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Absorption line

Summary

Spectroscopy of the stellar wind in the Cygnus X-1 system

lvica Miškovičová*, Manfred Hanke* J. Wilms*, M. A. Nowak, K. Pottschmidt, N. S. Schulz



* Dr. Remeis Observatory, Bamberg Erlangen Centre for Astroparticle Physics University Erlangen-Nuremberg, Germany





September 22, 2010

Ivica Miškovičová: Spectroscopy of the stellar wind in the Cyg X-1

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Outline of the talk

Introduction

- Accretion in X-ray Binaries
- Stellar wind
- 2 Cygnus X-1
 - Cygnus X-1 and its companion HDE 226868
 - Stellar wind in the Cygnus X-1
 - Source states
 - Chandra observations
- 3 Data and data analysis
 - Instruments
 - ObsID 3815, $\phi \approx 0.76$
- 4 Light Curves and Dipping
 - Light curves



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Summary

Accretion in X-ray Binaries



- stellar wind accretion in High Mass X-ray Binaries (HMXB)
- accretion disk accretion in Low Mass X-ray Binaries (LMXB)
- $\bullet\,$ efficient energy release, X-ray luminosities $\sim 10^{38}\; {\rm erg/s}$

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Summary

Stellar wind of HMXBs

- hot, O or early B stars: winds driven by absorption lines
- very strong: mass loss rate $\sim 10^{-6} M_{\odot}/{\rm year}$
- Theory: two components of the wind: cool dense clumps embedded by hot photoionized gas (Castor, Abbot, Klein, 1975; Sako et al. 2002)

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Summary

Stellar wind of HMXBs

- hot, O or early B stars: winds driven by absorption lines
- very strong: mass loss rate $\sim 10^{-6} M_{\odot}/{\rm year}$
- Theory: two components of the wind: cool dense clumps embedded by hot photoionized gas (Castor, Abbot, Klein, 1975; Sako et al. 2002)
- wind structure can be probed directly by Chandra high-resolution spectroscopy (with bright sources like Cyg X-1)

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The high-mass X-ray binary system Cygnus X-1



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Focused stellar wind in the system



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Hard and Soft State of the Cygnus X-1

• hard or soft

Cygnus X-1



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Chandra observations of Cygnus X-1



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Summary

Goals and aims of the research

We focus on

- High Mass X-ray Binaries, especially Cyg X-1
- strong and focused stellar wind and its properties
- source states transitions
- understanding of the accretion process

by detailed

- study of photoionization of material (high X-ray luminosity)
- spectral analysis of absorption lines

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Chandra High Energy Transmission Grating (HETG)

• two sets of gratings: the High and the Medium Energy Grating (HEG and MEG)



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Data reduction with CIAO 4.2 and order-sorting problem



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Solution: tg_resolve_events \Rightarrow osipfile="none", osip_lo and osip_hi



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Telemetry saturation Fractional exposure CCD 4 0.5 9 CCD 5 0.5 9 CCD 6 0.5 9 CCD 7 0.5 9 CCD 8 0.5 9 CCD 9 0.5 0 10 20 30 50 0 40

Time since MJD 52702.665 [ks]

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ObsID 3815 - corrected light curve



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Compared Chandra observations of Cygnus X-1



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Light curves of Cyg X-1 at prominent phases



- $\phi \approx 0$: violent absorption dips
- dipping occurs already at $\phi \approx 0.7$ and has not ceased at $\phi \approx 0.2$
- $\phi \approx 0.5$: totally free of dips!

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ObsID 3815 - Color-color diagram



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Color-color diagrams - comparison









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Absorption and P Cygni profiles of Si ${\rm XIV},~{\rm Mg}\,{\rm XII},~{\rm Ne}\,{\rm x}$



- $\phi{\approx}0$: strong absorption lines, $v_{\rm rad}{\approx}0$
- $\phi \approx 0.5$: P Cygni profiles: strong emission at $v_{\rm rad} \approx 0$ and weak absorption tail blueshifted by $\sim 500 - 1\,000 \, km/s$
- \Rightarrow if the same plasma is observed in both cases \Rightarrow the real velocity has to be small \Rightarrow we see a dense wind close to the stellar surface
 - $\phi \approx 0.7$: absorption lines, but redshifted by $\sim 200 300 km/s$

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Summary

- Comparison of $\phi \approx 0$, $\phi \approx 0.2$, $\phi \approx 0.5$, $\phi \approx 0.7$
- Strong absorption dips around $\phi \approx 0$, while NO dips at $\phi \approx 0.5$
- P Cygni profiles observed for the first time in Cyg X-1! at $\phi \approx 0.5$ in contrast to strong pure absorption at $\phi \approx 0 \Rightarrow$ environment close to stellar surface
- Si absorption lines of lower ionization stages present only in dip spectra⇒ inhomogeneities of lower temperature in the wind

Outlook

- Photoionization modeling
- Wind structure modeling

The high-mass X-ray binary HDE 226868/Cygnus X-1

HDE 226868 parameters:

- O9.7 lab supergiant
- $M_{\star} = 18 M_{\odot}$
- $T_{\rm eff} = 32\,000\,{\rm K}$
- $L_{\star} = 250\,000\,L_{\odot}$
- $R_{\star} \approx 17 \, R_{\odot}$
- $v \sin i = 76 \,\mathrm{km/s}$
- fills ≈90 % of Roche lobe volume

•
$$\dot{M}_{\star} = 3 \times 10^{-6} \, M_{\odot} / \mathrm{yr}$$

Binary system parameters:

- $\bullet~$ orbital period $P=5.6\,{\rm d}$
- $\bullet~{\rm distance}~d\approx 2.5\,{\rm kpc}$
- binary separation $a = 41 R_{\odot}$
- Cyg X-1 parameters:

•
$$M_{\rm BH} = 10 \, M_{\odot}$$

• $L_X \approx 10\,000\,L_{\odot}$

Advanced CCD Imaging Spectrometer (ACIS) focal plane ACIS FLIGHT FOCAL PLANE



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