Event Horizon Telescope

Numerical Modeling of EHT Sgr A* Results

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with Ben Prather, Michi Baubock, George Wong, Vedant Dhruv, Abhishek Joshi
including work presented on behalf of the
Event Horizon Telescope Collaboration

ICASU conference, May 2022

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EHTC et al. 2022, Paper III

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Interferometry

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millimeter VLBI

- 1.3mm VLBI network, $\Delta\theta \sim \lambda/D \sim (1.3\text{mm})/(2\ R_\oplus) \sim 25\mu\text{as}$
- 2017 campaign: April 5, 6, 7, 10, 11; 6 targets, incl M87 & Sgr A*
- 8 telescopes at 6 sites

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credit: ESO+

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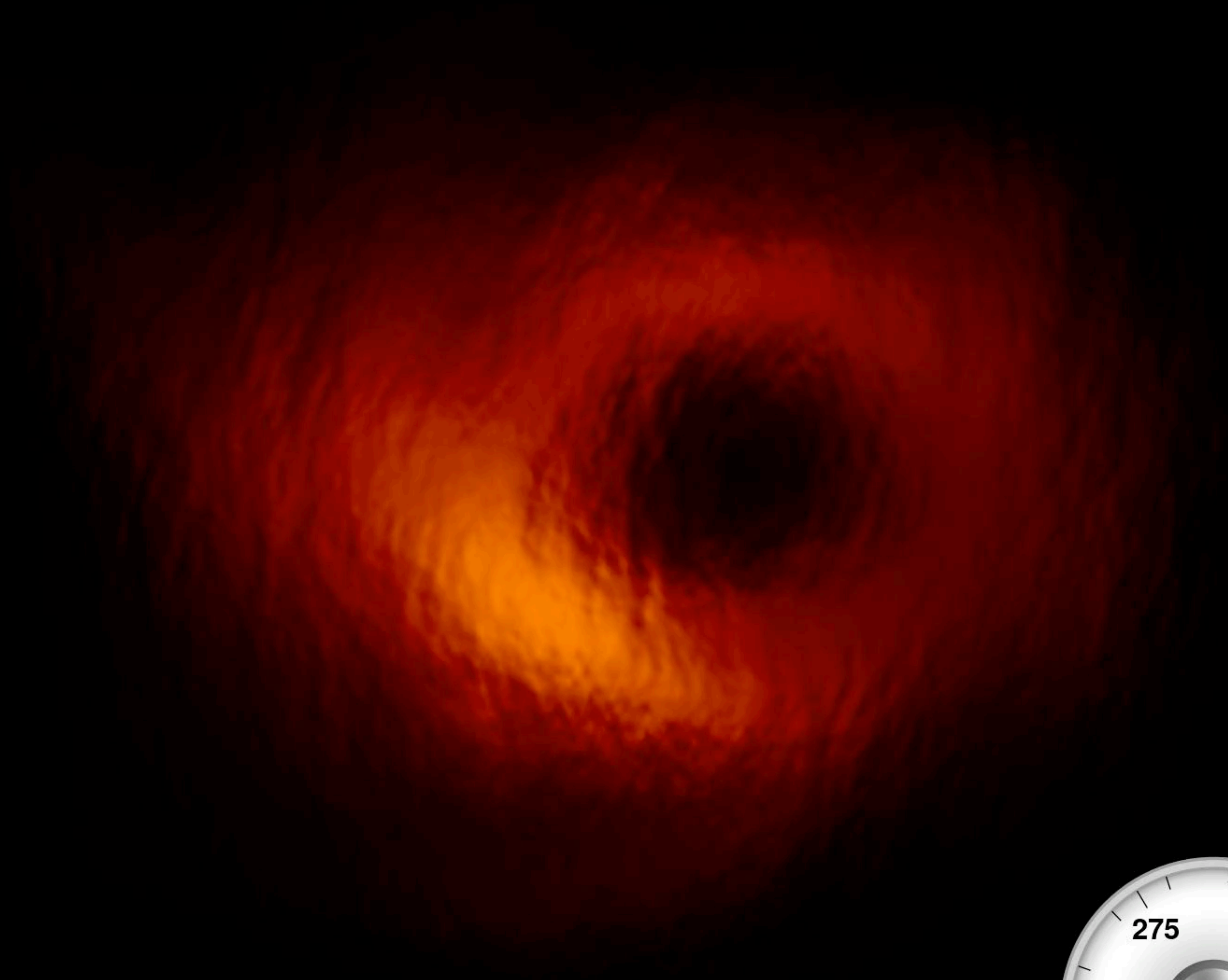
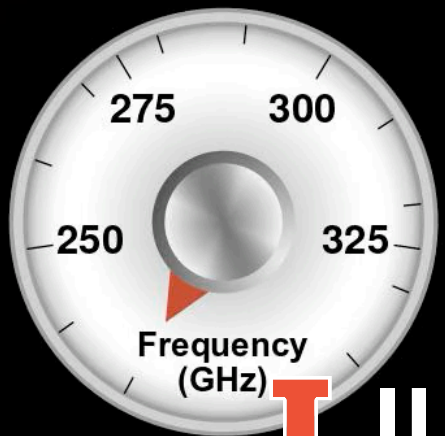
Why is Sgr A* harder than M87*?





credit: M. Johnson

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$$M \simeq 6.6 \times 10^9\,\mathrm{M}_\odot$$

$$\theta_g \equiv \frac{GM}{c^2 D} \simeq 3.8\,\mu\mathrm{as}$$

$$t_g \equiv \frac{GM}{c^3} \simeq 9.0\,\mathrm{hr}$$

$$M \simeq 4.1 \times 10^6\,\mathrm{M}_\odot$$

$$\theta_g \equiv \frac{GM}{c^2 D} \simeq 5.0\,\mu\mathrm{as}$$

$$t_g \equiv \frac{GM}{c^3} \simeq 20.4\,\mathrm{sec}$$

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M87

Sgr A*

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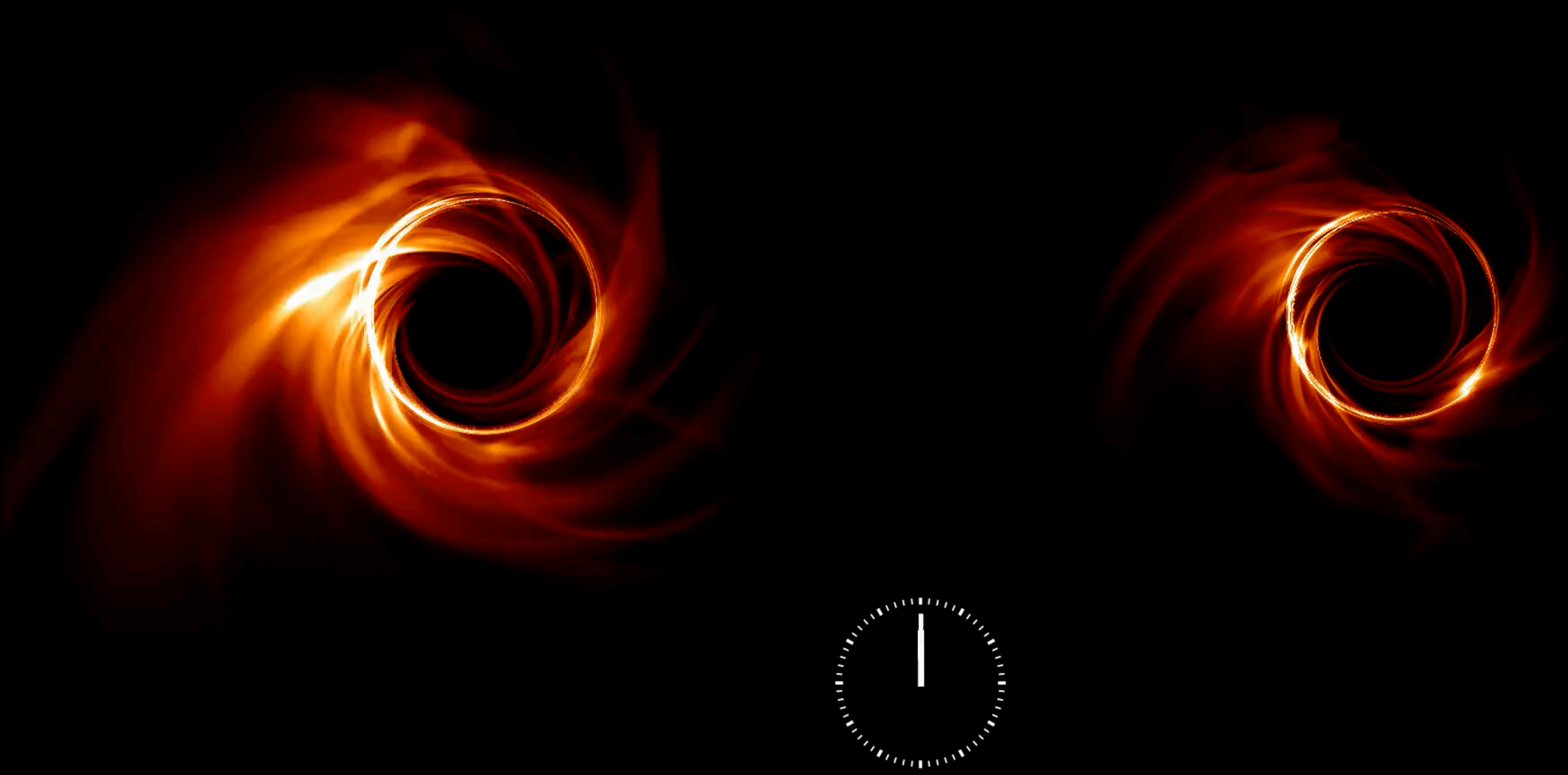

credit: A. Joshi

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Simulations and Numerical Experiments

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credit: Raley et al., Uni Primary School

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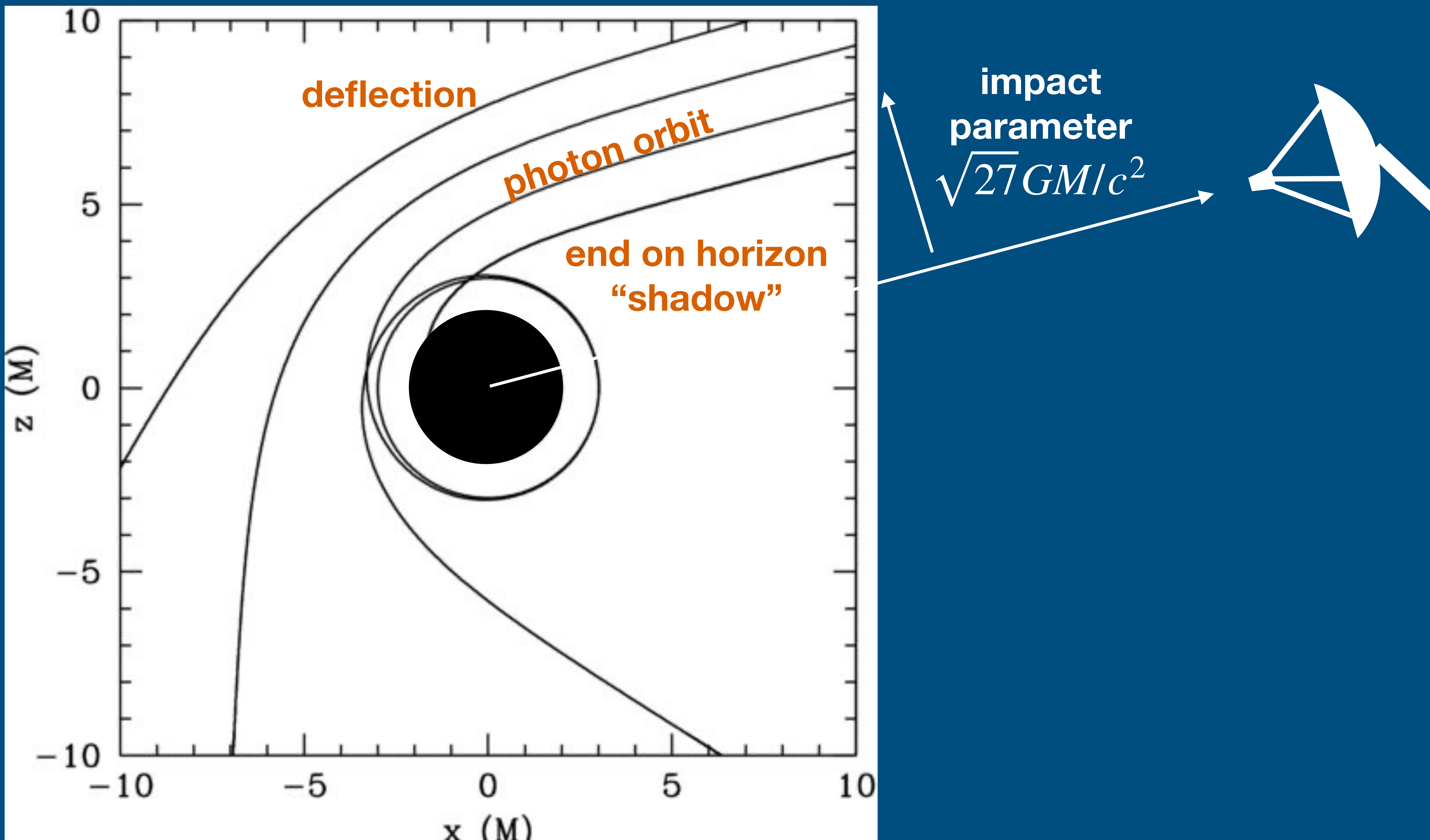
Gravitational Macrolensing



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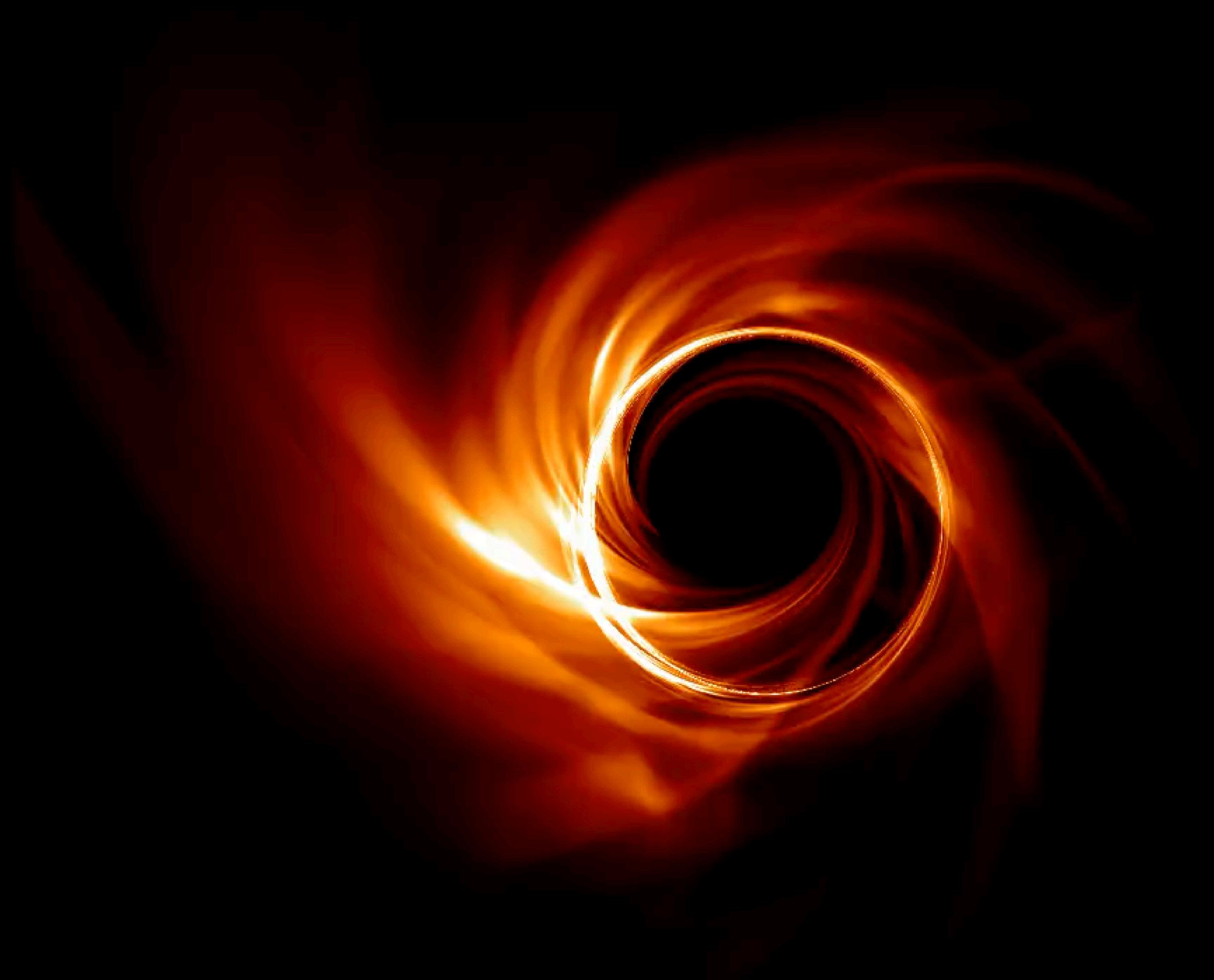
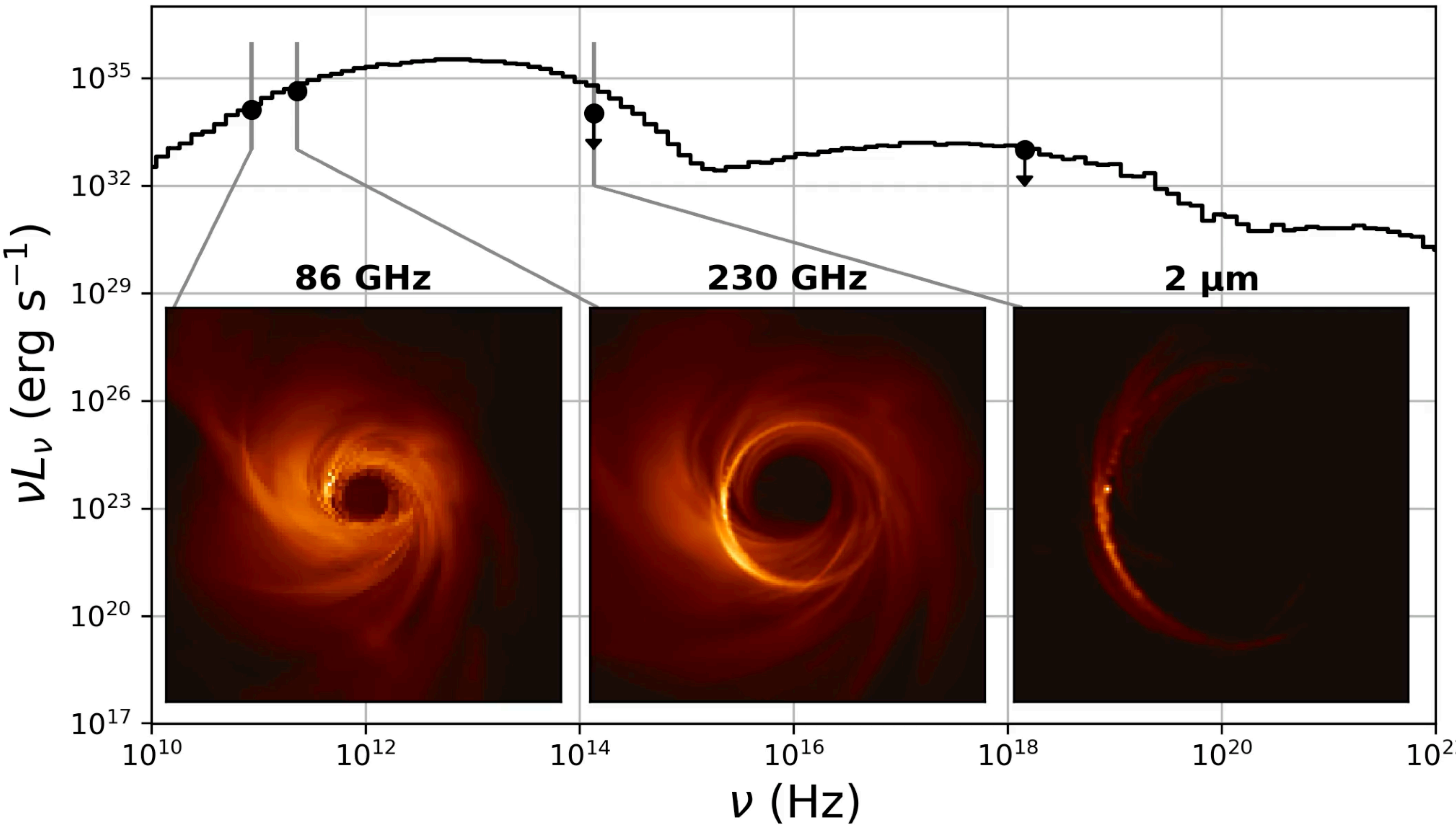
1. ideal GRMHD simulation
2. assignment of electron DF
3. radiative transfer calculation

$\Rightarrow$ Stokes IQUV(ν,x,y,t)



credit: A. Joshi



credit: B. Prather

Constraints on Models

EHTC et al. 2022, Paper I, V

Constraints

EHT-derived constraints

- 5, including 2nd moment, ring width

non-EHT constraints

- 4, including 86GHz size, flux

Variability constraints

- 2: structural variability, 230GHz flux var.

EHTC et al. 2022, Paper I, V

Model Parameters

1. spin
2. magnetization (MAD vs SANE)
3. inclination
4. electron DF assignment parameter R_{high}

EHTC et al. 2022, Paper I, V

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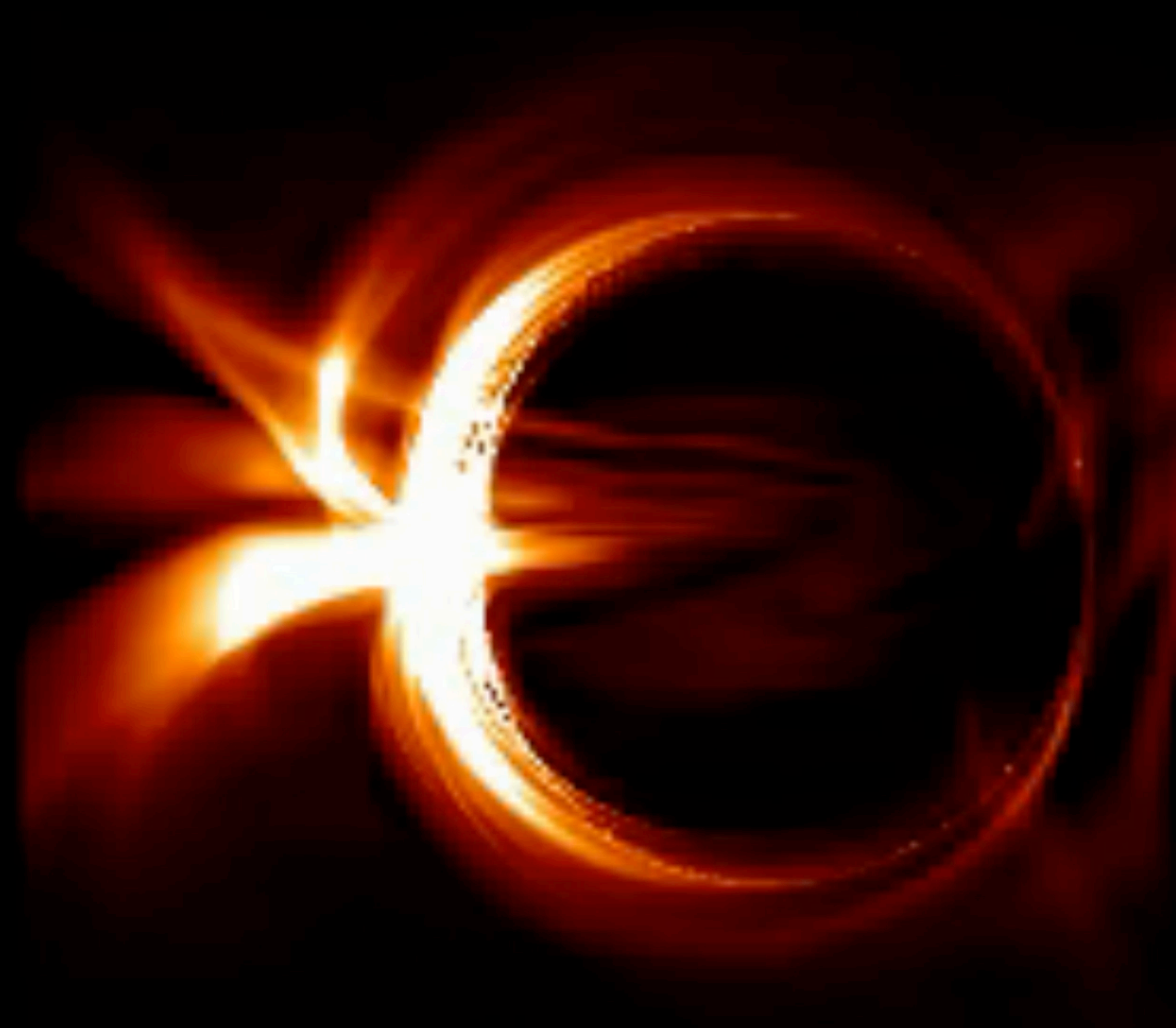
credit: B. Prather



MAD

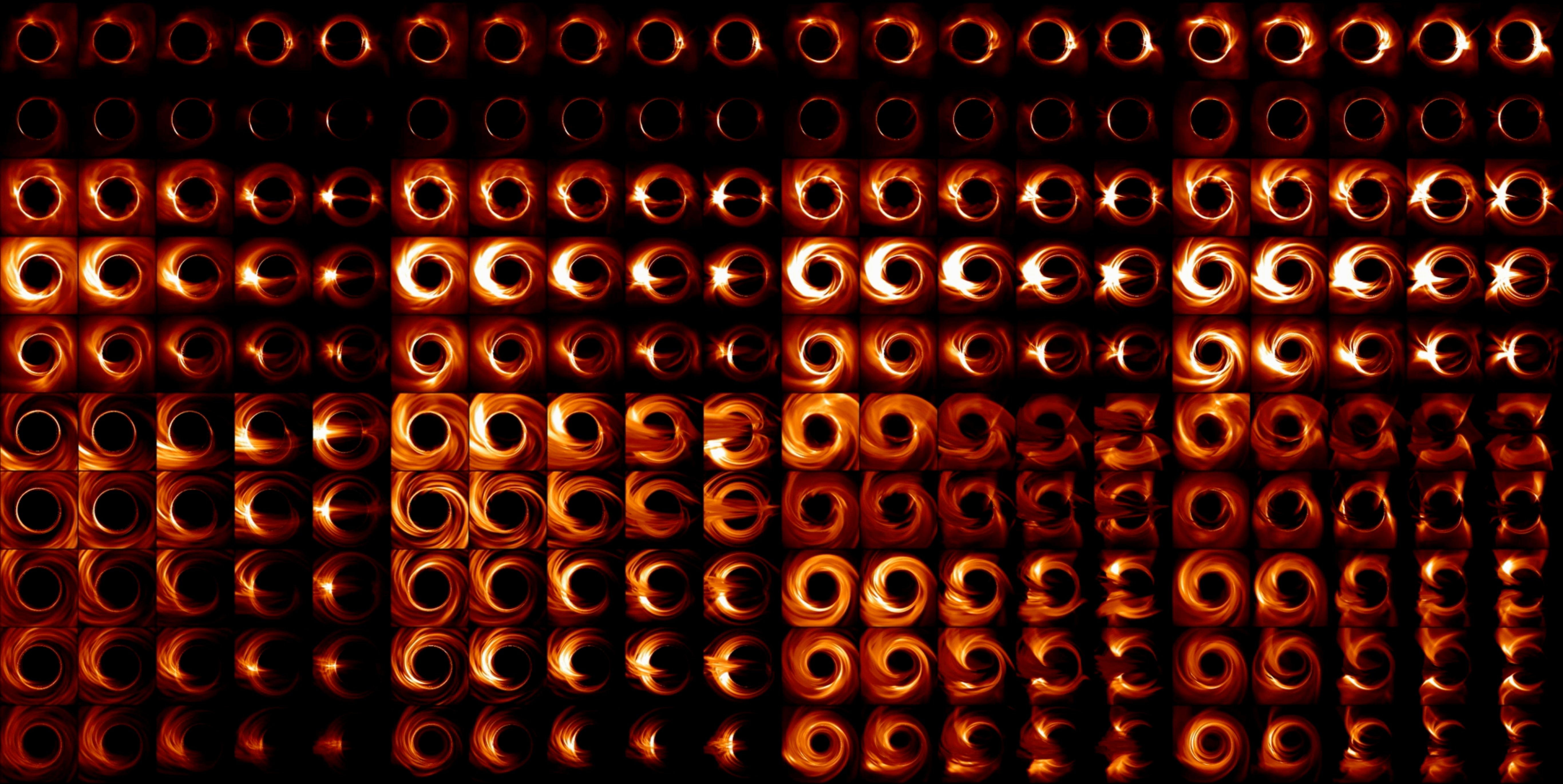
$R_{high} = 160$

$a = +0.94$

$i = 90$

EHTC et al. 2022, Paper V

credit: B. Prather



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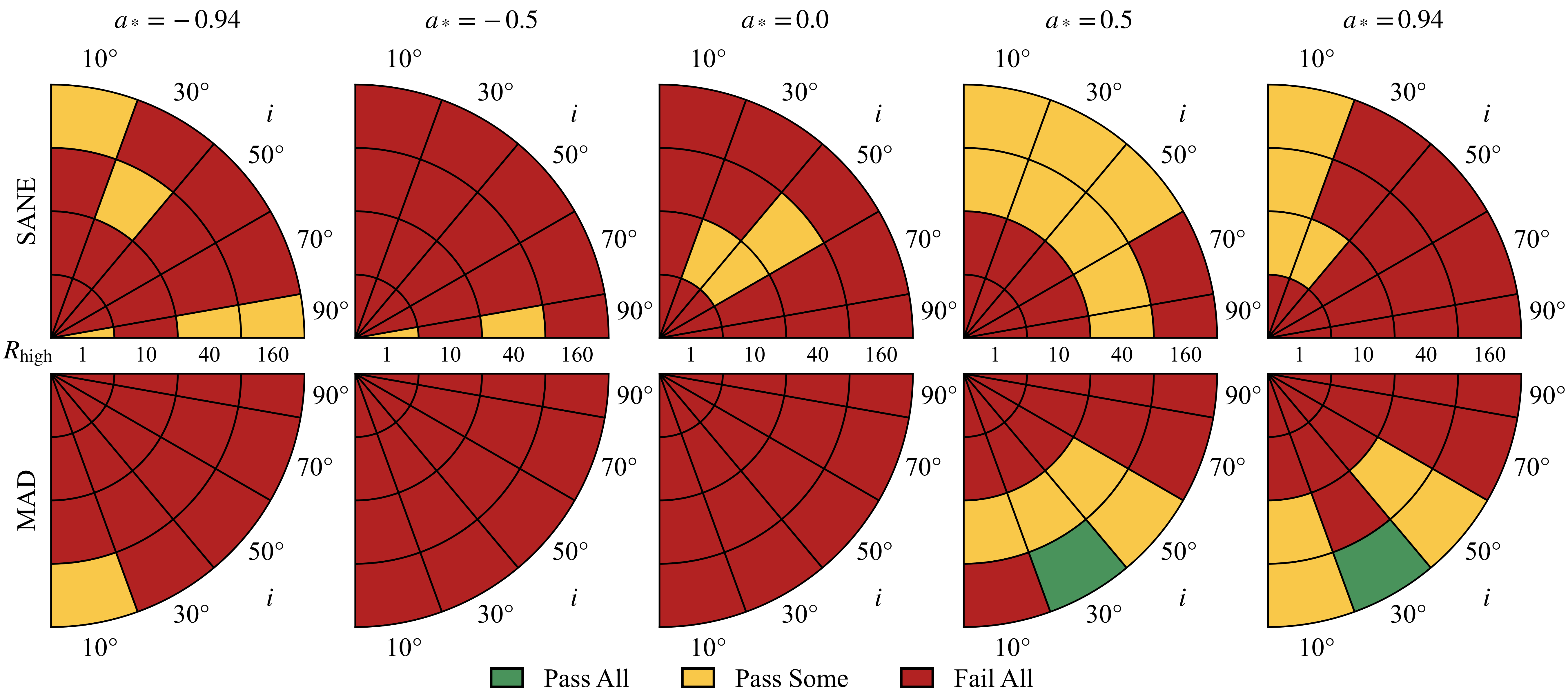
All constraints except variability



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Uncertainties

EHTC et al. 2022, Paper I, V

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If you make a theory, for example, and advertise it, or put it out, then you must also put down all the facts that disagree with it, as well as those that agree with it.

-Feynman

- fluid model for collisionless plasma
    - $\mathrm{Kn} \sim 10^5$
    - nonthermal electron DF
- boundary conditions (wind-fed?)
- model duration
- numerical resolution

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Future Prospects

Future Prospects

polarization for Sgr A*

denser Fourier space coverage

movies

345GHz observations

space-based antenna?

more predictive numerical models including viscosity and conduction

precision bothrology!

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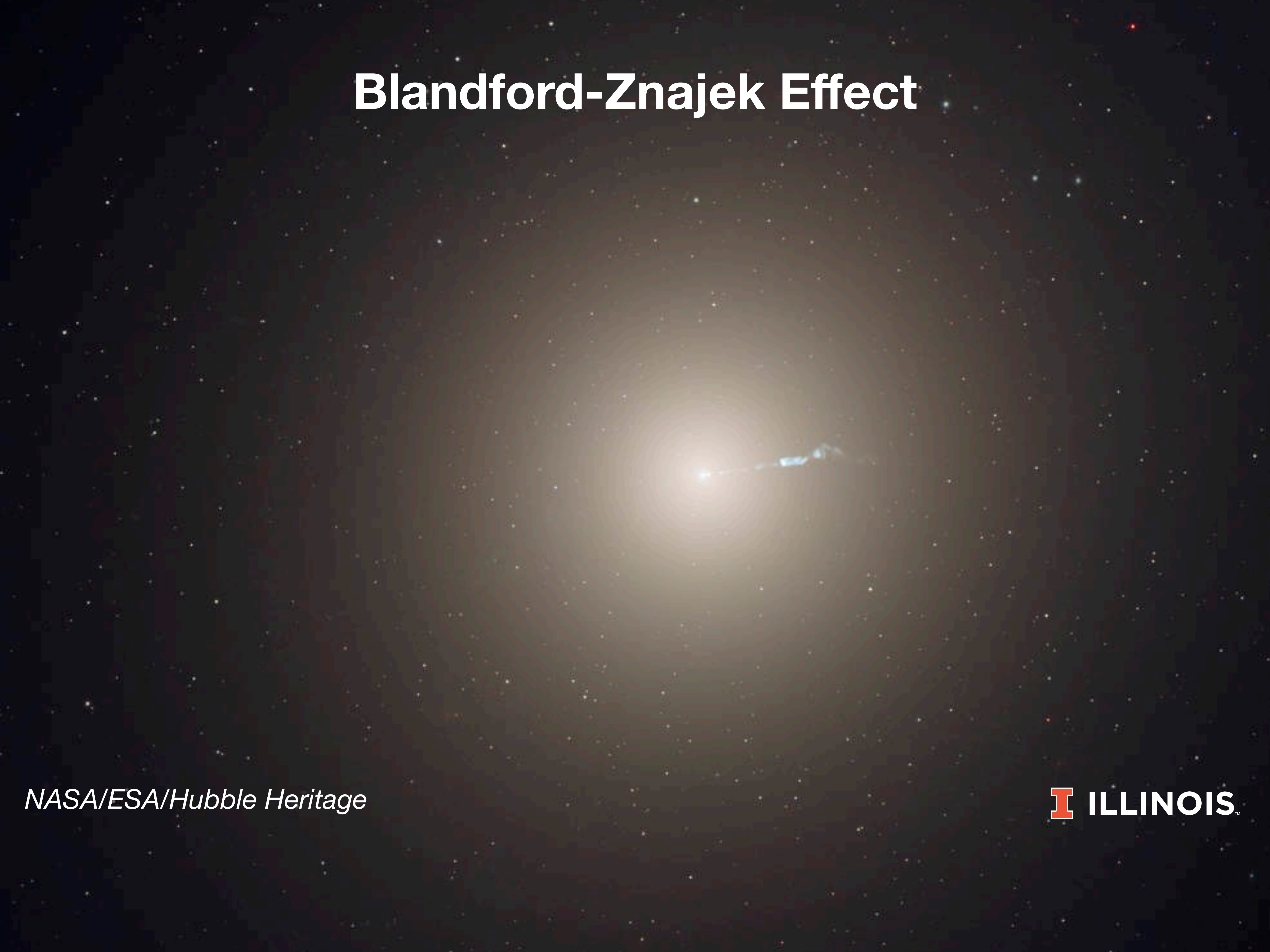
Blandford-Znajek Effect



NASA/ESA/Hubble Heritage

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Conclusions

- first image of galactic center black hole
- new, improved measurements on the way
- models explain all the data *except* variability
- variability crisis: origins of flow fluctuations?

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