X-ray Reverberation with Athena

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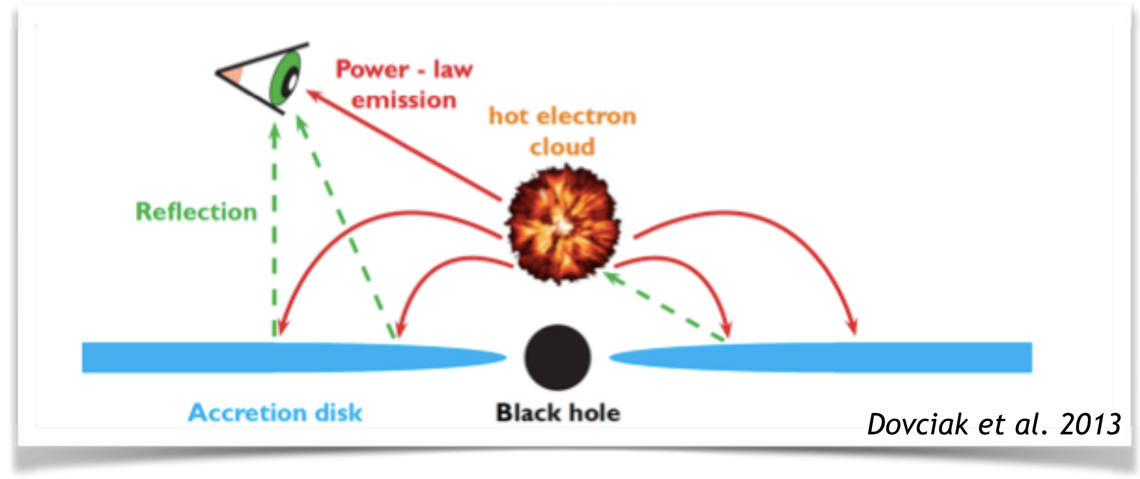

Introduction

Reprocessing of the primary X-ray continuum in the accretion disc produces reverberation lags which are powerful tools to map the close environments of accreting black holes (BH).
Through simulations of Wide Field Imager (WFI) light curves, **we show that time lag measurements will allow us to distinguish among different corona geometries, and to provide independent constraints on the black hole spin.**

- X-ray reverberation lags have been measured in radio quiet active galactic nuclei (AGN) with XMM-Newton (e.g. Fabian et al. 2009), giving constraints of a few gravitational radii, r_g, on the distance between the corona and the accretion disc (Fig. 1, De Marco et al. 2013).
- Nonetheless, constraining the disc-corona geometry (e.g. Wilkins & Fabian 2013; Emmanoulopoulos et al. 2014) requires data of much better quality (Dovciak et al. 2013).

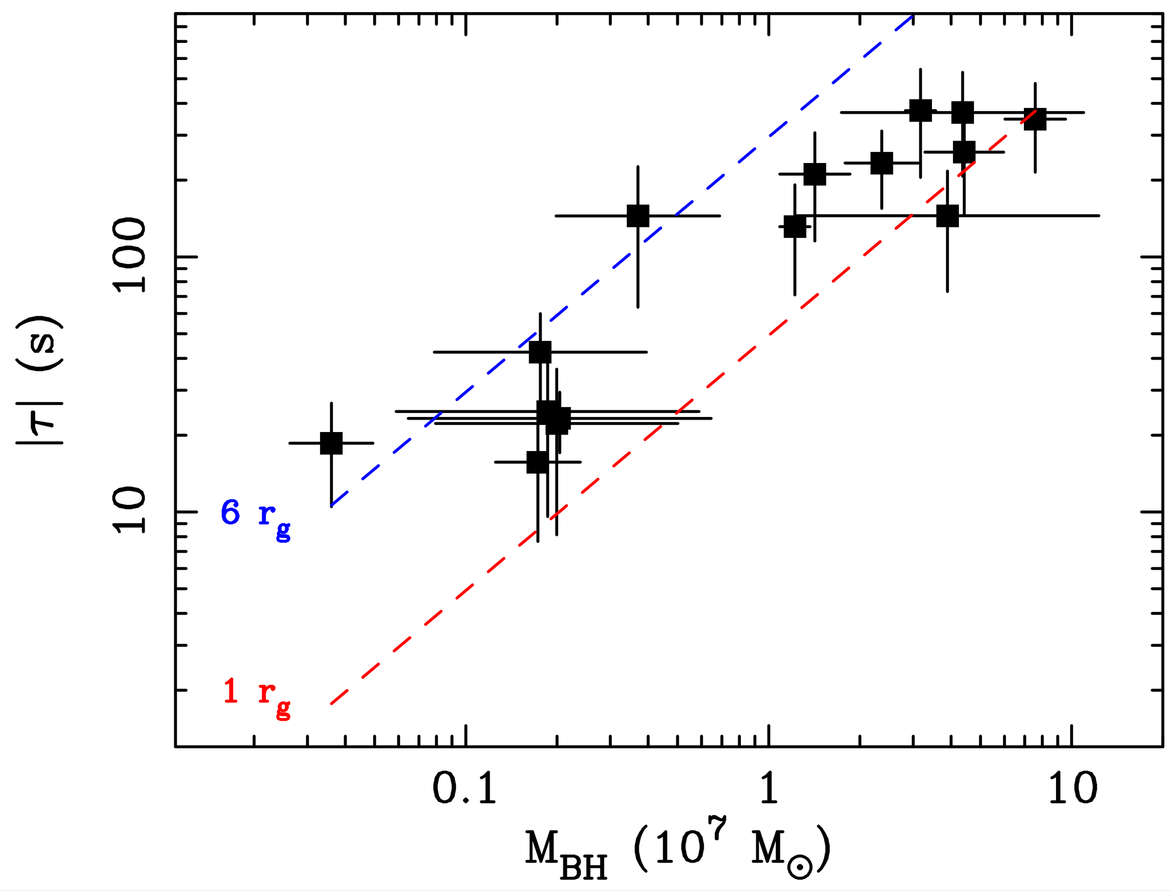

Fig. 1: *Soft X-ray (~0.3-1 keV) reverberation lags in radio quiet AGN as a function of BH mass. The distance between the corona and the disc reprocessing region is constrained to be on the order of 1-6 r_g (dashed lines).*

Theoretical lag-frequency spectra

The time-delayed response of the disc to X-ray illumination from the corona depends on different parameters, such as the height and extension of the corona, and the BH spin.

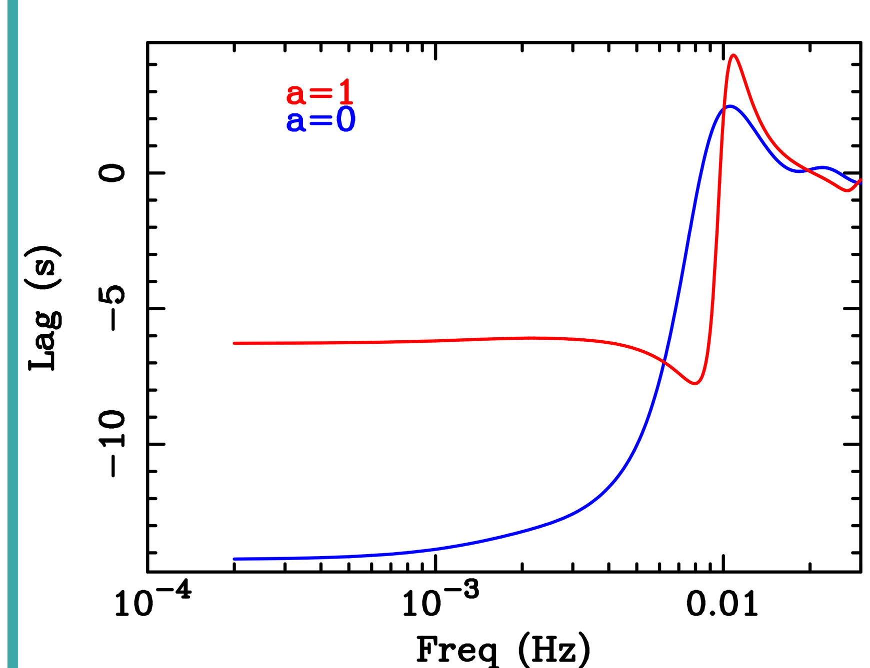

Fig. 2: *Theoretical lag profiles for BH spin values a=0 and a=1, assuming illumination from a point source corona located at height h=2.5r_g, in a lamp-post geometry.*

Increased sensitivity of lag measurements

Our ability to derive constraints on the disc-corona geometry depends on the sensitivity of lag measurements. For AGN, the error on the lag scales as *1/√(count rate)* (Uttley et al. 2014 and Fig. 3). **The WFI on board Athena will significantly increase the sensitivity of soft X-ray lag measurements (Fig. 3), and will more than double the number of current detections.**

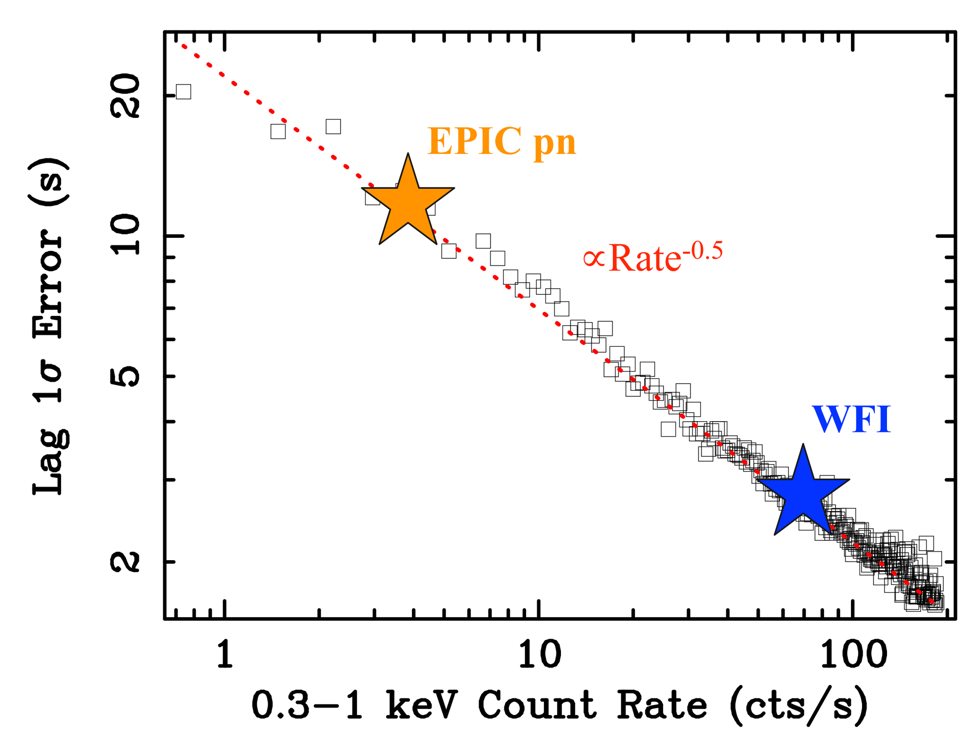

Fig. 3: *The 1σ error of soft X-ray lag measurements as a function of 0.3-1 keV count rate. The black squares are obtained from simulated lag measurements assuming 20% fractional rms (e.g. Vaughan et al. 2003) at frequencies >5x10^{-5} Hz, $F_{0.3\text{-}1keV}$=4x10^{-12} erg/s/cm^2, the theoretical lag profile shown in Fig. 2 (a=0), and 200 ks exposure. The stars refer to EPIC pn and WFI lag uncertainties.*

Constraining disc-corona geometry and BH spin

Compared to XMM-Newton, **the Athena collecting area will be a factor ~16 @1keV and a factor ~3-4 @6.4keV larger.** Fig. 4 shows WFI simulations of soft X-ray lags for different disc-corona geometries and BH spin values. For comparison, EPIC pn 1σ contours are also shown. **Athena large collecting area will allow to distinguish among different geometries (Fig. 4 lower panel), and will provide independent constraints on the BH spin (Fig. 4 upper panel).**

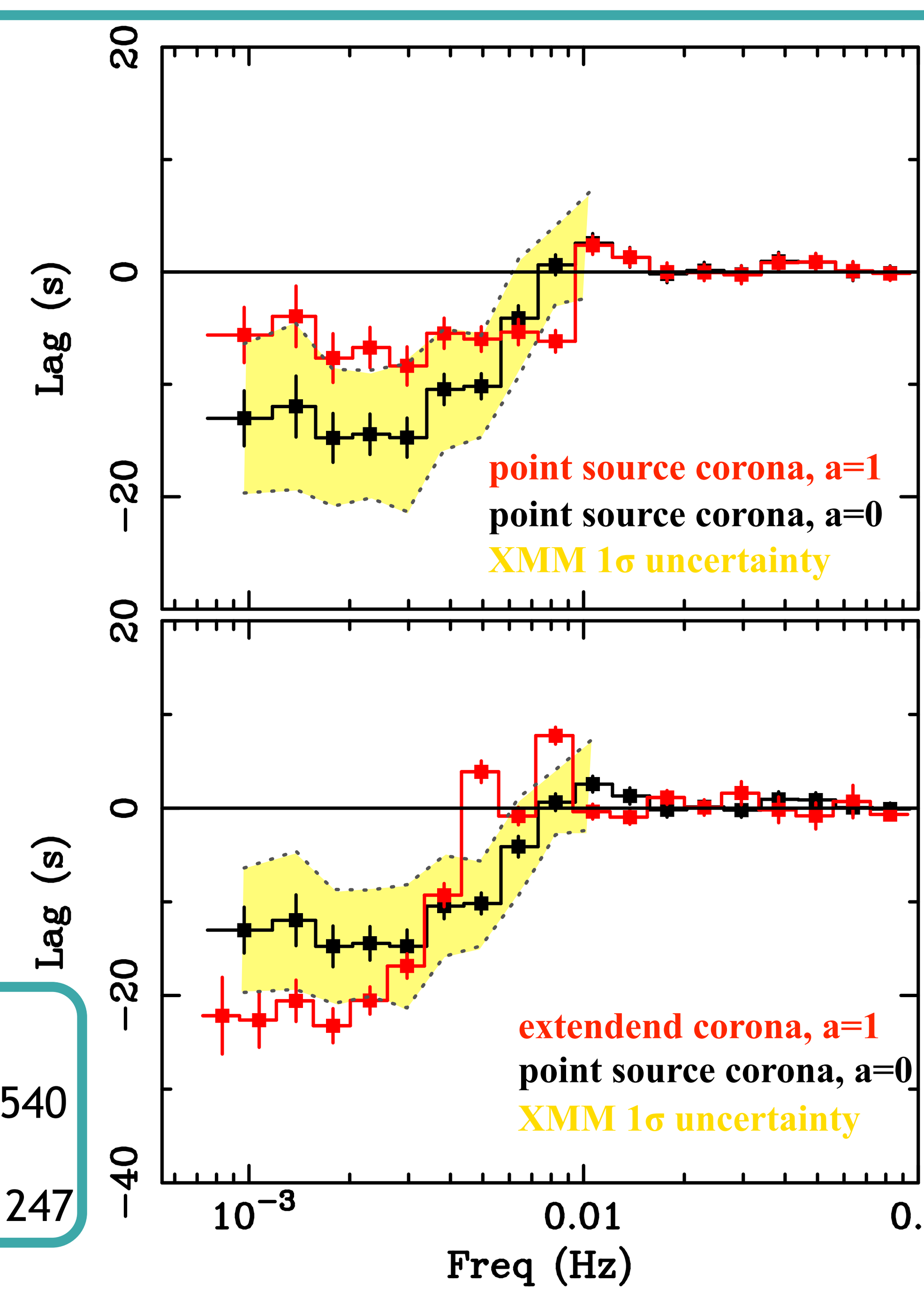

Fig. 4: *WFI simulations of soft X-ray lags. Upper panel: BH spin a=0 vs. a=1, assuming in both cases a centrally concentrated, point source corona geometry (at a height h=2.5r_g). Lower panel: centrally concentrated, point source corona (a=0) vs. radially extended (up to a radius of ~35r_g) corona (a=1) geometry. The yellow shaded areas mark the 1σ uncertainties of EPIC pn lag measurements (assuming a point source corona and a=0).*

References:

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