X-ray timing constraints on AGN Winds

Tracey Jane Turner (UMBC), Lance Miller (Oxford), James Reeves (Keele)

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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 $N_H$, $\xi$ and velocity

Blue-shifted absorption lines, $100's$ $\text{km/s}$ - 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

Turner et al 2007
Monte Carlo photon shooting simulated spectra

3D cloud distribution (1000 interconnected “blobs”) neutral gas only

multiple Compton scattering, photoelectric absorption & Fe K line production

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

- 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

Fraction of signal

Time domain

Time delay

Frequency / Hz

Delay / s

Fourier domain
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)
- 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.
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 τ ~ 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 $\sim 10r_g$ (Czerny 2004)
Conclusions

- Complex X-ray absorption & scattering from outflowing wind $\rightarrow$ imprints $\sim$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