Probing supermassive compact objects with GRAVITY and the EHT

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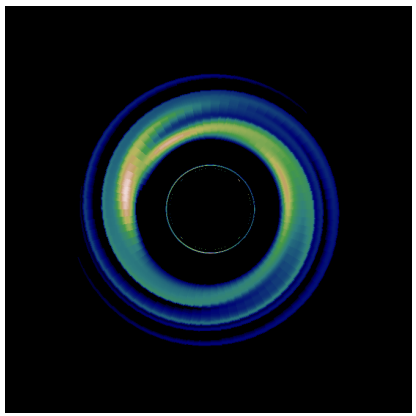
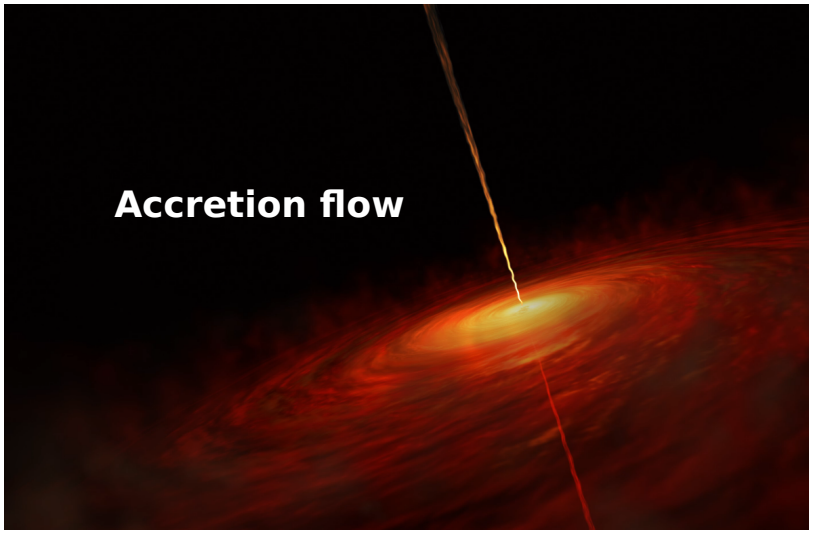
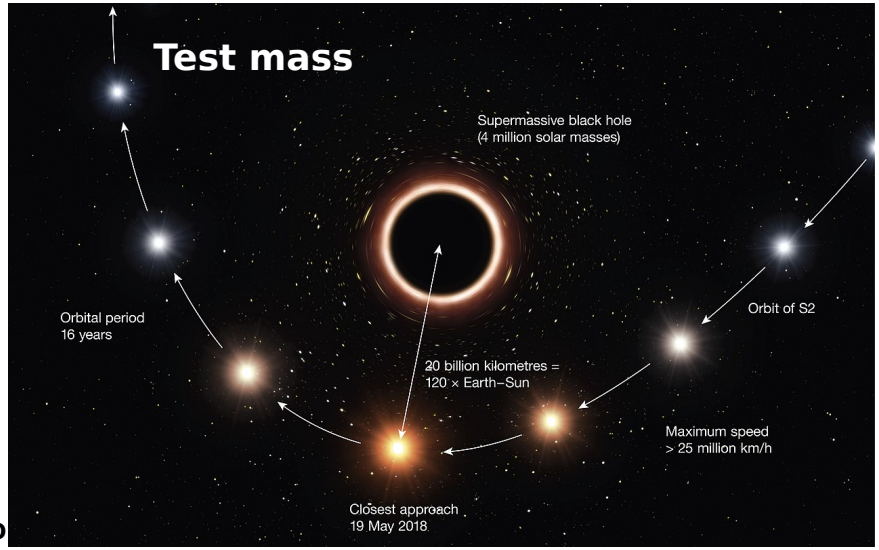




Pros: very close
Cons: very complex

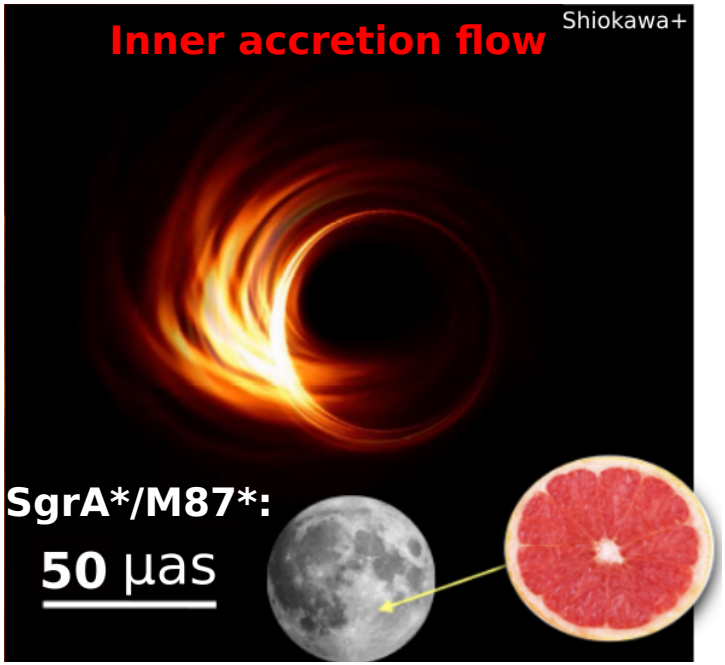
Pros: simple probe
Cons: rather far

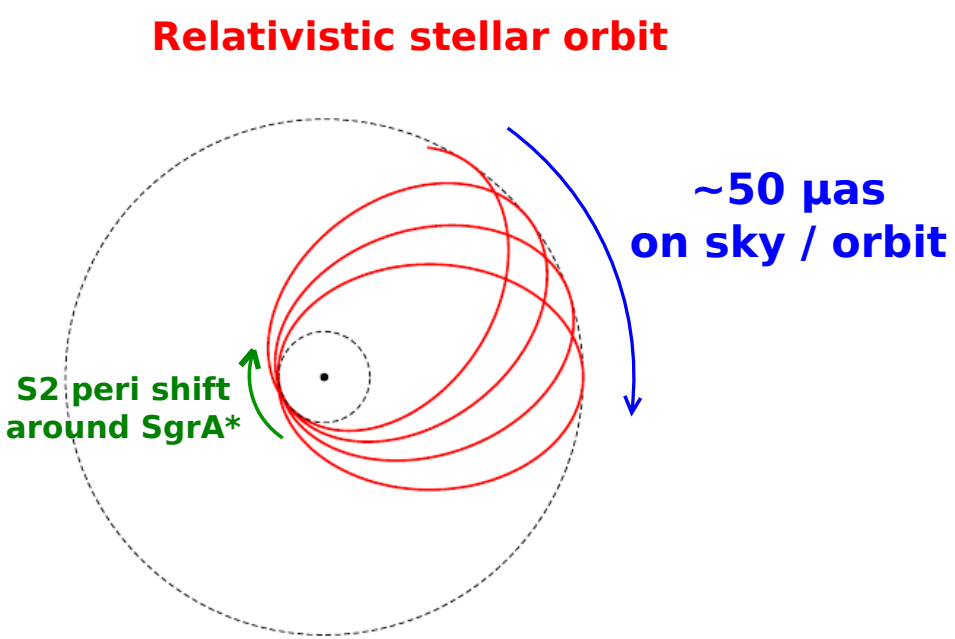


Credit: ESO

Electromagnetic probes of BH surroundings

- Star (test mass): clean, but far
- Accretion: close, but astrophysics-poluted

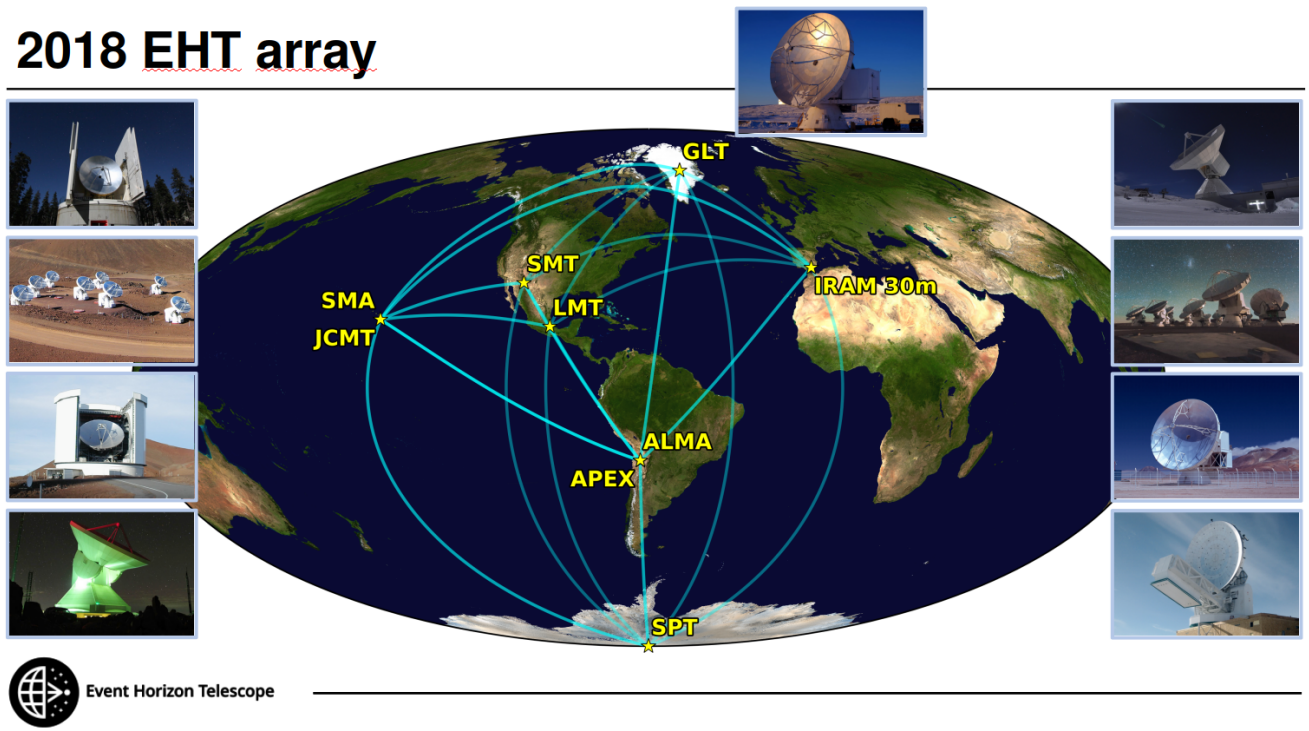




Strong-field test at SgrA*/M87*

- Tens of μas scale astrometry / imaging
- $\rightarrow$ GRAVITY / EHT

VLTI/GRAVITY


2018 EHT array
GLT
SMT
IRAM 30m
SMA
LMT
JCMT
ALMA
APEX
SPT
Event Horizon Telescope

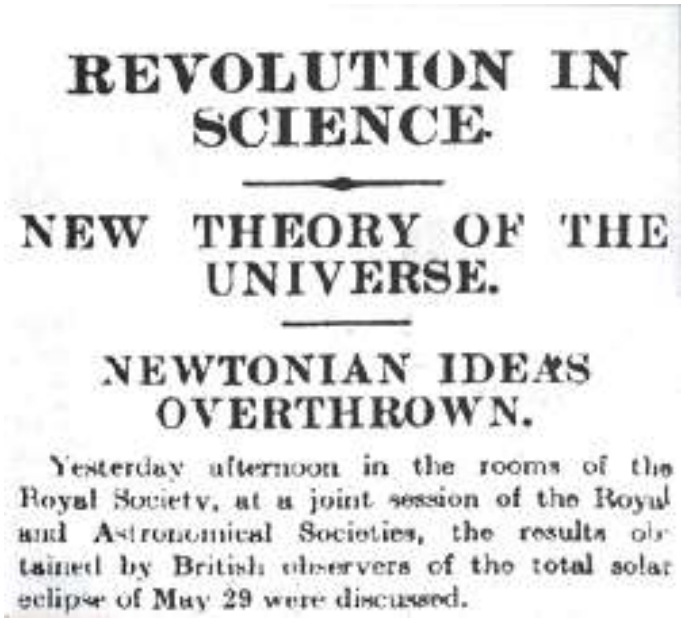
Testing gravity?

Consistency test

- Using only Kerr
- Check that observables are consistent
- Would also certainly be consistent with non-Kerr spacetimes

Model-comparison test

- Fit data with Kerr and spacetime X
- Show that Kerr is statistically favored
- Big difficulty: degeneracy gravity/astrophysics



REVOLUTION IN SCIENCE.

NEW THEORY OF THE UNIVERSE.

NEWTONIAN IDEAS OVERTHROWN.

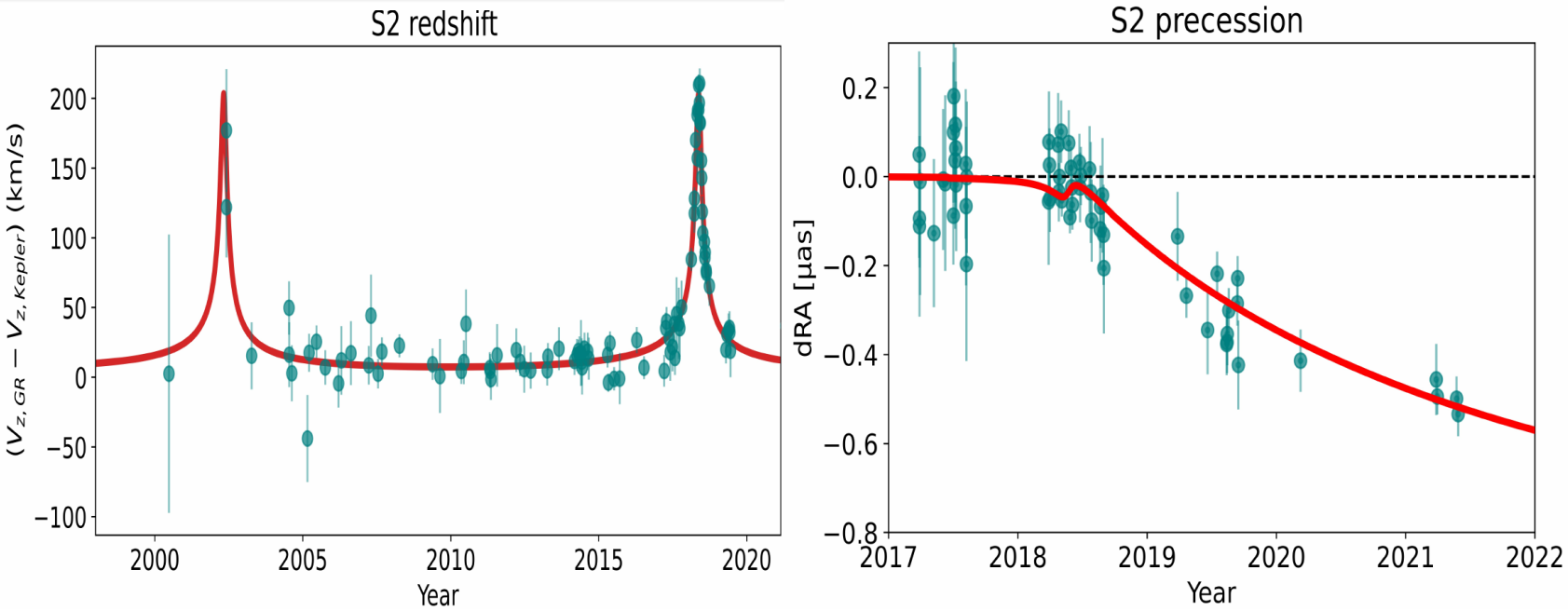
Yesterday afternoon in the rooms of the Royal Society, at a joint session of the Royal and Astronomical Societies, the results obtained by British observers of the total solar eclipse of May 29 were discussed.

London Times, Nov 7th 1919

- Eddington's test was a model-comparison one

1 GRAVITY: stars and flares

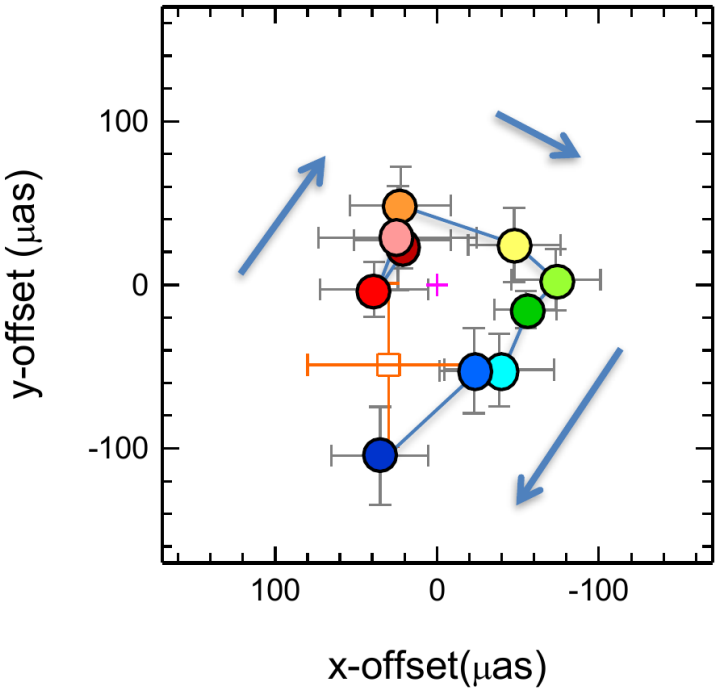
2 EHT (and future) : inner accretion flow



GRAVITY Collab. 2018a, 2019b, 2020

Redshift / Precession (2018-2021)

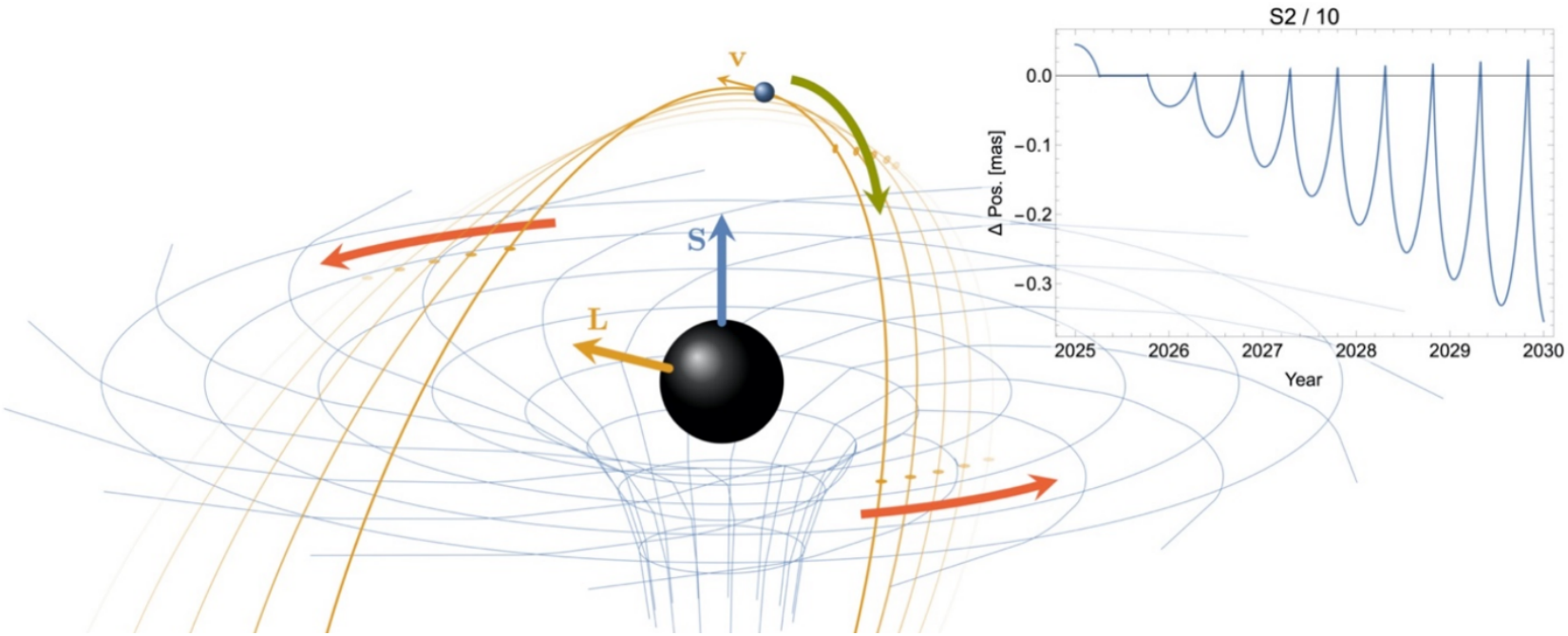
- f-parameter fit: 0 for Newton, 1 for GR (1PN)
- $f_{\text{redshift}} = 1.04 \pm 0.05 \Rightarrow \mathbf{20\sigma}$ grav. redshift detection
  compatible results with Keck: Do,Hees,Ghez+19
- $f_{\text{precession}} = 0.997 \pm 0.144 \Rightarrow \mathbf{7\sigma}$ Sch. precession detection
- $\rightarrow$ strong consistency tests of BH paradigm



GRAVITY Collab. 2018b

Orbital motion near horizon (2018)

- Location coincident with Sgr A*
- Compatible with Keplerian motion at $r = 7M$ (compact!)
- Light curve + polarization $\Rightarrow$ low inclination, B poloidal
- $\rightarrow$ strong consistency test of BH paradigm



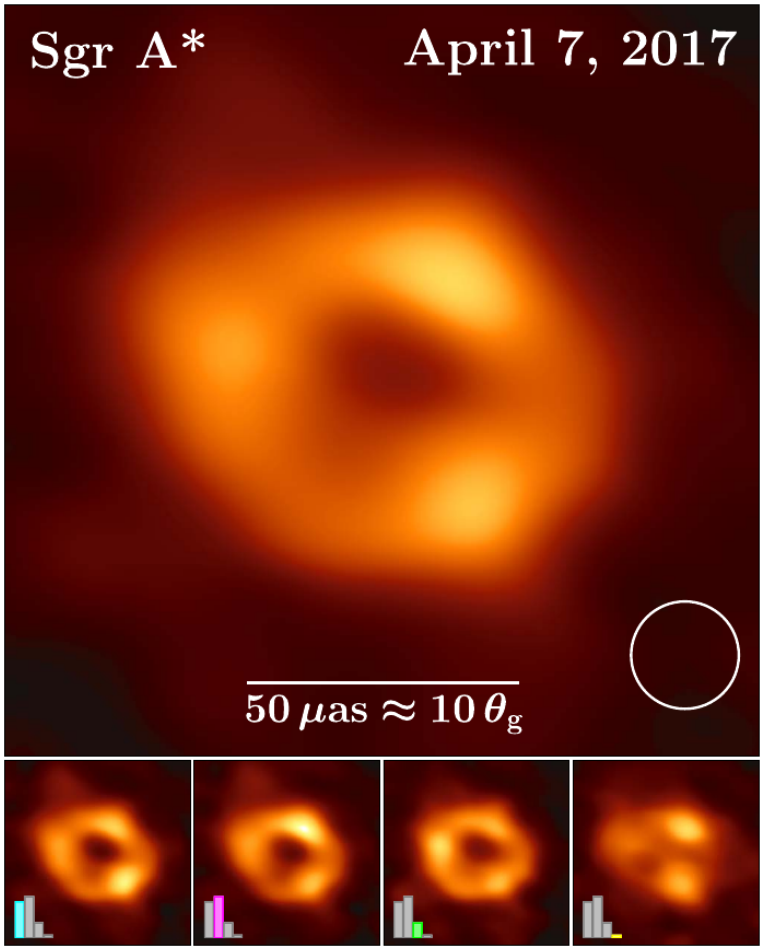
GRAVITY+ Phase A Science Case 2021

Future: GRAVITY+

- Go fainter, and closer
- Constrain the **spin**!
- Even further: quadrupole and **no-hair**?
- Can we go from consistency to model-comparison test?

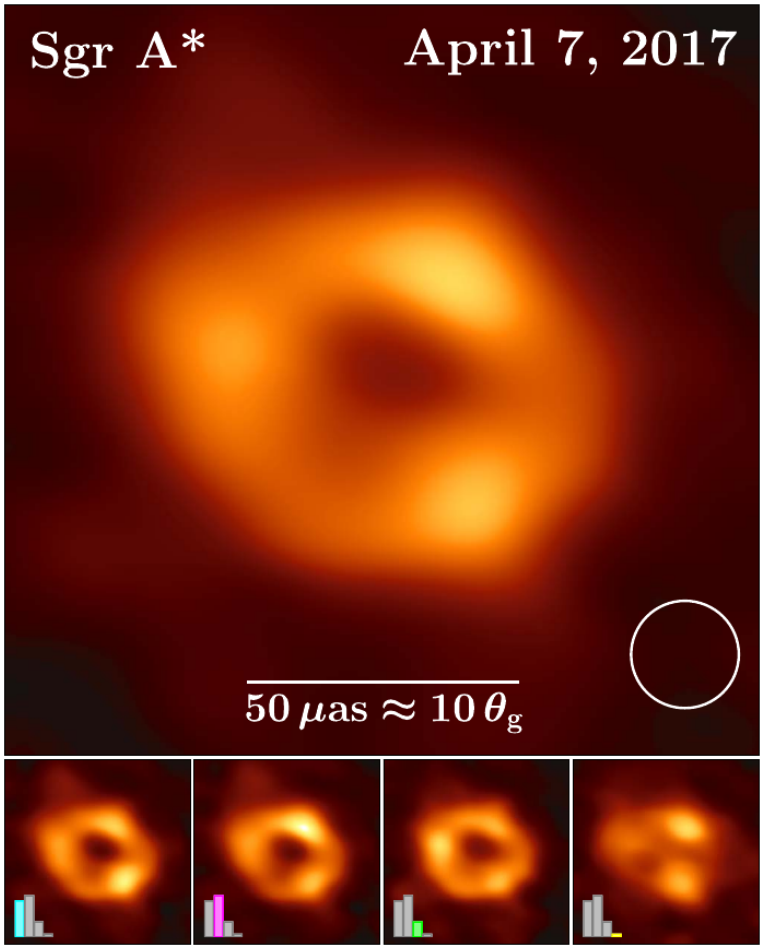
1 GRAVITY: stars and flares

2 EHT (and future) : inner accretion flow



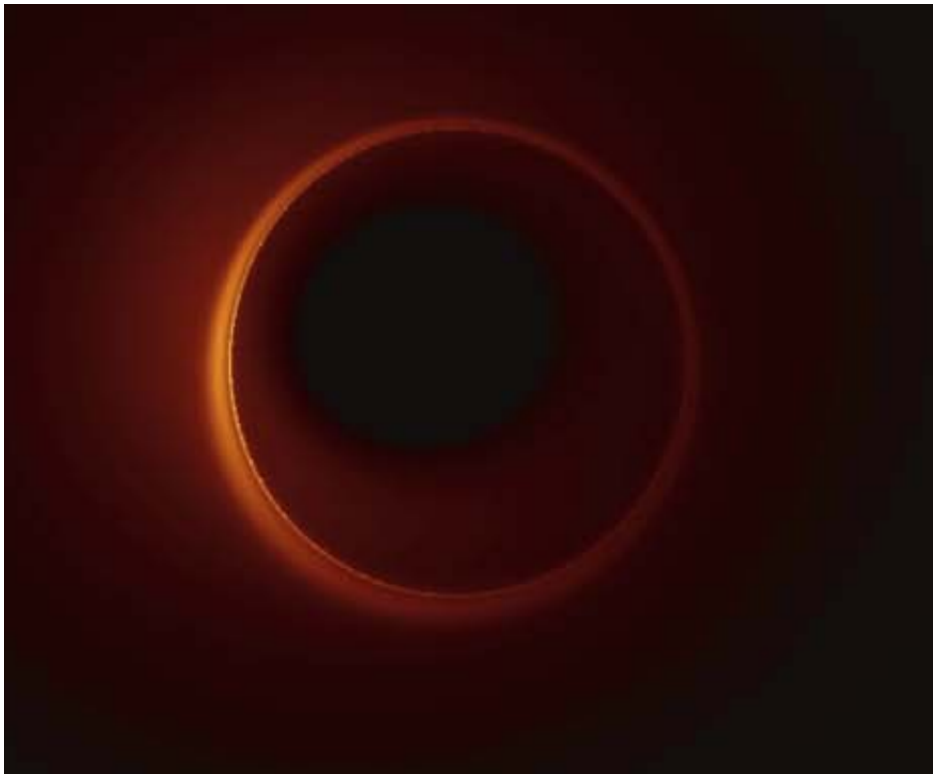
Event Horizon Telescope Collaboration 2022

- Very interesting for testing the plasma properties
- What about gravity?



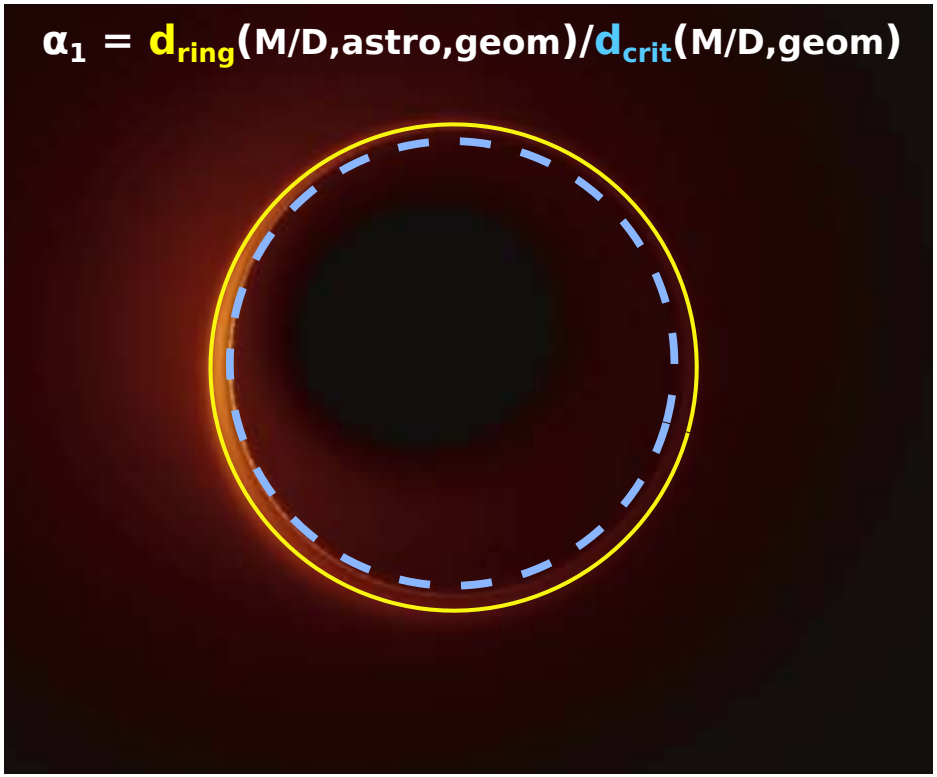
Event Horizon Telescope Collaboration 2022

- See **talk by M. Wielgus** tomorrow 11:00, *Denisse room*



Diameter of BH shadow

- Scale emission ring to “shadow” (actually, critical curve)
  Compare to critical curve given M/D prior
  Advocate Kerr consistency test
- Can we trust the GRMHD prediction?



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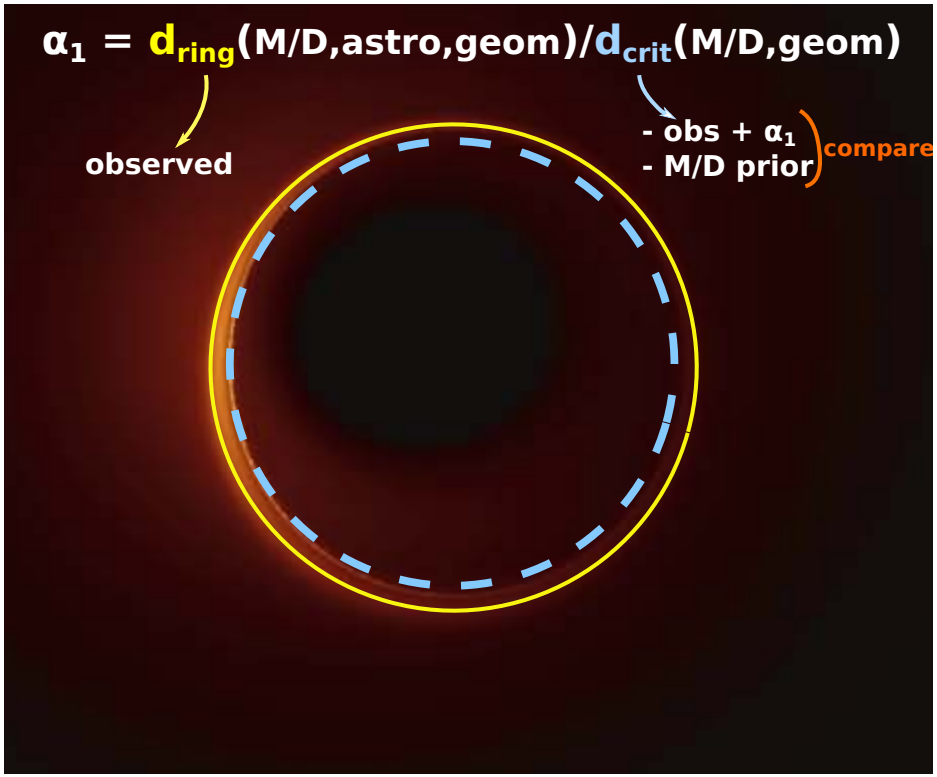

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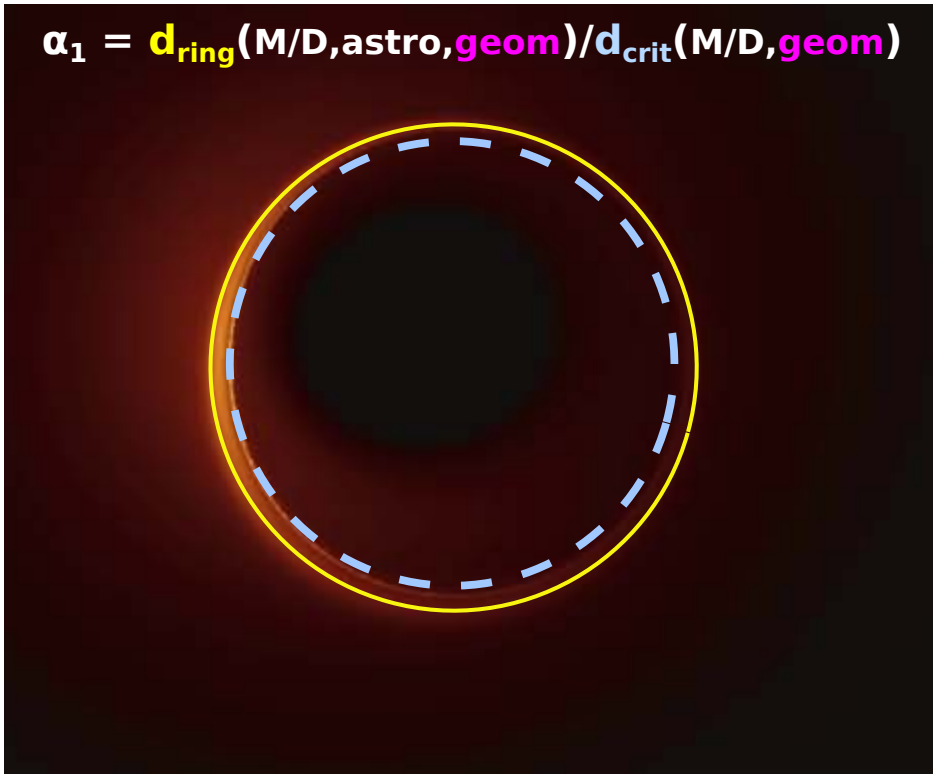

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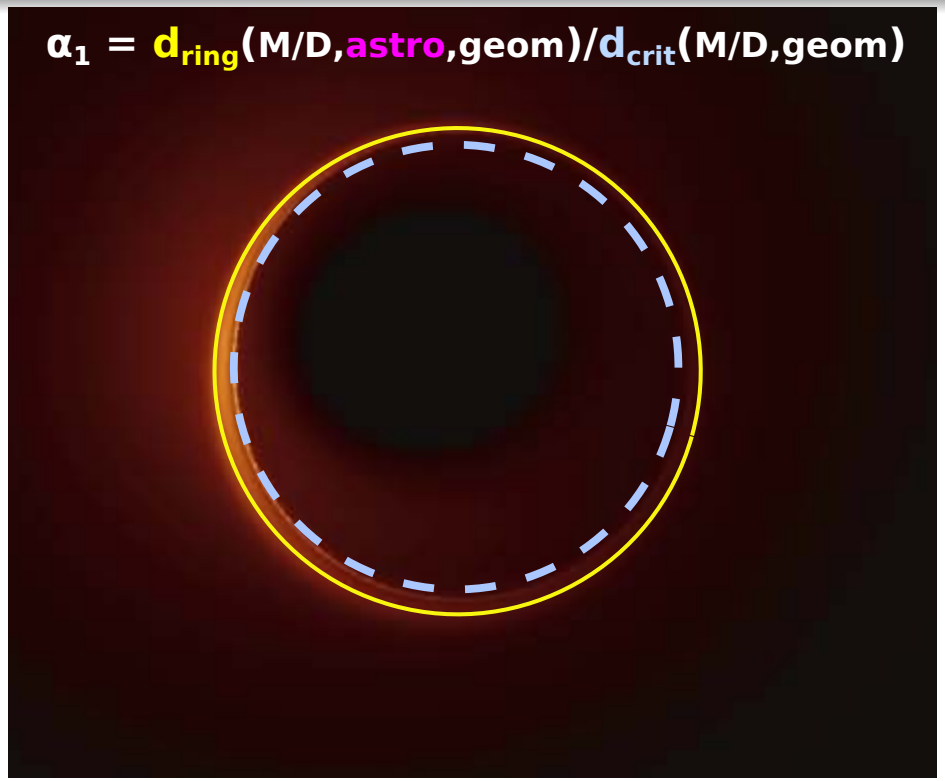

Diameter of BH shadow

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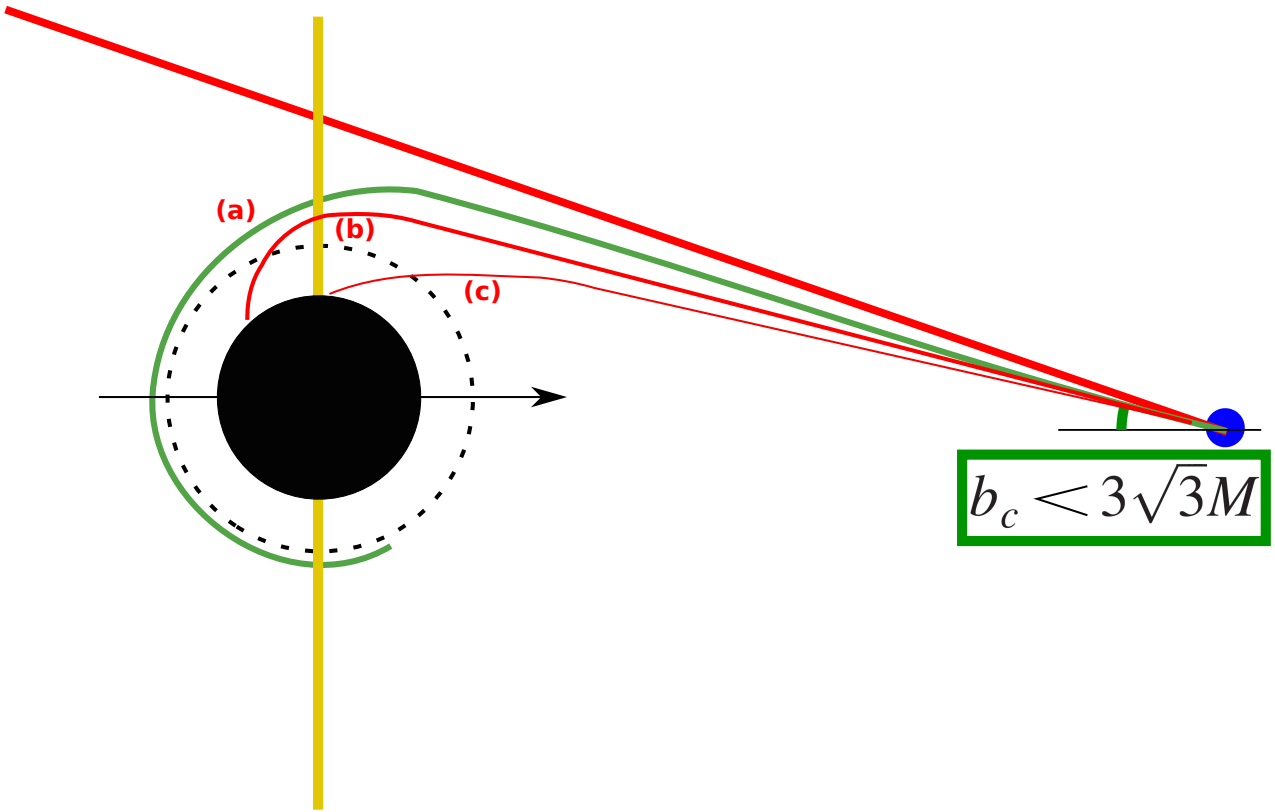
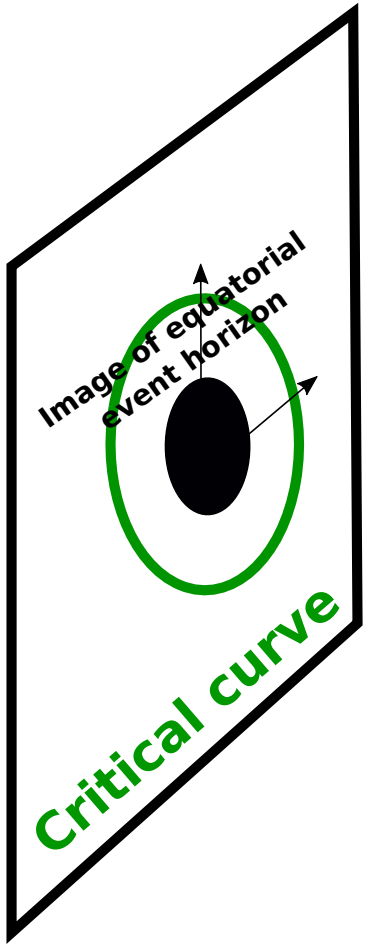
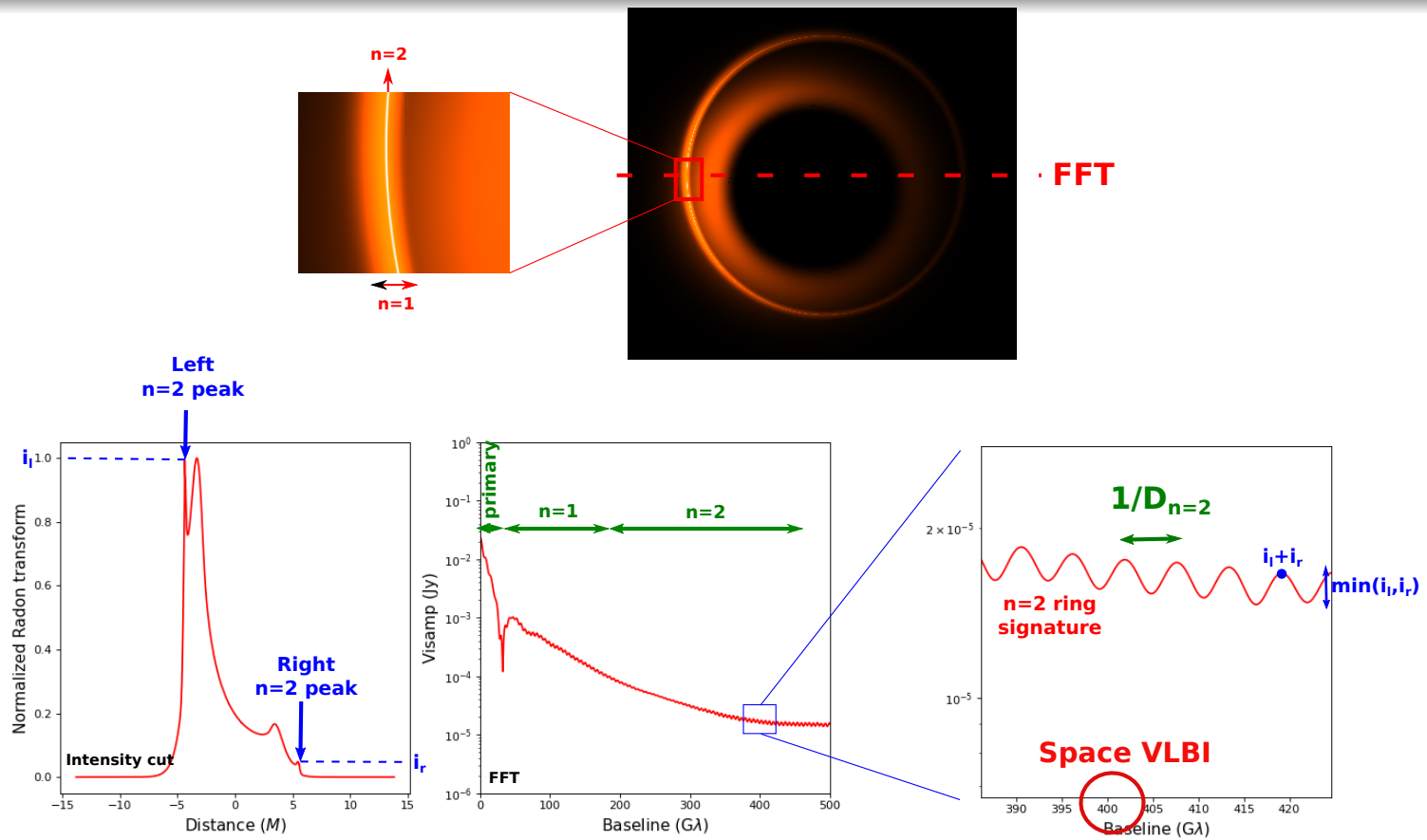
- Can we trust the GRMHD prediction?
  - $\rightarrow$ Rather: plasma modeling consistency test



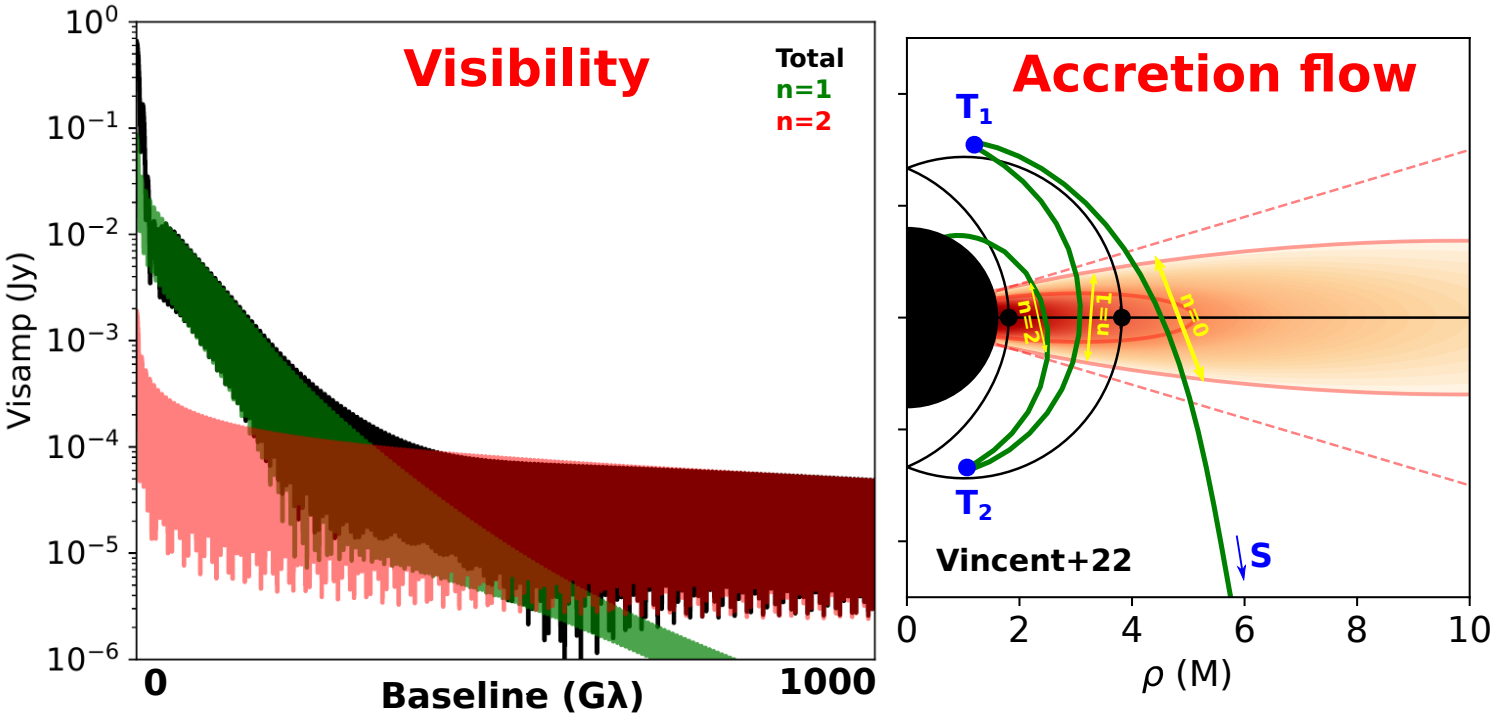


Shadow is astrophysics-dependent



Direct detection of photon rings

- FT(primary + narrow ring): rings dominate at large B
- $n = 2$ ring $\approx$ critical curve $\rightarrow$ BH probe?
- Johnson+2020, Gralla+20 (Kerr consistency test), recent developments: Wielgus21, Paugnat+22, Vincent+22



Photon rings Fourier signature

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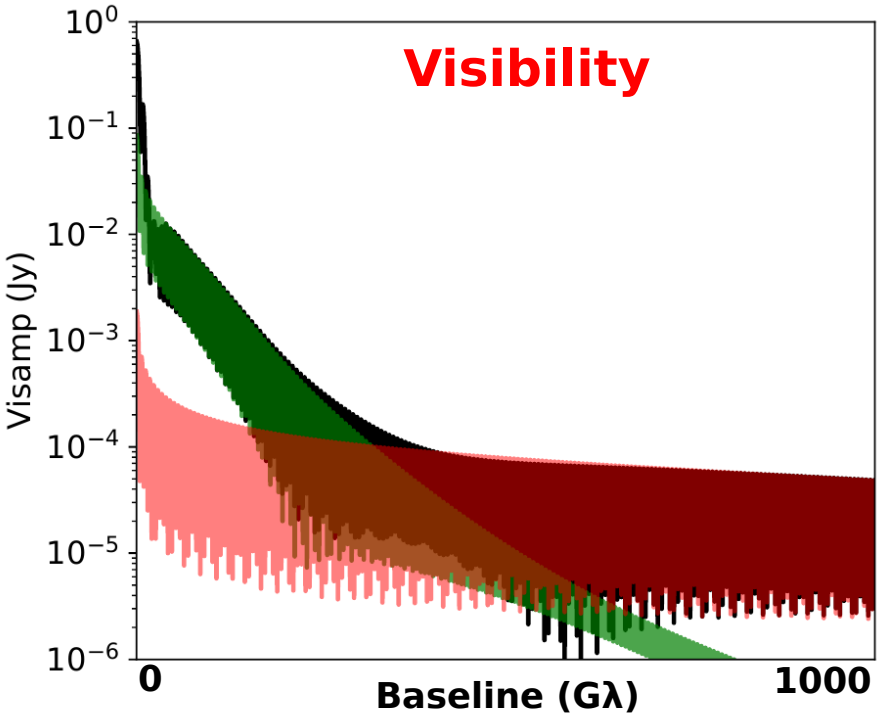

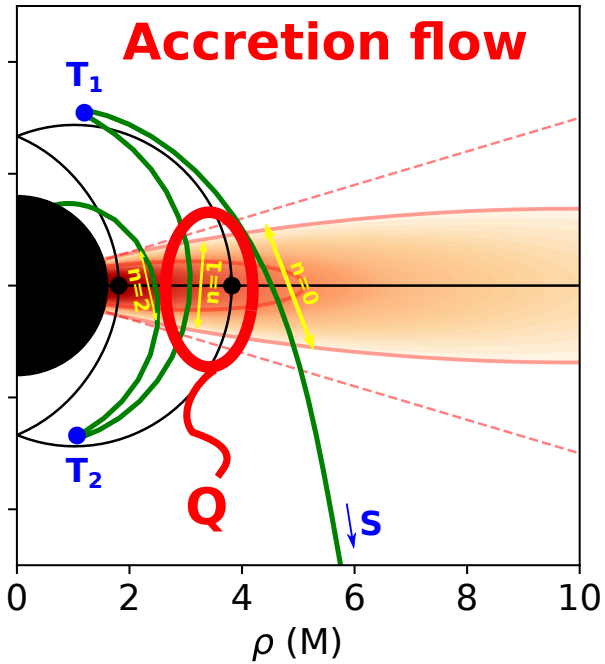

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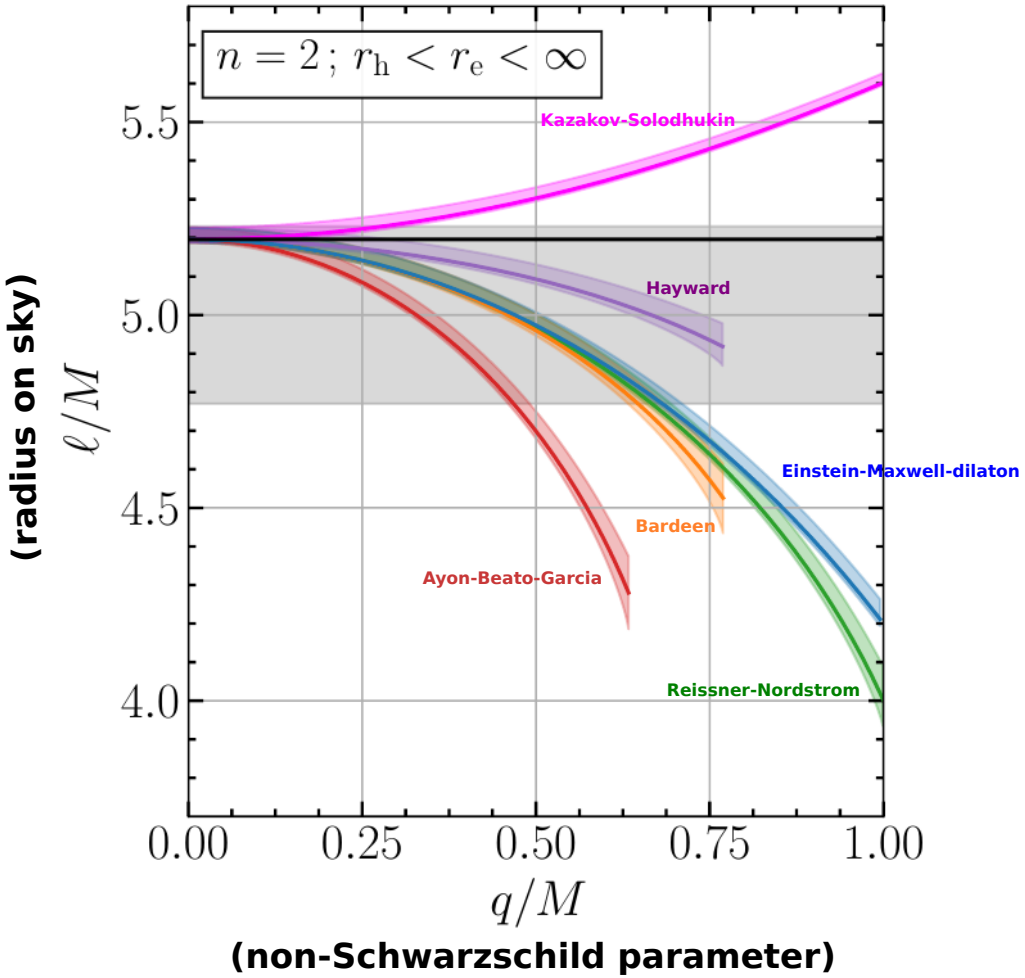

Towards model-comparison test on photon rings?

- Wielgus 2021