Effects of clumpy stellar wind in the microquasar Cyg X-1

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J. Garcia, J. Wilms, P. Uttley, J. Miller-Jones, & others

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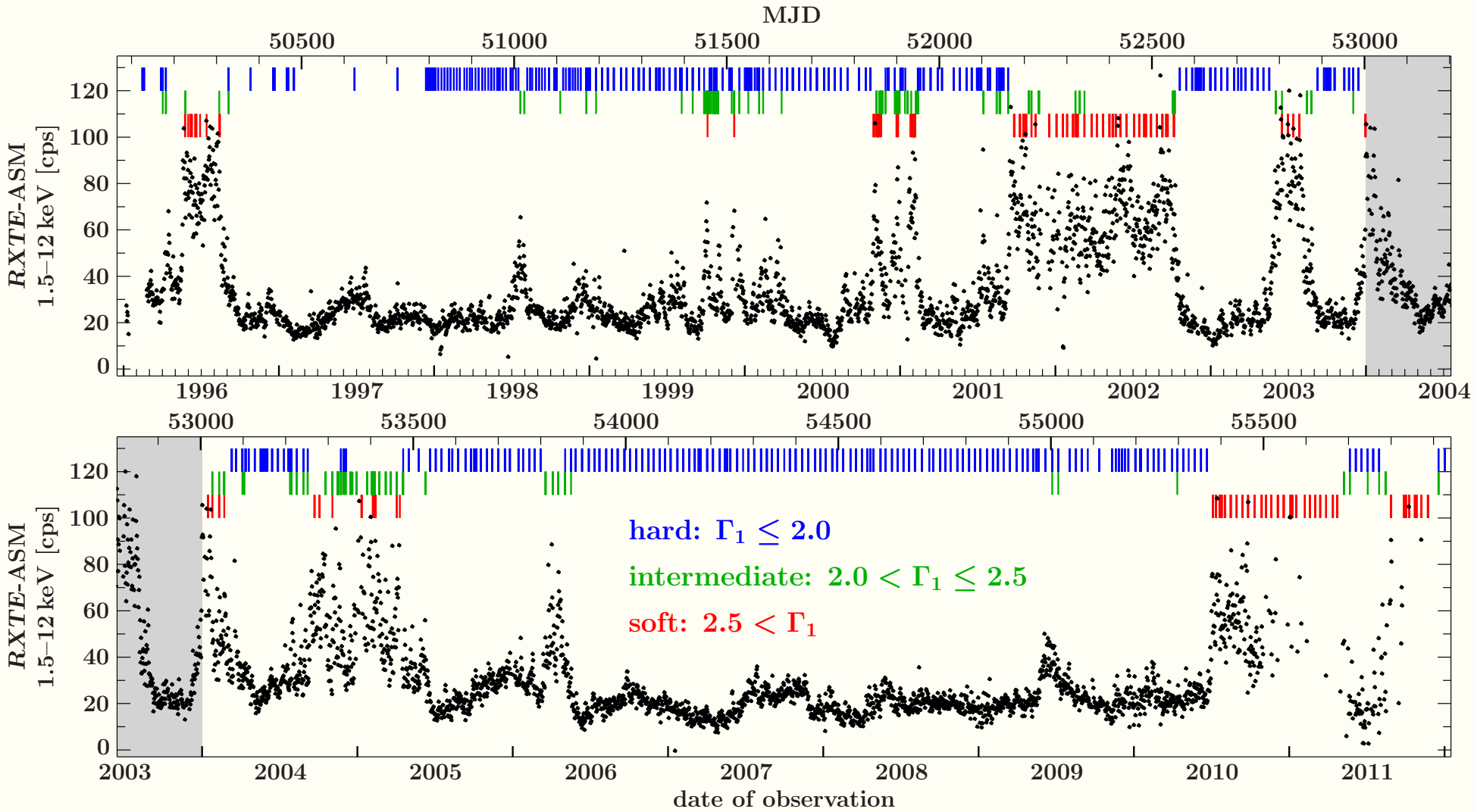
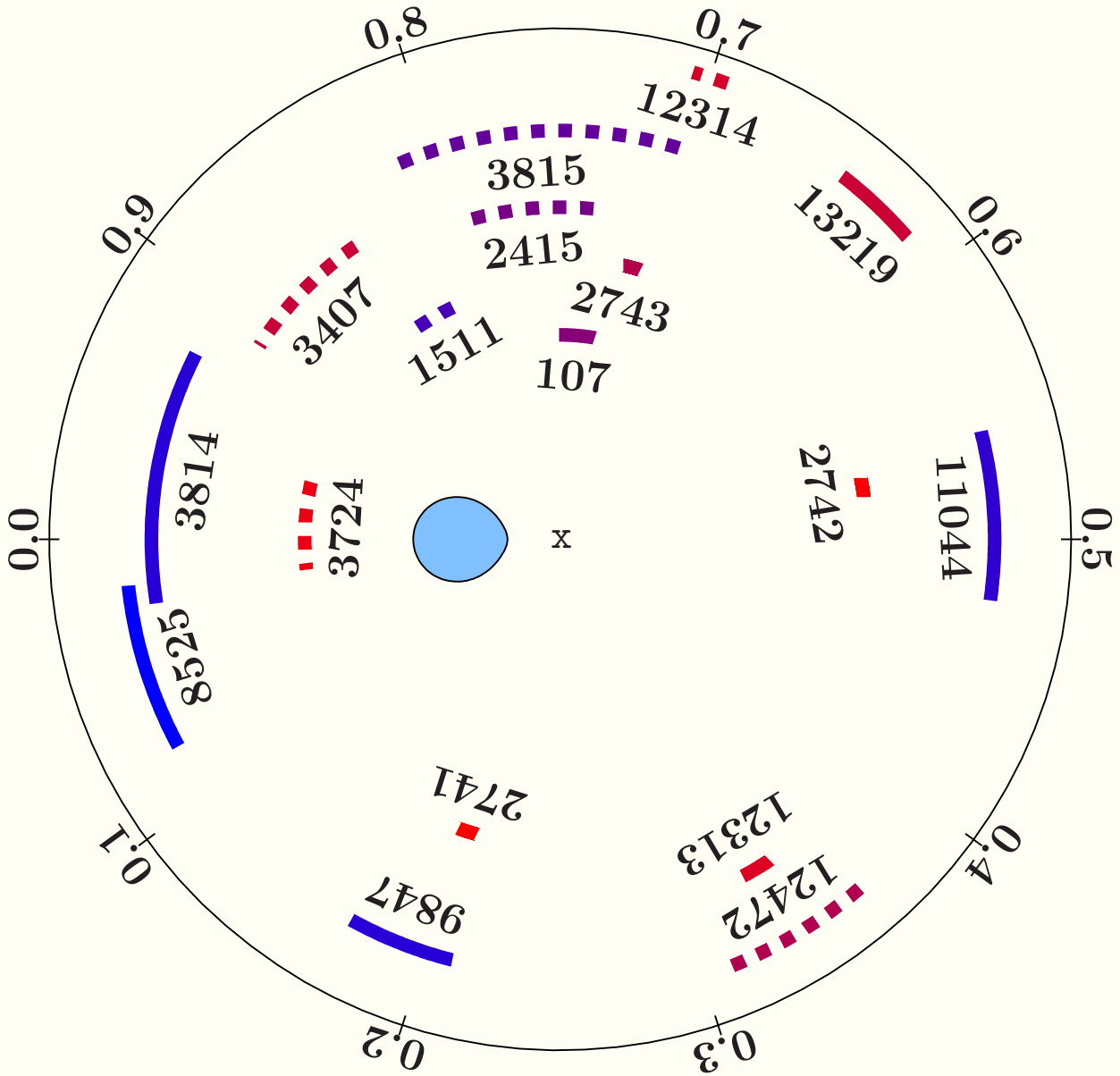
Observational campaigns: RXTE monitoring



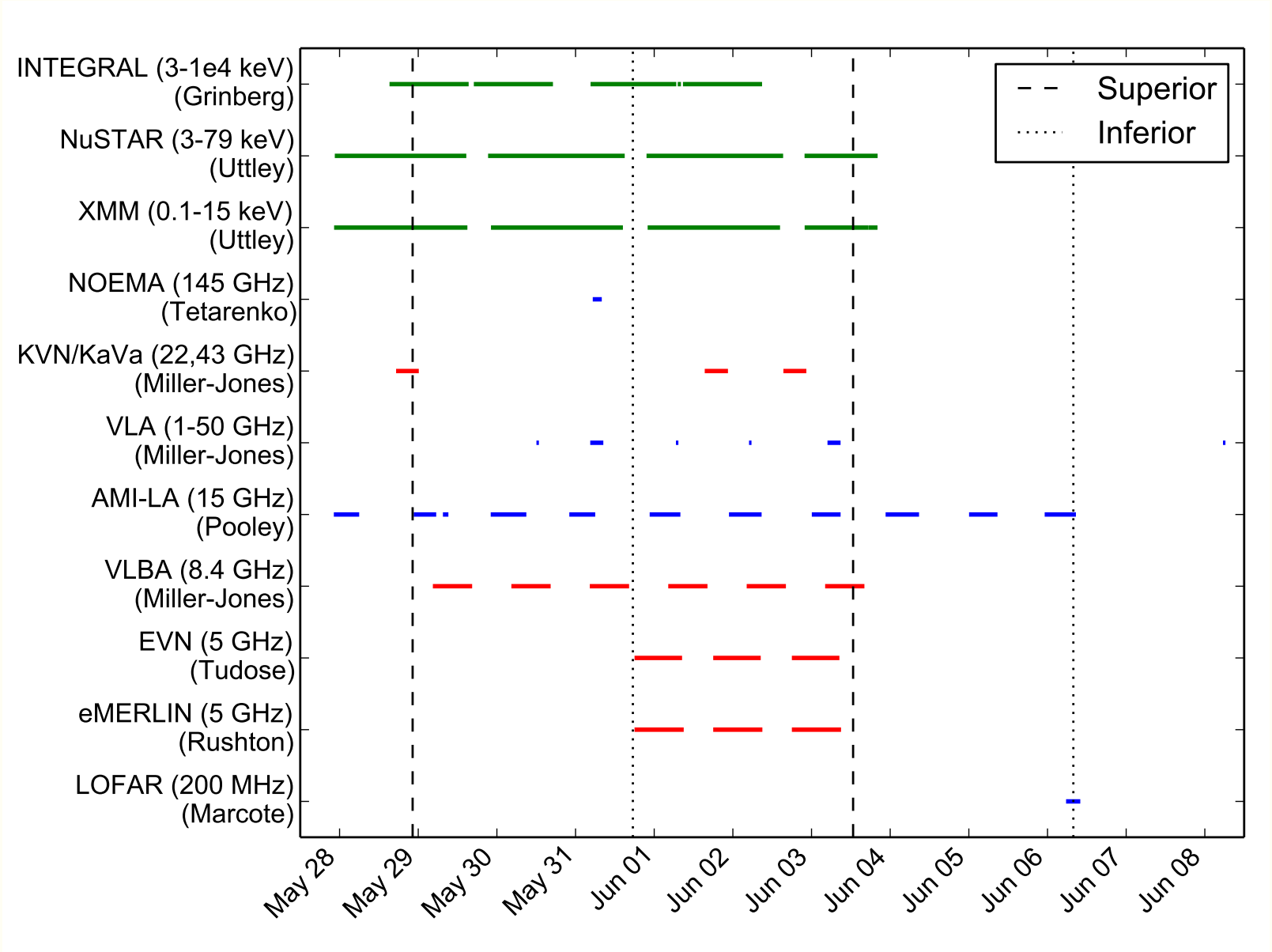
Grinberg et al. 2013, 2014

Observational campaigns: Chandra



Miskovicova et al. 2016

Observational campaigns: CHOCBOX



Uttley et al. in prep., Miller-Jones et al. in prep.

Why Cygnus X-1?

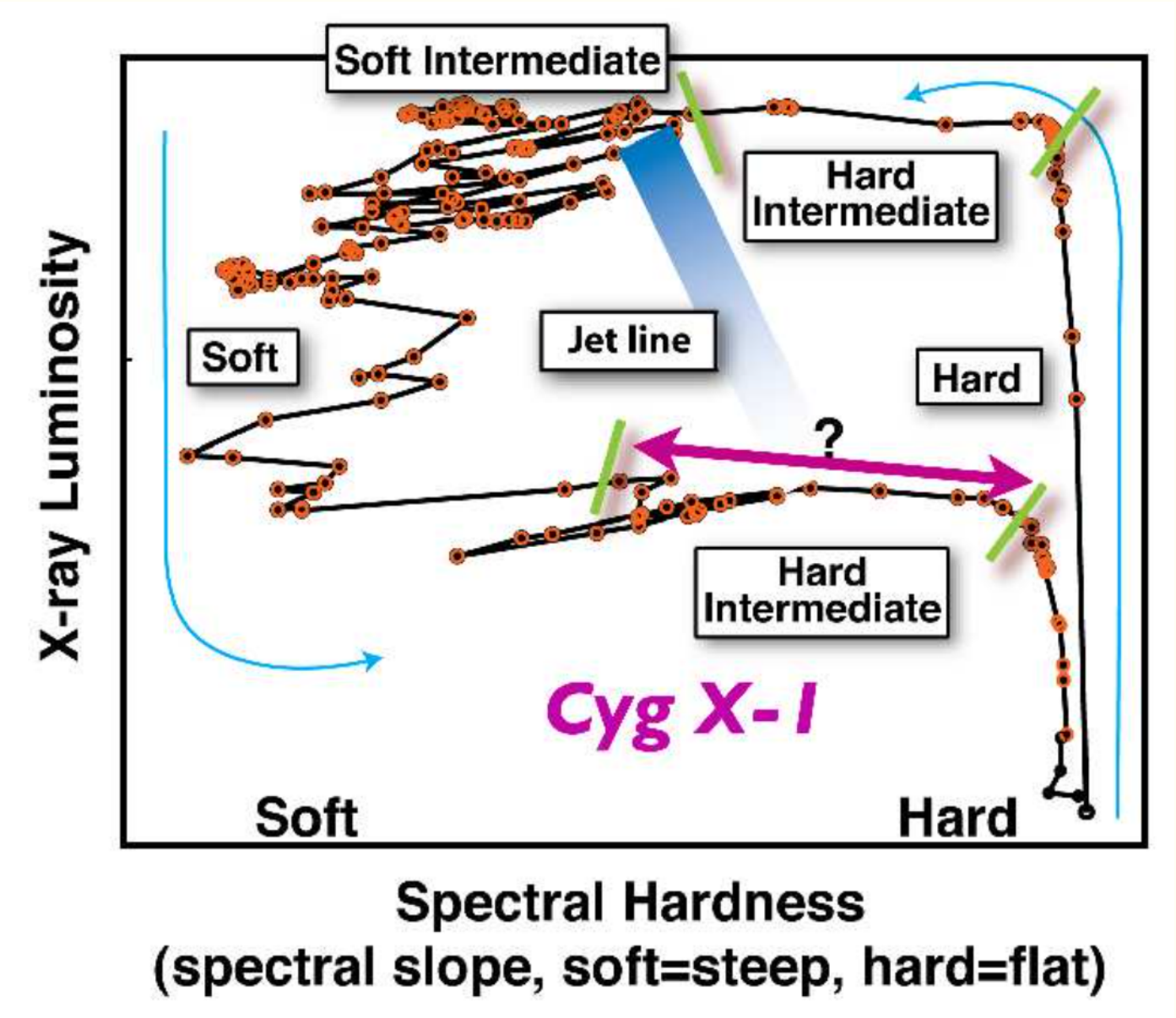


Figure: Nowak et al., 2012

bright

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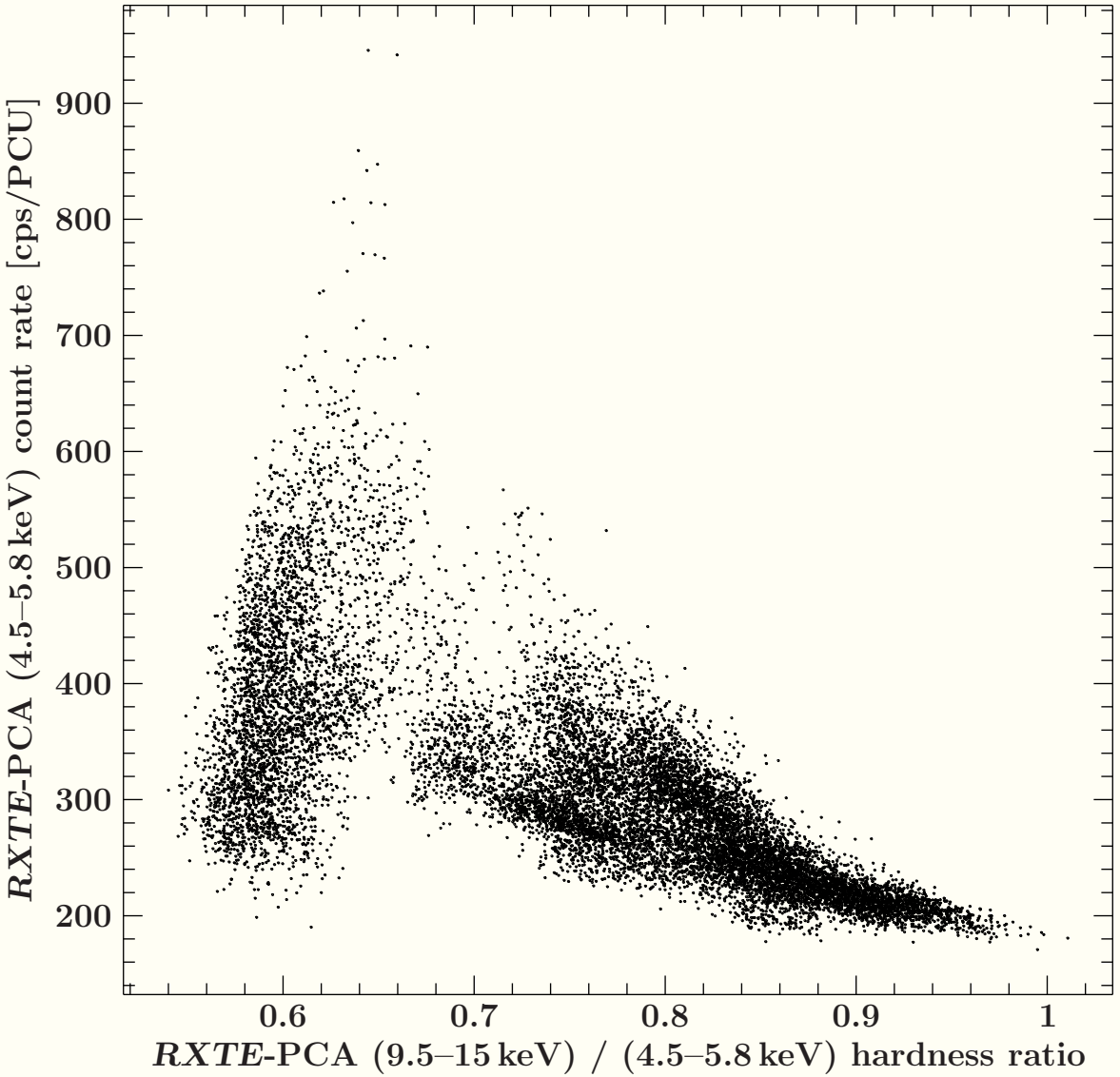
persistent

•

constantly crosses the jet line

Fast state transitions

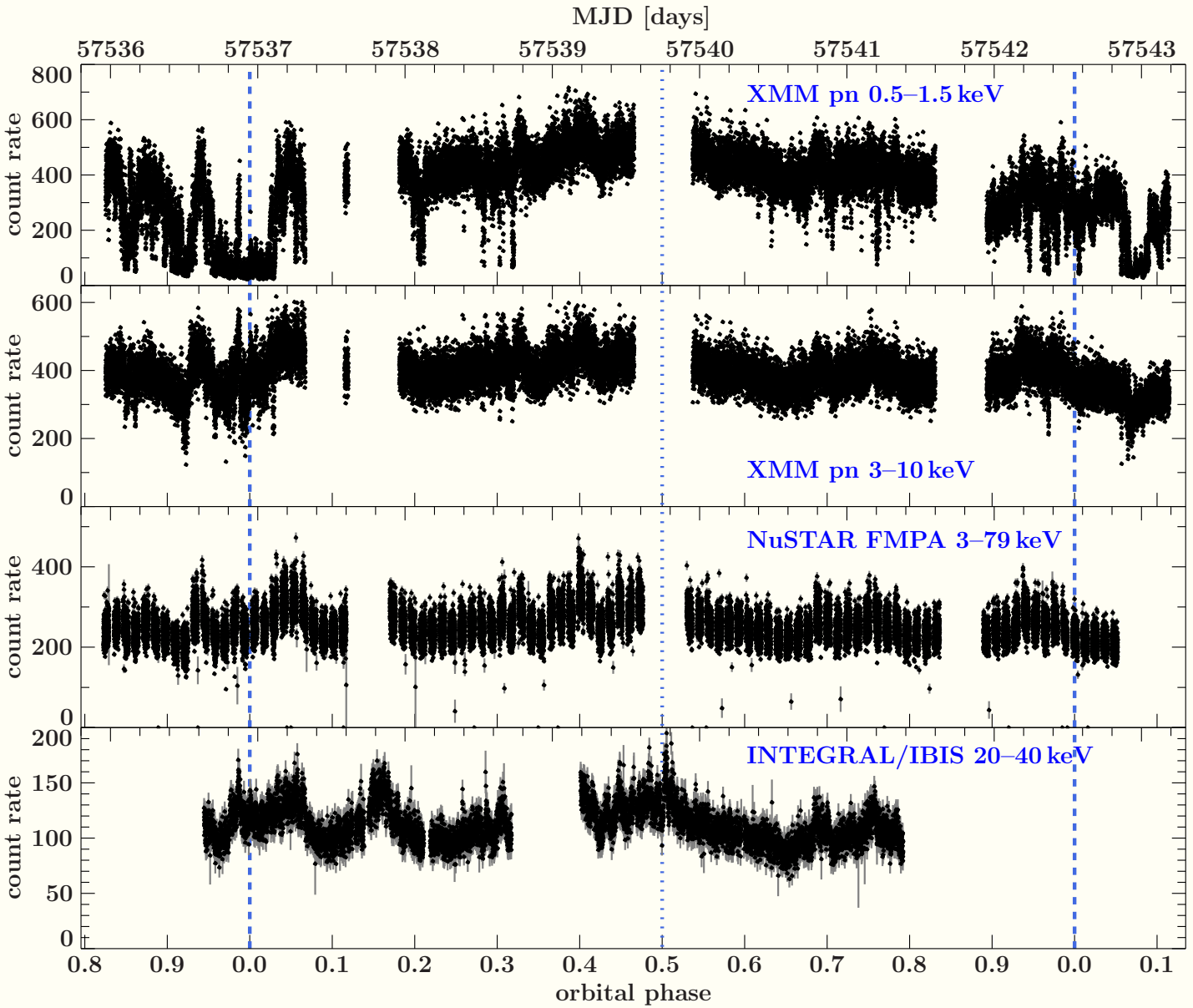


Boeck et al. 2011

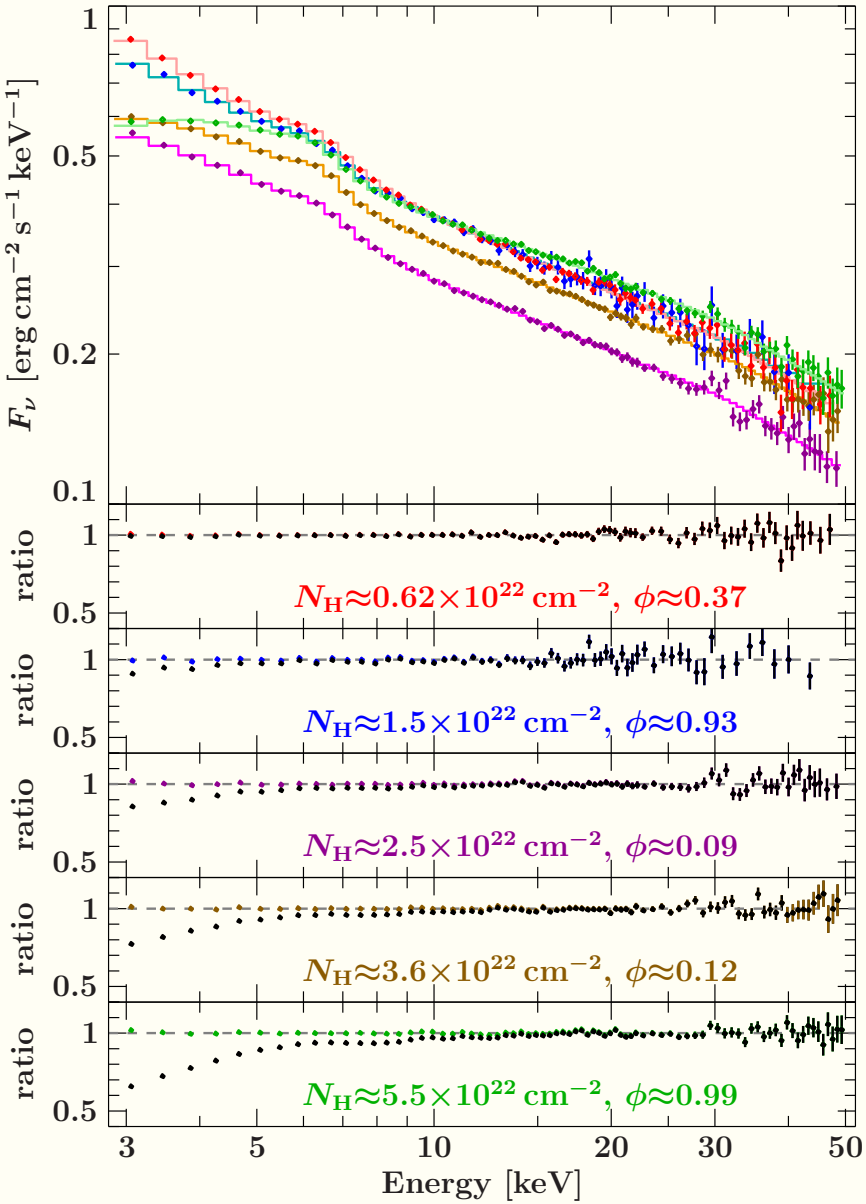
state transitions
can happen on
timescale of $\sim$ hours

(see also NICER observation;
talks by Ron & Jack)

Why not Cygnus X-1?

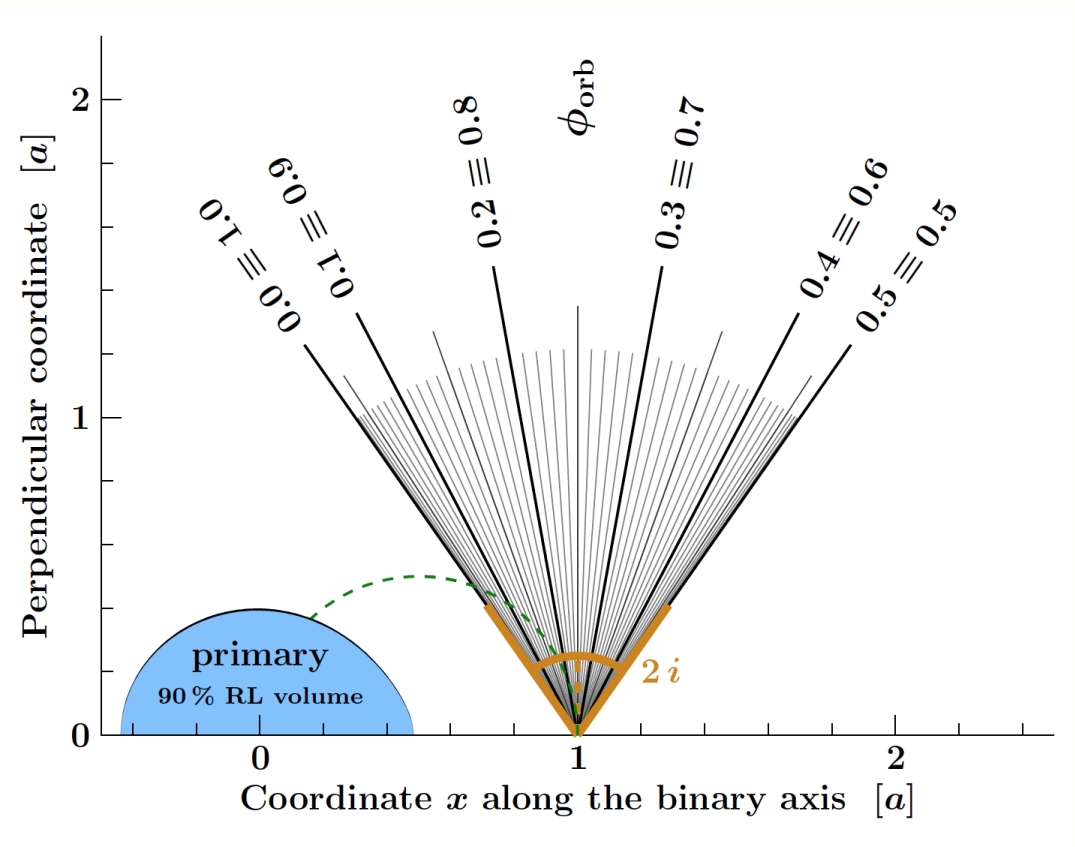


How strongly does absorption change?



Grinberg et al. 2015

Cyg X-1 / HDE 226868 system



Hanke 2011

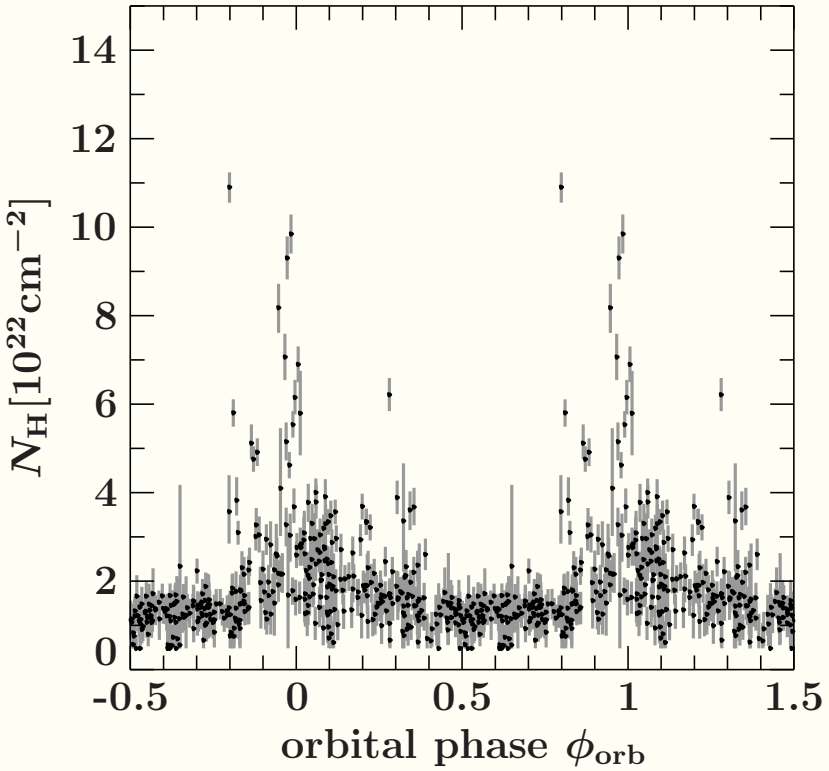
black hole + O-type super-giant

$\dot{M} \sim 2 \times 10^{-6}\, M_\odot\, yr^{-1}$

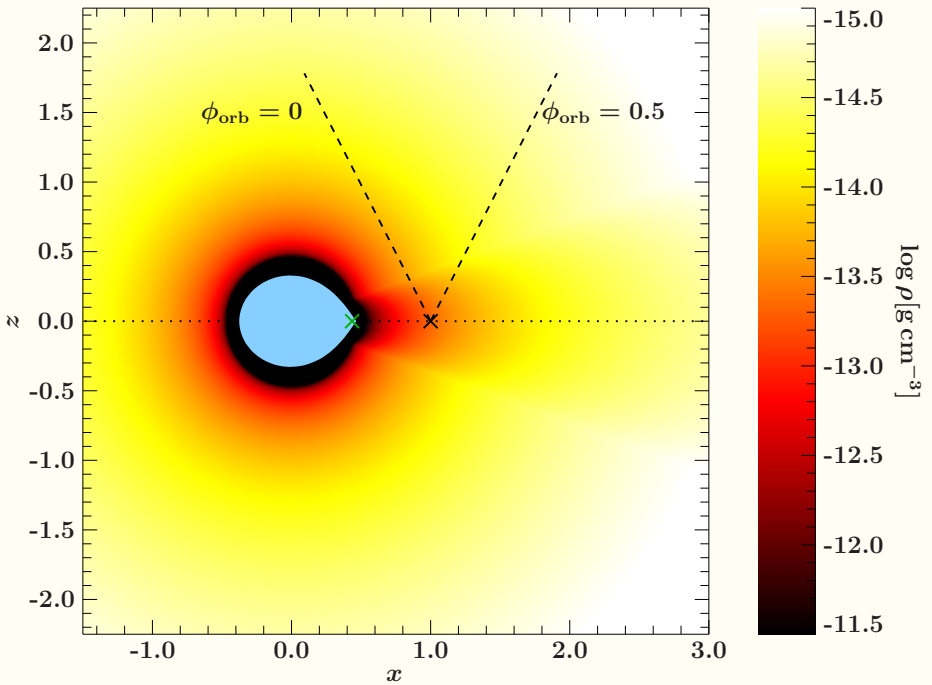
orbital period: 5.6 days

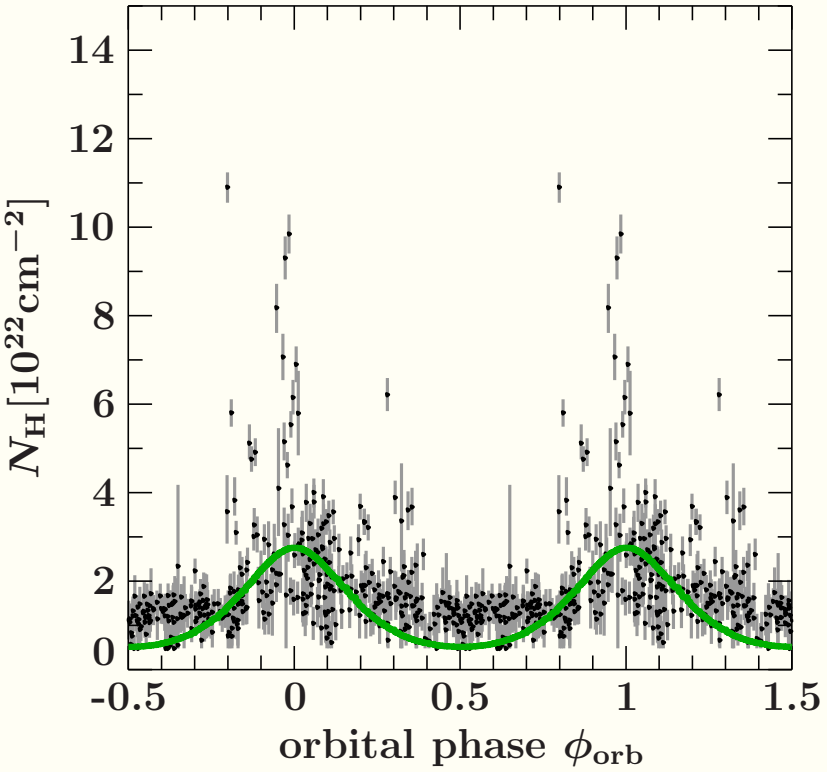
inclination: $i \approx 27°$ *(Orosz et al., 2011)*

Variable absorption in hard state



Variable absorption in hard state





homogeneous, focussed wind cannot explain the variability

Grinberg et al., 2015

Clumpy winds

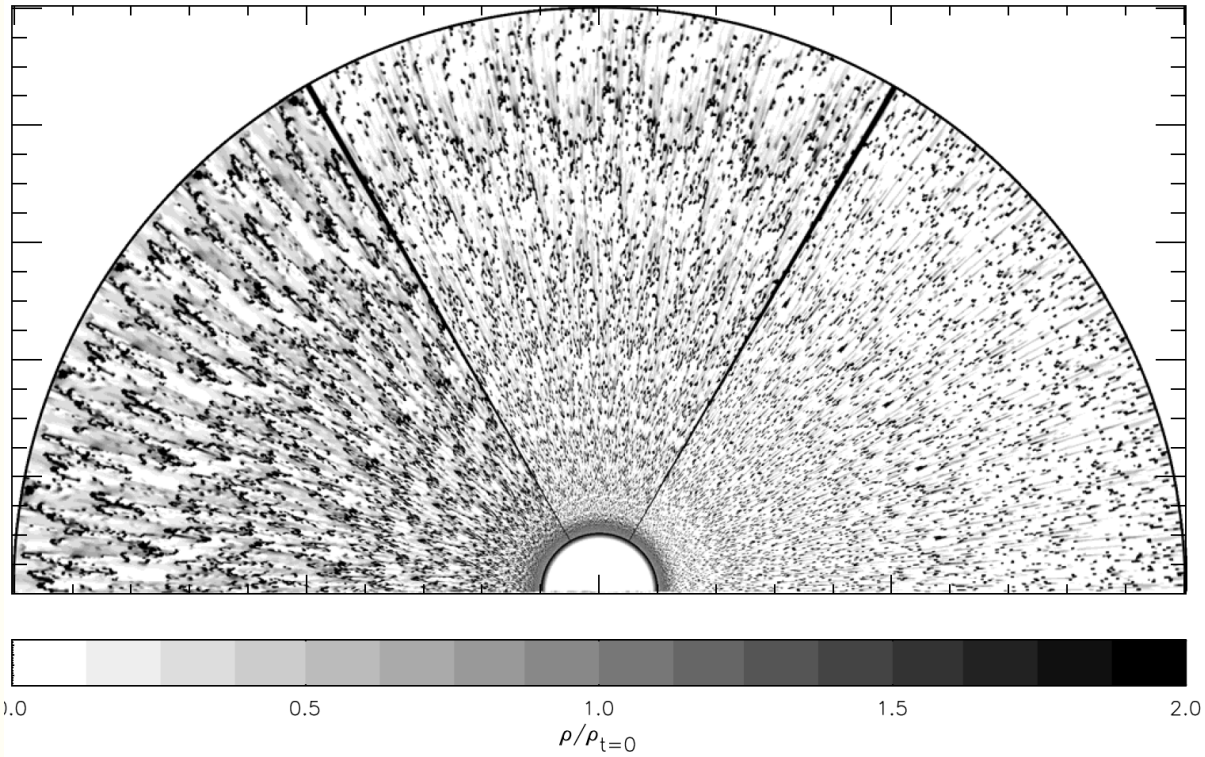
line-driven winds
unstable to velocity perturbations

$\Rightarrow$ perturbations grow rapidly

$\Rightarrow$ strong shocks

$\Rightarrow$ formation of dense gas-shells

$\Rightarrow$ wind clumping

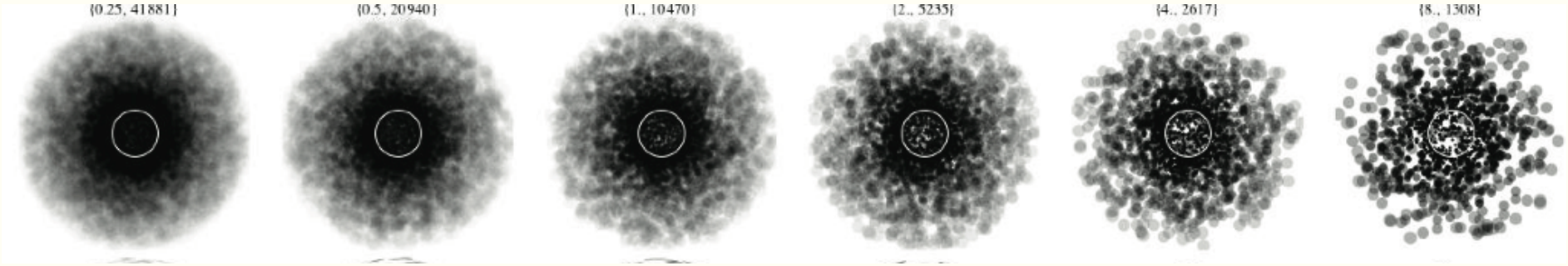


Dessart & Owocki, 2005; 2D simulations

Multiple observational lines of evidence for clumping from single stars

Absorption variability: a clumpy wind model

(Owocki&Cohen 2006, Sundqvist et al. 2012, but see also Oskinova et al. 2012)

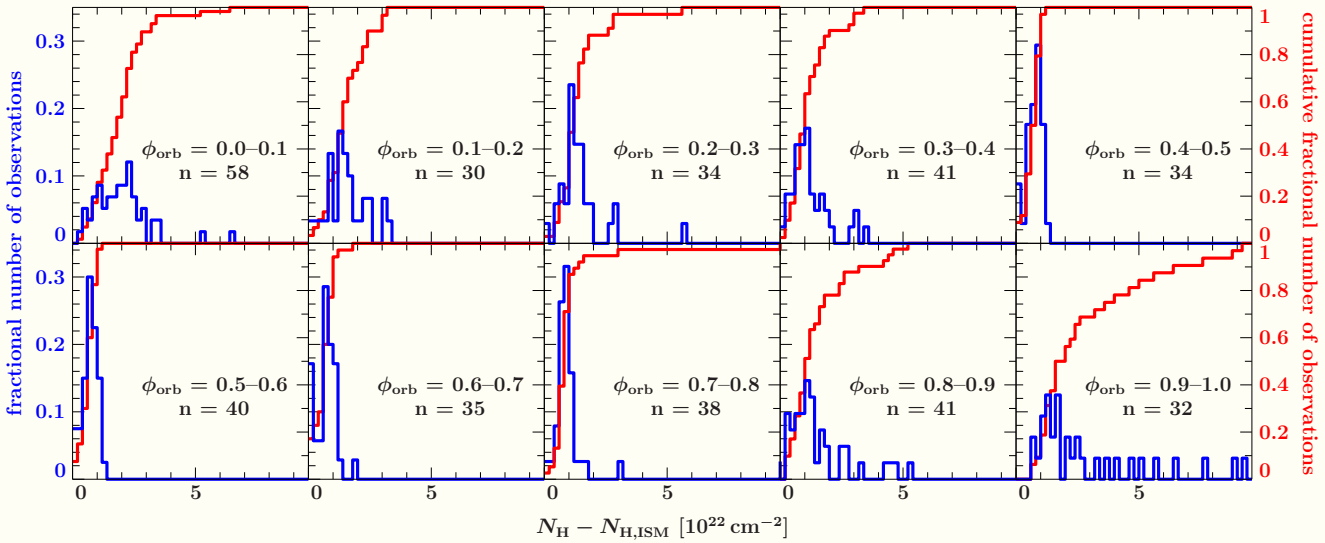


(Fig. from Sundqvist et al. 2012)

- discrete, spherical clumps
- β velocity law: $v = v_\infty(1 - \frac{R_*}{r})^\beta$
- no focussed wind component (yet)

- known: stellar parameters, terminal velocity, mass loss rate
- variable: number of clumps N and terminal porosity length h_∞ ($h_\infty = 3\frac{R_*}{L_*^2 N}$ with L_* initial radial size of the clump)

Absorption variability: a clumpy wind model

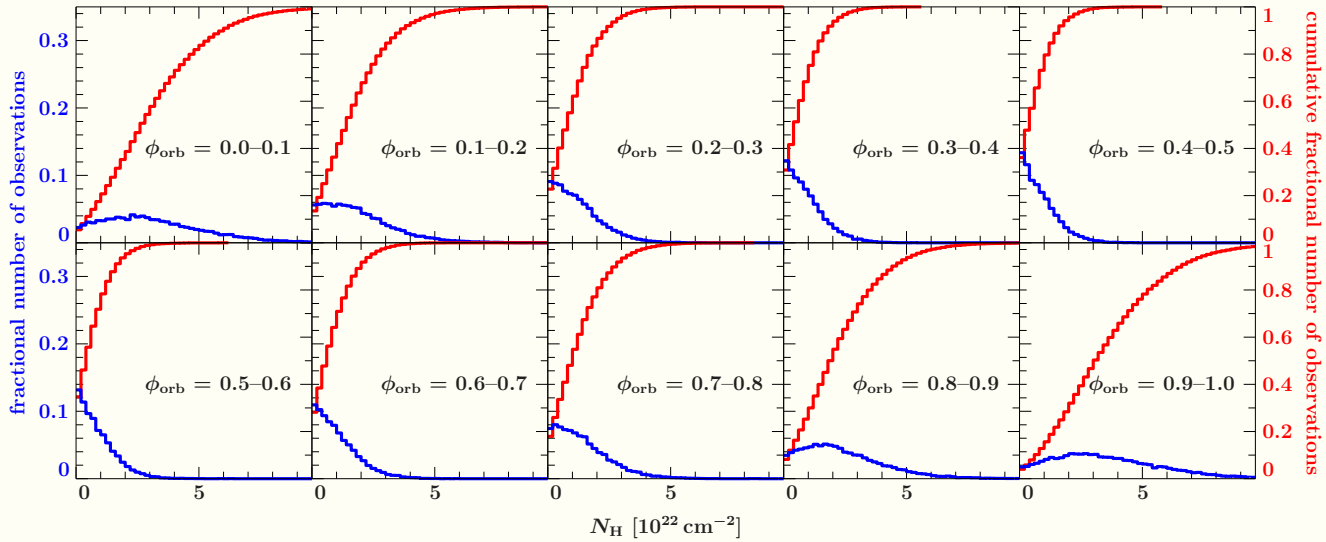


observations

model

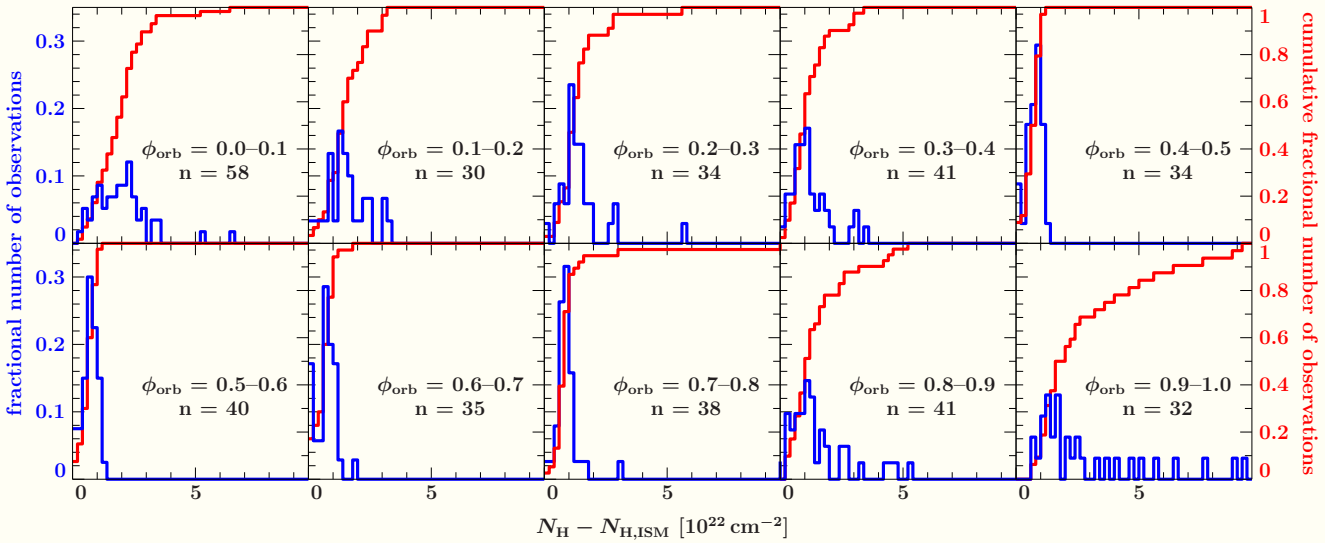
$h_\infty = 0.1\,R_*$

X



Grinberg et al. 2015

Absorption variability: a clumpy wind model

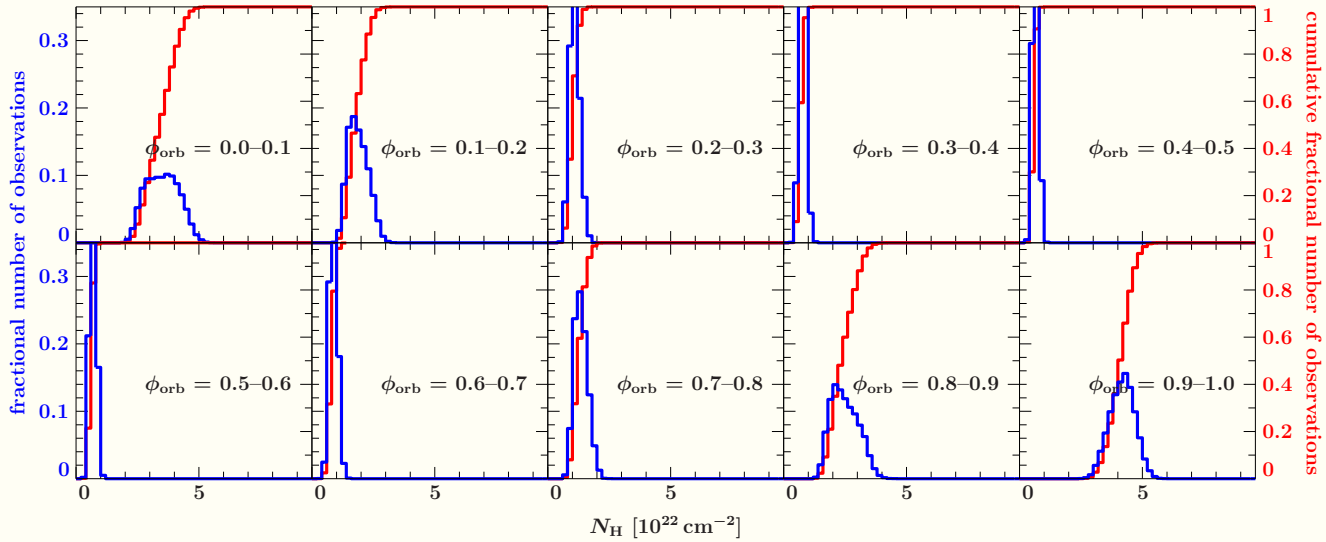


observations

model

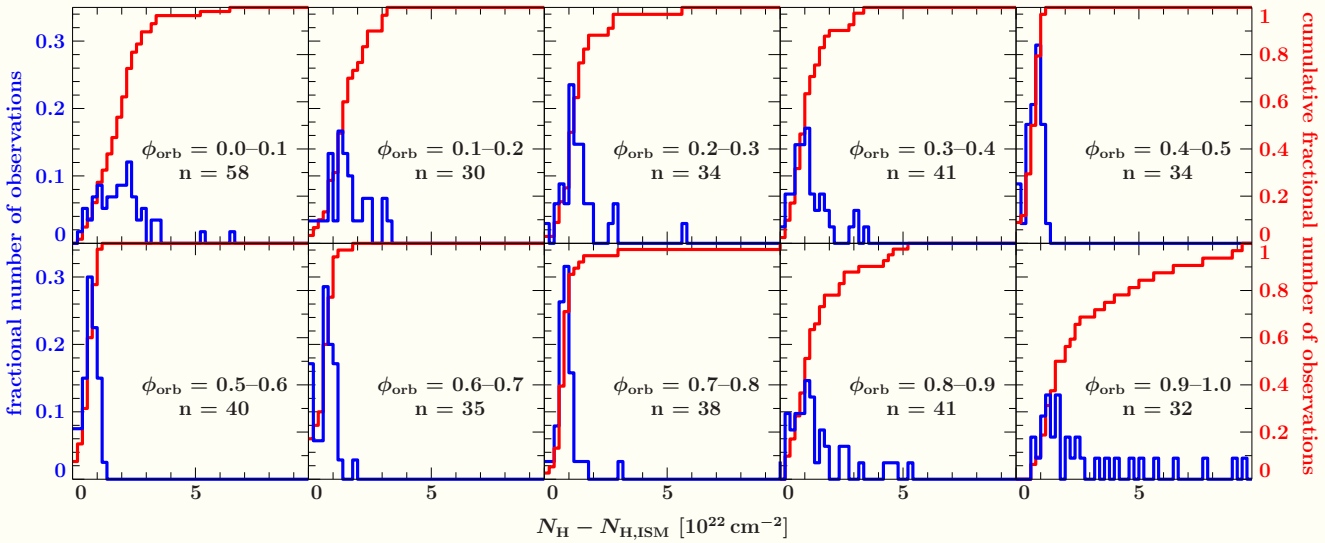
$h_\infty = 10\,R_*$

X



Grinberg et al. 2015

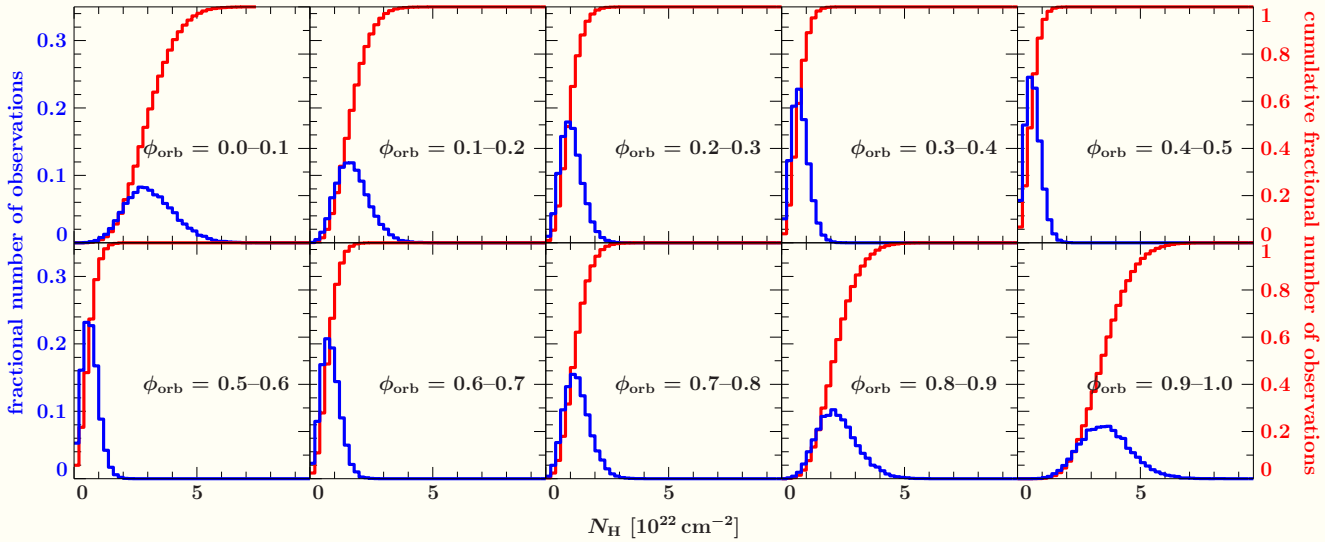
Absorption variability: a clumpy wind model



observations

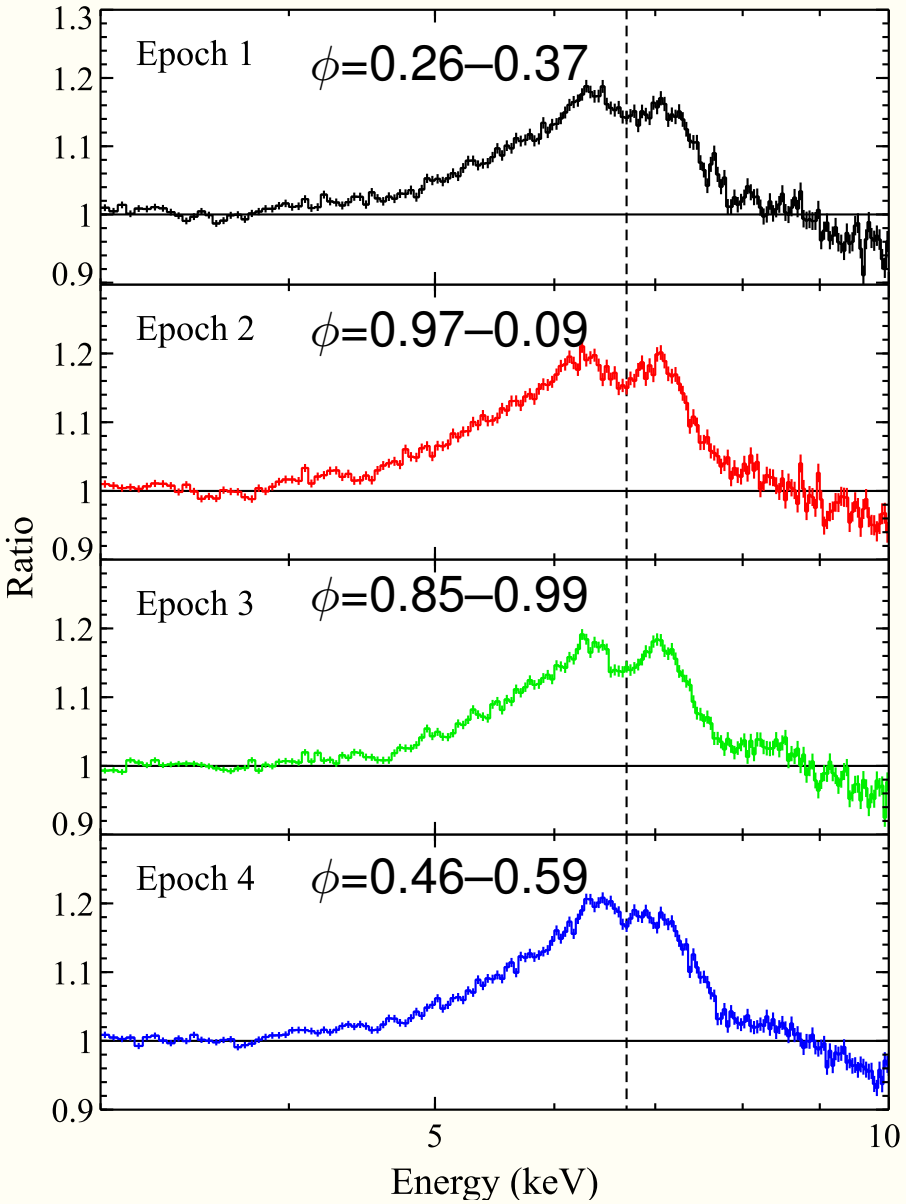
model

$h_\infty = R_*$



Grinberg et al. 2015

Wind effects & reflection



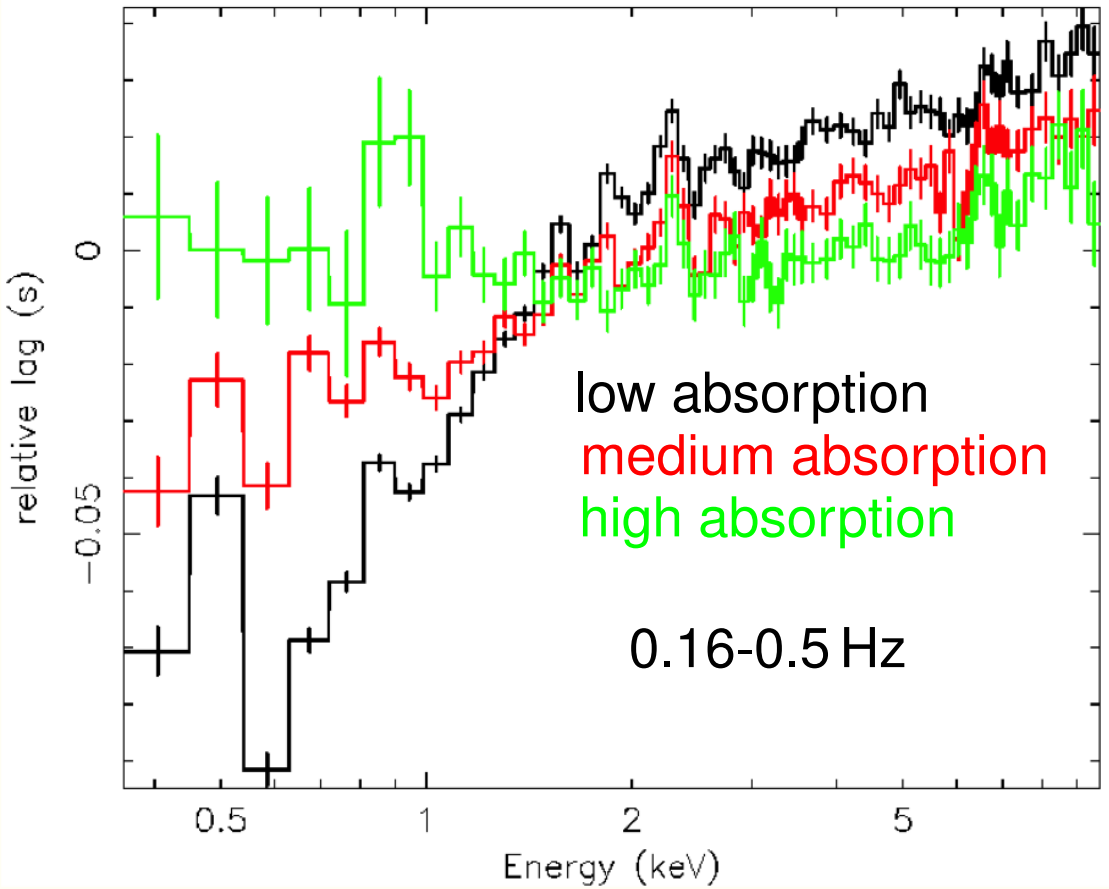
Cyg X-1: NuSTAR soft state observations

similar relativistically broadened iron line
$\Rightarrow$ high spin, i$\approx$40°

variable ionized absorption at $\sim$6.7 keV
$\Rightarrow$ focussed wind
$\Rightarrow$ needs to be taken into account when modelling reflection

Walton et al. 2016

CHOCBOX Timing: wind effects

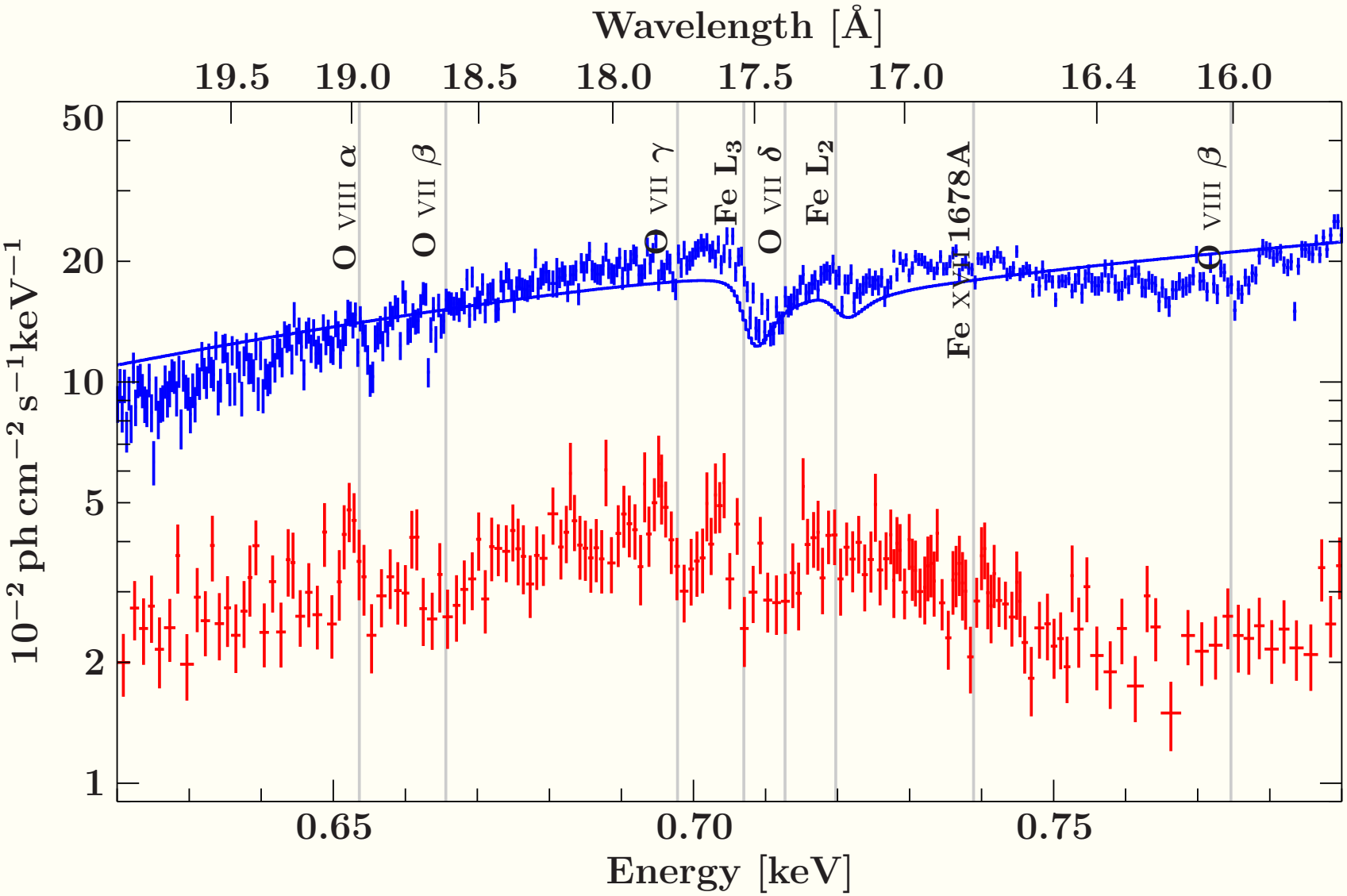


P. Uttley et al., in prep.

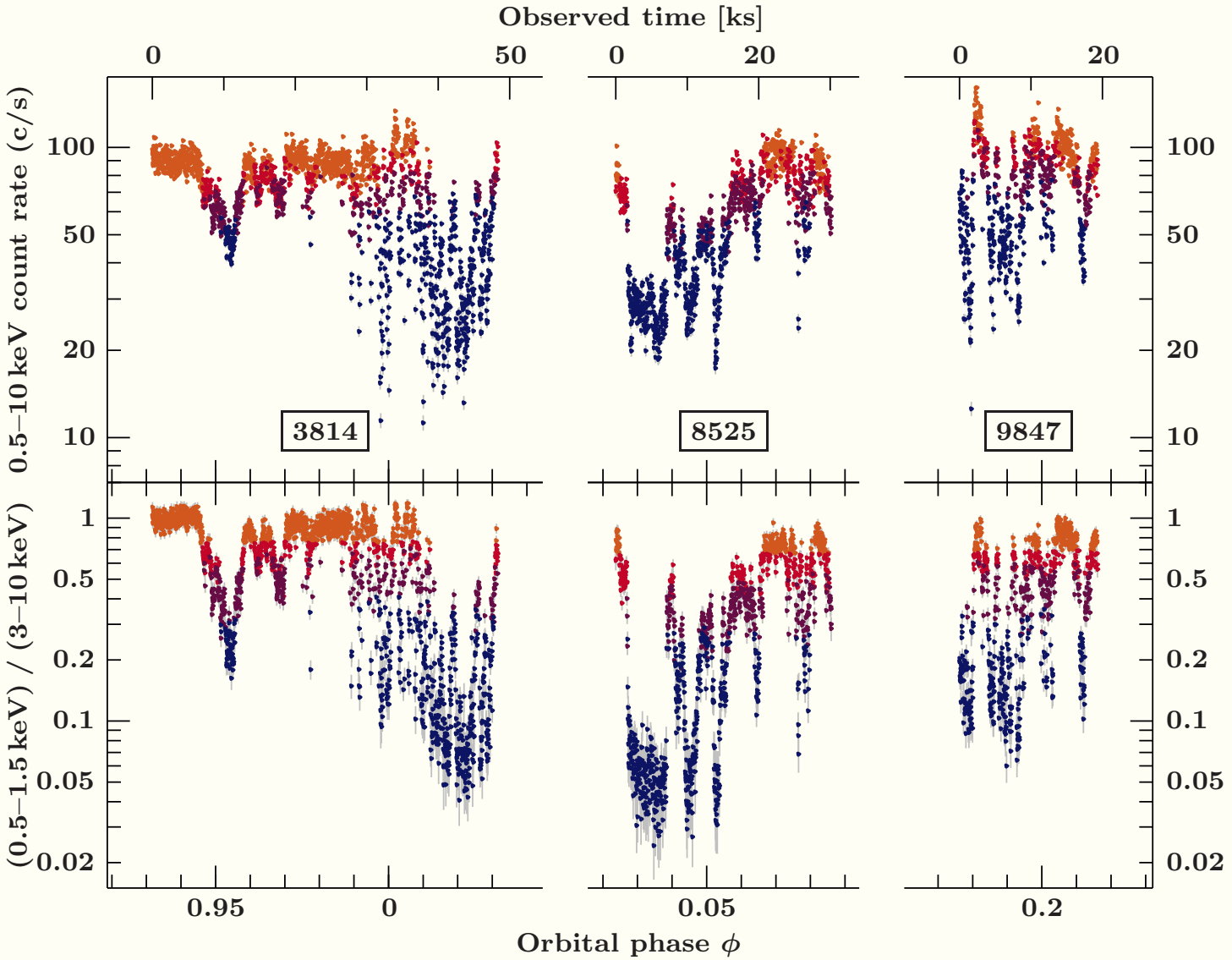
Cyg X-1:

- wind strongly affects spectro-timing at low energies
- possibility of wind reverberation studies?

CHOCBOX: Fe L edge

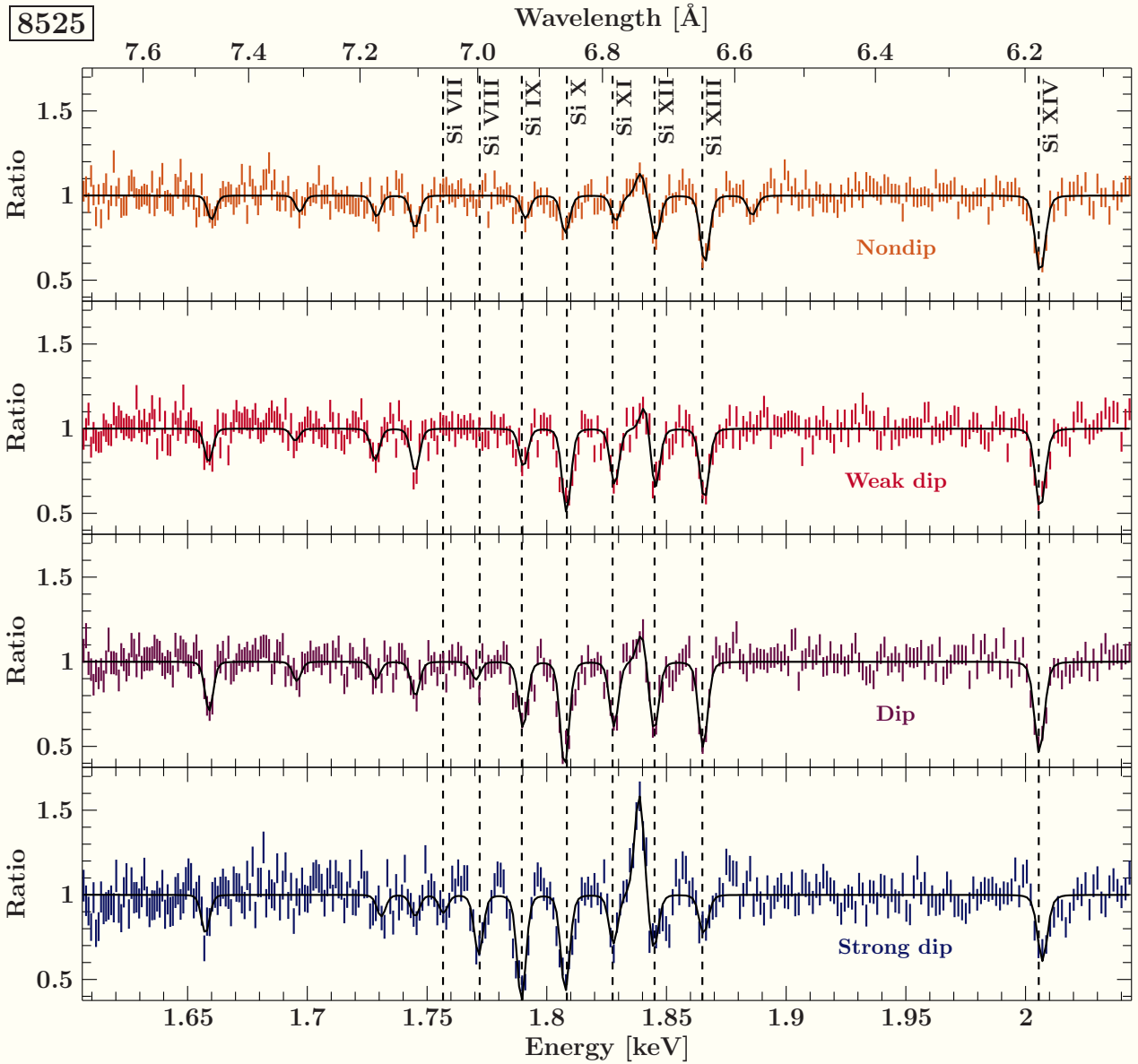


Clump structure



Hirsch et al., in prep.; see also Miskovicova et al. 2016

Clump structure



Cyg X-1

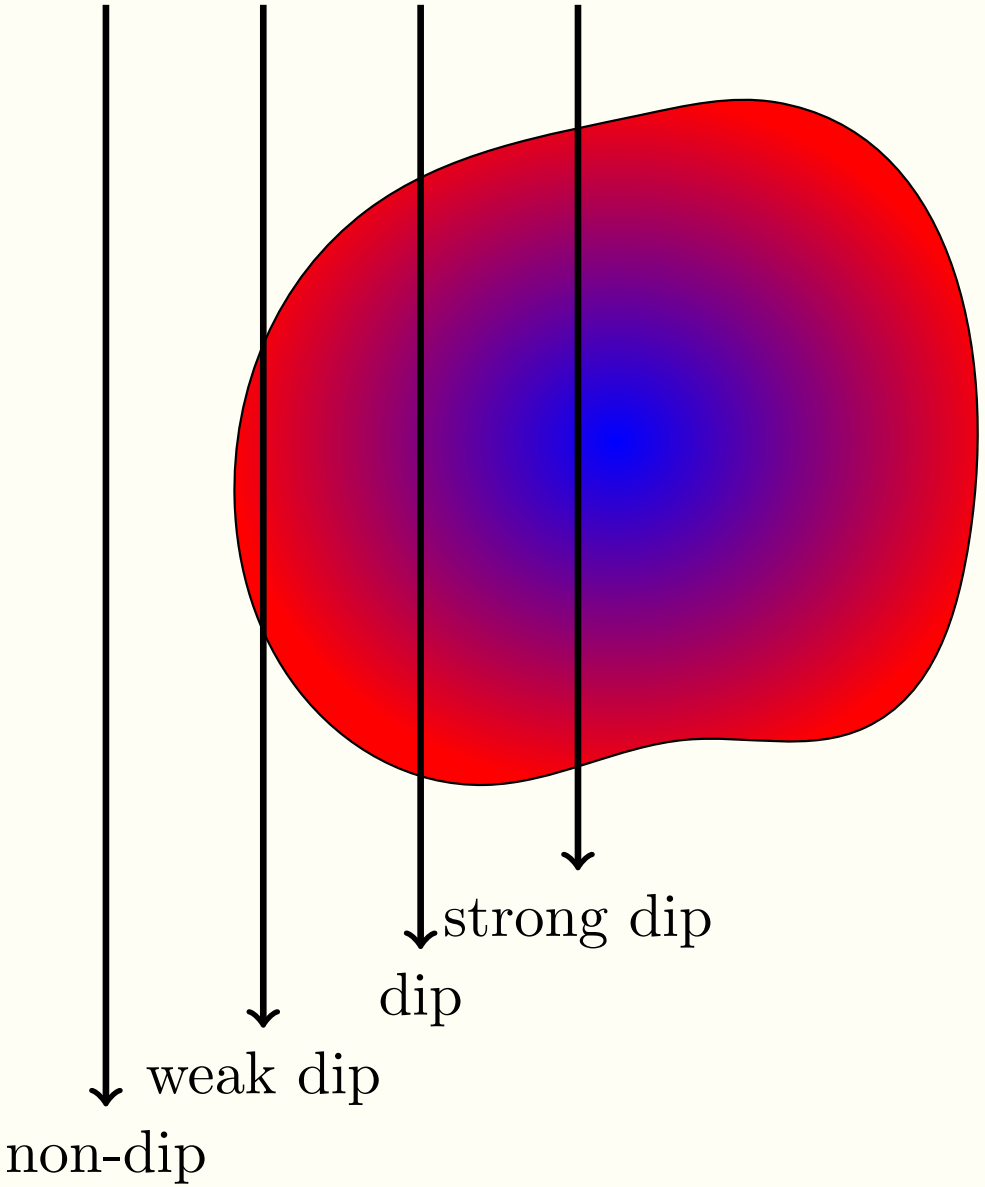
same Dopplershift
⇒ origin in the same medium

lower ionization lines when absorption higher

⇒ onion-like clump structure

Hirsch et al., in prep.; see also Miskovicova et al. 2016

Clump structure



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One astronomers's noise is another astronomer's data.

variable absorption makes analysis even more complex

$\Updownarrow$

constraints on clumpy wind structure

Variable absorption affects:

- broadband spectral shape
- iron line
- (some) variability properties

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Other possible wind effects:

- disk outer boundary
- jet shape (S. Heinz's talk)
- γ-rays from jet-wind interaction