

Imaging distortions in black hole jets via next-gen GRMHD simulations

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Jets2021

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Ramesh Narayan, Michiel van der Klis, Sasha Philippov

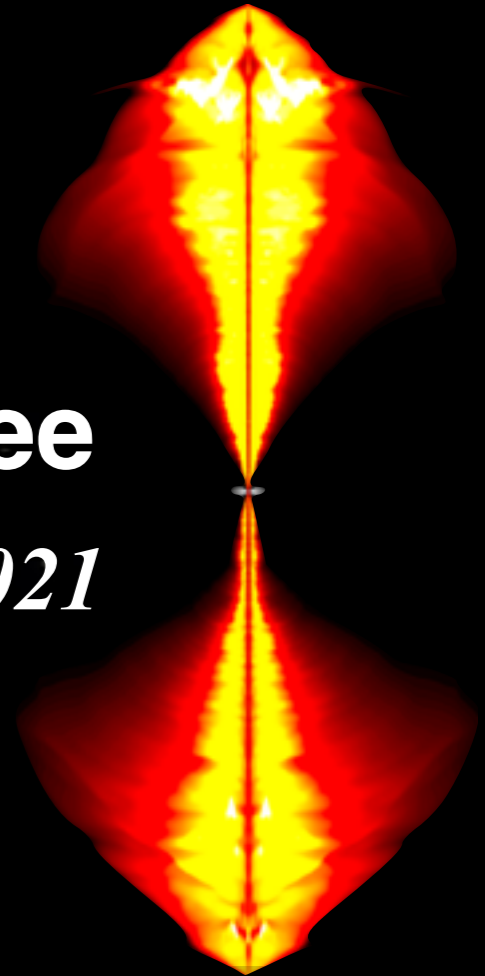


Image credit: NASA and The Hubble Heritage Team (STScI/AURA)



Event Horizon Telescope



BLACK HOLE
INITIATIVE

HARVARD UNIVERSITY



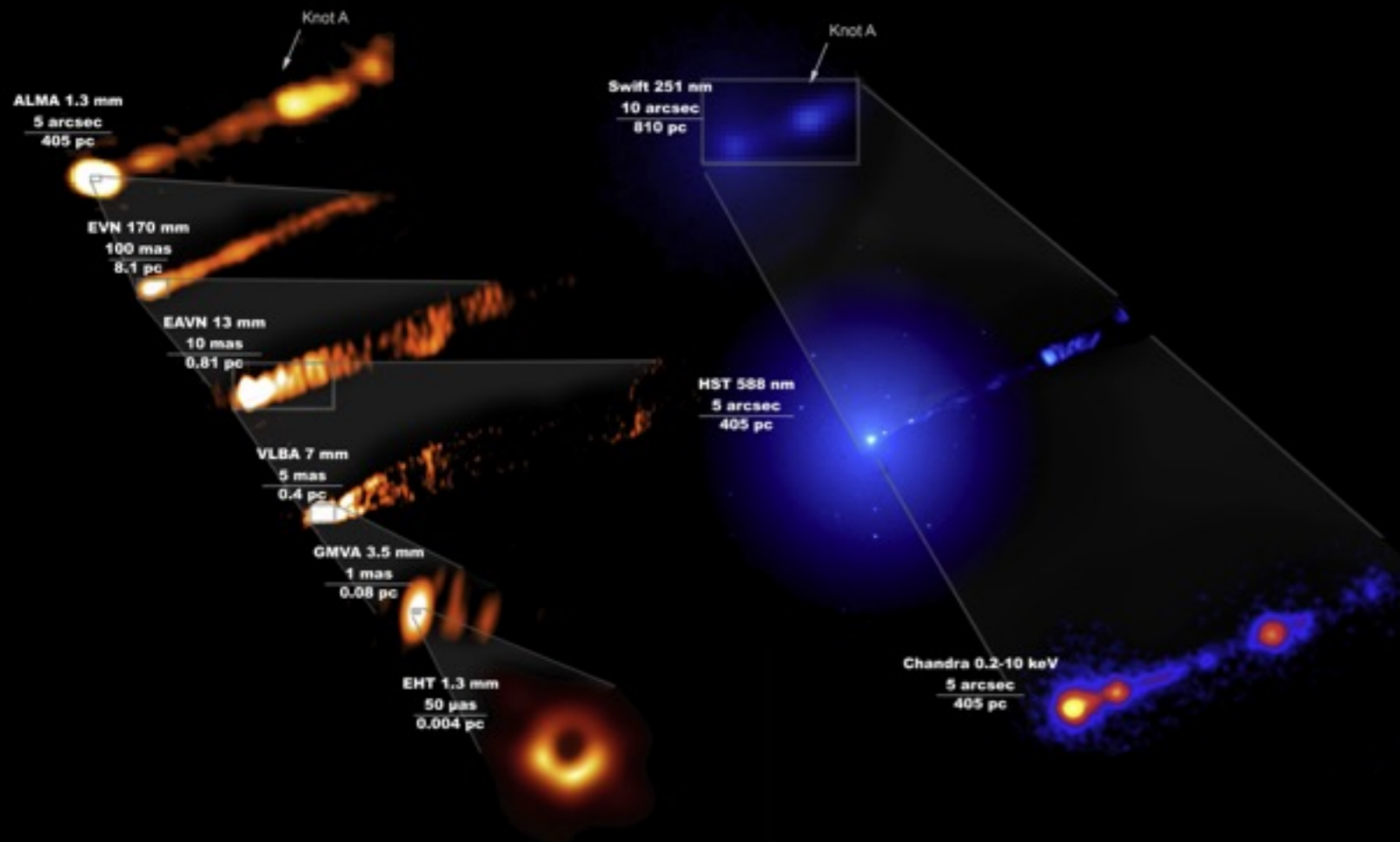
ANTON PANNEKOEK
INSTITUTE



summit

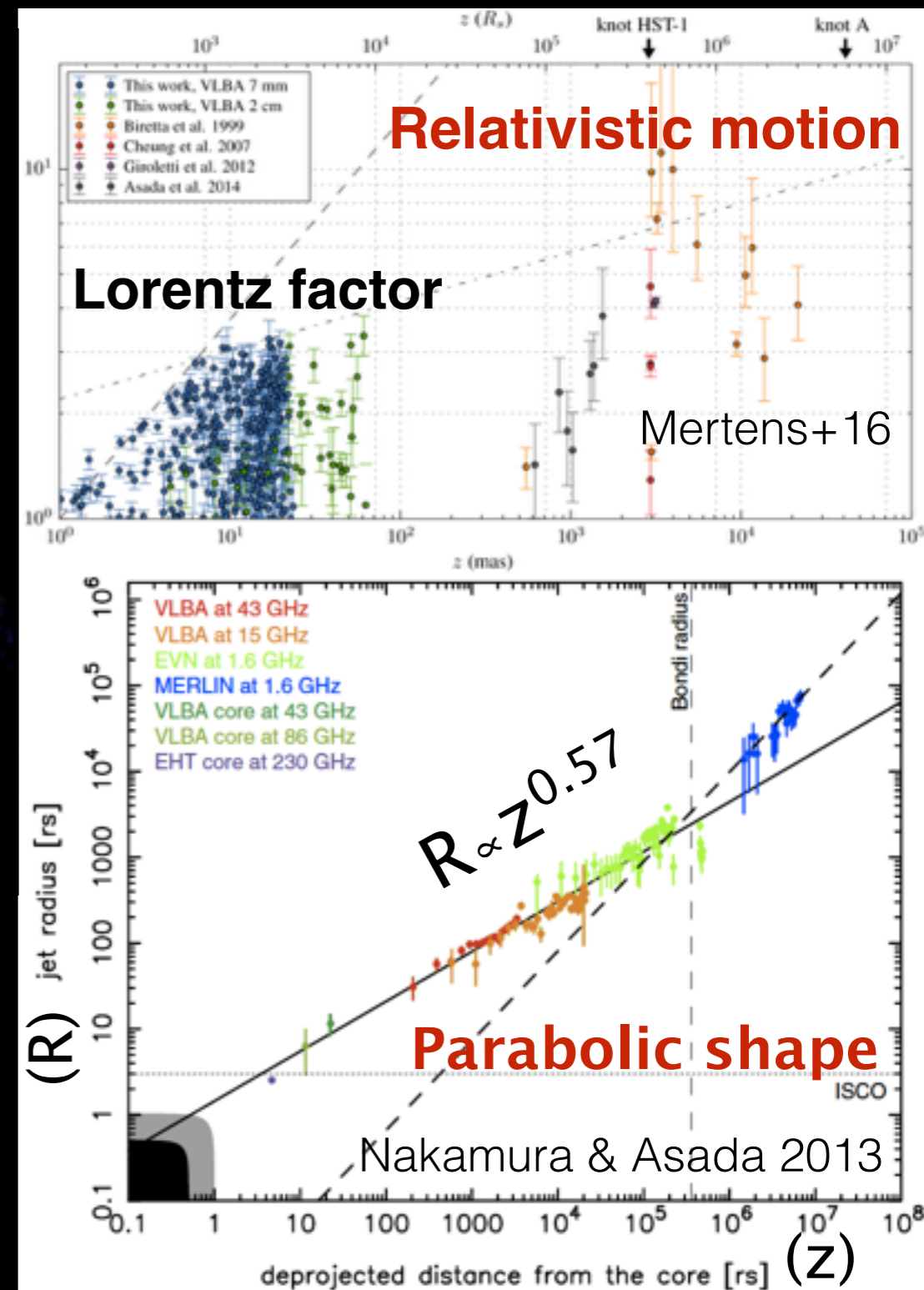
The M87 jet in scales

Jet properties



Multi-Collab M87 MWL +21

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Extreme resolutions

with H-AMR (arXiv: Liska, KC+19)

Producing 2D large scale jets

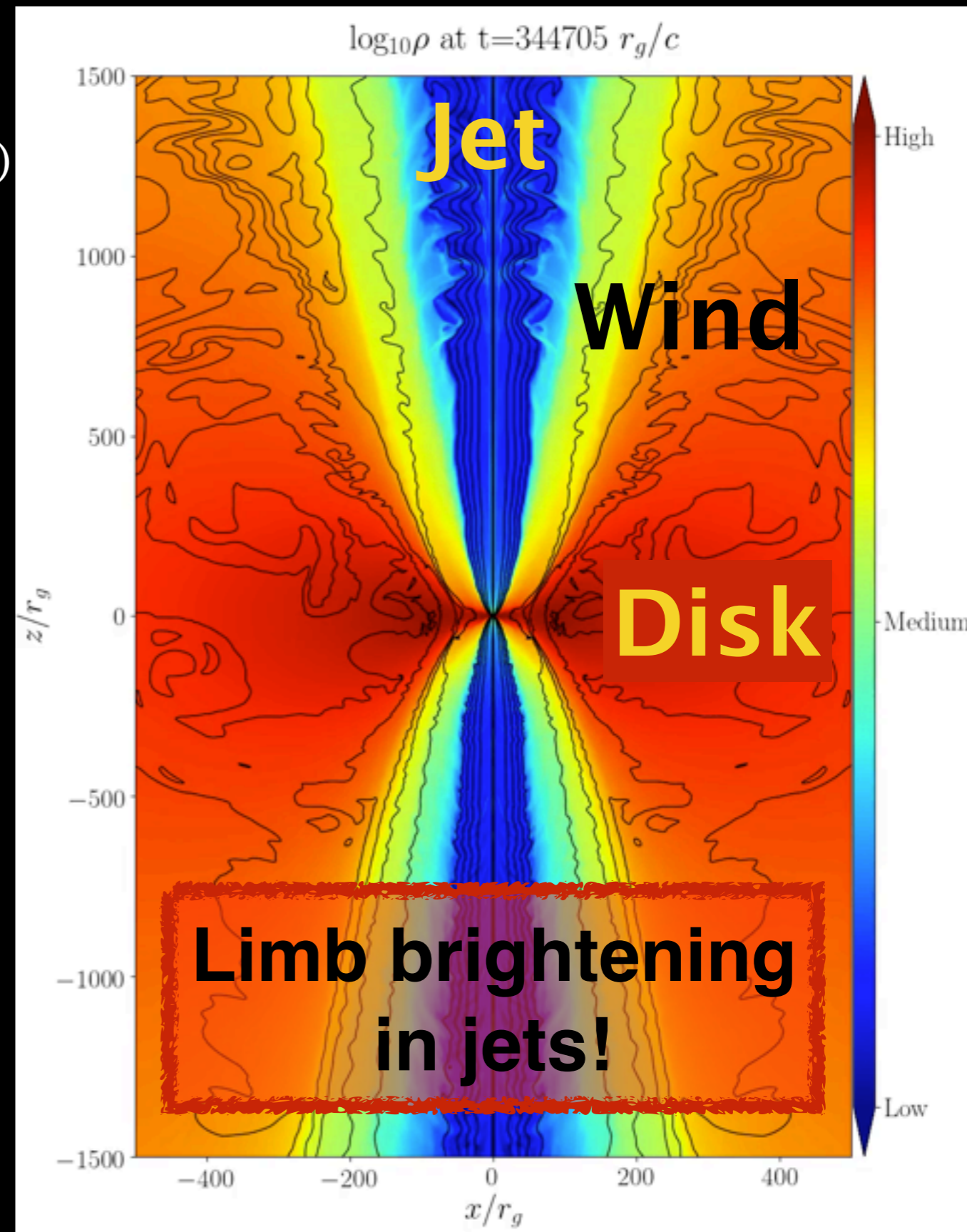
Matches properties of M87's jet:

- Velocity profile
- Shape

All-in-one (ideal!) simulation?

- Black hole accretion
- Jet launching & acceleration
- Jet mass loading & deceleration

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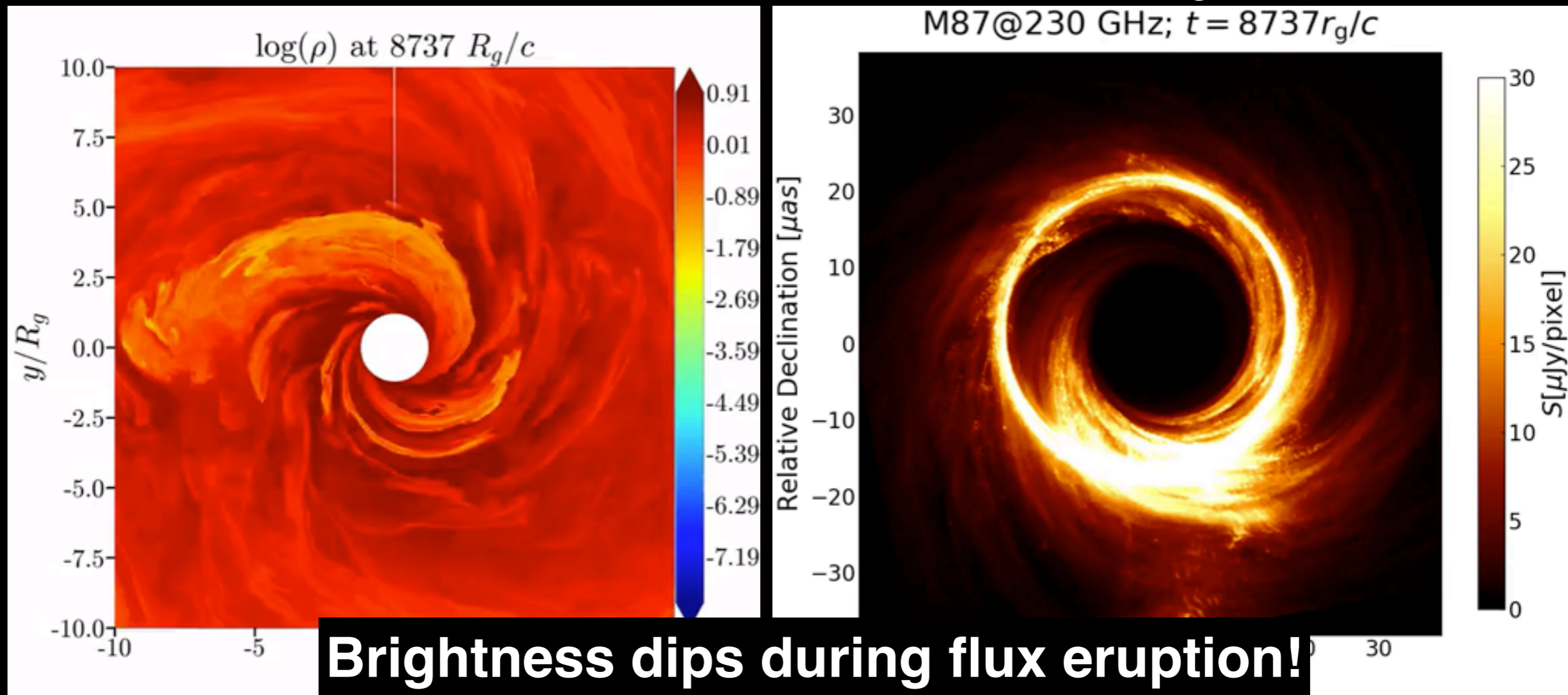
KC, Liska, Tchekhovskoy & Markoff 2019

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Extreme resolutions with H-AMR

Imaging a $5376 \times 2304 \times 2304$ GRMHD simulation

Done using BHOSS: Younsi+20

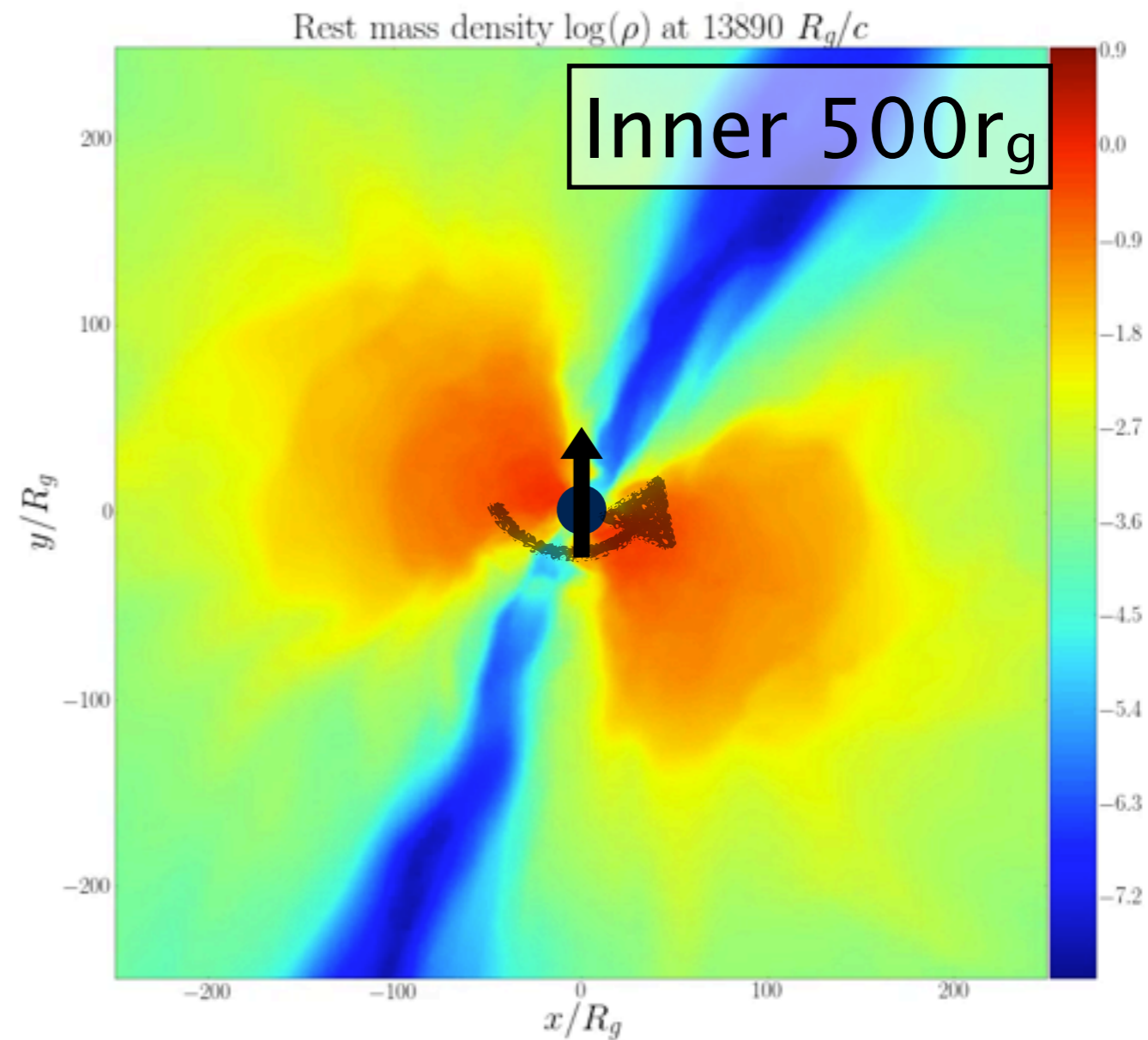
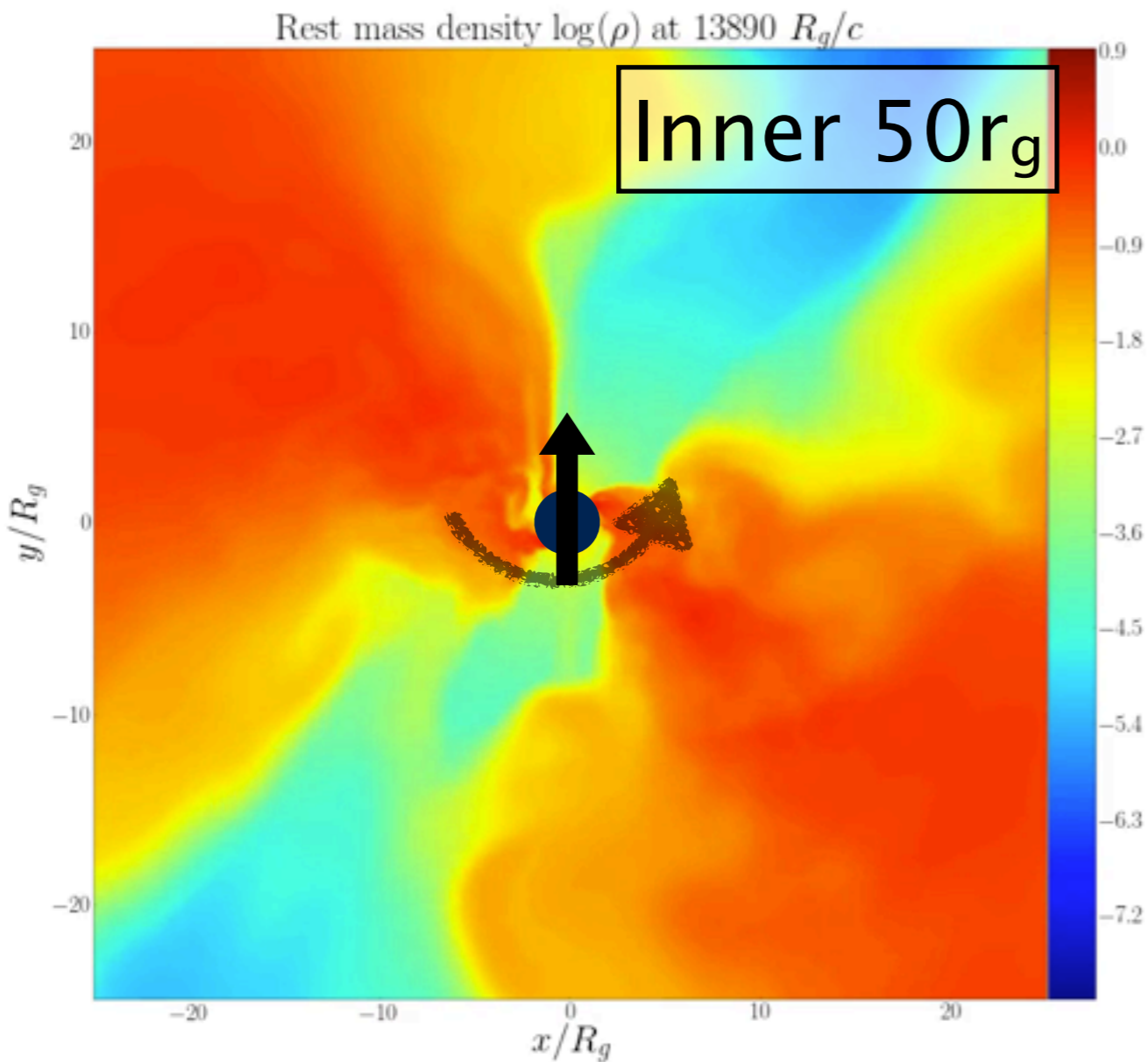


GRMHD: Ripperda, Liska, **KC**+,
(H-AMR group) in prep

GRRT: **KC**, Younsi, Markoff+,
(H-AMR+BHOSS) in prep

Exploring new geometries misaligned disks & jets

Liska+18; KC+20



**Jet aligns with the disk at
large distances!**

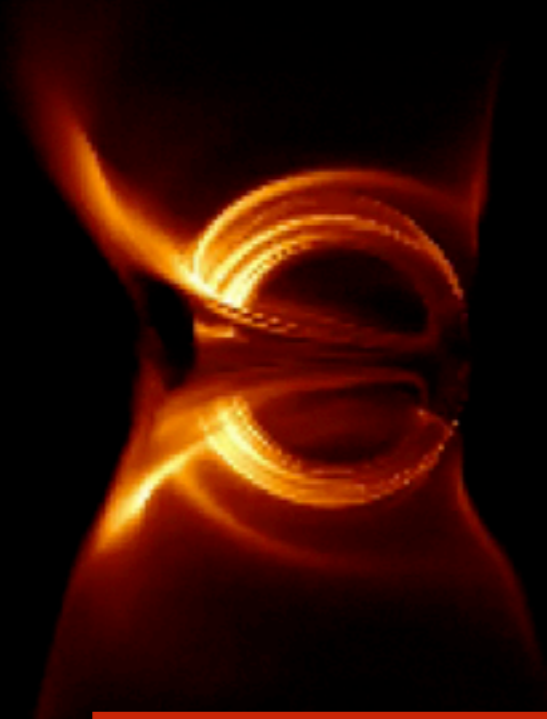
Misaligned disks: Edge-on@230 GHz (SgrA*?)

(a) Aligned disk 20 μ as

(b) Misaligned disk 20 μ as

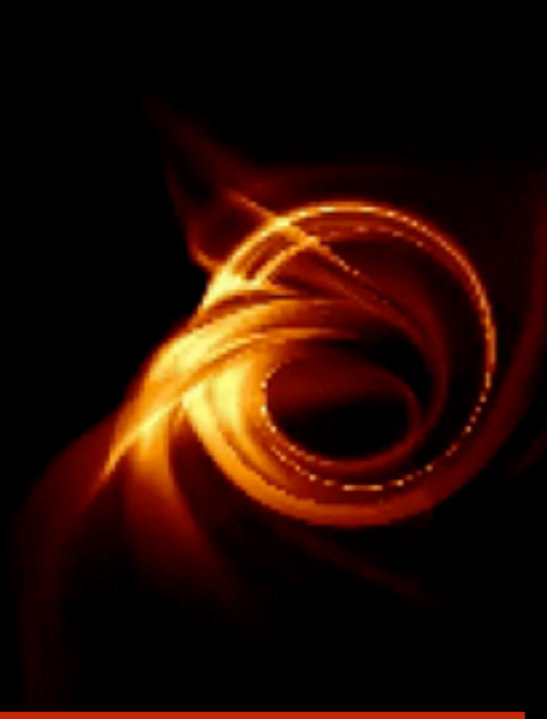
↑
Jet
direction

↑
black hole
spin
direction



↑
Jet
direction

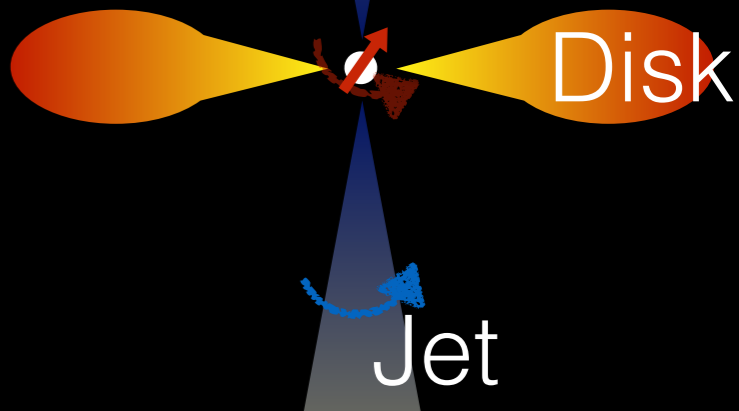
↗
black hole
spin
direction



Tracking time & spatial variability is crucial



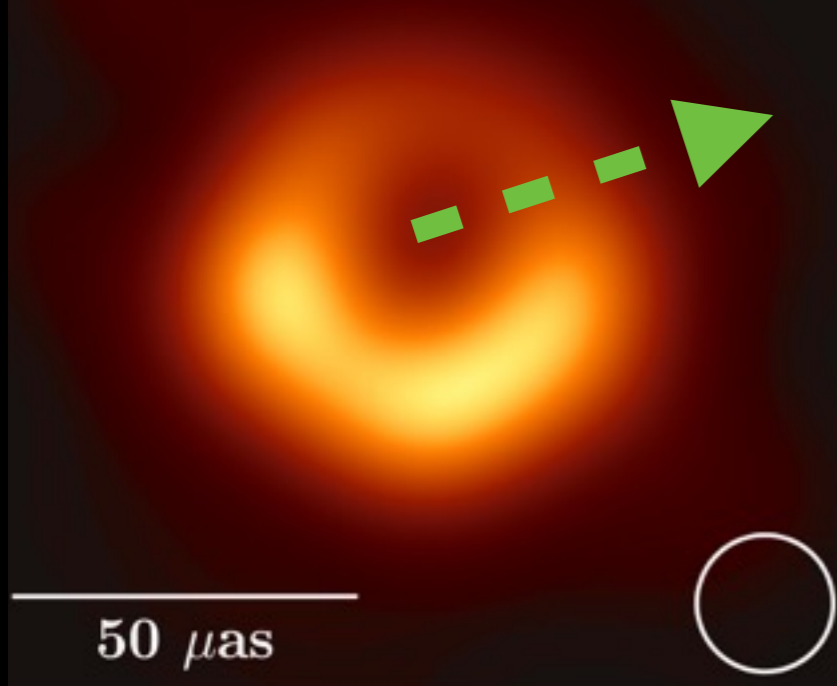
Large scale jet is pointing up
(+z direction)



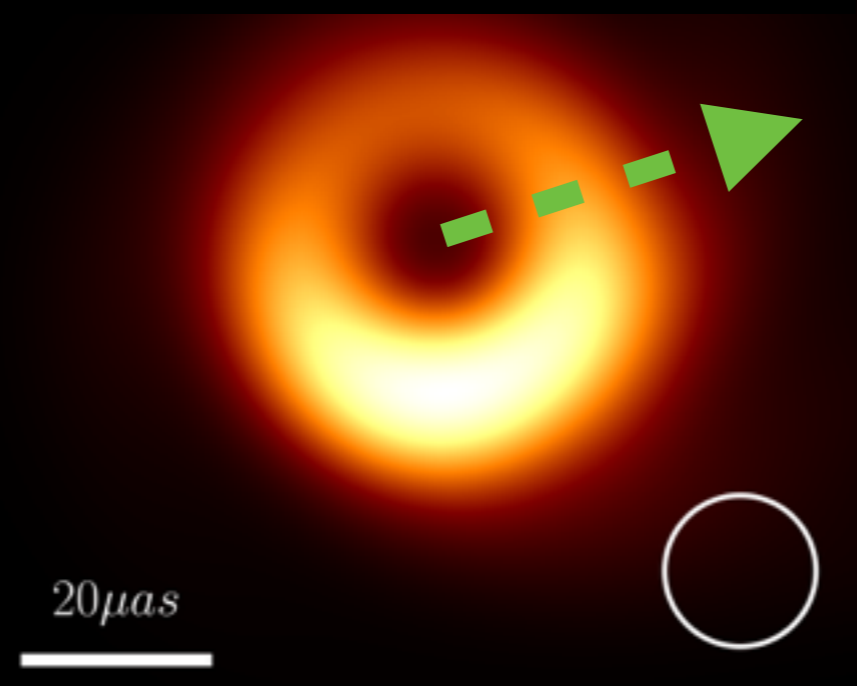
KC, Younsi, Liska+20,
MNRAS, 499, 362

Misaligned disks: M87@230 GHz

M87* April 11, 2017
EHT(paper I, 2019)

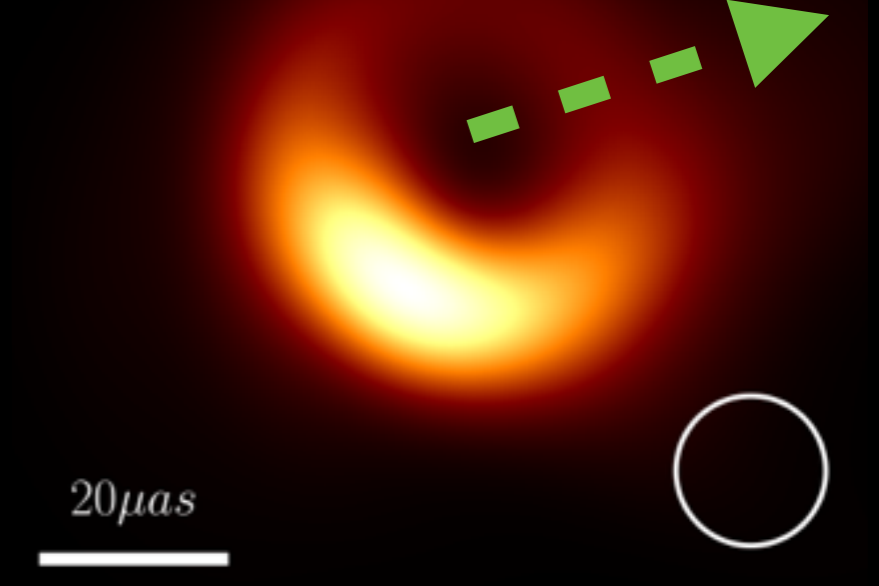


(a) Aligned disk

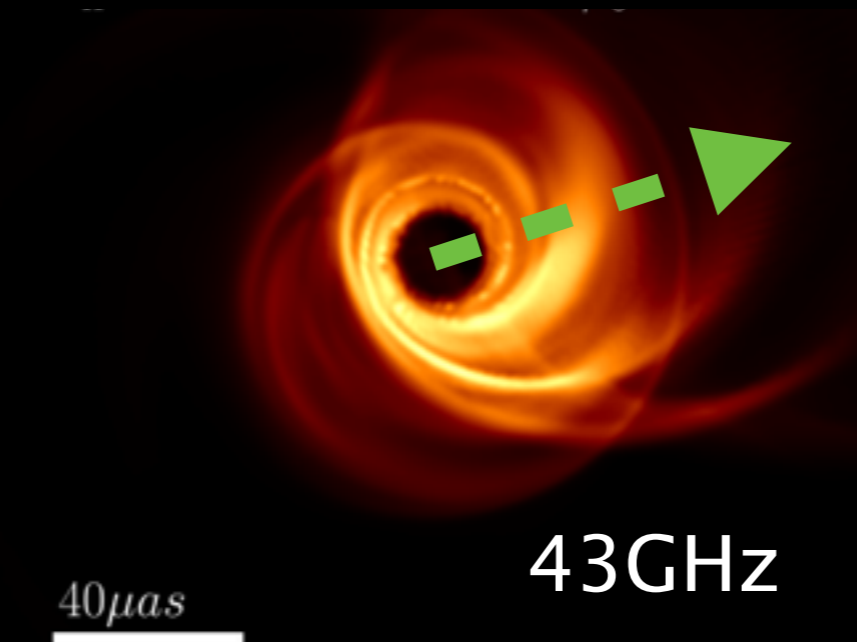
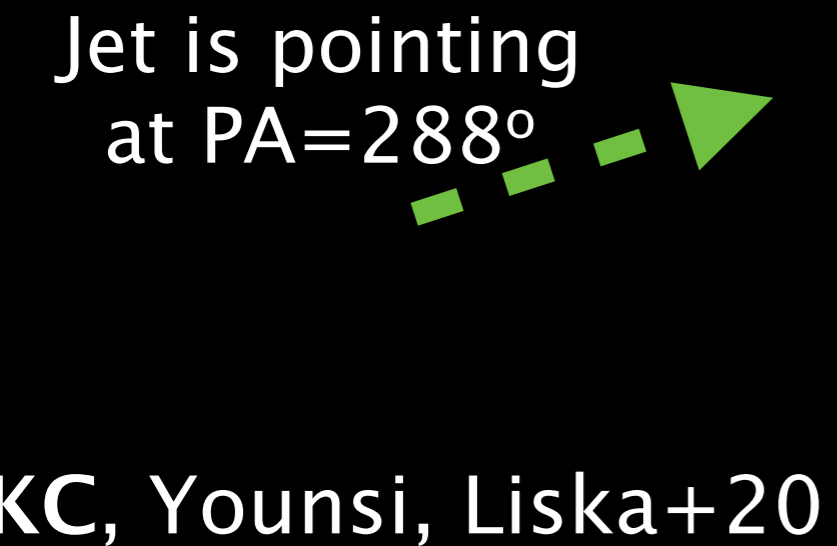


(b) Misaligned disk

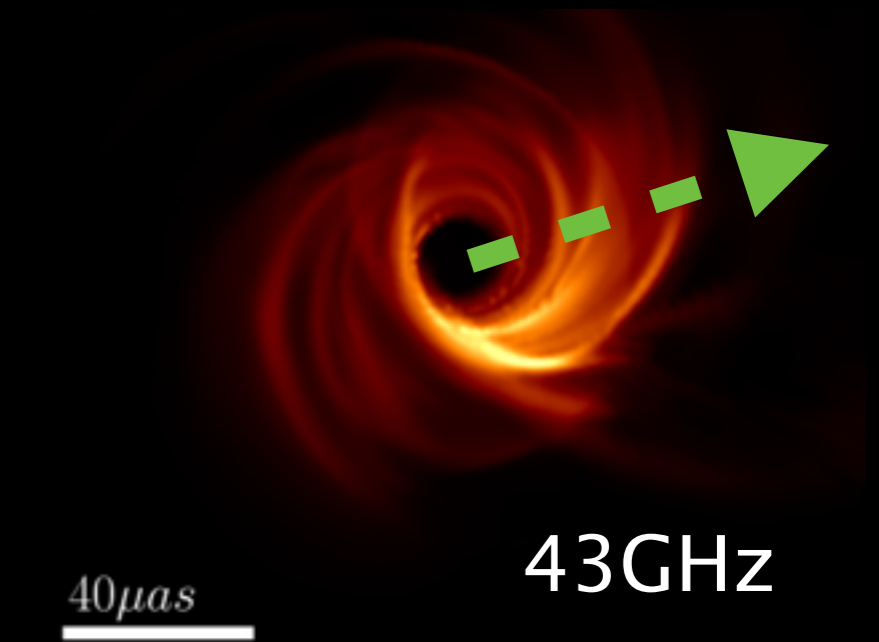
Crescent can shift!



Jet is pointing
at PA=288°



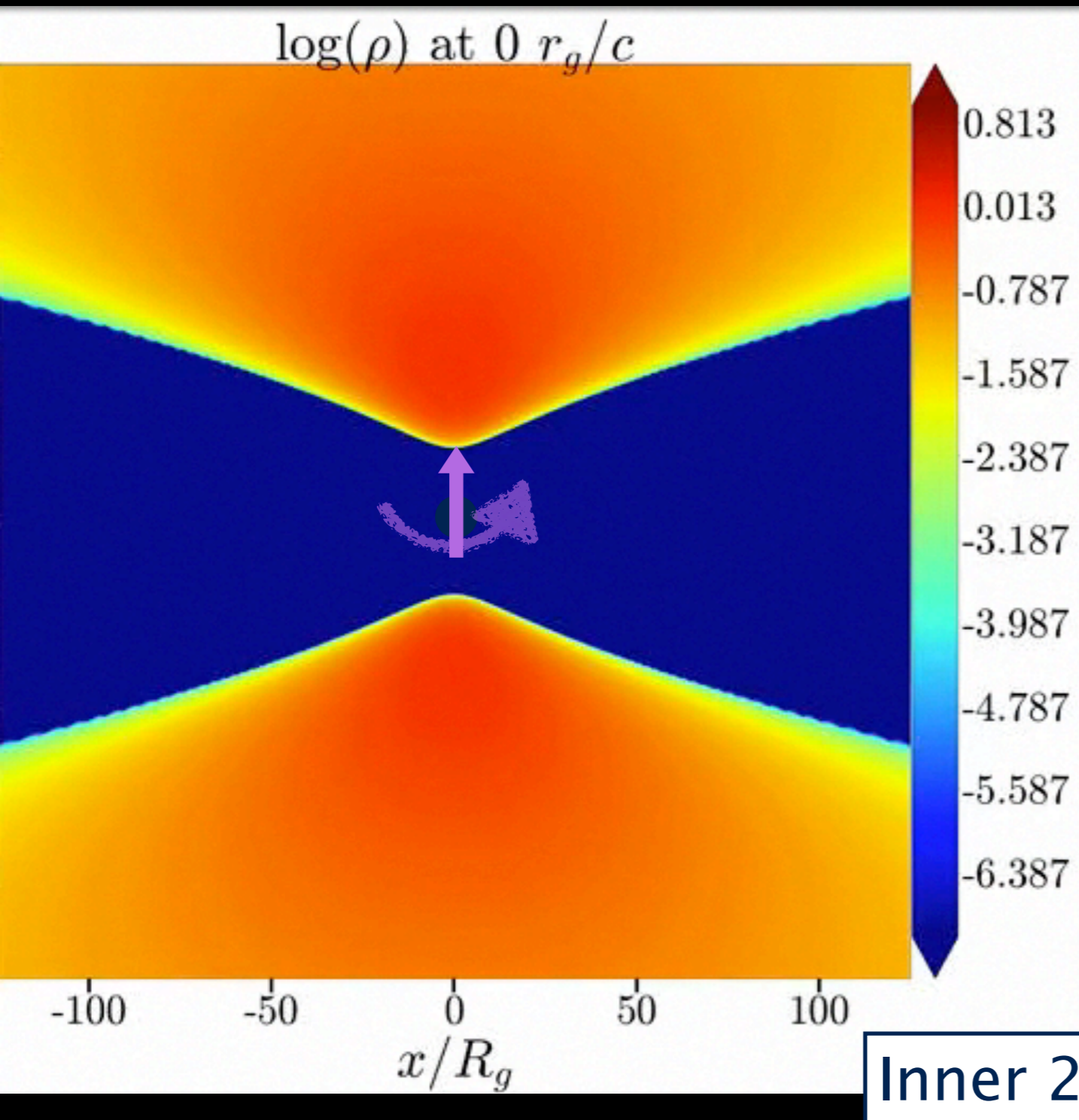
43GHz



43GHz

KC, Younsi, Liska+20

A 90 degrees misaligned disk



- A jet still forms!
- Some precession & lots of twists:
high cadence monitoring required

Connections to other types of inflow conditions will be important!

Summary: exploring macro–micro physics in jets!

- **Morphological changes due to misalignment:** shadow size differences detectable; bend in jet visible at radio frequencies
- **Variability in all shapes and forms:** warped disks, bent jets, eruptions, pinches, kinks
- **VLBI:** connecting the event horizon to the jet → testing tilt and inflow/outflow variability

