Highly variable AGN discovered in the XMM Slew Survey

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Introduction

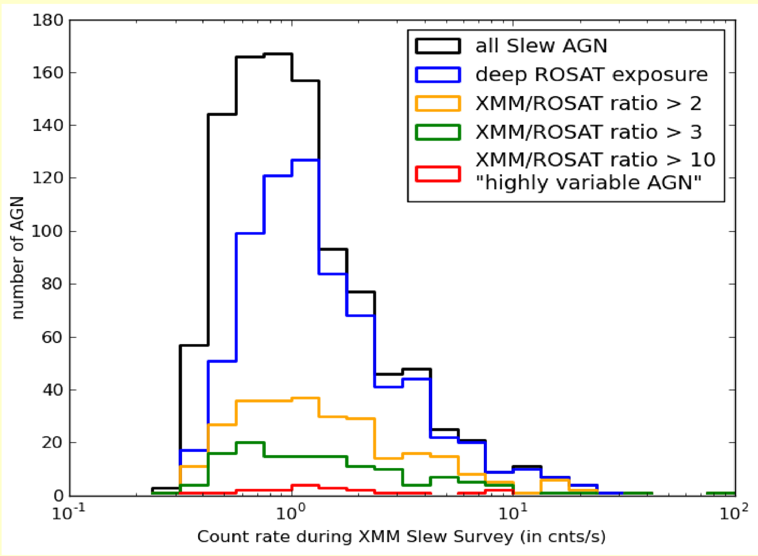
If AGN are scaled-up versions of x-ray binaries, they are expected to undergo different luminosity states. However the time scales of those transitions would be so long, that they are difficult to observe. By comparing XMM Slew observations to data taken by ROSAT up to 20 years earlier, we find that only 2-3% of all observed AGN have changed their flux by more than one order of magnitude. We compare those highly variable sources to a constant AGN population and explore the mechanisms that lead to high variabilities on long time scales.

Sample Studies

Sample Selection

- 1038 AGN were observed during the XMM Slew survey [1]
- compare soft x-ray fluxes 0.2-2.0 keV (band covered by ROSAT)
- 728 sources have deep enough ROSAT exposures, such that a high variability could be detected
- XMM fluxes (0.2-10 keV) are converted to ROSAT range assuming a powerlaw Γ=1.7 and galactic absorption of 3E20 1/cm/cm
- **the soft x-ray flux is constant within a factor of 3 for ~80% of all AGN ("constant sources")**
- **24 sources show a change by a factor of >10 ("variable sources")**

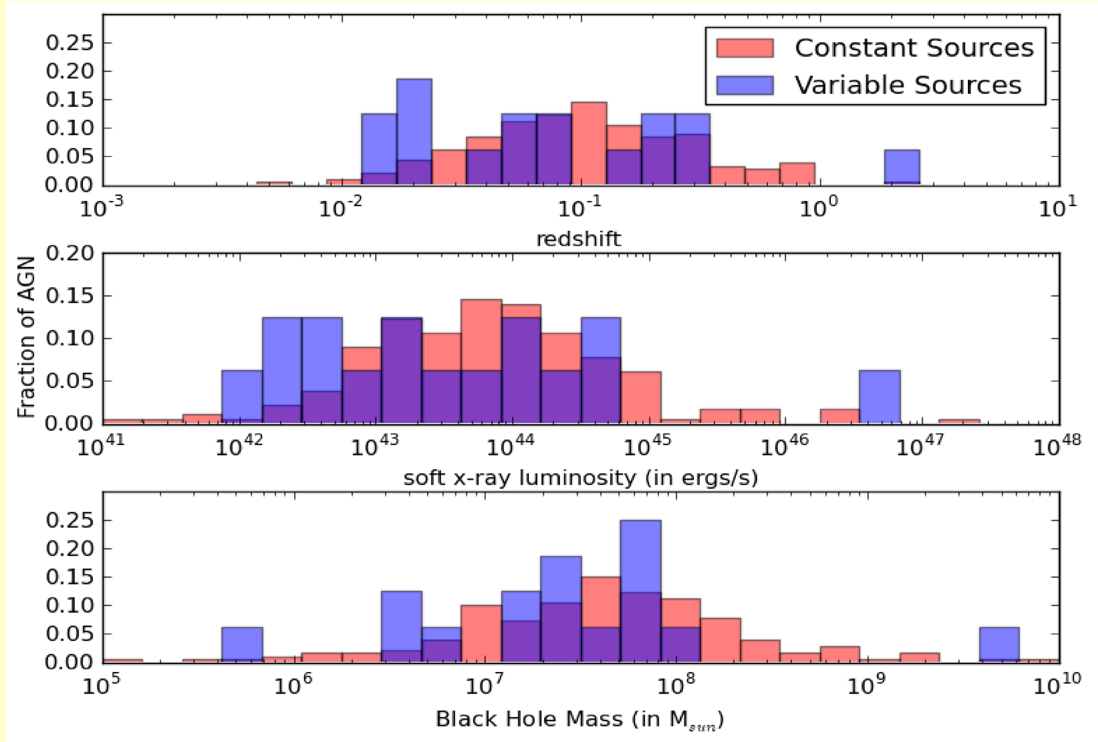
- 2ks Swift observations were obtained for the variable sources
- light curves with observations by Einstein, ROSAT, XMM, Swift and Suzaku



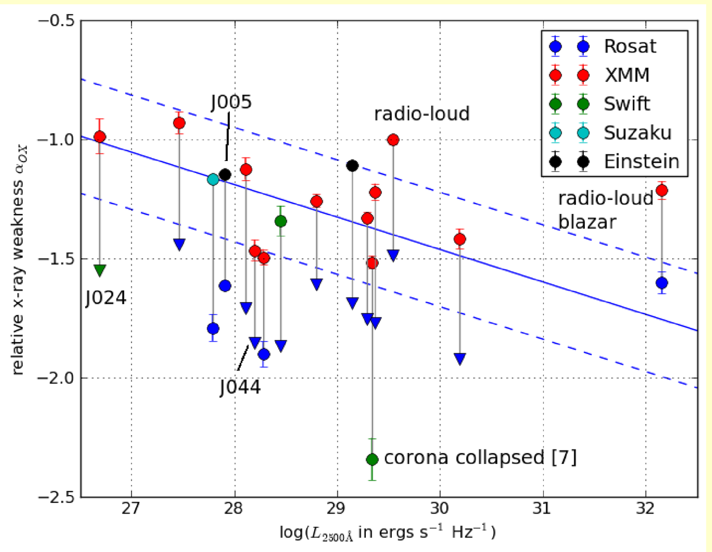
X-Ray luminosity and black hole masses

- compared to the constant sources the variable ones have **lower x-ray luminosities** (significance of 1.7 σ) and redshifts (2 σ deviation)
- however when using the k-band luminosity [2] to calculate the **black hole mass** the results are **similar for both samples**
- some variability mechanism might be more common in low-mass black holes, while others are not

- the AGN with high redshift, luminosity and mass is a blazar (a massive AGN with its jet pointed at us)



Relative X-Ray Brightness



- from the UV luminosity the expected x-ray luminosity can be calculated (shown by the blue line, dashed lines correspond to 1 σ region) [3]
- UV flux from OM, UVOT, Galex or other UV observations
- data are sometimes simultaneous, sometimes few years apart
- the plot shows the relative x-ray brightness α_{OX}=0.3838 log(L_X/L_{UV}) of the variable sources for the brightest and faintest observations
- dots mark detections, while triangles stand for 90% upper limits

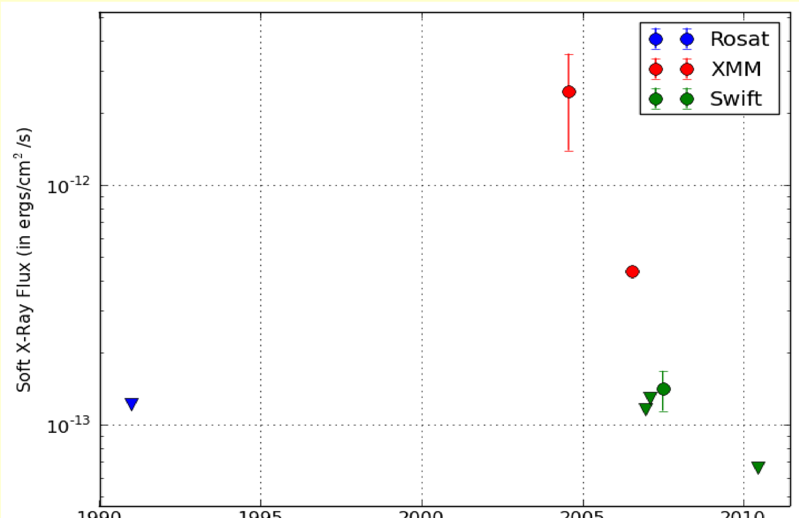
- radio-loud sources are expected to be x-ray bright, due to additional x-ray emission from the jet [4]
- **All other sources are x-ray weak, some of them even in their brightest observed state.**

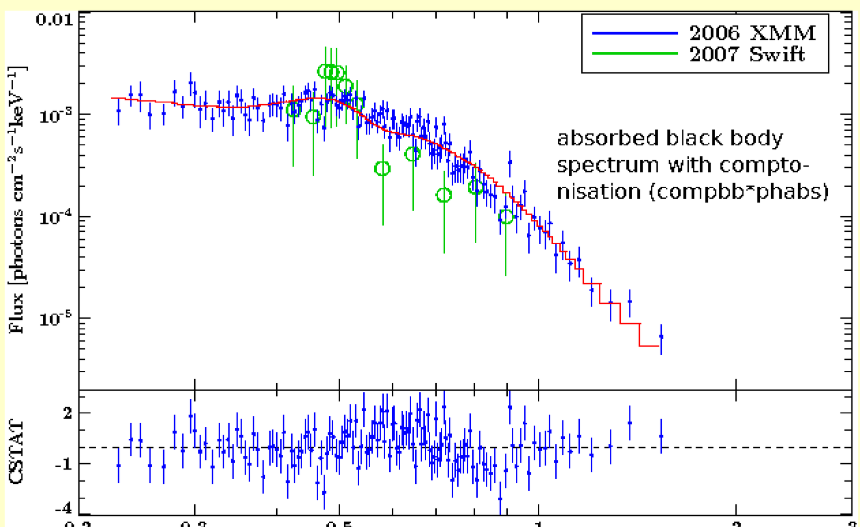
Variability Mechanisms – Some examples

XMMSL1 J024916.6-041244: A Seyfert 1.9 with a pure thermal spectrum

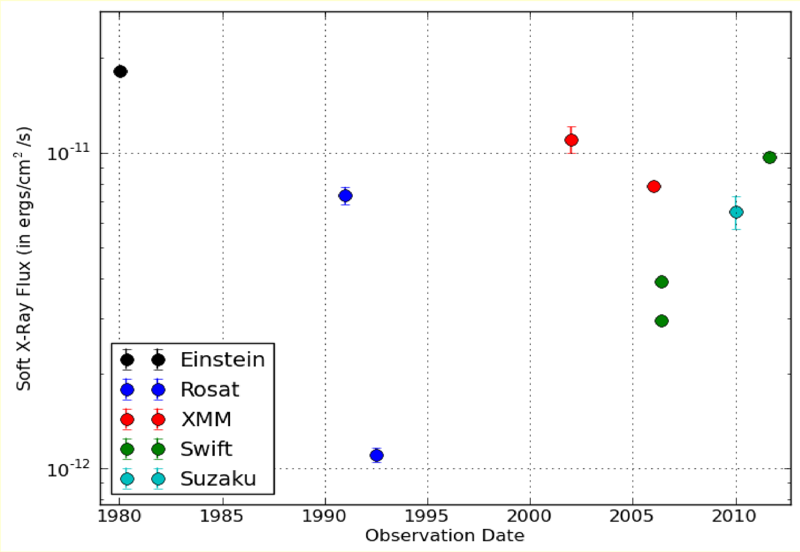
- the light curve and the XMM spectrum of this source are typical for a tidal disruption event (a rapid decay after **a single bright flare** and a pure **soft black body spectrum** with kT=0.08 keV) [5], however the optical spectrum shows clear signs of AGN activity
- while tidal disruptions might occur in AGN, this does not explain the missing hard emission
- **likely the x-ray corona is missing and the emission comes from the accretion disk only**, which might have such a high temperature for the small black hole mass of 5.7 M_{SUN}

- the spectrum of the Swift observation in 2007 has a similar form and but only half the flux





XMMSL1 J005953.1+314934: A variable soft excess



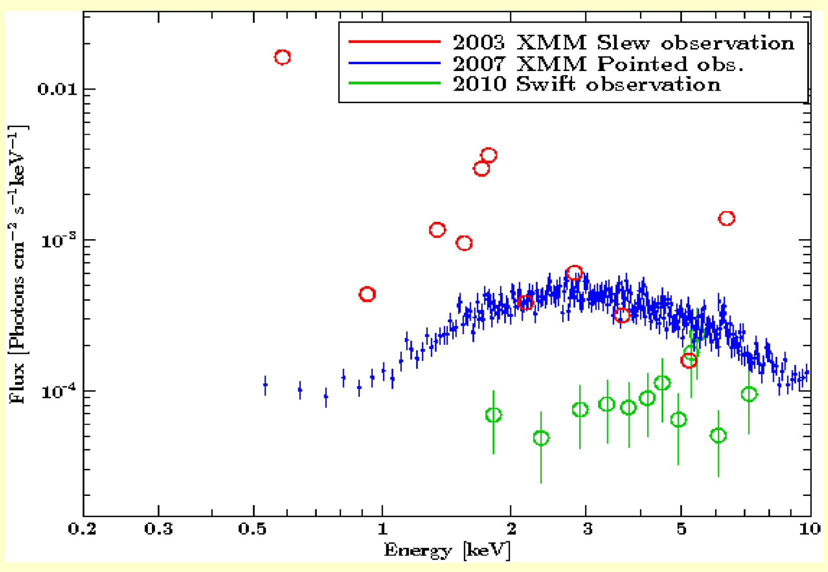
- This bright Seyfert 1.2 has been highly variable over decades.
- Fitting the hard part of the spectra only (above 2 keV) the **photon indices vary significantly**
- One sees either a rather shallow photon index and a soft excess, which can be fitted by a black body (XMM and Suzaku observation) or a steeper powerlaw and a soft deficit (XMM Slew and the three Swift observations).

Absorption

- analysing the Swift spectra, we determine whether absorption by neutral or ionised material can explain the flux change relatively to the brightest observation of the source
- **for 14 out of 18 sources with spectra absorption as a dominating variability mechanism can be excluded**
- one spectrum shows signs of absorption by moderately ionised material, which can account for the flux change by a factor of 5 between the Swift spectrum and the Slew observation
- in two cases the spectra are too poor to exclude absorption
- one source is known to exhibit several neutral partially covering absorbers (see below)

XMMSL1 J044347.0+285822 – variability due to absorption

- The 2003 Slew spectrum excludes thick absorbers with covering fractions higher than 90%, while the other observations require those
- the XMM observation from 2007 requires two partially covering neutral absorbers [6], which can easily account for the observed reduction in flux
- the Swift observation from 2010 favours higher column densities and slightly higher covering fractions
- We conclude thus that this source is variable due to the presence of **moving clumpy clouds of neutral gas**.



Variability Mechanisms found in this sample

- 2 tidal disruption events [5]
- 1 blazar (jet activity)
- 1 collapse of corona [7]
- 1 source with moving absorbers [6]
- 2 false detections during the Slew survey

For the other 17 AGN the variability mechanism remains unclear. Among those are:

- 2 sources with a variable soft excess
- 1 with indications for an ionised absorber
- 1 pure thermal spectrum (likely missing corona)
- 1 NL Quasar with pure powerlaw spectra
- 4 cases for which absorption can not be excluded (no or poor spectra)

Conclusions

- On time scales of ~10 years 2-3 % of all AGN show variations in their soft x-ray flux by more than one order of magnitude.
- Those sources seem to be fainter in x-rays than a comparable sample of constant sources, however their black hole masses could not be observed to be different.
- While the bright state of most sources corresponds to the expected relative x-ray luminosity, the faint states are x-ray weak. Some few AGN are even faint in the brightest observed luminosity state.
- Several very different mechanisms lead to the observed high variabilities, however significant absorption was only found in 2 out of 24 cases.
- For many sources the reason for their variability can not be revealed with the data available in this study.

References

[1] R. D. Saxton et al., in preparation
[2] A. Marconi et al., Astrophysical Journal 2003
[3] A. T. Steffen et al., The Astrophysical Journal 2006
[4] R. R. Gibson et al., The Astrophysical Journal 2008
[5] P. Esquej et al., Astronomy and Astrophysics 2007
[6] C. Ricci et al., Astronomy and Astrophysics 2010
[7] A. C. Fabian et al., MNRAS 2012