

Absorption resolved spectroscopy (using HMXBs as an example)

Victoria Grinberg, IAAT Tübingen



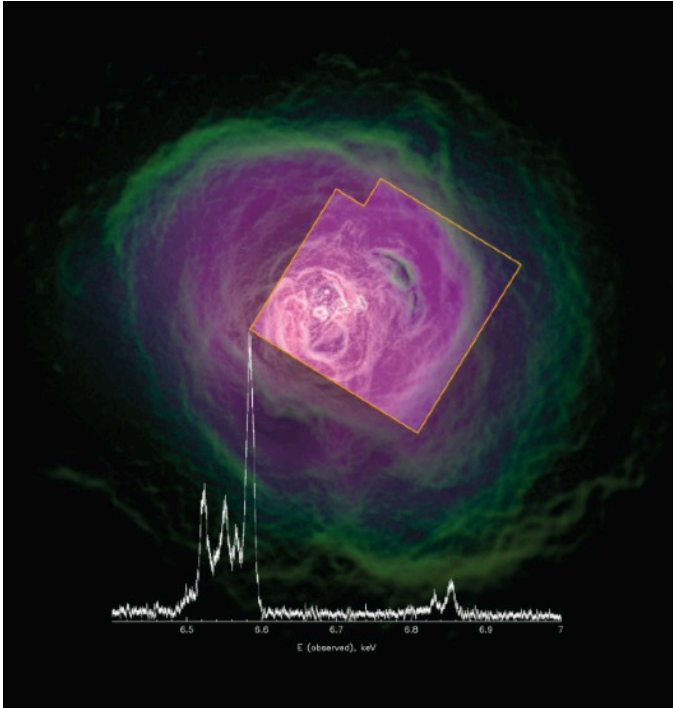
time resolved \Rightarrow absorption resolved

1. How do we disentangle absorption in HMXBs?
2. Why is this important for high resolution spectroscopy?

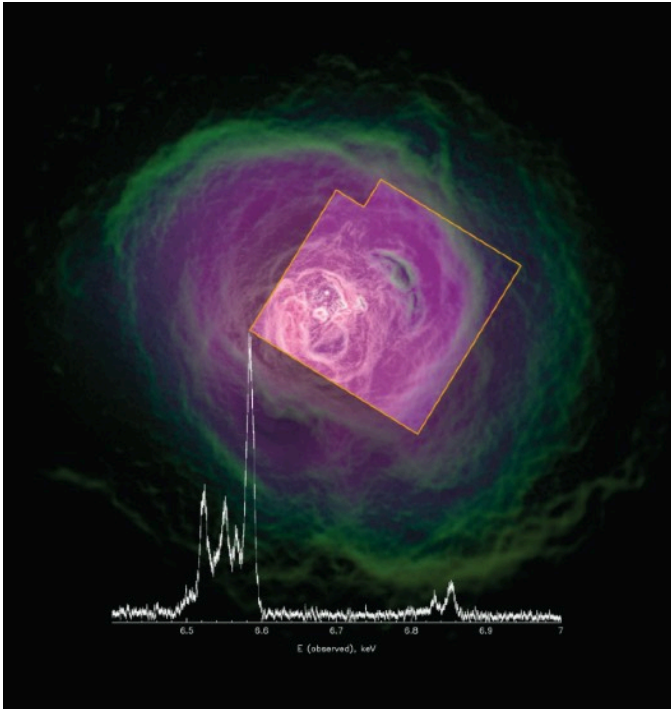
caveat 1: compared to previous talks, this is a bit more about how to prep your data for high resolution spectroscopy than actual narrow feature modelling

caveat 2: I discuss HMXBs, but could also be applicable to other sources, e.g., absorption by warped disks in LMXBs, long-term monitoring of AGN with clumpy torii ...

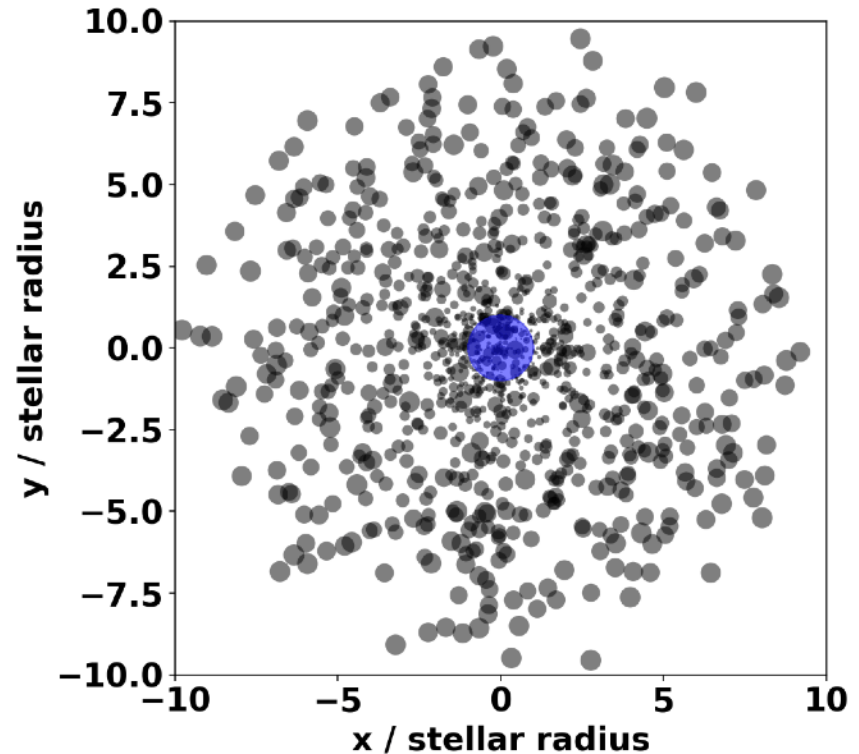
Discussion based on Hirsch et al. 2019 & Grinberg et al. 2017, hands on part from Grinberg et al. 2017



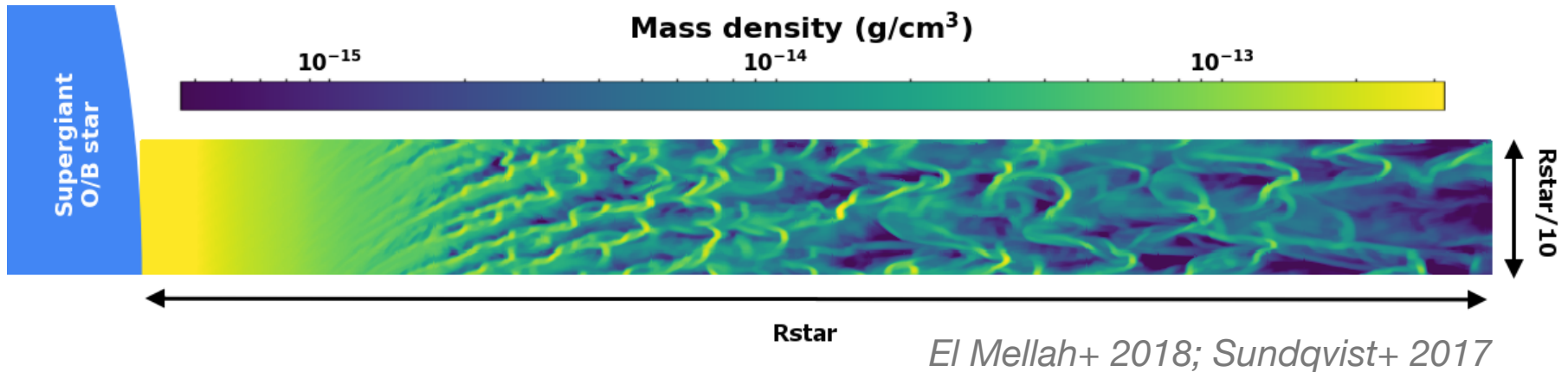
spectral properties
do not change on timescales
of single observations



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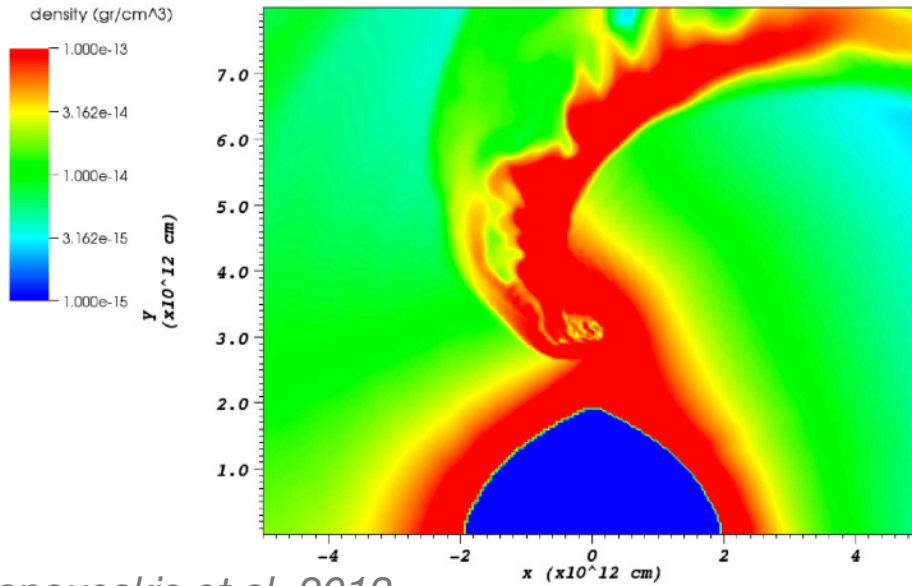
spectral properties
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Line-driven winds:

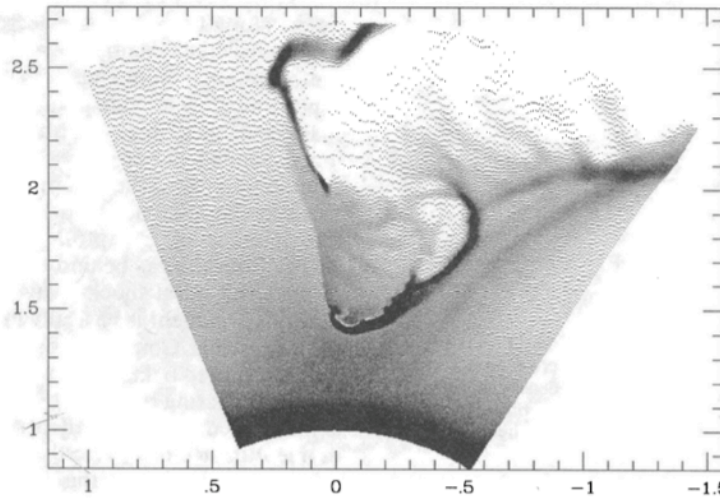
- mass loss
 $10^{-7} - 10^{-4} M_{\odot}/\text{yr}$
- terminal velocity up to
3000 km/s

unstable to **velocity perturbations**
 \Rightarrow rapid growth of perturbation
 \Rightarrow strong shocks
 \Rightarrow **wind clumping**



Manousakis et al. 2013

NS/BH disturbs the wind, resulting in large-scale wind structure (accretion and photoionization wakes, focussed wind)



Blondin+ 1990



Wind properties:

- clumps: structure, size, shape & occurrence
- clumping onset
- wind acceleration zone
- wind's response to changes in irradiation

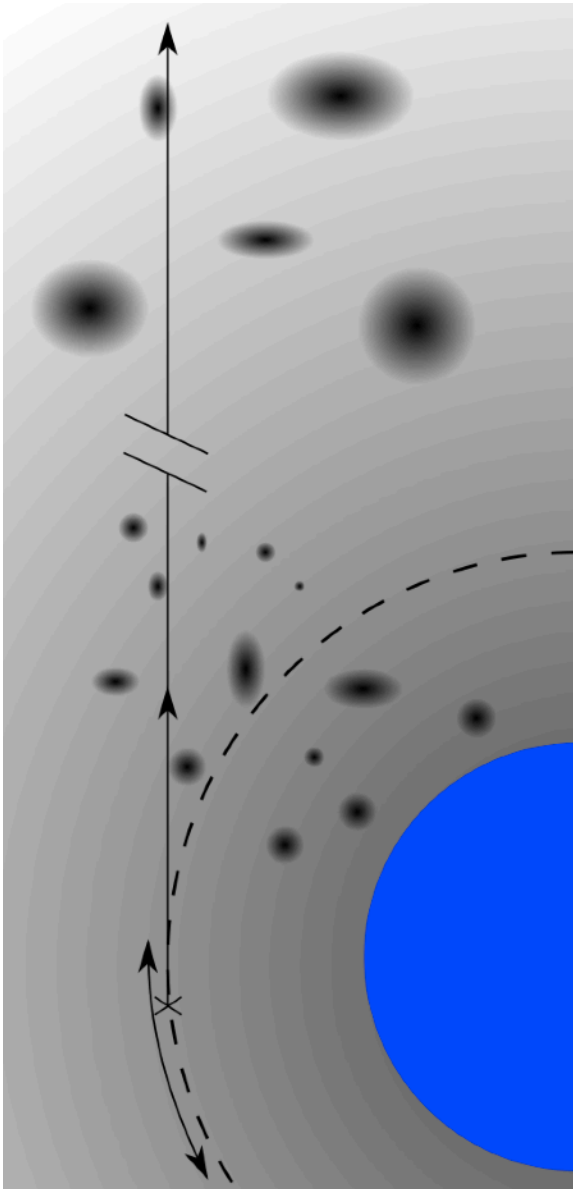
Accretion structure:

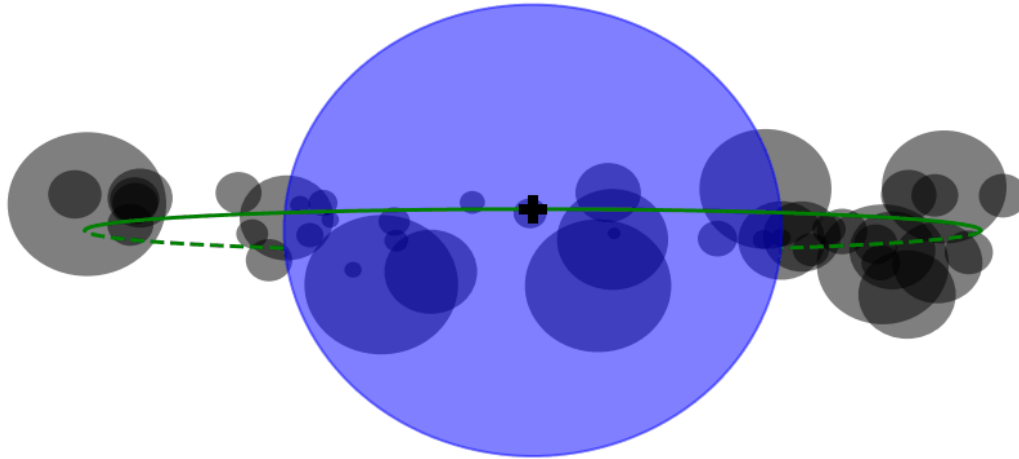
- accretion & photoionization wake structure
- clumpy accretion
- disk formation

transferable to any other system with variable absorbers whose properties we want to know

stellar winds & HMXB review: Martínez-Núñez+ 2017

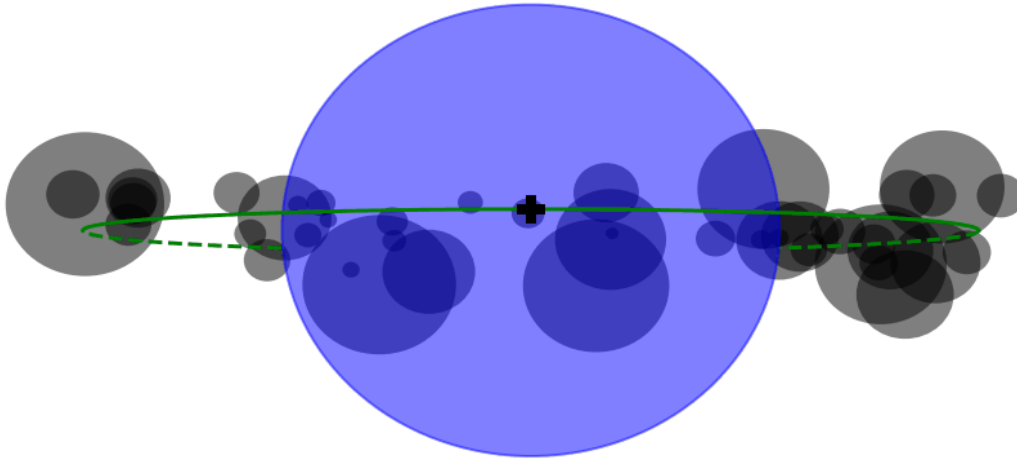
Grinberg+ 2017





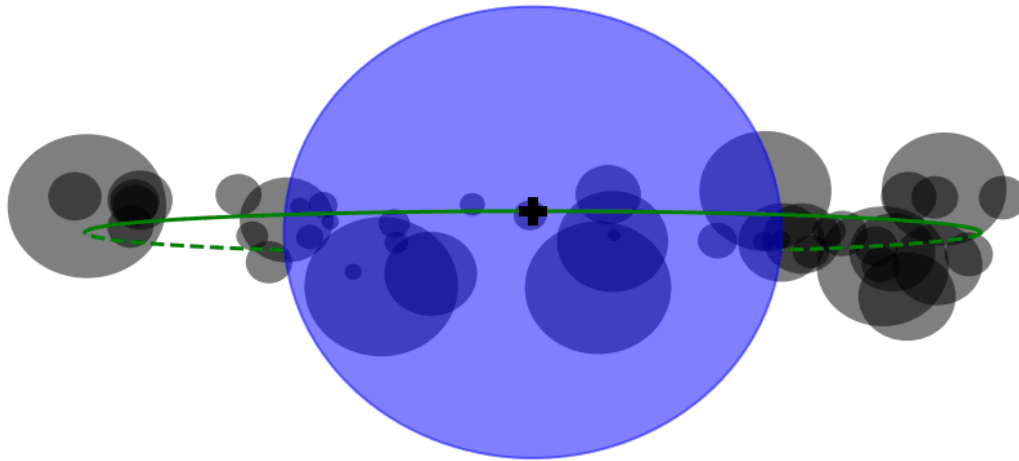
varying absorption as
clumps pass through
the line of sight

El Mellah, A&A subm., arXiv:2006.16216



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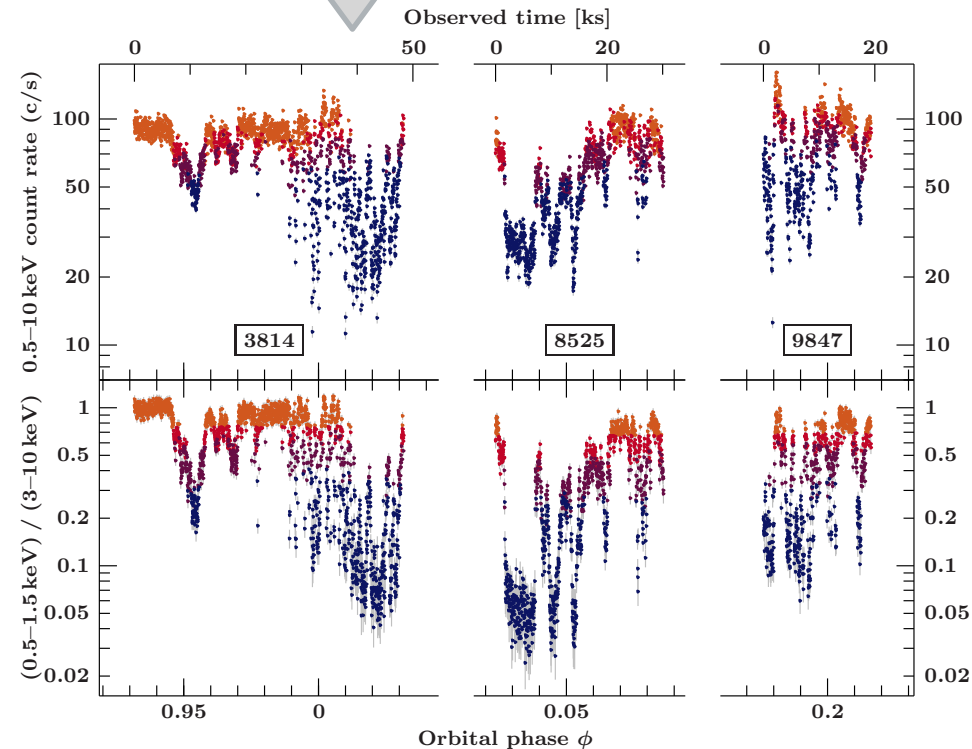


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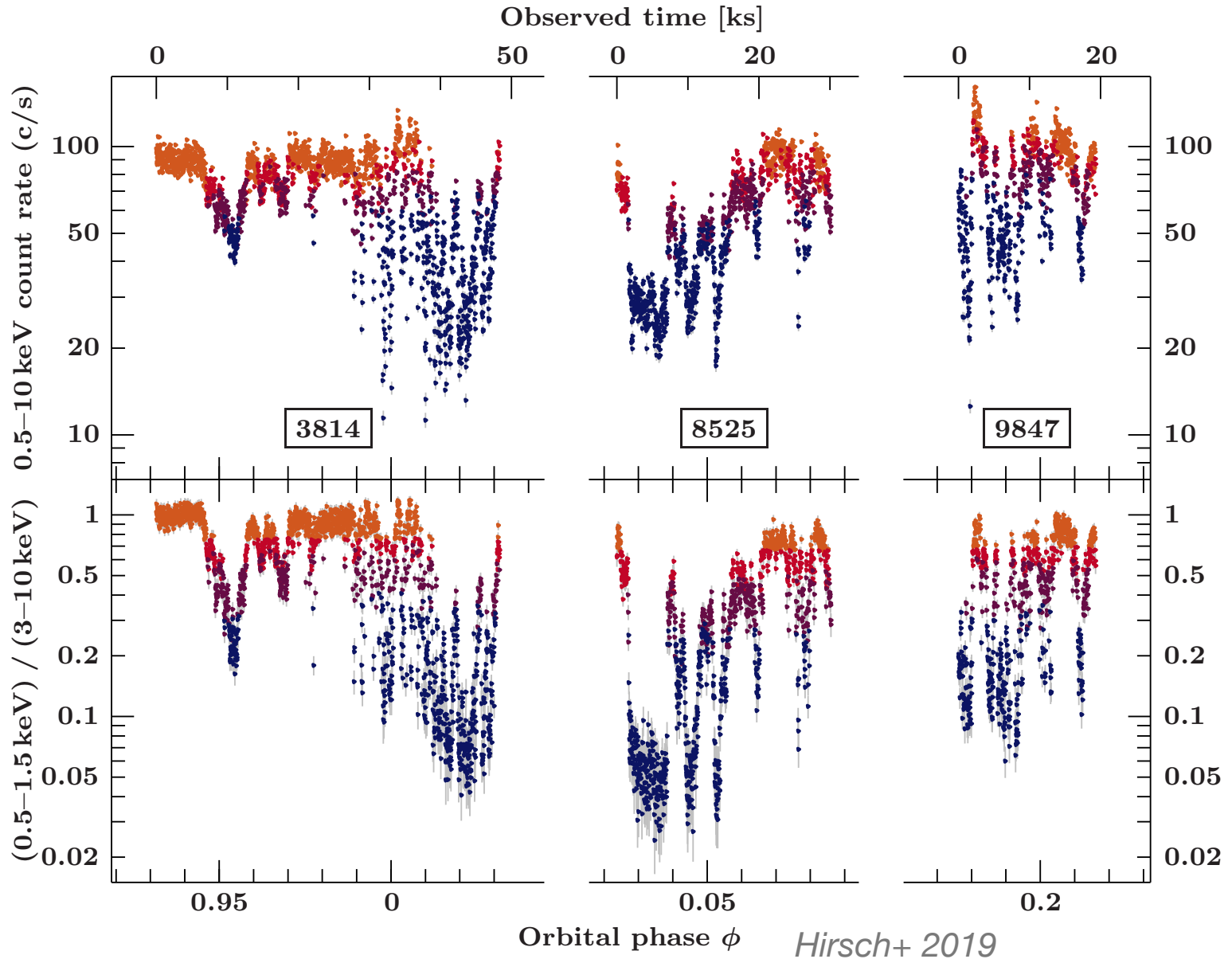
Typical clump crossing times
~a few 10s-100s
⇒ not accessible with
today's high res instruments
⇒ chance to probe the
structure of clump plasma

Hirsch+ 2019





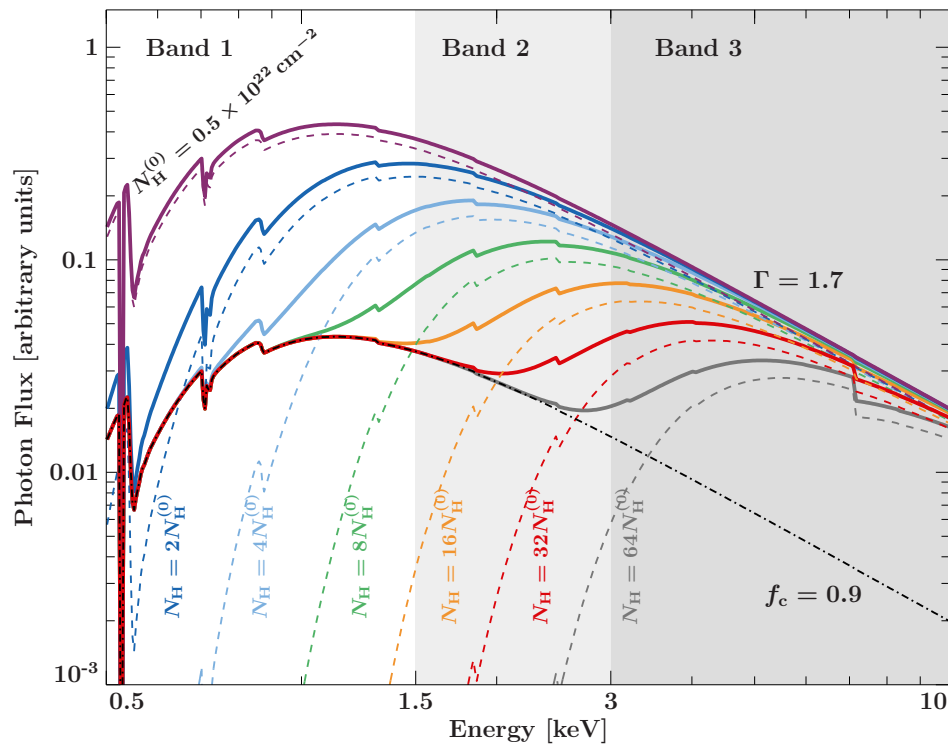
Cyg X-1: Absorption variability patterns





Partial coverer:

- spatial
- temporal
- scattering halo



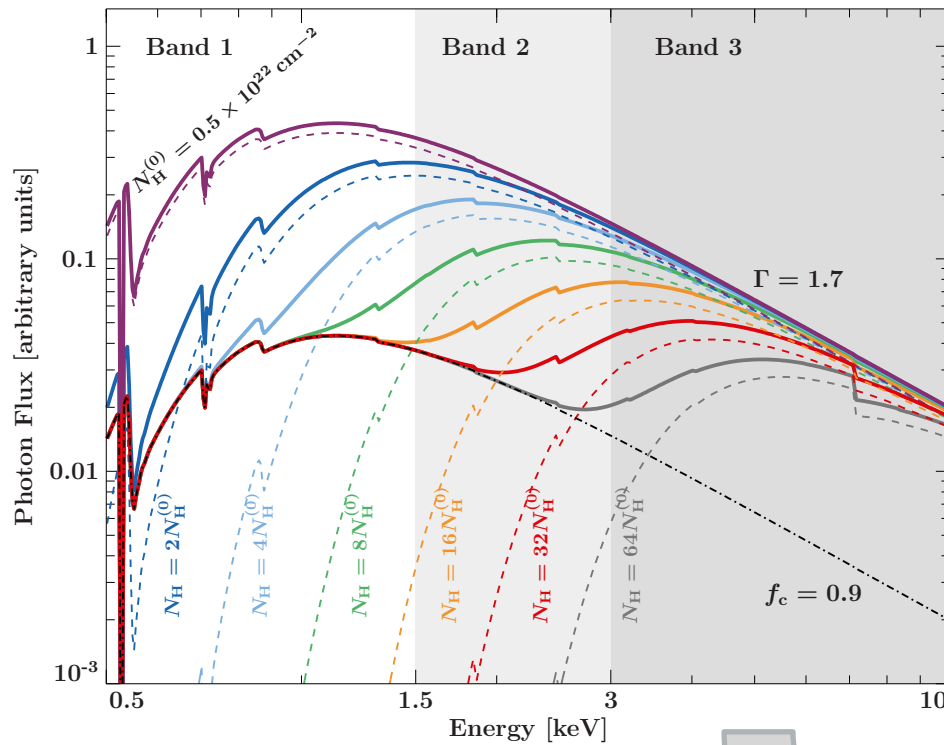
after: Hirsch+ 2019

Grinberg+ in prep.

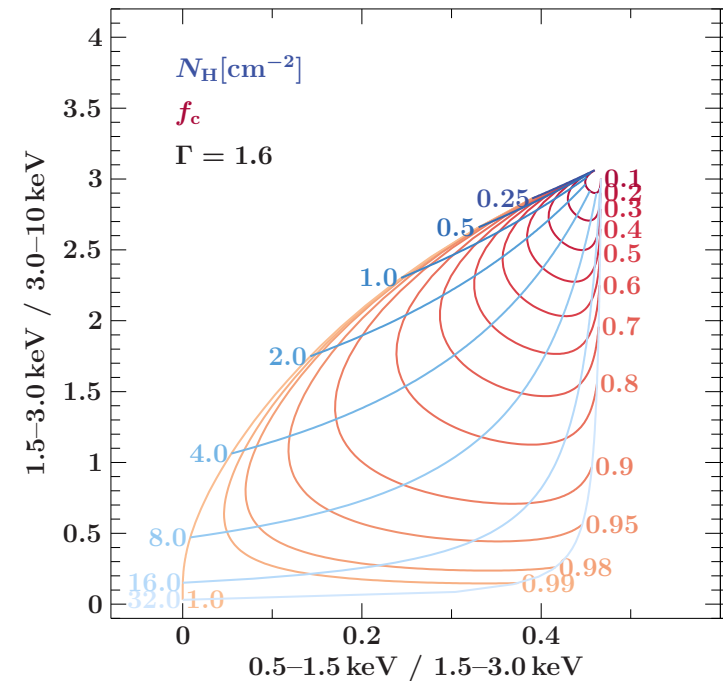
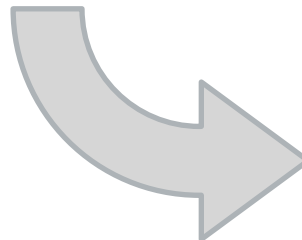


Partial coverer:

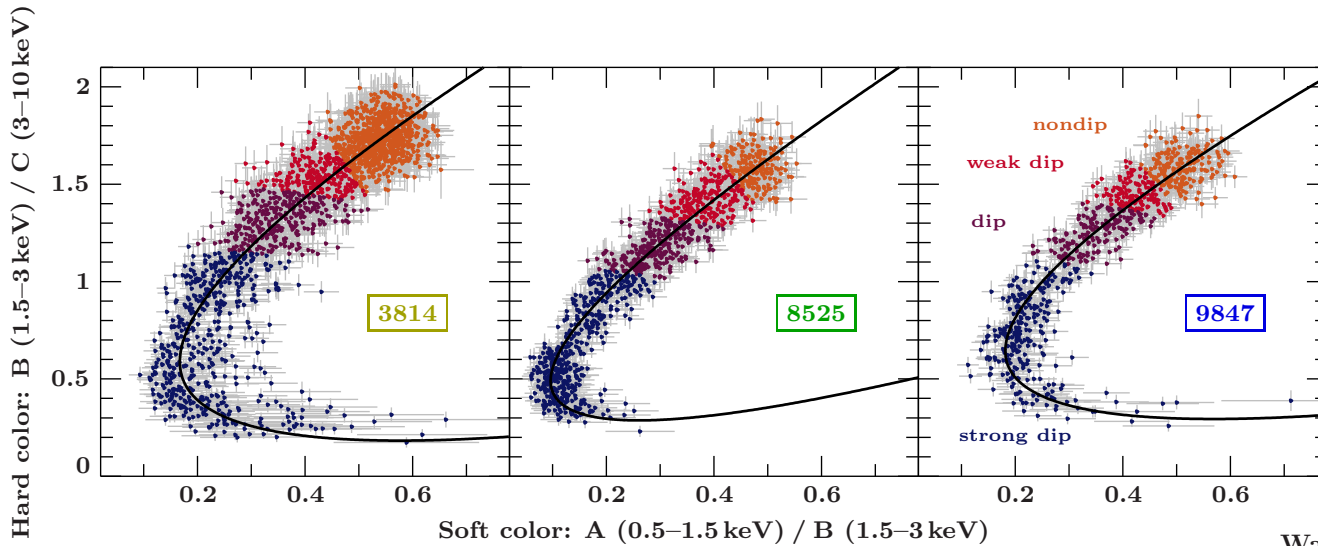
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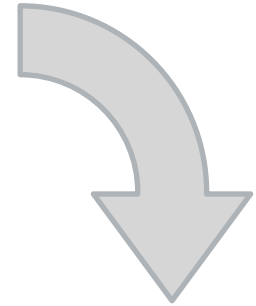
after: Hirsch+ 2019



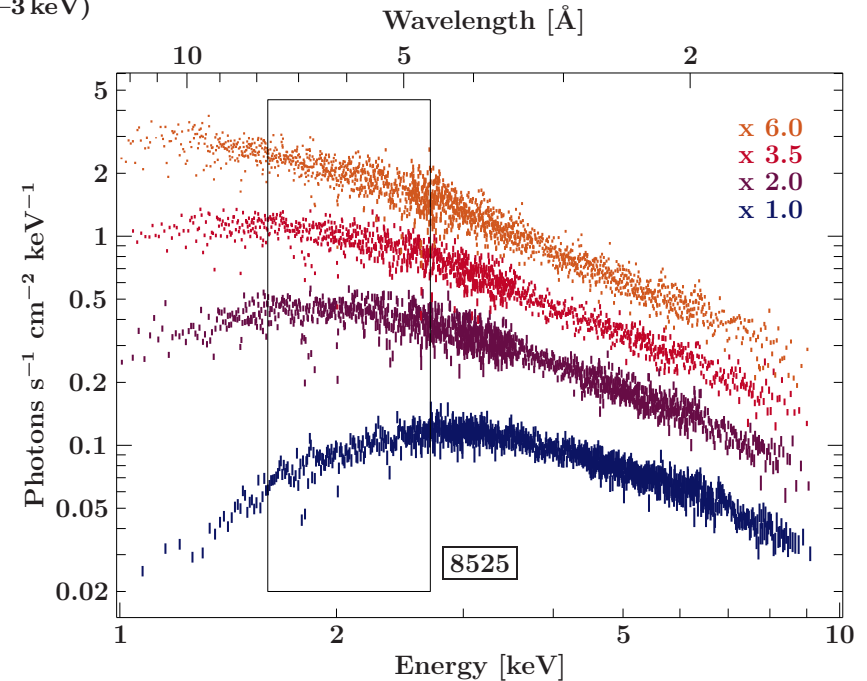
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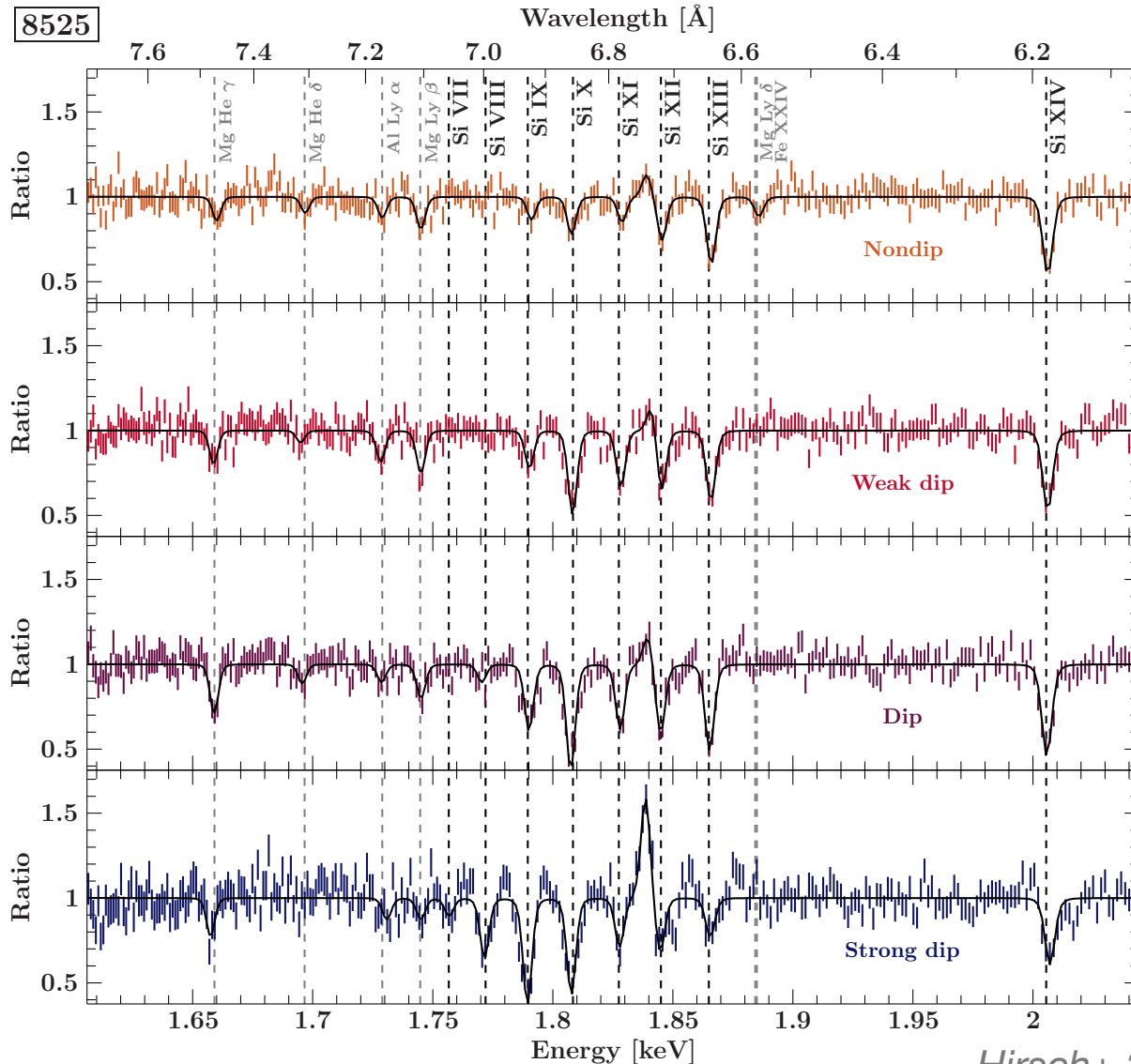


Hirsch+ 2019



cuts in color-color space
⇒ same continuum shape,
different absorption



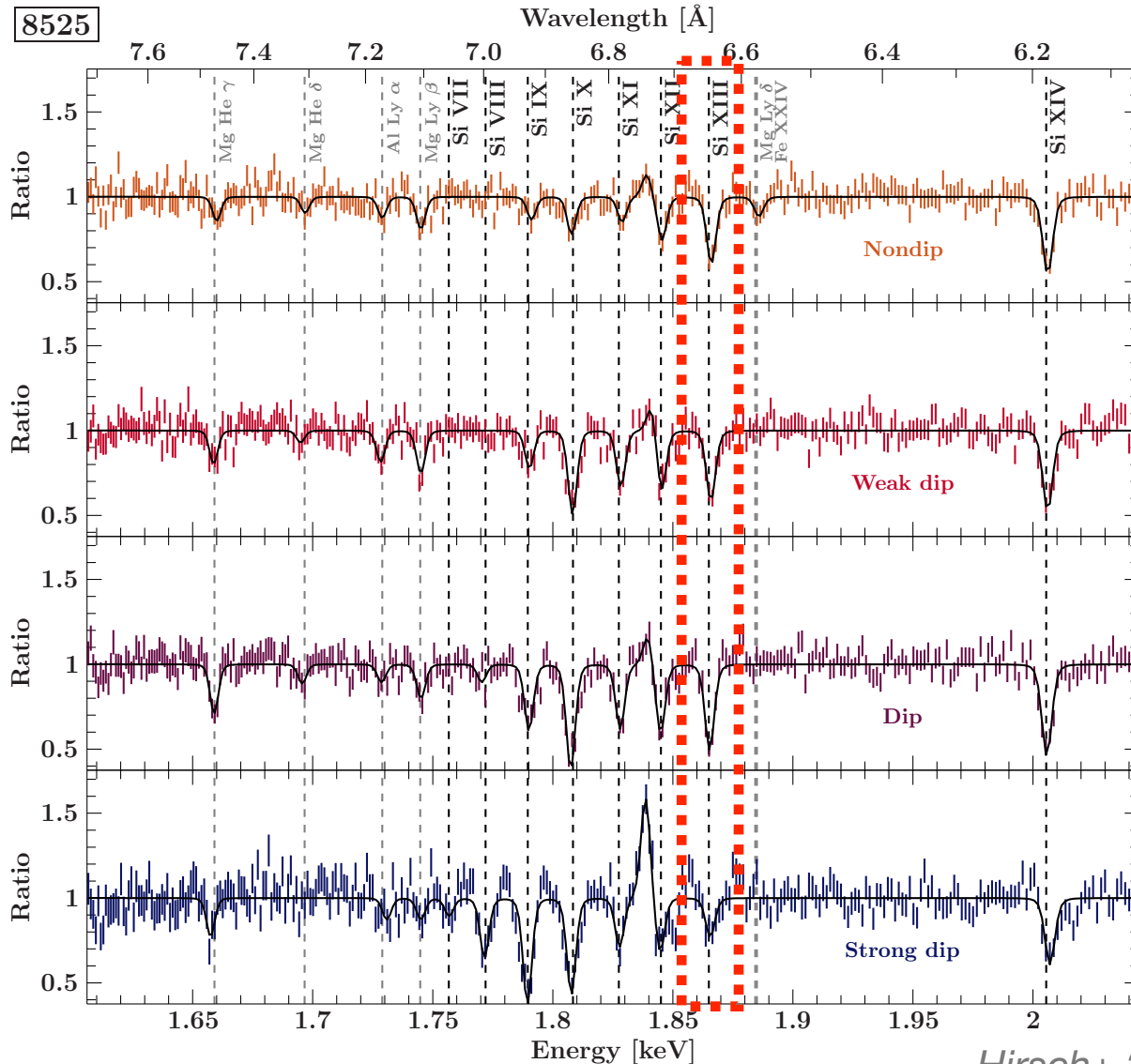


Hirsch+ 2019

divided in four
absorption stages
using color-color
diagrams

stronger
absorption
⇒ lower ionization
stages of Si & S

same Doppler-shift
for all lines

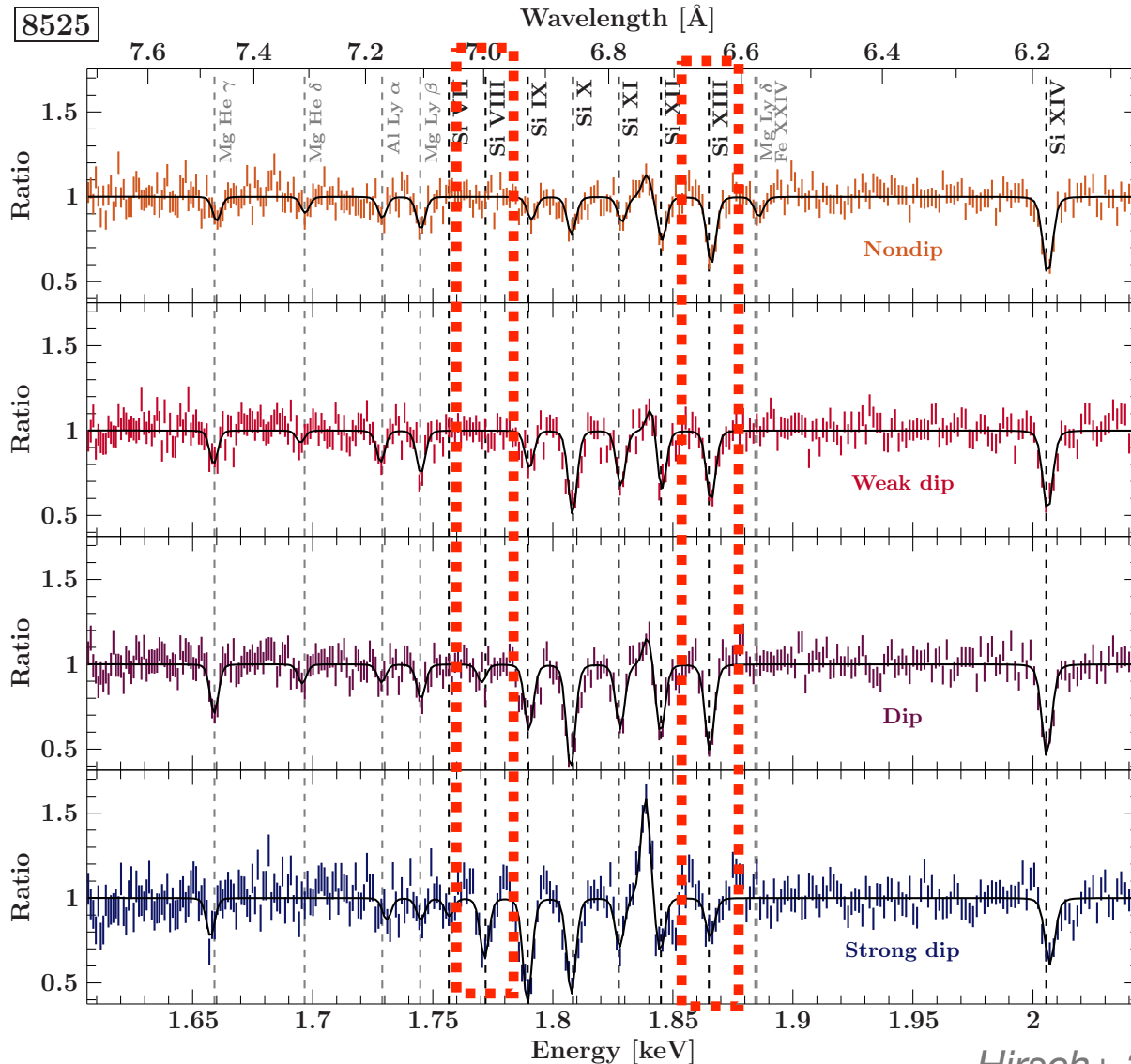


Hirsch+ 2019

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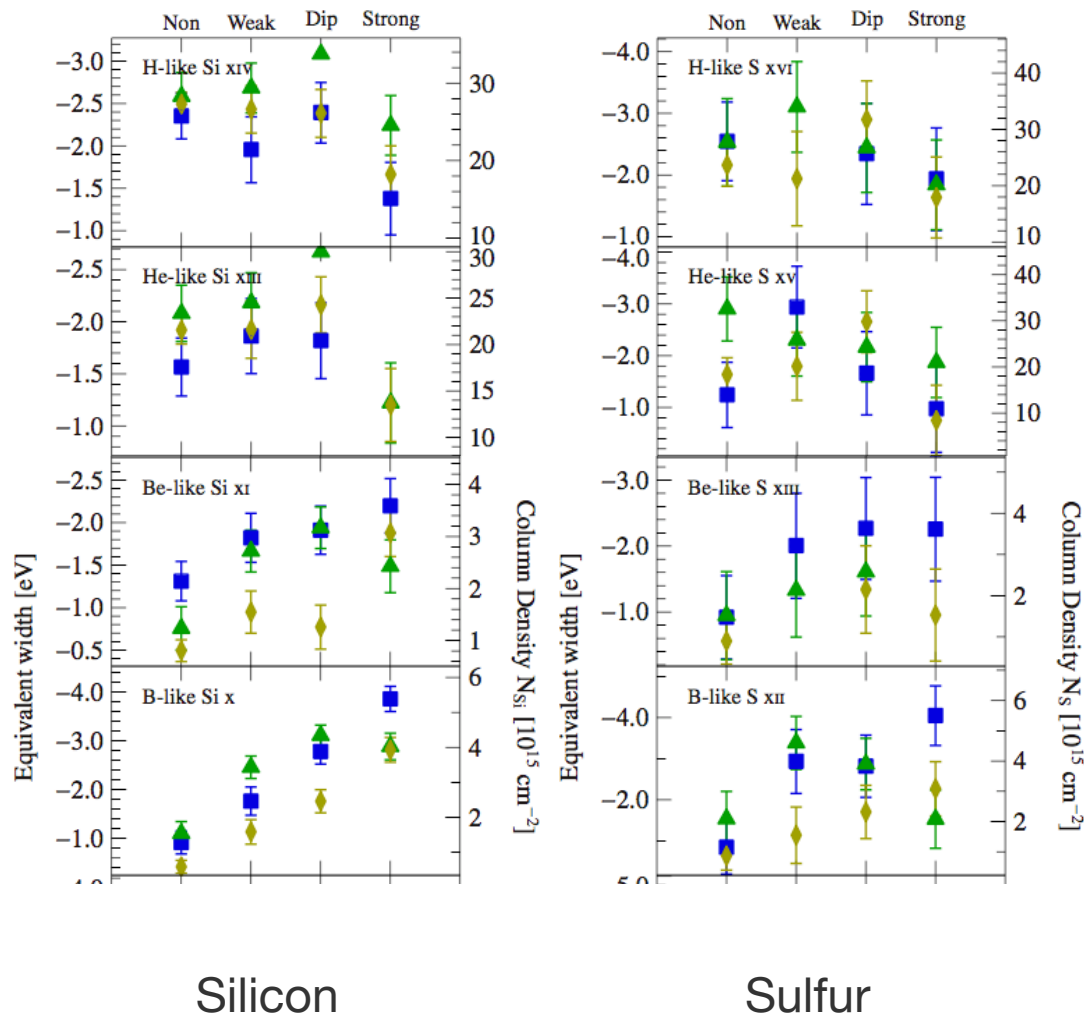


Hirsch+ 2019

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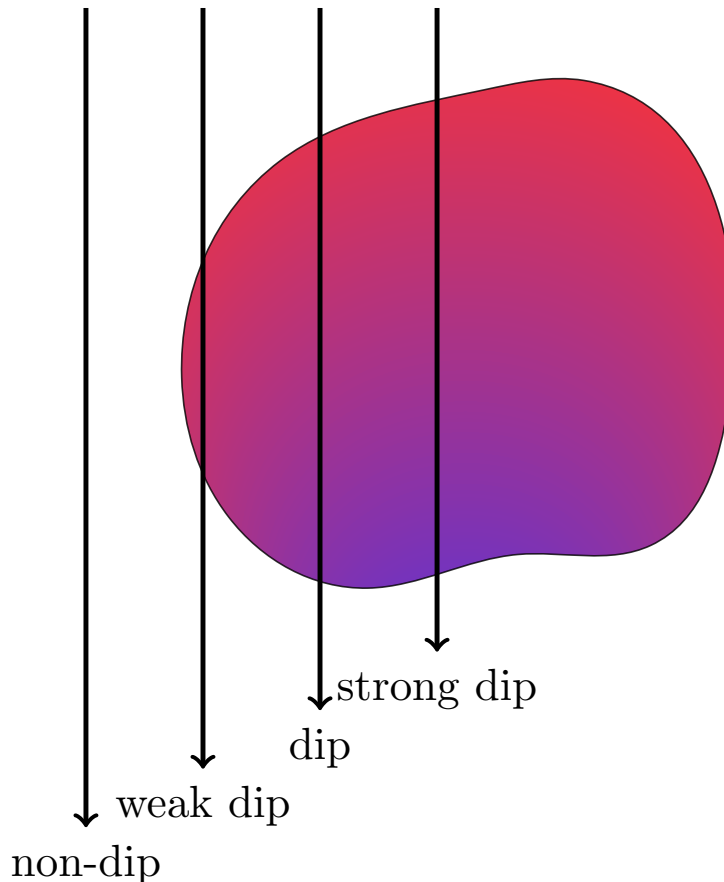
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Cyg X-1: Clump structure

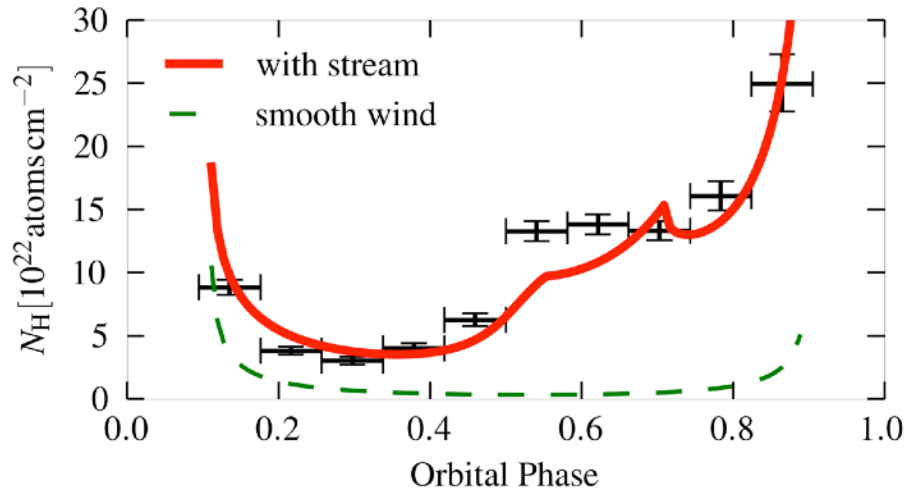


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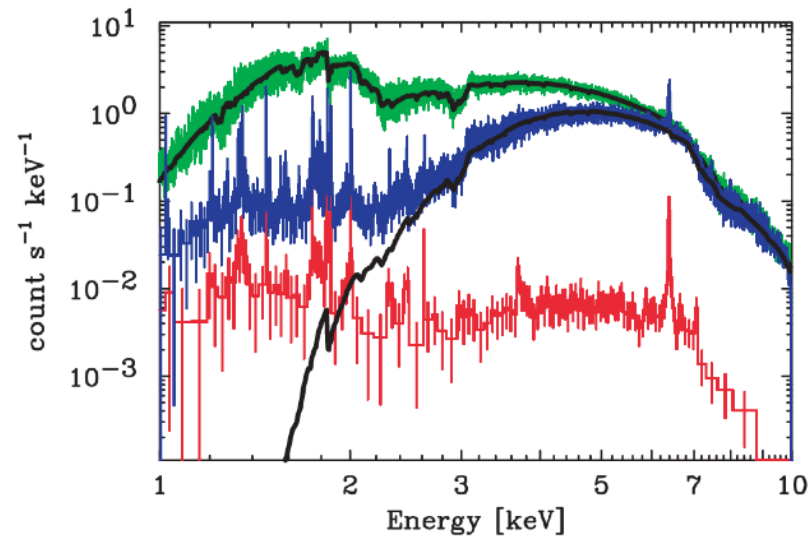
same Doppler-shift
for all lines

⇒ structured clumps
with cold cores



+ orbit to orbit variability

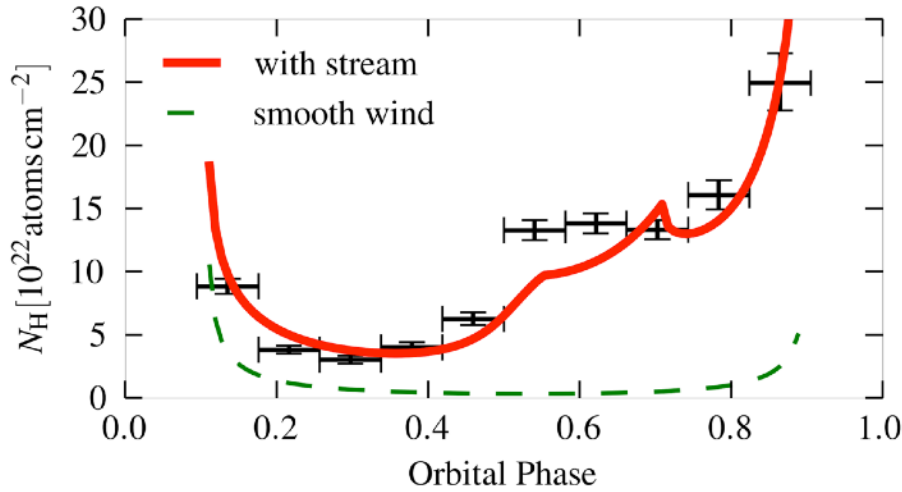
Doroshenko + 2013



Watanabe + 2006

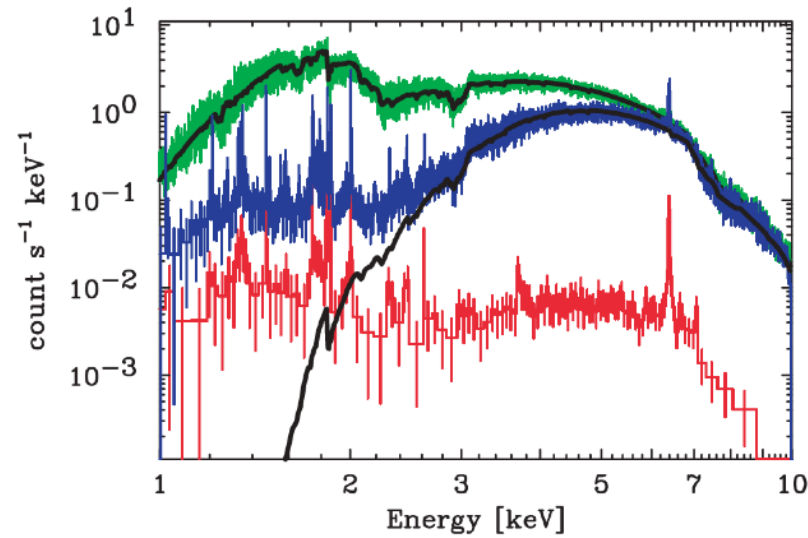


Orbital variability of absorption

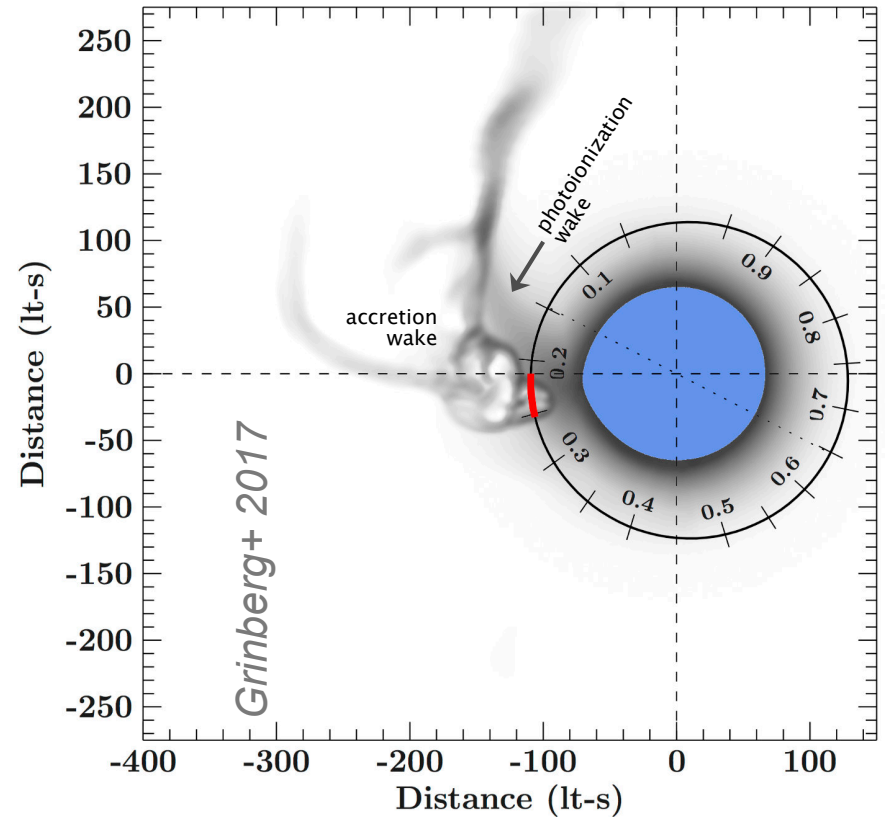


+ orbit to orbit variability

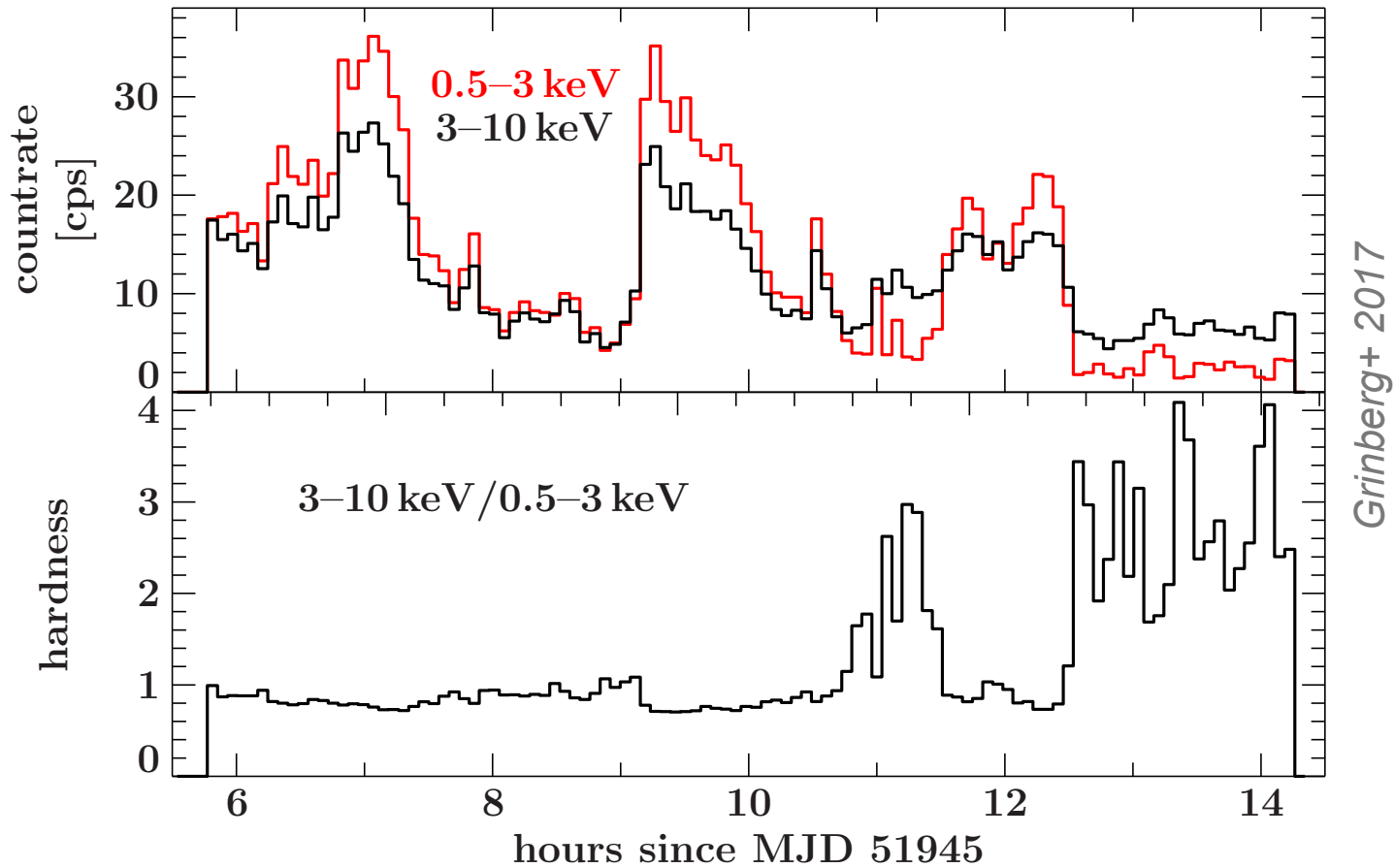
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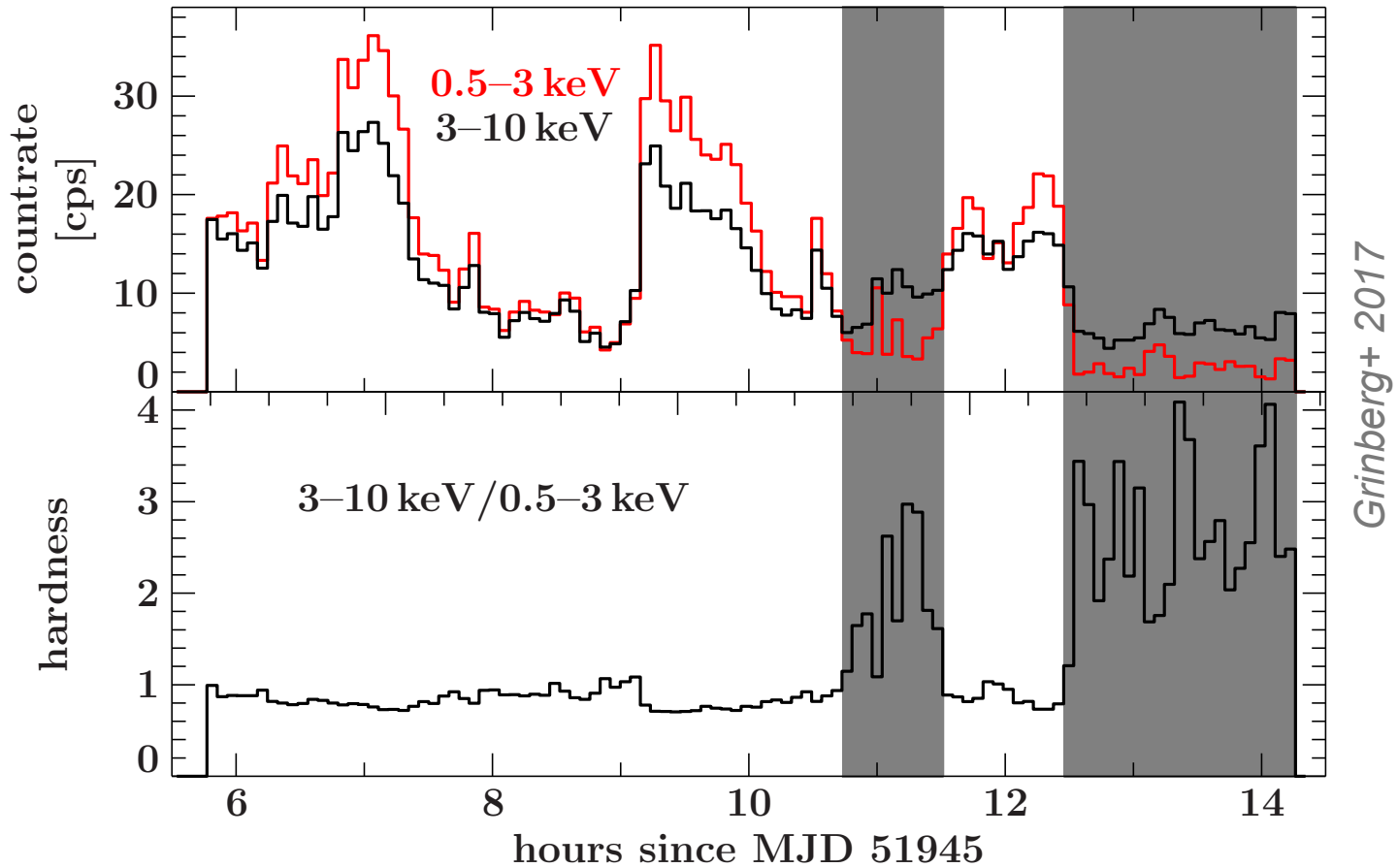


Grinberg + 2017



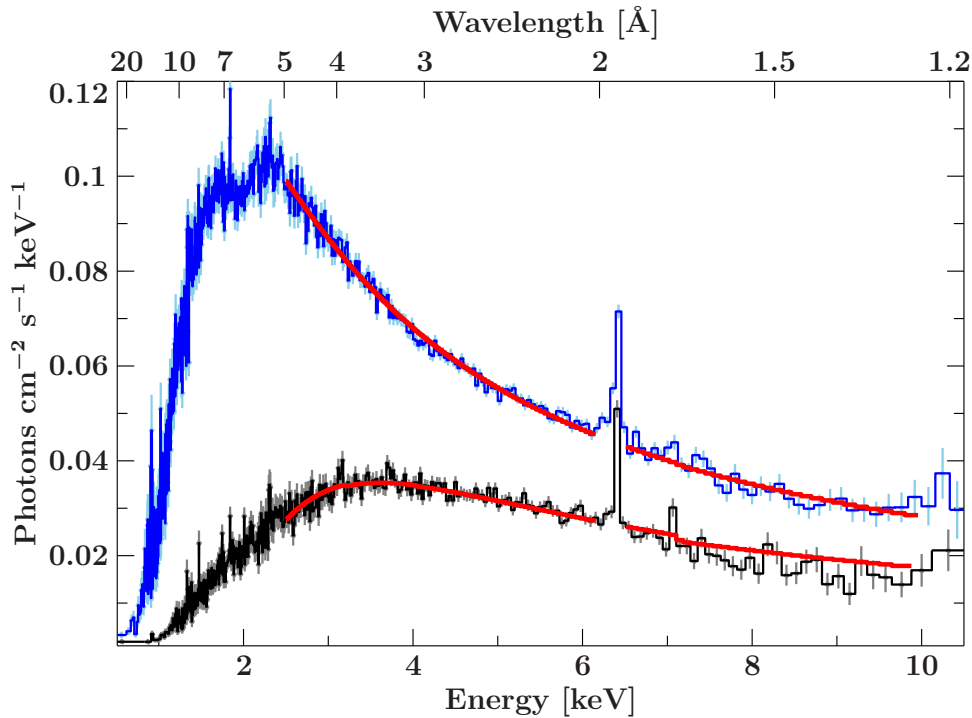
ObsID 1928, Feb 11 2001

⇒ clearly defined periods of enhanced hardness



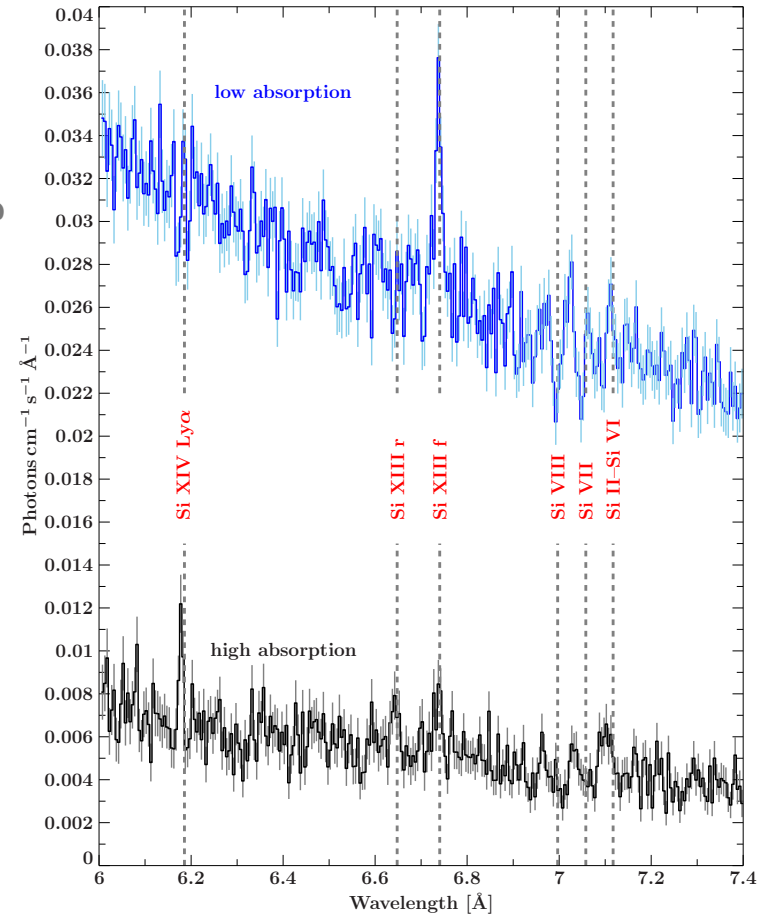
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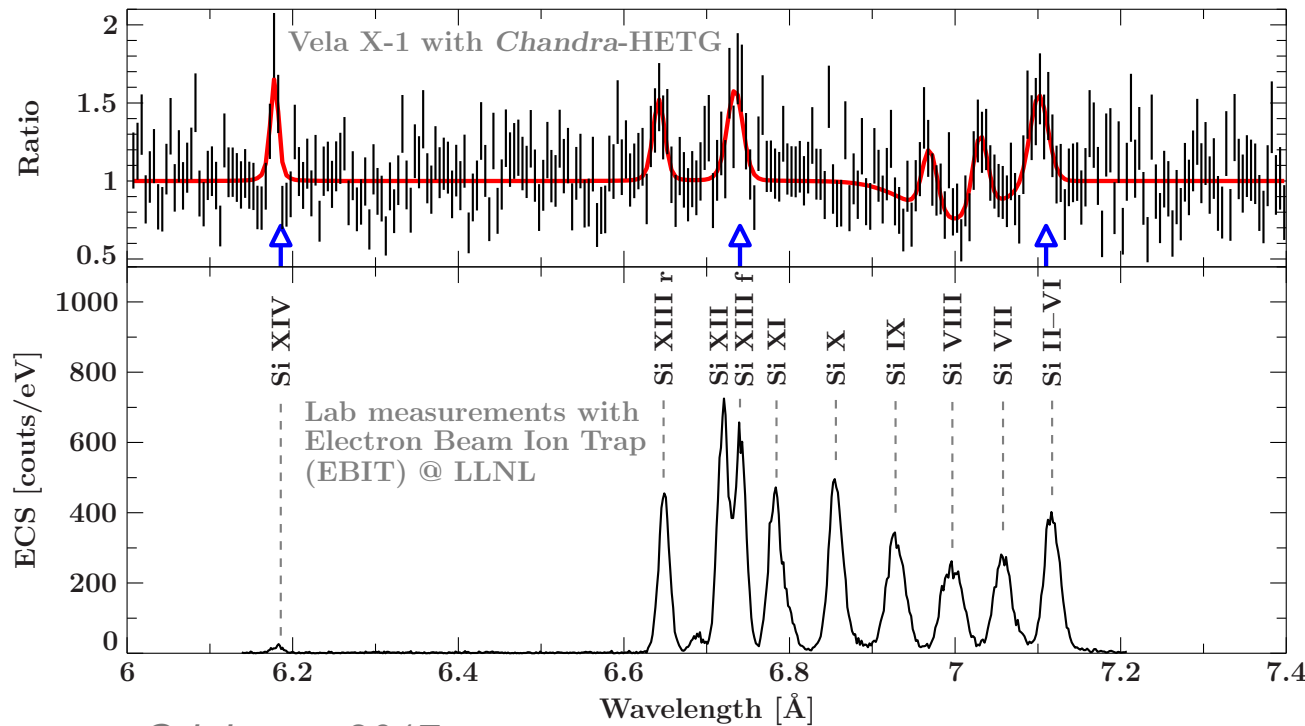
changes in continuum shape driven by changes in absorption

Grinberg+ 2017





periods of enhanced absorption:



Grinberg+ 2017

high & low ionization
ions present
⇒ hot & cold(er) gas
present

*For CLOUDY + SPEX
modelling at orbital
phase ~ 0.75 ⇒ Amato
et al. to be submitted*

highly ionised hot part of the wind vs. colder clumps
⇒ shocks? clump interaction with compact object?



Aim:

get a feeling for the absorption-resolved analysis of the HMXB Vela X-1 in Grinberg+ 2017

Step 0:

- time-averaged spectra (with tgcat)

Step 1:

- lightcurves
- gti creation

Step 2:

- absorption-resolved spectra
- Bayesian Block methods for narrow feature detection