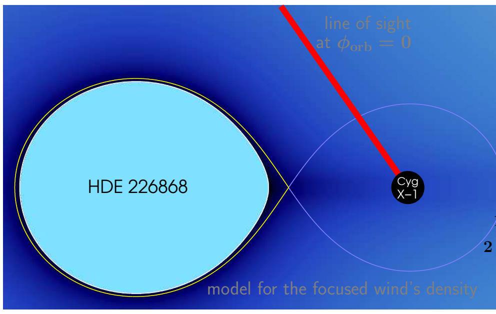

A Thorough Look at the Photoionized Wind and Absorption Dips in the Cyg X-1 System

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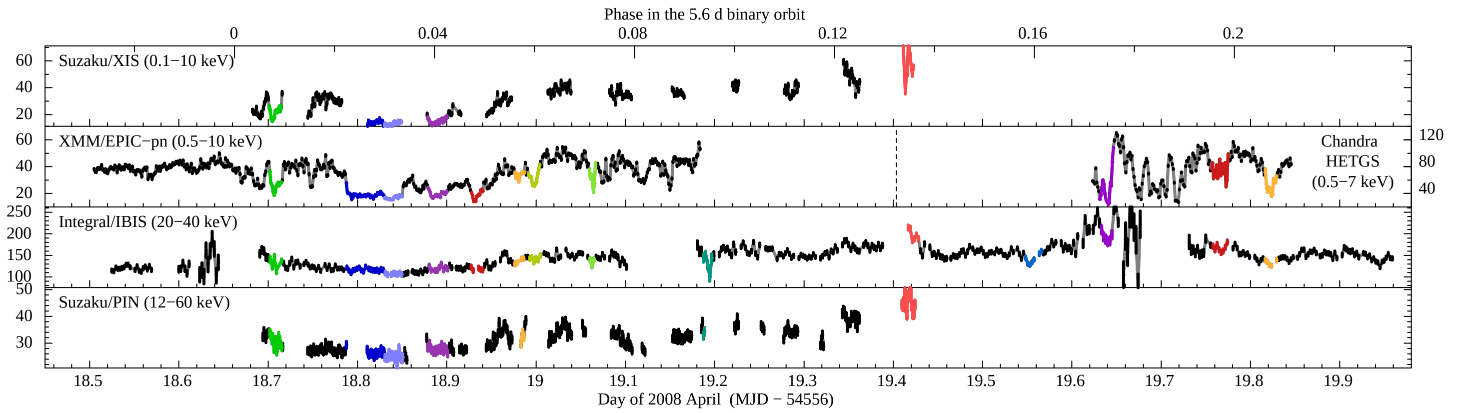
Abstract

We present results from our simultaneous observations of the high-mass X-ray binary system Cygnus X-1 / HDE 226868 with *Suzaku*, *Chandra*-HETGS, *XMM-Newton*, *RXTE*, *INTEGRAL*, and *Swift* in 2008 April. The observations have been performed shortly after phase 0 of the 5.6 d orbit when our line of sight to the accreting black hole passes through the densest part of the wind of the donor star.

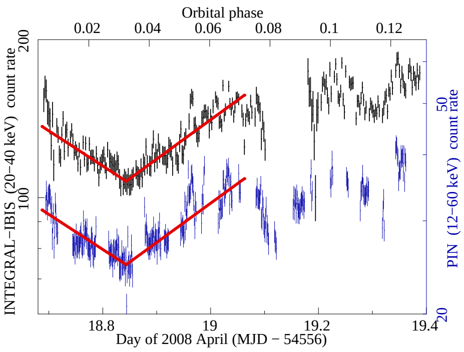
This contribution focuses on the analysis of the high resolution gratings spectra, which, in the context of a consistent description for the 0.5–600 keV spectrum, allow us to study the composition and dynamics of the highly photoionized wind. The soft X-ray band is strongly affected by transient absorption dips, caused by dense structures in the clumpy O-star wind. A color-color diagram shows evidence that the additional absorber causing the dips only covers part of the X-ray emitting region. The spectroscopic analysis reveals changes in the ionization state of the wind material between dip and non-dip phases.

Light curves of Cygnus X-1, observed with various instruments in different energy bands



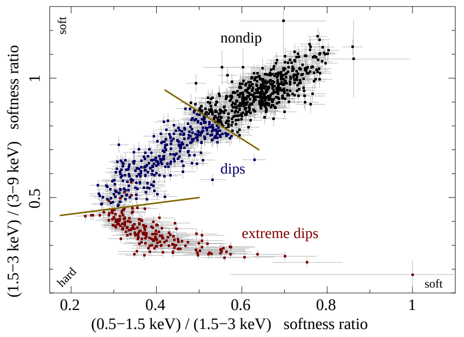
Several absorption dips with complex substructure significantly reduce the count rate in the soft X-ray band (*Suzaku*-XIS, *XMM*-EPIC-pn, *Chandra*-HETGS). Some of the dips (a selection of them has been colored) are even apparent at higher energies (*RXTE*-PCA, *Suzaku*-PIN, *INTEGRAL*-IBIS). The *RXTE*-PCA light curves are not shown here to improve the visual clarity, as they are very similar to the ones from *Suzaku*-PIN in the corresponding energy band. Hard X-rays are scattered out of the line of sight in the dense, photoionized wind seen at $\phi_{orb} \approx 0$.

Scattering of hard X-rays in the wind



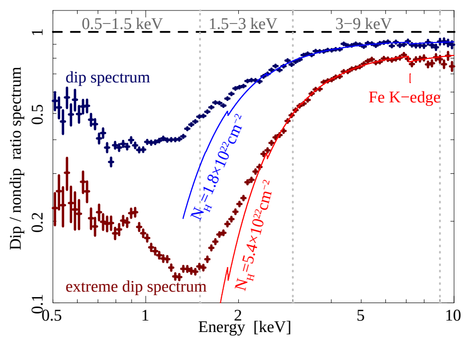
Both hard X-ray light curves (in different energy bands) show the same scattering troughs. The linear fit (red line) to the minimum at $\phi \approx 0.03$ reveals a 30 % reduction, corresponding to $N_e = 6\times10^{23}\,\mathrm{cm}^{-2}$ if caused by Compton scattering.

Suzaku-XIS color-color diagram during dips



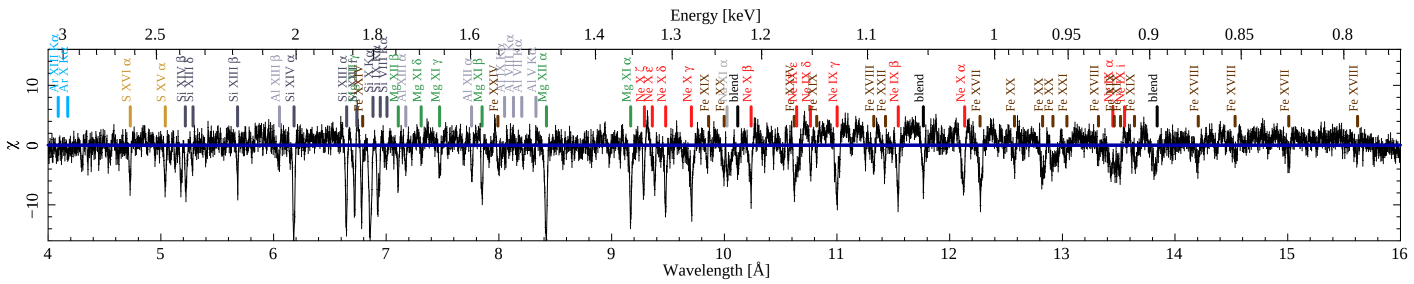
Dipping produces a clear track in this color-color diagram, which was calculated from light curves at 32 s resolution. Both colors harden during dips (blue) due to the increased absorption. The final softening (red) of the soft color indicates that the absorber only partially covers the X-ray source.

Suzaku-XIS spectra during dips



The ratios between the dip (blue) or extreme dip (red) spectra and the nondip spectrum show absorption at $E \gtrsim 3$ keV and a soft excess due to partial covering. The latter is *not only* caused by the unresolved and time-delayed scattering halo.

High-resolution *Chandra*-HETGS spectrum showing highly ionized wind absorption lines and lower ionization stages due to dips



The high resolution *Chandra*-HETGS and *XMM*-RGS spectra reveal a multitude of absorption lines of mostly highly ionized (H- and He-like) as well as Fe L-shell ions, which are formed in the wind of the supergiant companion star (see Hanke et al., 2009). While the spectrum shown above comprises both dip and nondip phases, a separate analysis of these parts shows that Kα resonance absorption lines from lower ionization stages (marked by slightly elevated labels) of, e.g., Ar (at ≈ 4–4.2 Å), Si (at ≈ 6.7–7.1 Å), or Al (at ≈ 7.9–8.3 Å) are linked to the dip phases. The dips are therefore likely to be caused by cooler clumps in the wind, which is otherwise highly photoionized by the X-ray source. A more detailed investigation of these spectra, using photoionization simulations like the XSTAR code, will allow to constrain – besides the dynamics – also densities and temperatures of the absorbing clumps (Hanke et al., in prep.).

References

Hanke, Wilms, Nowak, Pottschmidt, Schulz, & Lee (2009), ApJ **690** : 330-346
Hanke, Wilms, Boeck, Nowak, Schulz, Pottschmidt, & Lee (2009), PoS, VII Microquasar Workshop Proc. (arXiv : 0811.0022)

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