Variable X-ray absorption in the mini-BAL QSO PG 1126-041

Margherita Giustini

Massimo Cappi, George Chartas, Mauro Dadina, Mike Eracleous, Gabriele Ponti, Daniel Proga, Francesco Tombesi, Cristian Vignali, and Giorgio G.C. Palumbo

A&A in press, arXiv:1109.6026

A

Intro

AGN accretion disk winds

BAL and mini-BAL QSOs

X-ray observations

B

The 2008/09 XMM-Newton campaign on PG 1126-041

The AGN structure

Wind kinetic efficiency

Future perspectives

So what?

C

There are strong evidences that outflowing matter is a key ingredient of the inner regions of AGN

observational

Saturday and Sunday sessions

theoretical

Monday session

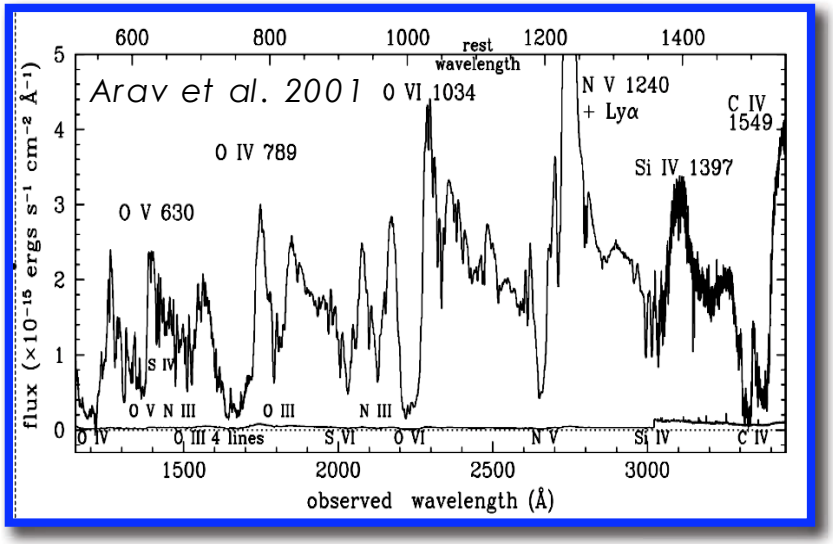
relevant to:

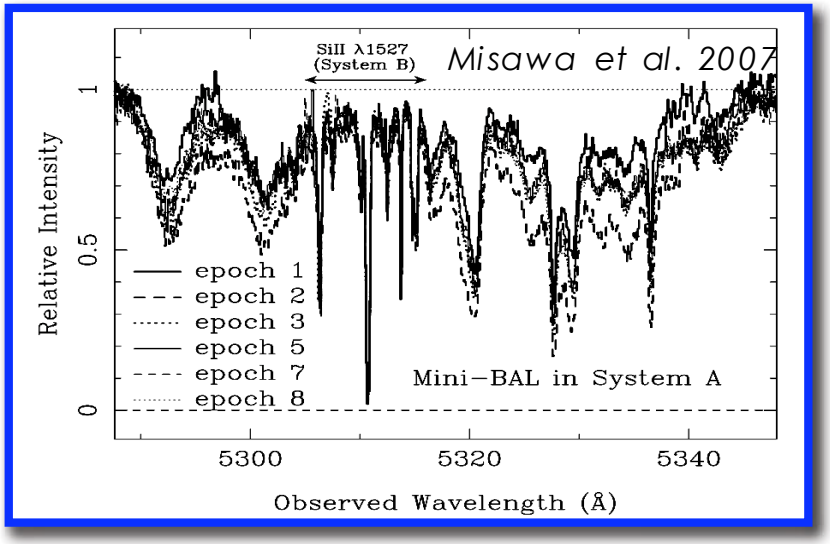
AGN structure and Cosmic feedback

Monday and Tuesday sessions

Powerful outflows from the inner regions of AGN

Broad (FWHM > 2000 km/s) and mini-Broad (FWHM < 2000 km/s) Absorption Line Quasars





- $\log \xi \sim 0$ erg cm s^{-1}
- $\log N_H \sim 21\text{-}23$ cm^{-2}
- $\upsilon_{out} \sim 0.01\text{-}0.2$ c

- **Observed fraction: ~16% among optically selected QSOs**

Hewett & Foltz 2003: Knigge et al. 2008; Gibson et al. 2009; Rodriguez Hidalgo 2009

- **Intrinsic fraction: ~40%**

Ganguly & Brotherton 2008; Allen et al. 2011

X-ray observations

- **Green et al. 1995 ApJ 450, 51** RASS x LBQS *First systematic survey*

BAL QSOs are X-ray weak : 1/37 BAL QSO detected

optical to X-ray spectral index $\alpha_{ox} = \frac{\log(f_{2keV} / f_{2500A})}{\log(\nu_{2keV} / \nu_{2500A})} < -2$

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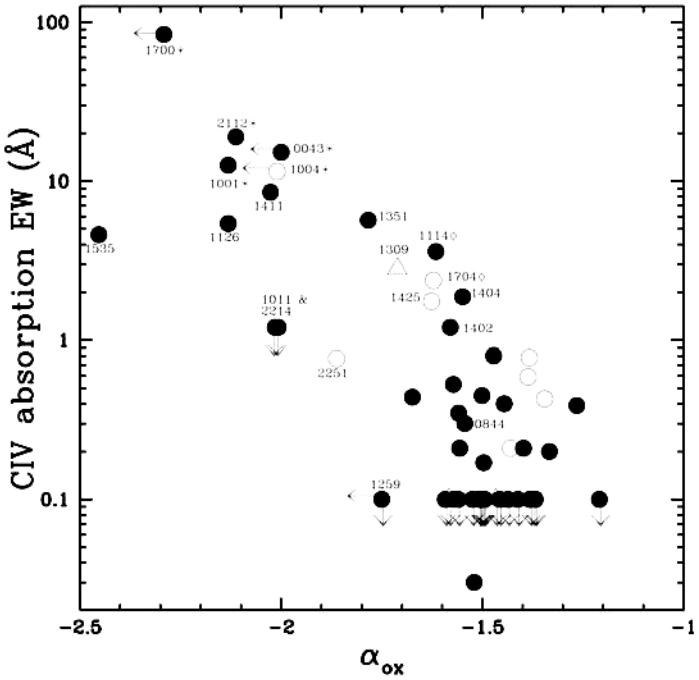
BAL QSOs X-ray weakness correlates with EW(C IV) and is thus consistent with being due to absorption



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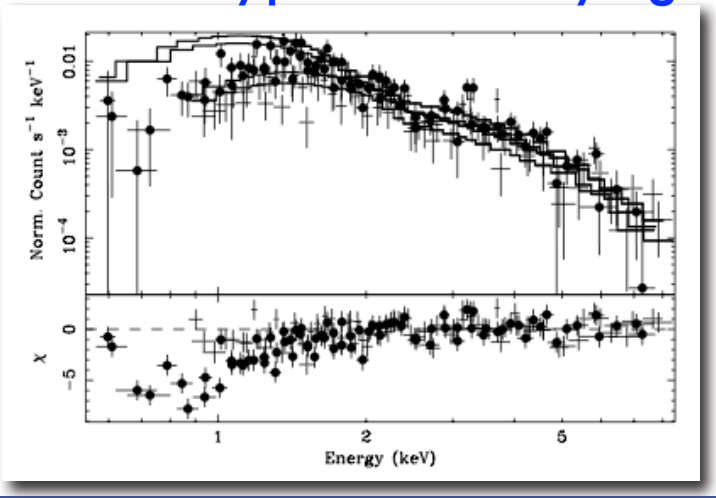
- **Gallagher et al. 2001 ApJ 546, 795** ASCA
- **Gallagher et al. 2004 ApJ 603, 425** Chandra

First spectra of BAL and mini-BAL QSOs

Complex absorption and a typical underlying intrinsic continuum



PG 1126-041

- $z=0.062$
- $M_{BH} \sim 1.2 \times 10^8 M_\odot$
- $r_g \sim 1.8 \times 10^{13}$ cm
- $t_L \sim 600$ s
- $L_{BOL} \sim 10^{12} L_\odot$
- $M_{acc} \sim 0.7 M_\odot$/yr
- $L/L_{Edd} \sim 0.26$

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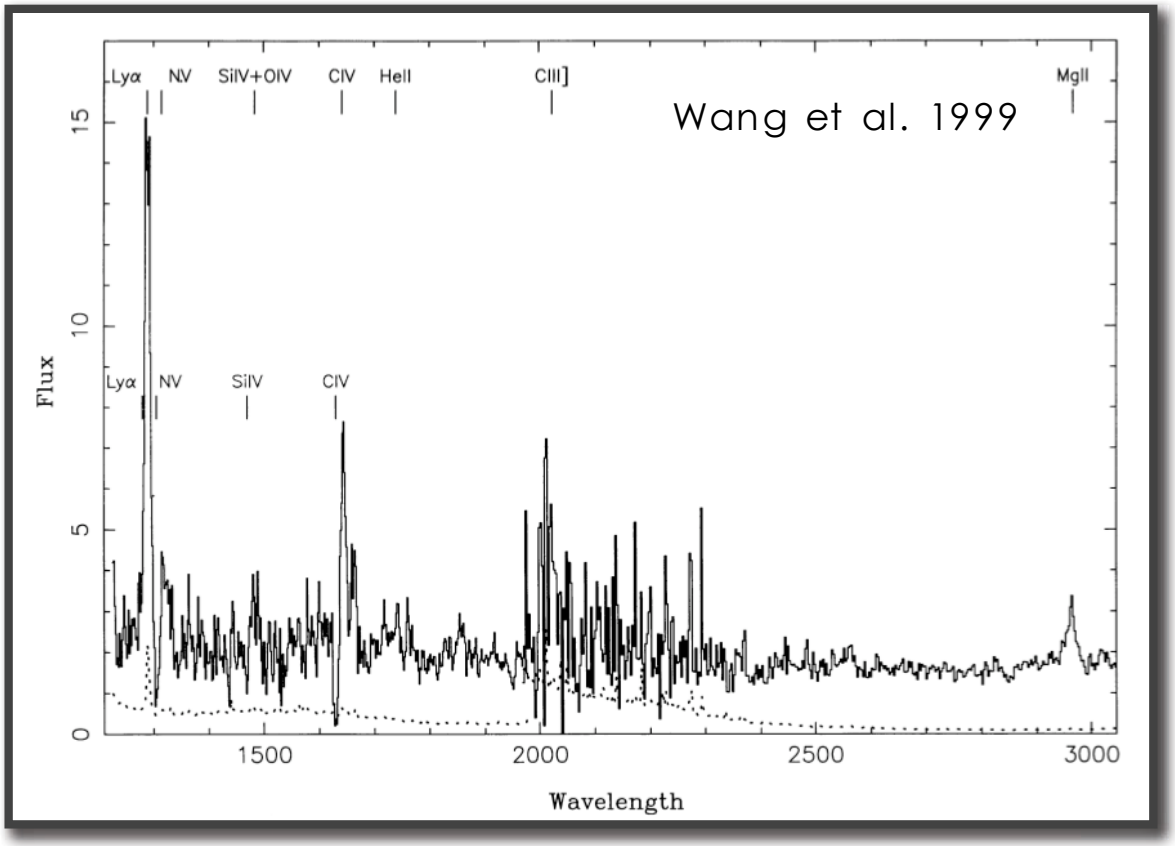

IUE: mini-BALs in C VI, Si IV, N V

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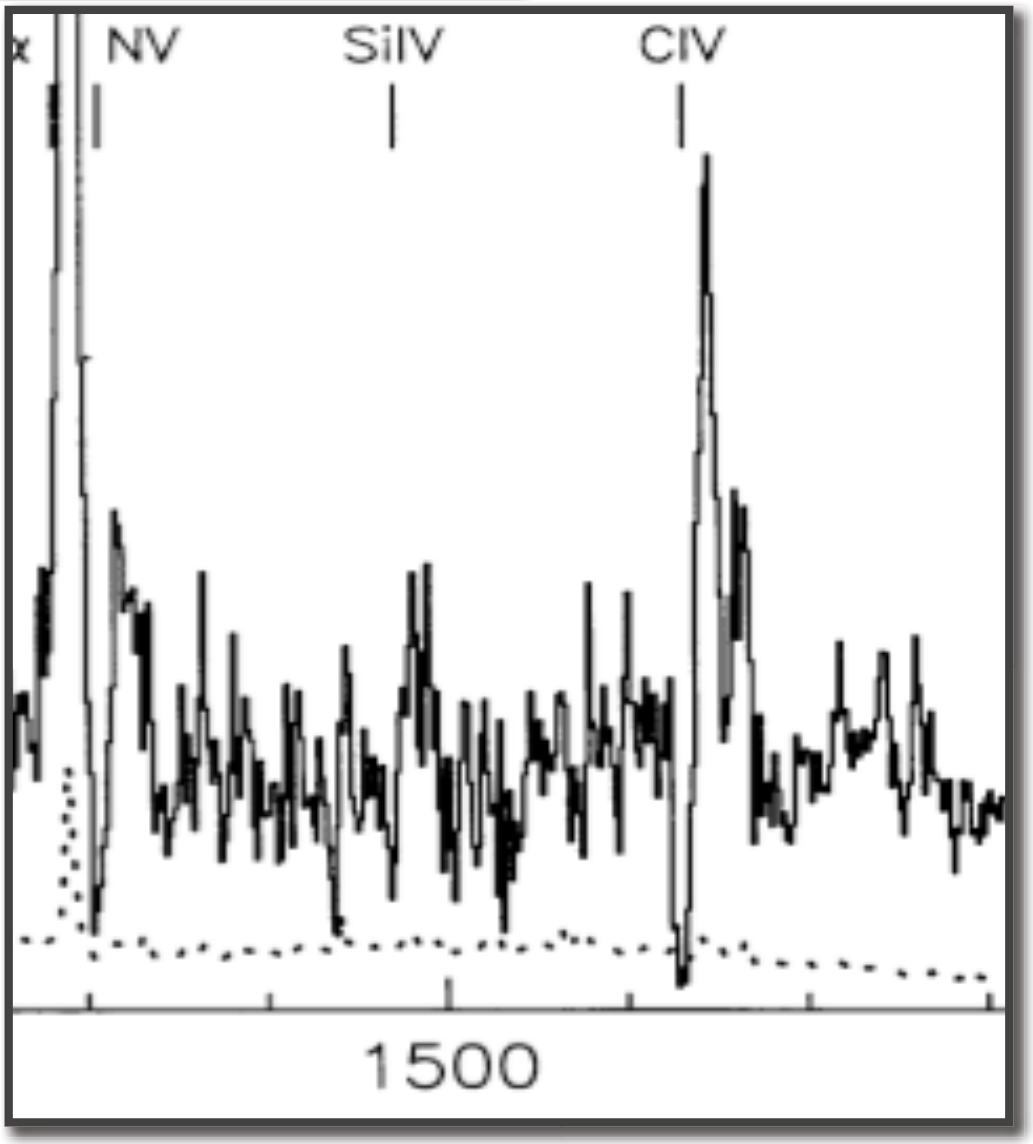

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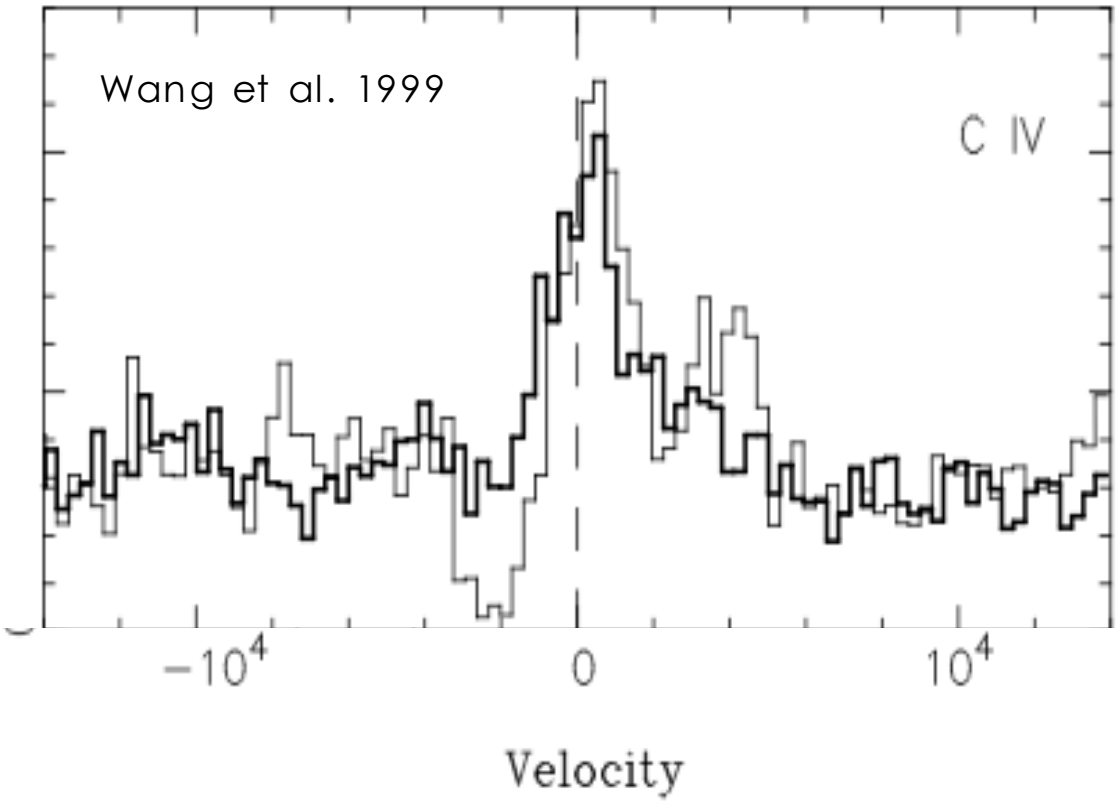

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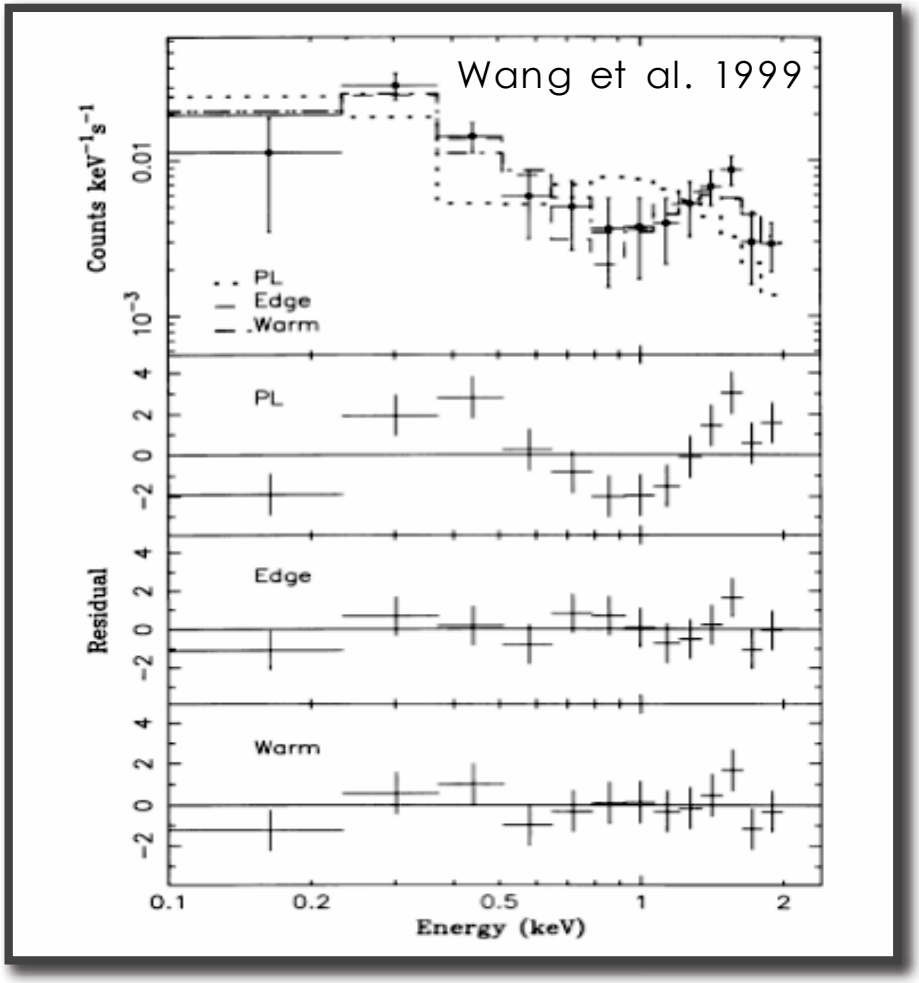

ROSAT: Soft X-ray absorption

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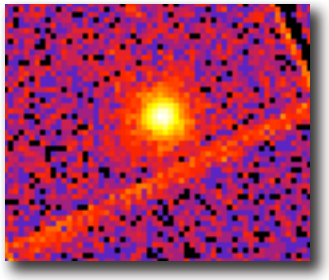
XMM Archive, December 2004 : 33 (28) ks



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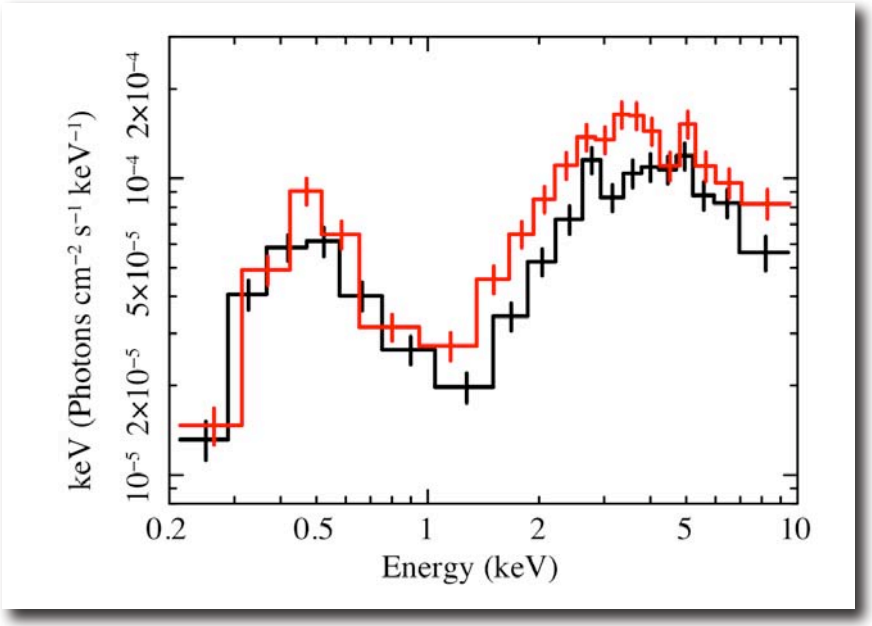

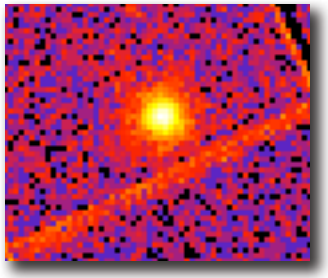

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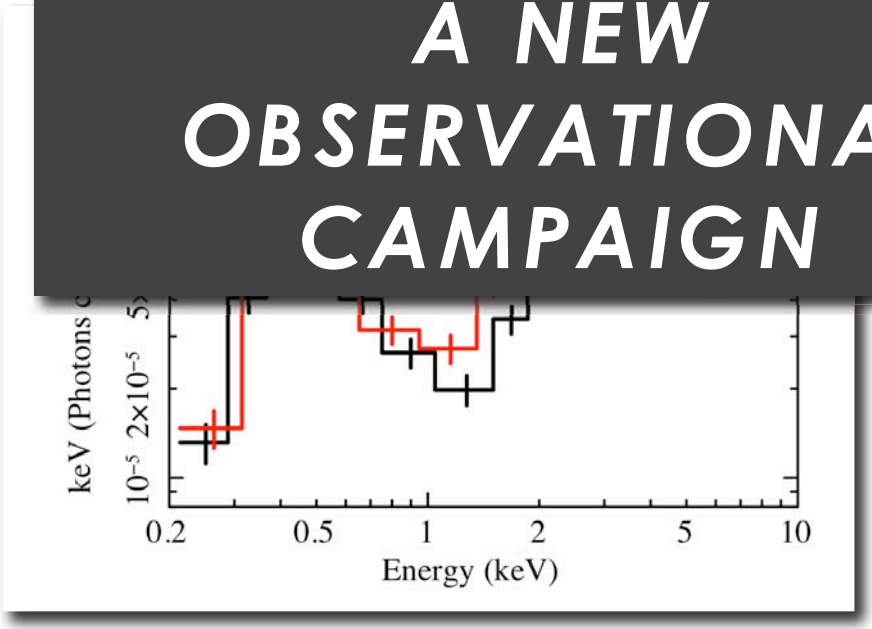
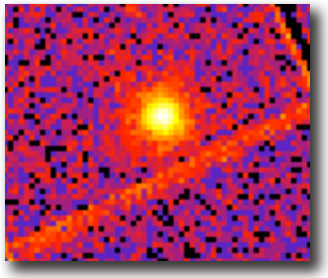
A NEW OBSERVATIONAL CAMPAIGN





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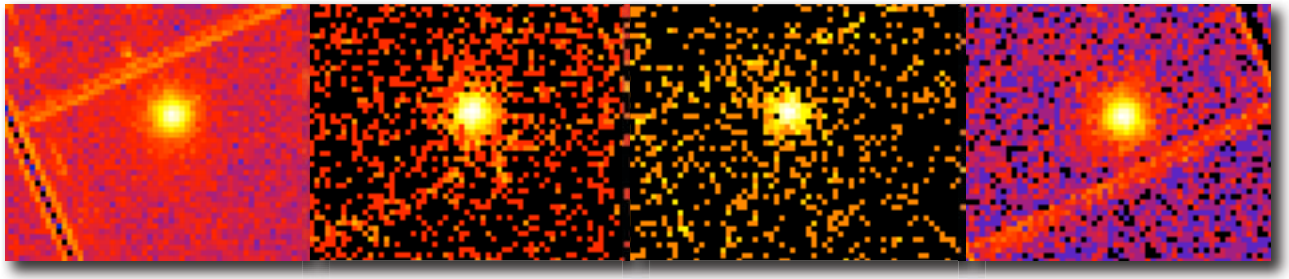
XMM Archive, December 2004 : 33 (28) ks

XMM AO-7, June 2008 : 31 (4) ks

XMM AO-7, December 2008 : 12 (4) ks

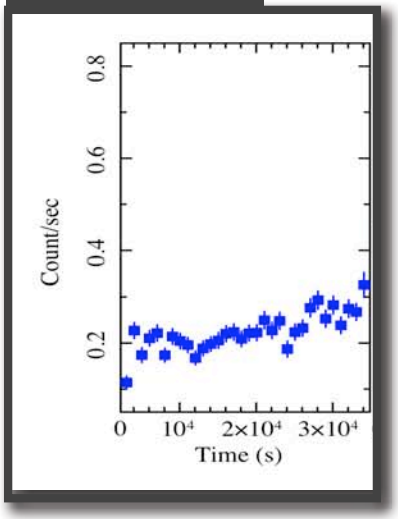
XMM AO-8, **June 2009** : 134 (92) ks



The longest X-ray look ever at a mini-BAL QSO

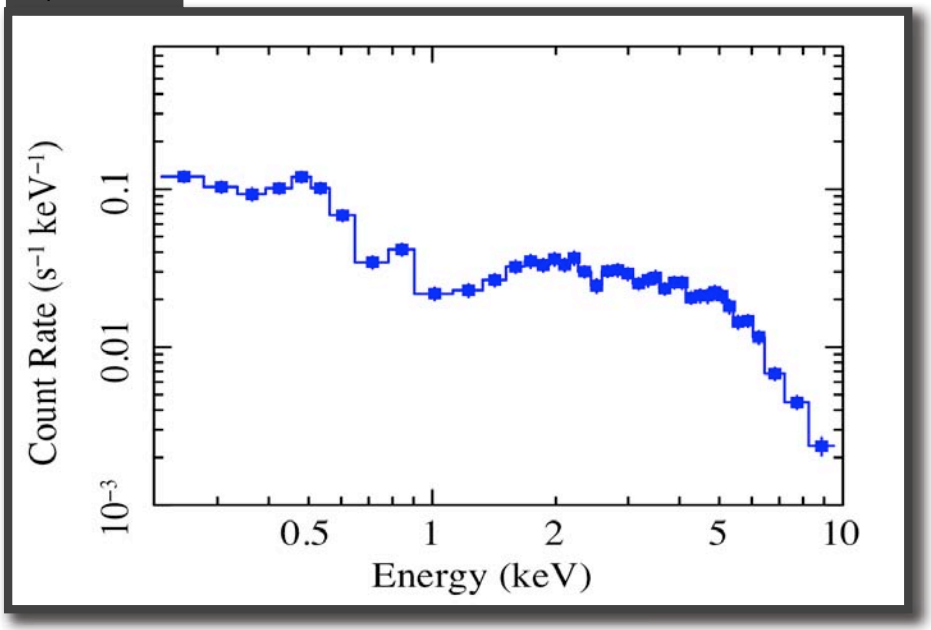
The new XMM-Newton observational campaign

Light Curves



December 2004 : 28 ks

Spectra



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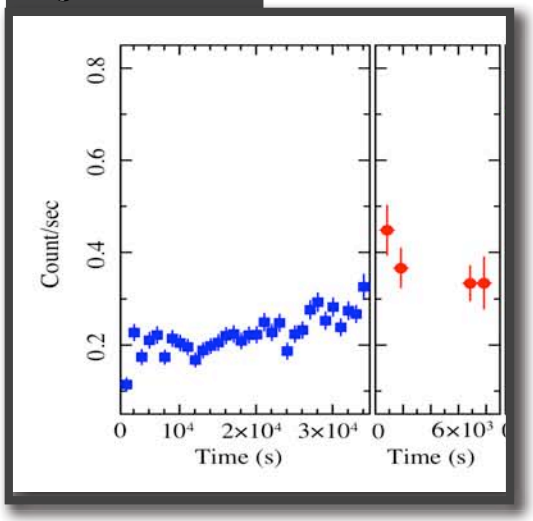
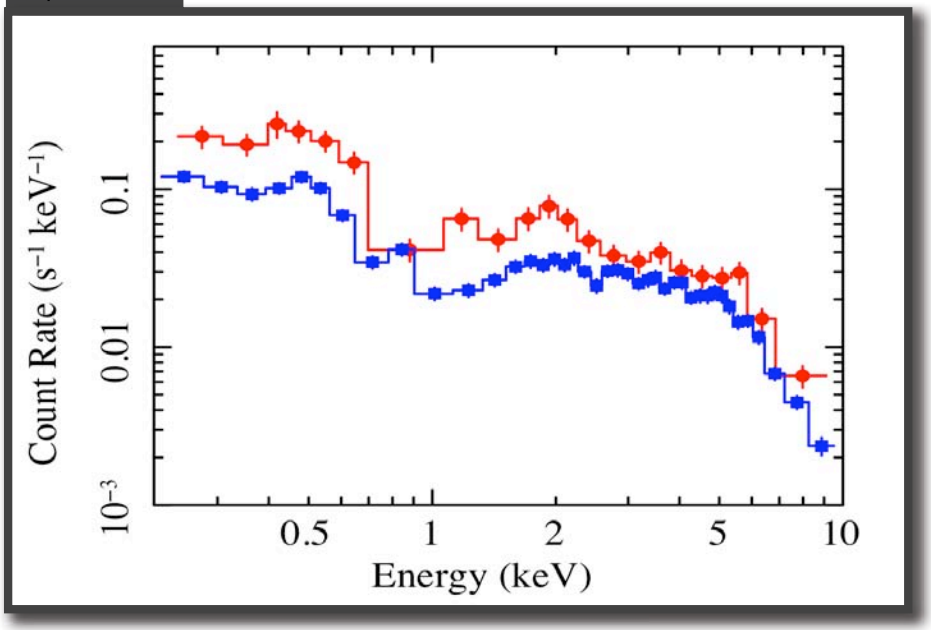


December 2004 : 28 ks

June 2008 : 4 ks

Spectra



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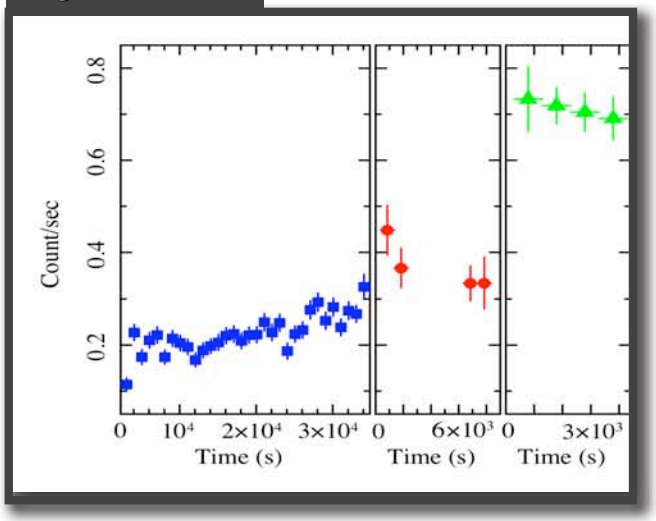
Light Curves



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December 2008 : 4 ks

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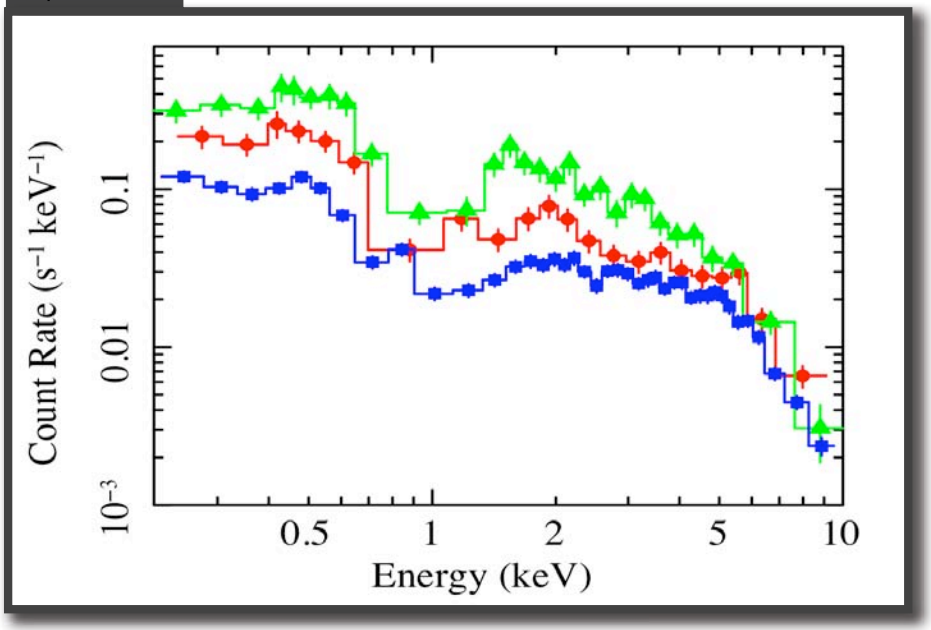

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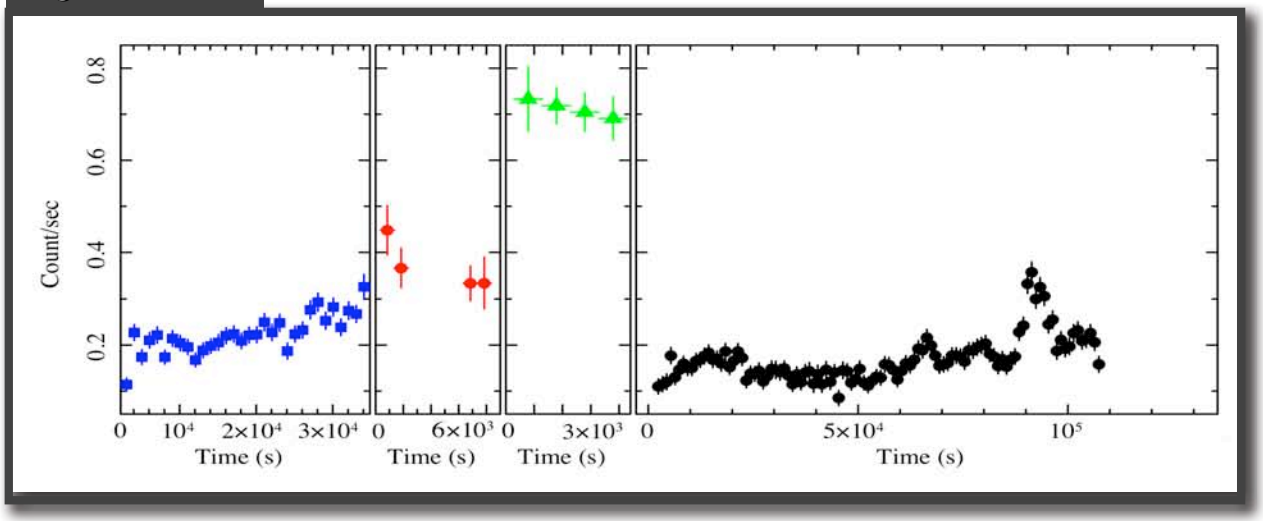

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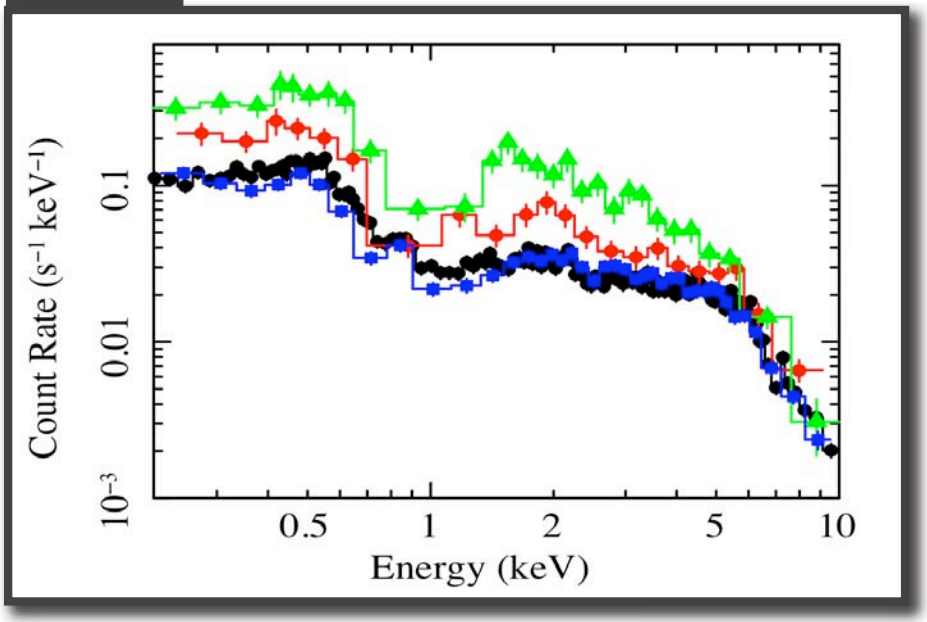

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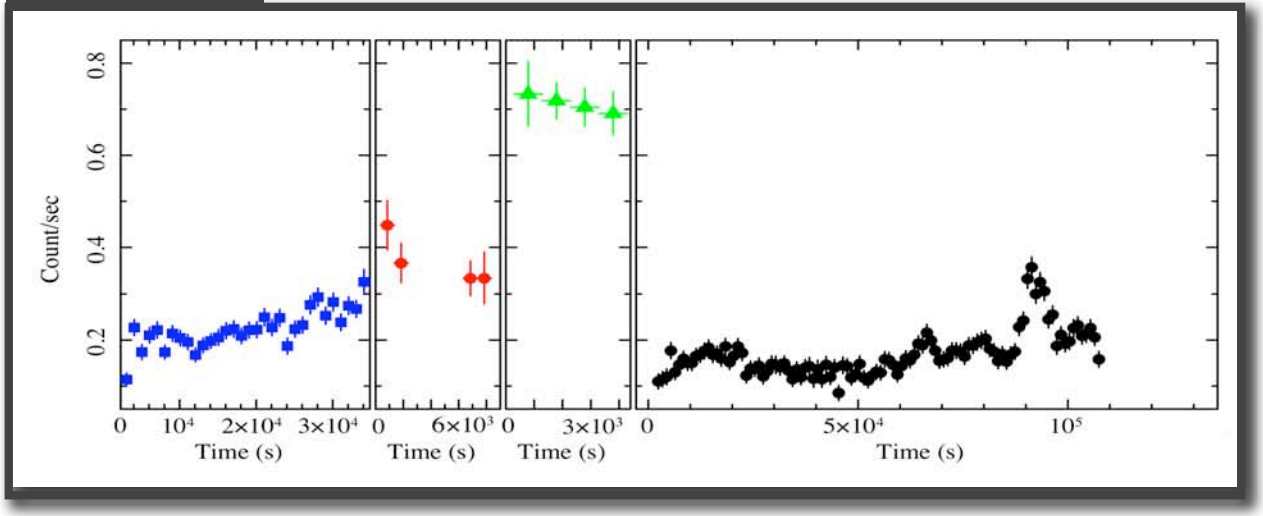

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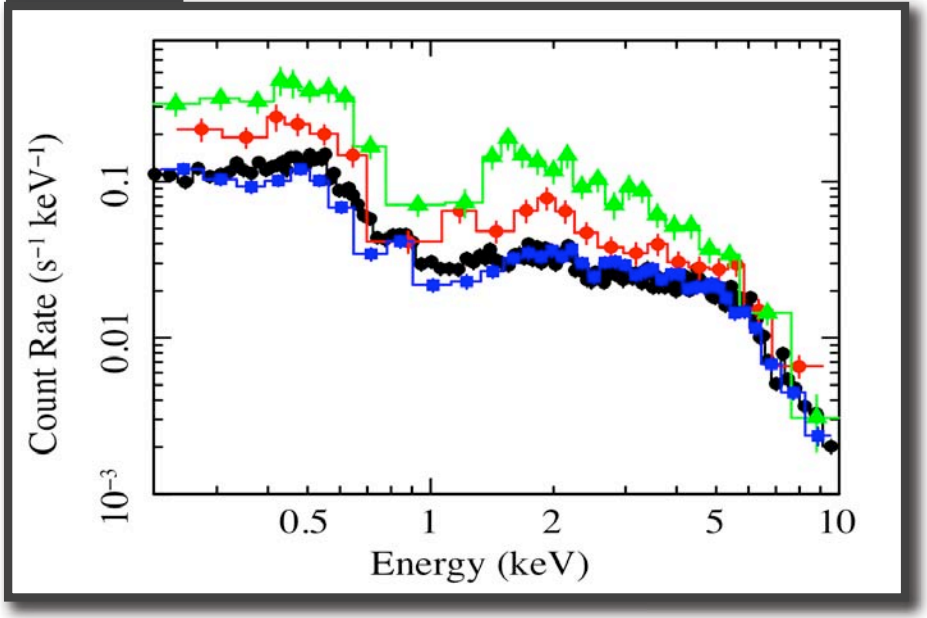
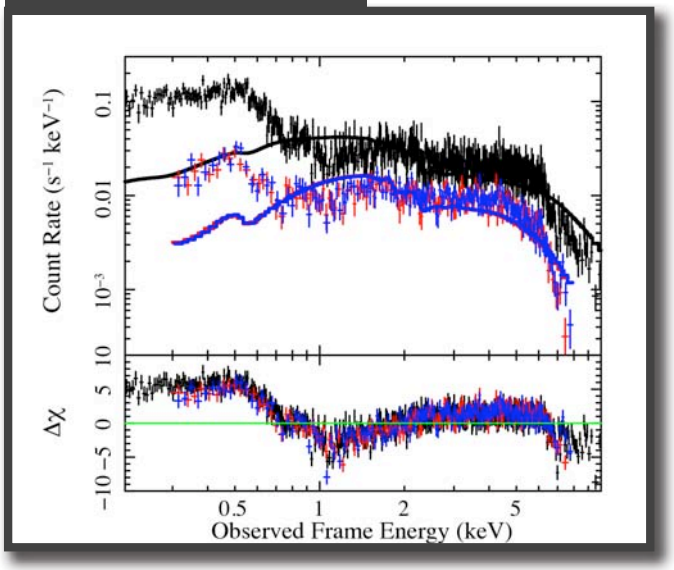


Strong X-ray variability

- ***on time scales of months***
- ***on time scales of hours***

Spectral analysis: the average spectra

Fit to a power law



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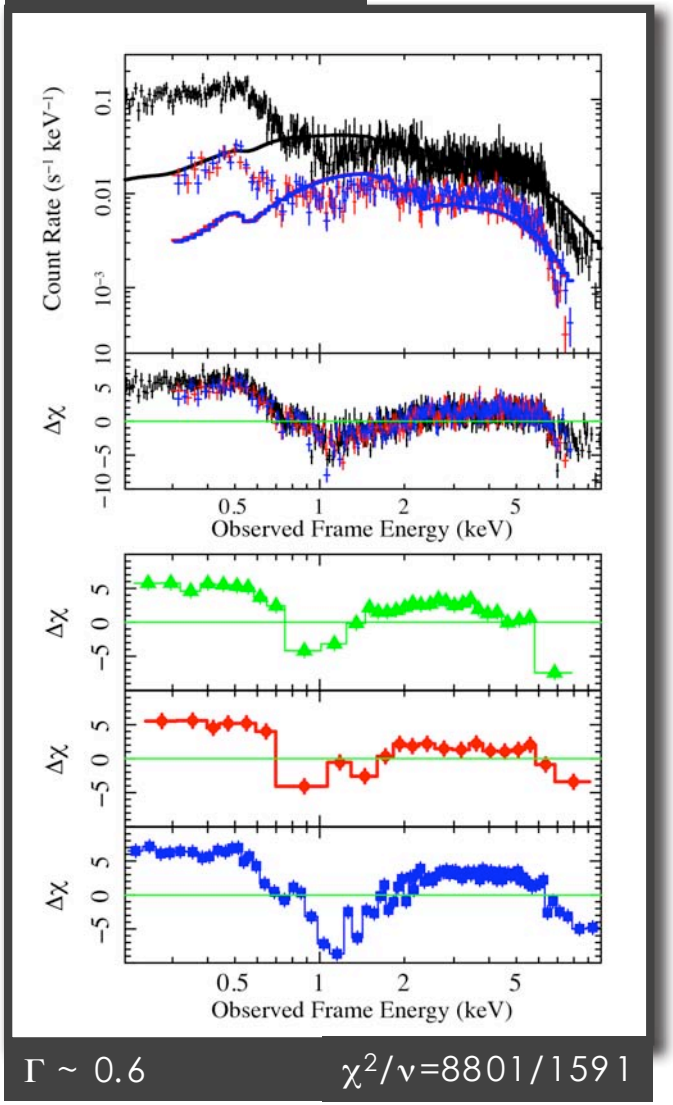
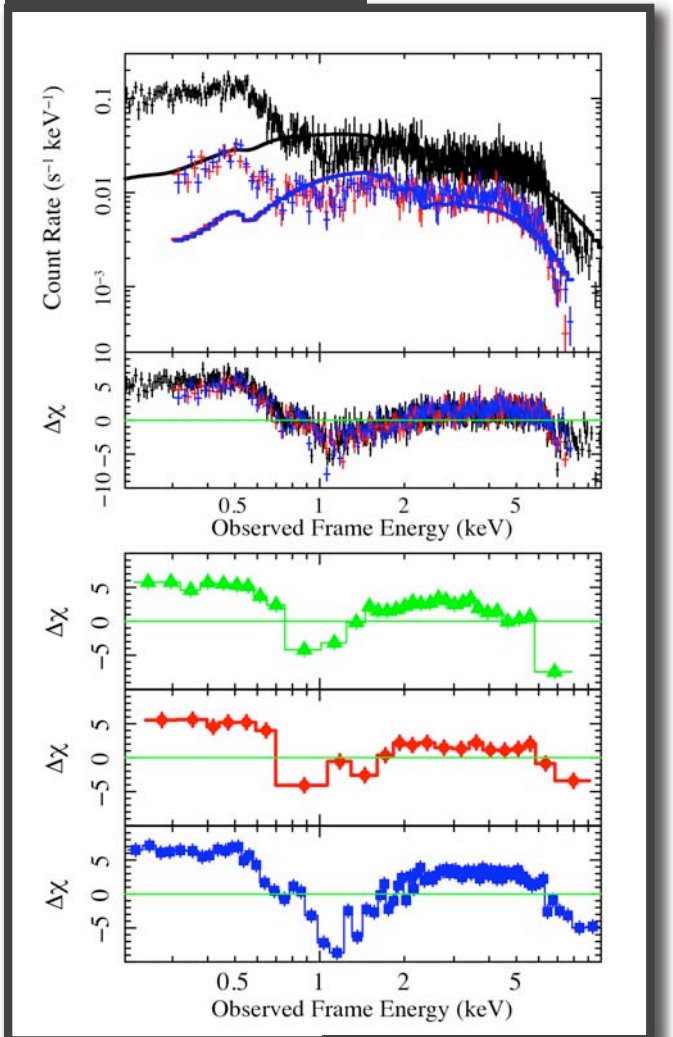


$\Gamma \sim 0.6$ $\chi^2/\nu=8801/1591$

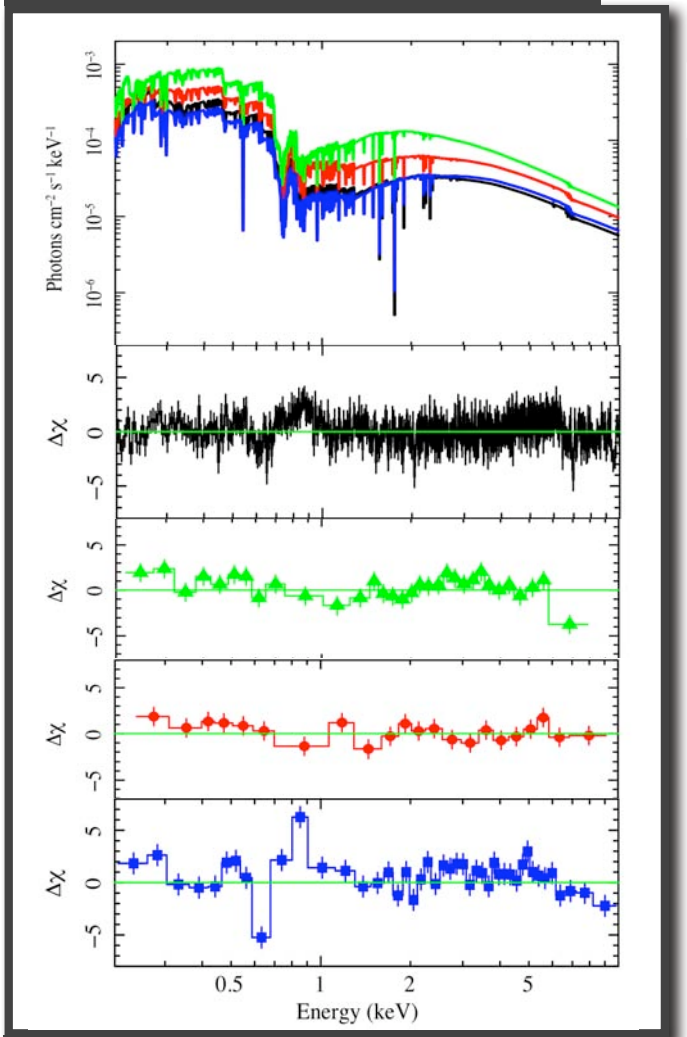
Spectral analysis: the average spectra

Fit to a power law



Γ ~ 0.6 χ^2/ν=8801/1591

A moderately-ionized absorber



Γ ~ 2.1 χ^2/ν=2234/1583

ionization parameter

logξ ~1.5 erg cm s^{-1}

column density

logN_W~23.1 cm^{-2}

logN_W~22.5 cm^{-2}

logN_W~22.8 cm^{-2}

logN_W~23.1 cm^{-2}

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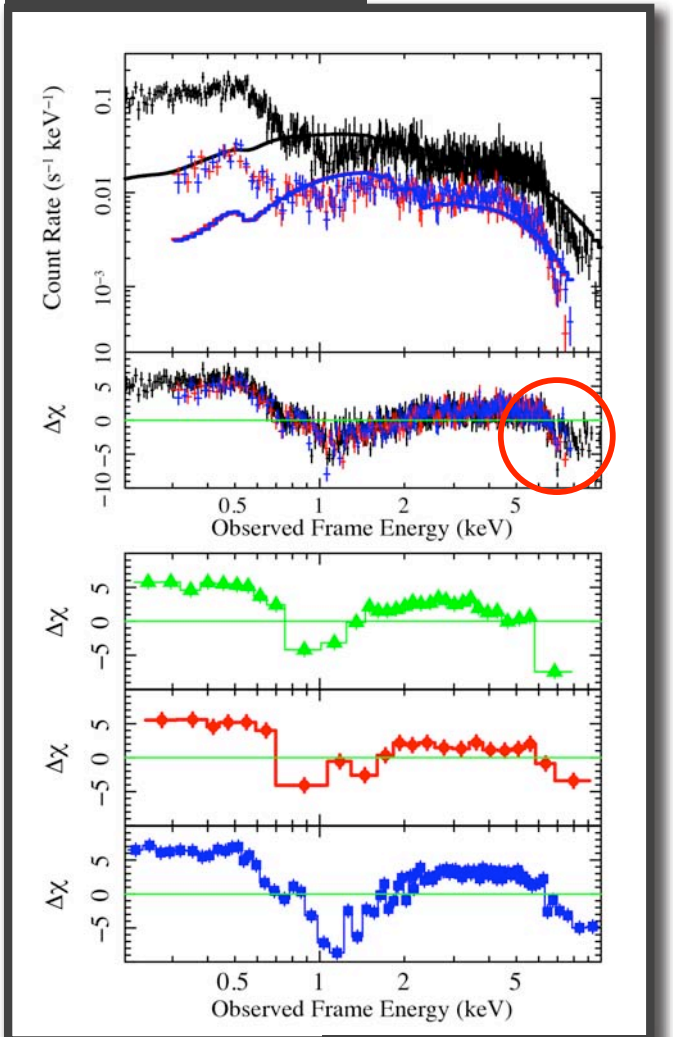
Fit to a power law



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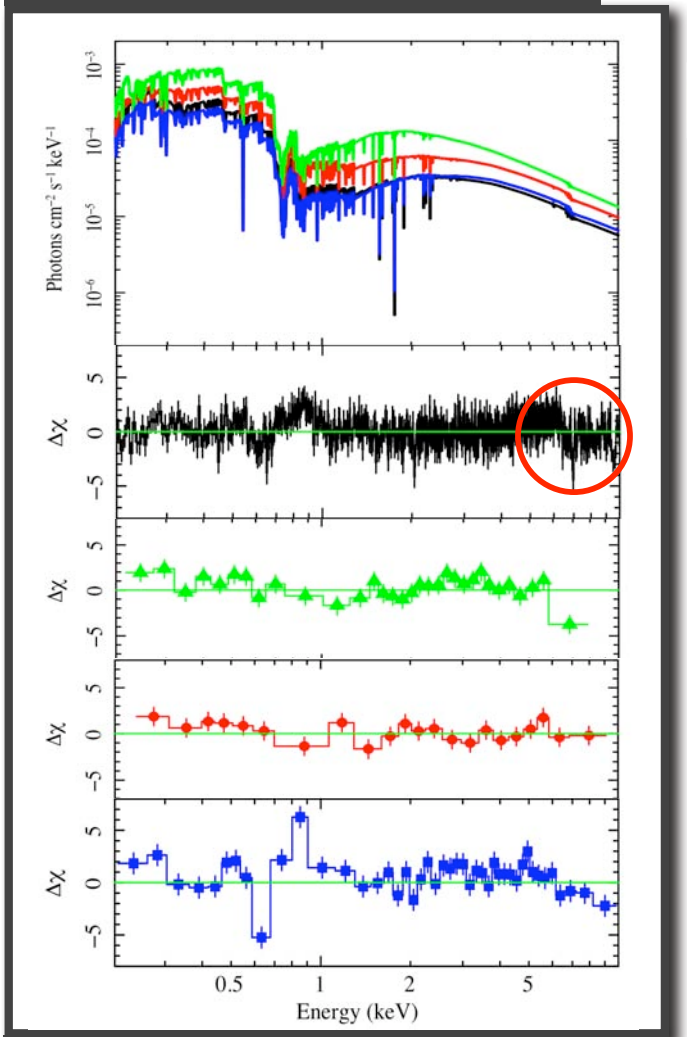

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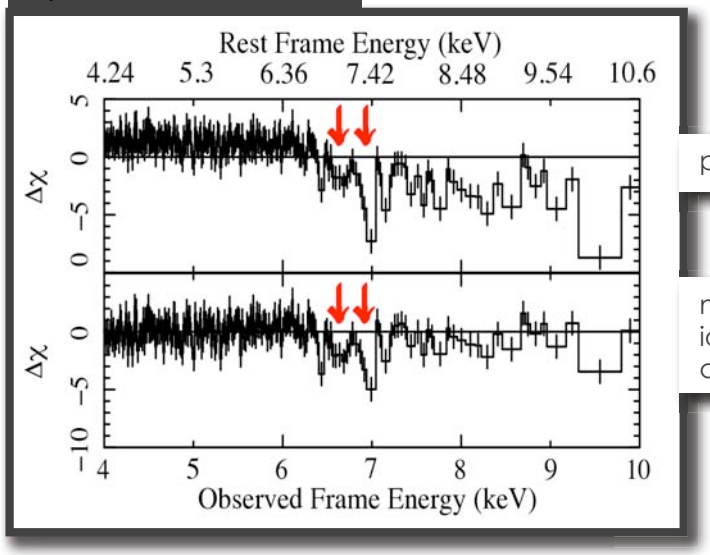
Spectral analysis: the average spectra

Spectral residuals

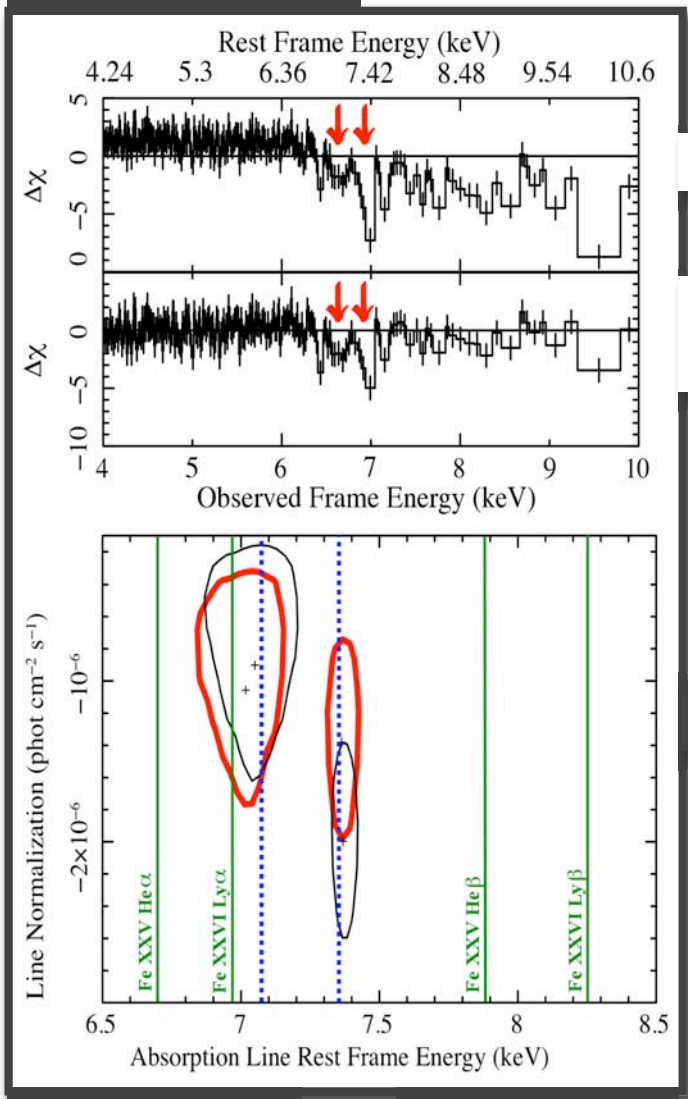


power law

moderately ionized absorber

Spectral analysis: the average spectra

Spectral residuals



power law

moderately ionized absorber

0.055 c

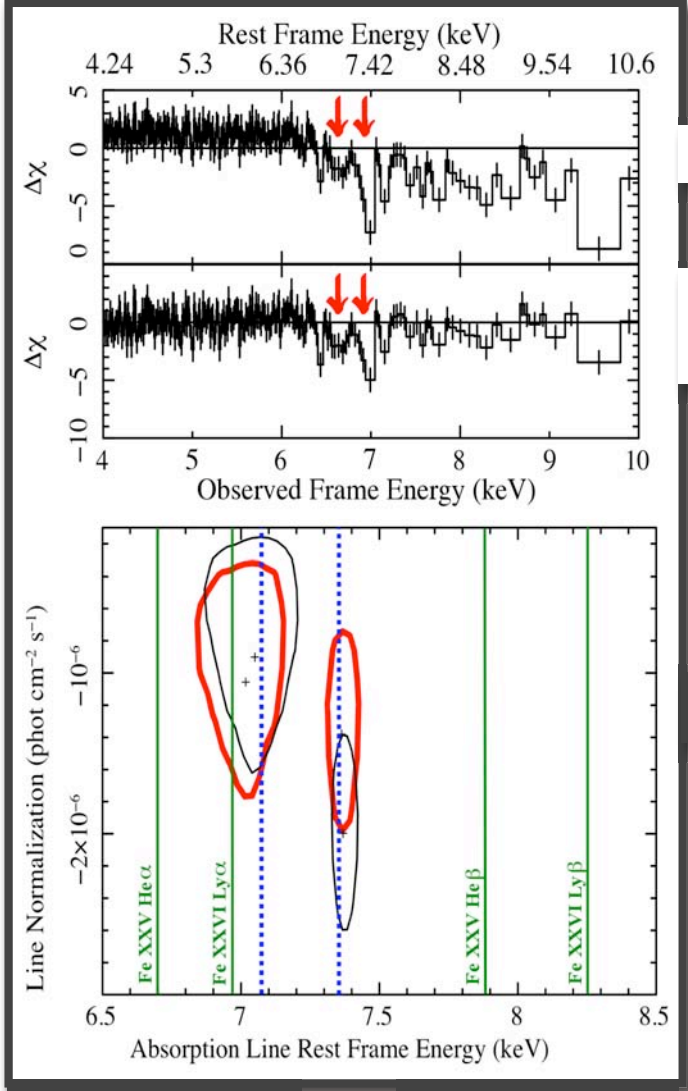
EW_1=80 ± 20 eV

EW_2=125 ± 25 eV

$\Delta\chi^2/\Delta\nu = 60/4$

Spectral analysis: the average spectra

Spectral residuals



power law

moderately ionized absorber

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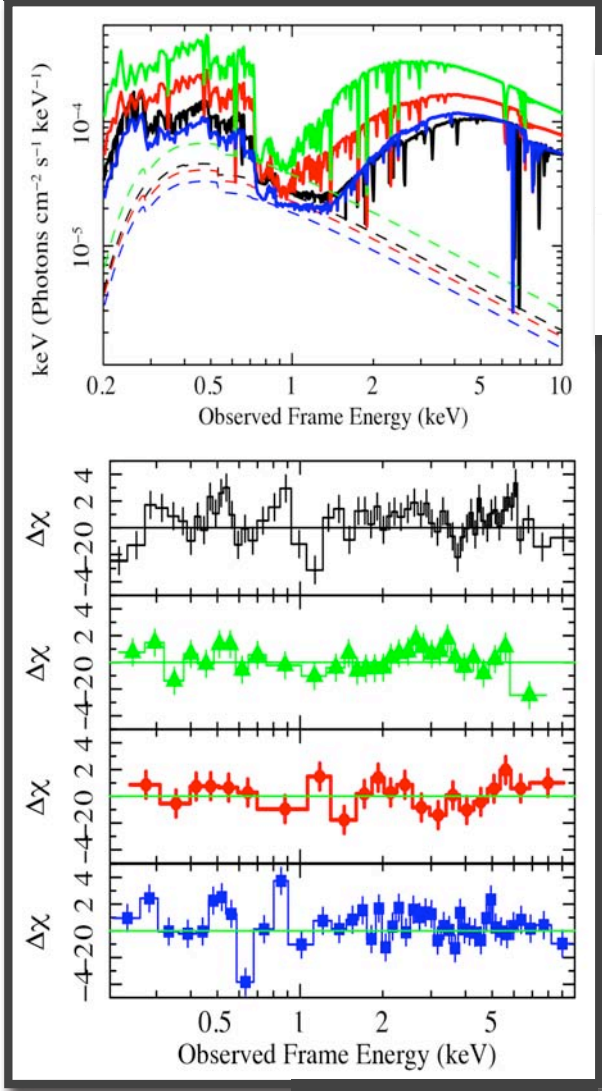
EW_1=80 ± 20 eV

EW_2=125 ± 25 eV

$\Delta\chi^2/\Delta\nu = 60/4$

A highly-ionized absorber



$\log N_W$~22.5-23 cgs

$\log \xi_W$ ~1.5 cgs

Γ~2.1

F_{scatt}~2-3%

$\log N_H$~23.8 cgs

$\log \xi_H$ ~3.5 cgs

υ_{out}~16,500 km/s

$\log N_H$<22.8 cgs

$\log N_H$<22.8 cgs

$\log N_H$~23.3 cgs

$\log \xi_H$ ~3.7 cgs

$\Delta\chi^2/\Delta\nu = 122/9$

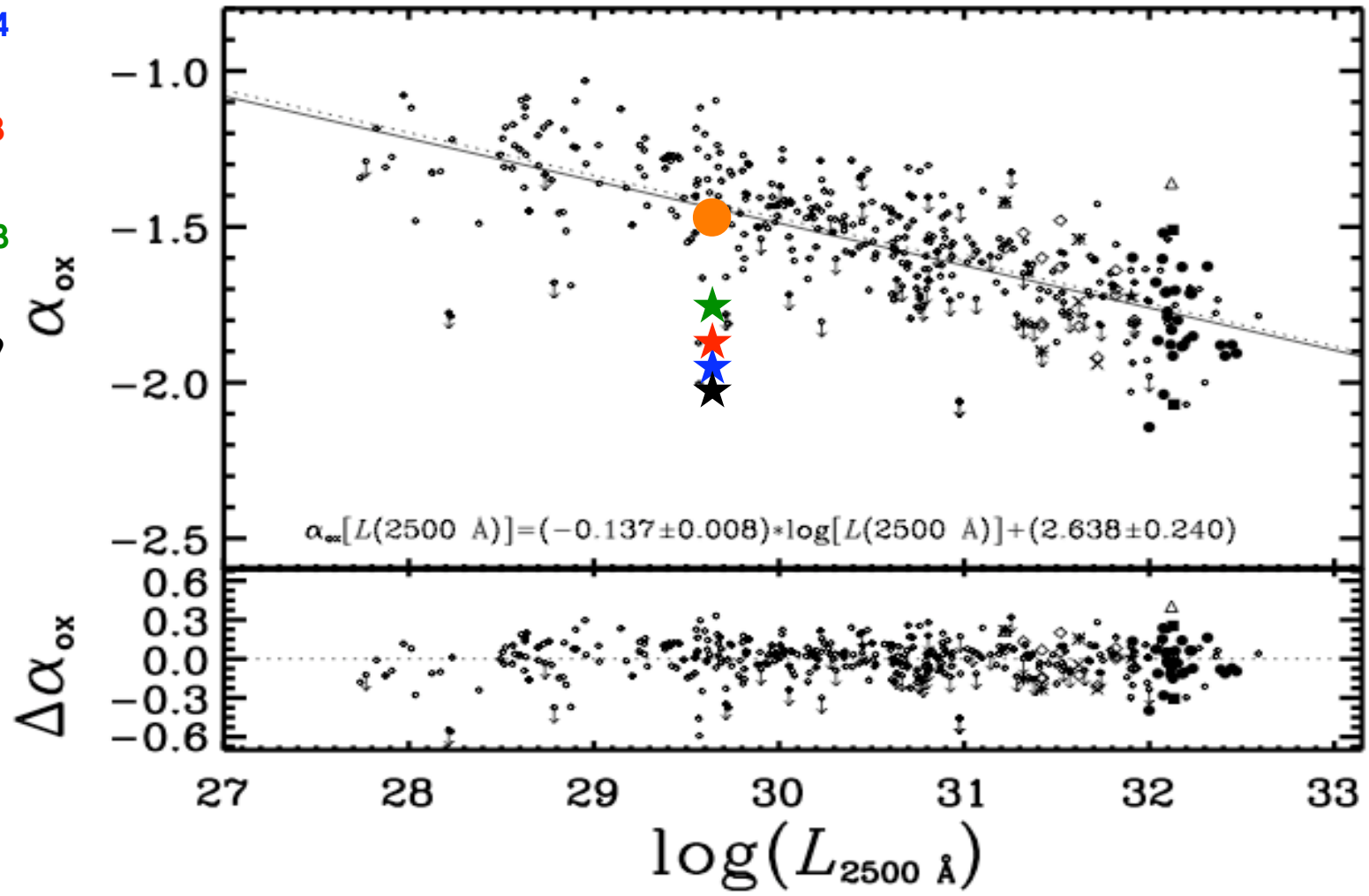
α_{ox} is variable

DEC 2004

JUN 2008

DEC 2008

JUN 2009



α_{ox} is variable

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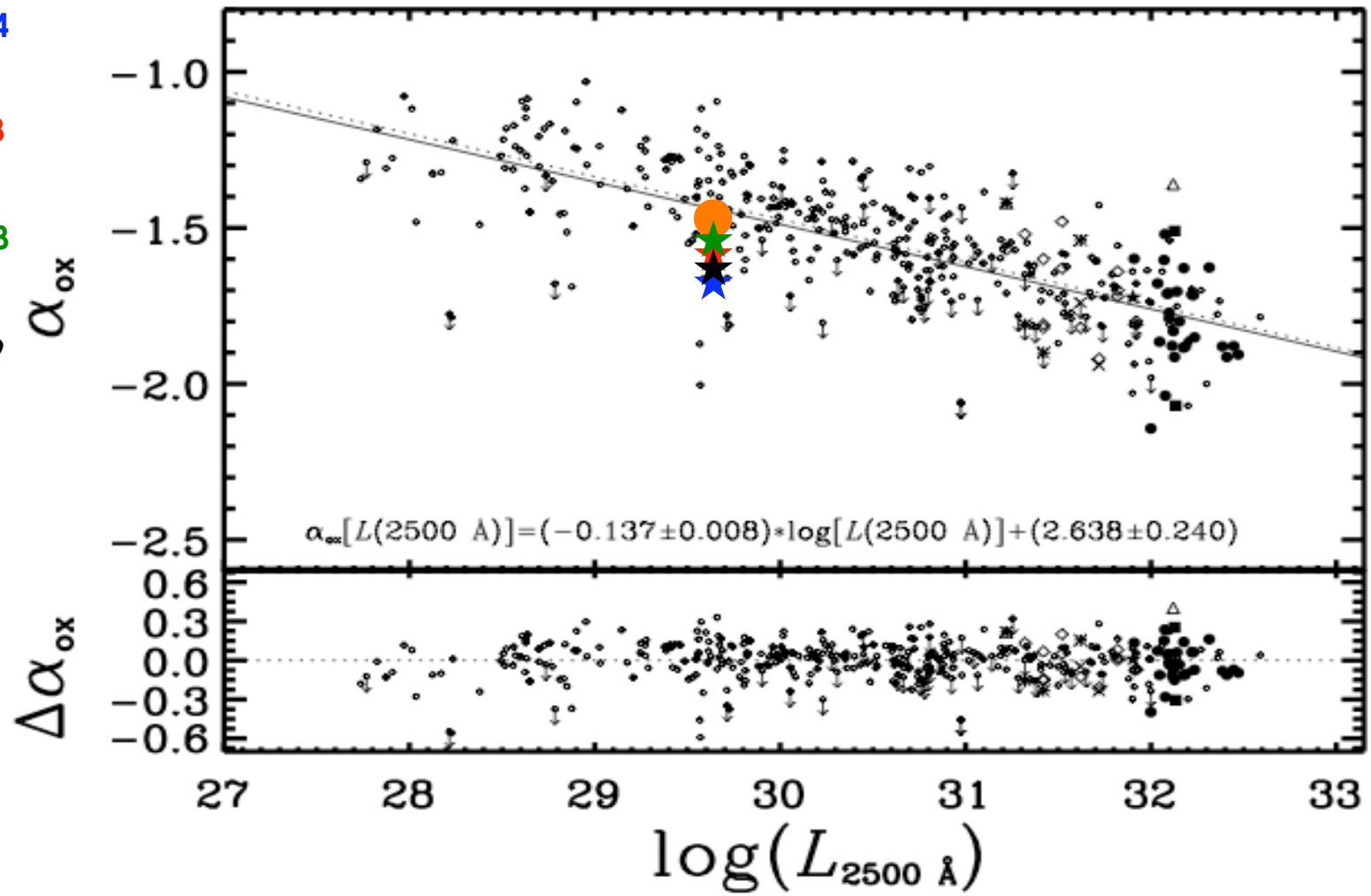
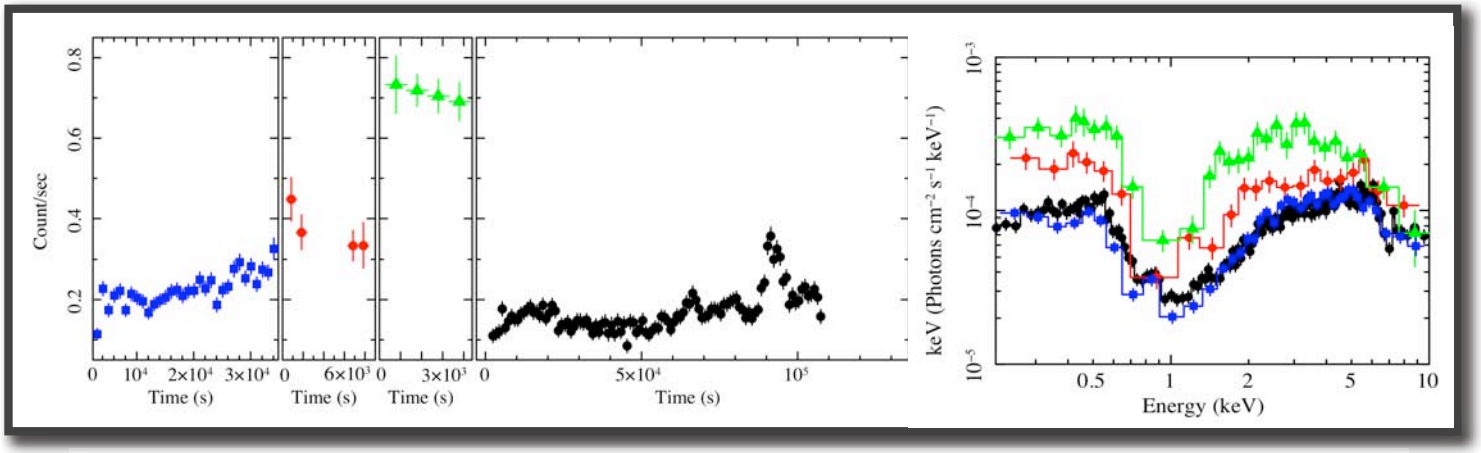
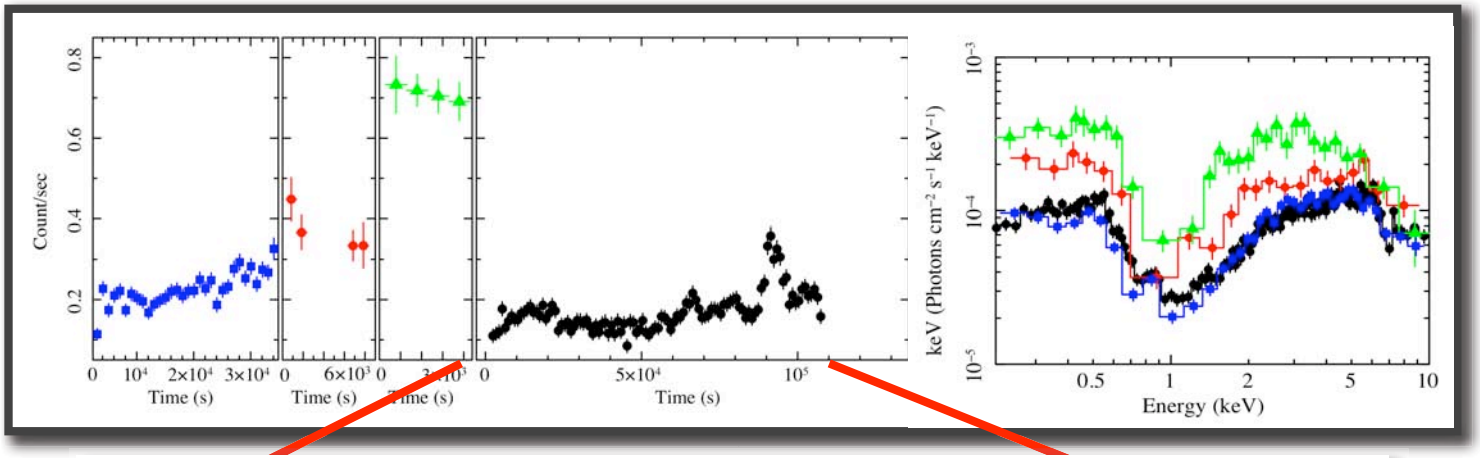


Time-resolved spectral analysis

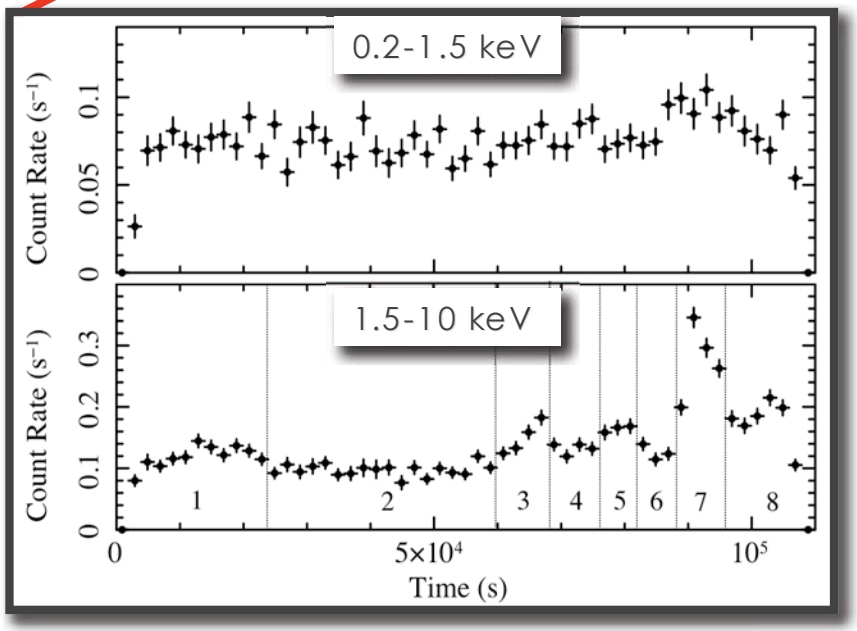


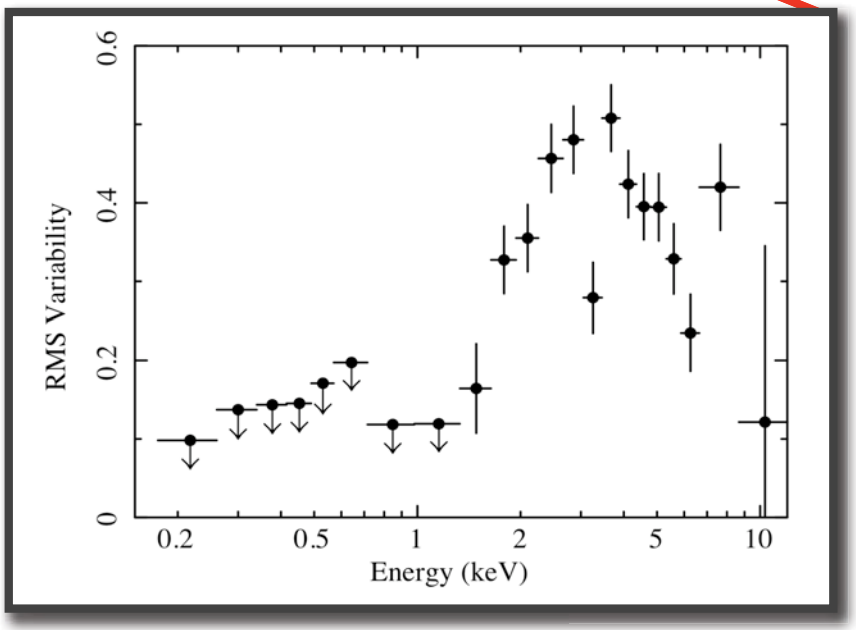
Strong variability on time scales of months and hours

Time-resolved spectral analysis

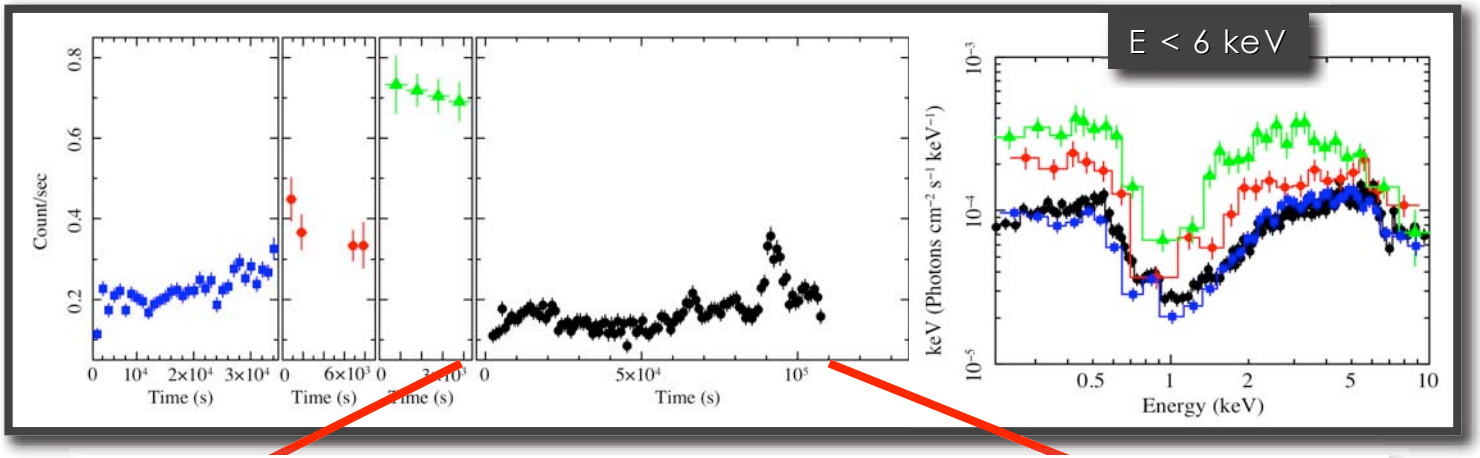


Strong variability on time scales of months and hours



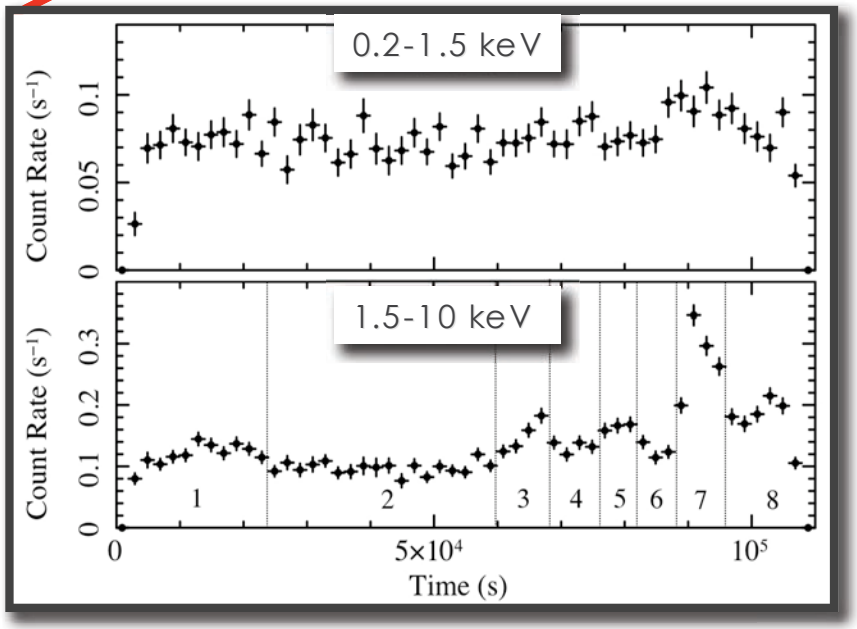


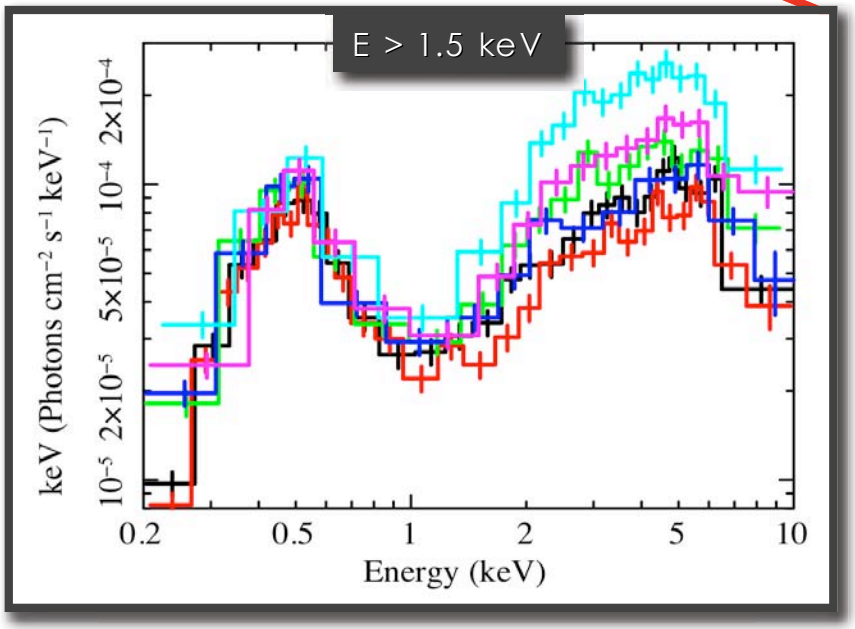
Time-resolved spectral analysis



Strong variability on time scales of months and hours

Two distinct spectral components





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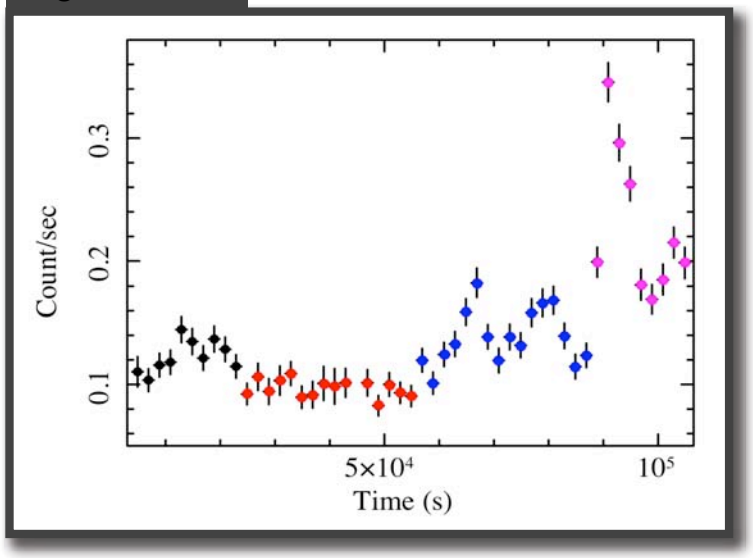

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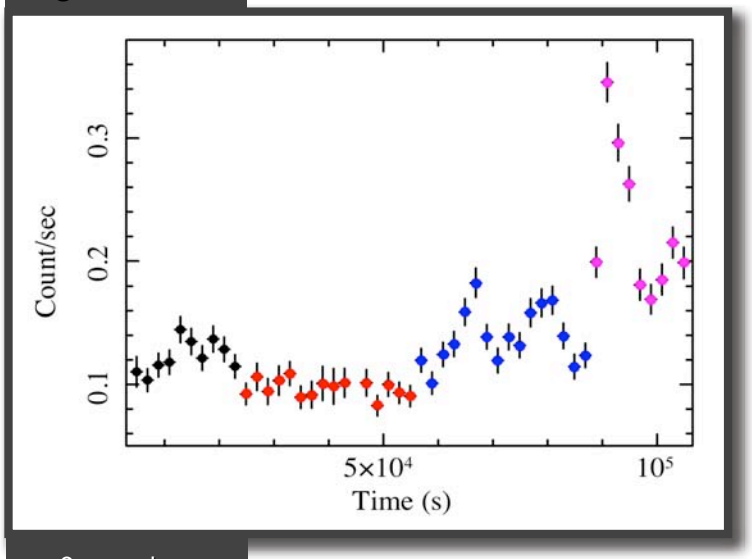
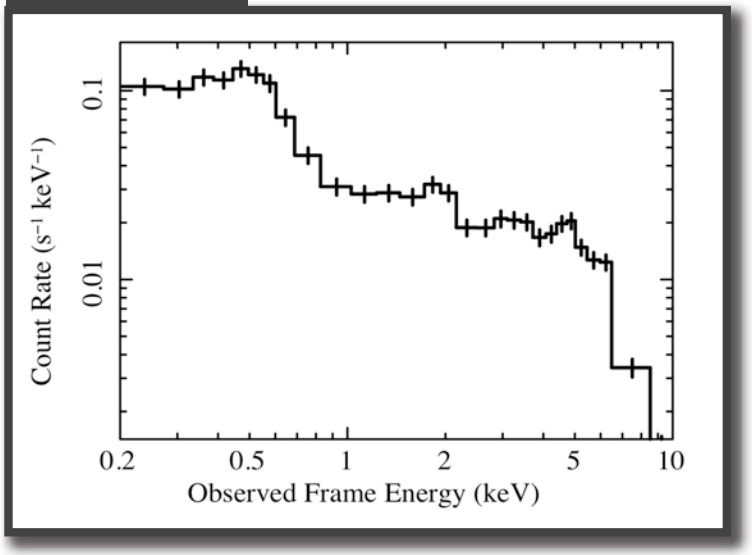


Spectra



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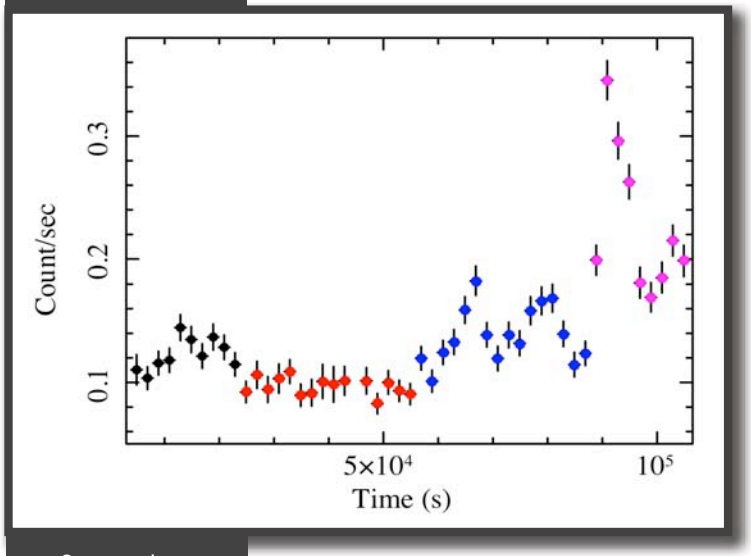

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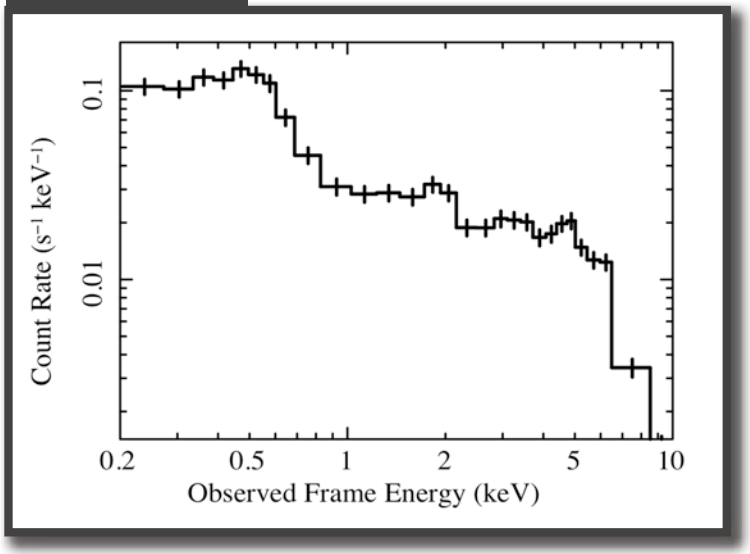
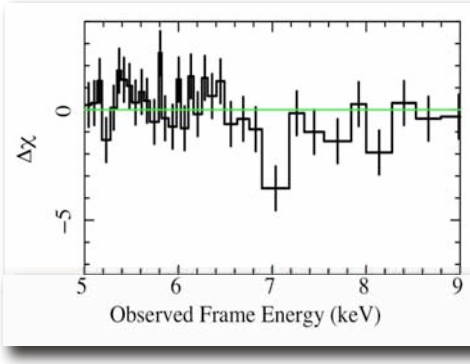
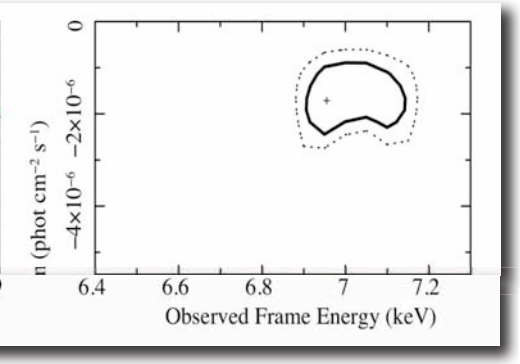


Fe K band residuals



68%,90% levels



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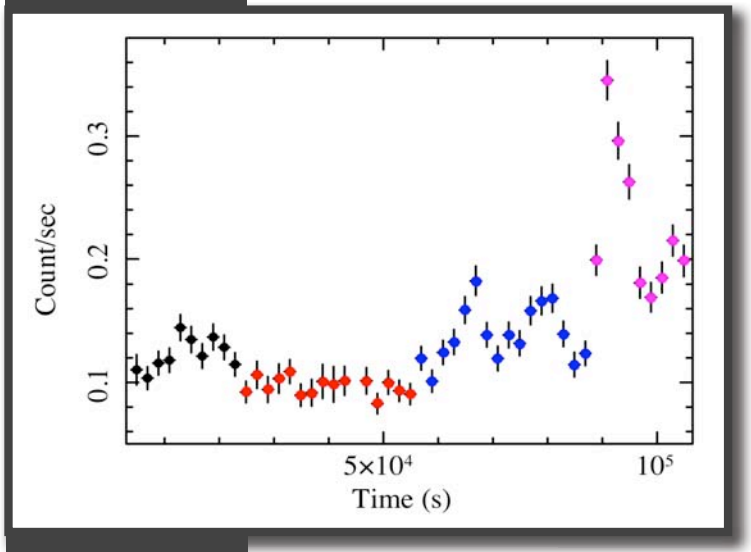
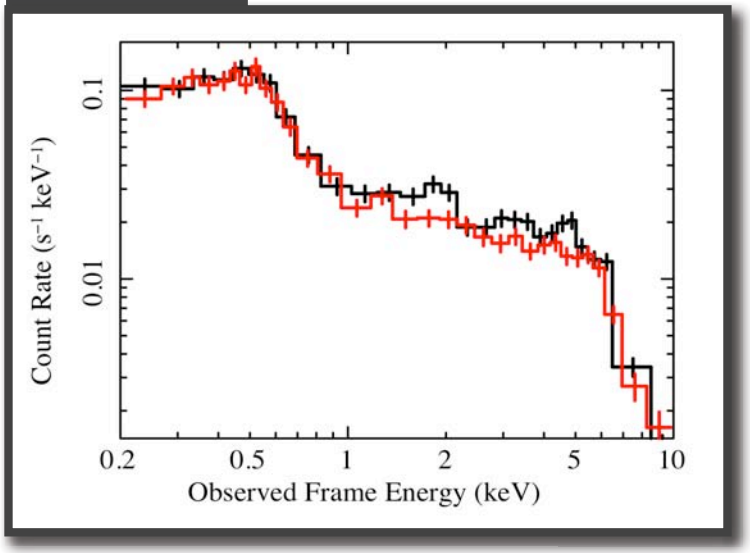


Spectra



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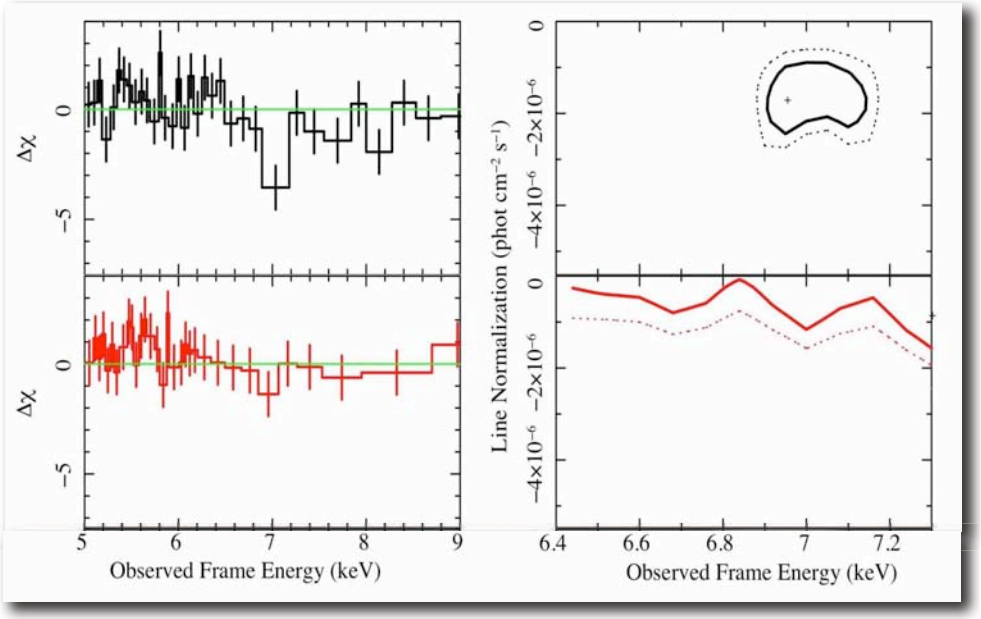

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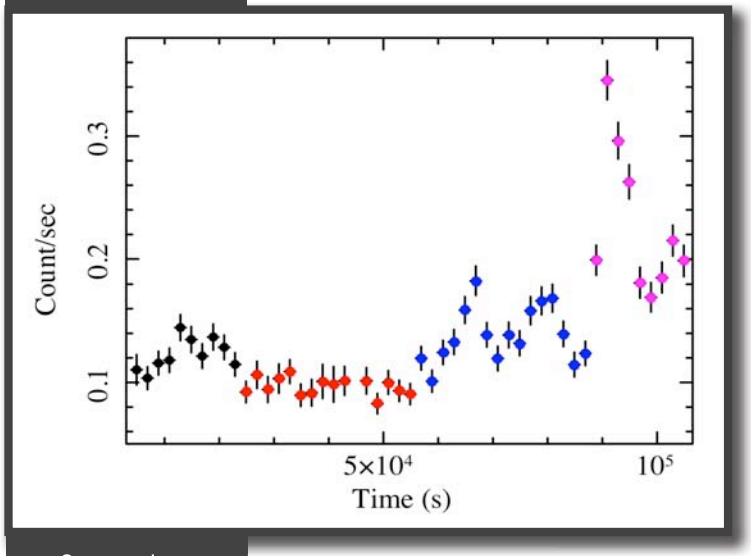

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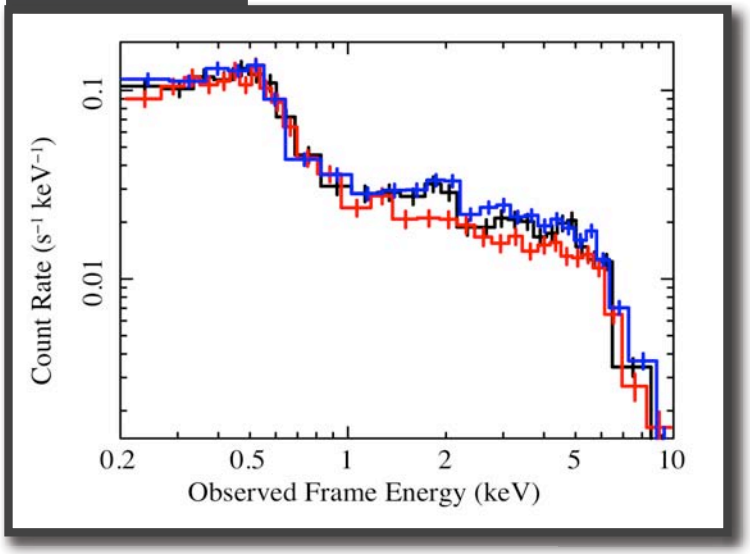

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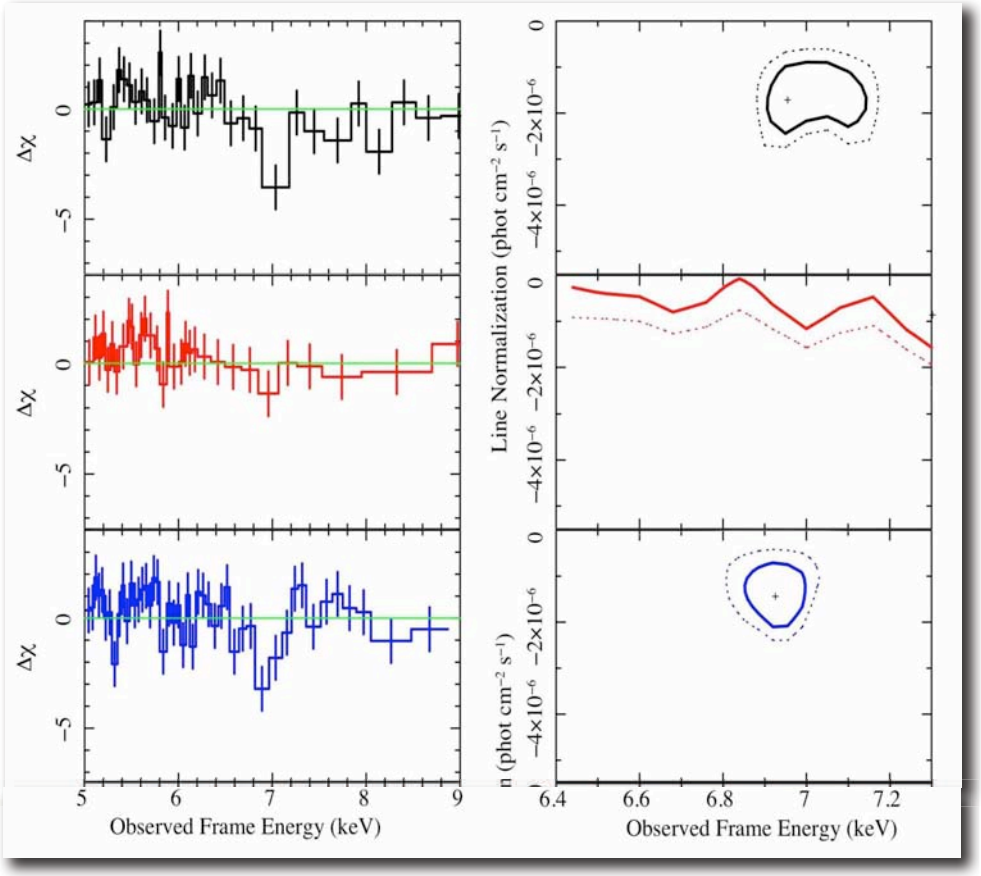

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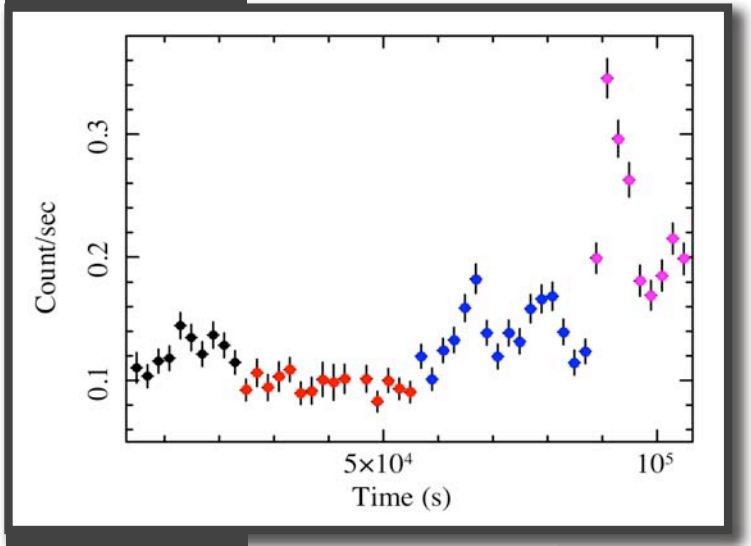

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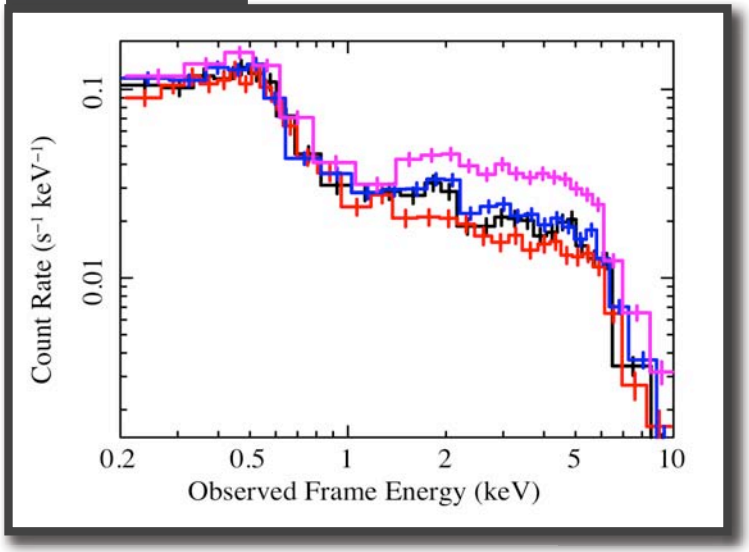

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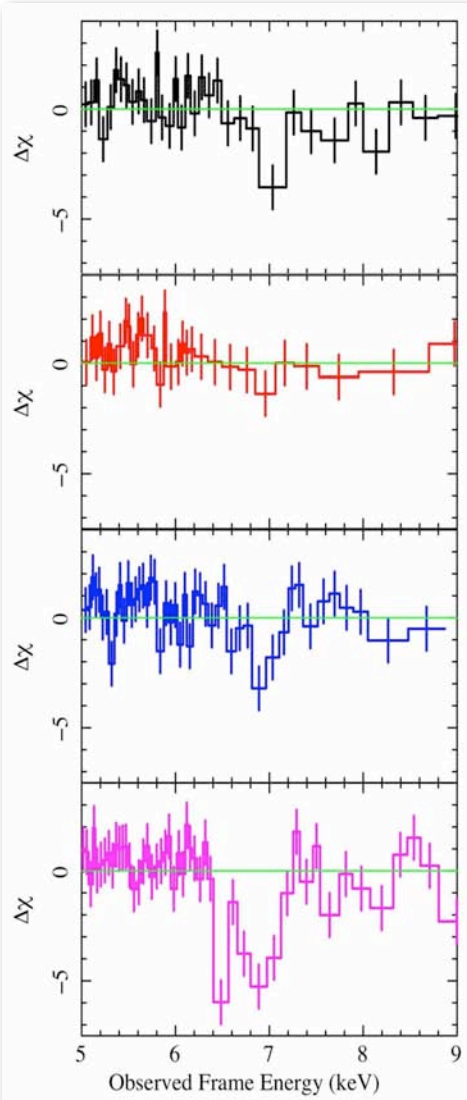

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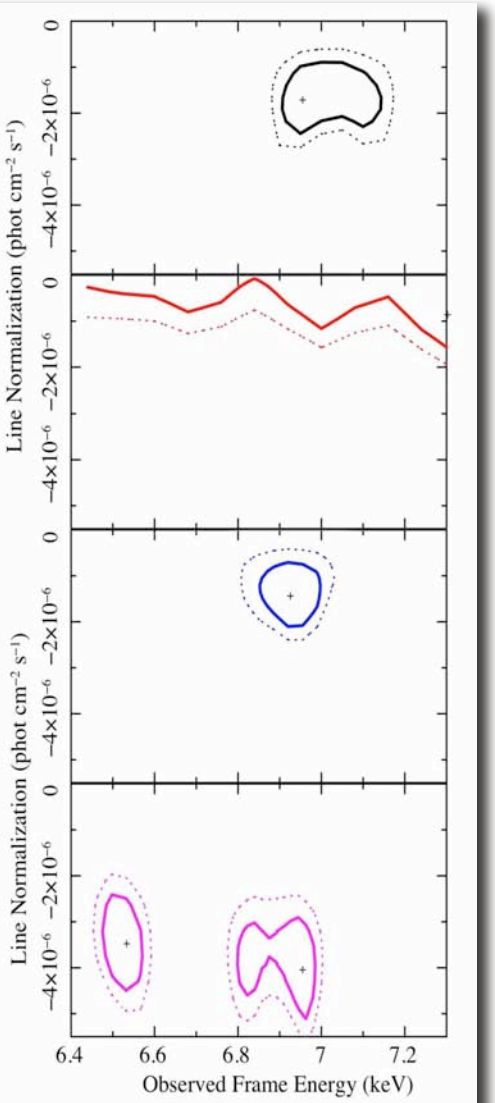

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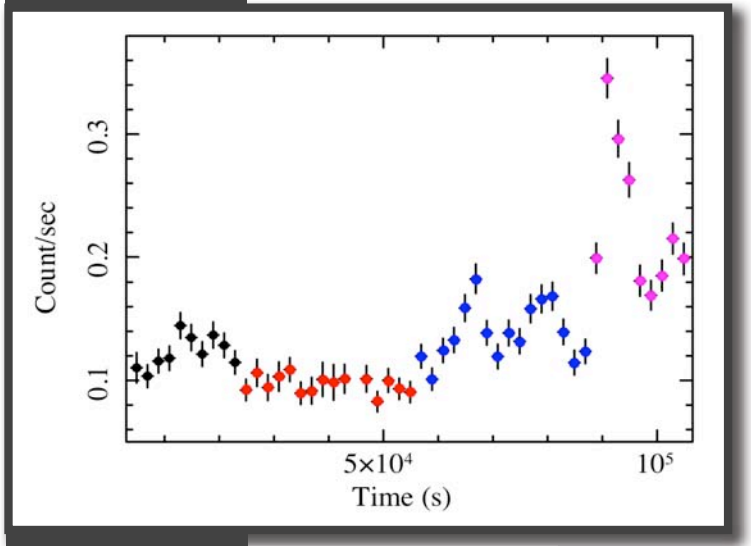

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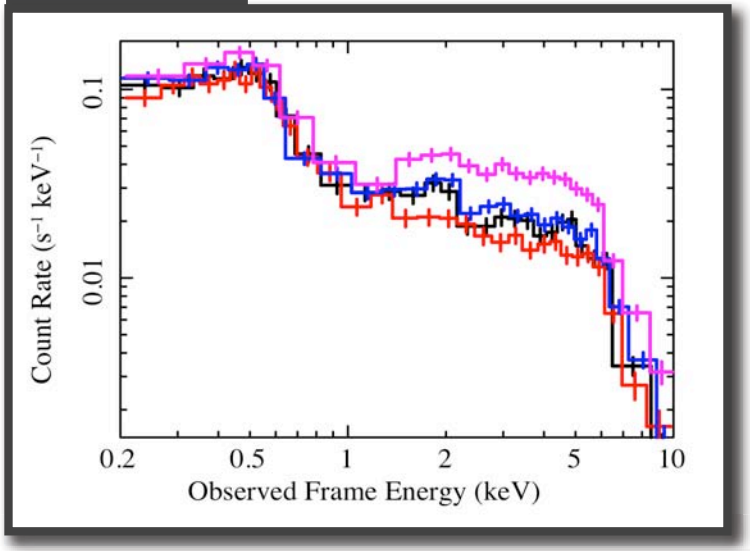

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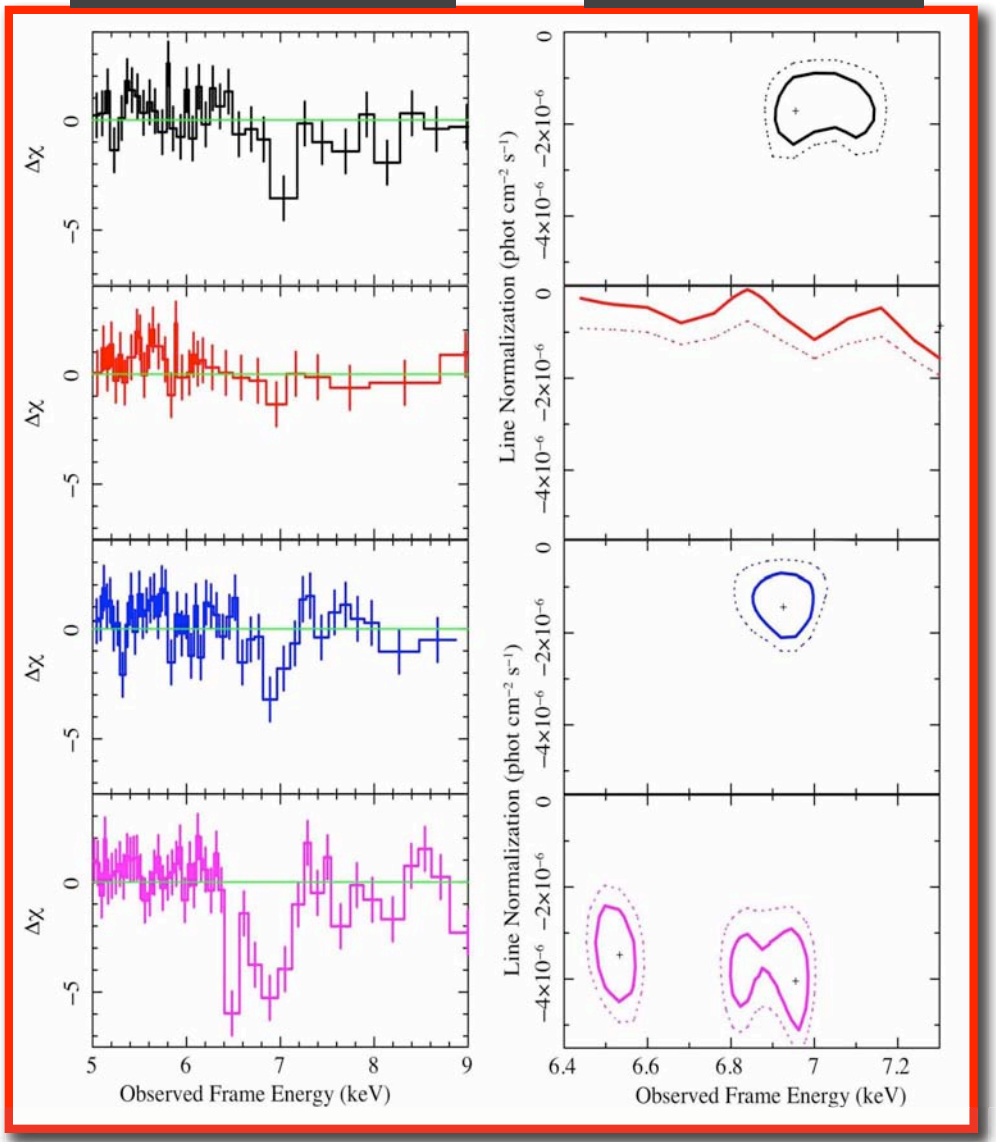

The highly-ionized absorber is variable over time scales of hours

- **Strong X-ray variability on time scales of months and hours**

- ***Two distinct spectral components: one emerging at E < 6 keV (months), the other at E > 1.5 keV (hours).***

- ***A moderately ionized absorber is varying on time scales of months.***

- ***A highly ionized absorber is varying on time scales of hours.***

WE ARE STARTING TO PROBE THE DYNAMICS OF THE INNER ACCRETION/EJECTION FLOW IN AGN

- ***The observed α_{ox} is varying as well. Is the wind "seeing" the variations at E ~ 6-10 keV or at E ~ 2 keV?***

So What - the wind kinetic efficiency

- **What about the feedback?**

kinetic efficiency

$$\varepsilon_w \propto \frac{\dot{M}_{out} v_{out}^2}{L_{acc}}$$

mass outflow rate

$$\dot{M}_{out} \propto A(r)\rho(r)v_{out}(r)$$

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$$\dot{M}_{out} \approx \dot{M}_{acc}$$

$$\varepsilon_w \approx \text{ up to a few \%}$$

For the highly ionized, high velocity phases.

BUT

All the assumptions are highly uncertain!

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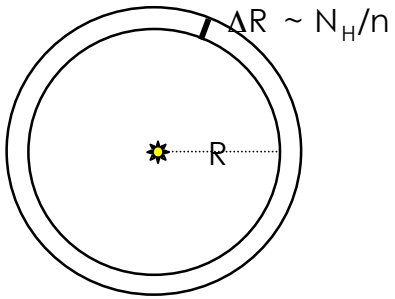

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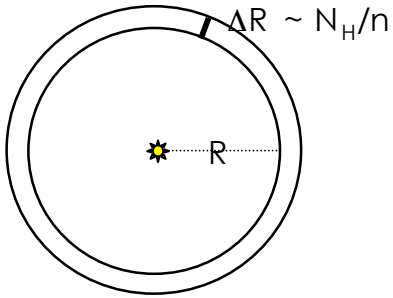

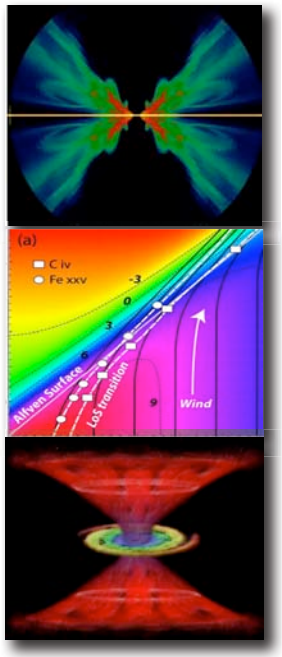

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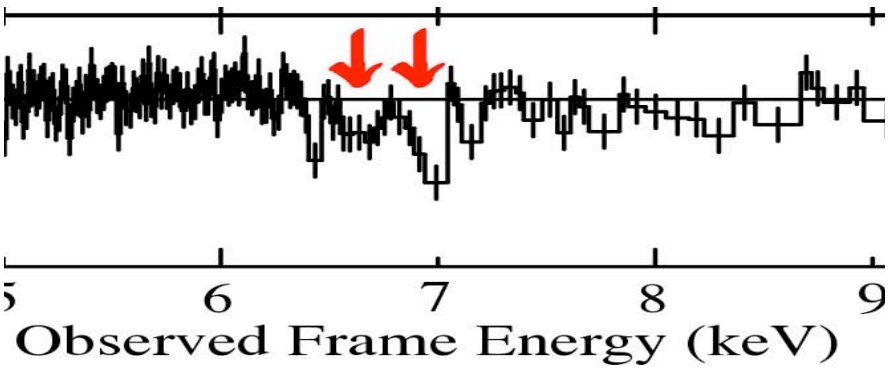

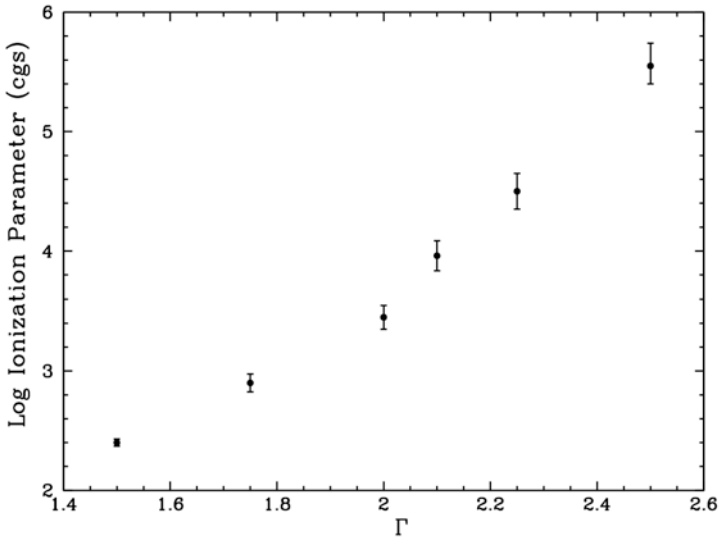

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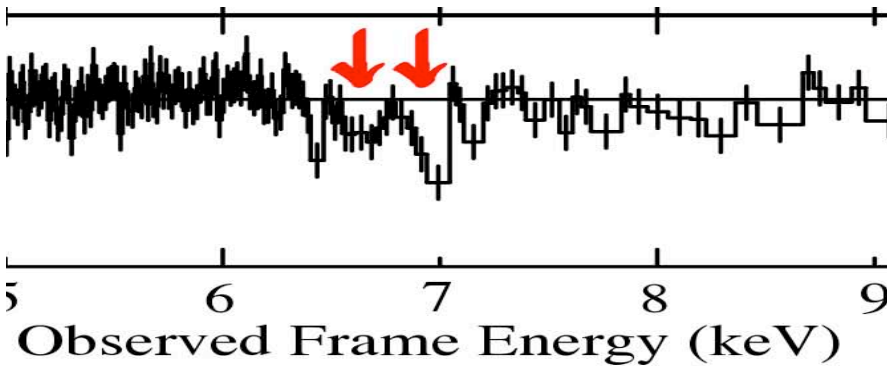

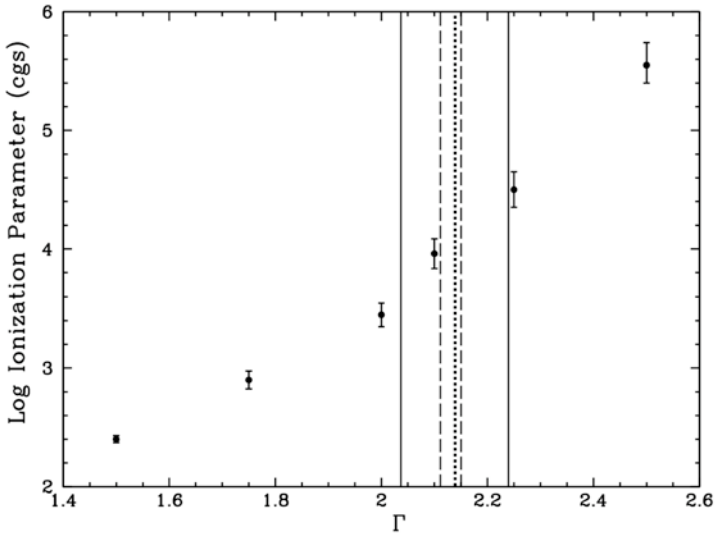

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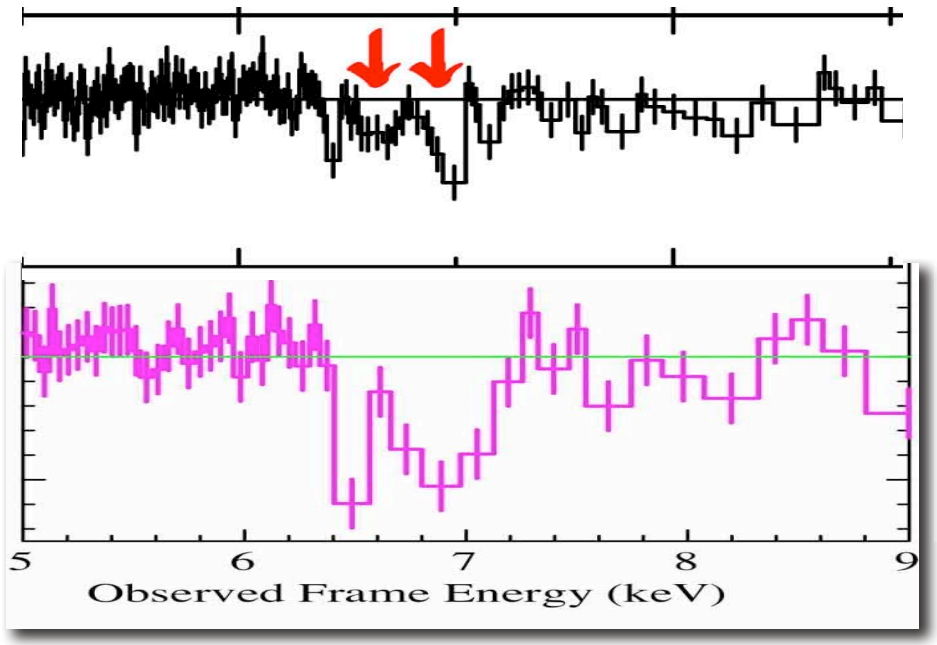

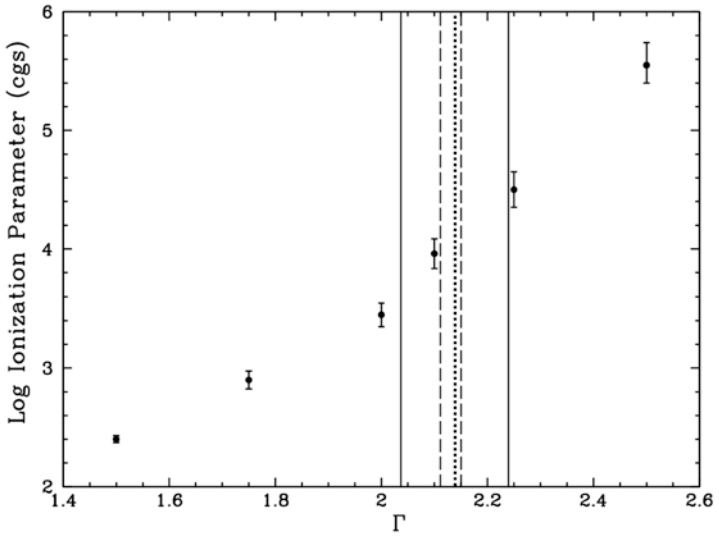

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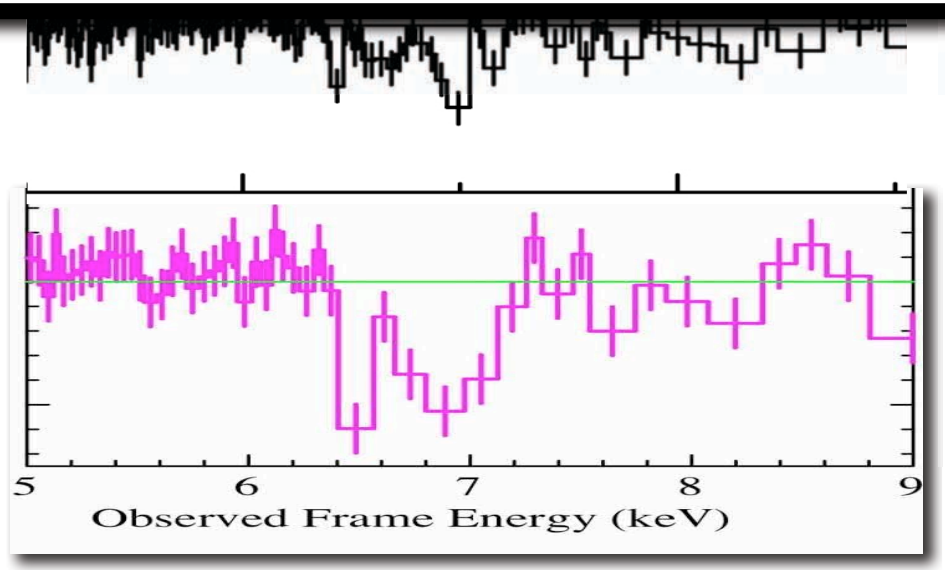
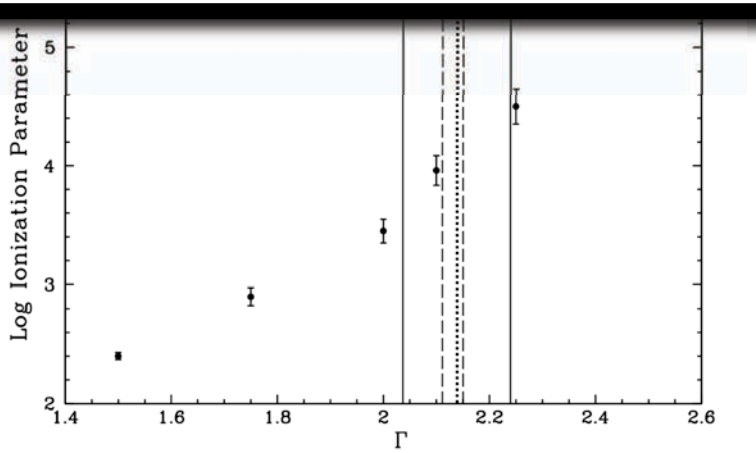
BE CAREFUL WITH MASS OUTFLOW RATE ESTIMATES!





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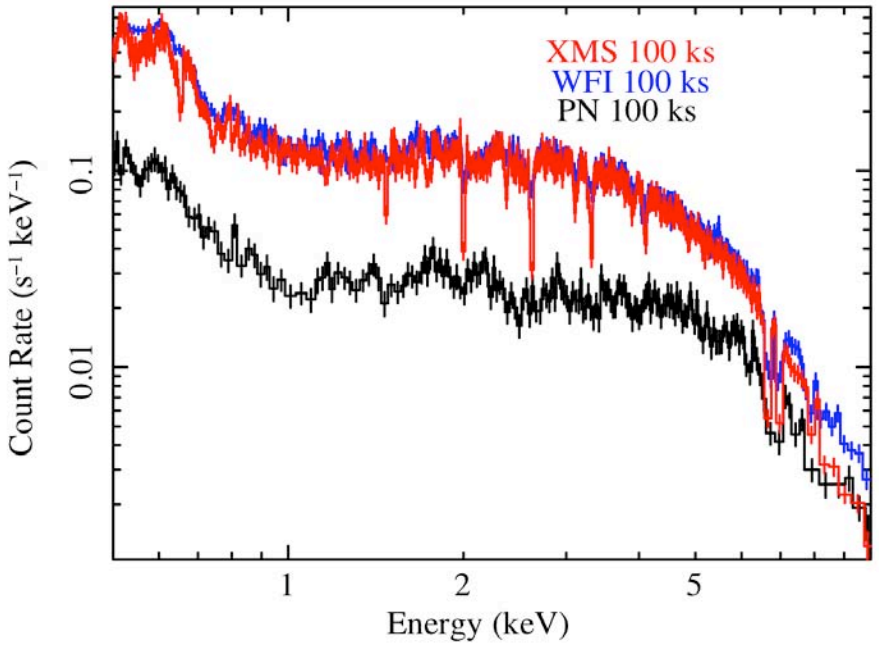
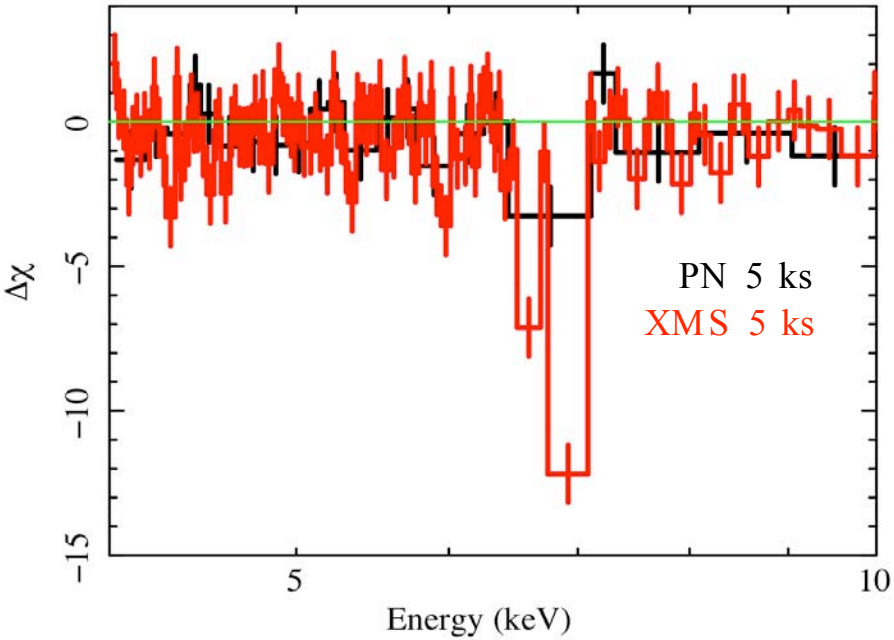
- **Enlarge the numbers:** **SDSS and XMM/Chandra data to be compared with AGN accretion disk winds theoretical predictions**

- **Refine the studies:** **deep observational campaigns on the most promising sources: unveiling the dynamics of the inner accretion/ejection flow**

- **The future:** **is now called ATHENA**, see Massimo Cappi's talk:





THANKS FOR YOUR ATTENTION!