Time Lags and Reflection in Black Hole X-ray Binaries

P. Cassatella[1], P. Uttley[1], J. Wilms[2]

[1] University of Southampton, United Kingdom

[2] Dr. Karl Remeis-Observatory, University of Erlangen-Nürnberg, Germany

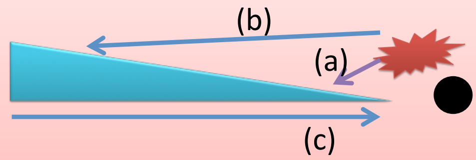
Quick Summary

1. Time lags can help constrain the geometry and properties of XRB.
2. Different explanations for lags have been proposed, such as accretion fluctuations, and large scale reflection.
3. There is evidence that distant reflection should play a role.
4. We are developing a set of lag spectra models to constrain its contribution.

Time lags can be a powerful tool to understand the geometry of X-ray binaries and other objects, as well as the links between different emitting regions. In X-ray binaries, time lags are observed between the soft and hard X-ray bands, where the hard emission usually follows the soft emission. This behaviour was studied for the first time by Priedhorsky et al, 1979.

The easiest and simplest explanation assumes that the reason is light travel time, where large lags are caused by reflection of the most internal X-ray emission in outer, distant radii of a flared accretion disc, whereas short lags are observed due to Compton scattering of soft photons in the corona.

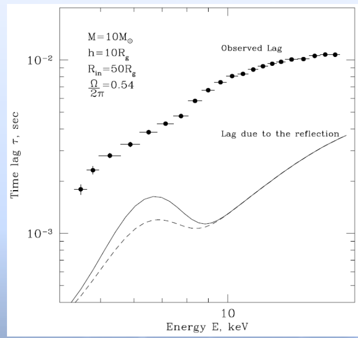
Possible reasons for the lags:



(a) Comptonisation
(b) Large scale reflection
(c) Propagation of accretion instabilities

However, accretion fluctuations are important

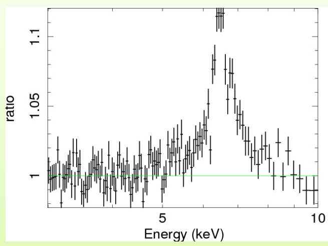
There are other possibilities that could be significant to explain the lags observed. Models (like Kotov et al, 2001 and Arevalo & Uttley, 2006) have been proposed where fluctuations in the local accretion rate at a certain r_0 propagate down to inner radii with different emissivities and thus modulate the emission at different Fourier frequencies, as well as the emission produced in the corona. In the case of Cygnus X-1, Kotov et al (2001) show the presence of a wiggle around the rest-frame energy of the Fe Kα transition that would be caused by reflection (see figure), although the whole behaviour couldn't be solely explained by this.



Kotov et al, 2001

Nevertheless, reflection is there

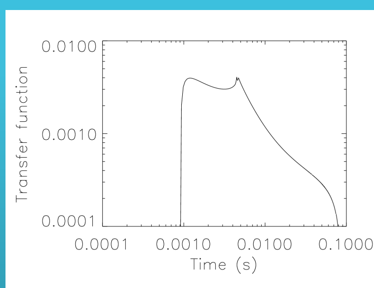
We have evidence that in GX 339-4 the Fe Kα line is narrow (EW ~ 70 eV). Recently, optical reprocessing has been found for the same source as well (Coriat, Corbel et al, 2009; van Paradijs & McClintock, 1994). This means that there should also be reflection that should account for the deviation of the observed lags from what would be expected from accretion fluctuation models.



Credits: T. Wilkinson

Therefore, **<u>we build new timing models to fit spectral lags</u>**

In order to understand the physical processes that cause lags and constrain the importance of reflection, we are developing timing models of reflection similar to those in Poutanen (2001) that will be fitted to lag spectra of X-ray binaries in the hard, using the following parameters: disc curvature, height of the source above the disc, R_{in}, R_{out} and reflection ratio.



One of our preliminary transfer functions
i=50°, r_{in}=50 r_g, r_{out}=1000 r_g, source height= 10 r_g, H/R=0.3, z(r)~r^2

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement number ITN 215212 "Black Hole Universe"