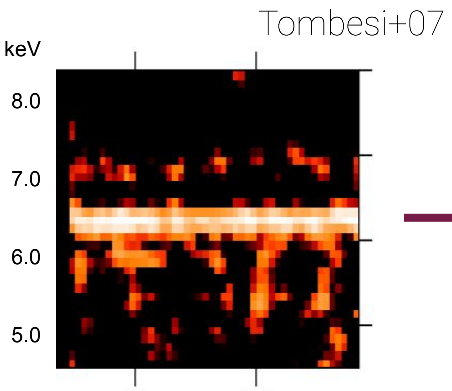
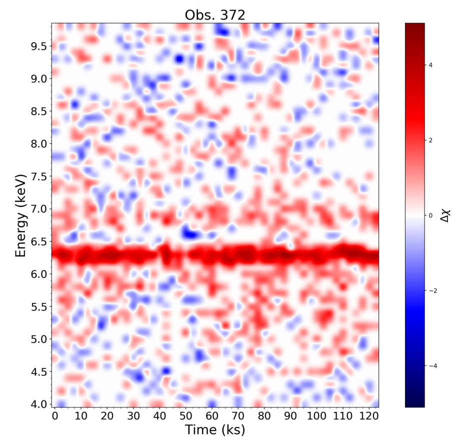
Deborah Costanzo[1,2], M. Cappi[2], M. Dadina[2], B. De Marco[3], C. Vignali[1]
[1] DIFA University of Bologna, [2] INAF-OAS, [3] N. Copernicus Astronomical Center of the Polish Academy of Science

Probing accretion/ejection flows in AGN via Fe K emission/absorption lines variability

QiC, Edinburgh 2019



Excess Map
only positive residuals
(Iwasawa+ 04, Turner+ 06, Tombesi+ 07, De Marco+ 09, Nardini+ 16, ...)



Residual Map
positive + negative residuals simultaneously
(Costanzo+ in prep.)

Residual maps:

- Time resolved spectral analysis technique
- Useful to study short time scale variability on bright sources (few ks ↔ few Rg)
- How to produce the maps:
  1. Observation is sliced in time
  2. For each time-bin a simple continuum is fitted on the extracted spectrum and then subtracted
  3. Residuals of all time-bins are put together in the time-energy plane
- Positive and negative residuals are used together, in order to map the evolution of both emission and absorption features

Goals:

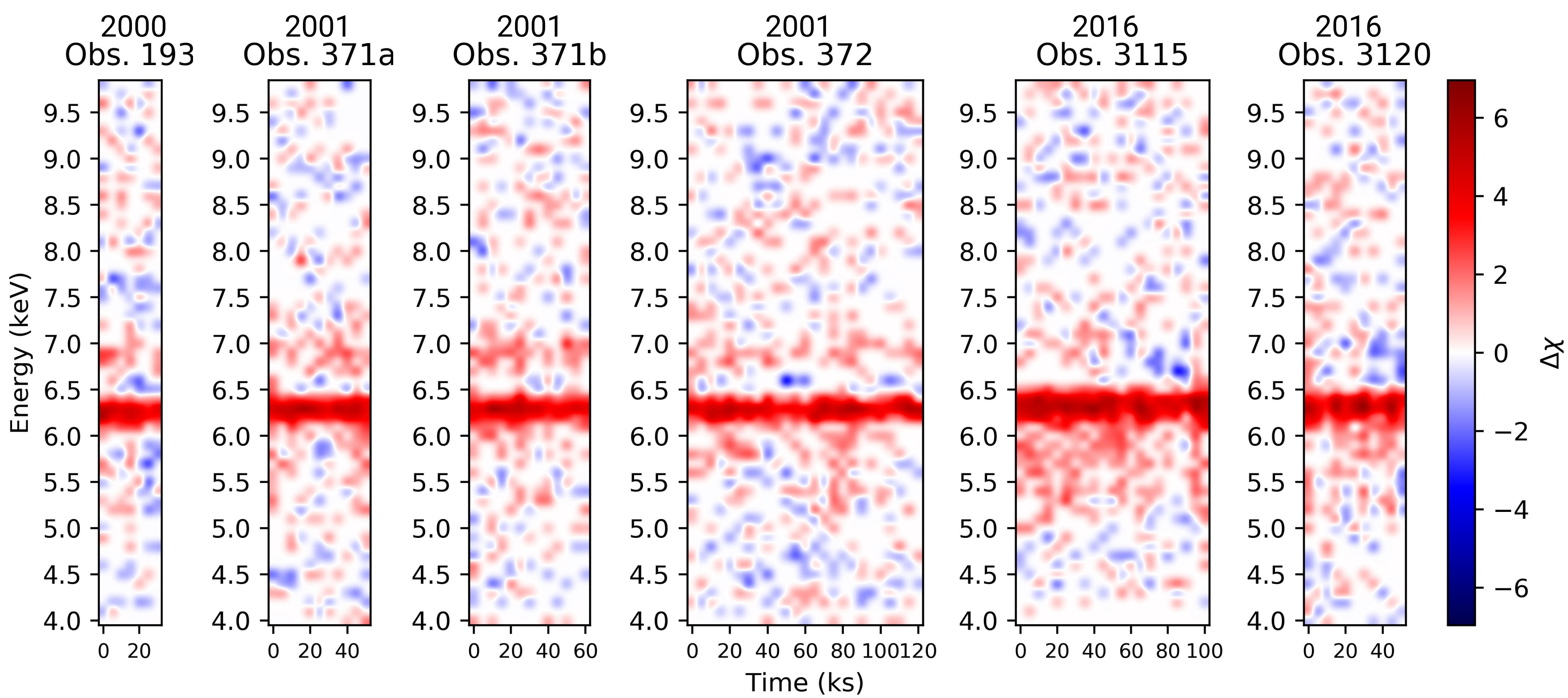
- Search for variability patterns
- Find correlations among patterns of different features

We analyzed **NGC 3783:**

- Seyfert 1
- z= 0.00973 (Theureau+ 98)
- $F_{4.5\text{-}12\,keV} \simeq 3.3\ 10^{-11}$ erg /cm²/ s
- Temporary obscuration in 2016 (Mehdipour+ 17)

In the residual maps we find:

- Persistent Fe Kα line, with variable normalization
- Variable blend of Fe Kβ and ionized Kα, mostly present in 2000/2001 observations (Reeves+ 2004)
- Variable excess from ~5.0 to 6.4 keV, stronger in 2016 data (due to complex absorption or relativistic deformation of the Fe Kα)
- Recurrent absorptions in 6.7-7.0 keV range



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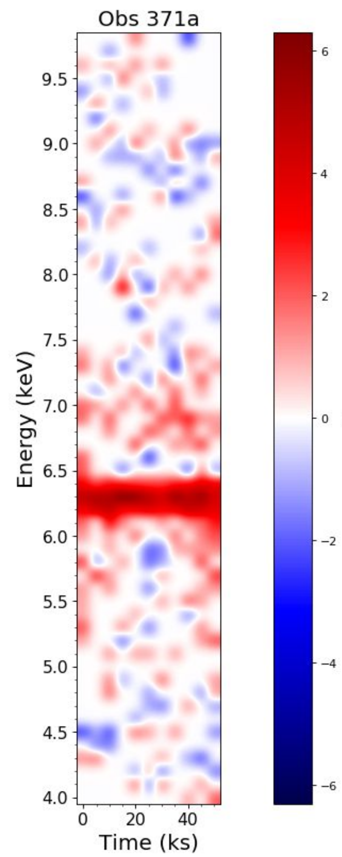
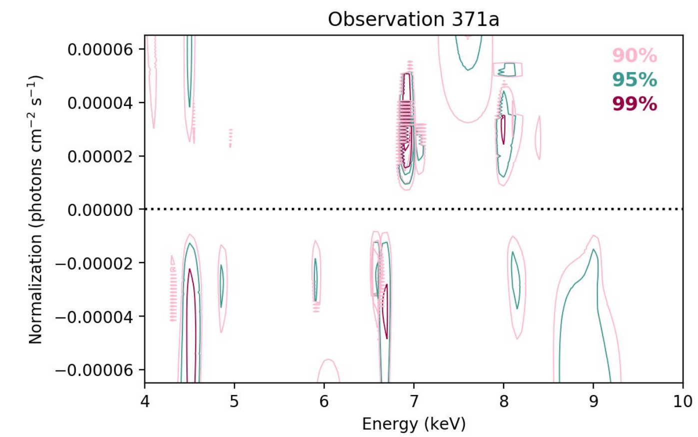
- Assessing features significance from residual maps is not trivial, so we did an independent blind search for emission/absorption features on the same time bins. All the features we find this way are also present in the residual maps.

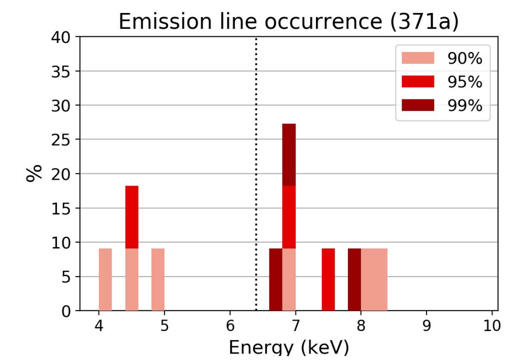
- Putting these methods together we know the significance of the features and can count how many times they are detected plus we can place in the time-energy plane to (easily) identify and characterize their eventual evolution/variability patterns.

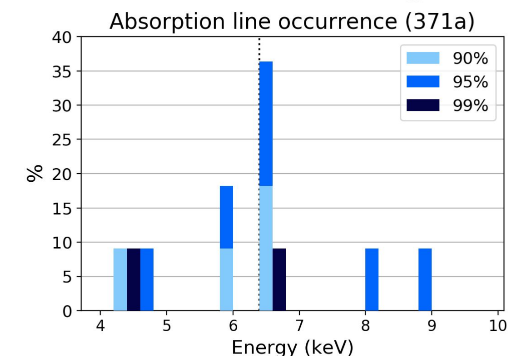


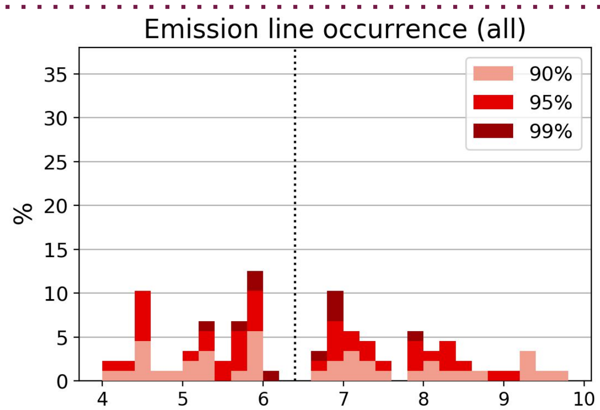
Example of the combined method used on Observation 371a (2001).

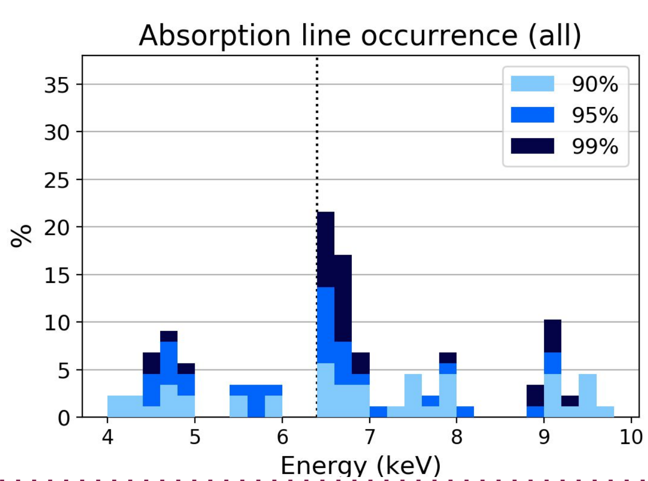
Left panel: Residual map of the observation. Right panel: stacked significance contours of the features found in the eleven 5ks time-bins . Bottom panels: their distributions in energy.







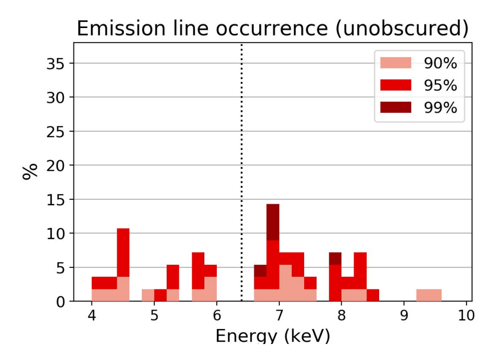


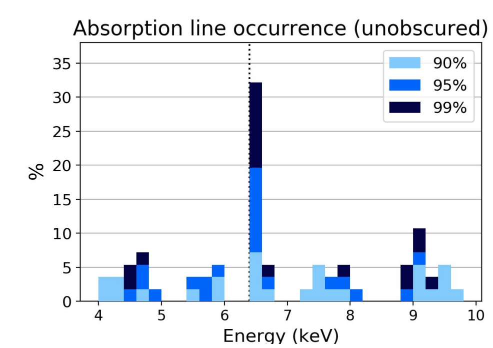


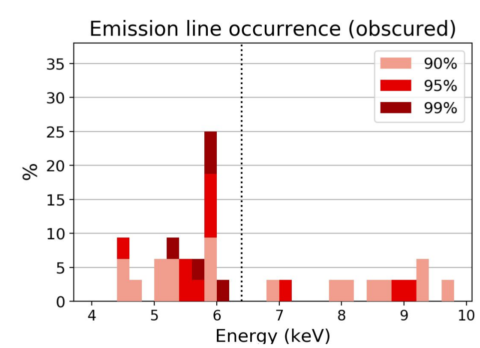
Left: distribution of emission (in red) and absorption (in blue) features found via blind search in the spectra of all observations (88 time-bins of 5 ks).

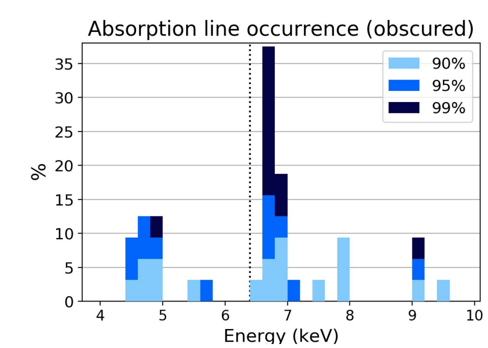
Right: same distributions for unobscured observations (2000, 2001) on top, and obscured observations (2016) below.
Main differences:

- In the 2000+2001 observations there is a peak in the emission line distribution around 7 keV, that is not present in 2016 data.
- The incidence of emission lines at energies between 5 and 6.4 keV is higher in the 2016 observations.
- The peak of absorption line distribution in 2016 observations is shifted at higher energies and broader.









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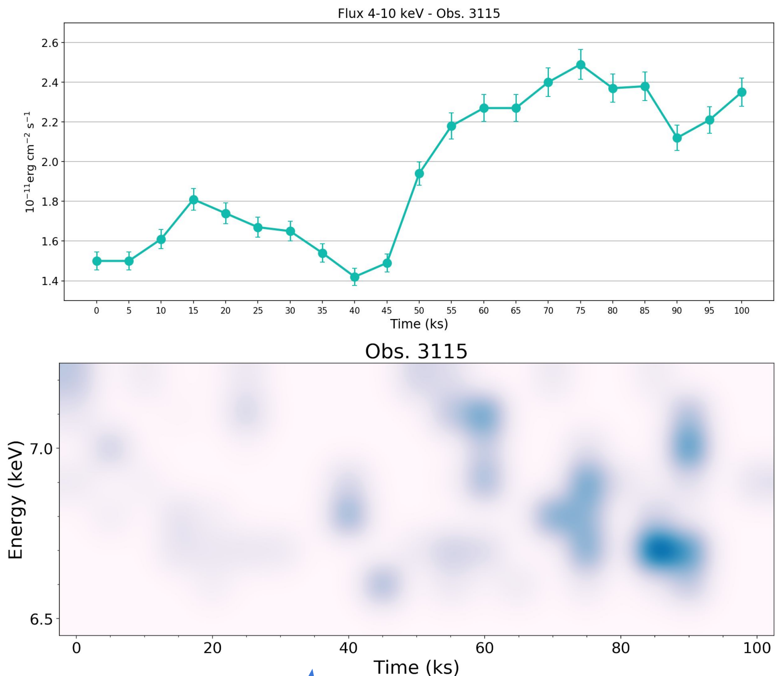
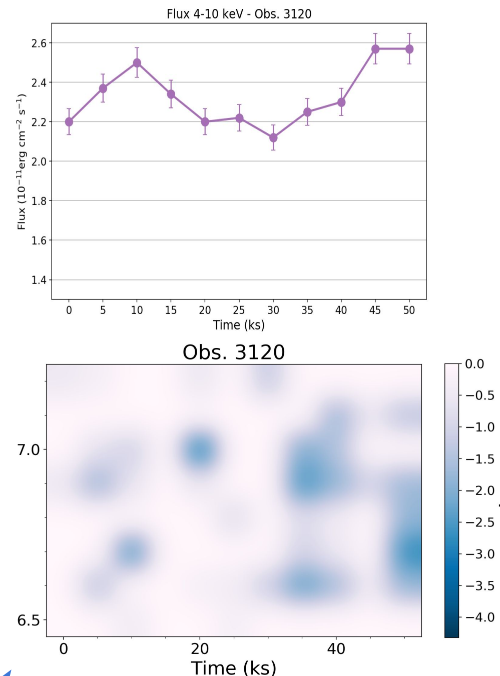
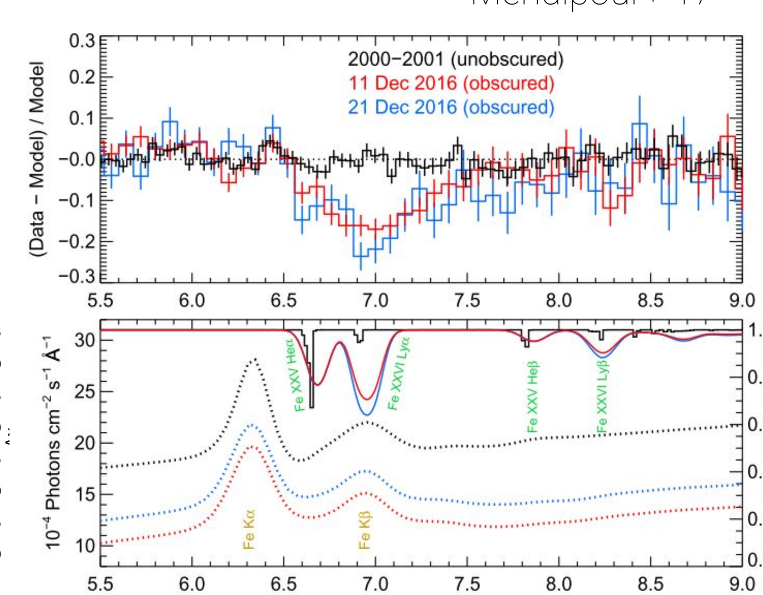
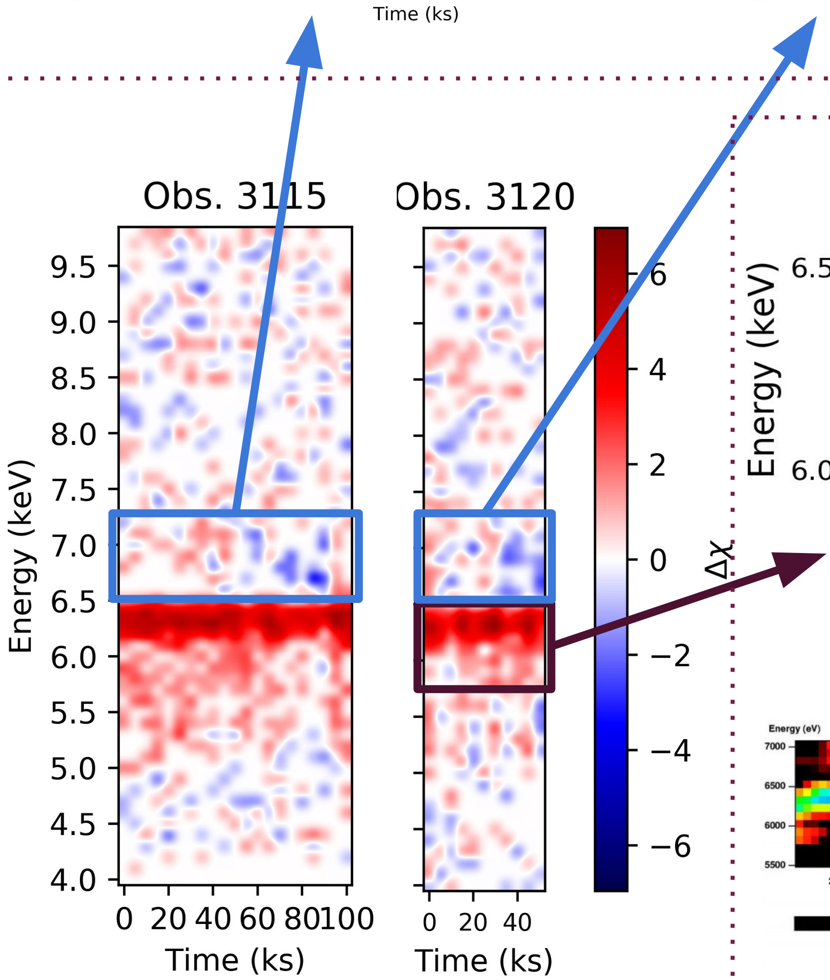


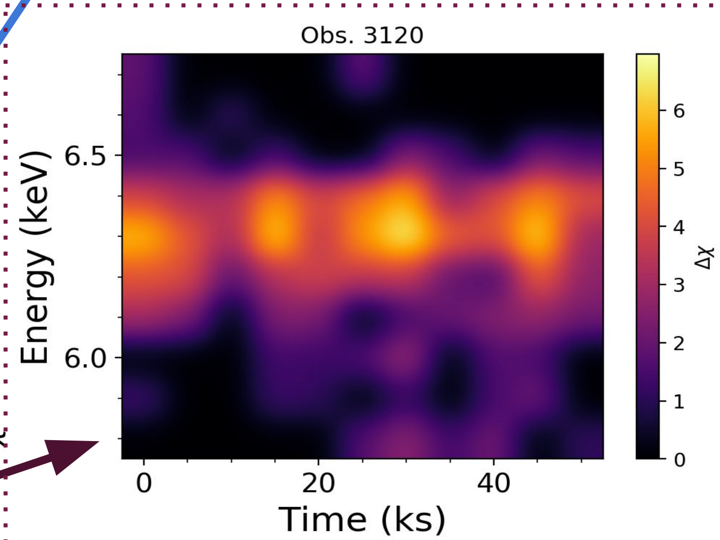


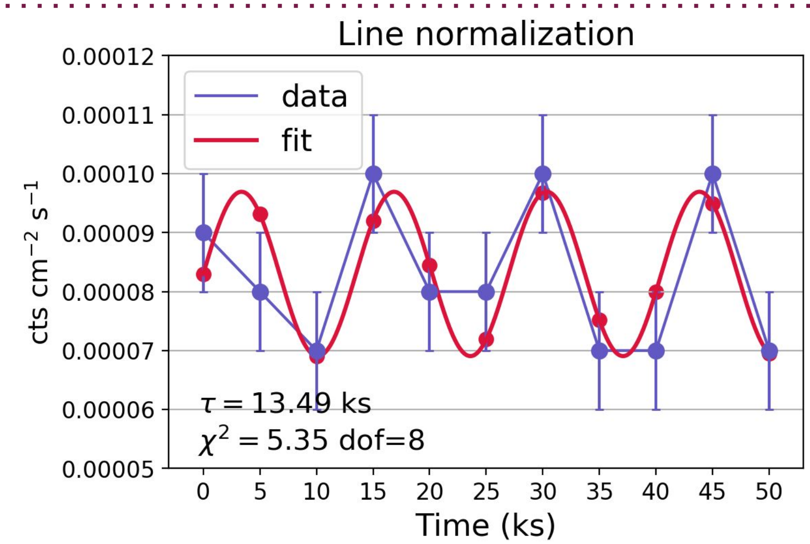


The medium causing the ~ 6.6 - 7.0 keV absorption features in the 2016 observations seems to respond to flux variations in a time shorter than 5 ks (residual maps time-bin size).

Fe XXVI Lyα and Fe XXV Heα absorption lines appear resolved in the residual maps. Results are in good agreement with Mehdipour+ 17.



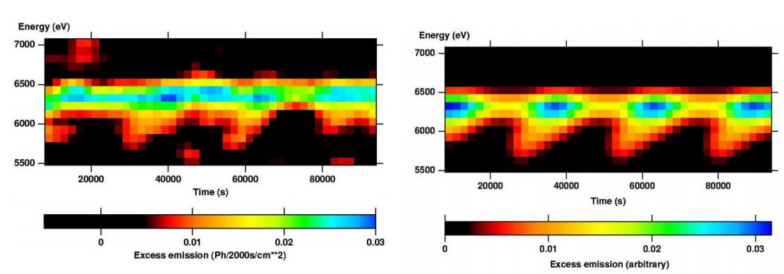




Bardeen+ 72

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

13.5 ks ↔ 6 Rg



Iwasawa+ 04

Last 2016 observation shows hints of modulated signal for the Fe Kα, similar to what was detected in NGC 3516 and explained as a rotating hot spot in the corona by Iwasawa+ 2004. The period corresponds to Keplerian orbits at 6 Rg for a maximally rotating BH of 3 10⁷ M⊙ (Peterson+ 2004), but too few point to asses actual periodicity.