Deciphering the accretion structure in Vela X-1

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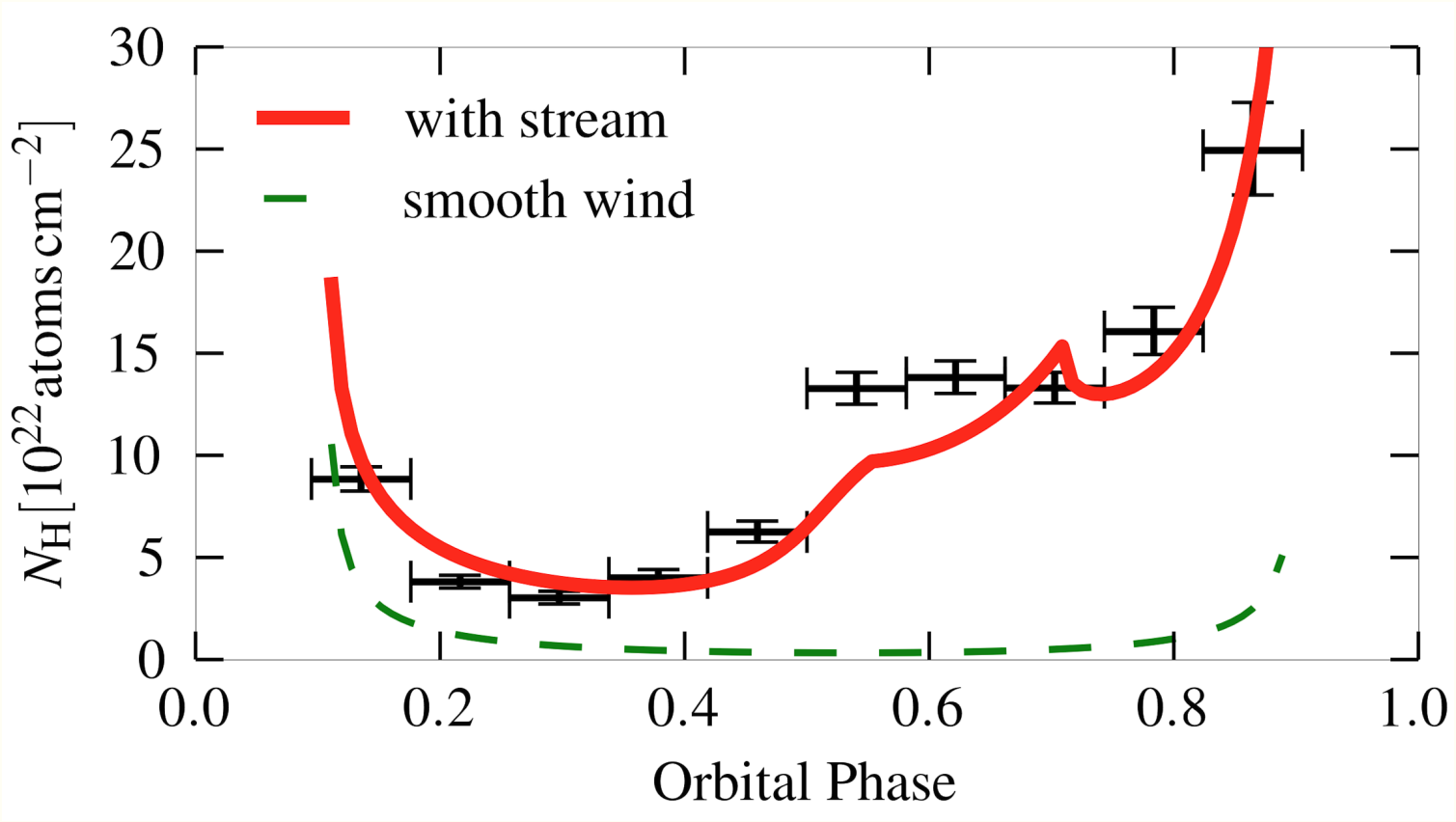
Vela X-1

- B0.5 Iab supergiant
- line-driven CAK winds
- possible presence of clumps in the wind

- 283 s pulsar
- eclipsing 9 d orbit
- binary separation: 53.4 $R_\odot$
  $\Rightarrow$ neutron star embedded in companion wind

Variability along the orbit

changing baseline absorption best accessed with all sky monitors, e.g., MAXI, averaging over many orbits:



Doroshenko et al. 2013

Wind and accretion structure

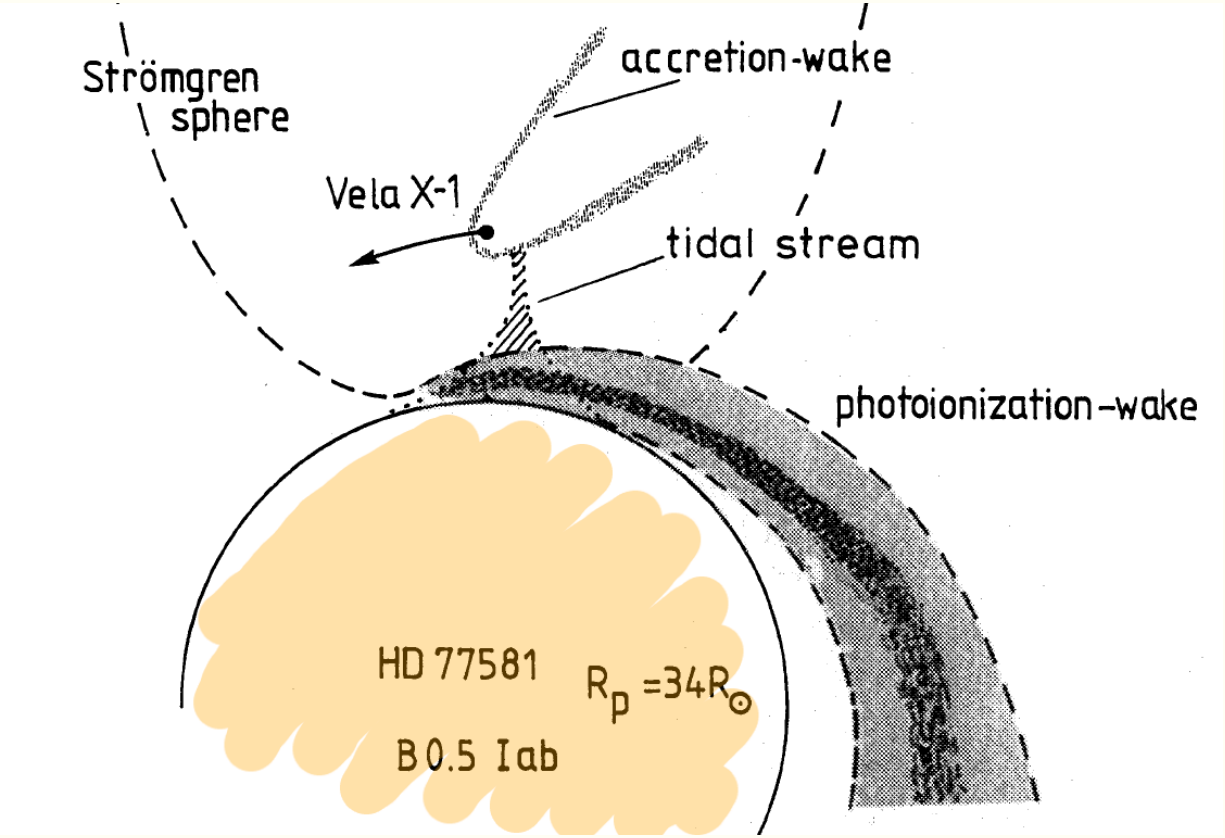


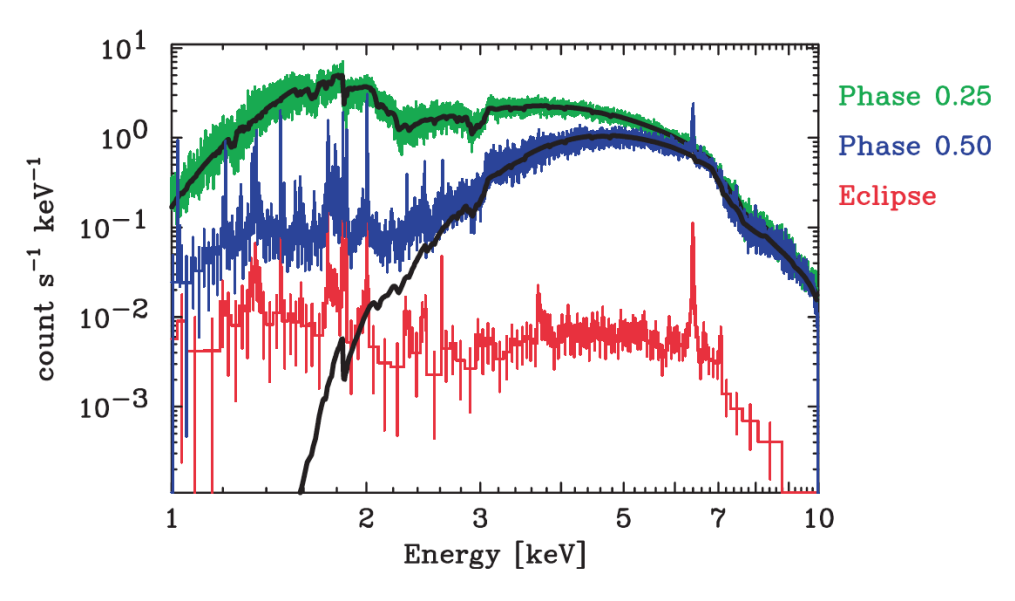
Fig. from Kaper et all, 1994

accretion wake
focussing of the wind through gravity

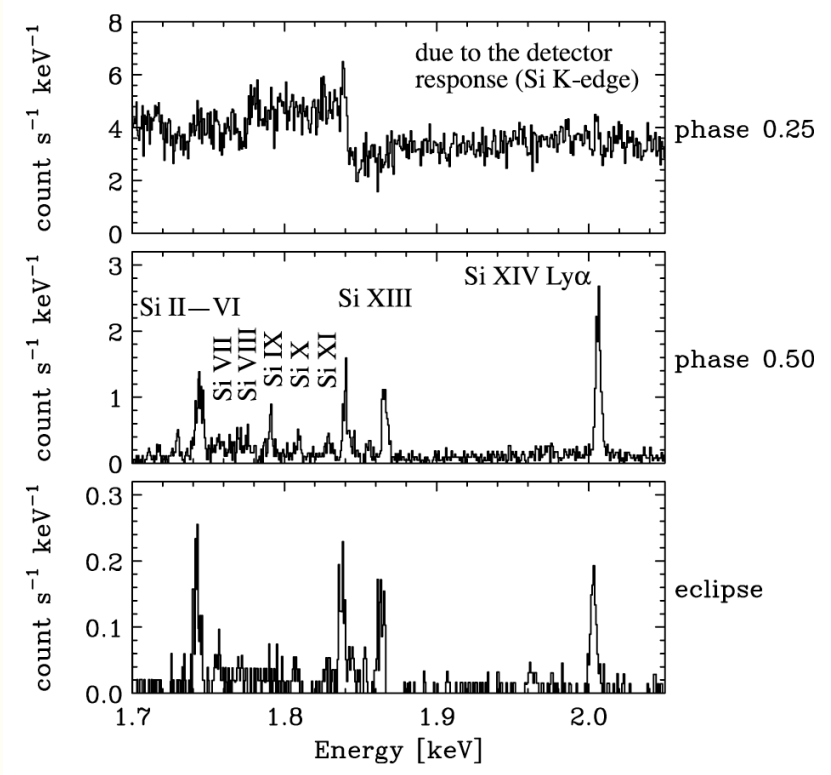
photoionization wake
shocks on interface between CAK-wind and ionized plasma around neutron star

$\Rightarrow$ absorption highly variable with orbital phase $\phi_{\rm orb}$

High resolution spectra along the orbit



Watanabe et al. 2006

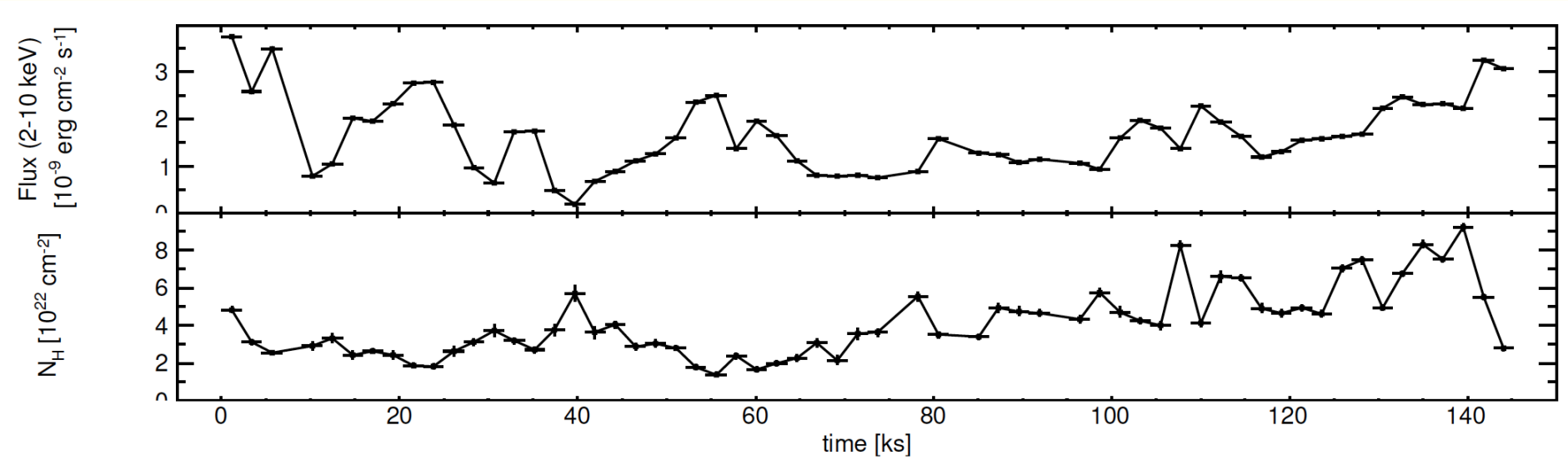


Watanabe et al. 2006

high & low ionization stages seen at $\phi_{\rm orb} \approx 0.5 \Rightarrow$ simultaneous presence of hot and cold gas

Short-term variability

Suzaku at $\phi_{\rm orb} = 0.17$–36:



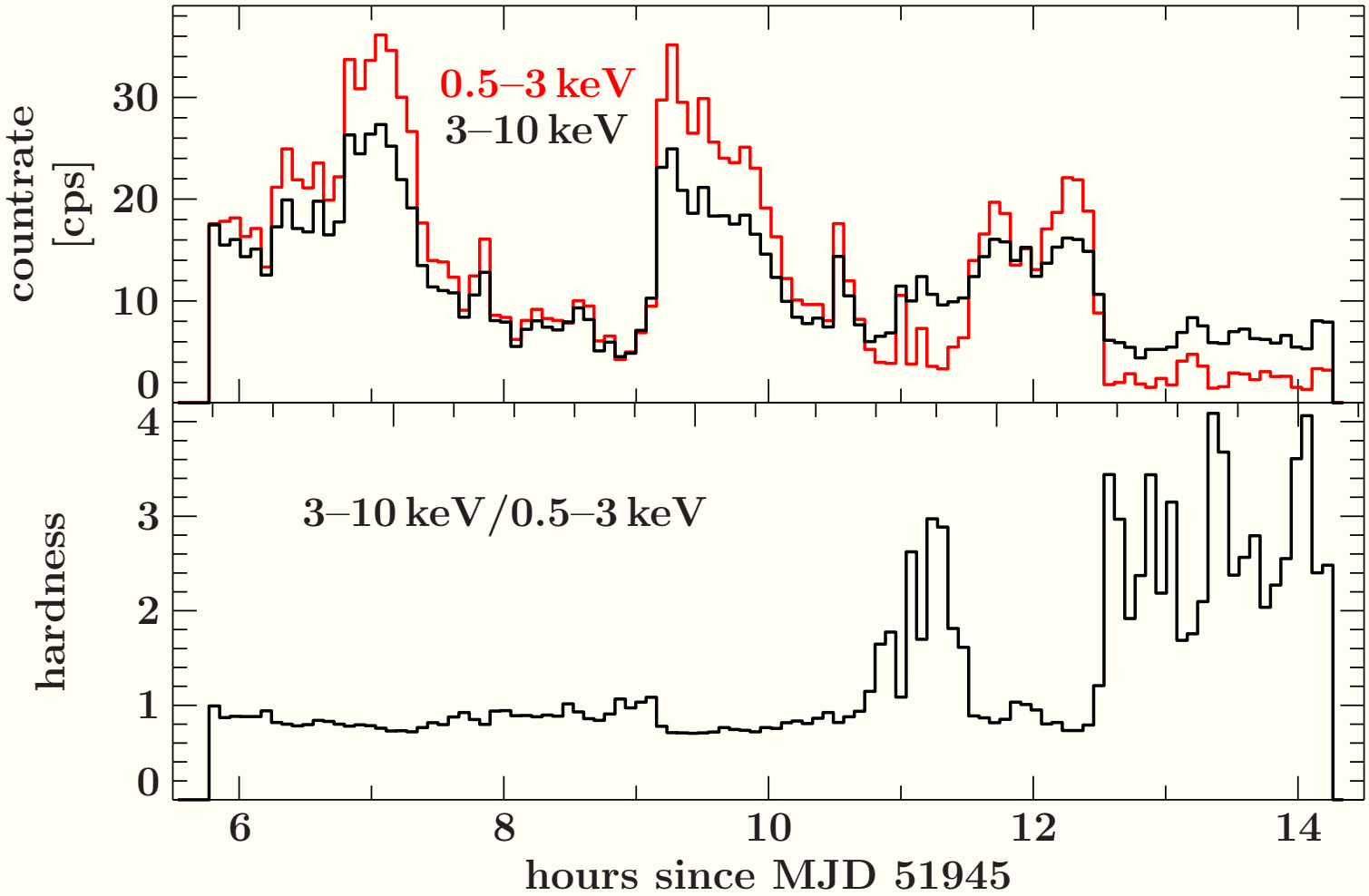
Odaka et al. 2013

$\Rightarrow$ highly variable absorption atop orbital variability

- time scales as short as 1–2 ks
- also seen in *XMM* (Martinez-Nunez et al. 2014) and *EXOSAT* (Haberl et al. 1990)

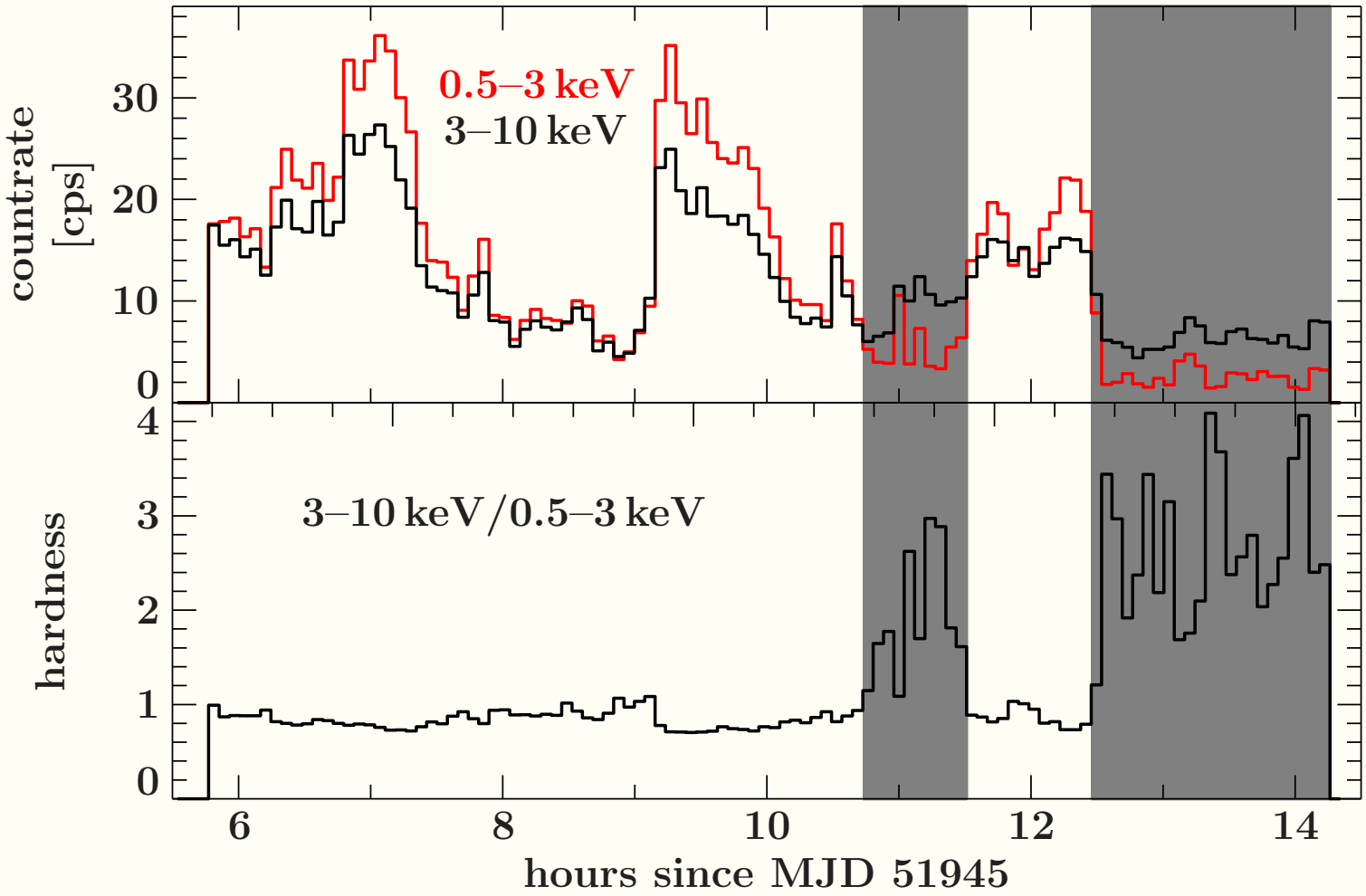
BUT: *Chandra*-HETG observations always been analyzed as a whole!

Short term variability in *Chandra* observations



ObsID 1928, Feb 11 2001

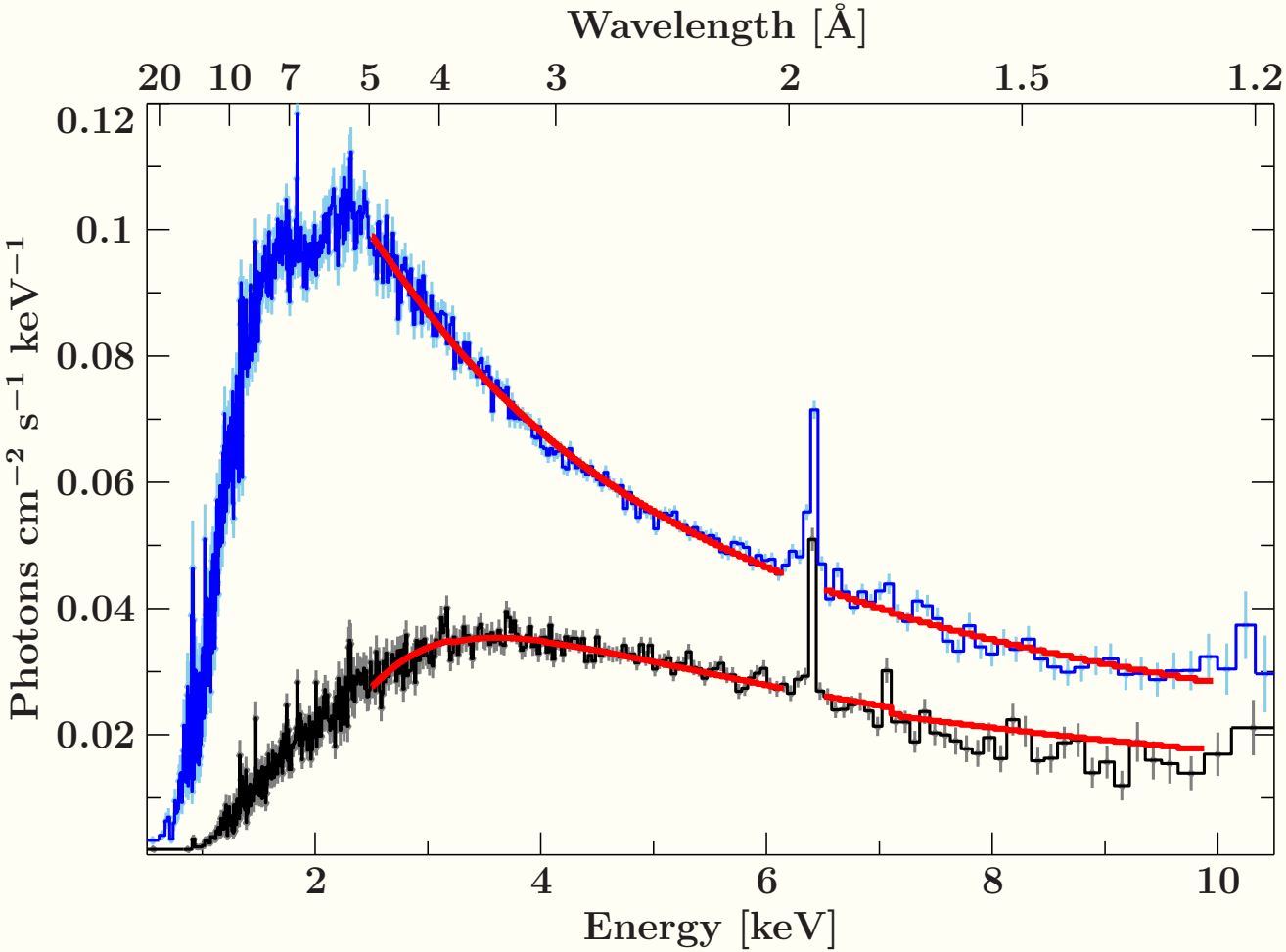
Short term variability in *Chandra* observations



ObsID 1928, Feb 11 2001

$\Rightarrow$ clearly defined periods of enhanced hardness

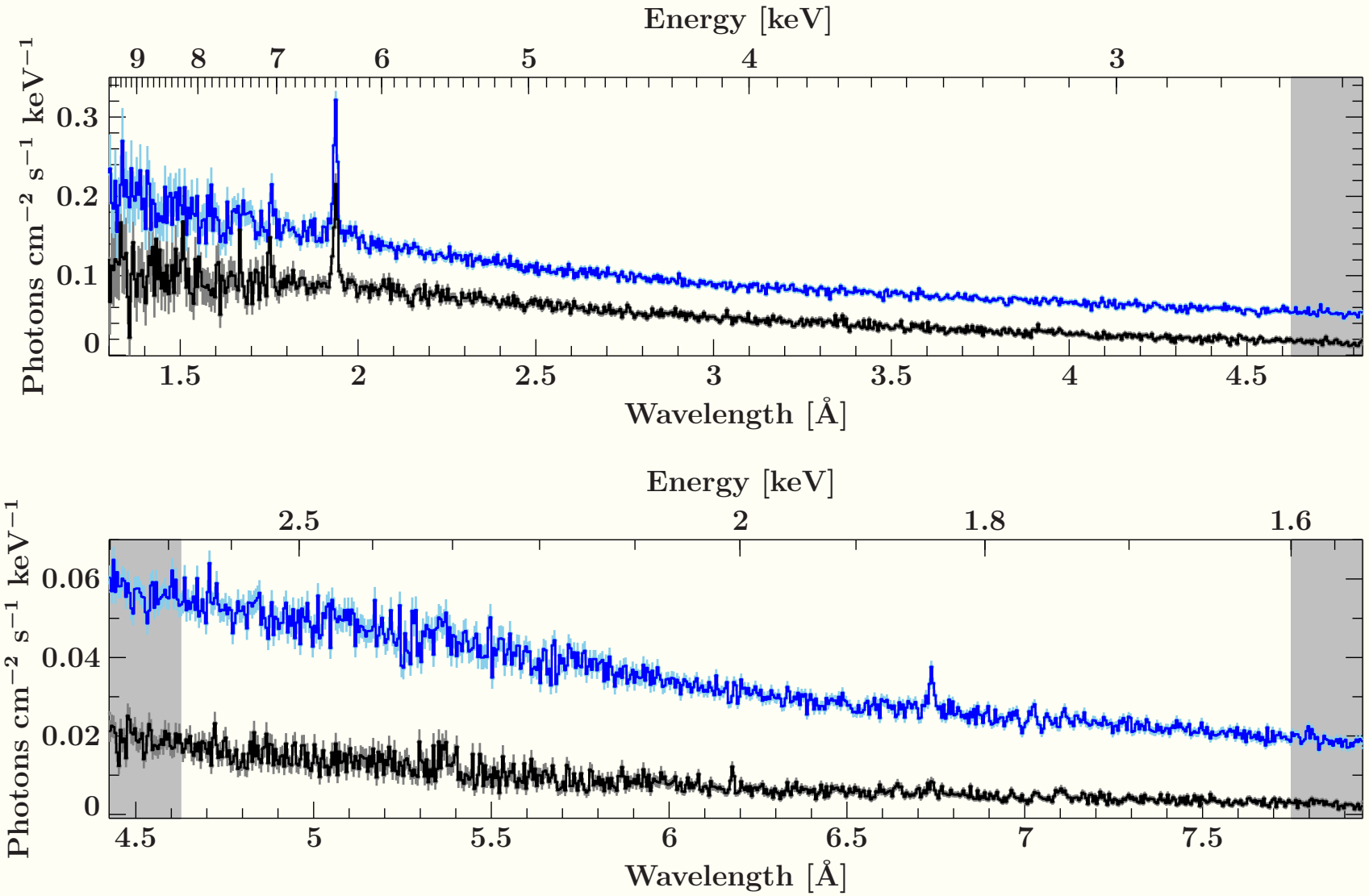
Hardness-resolved spectra



the 2.5–10 keV continuum:

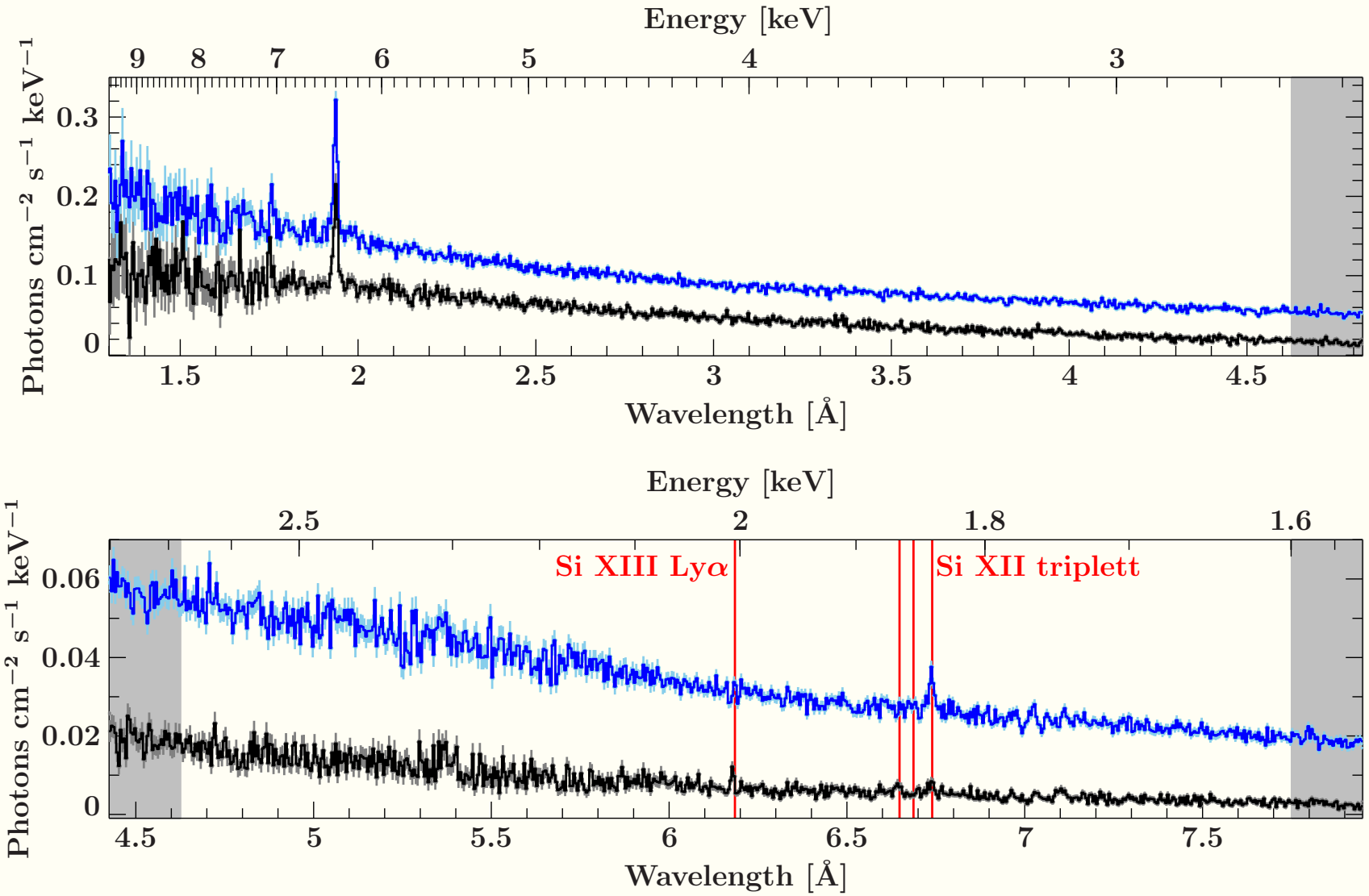
- cannot be described with same N_h, but different power laws
- can be described with same power law, but different N_h

Hardness-resolved spectra



Marked: detection in composite spectrum (Goldstein et al. 2004)

Hardness-resolved spectra



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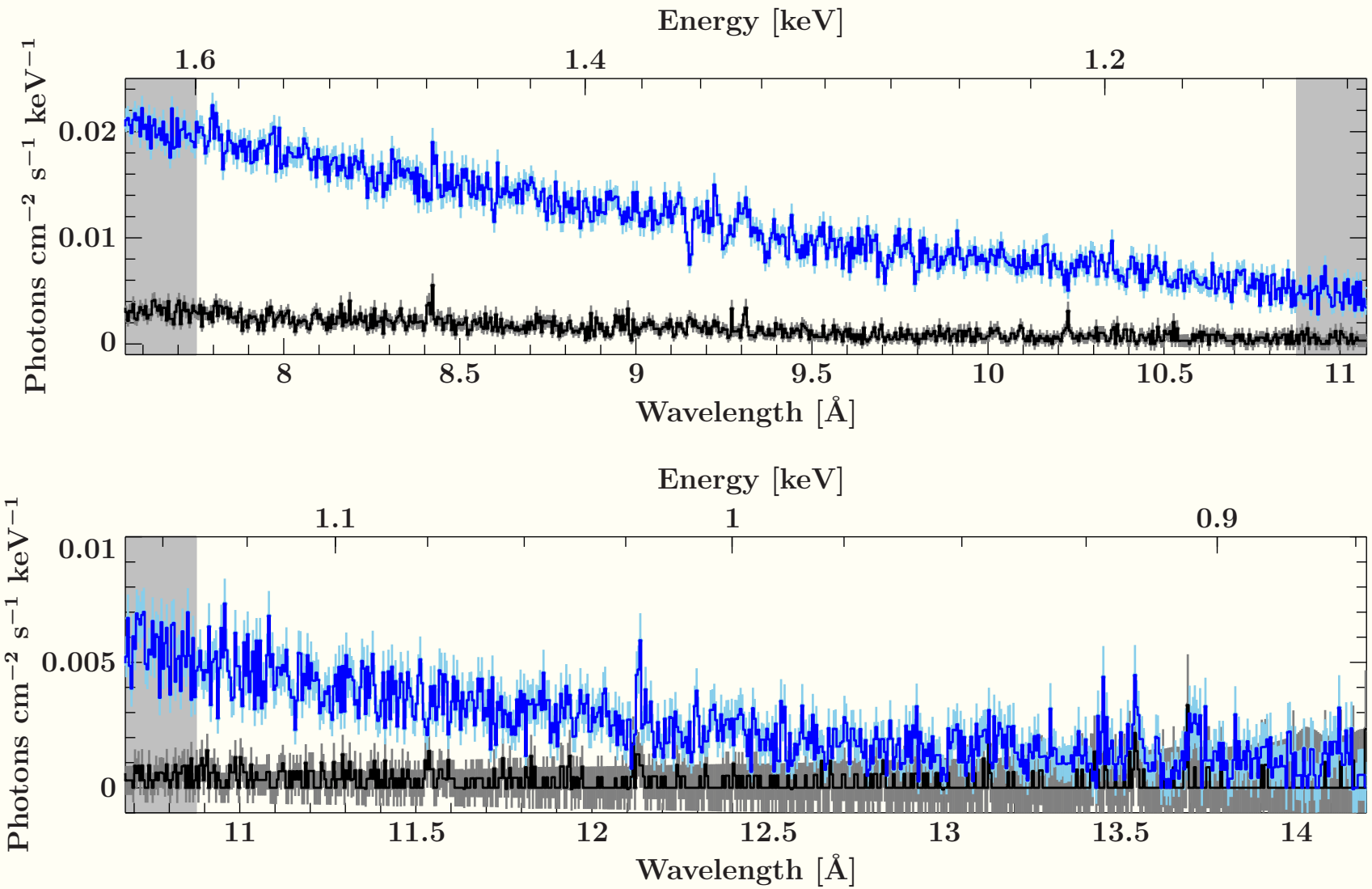

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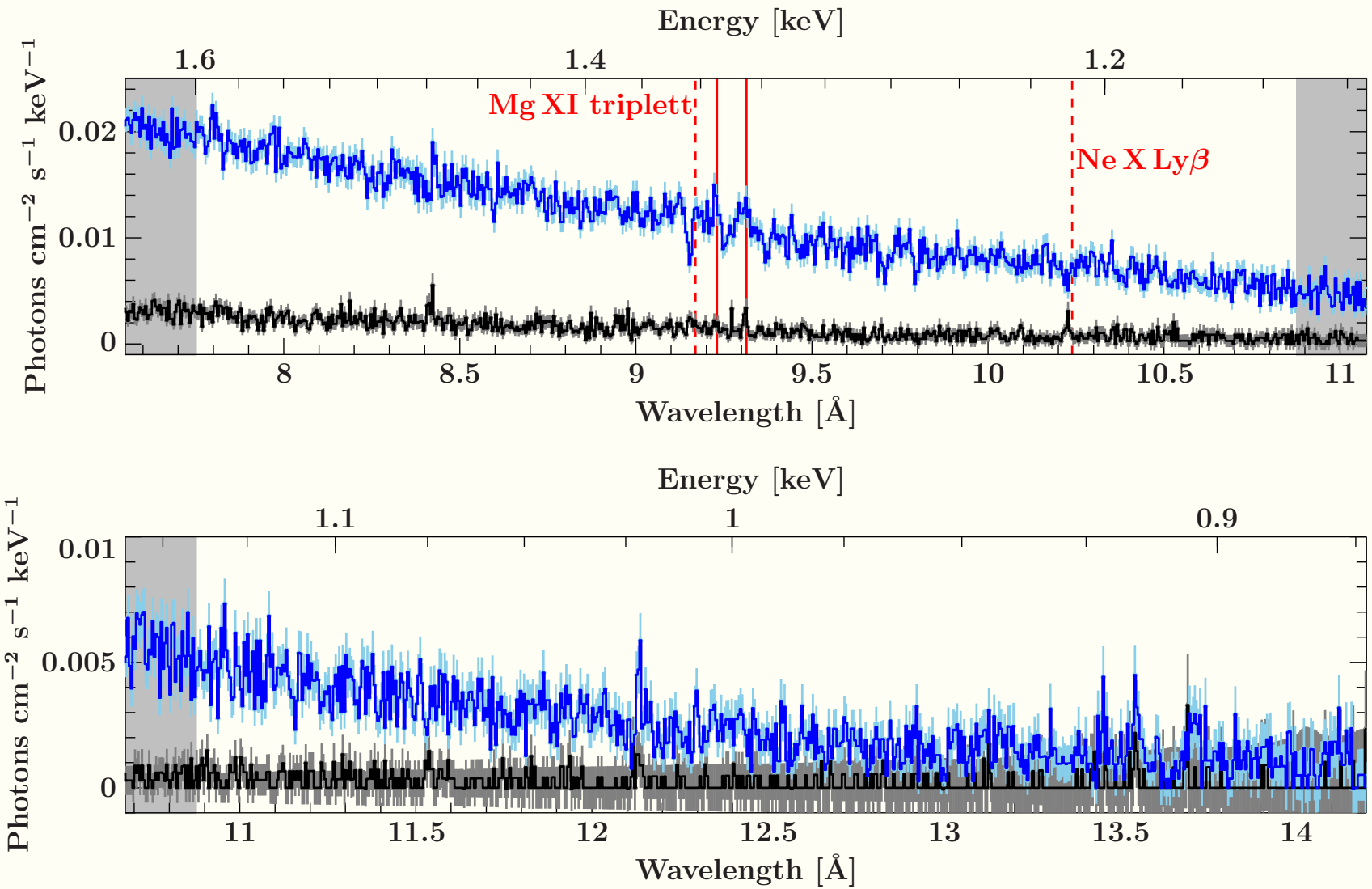

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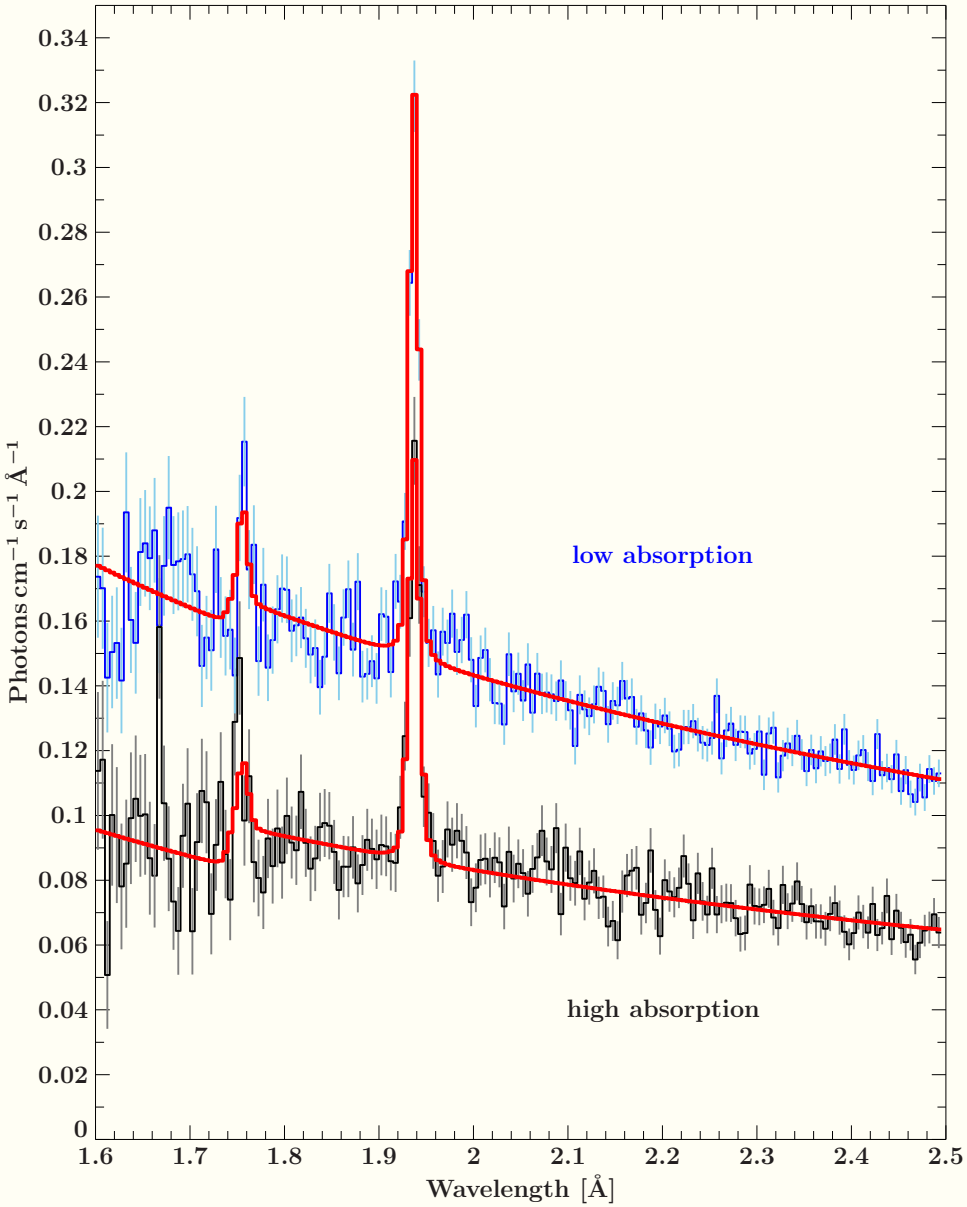
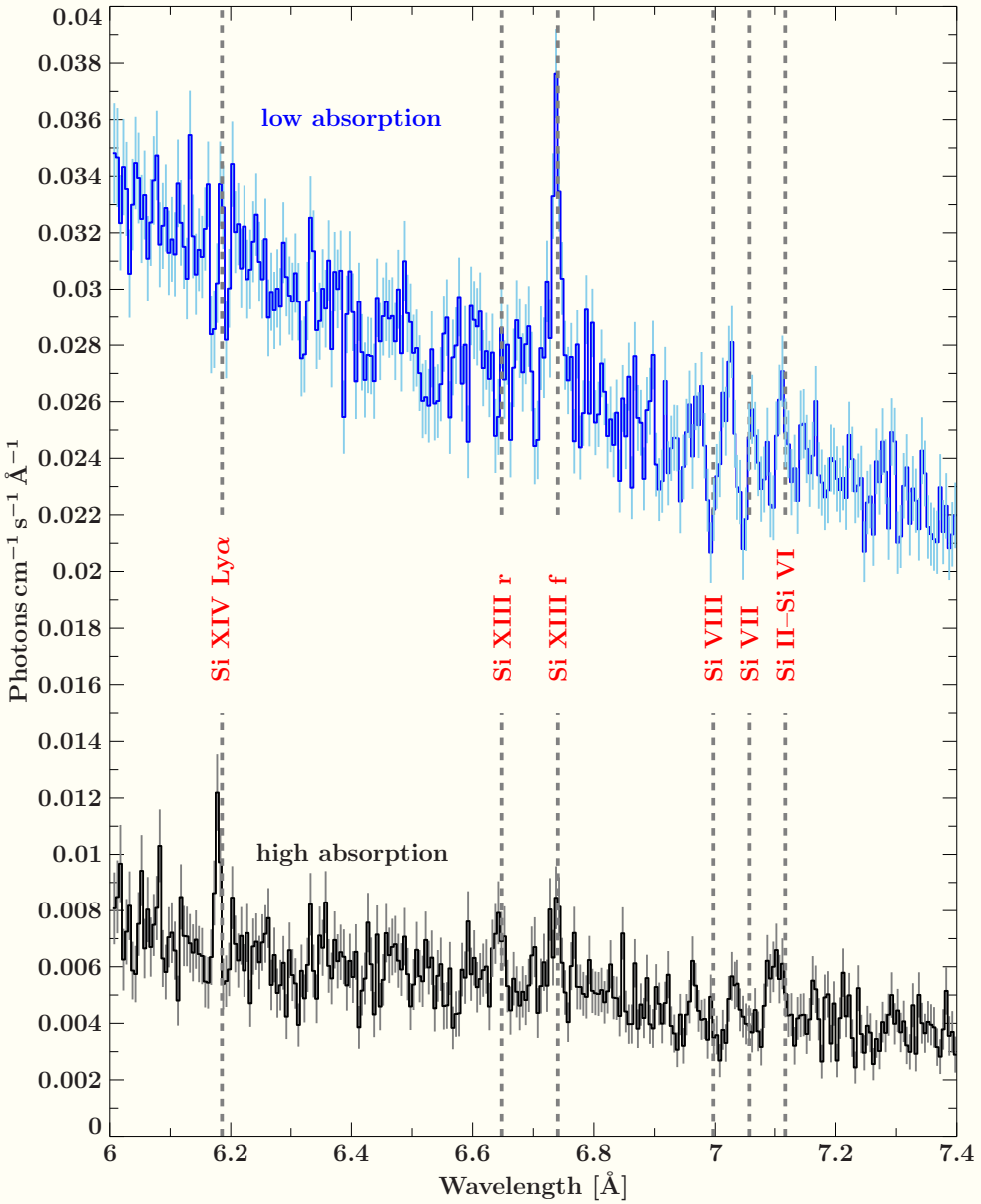
Fe region



$v \approx 200$ km/s

similar strength

Si region

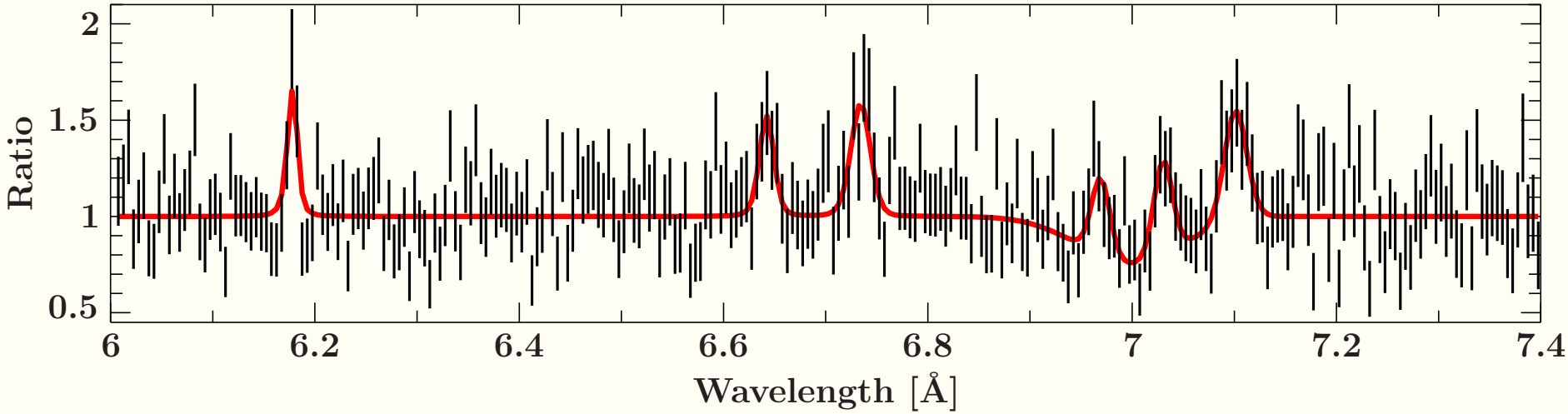


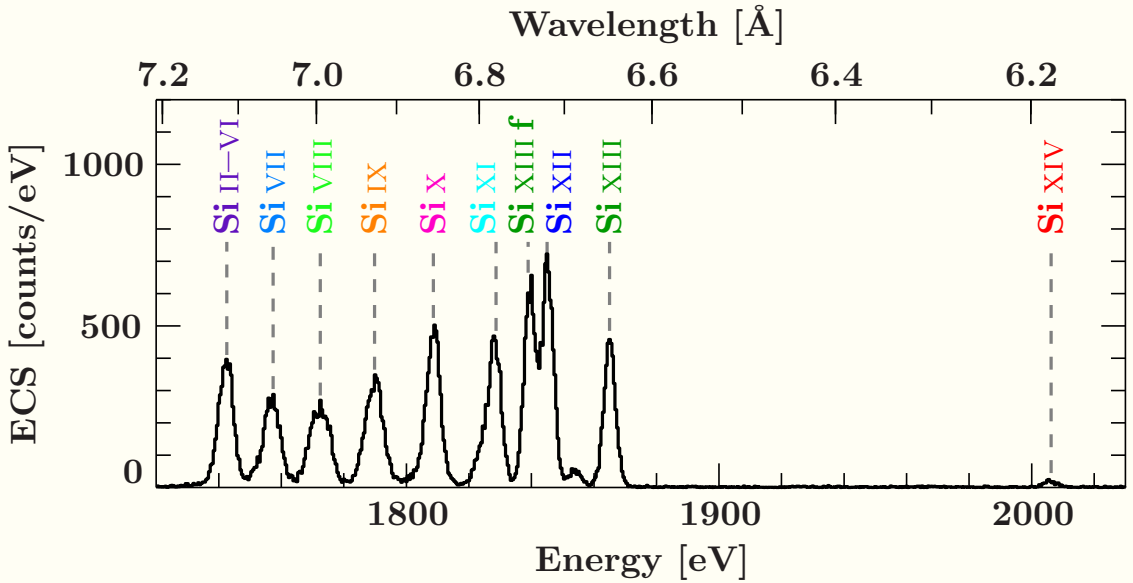
no Si lines except of Si XIII triplett have been previously detected in the composite spectra (Goldstein et al. 2004)

lines in the high hardness/high absorption spectrum

complex structure in low absorption spectrum

Si region





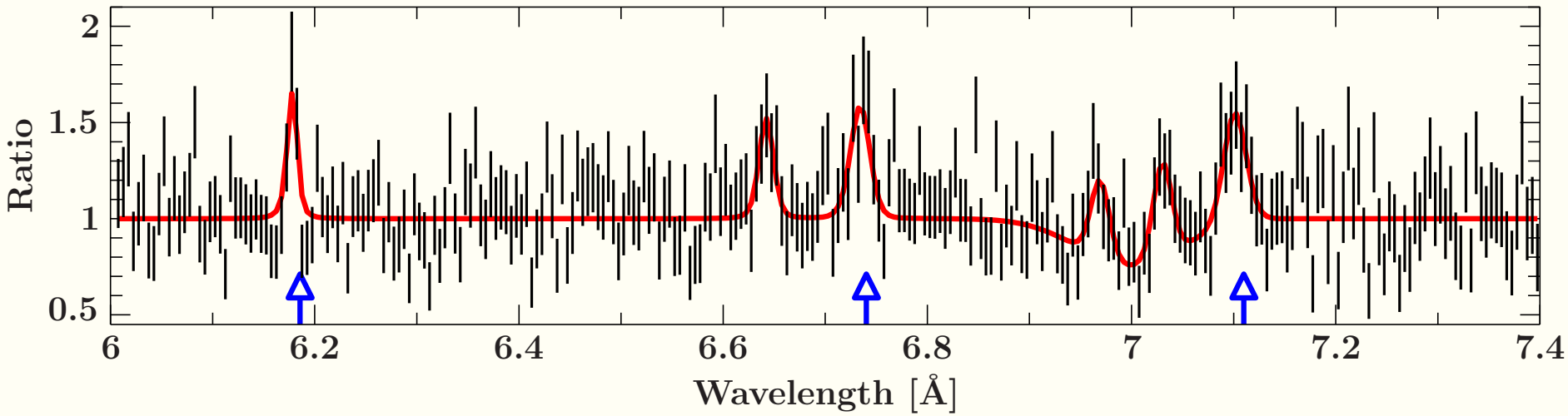
EBIT measurements; see talk by N. Hell

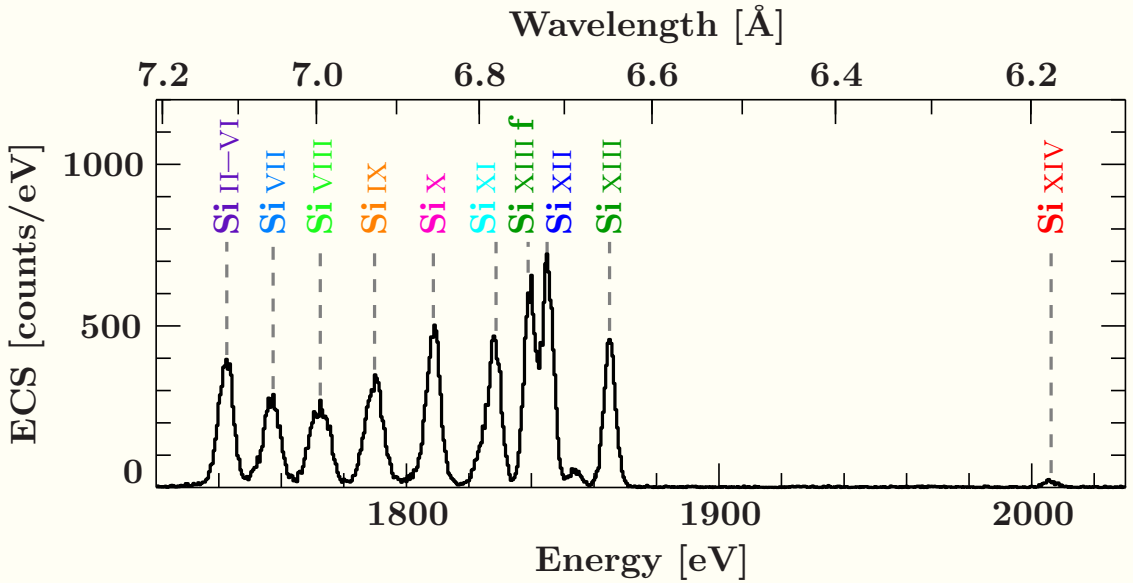
high hardness/ high absorption

$v \approx -300$ km/s for high ionization lines

$v \approx -1000$ km/s for low ionization lines

Si region





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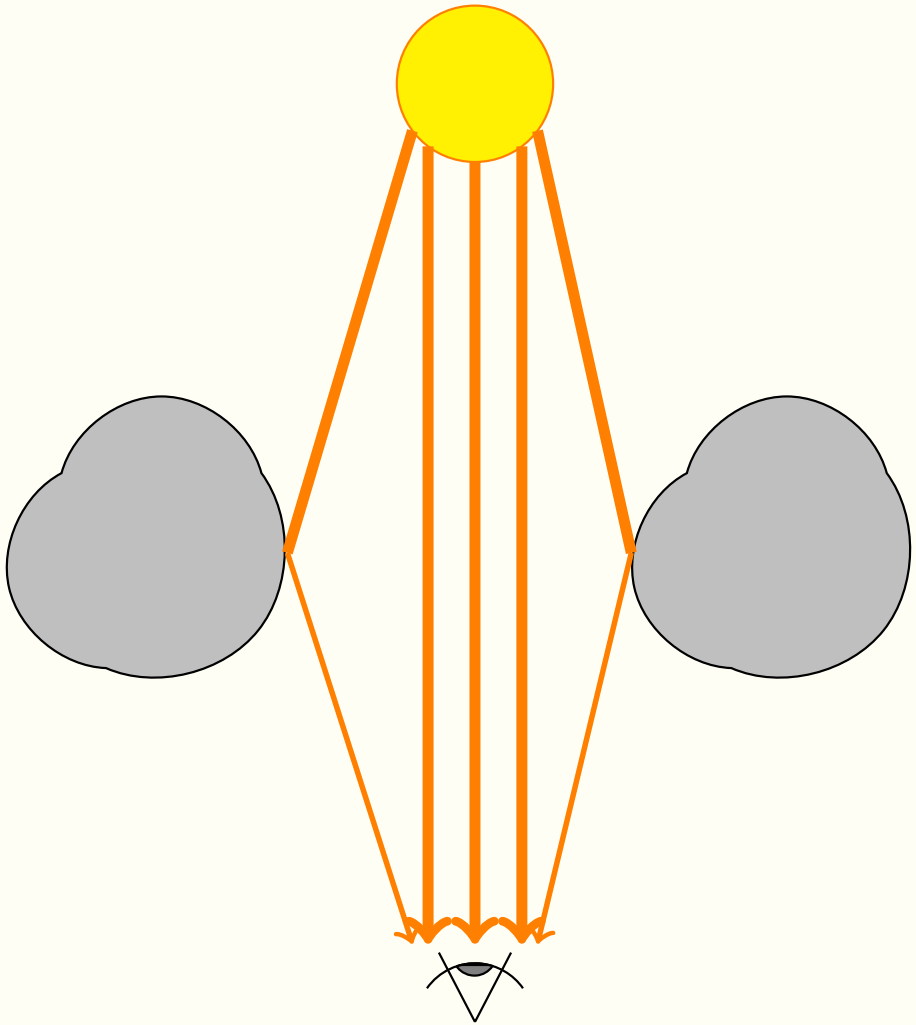
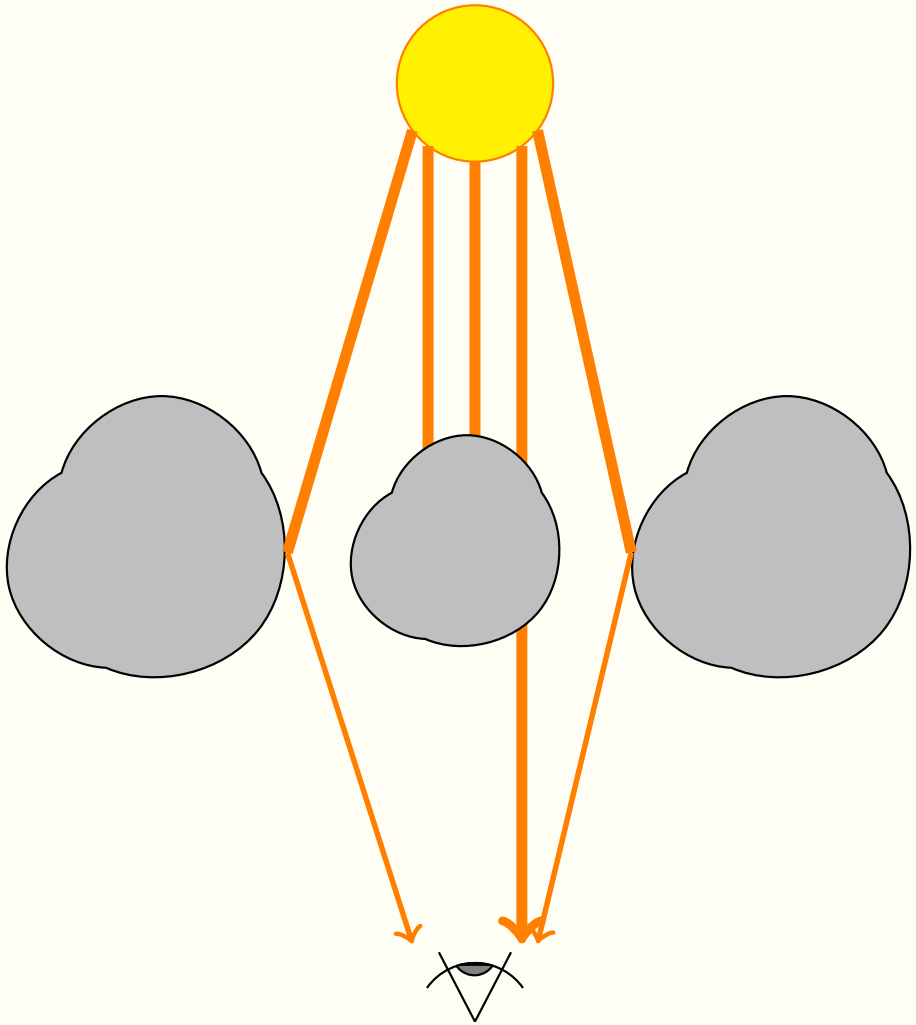
Toy geometry



low hardness/absorption

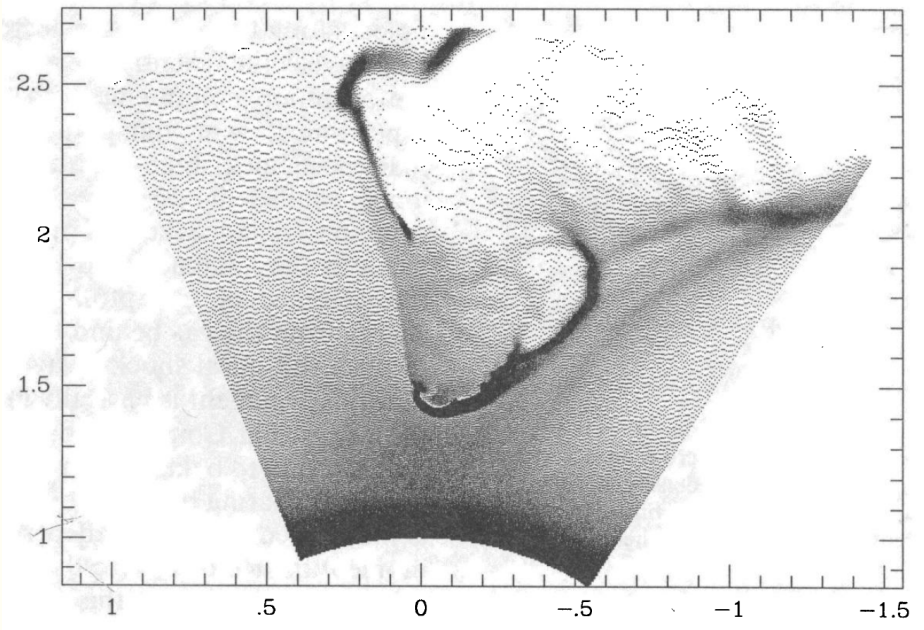
Toy geometry



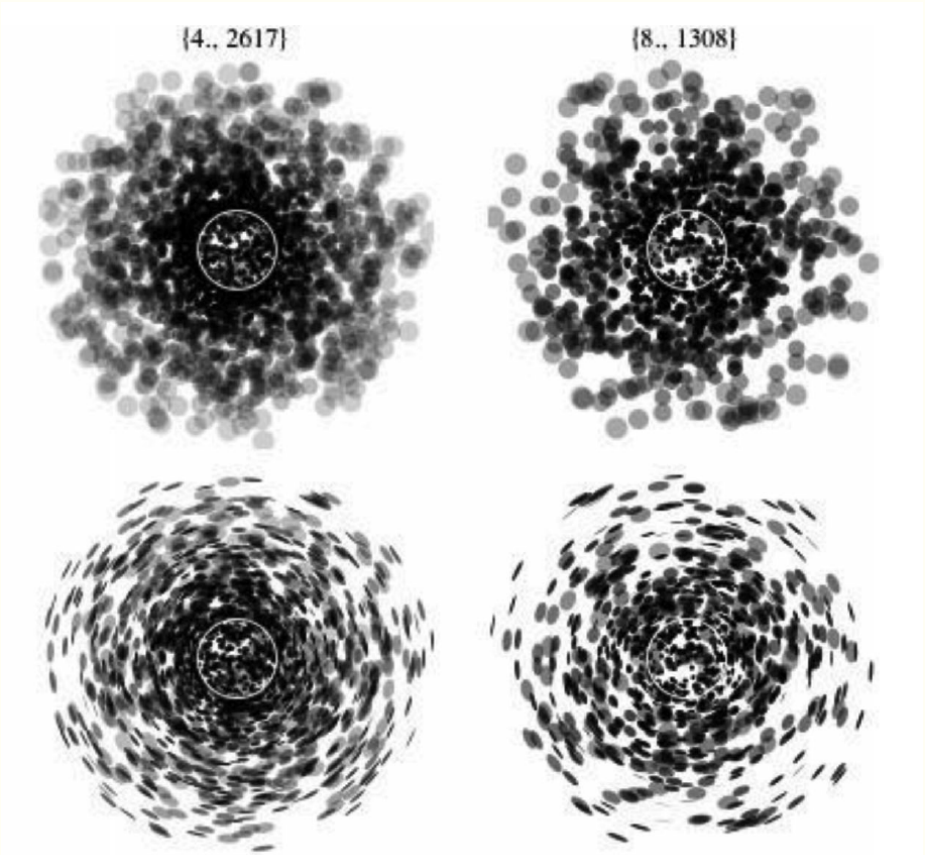
high hardness/absorption

- clumps coming into the line of sight
- reduced continuum, makes fluorescent lines visible
- but also: possible different absorption in the presence of the clumps?
- wind clumps or a patchy accretion wake?

Absorption variability time scales



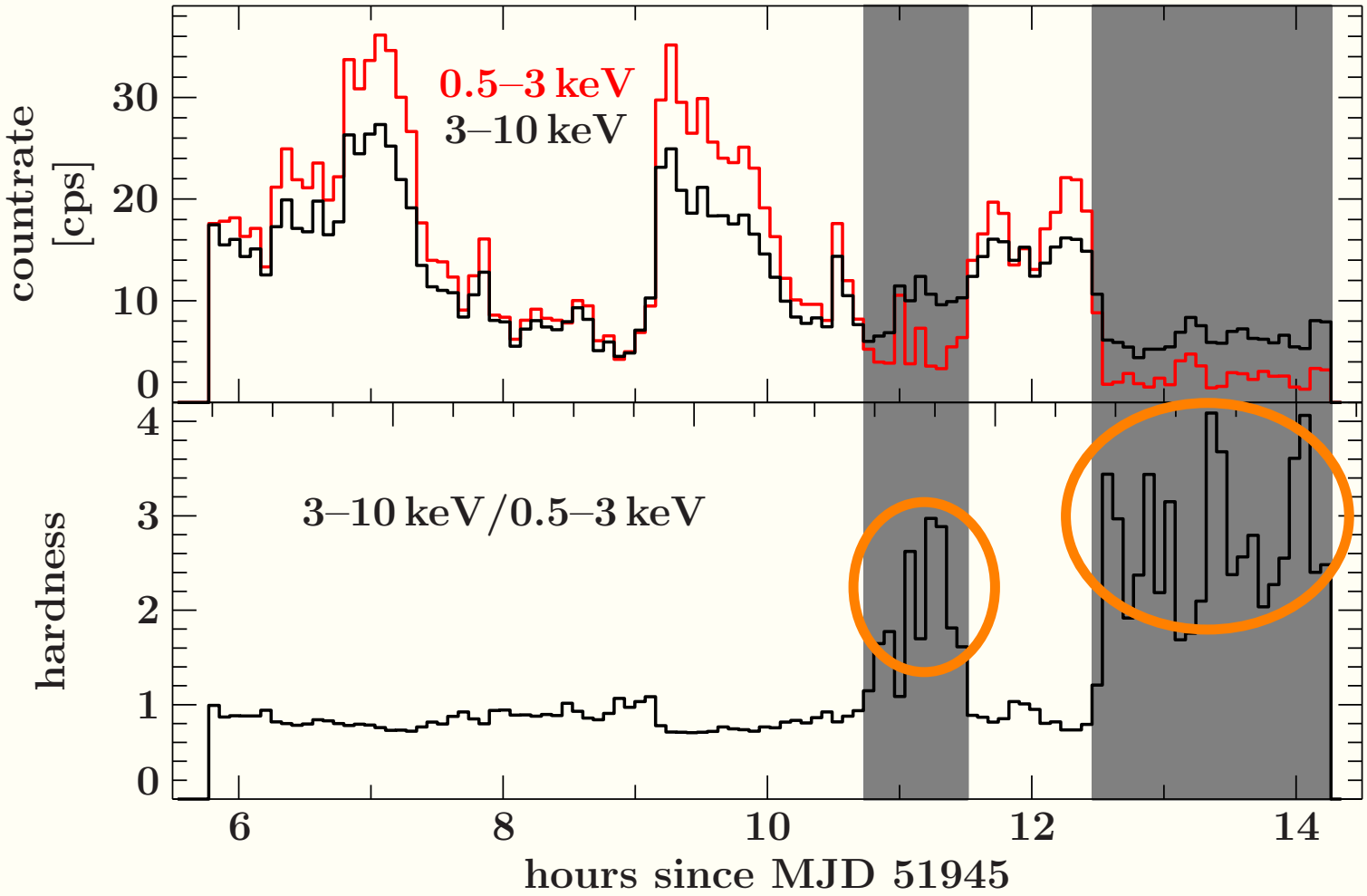
(Blondin et al. 1990)



(Sundqvist et al. 2012)

- 2D hydro simulations $\Rightarrow$ consistent time scales
- wind clump timescales?

Even shorter timescales?



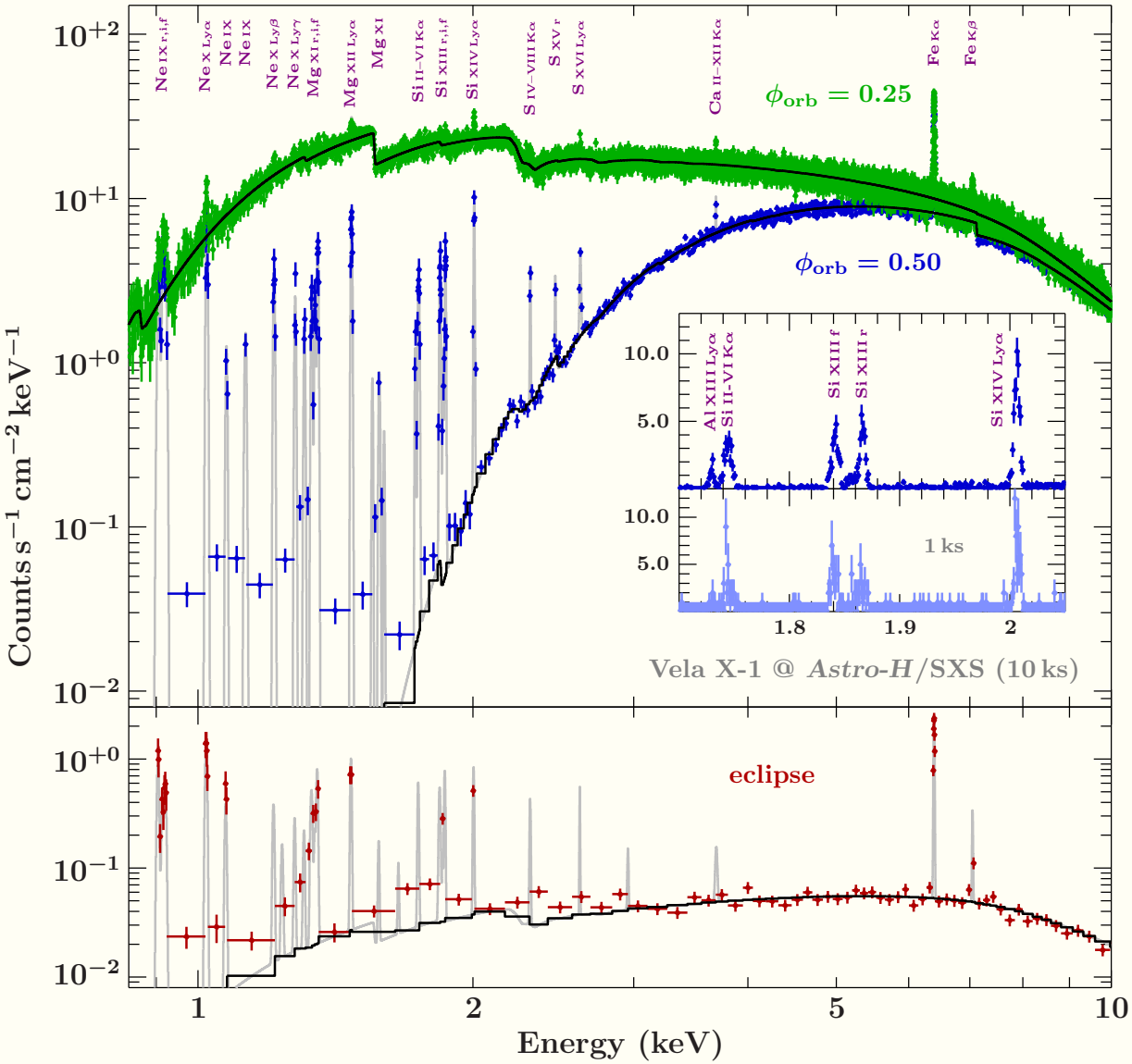
⇒ shorter-term variability not yet accessible, but possibly crucial

Outlook: *Chandra* & *Astro-H*

***Chandra*-HETGS**
$\sim$180 ks at
$\phi_{\rm orb} = 0.15$–0.45
forthcoming

Astro-H
higher effective area, but lower energy resolution in Si-region

Athena?
potential to resolve down to timescales of 100 s at $\phi_{\rm orb} \approx 0.5$



Kitamoto et al. 2014; plot by M. Kühnel & N. Hell

Summary

- absorption variability on short timescales influences high resolution data
- low charge states of Si visible during high absorption / high hardness periods
- variability possibly sign of clumps passing through the line of sight
- disentangling the different absorption stages will be crucial to understaning structure close to neutron star