X-ray timing constraints on AGN Winds

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St Thomas, July 2017

Need to separate variability signatures from different phenomena

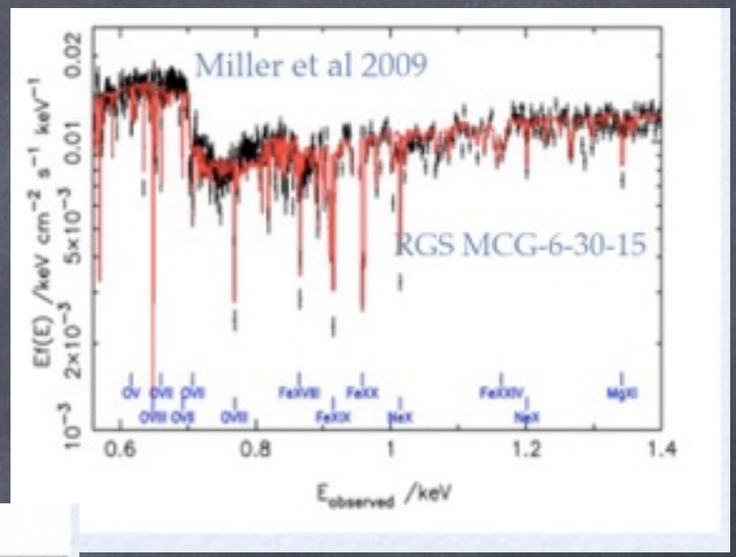
A lot going on in the X-ray band

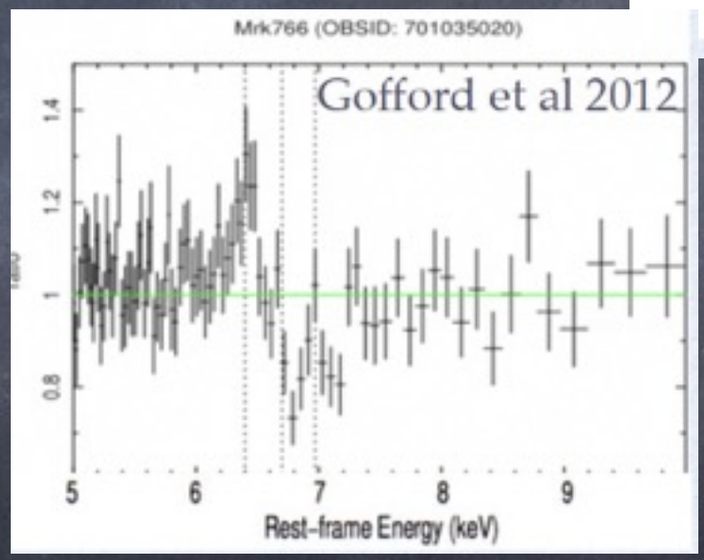
- Absorption/outflow changes
- Reverberation signatures
- Accretion changes

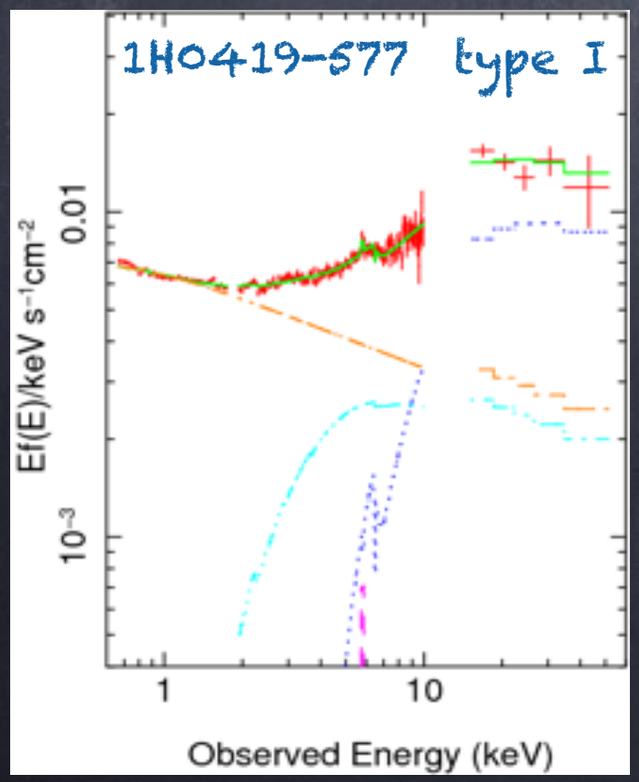
X-ray outflows

Broad range N_H, ξ and velocity

Blue-shifted absorption lines, 100's km/s - fraction of c (Tombesi et al 2010)





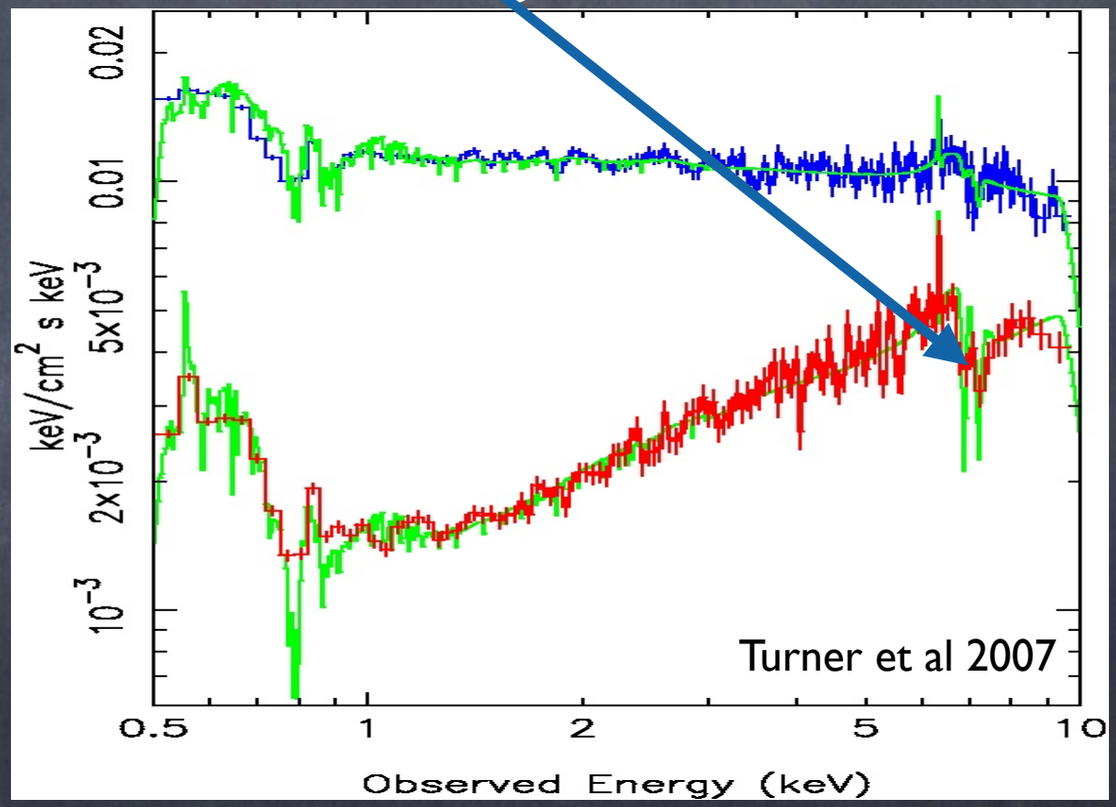


...extending to CT clumps, e.g. Turner et al 2009, Tatum et al 2013, 2016

Variable X-ray absorption on days

- A source of variability in some AGN on days (e.g. MCG-6-30-15 McKernan et al 1998; NGC 3516 Turner et al 2008)

Mrk 766: blue shifted absorption lines - wind signature

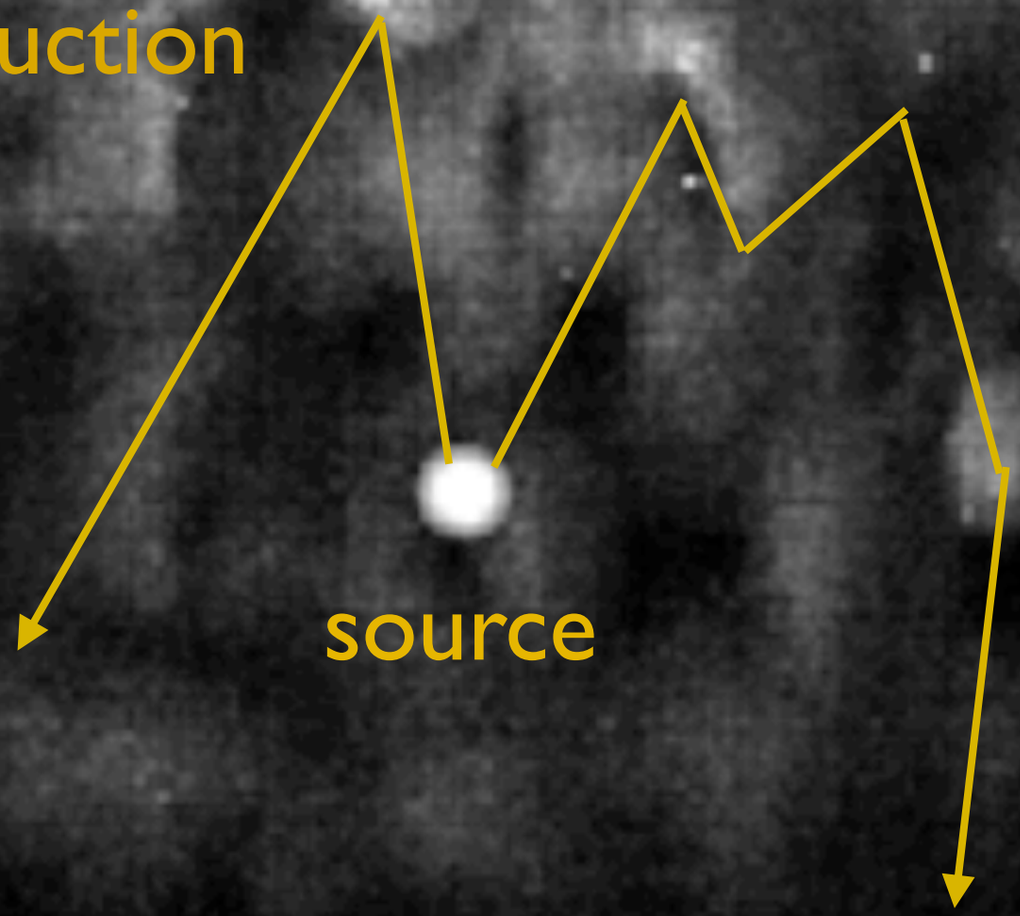


Monte Carlo photon shooting simulated spectra

3D cloud distribution
(1000 interconnected "blobs")

multiple Compton scattering,
photoelectric absorption &
Fe K line production

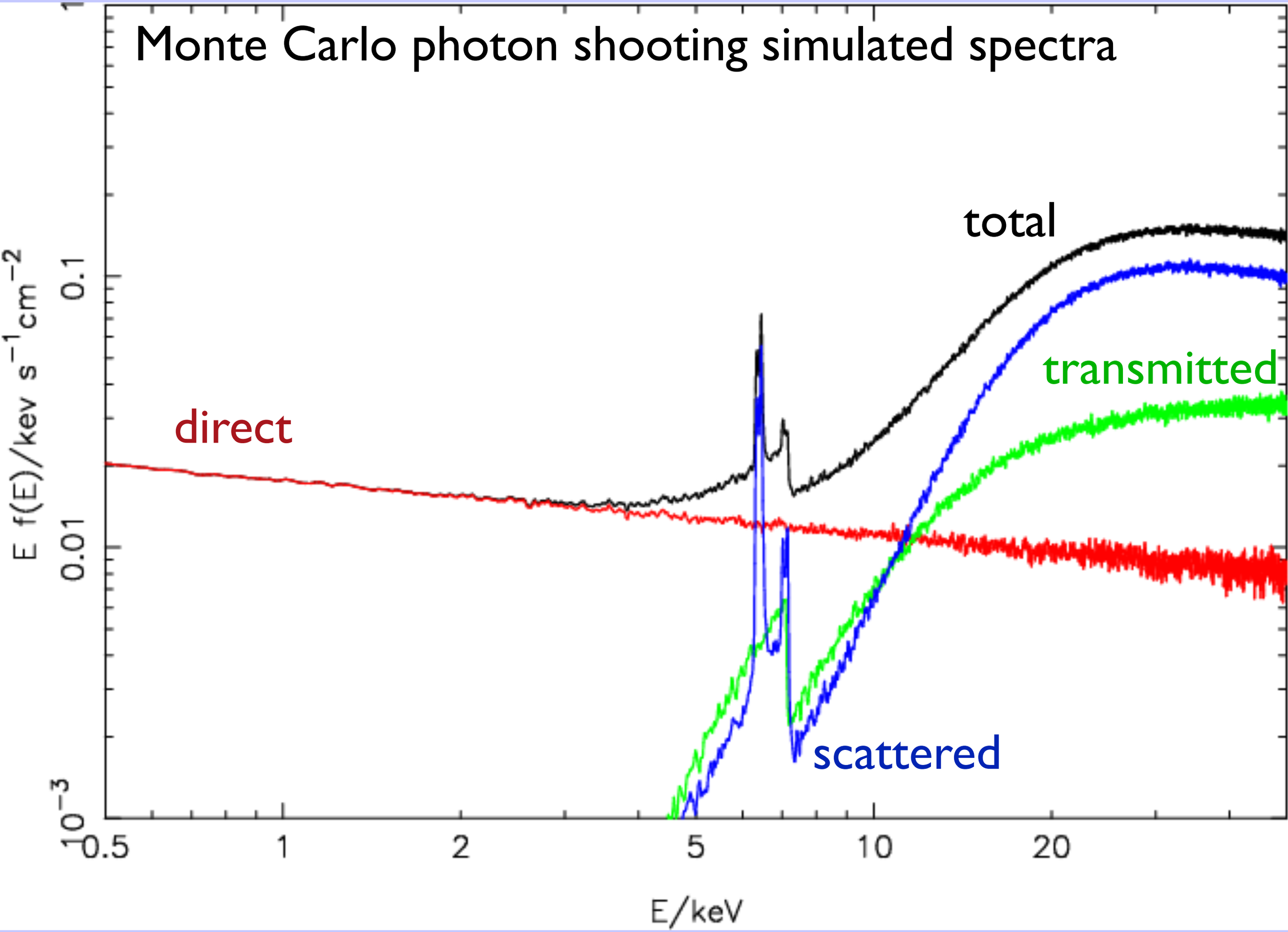
neutral gas only



source

60 billion
photon packets

Monte Carlo photon shooting simulated spectra

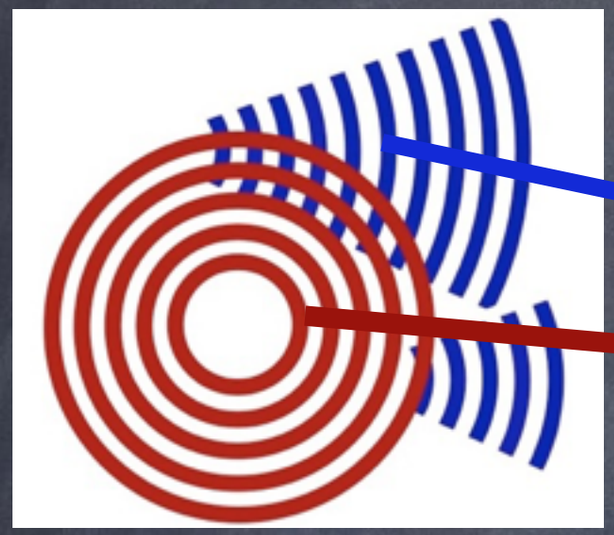


X-ray time lags

- lags between hard and soft X-ray photons known in Galactic sources and common in AGN (e.g. DeMarco et al 2013, Kara et al 2016)

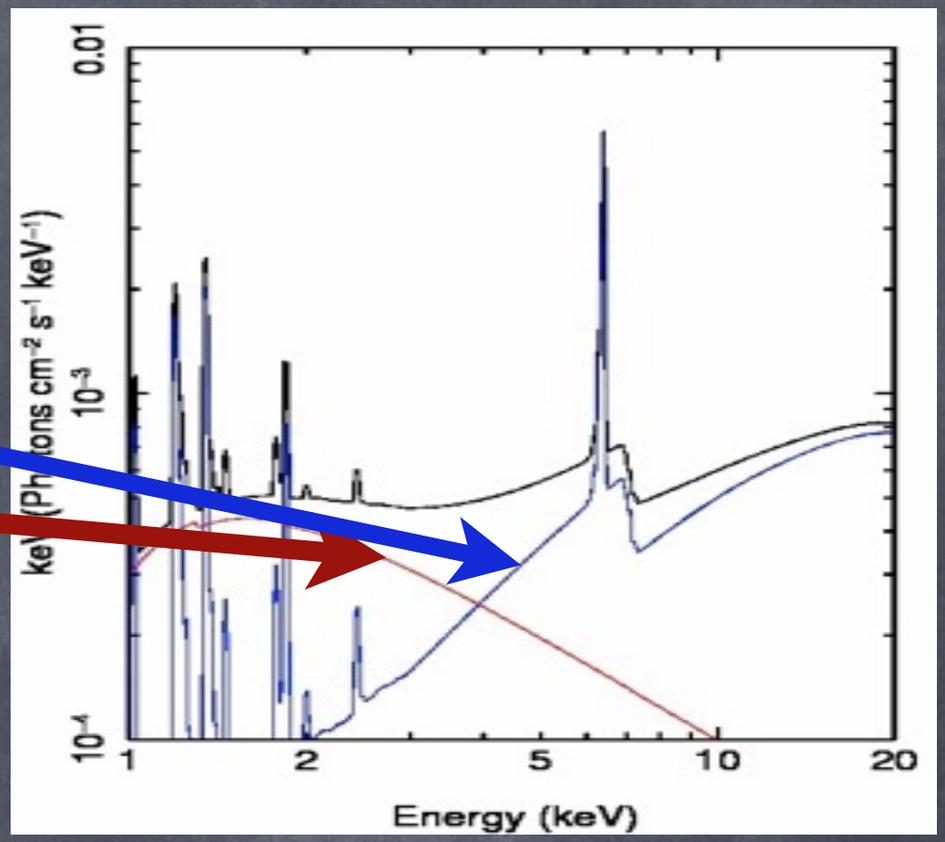
- Lags imply not all flux variations caused by absorption events... rapid (ks) events likely intrinsic... X-ray reverberation?

X-ray Reverberation



hard spectrum, scattered, delayed X-rays

direct X-rays

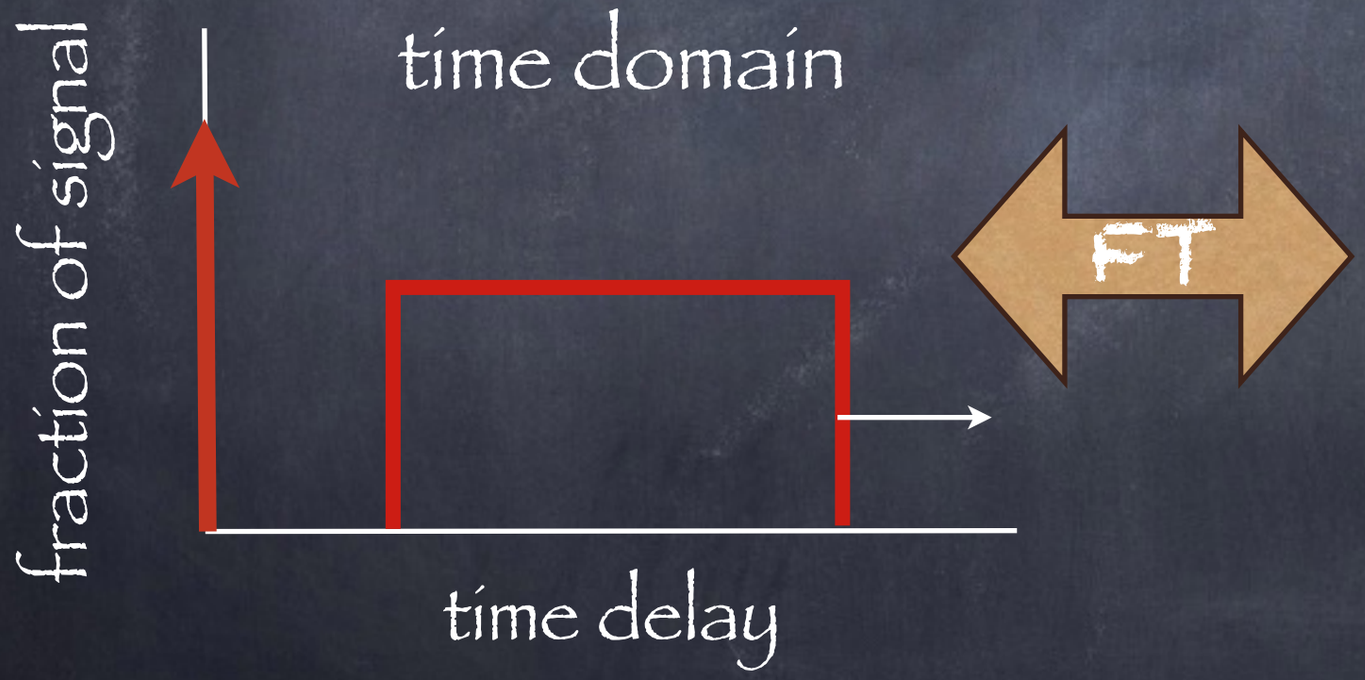


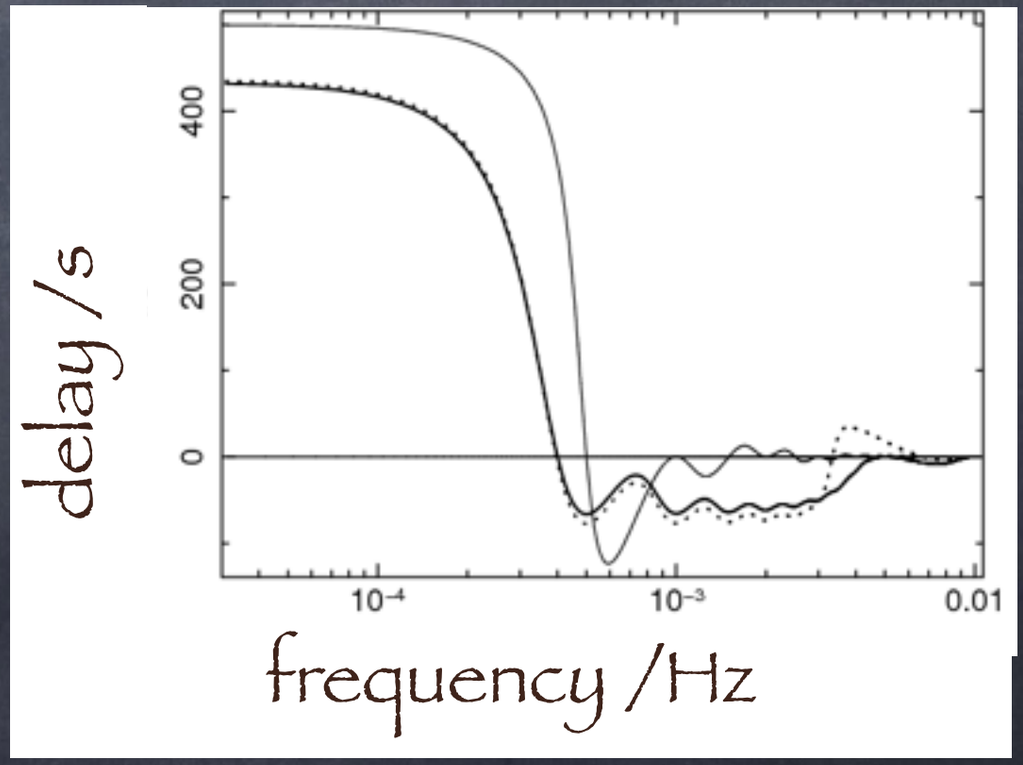
- Insufficient counts to separate lines and continuum on short timescales
- Measure reverberation between broad bands
- Reflected & direct mixed in different fractions in the bands

- Estimate cross-band power spectrum (max likelihood) -> time delay as function of source variations

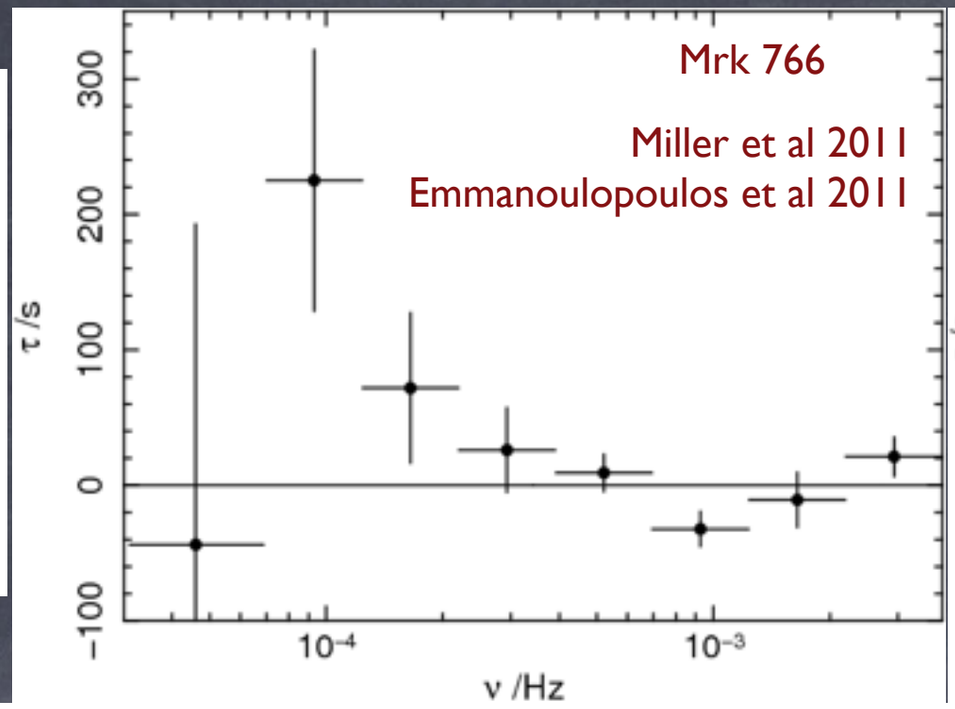
- Lag spectrum given by phases of Fourier transform of transfer function - describes spread of time delays in signal

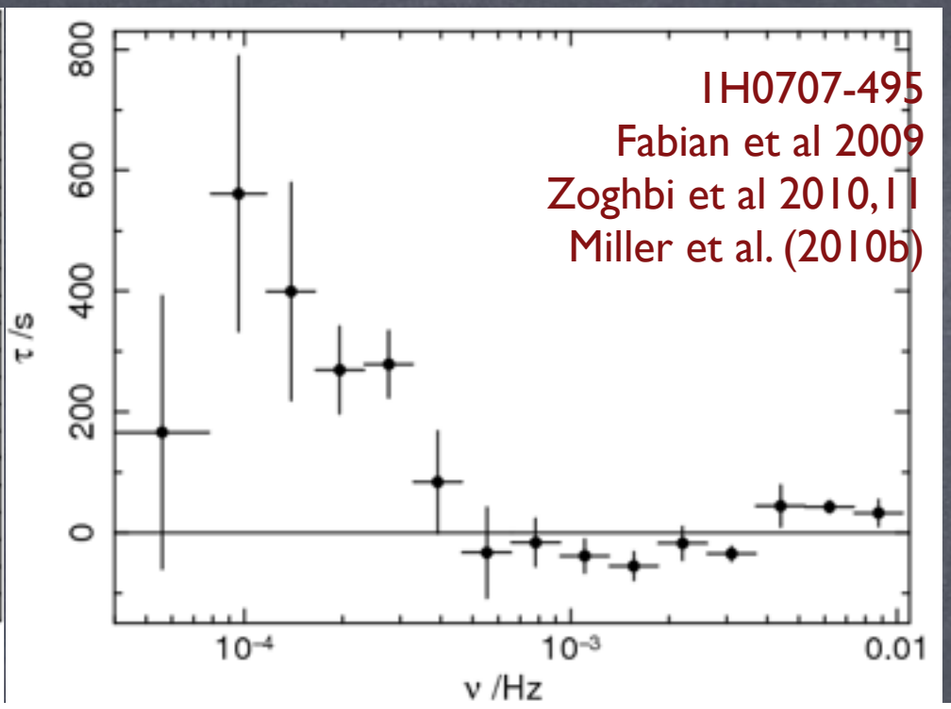
Fourier domain





lag/s





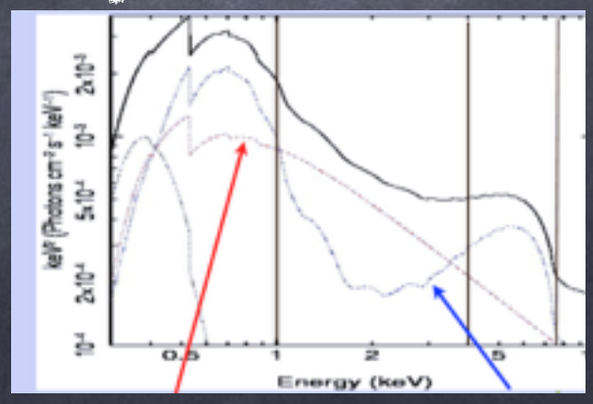
frequency /Hz

frequency /Hz

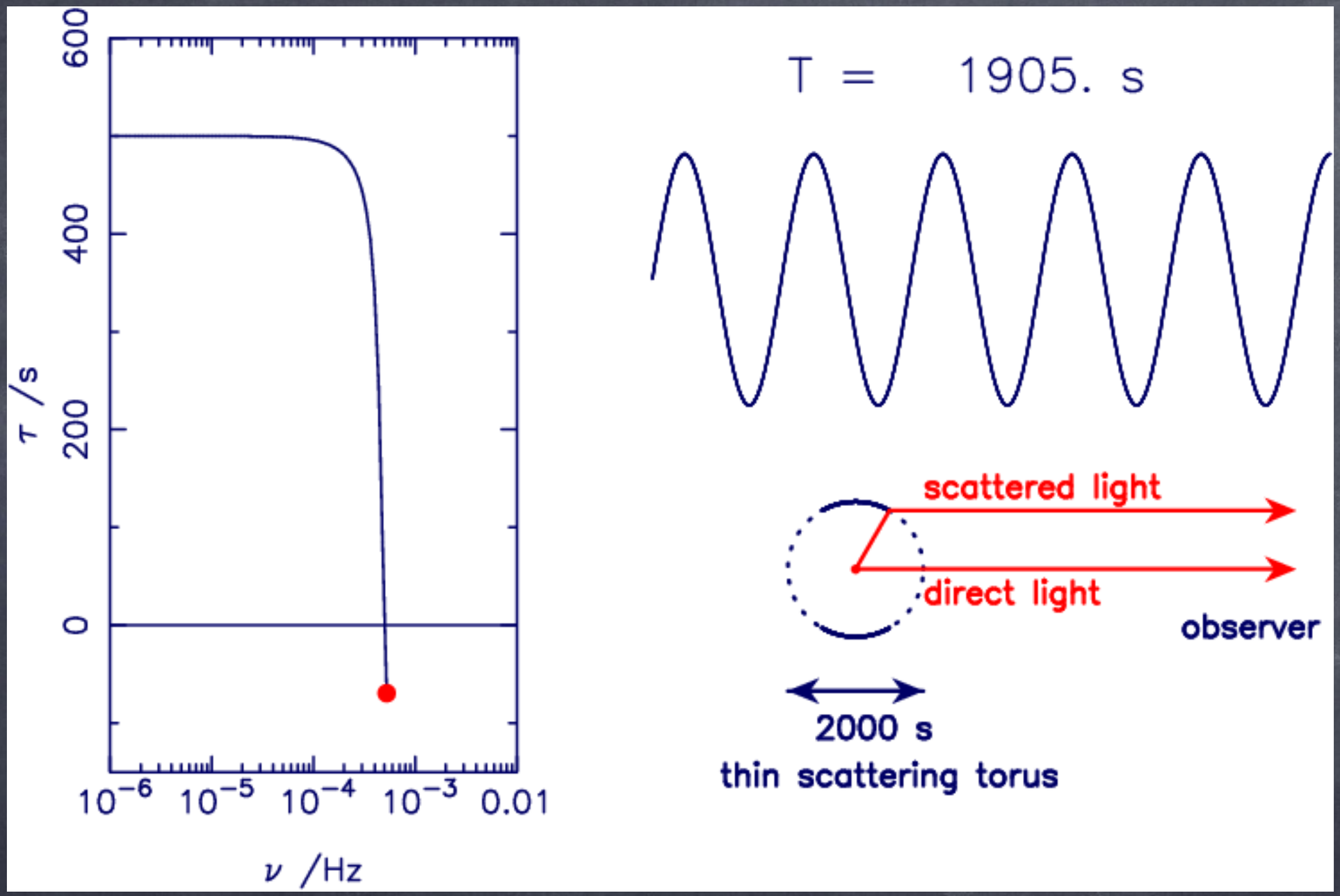
- Hard X-rays delayed wrt soft defined as positive lag

- Two ways to obtain negative lags (soft delayed wrt hard) from reverberation

  - either soft band also has delays (e.g. Zoghbi et al 2010, 2011) OR



  - reprocessor is clumpy - negative lags arise from Fourier transform of transfer function

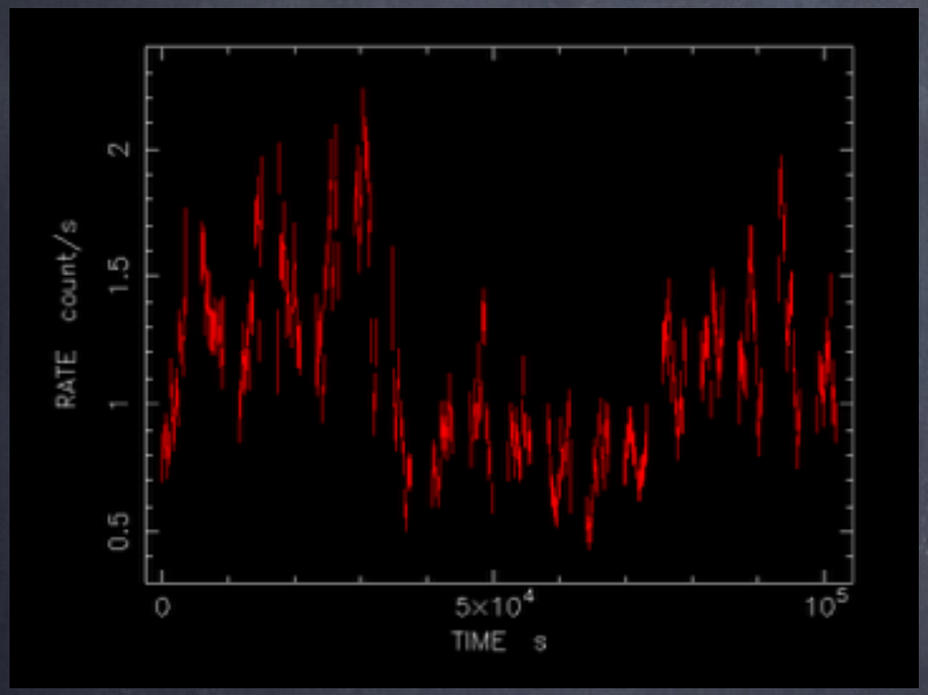


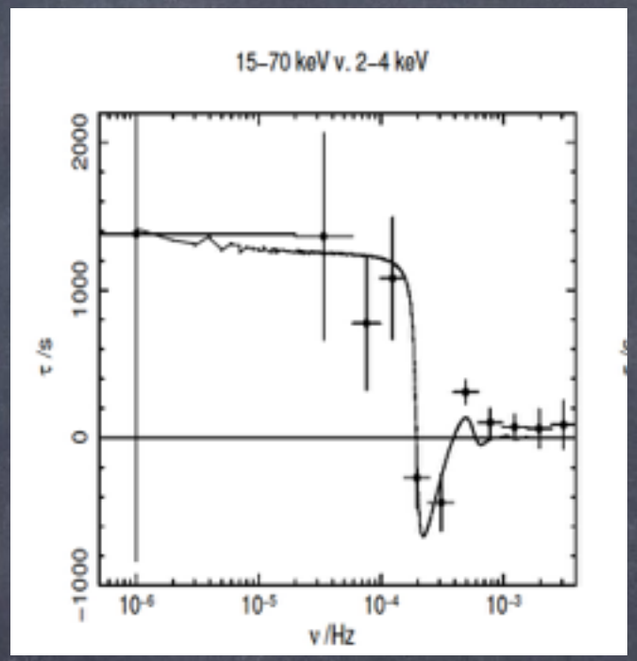
- All this helps place absorber/reprocessor which gives us the correct timescale to attribute to that phenomenon

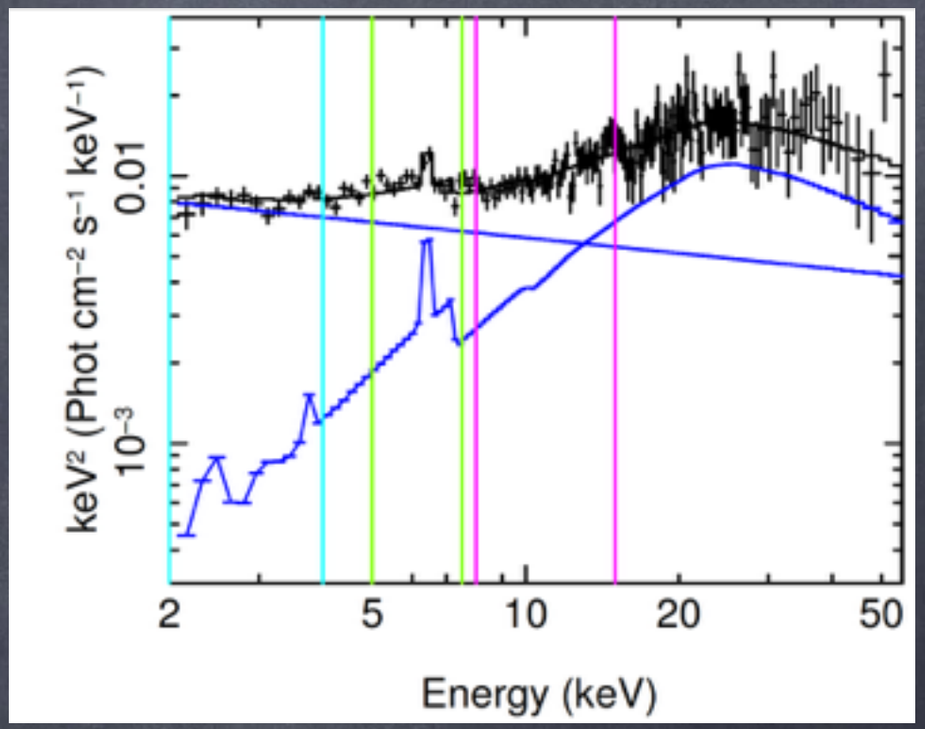
NuSTAR - NGC 4051

Turner et al 2017

- negative lags not due to reflection in soft band- that band has no reflection!



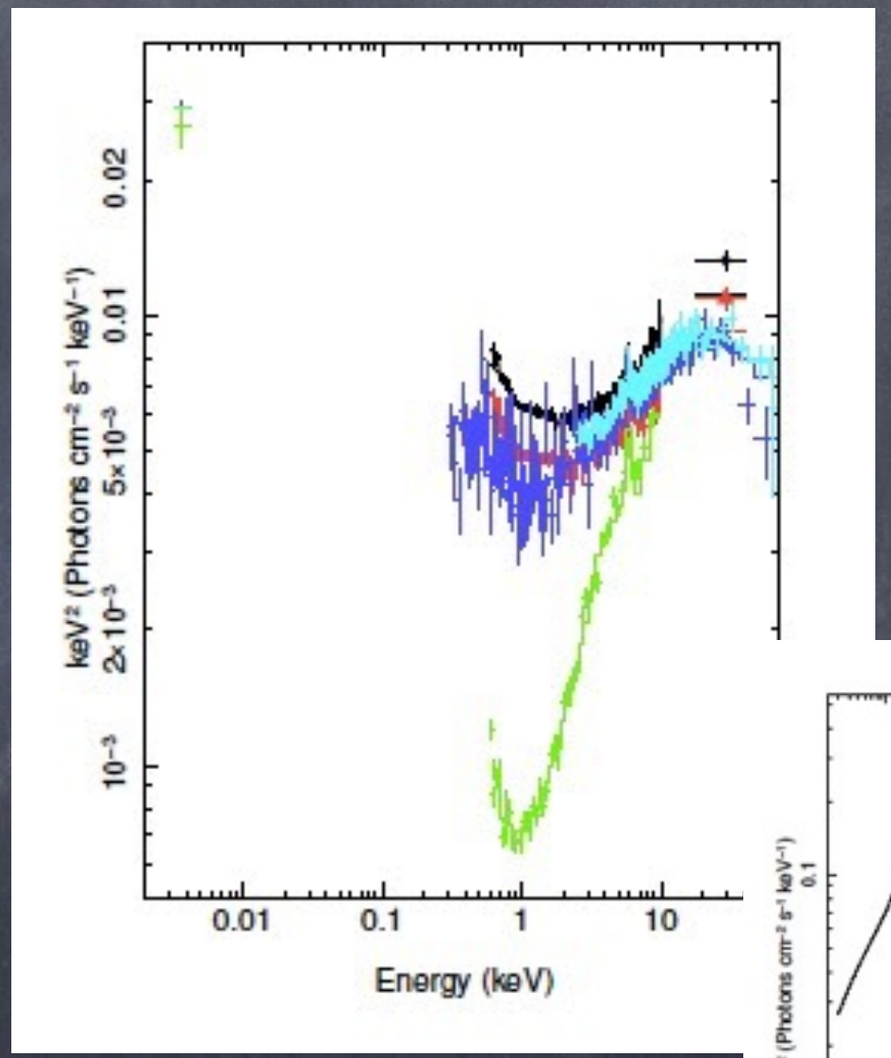


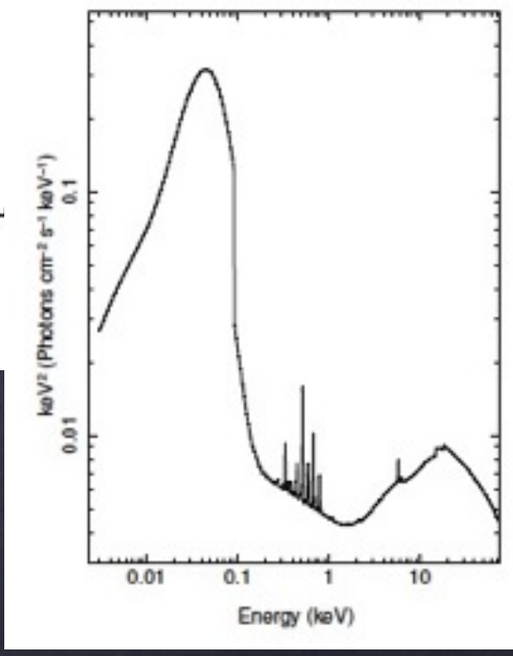


- light travel time across shell places reprocessor at few hundred r_g

Changes in Accretion Flow: 1H 0419-577

- Isolate absorber variability to see underlying SED changes in 1H 0419-577

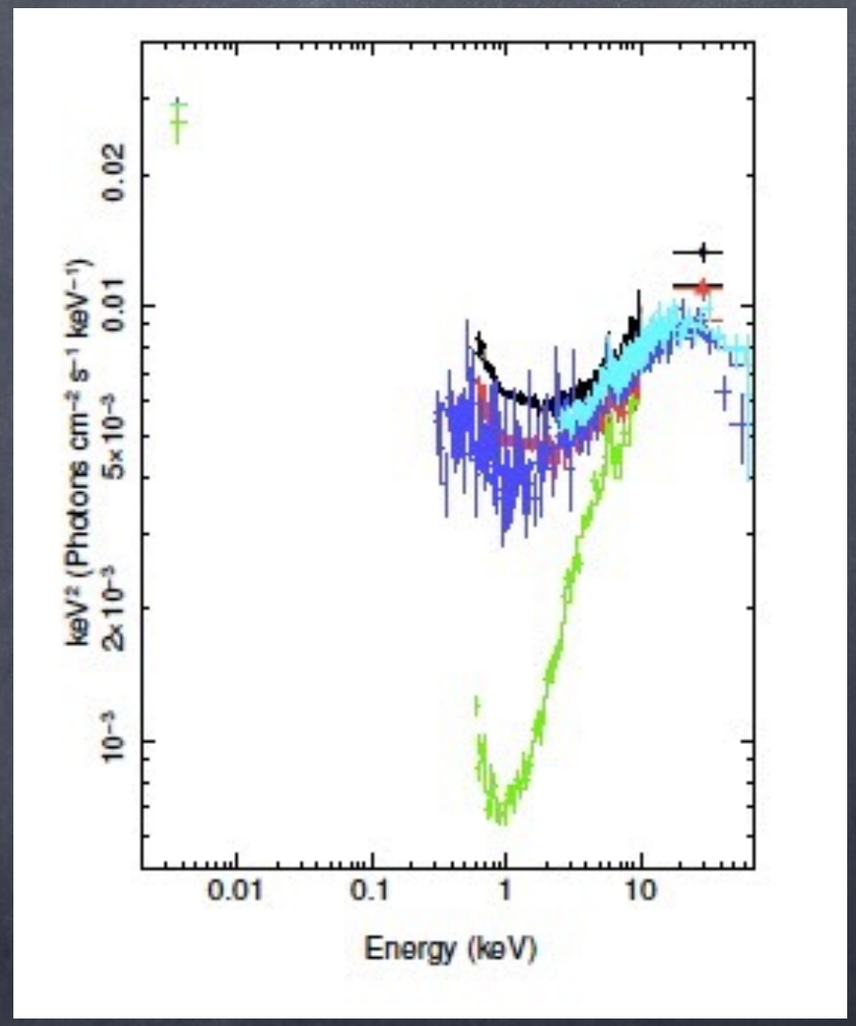




- color-corrected accretion disk down to $6r_g$ with comptonization in $\tau \sim 4$-5 corona

Changes in Accretion Flow: 1H 0419-577

- Isolate SED var component that is on timescales of years
- For this mass and Eddington ratio, assuming this is a viscous timescale suggests this may be from fluctuations in the inner disk ~10r_g (Czerny 2004)



Conclusions

- Complex X-ray absorption & scattering from outflowing wind -> imprints ~days variability
- Time lag spectra consistent with reverberation - X-ray reprocessor lies at 10-100 GM/c^2
- "Negative" time lags arise from ringing in Fourier transform of hard-band transfer function, not from excess soft-band reflection
- Accounting for absorption allows us to probe the accretion-related changes hidden beneath