

# Beyond the Lamppost: Probing the Structure of the Extended Corona

Dan Wilkins

Einstein Fellow, Kavli Institute for Particle Astrophysics & Cosmology, Stanford University

16th HEAD Meeting, Sun Valley, ID



# Outline

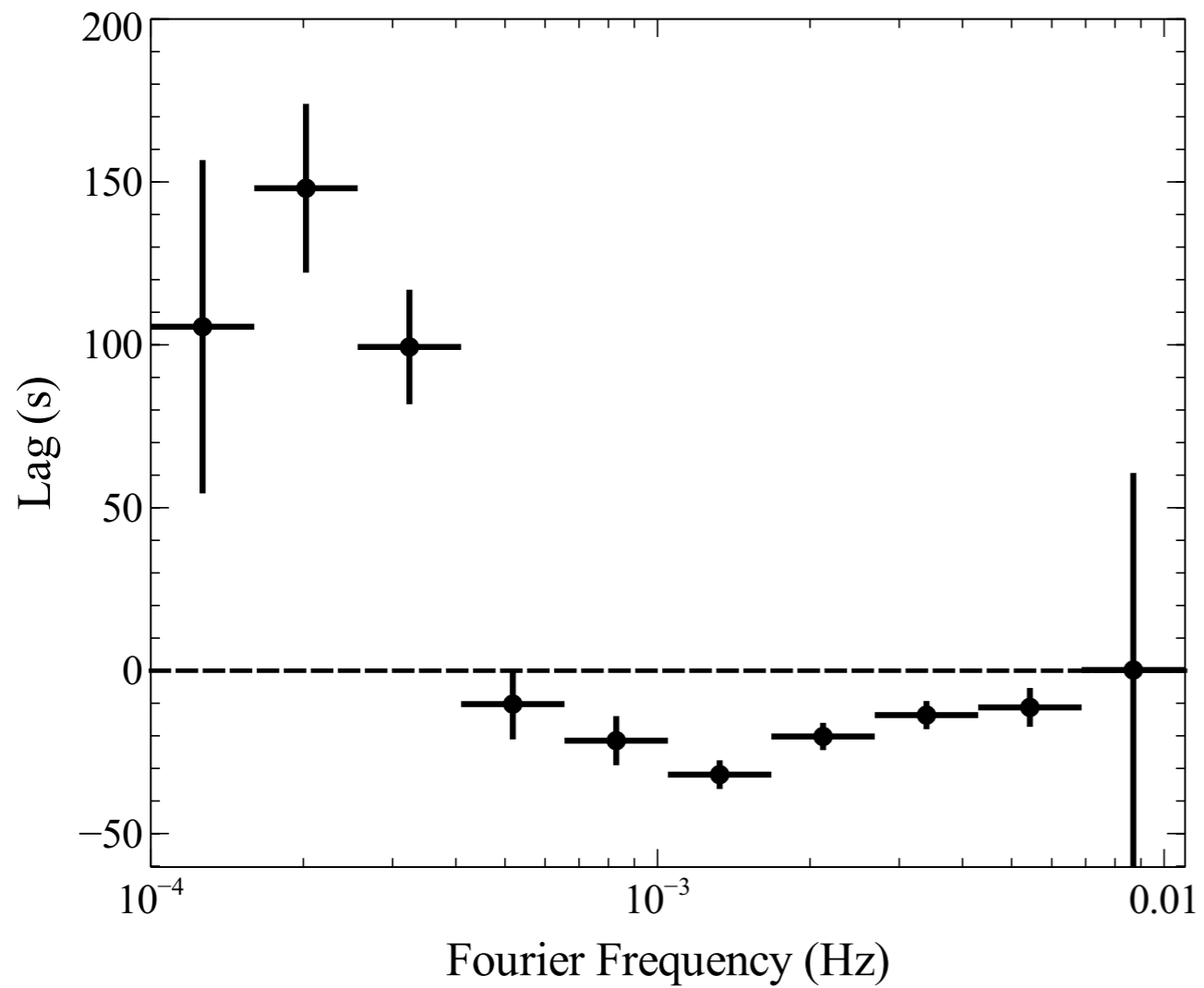
---

- Why do we want to consider the corona as something more than a lamppost?
- Developing a physical, self-consistent model for extended coronae and propagating fluctuations
- Piecing together the extended corona

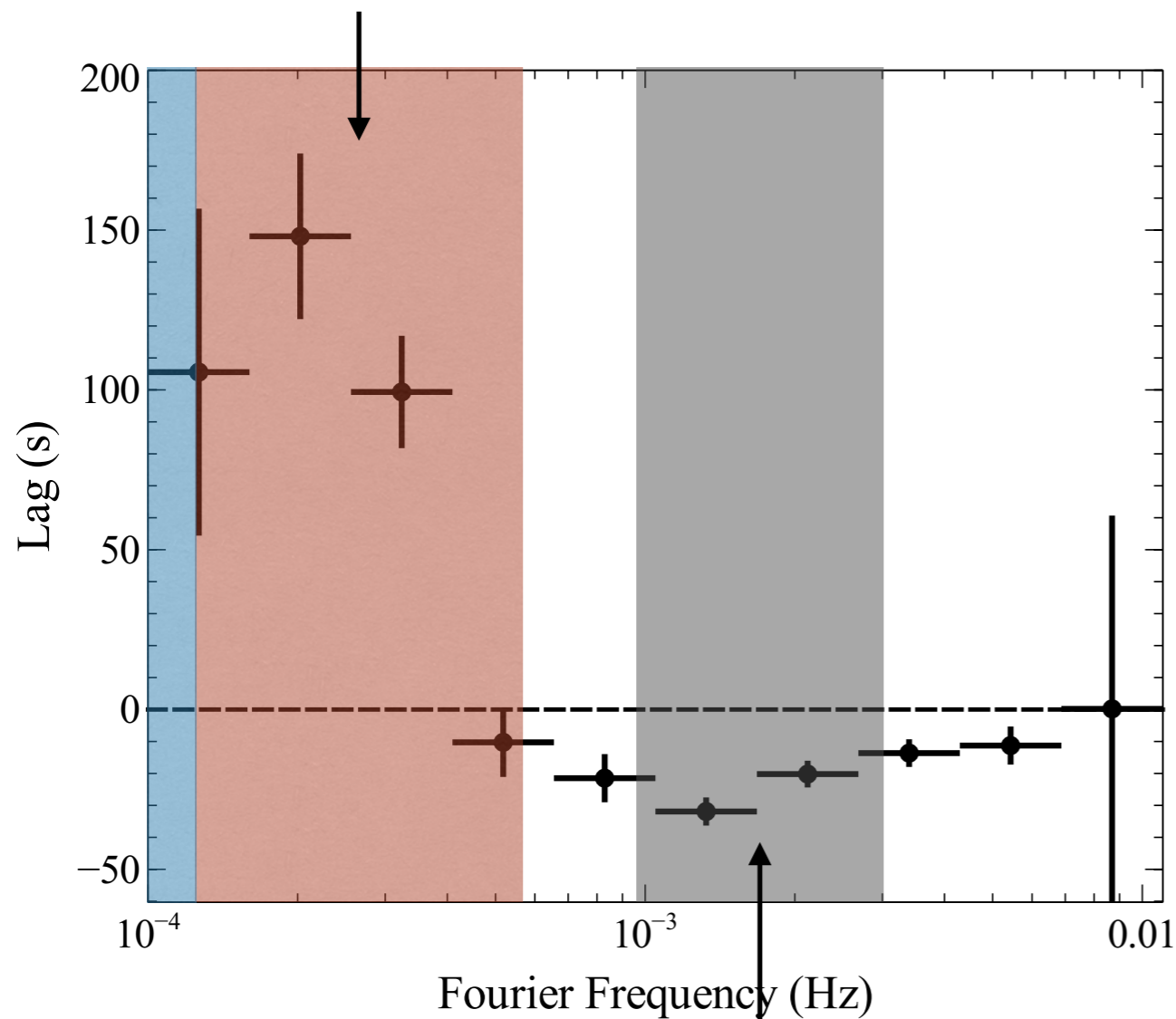
# Why do we care?

---

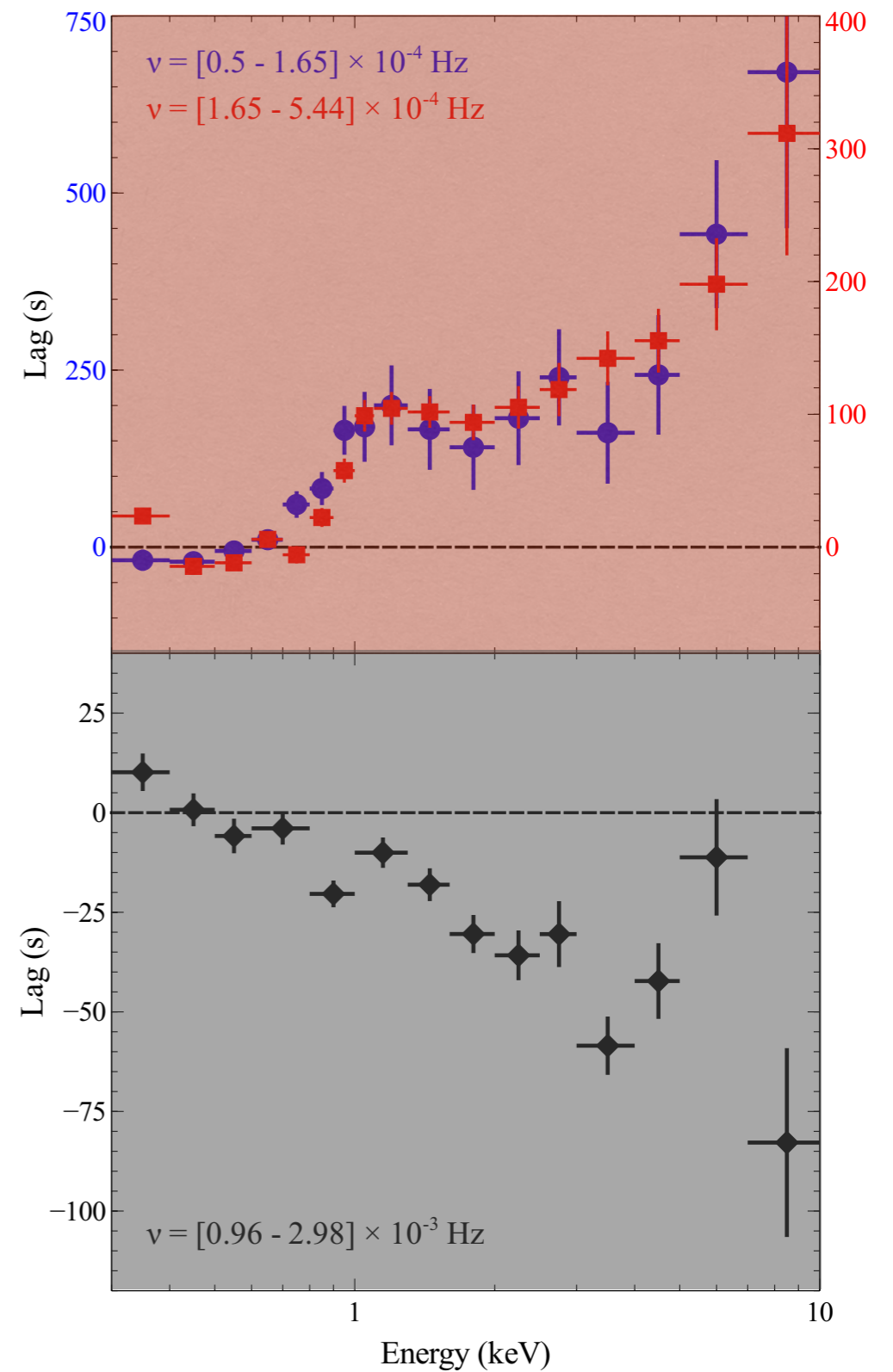
- How are some of the brightest objects in the Universe powered?
- How is the corona formed and powered by the accretion flow?
- What is the structure of the corona?
- How does the corona evolve in time? What regulates AGN activity?
- How are jets launched and are they related to the corona?



# Hard X-rays lag soft (in continuum)

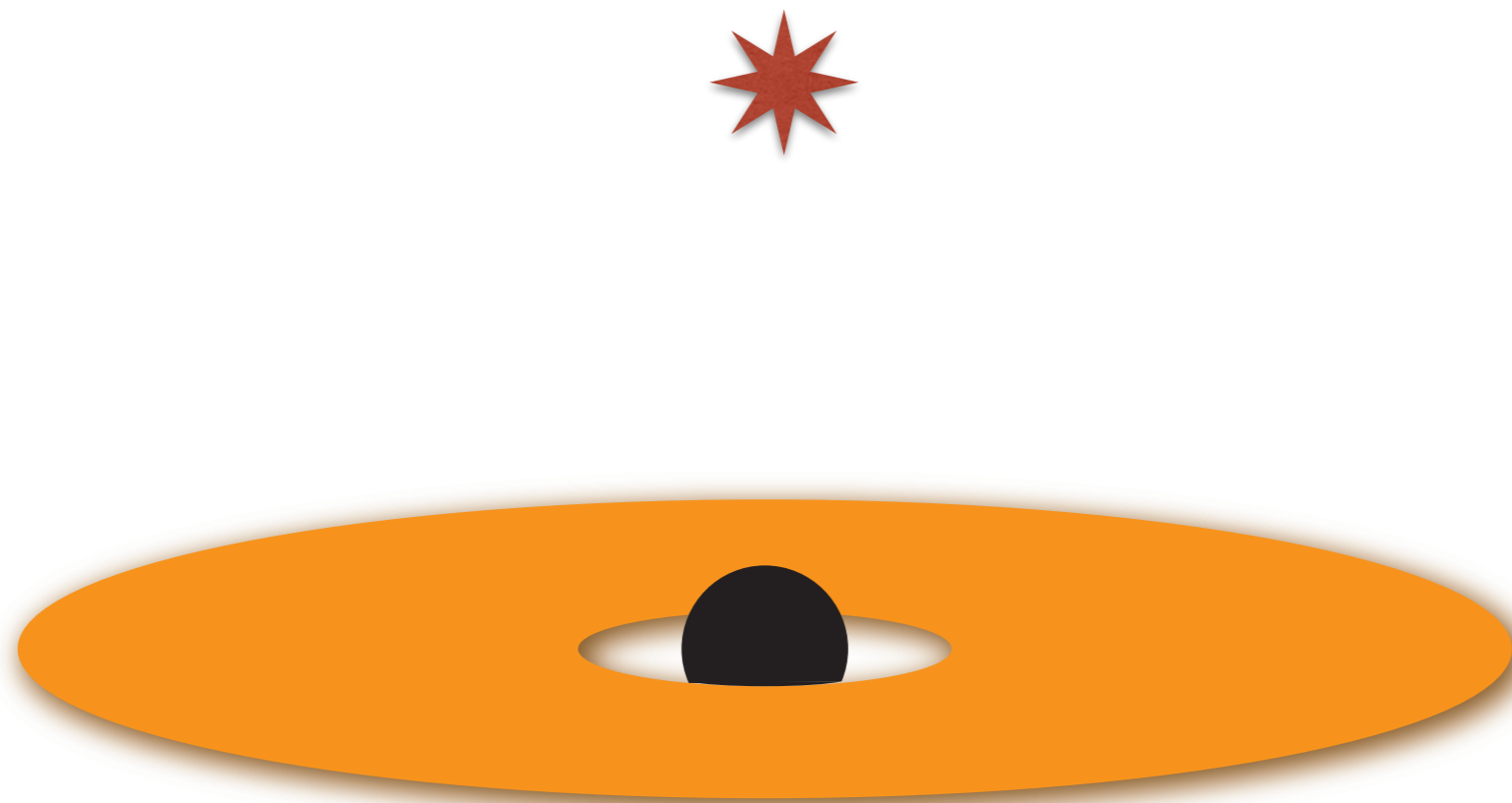


Soft (reflection-dominated)  
lags hard (continuum)

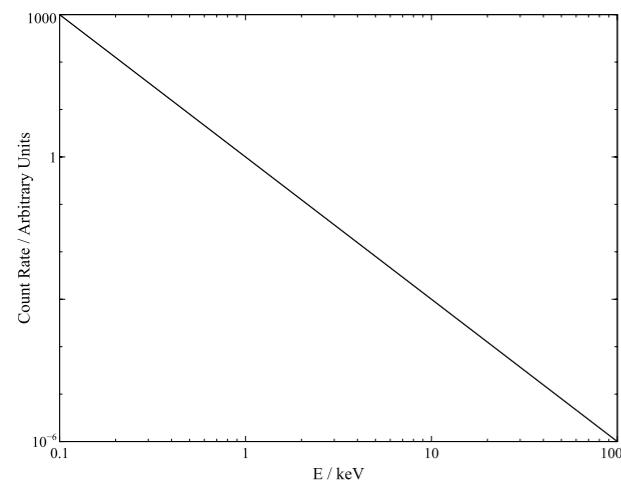


# Simulating X-ray Reverberation

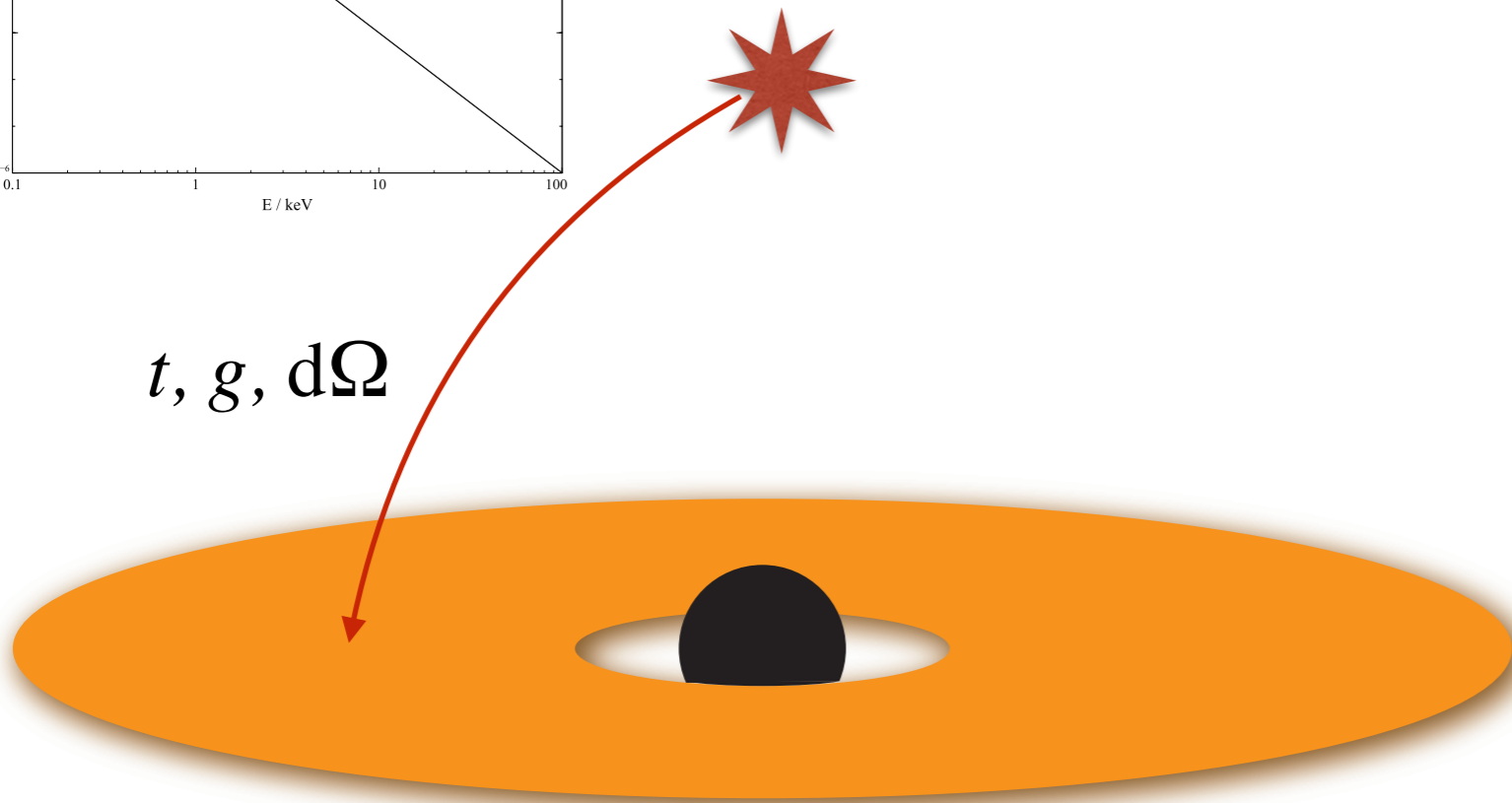
---



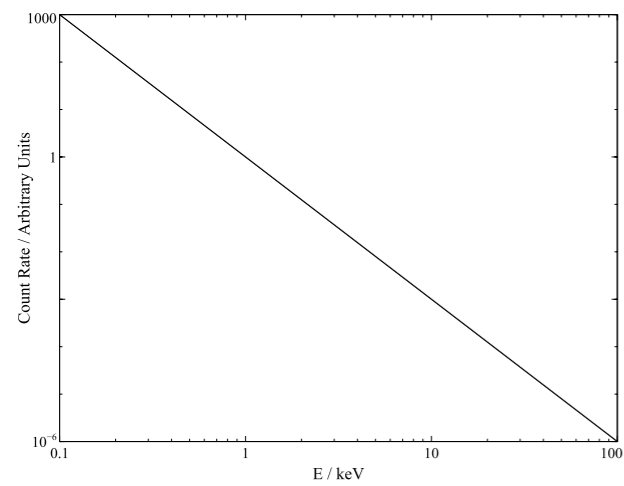
# Simulating X-ray Reverberation



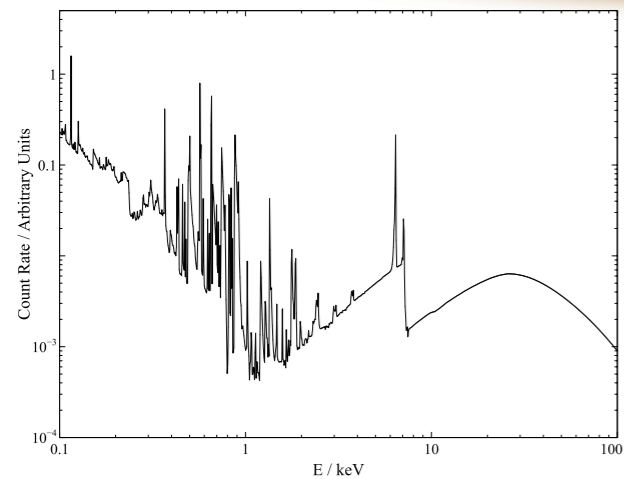
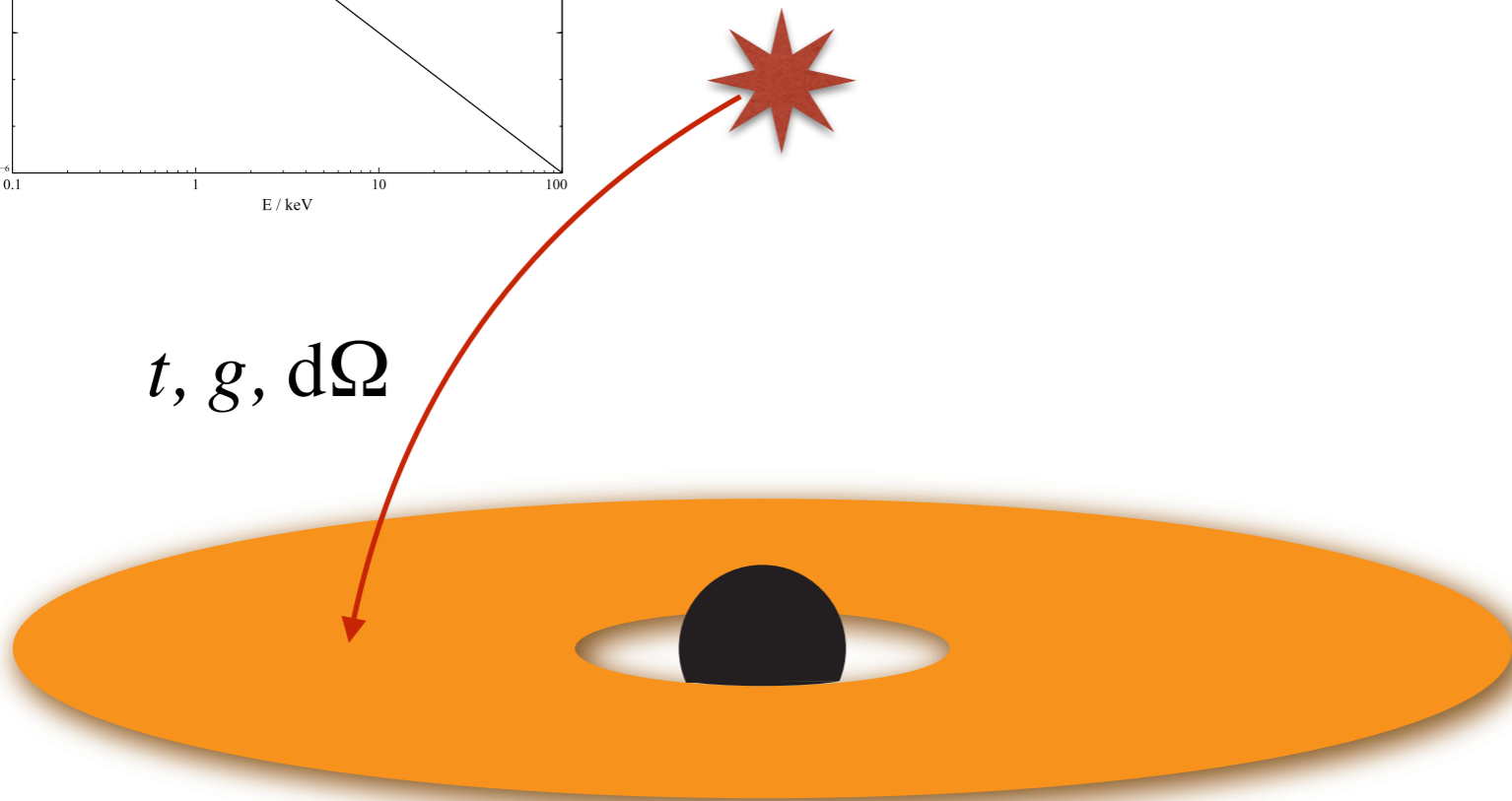
$t, g, d\Omega$



# Simulating X-ray Reverberation

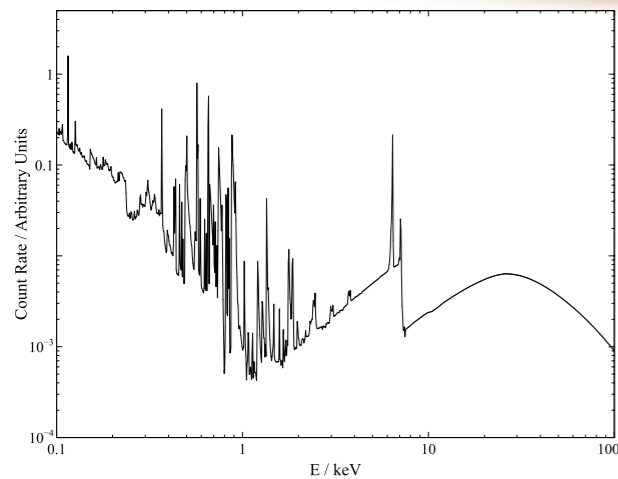
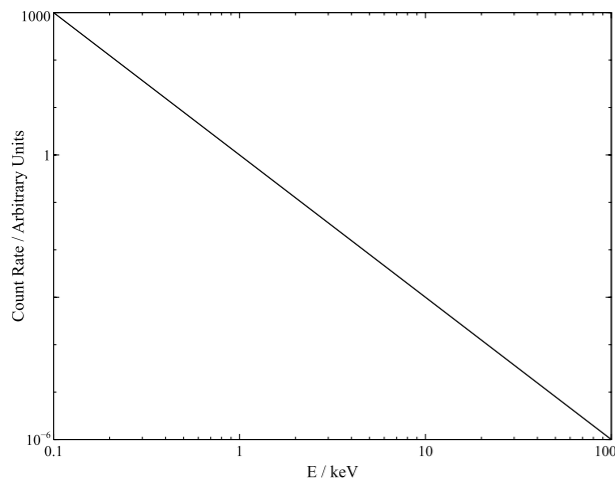
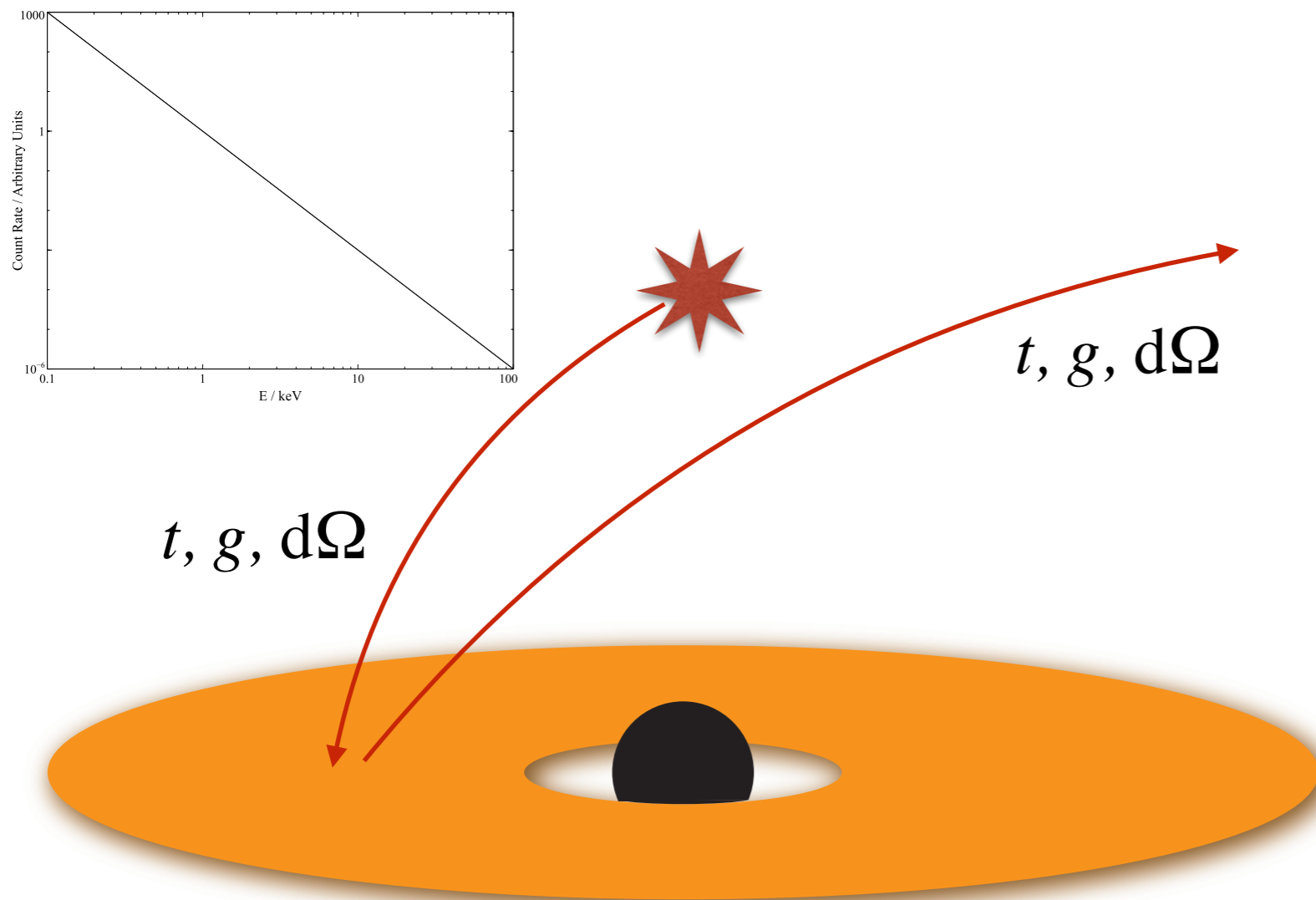


$t, g, d\Omega$

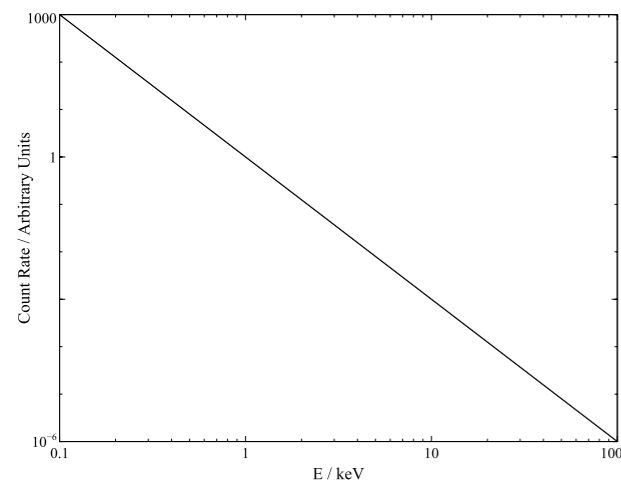




# Simulating X-ray Reverberation

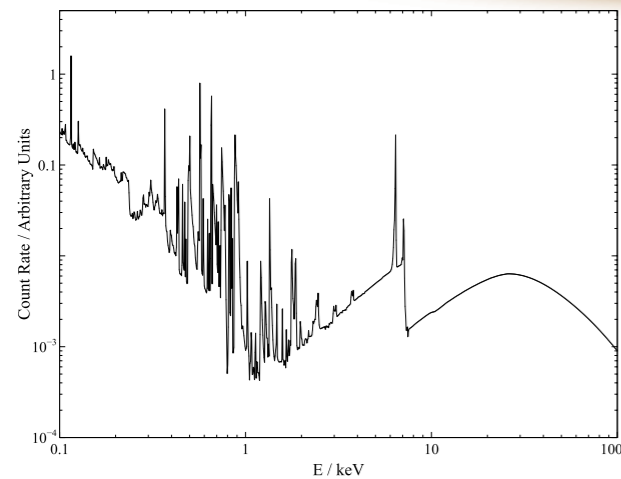
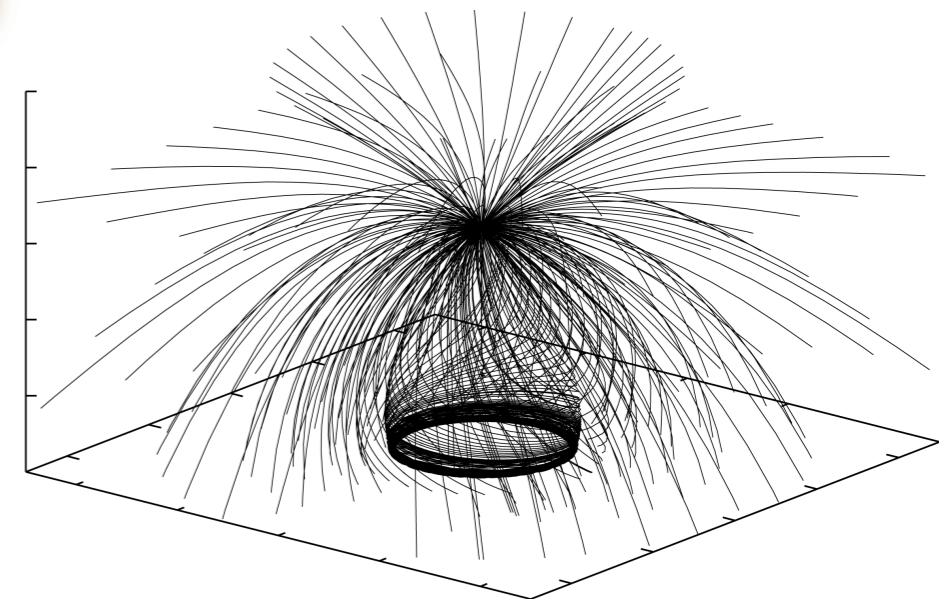
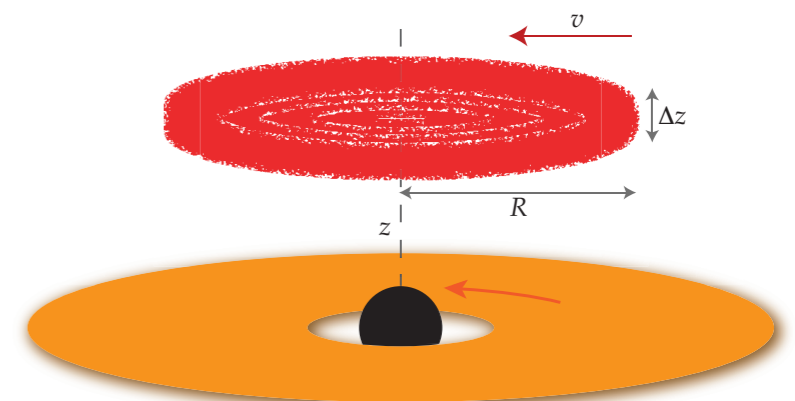
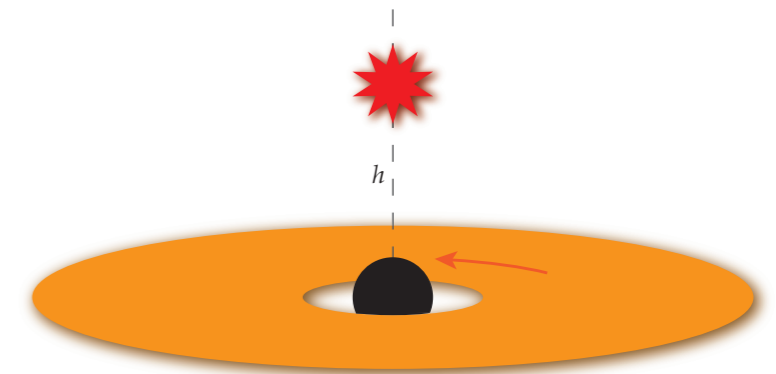


# Simulating X-ray Reverberation



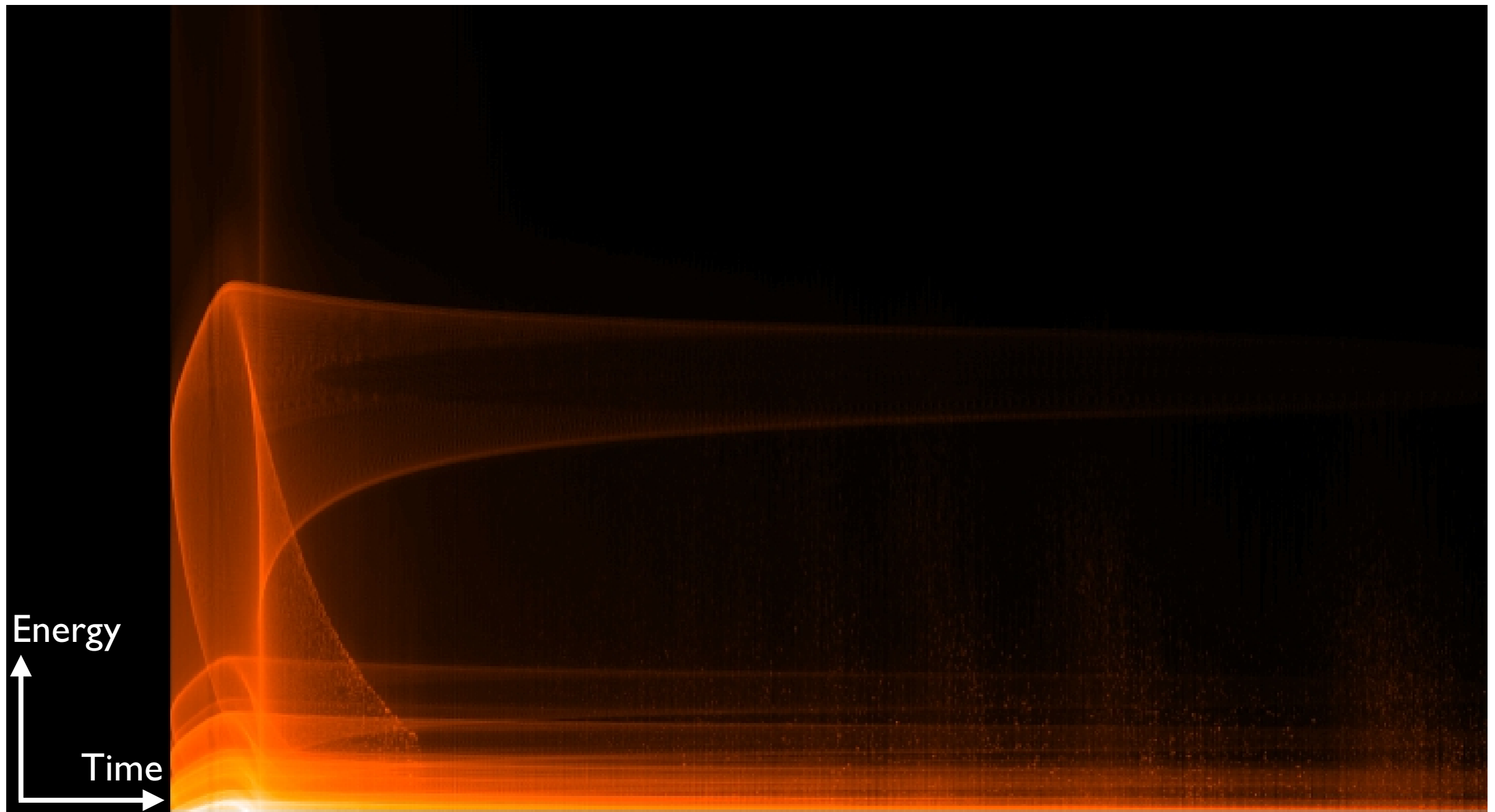
$t, g, d\Omega$

$t, g, d\Omega$

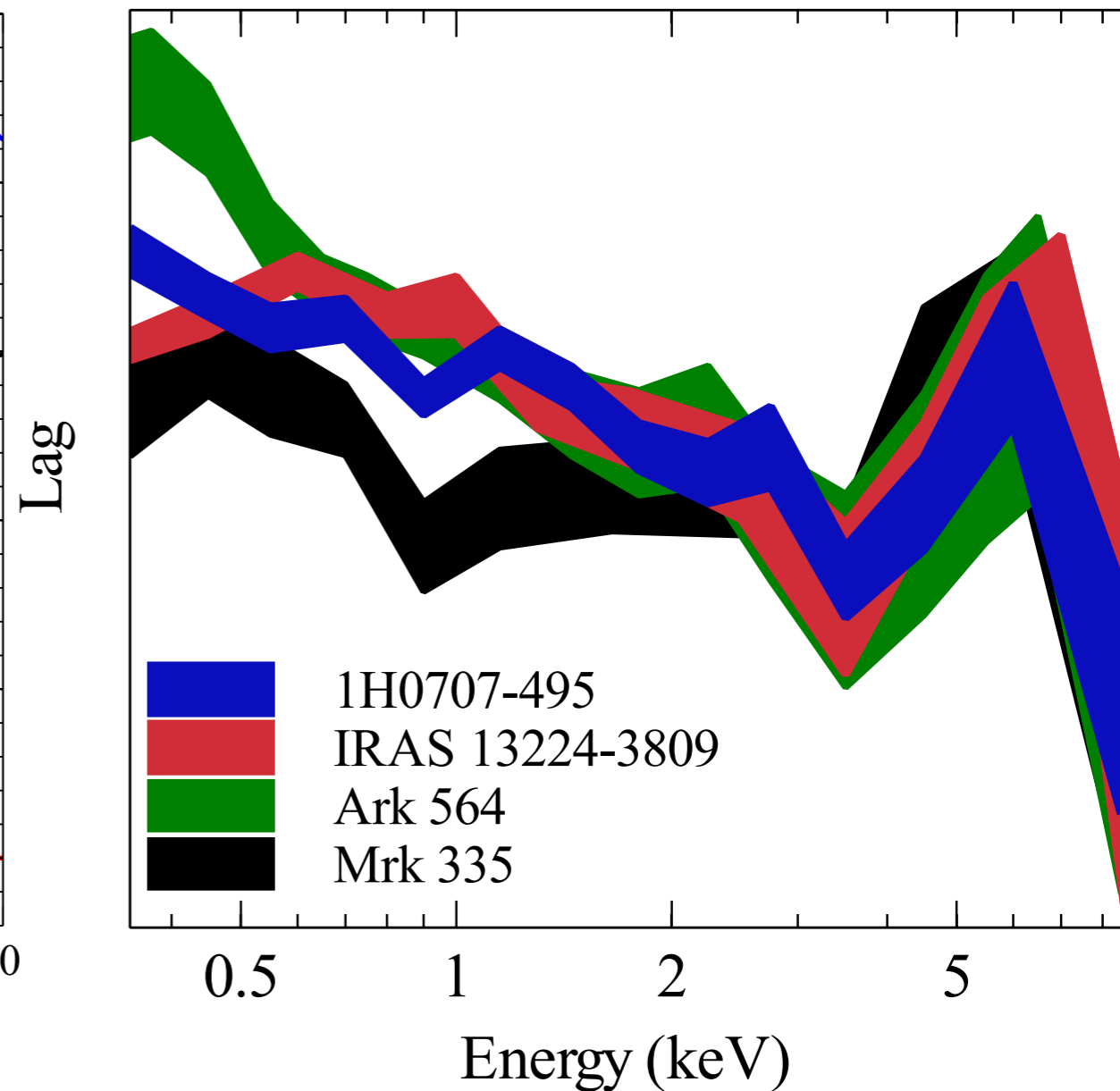
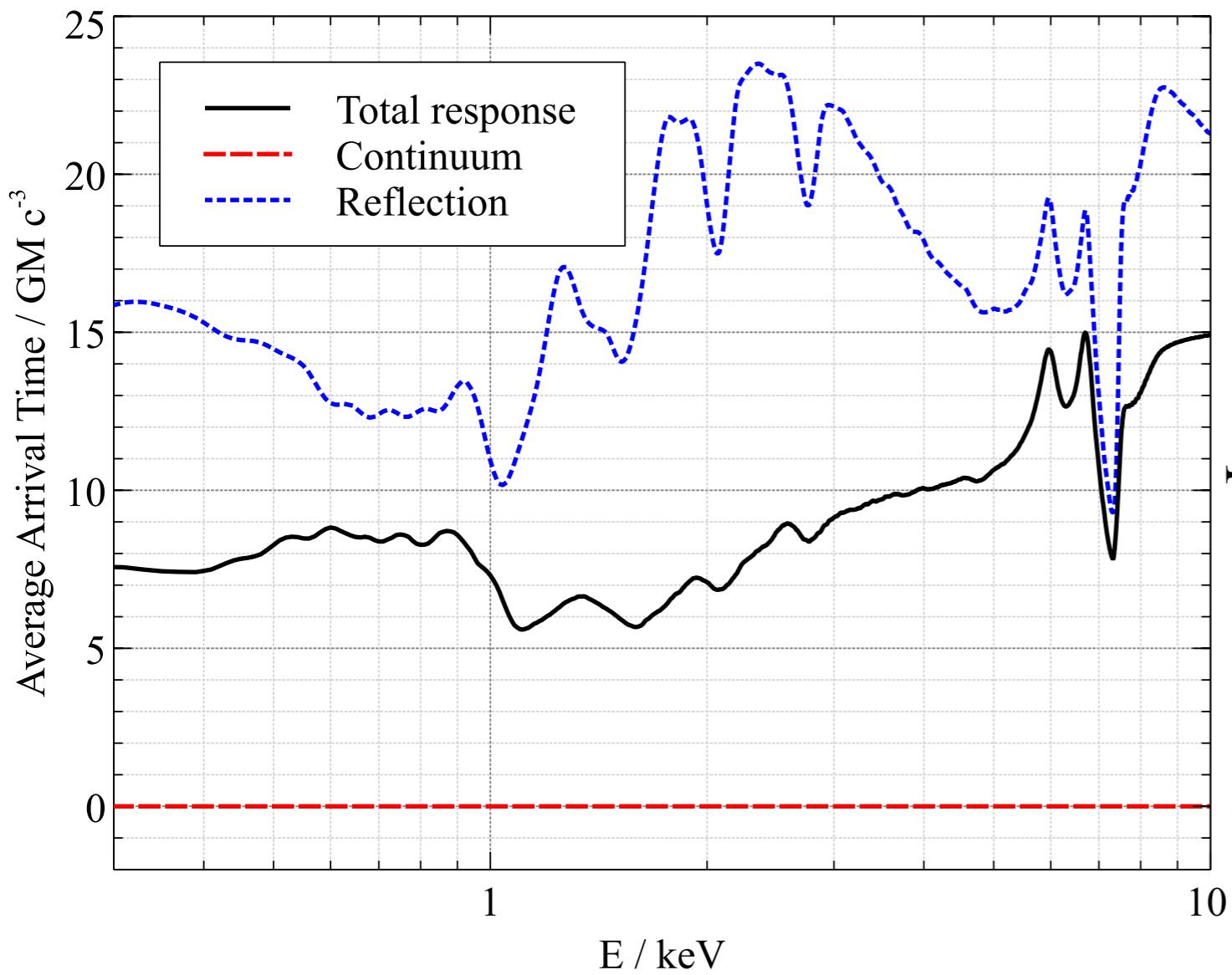


# Reverberation Response

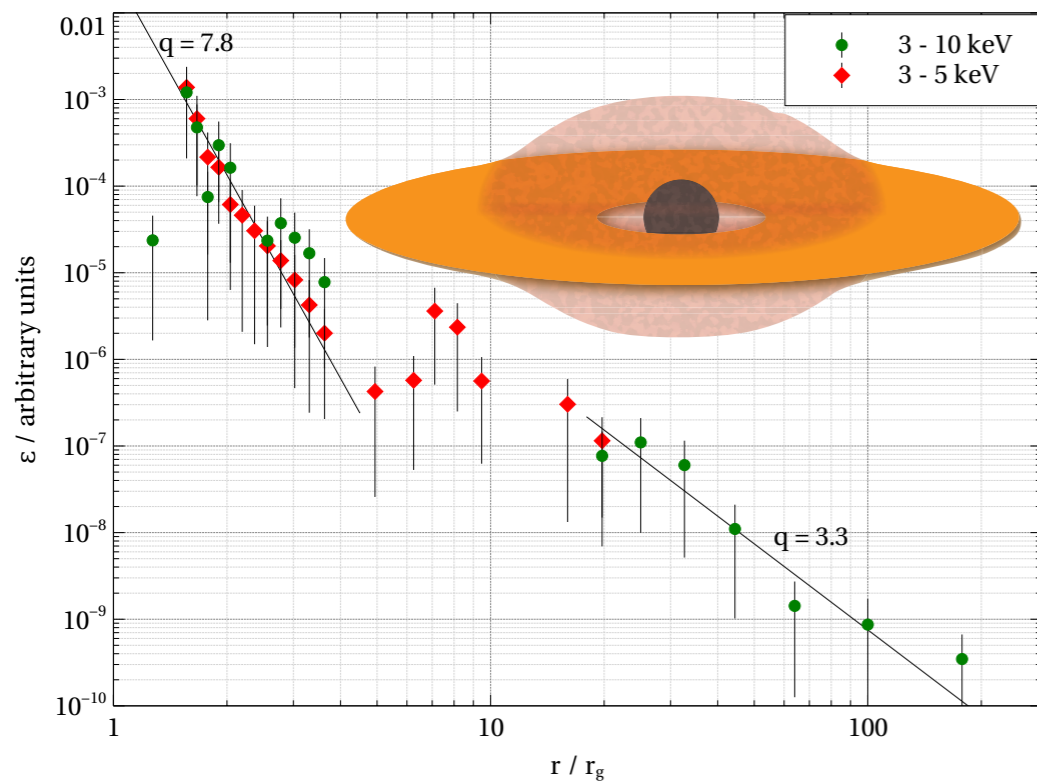
---



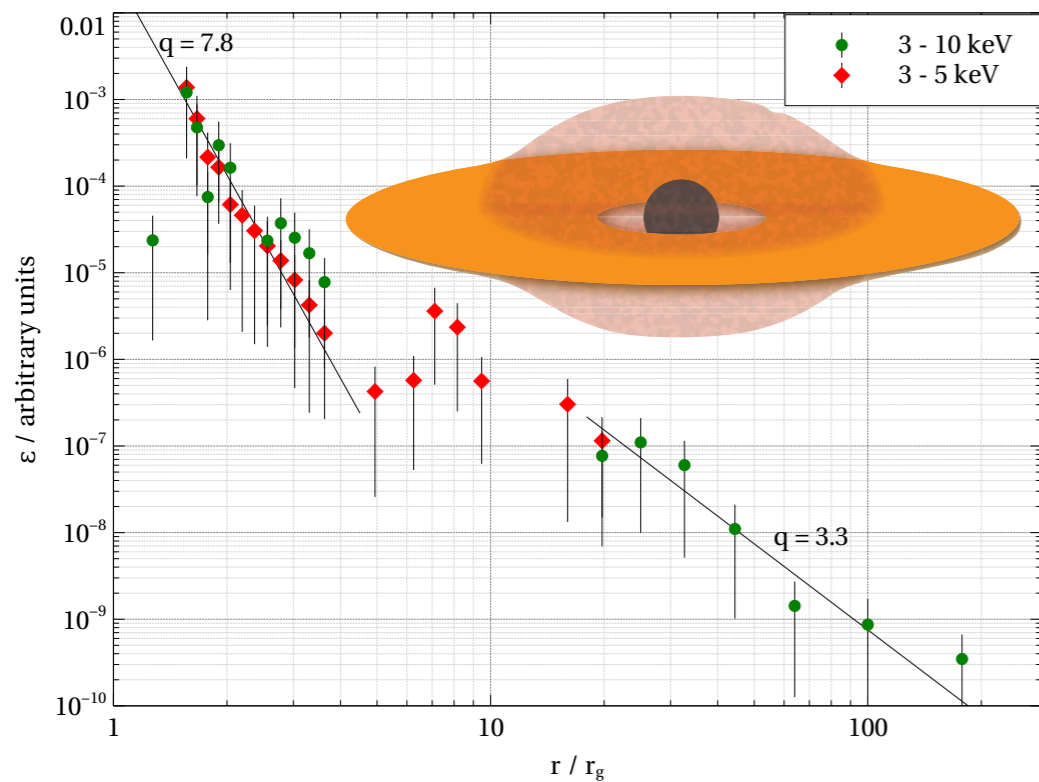
# The Lag-Energy Problem



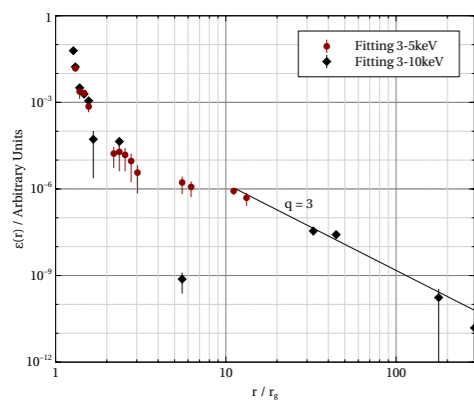
# What about an Extended Corona?



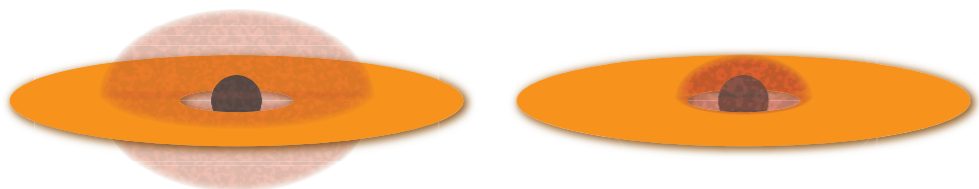
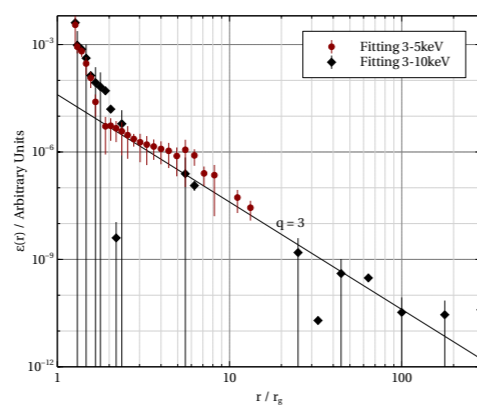
# What about an Extended Corona?



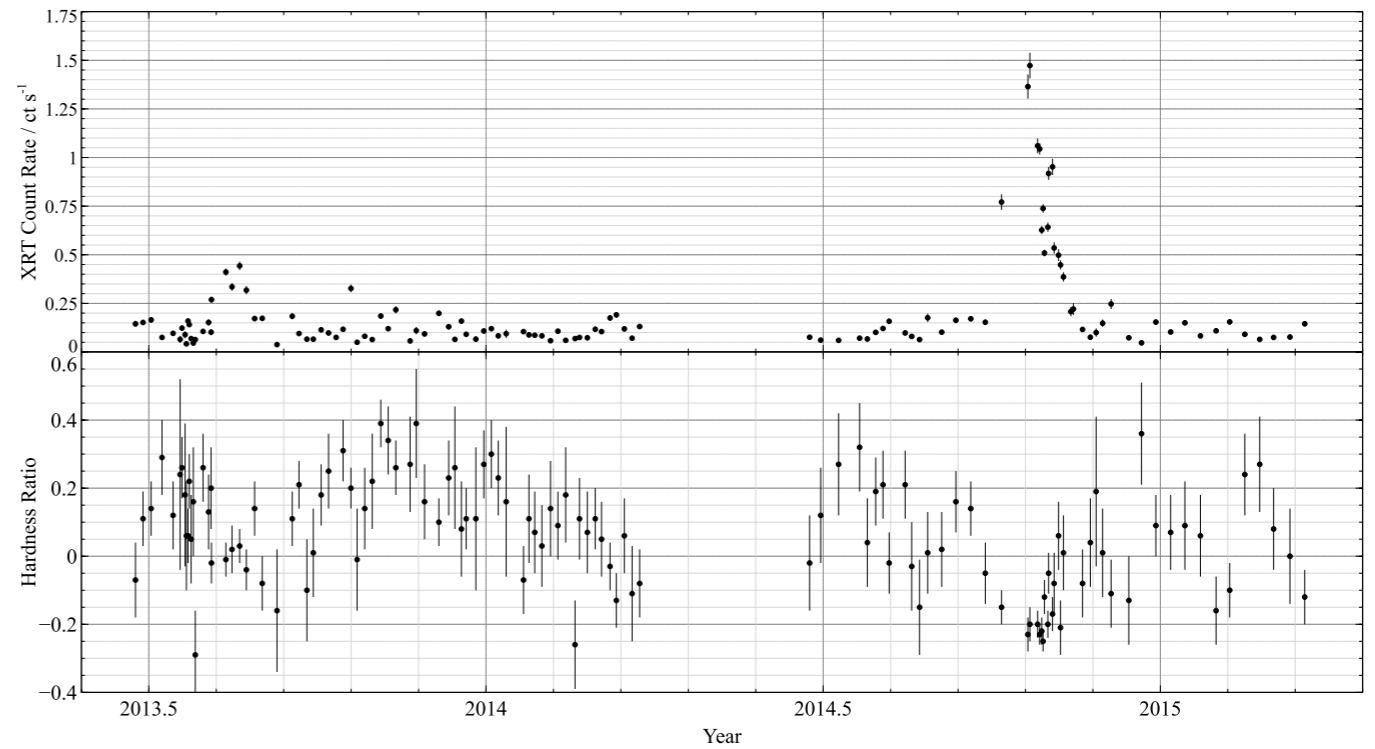
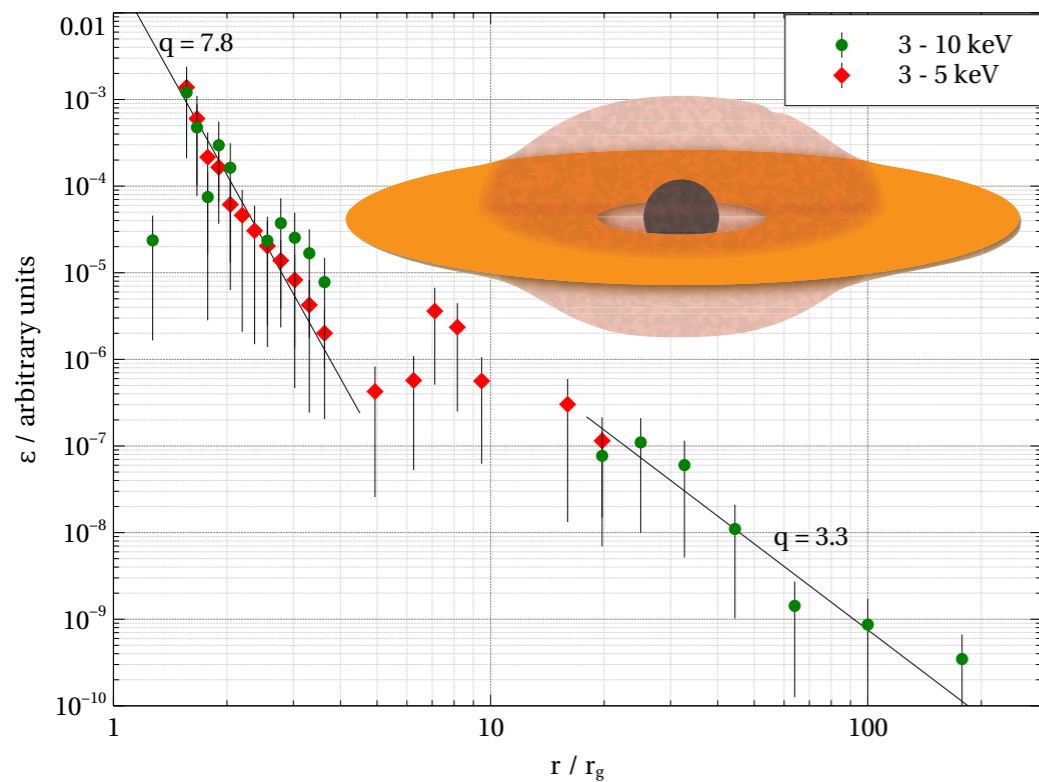
High Flux



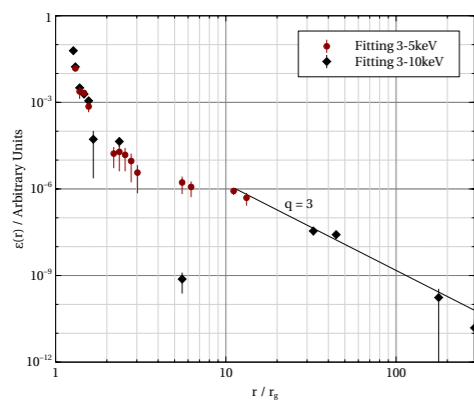
Low Flux



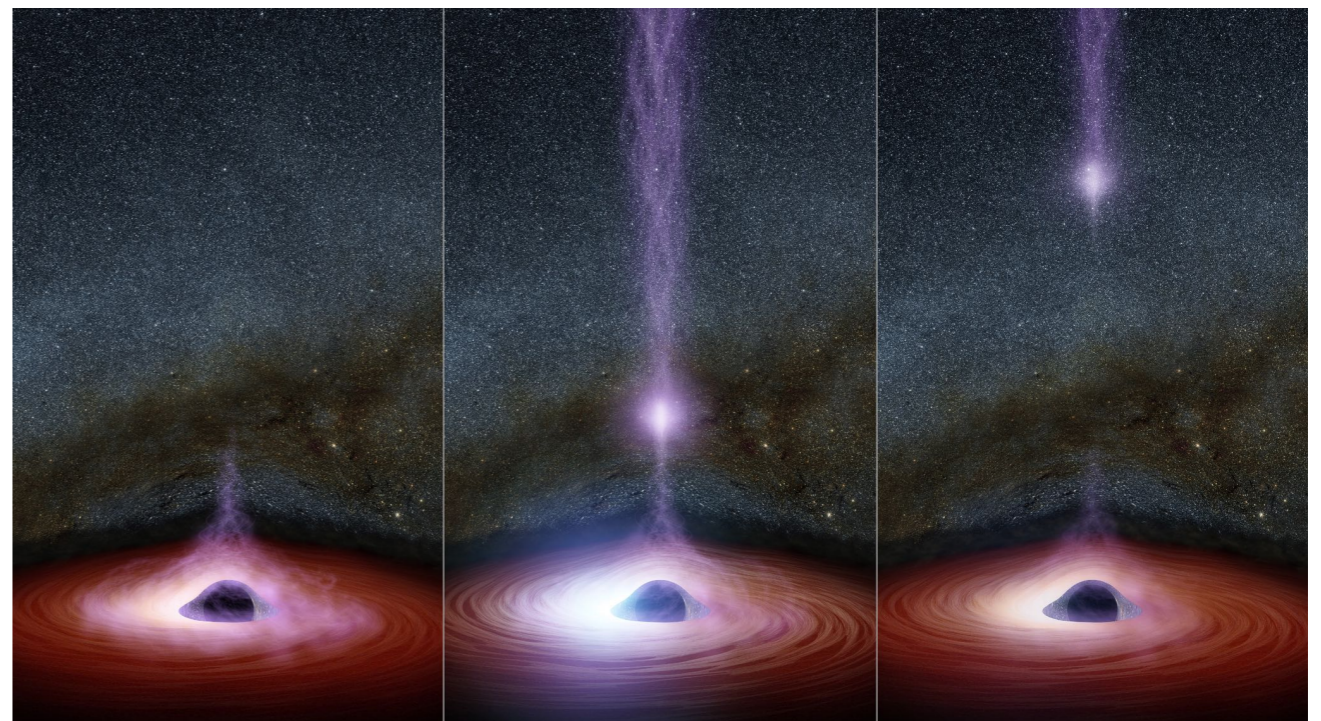
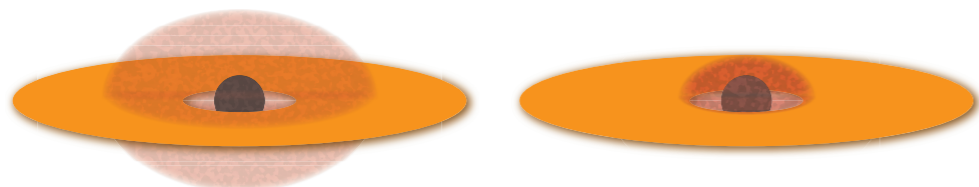
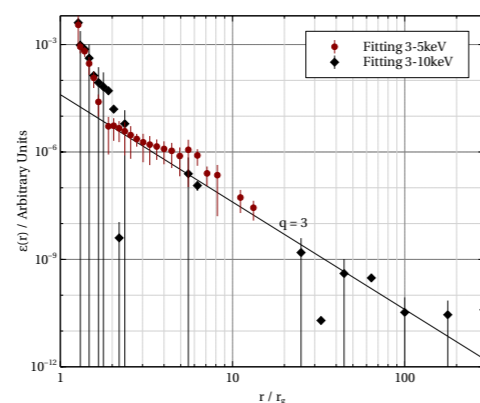
# What about an Extended Corona?



High Flux

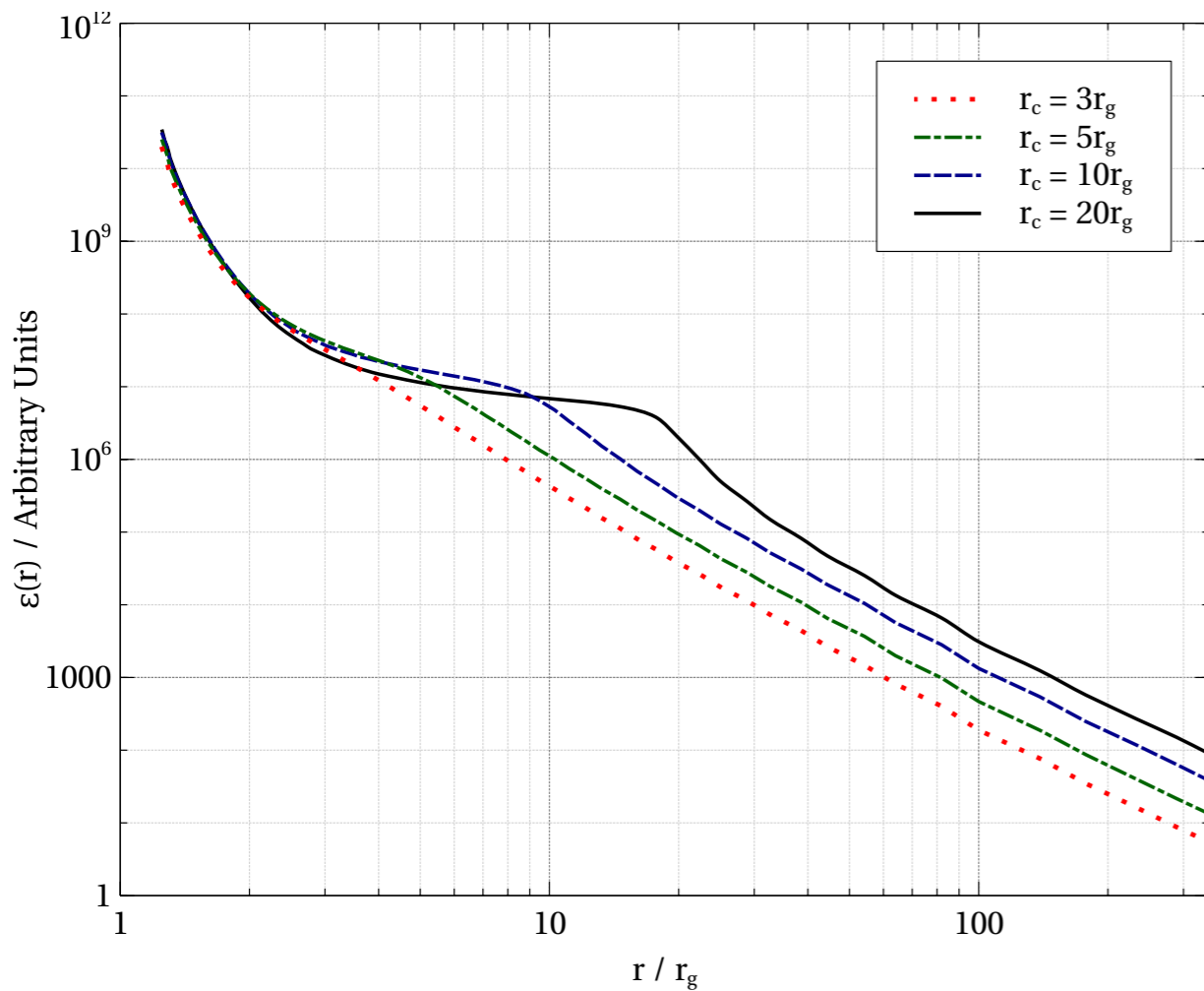
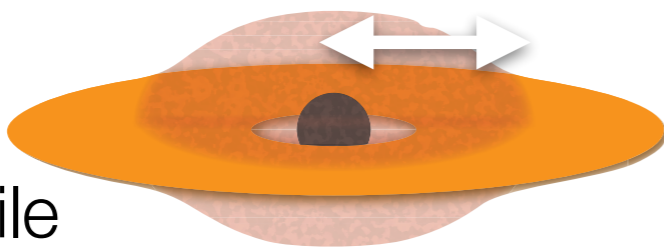


Low Flux

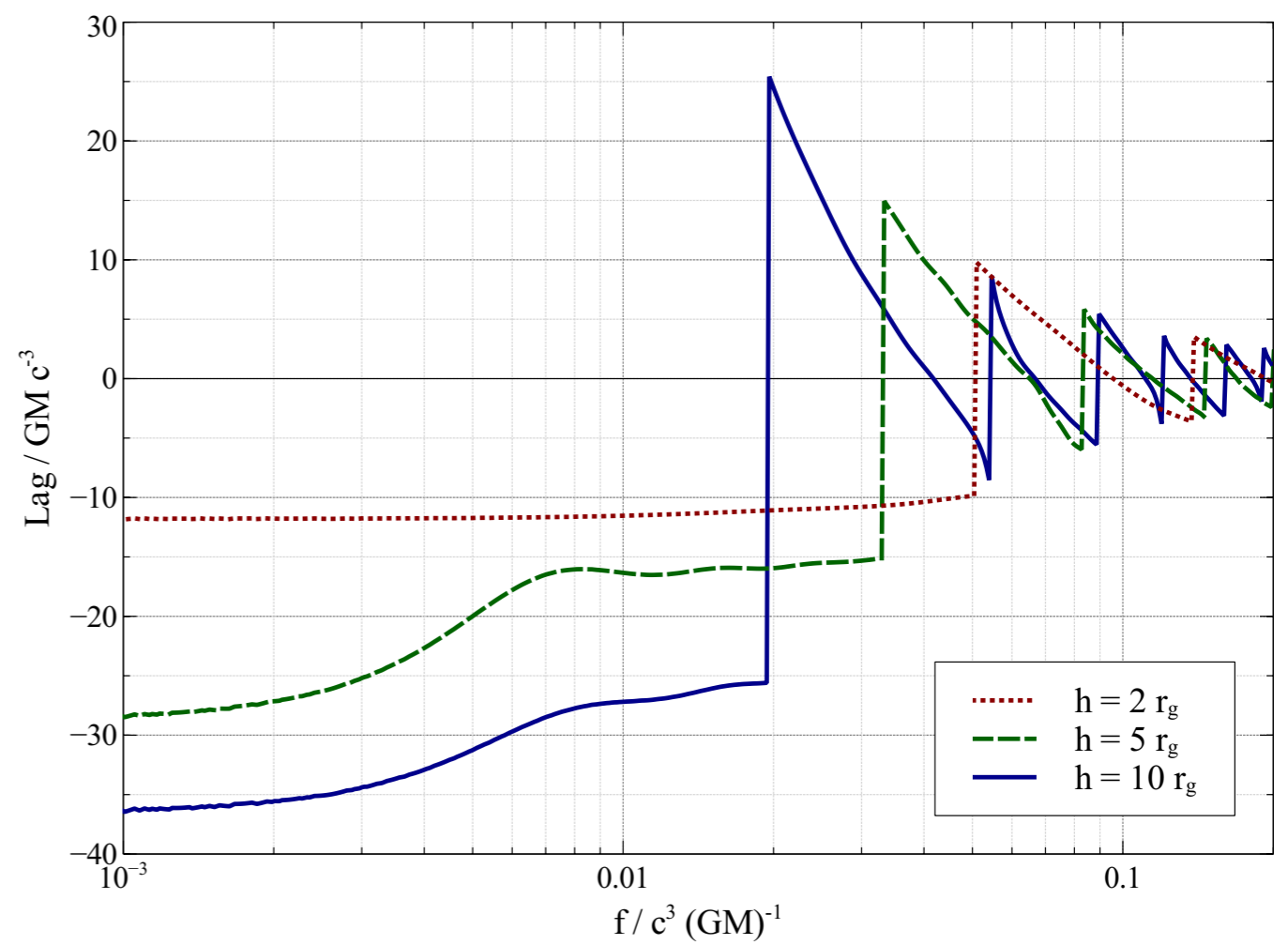
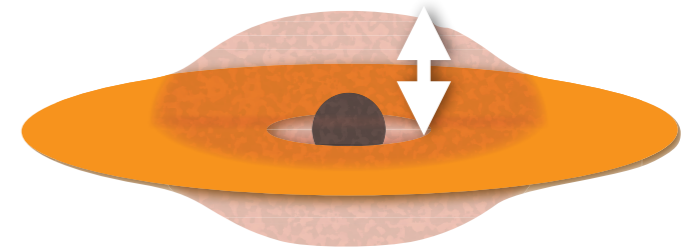


# Complimentary Probes

Accretion Disc  
Emissivity Profile

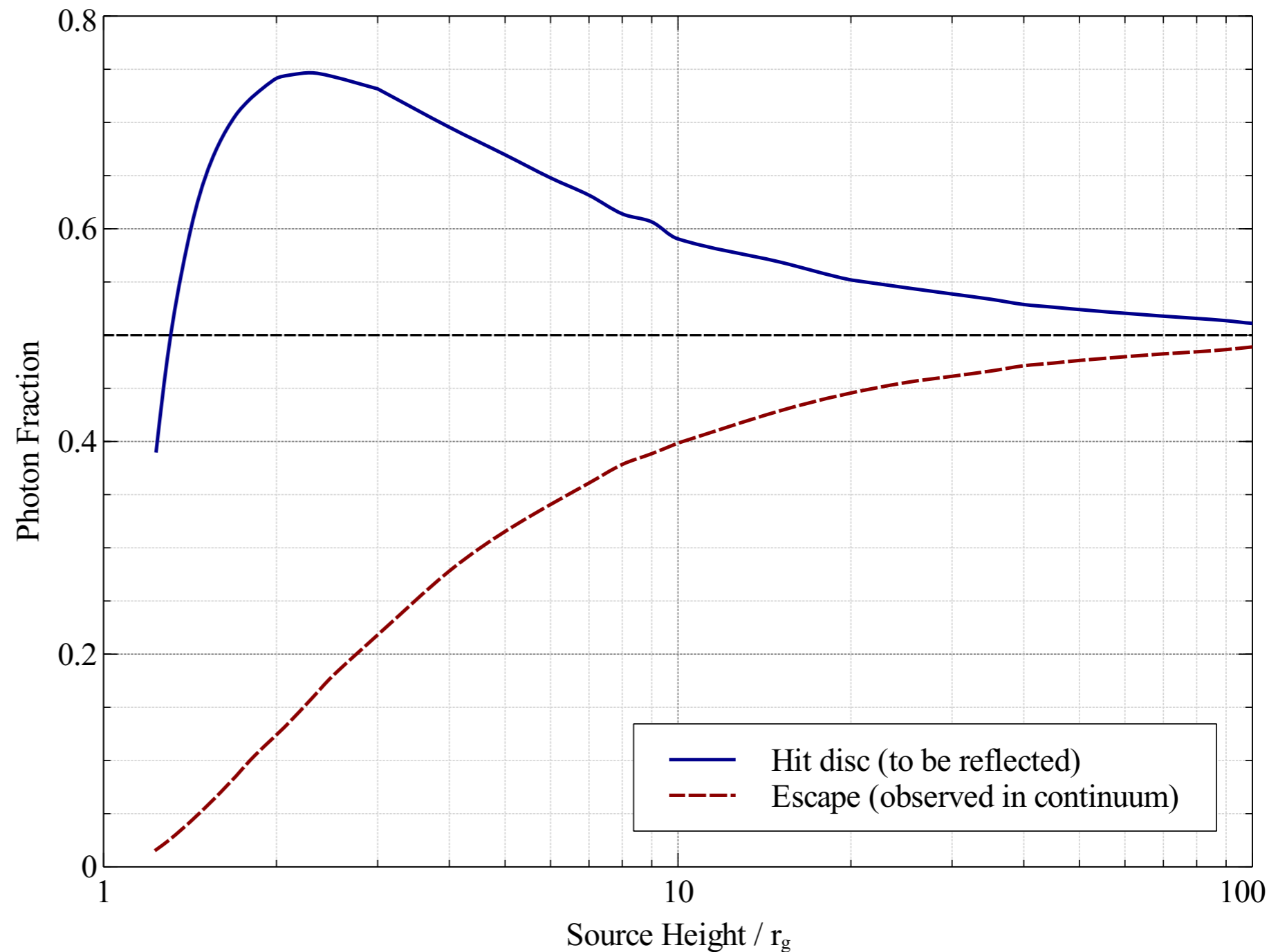
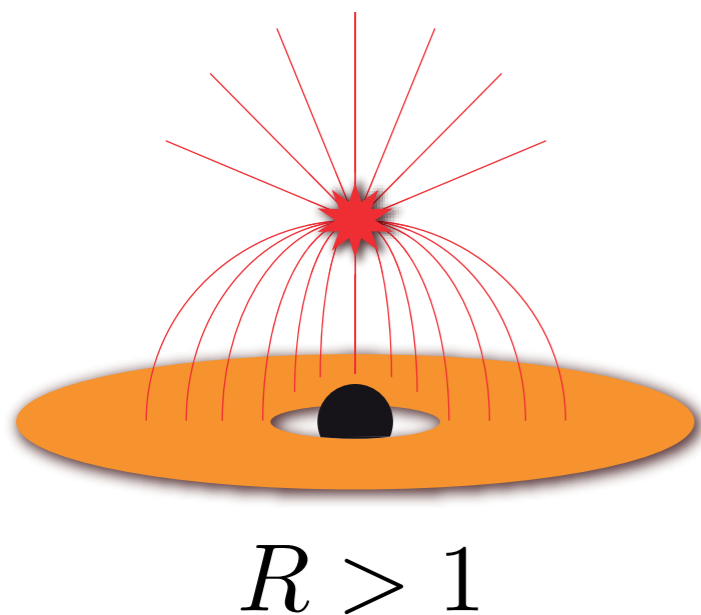
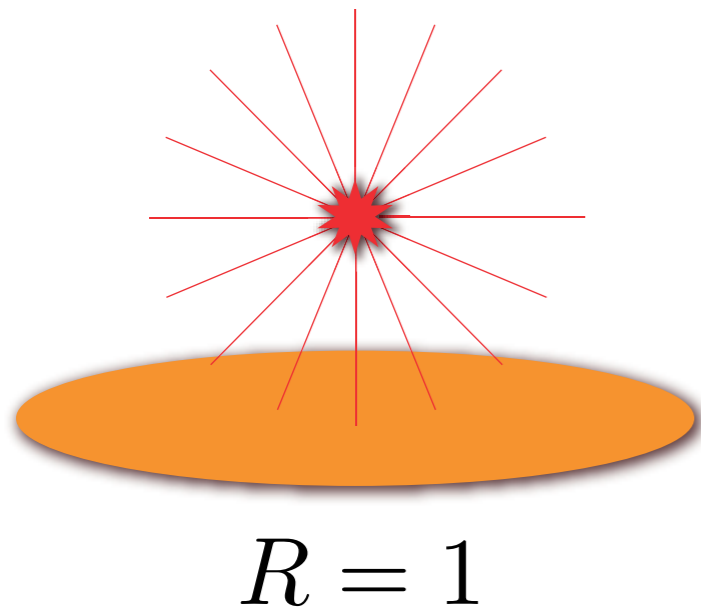


Reverberation  
Time Lag

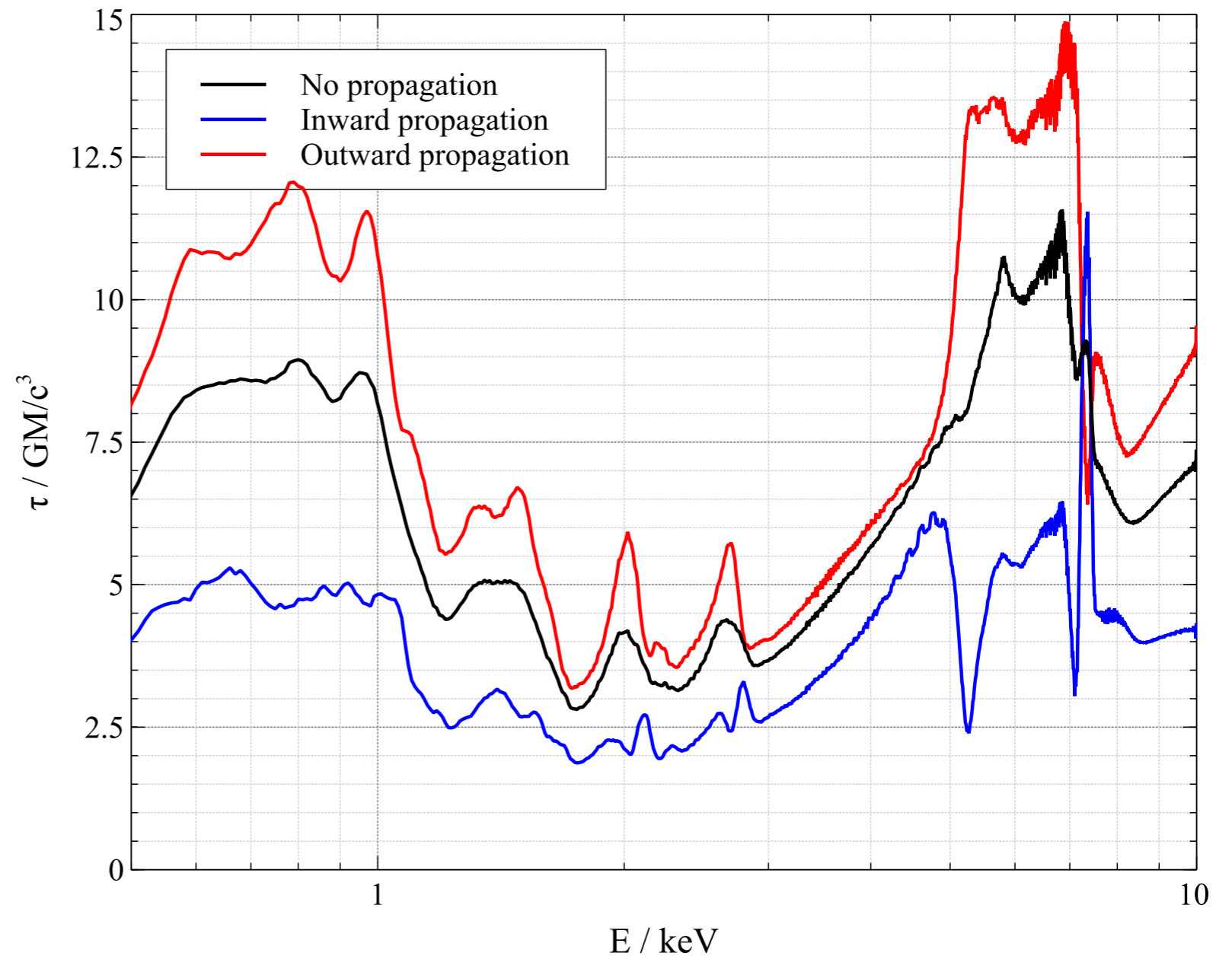
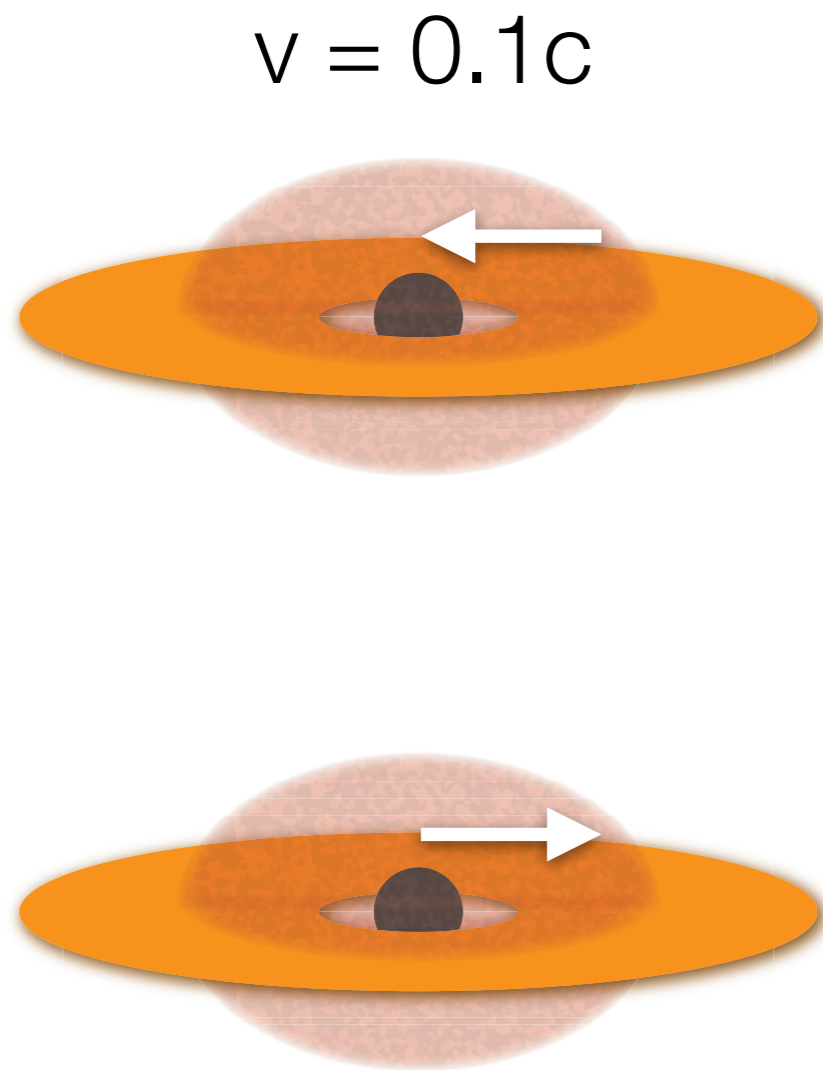




# The Reflection Fraction

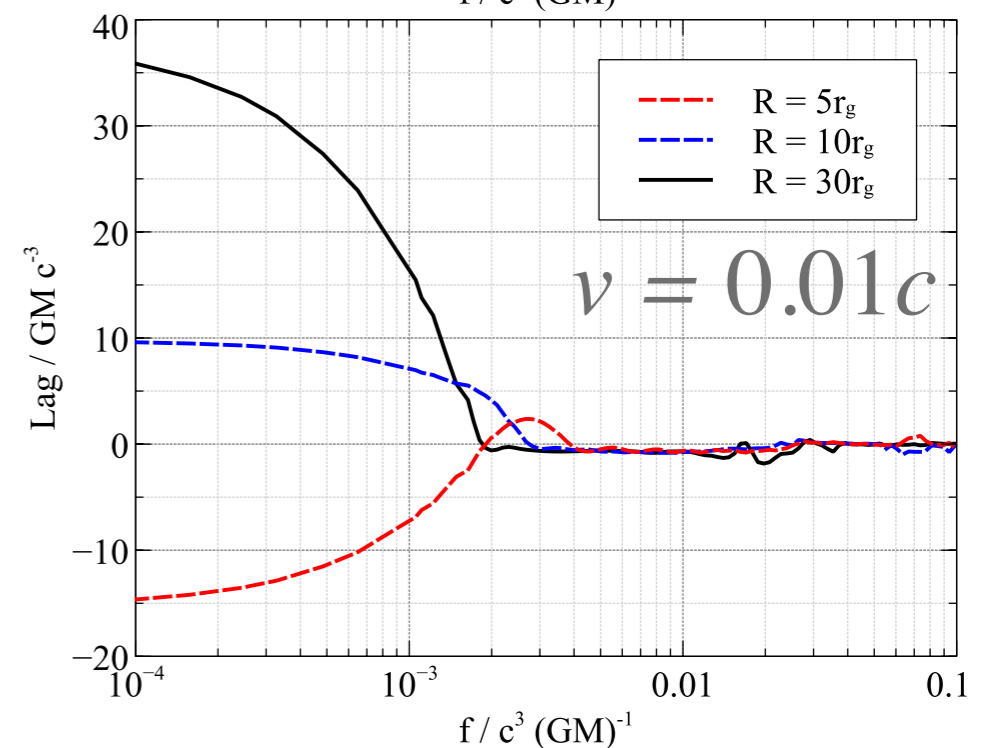
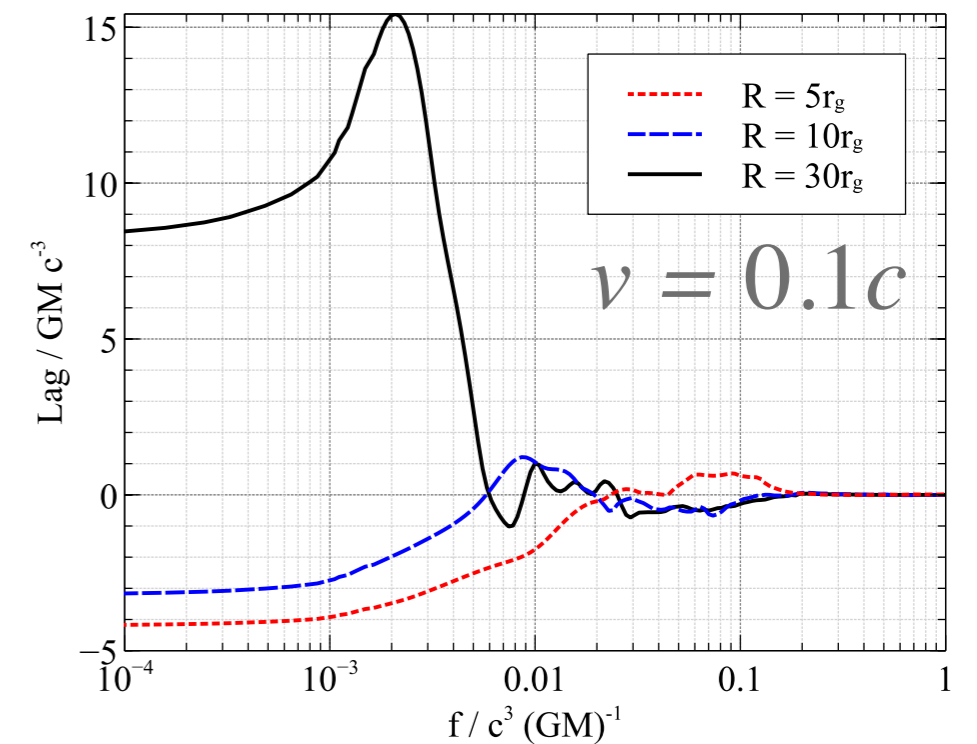
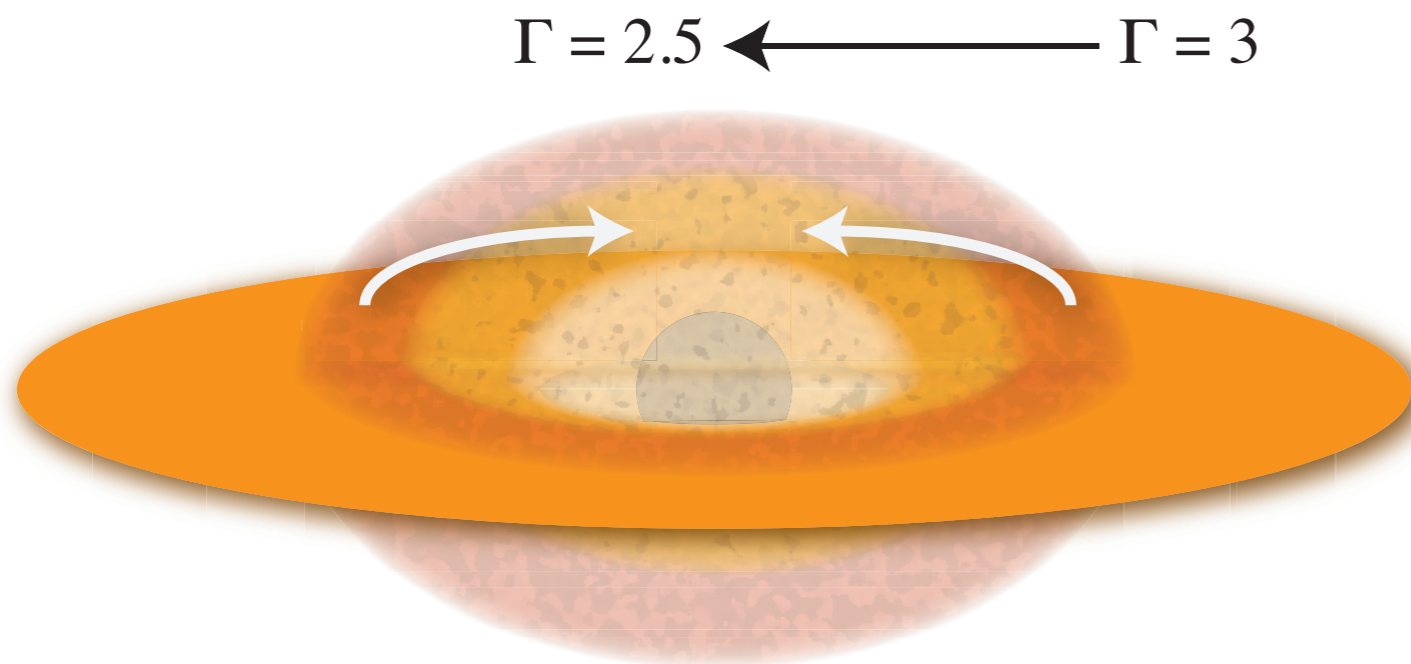


# Extended Coronae in Lag-Energy

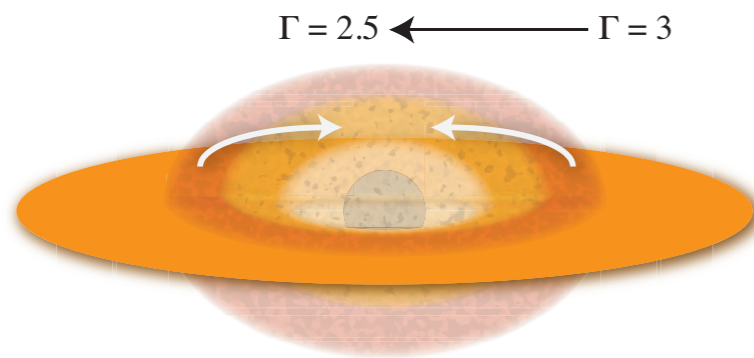


# The Hard Lag

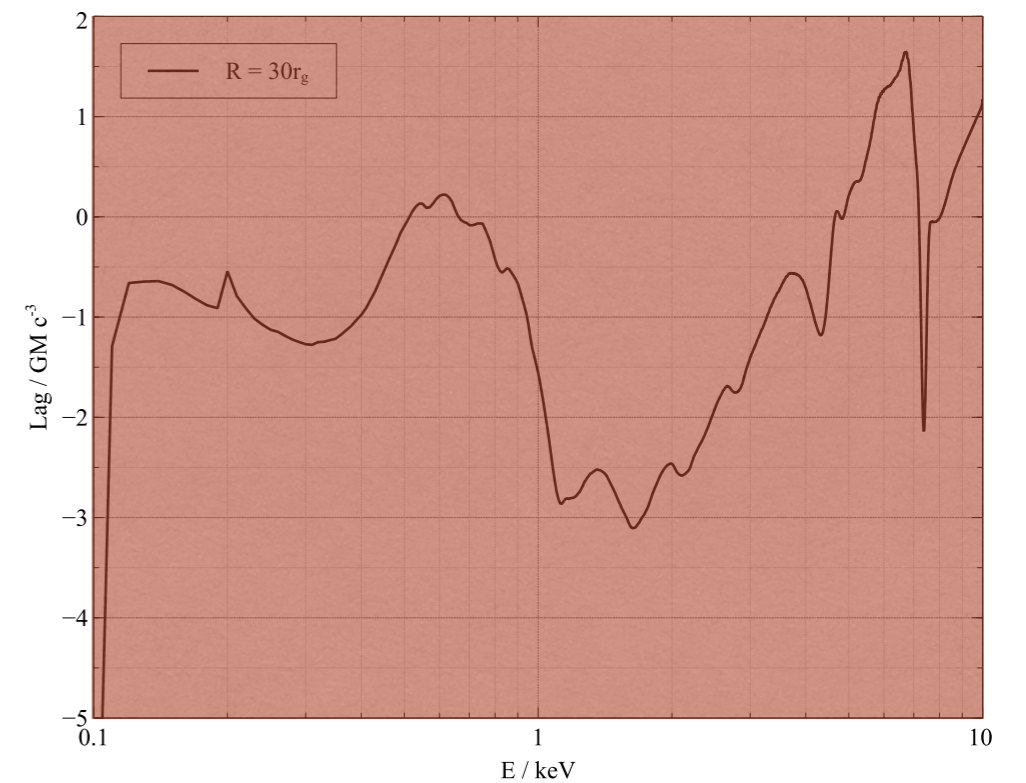
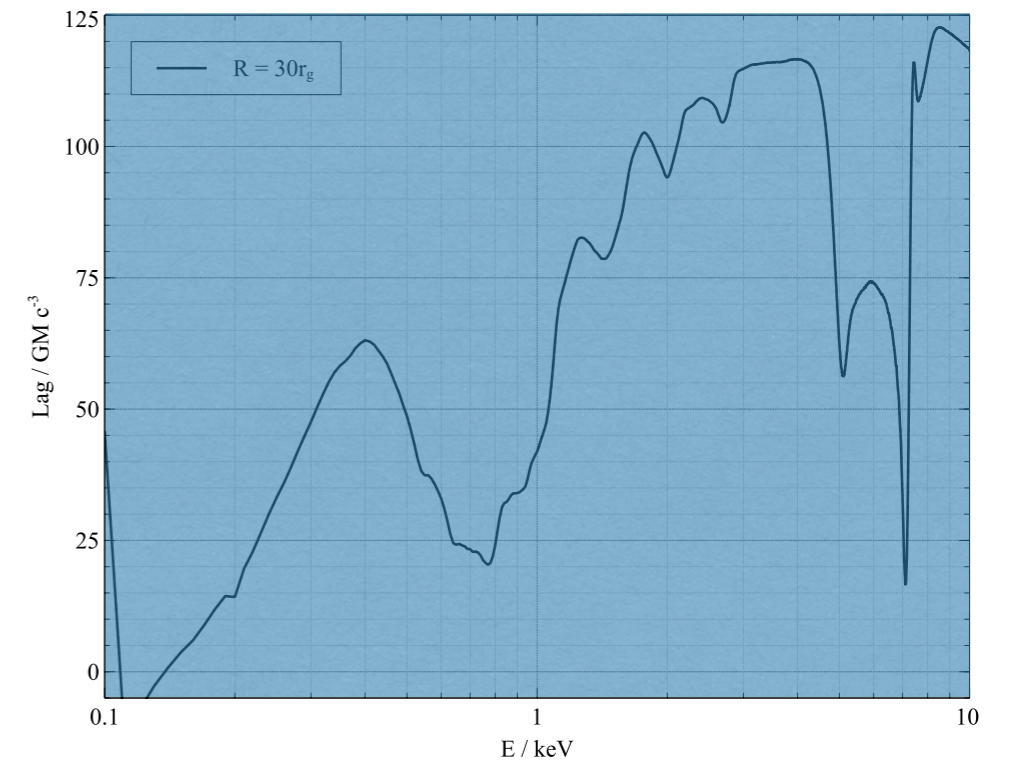
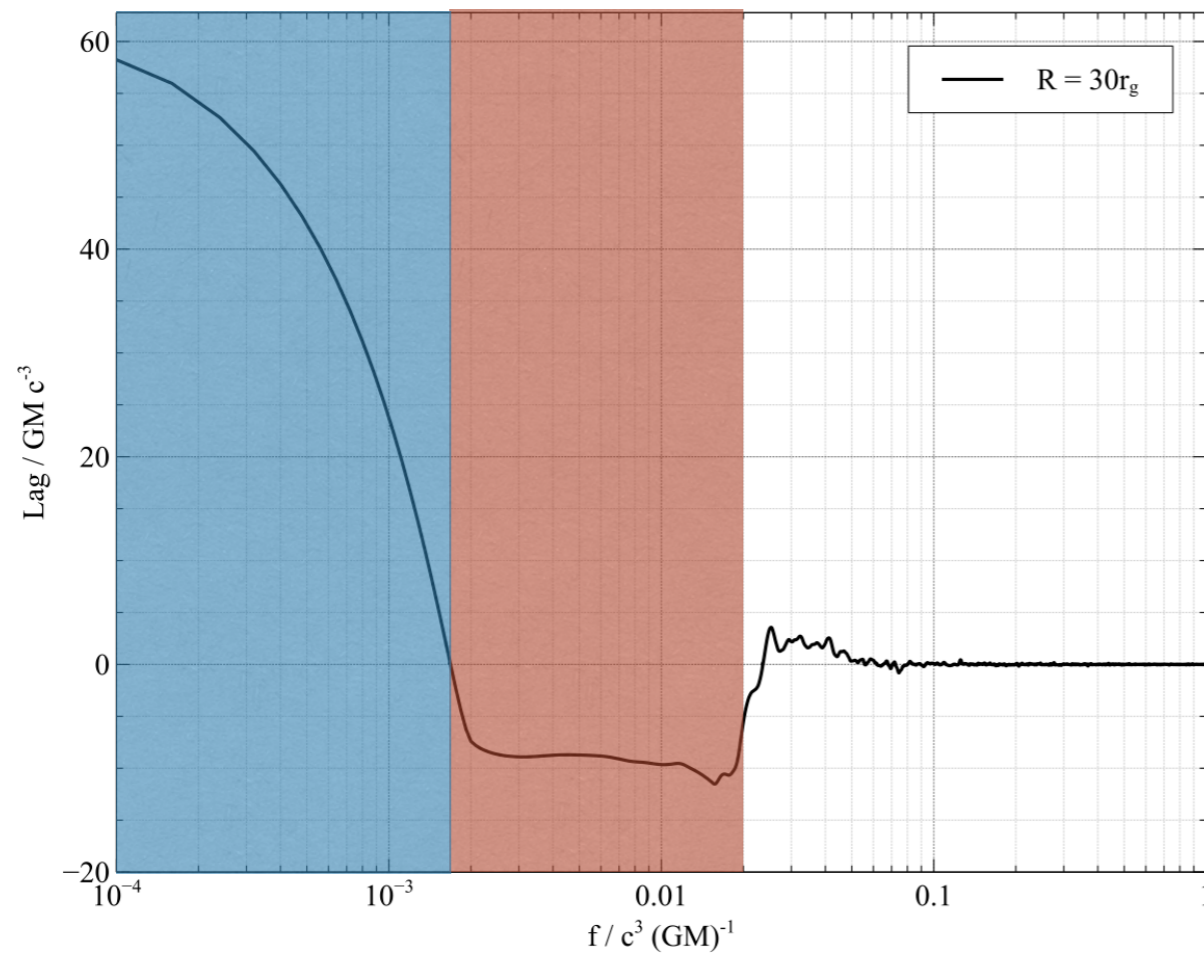
Modified version of Arévalo & Uttley 2006



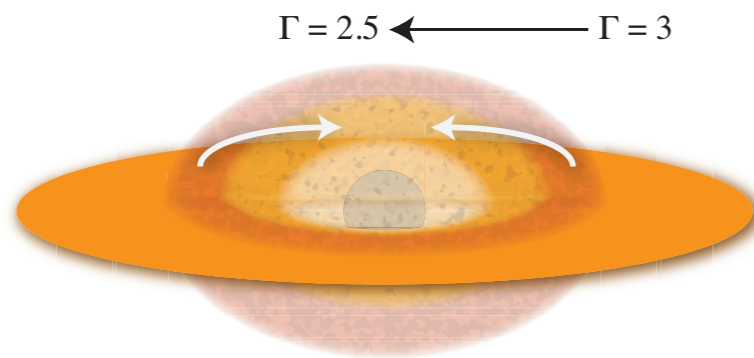
# Viscous Propagation



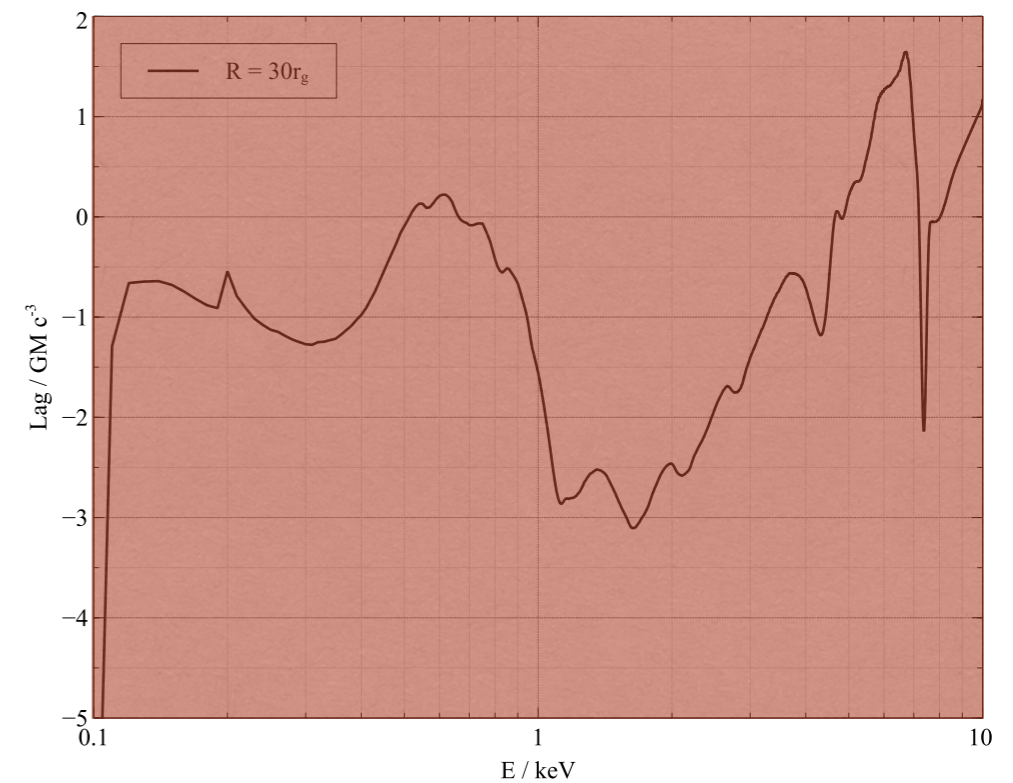
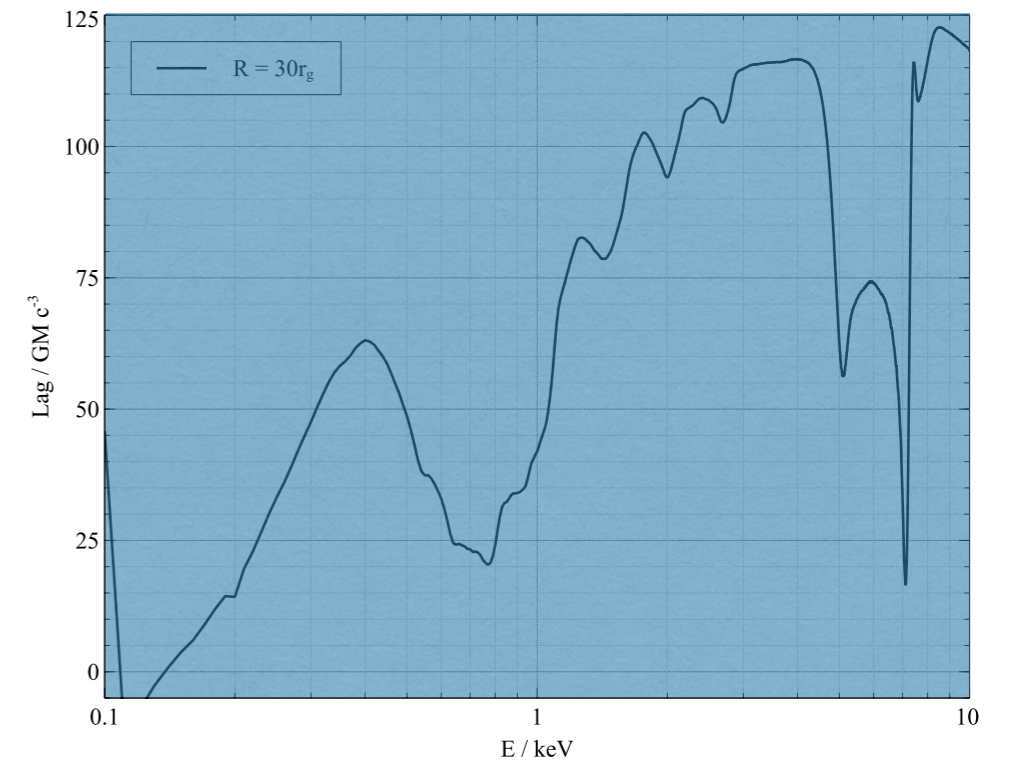
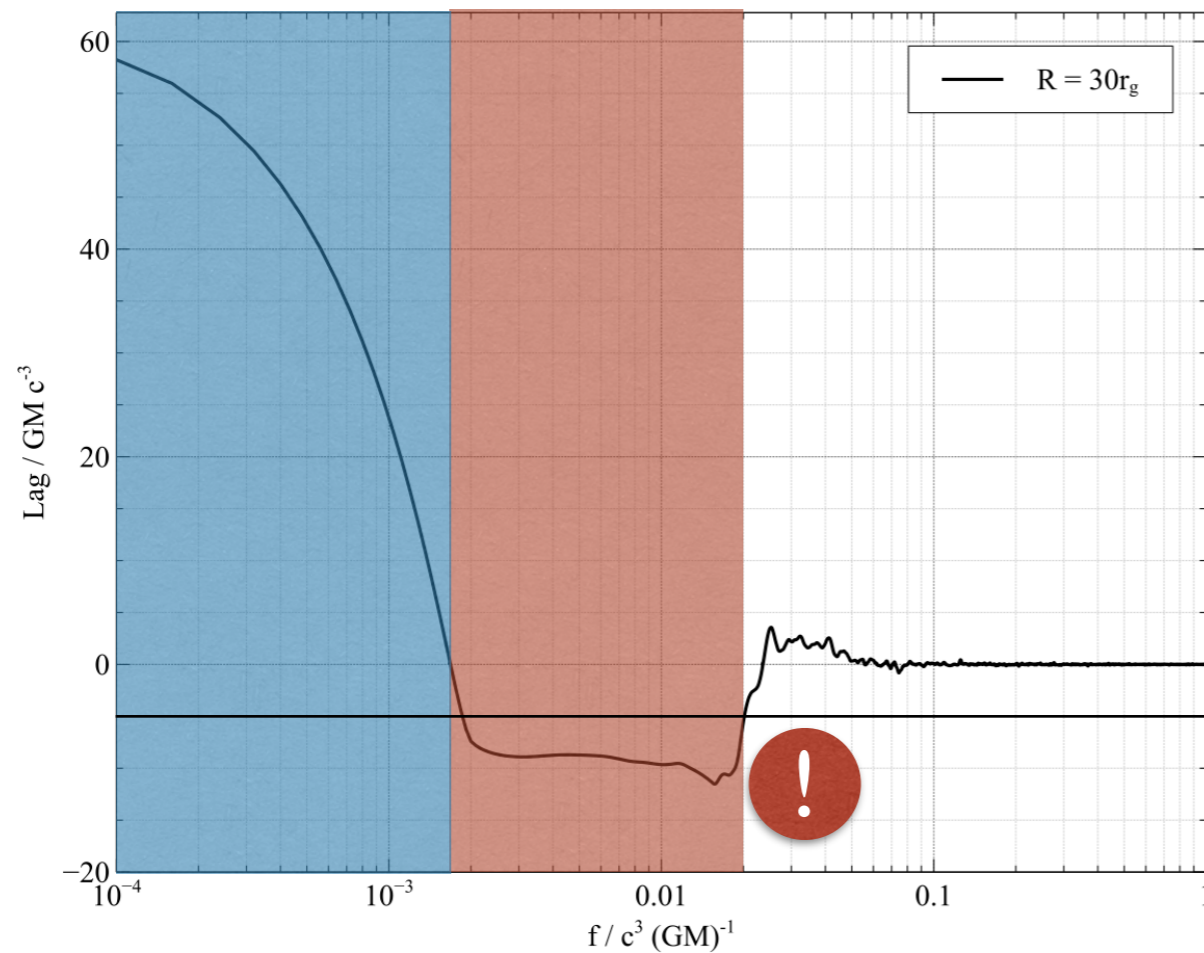
$$\dot{r} = r^{-\frac{1}{2}} \frac{\alpha}{\sqrt{GM}} \left( \frac{h}{r} \right)^2$$



# Viscous Propagation

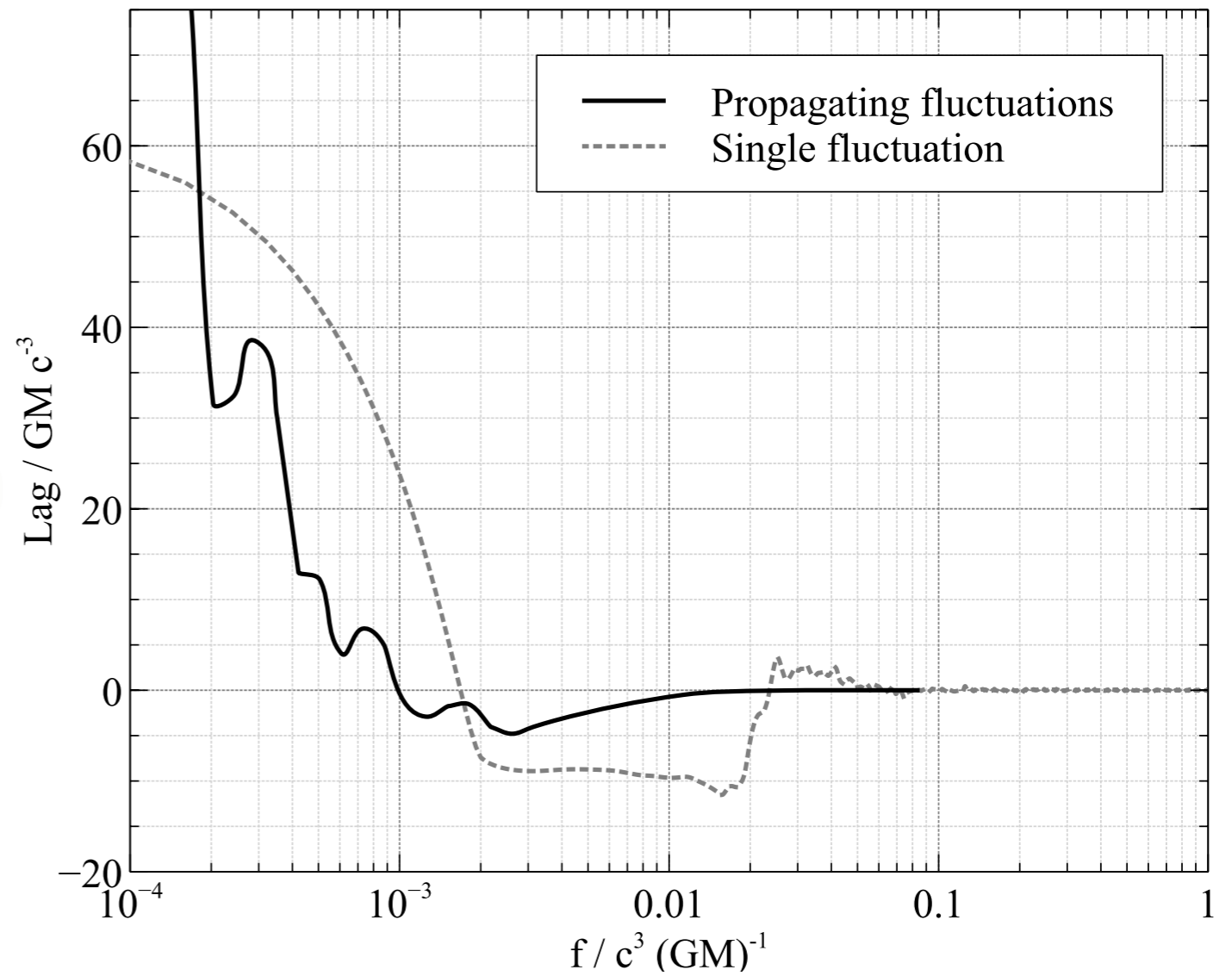
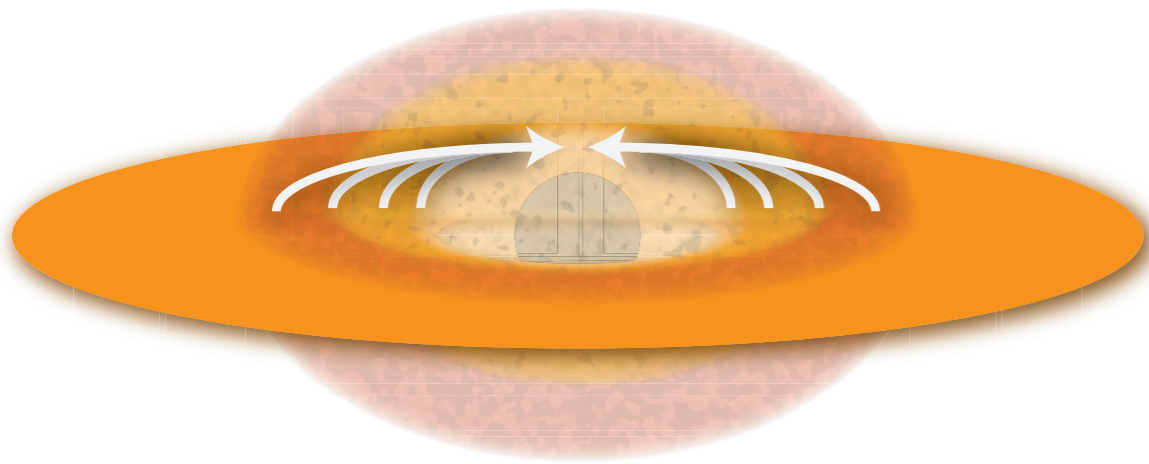


$$\dot{r} = r^{-\frac{1}{2}} \frac{\alpha}{\sqrt{GM}} \left( \frac{h}{r} \right)^2$$

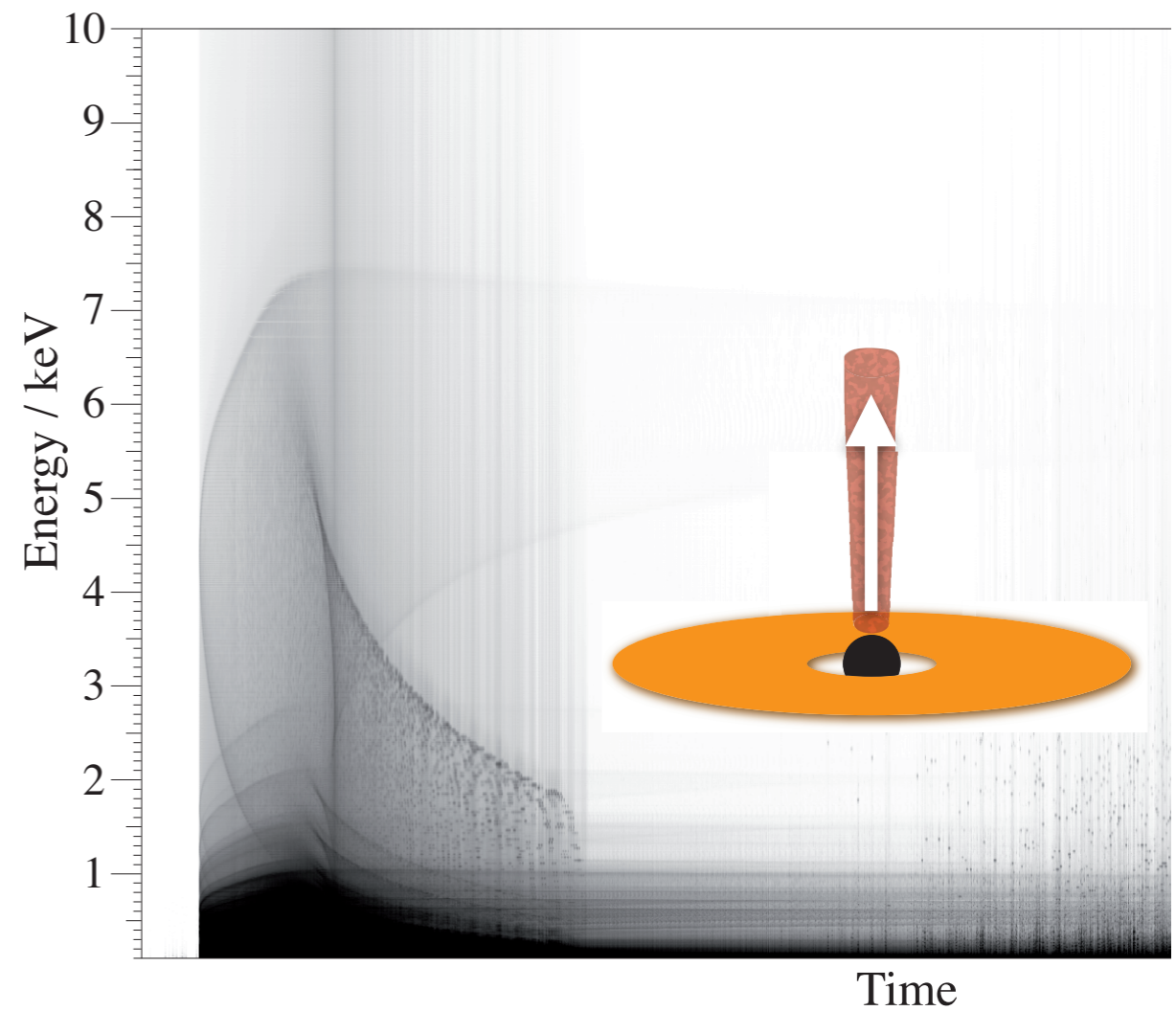
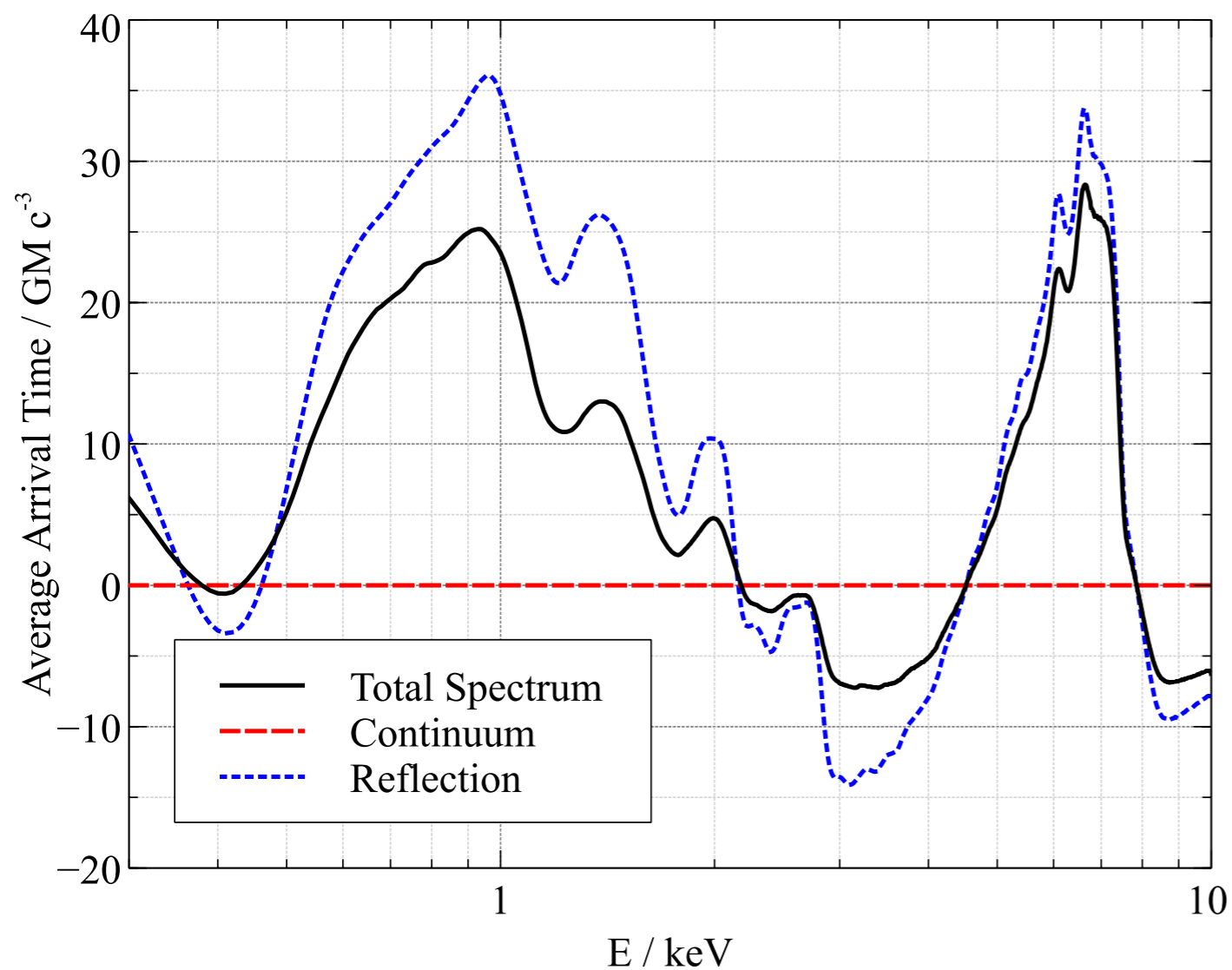


# Propagating Fluctuations

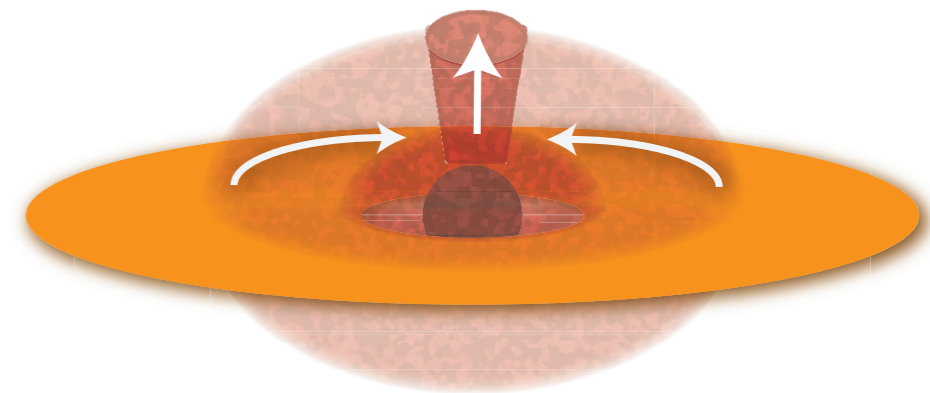
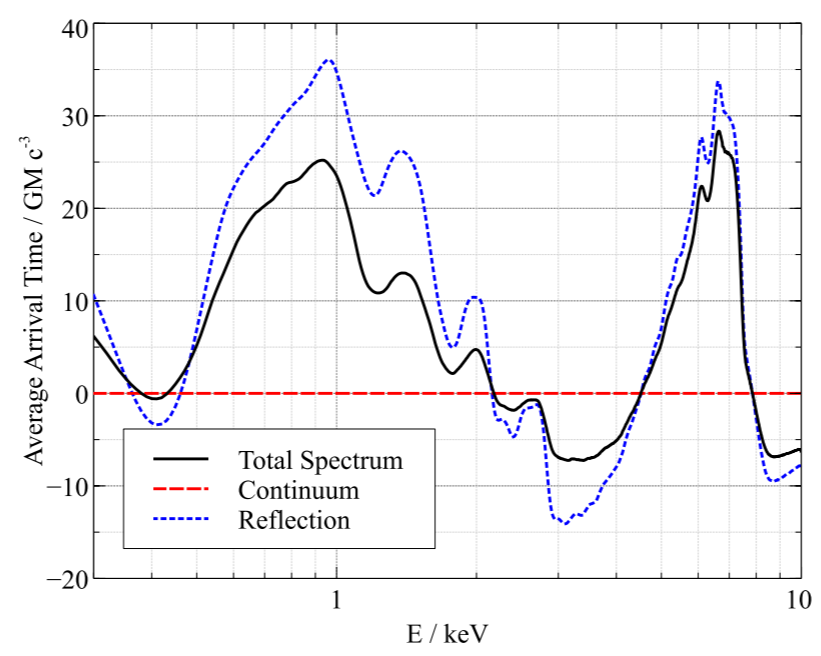
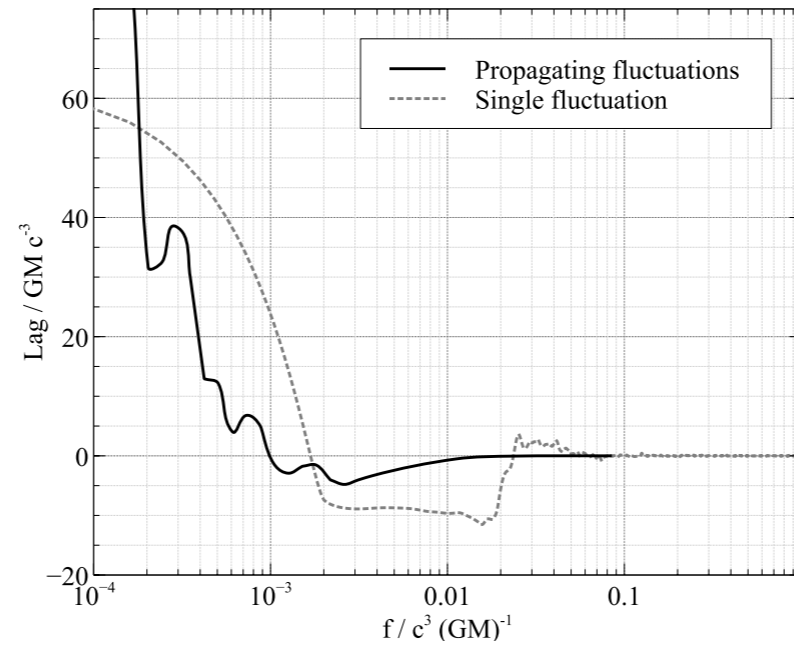
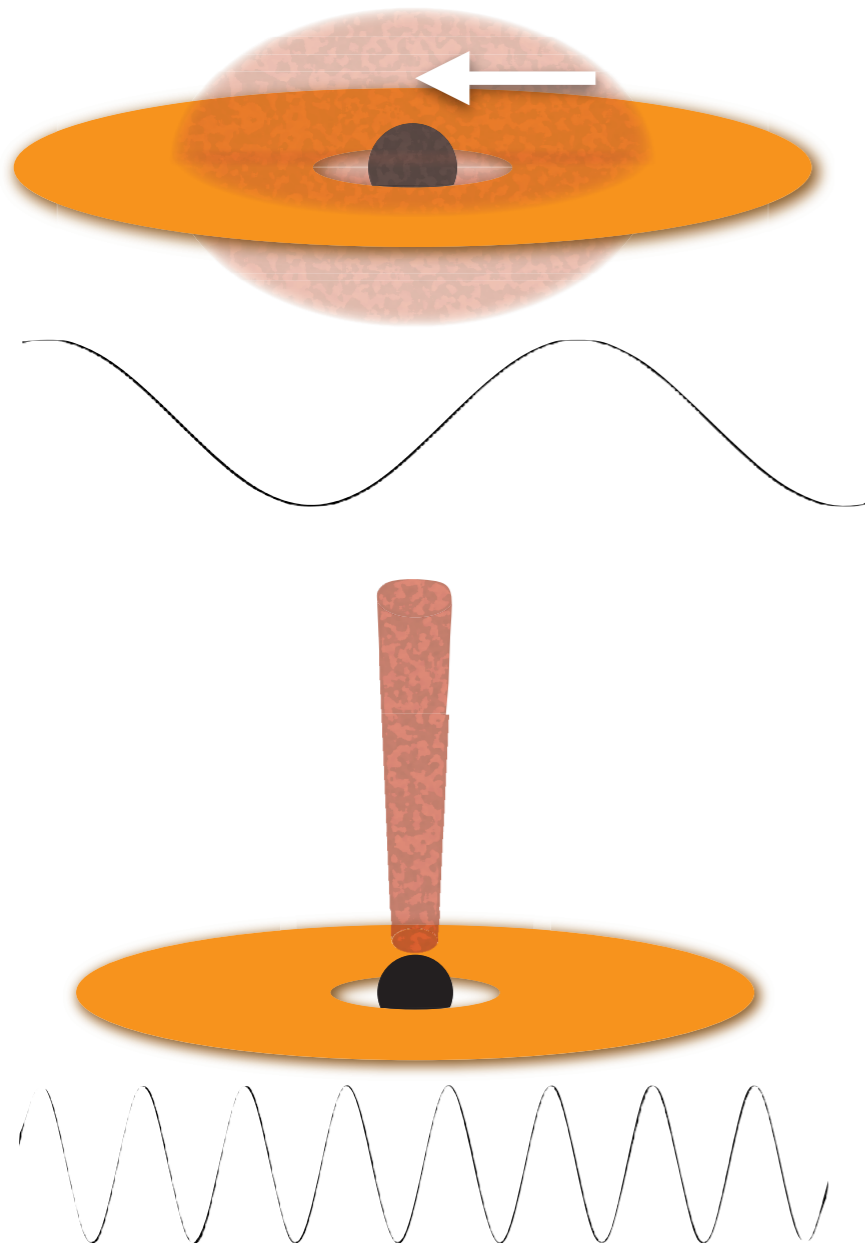
$\Gamma = 2.5$  ←  $\Gamma = 3$



# What is the dip at 3keV?



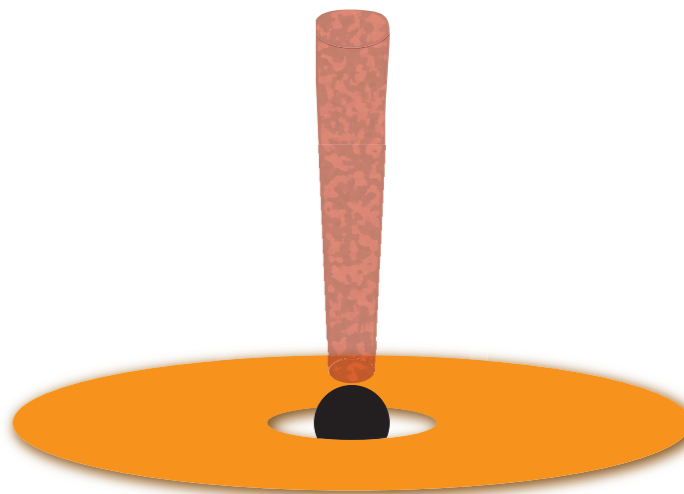
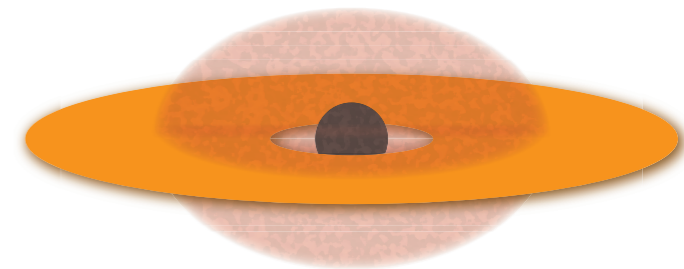
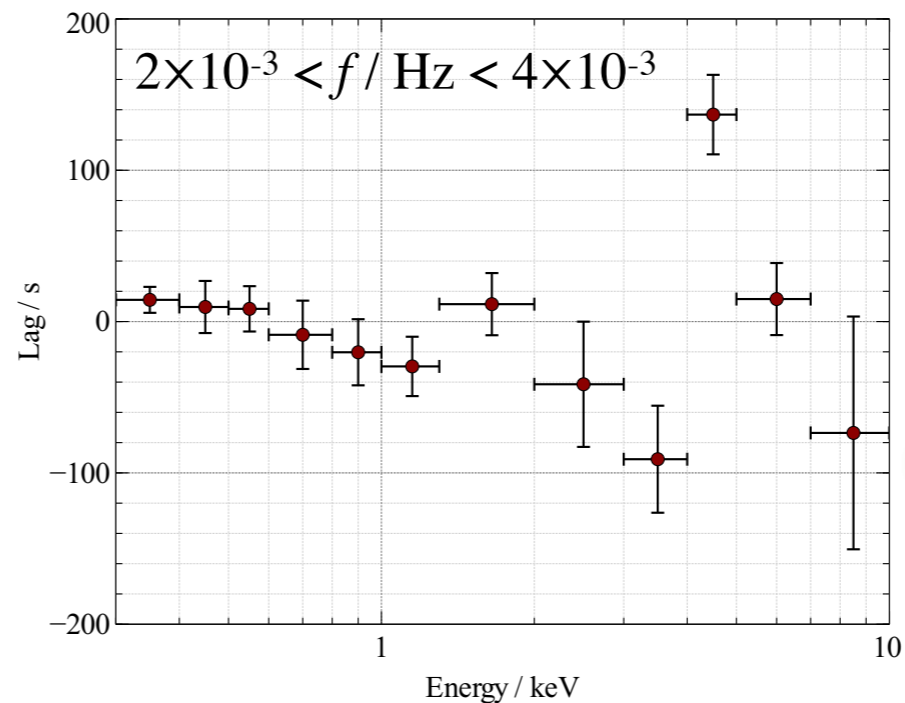
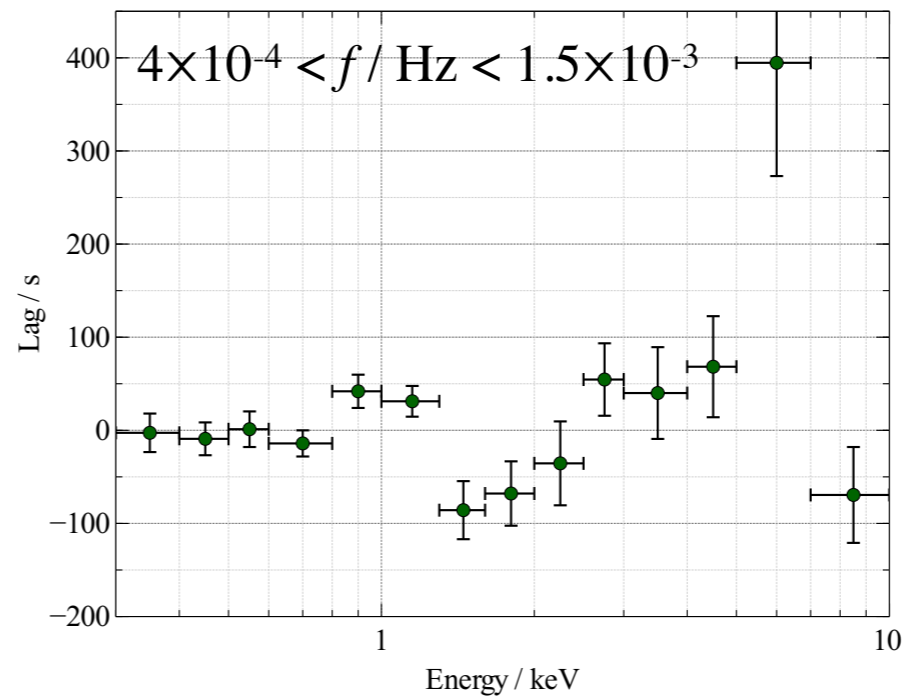
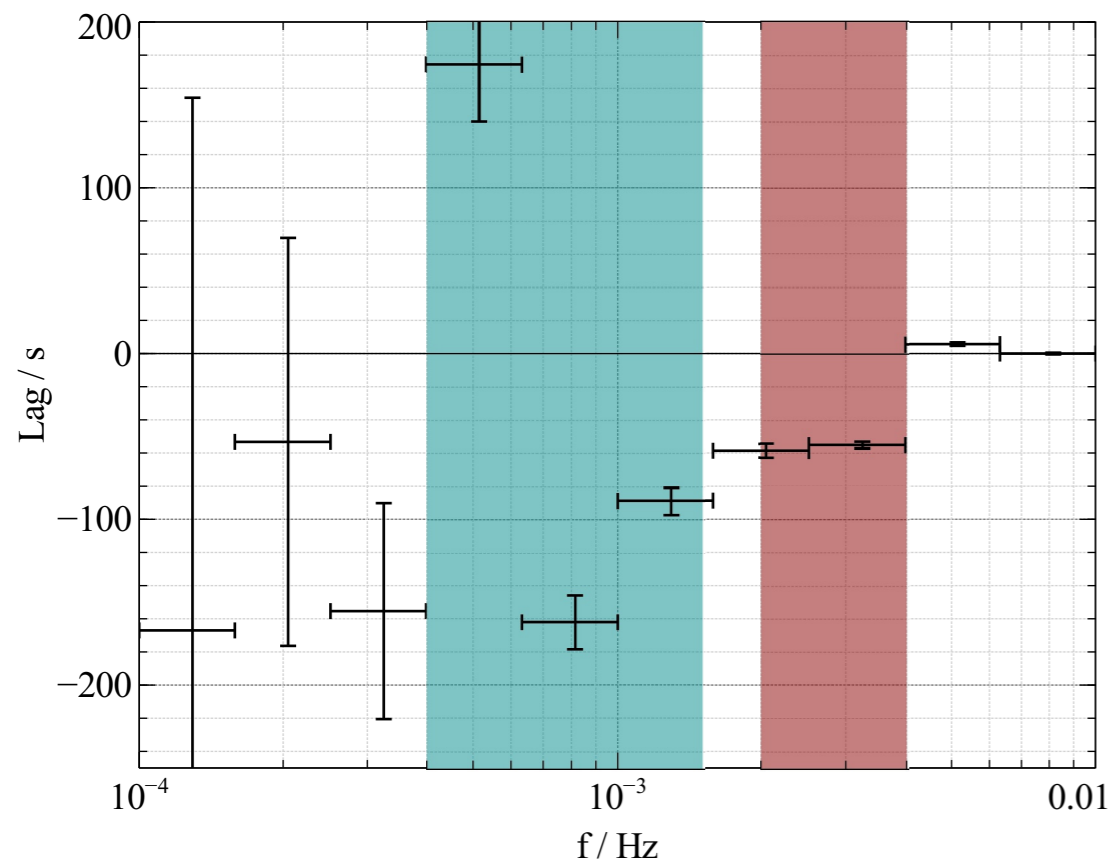
# A tale of two coronae?





# Seeing the structure in 1Zw1

XMM Newton, January 2015  
2 orbits (275ks)



# Summary

[dan.wilkins@stanford.edu](mailto:dan.wilkins@stanford.edu)

---

- X-ray reflection and reverberation reveals structure right down to the innermost stable orbit and even the event horizon
- Time-averaged spectra and low frequency variability are well-described by a corona extended over the disc but reverberation lag-energy spectra require upward propagation through a collimated corona
- Starting to see evidence of a persistent collimated core within an extended corona – the base of a (failed) jet?
- Understand the physics of the corona, how it is powered by the accretion flow and how jets are launched