A search for non-thermal X-ray emission in the colliding wind binary Cyg OB2 #8A

Enmanuelle Mossoux et al. 2019 (in preparation)

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Outline

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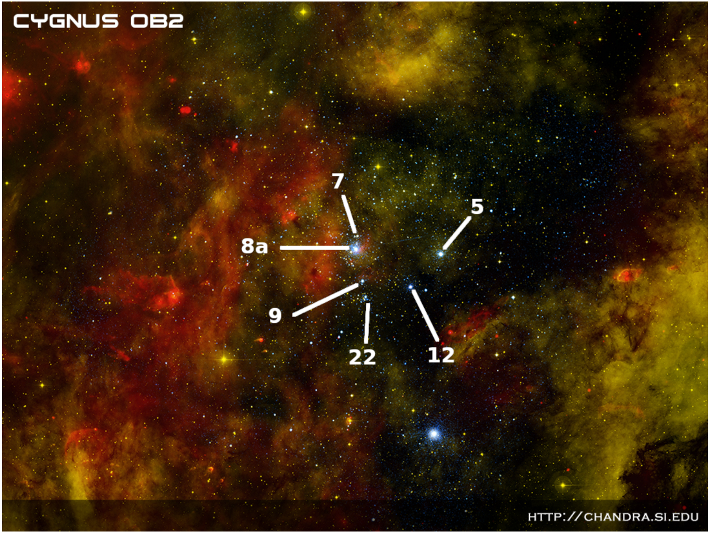
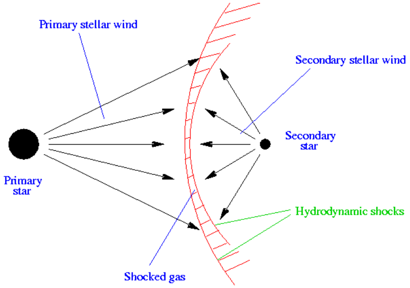
Cygnus OB2



Optical, infrared and X-ray composite image

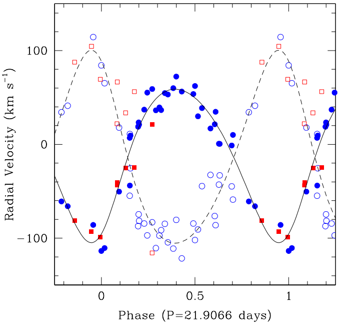
Colliding wind binaries (CWB)



De Becker et al. (2008)

- Kinetic energy of the winds → heating up to 10^7K → thermal X-rays;
- Diffusive shock acceleration → relativistic particles → non-thermal radio;
- UV emission from the stars + relativistic particles = inverse Compton (IC) → non-thermal hard X-rays.

Cyg OB2 #8A (BD+40°4227A, Schulte 8A)



	Primary	Secondary
$P_{\rm orb}$ (days)	21.9066 ± 0.0013	
e	0.18 ± 0.03	
T_0 (HJD−2 450 000)	8005.66 ± 0.62	
ω (°)	207.6 ± 11.9	
γ (km s^{-1})	-10.0 ± 2.8	-18.8 ± 3.2
K (km s^{-1})	81.8 ± 2.9	102.8 ± 3.6
$a \sin i$ ($R_\odot$)	34.8 ± 1.2	43.8 ± 1.5
$m \sin^3 i$ ($M_\odot$)	7.6 ± 0.6	6.0 ± 0.5

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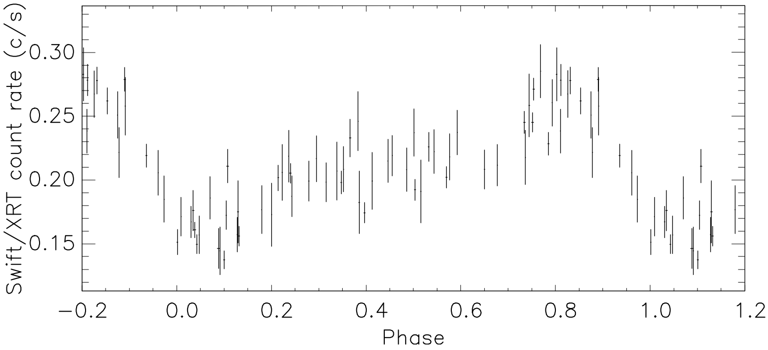
Swift and XMM-Newton observations

Swift: 67 new observations + 6 already analyzed observations
XMM-Newton: 5 new observations + 7 already analyzed observations

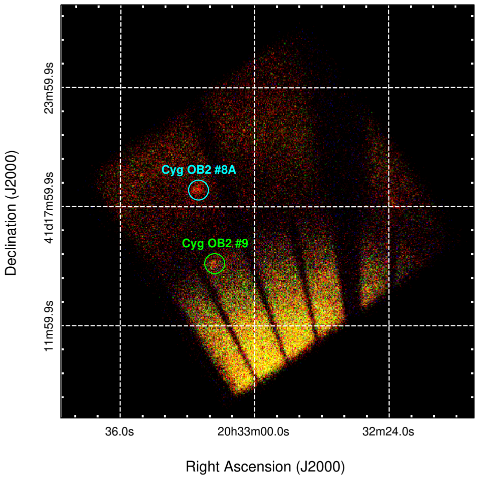


Swift light curve in 2–10 keV

⇒ Phase-locked variation

NuSTAR observations

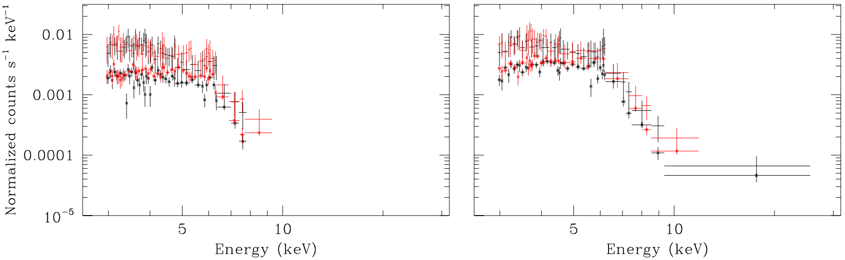
2 new observations close to the pericenter



NuSTAR RGB image (red=1.6–5.6 keV, green=5.6–13.6 keV, blue=13.6–21.6 keV)

NuSTAR spectra

2018 August 25 ($\phi = 0.028$) 2018 August 26 ($\phi = 0.085$)



Grouping: SNR=2. Red: FPMA. Black: FPMB. Crosses: background.

$\Rightarrow$ X-ray emission above 10 keV at $\phi = 0.085$

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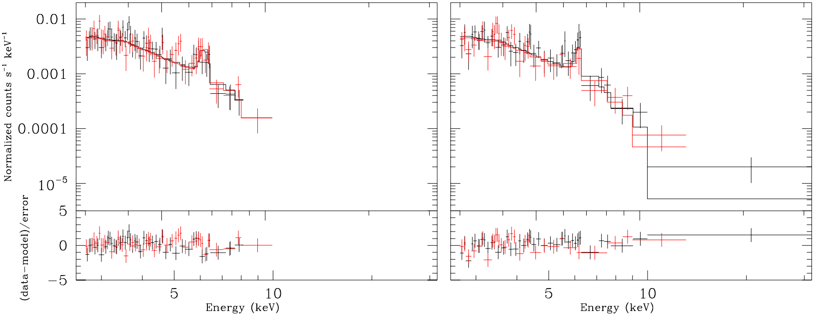
Search for non-thermal emission from Cyg OB2 #8A

Fitting model: 3 absorbed thermal plasma (APEC) (Cazorla et al. 2014)

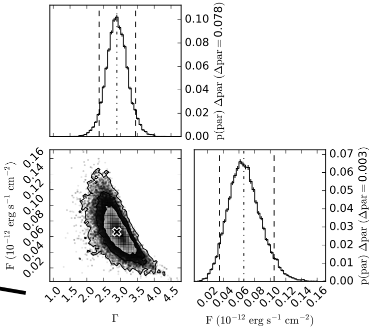
- Fit of the 12 XMM-Newton spectra
  $\rightarrow \kappa T$ =0.34, 0.83 and 2.13 keV and $n_1 = 2.11 \times 10^{-2}\,\mathrm{cm}^{-5}$
- Interpolating the value of n_2 to the phases of NuSTAR observations
- Fitting n_3 to the NuSTAR spectra



Search for non-thermal emission from Cyg OB2 #8A

- Adding a powerlaw component to the NuSTAR spectra at $\phi = 0.085$
  $\rightarrow \Gamma < 0$, flux consistent with 0 and fit not significantly improved
- Fit of the XMM-Newton spectra at $\phi = 0.042$ & 0.056 **AND** all the NuSTAR spectra
  $\rightarrow n_3 = 3.86 \times 10^{-3}\,\mathrm{cm}^{-5}$
- Adding a powerlaw component to the NuSTAR and XMM-Newton spectra

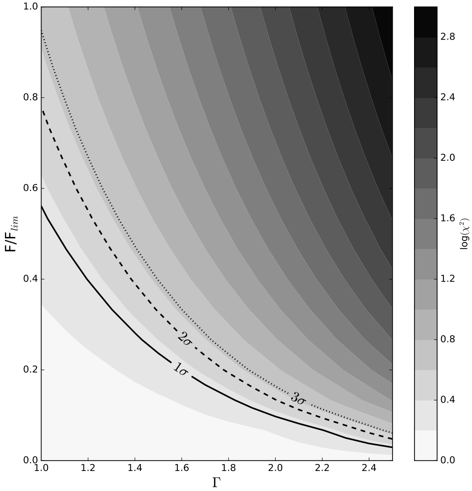
> 1.5 for IC



$\Rightarrow$ No stringent detection of non-thermal component

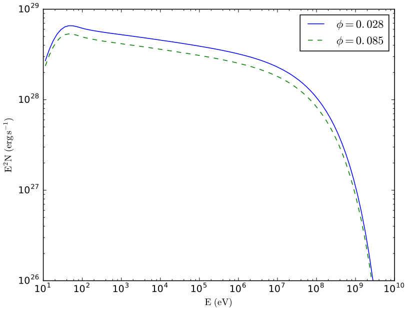
Upper limit on the non-thermal emission

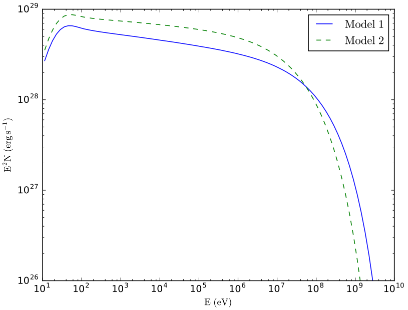
- Computation of the hard X-ray flux reproducing the upper limit count rates observed by INTEGRAL/IBIS for several Γ
- Creation of a model grid (3T + powerlaw) for these Γ and several fluxes
- Comparison of these models with the XMM-Newton spectra at $\phi = 0.042$ & 0.056 and the 4 NuSTAR spectra



Predictions on the non-thermal inverse Compton emission

- Improvement of the del Palacio et al. (2016)'s model with an energy-dependent non-thermal particle distribution (Blasi et al. 2005)
- Calculation of the anisotropic IC emission (Cerutti 2007) for the NuSTAR phases





Model parameters: $\mathrm{ep}_{\mathrm{ratio}} = 0.01$, $\chi_{\mathrm{inj}} = 3.5$ and $\zeta_{\mathrm{B}} = 10^{-3}$ and 10^{-4} for model 1 and 2.

$\Rightarrow$ At $E = 10\,\mathrm{keV}$: 10^{-4} times the 1σ upper limit and $\sim 2 \times 10^{-3}$ times the best-fit flux for $\Gamma = 1.5$

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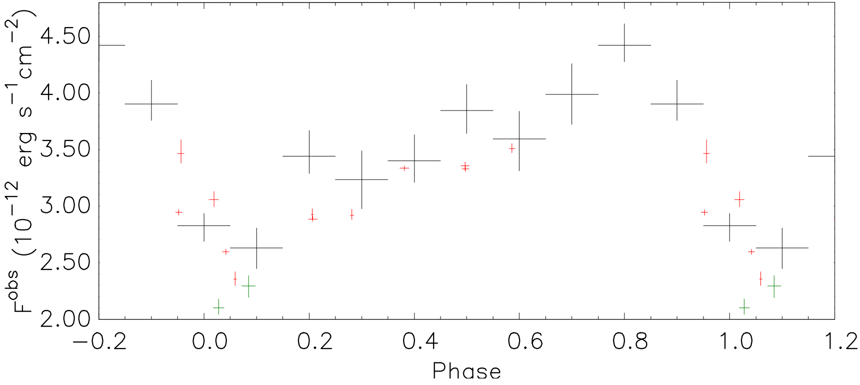
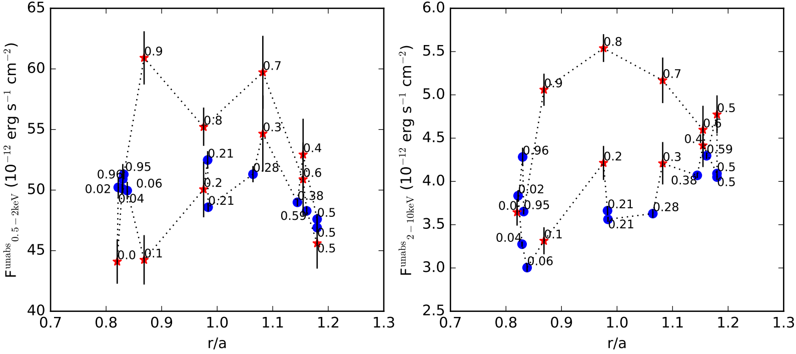
Conclusion

- Revised orbital solution
- Better phase coverage with the X-ray observations
- Improved fitting of the X-ray spectra with a 3T model
- NuSTAR observations up to 30 keV
- Fitting of the spectra close to the periastron with a 3T+powerlaw model
- Better constrain of the upper limit of the non-thermal emission
- Construction of a new model to compute the anisotropic IC emission

Light curve of Cyg OB2 #8A



Hysteresis curve of Cyg OB2 #8A



del Palacio et al. (2016)'s model