Abstract
Temporal studies of X-ray binaries and Active Galactic Nuclei have shown that hard flux react to variation of soft flux with a time lag. The reverse case, or soft lag, has only been seen in a few rare quasi-periodic Oscillations in X-ray binaries and recently for the XMM-Newton analysis of Mrk 1040, on 13 February, 2009 for the duration of 90.9 ks.

XMM-Newton Analysis of Mrk 1040
- We processed and filtered the EPIC-pn data in a standard way using the Science Analysis Software (SAS) version 16.0 and using the recent calibration files.
- Flaring particle background were identified above 10 keV in the full field lightcurve and excluded.
- A continuous exposure of 70.4 ks used for both spectral and temporal analysis.
- We extracted source and background spectra from a source-centered circular region of radius 36" and an off-source region, respectively, and using single and double events with L2A abs.

Introduction
- Active Galactic Nuclei (AGN) show large amplitude variability in X-rays.
- Study of time lag is vital to understand the nature of variability, geometry of system and physical process.
- Typically, AGN and Galactic black hole systems exhibit hard time lags, e.g.

NGC 4051
Cyg X-1

Time lag versus
Fourier period for the cross-spectrum of the soft energy band (0.1-0.5 keV) versus 0.3-2.0, 2.5-5.0 keV bands (filled open circles and filled squares, respectively) (McICardy, 2004)

The opposite trend or SOFT LAG is seen in very few cases:
1H 0707-495
GRS 1915-105

Soft lag in AGN
1H 0707-495 between 0.3-1.0 keV 1.0-4.0 keV (0.3-2.0, 2.5-5.0 keV bands (filled open circles and filled squares, respectively) (Fabian et al. 2009)

Mrk 1040: Surprising Case
- Seeks to exhibit soft lags in the dominant variability timescale of 10^4 s.
- This is revealed in the XMM-Newton observation of this source.

XMM-Newton analysis of Mrk 1040
- We extracted source and background spectra from a source-centered circular region of radius 36" and an off-source region, respectively, and using single and double events with L2A abs.

Unfolded Spectrum
- Fitted by an empirical model consisting of absorbed dual-Comptonization components and some prominent lines and edges.
- There is intrinsic neutral absorption, a soft excess, multiple Iron line emissions, plus edges and absorption features, probably due to a warm absorber.
- The complex Iron line features indicate the possibility of a complex blended reflection component.
- With a high energy spectral index of ~1.7, moderate intrinsic absorption and soft excess, the spectrum of Mrk 1040 is typical of AGNs of this class.

Hardness Ratio
- Bottom panel shows that the hardness ratio significantly decreases from 0.6 to 2.0 keV during the observed evolution of the source on long (~10^5) timescales.
- Variation in the hardness ratio is clearly uncorrelated with the variability of the lightcurves.
- Hence its origin cannot be due to changes in the absorption medium which would effect primarily the soft band.

Cross-Correlation Analysis
- XRONOS task "crosscorr", norm=2, "slow" mode.
- 64 e binned lightcurves.
- Well correlated with cross-correlation function peaking at values ~ 0.8.
- We function with a Gaussian and obtain the best-fit centroid.

Discussion
- Soft lags could be possible as a result of Comptonization, where hard X-rays may impinge back on the input photons producing region and hence affect the soft photons.
- Alternatively, it could be due to reverberation of a complex gravitationally broadened reflection component to variations of the continuum.
- Both models can be tested and their parameters tightly constrained to self-consistently explain the lag and r.m.s. variability energy as well as the photon spectrum.
- Note however, that for both scenarios, the time lag should not be frequency dependent.

References
- Fabian et al. (2009).
- McICardin, S. XMM-Newton Observation of Mrk 1040.
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