

# Unveiling the Structure and Evolution of Black Hole Coronae

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# Why do we care about the corona?

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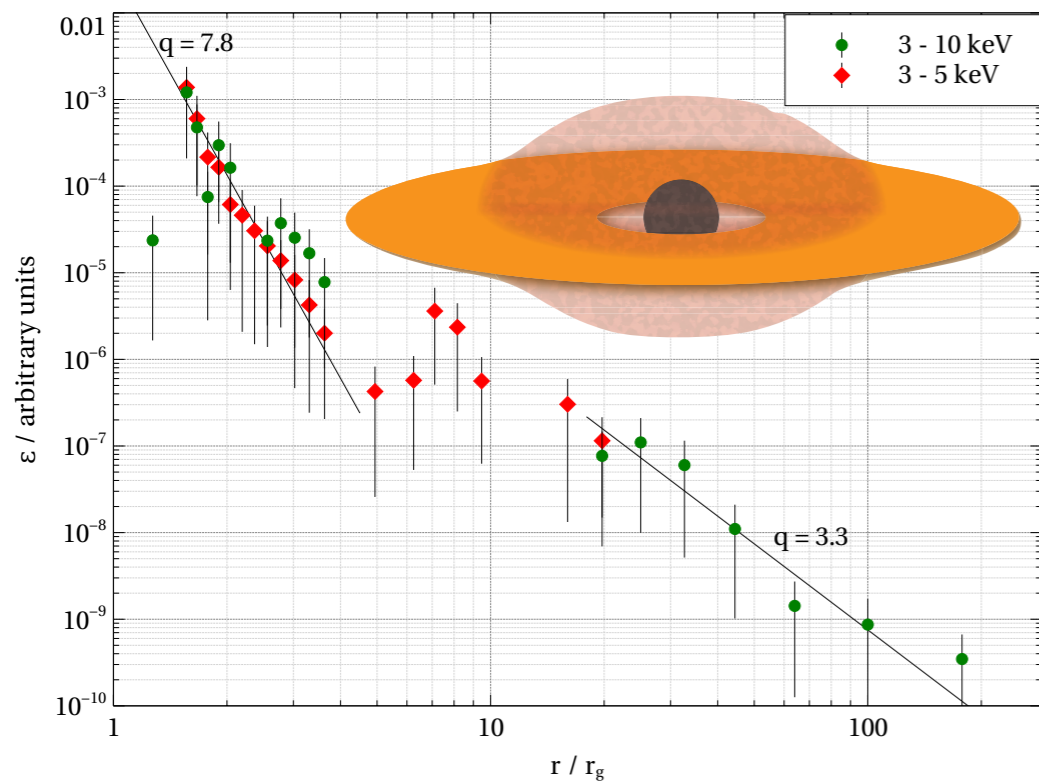
- How are some of the brightest objects in the Universe powered?
- How is the corona formed and powered by the accretion flow?
- How does the corona evolve in time? What regulates AGN activity?
- How are jets launched and are they related to the corona?

# Outline

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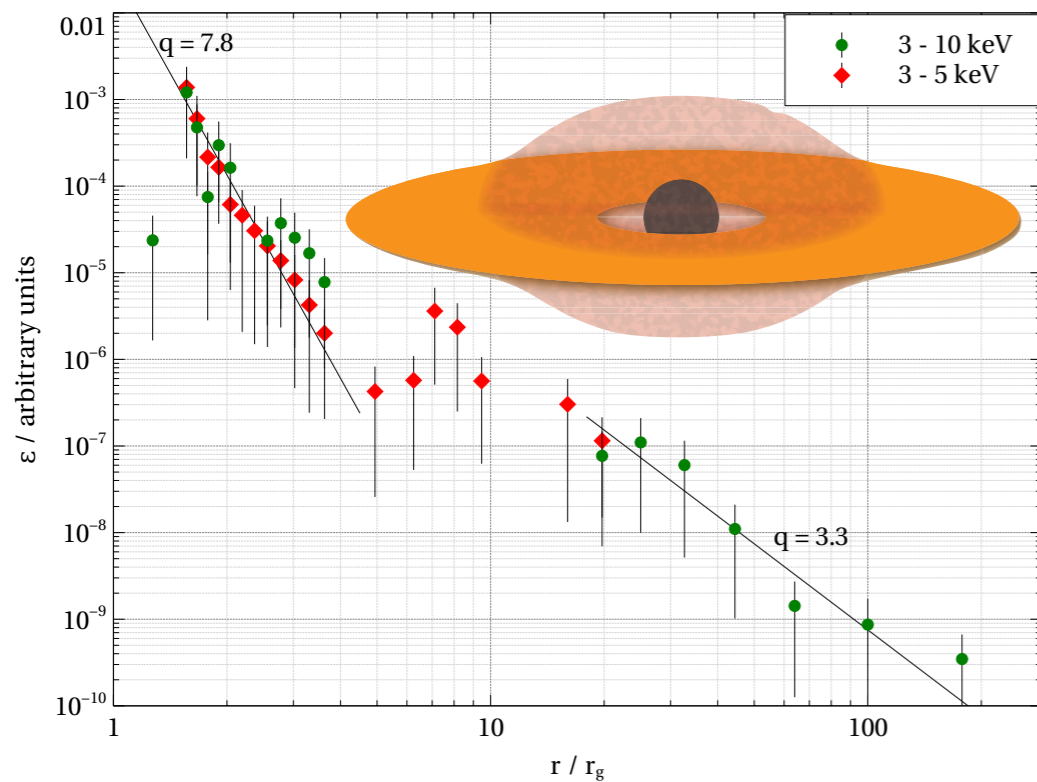
- What can X-ray reverberation tell us about the structure of the corona?
- Structure in the corona of I Zw 1
- Evolution of the corona during flares

# What we know about the corona?

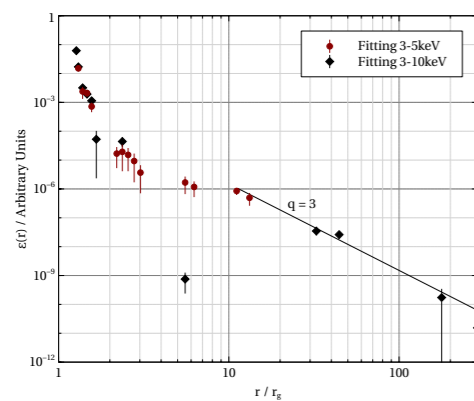




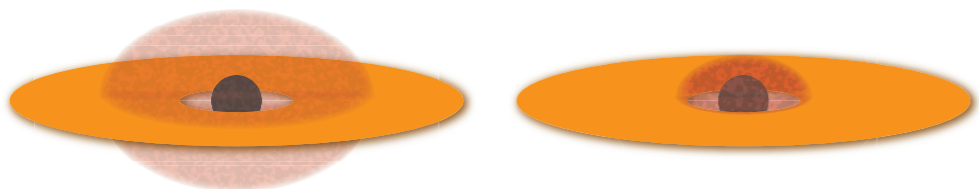
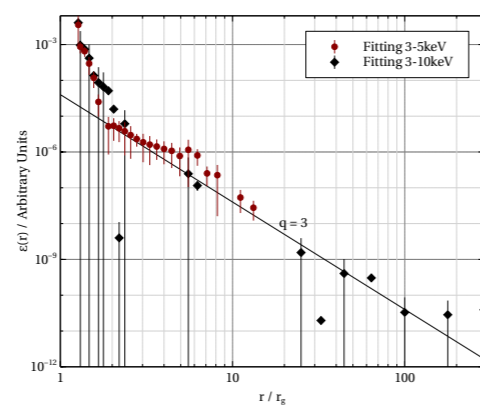
# What we know about the corona?



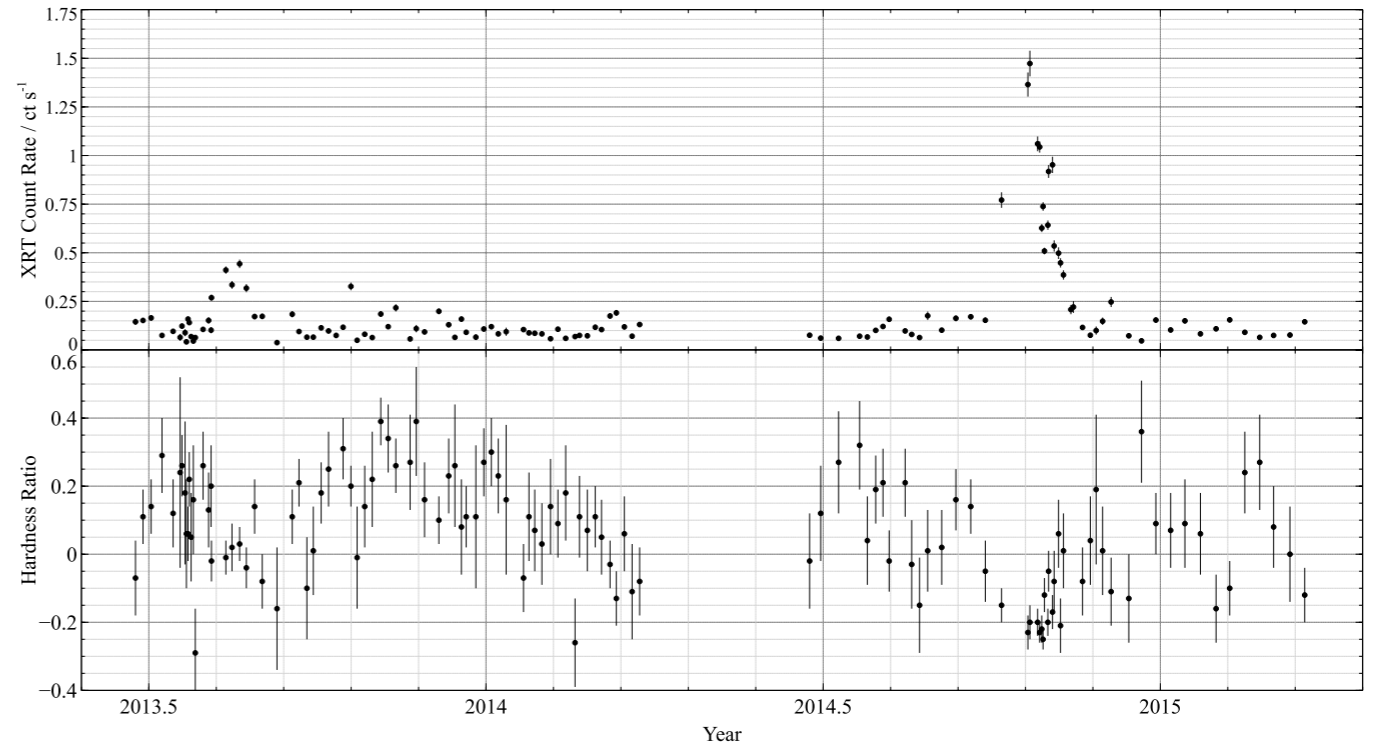
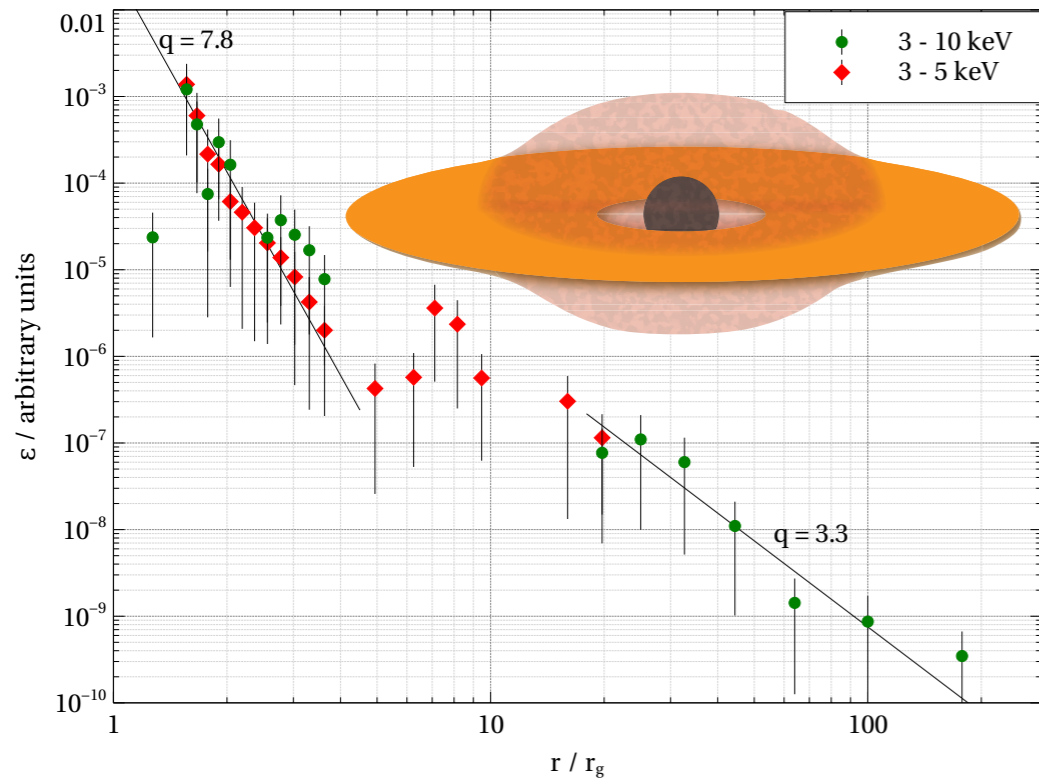
High Flux



Low Flux

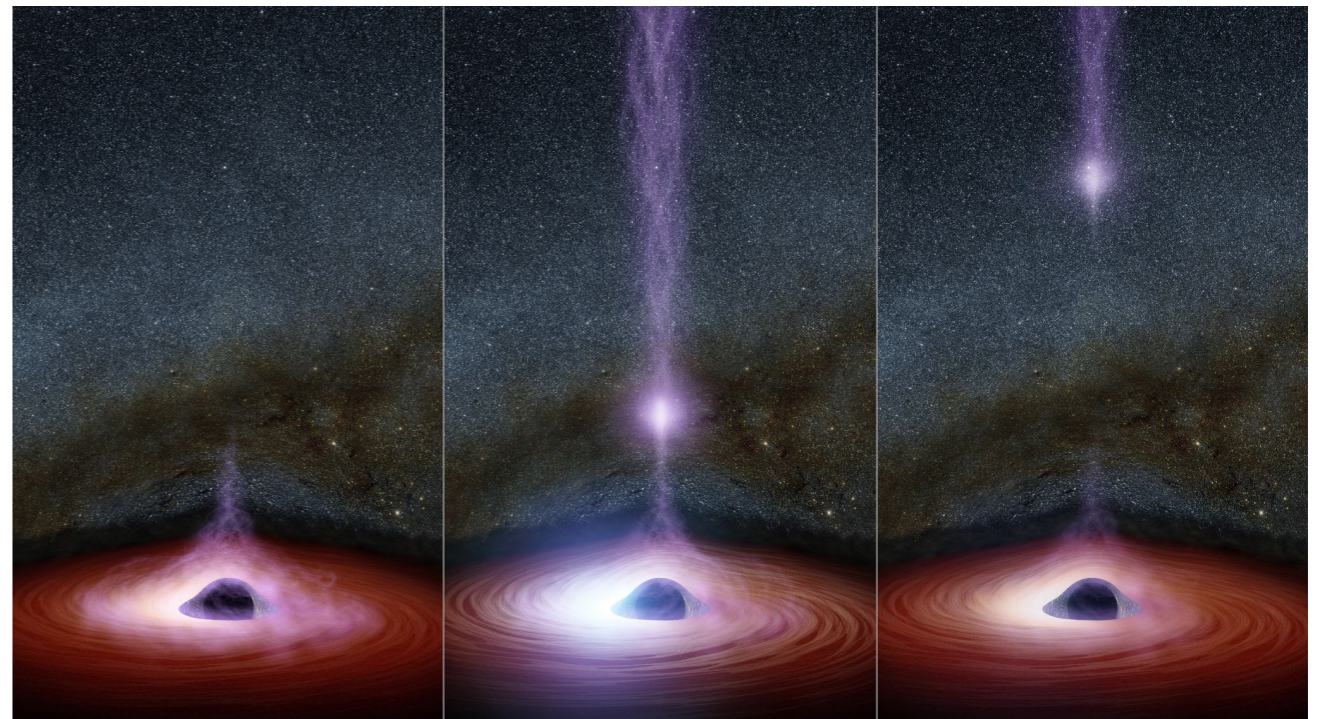
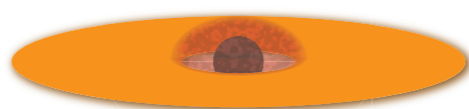
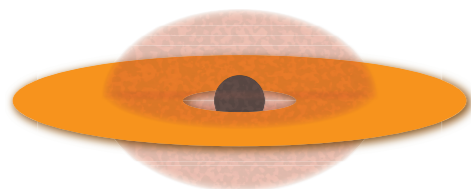
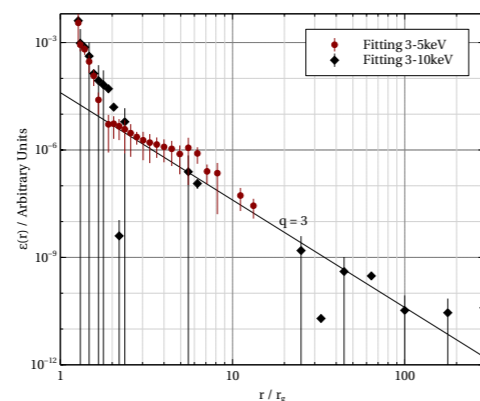
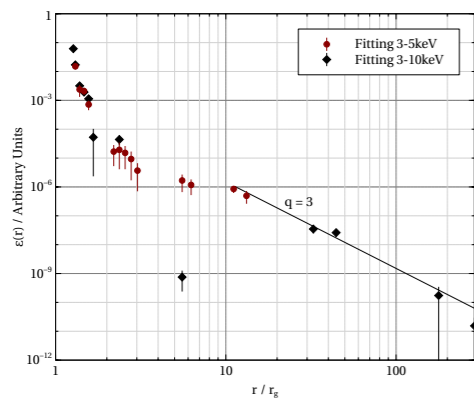


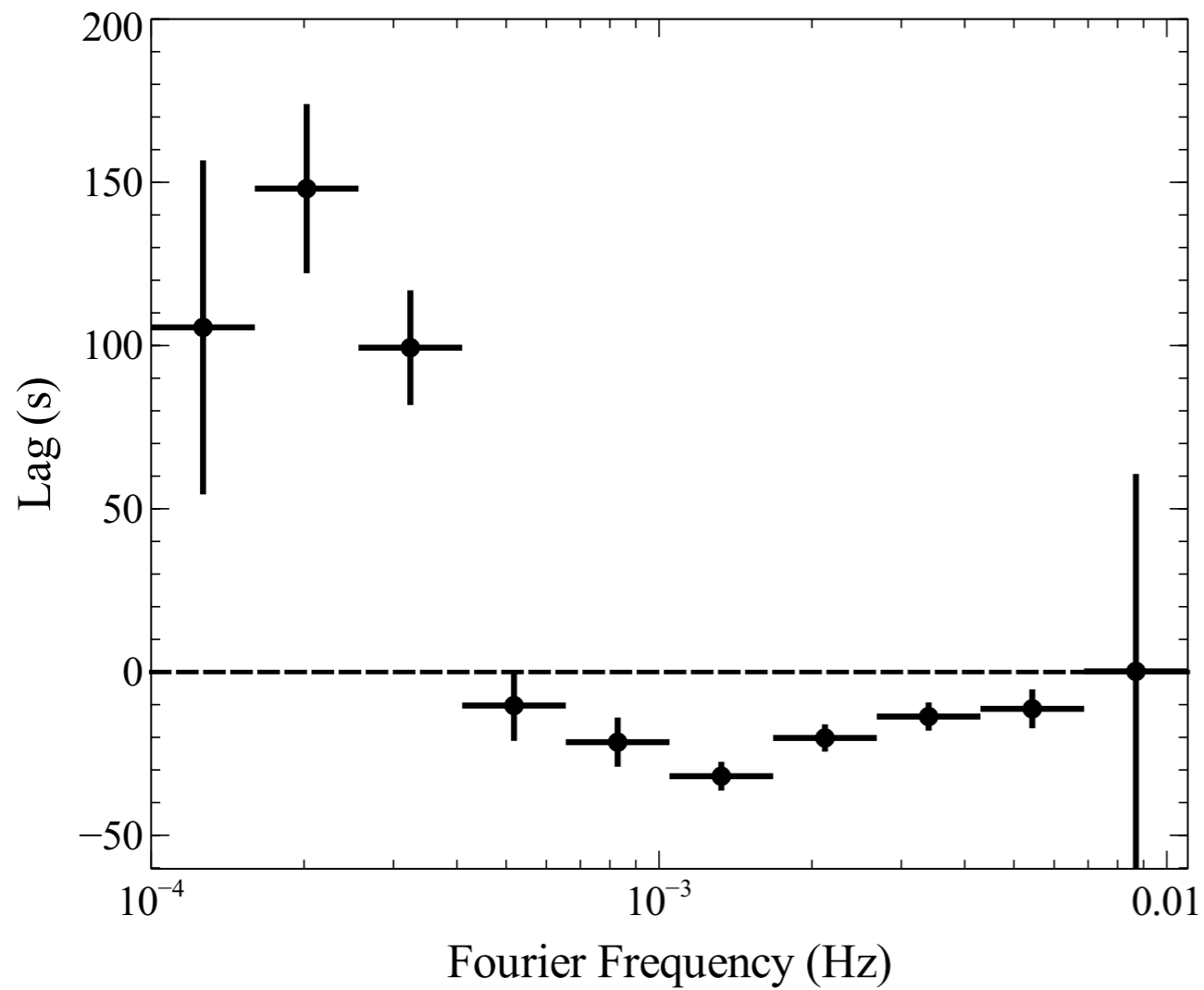
# What we know about the corona?



High Flux

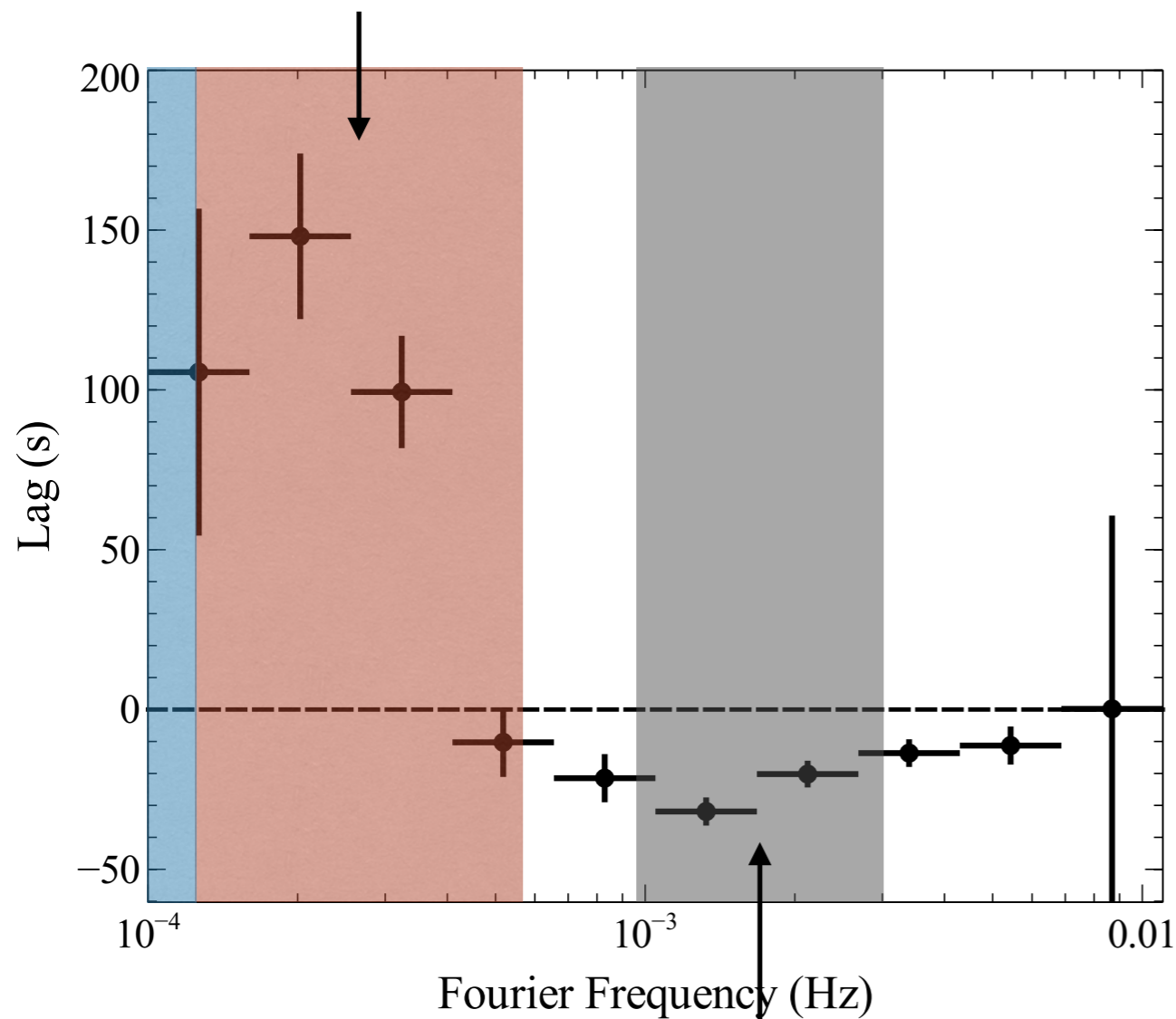
Low Flux



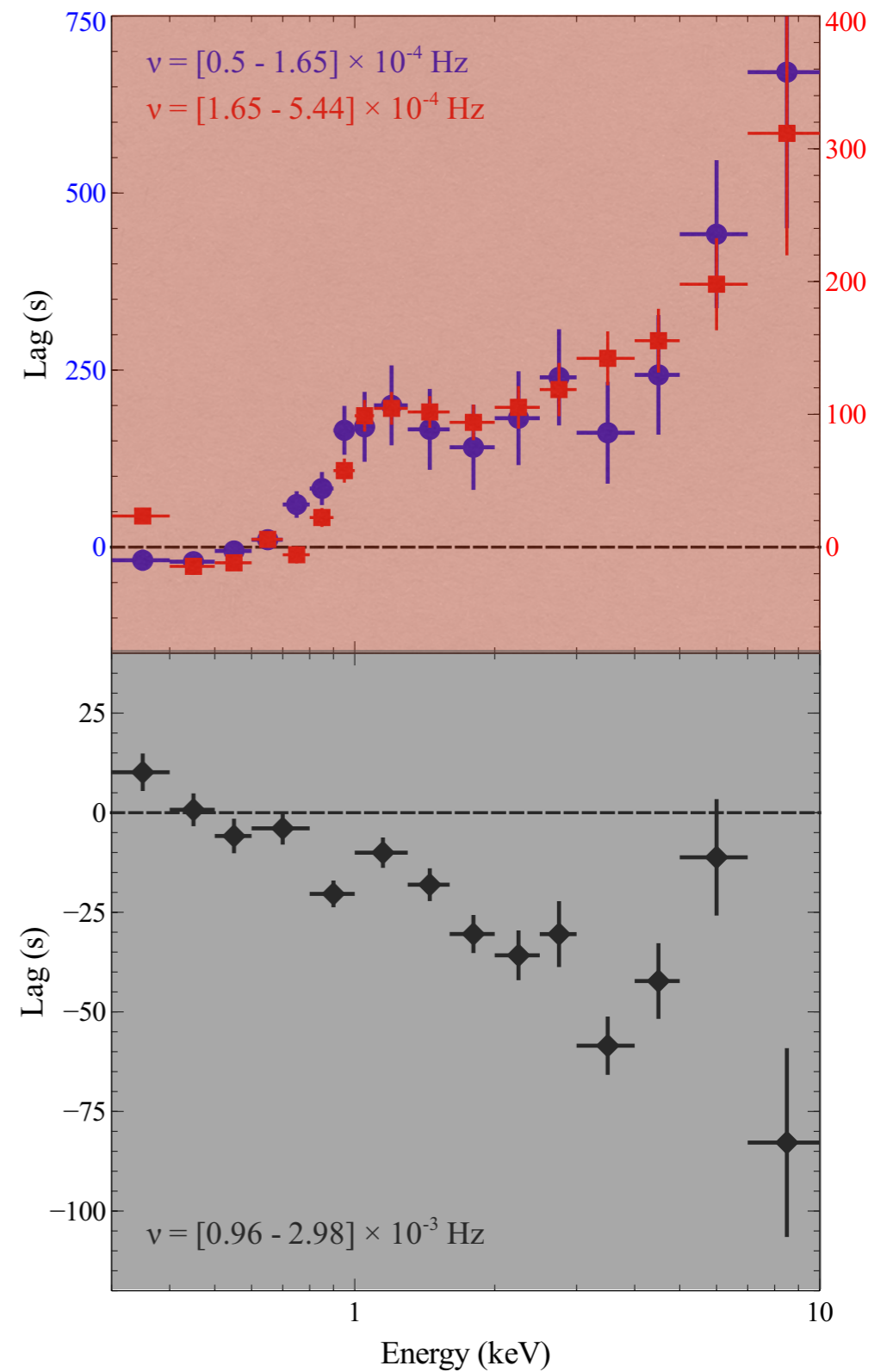




# Hard X-rays lag soft (in continuum)

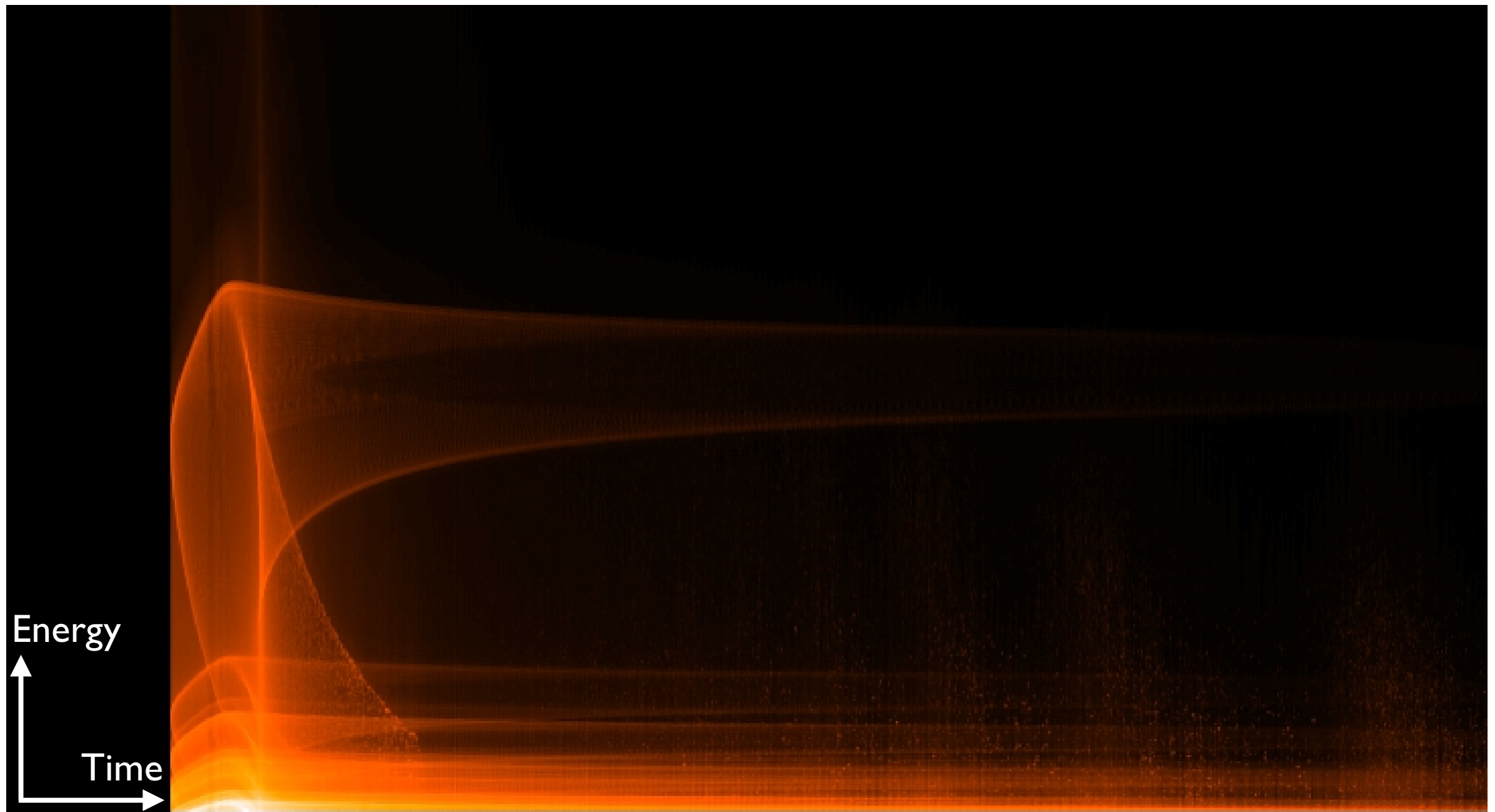


Soft (reflection-dominated)  
lags hard (continuum)

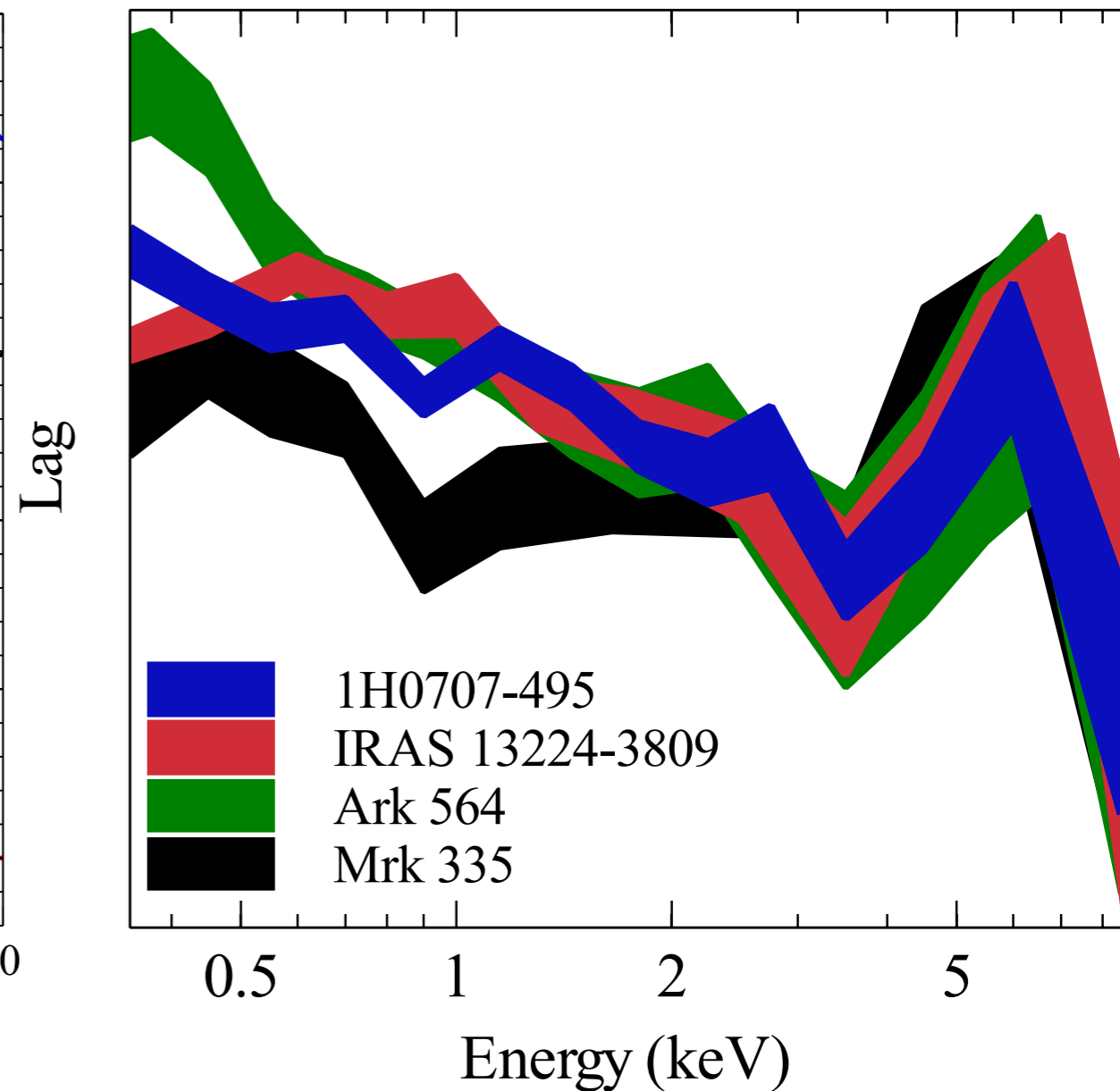
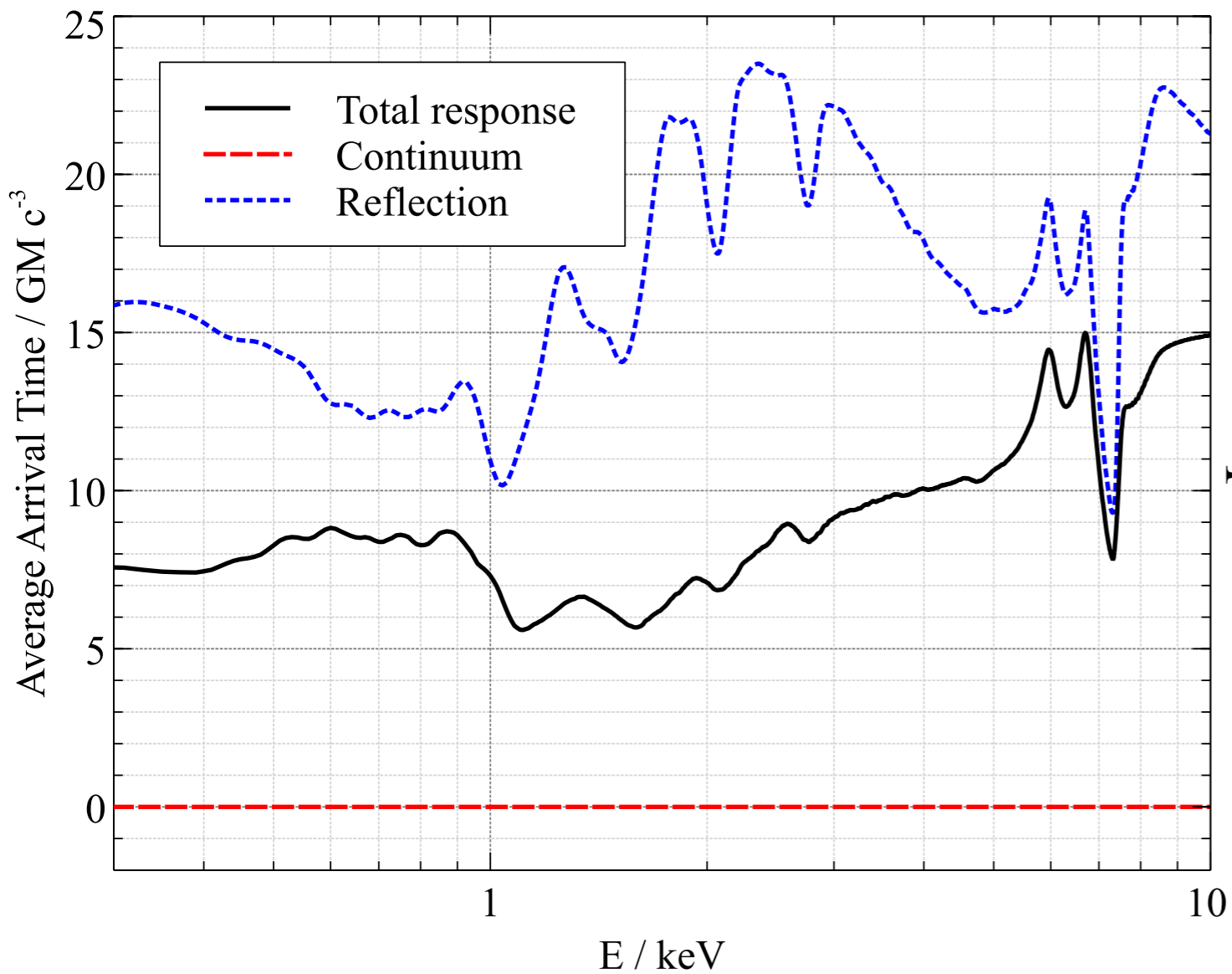


# Reverberation Response

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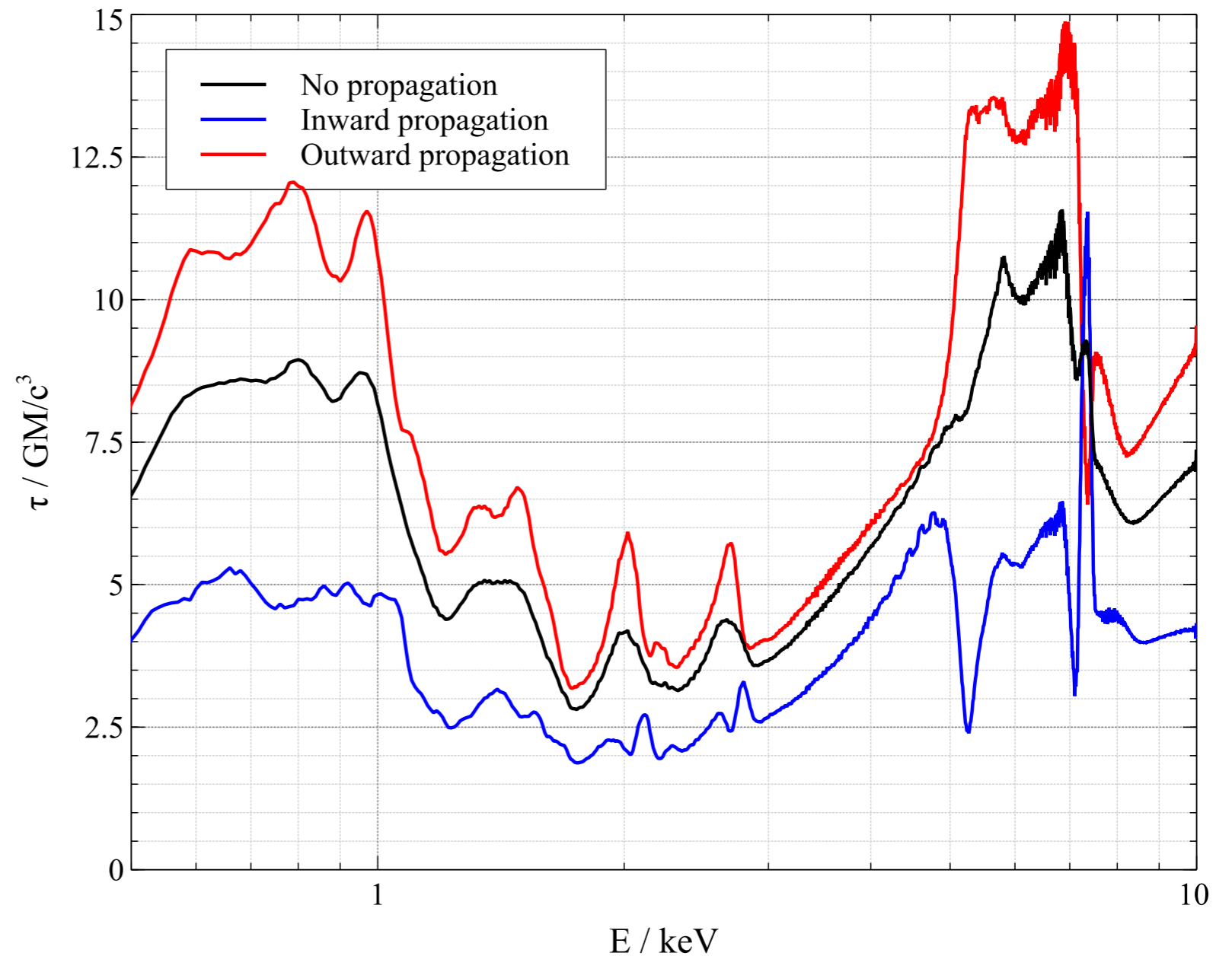
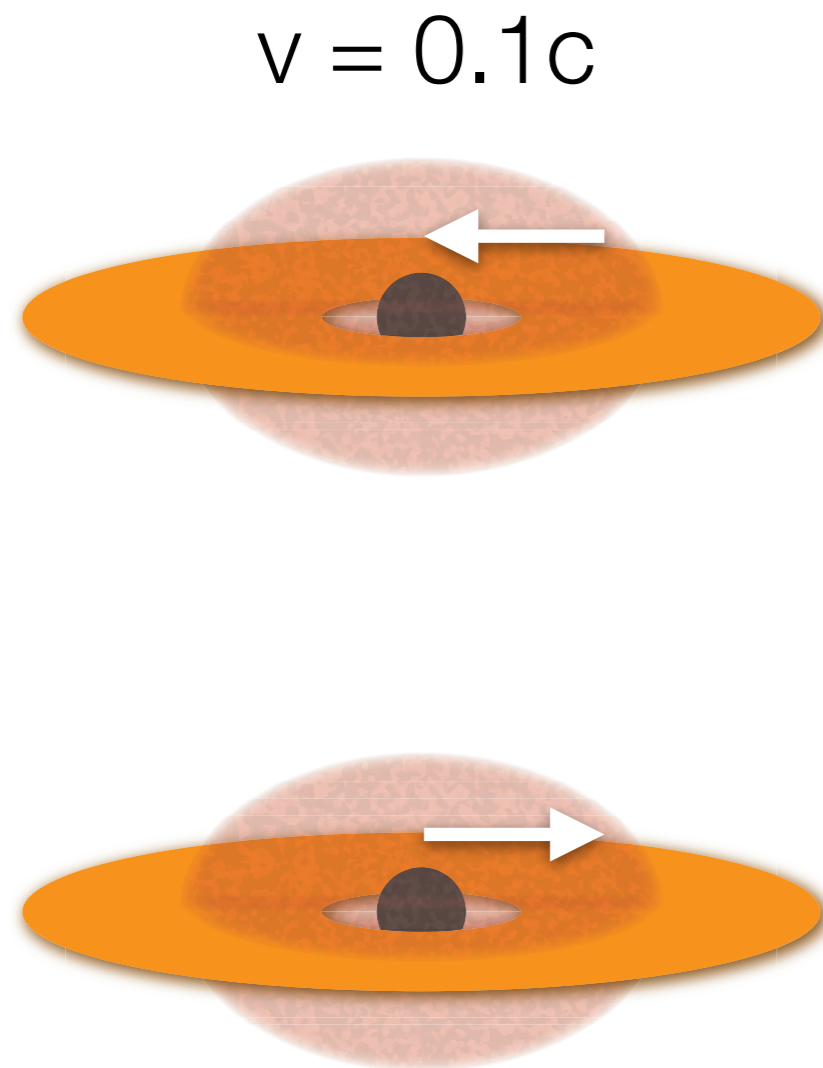


# The Lag-Energy Problem

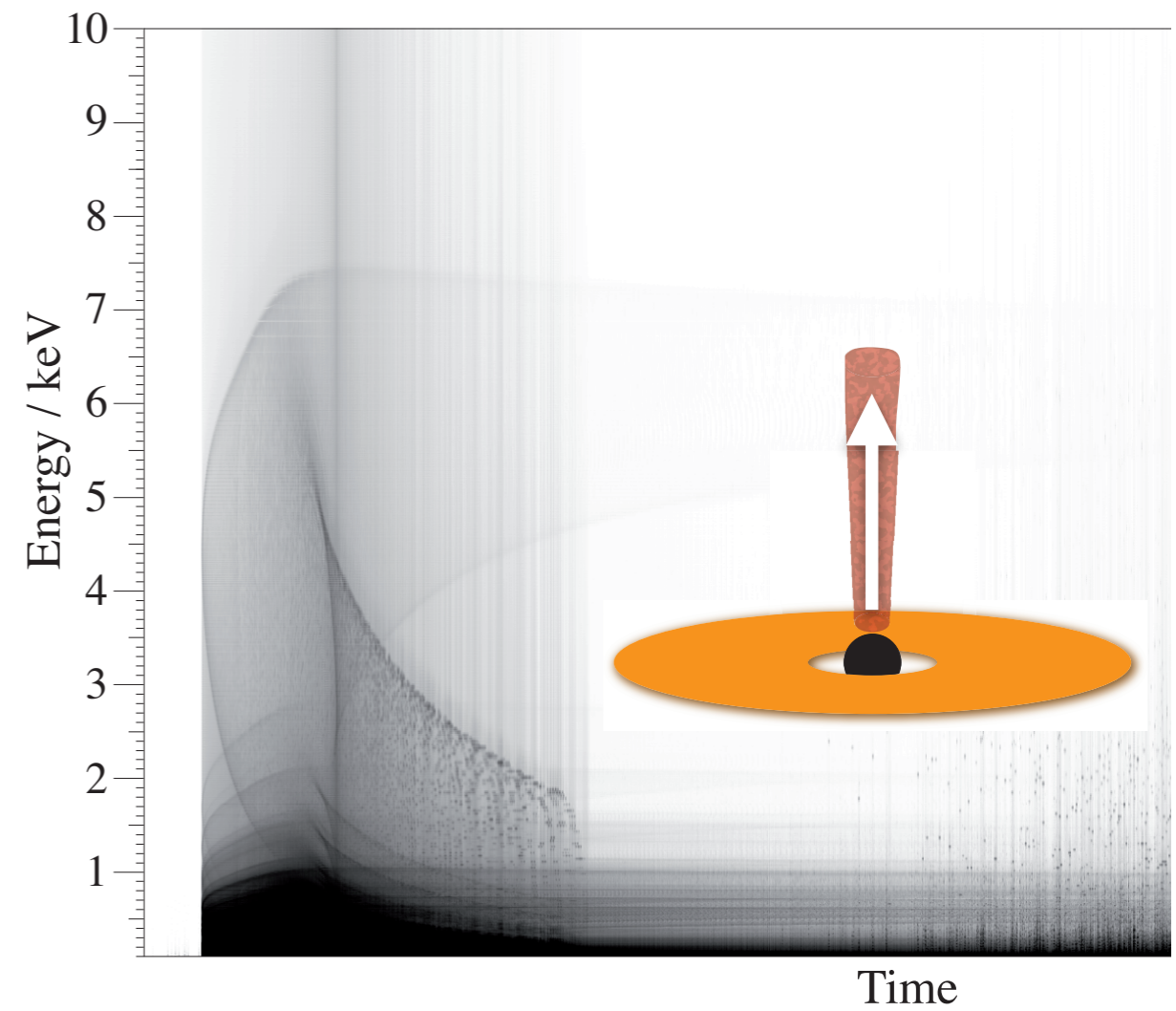
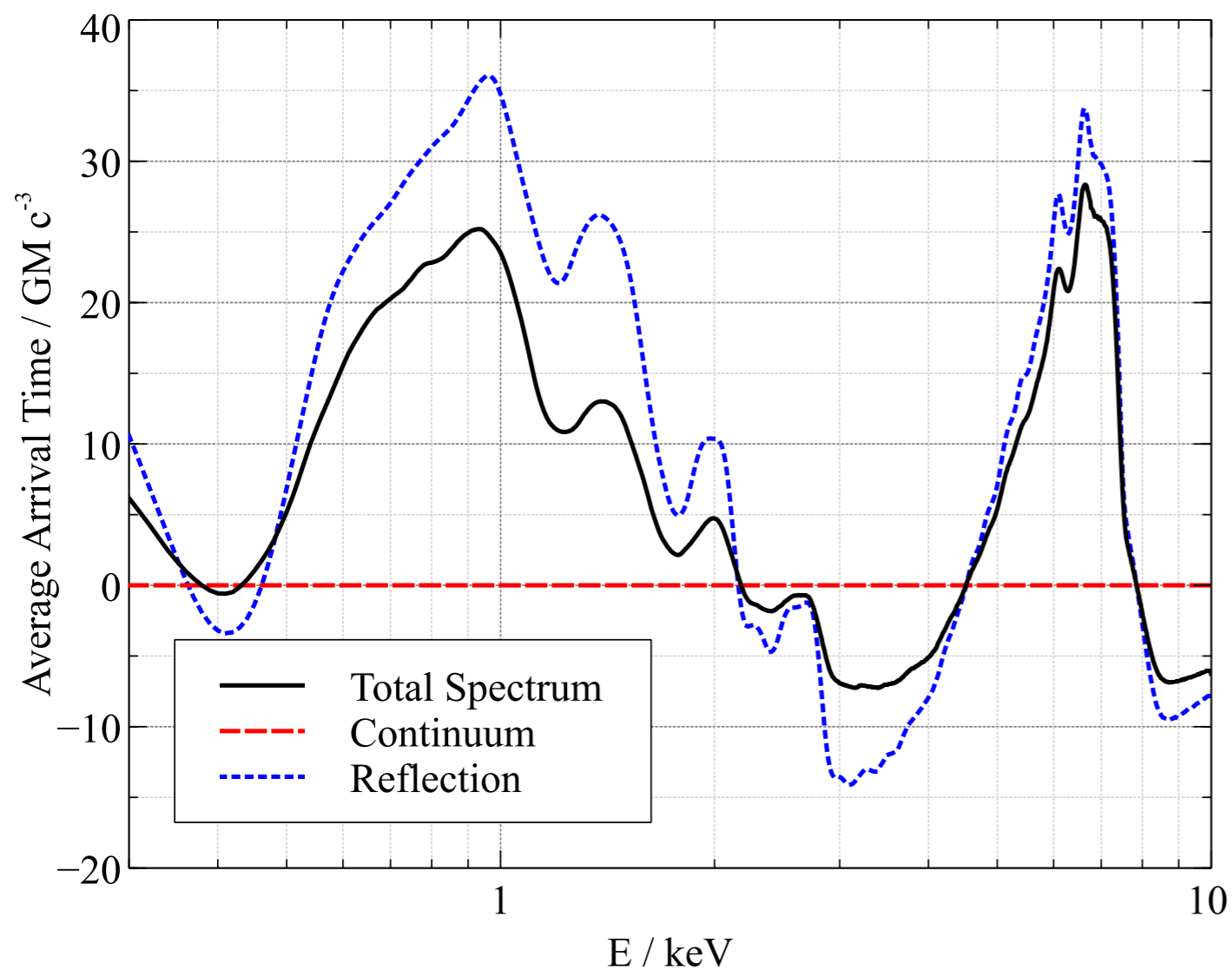




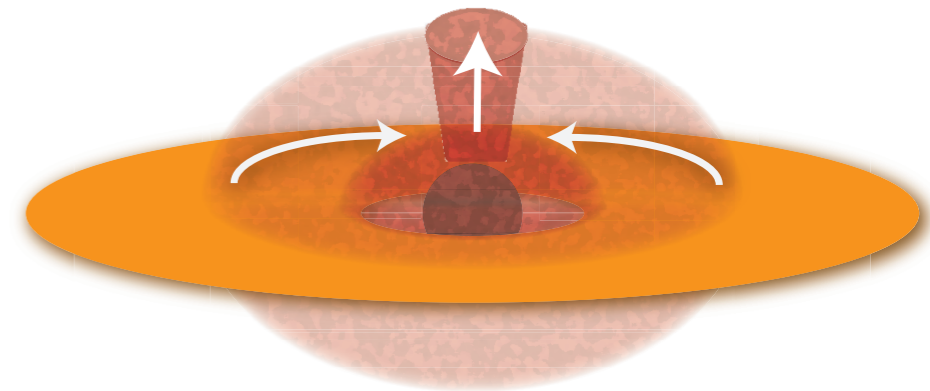
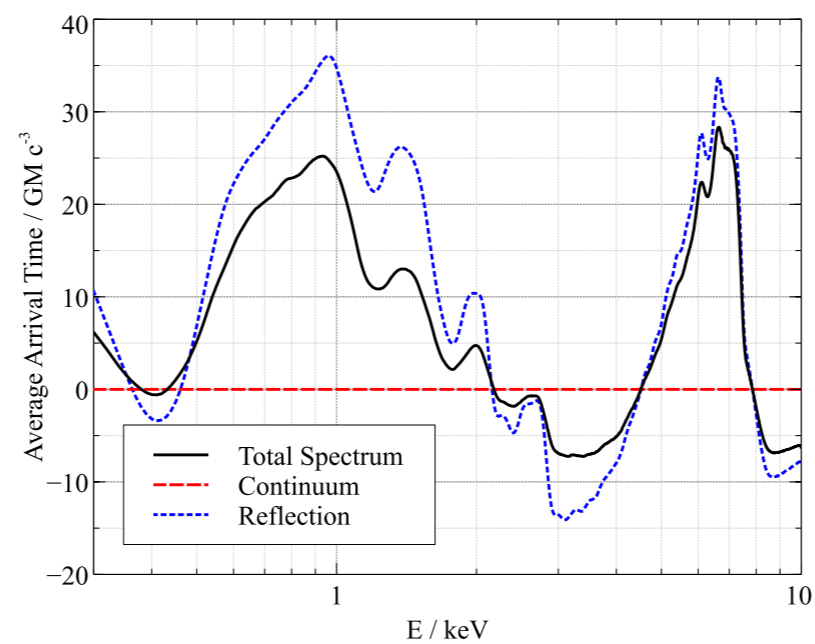
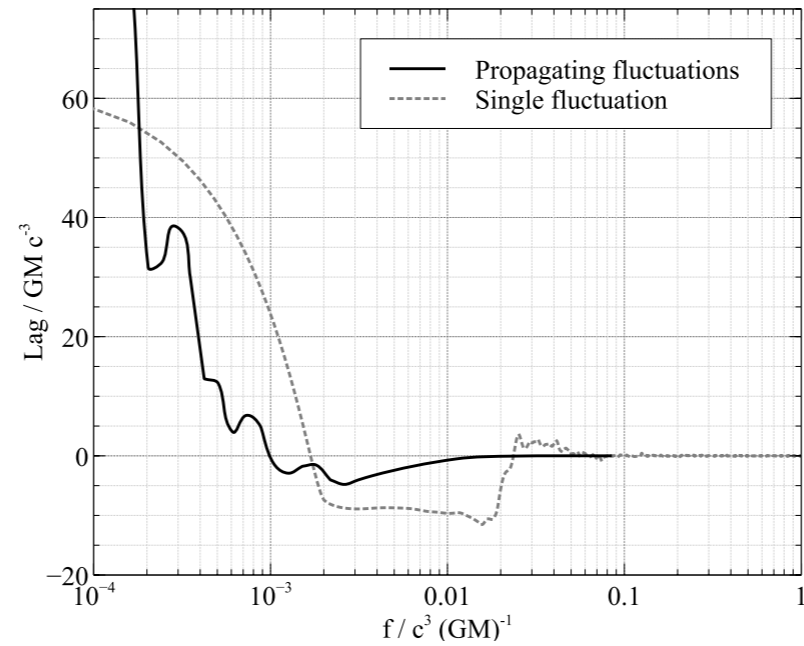
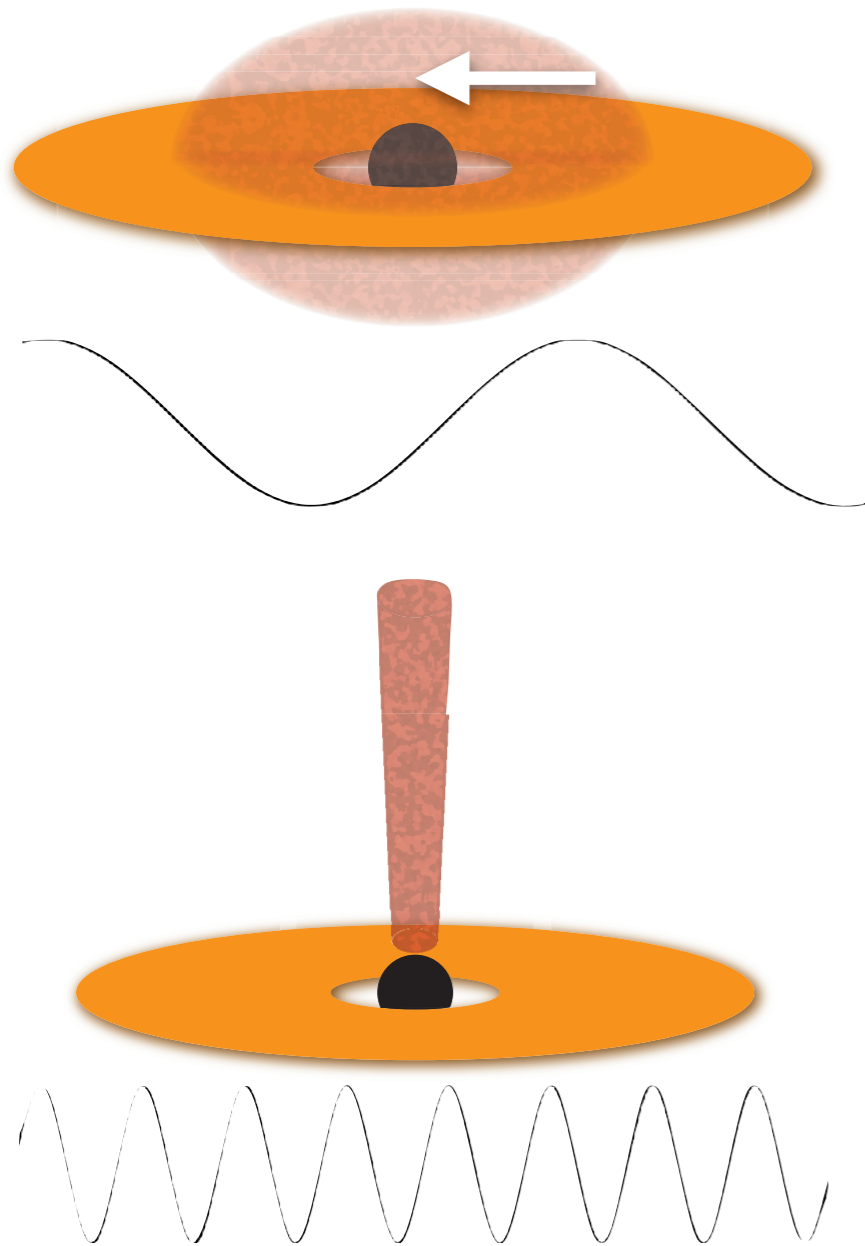
# Extended Coronae in Lag-Energy



# What is the dip at 3keV?



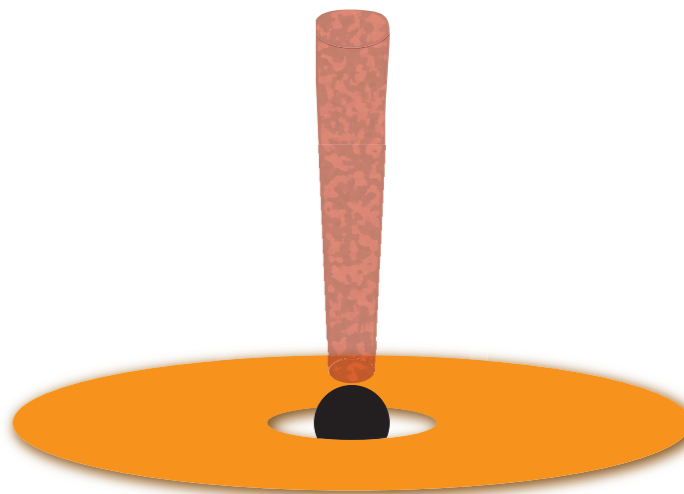
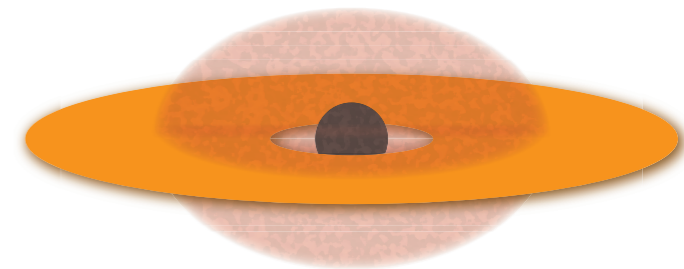
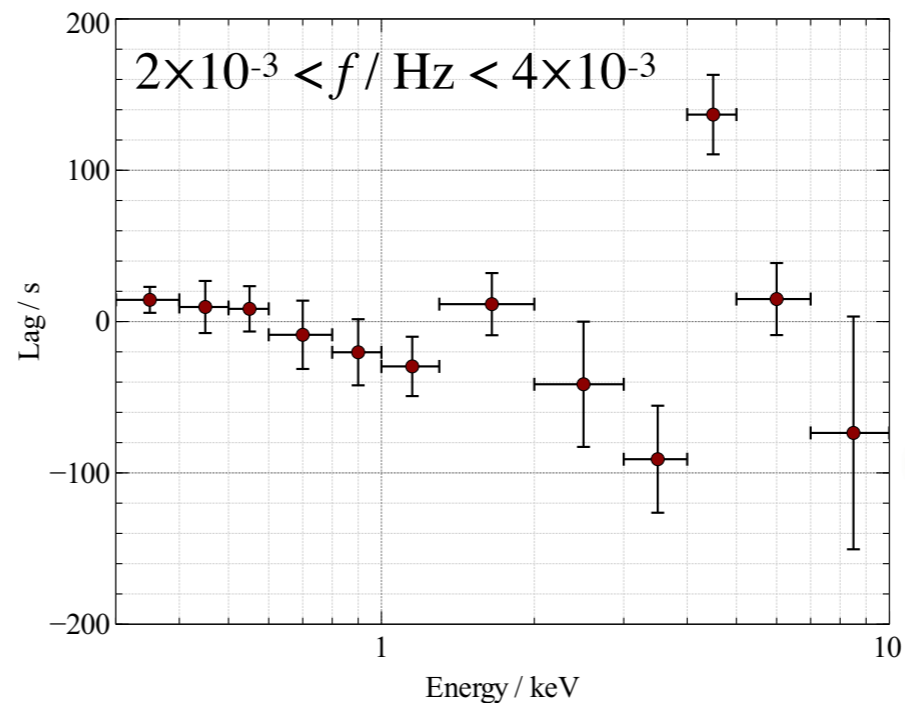
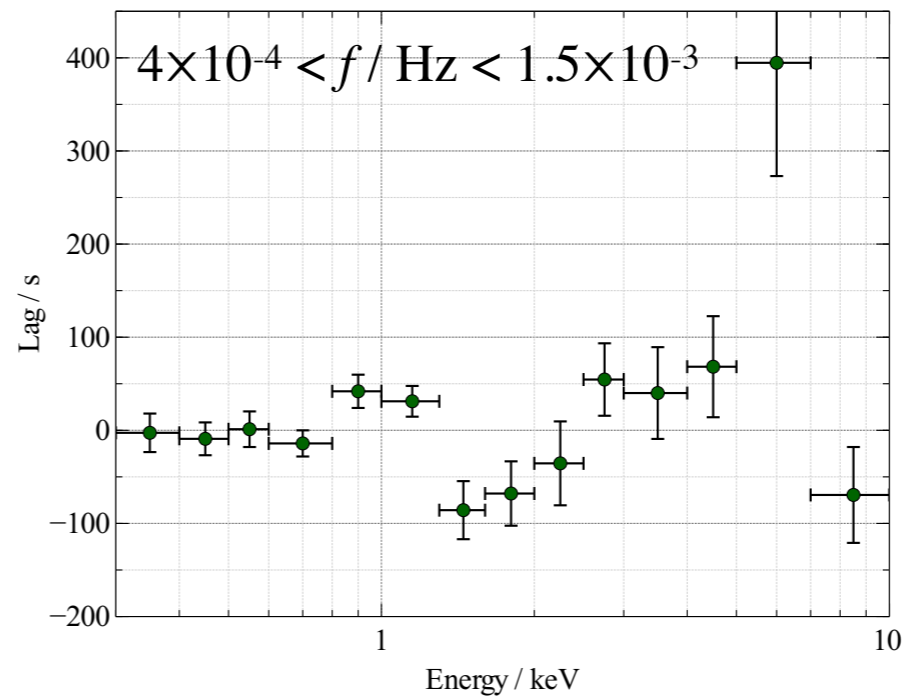
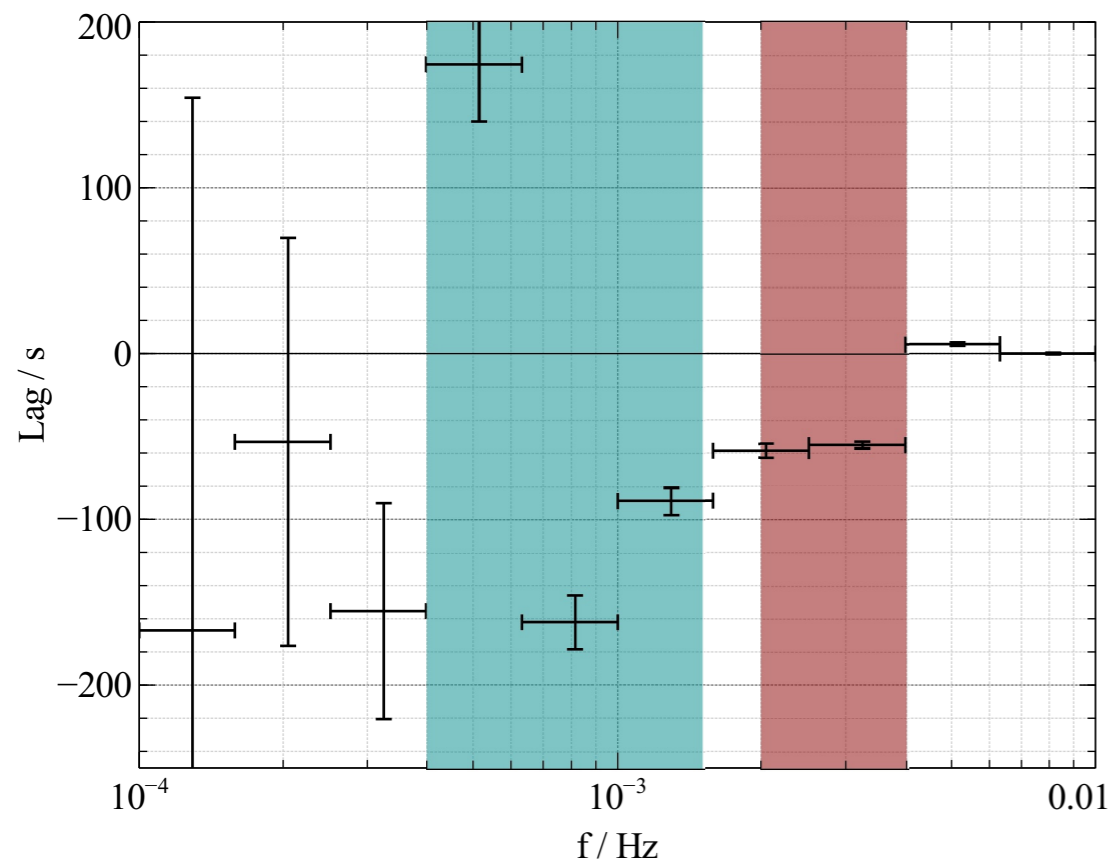
# A tale of two coronae?



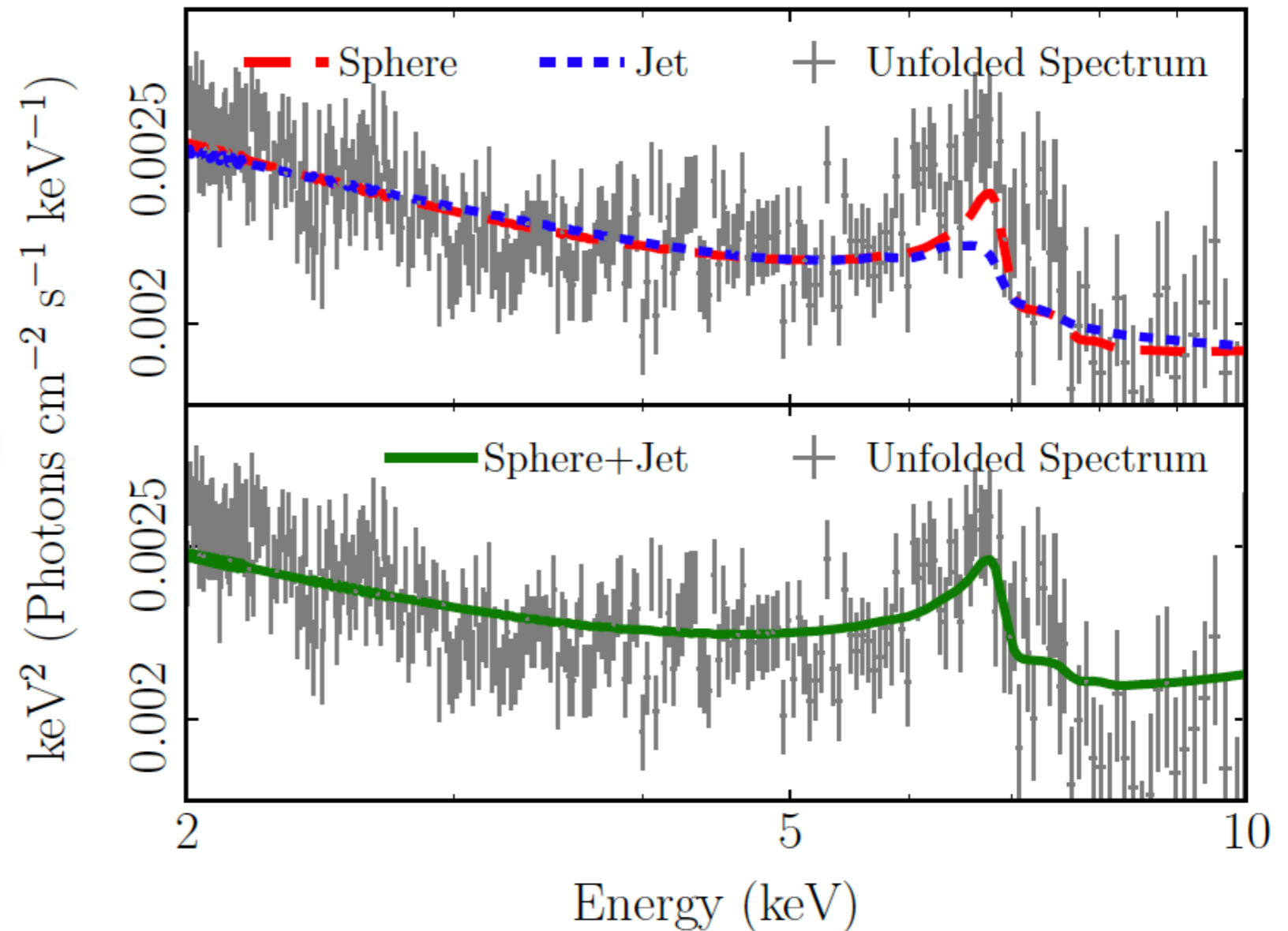
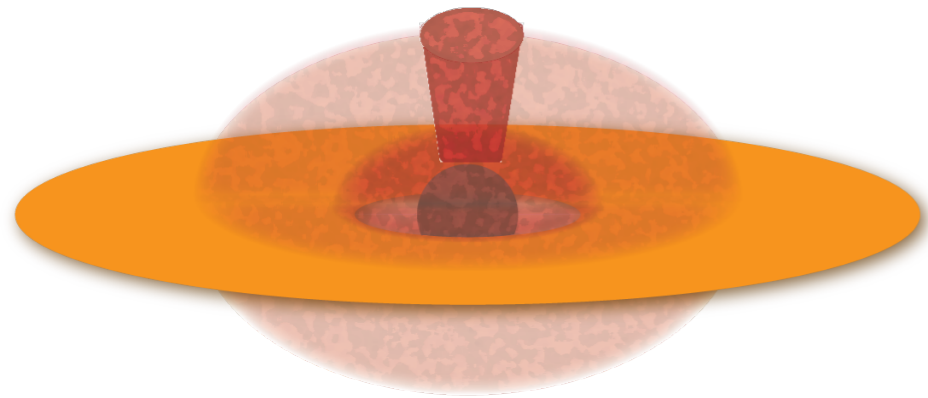


# Seeing the structure in 1Zw1

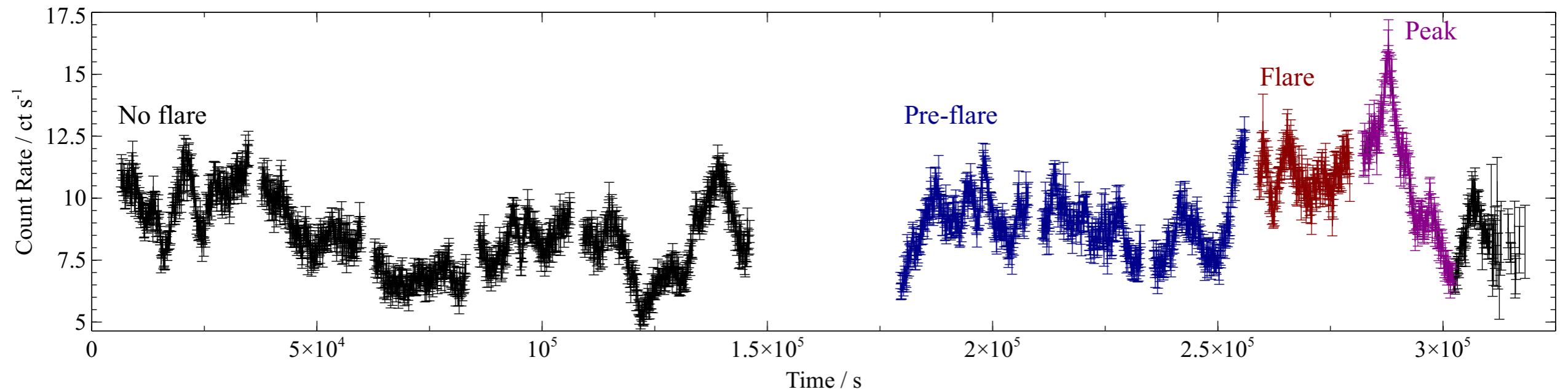
XMM Newton, January 2015  
2 orbits (275ks)



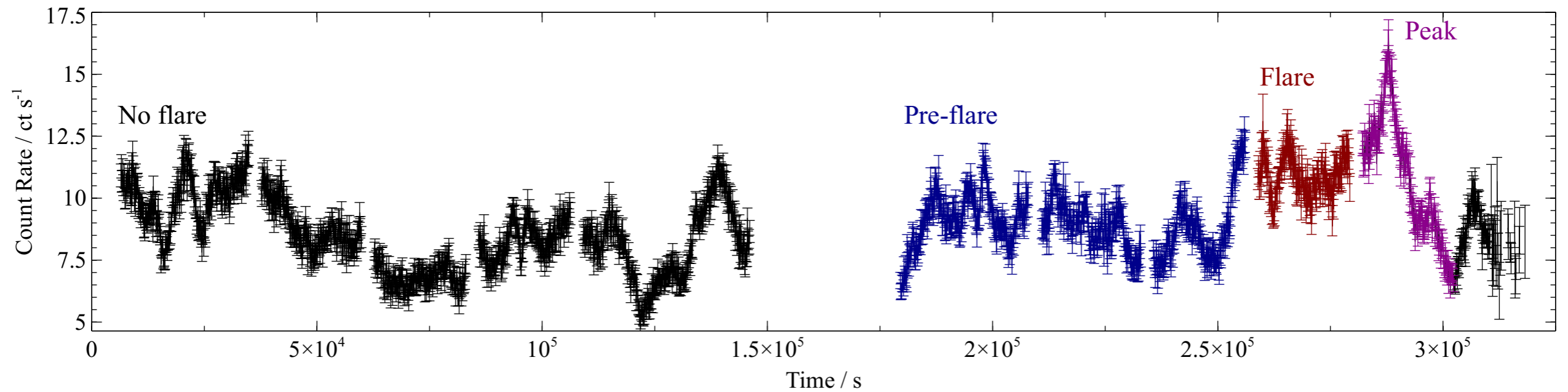
# Evidence from the Spectrum



# Evolution of the Corona in I Zw 1

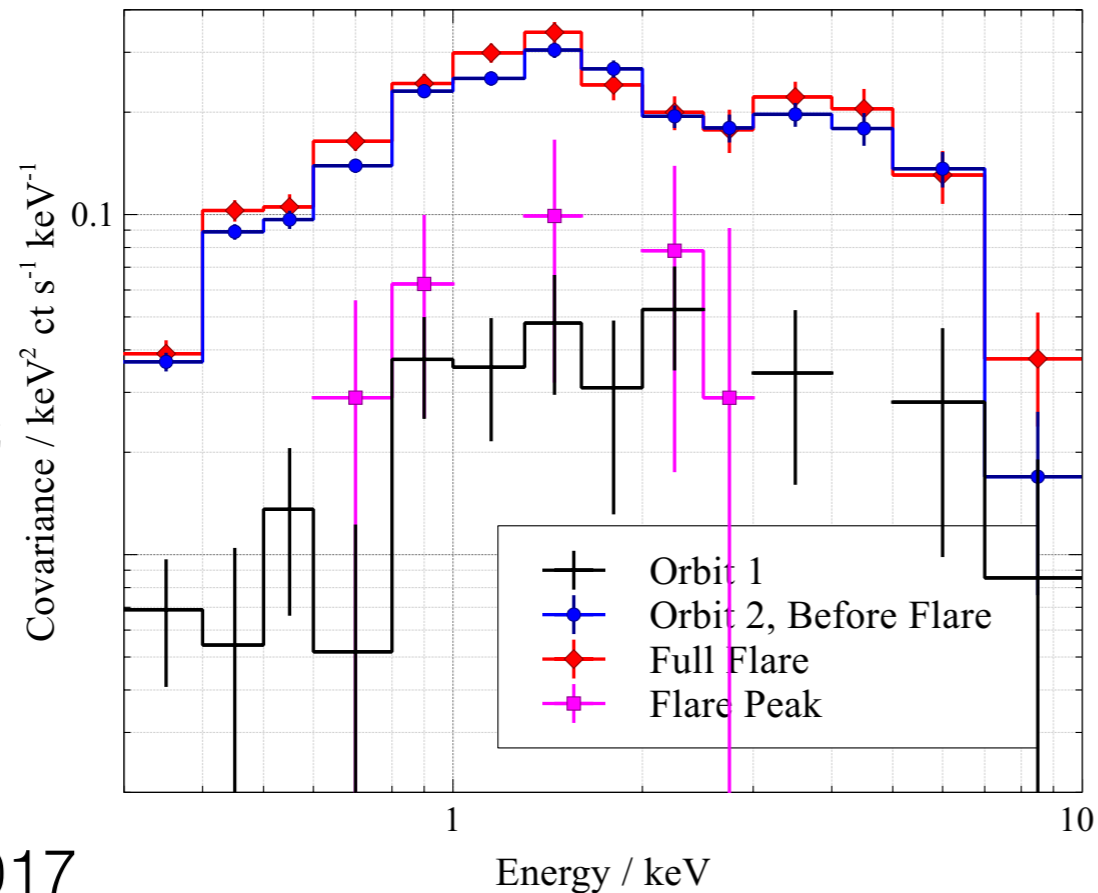


# Evolution of the Corona in I Zw 1



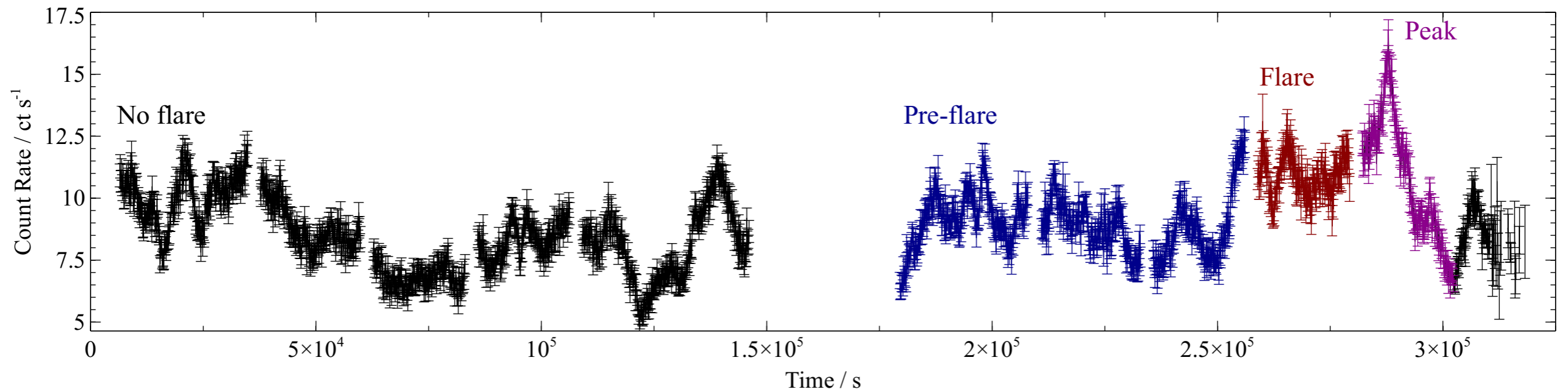
## Covariance Spectrum

Left:  
Low Frequency  
 $4 \times 10^{-4} - 1.5 \times 10^{-3}$  Hz





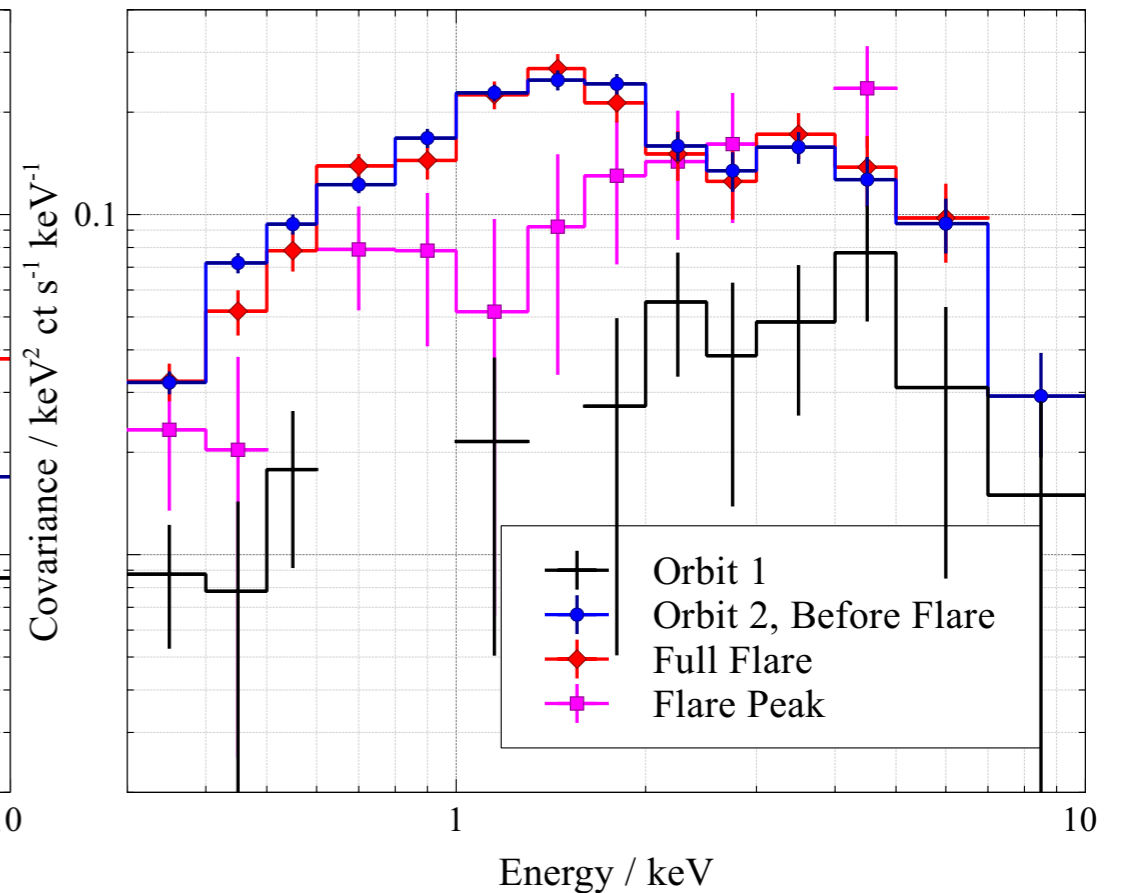
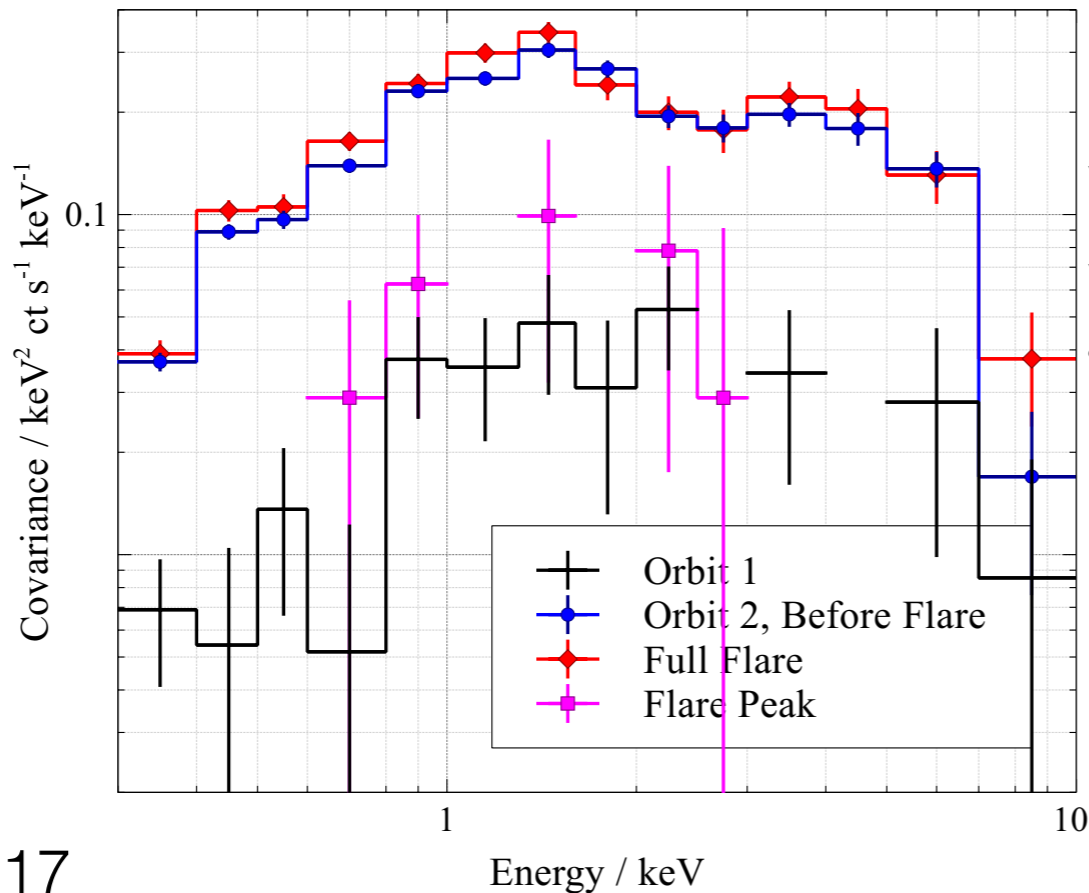
# Evolution of the Corona in I Zw 1



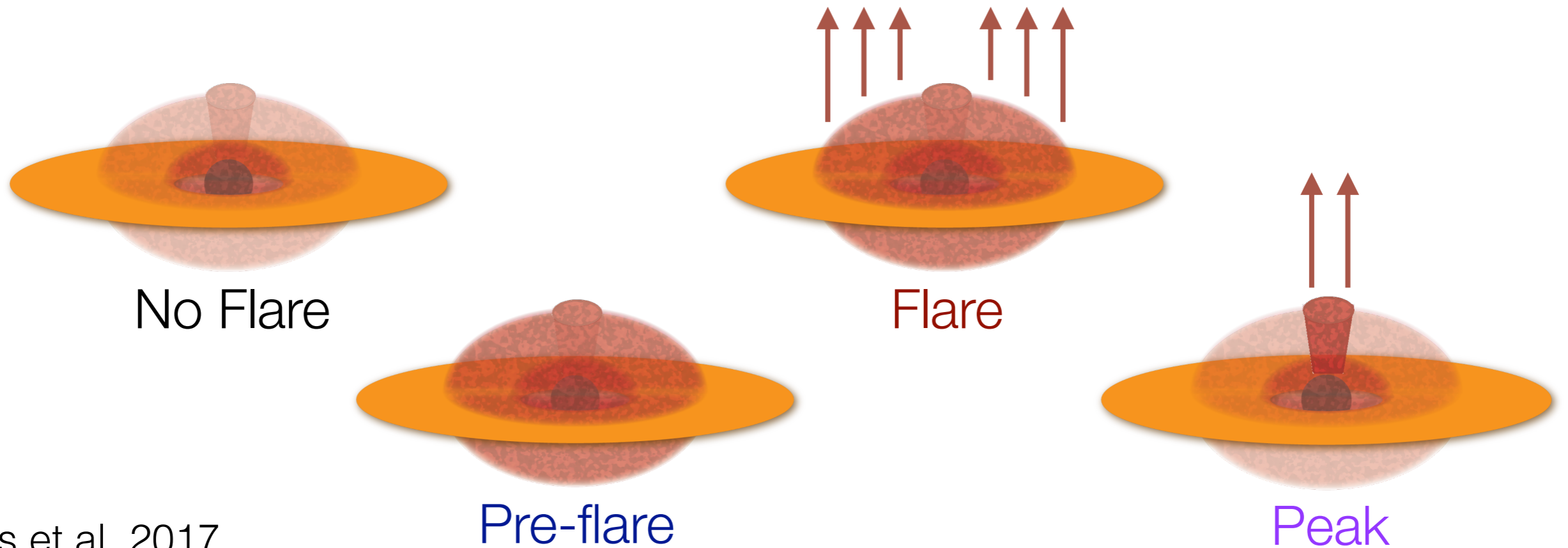
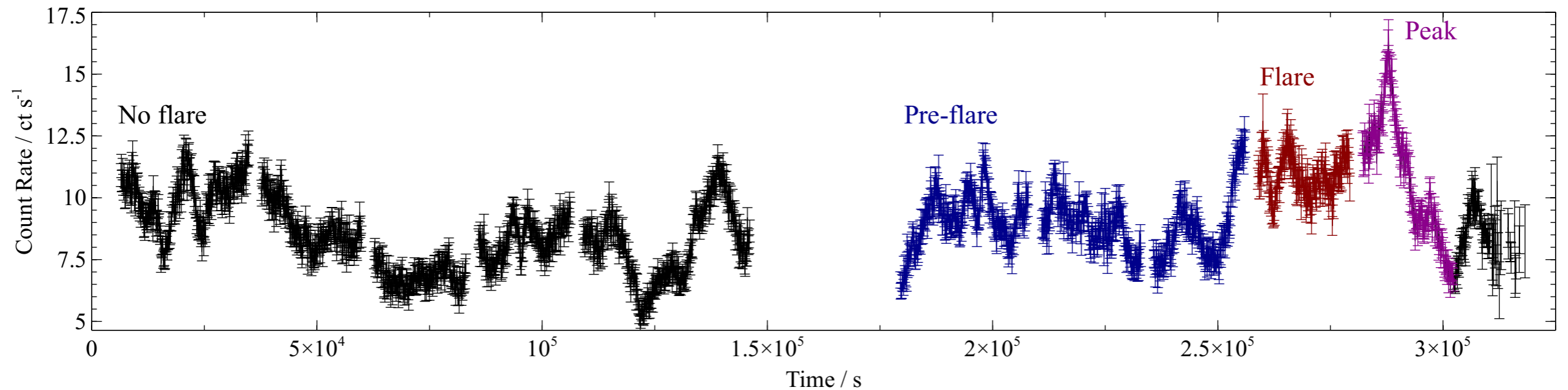
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Left:  
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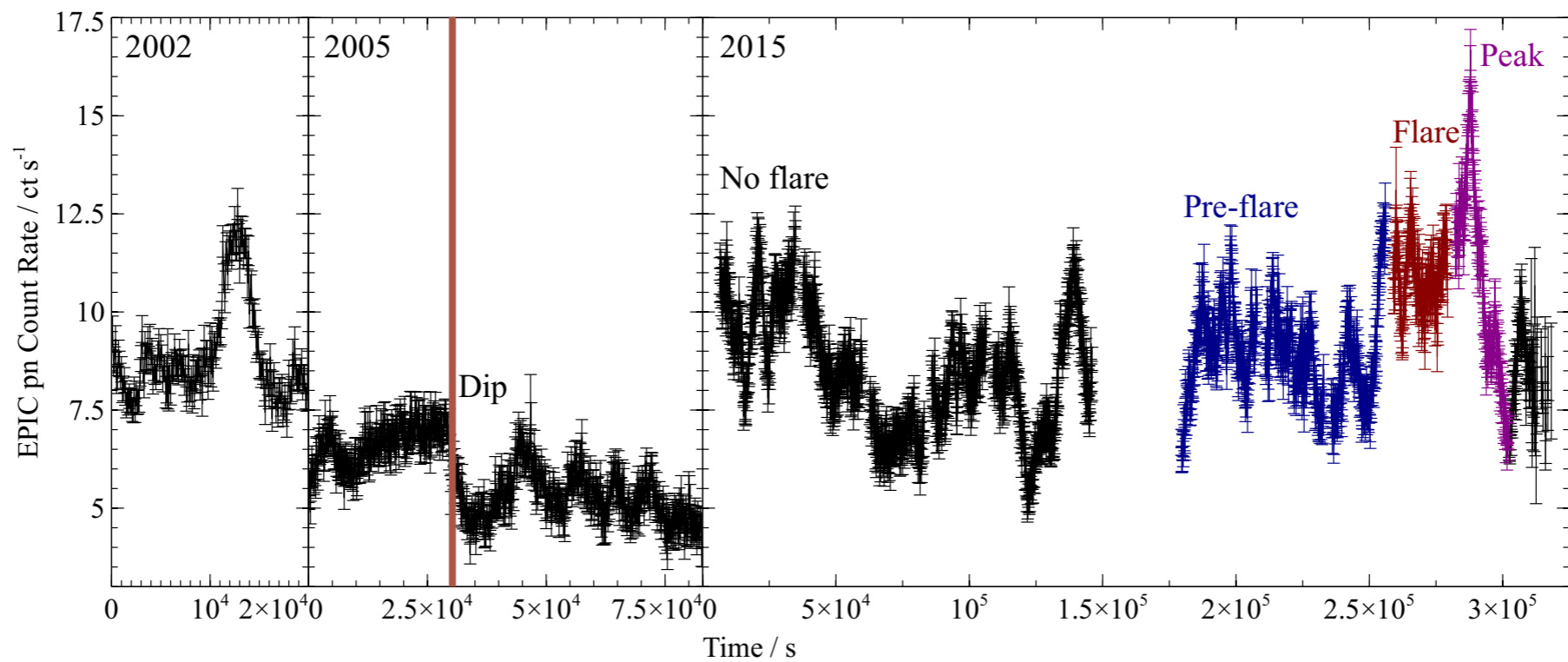
Right:  
High Frequency  
 $2 \times 10^{-3} - 4 \times 10^{-3}$  Hz



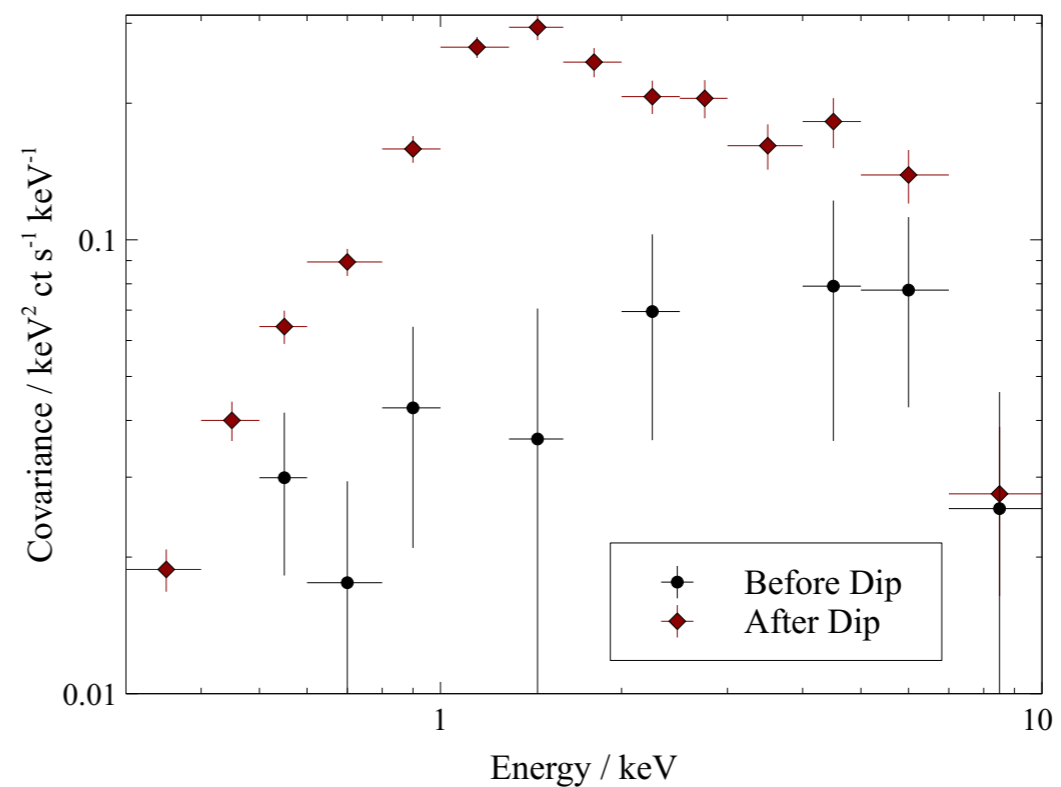
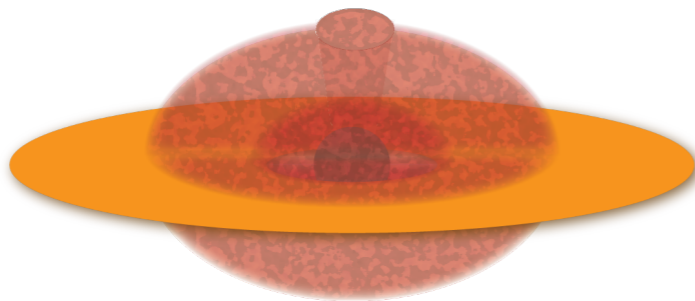
# What is the corona doing?



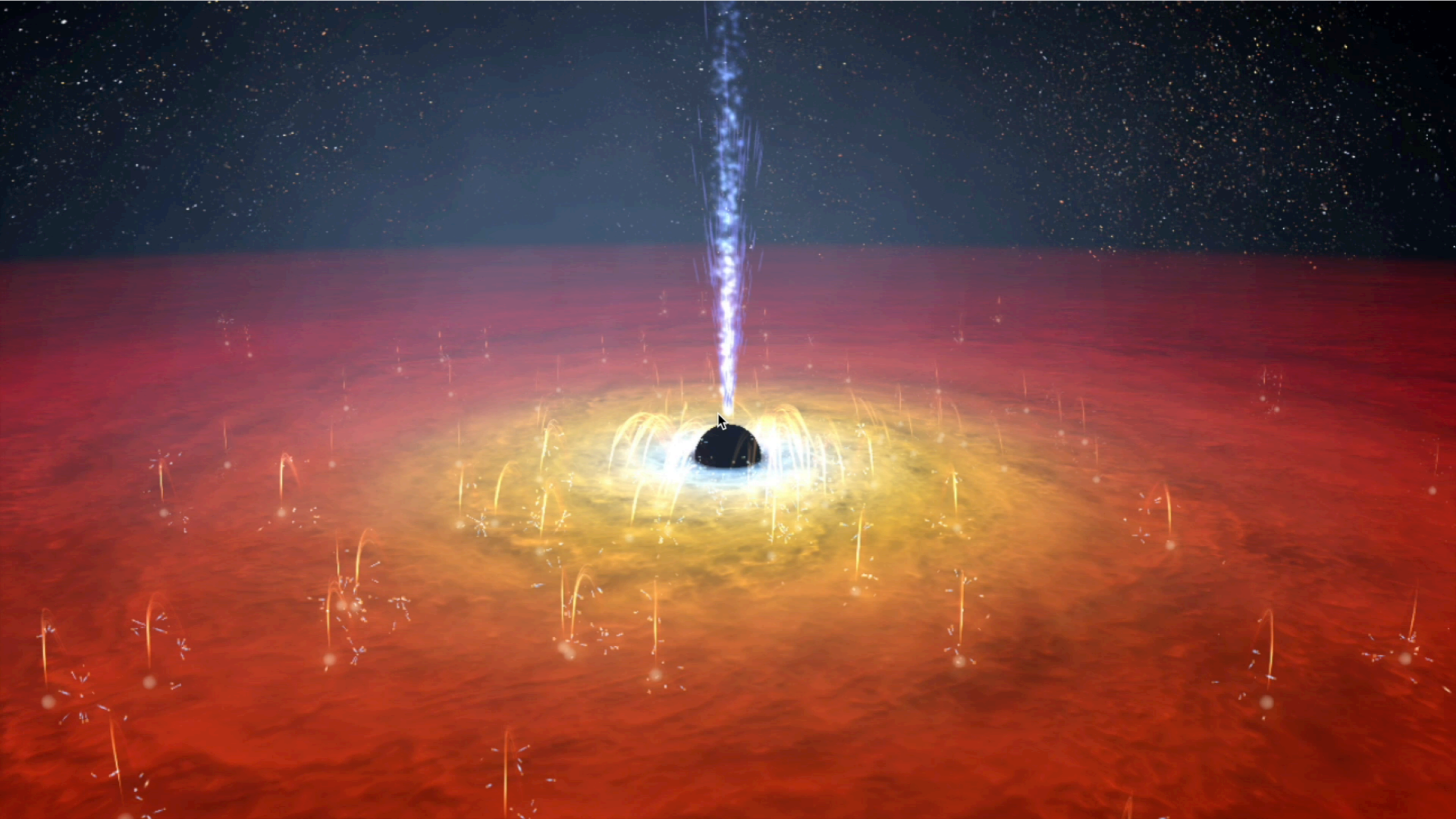
# More From the Disc Corona



Low Frequency  
 $4 \times 10^{-4} - 1.5 \times 10^{-3}$  Hz

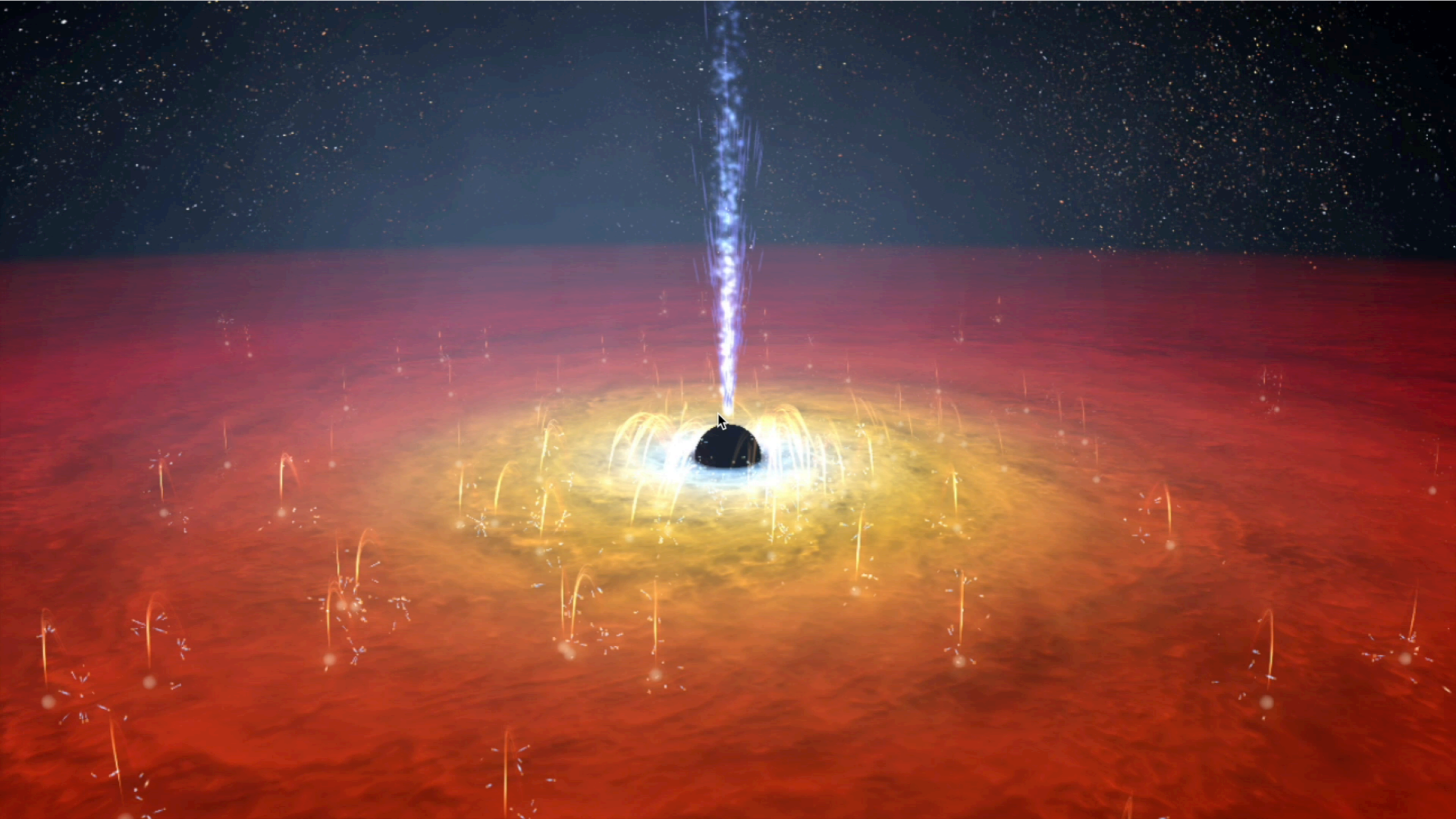






Animation: Niel Brandt & Nahks Tr'Ehnl





Animation: Niel Brandt & Nahks Tr'Ehnl

# Summary

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- 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?
- Flaring seen to originate in the disc corona which becomes more turbulent before the count rate increases, then flare passes to core