Probing accretion/ejection flows in AGN by characterizing Fe K emission/absorption lines variability with residual maps

D. Costanzo★[1,2], M. Cappi[2], M. Dadina[2], B. De Marco[3], C. Vignali[1,2]

★ deborah.costanzo2@unibo.it

[(1) Physics and Astronomy Department, University of Bologna; (2) OAS - Bologna; (3) Nicolaus Copernicus Astronomical Center, Polish Academy of Sciences, Warszawa, Poland]

Abstract

The dynamics and geometry of the material close to the SMBH in AGN are still largely uncertain, both as regards the inflows via accretion disk and the outflows.The latter phenomena may have a fundamental role in the AGN feedback on the host galaxy, so it is important to understand their properties and extent. A simultaneous investigation of inflows and outflows may highlight some kind of correlation, that shall help to unravel the driving mechanisms of massive winds from the disk, still an open issue. Time-resolved spectral analysis is a key tool to investigate these phenomena.

The 4.0-10.0 keV energy band is the most suitable for these aims, because it includes the Fe Kα fluorescence emission line at 6.4 keV, a fundamental proxy of the motions around the SMBH, and possibly Fe resonant absorption lines, features that indicate the presence of massive, relativistic (<v>~0.1c) disk winds (Ultra Fast Outflows, Tombesi et al. 2010), observed in about 50% of local AGN for which good quality data exist.

We use a technique, *Residual maps*, that couples time and spectral analysis to the two X-ray brightest Seyfert 1 observed to date: NGC 3783 and Mrk 509. It allows to identify spectral features and trace their evolution in time. Residual maps can be used to detect potentially interesting time intervals, on which a deep spectral analysis can be (and will be) carried out to characterize the physical phenomena in act.

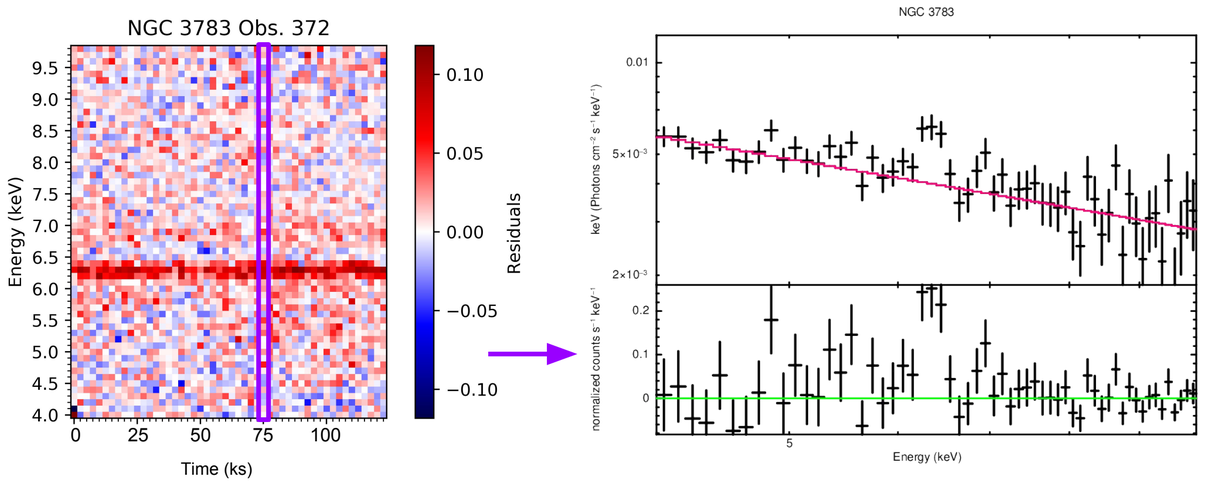
Source selection

Seyfert 1 with $F_{4.5-12keV} > 10^{-11}$ erg s^{-1} cm^{-2} and long exposures (at least few hundreds ks) from 3XMM-DR7 catalogue (XMM-*Newton*)

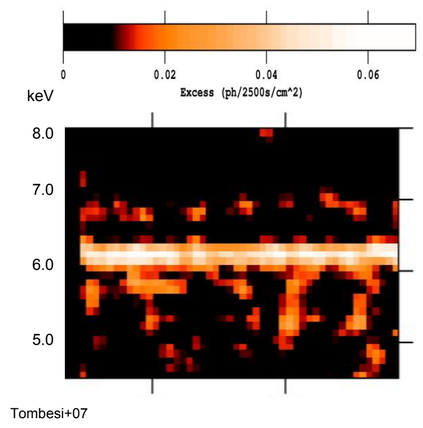
- NGC 3783: observed in 2000, 2001, 2016; 453 ks total exposure; $F_{4.5-12keV} = 3.34 \times 10^{-11}$ erg s^{-1} cm^{-2}
- Mrk 509: observed in 2000, 2001, 2005, 2006, 2009; 834 ks total exposure; $F_{4.5-12keV} = 3.08 \times 10^{-11}$ erg s^{-1} cm^{-2}

Residual Maps

- Time resolution: trade-off between photon statistics and sampling short time-scales (fractions of the orbital period at 10 Rg ~10 ks)
- Spectra for a duration of the chosen exposure time are extracted in time sequence
- For each spectrum the continuum (power law + cold absorption) is determined (in 4-5 keV and 7.5-10 keV bands) and then subtracted
- The residuals are put together in time sequence to construct an image in the time-energy plane



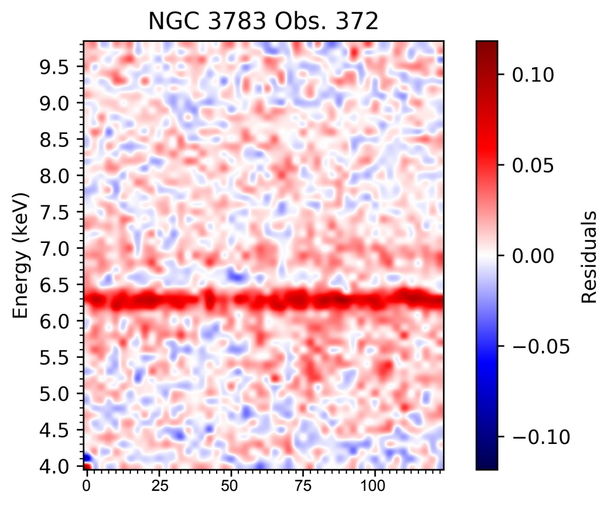
What is new



Excess map

(Iwasawa et al. 2004; Turner et al. 2006; Tombesi et al. 2007; De Marco et al. 2009)

Only **positive** residuals (Time-evolution of emission features above the continuum)

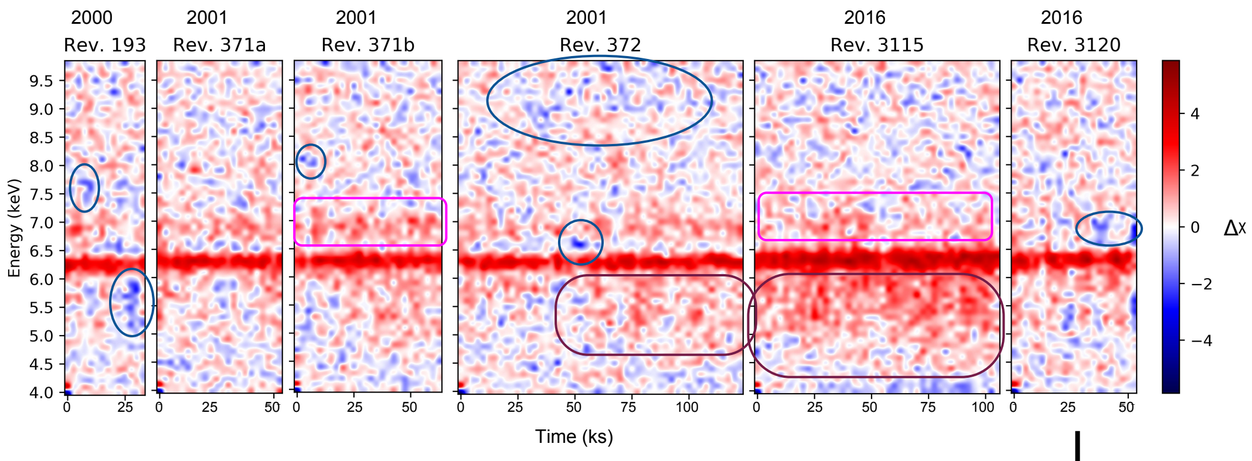


Residual map

(smoothed)

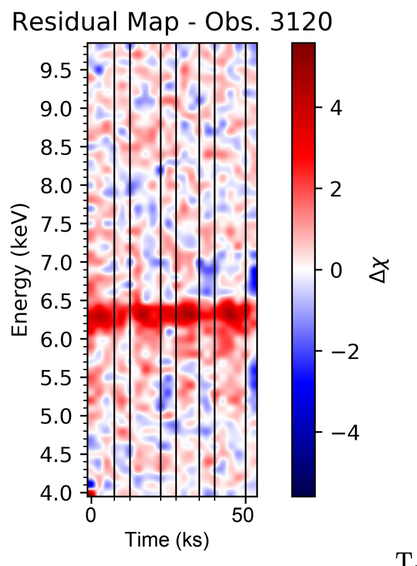
Both **positive** and **negative** residuals (Time-evolution of emission/absorption features above/below the continuum)

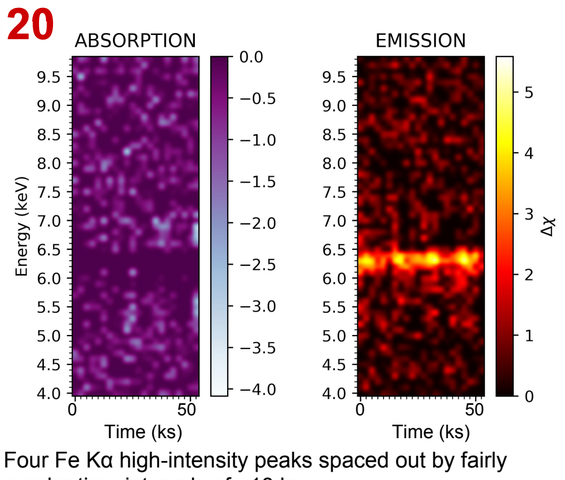
NGC 3783



- Fe Kα always present, variable intensity
- Variable Fe Kβ/ ionized Kα blend
- Variable broadened line component
- Multiple absorptions

NGC 3783 - Revolution 3120





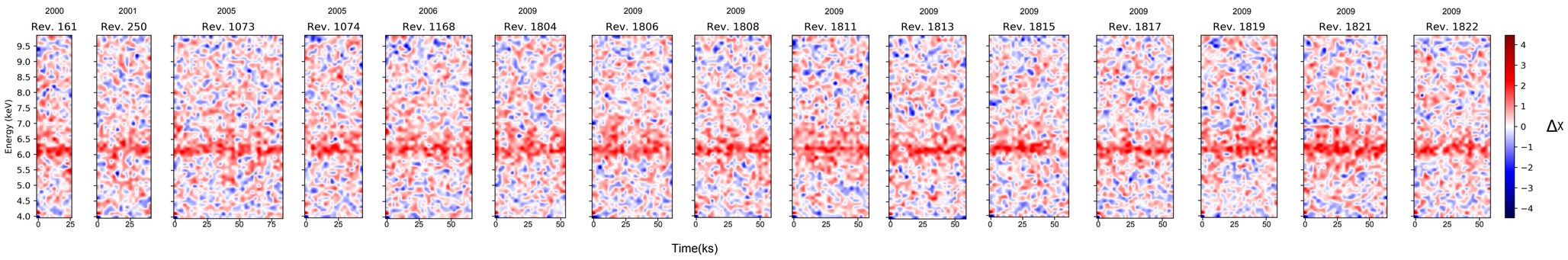
- Four Fe Kα high-intensity peaks spaced out by fairly regular time intervals of ~13 ks
- Indications of a possible periodic variability
- Time-scale corresponding to orbital period of a blob in a Keplerian orbit at ~6 Rg
- Deeper spectral analysis needed - work in progress!

$$T_{orb} = 310 \left[a + \left(\frac{r}{r_g} \right)^{3/2} \right] M_7 \ \ s$$

Bardeen+ 72

~13 ks ⟷ **~6 Rg**

Mrk 509



Structured Fe Kα lines, variable in time and energy

Reliability of the method

- Systematics: check for the balance between positive and negative pixels in the fitting bands on all residual maps (21 in total) → good balance in 4-5 keV band, slight predominance of positive residuals in the 7.5-10 keV band (~57%)
- Model-dependencies: search for possible correlation between the photon index of the power law and intensity of the narrow Fe Kα line intensity of the red wing (both measured by summing the residuals in the corresponding energy channels for each spectrum of each observation) →no strong correlation present: Narrow line vs Γ: ϱ = -0.036; Red wing vs Γ: ϱ =-0.006 (ϱ being the Spearman correlation coefficient)

Conclusions

- Residual maps provide an immediate idea of the variability of the emission/absorption features and their time scales, allowing targeted deeper spectral analysis on selected time intervals
- No strong hints of systematics or model-depency revealed, further check foreseen
- Direct comparison with (simple) spectral analysis confirms that features in the residual maps are likely present also in the spectra and thus are not artifacts of the procedure
- Deeper spectral modeling is ongoing

References: • Bardeen et al. 1972, ApJ 178, 347–370 • Iwasawa et al. 2004, MNRAS 355, 1073–1079 • Turner et al. 2006, A&A 445, 59–67 • Tombesi et al. 2007, A&A 467, 1057–1063 • De Marco et al.2009, A&A 507, 159–169 • Tombesi et al. 2010 A&A 521, A57