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TIME LAGS FROM REFLECTION IN BLACK HOLE BINARIES

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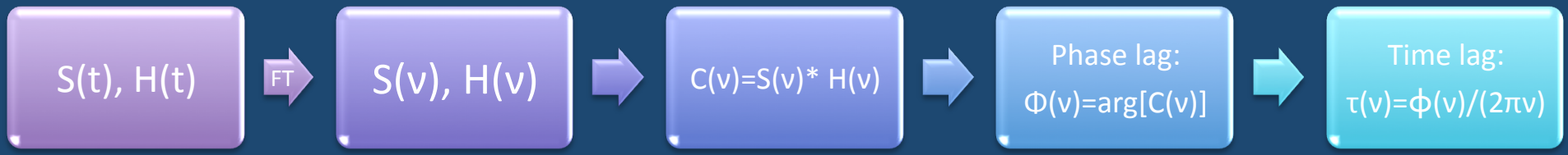
HIGH ENERGY VIEW OF ACCRETING OBJECTS: AGN AND X-RAY BINARIES

Time lags?

Time lags are observed delays in the arrival times of two signals coming from the same source, e.g. in two different bands (soft and hard)

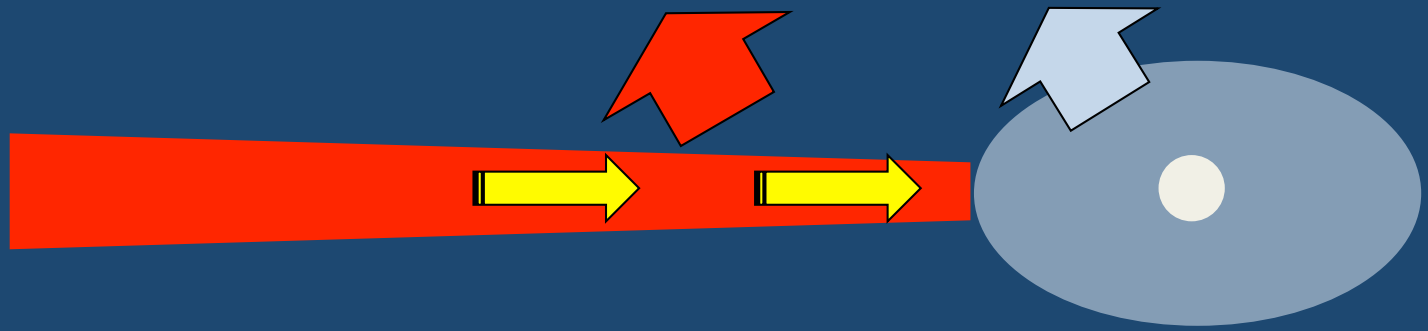
Firstly introduced by Miyamoto et al (1989), who showed that hard band photons are usually observed after soft photons

Allow mapping of emission mechanisms onto the accreting system, and give constraints on the geometry/physics

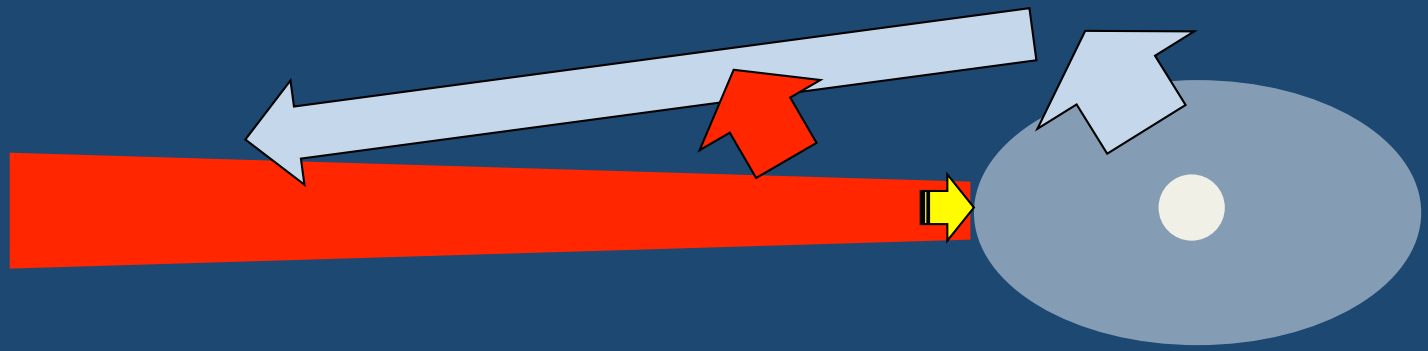


What can cause lags?

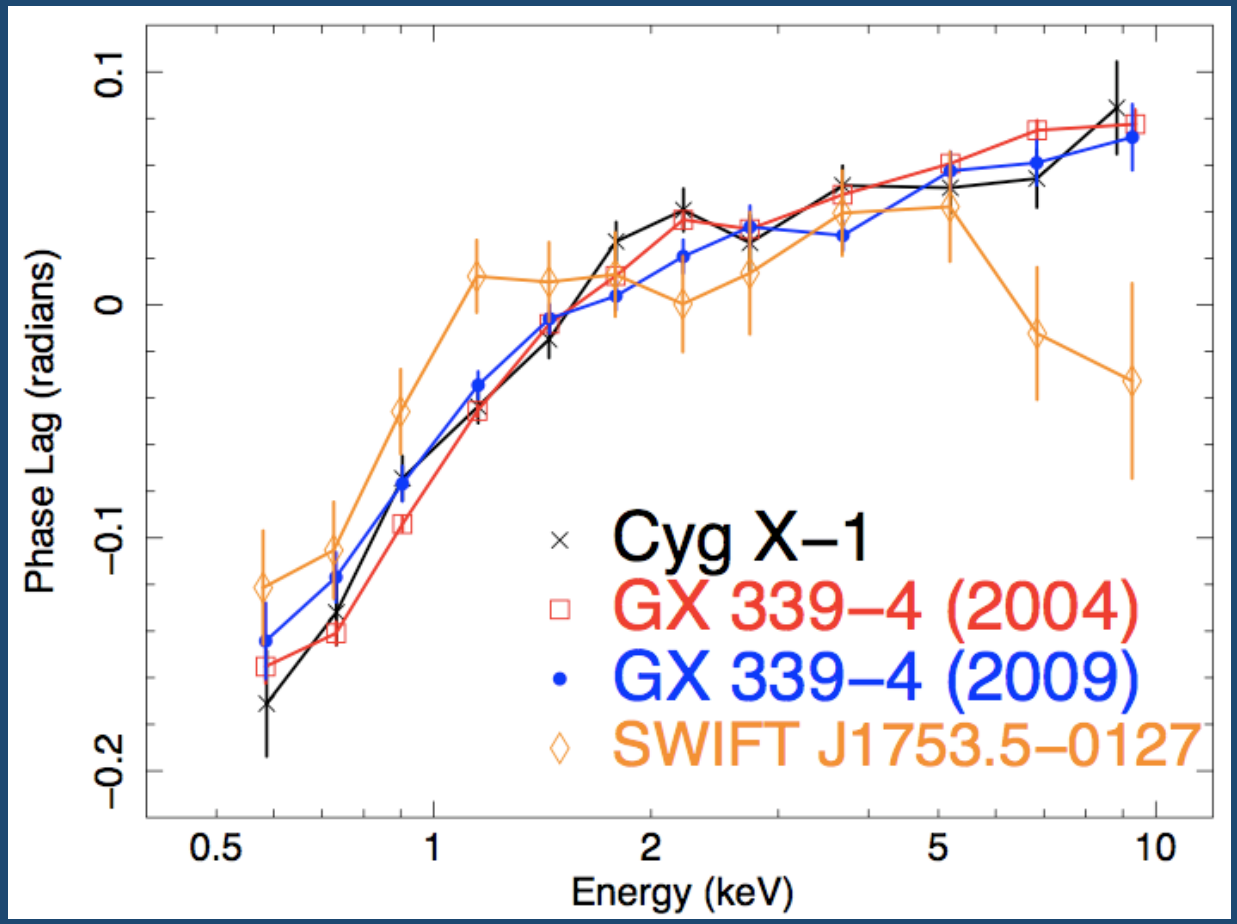
1. ***Propagation of accretion instabilities*** (Arévalo & Uttley, 2006; Kotov et al, 2001…)



2. ***Large scale reflection*** (Kotov et al, 2001; Poutanen, 2002…)

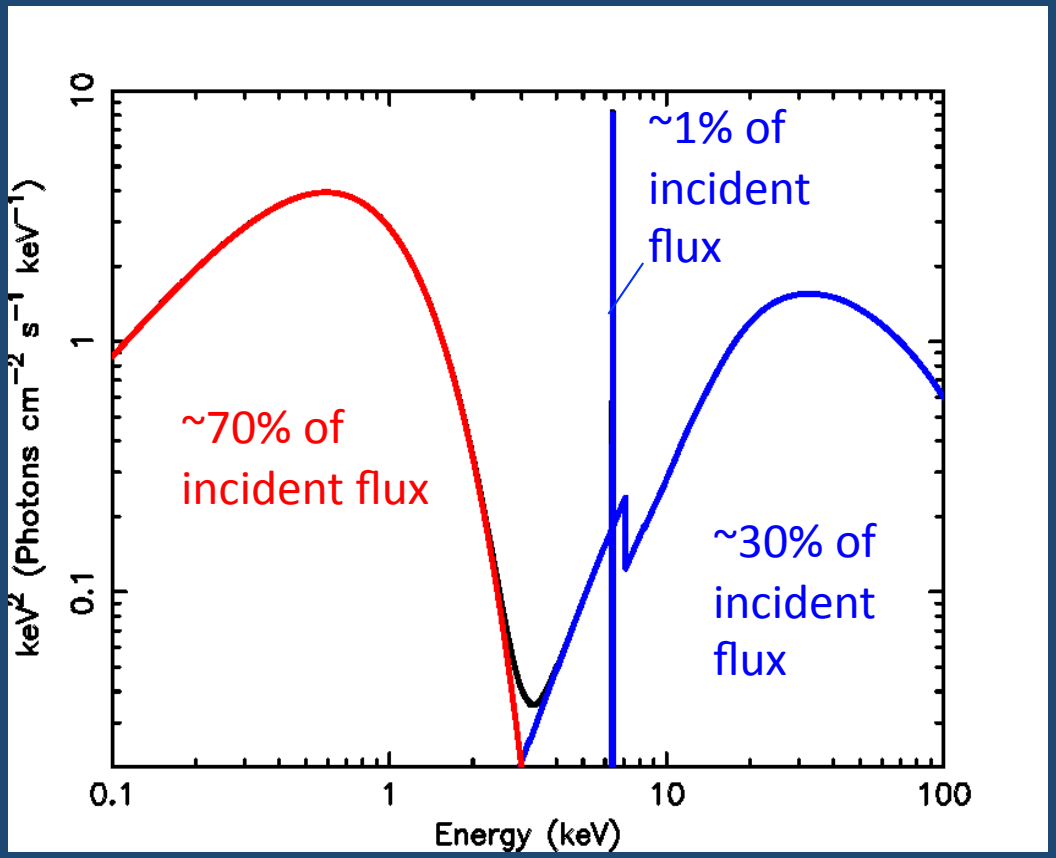


Disc fluctuations drive variability



But what's the role of reverberation?

Disc reverberation



About 70% of the incident flux contributes to heating the disc, thus emitting at the local temperature

~ 30% is reflected

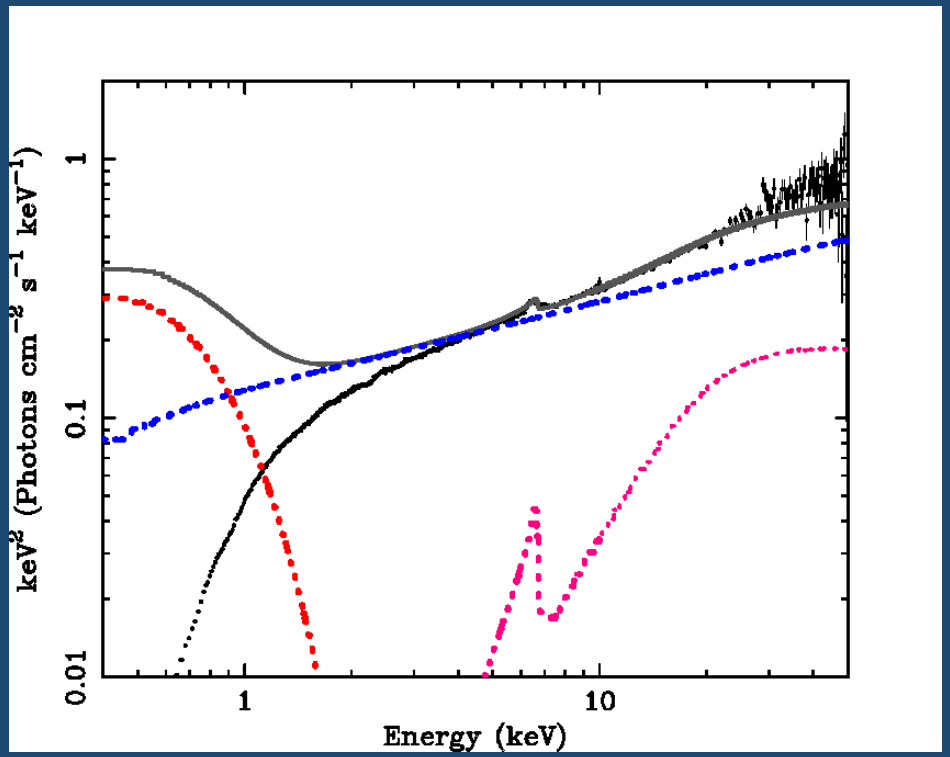
But approximately 1% of the incident flux contributes to the Fe Kα line

➔ Constraints on the solid angle subtended by the disc: how much direct emission can the disc see?

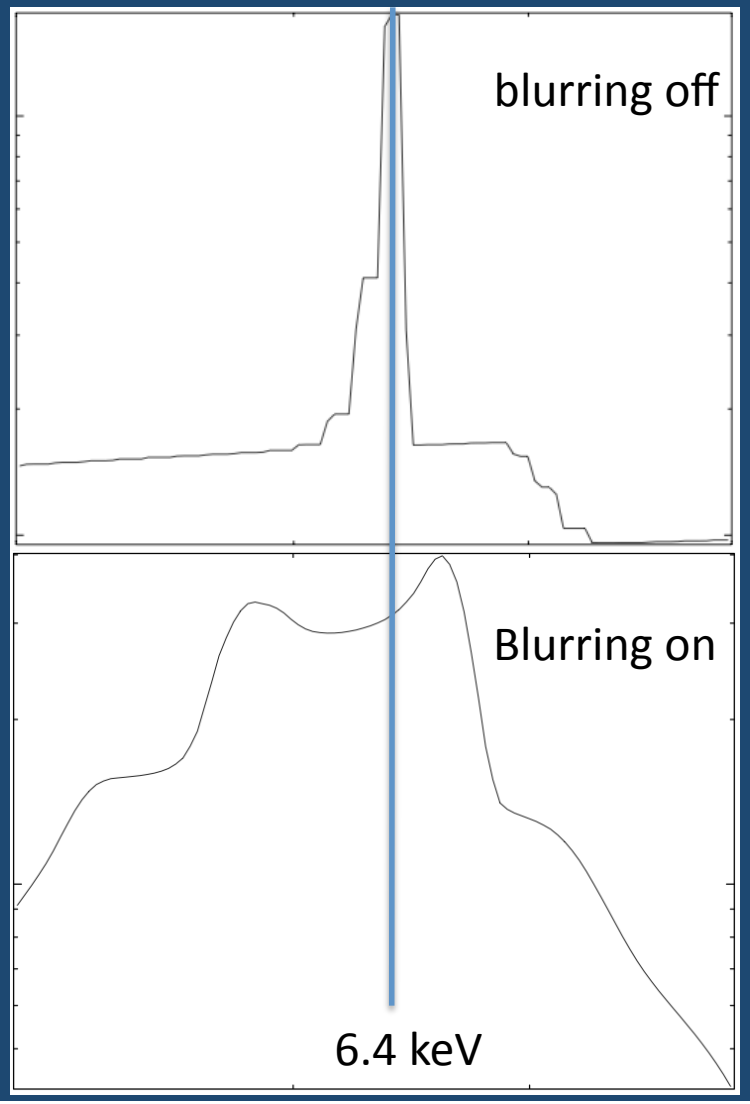
Disc reflection

- ‘Quite hard’ X-ray photons (E > 14 keV) hit the disc

→ Compton (down)scattering until they leave the medium or are photoabsorbed. Neutral iron contributes a fluorescence line at 6.4 keV

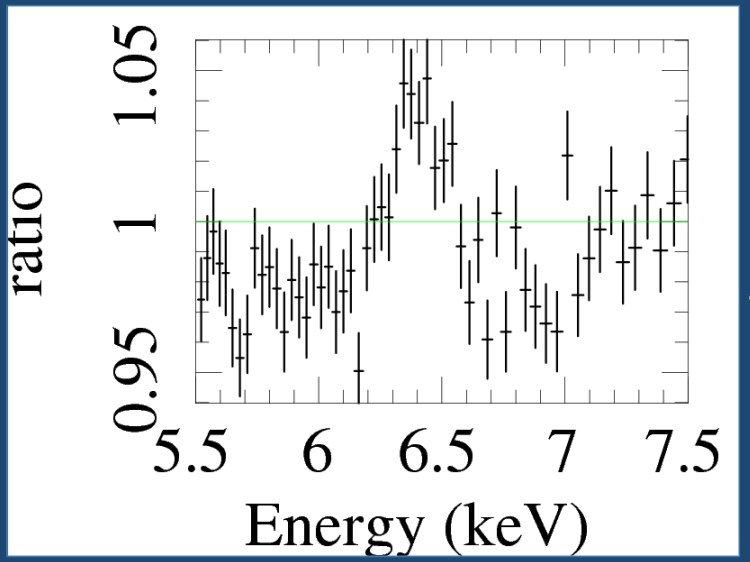


The contribution of the line to the total spectrum does depends on radius



Lags from reflection: evidence (i)

GX 339-4 (2004): Fitting the iron line with a relativistic profile leaves an unresolved excess $F_{excess} \sim 5.6 \times 10^{-13}$ erg s^{-1} cm^{-2}

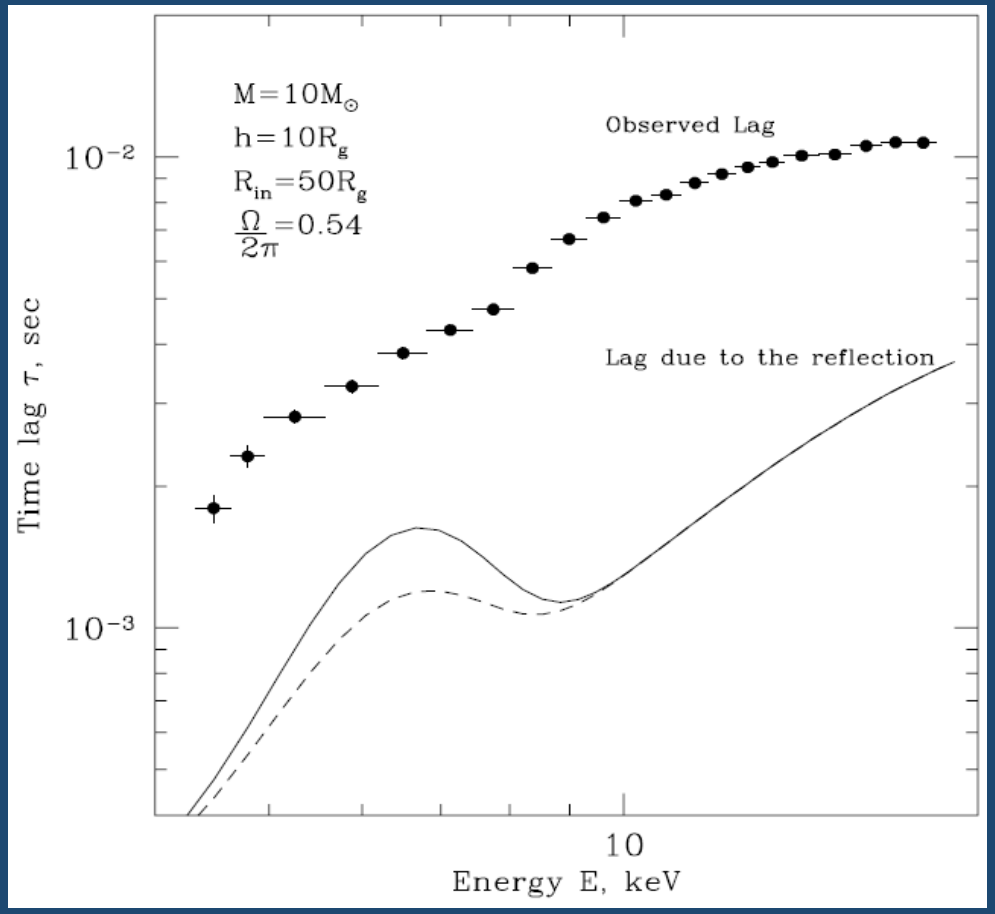


T. Wilkinson, priv. comm.

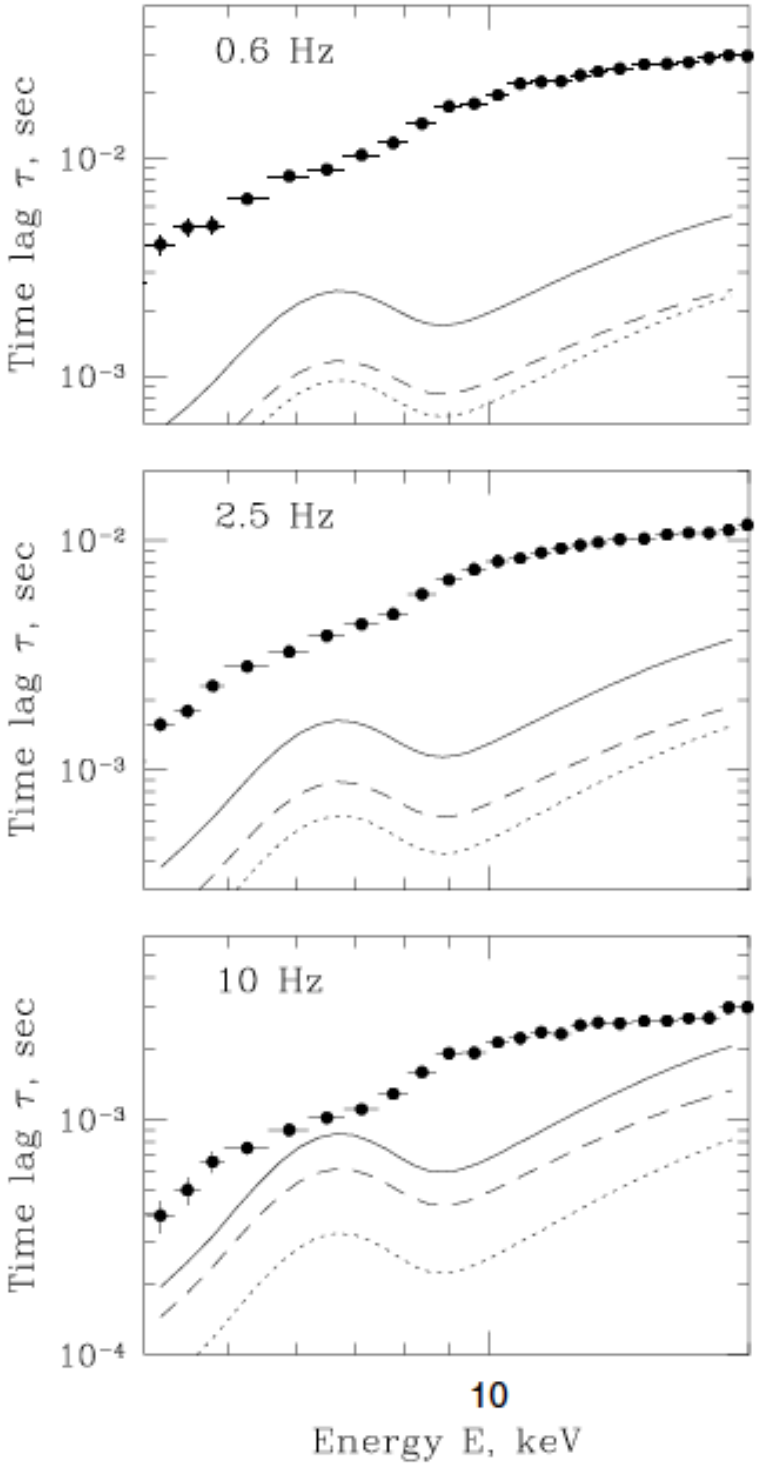
This is in agreement with the optical flux reprocessed by the outer disc found by
Coriat, Corbel et al (2009)

➔ Large scale reflection is present

Lags from reflection: evidence (ii)



Kotov et al (2001) show a wiggle in the energy dependence of time lags at 6.4 keV, in agreement with a reflection origin.
Different line shapes could cause this?



Distance reflection is present, but how can it be constrained from lags spectra?

Fitting lags is the way forward!

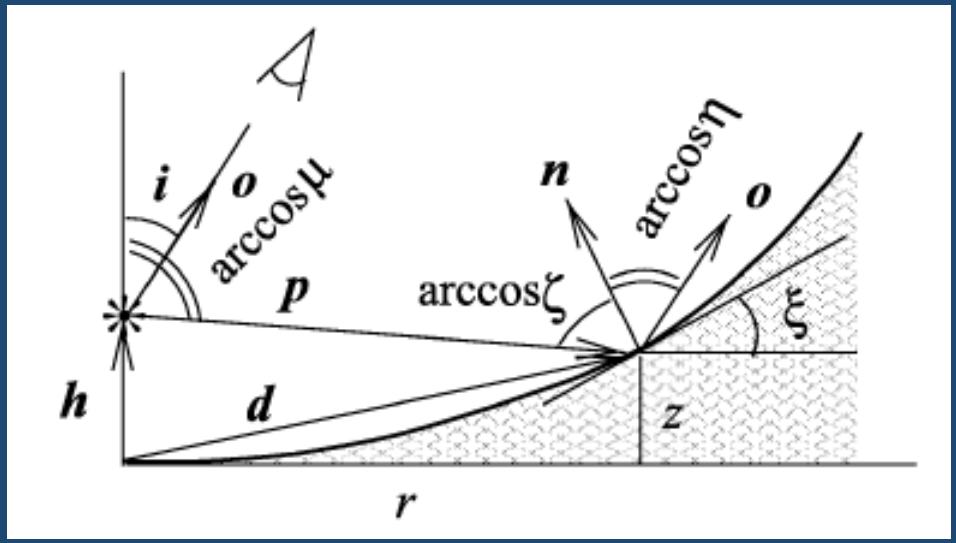
- Mean spectrum (aka spectrum)
- Iron line flux and shape
- Solid angle subtended by the disc
- Optical flux
- Lag vs spectra

} should be consistent!

- Existing packages allow fitting of non-spectral data, need to treat frequencies like energy and create diagonal responses

A model for disc reflection from flared discs

A central source at a height h from the disc plane emits photons, which are in part intercepted by the flared disc (ie $r \sim r^{\alpha}$) and reflected



Poutanen (2002)

Depends on:

Inner disc radius	**Flaring index α ($r \sim z^{\alpha}$)**
Outer disc radius	**Central source height above the disc**
Black hole mass	**System inclination**
H_{max}/R_{out} scale height ratio	**Spectral shape/albedos**

From the geometry to the response (i)

$H/R = 0.2$

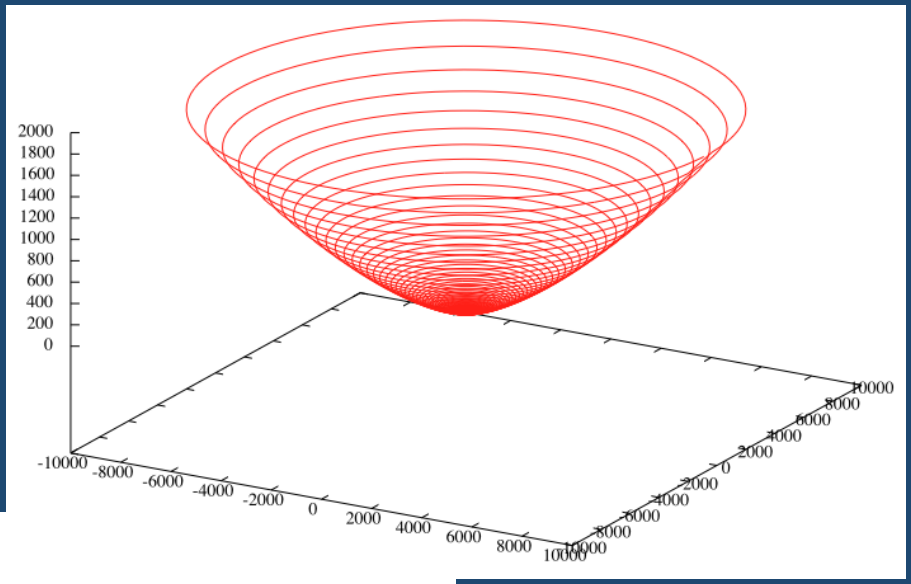
$R_{in} = 10\ R_s$

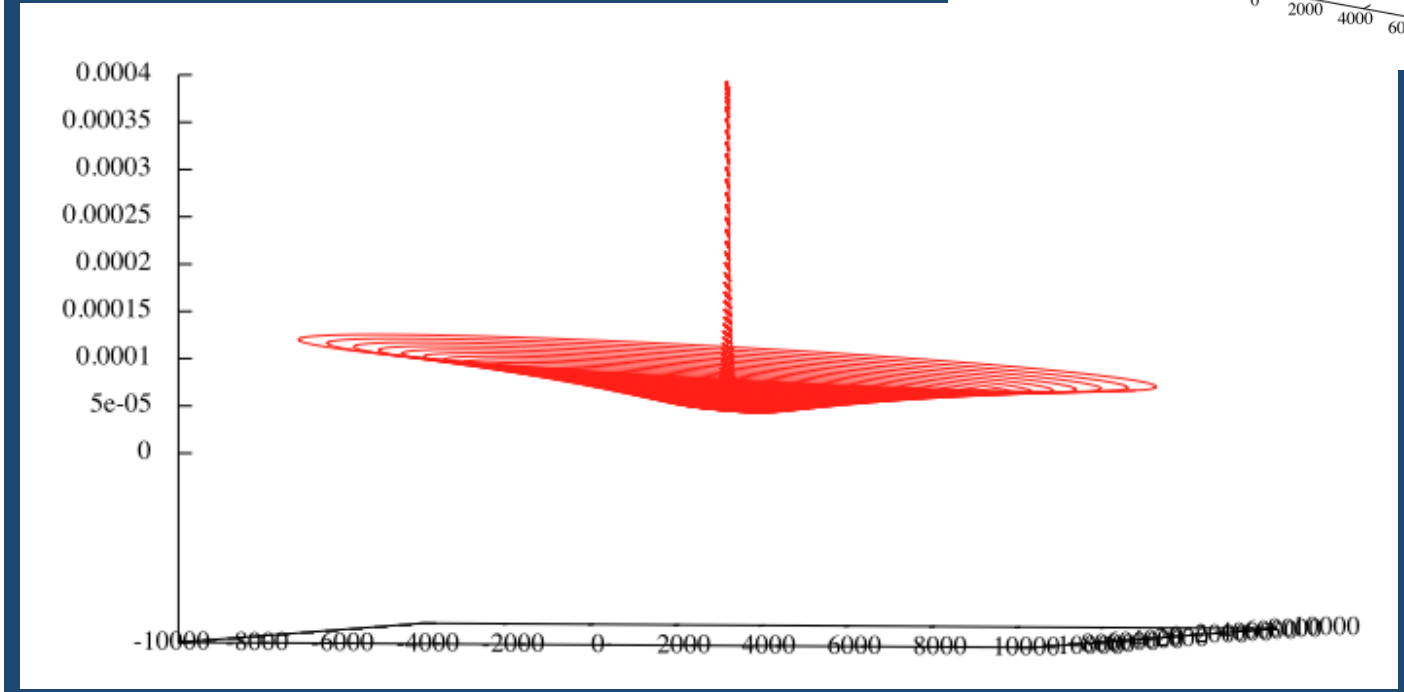
$R_{out} = 10000\ R_s$

$H_{src}=10\ R_s$

$z(r) = H_{max}(r/R_{max})^{1.5}$

$a_s=0,\ a_H=1$





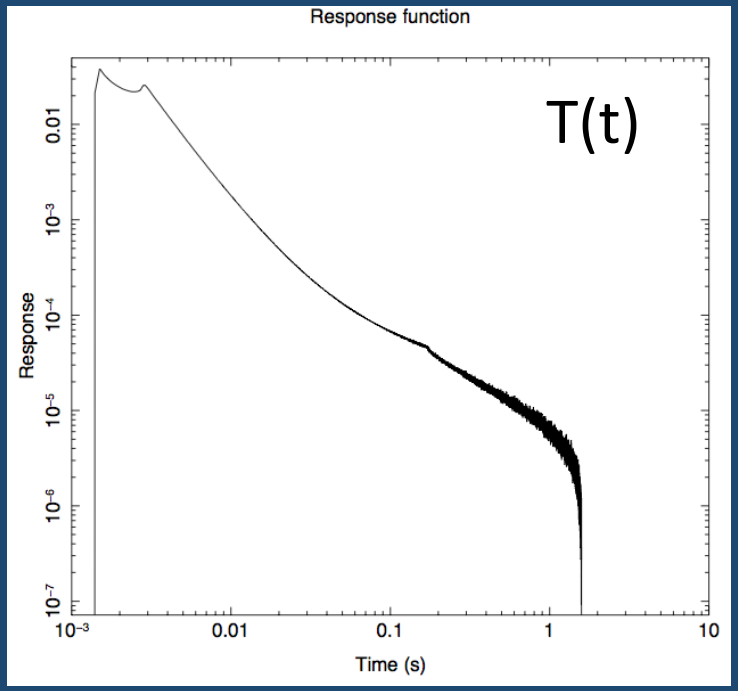
From the geometry to the response (ii)

$$L_S(\nu) = L_D(\nu)[1+a_S T(\nu)]$$

$$L_H(\nu) = L_D(\nu)[1+a_H T(\nu)]$$

$$C(\nu)=|L_D(\nu)|^2 [1+a_S T^*(\nu)+a_H T(\nu)+a_S a_H |T(\nu)|^2]$$

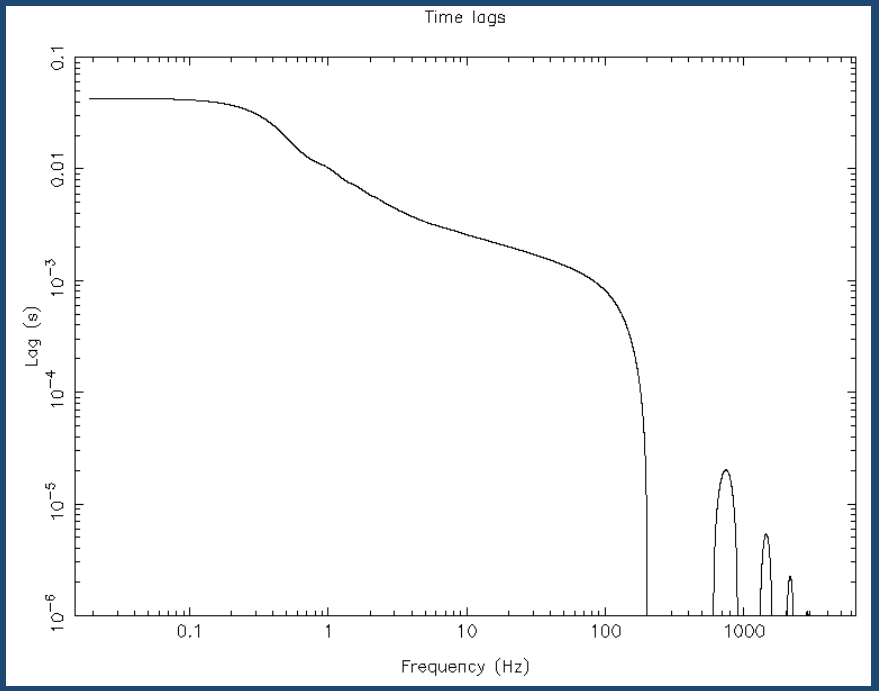
Example of a simple two albedo values case



Response

Frequency (Hz)

Disc response



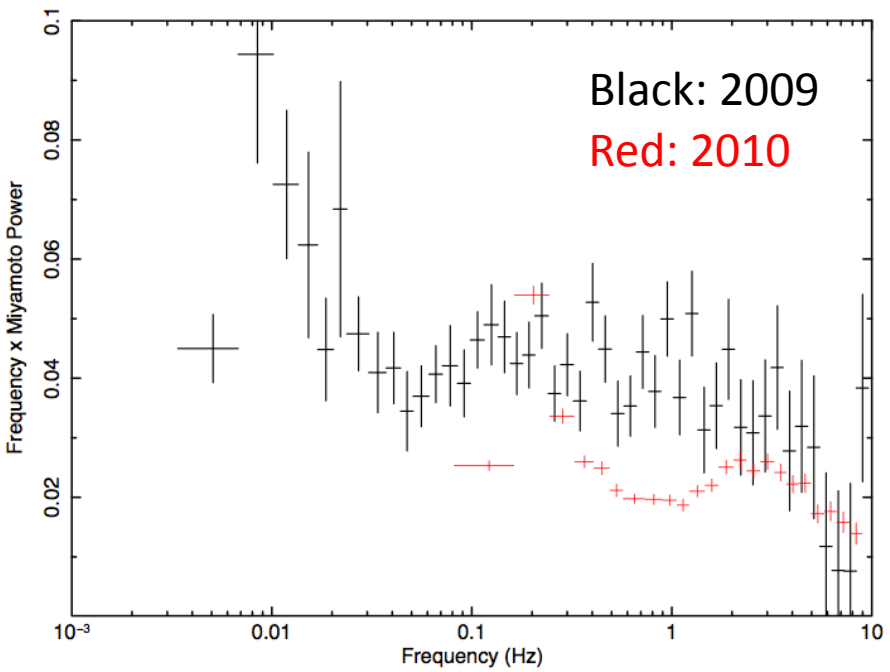
Time lag (s)

Frequency (Hz)

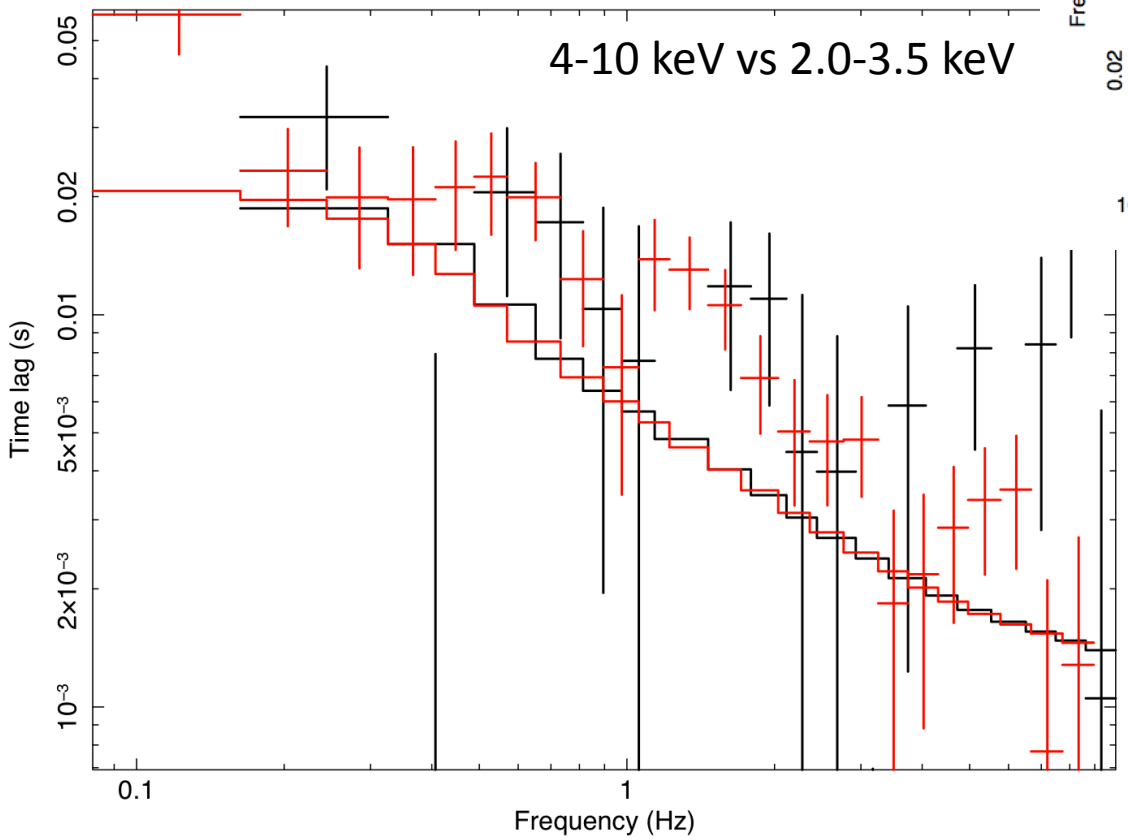
Time lags

GX 339-4 in 2009 and 2010

PSDs



Time lag vs frequency



Reflection using Ballantyne's reflection model

In progress

- Constrain solid angle from iron line and optical flux
- Lags vs energy
- Mean spectra
- Covariance spectra