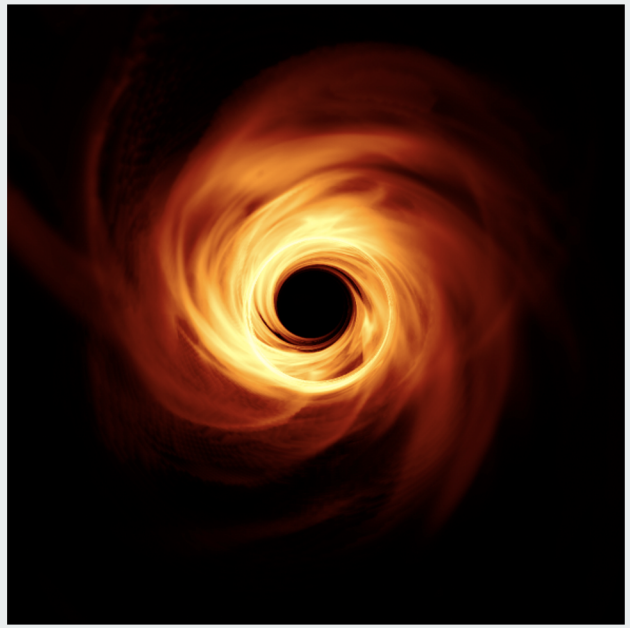
Relativistic Signatures of Flux Eruption Events Near Black Holes



Zack Gelles, Koushik Chatterjee,
Michael Johnson, Bart Ripperda,
Matthew Liska

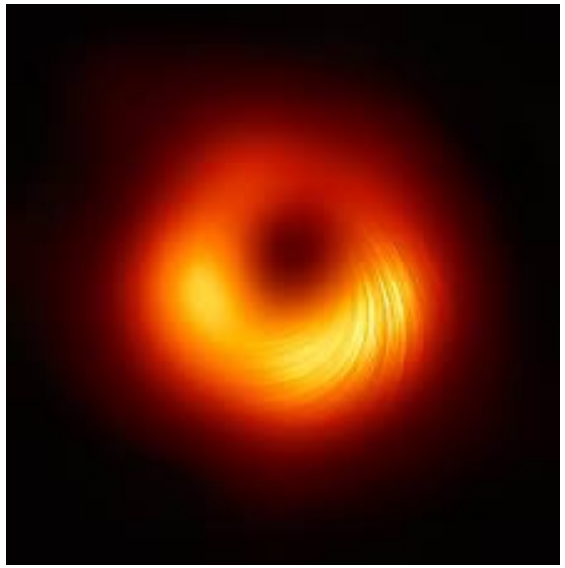
arXiv: 2210.07273

PRINCETON UNIVERSITY

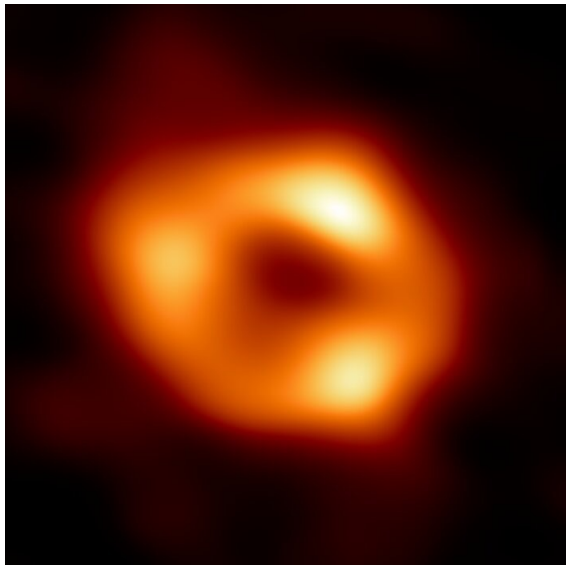
Event Horizon Telescope

Black Hole Imaging with the Event Horizon Telescope

Messier 87* (2019, 2021)



Sagittarius A* (2022)



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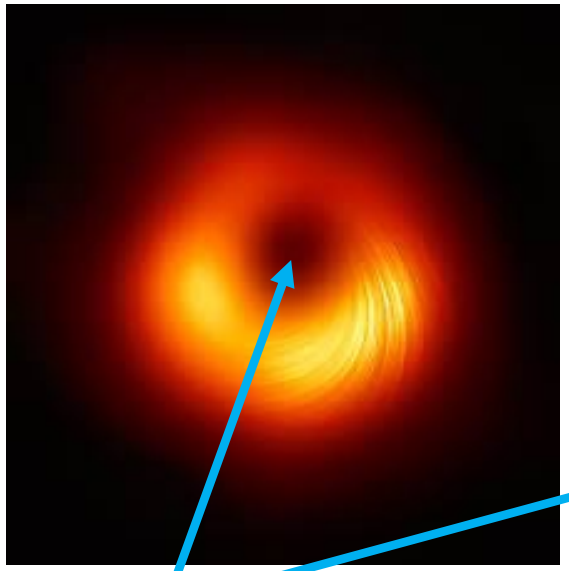

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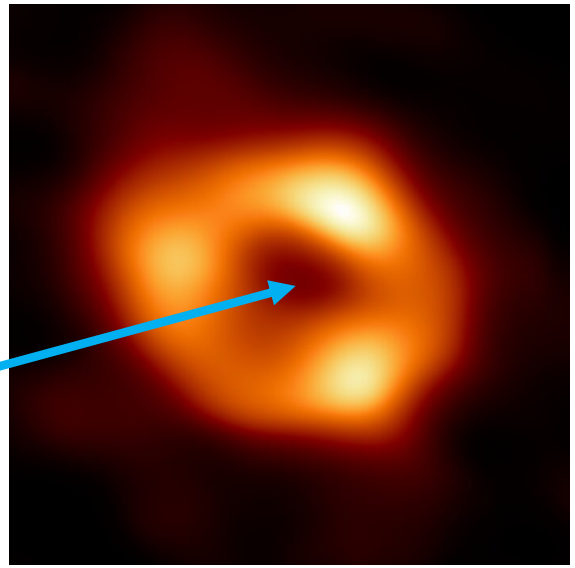

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- Dark “shadow” caused by presence of event horizon

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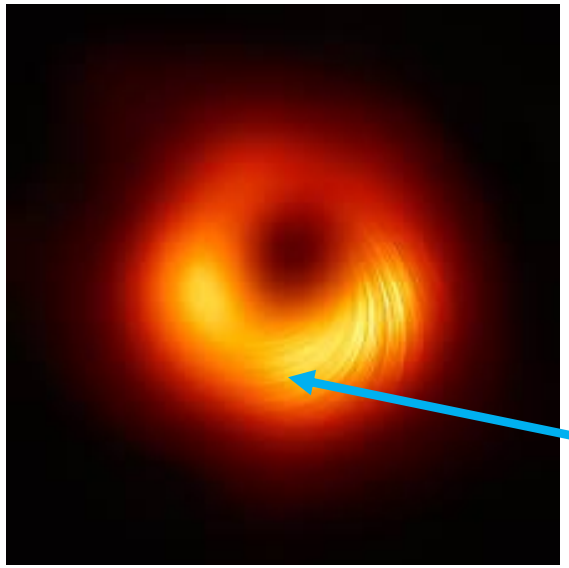

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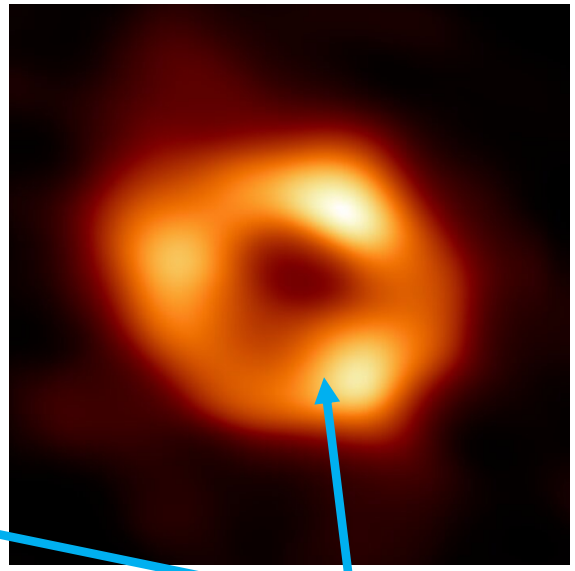

1. Central Depression
- Dark "shadow" caused by presence of event horizon

2. Accretion Flow
- Hot plasma emits primarily in synchrotron

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- "Shadow" corresponds to rays terminating on the horizon (Falcke et al. 2000, Bardeen 1973, Luminet 1979)
- Edge of the shadow corresponds to a *critical curve*: delineates the boundary between plunge and escape

Photon Ring

Image: Wong (2022)

Photon Ring

- What about rays that lie *exactly on* the critical curve?

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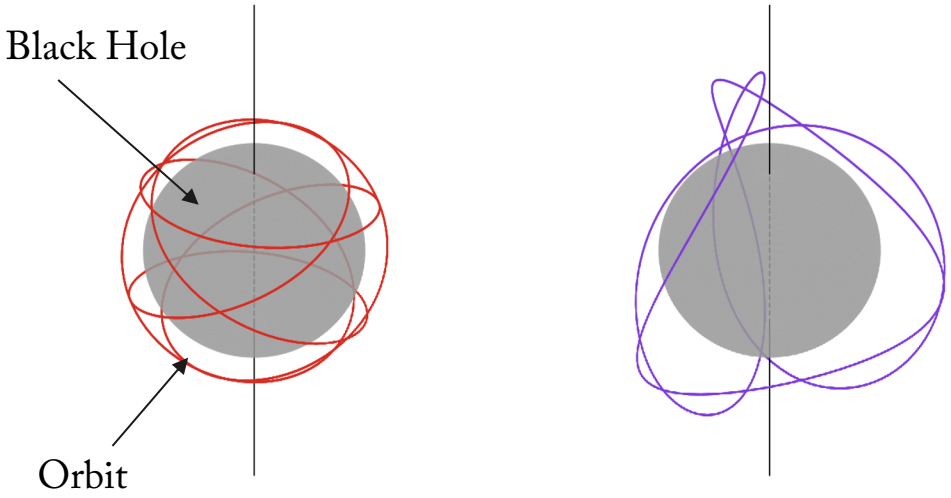

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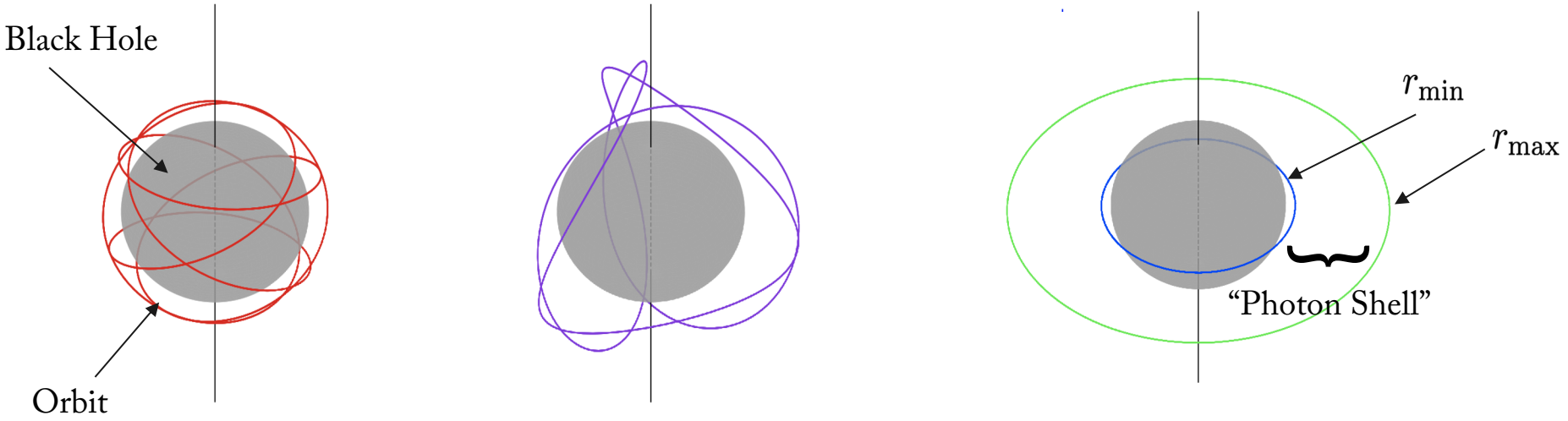

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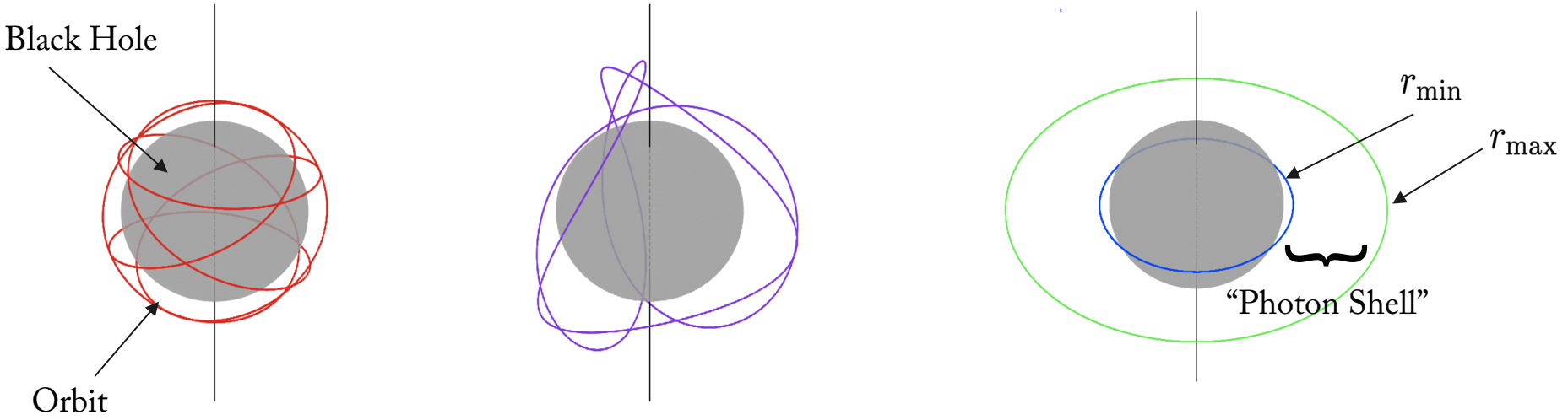

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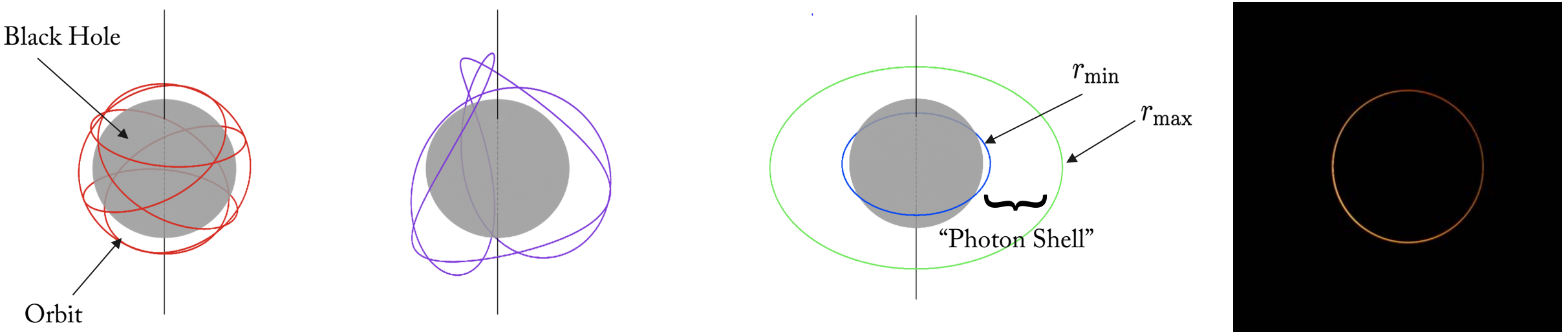

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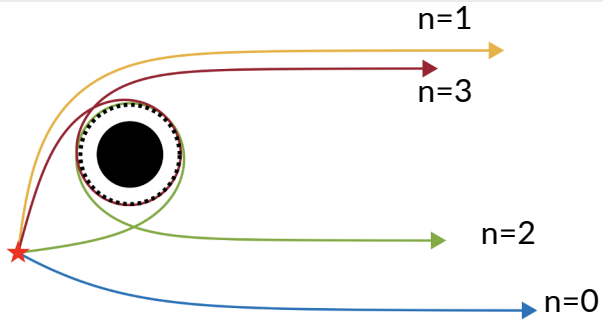

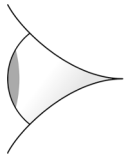

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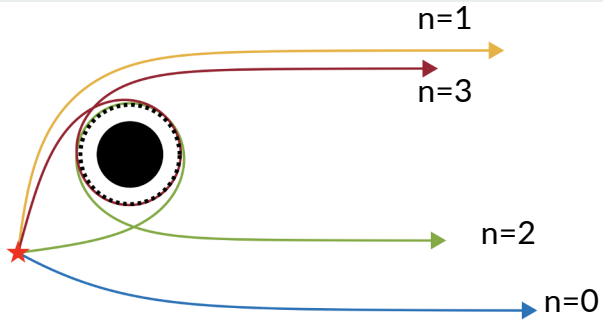

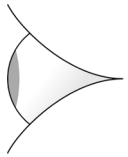

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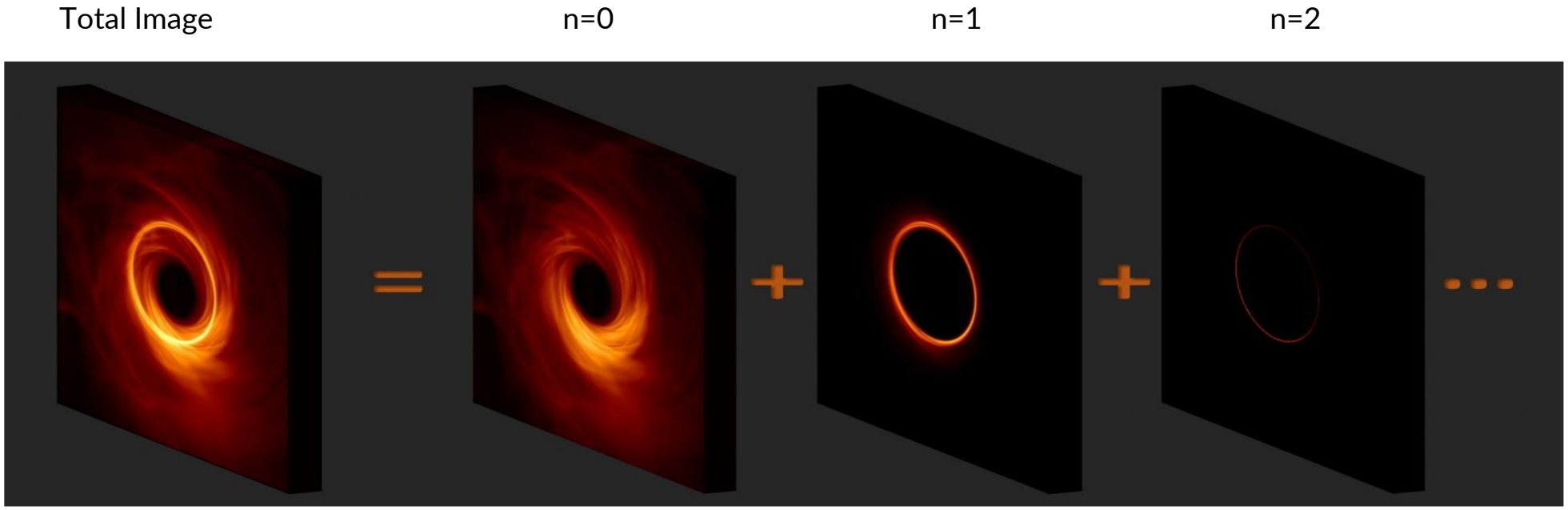

Images: Chesler et al. (2020), George Wong

Simulating Images of the Photon Ring

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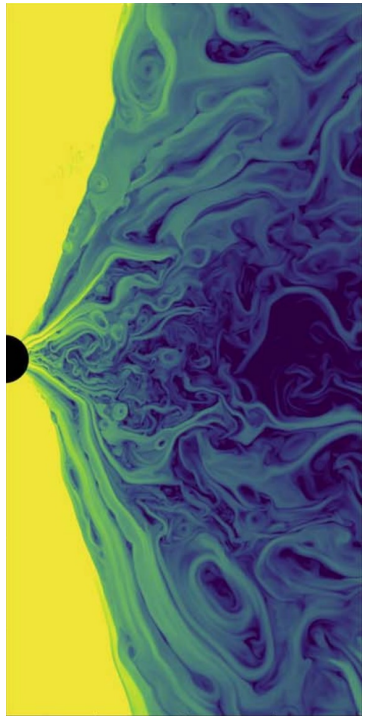

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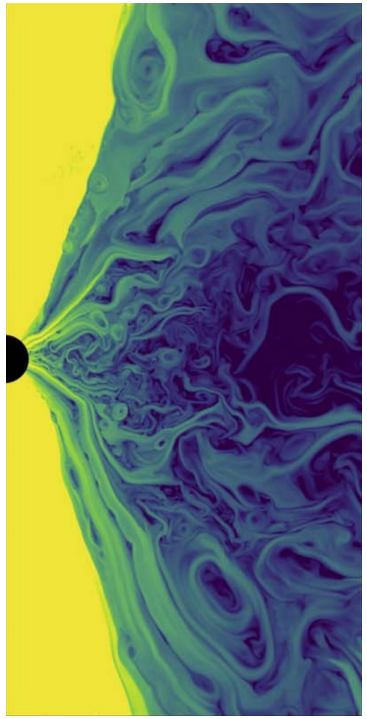

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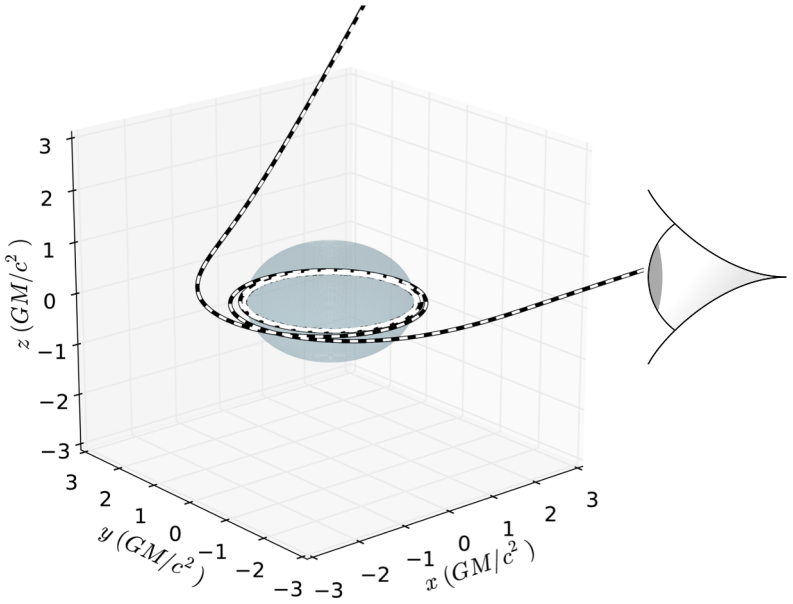

Images: Ripperda et al. (2020), Bronzwaer et al. (2019)

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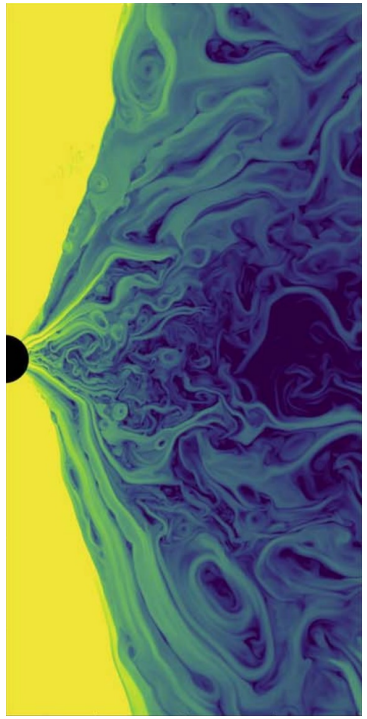

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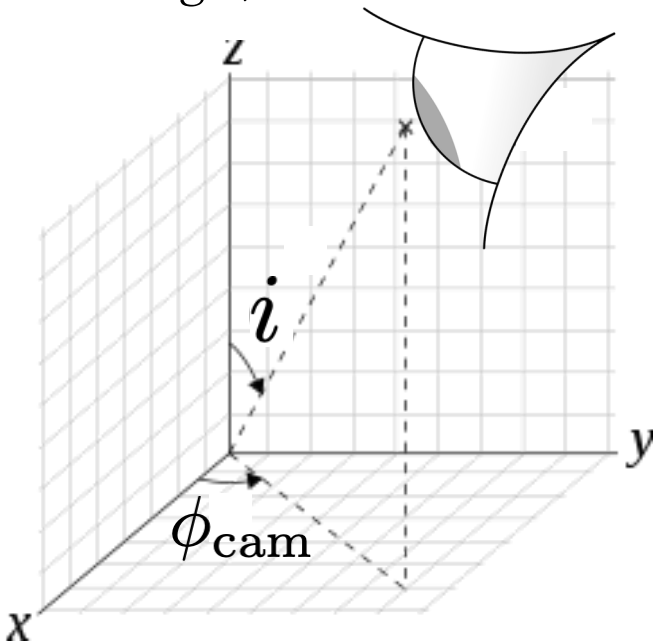

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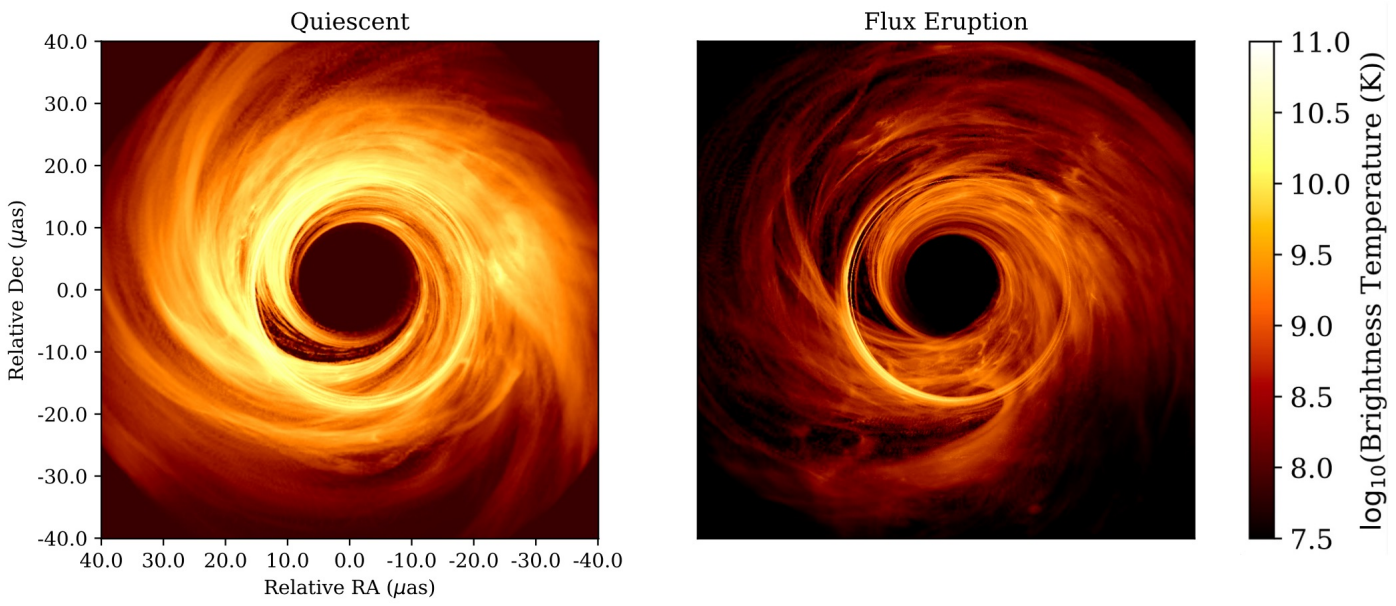

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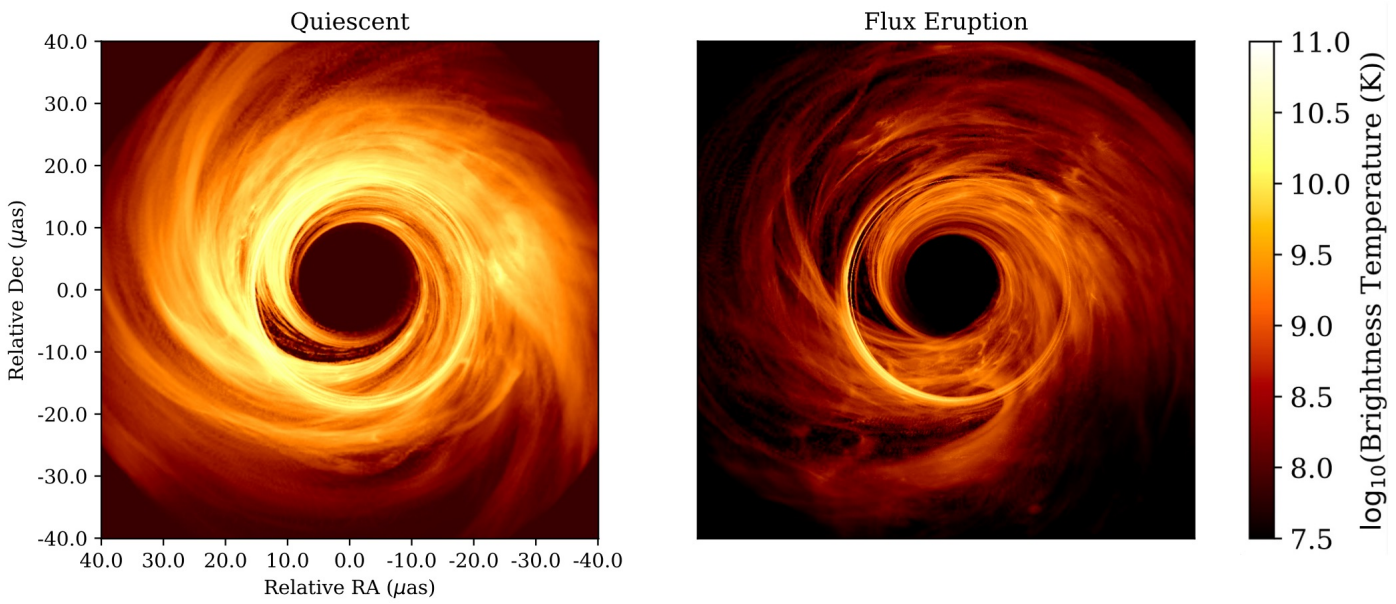

- Photon ring flux is highly variable during eruption

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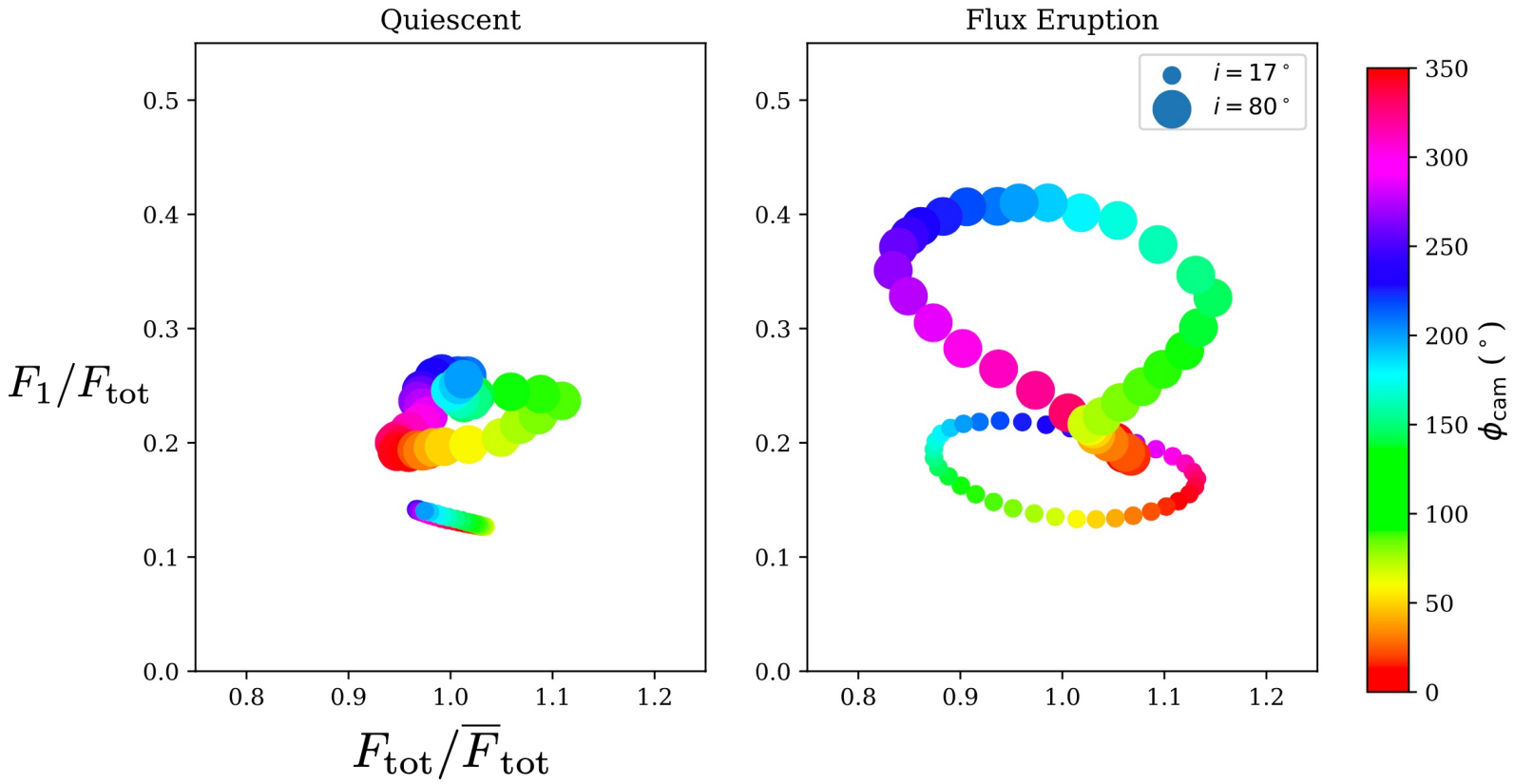

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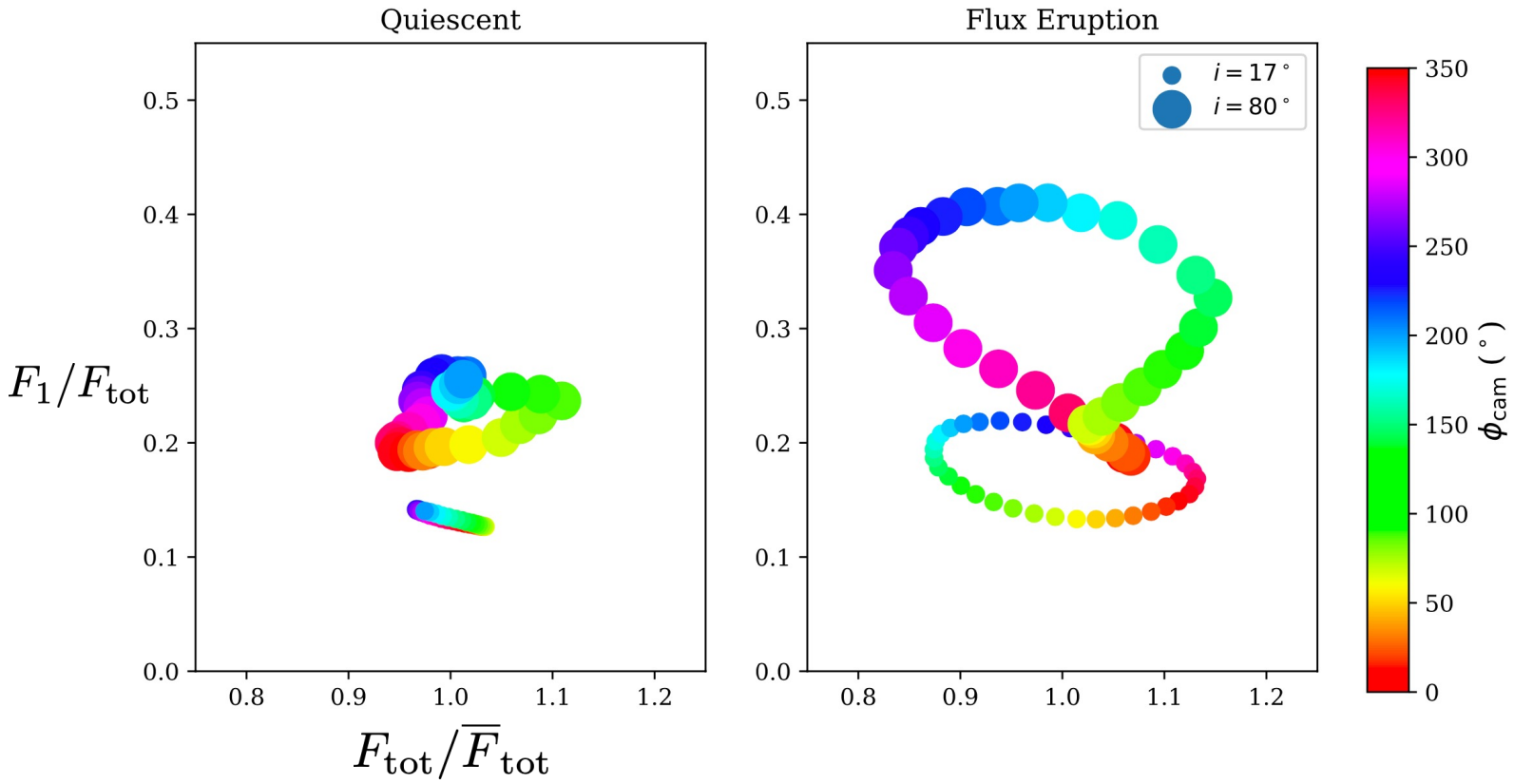

- What's causing this loop?

Semianalytic Toy Model

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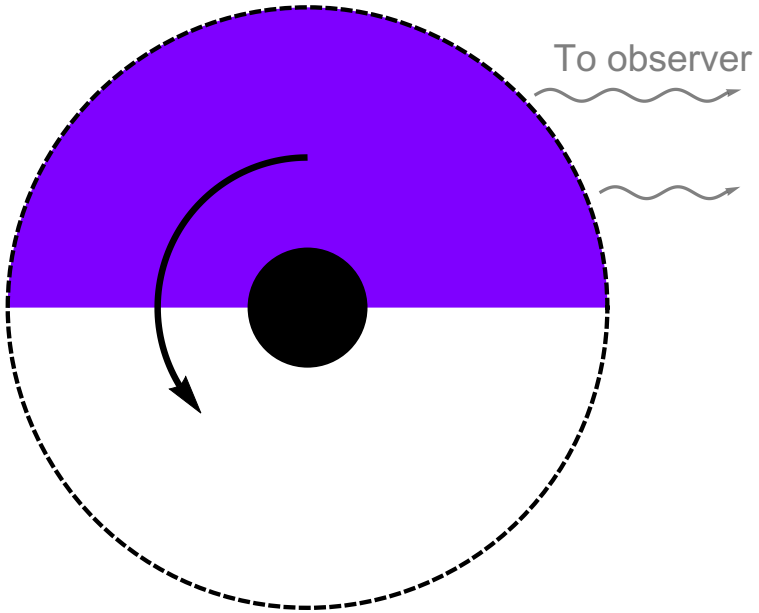

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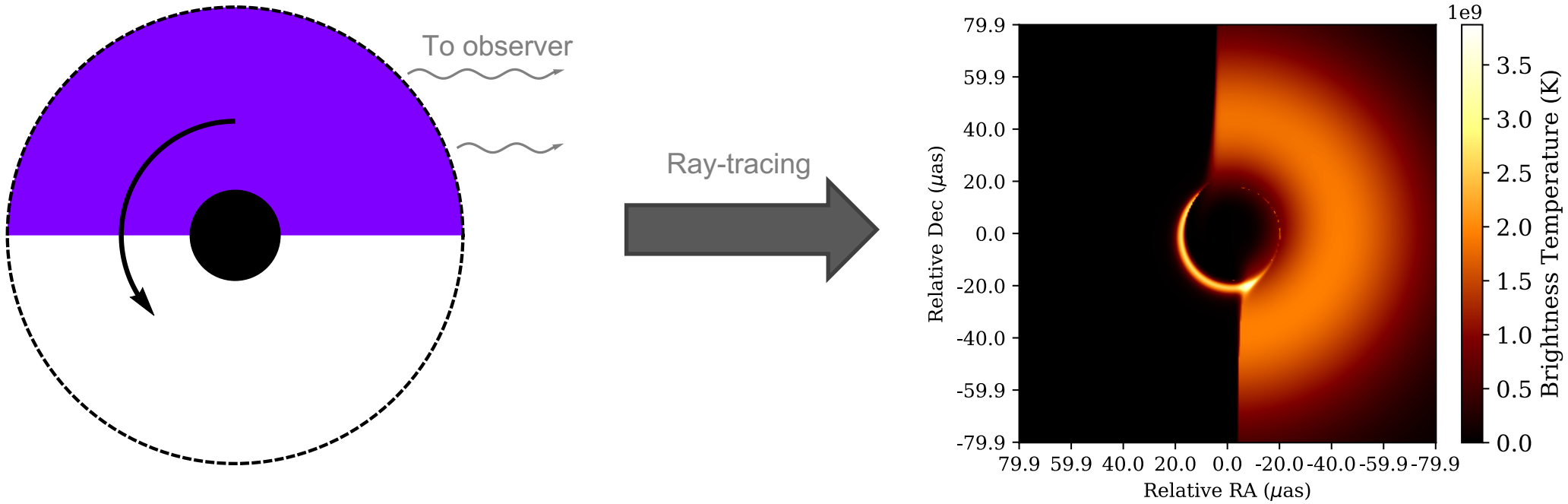

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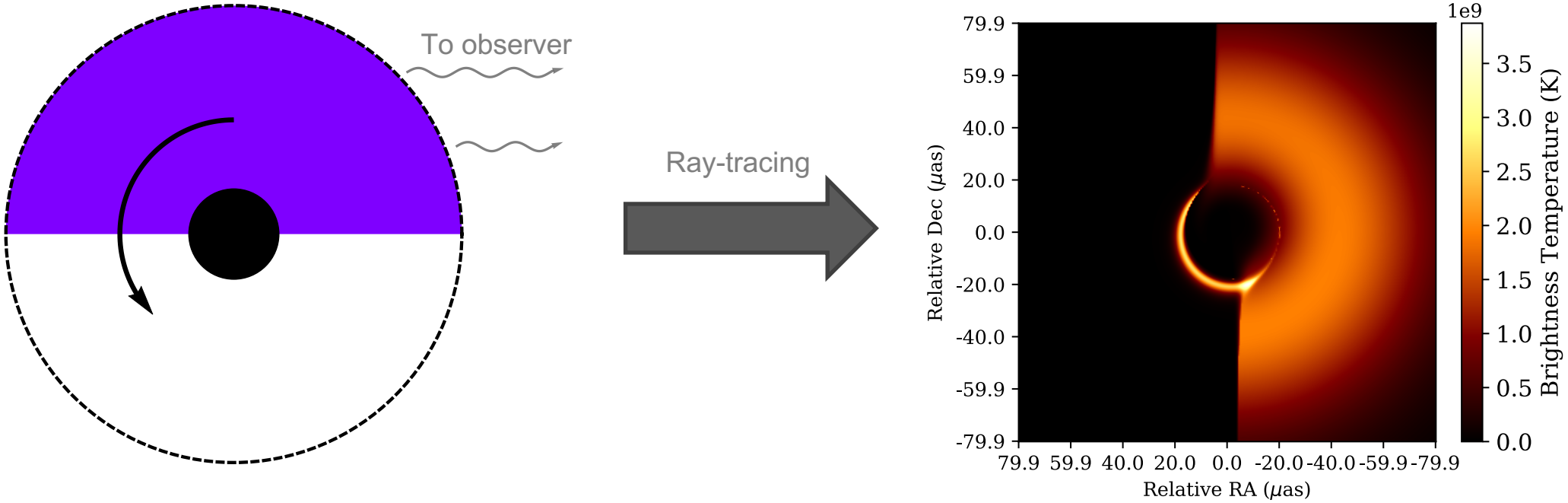

- Ray-trace the model for different values of ϕ_{cam} and compute photon ring fluxes

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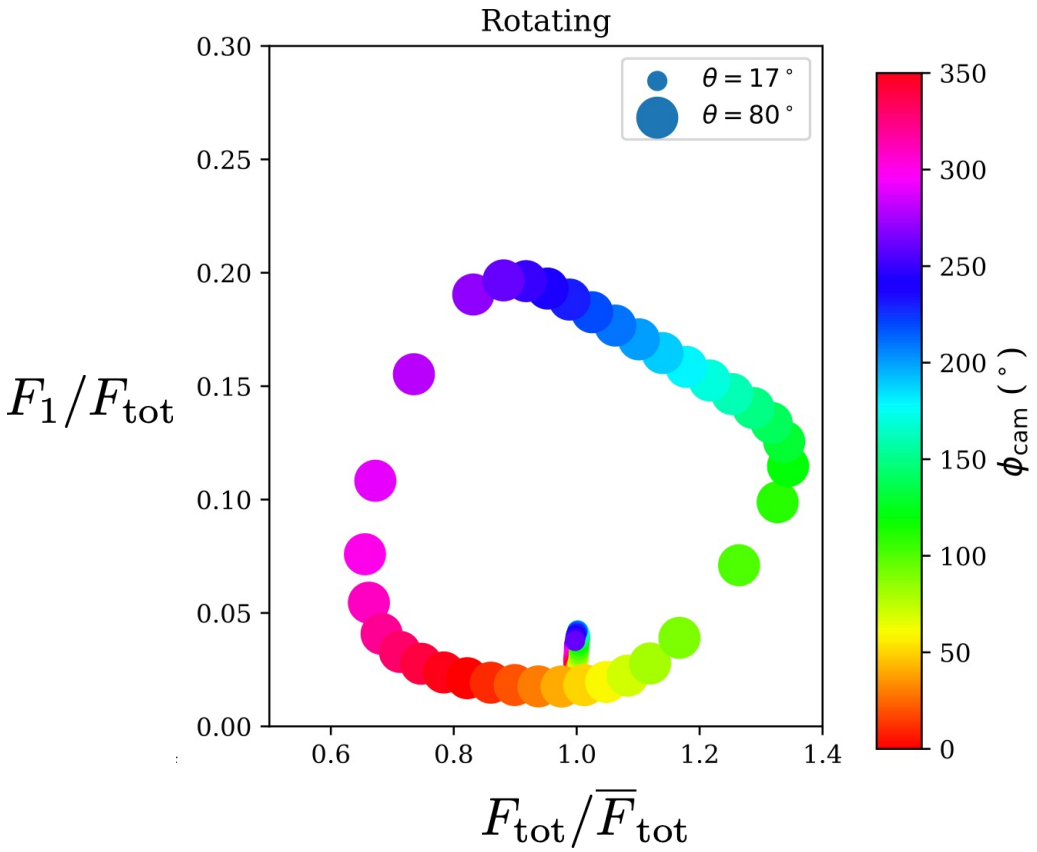

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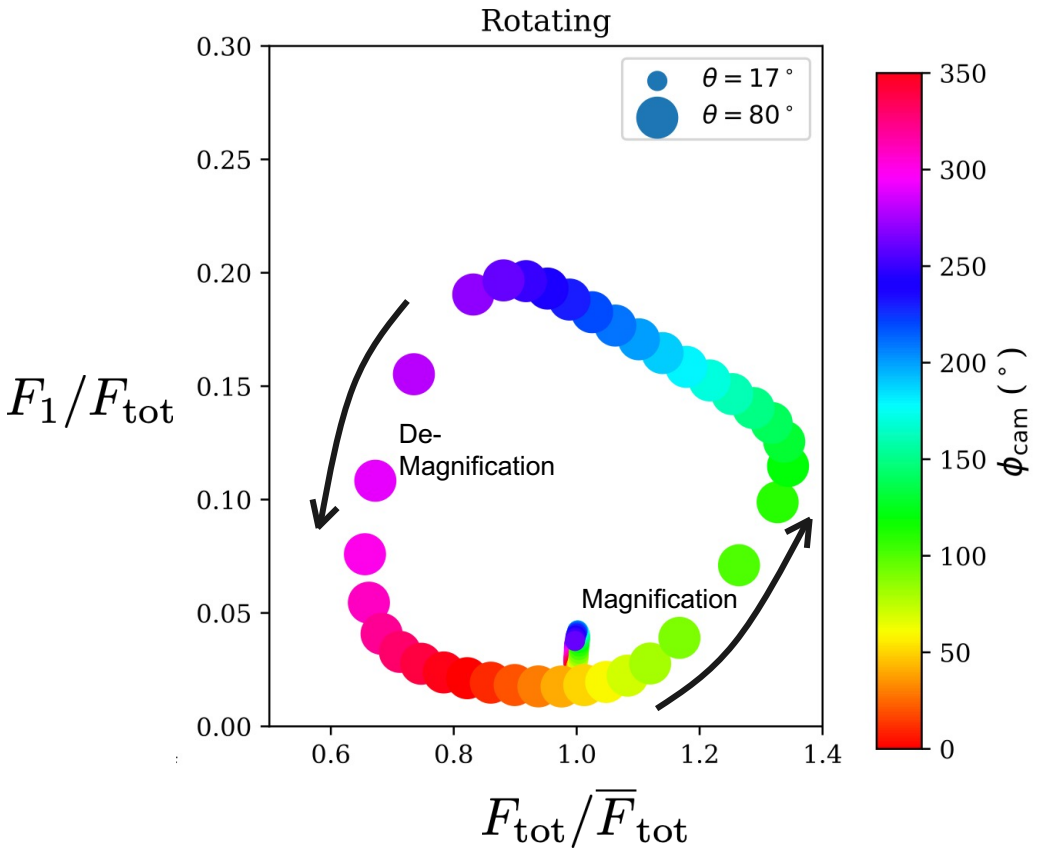

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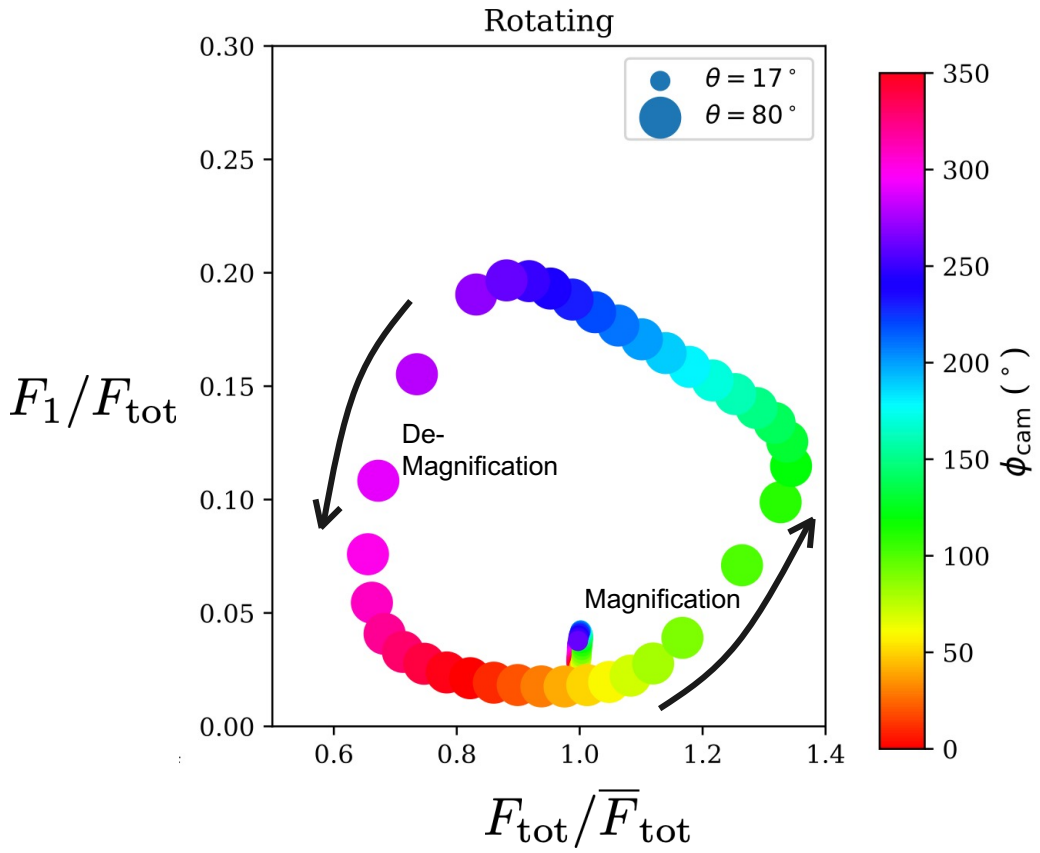

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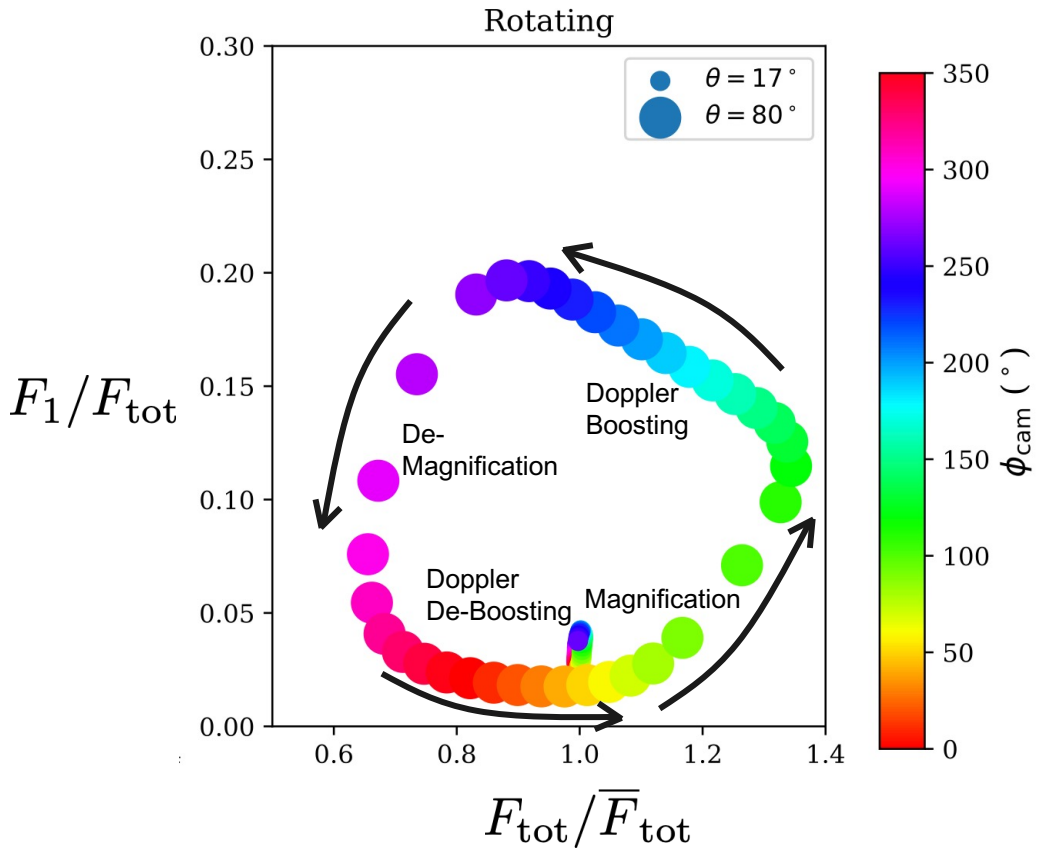

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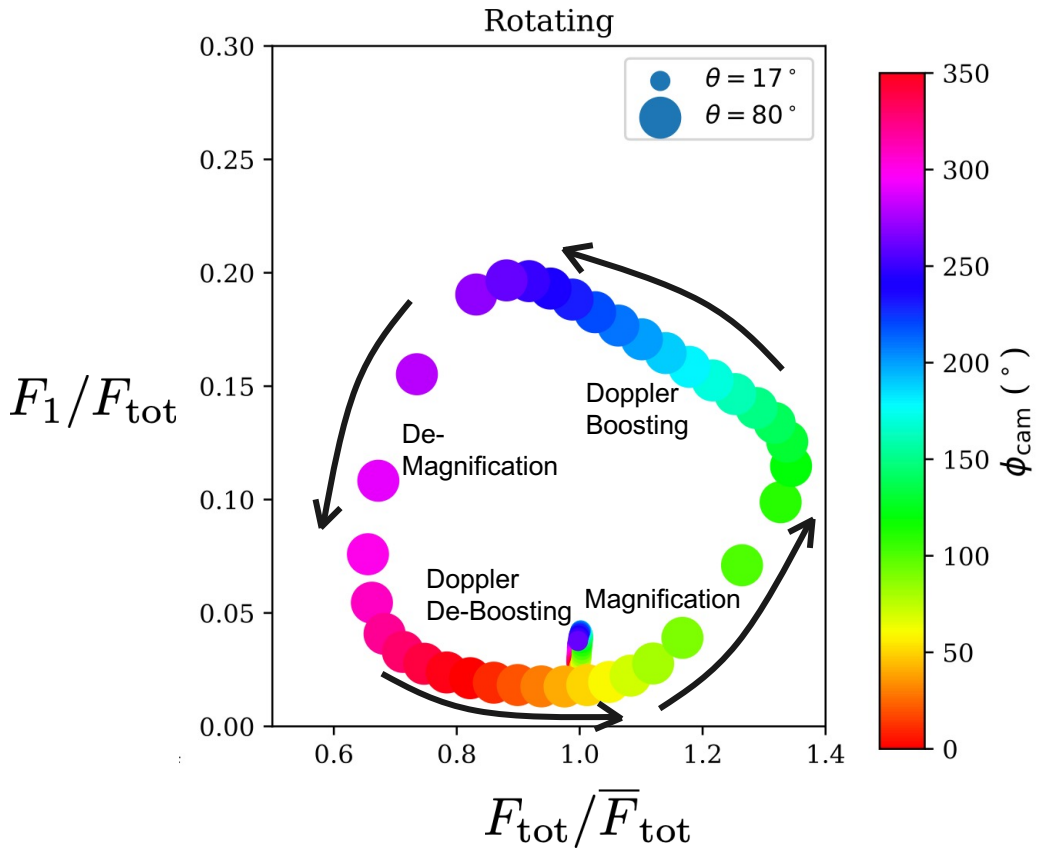

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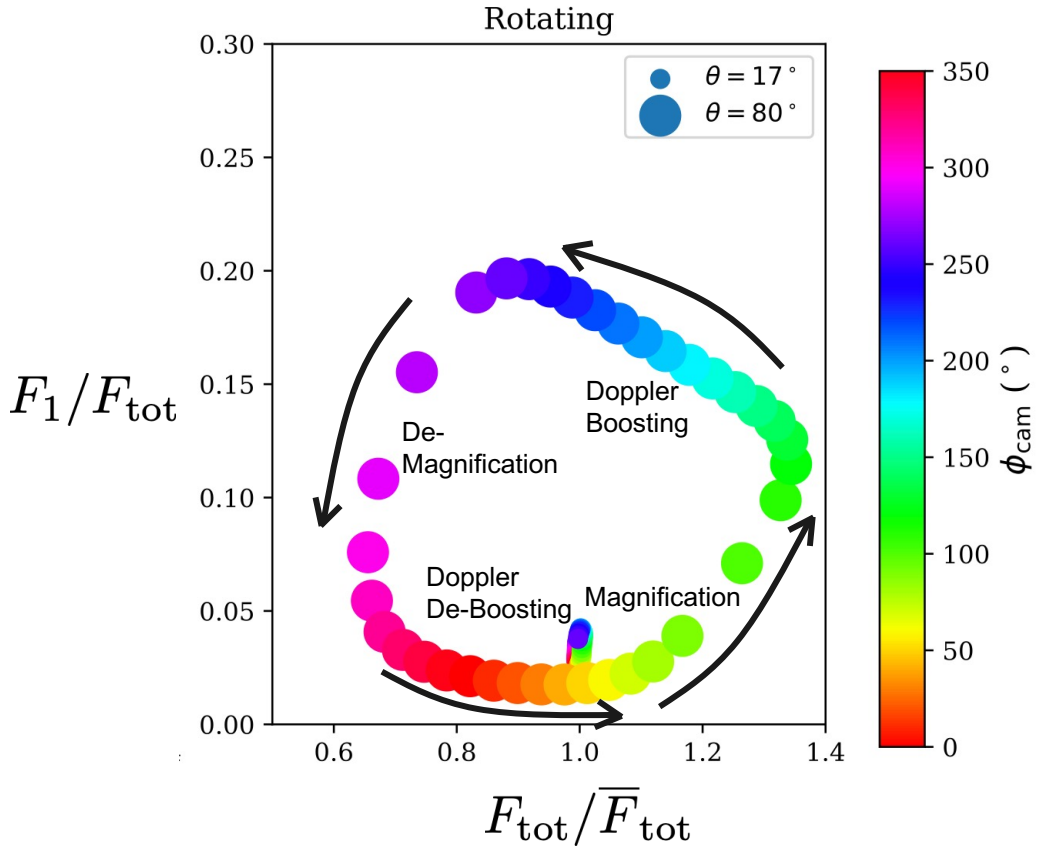

- Loop created from magnification (gravitational lensing) *and* Doppler effects

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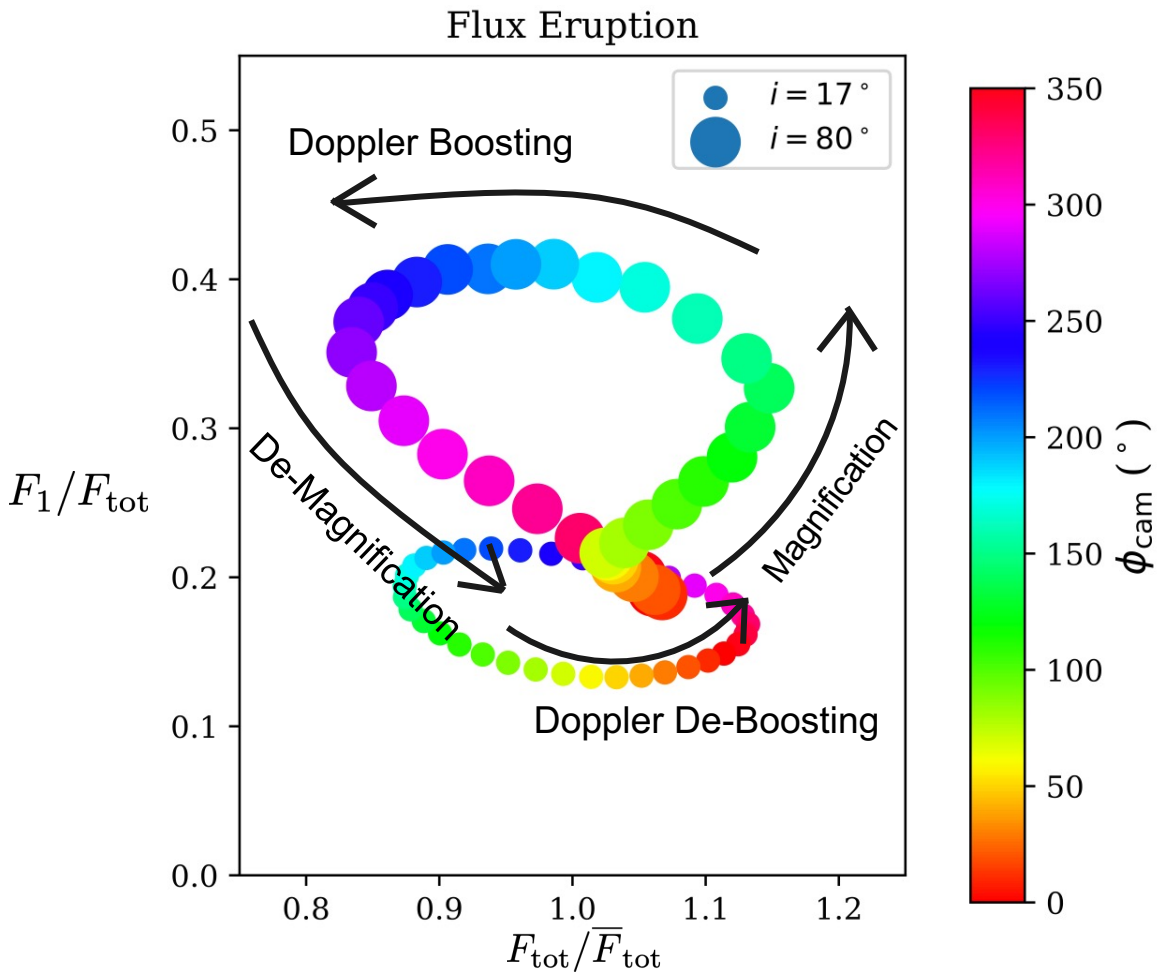

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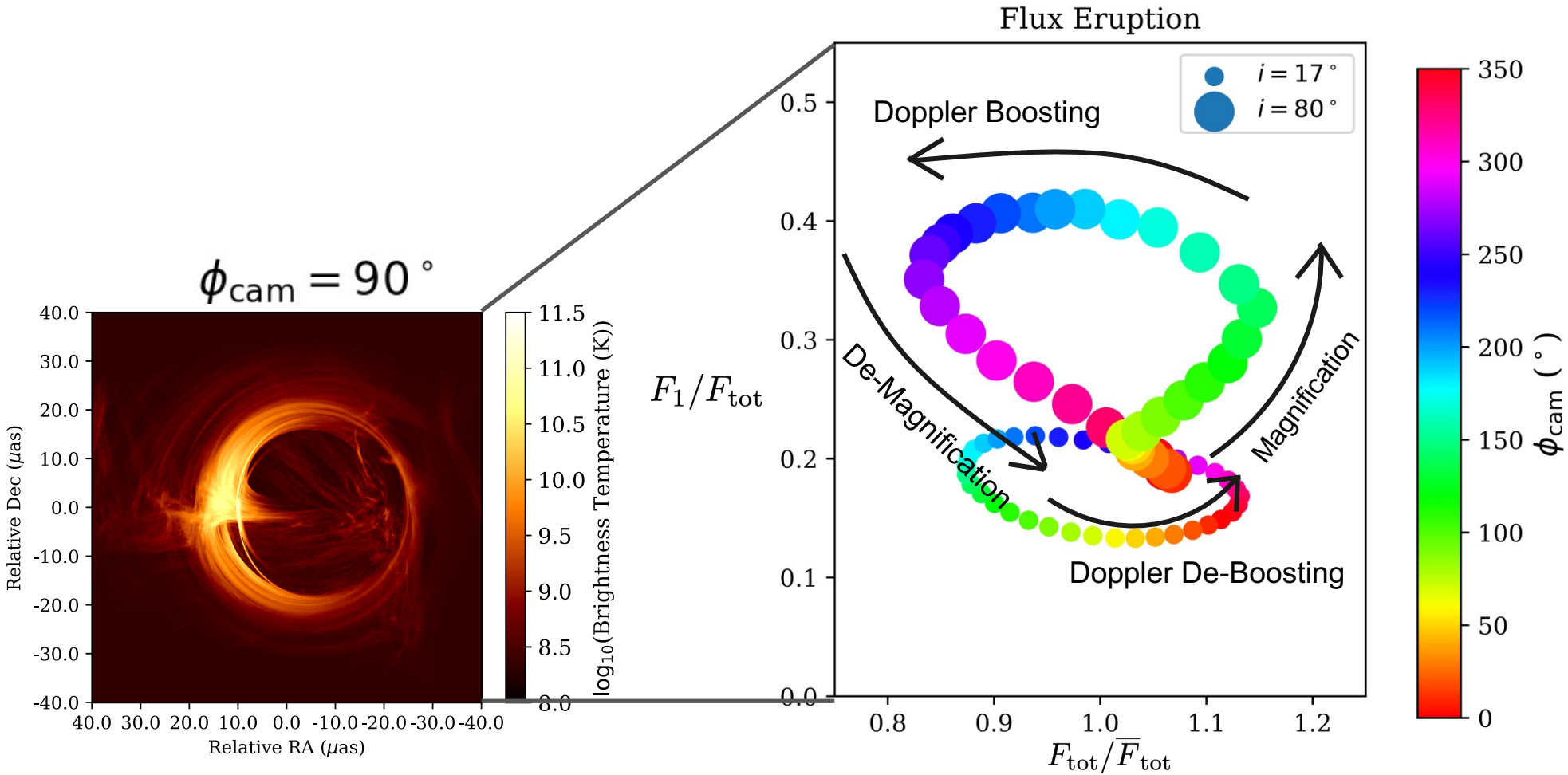

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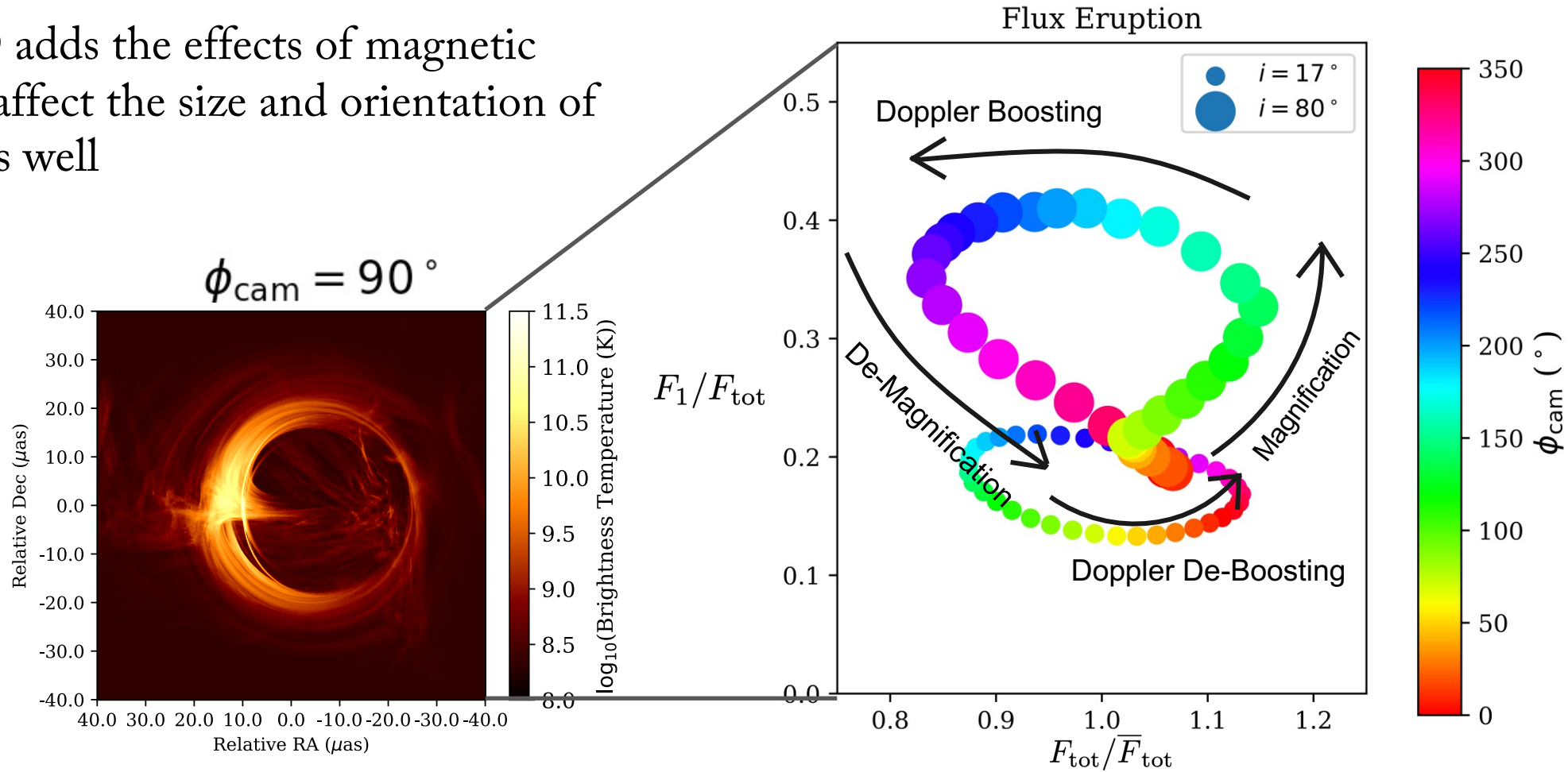
- GRMHD adds the effects of magnetic field: can affect the size and orientation of the loop as well



Conclusion

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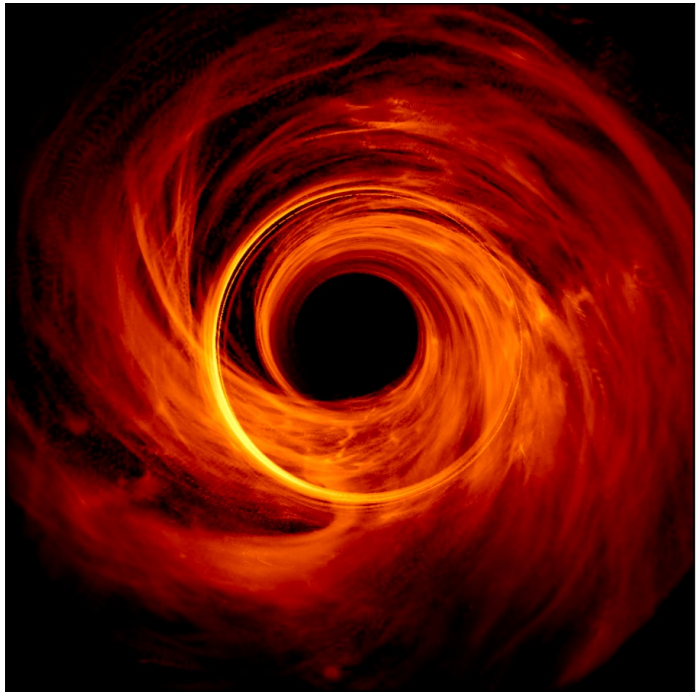

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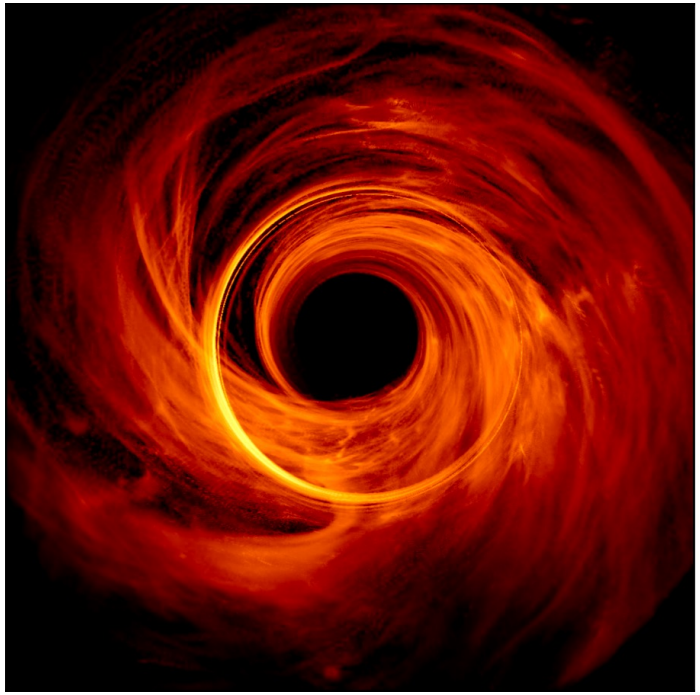

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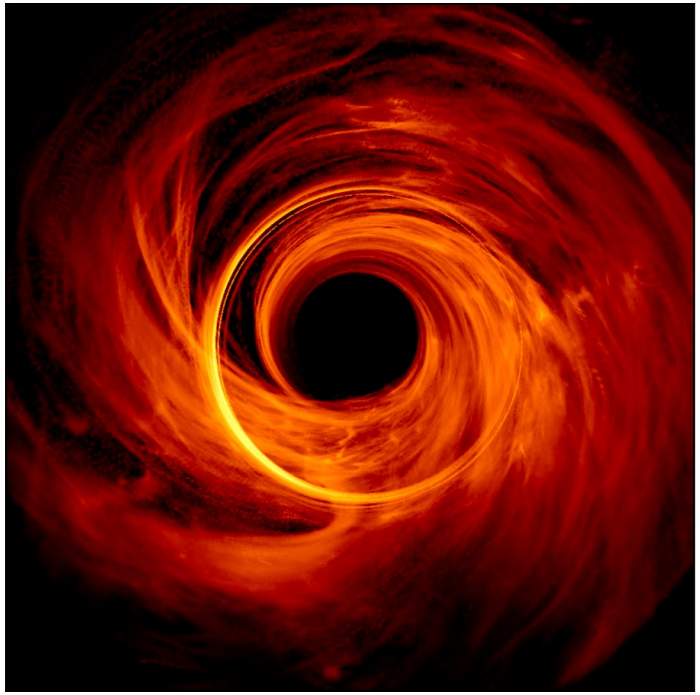

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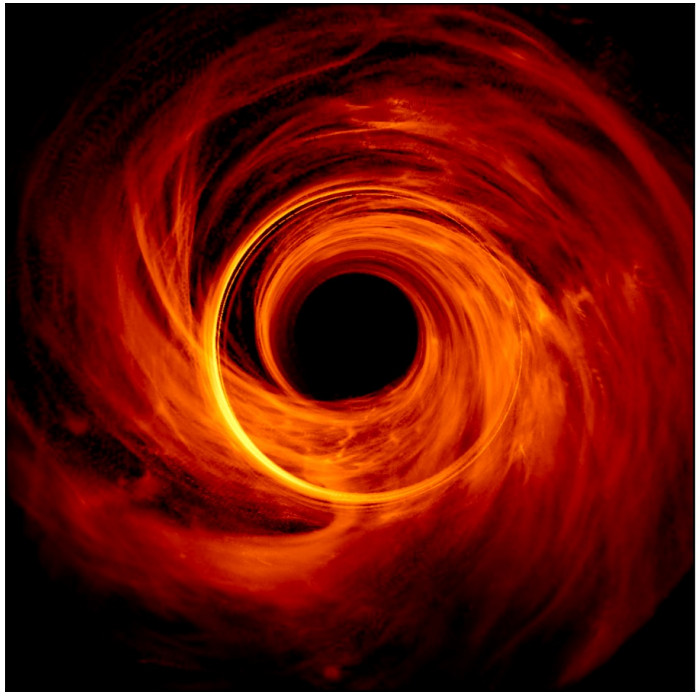

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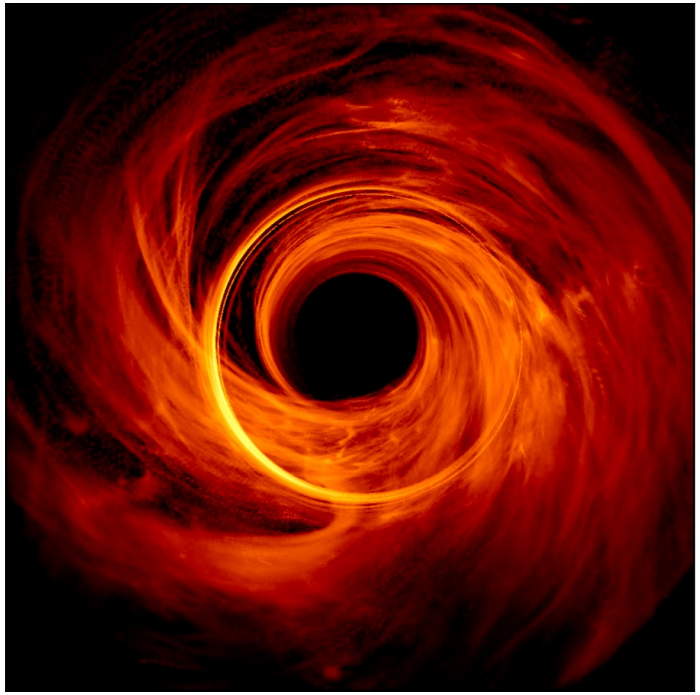

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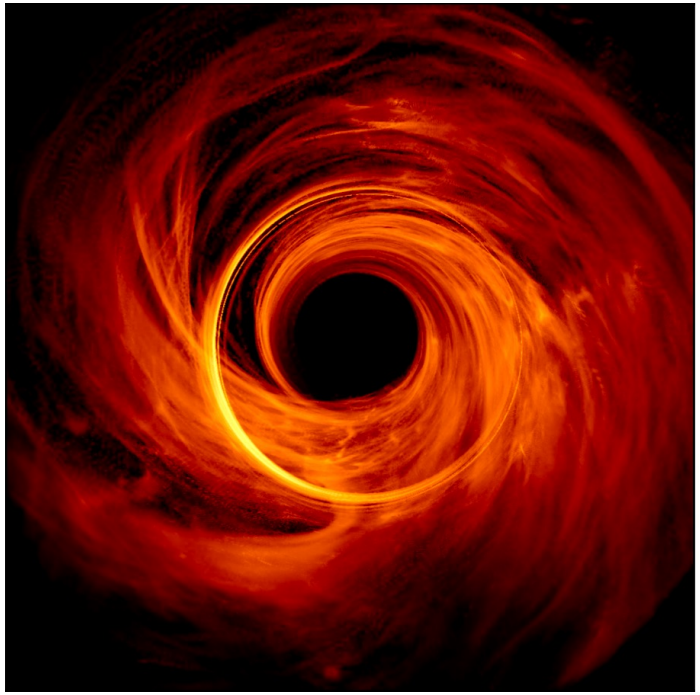
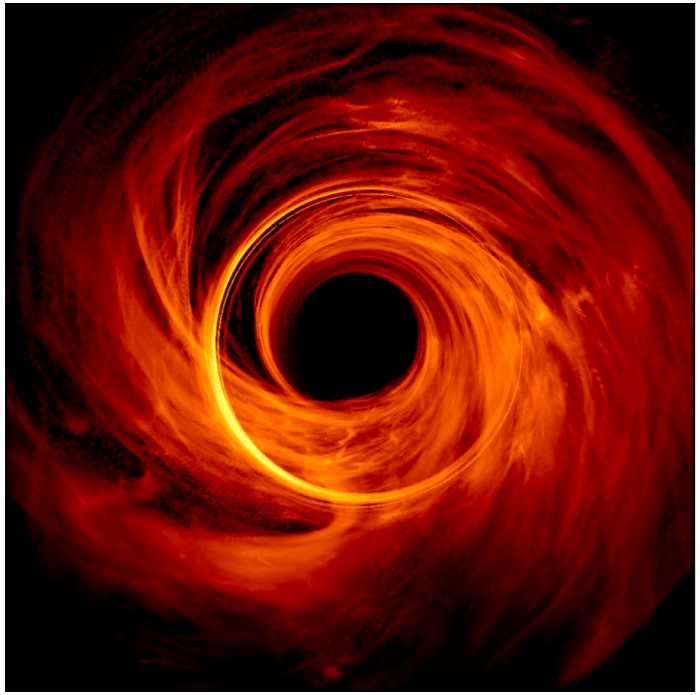
  - We can use lensing to probe the nature of turbulence in the accretion flow, and vice versa



Conclusion

- Flux eruption events cause highly variable photon ring
  - PFR traces out loop in parameter space
  - Arises from combination of gravitational lensing, Doppler boosting, & magnetic field
- Presents an observable signature for EHT and next-generation EHT
  - Analysis methods have been developed to extract PFR from data (e.g. Broderick et al. 2020)
  - We can use lensing to probe the nature of turbulence in the accretion flow, and vice versa



Feel free to reach out with questions!
zgelles@princeton.edu