Focused winds in high mass X-ray binaries: the case of Cyg X-1/HDE 226868

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June 9, 2015

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Cyg X-1 / HDE 226868 system

high mass X-ray binary

bright, persistent source

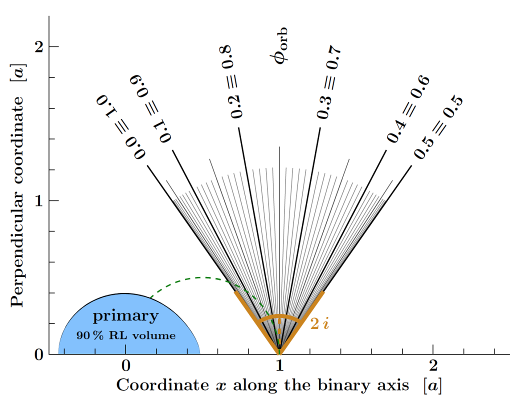
companion: O-type supergiant

line-driven winds (CAK-mechanism)

mass loss: $\sim 2 \times 10^{-6}\, M_{\odot}\, yr^{-1}$

ISM equivalent hydrogen density: $\sim 0.5 \times 10^{22}\,\mathrm{cm}^{-2}$ *(Xiang et al., 2011)*

Orbital variability

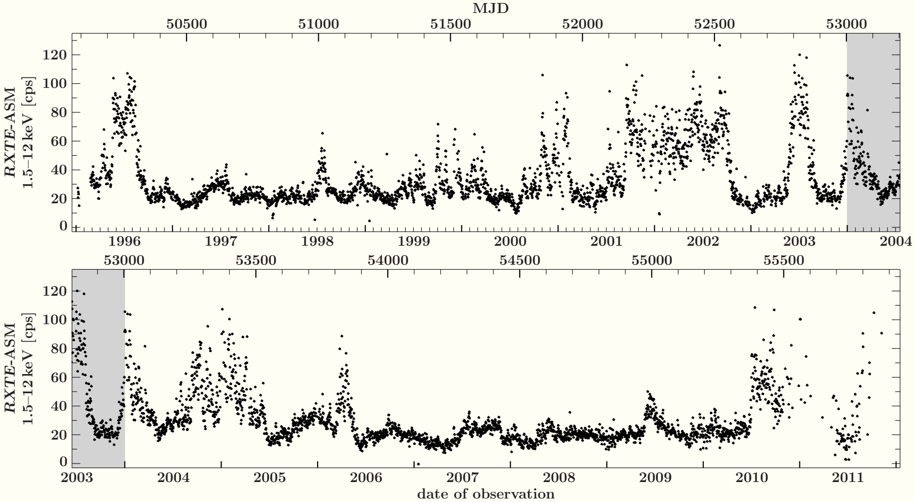


Hanke 2011

- orbital variability of overall absorption
  $\Rightarrow$ focussed wind
- orbital variability of 'dip'-occurence
  $\Rightarrow$ individual clumps in the wind

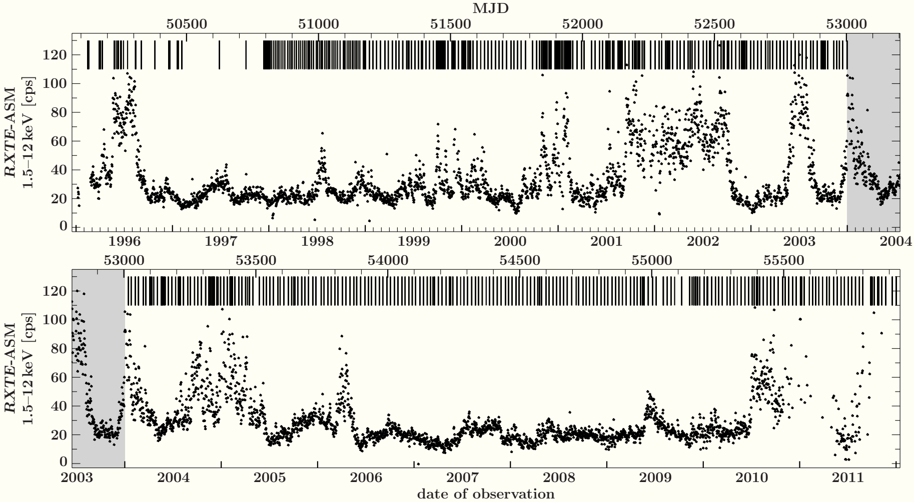
- orbital period: 5.6 days
- inclination: 27° *(Orosz et al., 2011)*

RXTE campaign



Grinberg et al., 2013, 2014

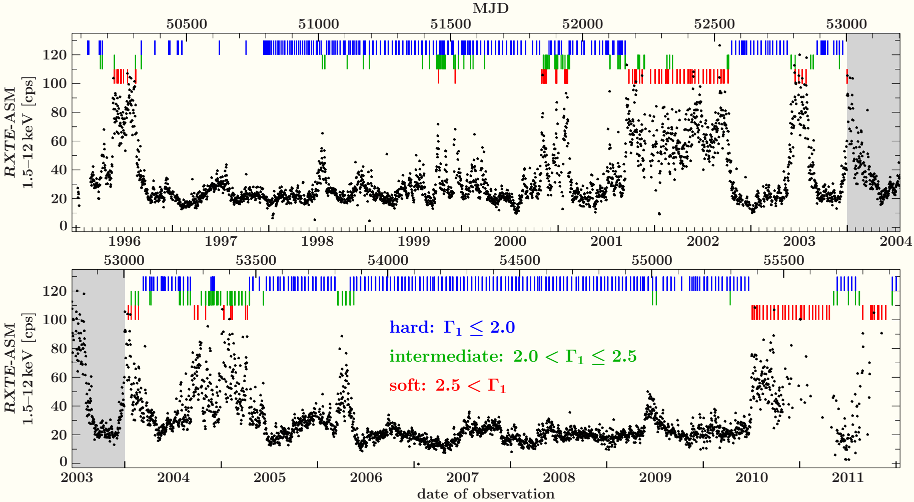
RXTE campaign



Grinberg et al., 2013, 2014

typical exposure: $\sim$2 ks

RXTE campaign

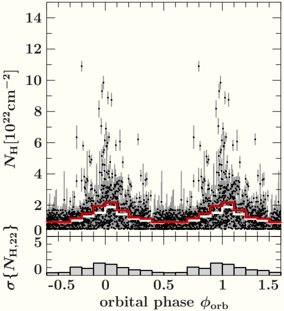


Grinberg et al., 2013, 2014

typical exposure: $\sim$2 ks

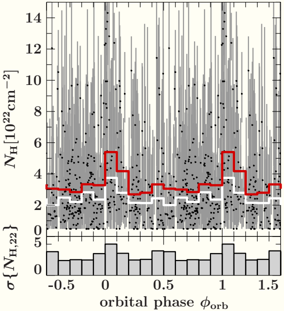
Orbital variability of absorption

hard state



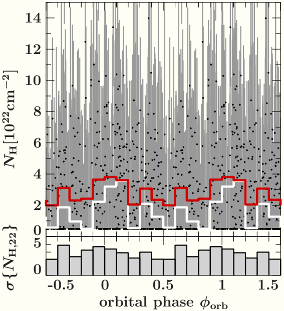
no disk component

intermediate state



disk component

soft state

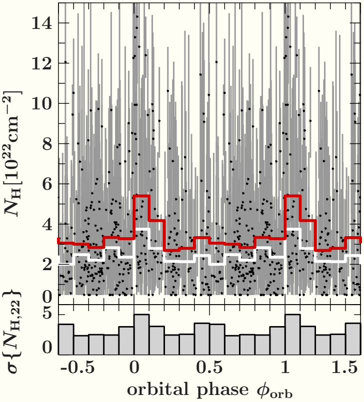


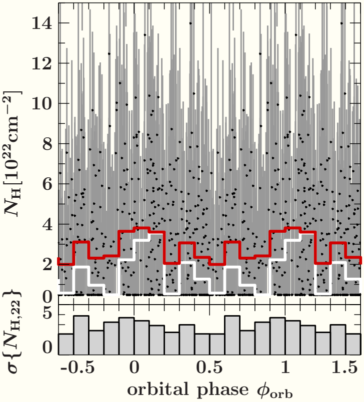
disk component

Grinberg et al., 2015

Orbital variability of absorption: soft and intermediate states

disk component ⇒ large uncertainties in N_{H}

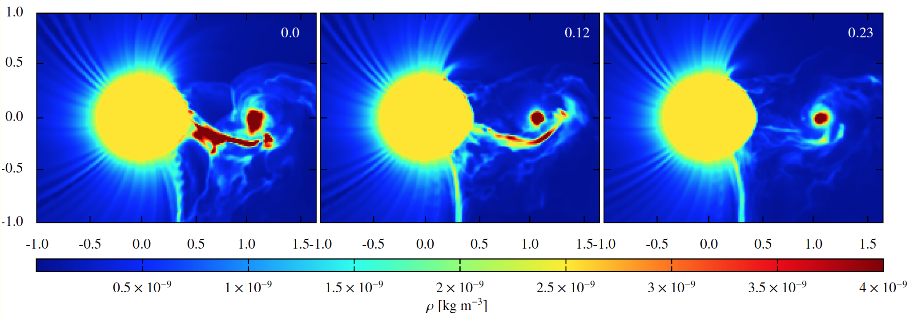




wind strongly ionized ⇒ mainly transparent to X-rays

Orbital variability of absorption: soft and intermediate states

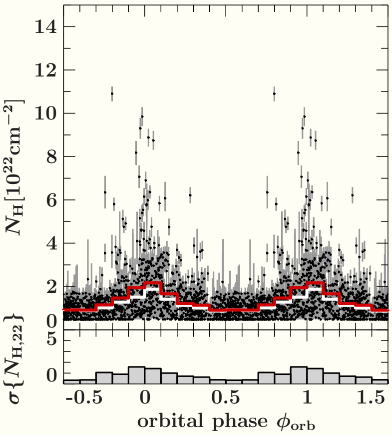
ionized material ⇒ line-driving mechanism breaks down ⇒ changes in the geometry of the system



Čechura & Hadrava, 2015

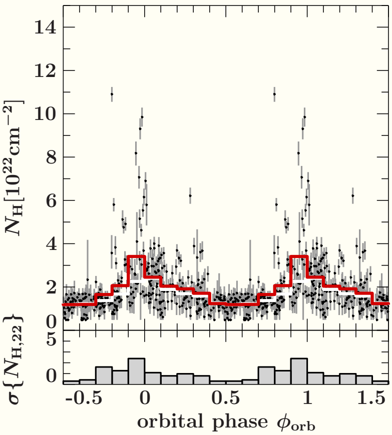
Orbital variability of absorption: hard state

all hard state data



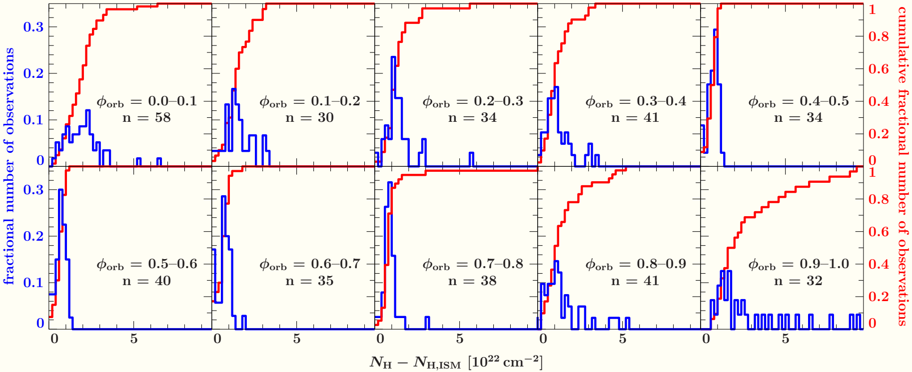
$\Rightarrow$

one long, stable hard state



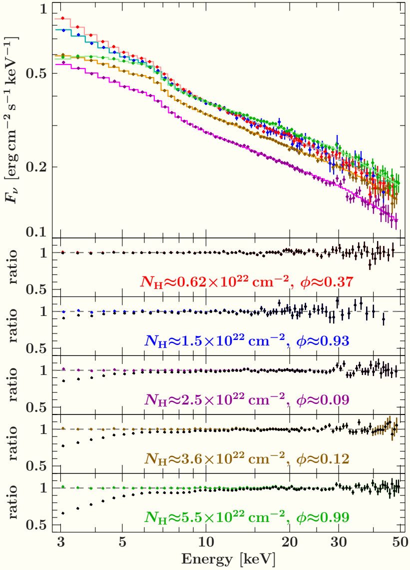
Grinberg et al., 2015

Orbital variability of absorption: hard state

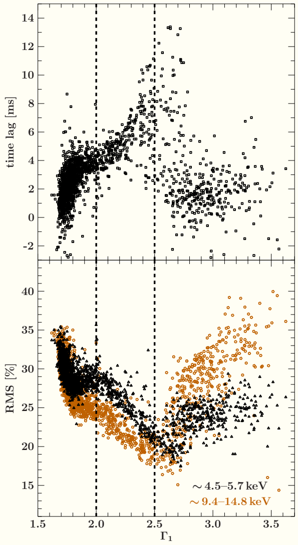


Grinberg et al., 2015

How important is absorption?



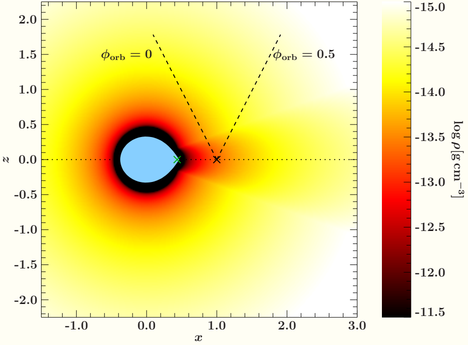
$\Rightarrow$

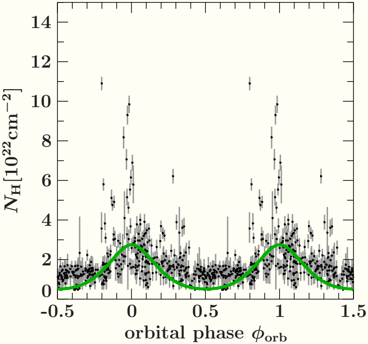


Grinberg et al., 2013, 2015

Hard state: a focussed wind model

- toy model for a focussed CAK wind *(Gies & Bolton, 1986; Friend & Castor, 1982)*



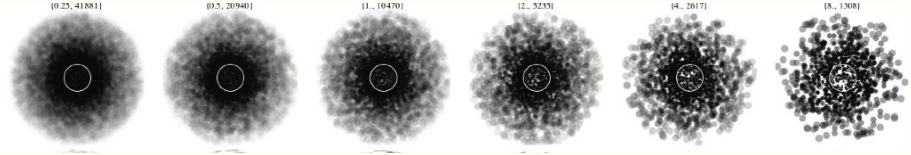


Grinberg et al., 2015

- fails to describe the variability due to lack of clumps

Hard state: a clumpy wind model

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



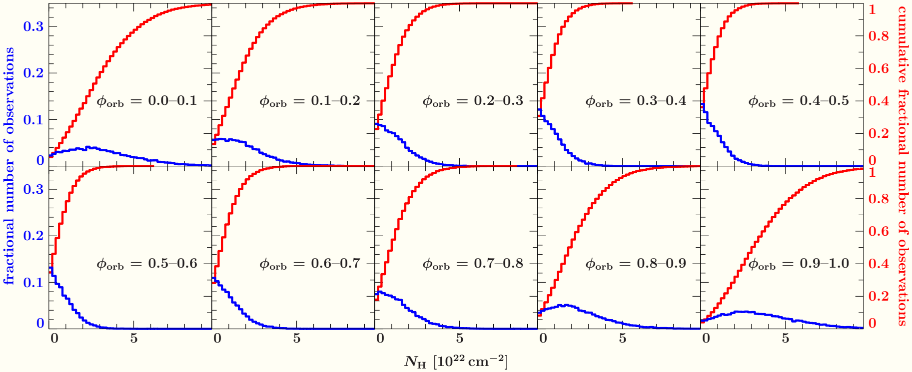
(Fig. from Sundqvist et al. 2012)

- discrete, spherical clumps
- β velocity law
- no focussed wind component (yet)

- known: stellar parameters, terminal velocity, mass loss rate
- variable: number of clumps N and terminal porosity length h_∞

Hard state: a clumpy wind model

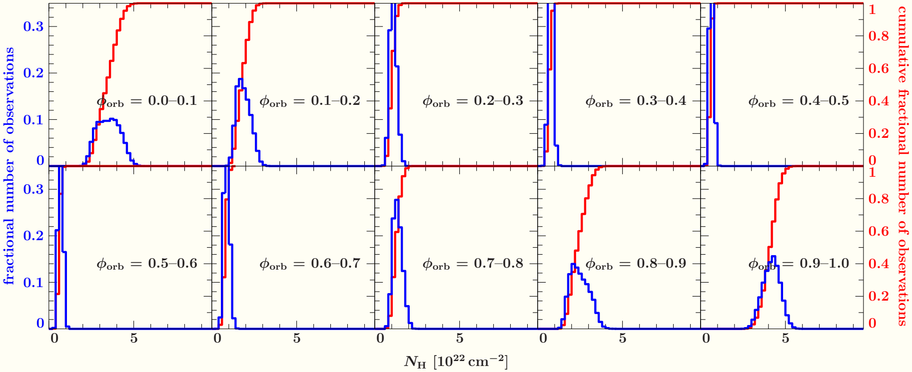
terminal porosity length $h_\infty = 0.1\ R_*$ stellar radii



Grinberg et al., 2015

Hard state: a clumpy wind model

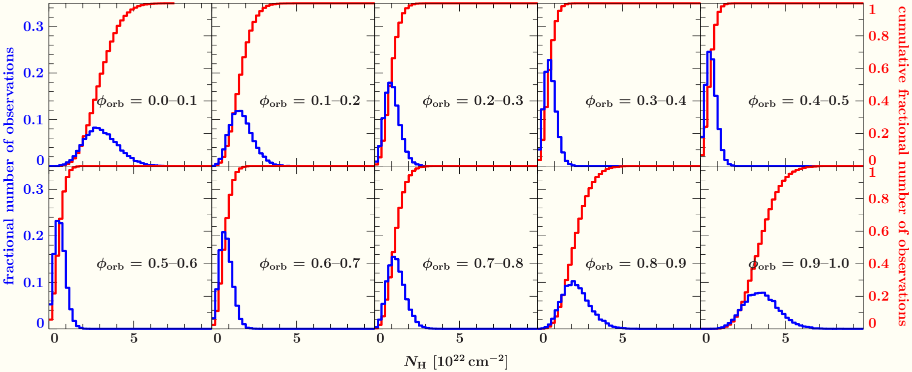
terminal porosity length $h_\infty = 10\,R_*$ stellar radii



Grinberg et al., 2015

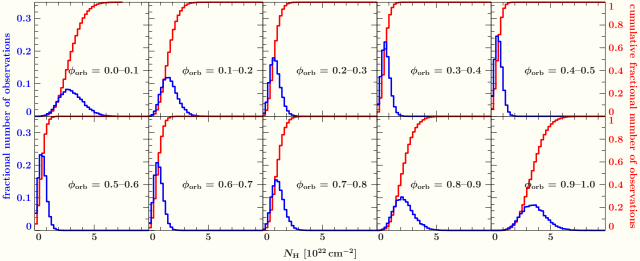
Hard state: a clumpy wind model

terminal porosity length h_∞ = R_* stellar radius



Grinberg et al., 2015

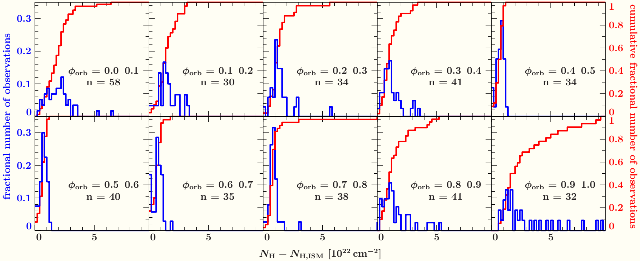
Hard state: a clumpy wind model



model

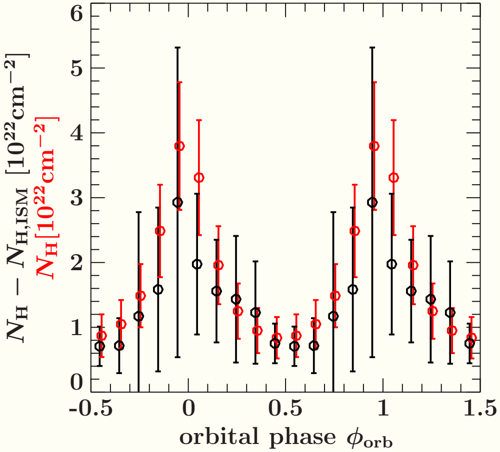
$h_\infty = R_*$

observations



✓

Hard state: a clumpy wind model



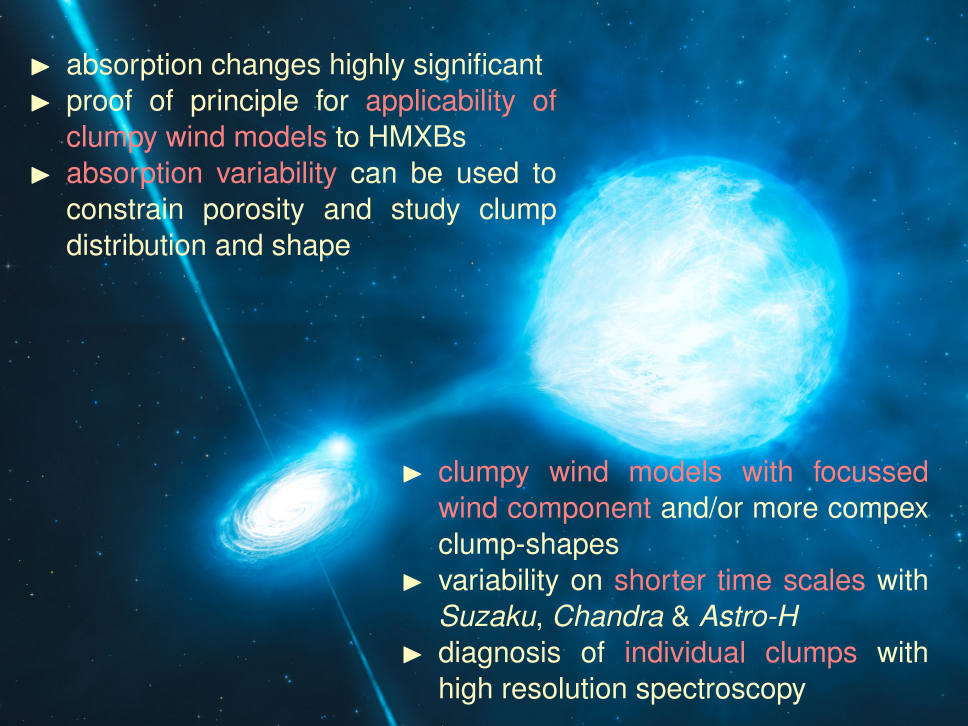
Grinberg et al., 2015

agreement between data (black) and model (red)

$h_\infty \approx R_*$ agrees with values for single O stars

non-Gaussian tail for $\phi_{\rm orb} \approx 0$ in data
$\Rightarrow$ structure in wind $\Rightarrow$ focussed wind? non-spherical clumps?

average values (circles) and standard deviations (error bars on the average values)



- absorption changes highly significant
- proof of principle for applicability of clumpy wind models to HMXBs
- absorption variability can be used to constrain porosity and study clump distribution and shape

- clumpy wind models with focussed wind component and/or more compex clump-shapes
- variability on shorter time scales with *Suzaku*, *Chandra* & *Astro-H*
- diagnosis of individual clumps with high resolution spectroscopy