



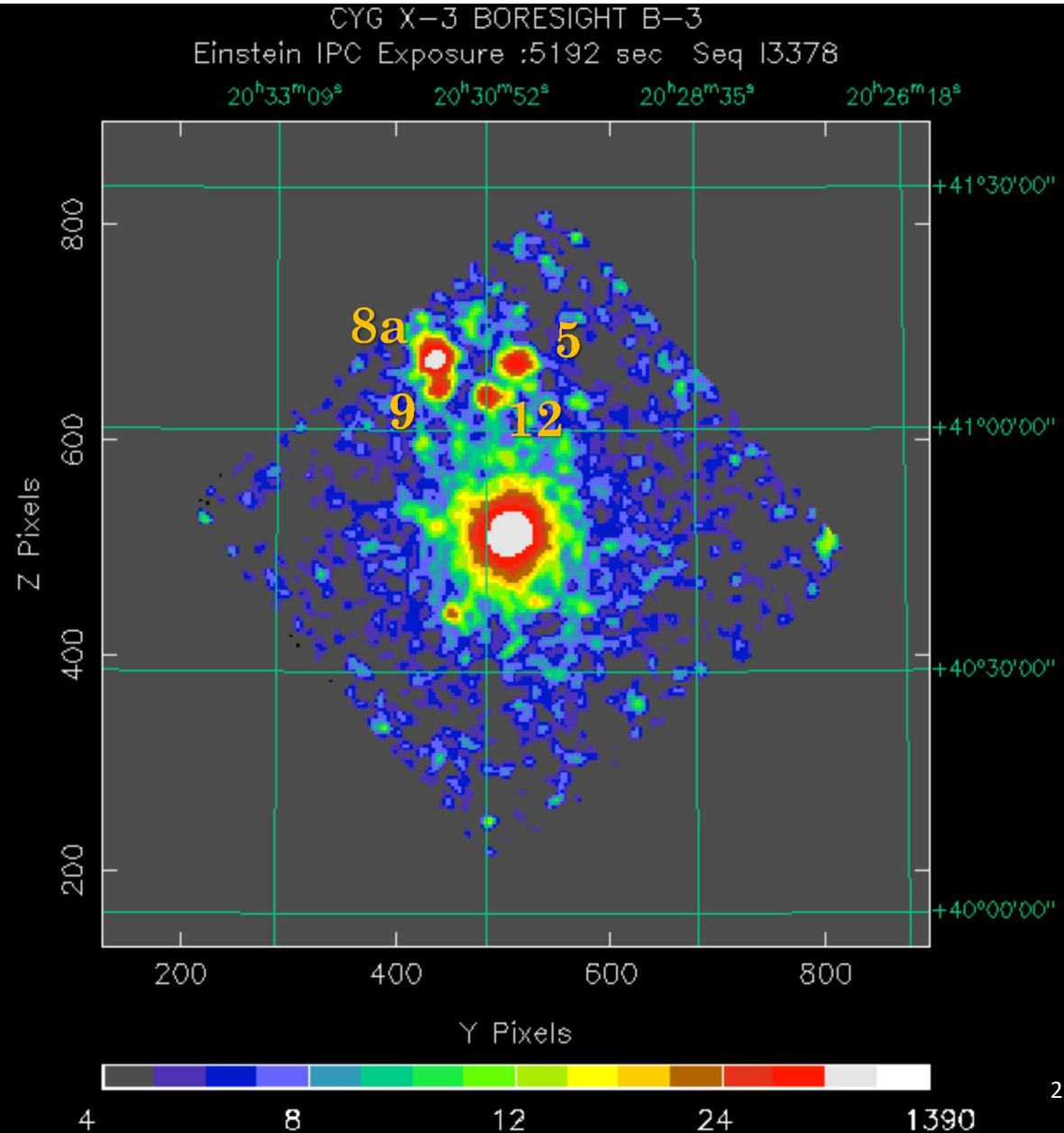
ON THE TRAIL OF CYGNUS

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STEFAN CZESLA (UHAMBURG)

YES, CYG OB2, AGAIN

- We have been following for decades the Cyg OB2 association, still finding new results...



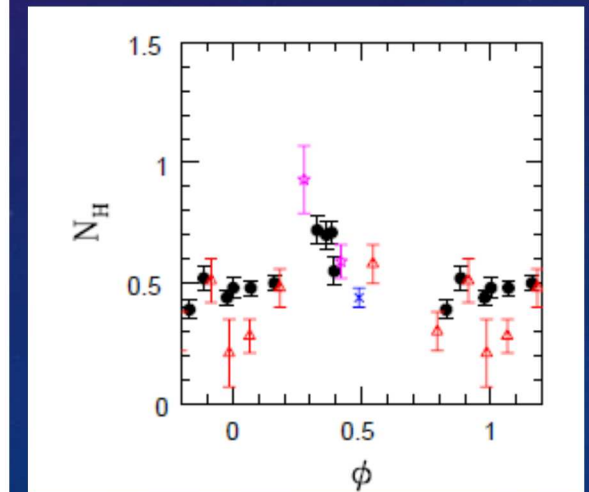
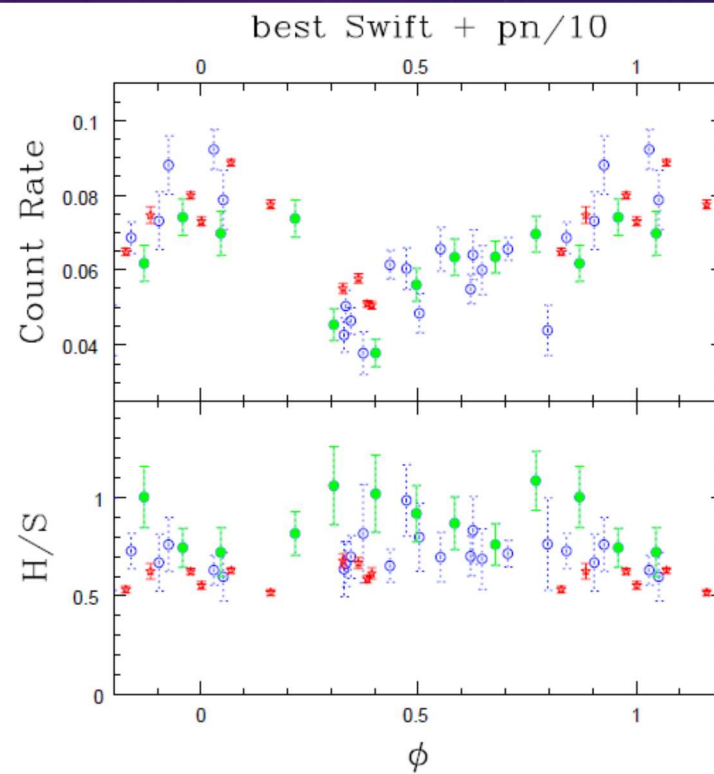
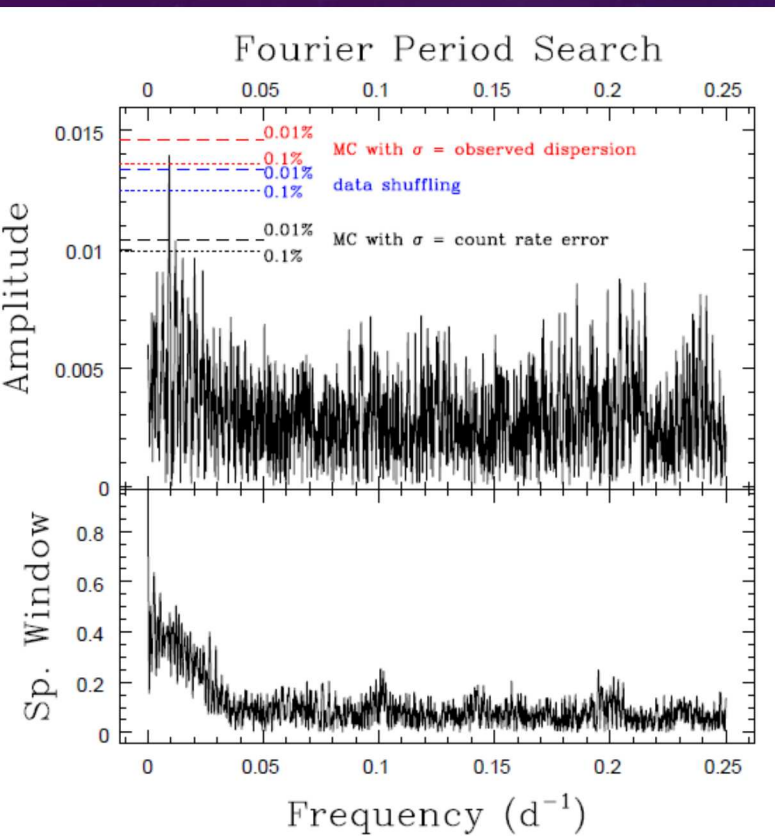
#12

- A B-type supergiant (LBV?)
- Very bright in X-rays ($\log L_x/L_{bol} \sim -6.1$ compared to -7 for O and early B-stars)
+ quite hard ($kT=2\text{keV}$ component!) \Rightarrow *colliding winds ?*
- Companion ?
 - Optical companions (Caballero-Nieves+ 2014, Maryeva+ 2016) : closest at 64mas ($P \sim$ century)
 \Rightarrow *too far from bright wind collision...*
 - RV variations & I_{pv} (e.g. Klotchkova & Chentsov 2014)+ X-ray changes (Cazorla+ 2014): periodicity ?
 - f line in He-like triplets, lack of strong absorption, no shift, narrow lines (Oskinova+ 2017): CW?
- Monitorings (*Nazé+ 2019*) 
 - Optical high-res spectroscopy : Hermes & Carmenes data
 - Optical photometry : NSVS, OMC, ASAS-SN, amateur data
 - X-ray data : Swift + archival Chandra & XMM

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X-ray results:

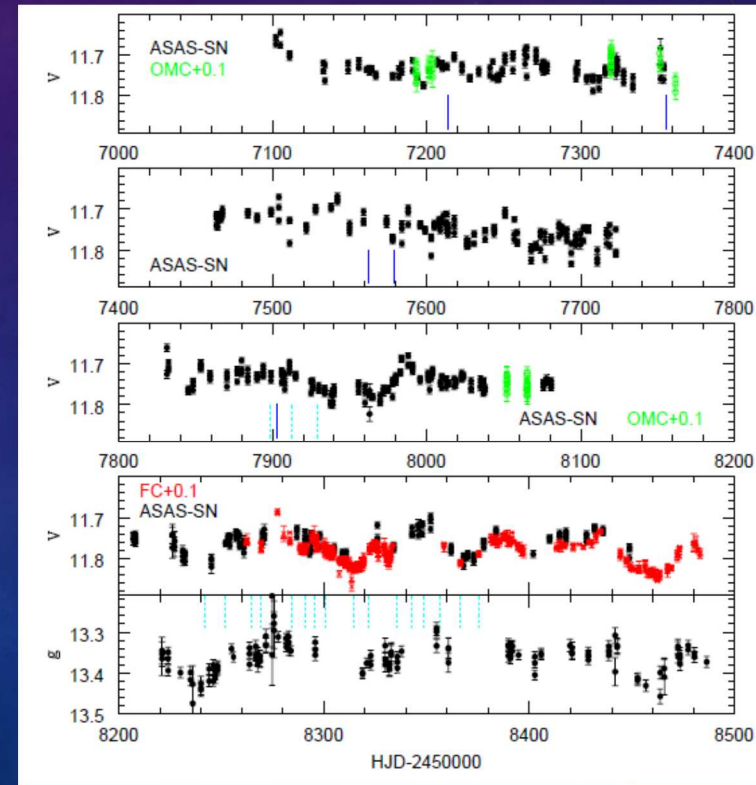
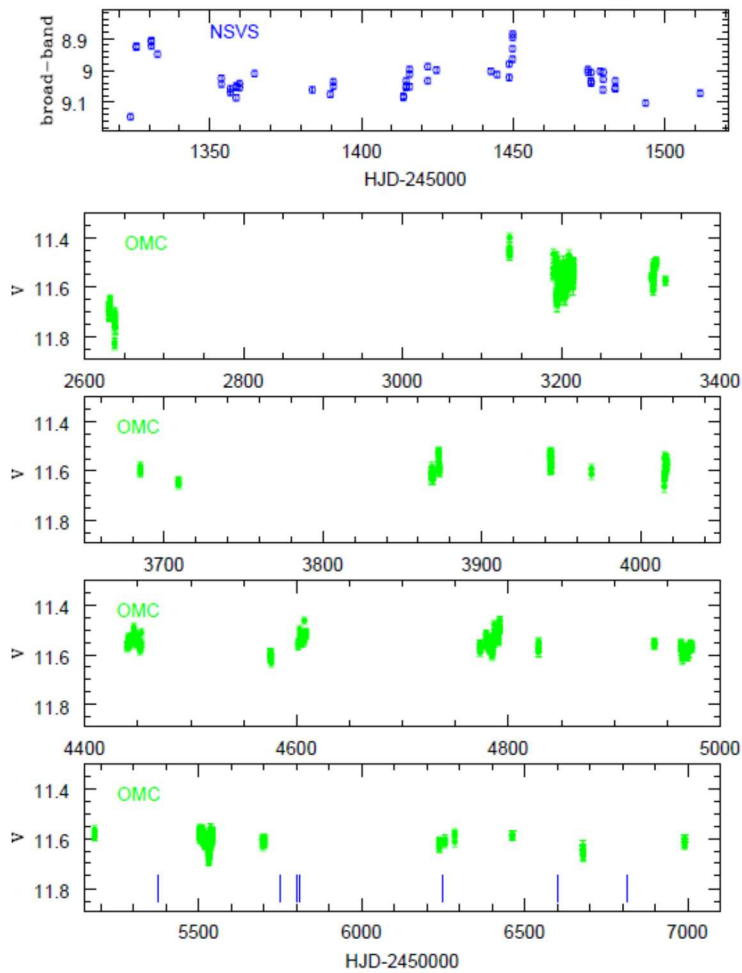
- $P=108.0\pm 0.2d$
- XMM data (red) perfectly phased with Swift (green & blue)
- Increase of abs and decrease of norm. factors when $F_x \ll$



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Photometry

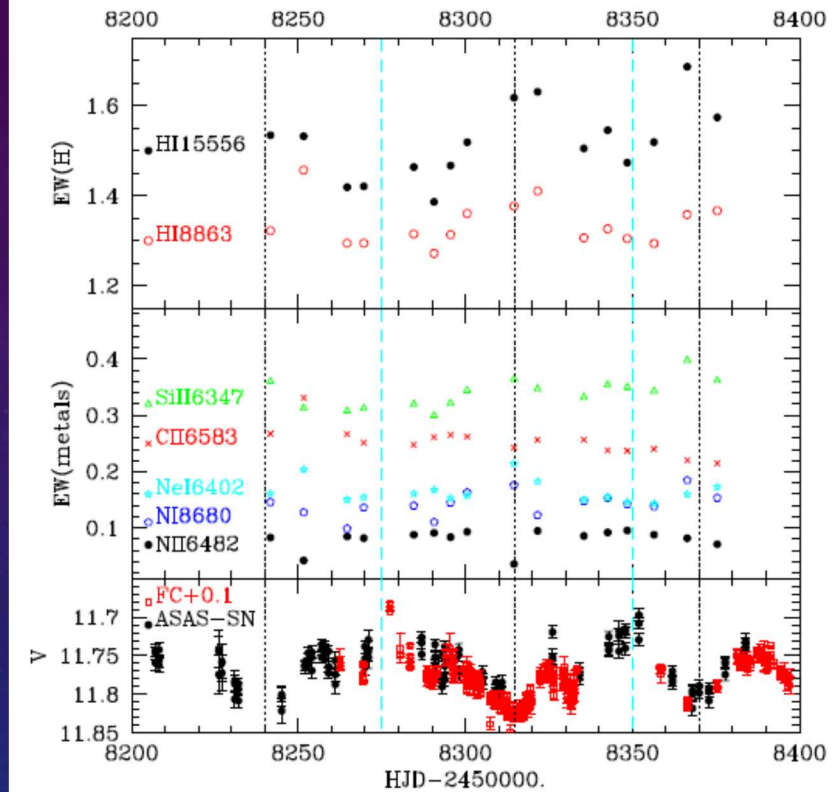
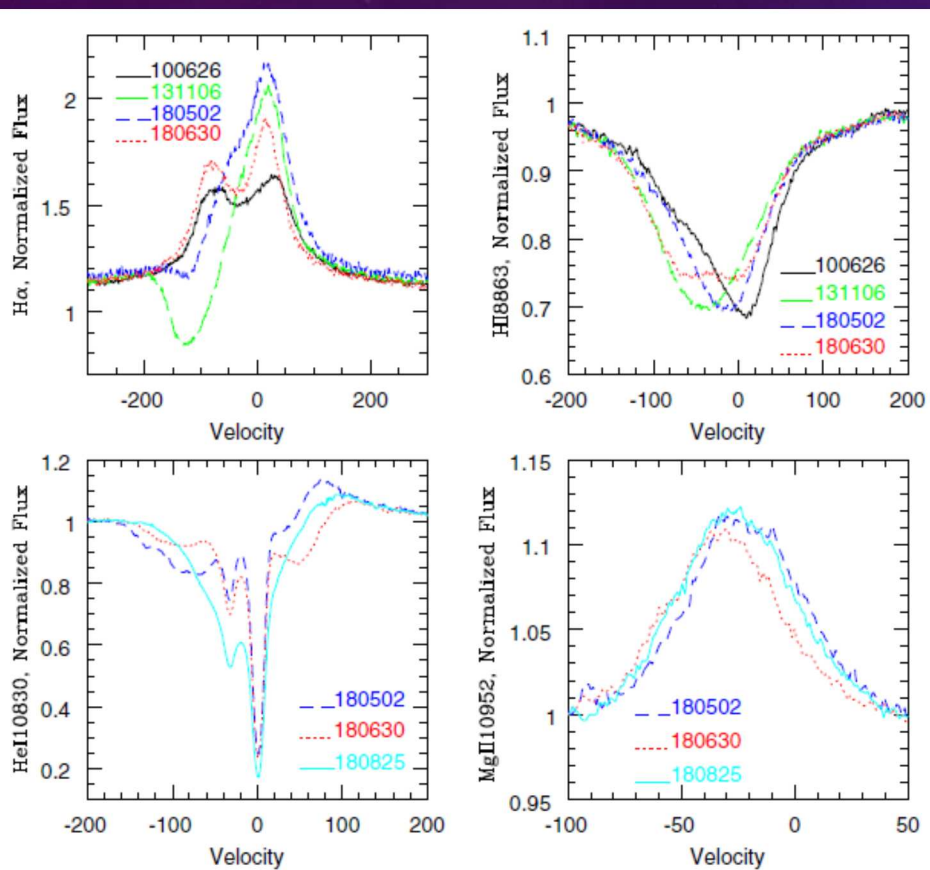
- Salas+ 2015 : $P \sim 54d$
- Actually, complicated LC with no strict periodicity



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Spectroscopy

- HI abs increase when star fainter and V-I larger
- Small variations of spectral type (B4-6)



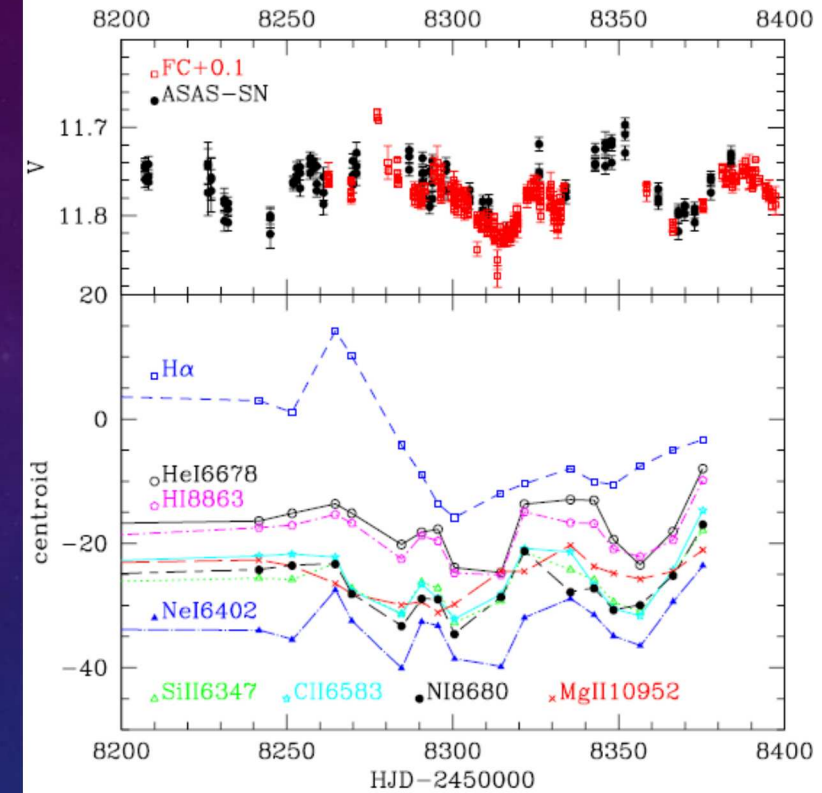
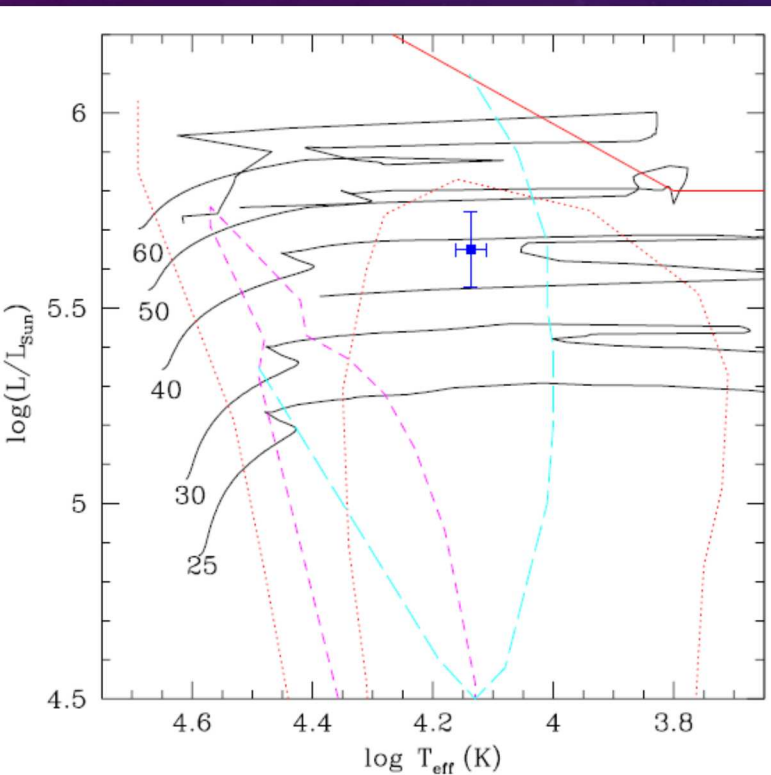
Spectroscopy

- Ipv & RV variations
 - Not linked to binarity (doubling with depth changes!)
 - MgII, FeII : smaller change in RV than HI, HeI, other metals but larger than for ISM features

#12

Spectroscopy

- RV of HI abs and HeI abs delayed compared to metals: link to formation depth
- No significant periodicity !



Clock scenarios ?

- Orbit in CWBs
 - OK for X-rays but no trace of companion (lines or induced RV)
- Pulsations
 - In region with (unstable) oscillatory convection modes
 - Compatible with I_{pv} & RV changes, but X-rays?
- Rotation with MCWs or CIRs
 - X-ray changes too large for CIRs, small B in supergiants...

#5

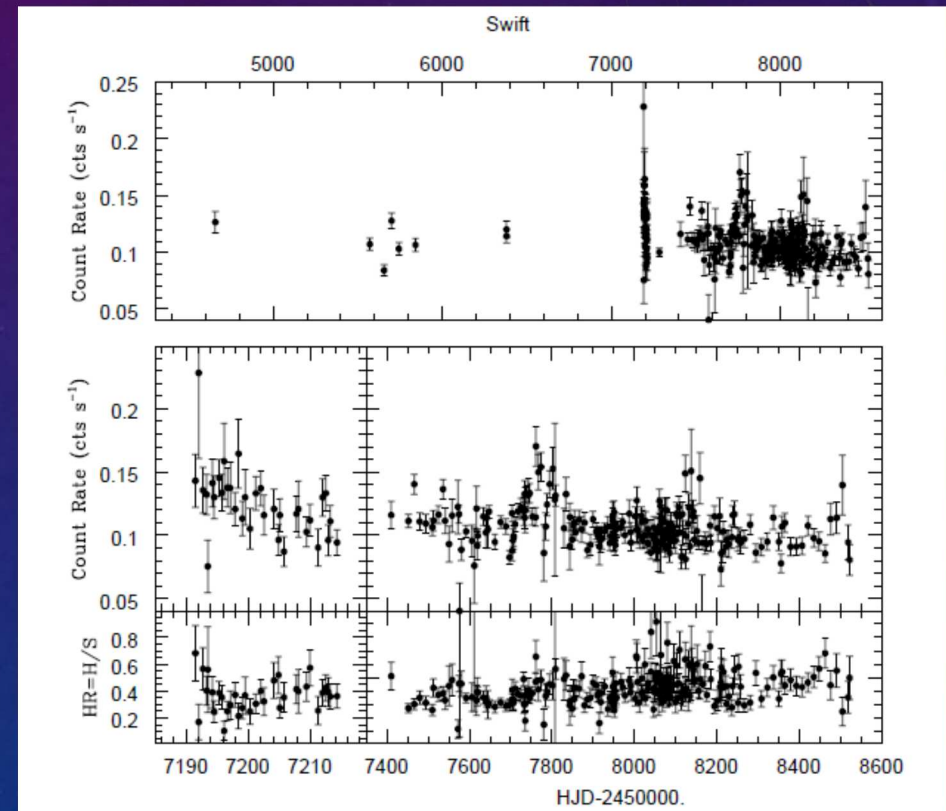
- Quadruple system : O6.5I+Ofpe in $P=6.6d$ + ? in $P\sim 6.7yr$ + early BIV in $P\gggg$
- Three wind-wind collisions ! (Rauw+ 1999, Kennedy+ 2010, Dzib+ 2013)
 - Optical for 6.6d
 - Radio NT emission for binary+C or triple+D

What are the orbit and properties of C ?

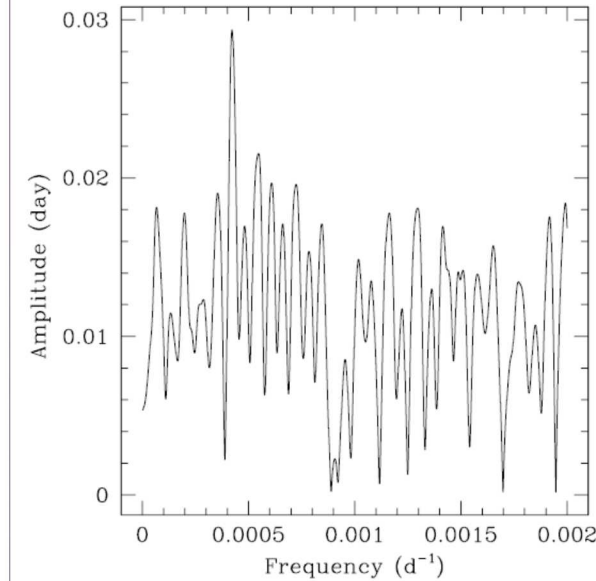
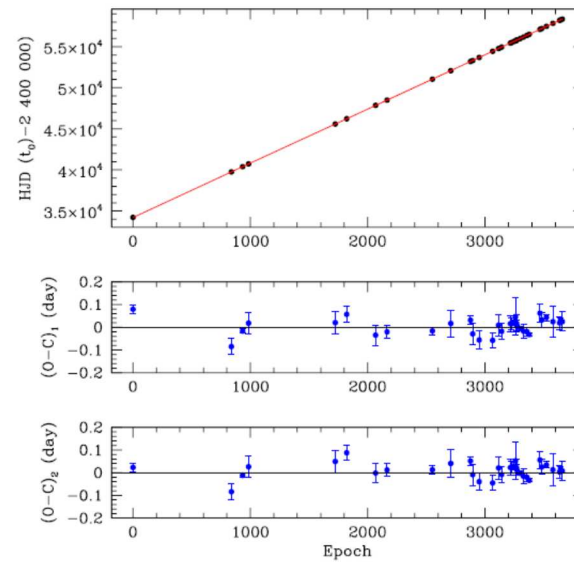
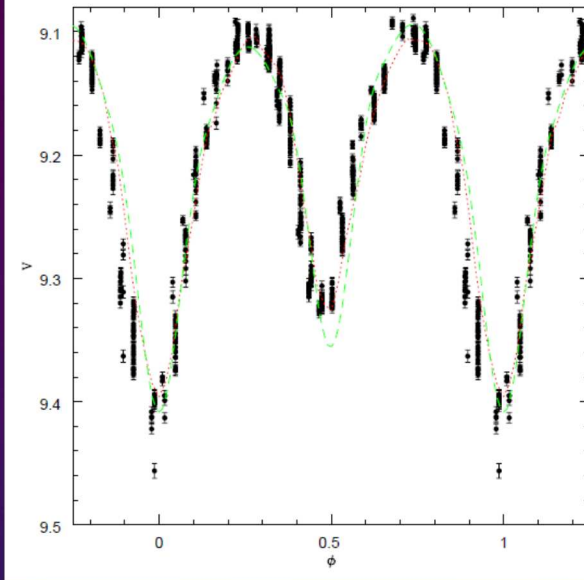
- Monitorings (*Rauw+ 2019*)
 - Optical spectroscopy : Aurélie + **TIGRE**
 - Optical photometry : OMC, ASAS-SN, amateur data + archives
 - X-rays : Swift + XMM archives

#5

- X-rays:
 - Yes #5 varies, yes it is bright, yes it is hard
 - NO, there is no period ;
LC is incompatible with both $P=6.6\text{d}$ or $\sim 7\text{yr}$



#5

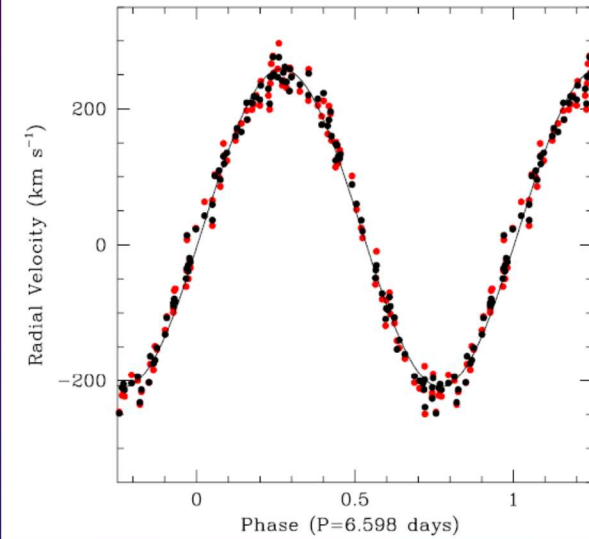


- Optical photometry

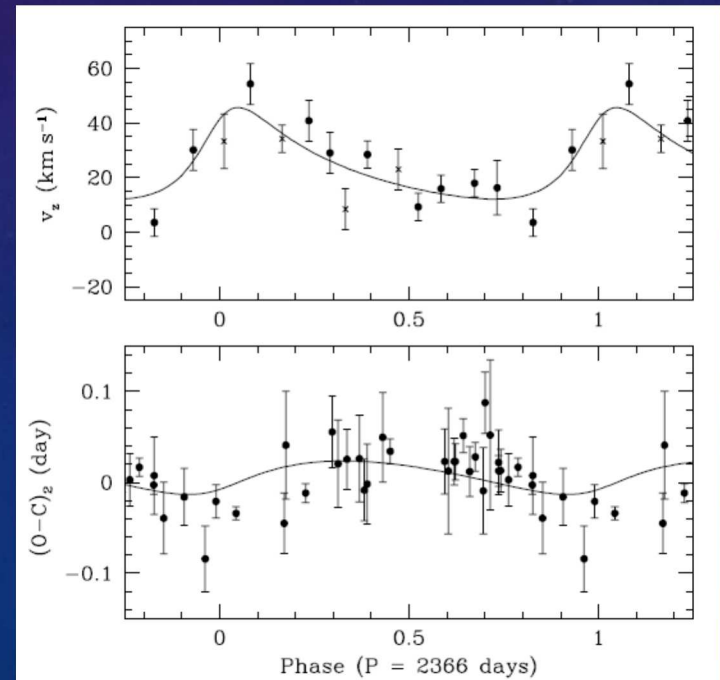
- Using eclipse dates from literature : lots of uncertainties and wrong values...
- Redetermination of eclipse times when data available (covering 66yrs!)
 - Fit to Linder+ 2009 theoretical LC & to mean LC
 - Derivation of linear & quadratic (Mdot!) ephemerides : residuals have P=6.5yr !

#5

- Optical spectroscopy (covering 25 yrs) :
 - RV curve for H ϵ 4686A line : slight global shifts !
- Combining spectro & photometry yields the orbital solution !
 - C is probably an early B with $M \sim 14 M_{\odot}$

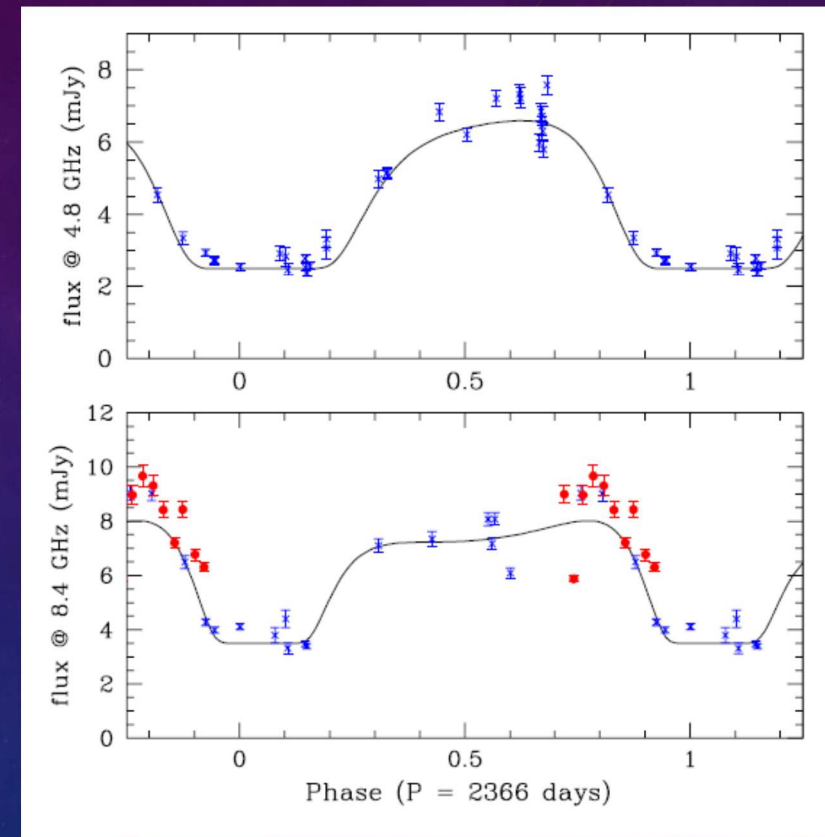
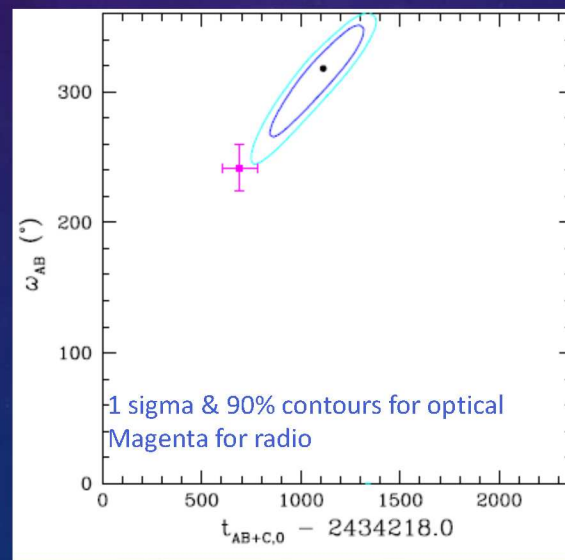
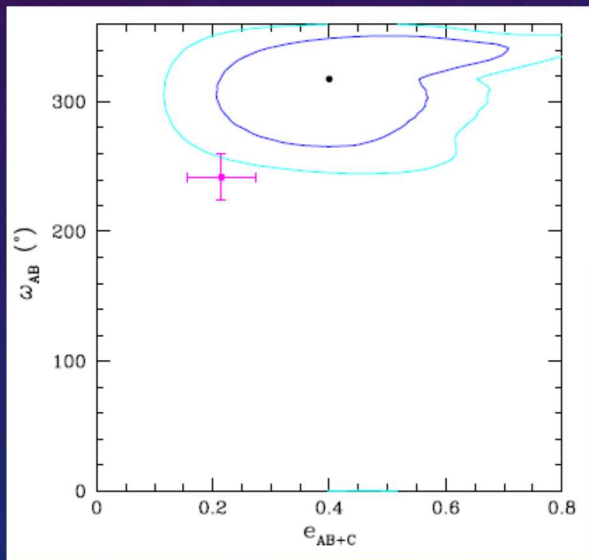


	Eclipsing binary		Tertiary orbit
	Star A	Star B	A+B
Period (d)	See Eq. (2)		2366 ± 23
t_0 (HJD-2 400 000)	See Eq. (2)		$35\,330^{+205}_{-265}$
e	0.0		$0.40^{+0.30}_{-0.19}$
ω (°)			318^{+44}_{-53}
K (km s ⁻¹)	87.7 ± 6.1	280 ± 31	16.8 ± 5.3
v_0 (km s ⁻¹)	7.0 ± 4.5	-100 ± 20	24^{+3}_{-3}
$a \sin i$ (R_{\odot})	11.4	36.4	720^{+185}_{-200}
$m \sin^3 i$ (M_{\odot})	25.8 ± 8.6	8.1 ± 1.9	
$f(m)$ (M_{\odot})			0.89 ± 0.87



#5

- Comparison with radio observations :
 - P of 6.5yr yields a smooth curve
 - Orbital parameters are compatible with optical results

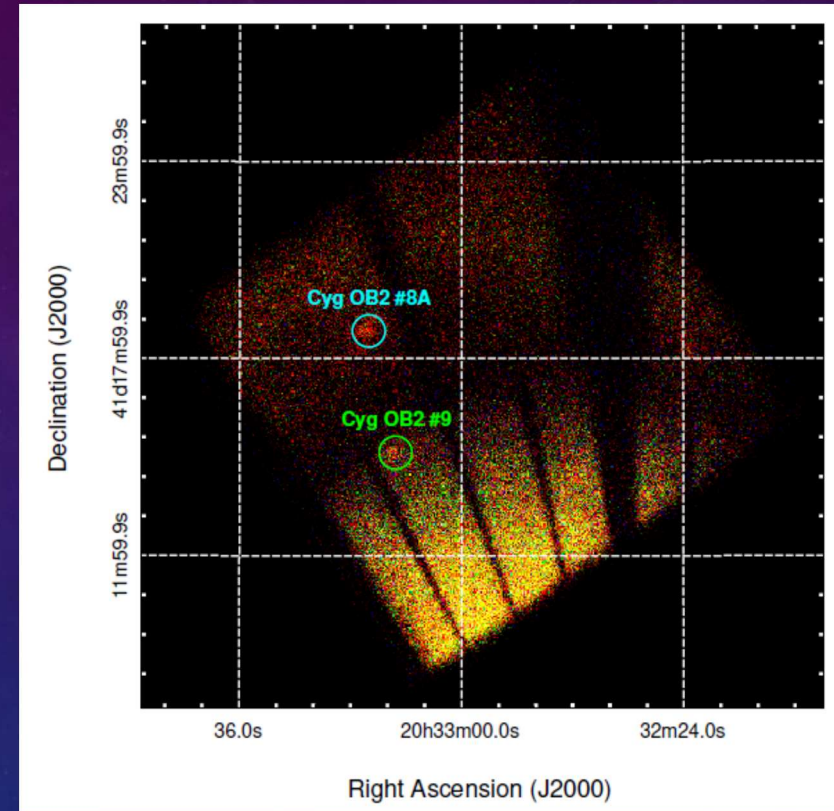


#8A

- O6If + O5.5III(f), P=21.9d
- NT radio emission, varying X-ray emission : CWB !

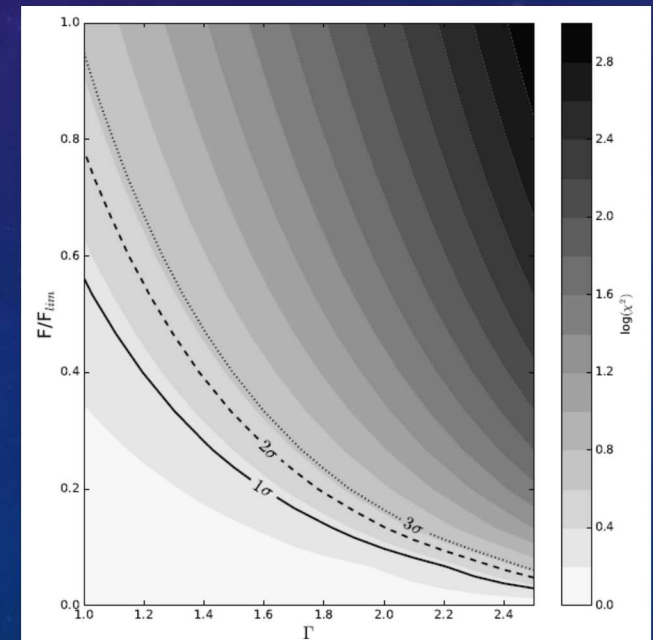
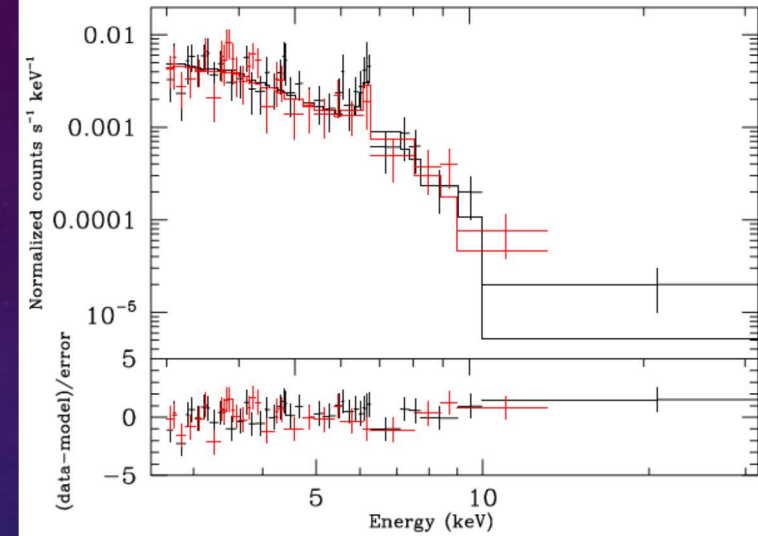
Non-thermal X-rays ?

- New X-ray data : (*Mossoux+ 2019*)
 - Opt. Spectroscopy: Aurélie
⇒ revised orbital solution
 - X-rays :
Swift + XMM ⇒ better coverage of orbit
NUSTAR !



#8A

- Simultaneous fit of NUSTAR & closest XMM spectra
 - χ^2 quite ok without power law
 - If power law added : $\Gamma=2.9 >$ expected 1.5
 - Compared to INTEGRAL data : more stringent limit
 - New models predict $F_x <$ observation limit



BONUS : THE GAIA VIEW OF CYG OB2...

- GAIA DR2 : (*Lim+2019*)
 - Positions and proper motions... + RVs from literature
 - Two subclusters + halo
 - Possible expansion of halo
 - Halo has a larger dispersion of motions ; size-line width correlation as in MC? (turbulent formation)

