The “Big Dipper” to probe the warm absorber in X-ray binaries

XMM observations of X 1624-490

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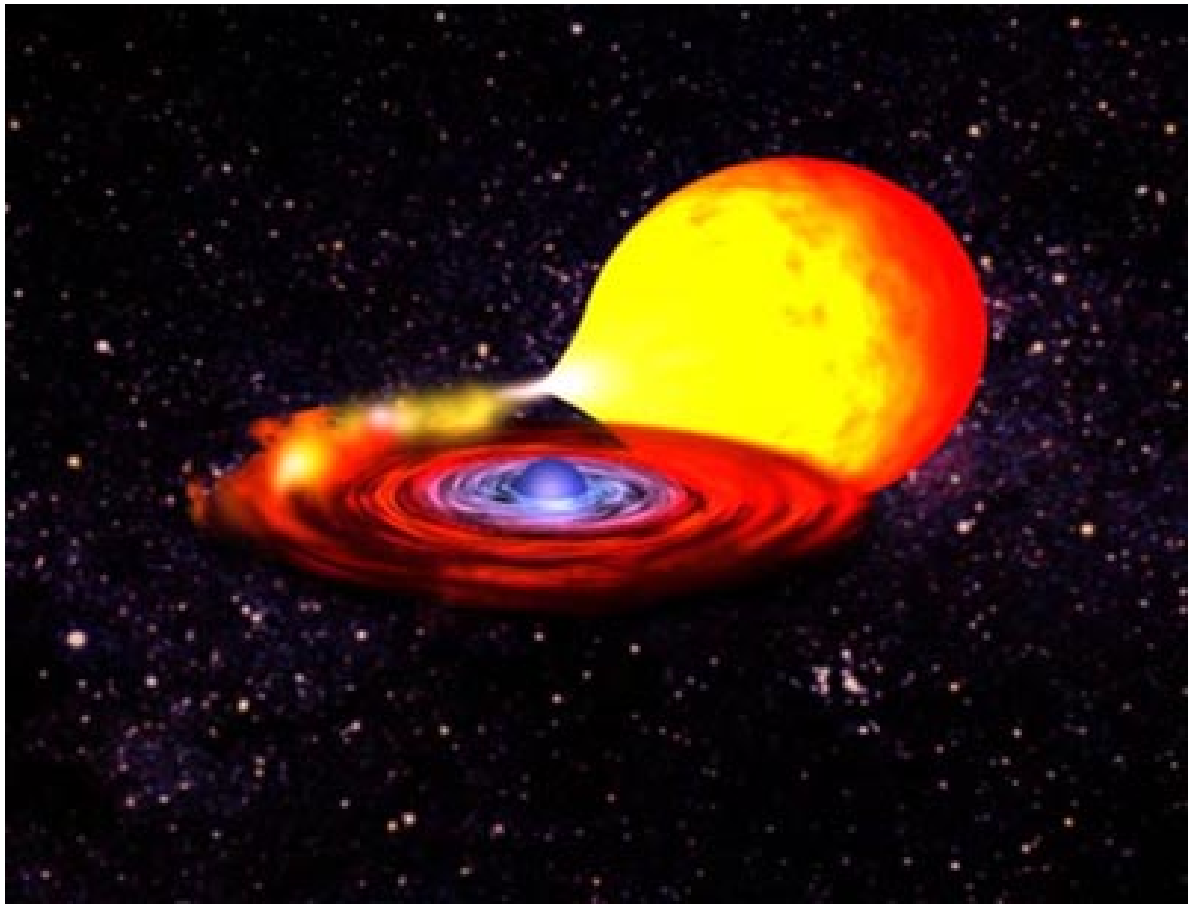
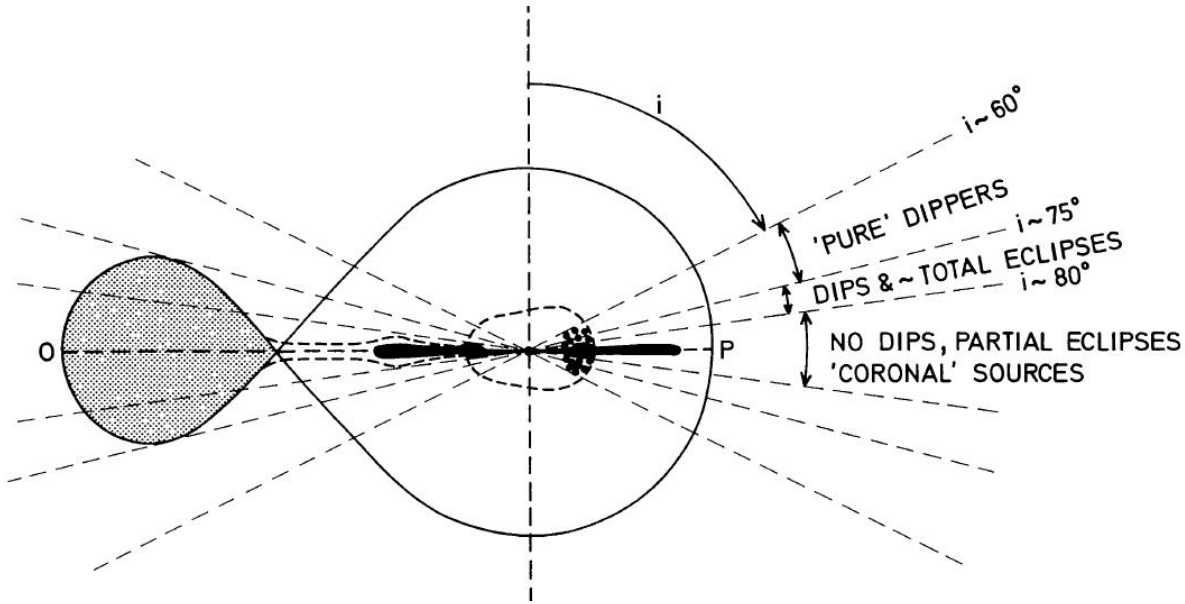
M. Díaz Trigo (ESAC), A. Parmar (ESTEC),
M. Méndez (U. Groeningen)

An artist impression of an accreting X-ray binary



X-ray orbital variability as a function of inclination



Frank et al. 1987

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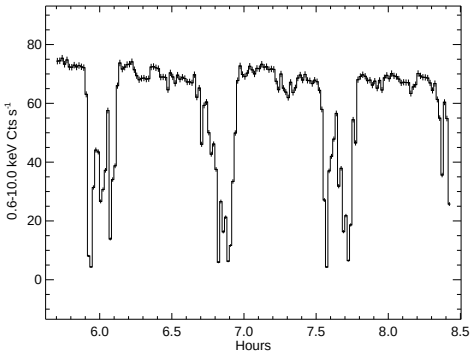

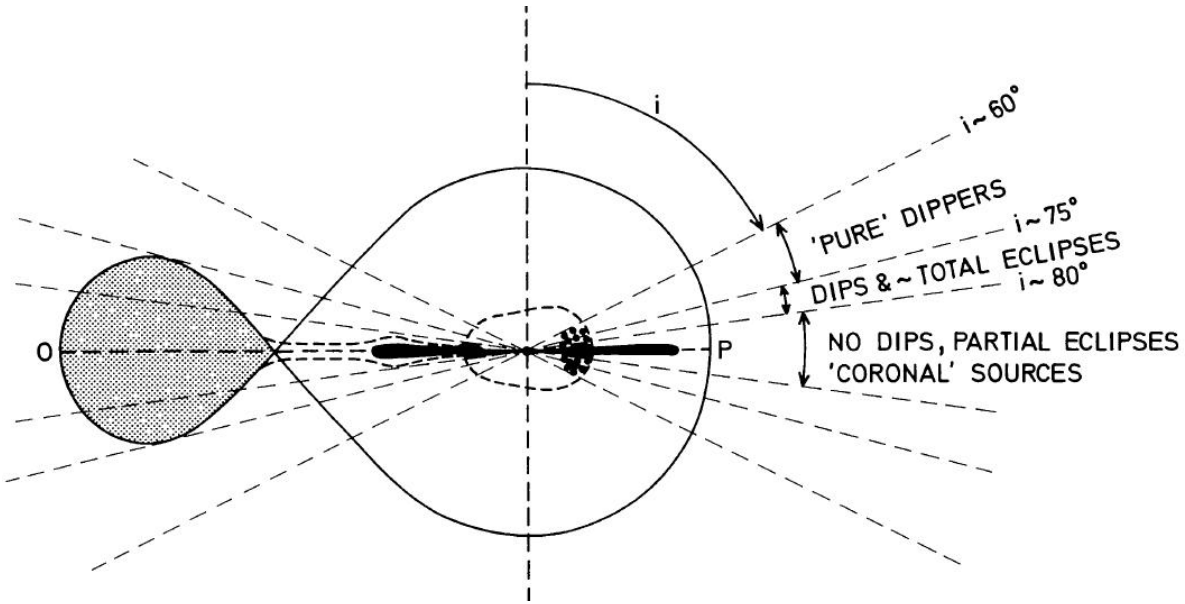

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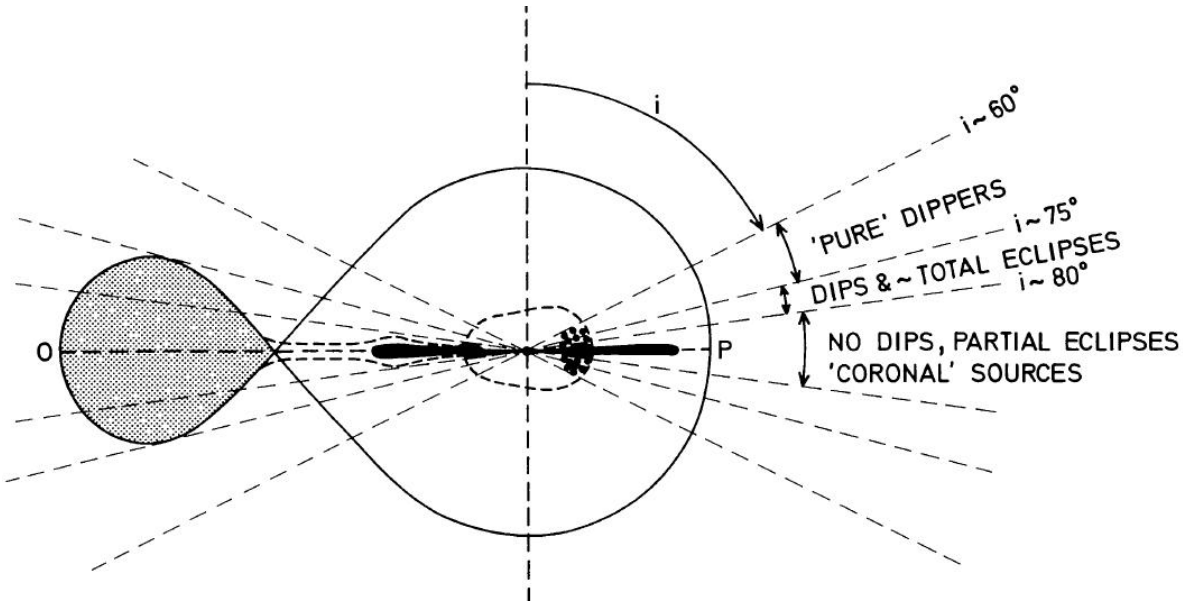

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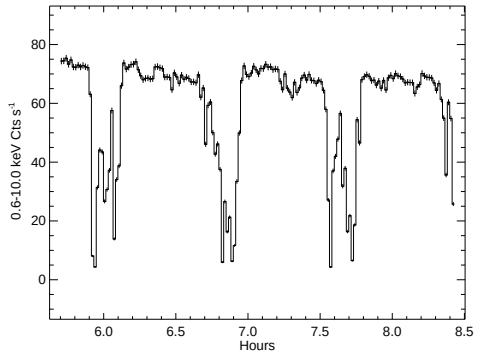

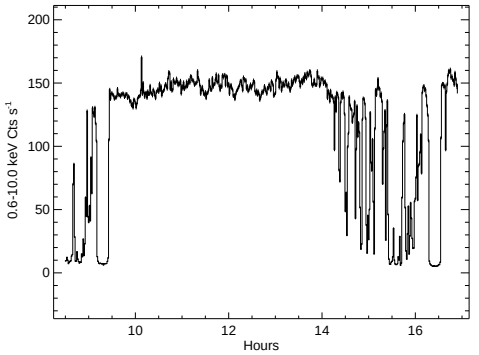

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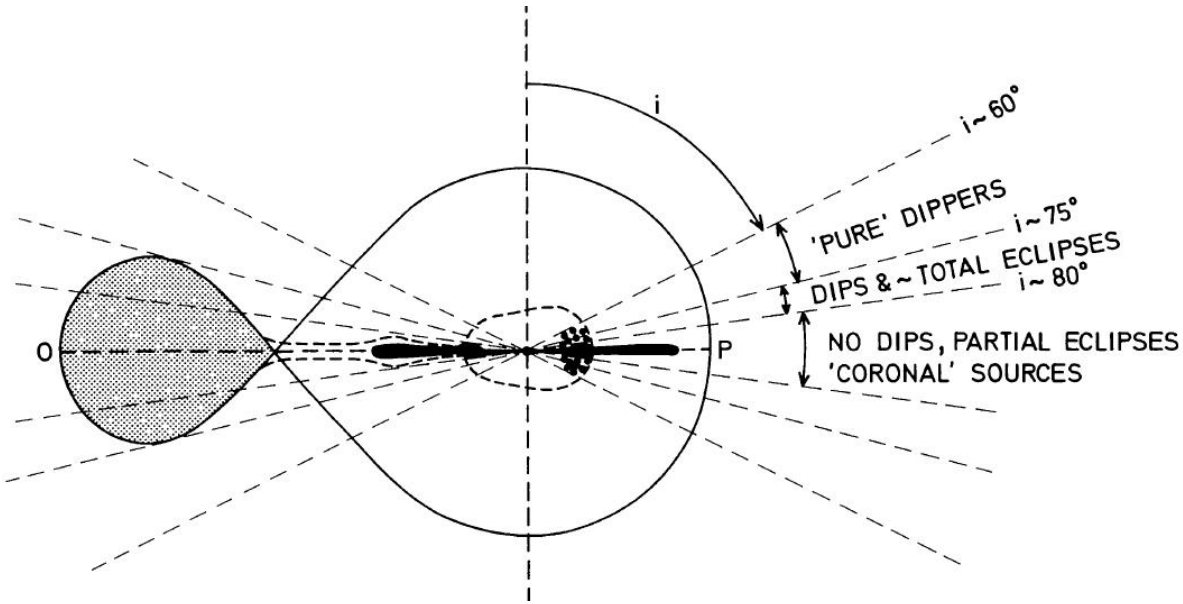

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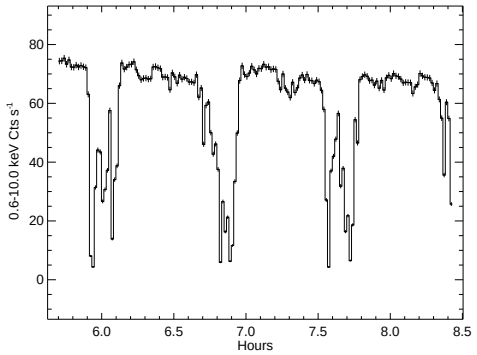

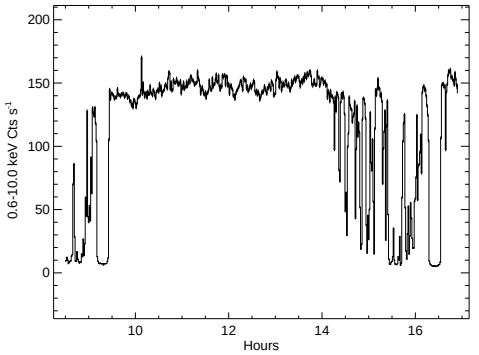

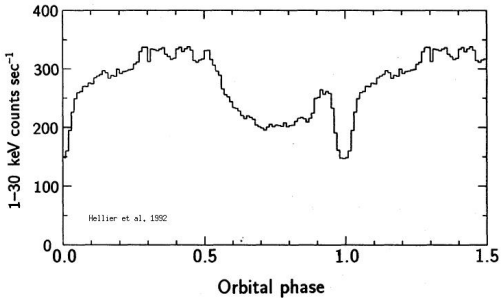

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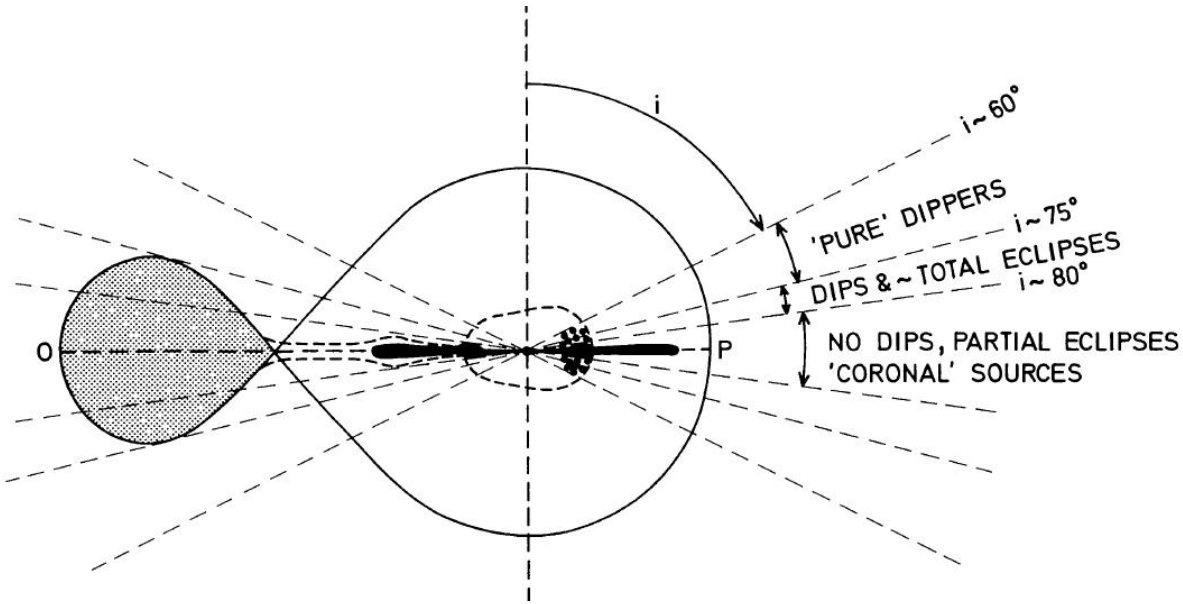

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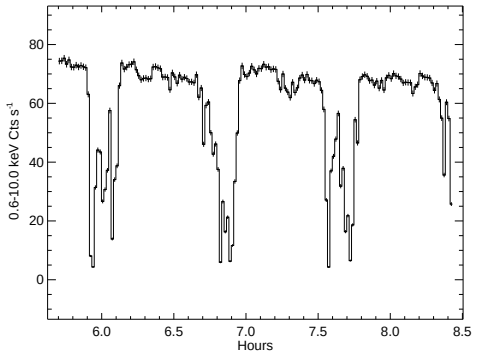

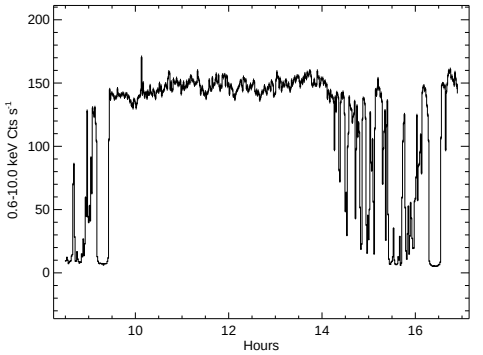

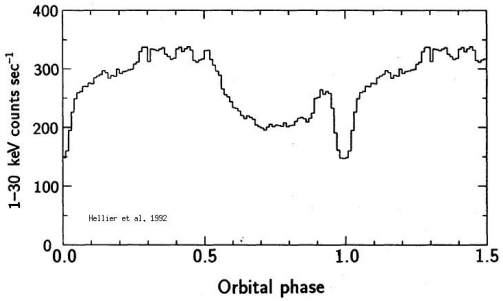

High inclination is ideal to probe the accretion disk.

Recent demonstration by XMM, Chandra and Suzaku

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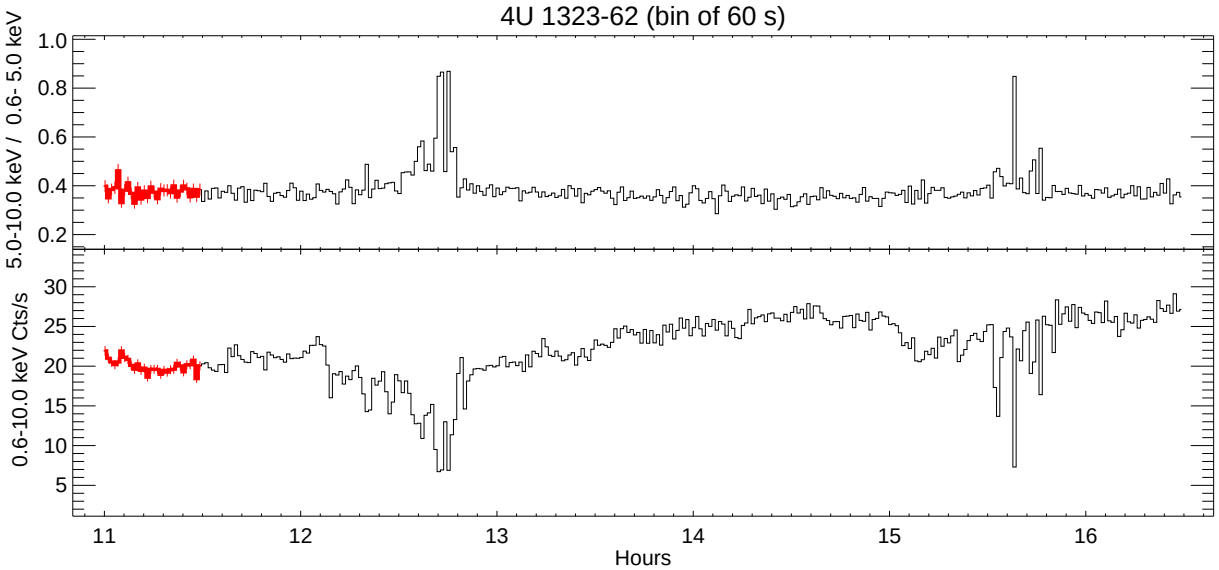
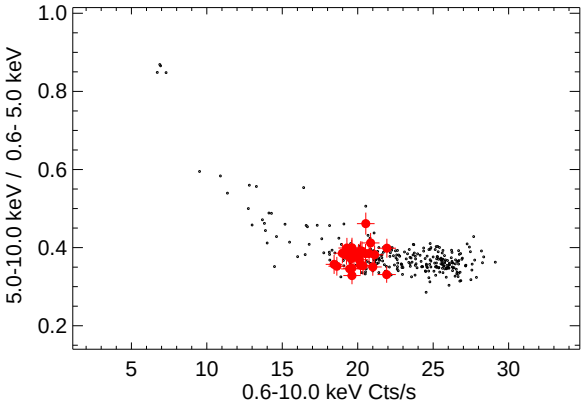
Jimenez-Garate et al. 2002

Dipping is associated with spectral hardening





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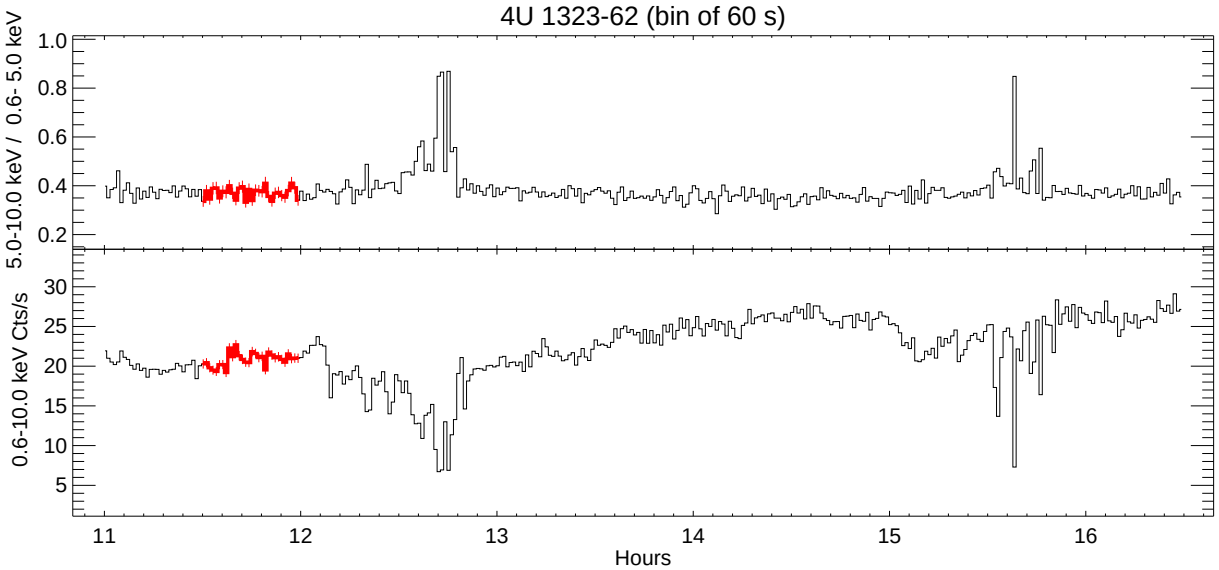

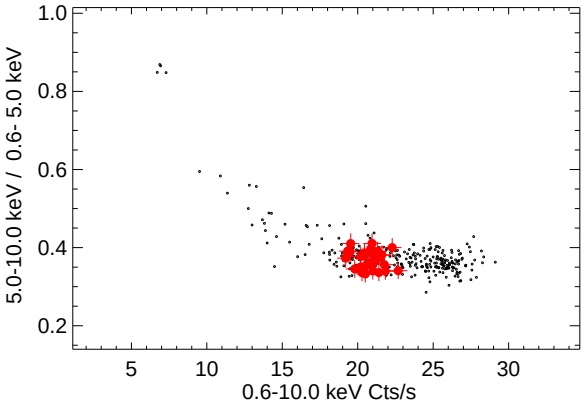

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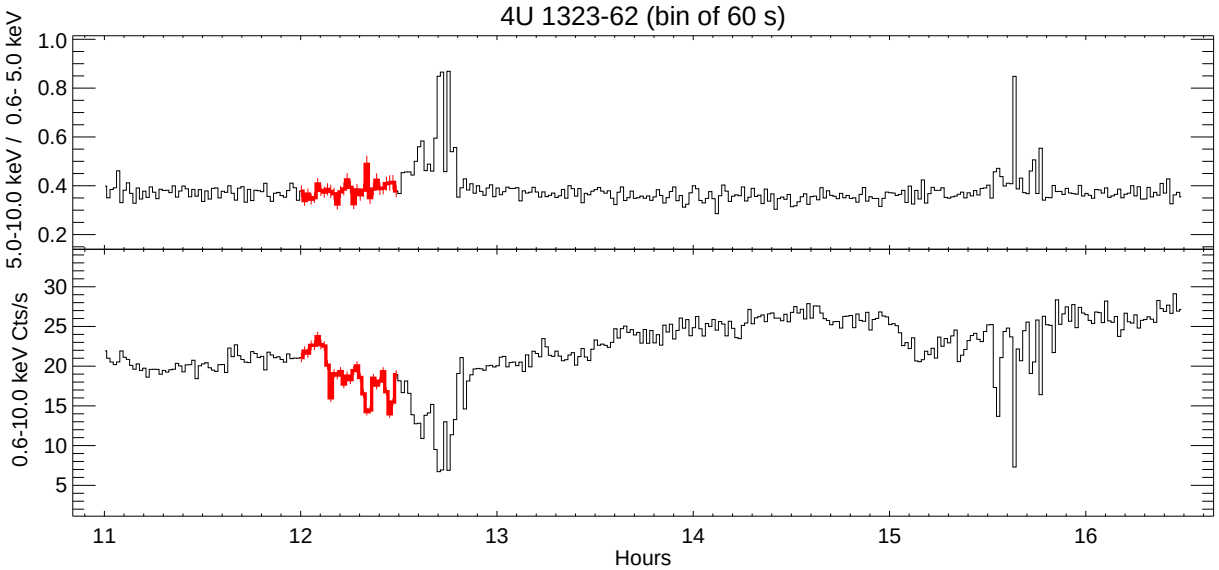

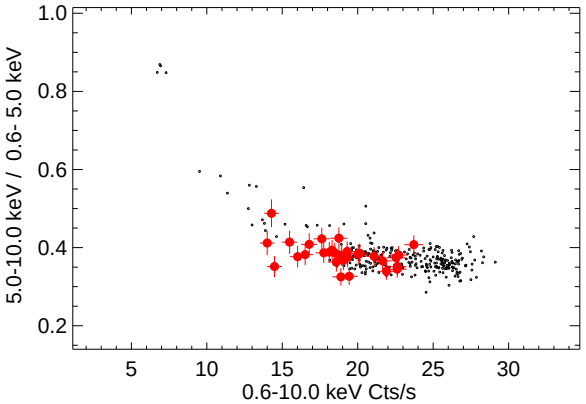

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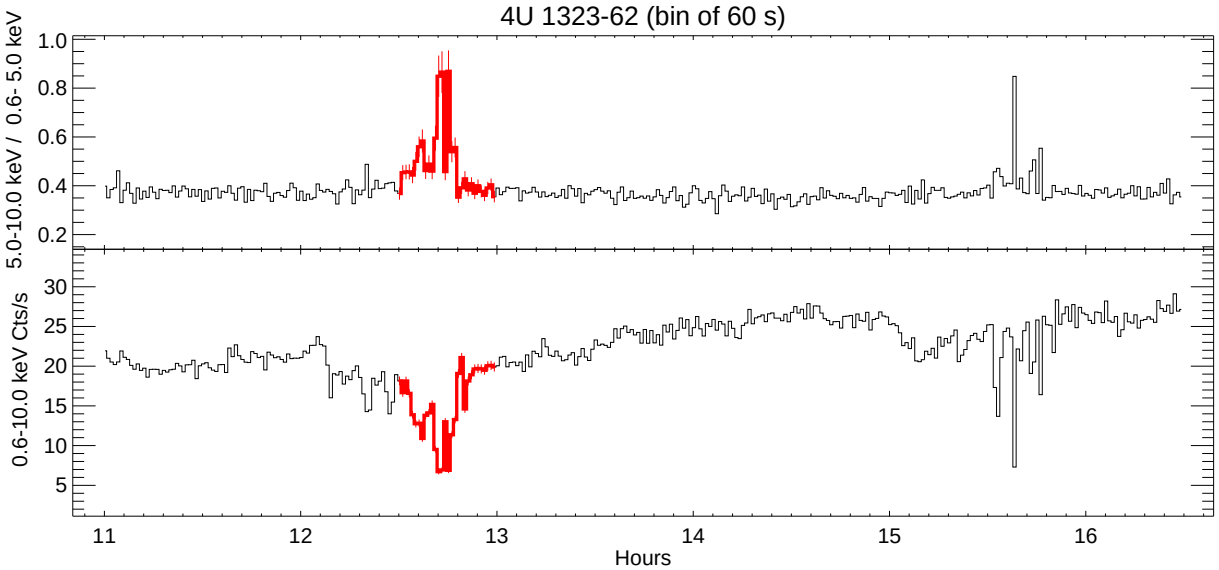

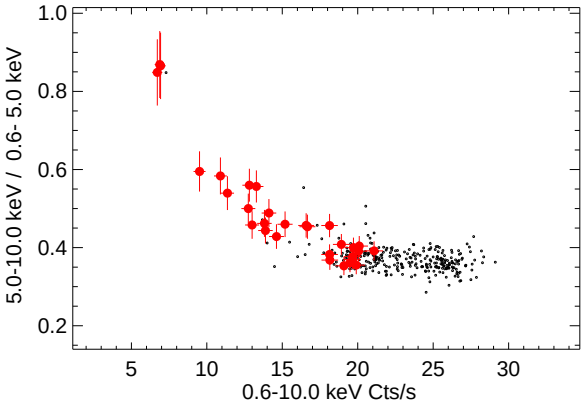

Absorption plays the main role in the spectral changes from persistent to dipping intervals

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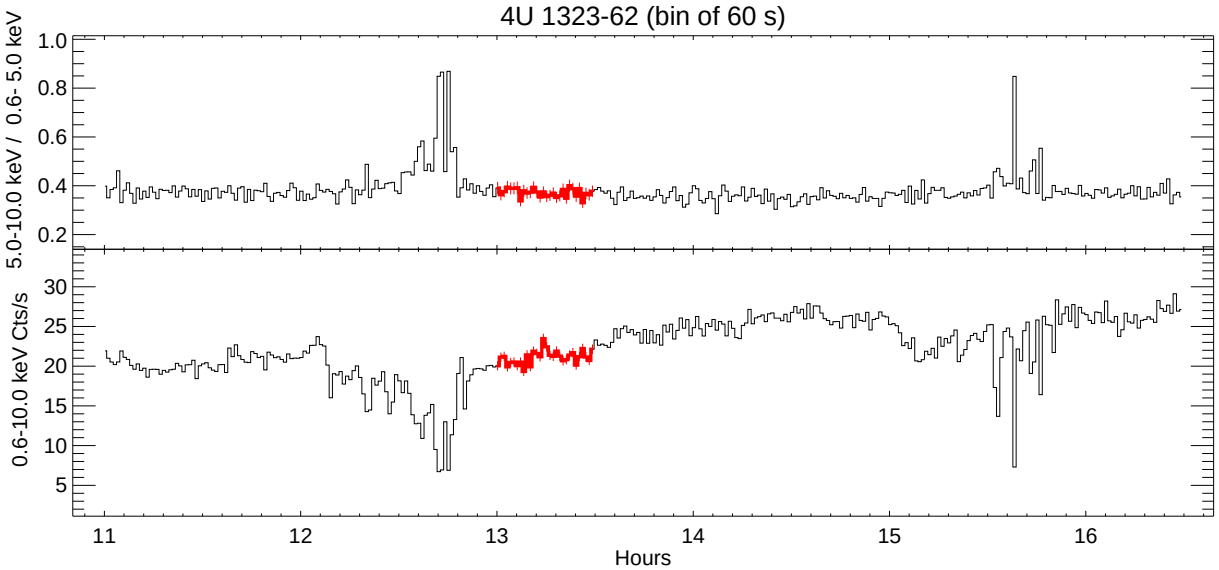

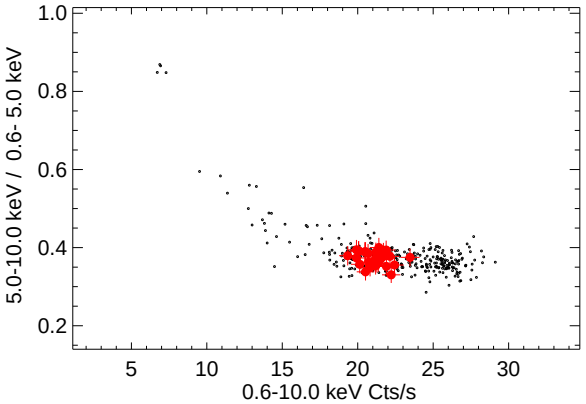

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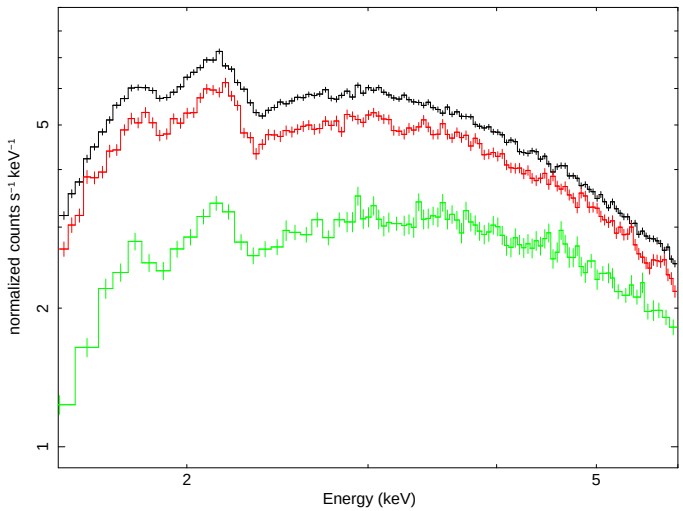
The game



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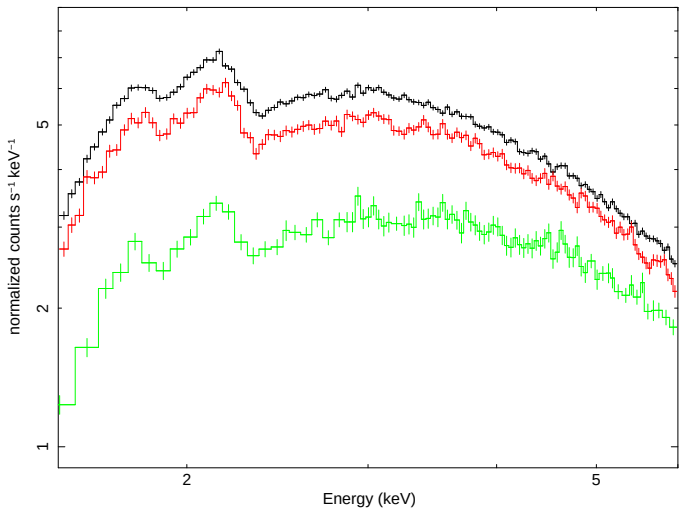

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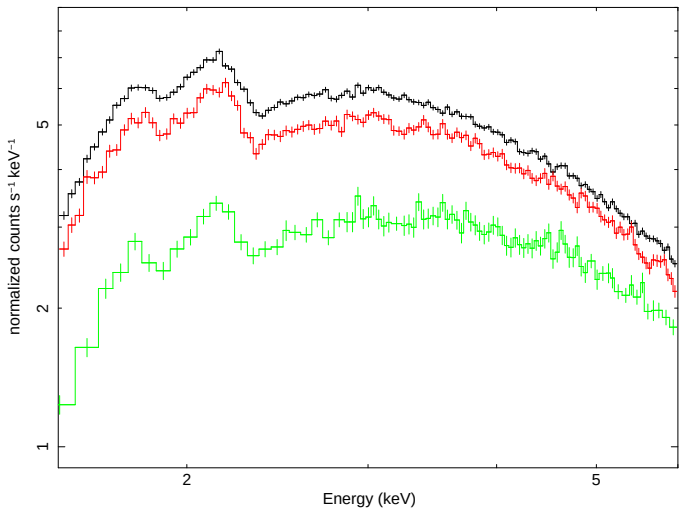

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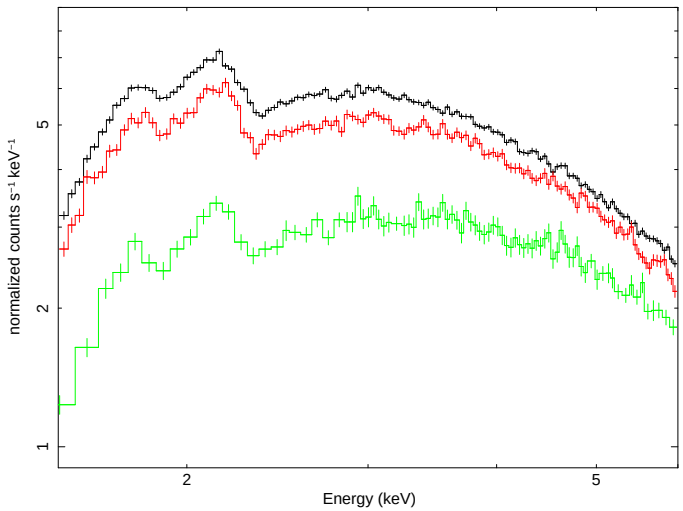

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  - the absorber (local to the system) may be different for each

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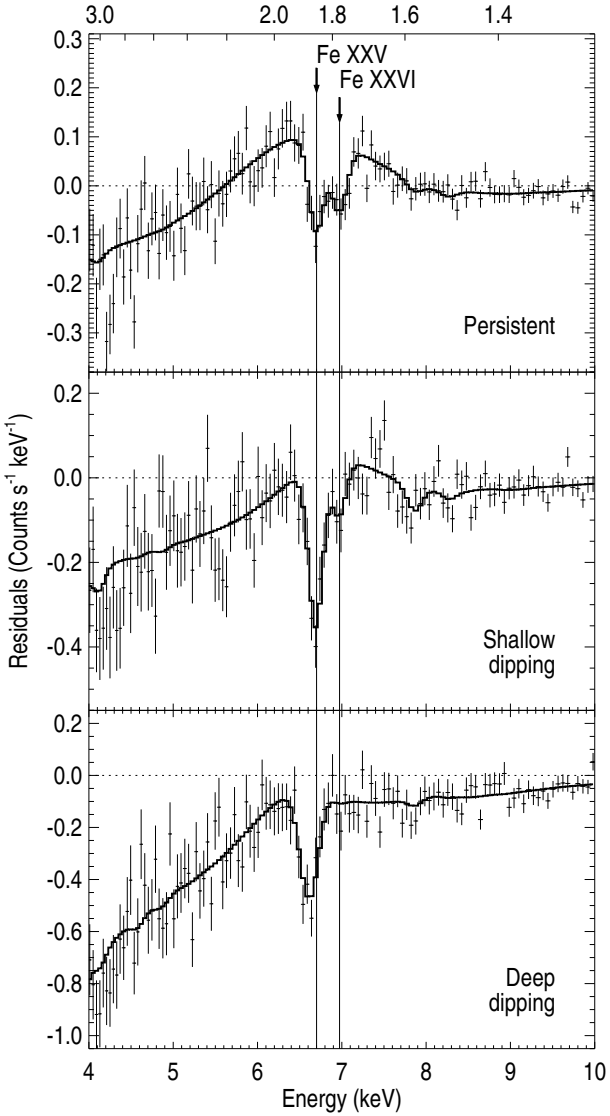
With XMM, Chandra and Suzaku: absorption lines



Boirin et al. 2005

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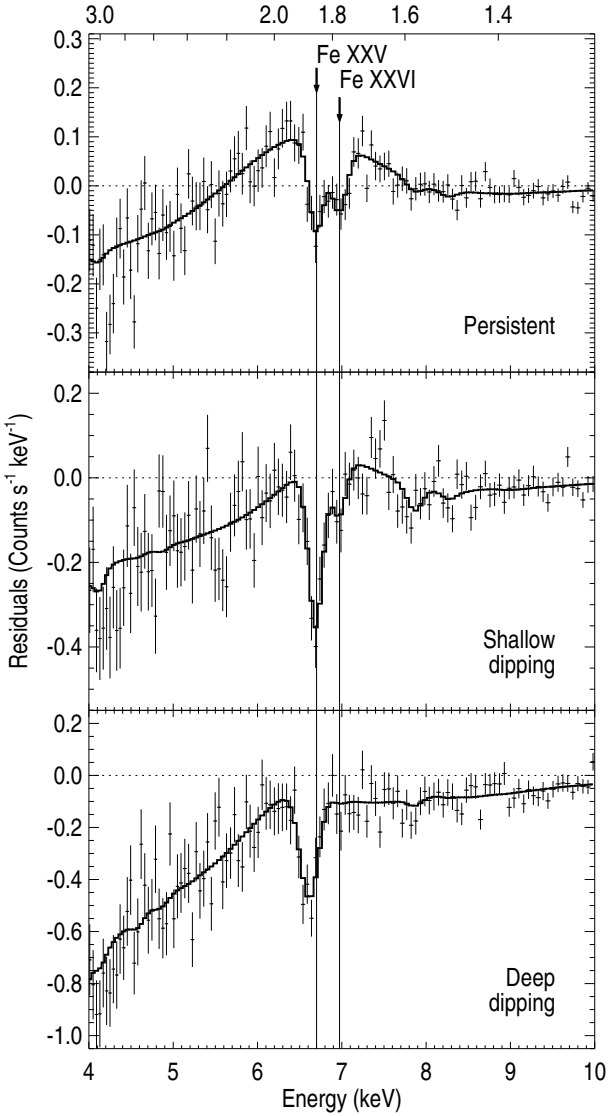

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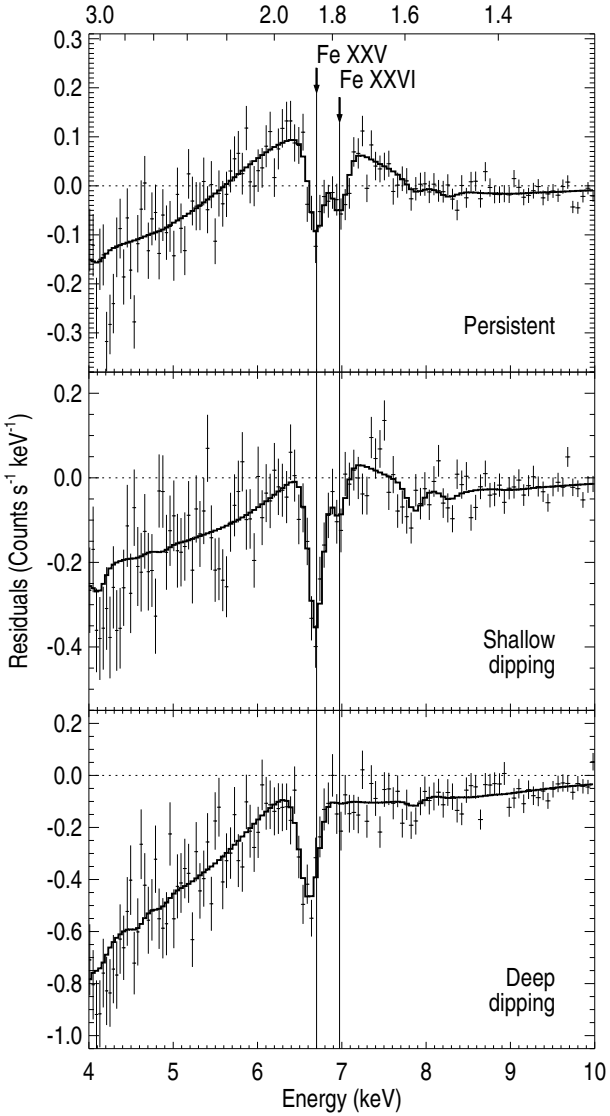

Boirin et al. 2005

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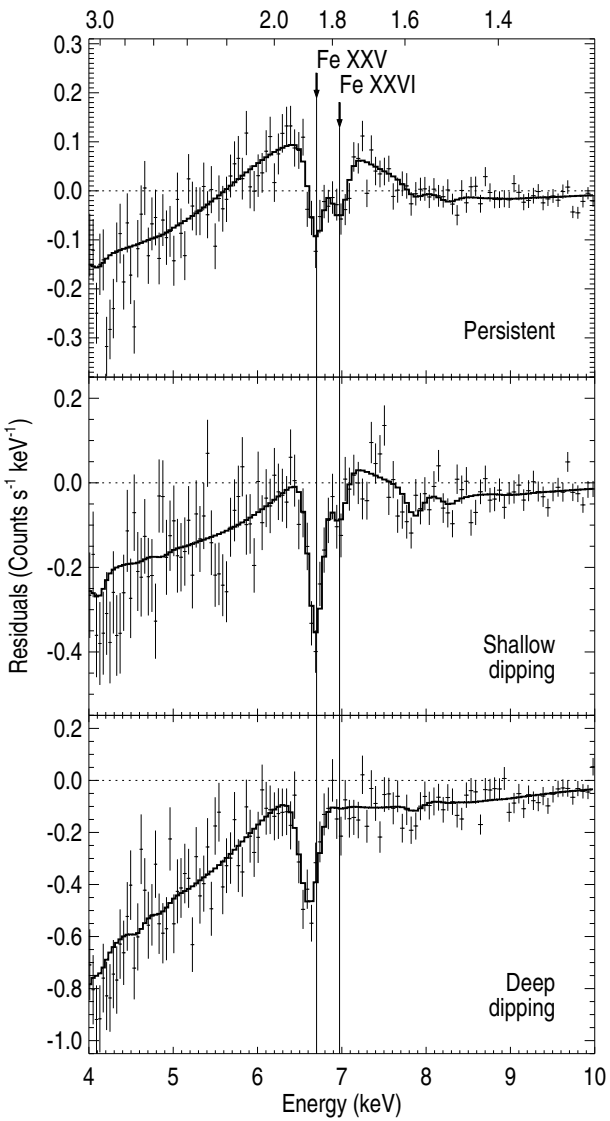
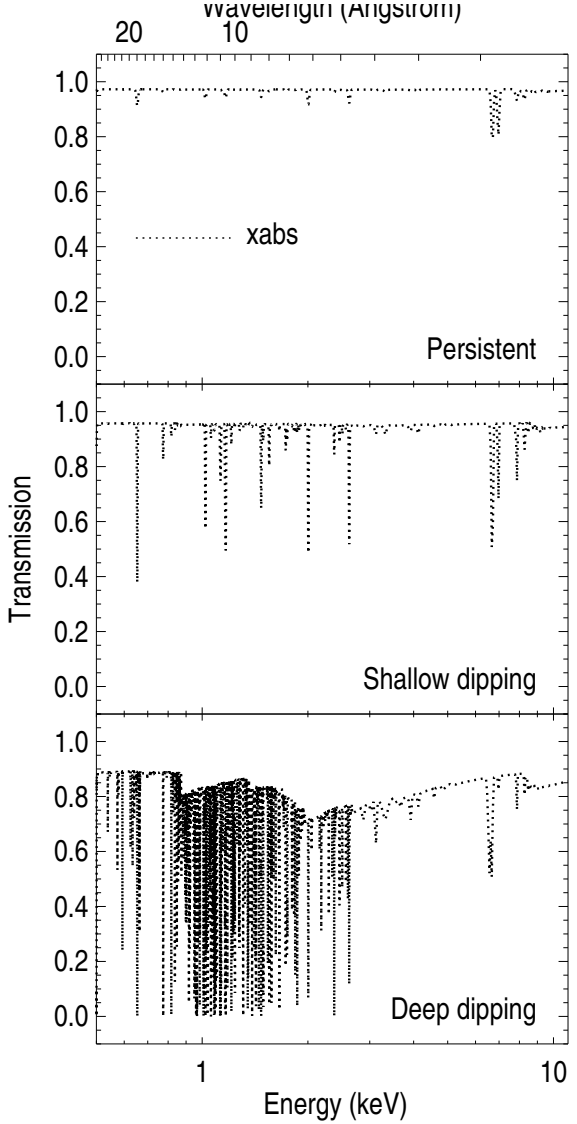
- The bulge is less strongly ionized

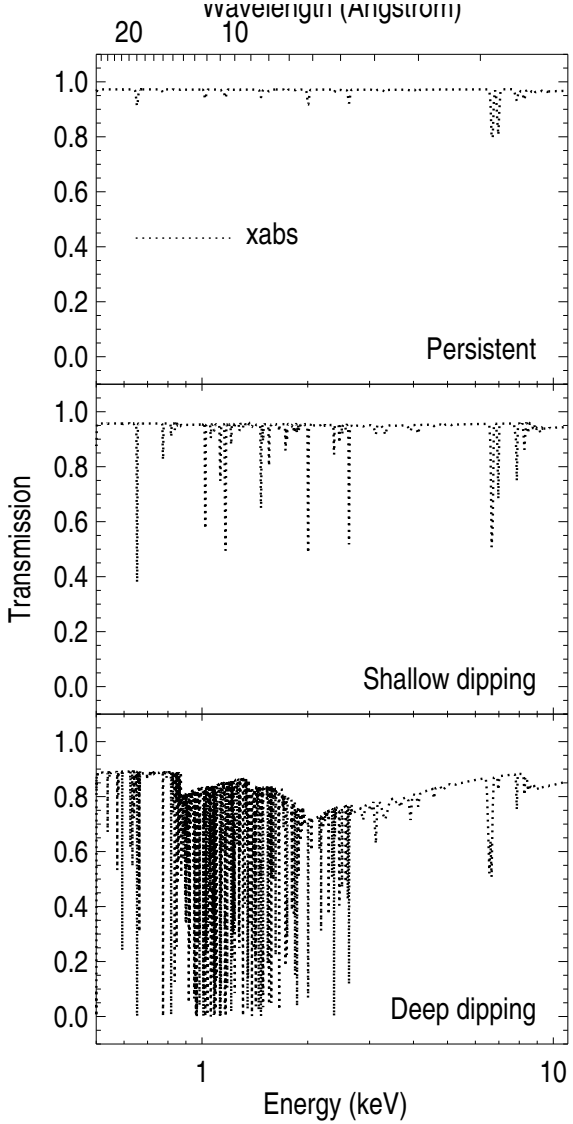
Using a physical photo-ionized absorber model





Boirin et al. 2005

Using a photo-ionized absorber and a neutral absorber



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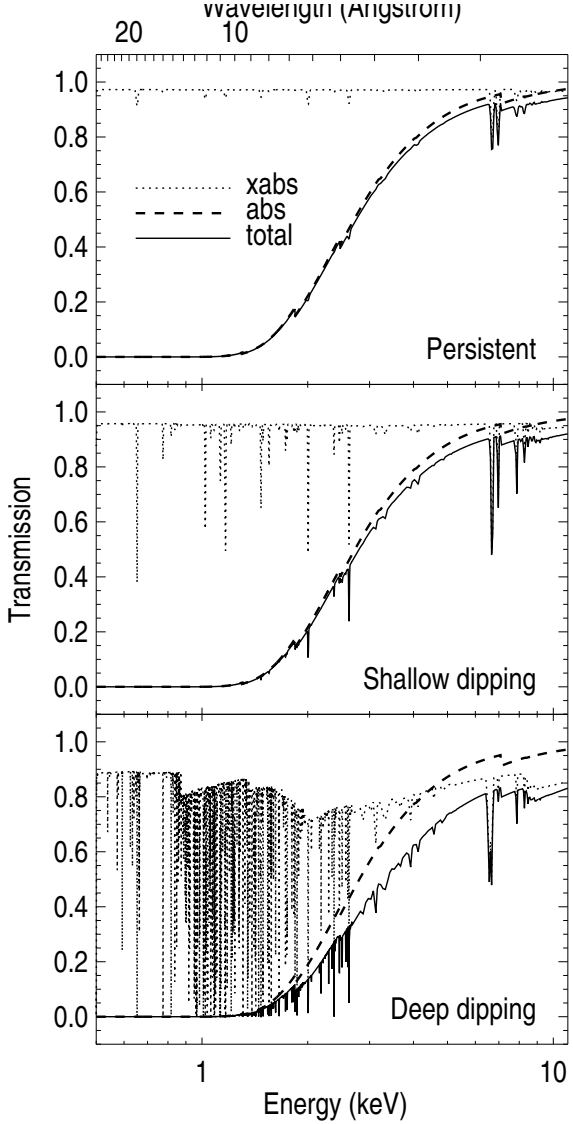

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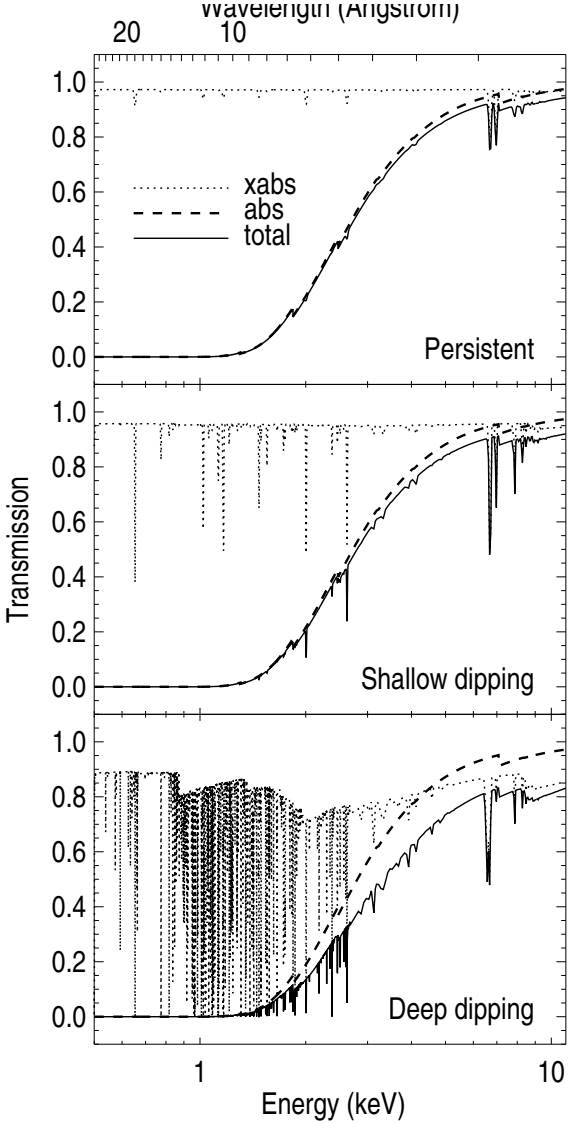

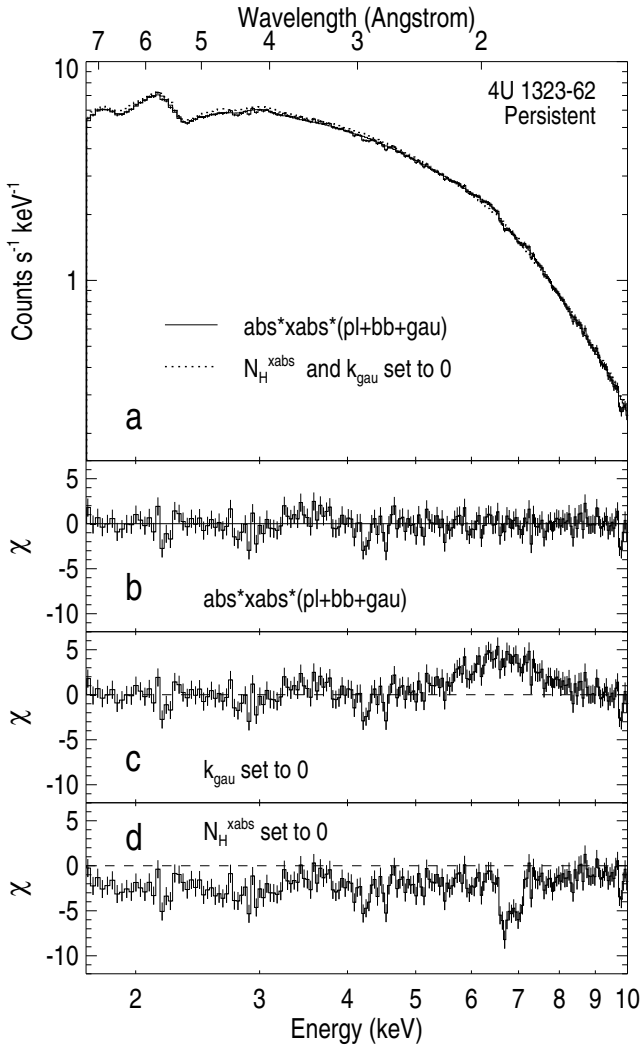

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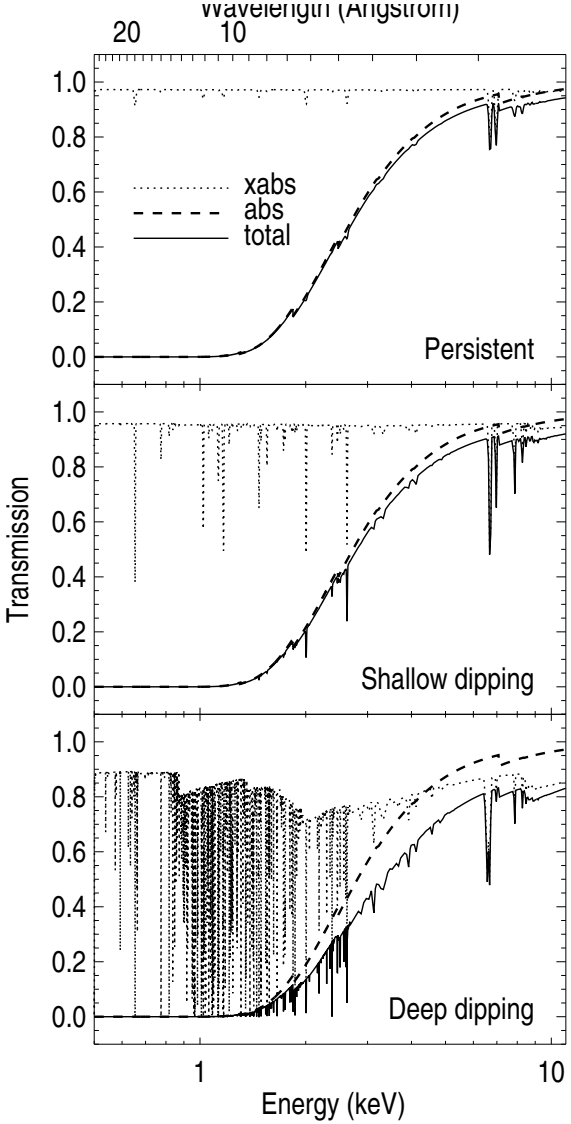

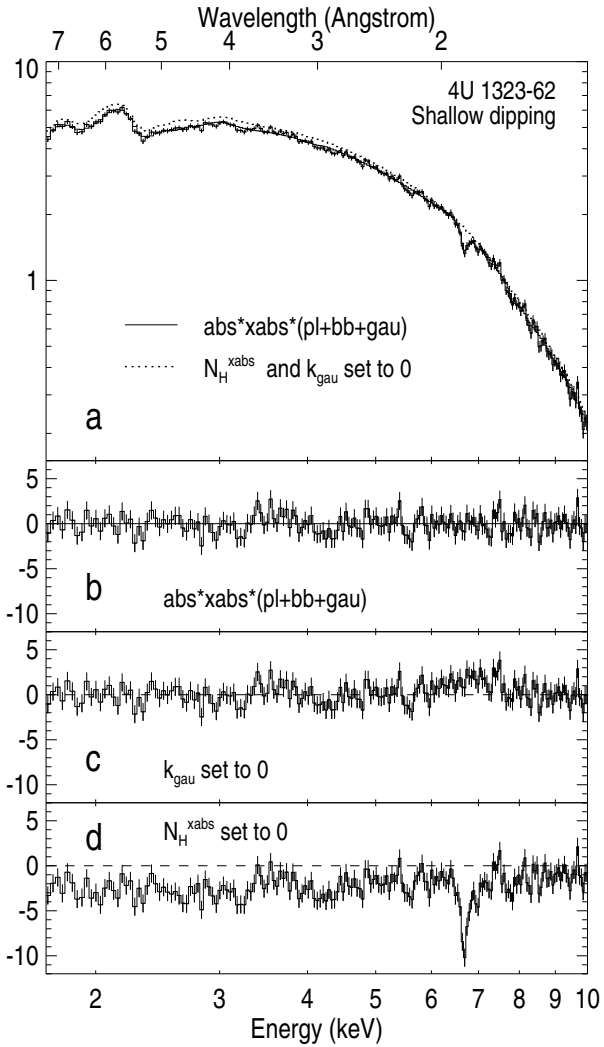

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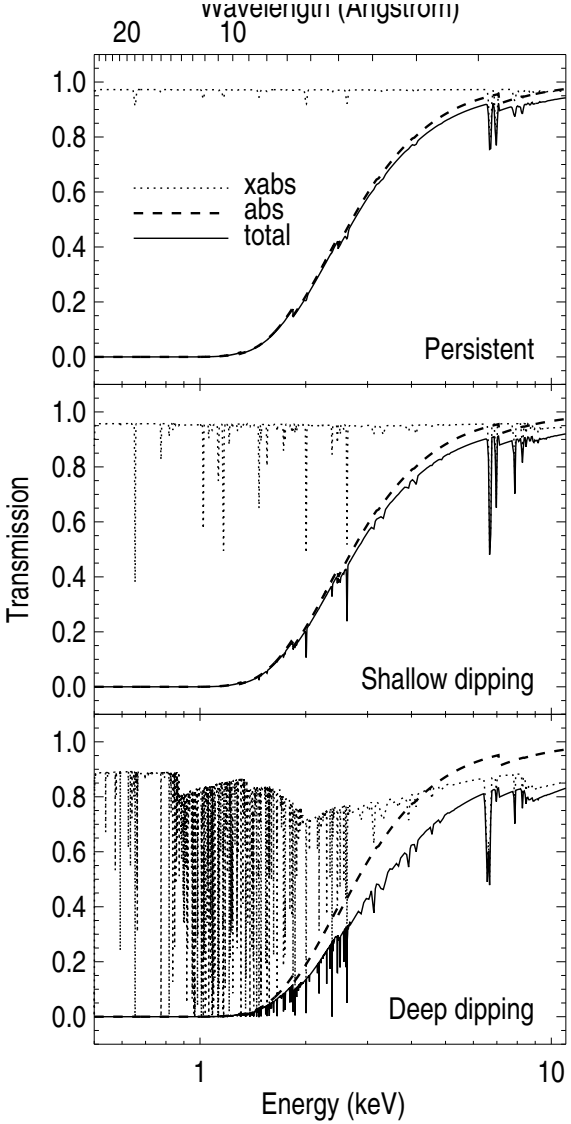
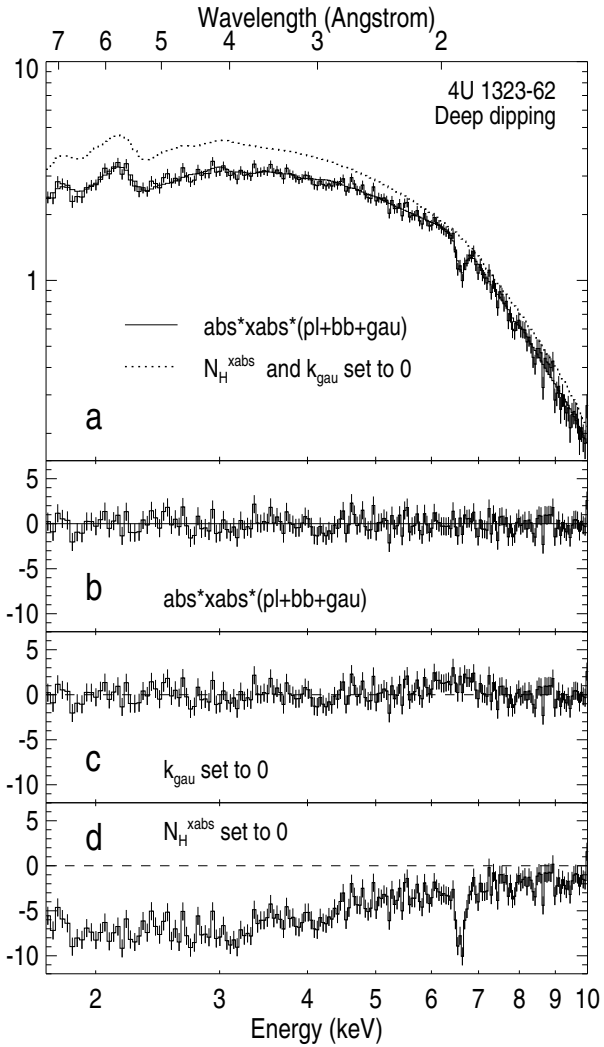
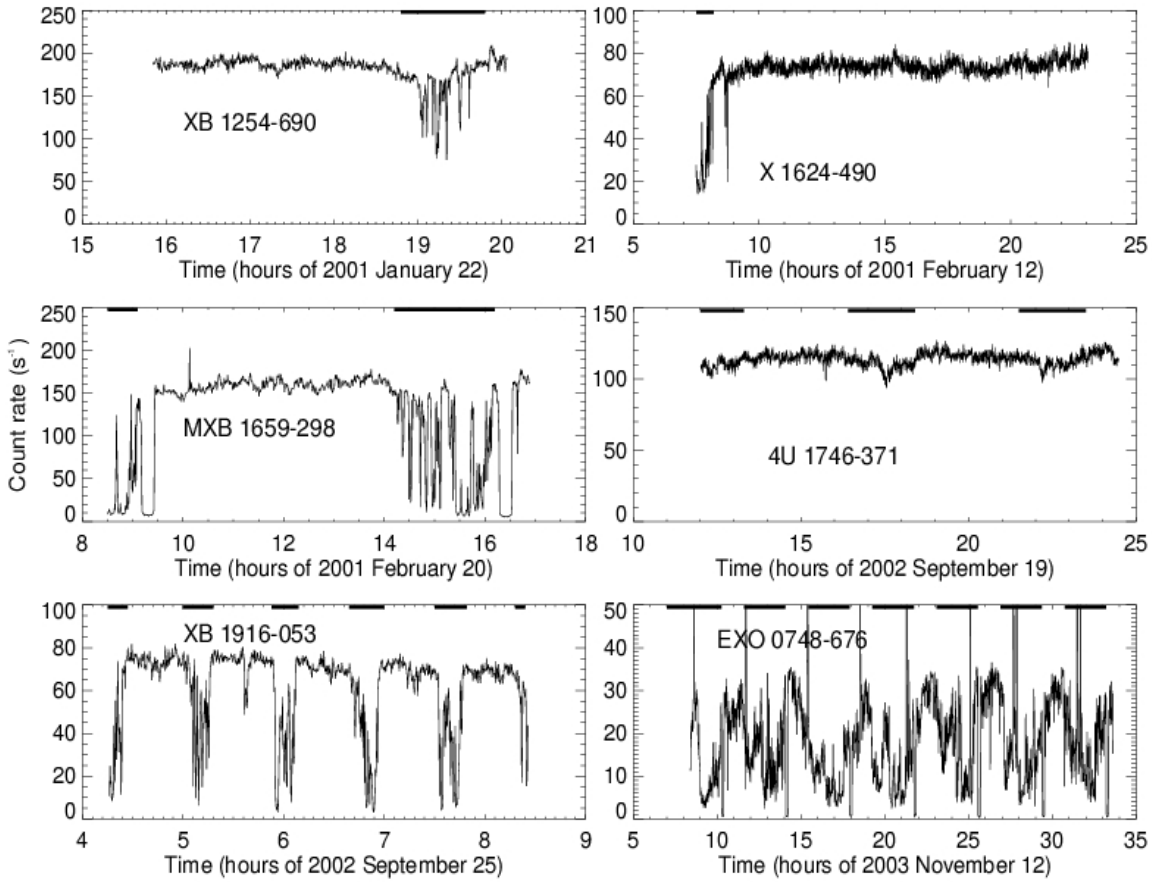




Boirin et al. 2005

The new approach: neutral + warm absorber

- succesfully applied to all the dippers observed with XMM



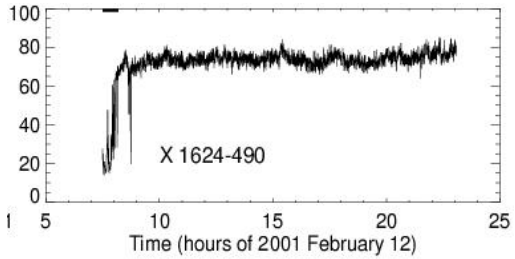
including X 1624-490, the “Big dipper”

Díaz Trigo et al. 2006

X 1624-490

- Orbital period: 21 h
- 4 h of dipping activity per cycle
- X-ray luminosity: $\sim 5 \times 10^{37}$ erg s^{-1}
- Distance: 15 kpc
- Strongly absorbed: $N_{\rm H} \sim 10 \times 10^{22}$ cm^{-2}
- Dust scattering halo
- Recently studied using Chandra *Xiang et al. 2008*
  - $N_{\rm H}^{abs} \sim 8 \times 10^{22}$ cm^{-2} (all the gas in the line-of-sight)
  - $N_{\rm H}^{sca} \sim 4 \times 10^{22}$ cm^{-2} (only the Galactic contribution)
  - a large fraction of the column is local to the system

XMM observation of X 1624-490 in 2001



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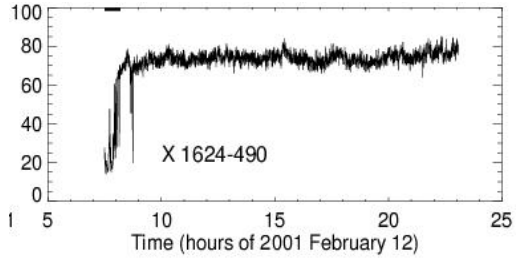

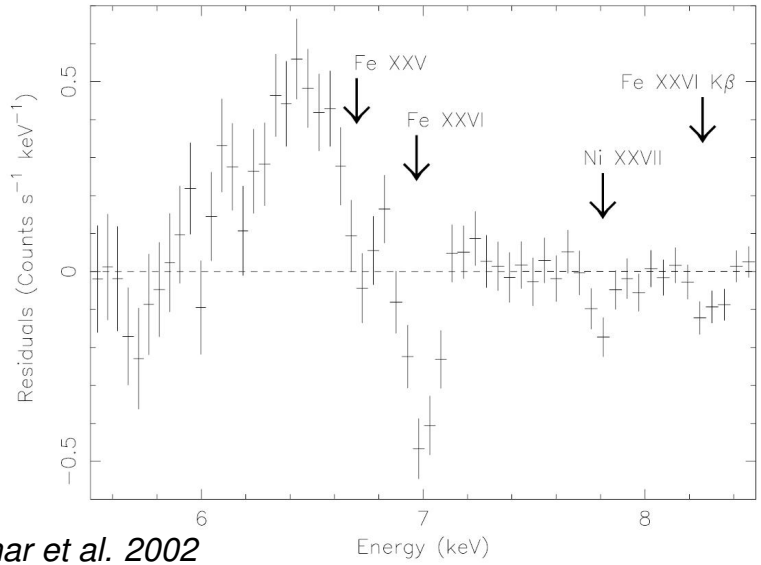

Parmar et al. 2002

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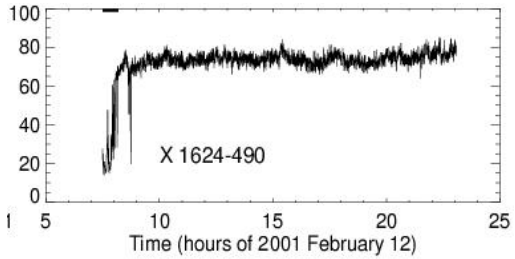

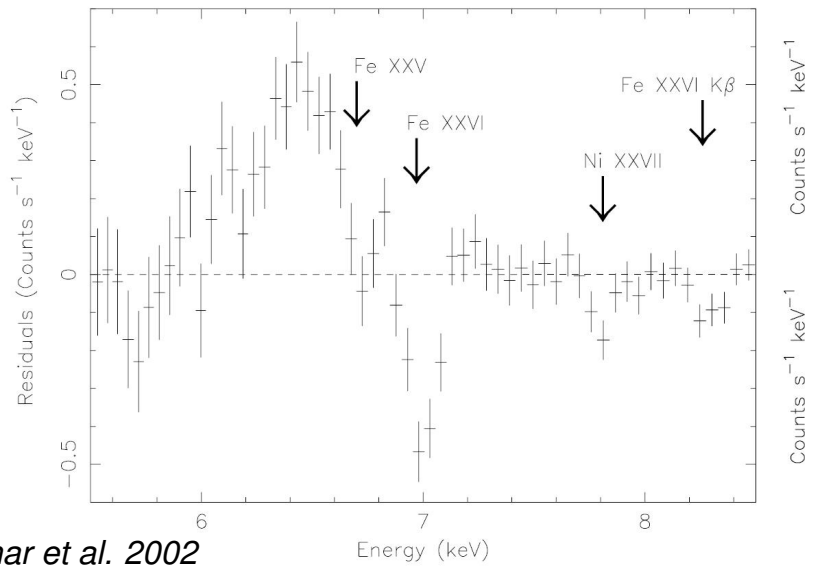

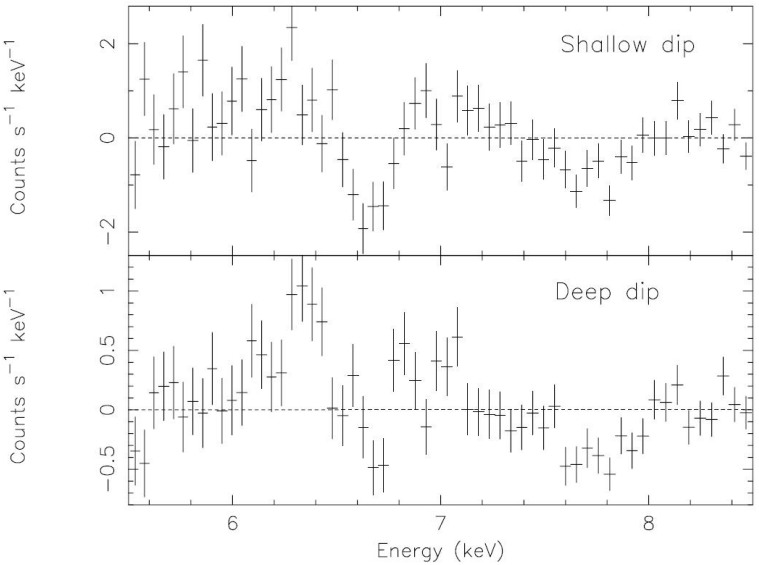

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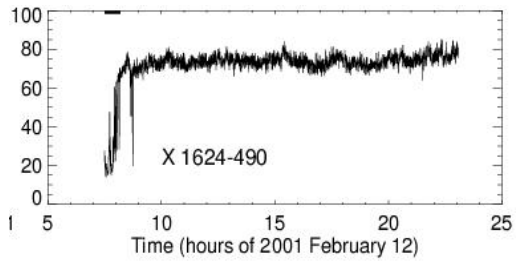

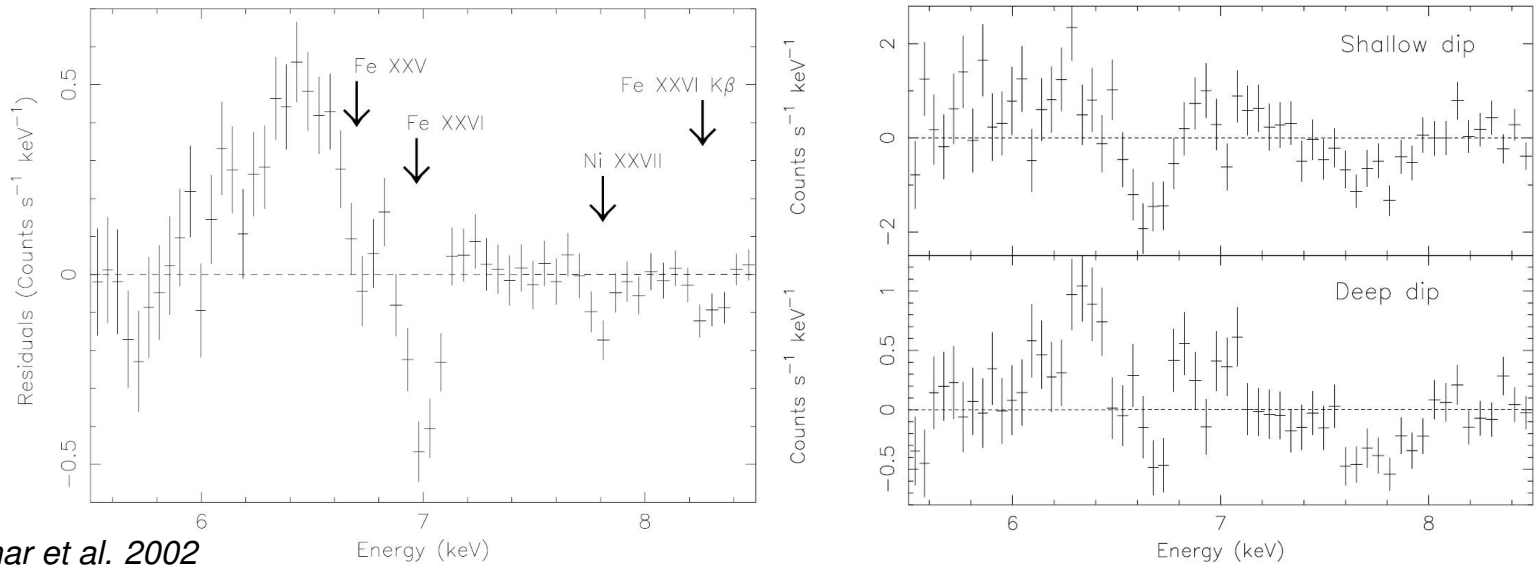

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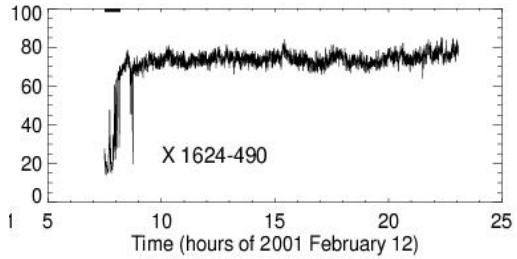
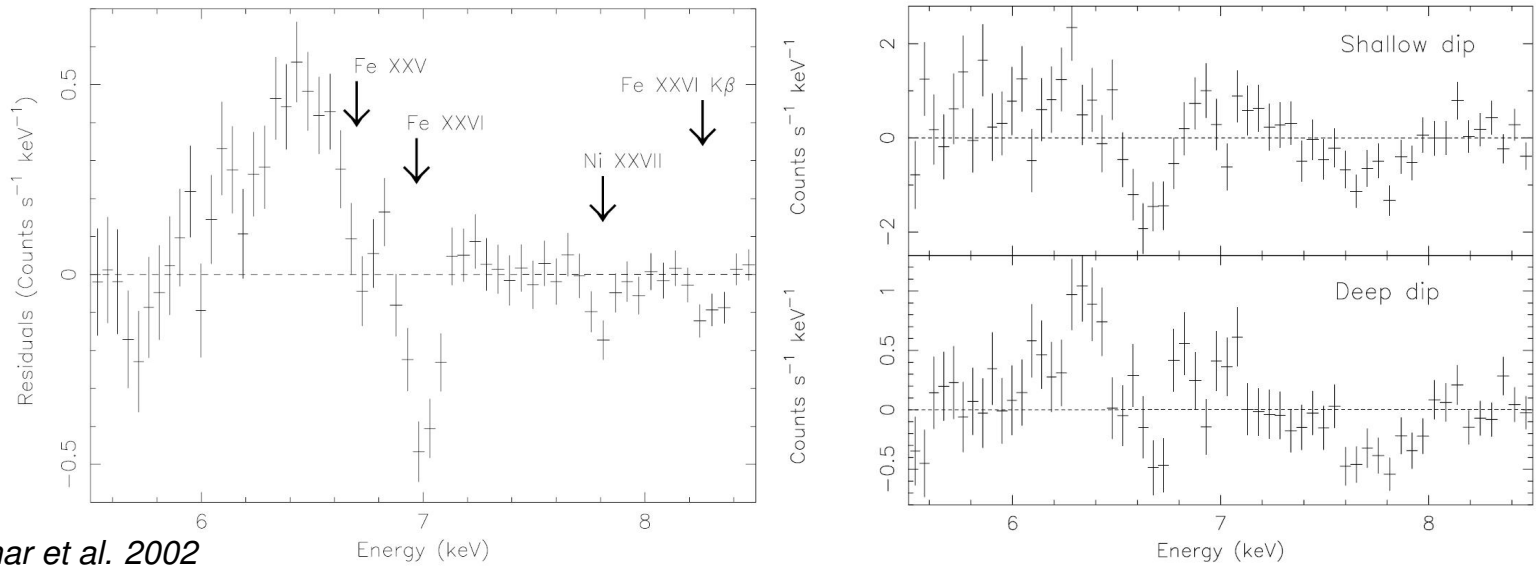
The observation was piled-up (Small Window mode)

XMM observation of X 1624-490 in 2001





Parmar et al. 2002

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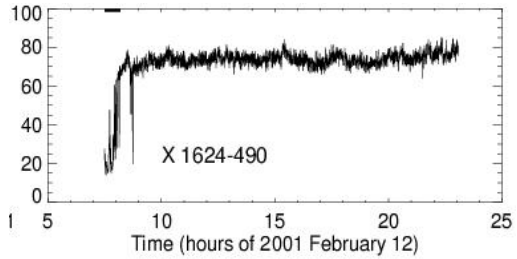

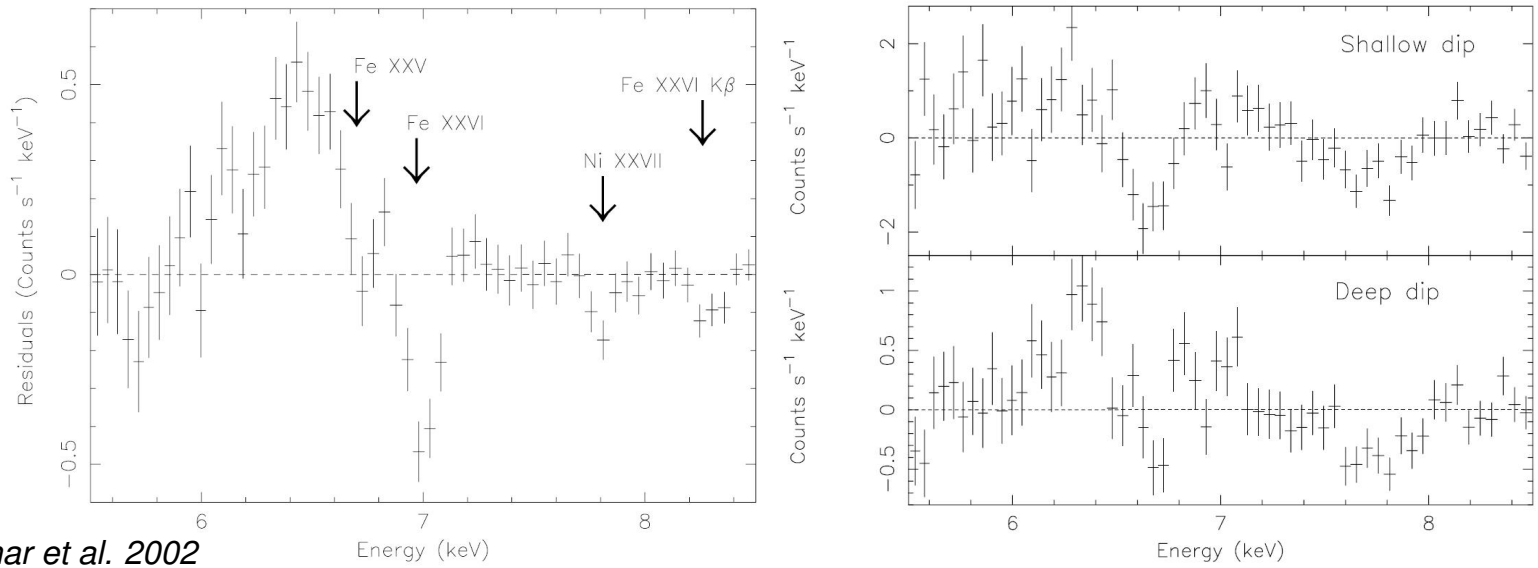

Parmar et al. 2002

The observation was piled-up (Small Window mode)

- difficult to fit simultaneously the persistent and dipping spectra
- Díaz Trigo et al. (2006) had to exclude the persistent one.

Observation strategy

- Avoid pile-up: timing mode

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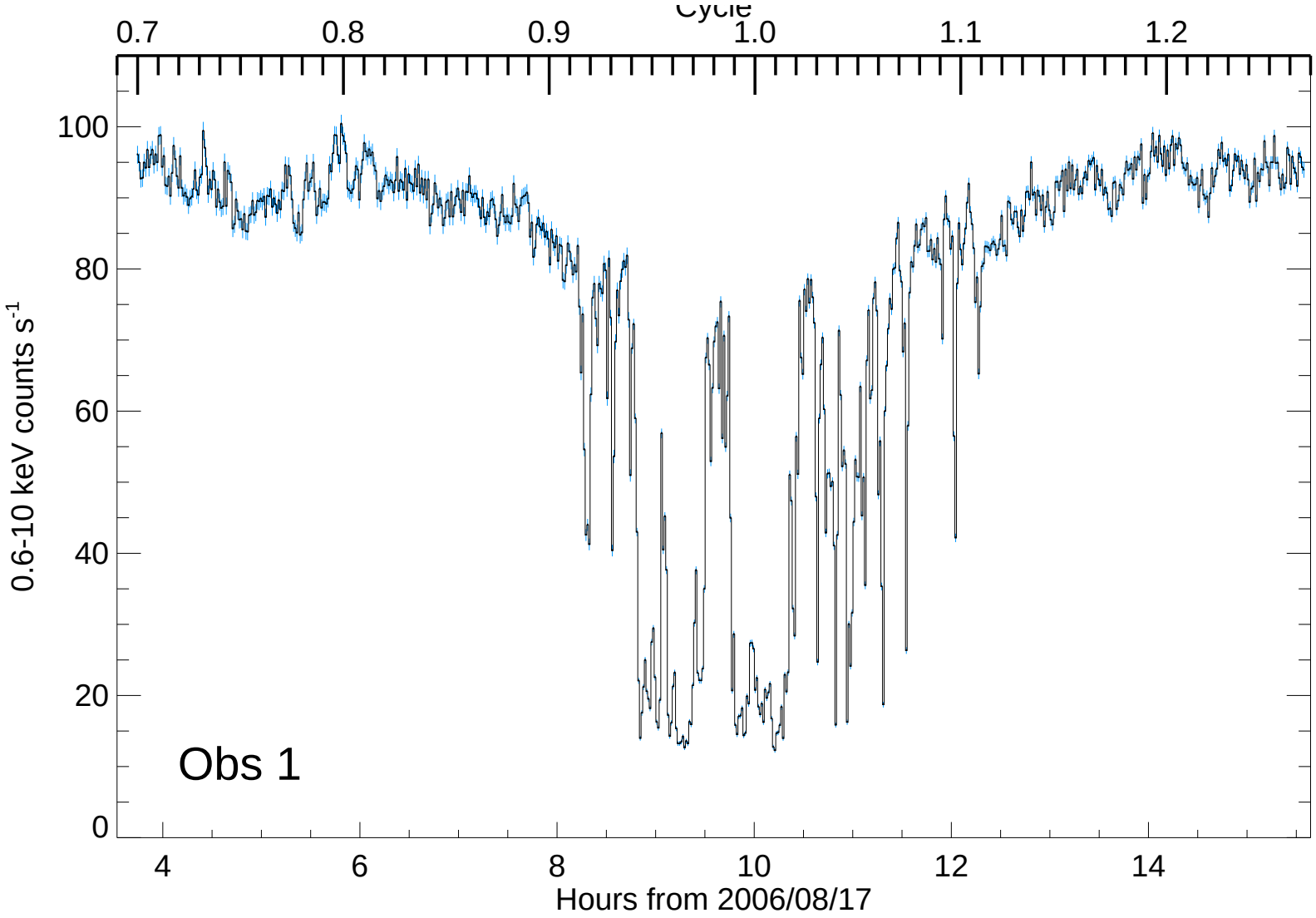
- Trigger 3 shorter (6 h) observations on a dip

EPIC PN 0.6-10 keV light curve



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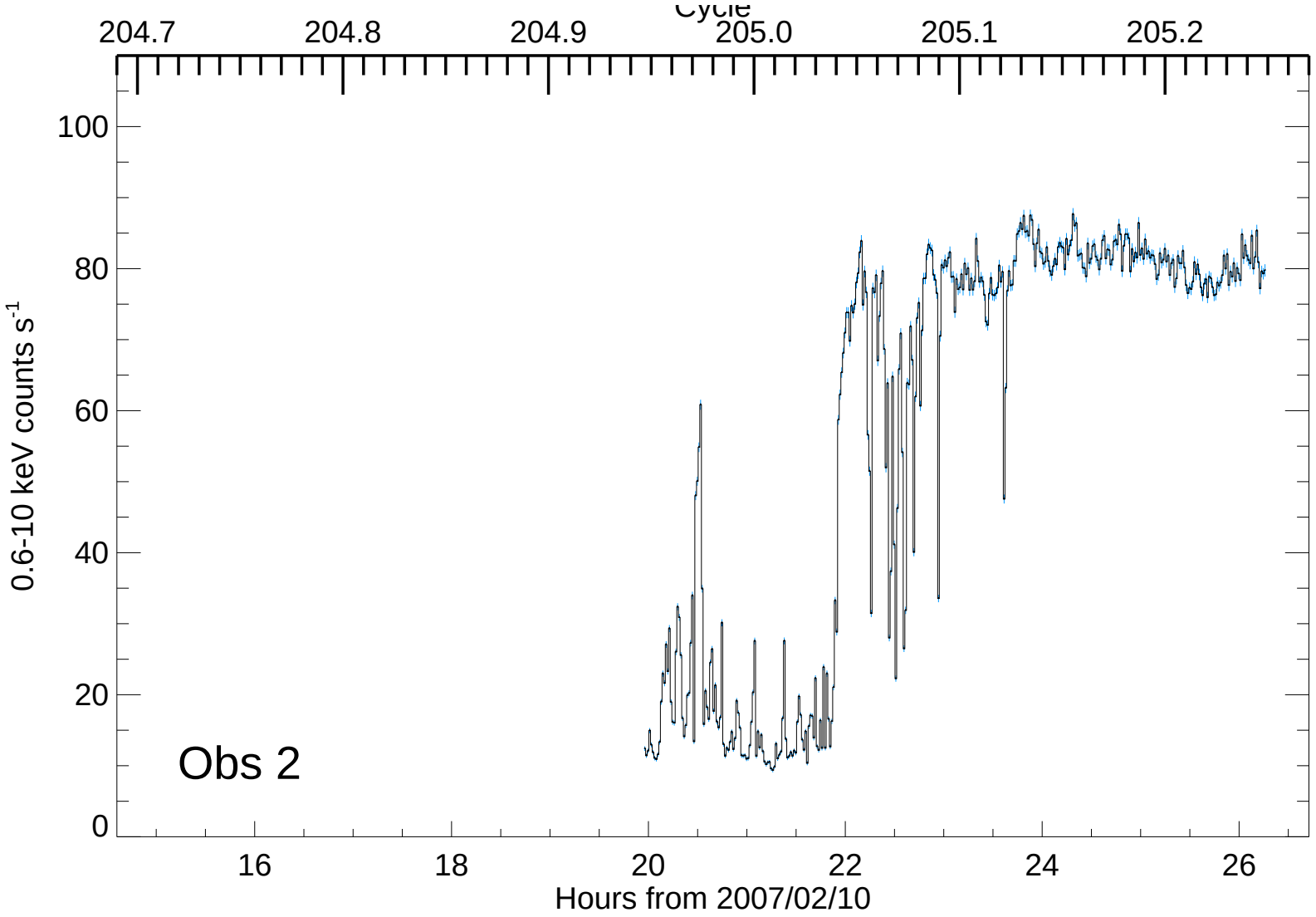
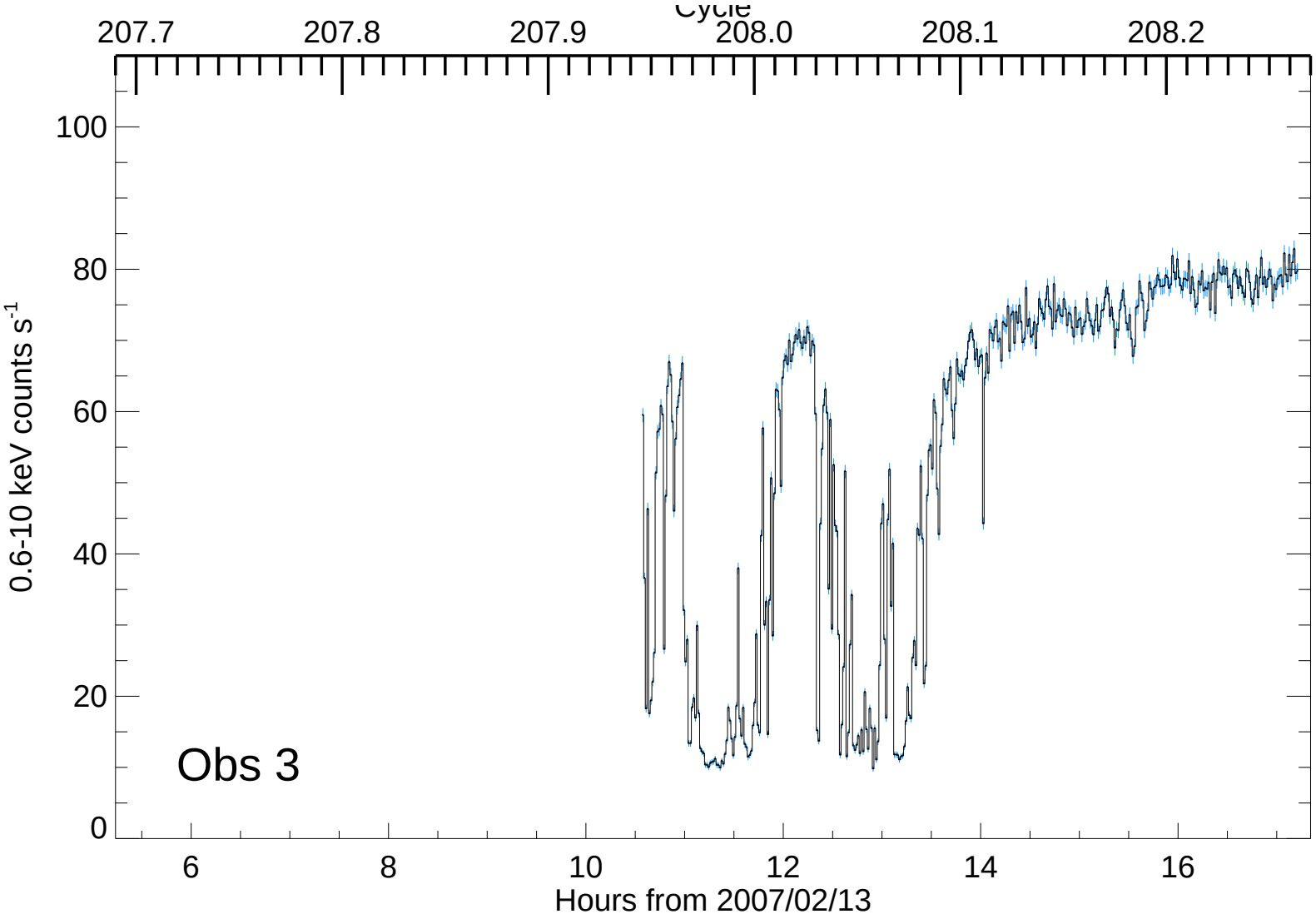


EPIC PN 0.6-10 keV light curve



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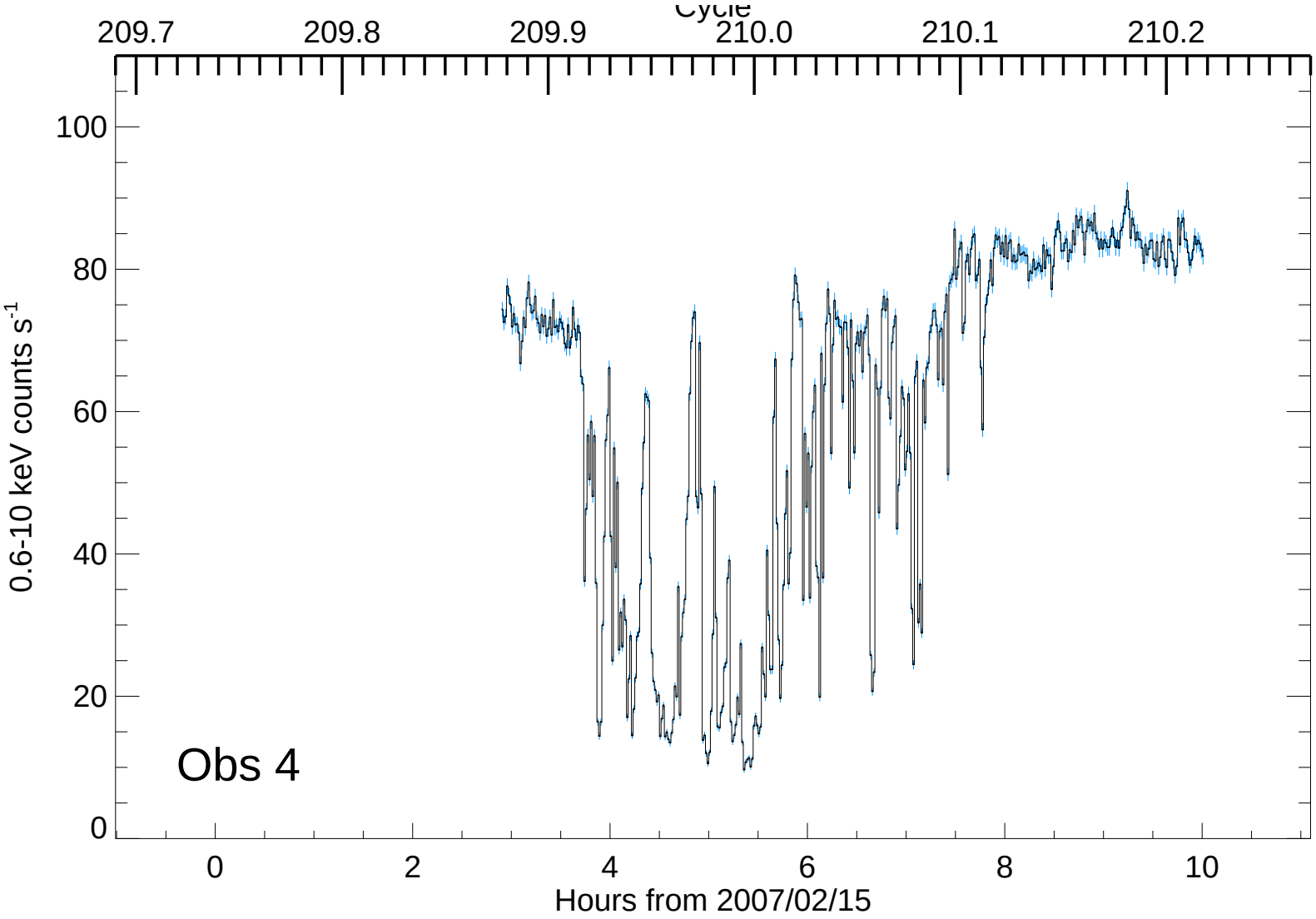
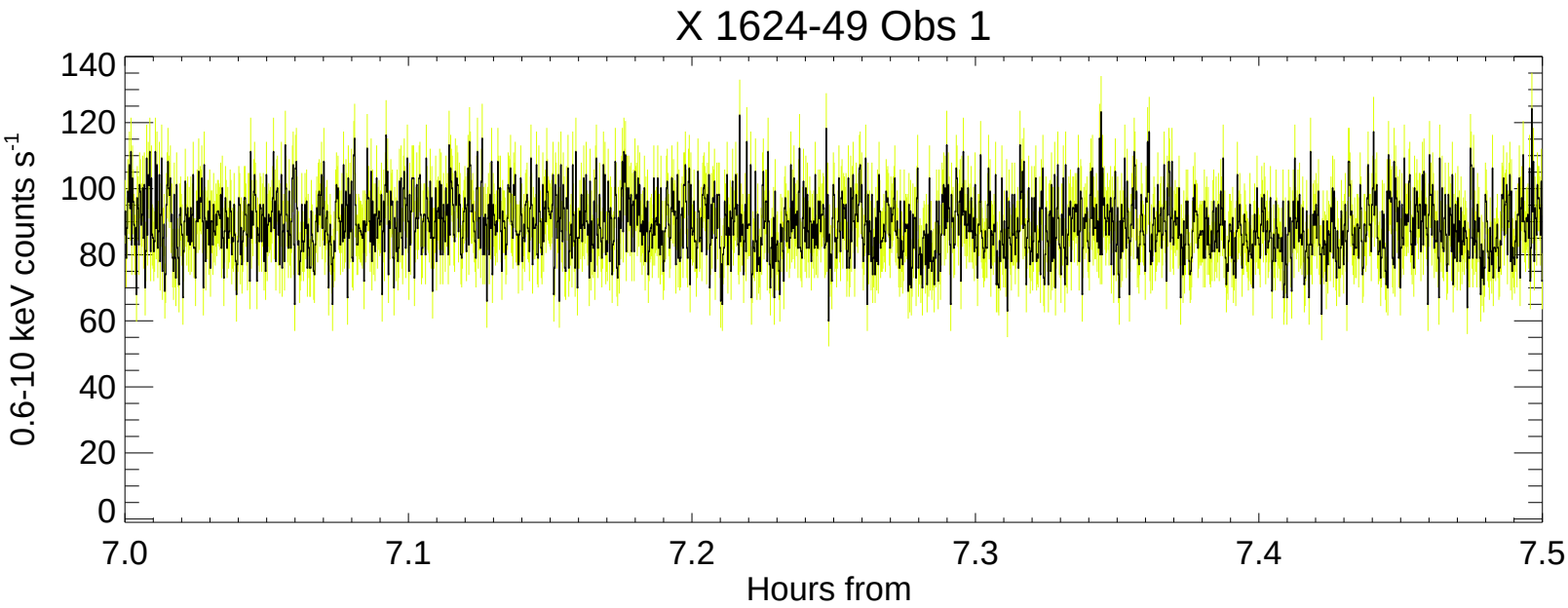
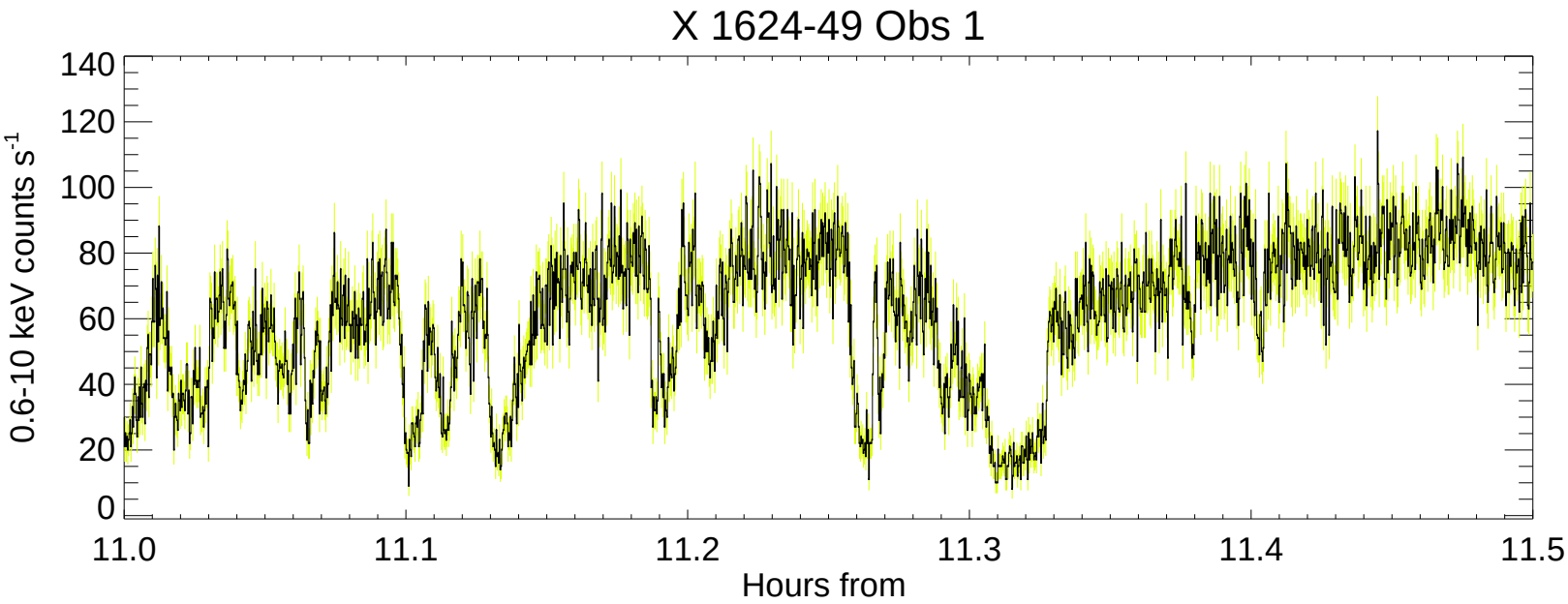


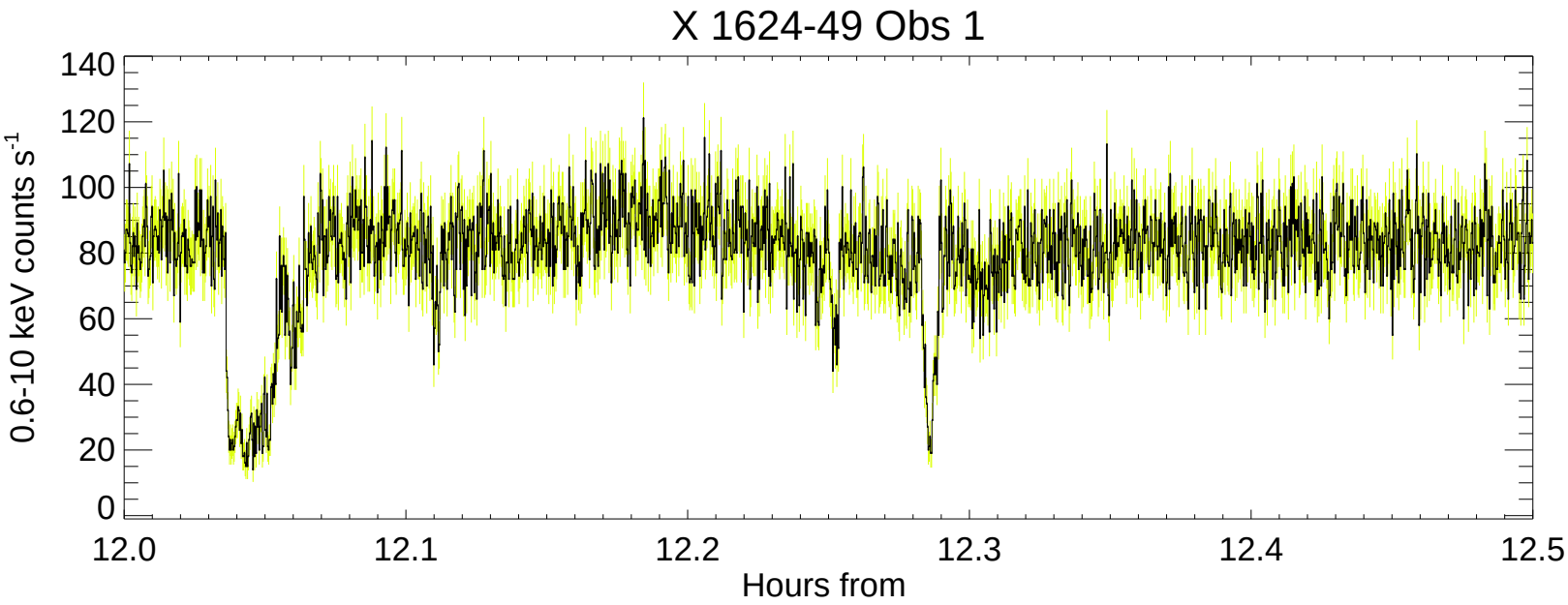
Light curve segments with a binning of 1 second



Light curve segments with a binning of 1 second



Light curve segments with a binning of 1 second



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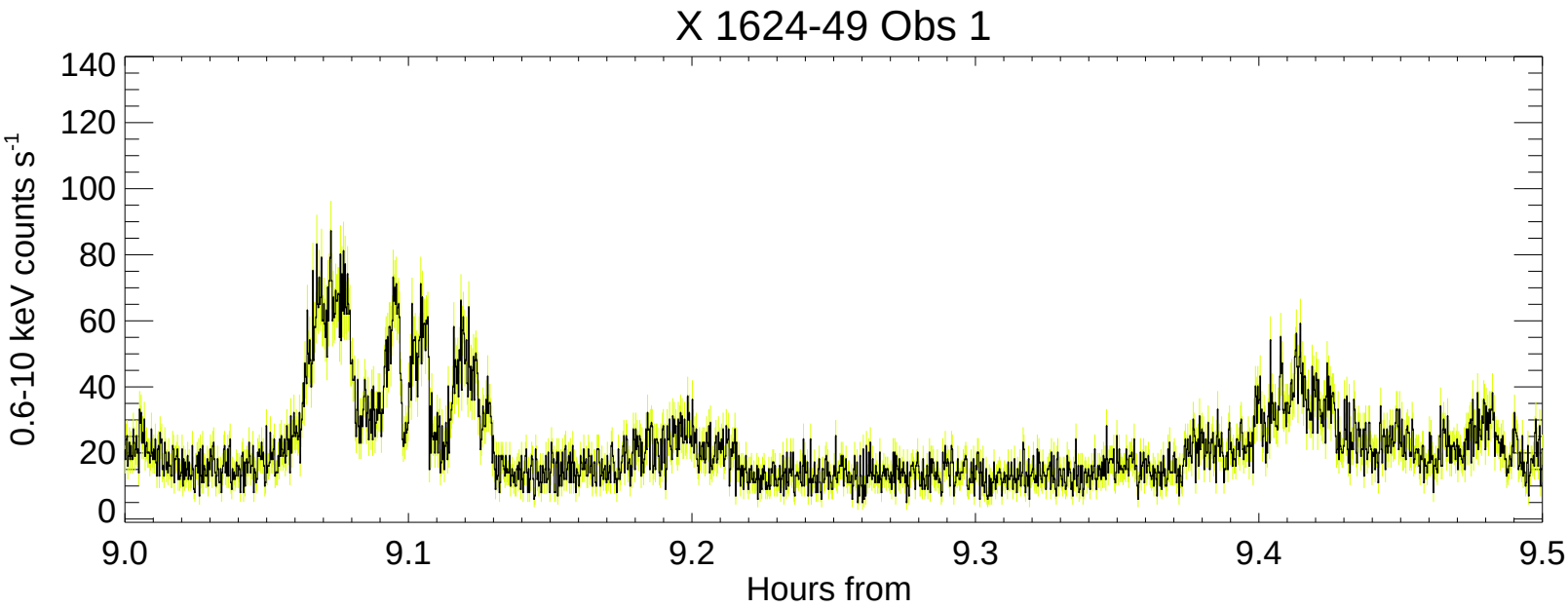
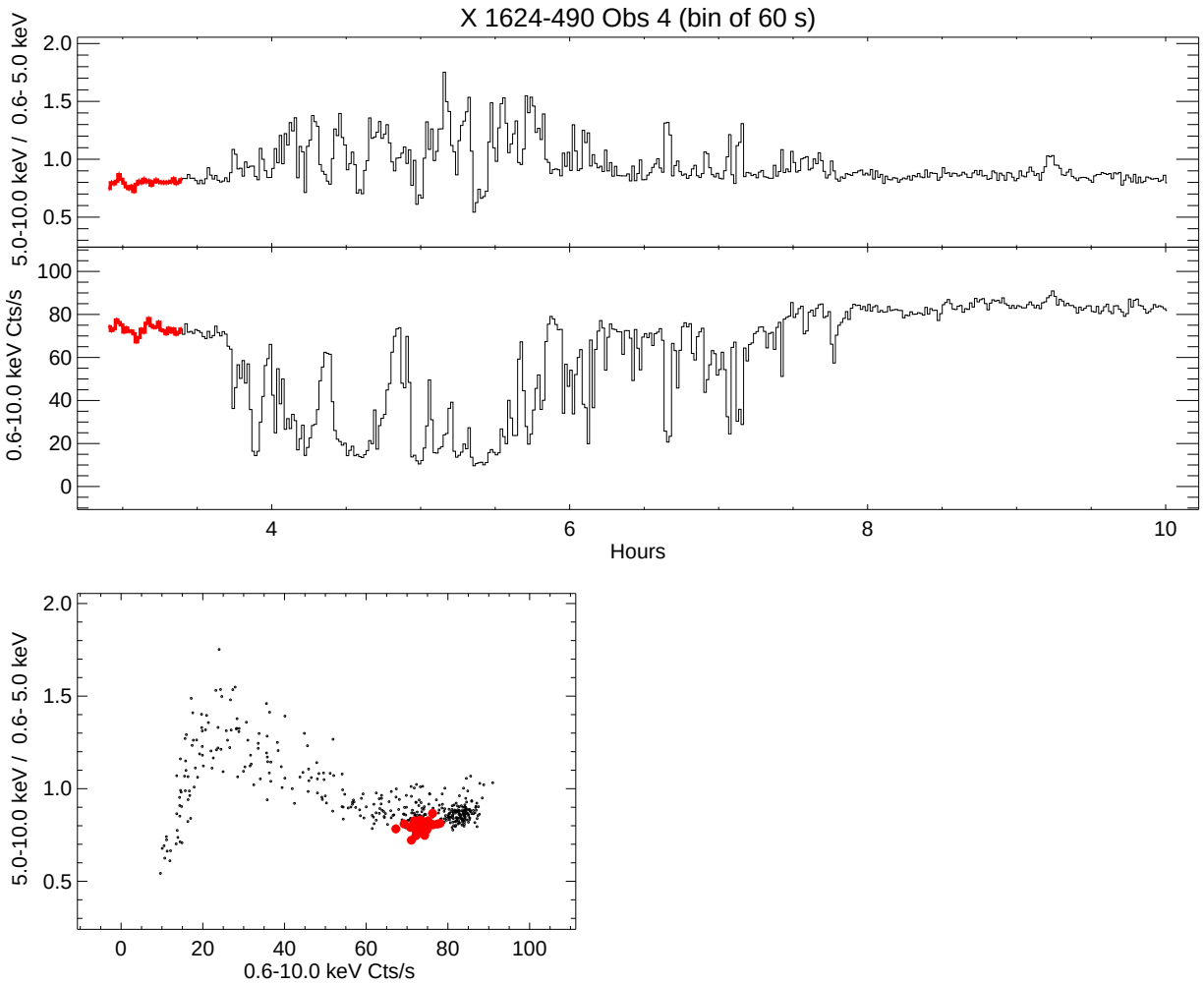


Intensity and color evolution



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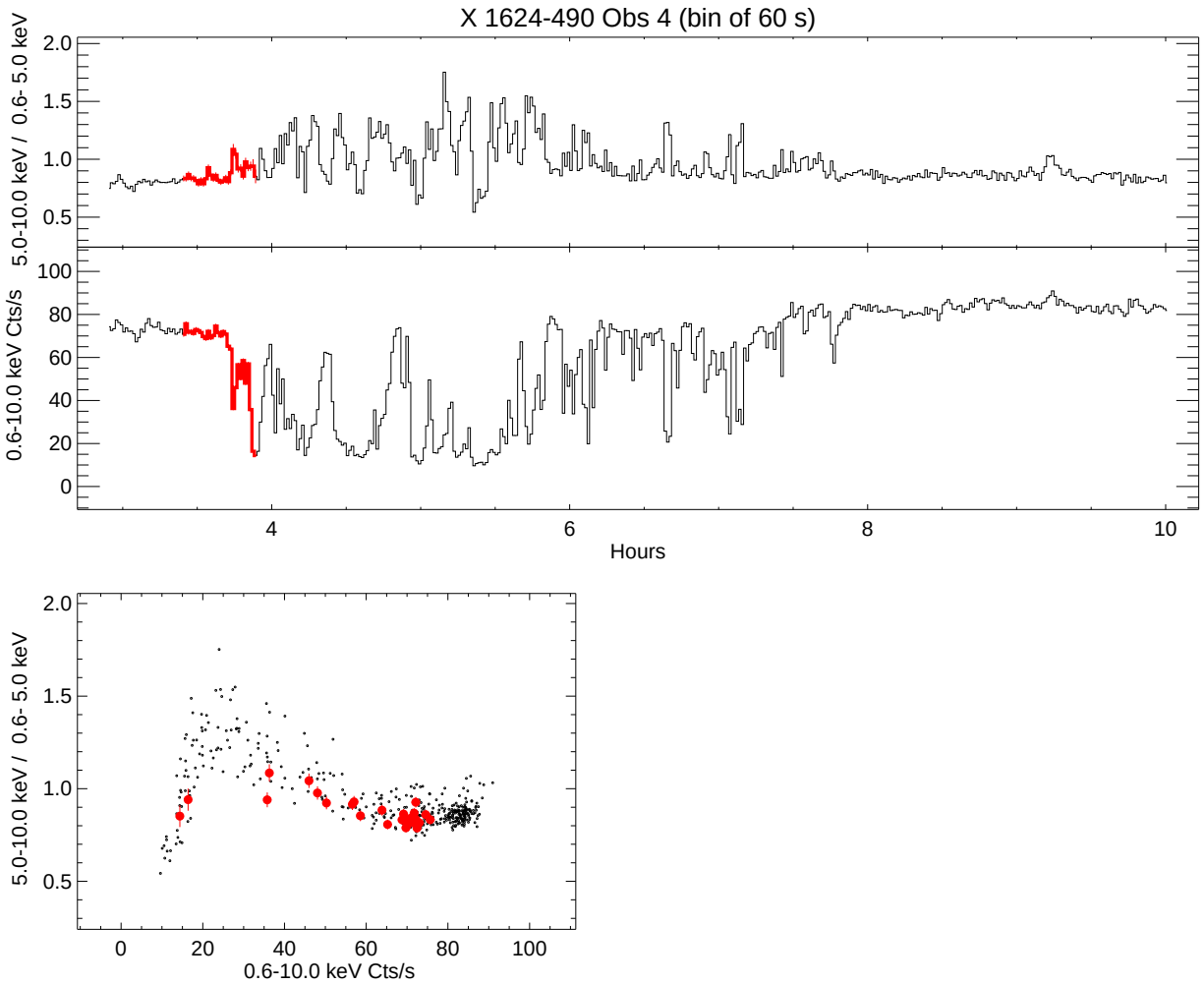
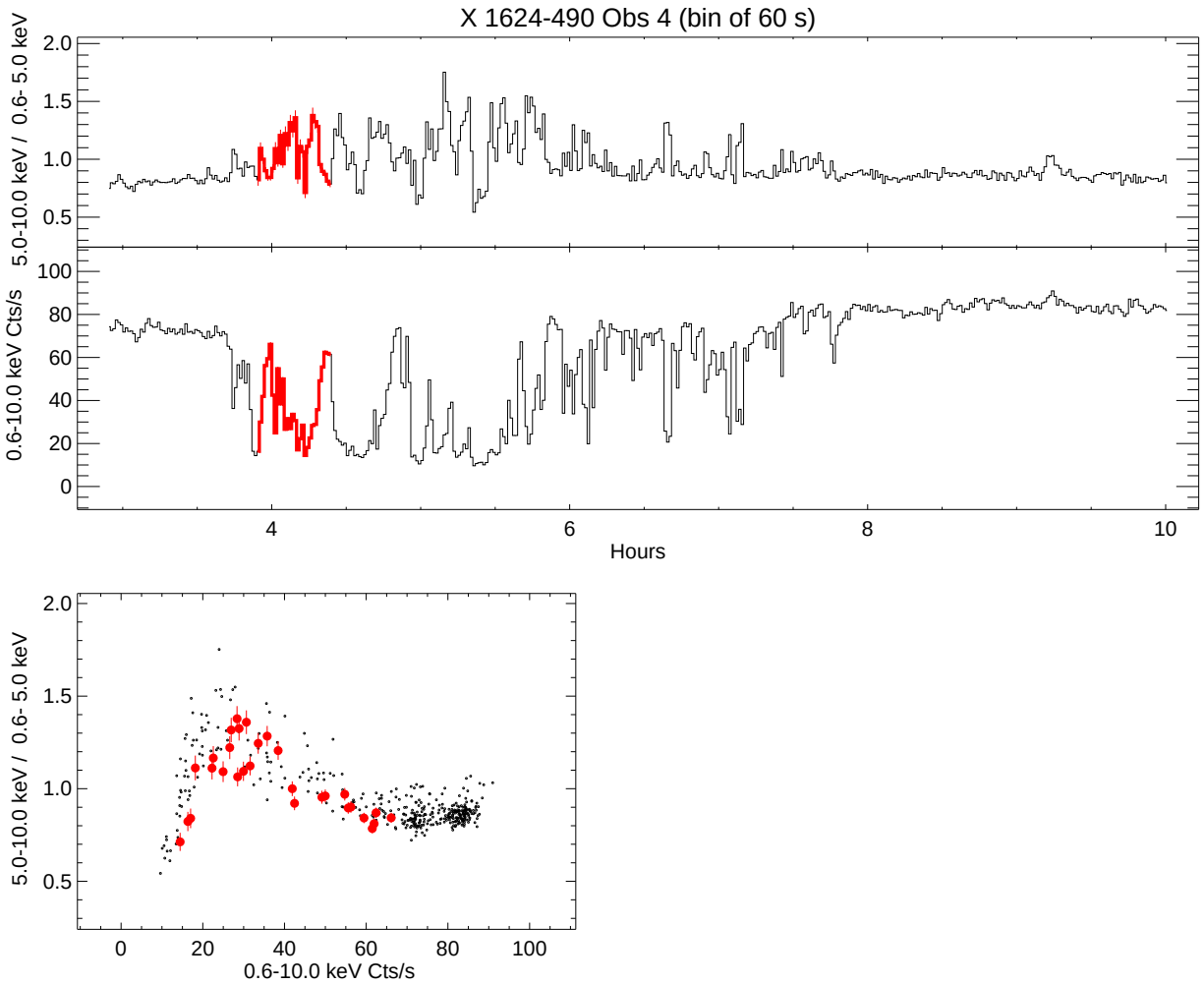
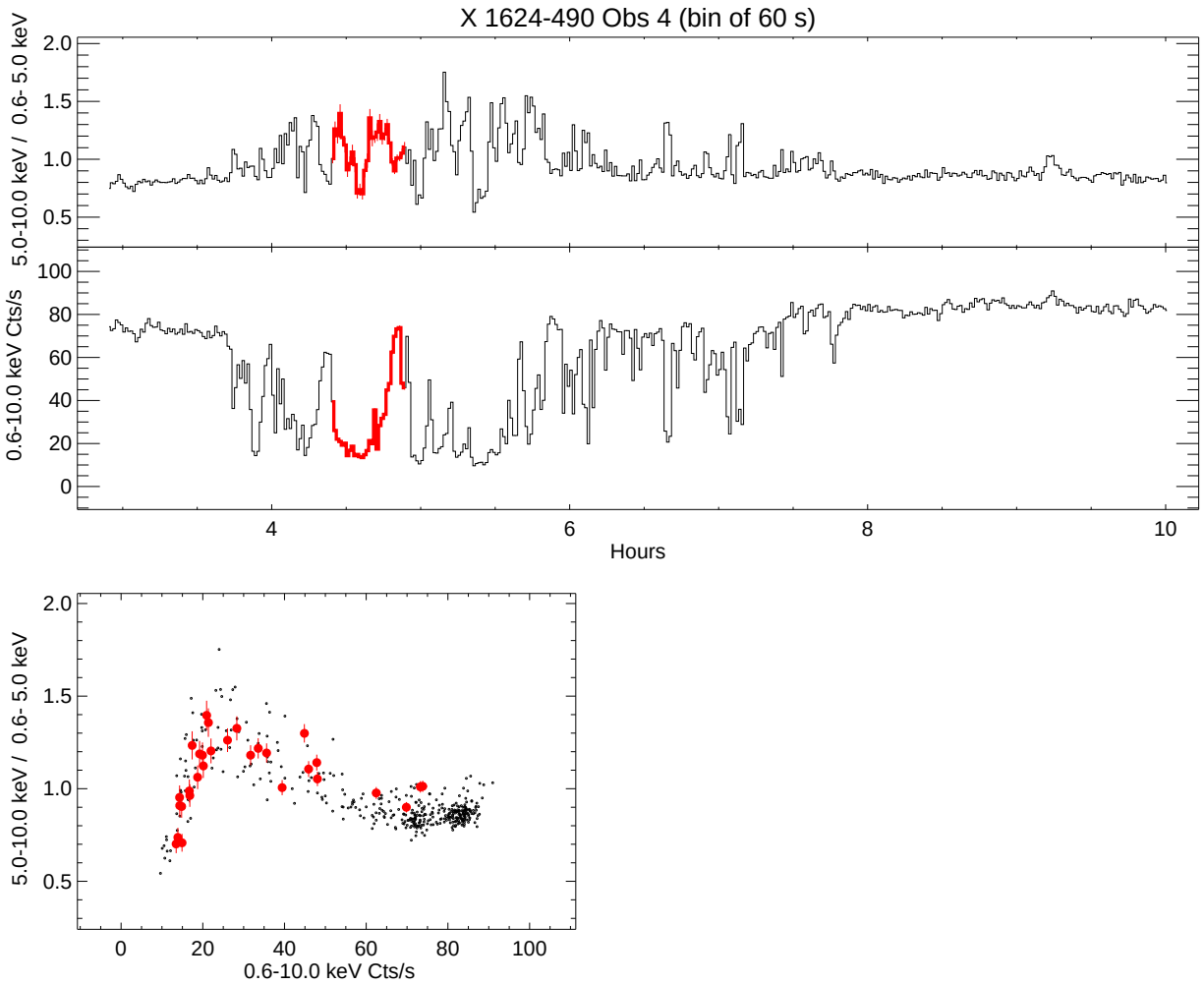


Intensity and color evolution



Intensity and color evolution



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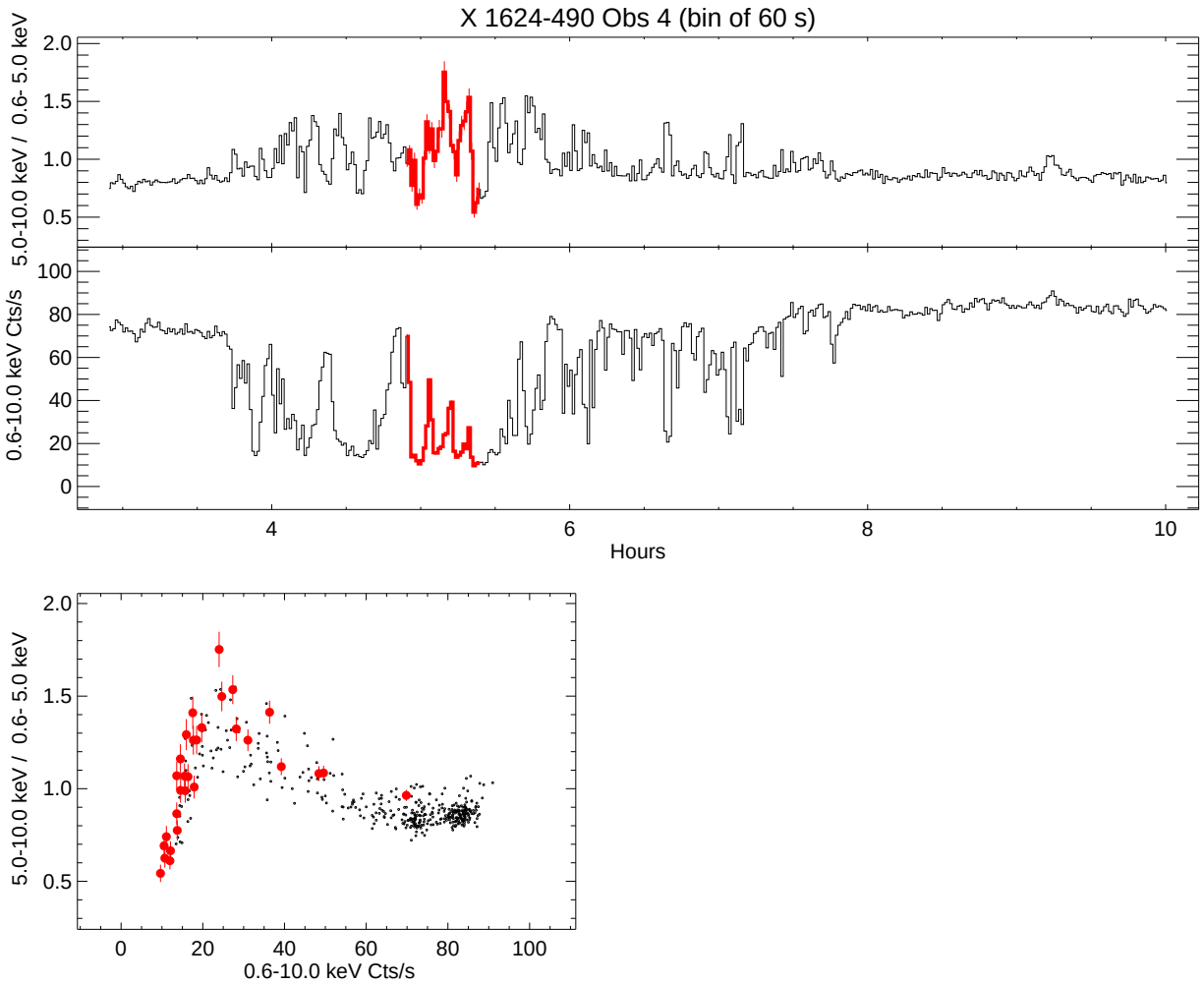
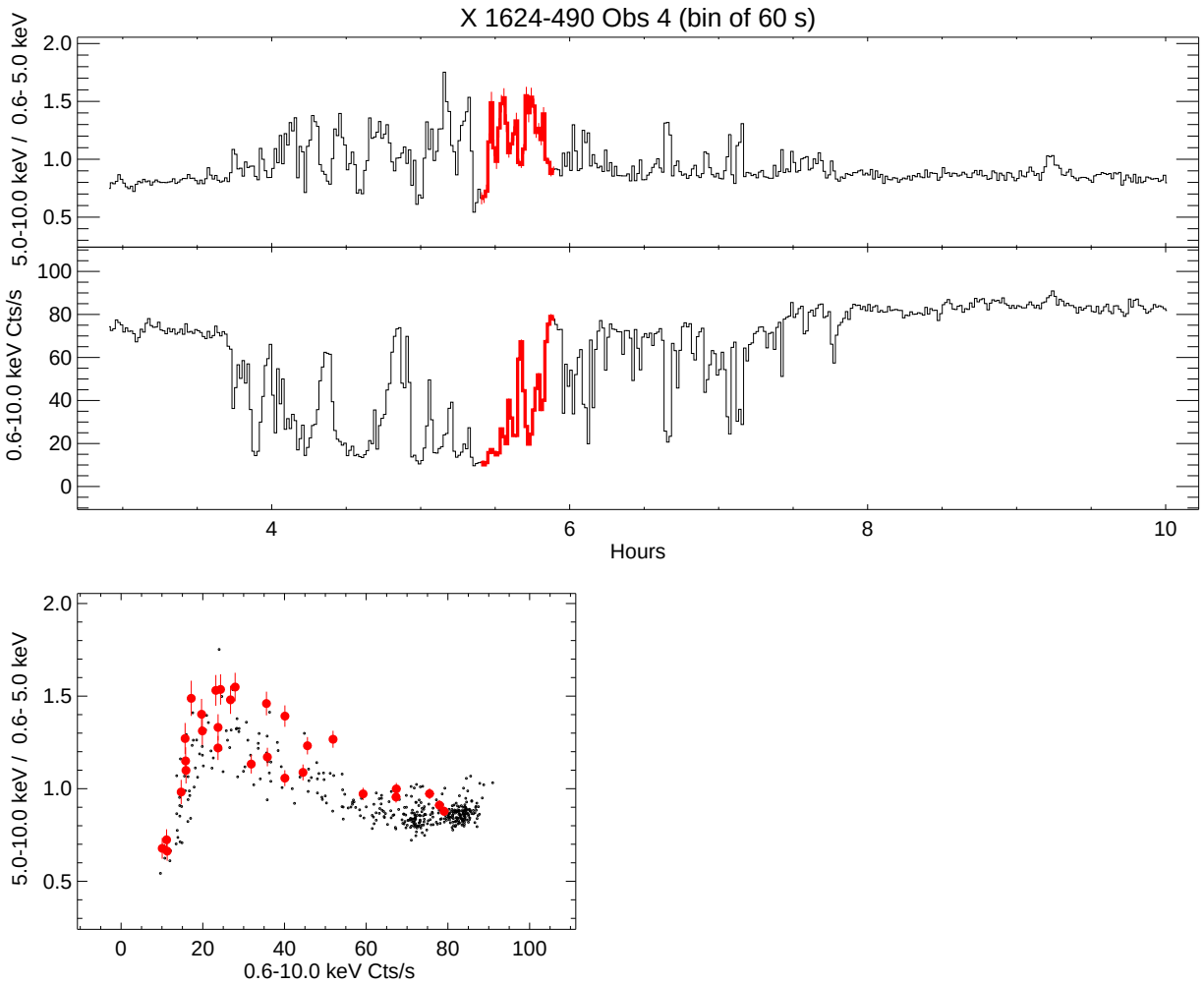
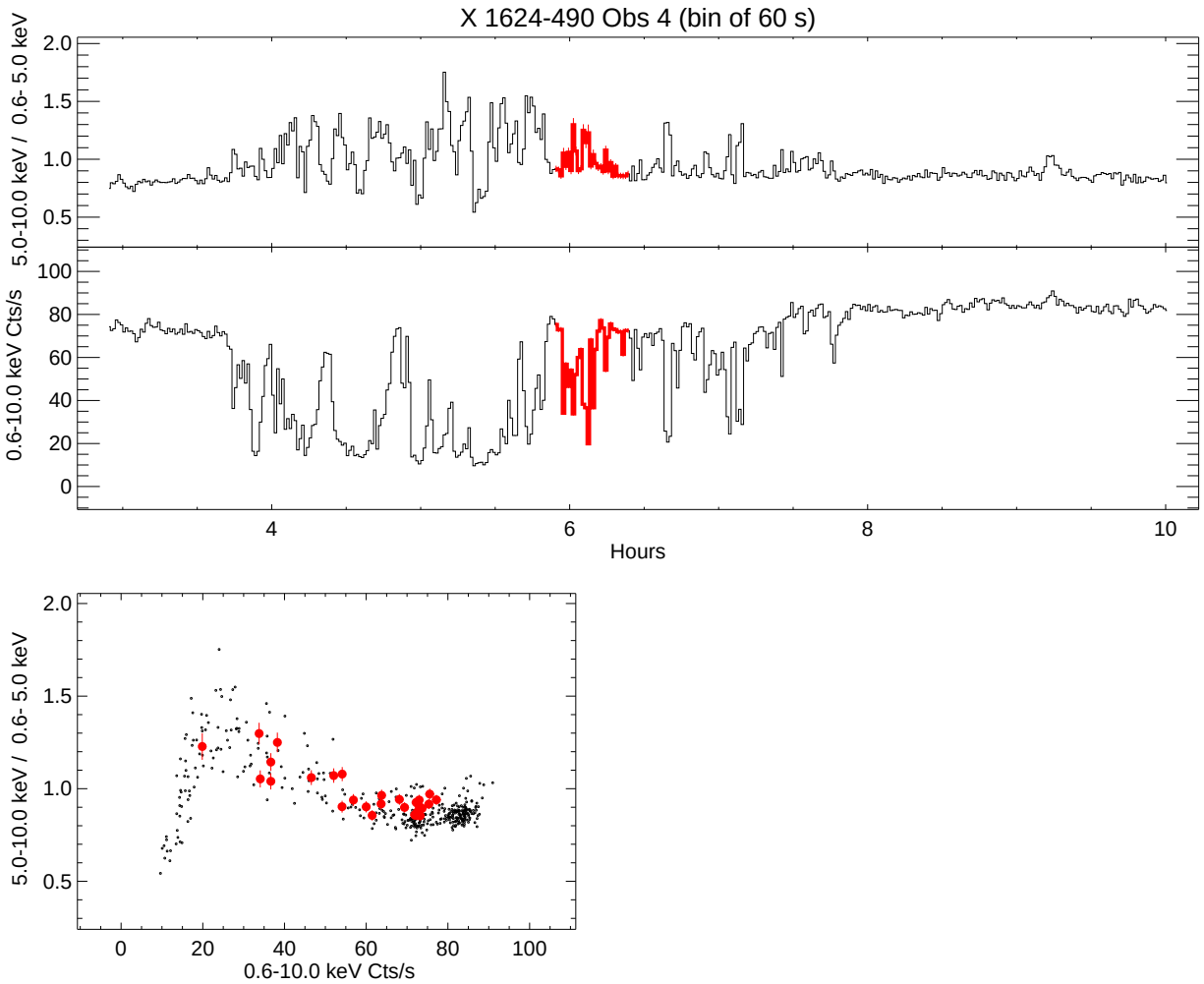


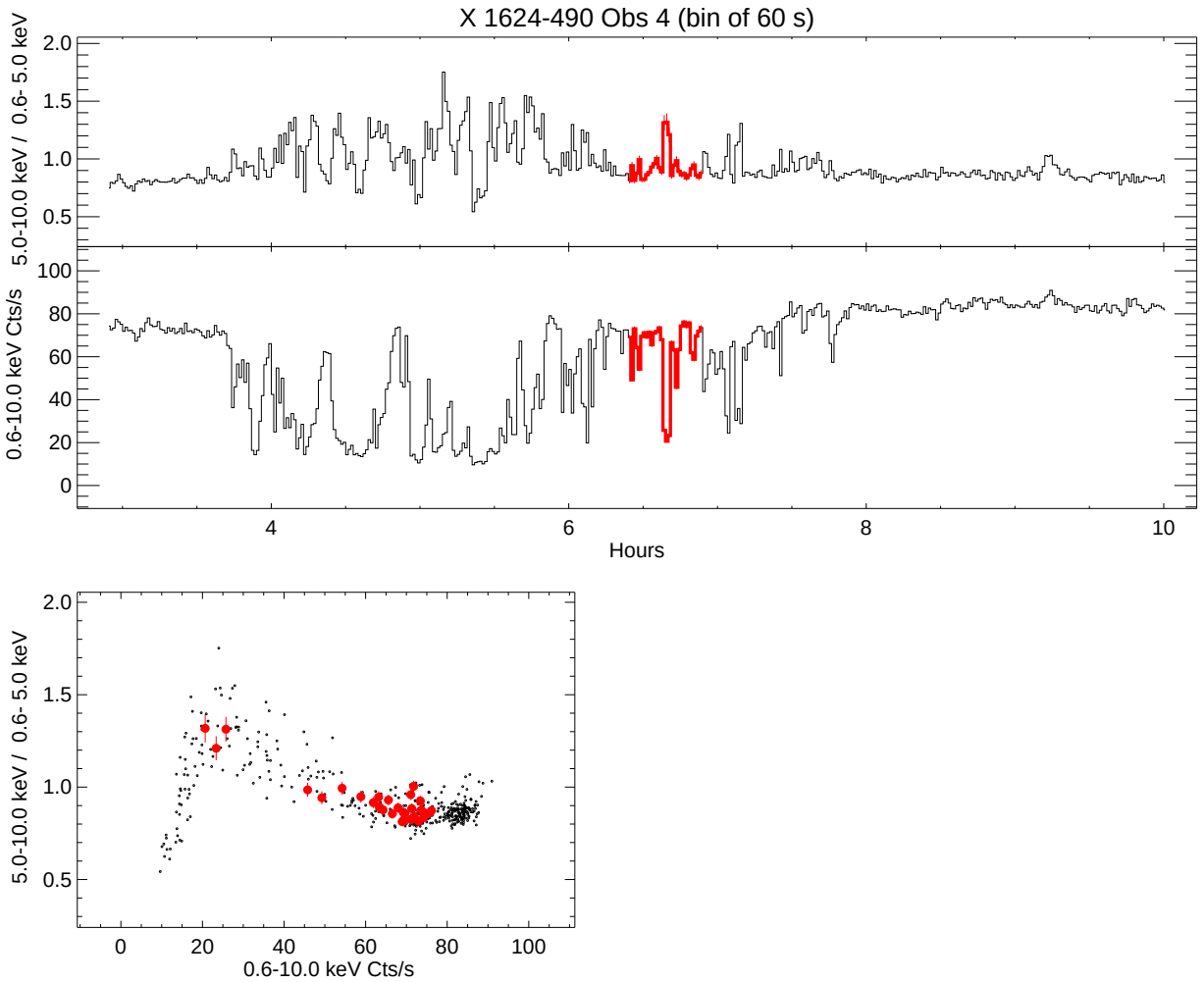
Intensity and color evolution



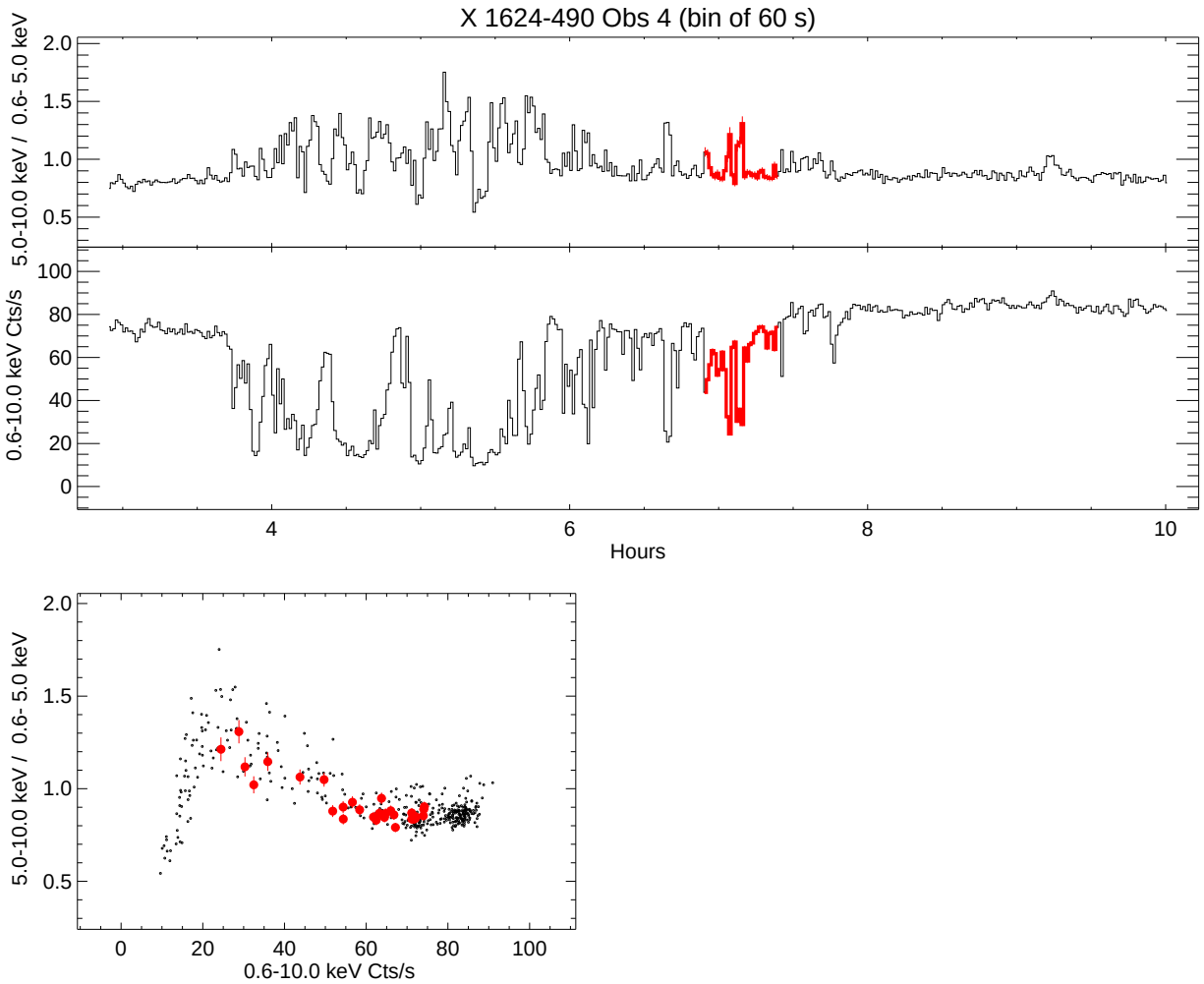
Intensity and color evolution



Intensity and color evolution



Intensity and color evolution



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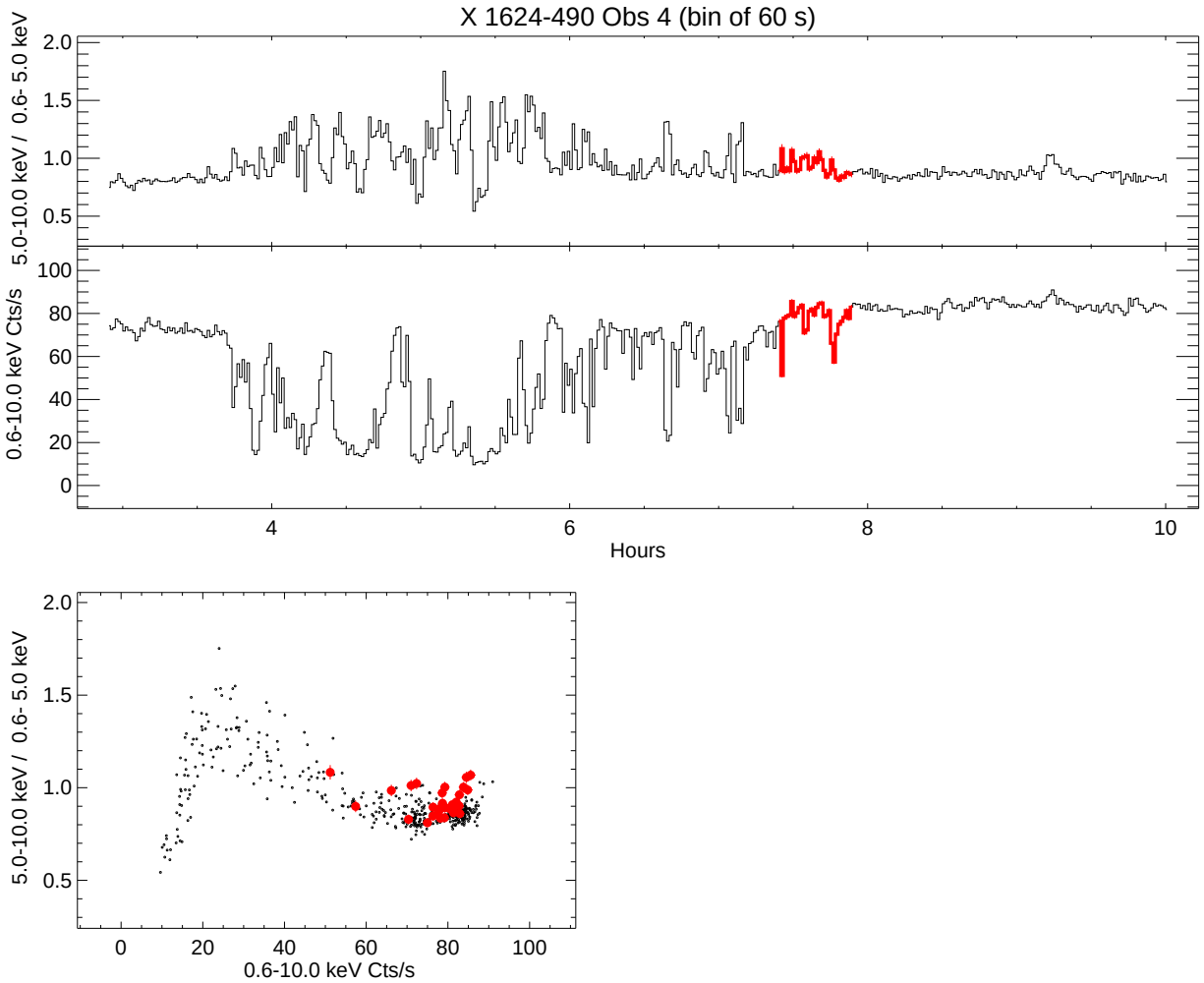

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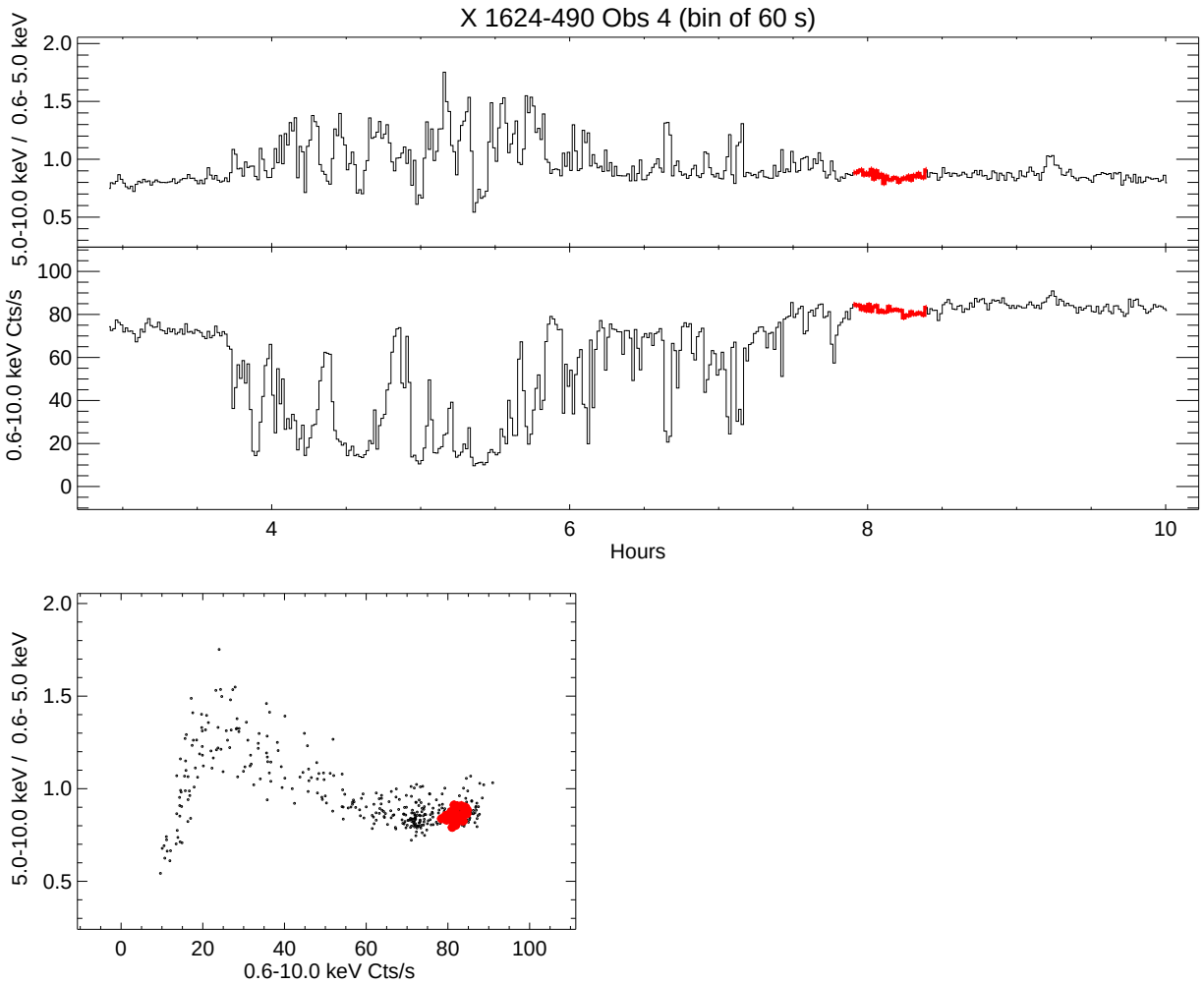

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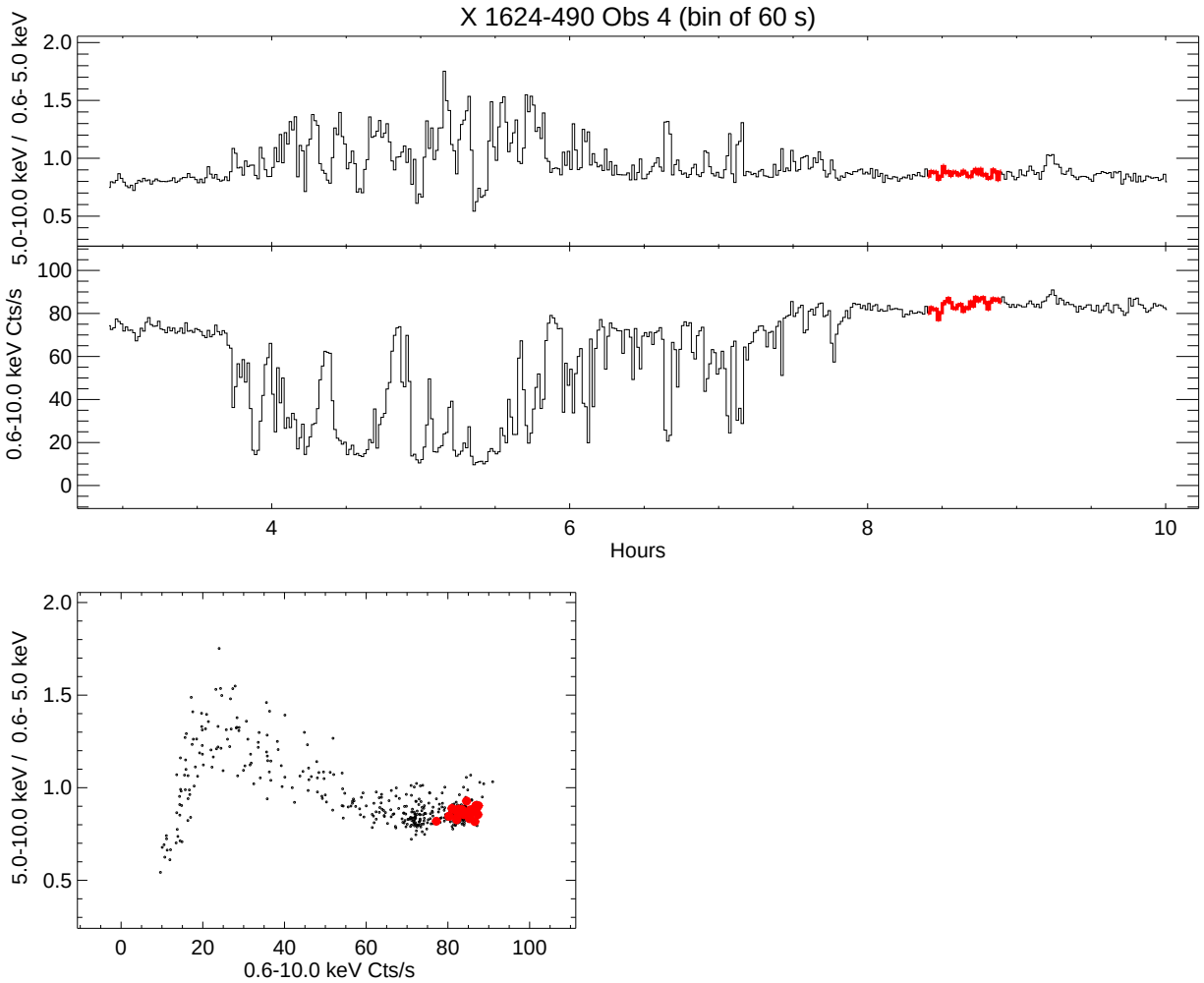

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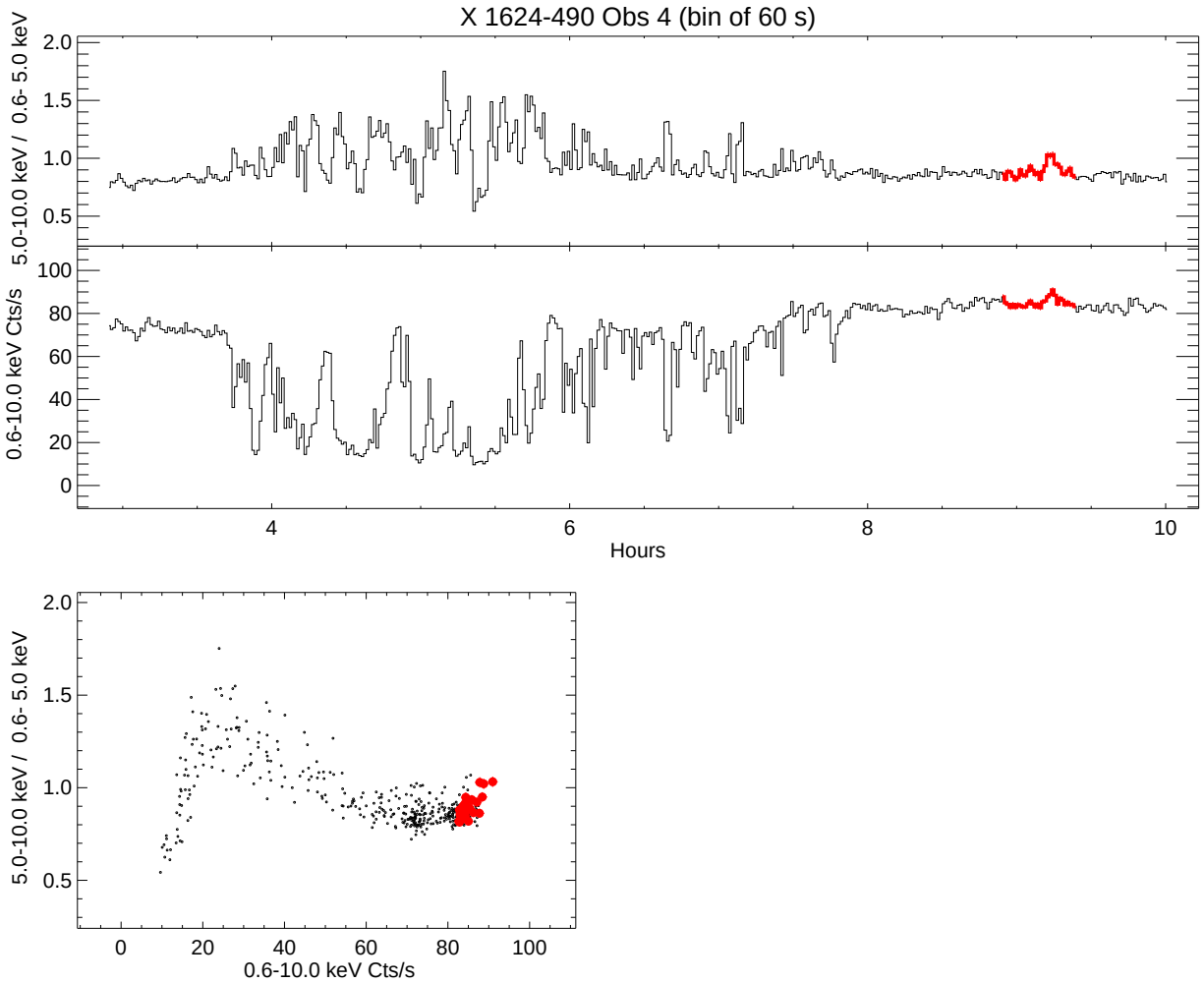

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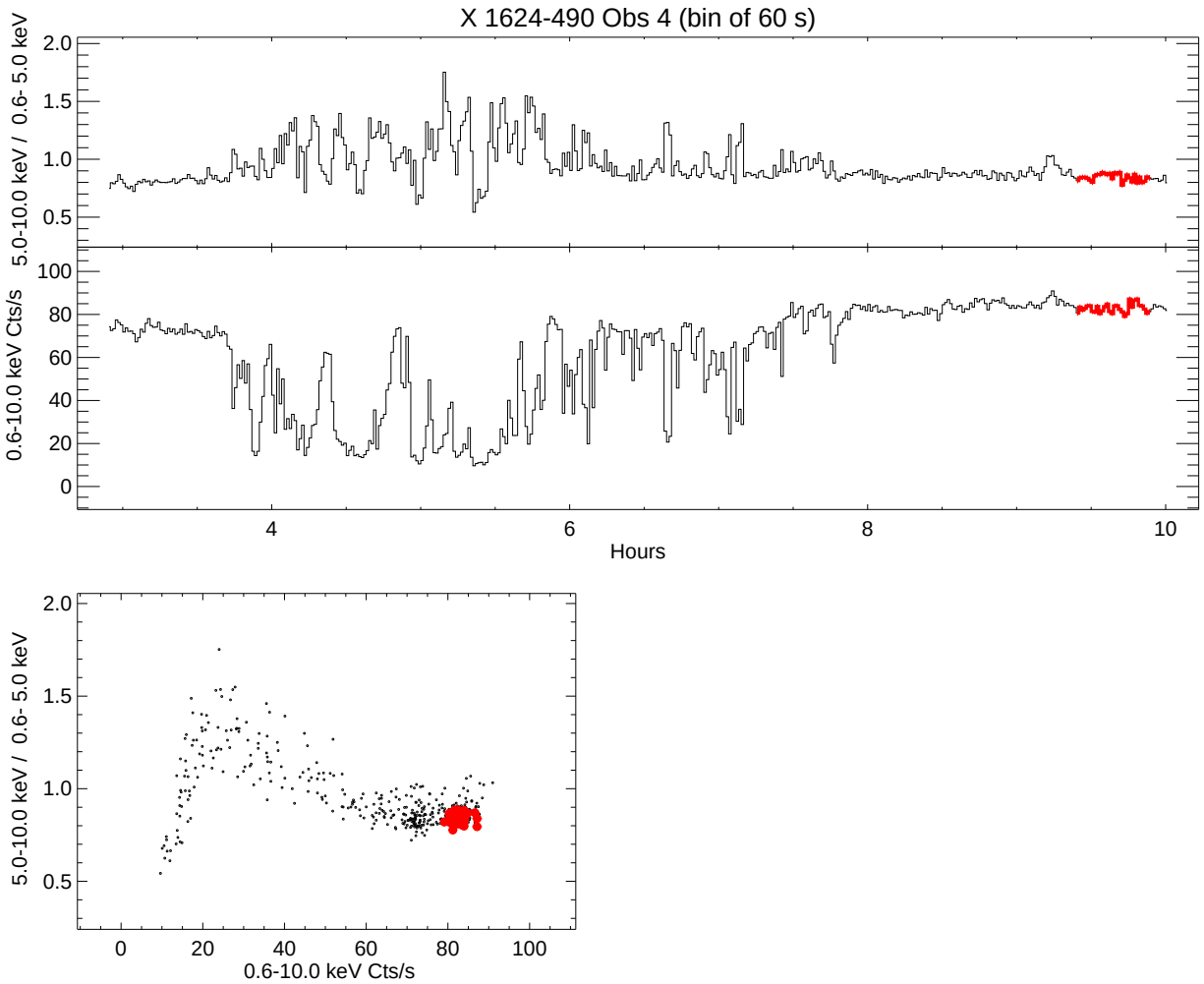
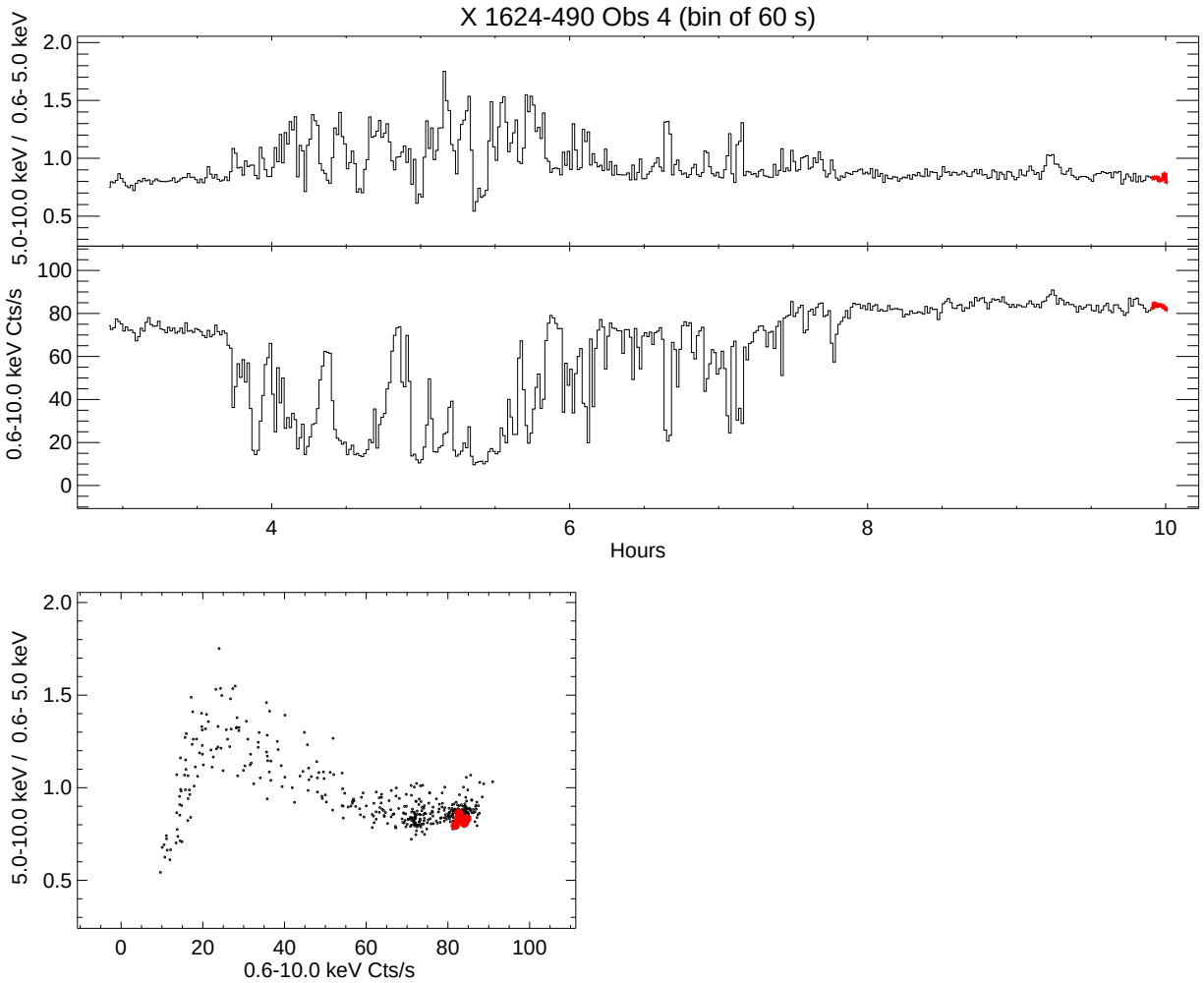
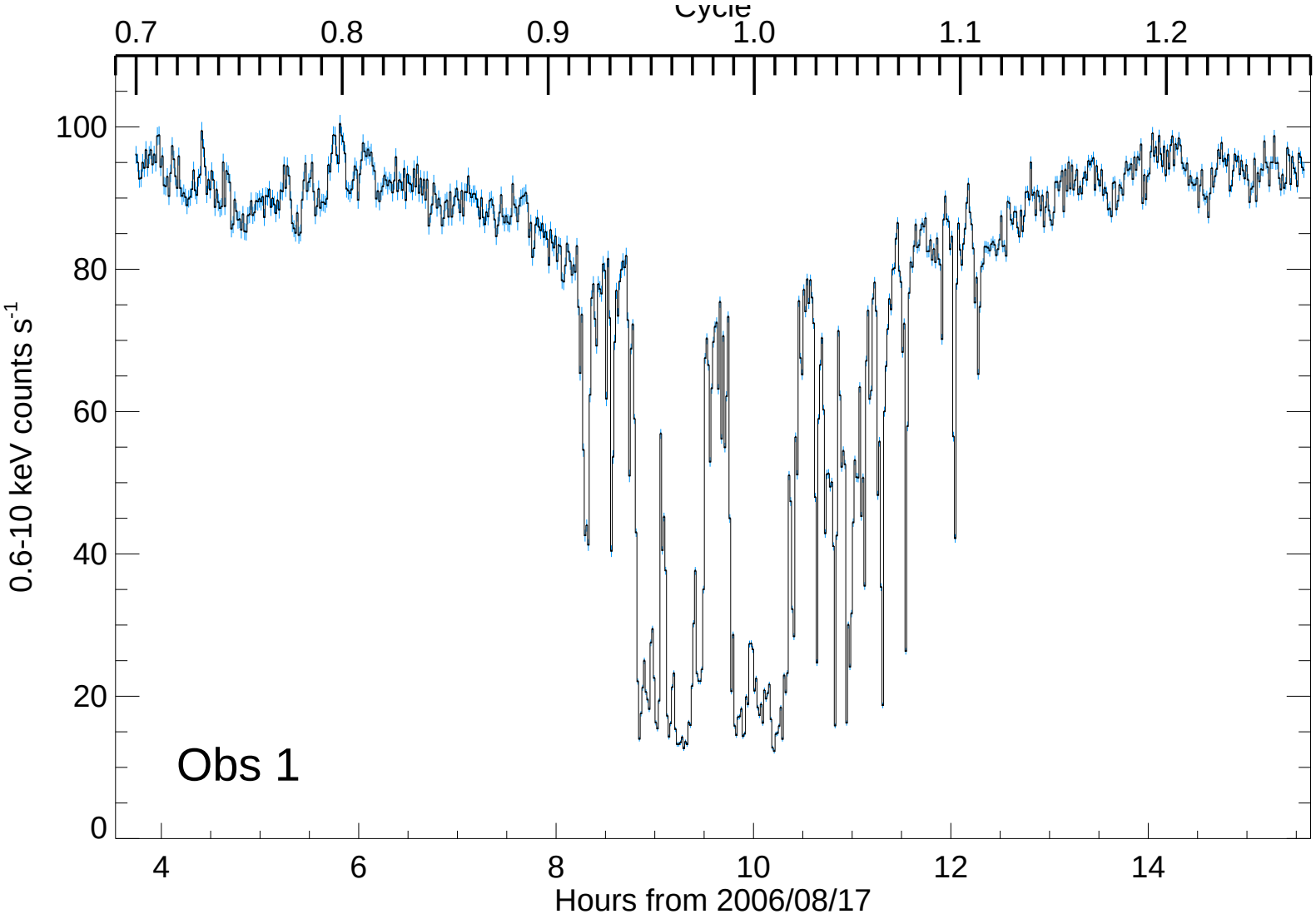


Intensity and color evolution



Selection criteria to extract the spectra



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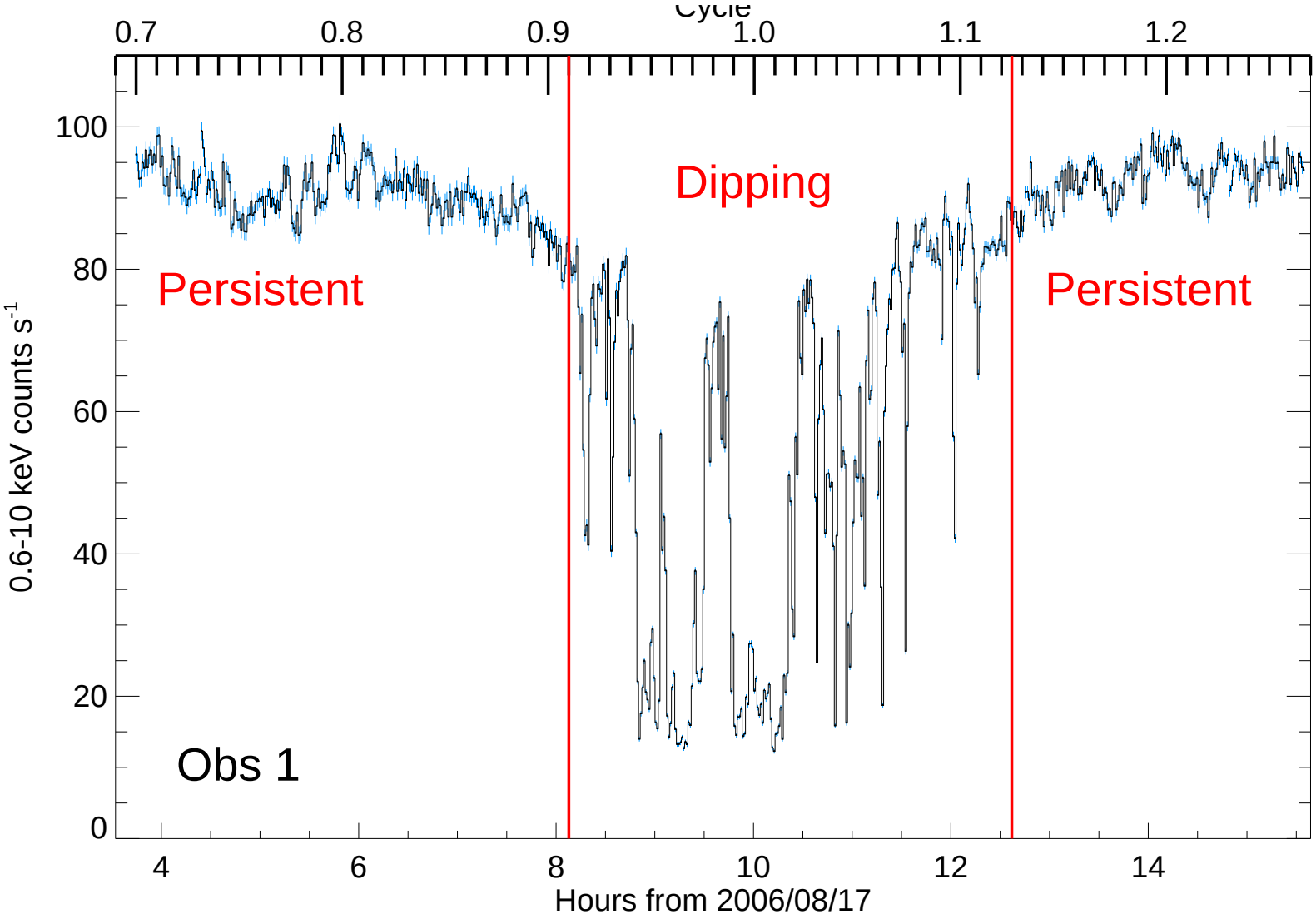

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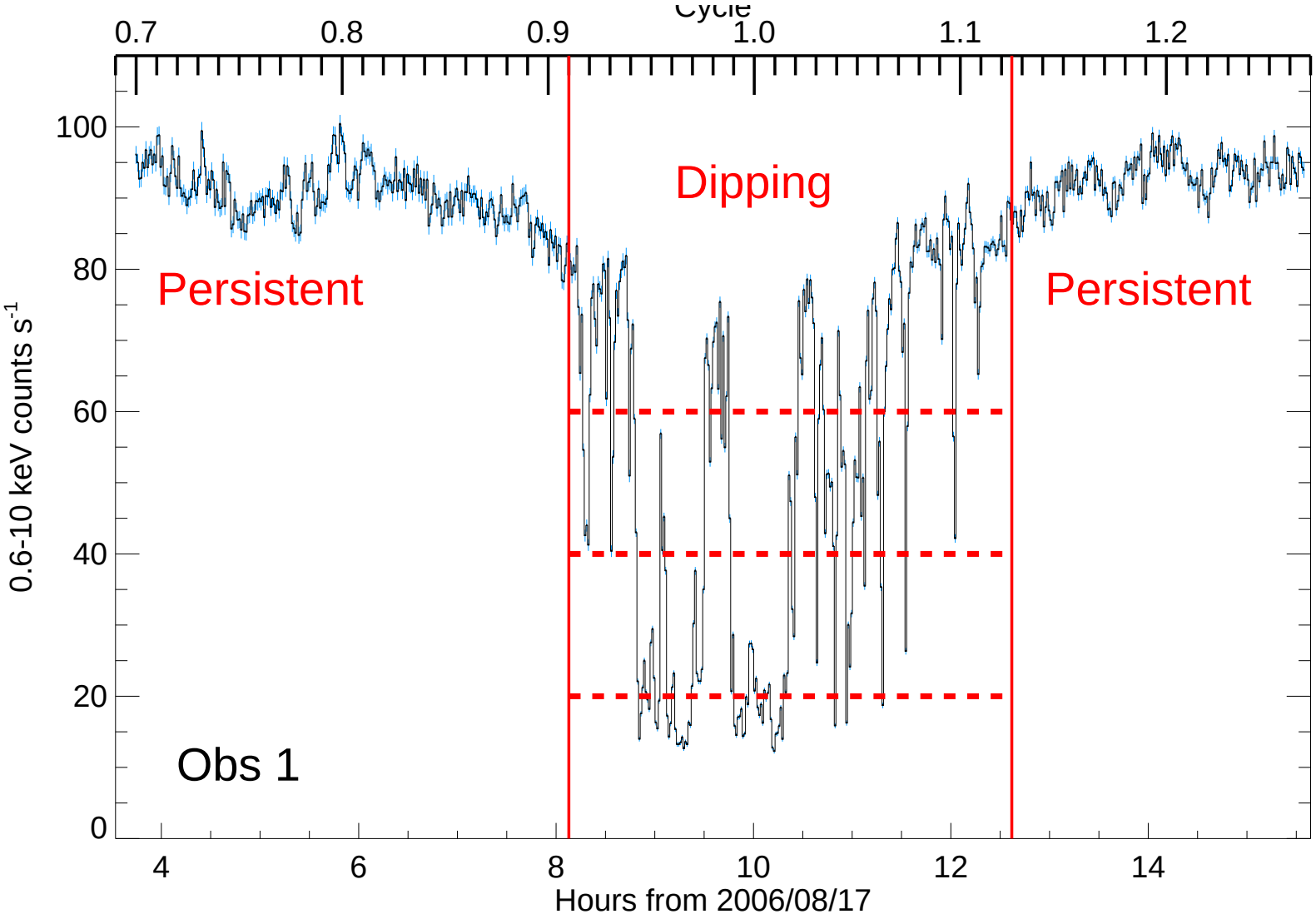
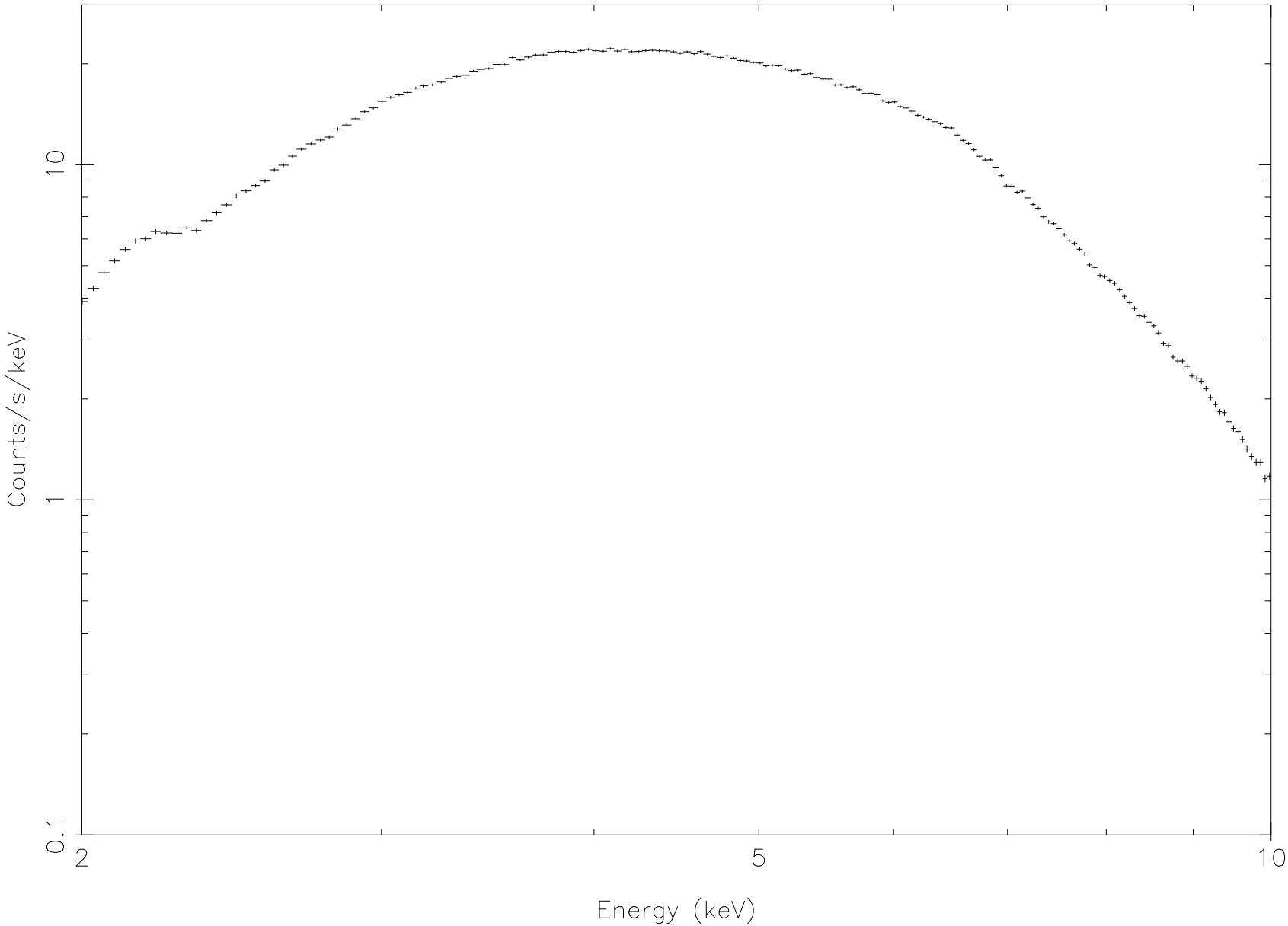
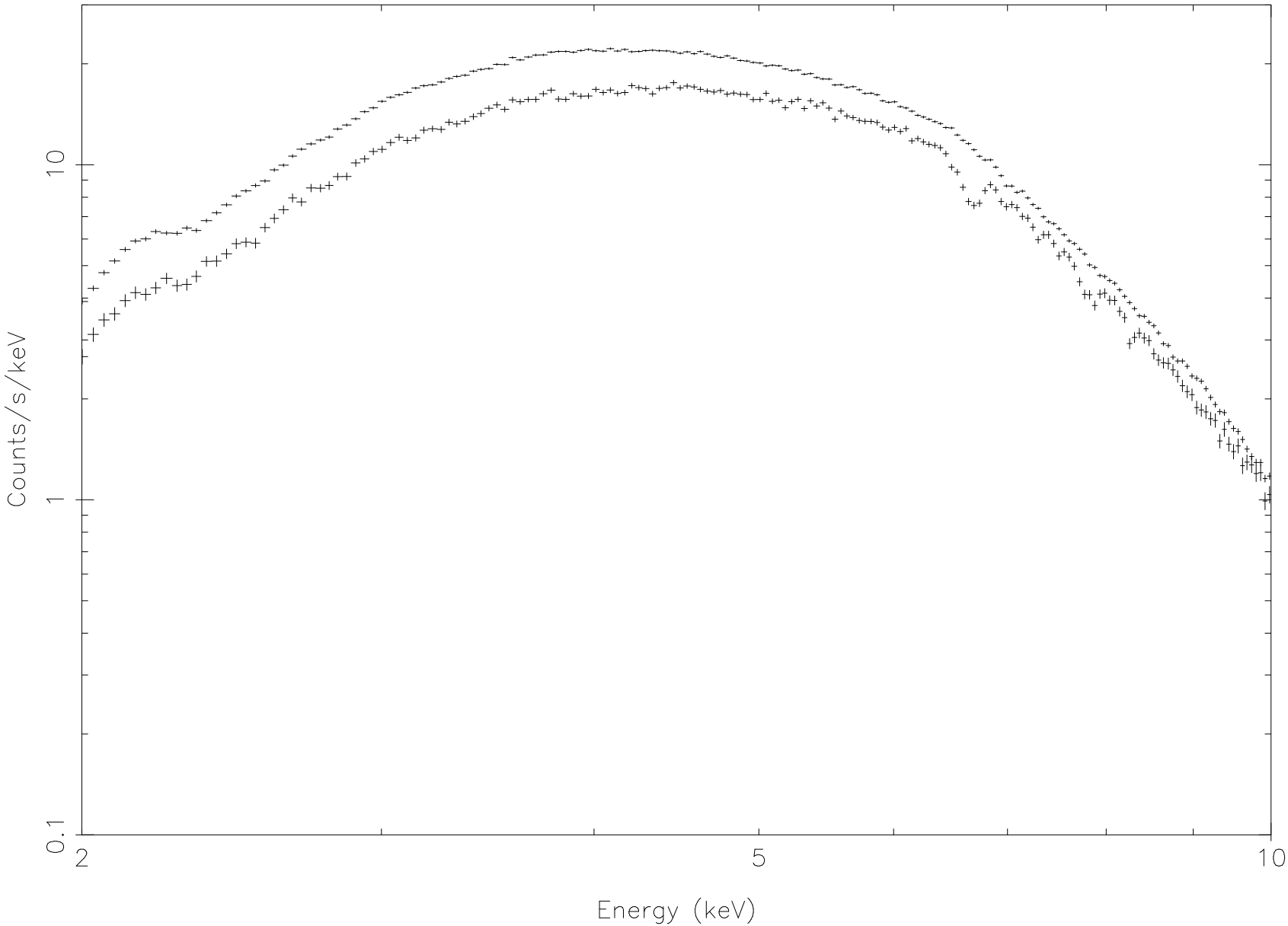


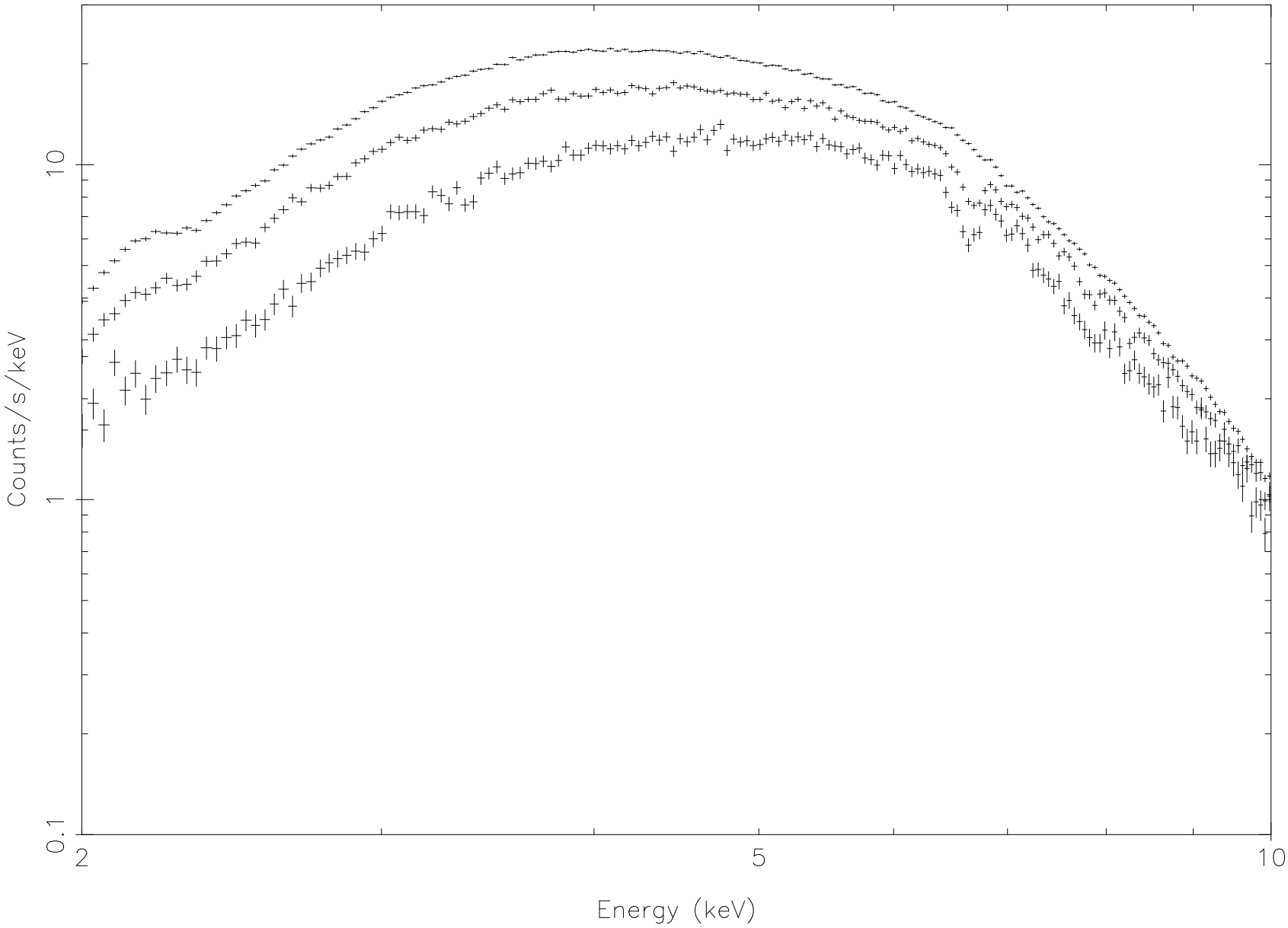
EPIC PN spectra



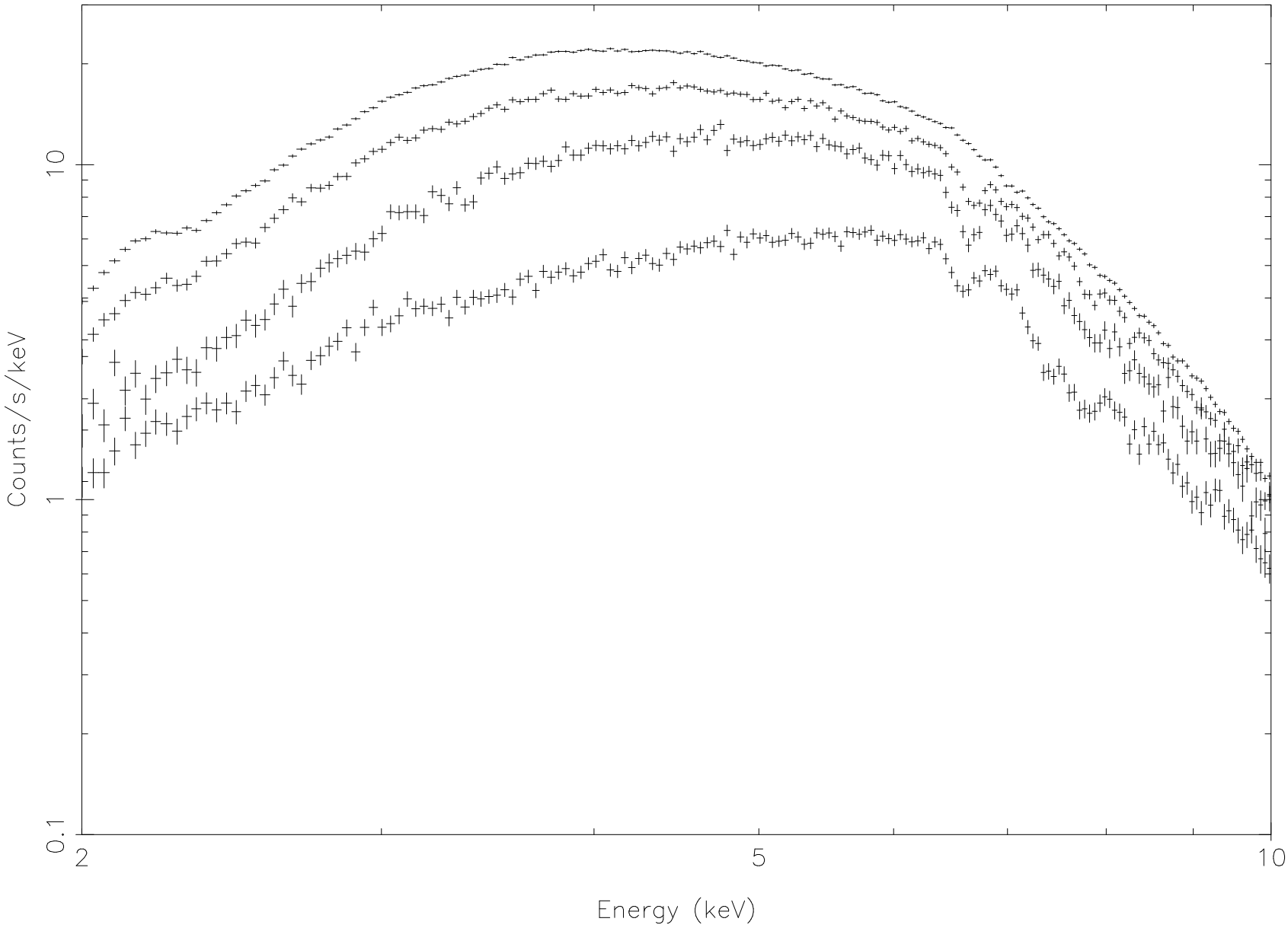
EPIC PN spectra



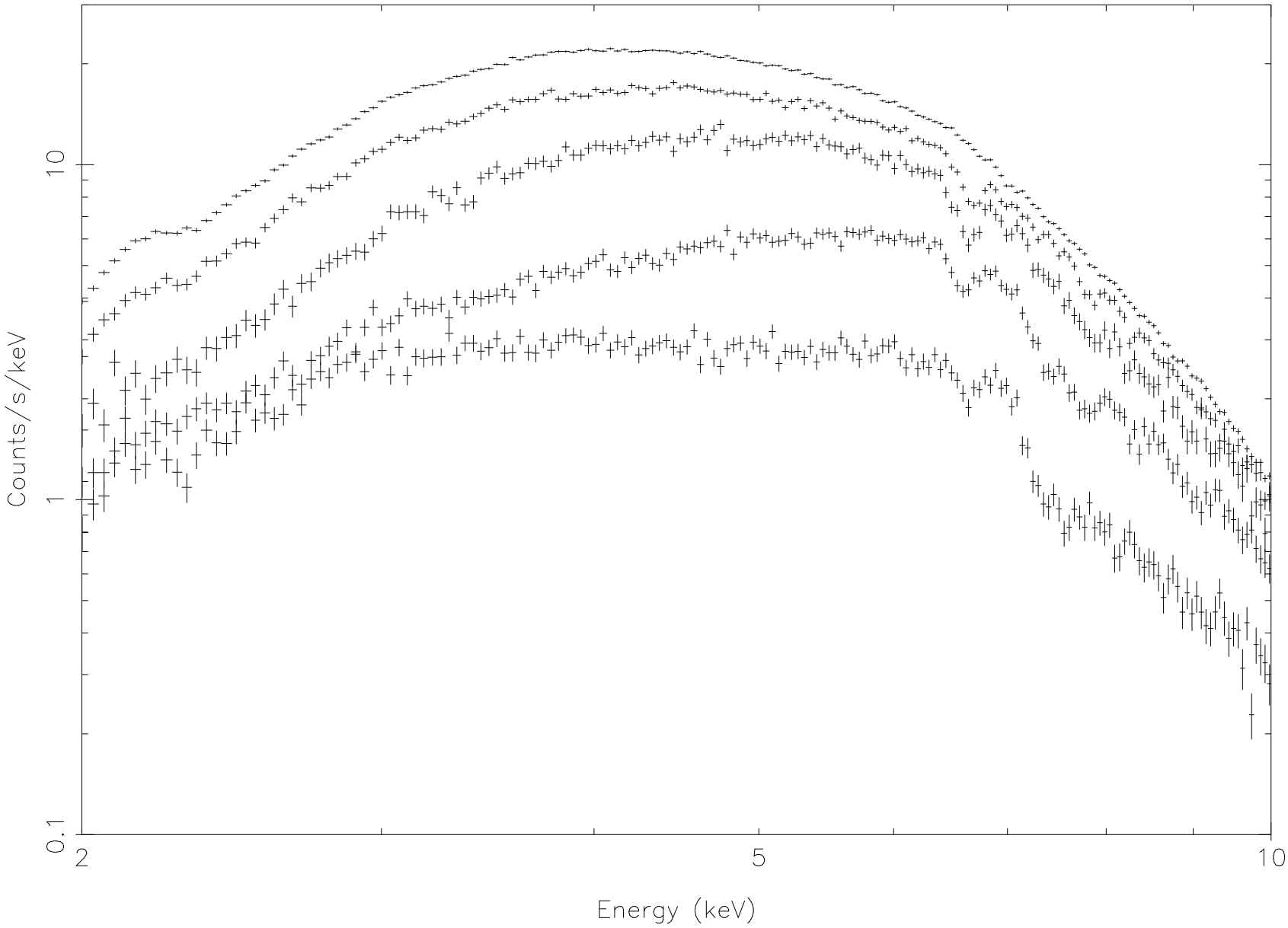
EPIC PN spectra



EPIC PN spectra



EPIC PN spectra



Model

within the SPEX fitting package by Kaastra et al.

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$(\mathrm{pl} + \mathrm{bb} + \mathrm{gau}_{em})$

- The underlying X-ray emission, common to all spectra

Model

within the SPEX fitting package by Kaastra et al.

Xabs (pl + bb + gau$_{em}$)

- The underlying X-ray emission, common to all spectra
- The photo-ionized absorber (local to the system)
  - line and continuum absorption by all relevant ions
  - Compton scattering by the free electrons

Model

within the SPEX fitting package by Kaastra et al.

Abs Xabs (pl + bb + gau_{em})

- The underlying X-ray emission, common to all spectra
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- The neutral absorber (Galactic and local contributions)

Model

within the SPEX fitting package by Kaastra et al.

$e^{-\tau E^{-2}}$ Abs Xabs (pl + bb + gau_{em})

- The underlying X-ray emission, common to all spectra
- The photo-ionized absorber (local to the system)
  - line and continuum absorption by all relevant ions
  - Compton scattering by the free electrons
- The neutral absorber (Galactic and local contributions)
- Dust scattering off the line-of-sight

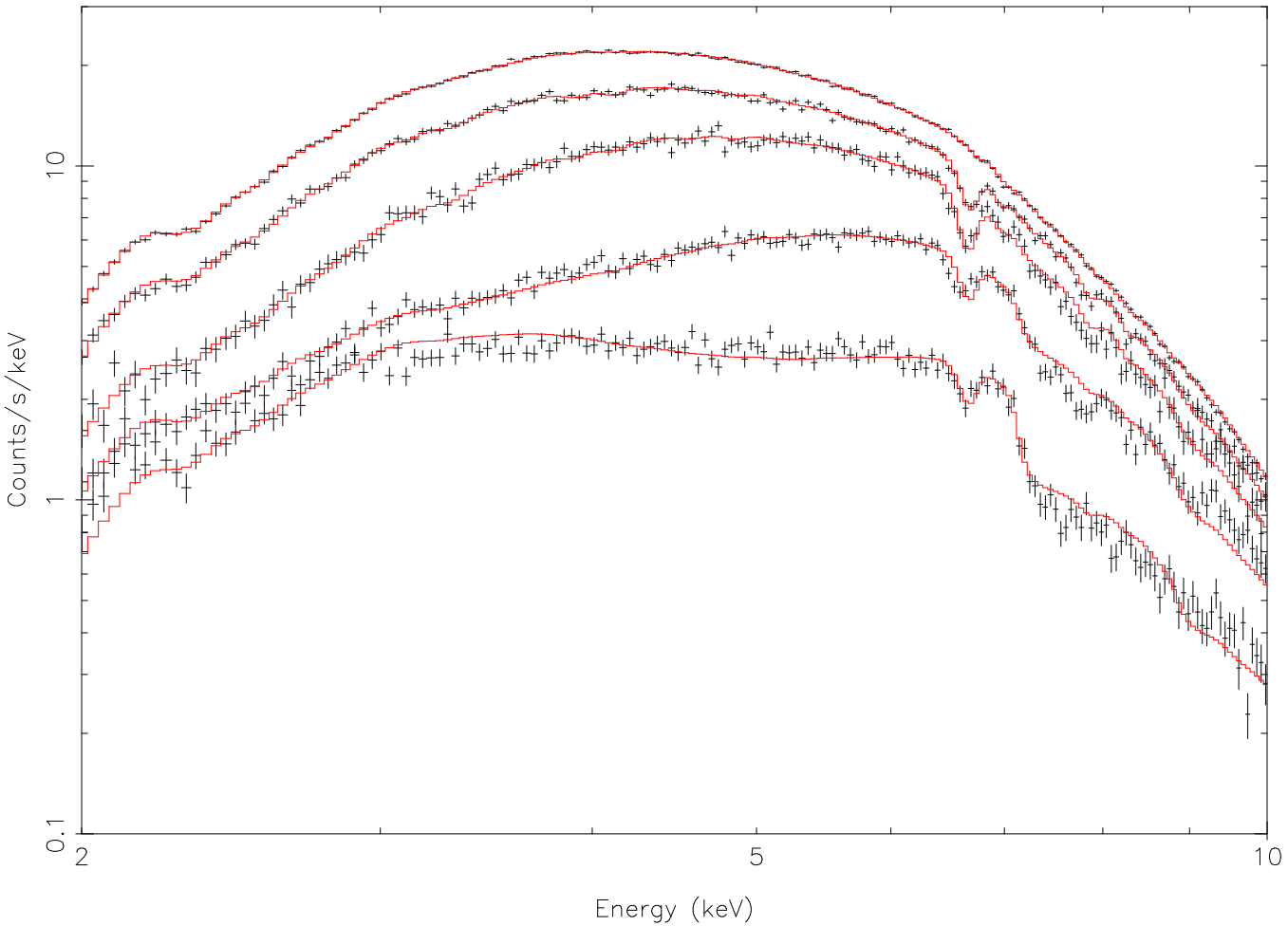
Model

within the SPEX fitting package by Kaastra et al.

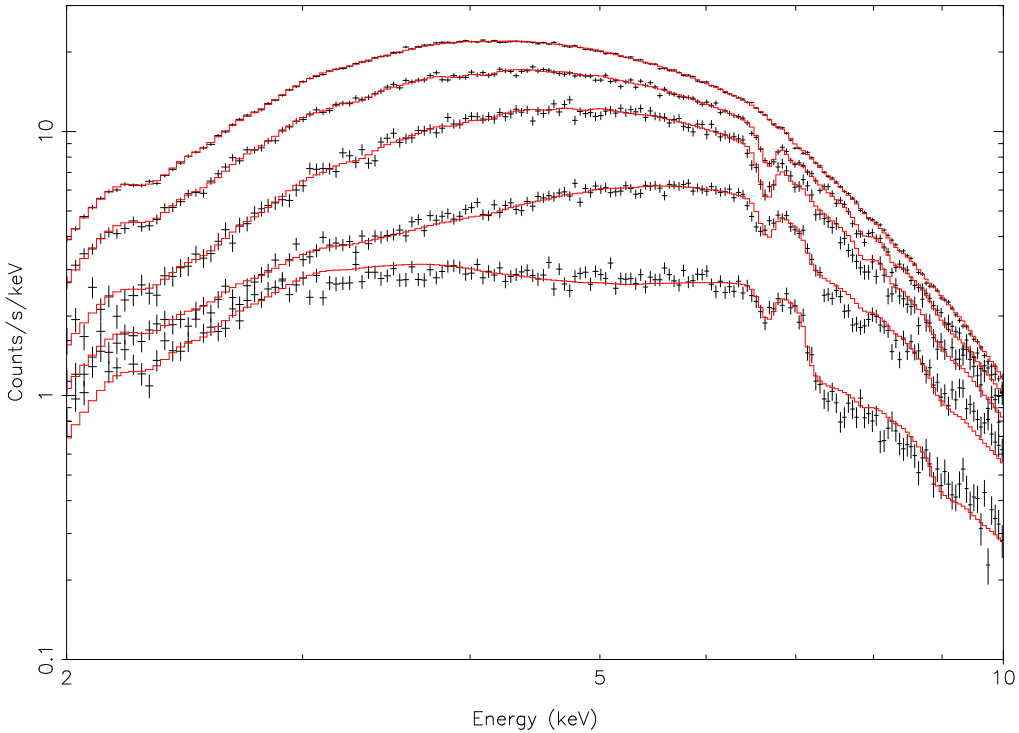
(1 - $e^{-\tau E^{-2}}$) Abs (pl + bb) + $e^{-\tau E^{-2}}$ Abs Xabs (pl + bb + gau_{em})

- The underlying X-ray emission, common to all spectra
- The photo-ionized absorber (local to the system)
  - line and continuum absorption by all relevant ions
  - Compton scattering by the free electrons
- The neutral absorber (Galactic and local contributions)
- Dust scattering off the line-of-sight
- Dust scattering back into the line-of-sight: the halo component

(Current) best-fit model

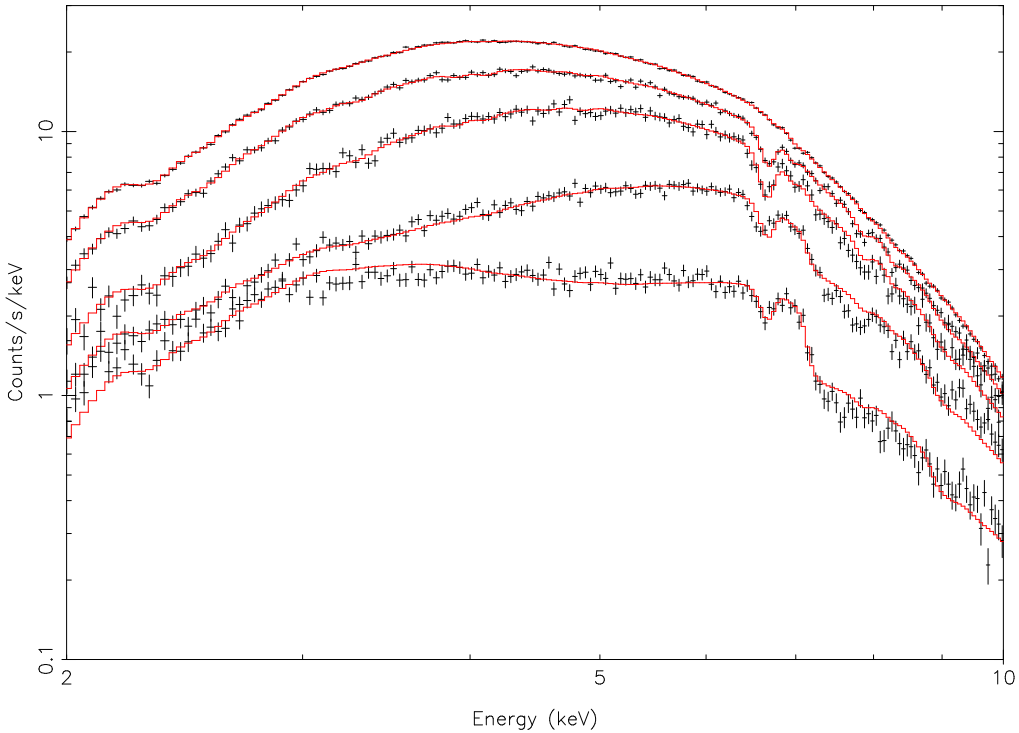


Contribution of the interstellar dust



- $\tau = 2.8$

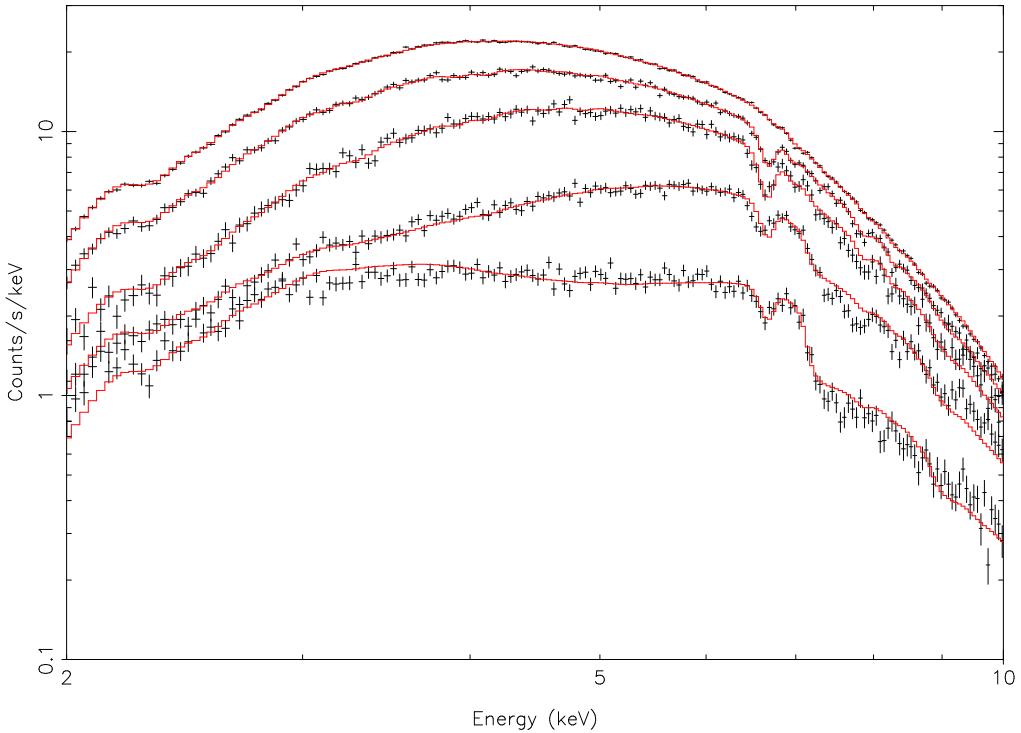
Contribution of the interstellar dust



- $\tau = 2.8$

  $N_{\mathrm{H}}{}^{Gal} = 5.8 \times 10^{22}\ \mathrm{cm}^{-2}$

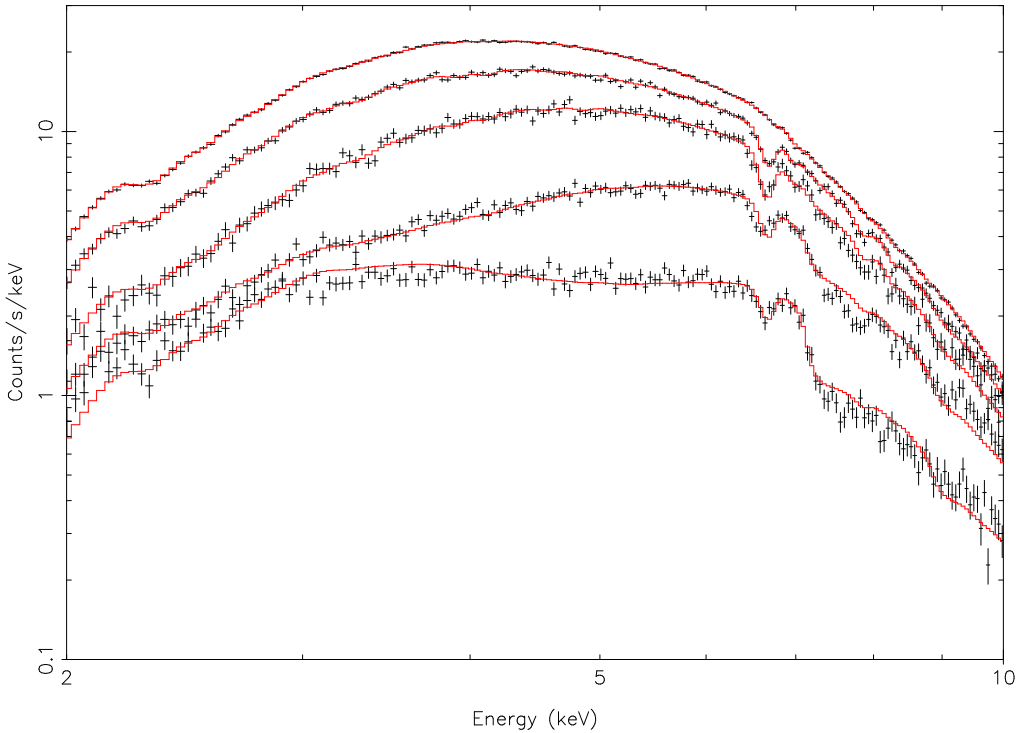
Contribution of the interstellar dust



- $\tau = 2.8$

  $N_{\mathrm{H}}{}^{Gal} = 5.8 \times 10^{22}$ cm^{-2}
- A large fraction of the neutral absorber must be local to the system

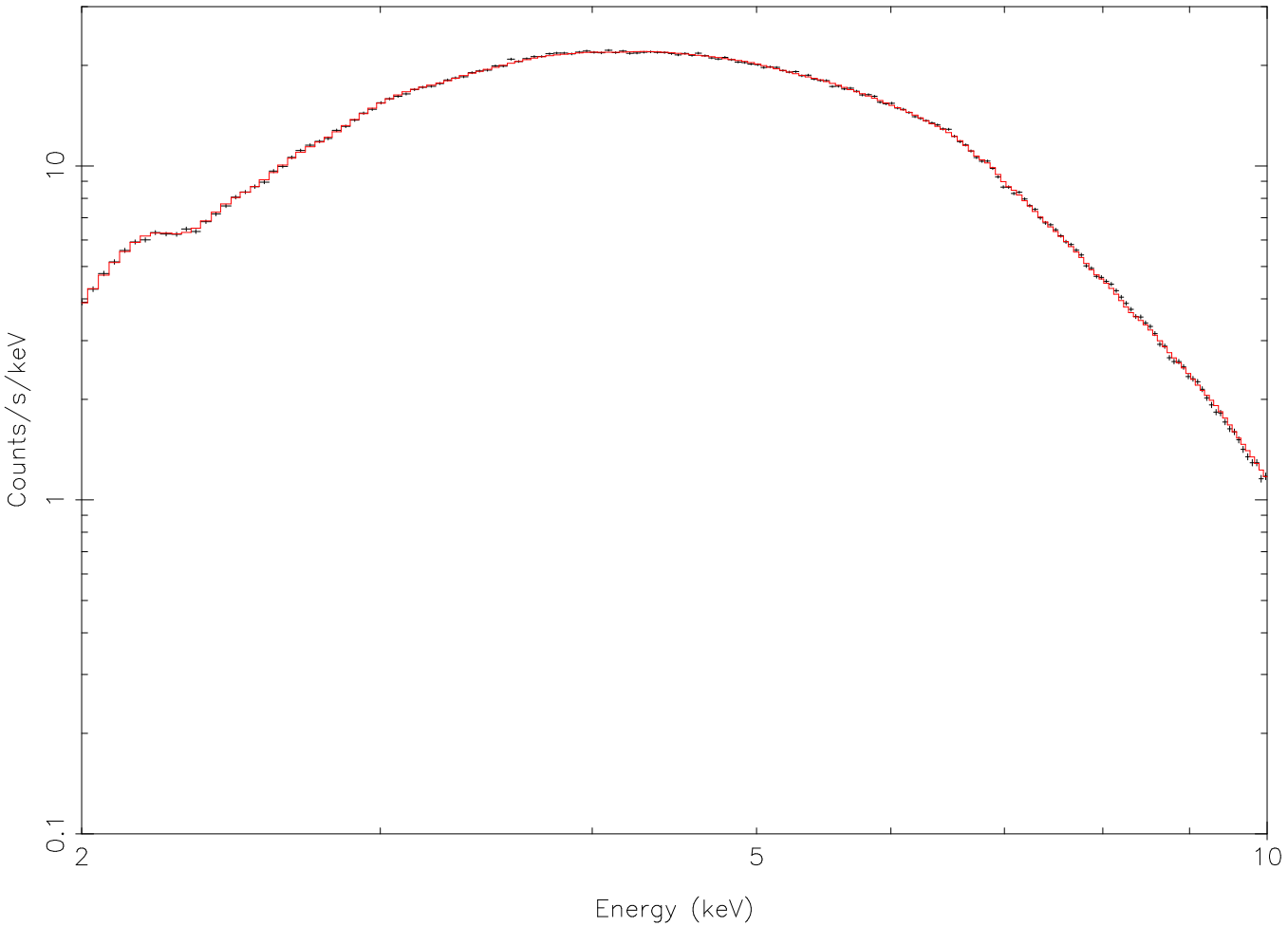
Contribution of the interstellar dust



- $\tau = 2.8$

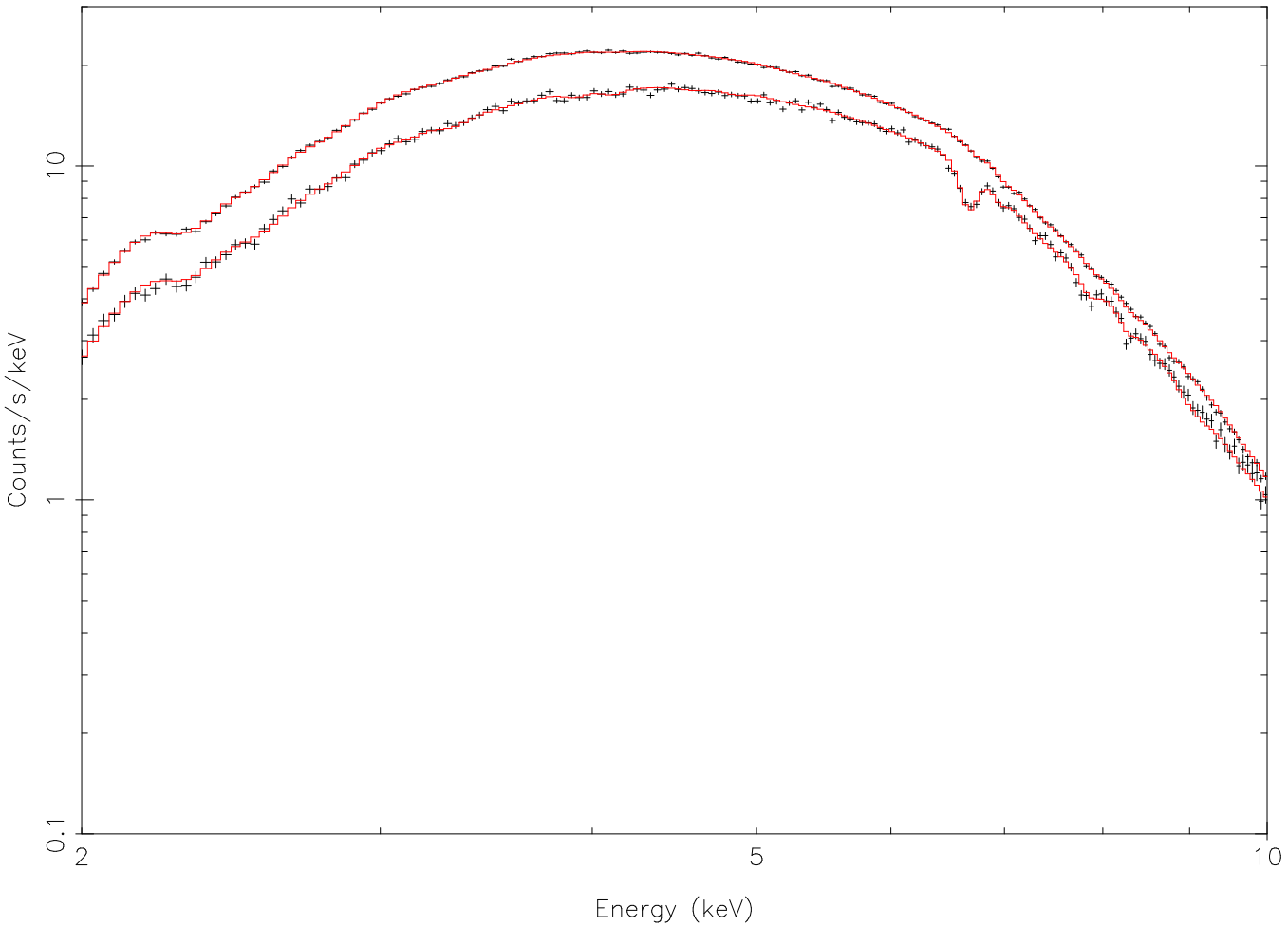
  $N_{\mathrm{H}}{}^{Gal} = 5.8 \times 10^{22}$ cm^{-2}
- A large fraction of the neutral absorber must be local to the system
- Consistent with the Chandra results

Contribution of the neutral and warm absorbers



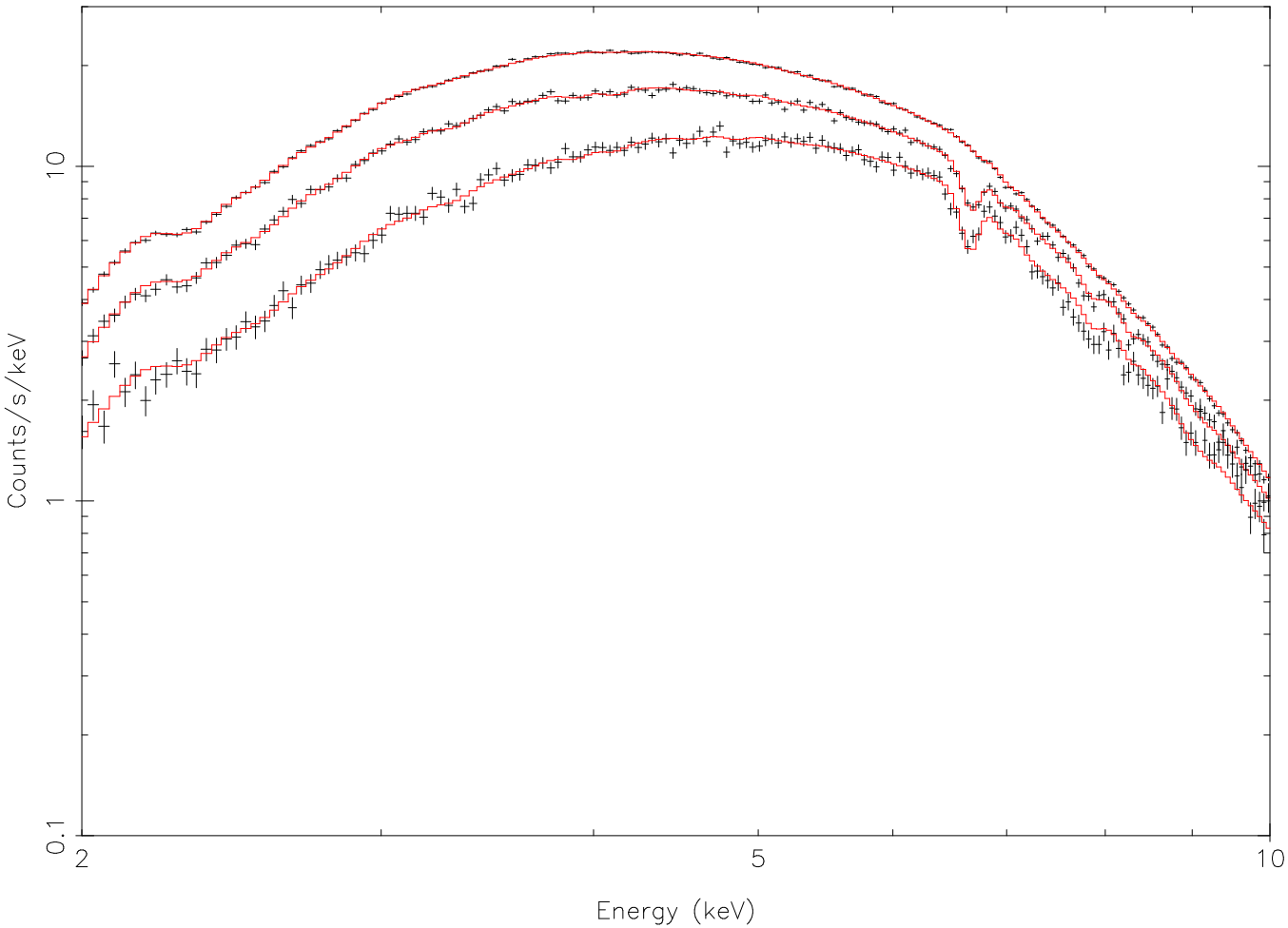
$N_{\rm H}^{\rm abs}$	$N_{\rm H}^{\rm xabs}$	$\log \xi$
$(\times\ 10^{22}\ {\rm cm}^{-2})$		
6.4	5.4	3.87

Contribution of the neutral and warm absorbers



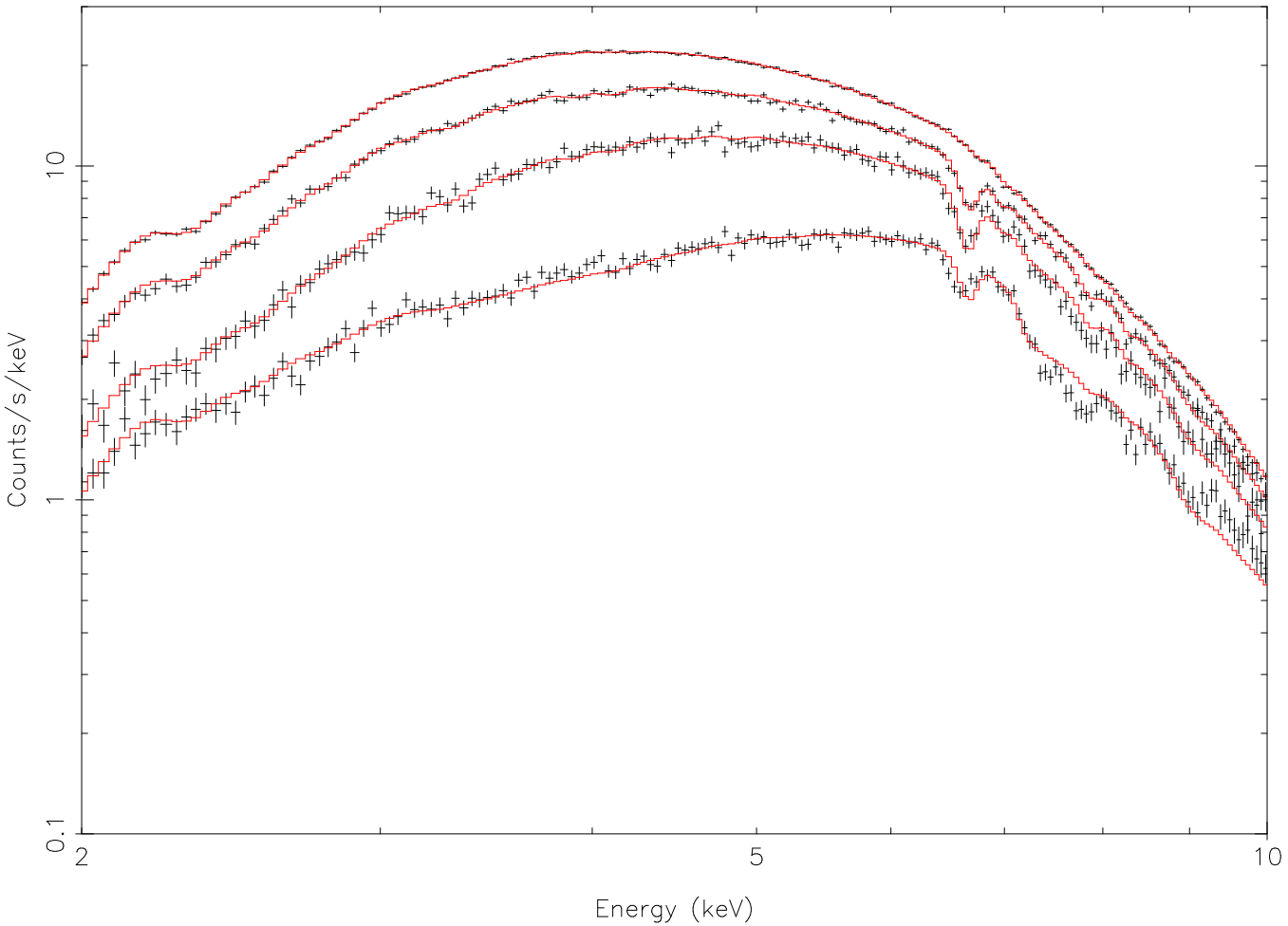
$N_{\rm H}^{\rm abs}$ ($\times 10^{22}$ cm^{-2})	$N_{\rm H}^{\rm xabs}$	$\log \xi$
6.4	5.4	3.87
8.9	35	3.43

Contribution of the neutral and warm absorbers



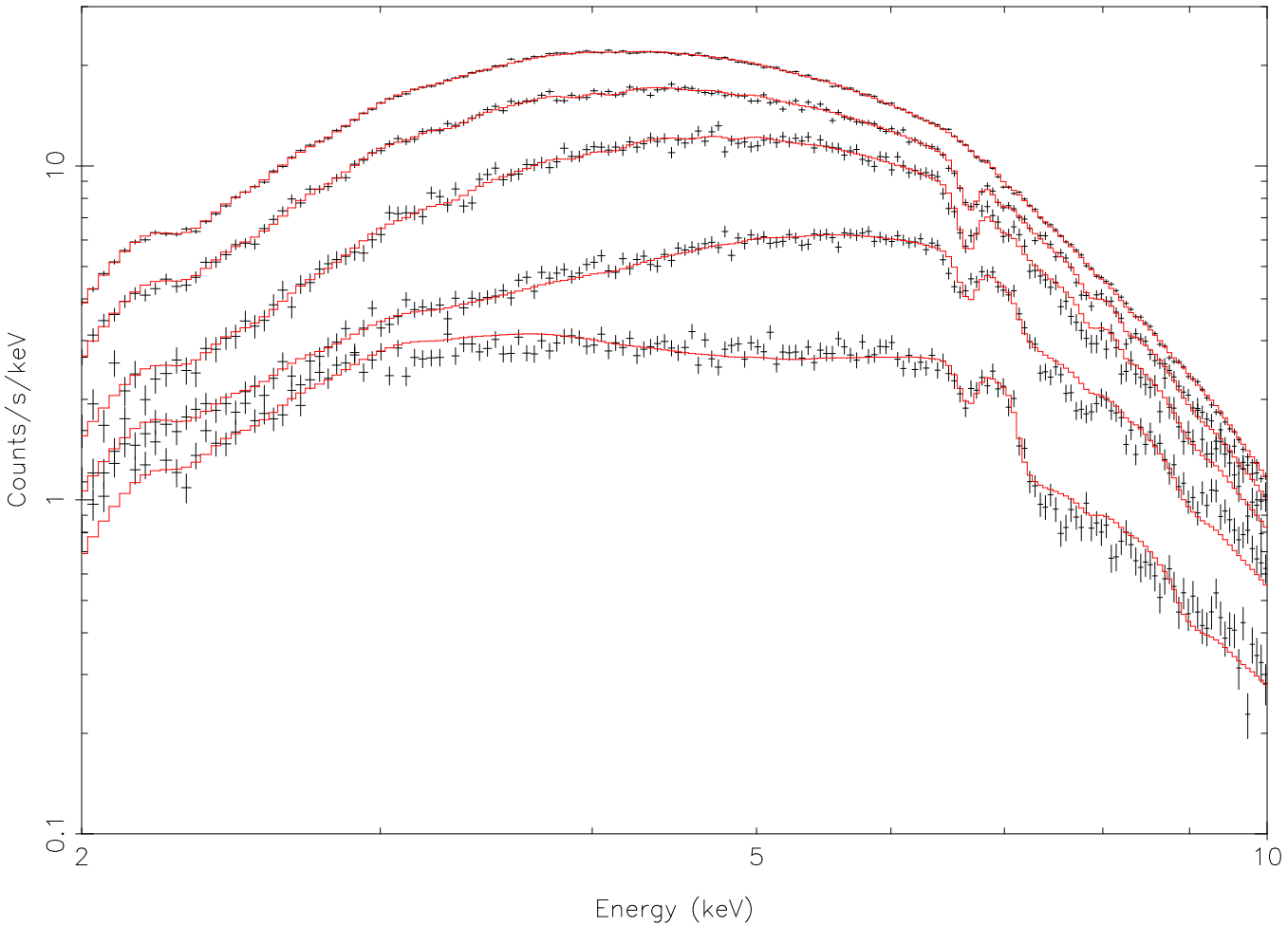
$N_{\rm H}^{\rm abs}$ ($\times 10^{22}$ cm^{-2})	$N_{\rm H}^{\rm xabs}$	$\log \xi$
6.4	5.4	3.87
8.9	35	3.43
14	47	3.36

Contribution of the neutral and warm absorbers



$N_{\rm H}^{\rm abs}$ ($\times 10^{22}$ cm^{-2})	$N_{\rm H}^{\rm xabs}$	$\log \xi$
6.4	5.4	3.87
8.9	35	3.43
14	47	3.36
36	66	3.4

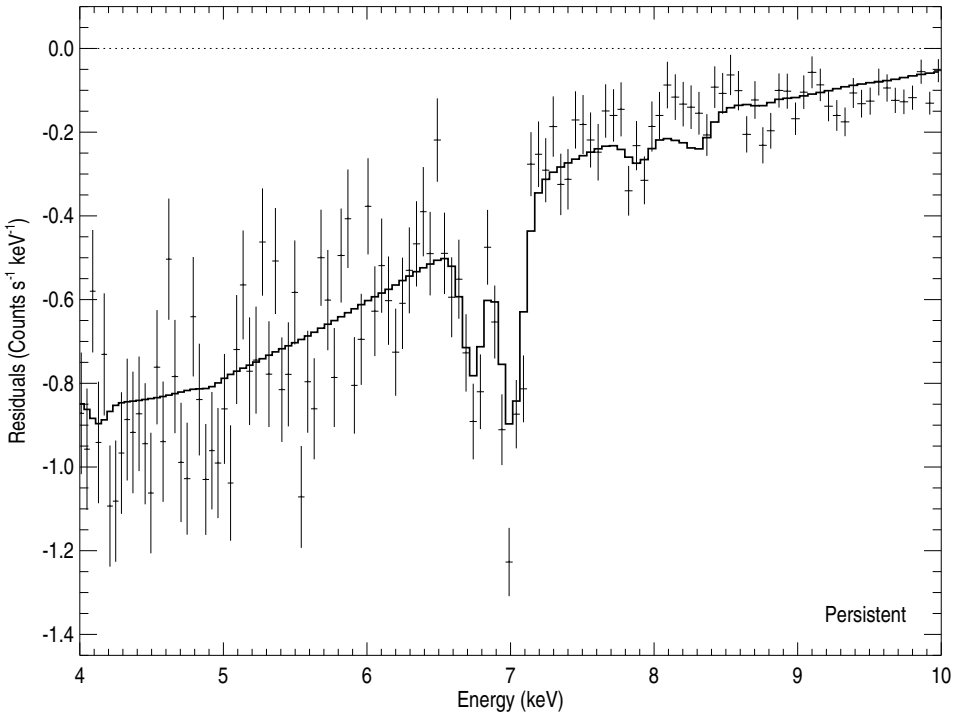
Contribution of the neutral and warm absorbers



$N_{\rm H}^{\rm abs}$ ($\times 10^{22}$ cm^{-2})	$N_{\rm H}^{\rm xabs}$	$\log \xi$
6.4	5.4	3.87
8.9	35	3.43
14	47	3.36
36	66	3.4
77	96	3.4

Contribution of the warm absorber

Persistent

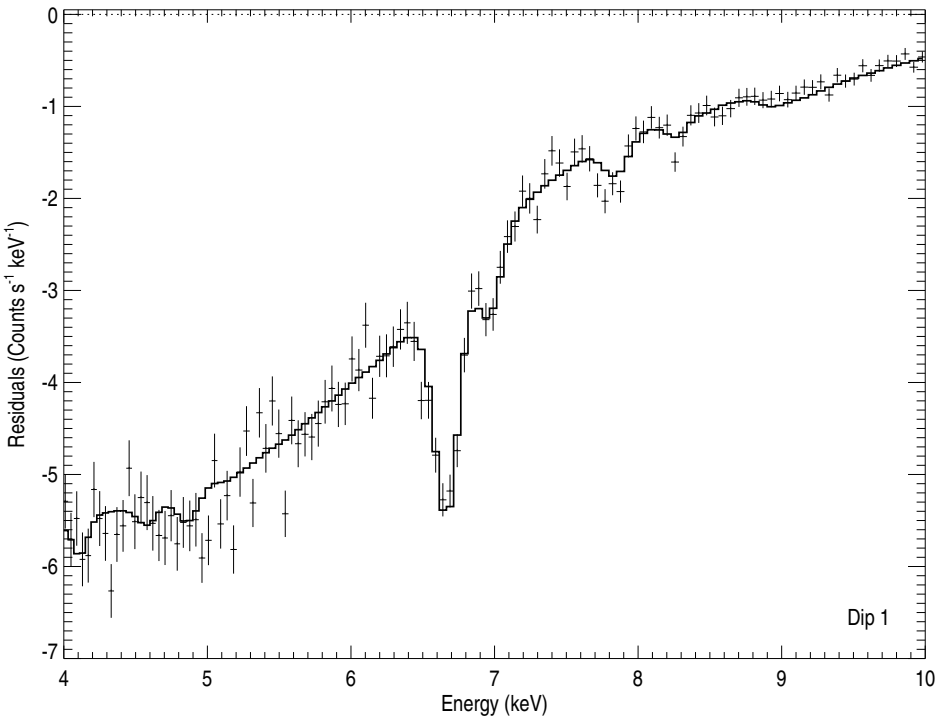


Strongest lines in the model

Rank	EW (eV)	Ion	Energy (keV)
2	5.8	Fe XXV	6.7004
3	4.8	Fe XXVI	6.9517
1	6.3	Fe XXVI	6.9732
5	2.2	Fe XXV	7.8810
6	1.5	Fe XXVI	8.2464
4	2.7	Fe XXVI	8.2524

Contribution of the warm absorber

Dip 1

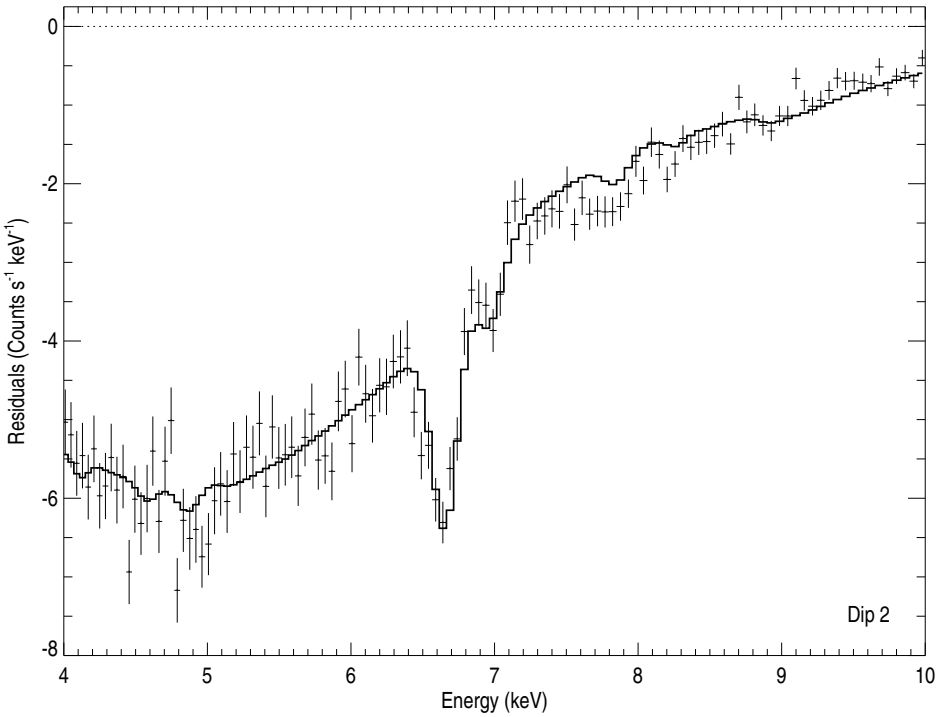


Strongest lines in the model

Rank	EW (eV)	Ion	Energy (keV)
3	10.	Fe XXIV	6.6619
1	21	Fe XXV	6.7004
5	9.1	Fe XXVI	6.9732
6	9.1	Ni XXVII	7.8051
2	11	Fe XXV	7.8810
4	9.3	Fe XXV	8.2955

Contribution of the warm absorber

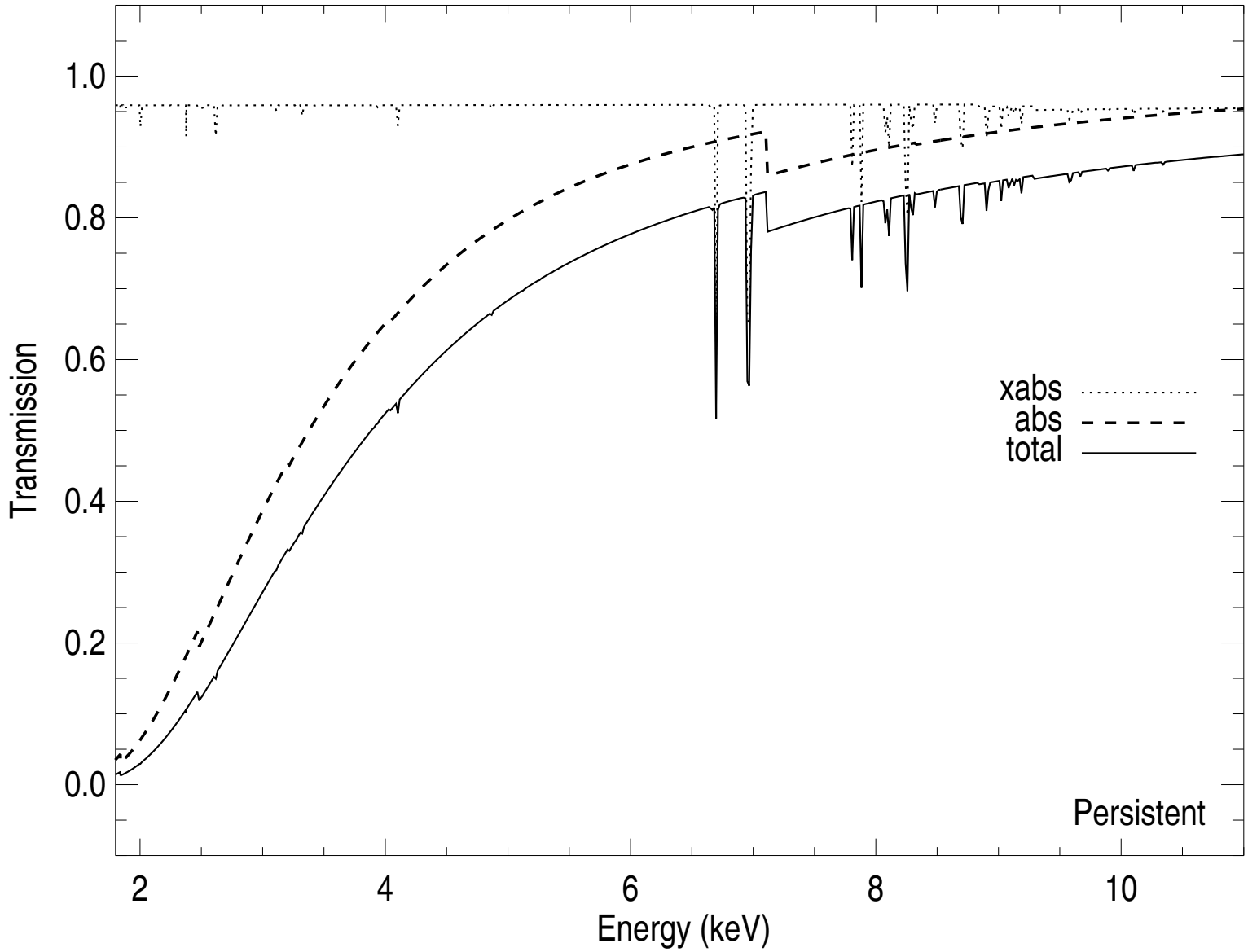
Dip 2



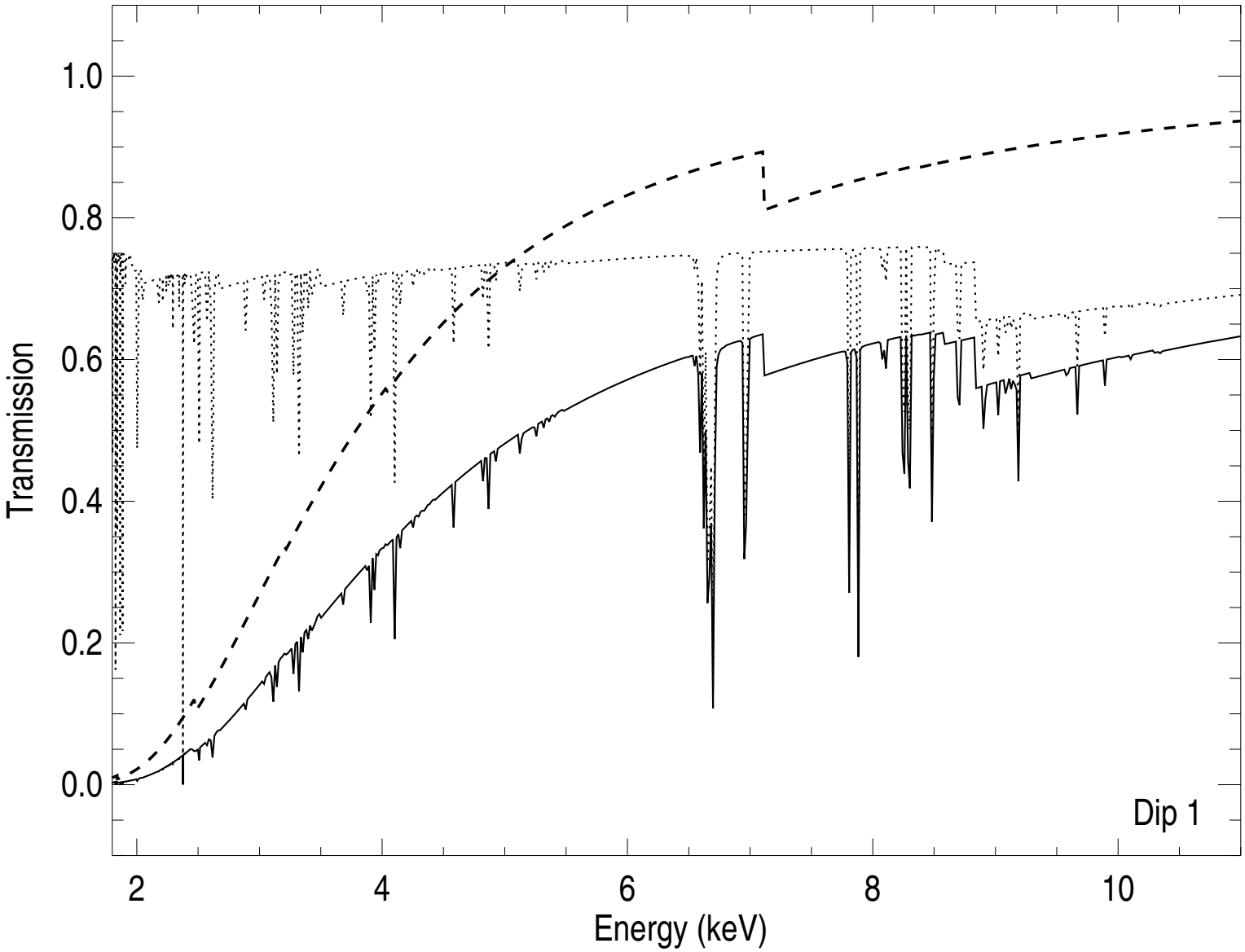
Strongest lines in the model

Rank	EW (eV)	Ion	Energy (keV)
4	11	Fe XXIII	6.6288
2	13	Fe XXIV	6.6619
1	24	Fe XXV	6.7004
6	9.7	Ni XXVII	7.8051
3	12	Fe XXV	7.8810
5	10.	Fe XXV	8.2955

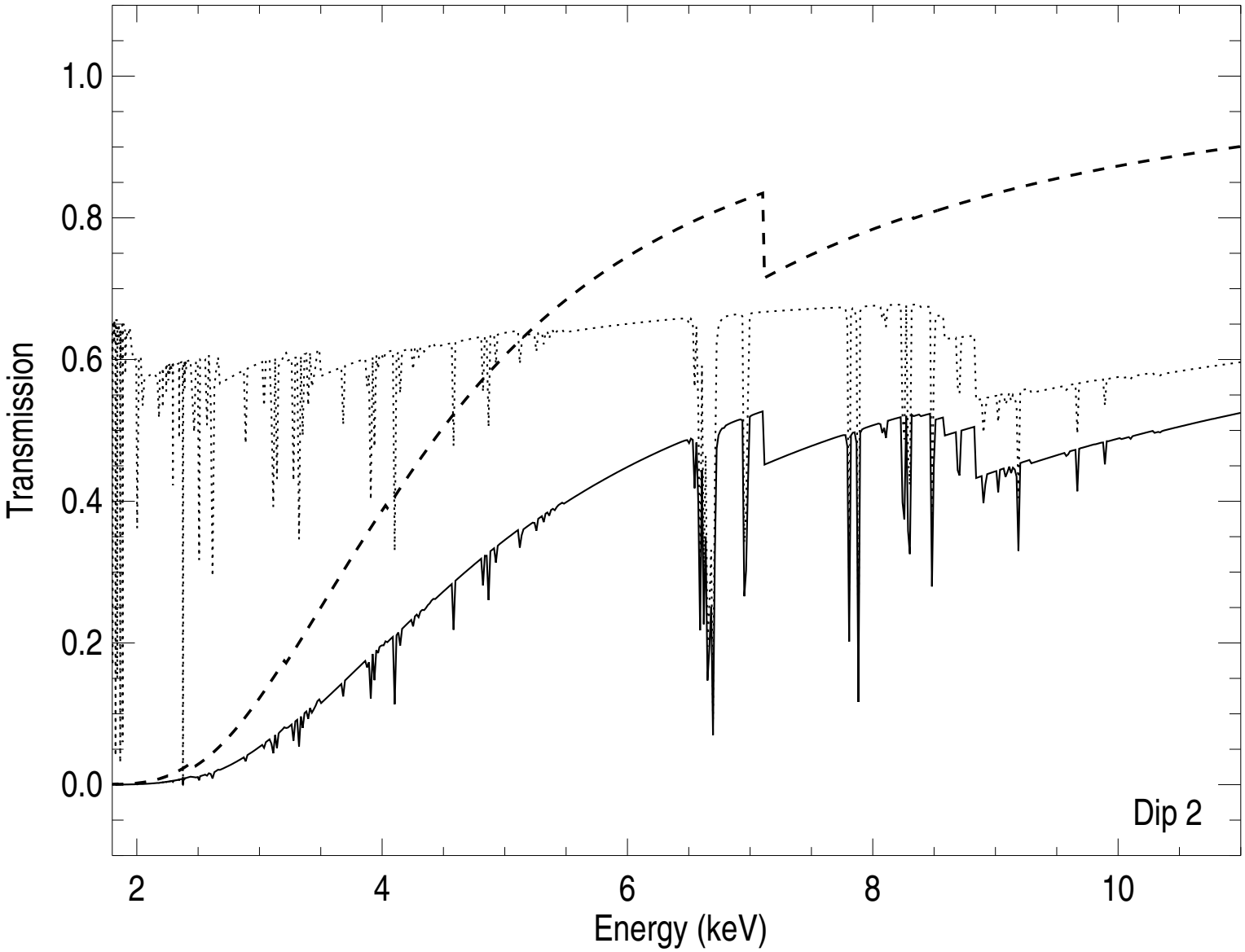
Transmission of the warm and neutral absorbers



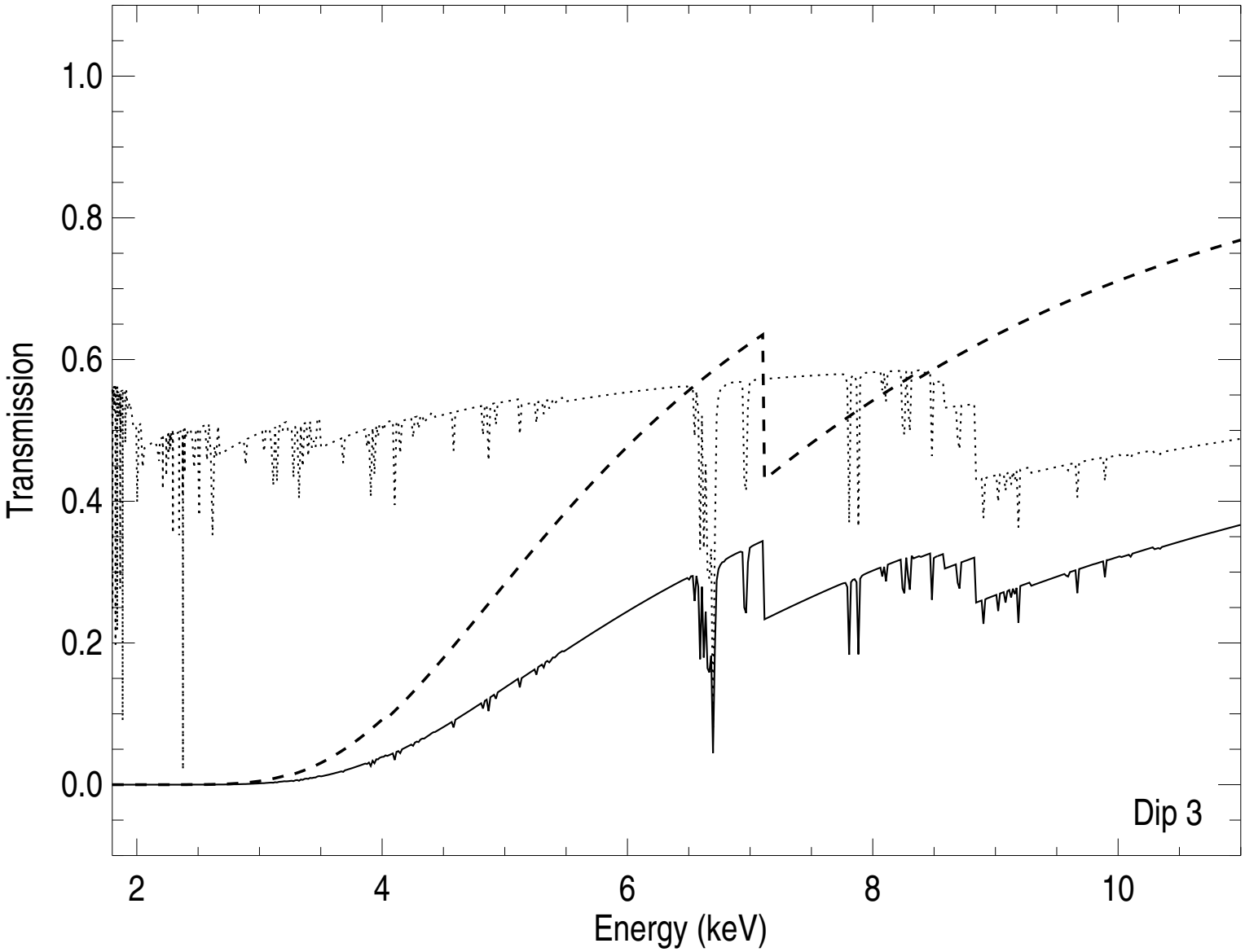
Transmission of the warm and neutral absorbers



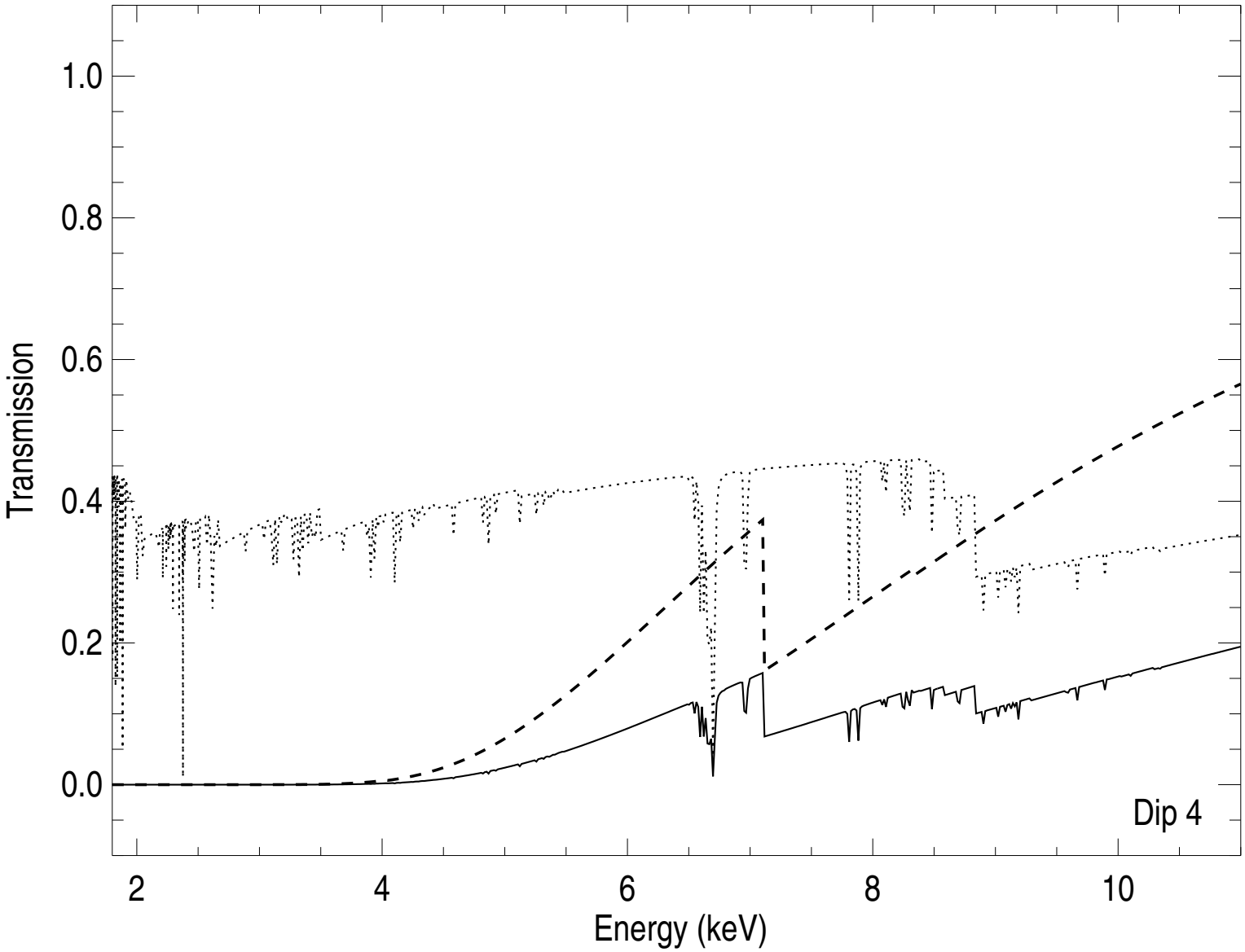
Transmission of the warm and neutral absorbers



Transmission of the warm and neutral absorbers



Transmission of the warm and neutral absorbers



Conclusions

- The spectral changes during the dips of X 1624-490 can be modeled by variations in the properties of a neutral and an ionized absorber in the line-of-sight.

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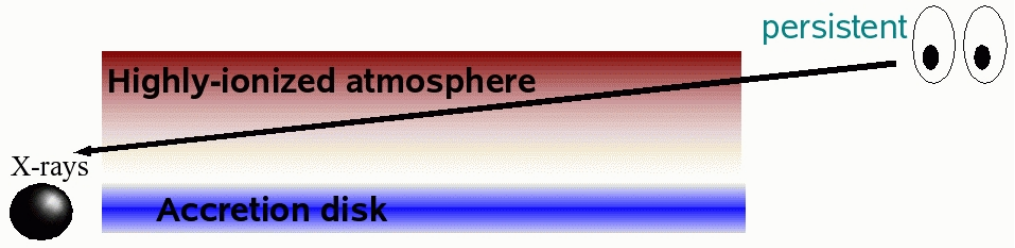

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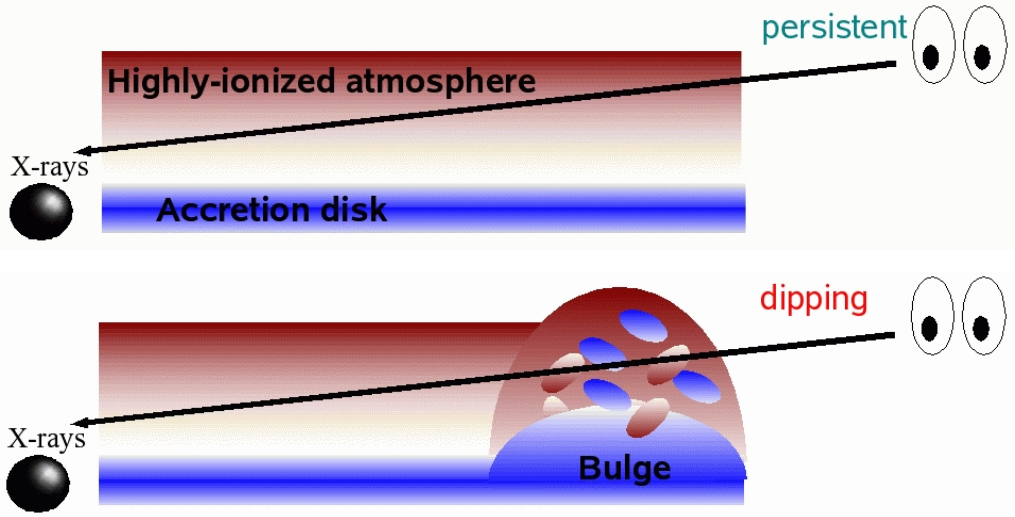

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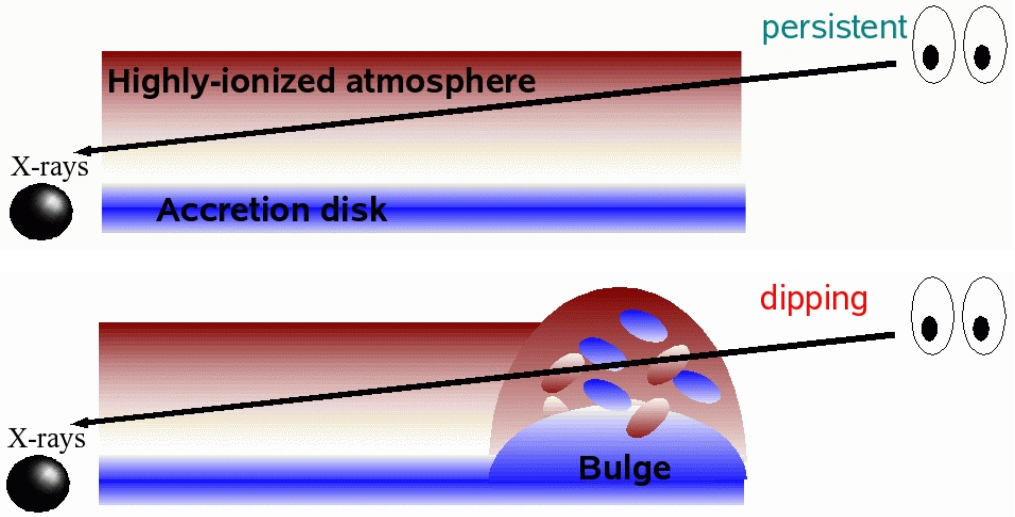

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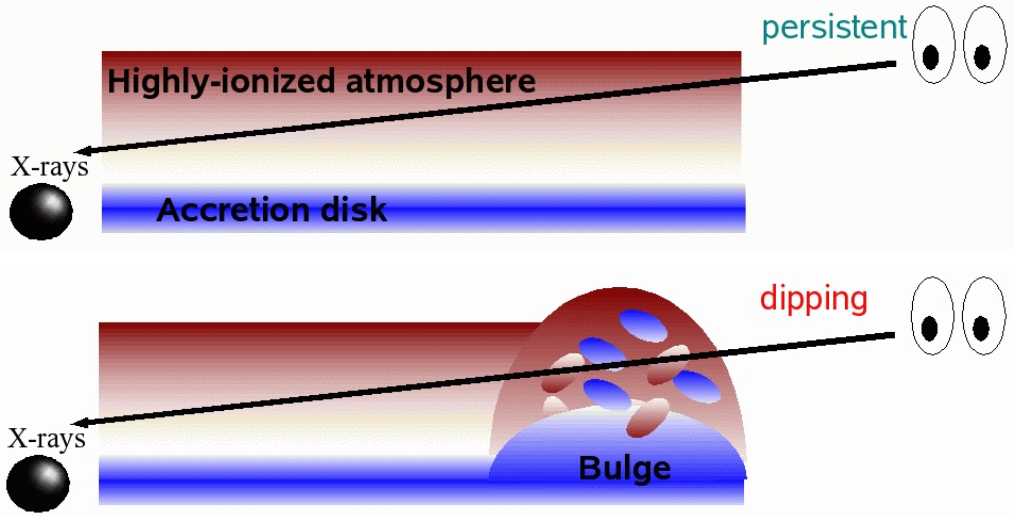

- A component suffering less absorption is present at low energy and interpreted as coming from the halo.
- The excellent quality of the data and the long exposure during dipping enable us to test other hypothesis and further constrain the properties of the absorbers (work in progress).