# Accretion in BHB and AGN

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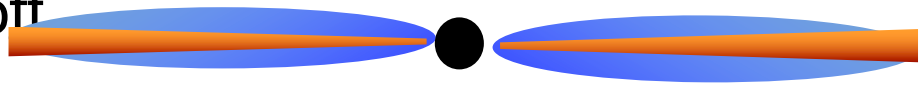
# Two Canonical XRB States

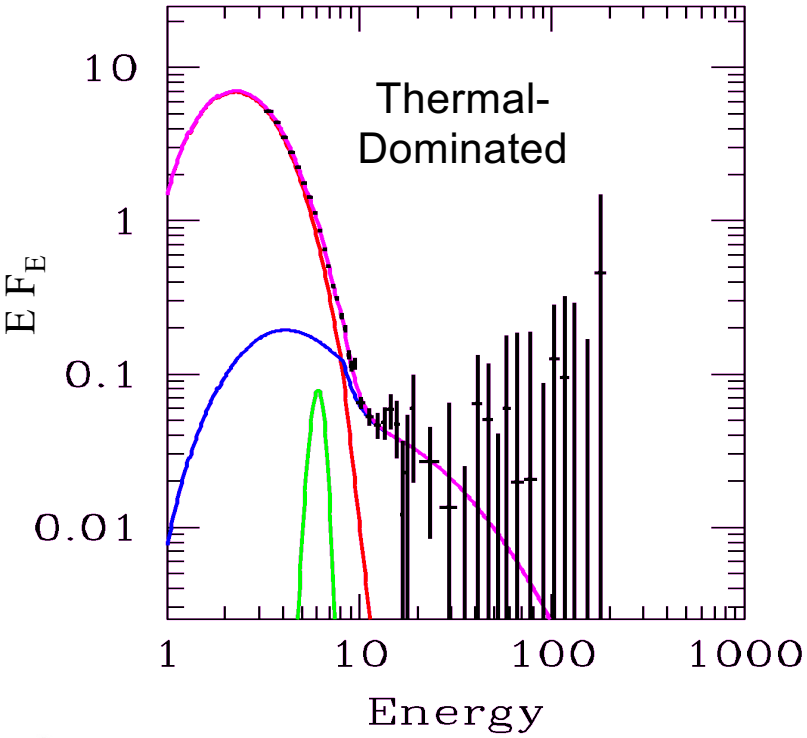
→ High luminosity, spectrally soft state is fairly simple.

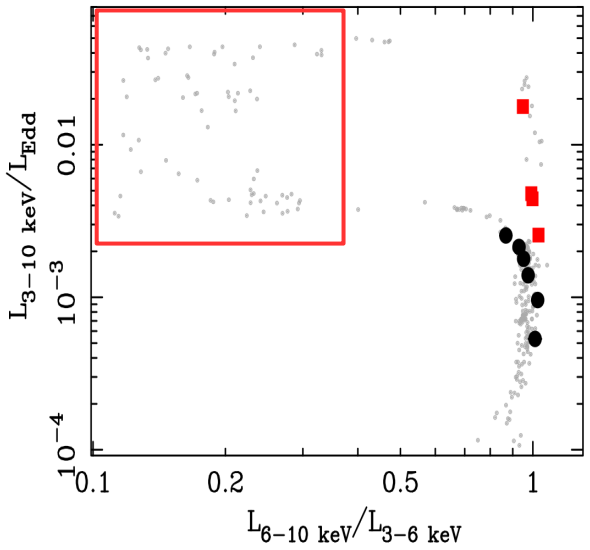
→ We understand this state *relatively* well.

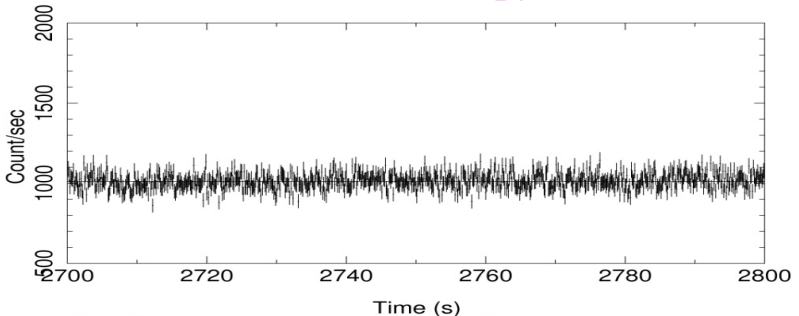
→ Very little fast variability.

→ Well explained by a thermal disc with a Comptonising atmosphere (Shakura & Sunyaev 1973).





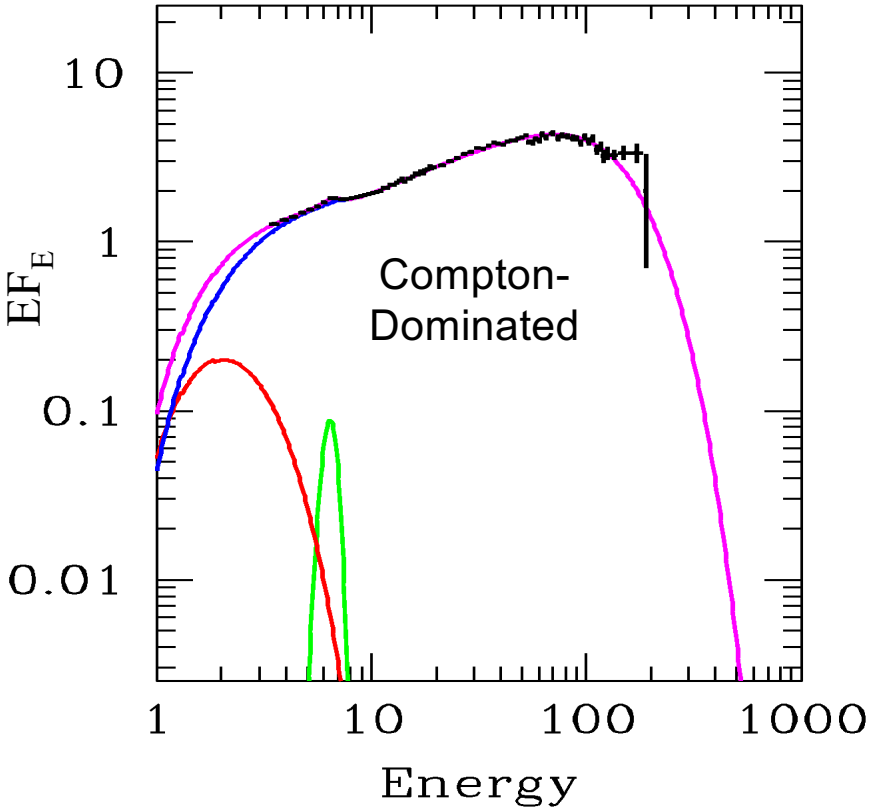



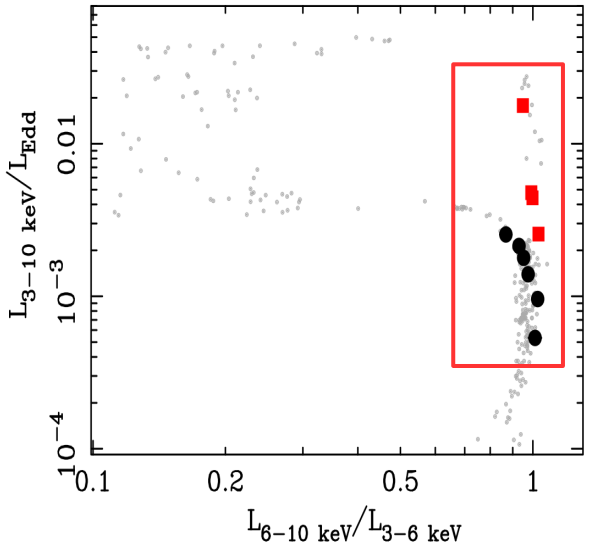
# Two Canonical XRB States

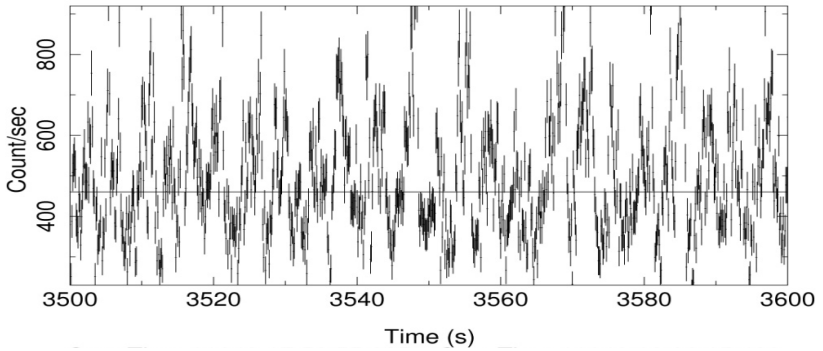
→ Low luminosity, hard state is more complex.

→ Highly variable on short timescales.

→ Something has changed about the accretion physics!!

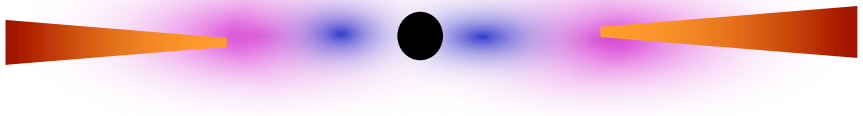


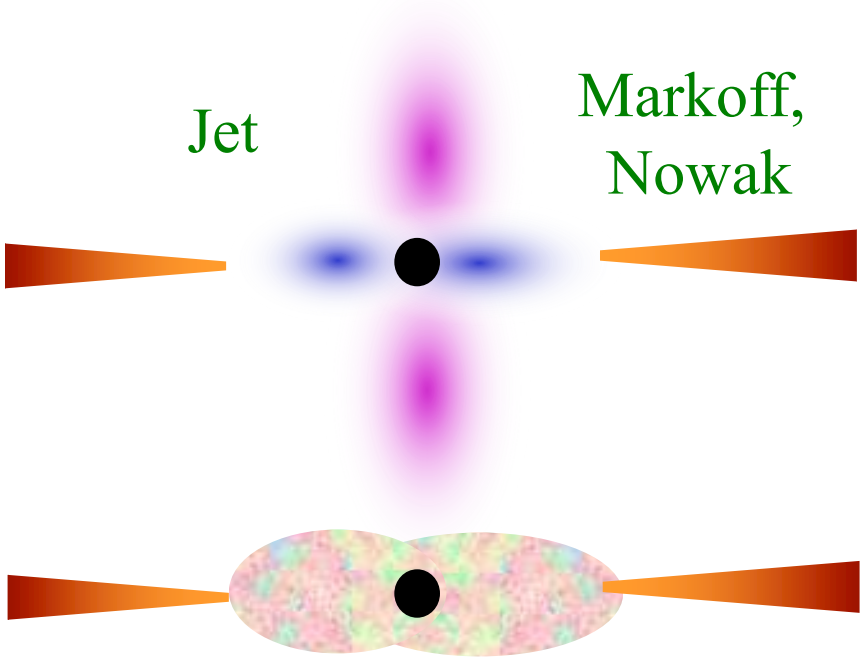
# Everyone agrees on data

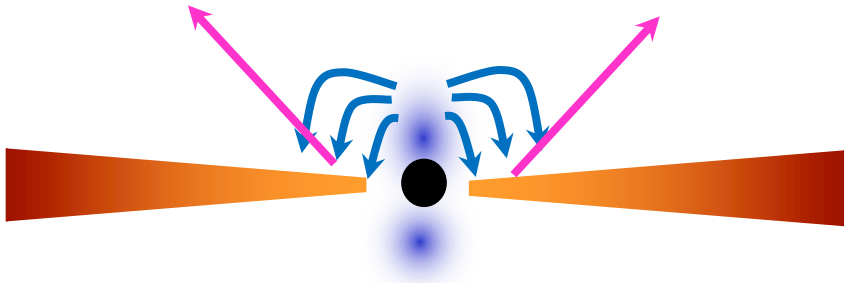
Inhomogeneous compton
Makishima et al 2008



Jet

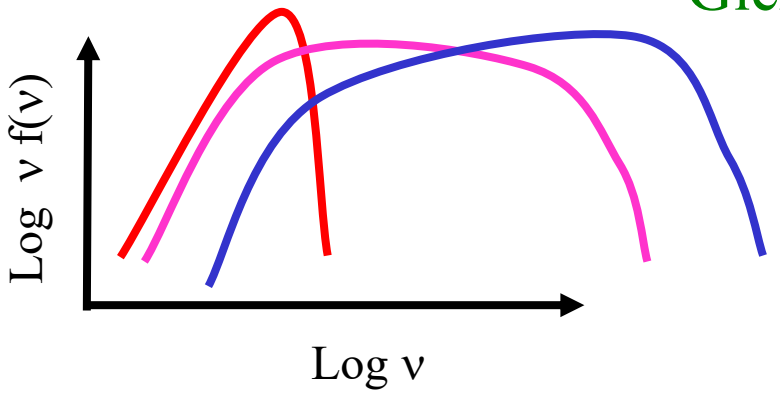
Markoff,
Nowak



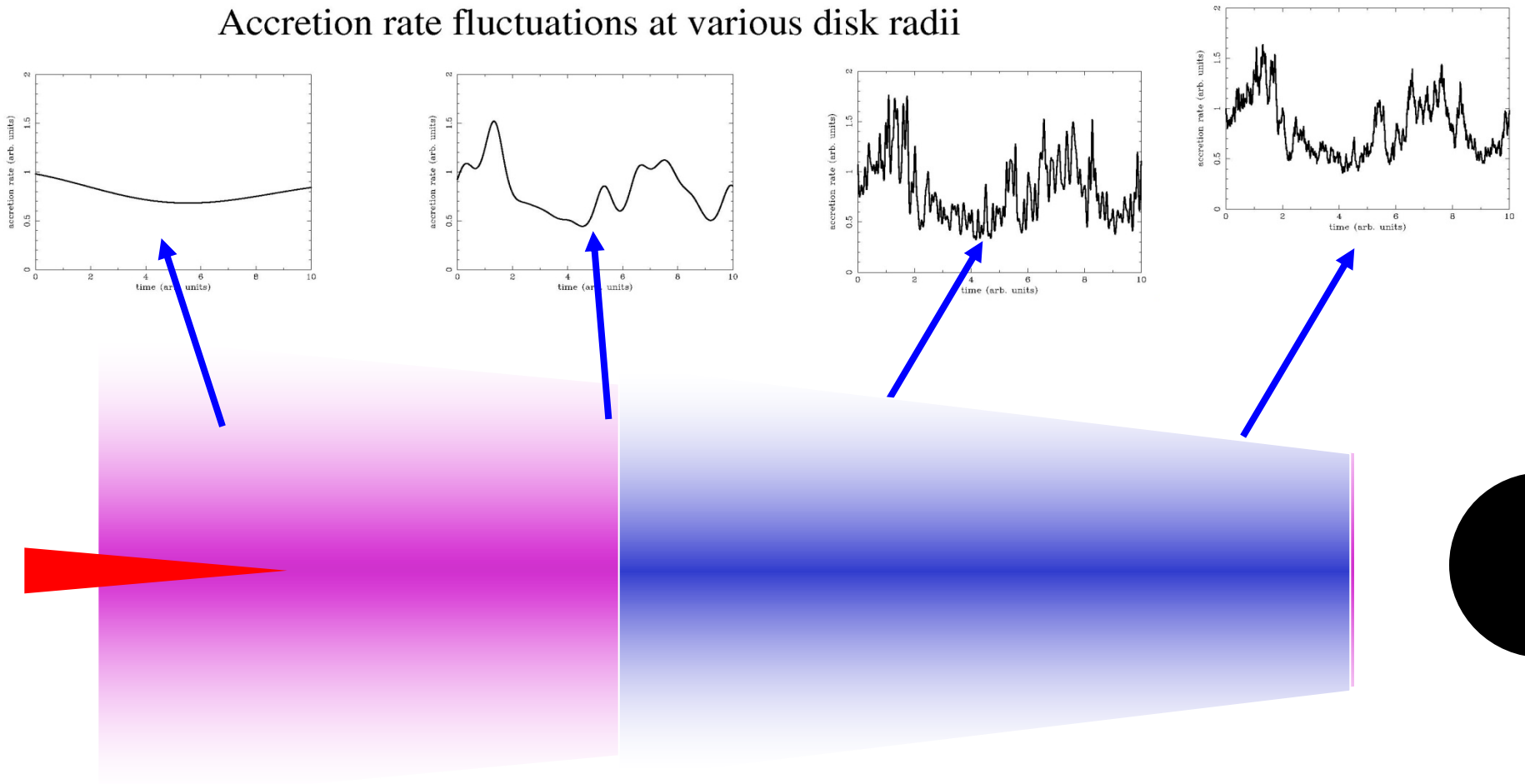


ionised, blurred reflection
Fabian et al 2012

hybrid (thermal-nonthermal)
Gierlinski et al 1999

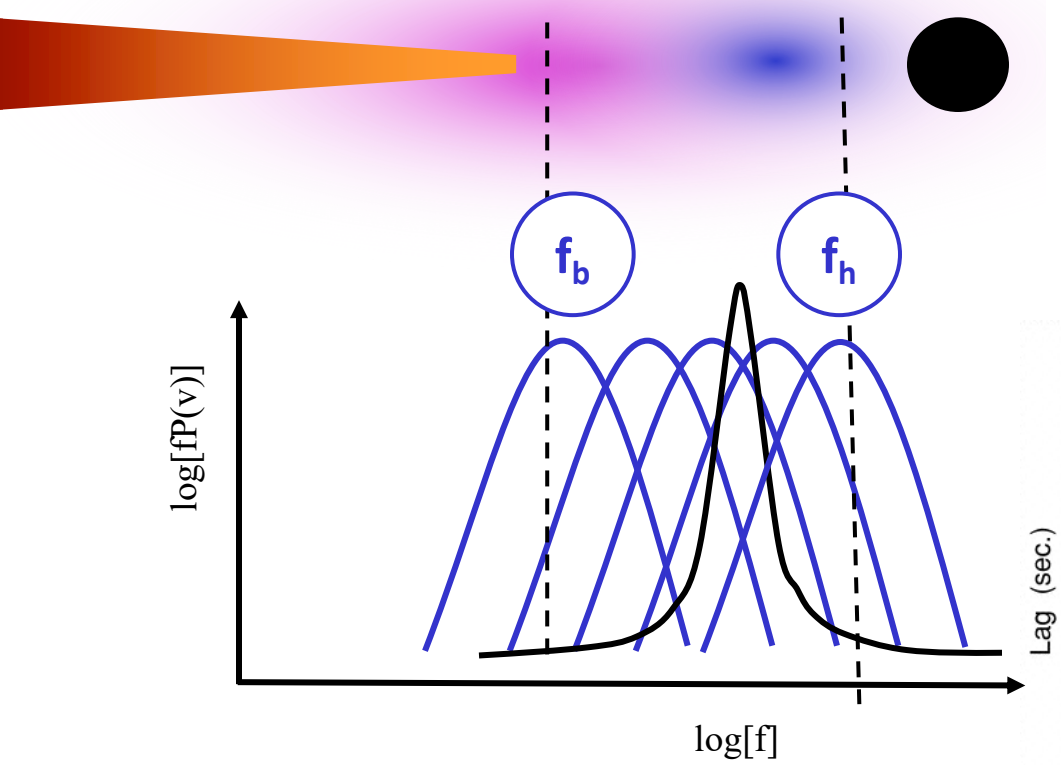


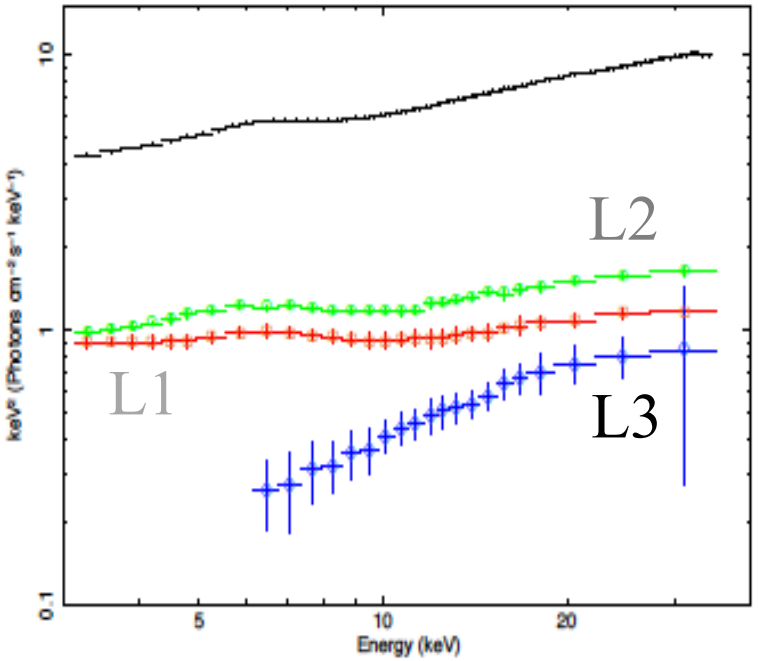
# Origin of broad band variability

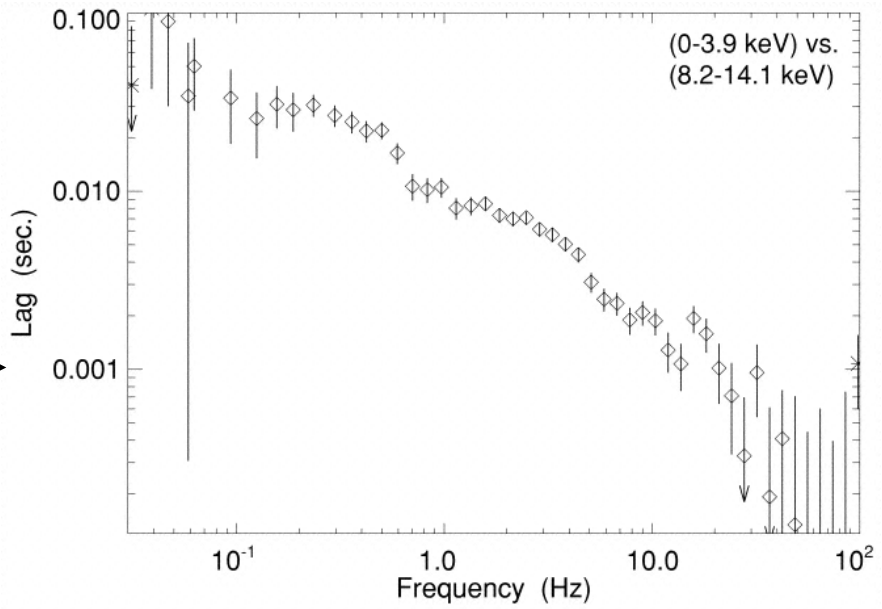



Fluctuations start at large radii – first, soft and slow with R
propagate down to smaller radii – lagged, harder and faster less R

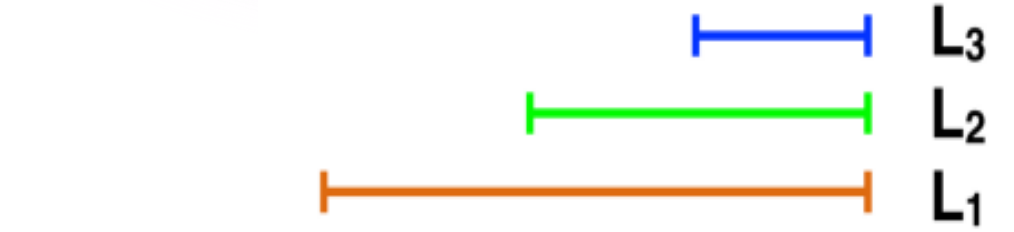
- Mass accretion rate fluc.
- Starts in soft region
- propagates down to hard

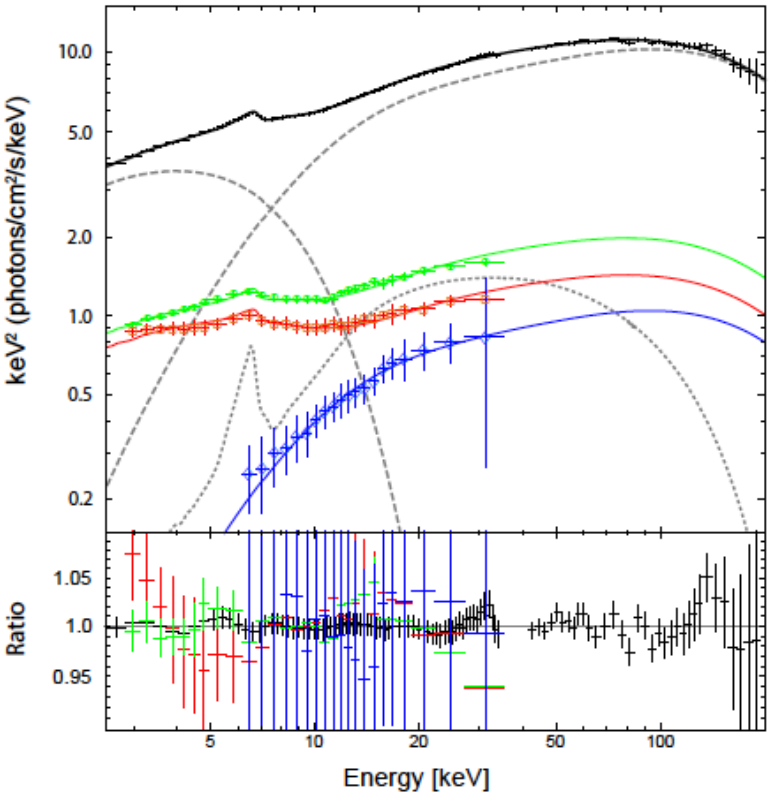


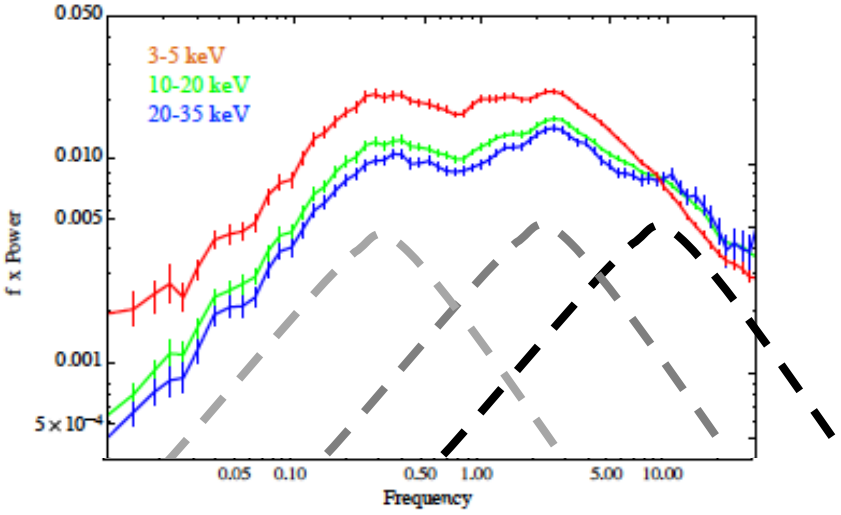



# Power Spectrum

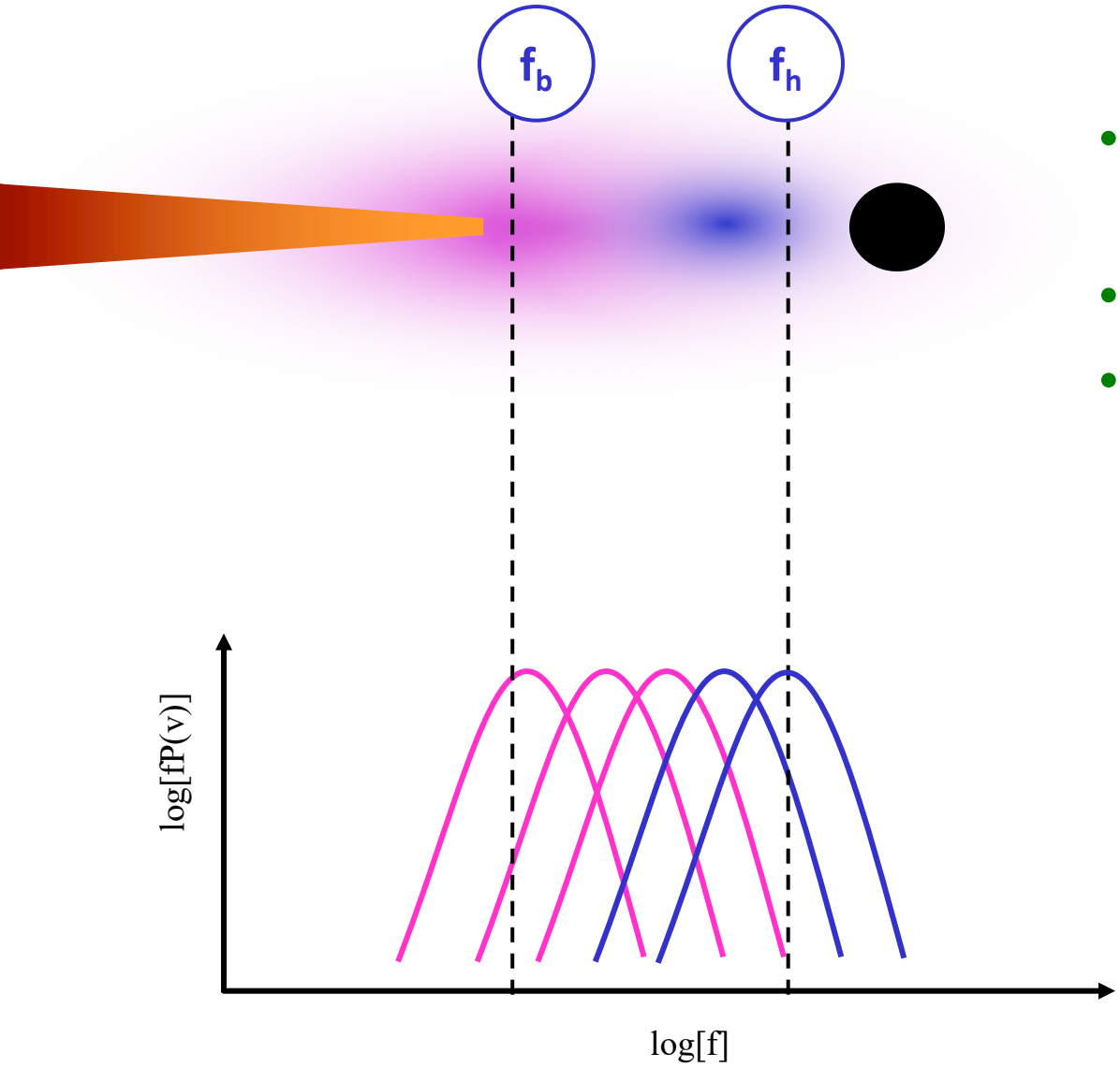


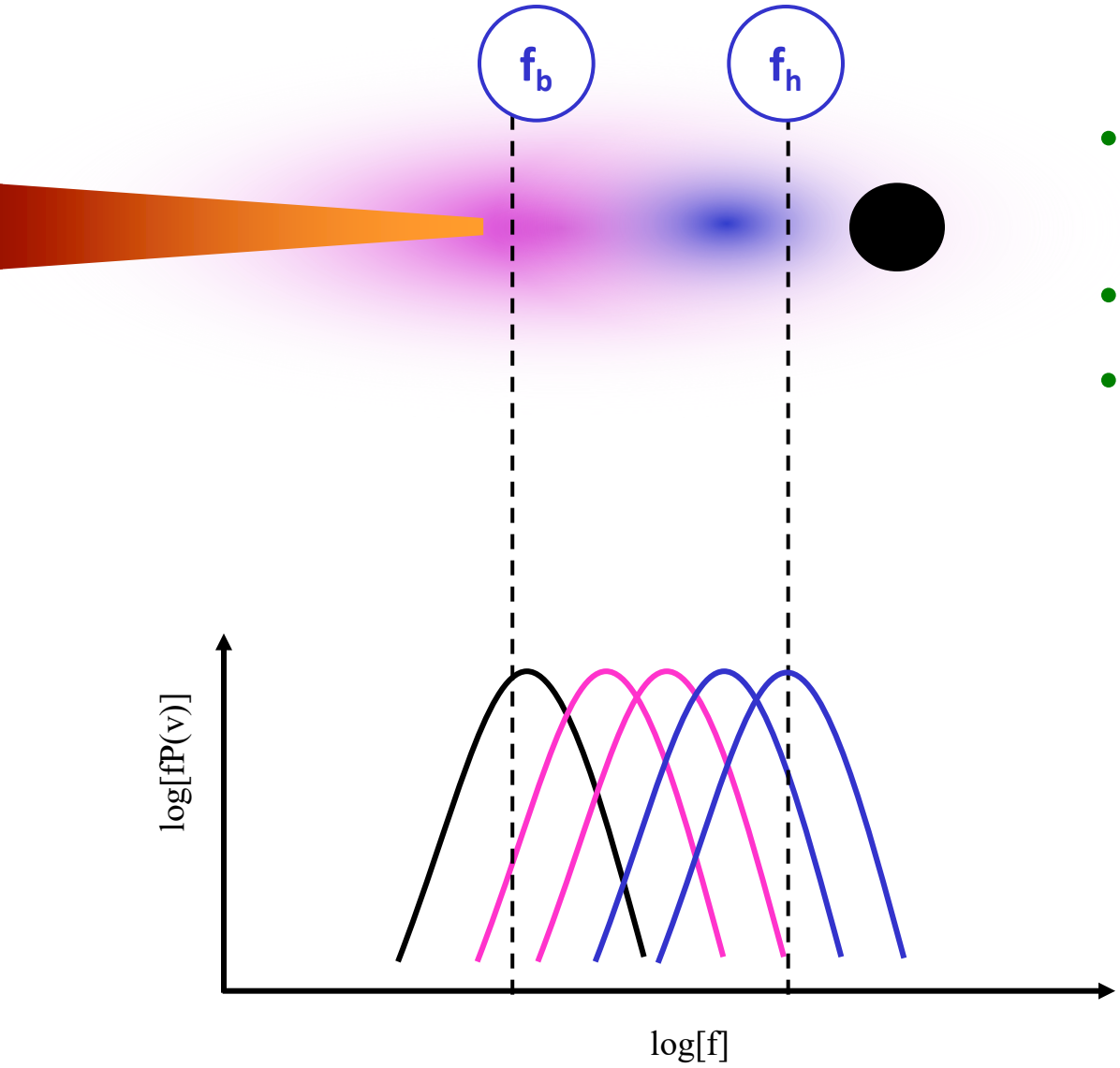

- Fluctuations as function of R:
- shape+normalization
- Shape is Lorenzian - fvisc
- Fvar(R) is normalisation

# Propagation




- Fluctuations as function of R:
- Propagate into each other
- Speed v=r fvisc
- But correlated so add

# Propagation

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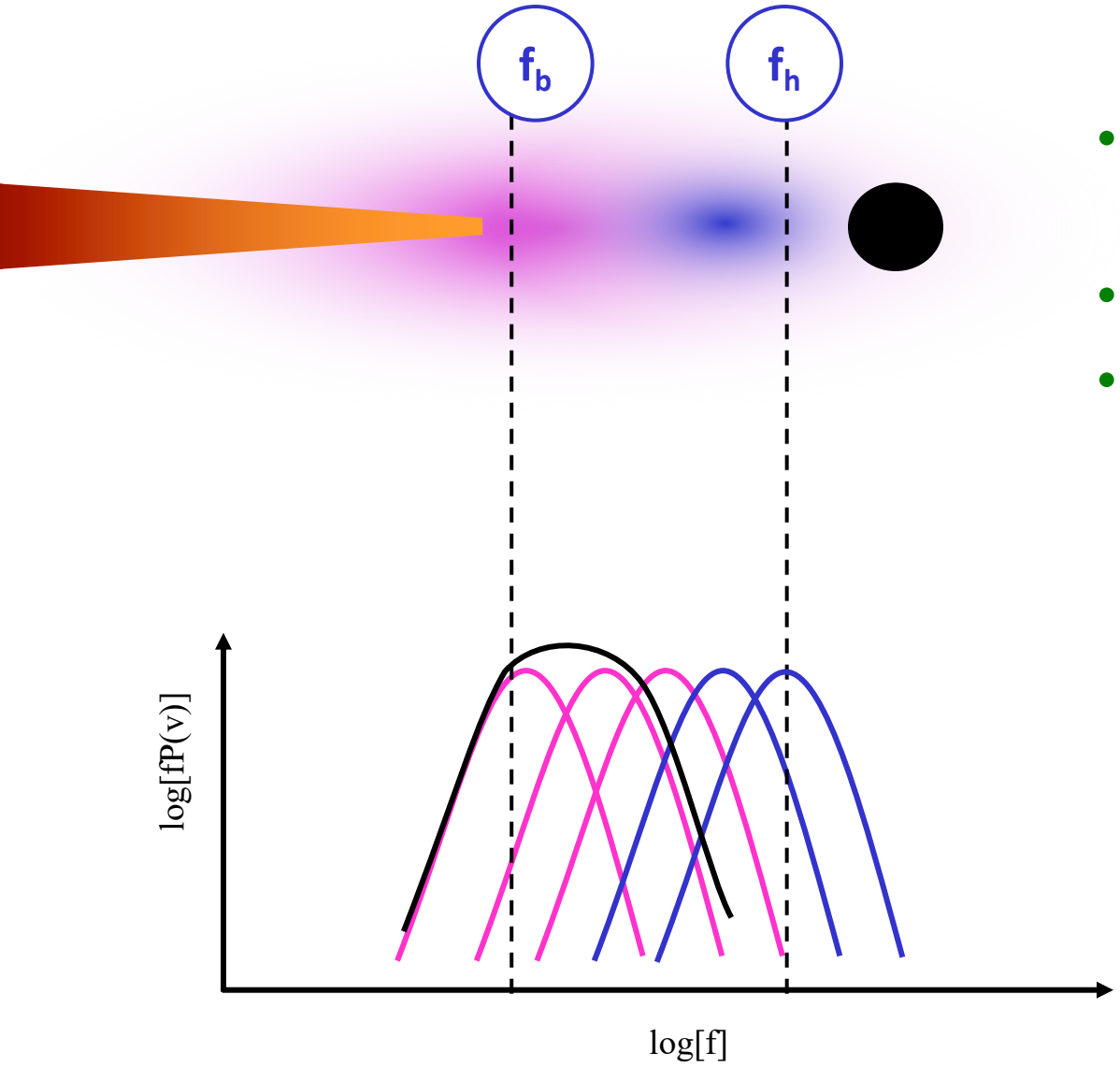


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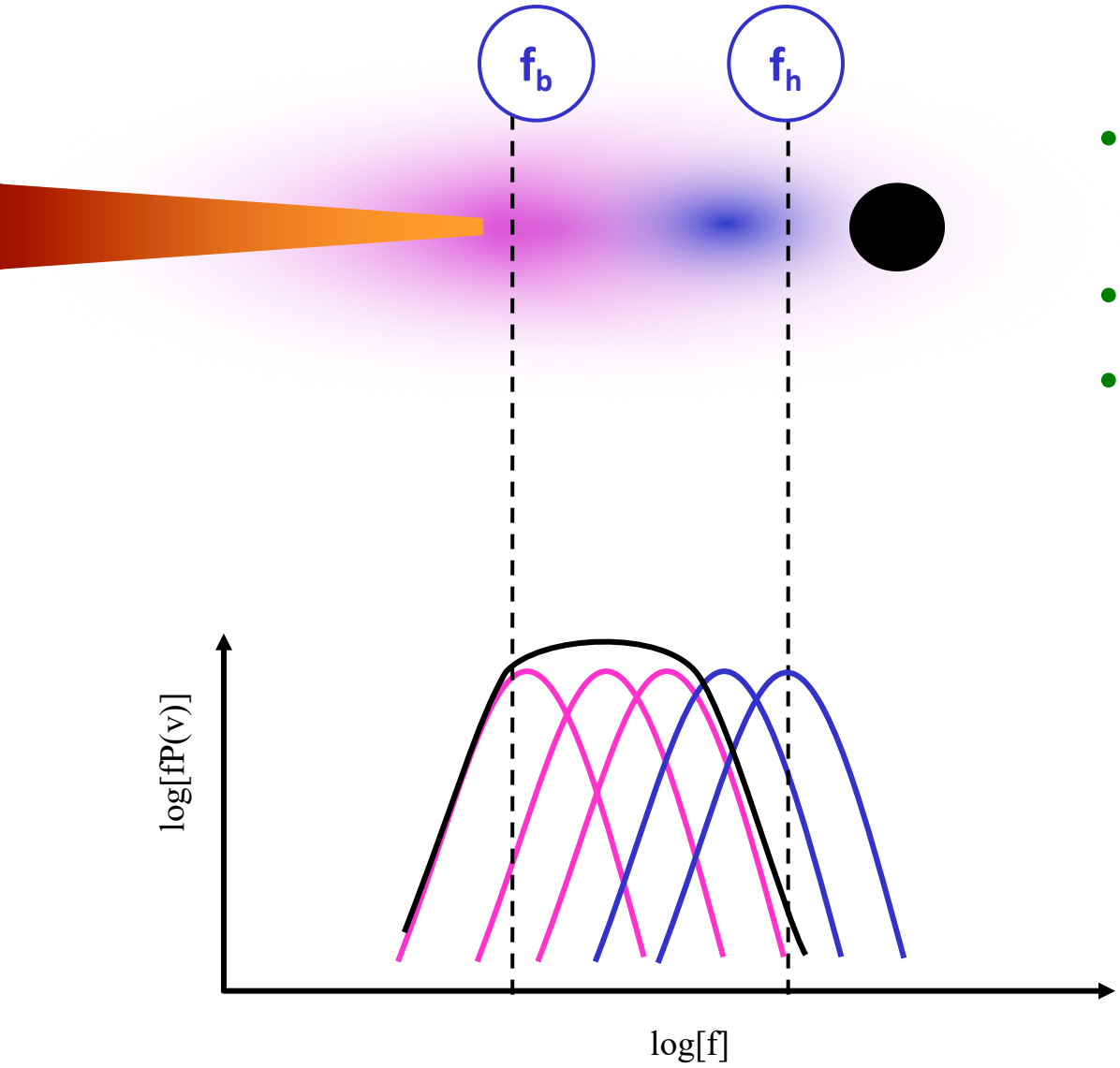


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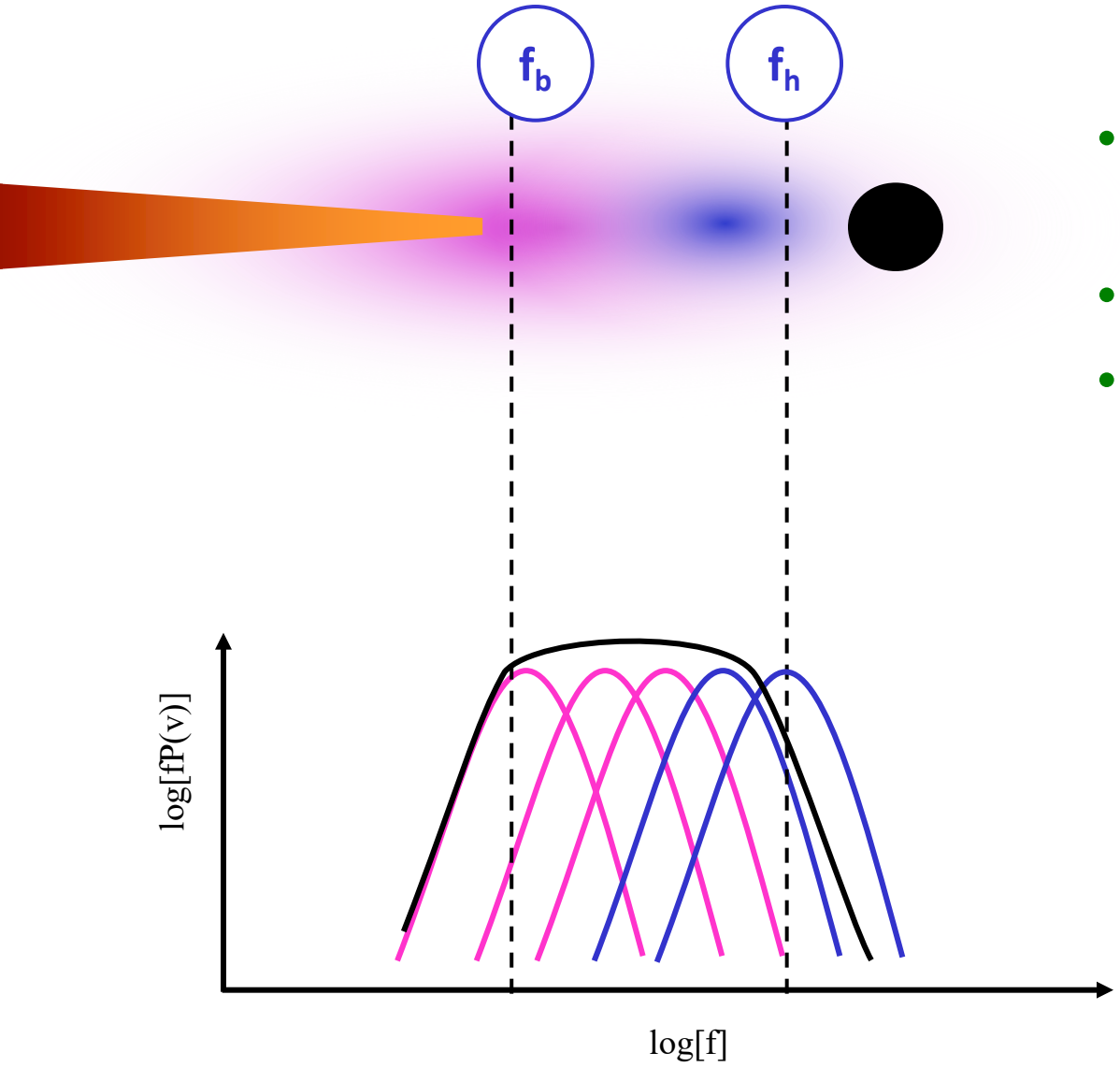


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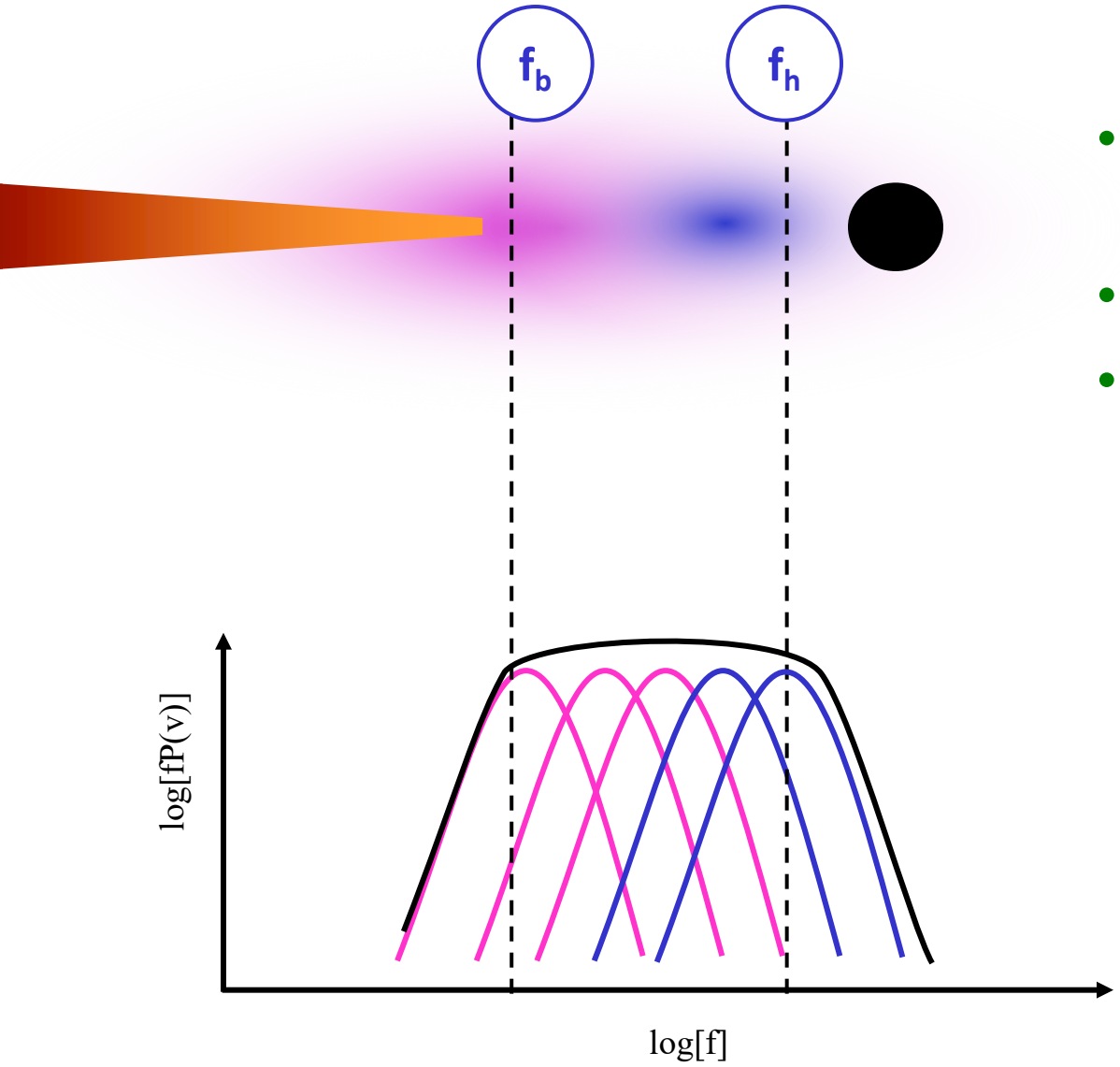


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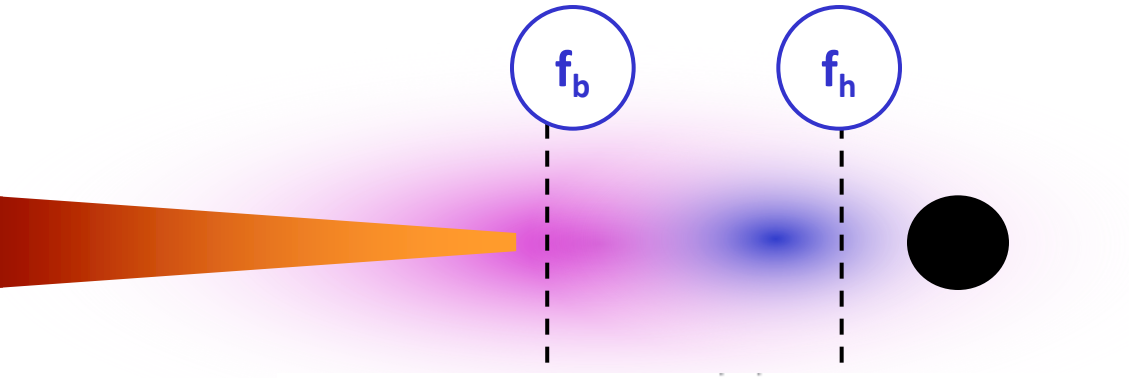
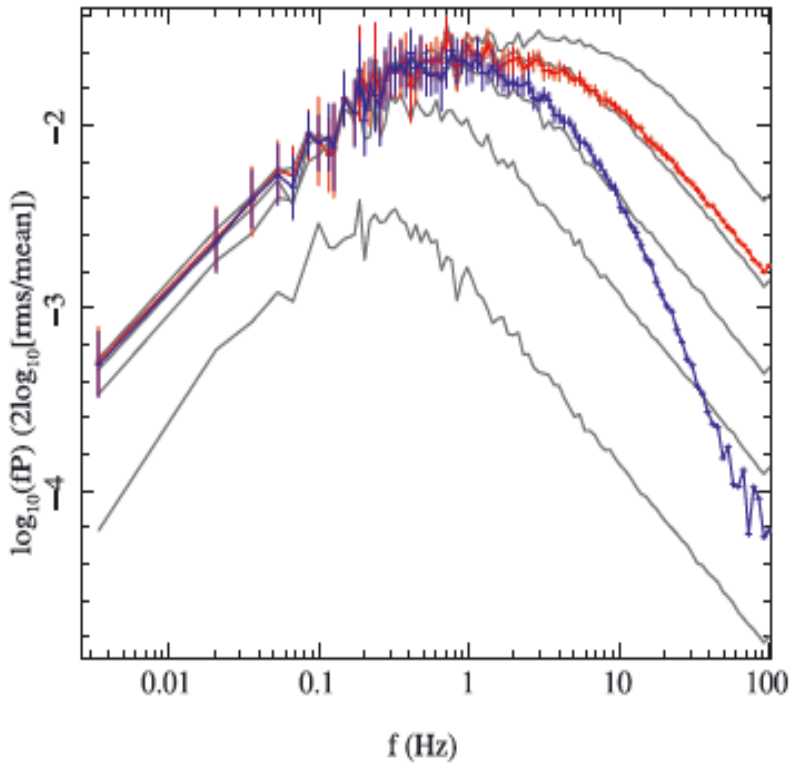
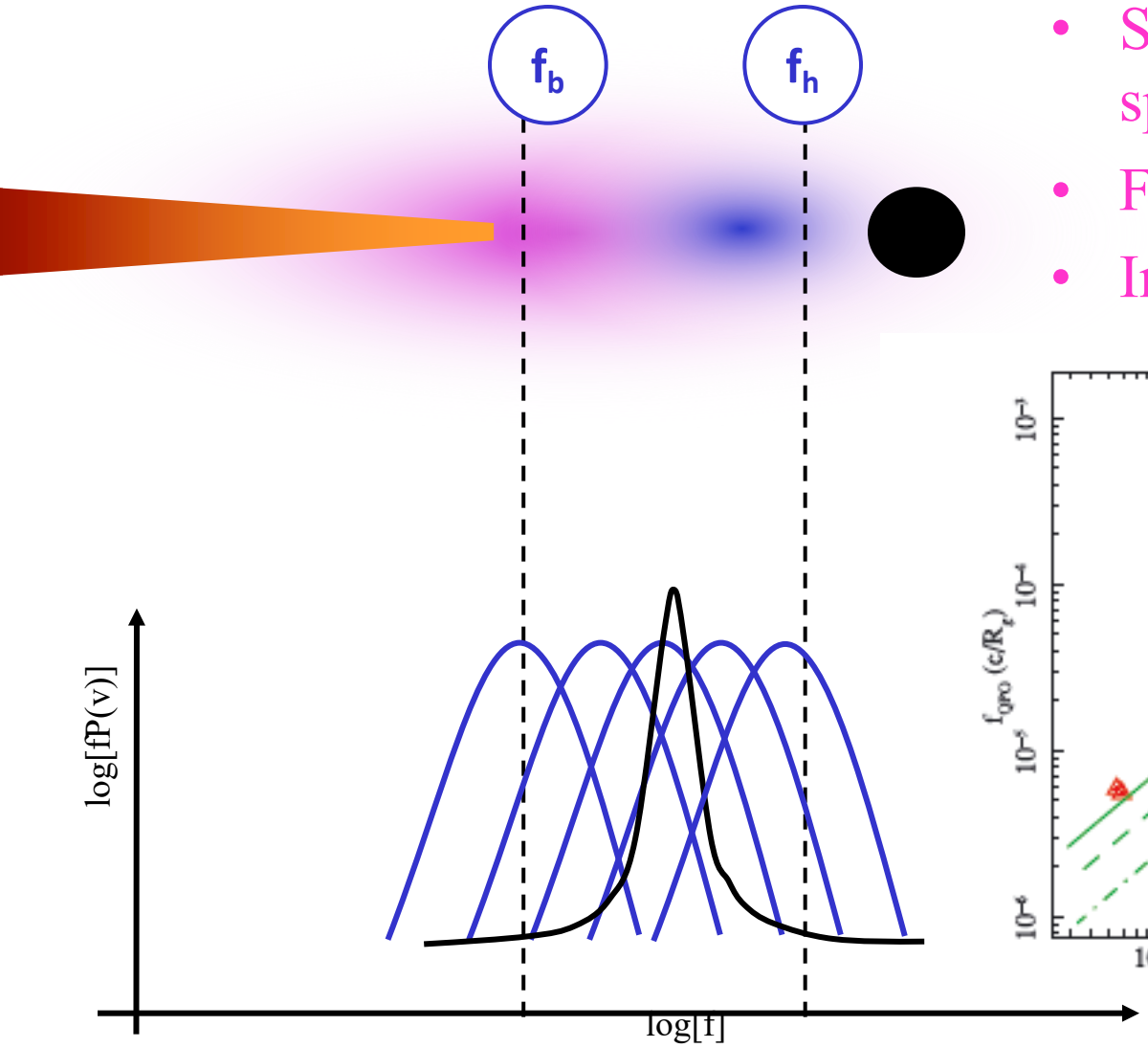


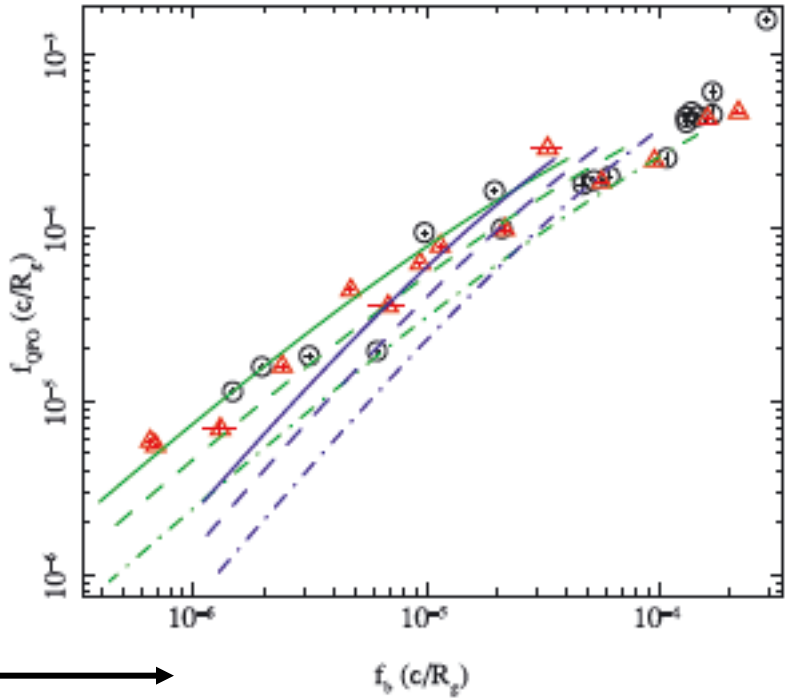




- Actually not so easy as lags decorrelate!!
- Arevelo & Uttley 2006
- Ingram & Done 2011
- HF break not simply fvisc(R)
- LF break IS fvisc(R)
- Speed=distance/time
- So still ambiguous as don't know Rout!!

# Propagation

- LF QPO from Lense-Thirring gives size
- So then use LF break to get speed v=Rfvisc(R)
- $Fvisc(R)=0.03f^{-1/2}\ f\varphi(R)$
- Ingram & Done 2011



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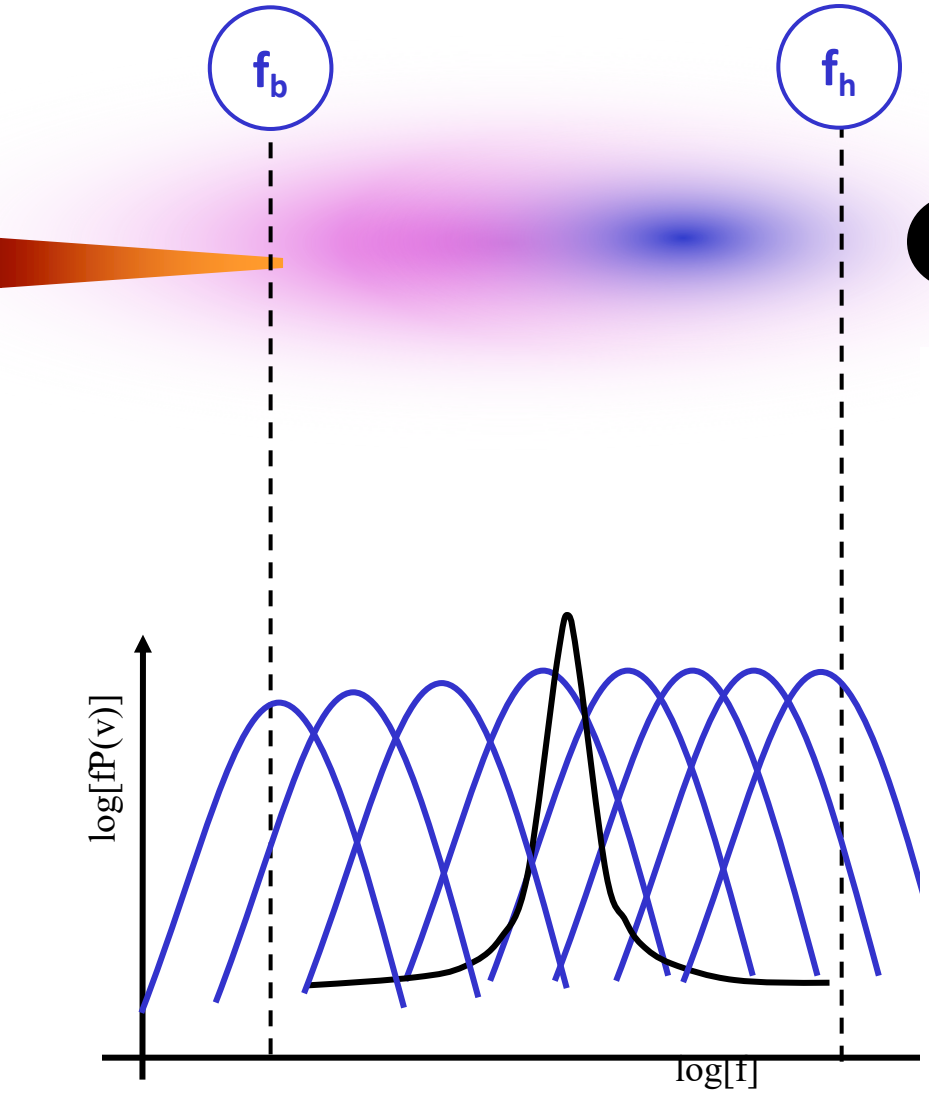


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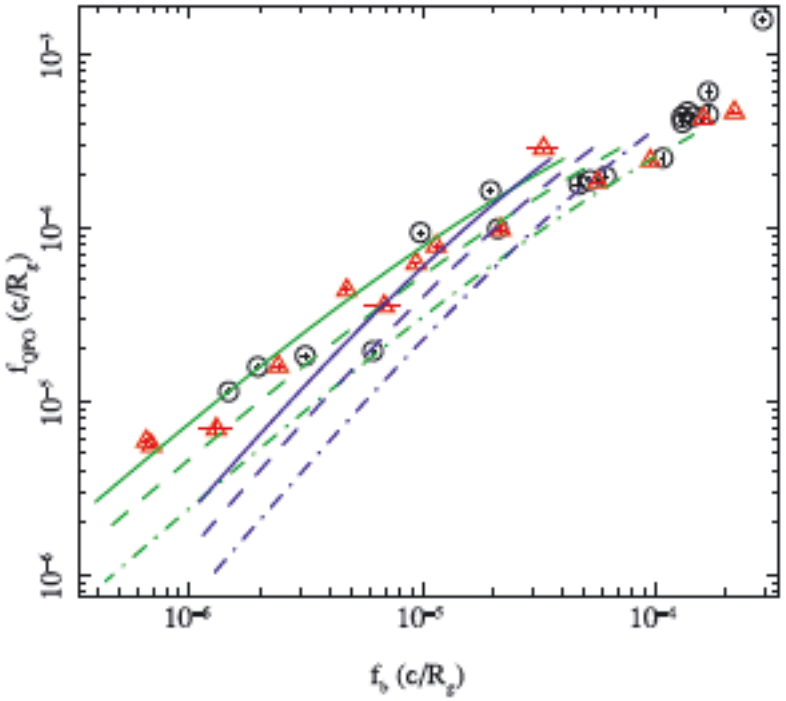

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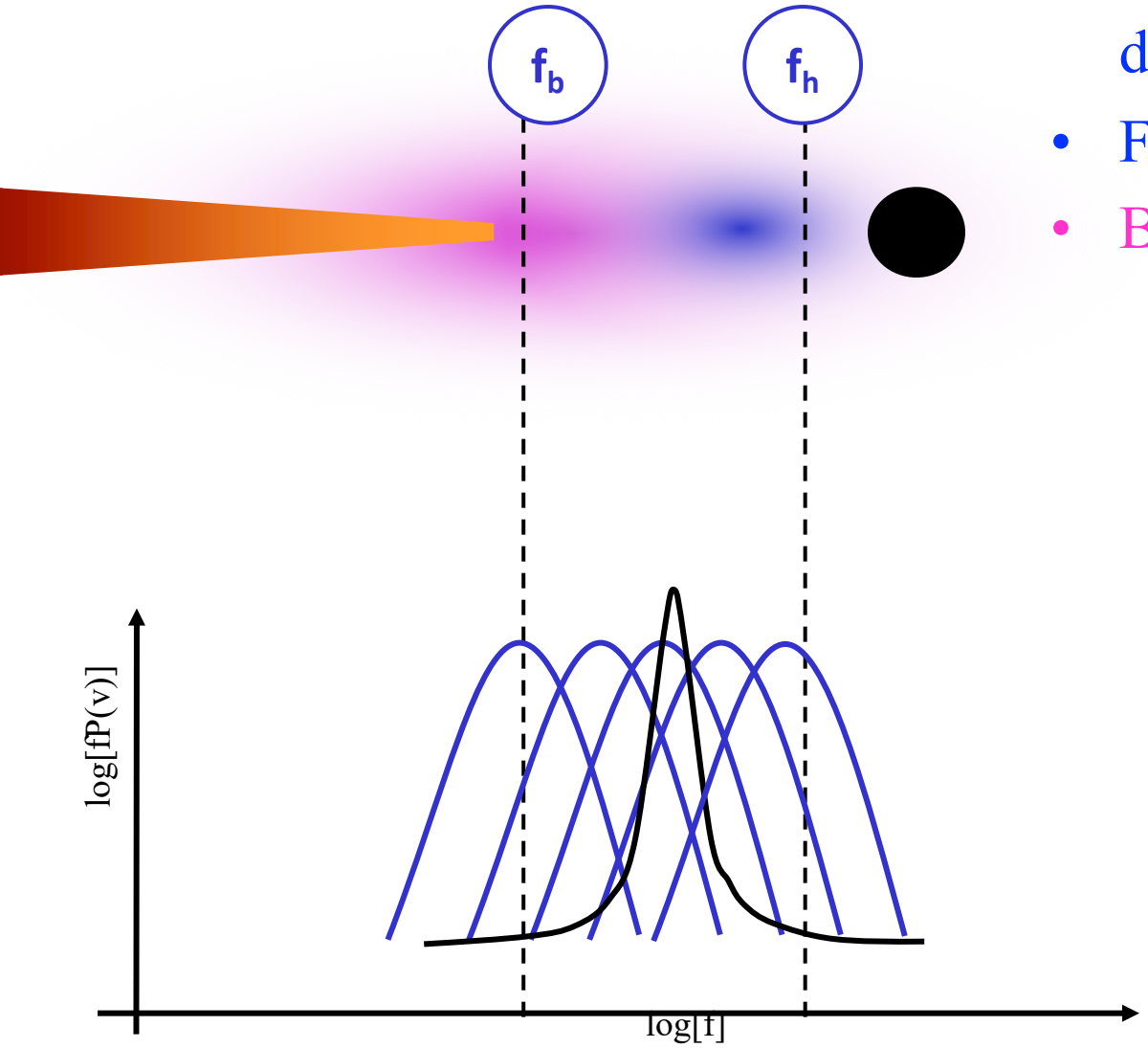
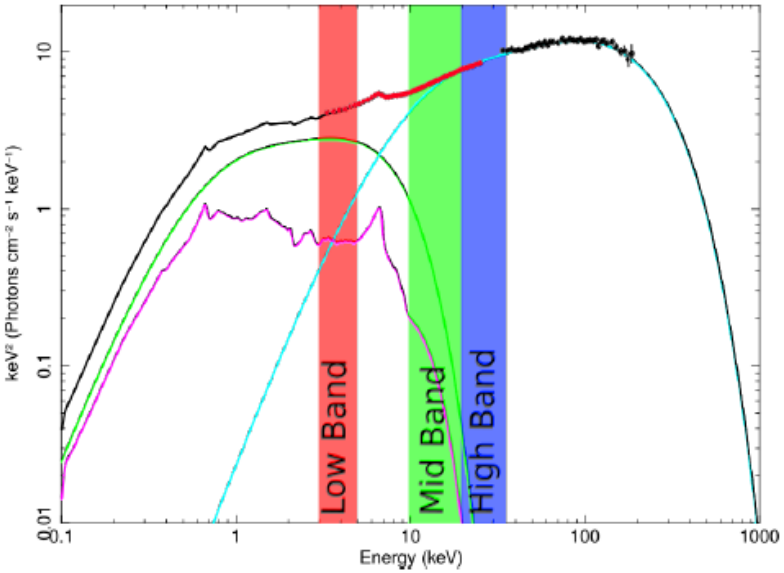
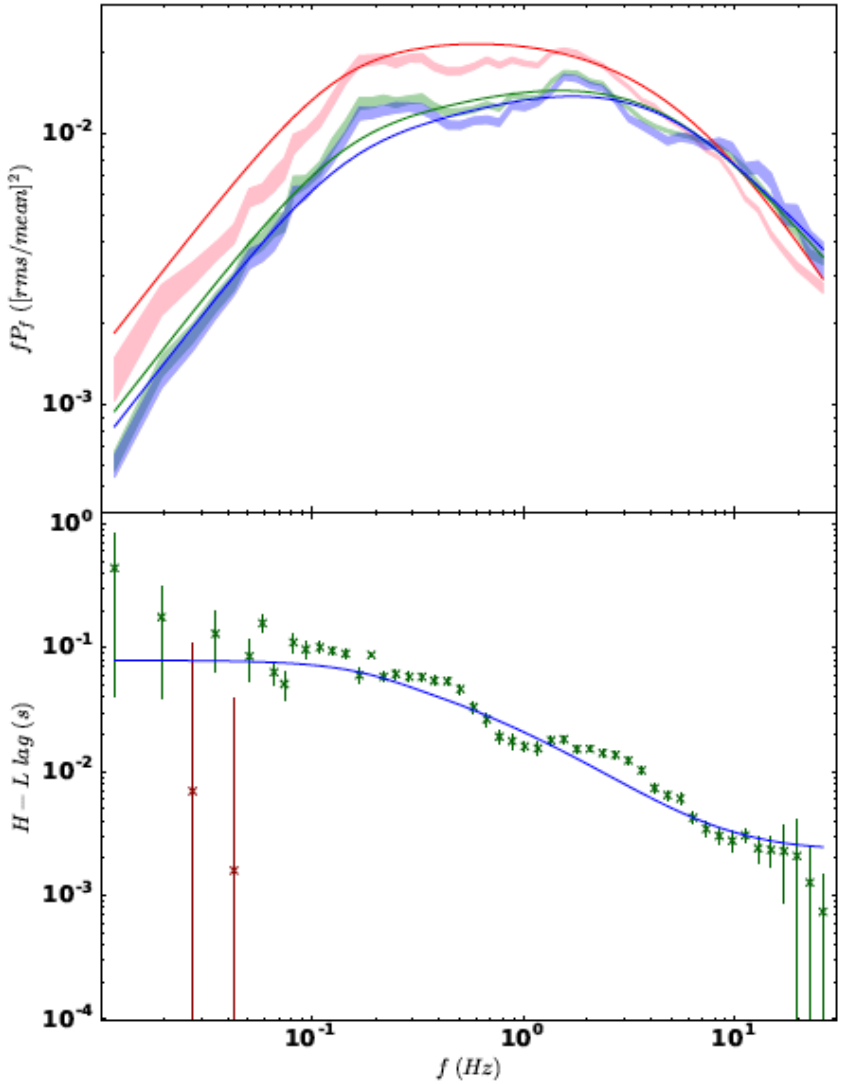



- Could be different in different regions
- Fvisc(R)=$B_H$ $f^{--mH}$ fφ(R)
- Bs =0.03 ms=0.5

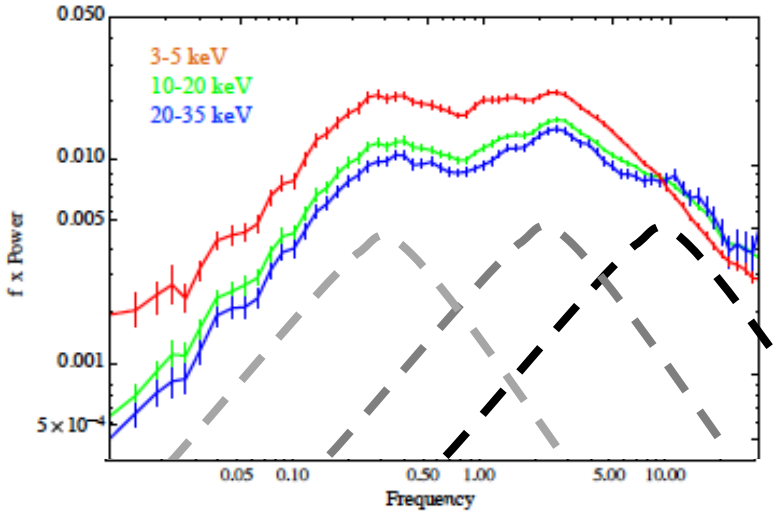
# Simplest spectral Model: 2 Comptonisation Zones

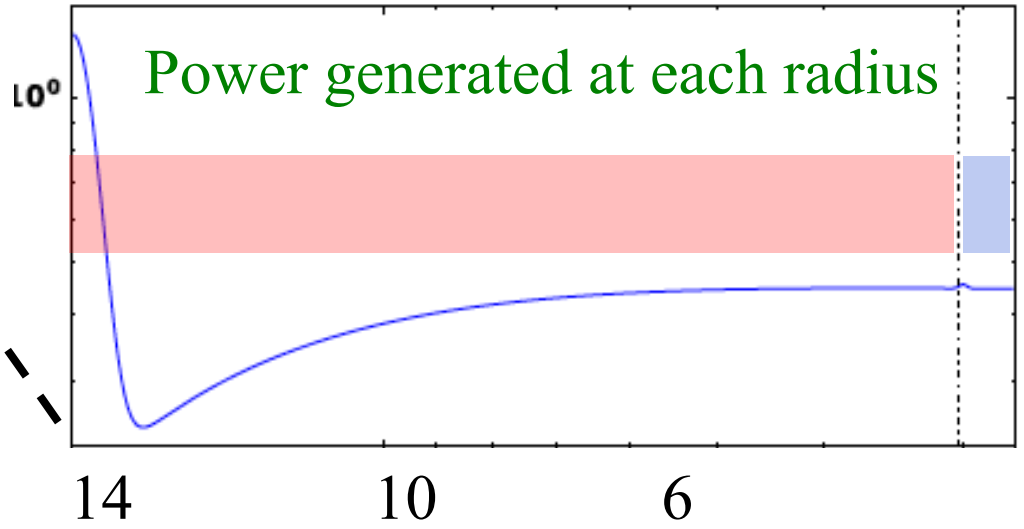


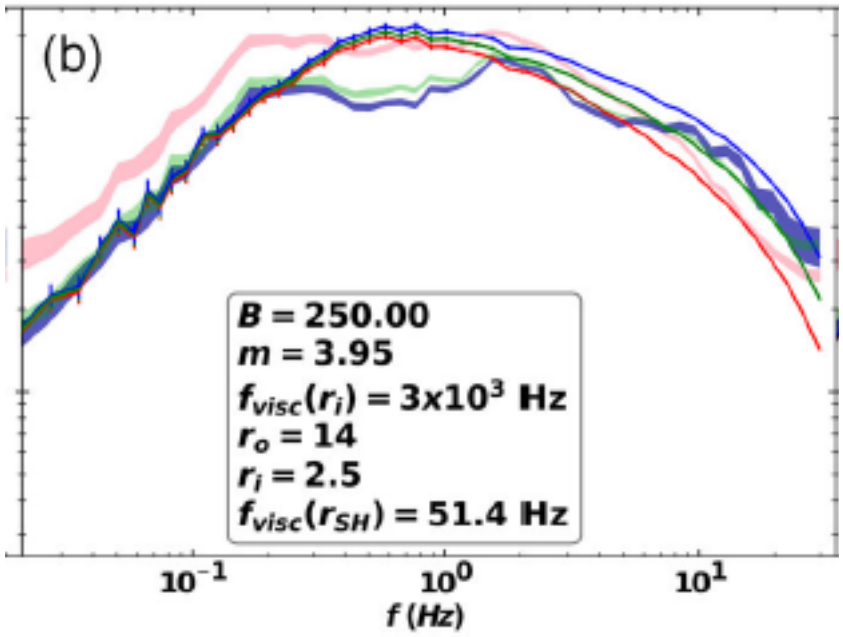




- Fit PSD(E) and lag(E) with soft R>RSH hard R<RSH
- Fluctuations Fvar(R)
- Emissivity ε(R)
- Propagation speed v(R)

Mahmoud & Done 2018b

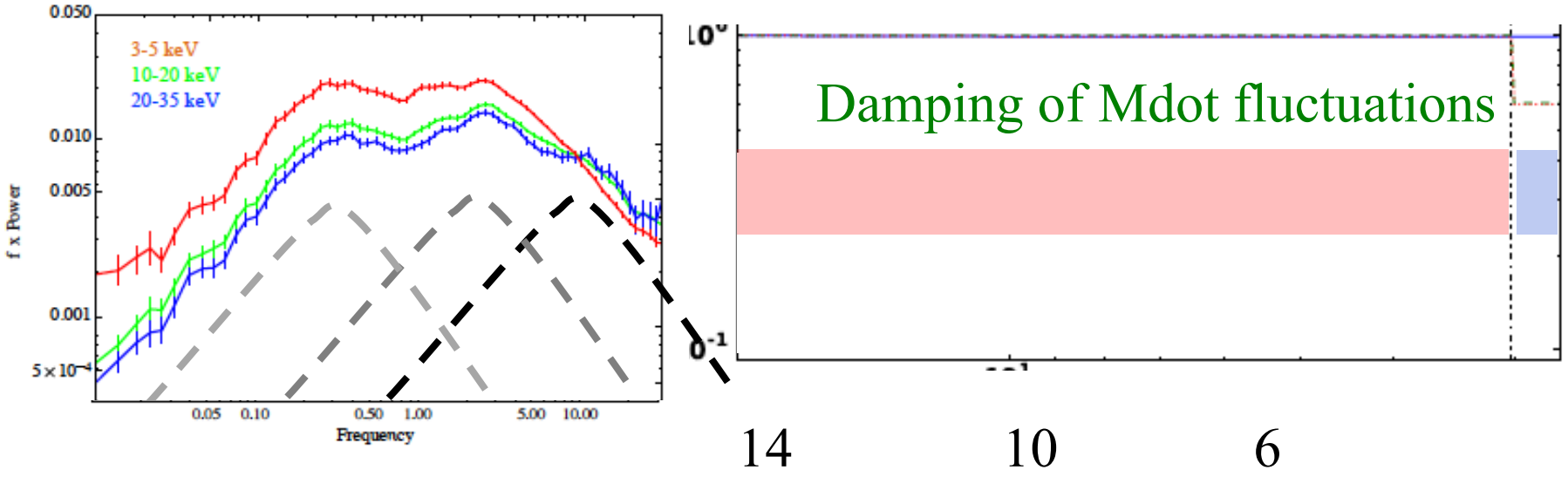


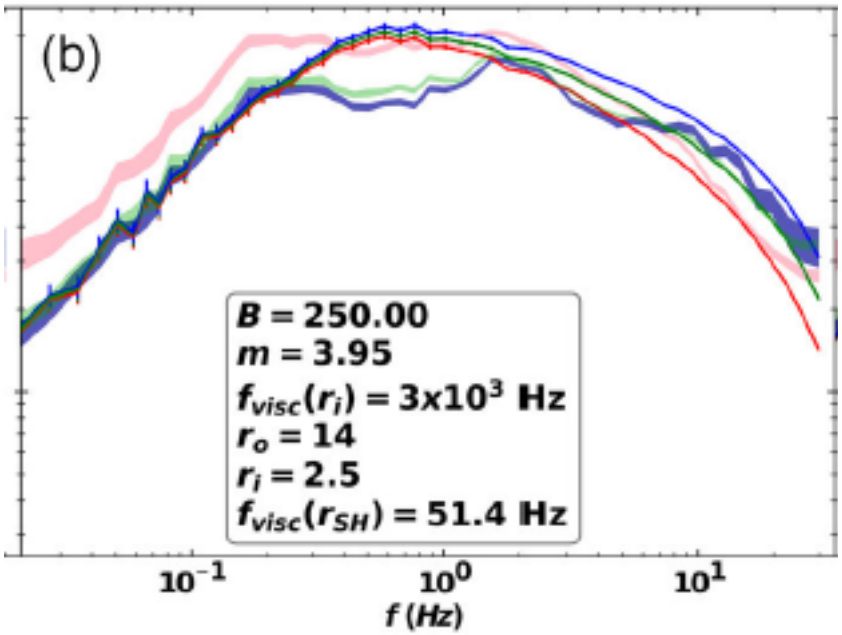




- bumpy power spectra
- Need more power generated at specific radii otherwise get smooth power spectra! Mahmoud & Done 2018a
- Turbulent transition from disc to flow?

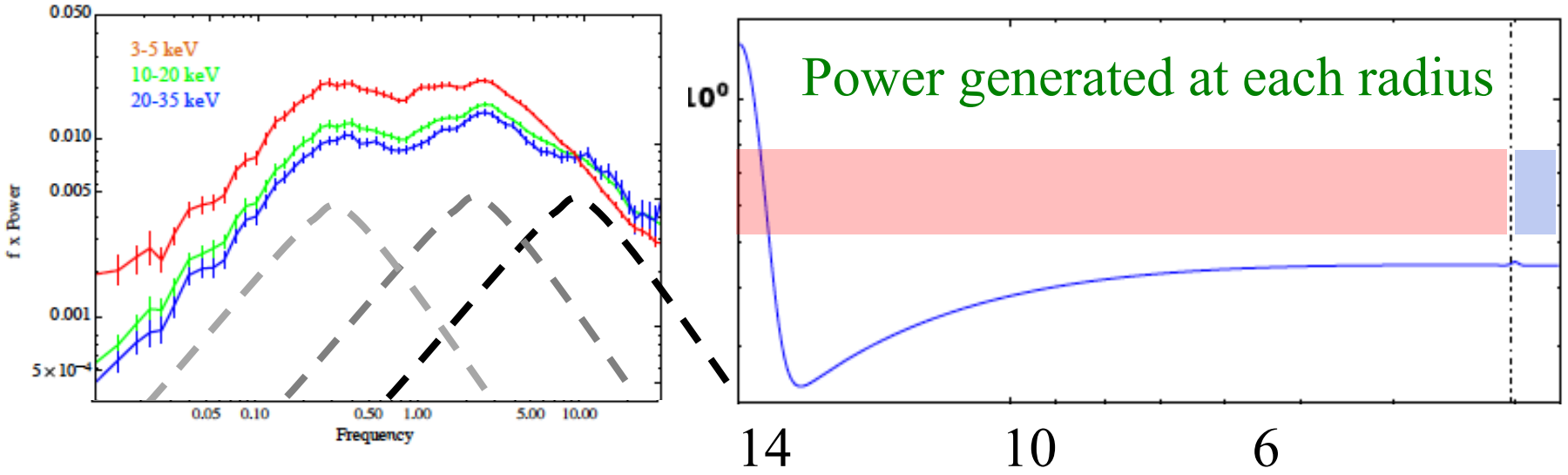
Mahmoud & Done 2018a

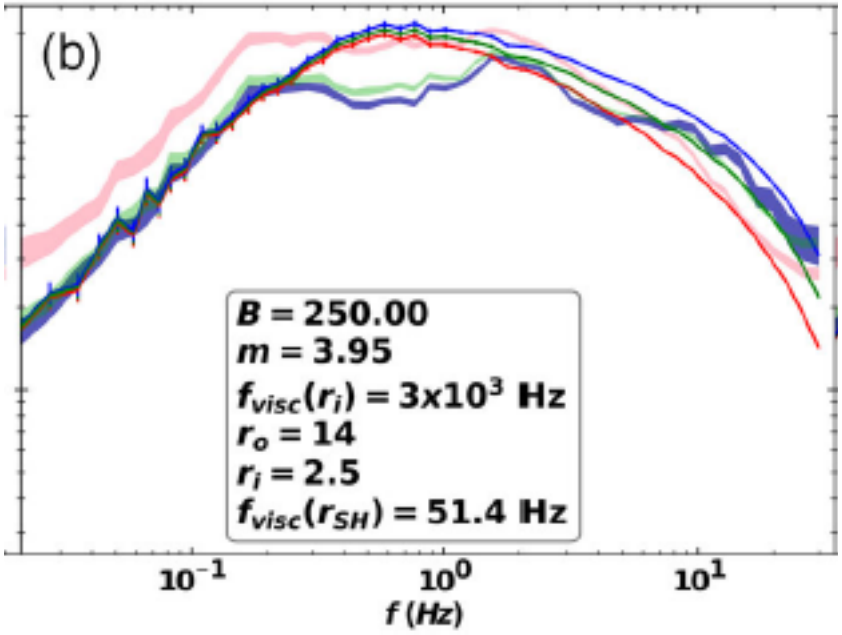



- Propagation needs to be damped at some radius
- Otherwise high energy power spectra ALWAYS bigger than low energy at low frequency

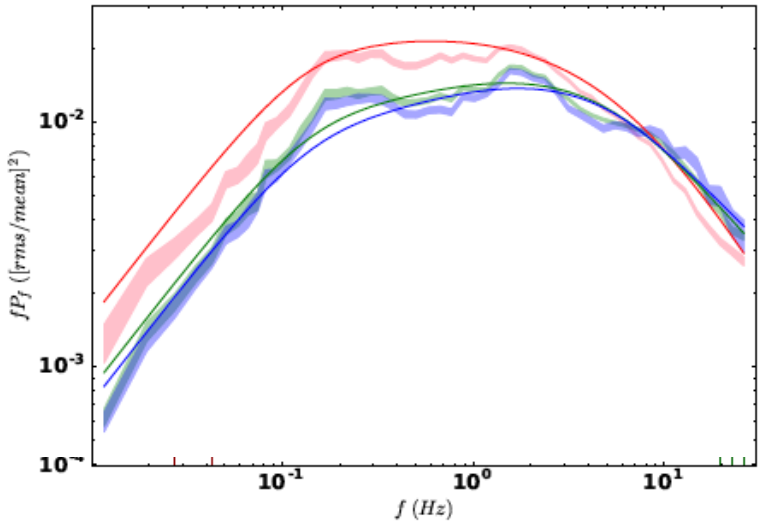
Mahmoud & Done 2018a



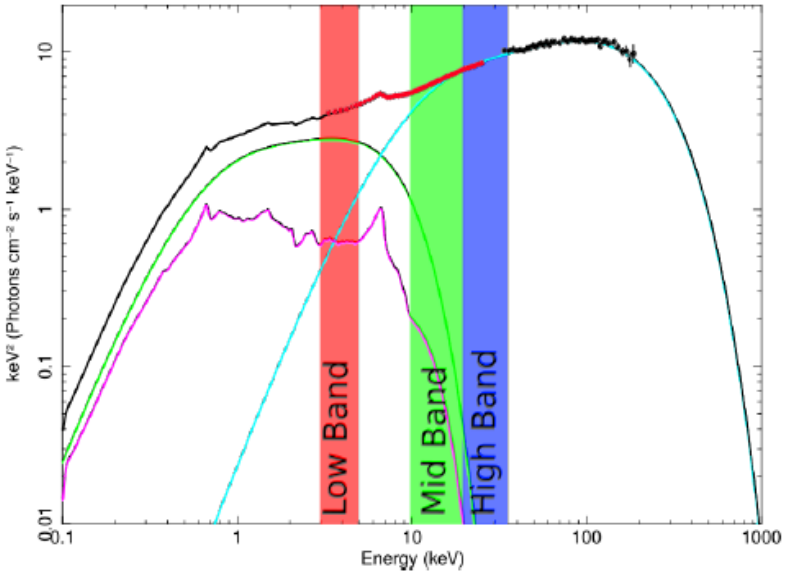



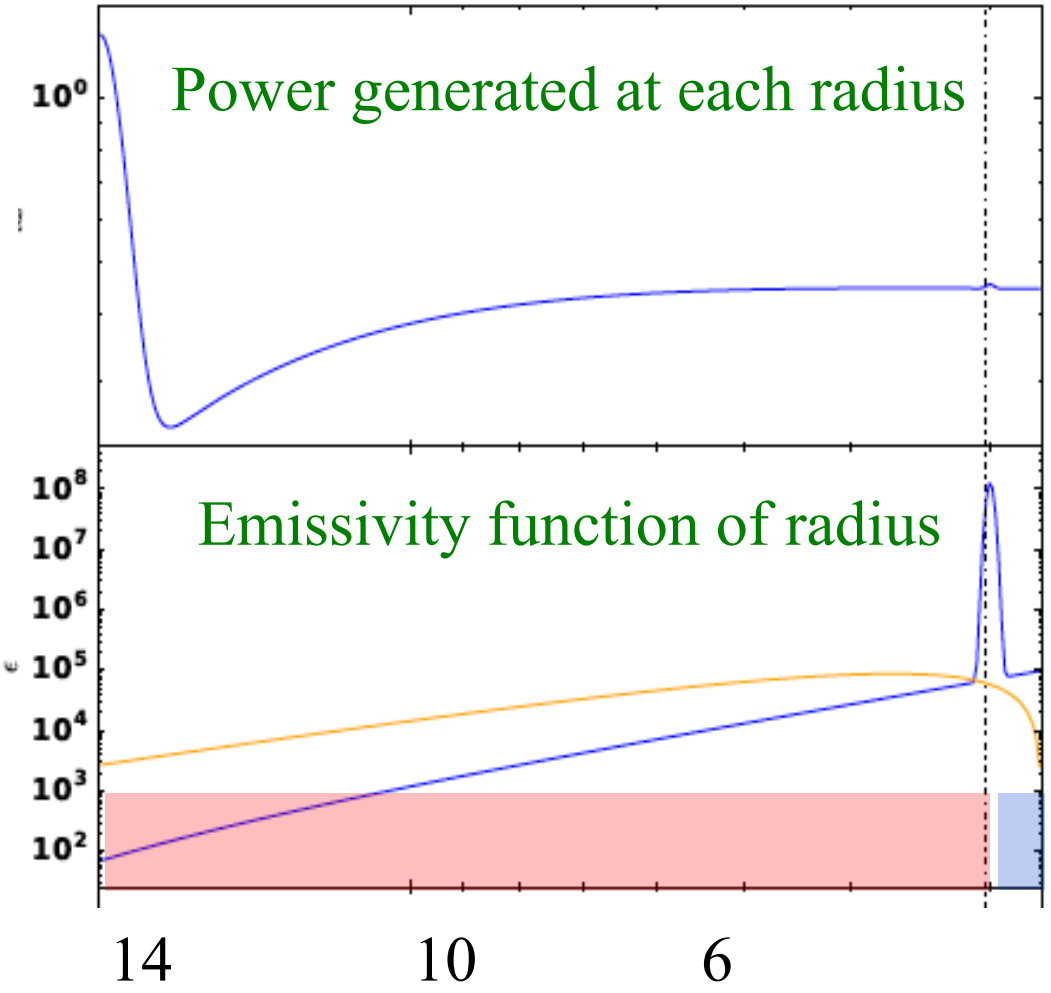

Mahmoud & Done 2018a

- Propagation and generation:
- $Fvisc(R)=Bf^{-m}\ f\varphi(R)$
- B=0.03 m=0.5 soft
- B=0.27 m=1 hard
- Decorrelation at high f means RSH VERY SMALL 3Rg



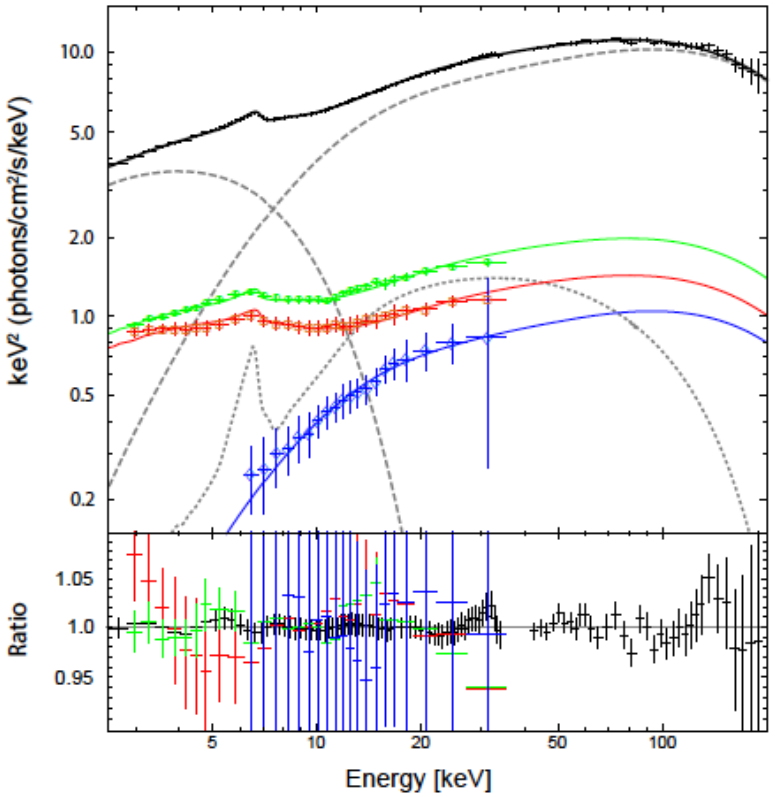

Mahmoud & Done 2018b



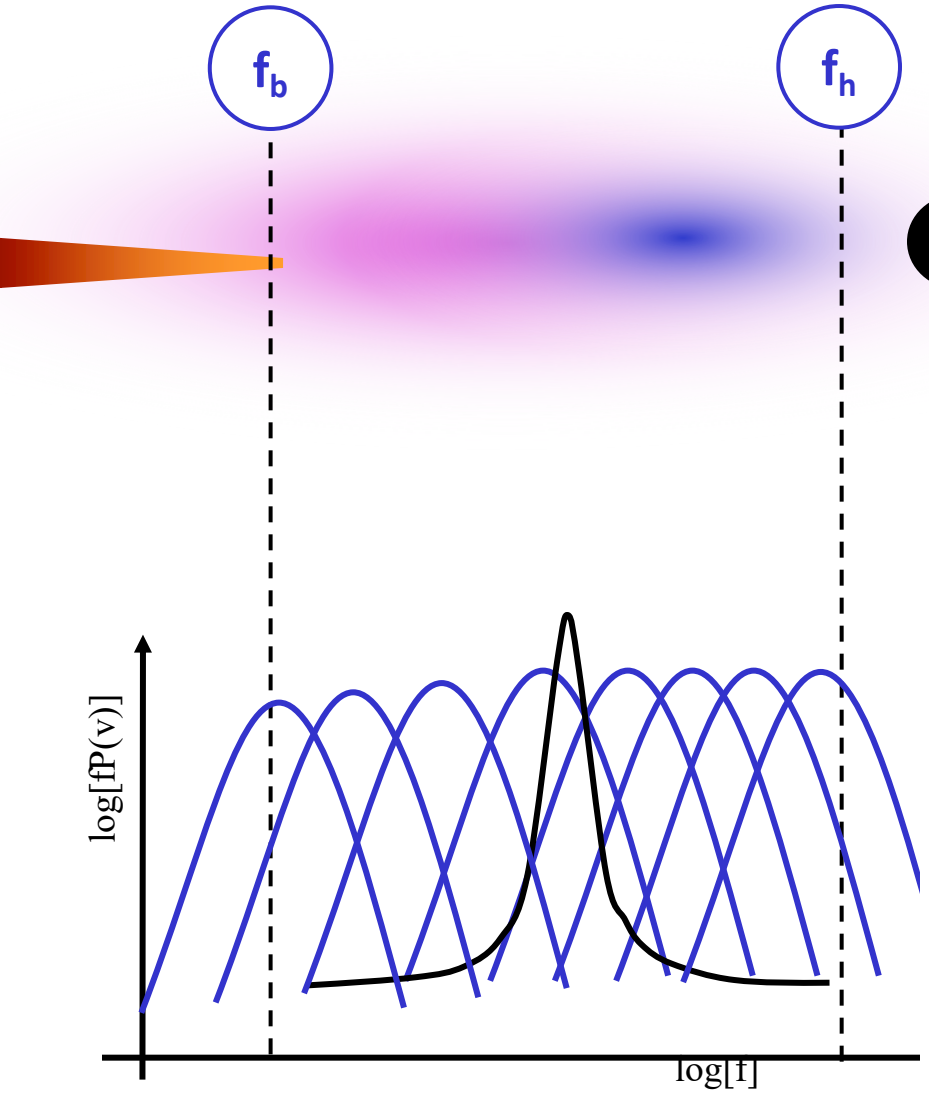

- Need enough emission associated with each radii to get total hard and soft spectra and correct shape of power spectra at each energy

# Assumptions!!! Spectral shape

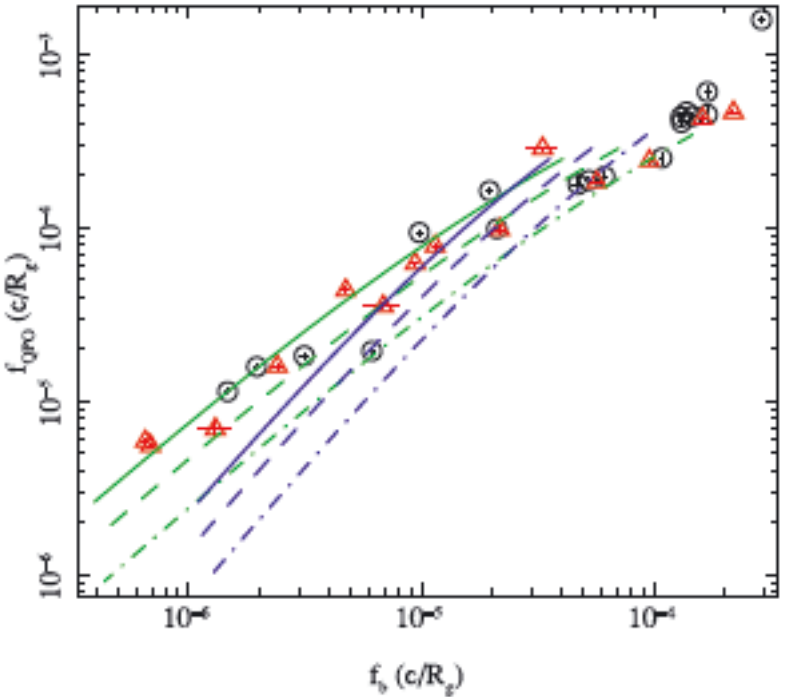



- Only norms change
- But might expect spectral shape to change as well - pivoting
- Seed photons on light speed, Mdot dissipation on propagation speed
- Veledina /Poutanen
- Mastreoserio / Ingram

# Assumptions!! Viscous timescale




- We want fvisc(R) for SAME geometry – same average Mdot



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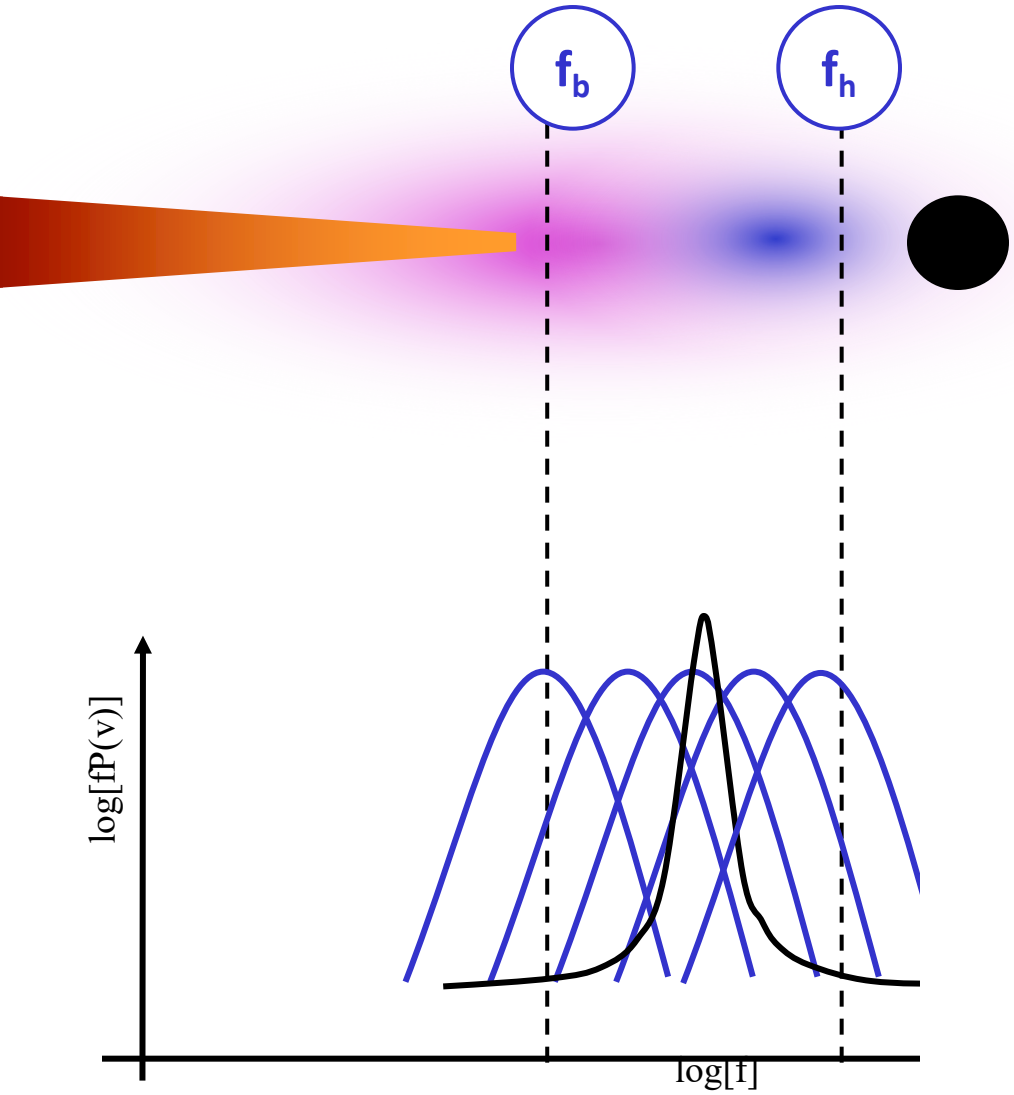


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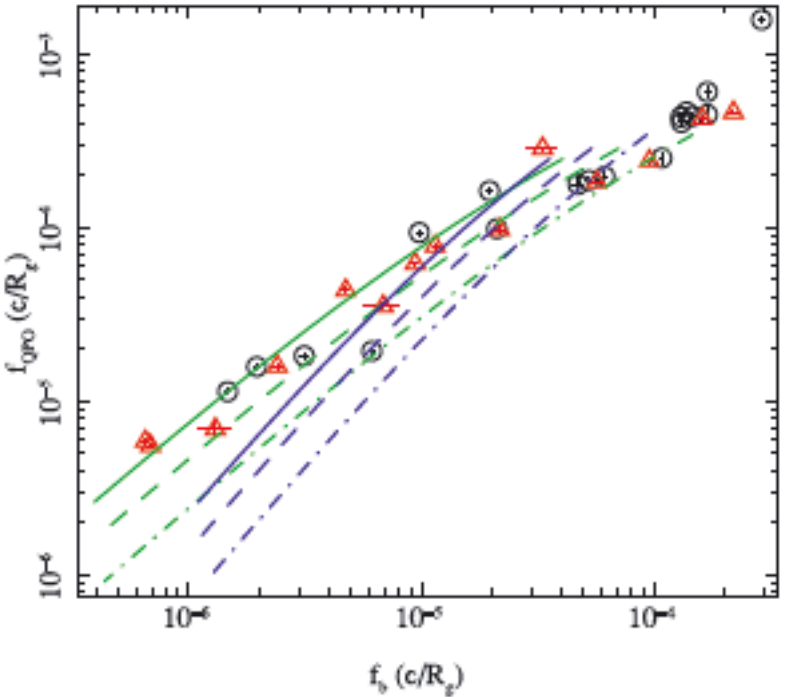

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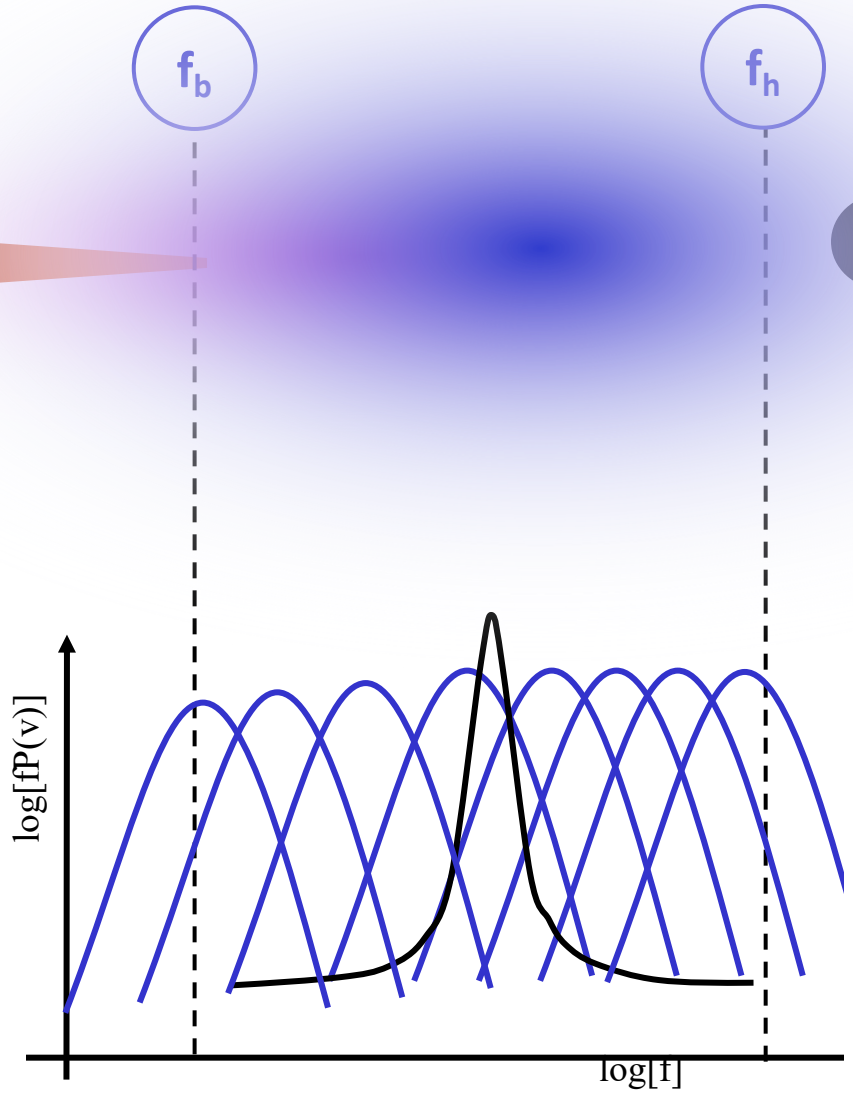
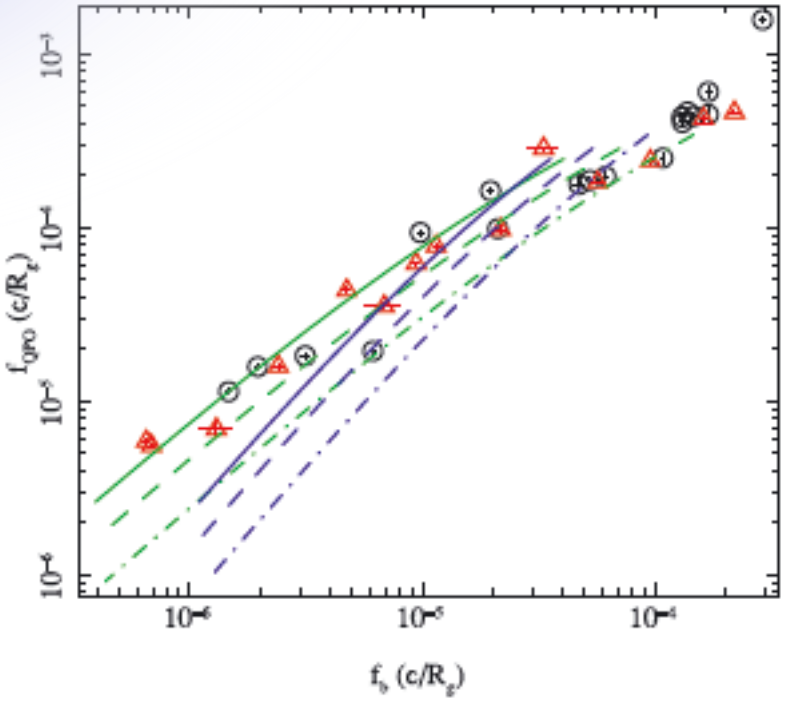
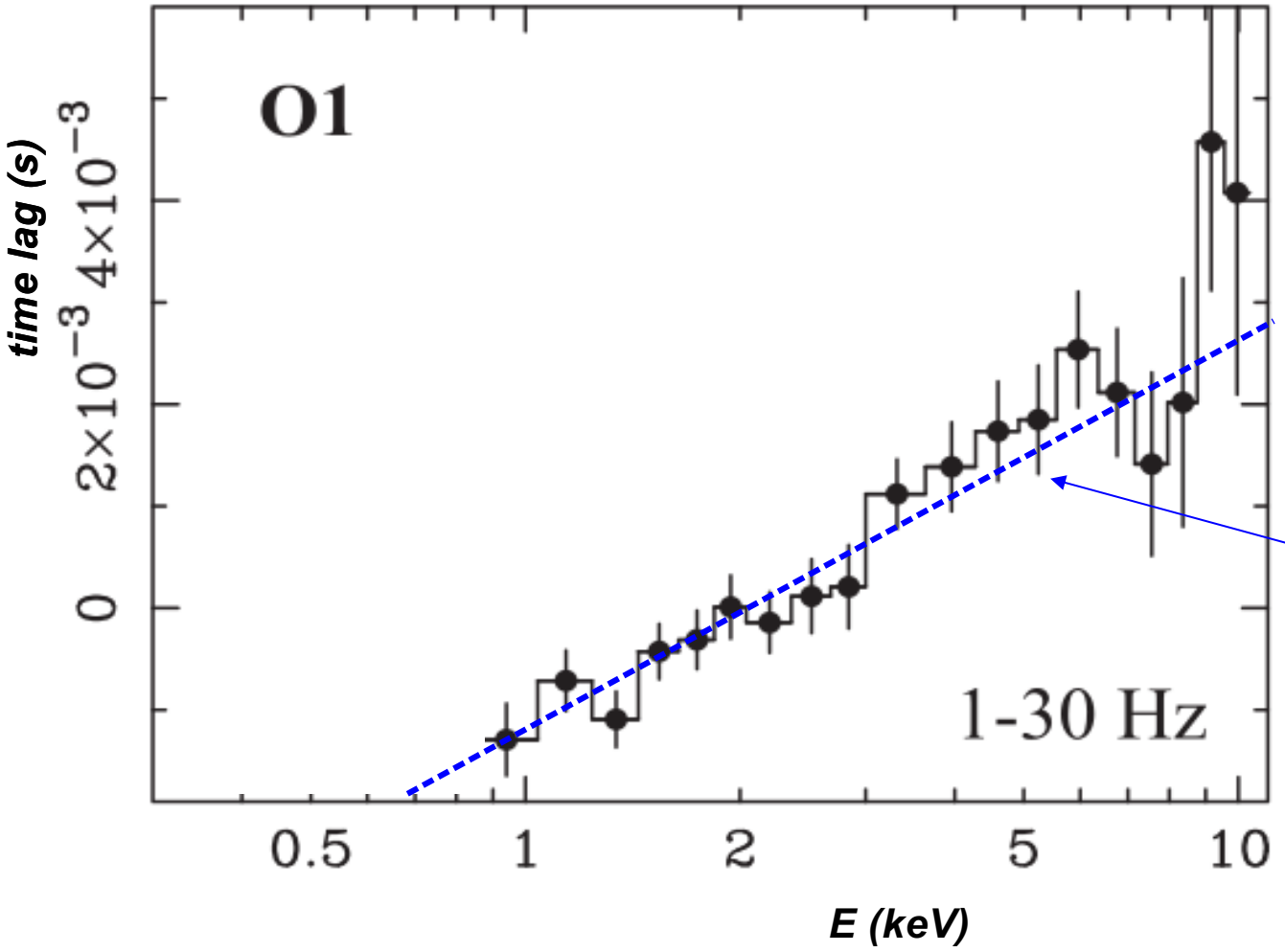



- We got fvisc(Rout) for changing Mdot / Rout
- What if geometry changed as well??



# Thermal Reverberation in X-ray Binaries: GX 339-4




Hard lags in continuum (propagating fluctuations?)

De Marco+ 2

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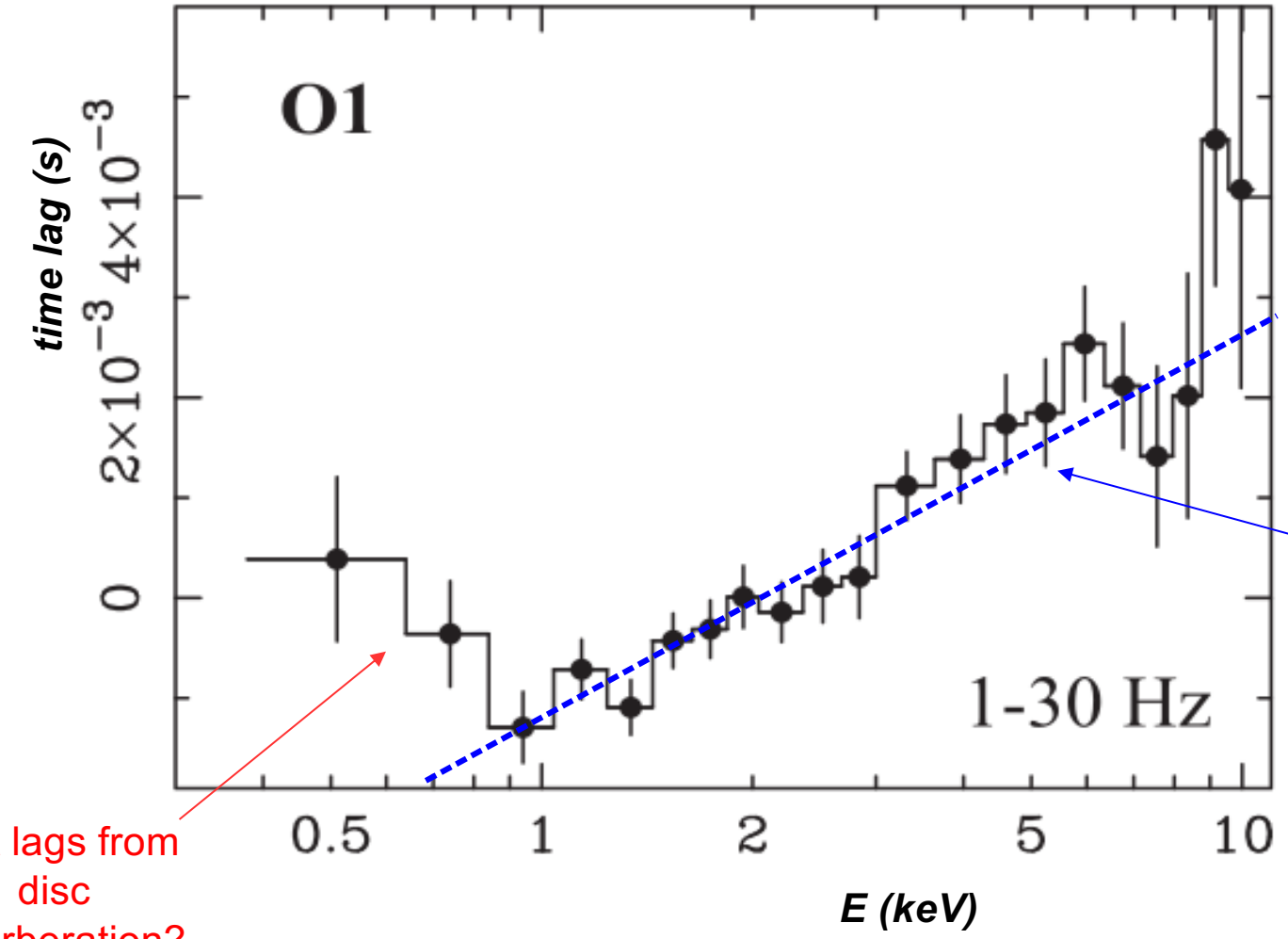
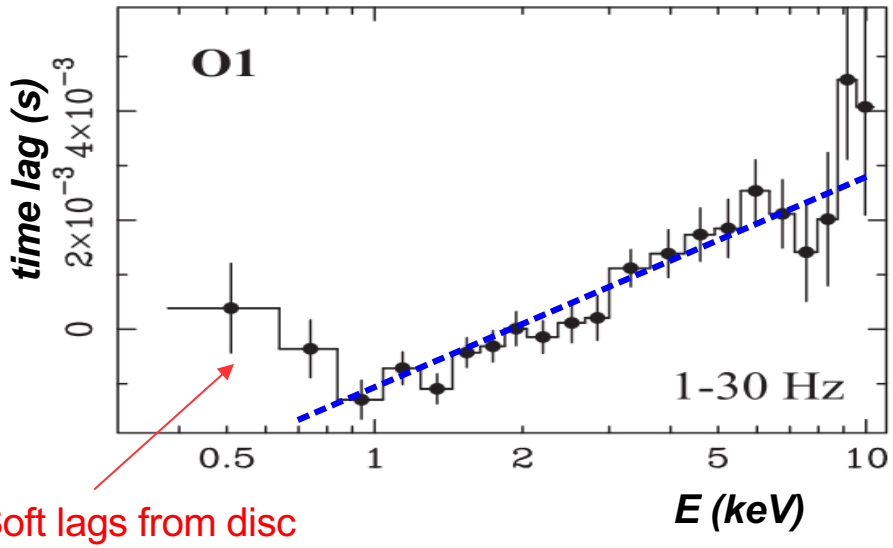



Soft lags from disc reverberation?

Hard lags in continuum (propagating fluctuations?)

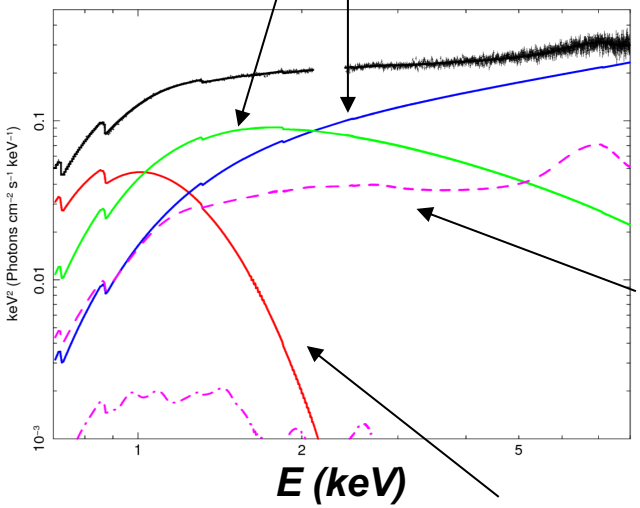
De Marco+ 2

# Thermal Reverberation in X-ray Binaries: GX 339-4

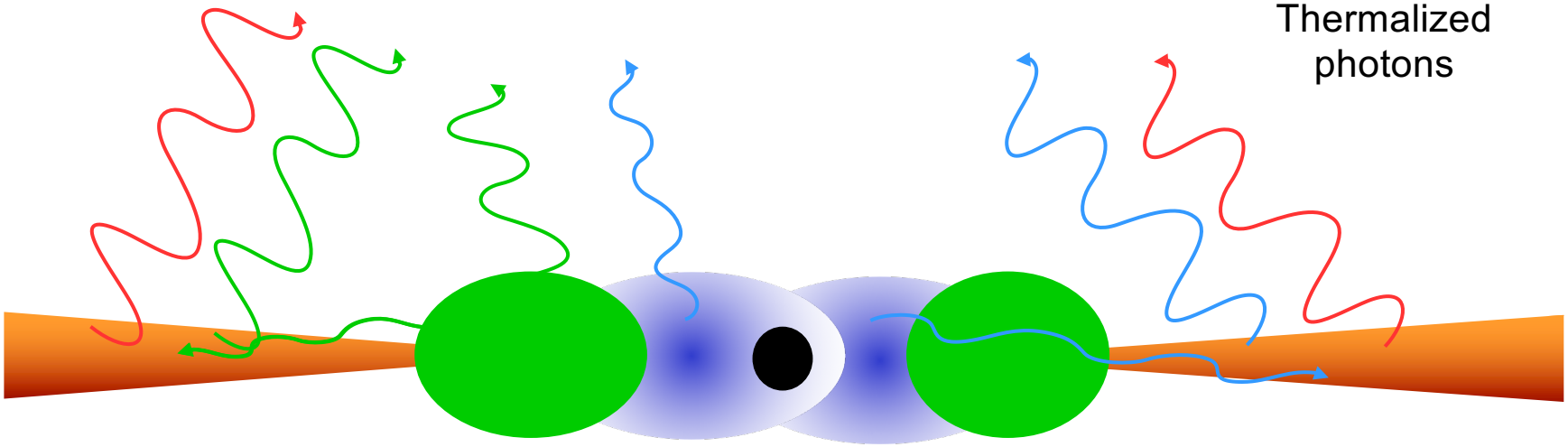



Soft lags from disc reverberation?

Comptonised photons



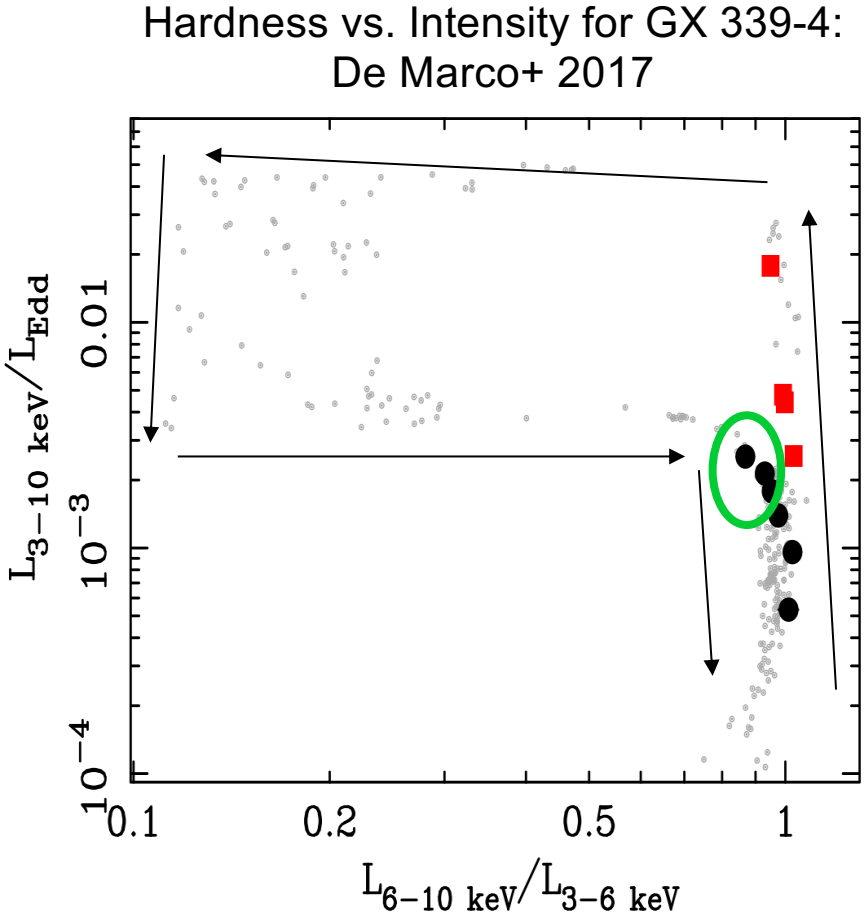

Reflecte photon



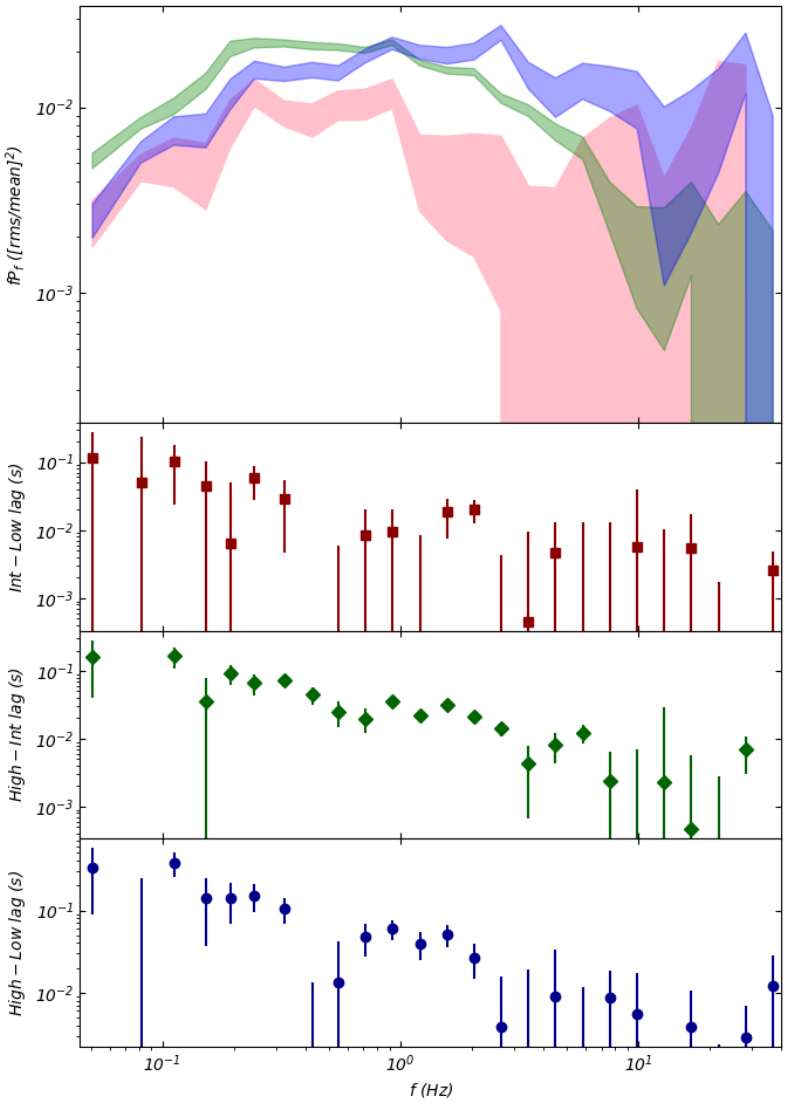
Thermalized photons

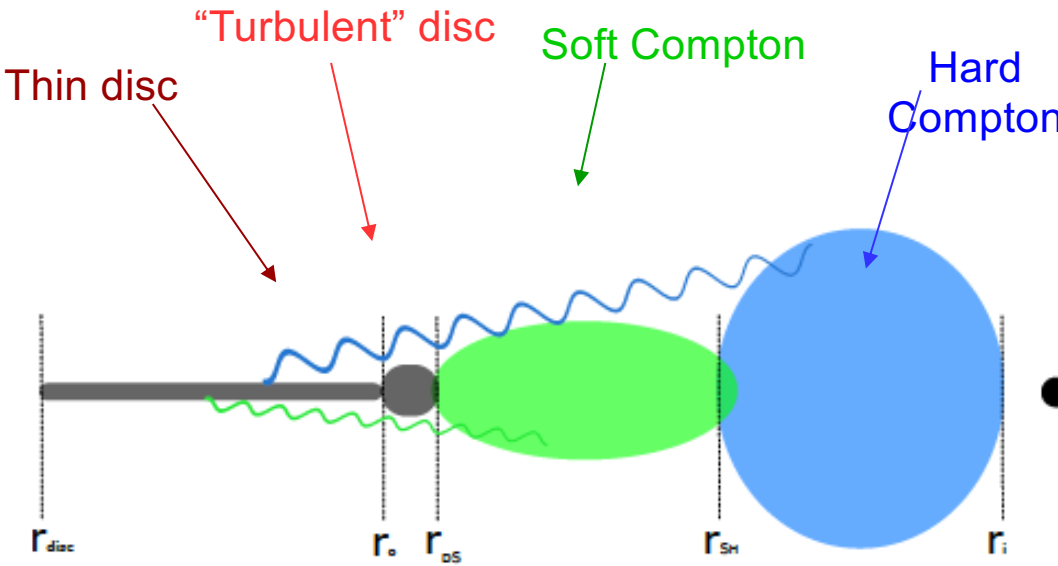
# GX 339-4: Data Selection

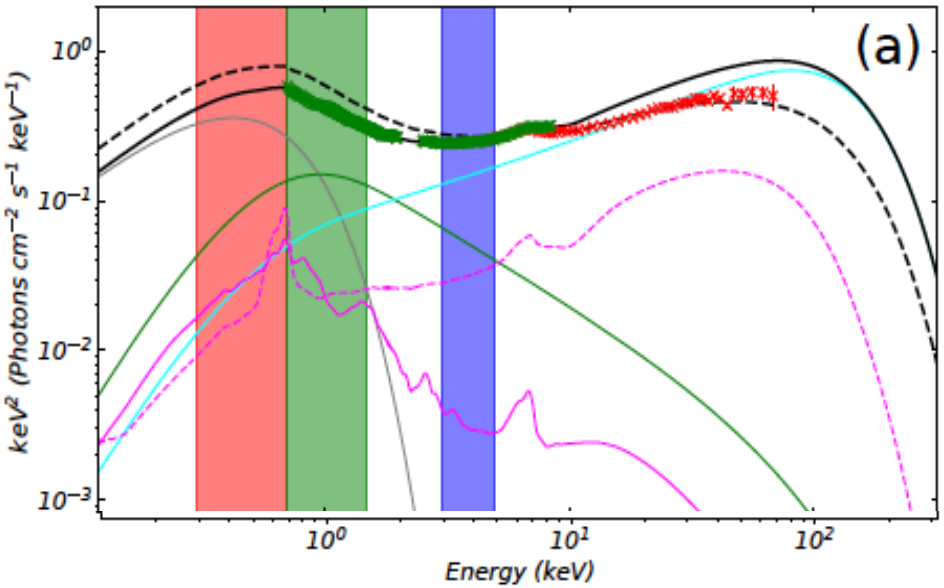
- we select ***dim*** **hard state** data and **extend our model to include reverberation**.
- Bright hard state more complex!



# Dim Hard State GX 339-4

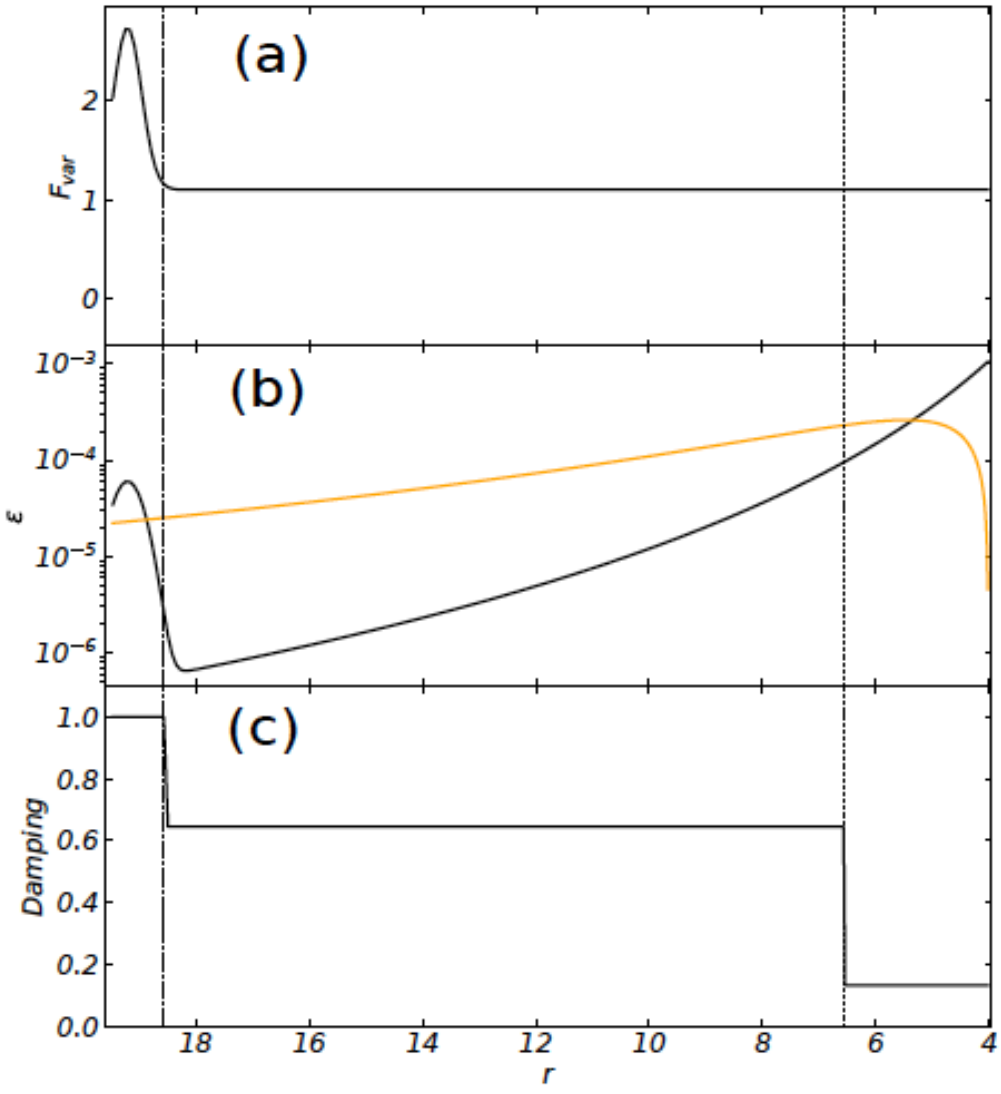


# Dim Hard State GX 339-4

- Big turbulent region at transition from disc to Compton!
- Big hump of emissivity there as well
- Highly peaked to low R as need to get enough high f and high E luminosity
- Damping as not all disc shredding power transmitted into Compton



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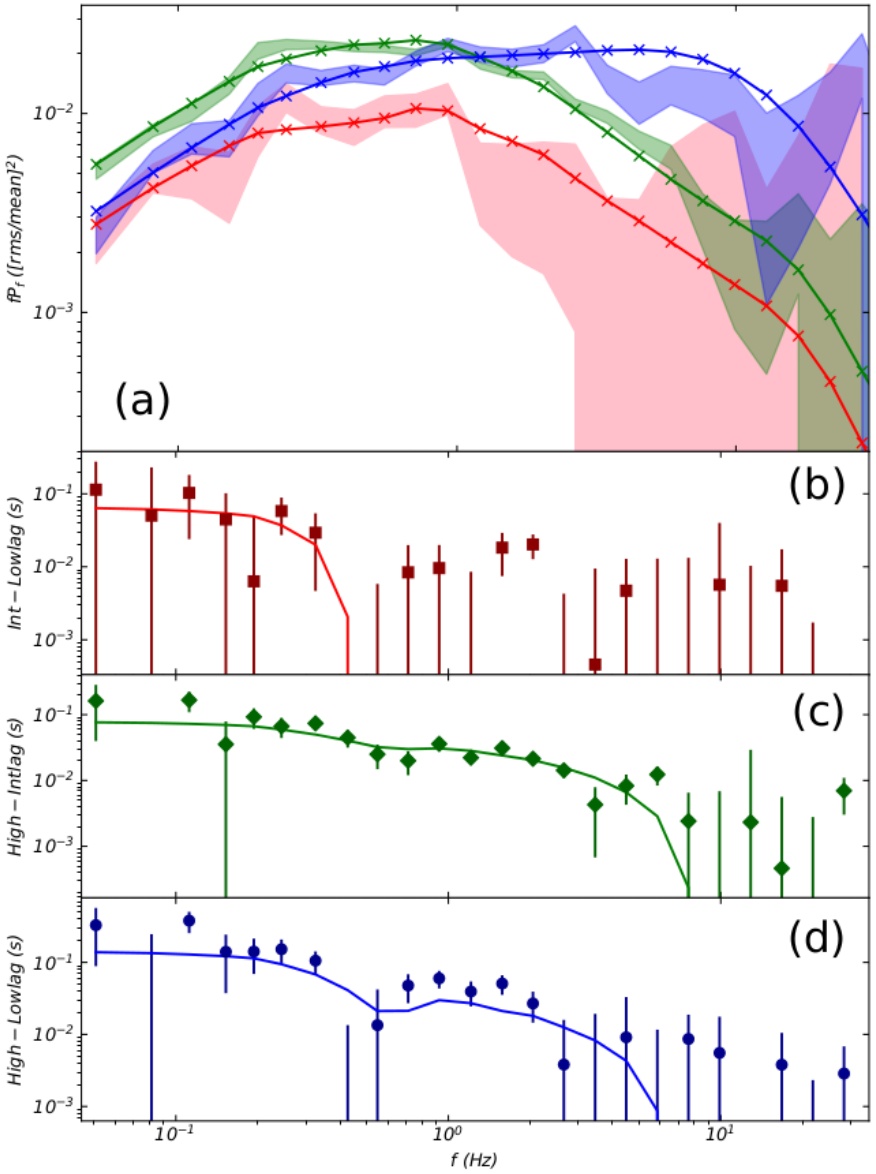
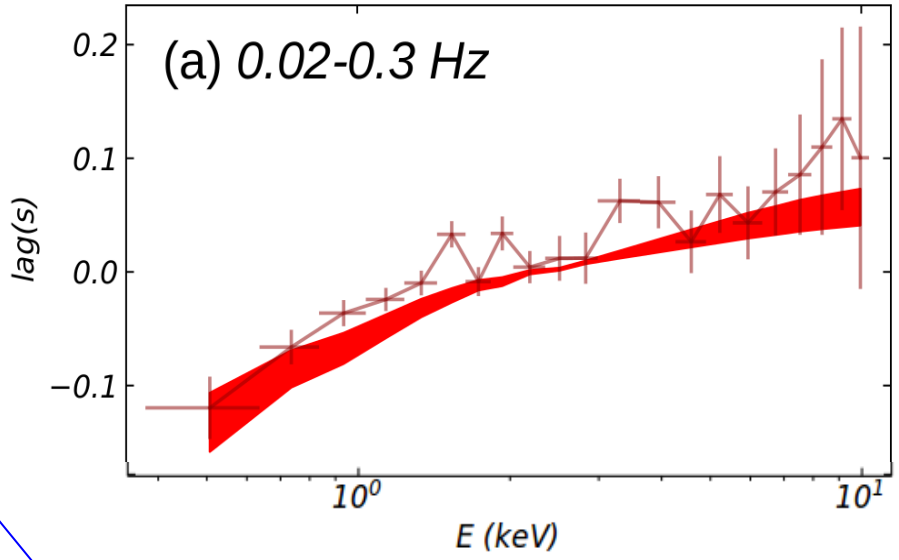
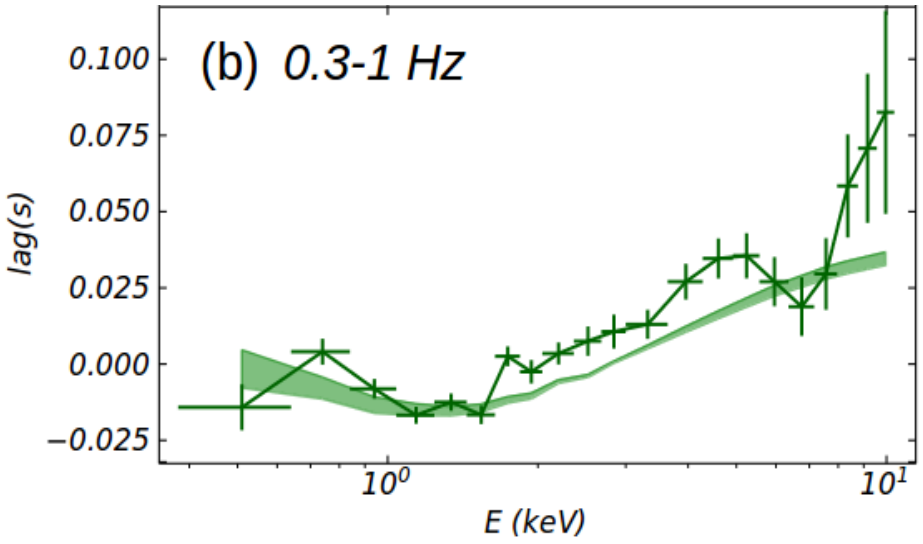
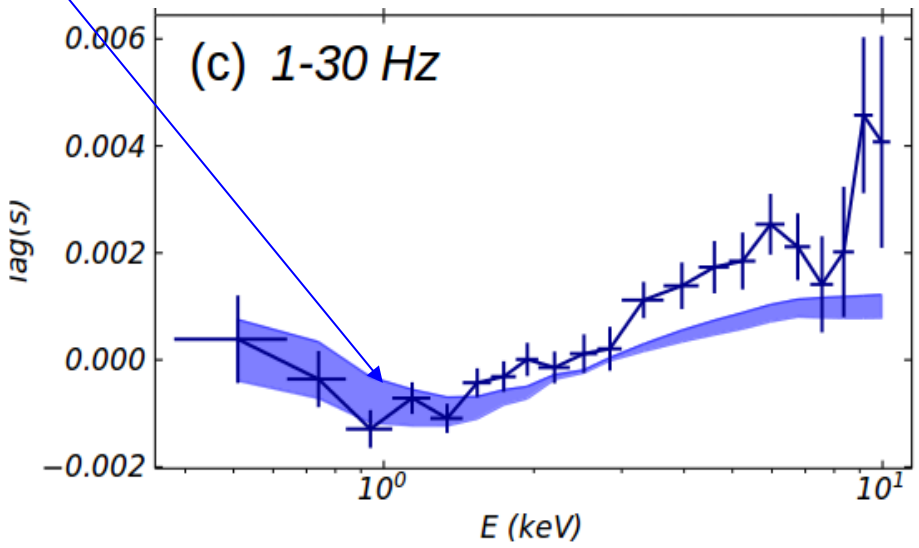


# PREDICTED Lag vs. Energy

- Lag-energy ***predictions*** from to power spectra & lag-frequency.
-
- Log-linear trend switch: reverberation lag signature.



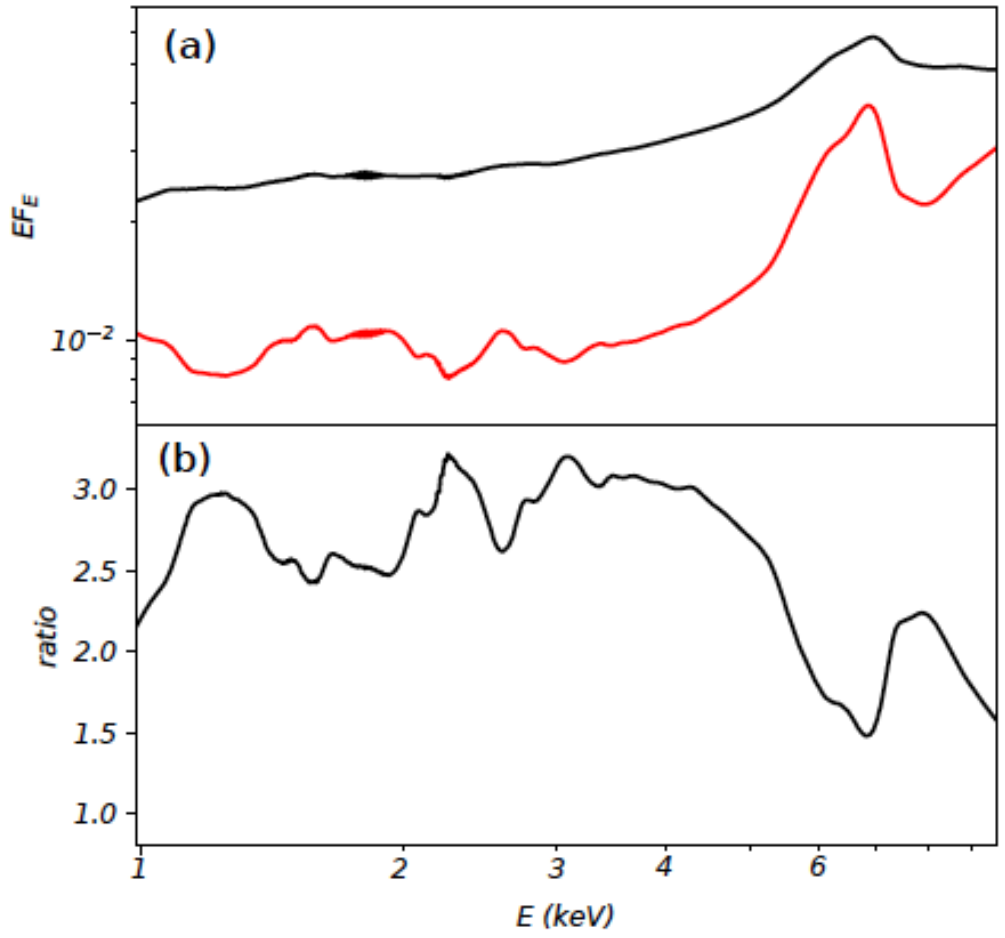




Mahmoud, Done + De Marco 20

# Reflection – changes ionisation!

- REFLECTION is not simply changing norm



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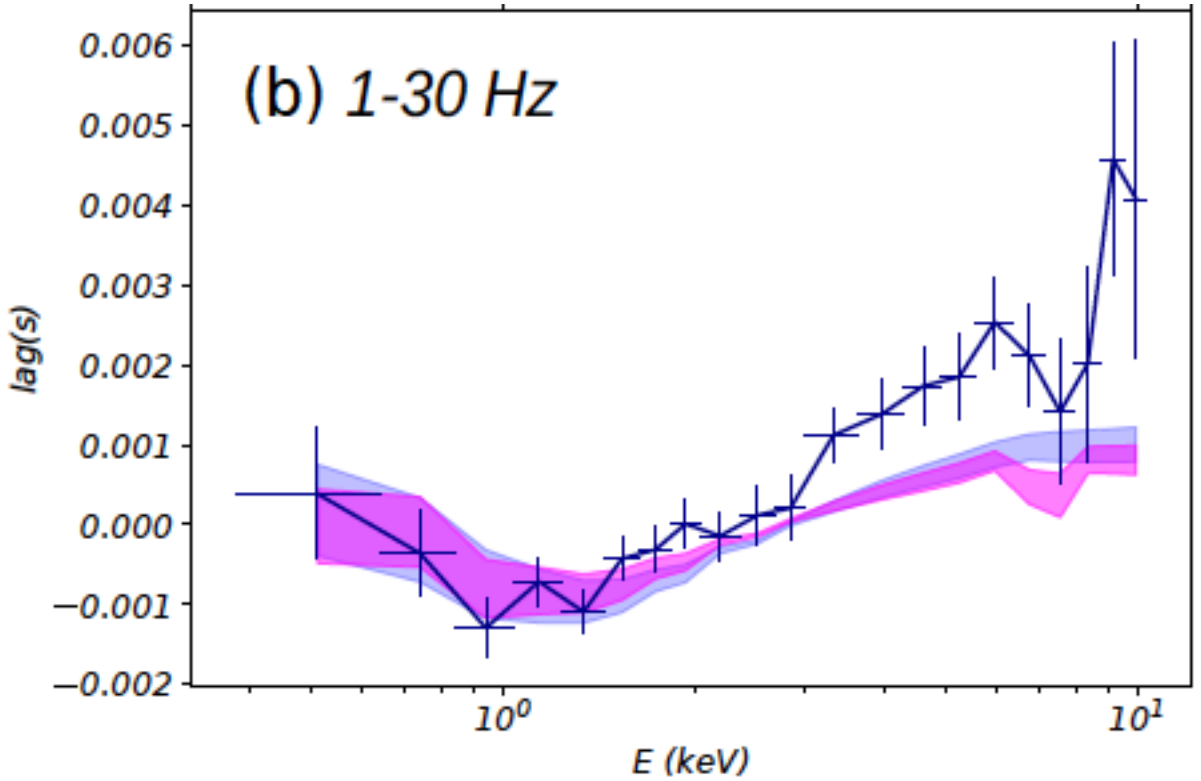
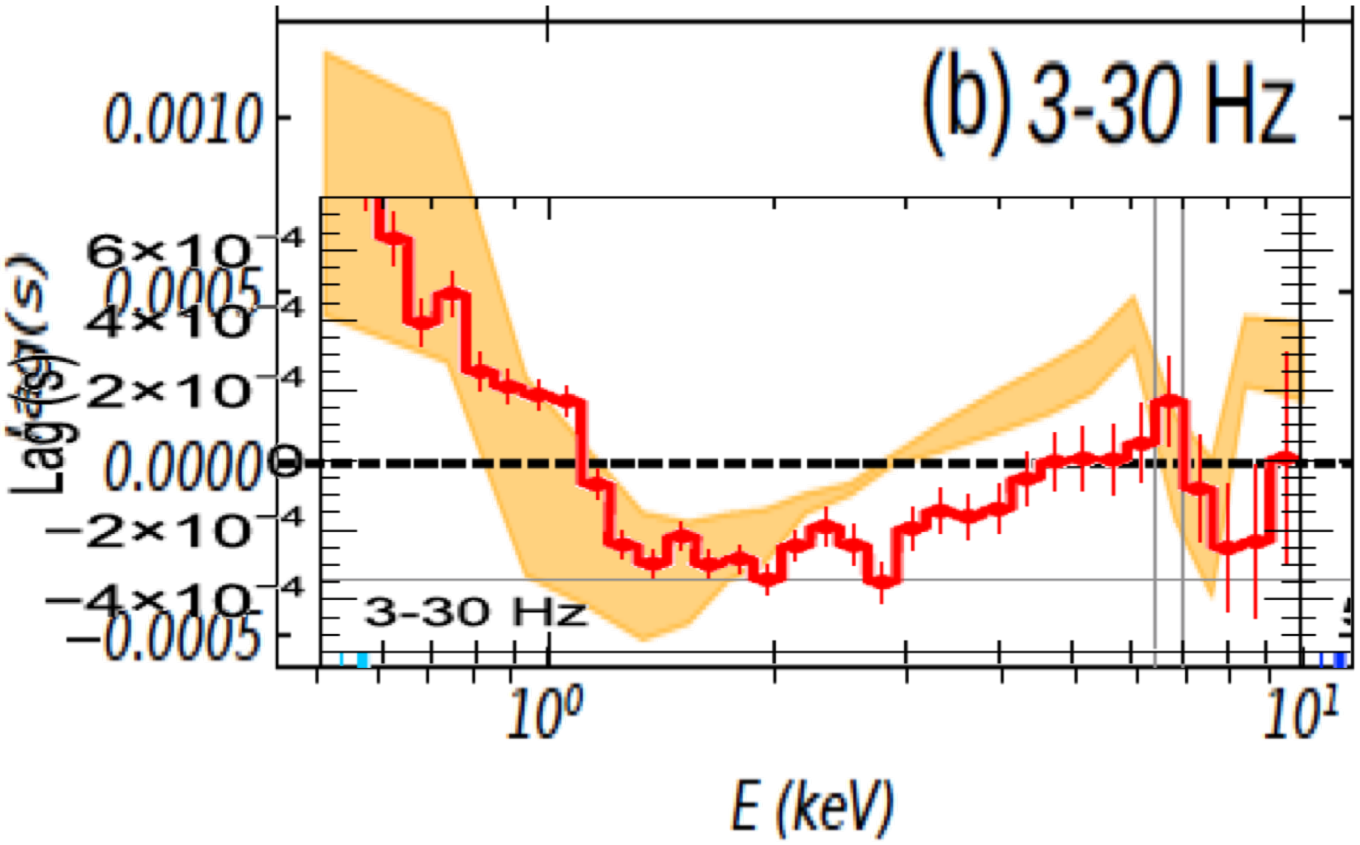



Mahmoud, Done + De Marco 20

# Comparison to J1820 NICER data




Mahmoud, Done + De Marco 20

# Conclusions:

- IT'S VERY HARD TO FIT EVERYTHING!!!
- But at least we tried!!
- Lamppost modellers – see if you can model the lags and PSD(E) and frequency resolved spectra!!
- Fundamental issue – propagation doesn't add coherently when lagged
- Makes it very hard to get high frequency power – needs enormous emissivity at small radii
- Power law fvisc in compton?
- Spectral changes – pivoting and reflection xi?
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