

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

**Victoria Grinberg**

Margarethe von Wrangell habilitation fellow  
University of Tübingen, Germany

Science Working Group 3.3



EBERHARD KARLS  
**UNIVERSITÄT**  
**TÜBINGEN**



# Athena Science Requirements



R-SCIOBJ-325

*Athena shall determine the geometry, porosity and mass-loss rate of stellar winds of isolated massive stars, especially in the presence of magnetic fields, for a sample of Galactic massive stars. Time resolved spectral analysis of X-ray emission from a sample of high mass X-ray binaries hosting supergiant companions will provide an independent and representative probe of massive star wind properties.*

# Winds of O/B stars

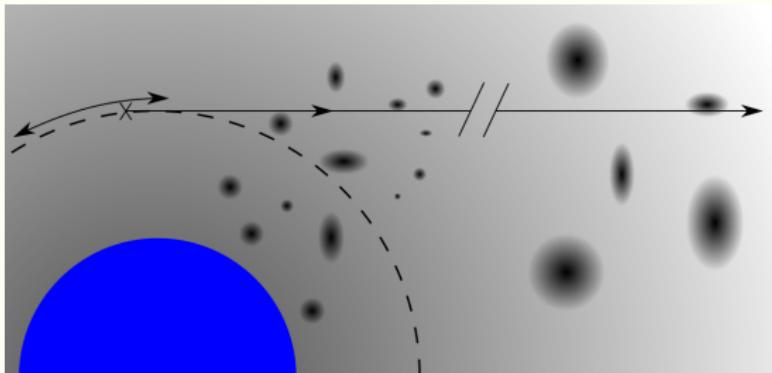


LH 72 in LMC; ESA/Hubble, NASA and  
D. A. Gouliermis

- line-driven (scattering of the star's UV radiation; CAK-winds after Castor, Abbott & Klein, 1975)
- mass loss:  
 $10^{-7}\text{--}10^{-4} M_{\odot}/\text{yr}$ 
  - ⇒ star formation
  - ⇒ enrichment
  - ⇒ stellar evolution

uncertainties in mass loss estimates because of uncertainties in clumpy wind structure

# Diagnostics

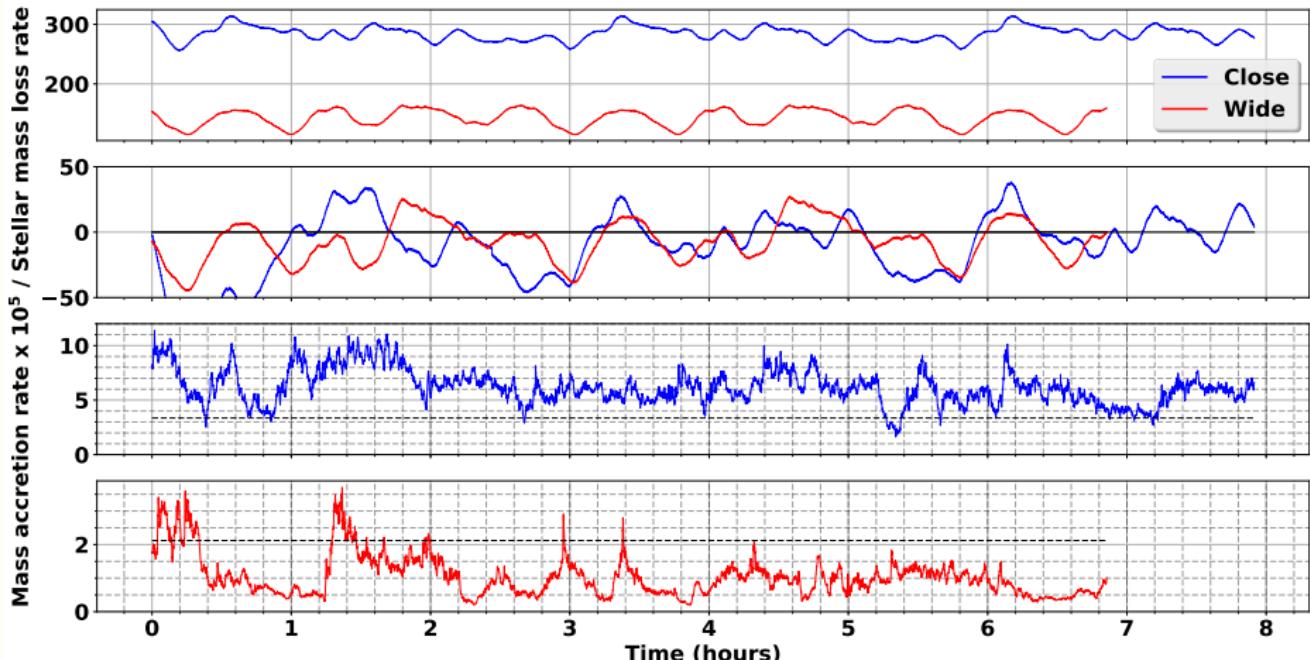


*Grinberg et al. 2017*

- line & edge presence  $\Rightarrow$  wind composition and clump structure
- line shifts  $\Rightarrow$  wind & clump dynamics
- He-like triplets  $\Rightarrow$  ionization processes
- RRCs  $\Rightarrow$  hot, thin wind component
- variability timescales  $\Rightarrow$  wind structure, clump-NS/BH interaction
- ingress/egress  $\Rightarrow$  wind density, ionization and accretion wakes
- Fe K $\alpha$  vs.  $N_{\text{H}}$   $\Rightarrow$  distribution of fluorescent material

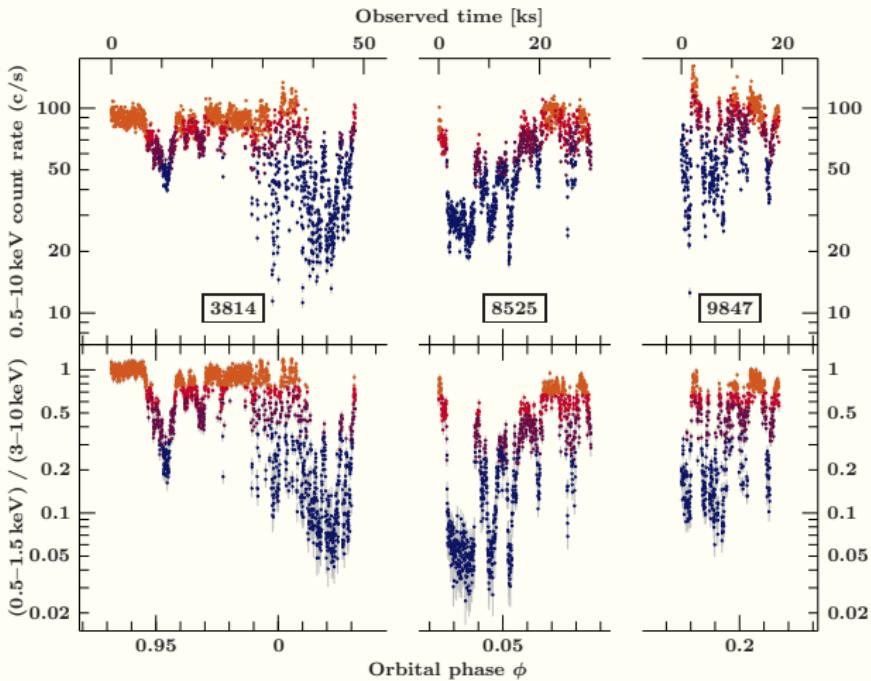
*stellar winds & HMXBs review: Martínez-Núñez et. al, 2017*

# Challenge I: variability



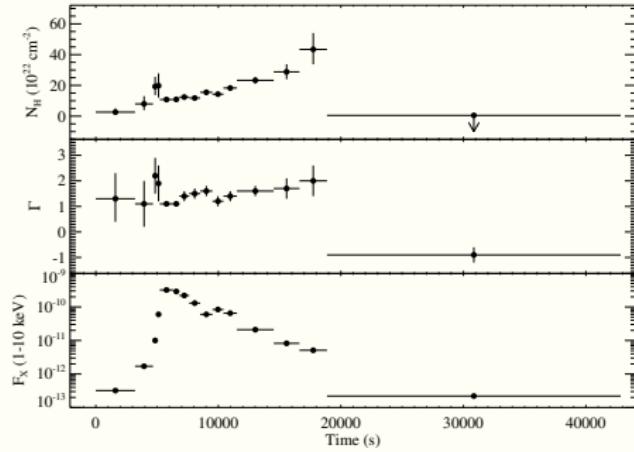
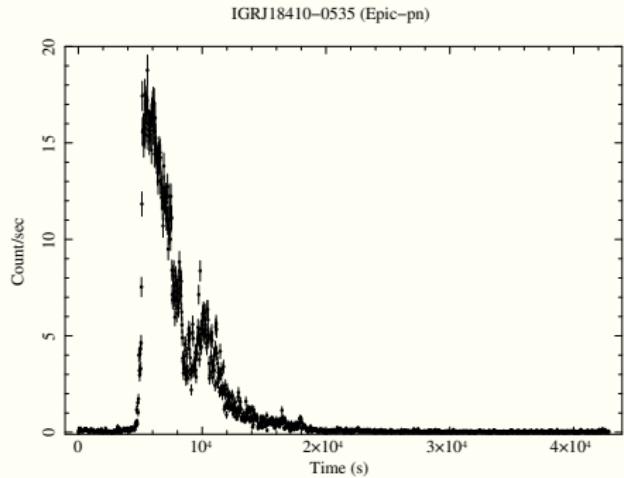
*El Mellah et al. 2018*

# Challenge I: variability



*Hirsch et al., in prep.*

# Challenge I: variability



Bozzo et al. 2011

⇒ exploit the large effective area of *Athena*

## Challenge II: atomic data

e.g., cold(er)  
clumps  $\Rightarrow$  low  
ionization lines

$$E_{\text{obs}} \neq E_{\text{lit}}$$

Doppler shifts  
or lack of knowl-  
edge of atomic  
physics?

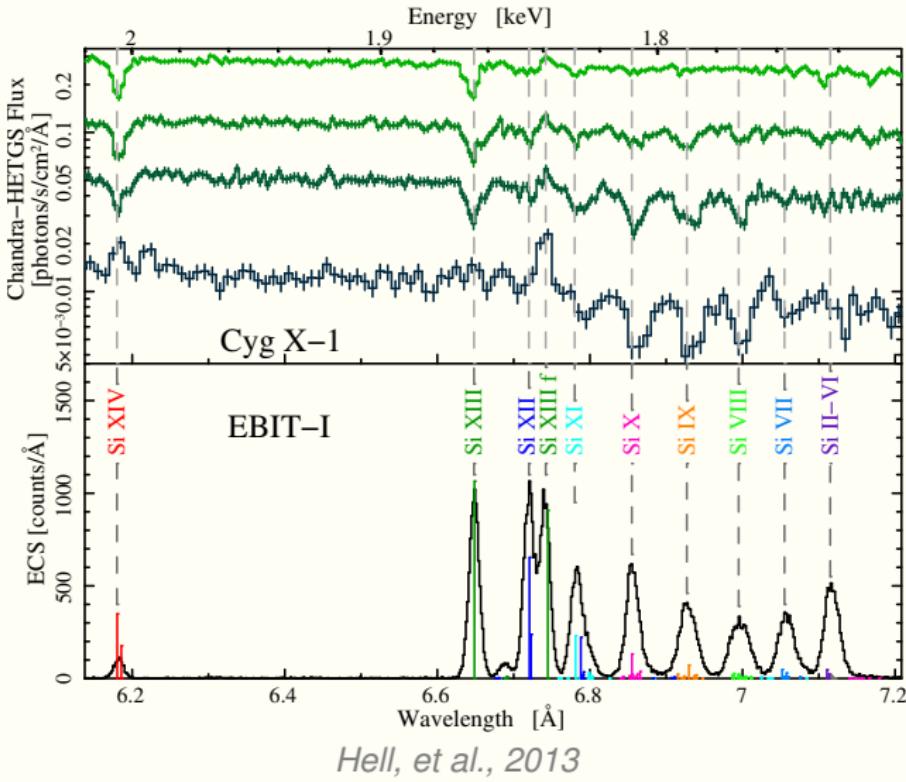
# Challenge II: atomic data

e.g., cold(er)  
clumps  $\Rightarrow$  low  
ionization lines

$$E_{\text{obs}} \neq E_{\text{lit}}$$

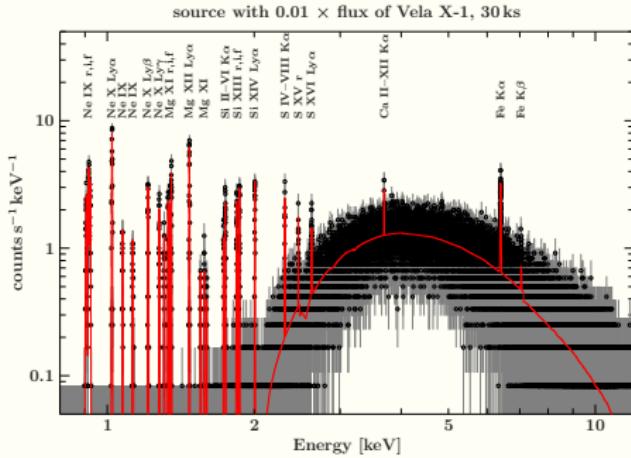
Doppler shifts  
or lack of knowl-  
edge of atomic  
physics?

do lab measure-  
ments NOW!

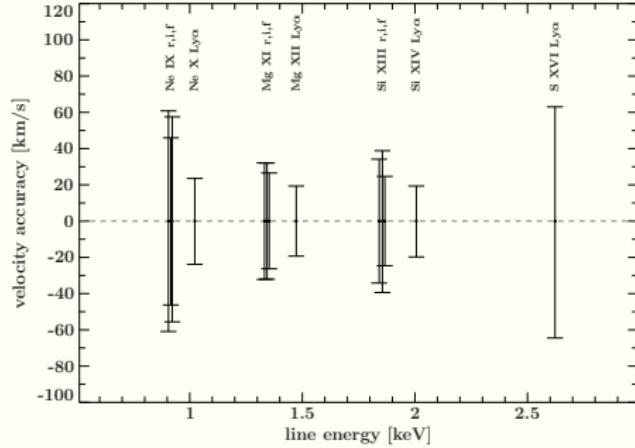


Hell, et al., 2013

# Increasing the sample: faint HMXBs

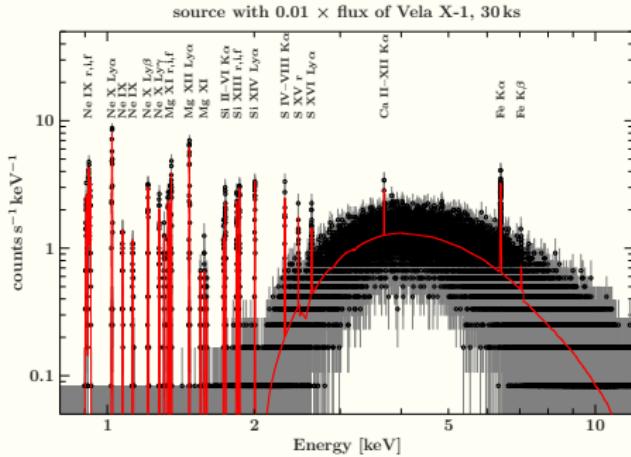


faint source, 0.01 flux of Vela X-1



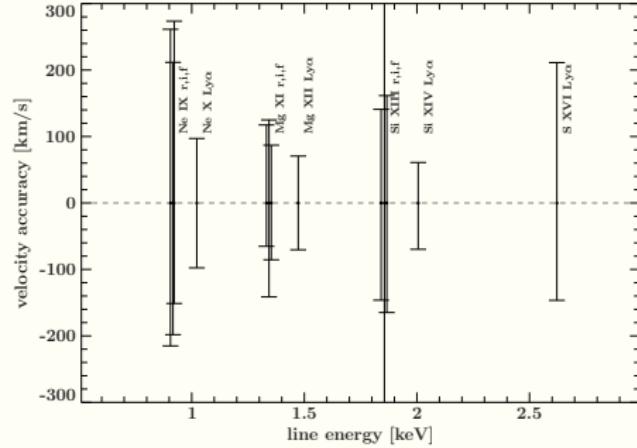
⇒ constraints on line velocities

# Increasing the sample: faint HMXBs



faint source, 0.01 flux of Vela X-1

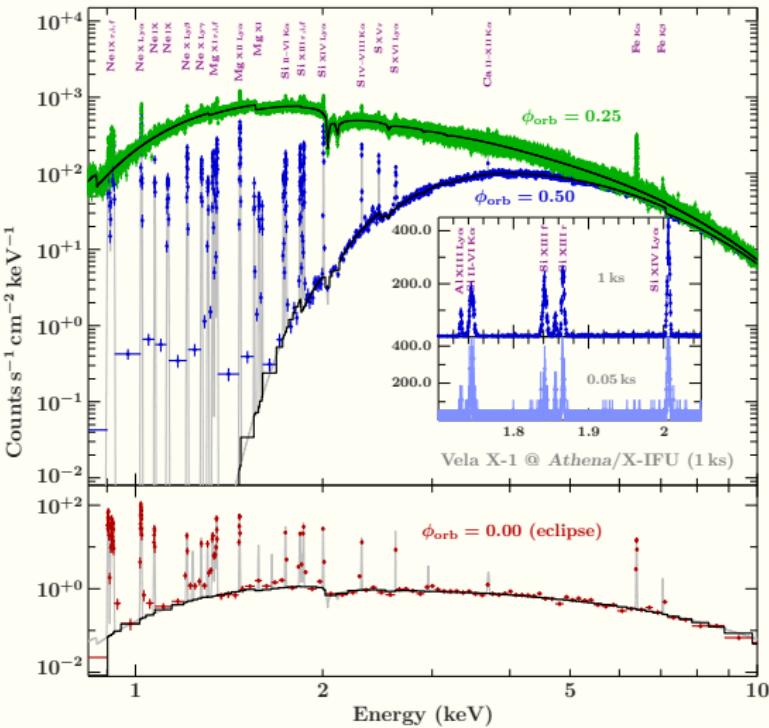
⇒ constraints on line velocities  
⇒ strongest lines contained even  
at 0.001 Vela X-1 flux



# Towards (much) shorter timescales

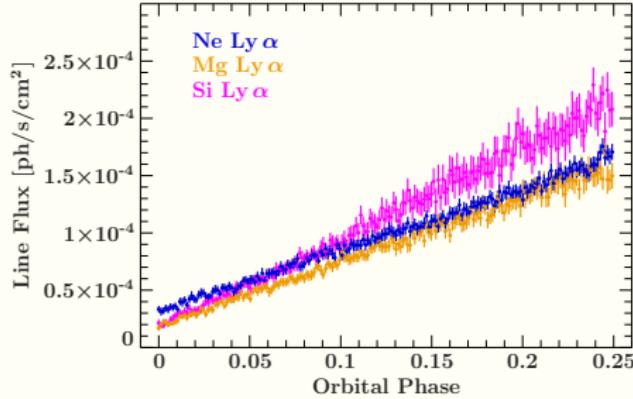
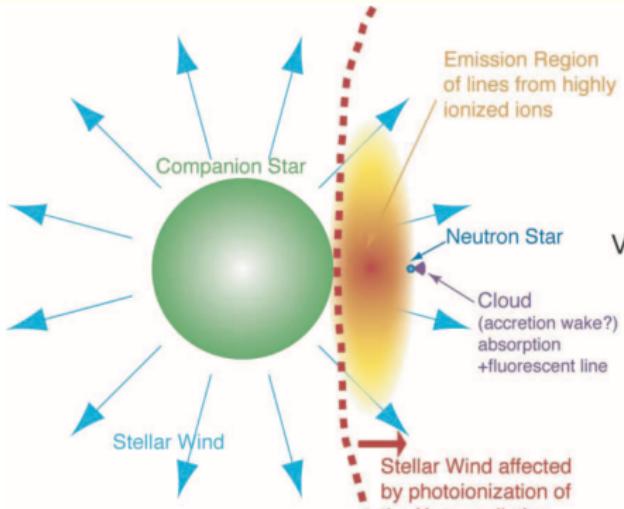
high quality spectra on timescales of 100 ks and below:

- ▶ structure of individual clumps
- ▶ wind reaction to continuum changes, e.g. flares
- ▶ pulse-to-pulse high resolution spectroscopy in NS-HMXBs



*simulation by N. Hell*

# Eclipse egress



simulation by N. Hell  
Watanabe et al. 2016

- ▶ linear extrapolation eclipse and  $\phi_{\text{orb}} = 0.25$
- ▶ line fluxes & overall absorption easily constrained in  $\lesssim 1 \text{ ks}$ 
  - ⇒ probe the ionization structure
  - ⇒ probe wind density structure, clumping onset

## Athena will re-define the field

(but we do need the bright source capabilities ...  
... and we do need to start getting the laboratory data now)