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ESF Chancen fördern
EUROPÄISCHER SOZIALFONDS IN BADEN-WÜRTTEMBERG

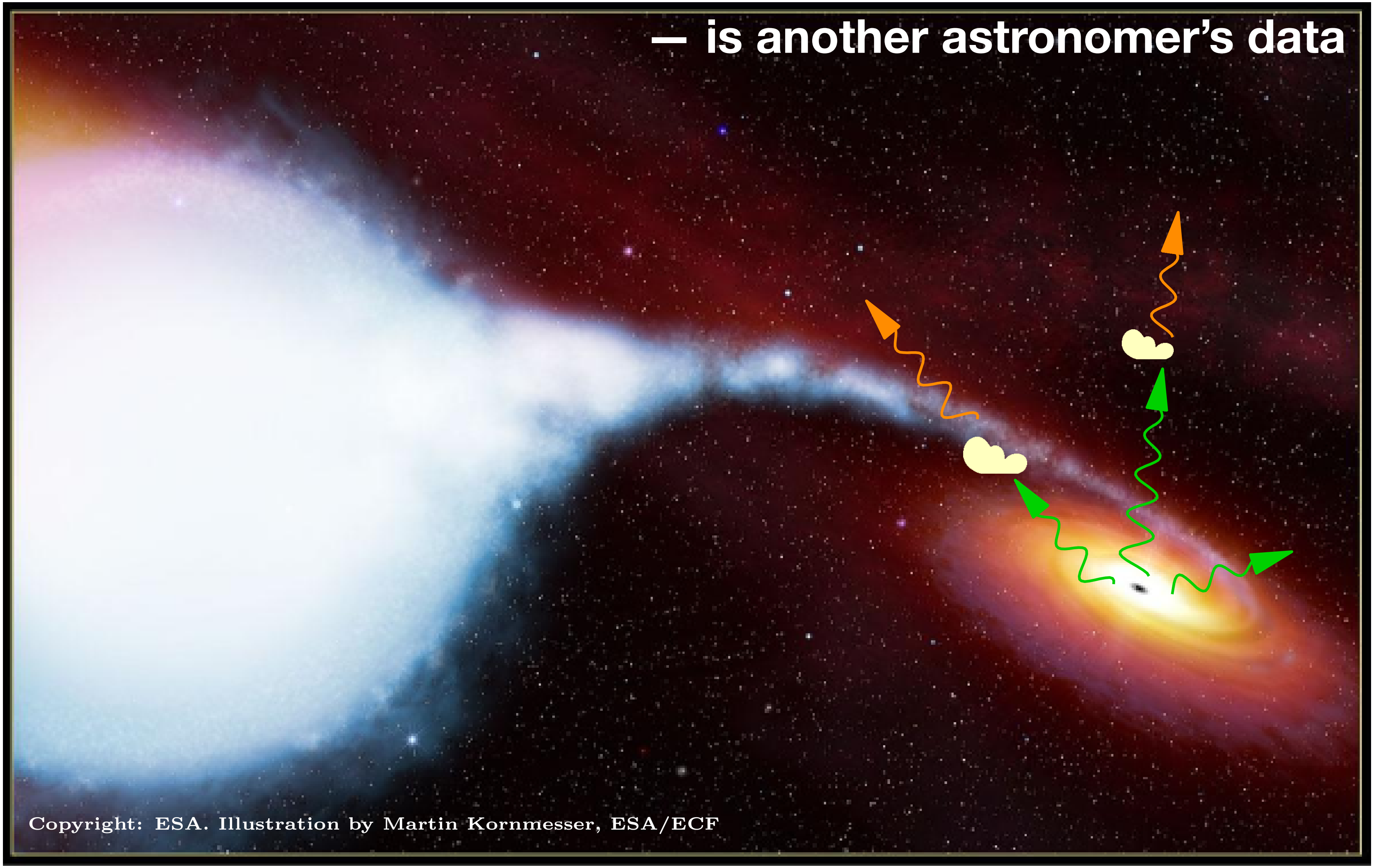
Baden-Württemberg
MINISTERIUM FÜR WISSENSCHAFT, FORSCHUNG UND KUNST

# X-raying stellar winds in high mass X-ray binaries

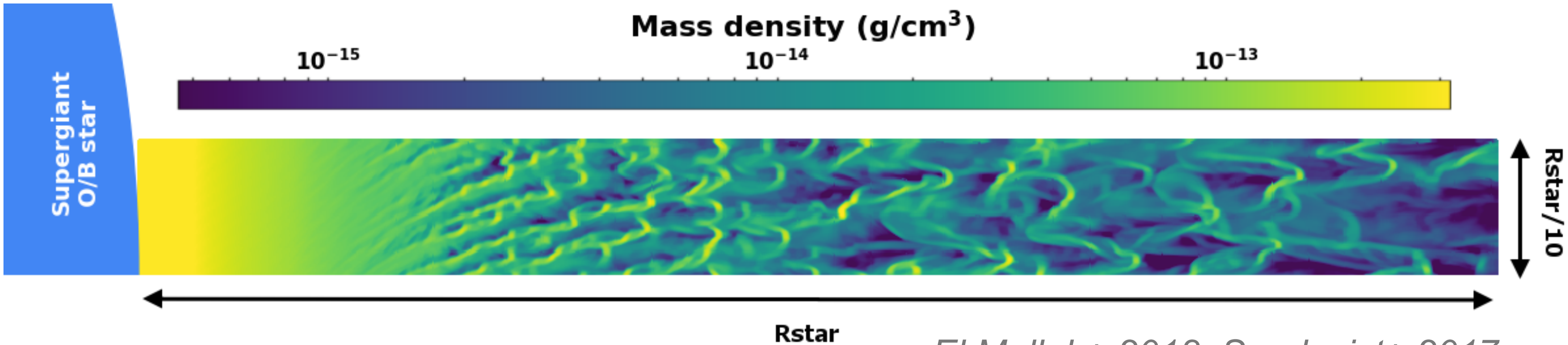
**Victoria Grinberg, IAAT Tübingen**

*with N. Hell,* ***M. Lomaeva, R. Amato,*** *M. Hirsch, I. El Mellah, P. Kretschmar, J. Wilms, M.A. Nowak, K. Pottschmidt, M. Leutenegger, S. Martínez Núñez & the* ***X-Wind collaboration***

# One astronomer's noise —



# Winds in massive stars




*El Mellah+ 2018; Sundqvist+ 2017*

Line-driven winds:

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

important for:

- star formation
- enrichment
- evolution of star itself

unstable to velocity perturbations

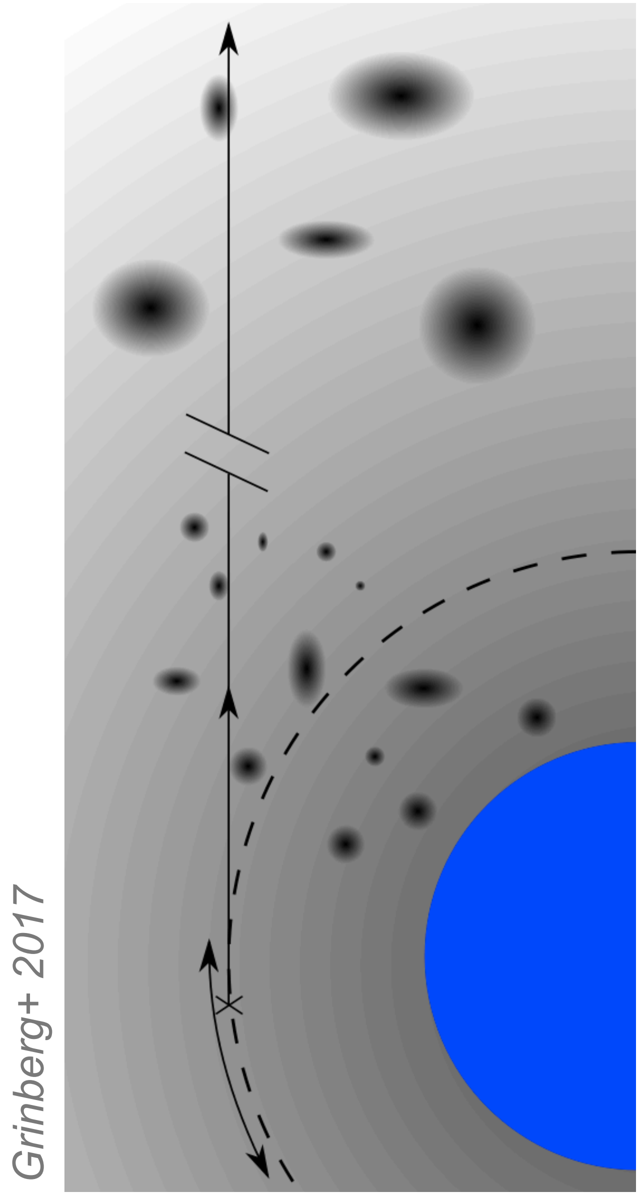
$\Longrightarrow$ rapid growth of perturbation

$\Longrightarrow$ strong shocks

$\Longrightarrow$ wind clumping

Multiple lines of evidence for wind clumping from single stars, but no way to probe clump structure

# Big questions




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

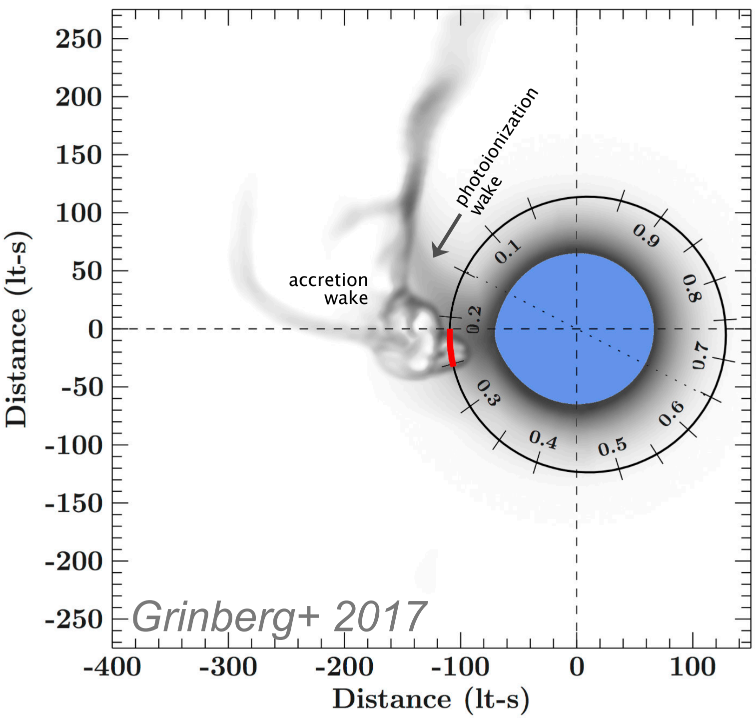
**Accretion structure:**
- accretion & photoinization wake
- accretion rate variability
- clumpy accretion
- disk formation

➤ mass loss rates in O/B stars
➤ accretion history of HMXBs

*stellar winds & HMXB review: Martínez-Núñez+ 2017*

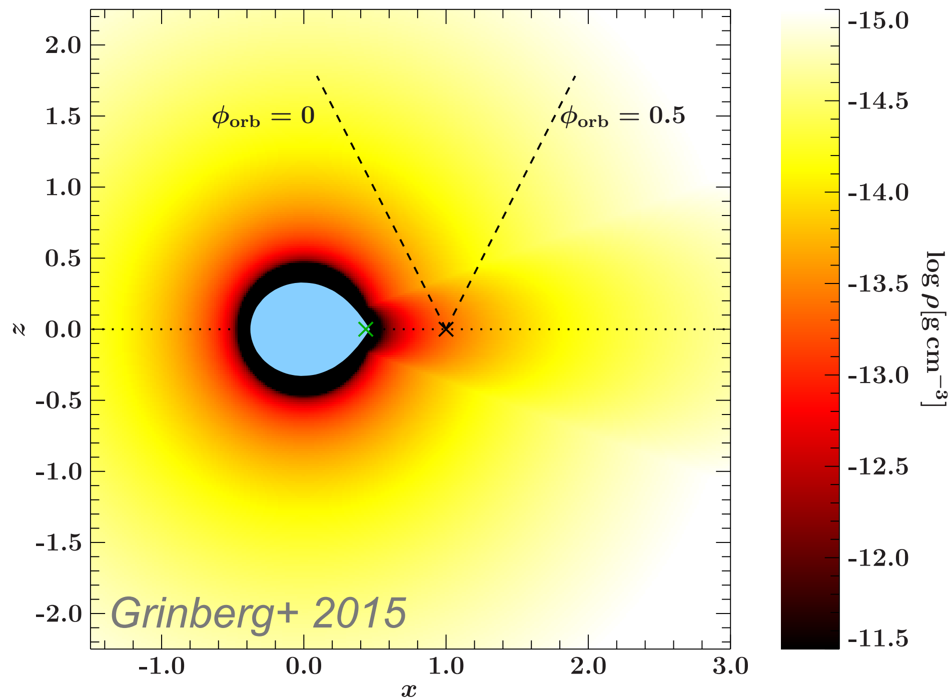
# Probing the innermost parts of the wind

**Vela X-1**/HD 77581 (B0.5 Ib)




- neutron star
- 9d eclipsing orbit
- accretion/photoionization wake

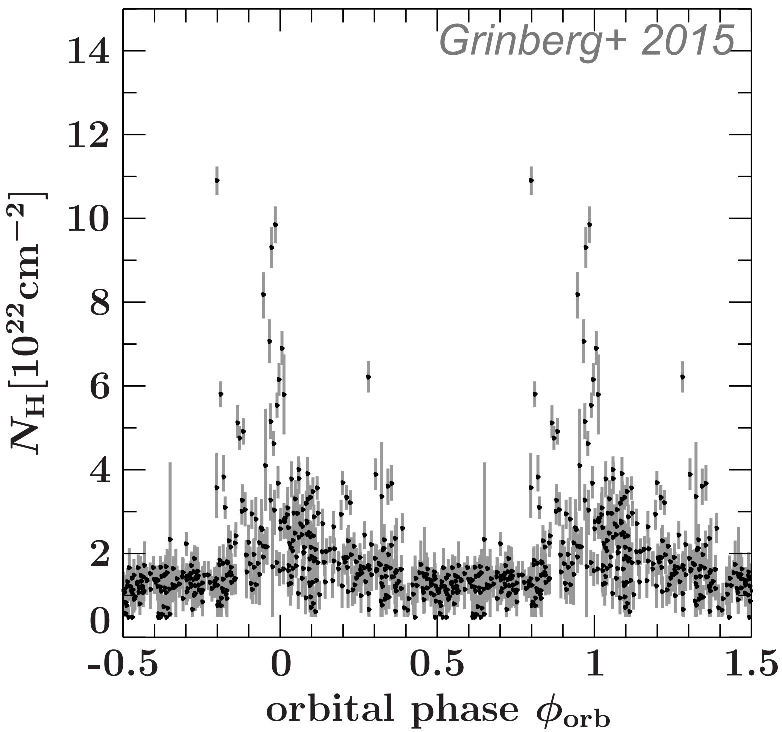
**Cyg X-1**/HDE 226868 (O9.7Iab)




- black hole
- 5.6d orbit, orbital inclination ~30°
- focussed wind accretion

# Cyg X-1: Orbital variability & dipping

## Smooth focused wind:




## Clumpy wind:

# Cyg X-1: Orbital variability & dipping

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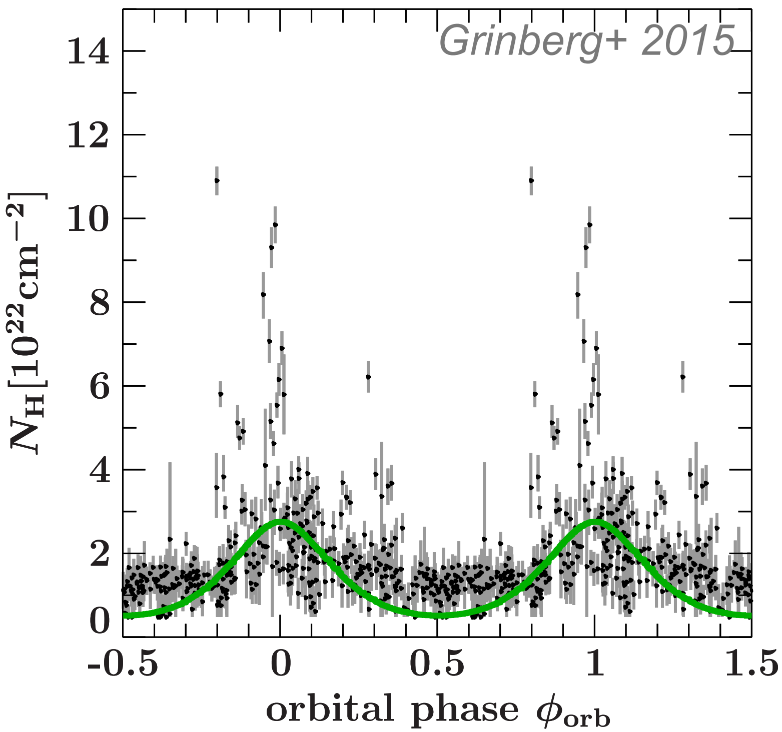


Does not explain the dips

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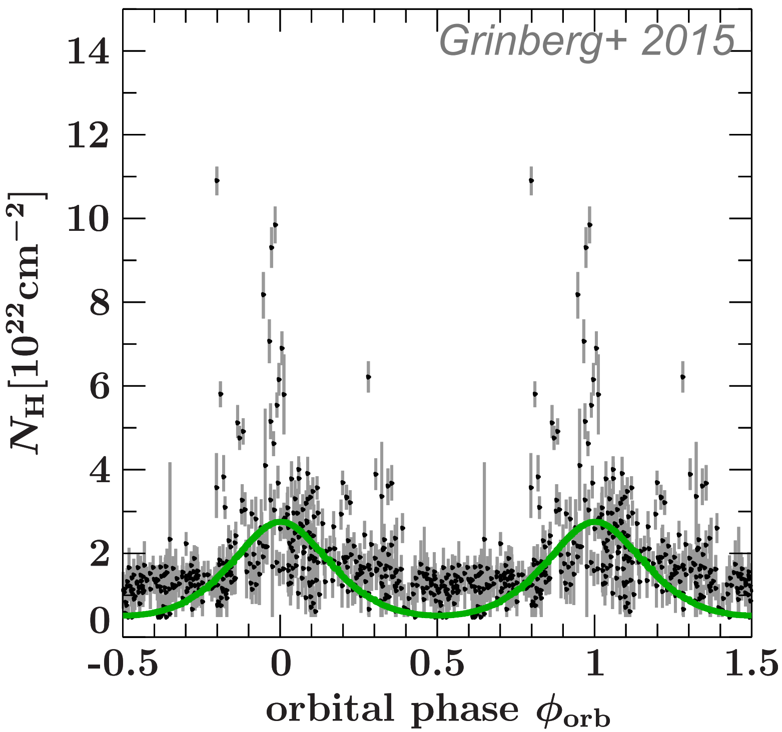


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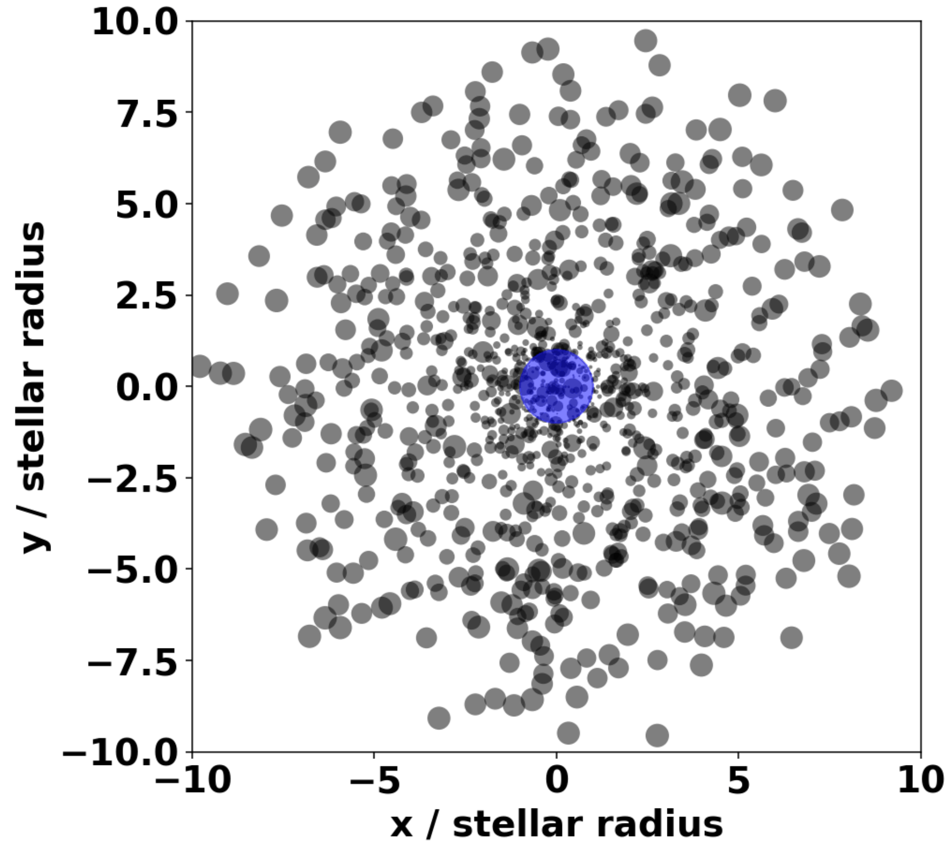


*El Mellah+ in prep.*

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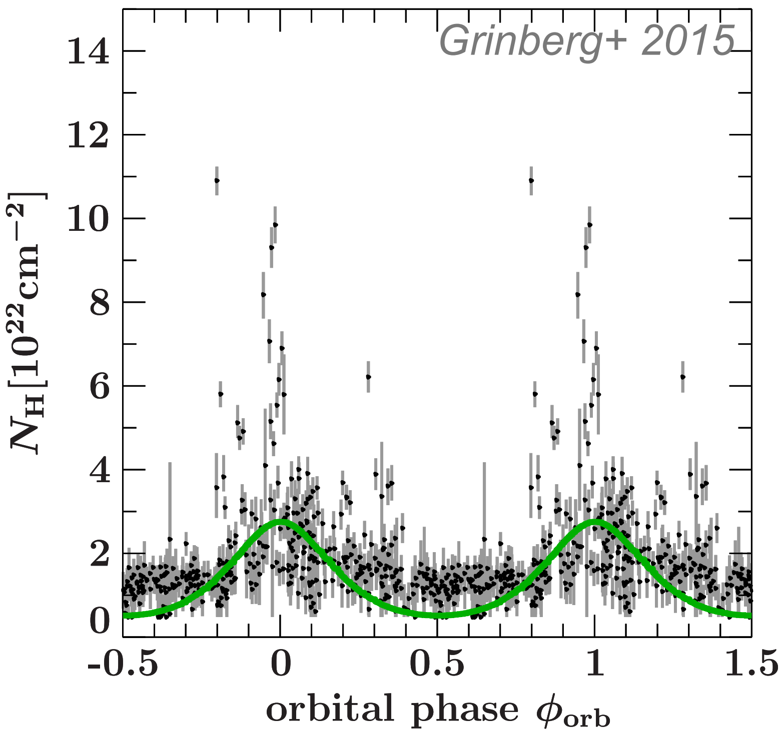


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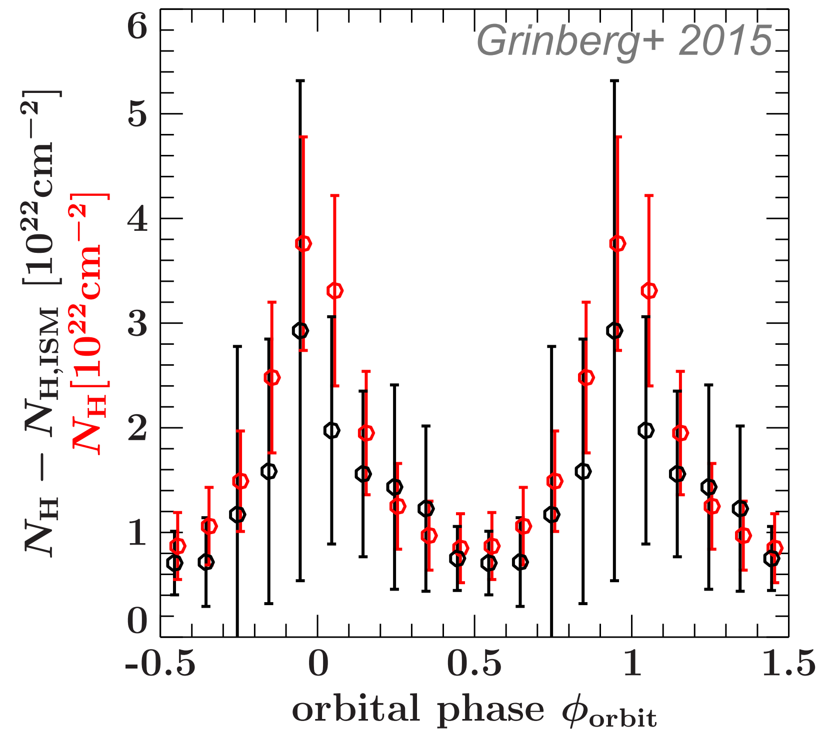
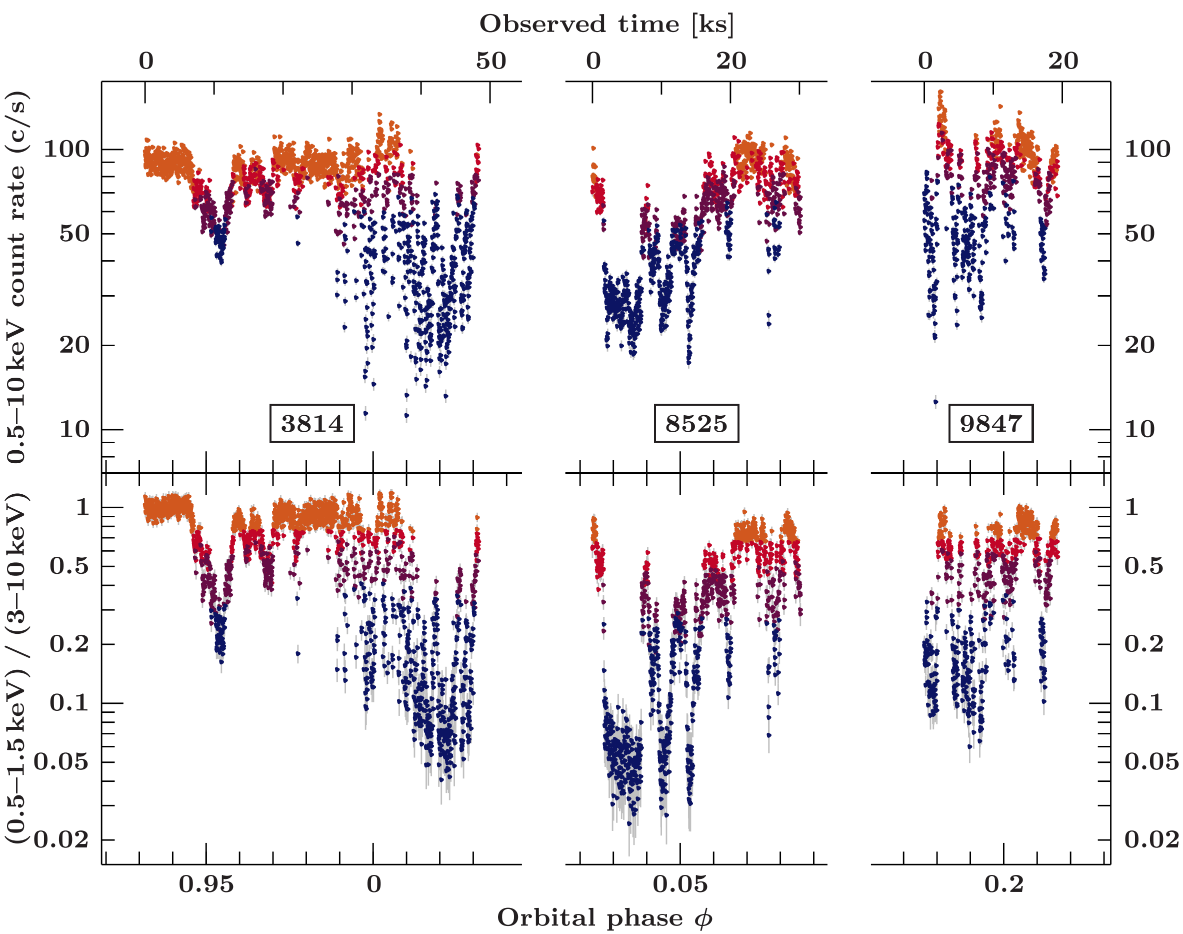



Explains dips and some of the variability, further studies necessary

# Cyg X-1: Clump structure

*Chandra HETG observations*




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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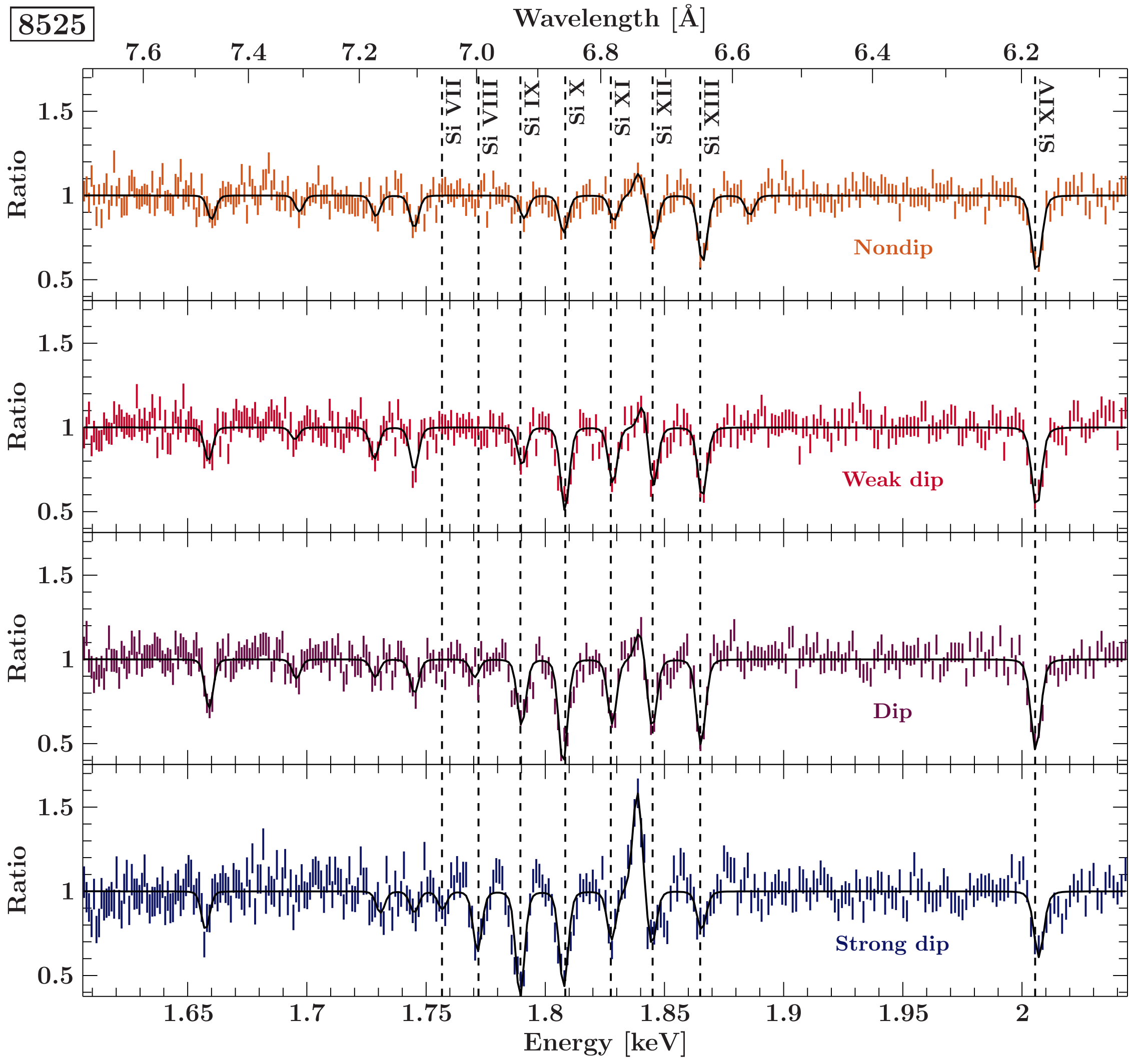


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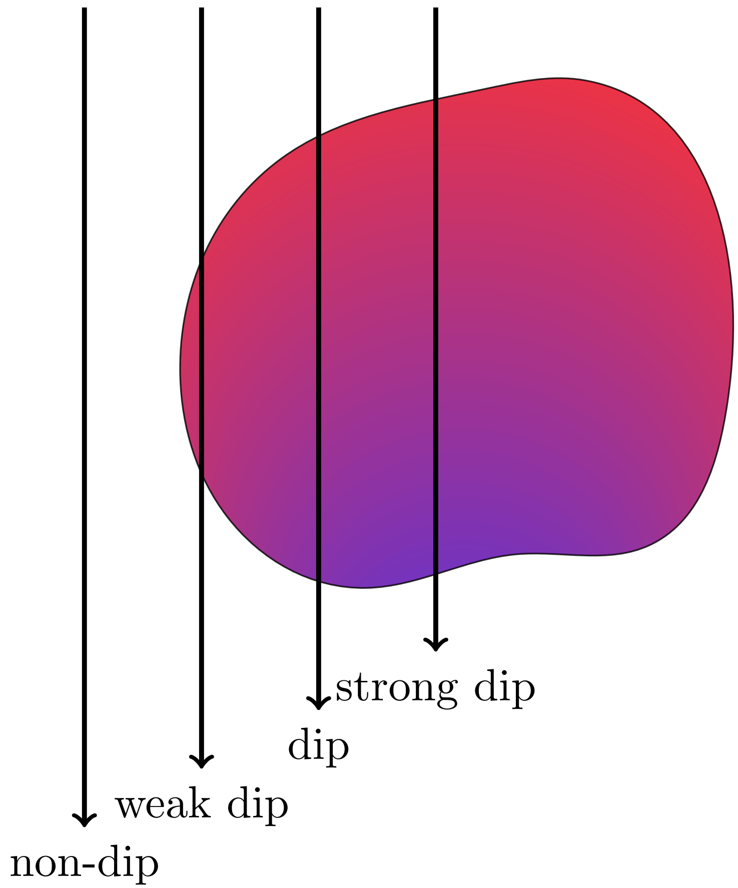



divided in four absorption stages using color-color diagrams

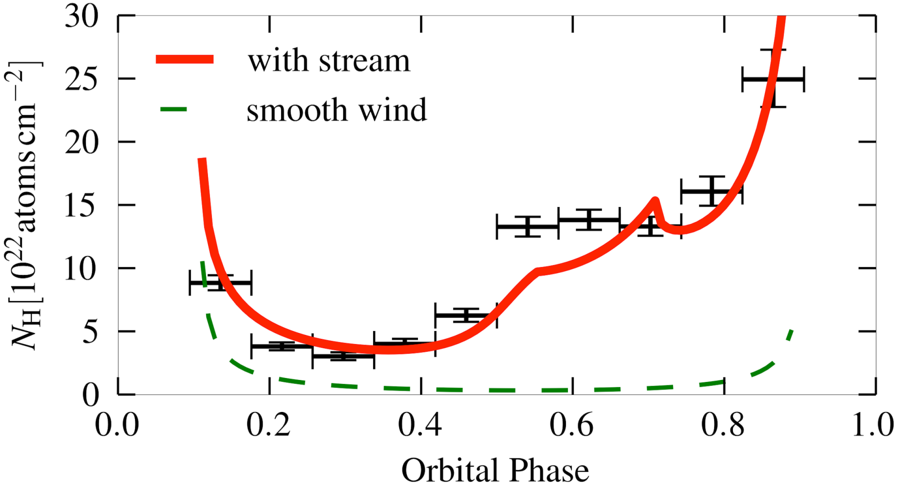
stronger absorption $\Longrightarrow$ lower ionization stages of Si & S

same Doppler-shift for all lines

$\Longrightarrow$ structured clumps with cold cores

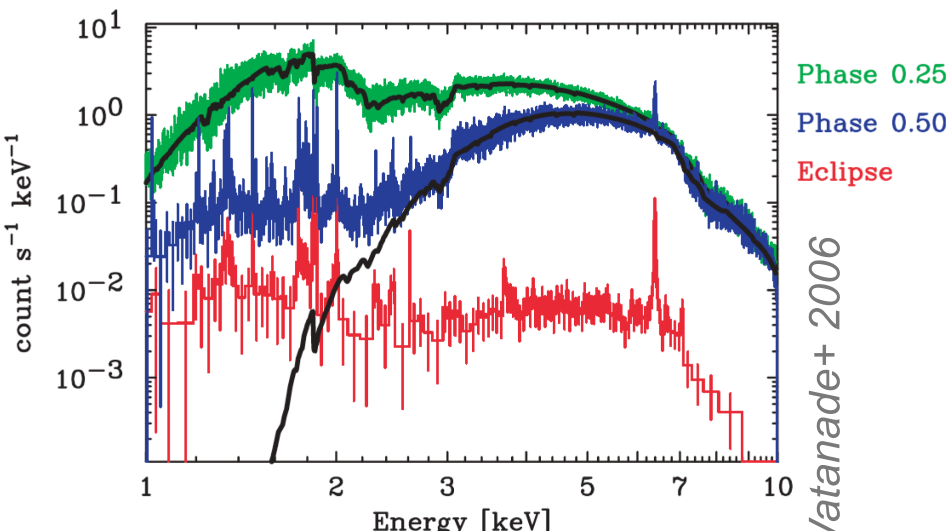
*Hirsch+ 2019*

# Vela X-1: multiphase medium




Doroshenko+ 2013

+ orbit to orbit variability




Watanade+ 2006

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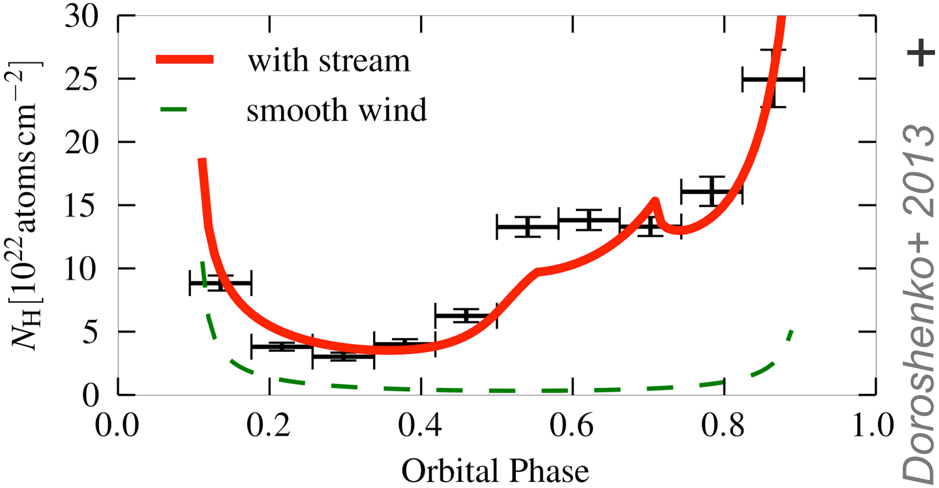


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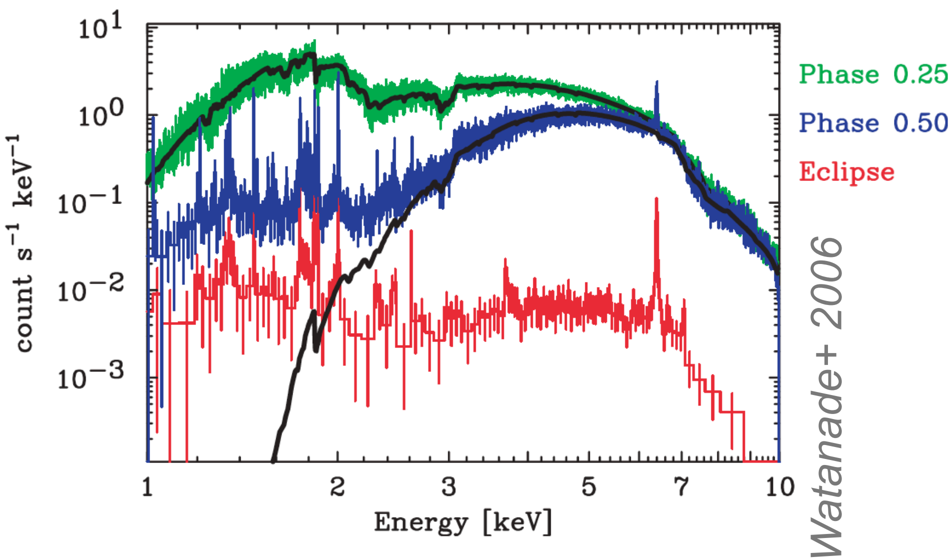
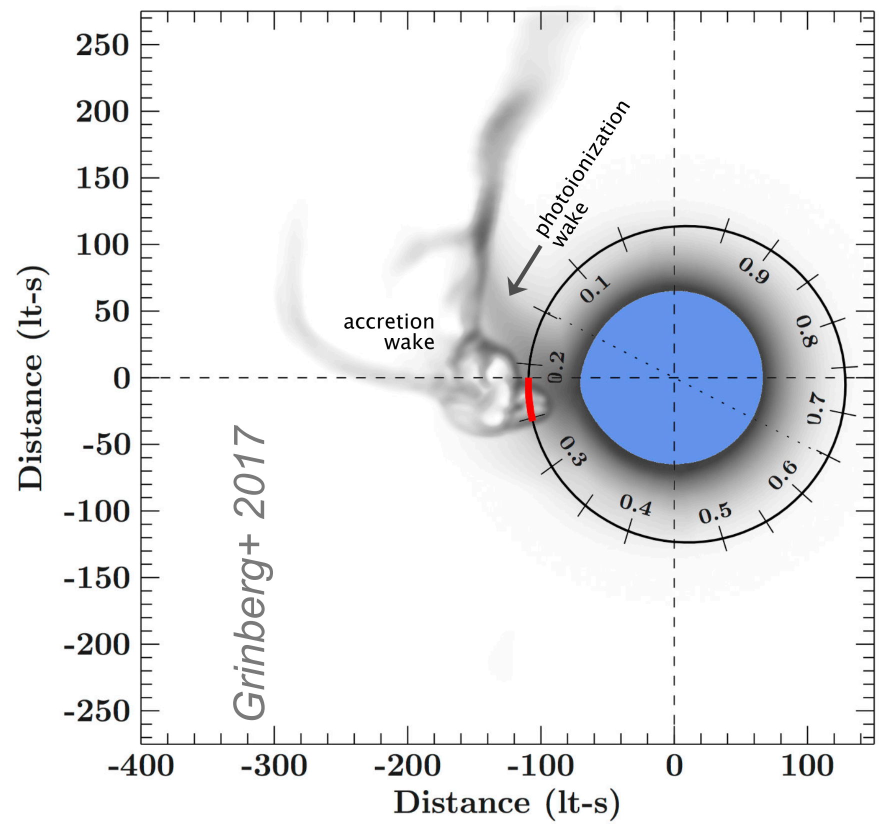
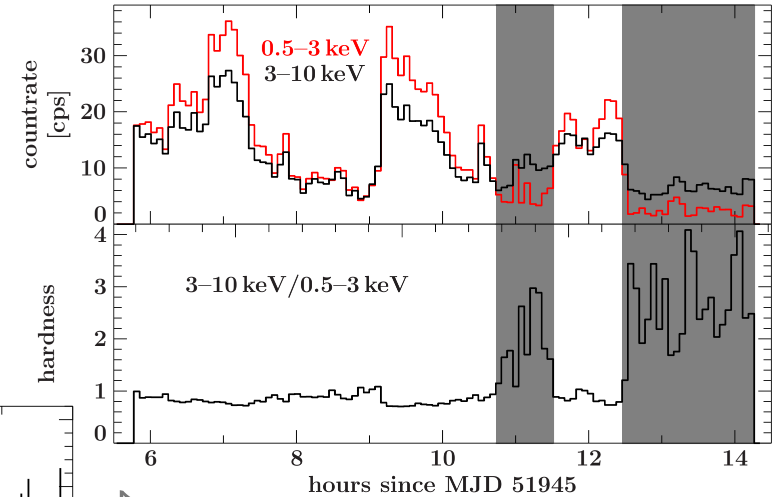
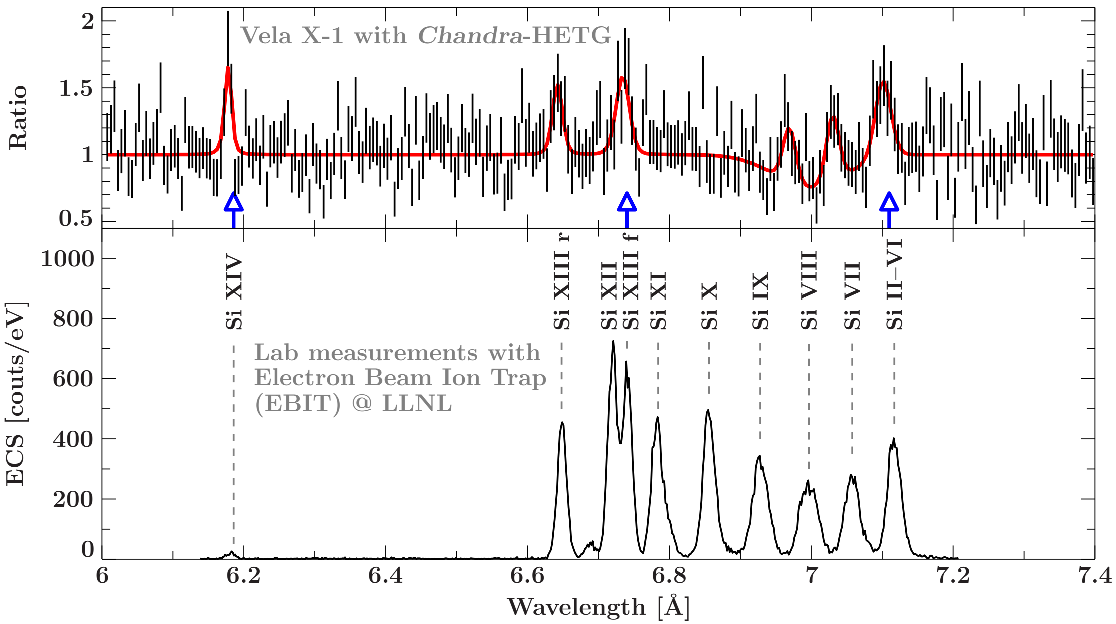


# Vela X-1: multiphase medium

ObsID 1928,
⟹ clearly defined periods of enhanced hardness



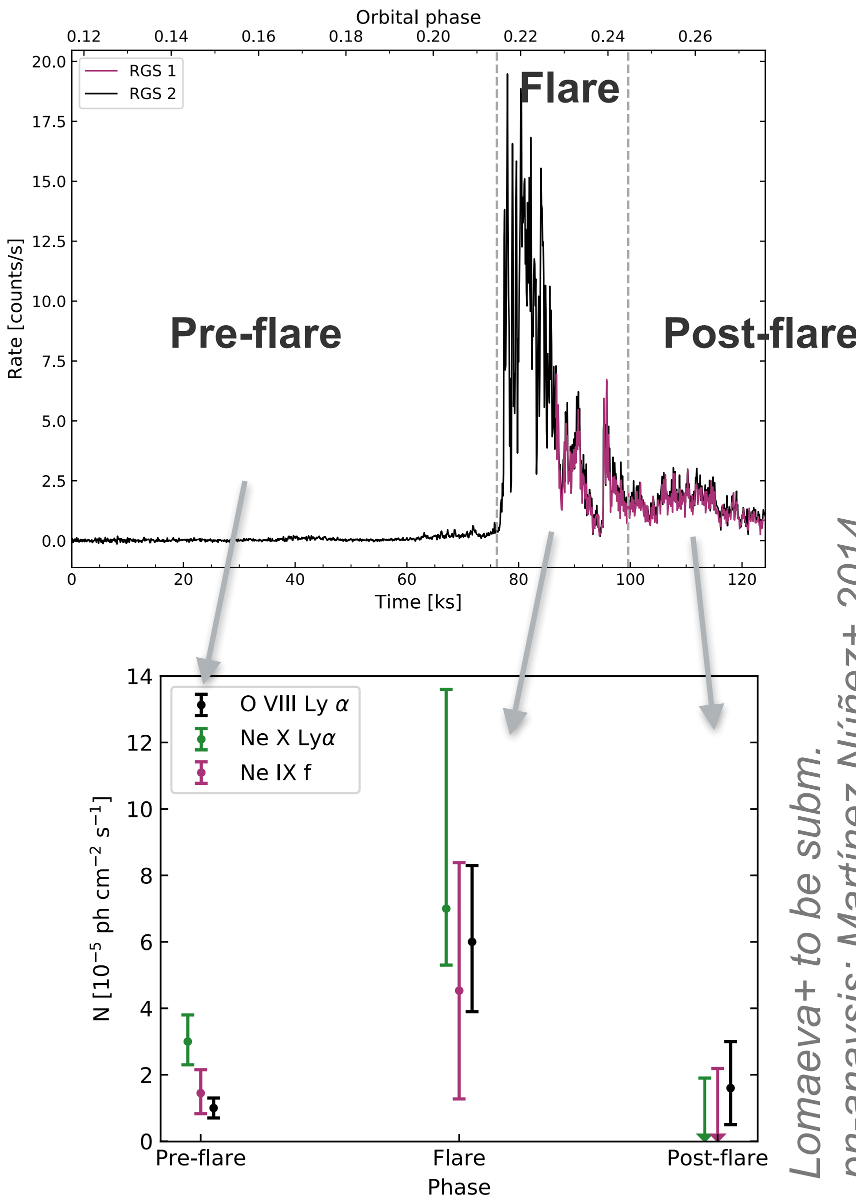

*Grinberg+ 2017*

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

*Other orbital phase: Amato et al. in prep.*

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

# Vela X-1: wind’s reaction to a flare




*Lomaeva+ to be subm.*

*pn-anaysis: Martínez Núñez+ 2014*

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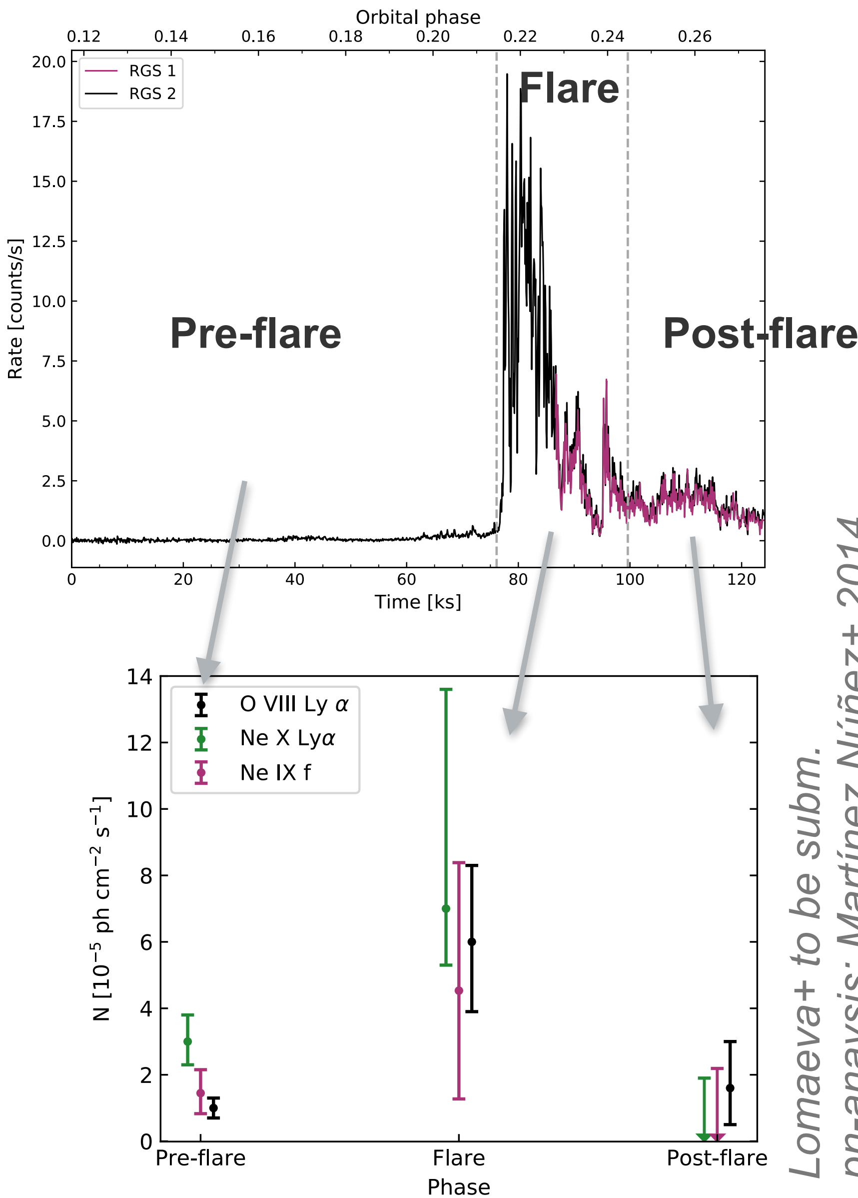
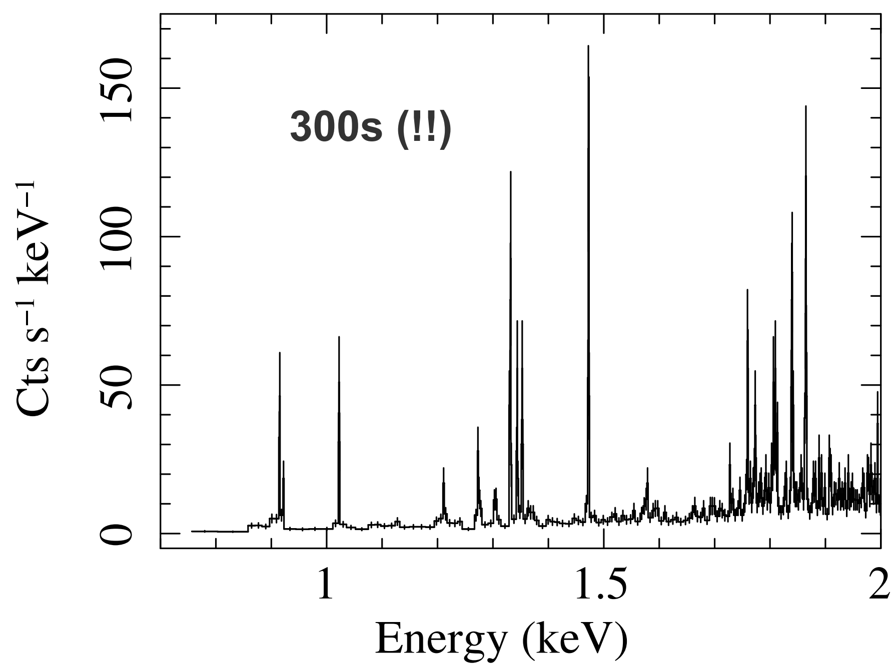



*Lomaeva+ to be subm.*
*pn-anaysis: Martínez Núñez+ 2014*

probing short timescales:

# Summary

➤ high mass X-ray binaries are unique tools to probe massive star winds & accretion structure
➤ absorption-resolved & time resolved analyses necessary
➤ Athena is going to revolutionize the field

*See also poster #228 by Silvia Martínez Núñez!*