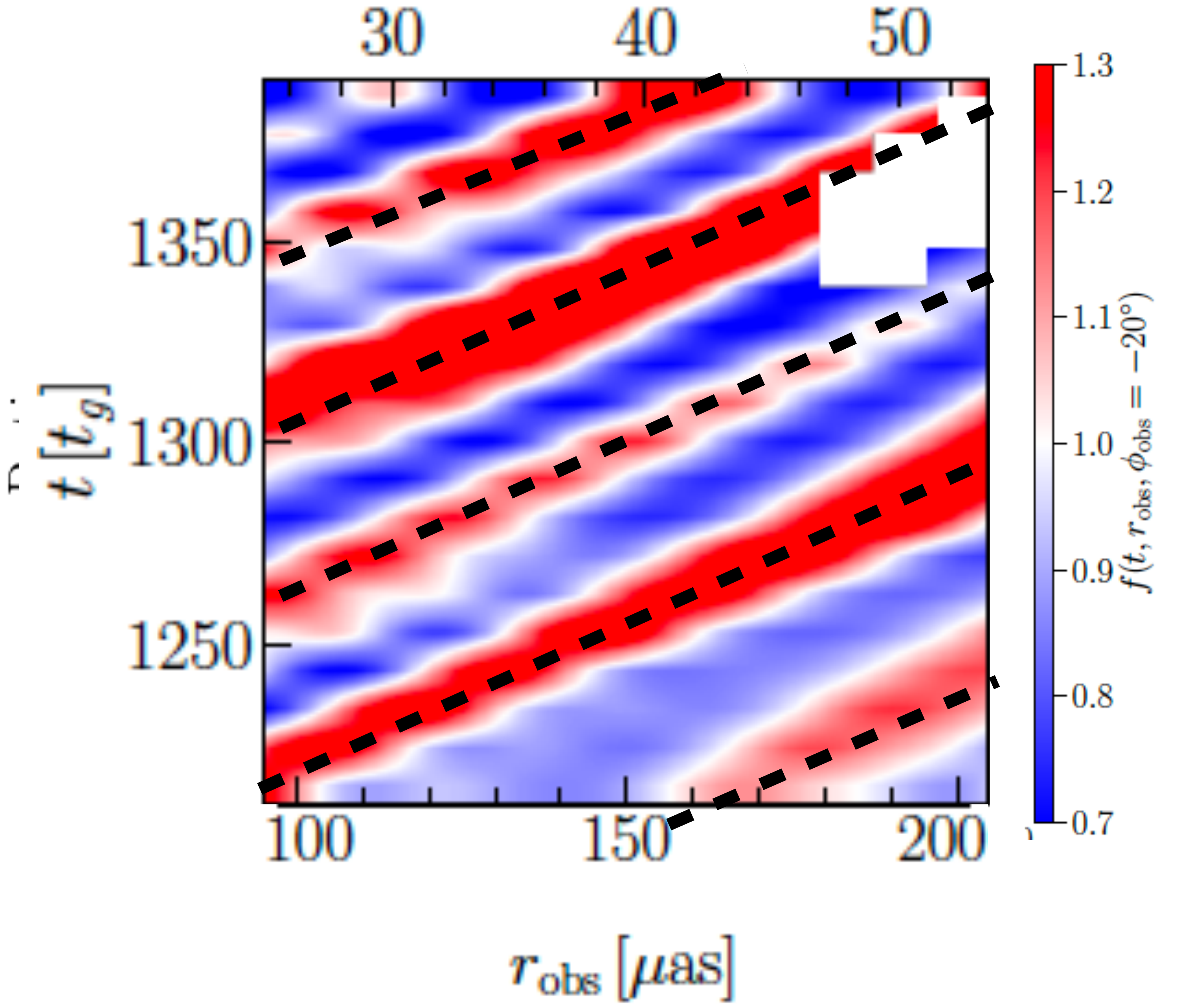
image brightness radially averaged within the jet region ($100\,\mu\mathrm{as} \leq r_{\rm obs} < 300\,\mu\mathrm{as}$)

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

EHT

Radial inhomogeneity of the jet





Neighborhood time images

Ratio=inhomogeneity

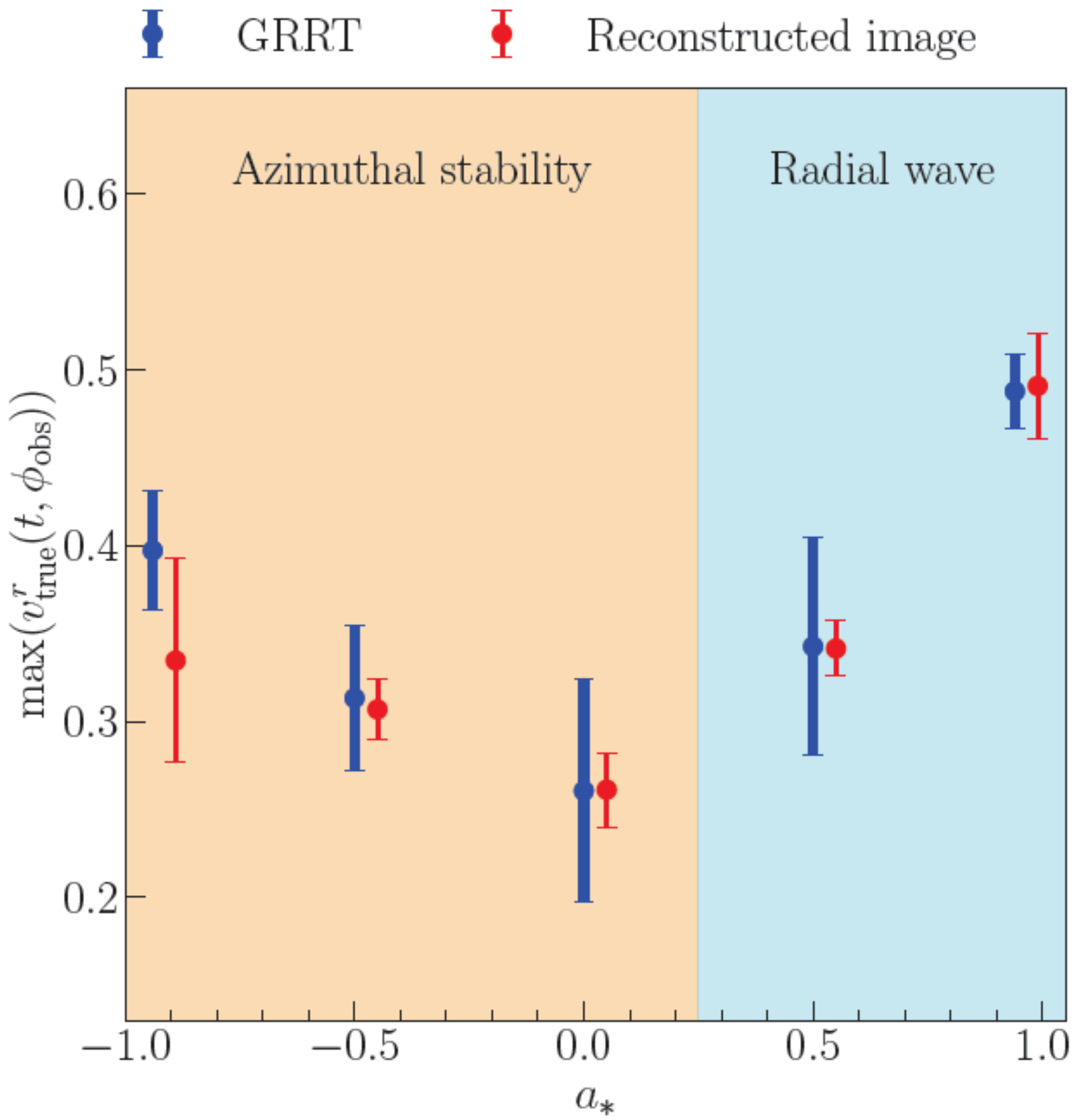
Monotonically propagate to the radial direction
Gradient=radial jet velocity

$$f(t, r_{\rm obs}, \phi_{\rm obs}) = \frac{T_B(t + \Delta t, r_{\rm obs}, \phi_{\rm obs})}{T_B(t, r_{\rm obs}, \phi_{\rm obs})}$$

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

EHT

Radial jet velocity



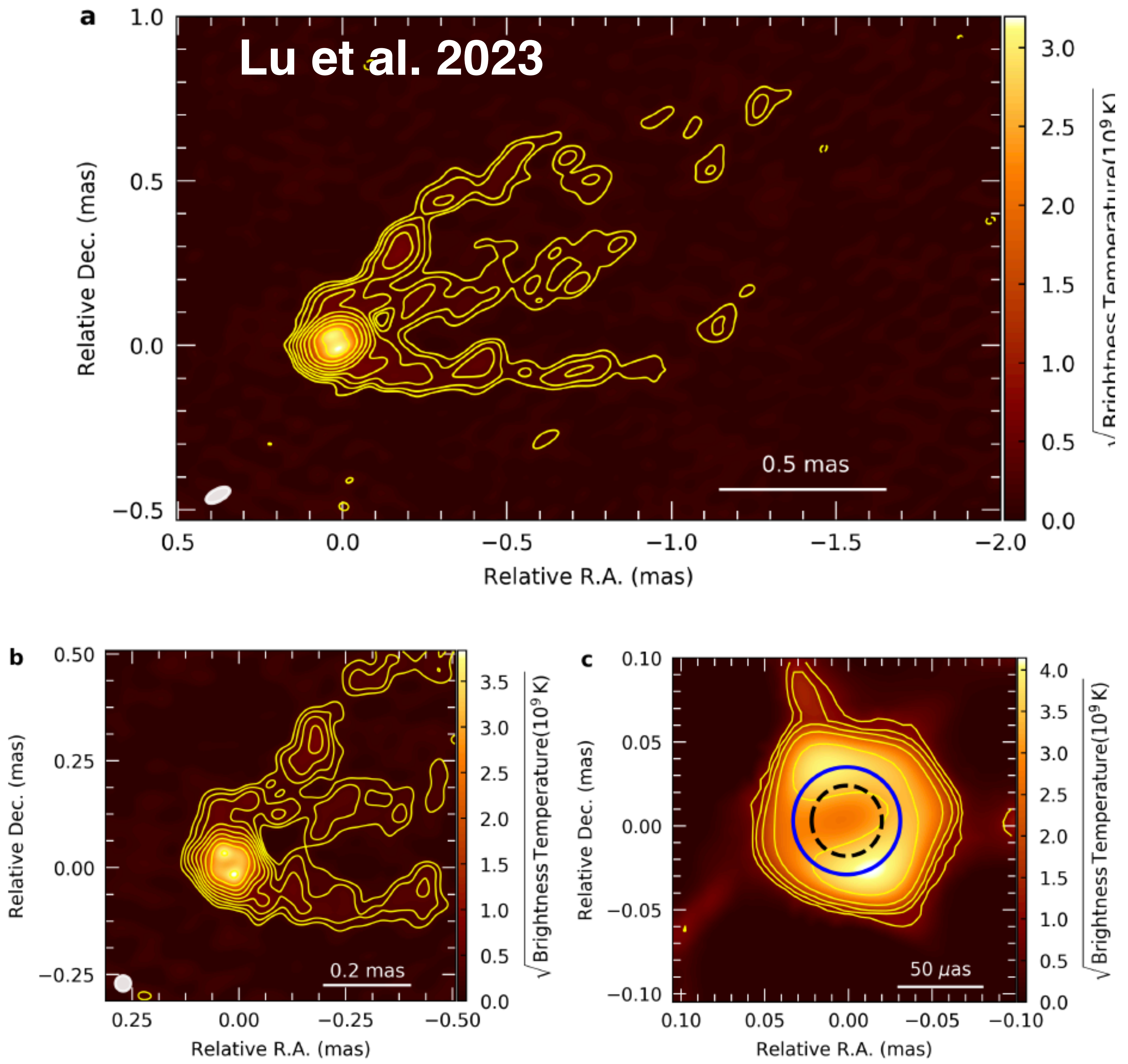
a_*	$\sigma_{\rm jet}(\phi_{\rm obs})$ [°]	$\sigma_{\rm disk}(\phi_{\rm obs})$ [°]	$v^r_{\rm true}$
0.9375	4 (4)	13 (11)	0.49± 0.02 (0.49± 0.03)
0.5	5 (6)	16 (13)	0.34± 0.06 (0.34± 0.02)
0.0	53 (52)	53 (49)	0.26± 0.06 (0.26± 0.02)
-0.5	42 (40)	91 (89)	0.31± 0.04 (0.31± 0.02)
-0.9375	72 (72)	73 (73)	0.40± 0.03 (0.33± 0.06)

Scenario of the black-hole spin constant:

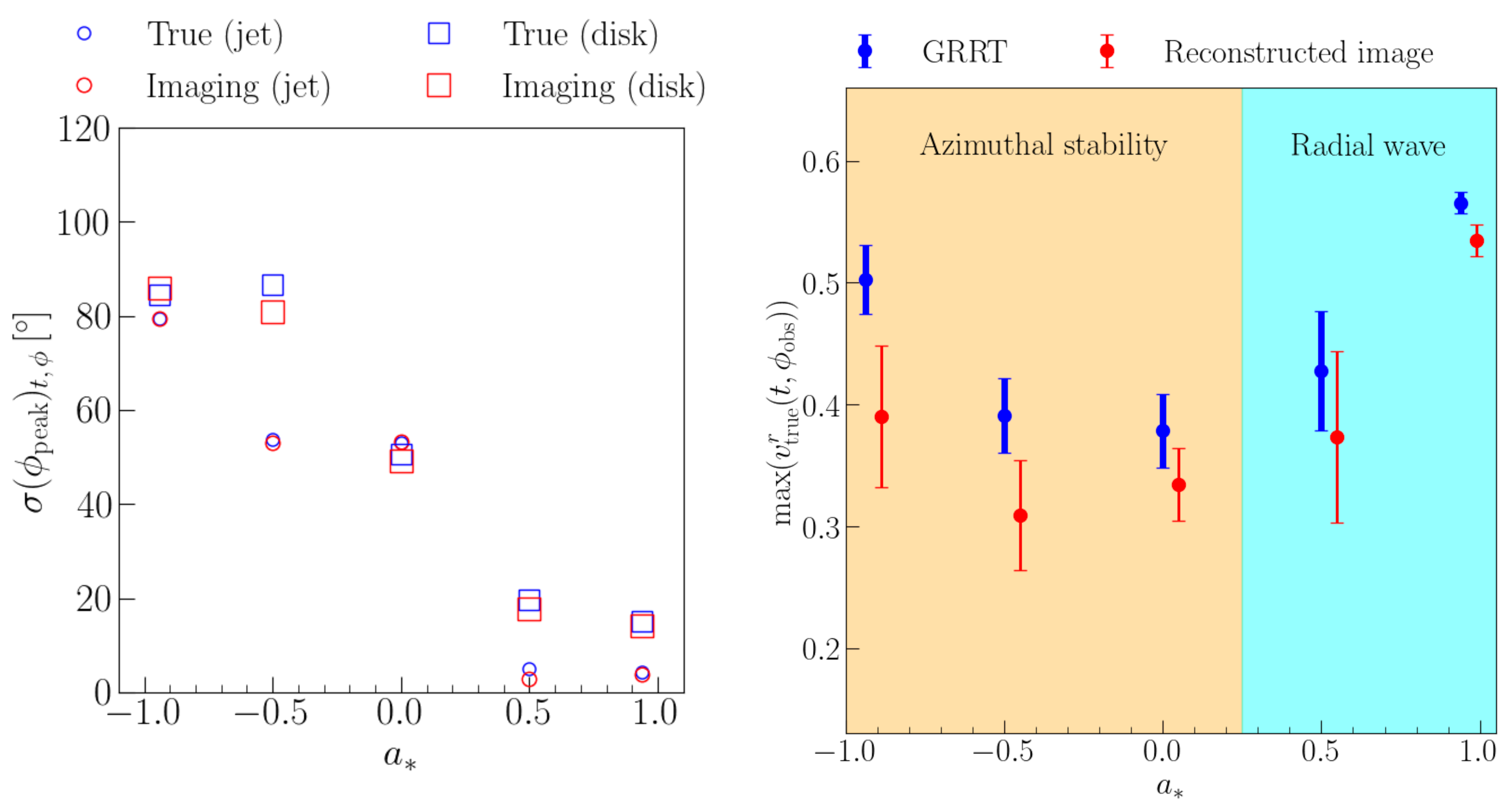
- **Spin direction: azimuthal variation**
- **Spin magnitude: radial jet velocity**

ngEHT has the potential to detect the dynamics

Synergy with 86 GHz observations



GRRT and ngEHT with 86GHz



Similar dynamical properties can be also seen at 86GHz

→Dynamics based on GMVA /w ALMA and GLT

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

EHT

Summary

Investigate the dynamics of jets and accretion disks with expected ngEHT:

- Azimuthal variation of the jet/disk includes info on the spin direction
- Jet involves the monotonical inhomogeneity with the radially propagation
- The radial wave velocity includes the info on the spin's magnitude
- ngEHT observations will enable us to detect the dynamics

Future study:

- synergy with low frequency observations
- broad parameter space
- polarization dynamics
- tilted disk