Examples of studies of massive stars with TIGRE + HEROS: some results and future perspectives

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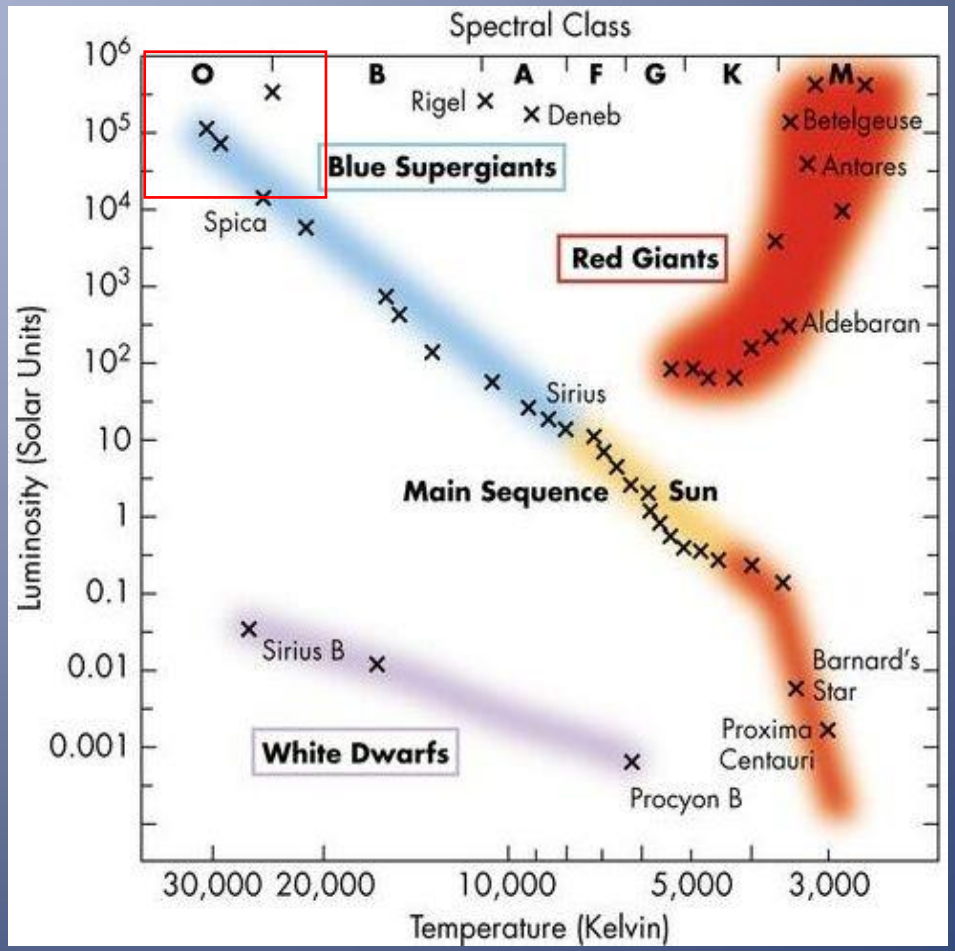
What are O-type stars?

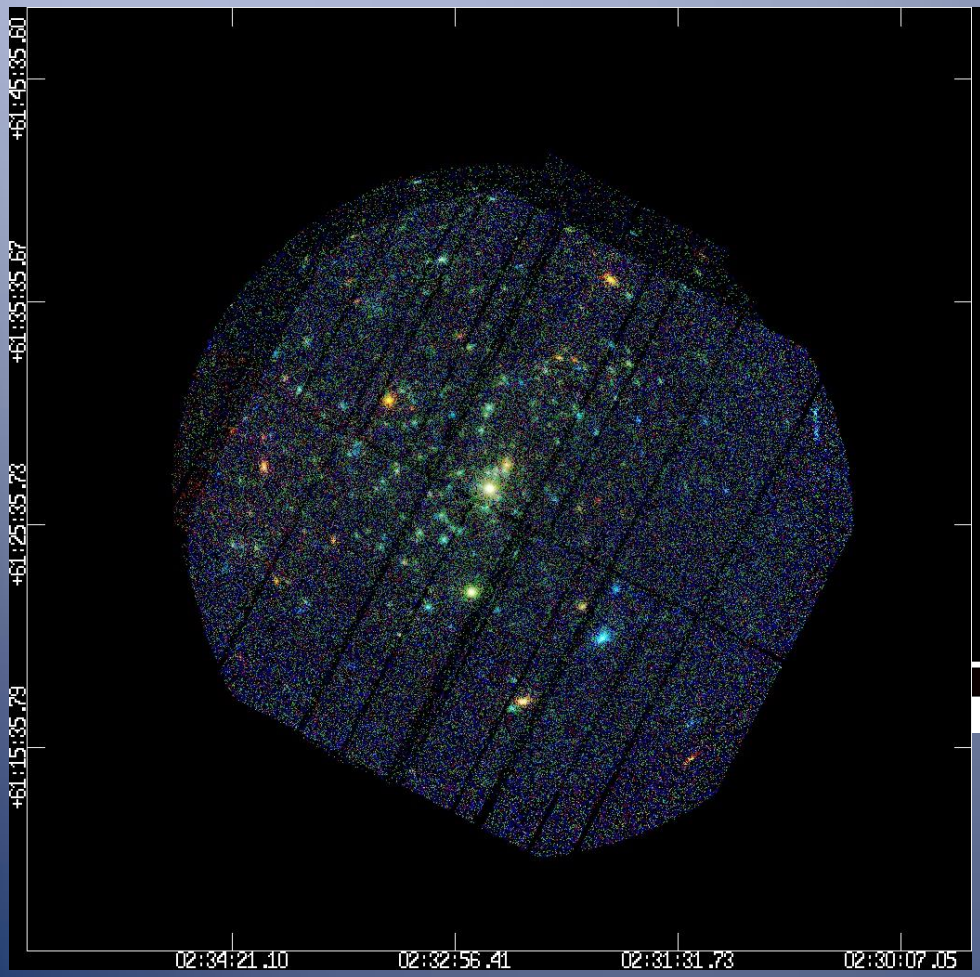
- O-type stars are hot ($T_{eff} \geq 20\,000$ K), luminous ($L \geq 10\,000\ L_{\odot}$) and massive objects ($M \geq 15\ M_{\odot}$). They have short lifetimes, but play an important role.

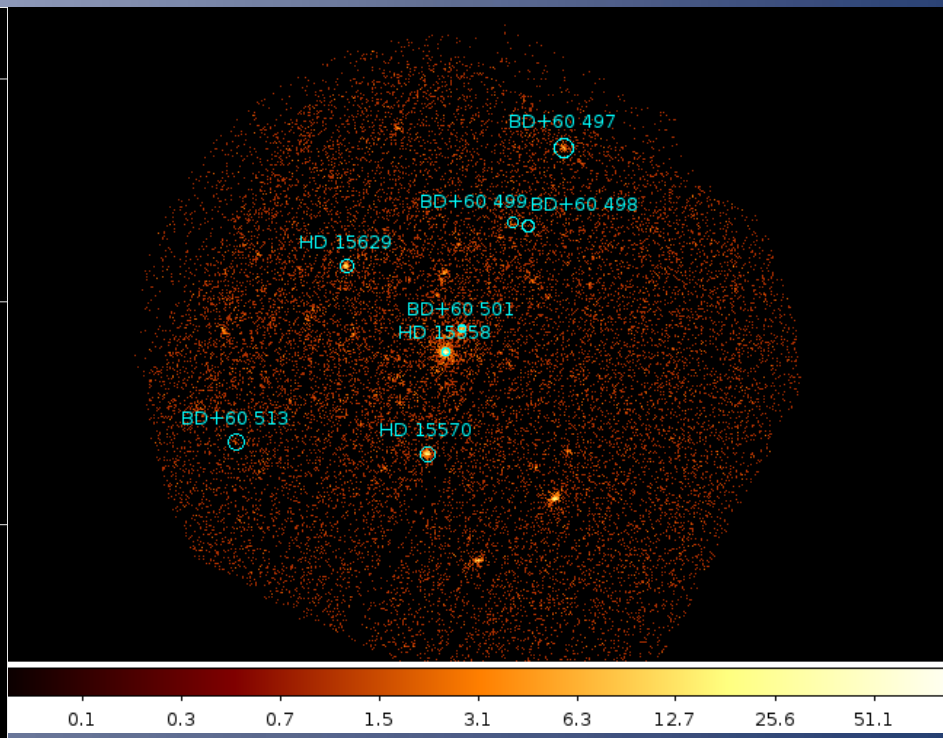


The O-type stars in IC1805

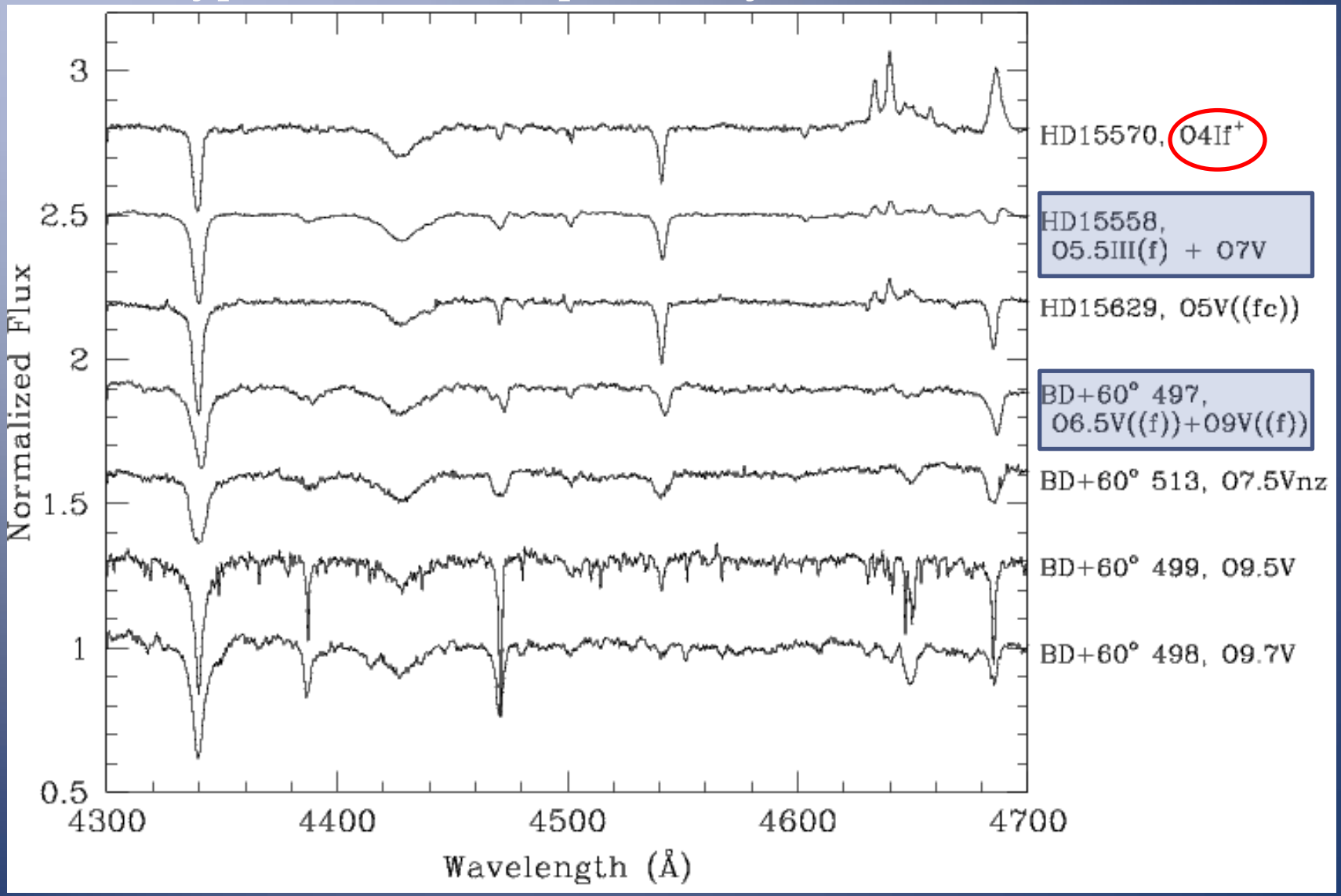
- IC 1805 is a very young open cluster in the Cas OB6 association dominated by a group of O-type stars.

- We have obtained an XMM-Newton observation of IC 1805 to study the L_X/L_{bol} relation of extreme O-stars (Rauw & Nazé 2016, A&A 594, A82).
- TIGRE was used in support of this campaign to observe 7 O-type stars.

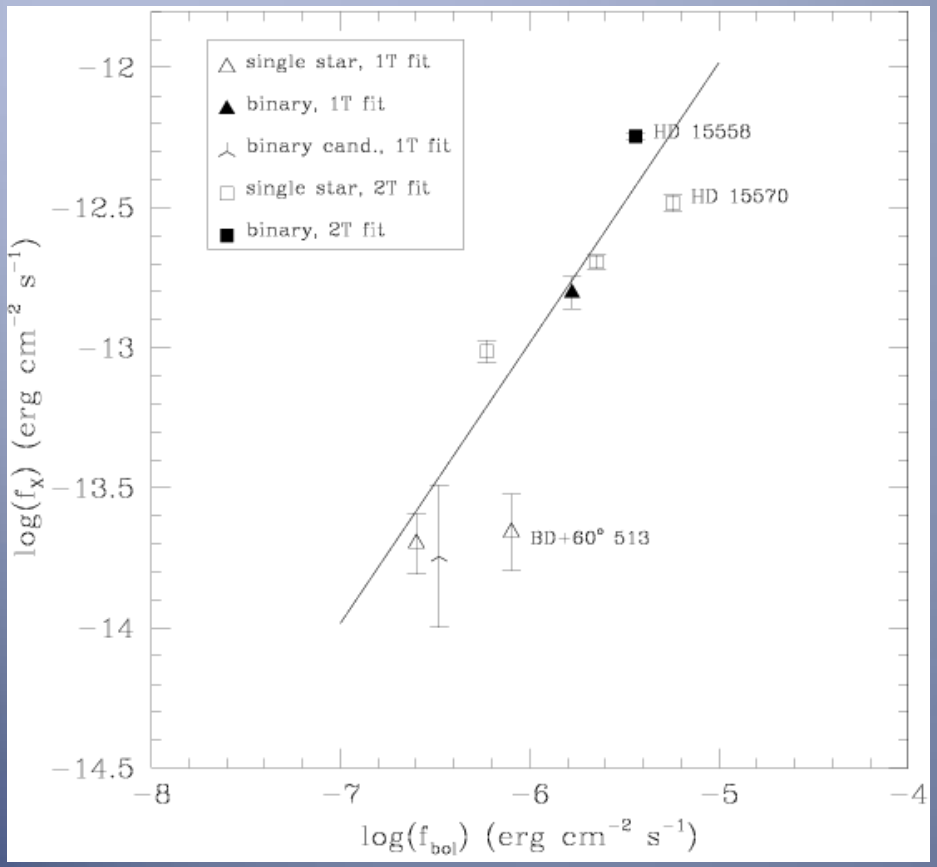


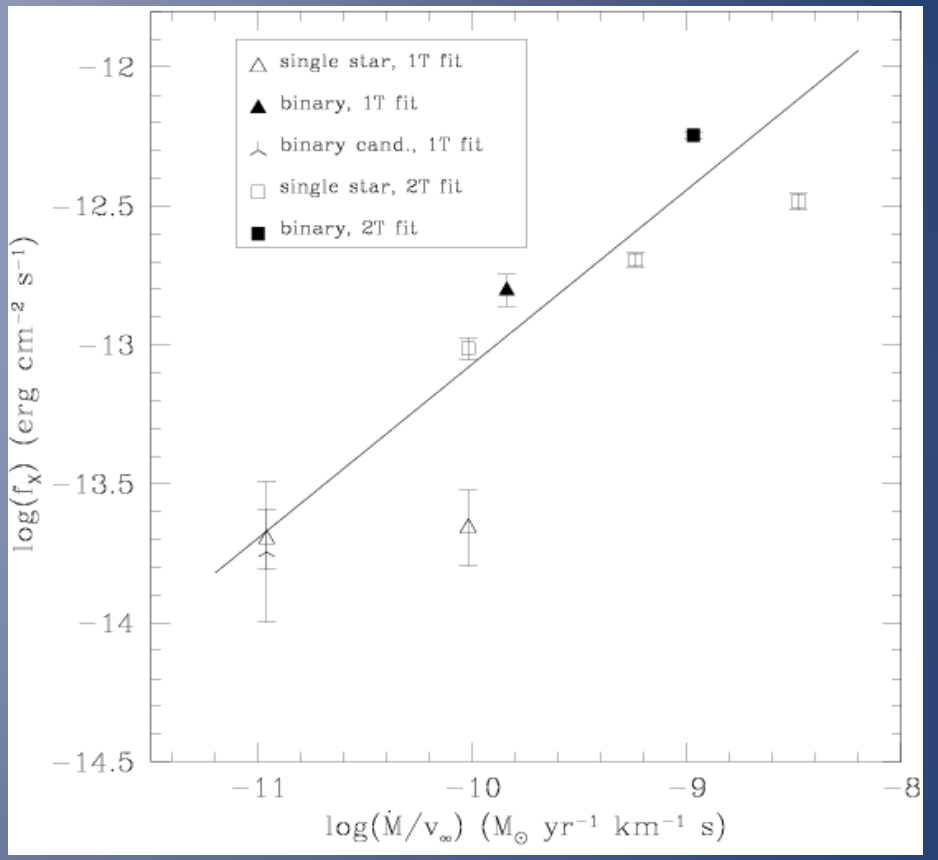


- IC 1805 contains an extreme O4If$^+$ star thought to be in an intermediate evolutionary stage between a normal O and a WN star.
- Two O-type binaries were previously known.



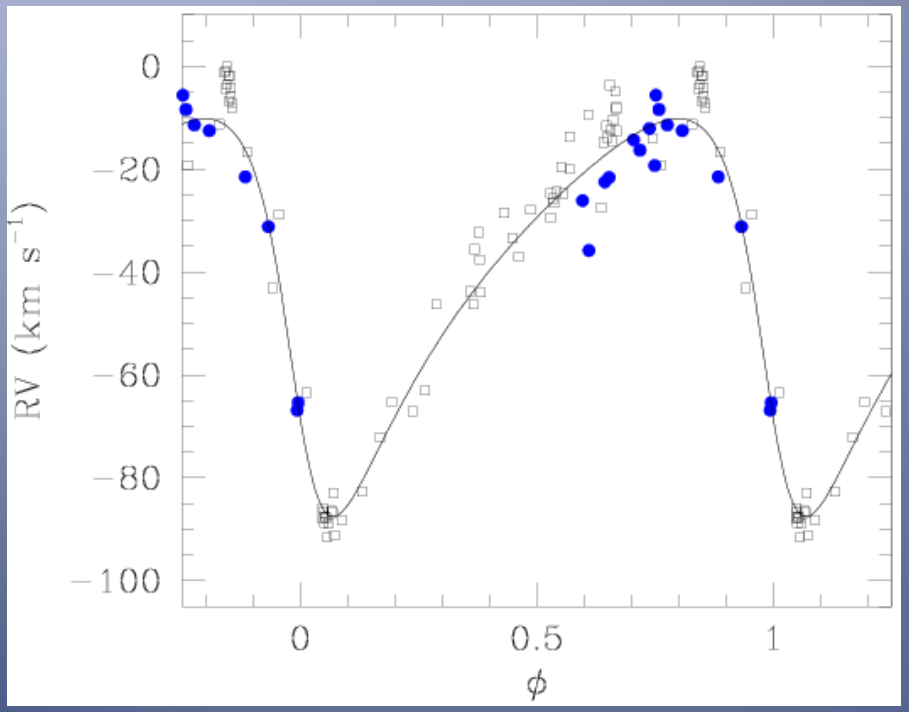
- The X-ray emission of HD 15570 falls slightly below the canonical relation, but this can be explained accounting for its wind properties.





Rauw & Nazé (2016)

- HD 15558 is a long-period (447 days) O5.5III(f) + O7V binary (Garmany & Massey 1981, PASP 93, 500, De Becker et al. 2006, A&A 456, 1121). A previous SB2 solution (De Becker et al. 2006) yielded a huge $m_1 \sin^3 i \geq 150\ M_\odot$. Such a value is unexpected for an O5.5III star.
- Our revised SB1 orbital solution leads to a lower mass function (2.0 vs. 2.5 $M_\odot$) indicating a need to establish a new full SB2 solution.

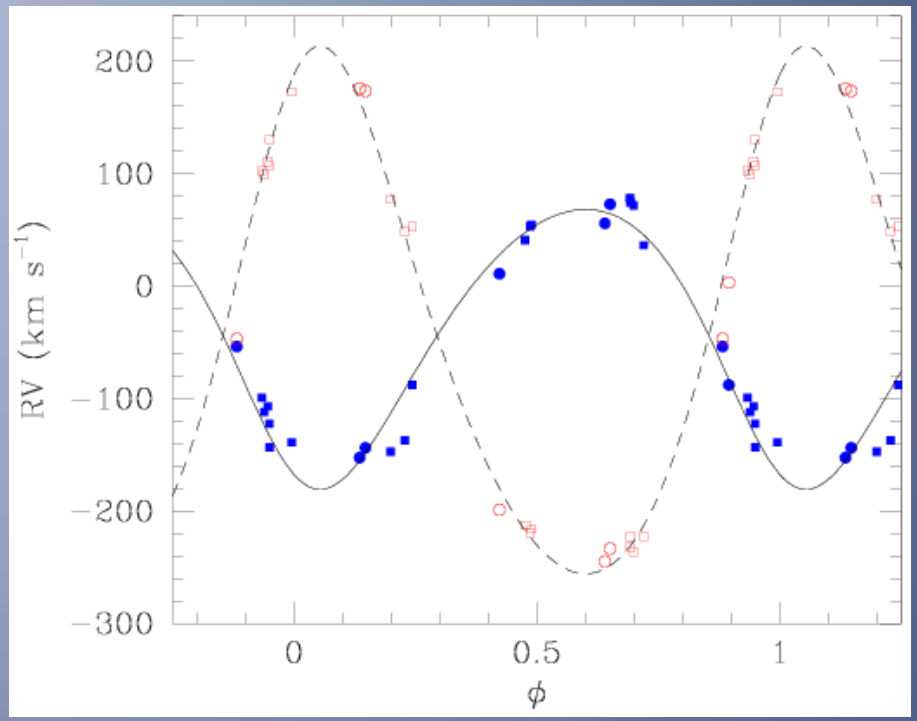


Element	Value
P_{orb} (days)	445.76 ± 0.42
e	0.42 ± 0.02
T_0 (HJD)	$2\,456\,692.47 \pm 3.71$
K (km s^{-1})	38.7 ± 1.1
γ (km s^{-1})	-40.7 ± 0.8
ω (°)	120.2 ± 4.3
$a \sin i$ ($R_\odot$)	309.4 ± 9.8
$f(m)$ ($M_\odot$)	2.00 ± 0.19

Rauw & Nazé (2016)

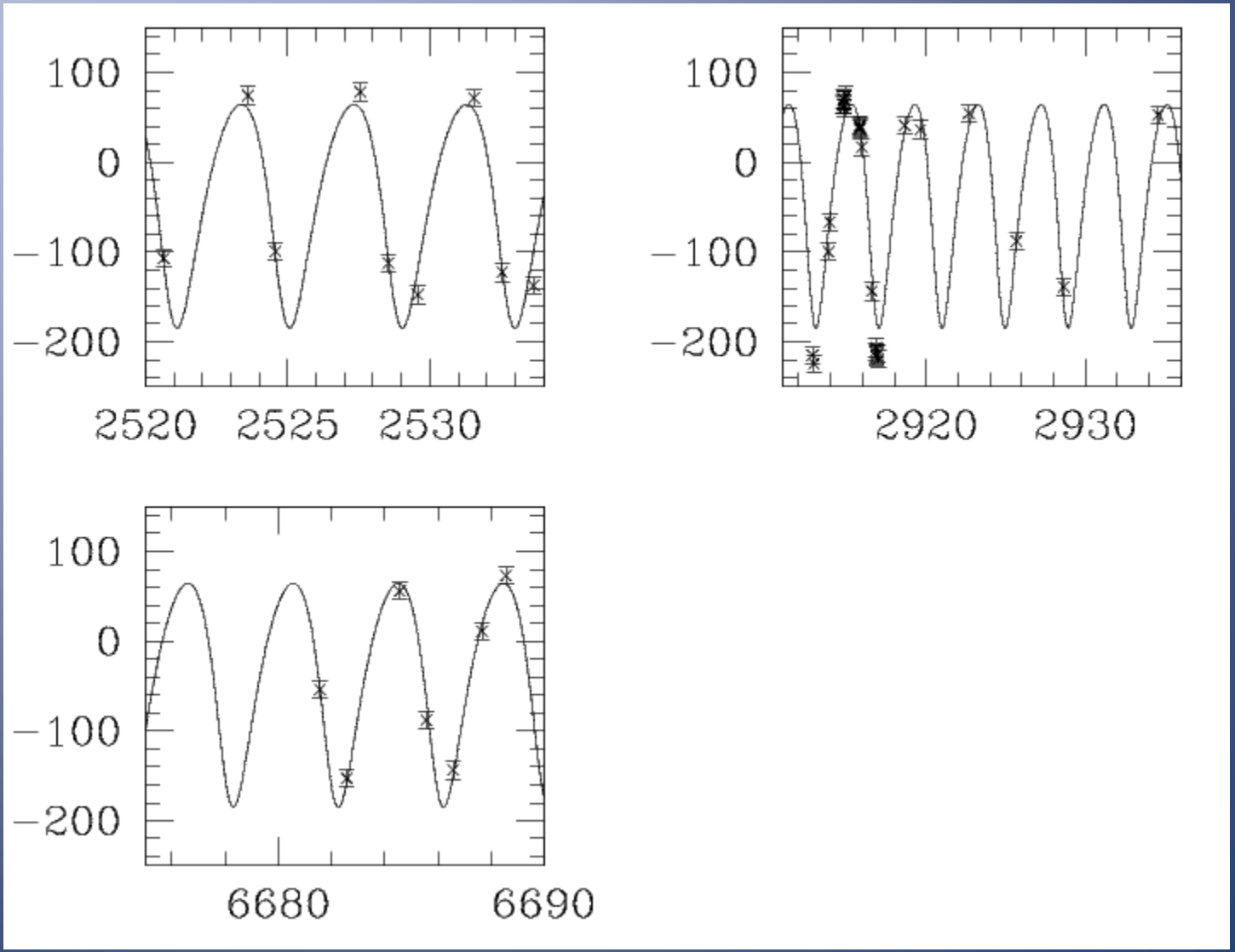
A long-term monitoring of HD 15558 with TIGRE+HEROS is needed to establish an improved orbital solution. This was proposed in AO3.

- BD+60° 497 is a short-period (3.95 days) O6.5V((f)) + O8.5-9.5V((f)) binary (Rauw & De Becker 2004, A&A 421, 693; Hillwig et al. 2006, ApJ 639, 1069).

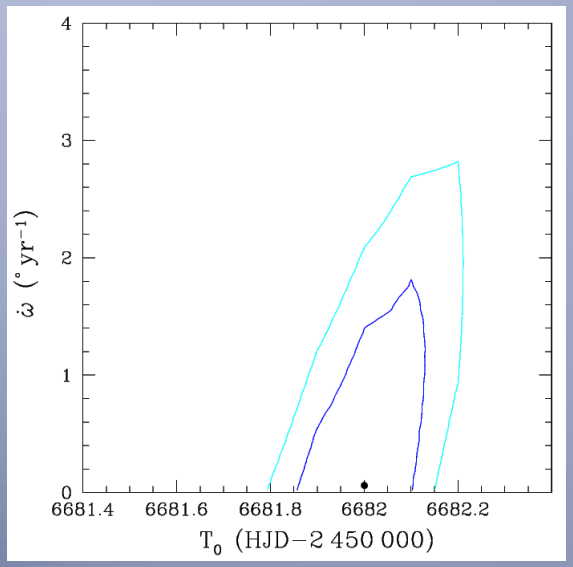


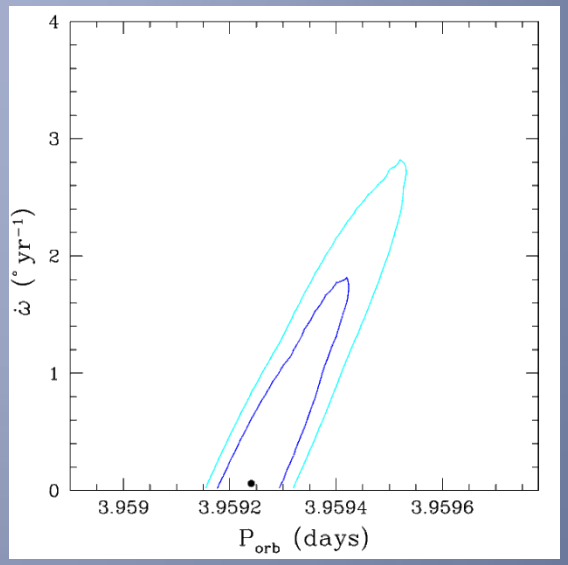
	Rauw & De Becker 2004	Hillwig et al. 2006	Rauw & Nazé 2016
P(days)	3.96	3.95863	3.95926
e	0.0 (adopted)	0.156 ± 0.019	0.149 ± 0.017
ω (°)	n/a	100.0 ± 11.0	148.0 ± 6.9
m_1/m_2	1.28 ± 0.12	1.30 ± 0.03	1.56 ± 0.06

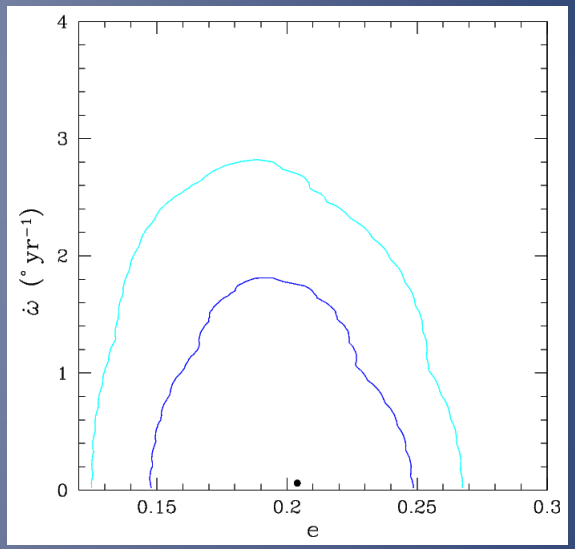
- Could there be apsidal motion in BD+60° 497? Theoretical models predict a value of dω/dt near 2°/year. We made a fit to the RV data allowing for apsidal motion.

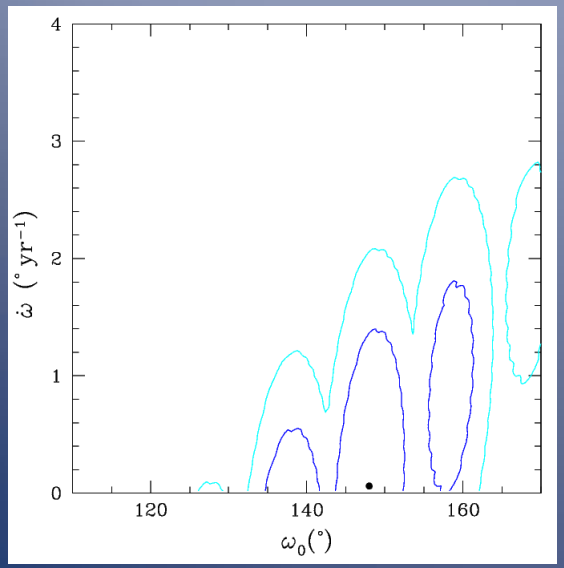


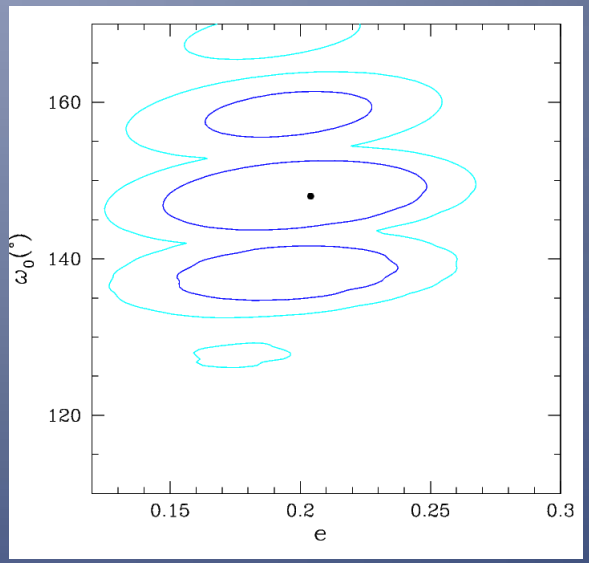
- The current best estimate of dω/dt from observations is 0.06°/year, but larger values cannot be ruled out. Current data are not sufficient to establish the presence or absence of apsidal motion.







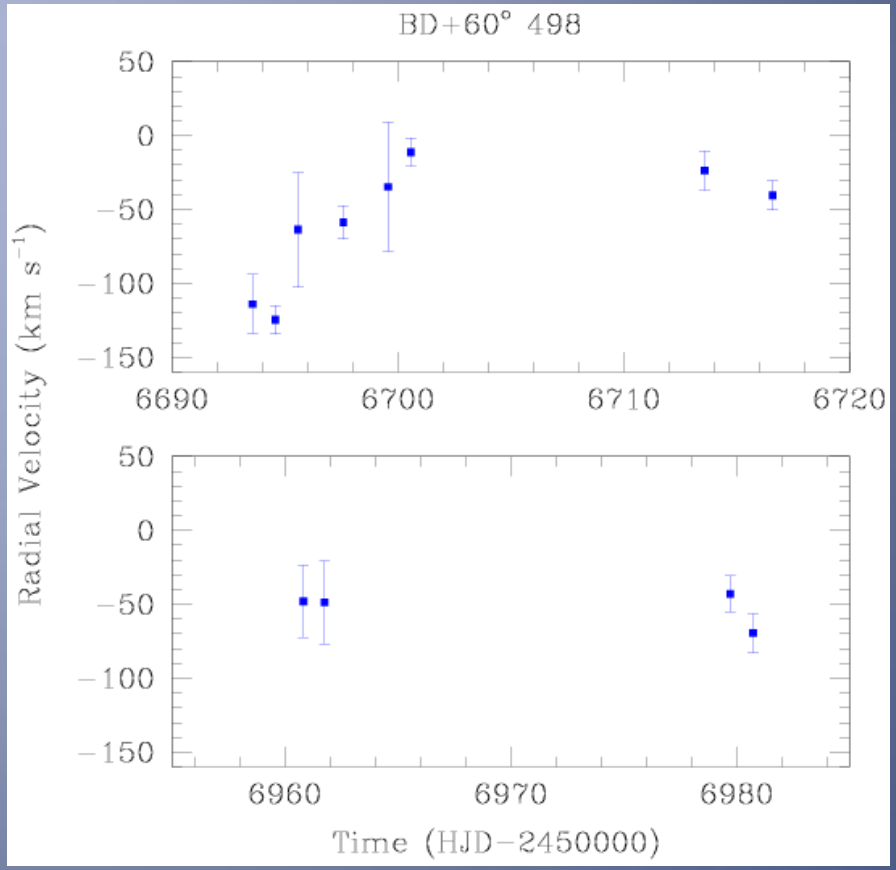




Blue : 1-σ
Cyan : 90% confidence

A long-term monitoring of BD+60° 497 with TIGRE+HEROS will be initiated in the next AO.

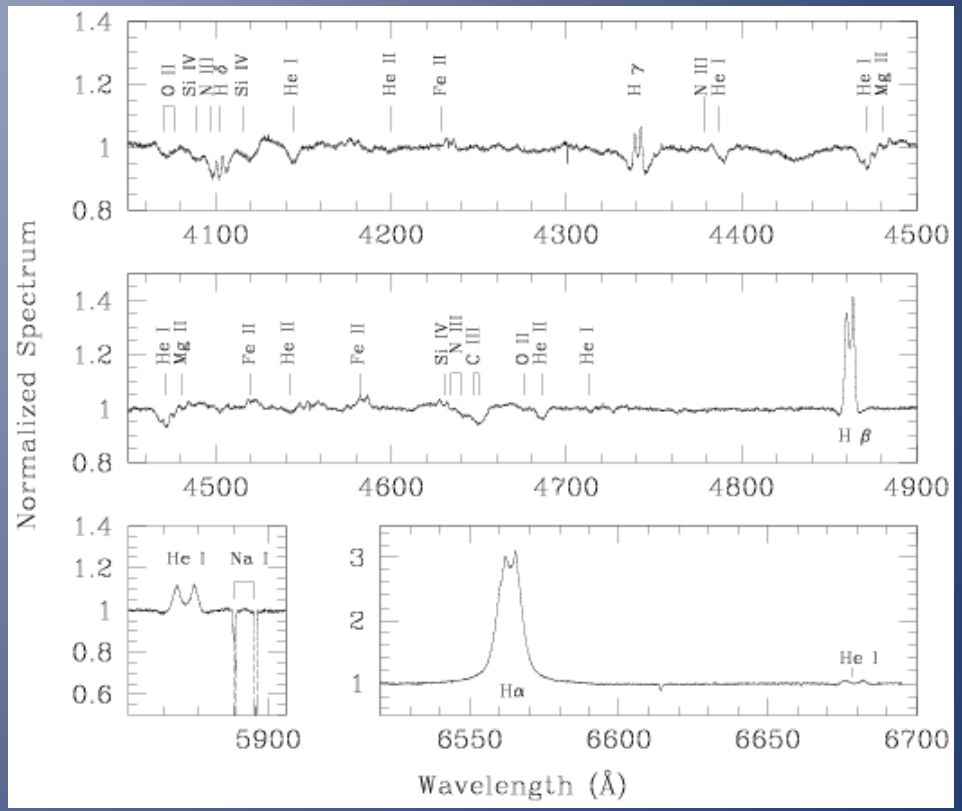
- BD+60° 498 was found to be a likely spectroscopic binary with a period of ≥ 10 days.



New TIGRE+HEROS observations are needed to establish a full orbital solution of BD+60° 498. This was proposed in AO3.

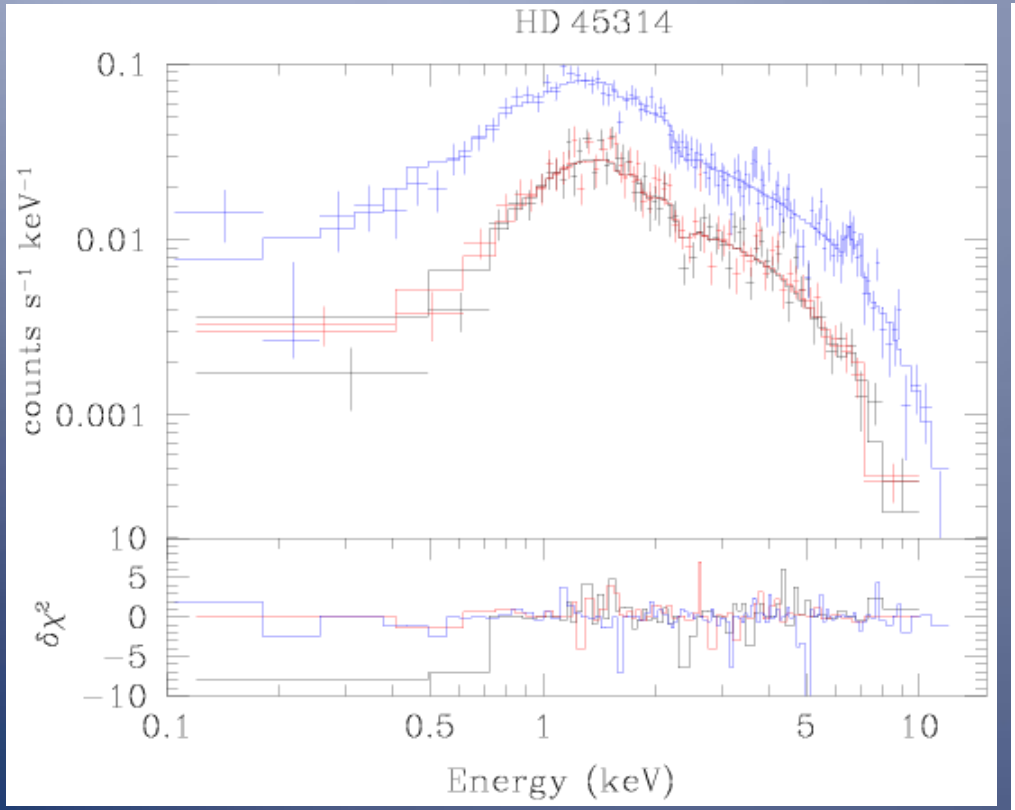
The Oe star/γ Cas analog HD45314

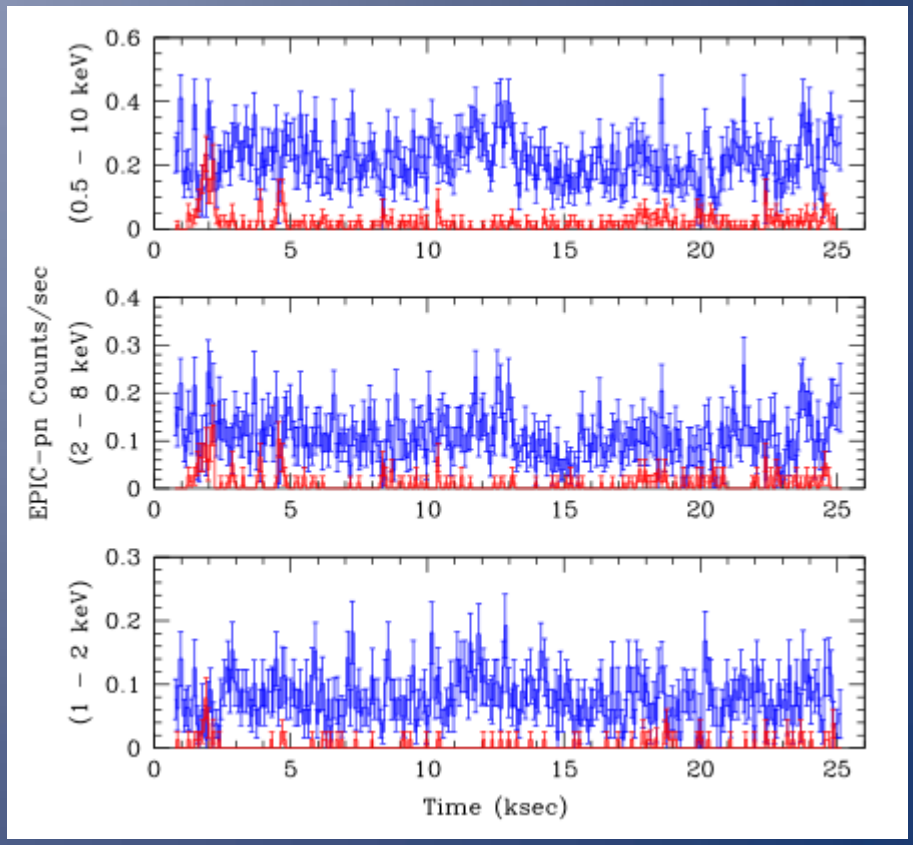
- Oe stars display emission in hydrogen lines, but not in He II λ4686 nor N III λλ4634–40 (Conti & Leep 1974, ApJ 193, 113, Negueruela et al. 2004, AN 325, 749). Like Be stars they are fast rotators, likely surrounded by a decretion disk.



HD 45314

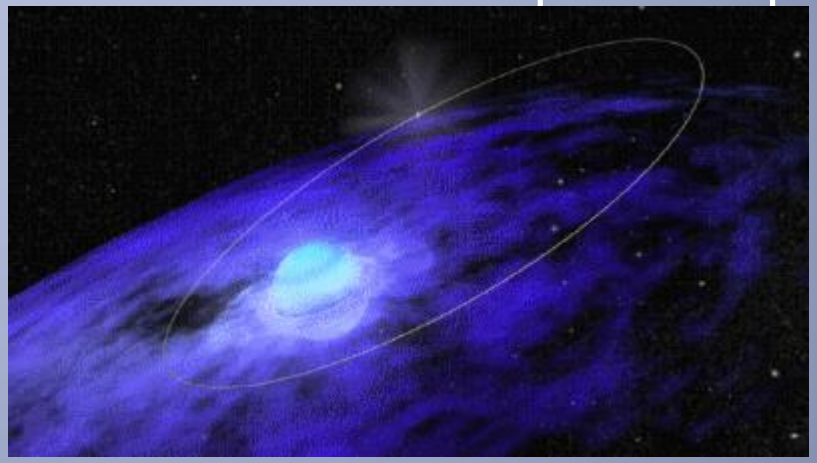
- A sub-class of the Be stars form the so-called γ Cas analogs: objects that are X-ray bright (showing a 10 × stronger L_X/L_{bol}) with a hard thermal spectrum (kT = 21 keV) and short-term X-ray variability (Smith et al. 2016, AdSpR 58, 782).
- HD 45314 was found to belong to this category (Rauw et al. 2013 A&A 555, L9).





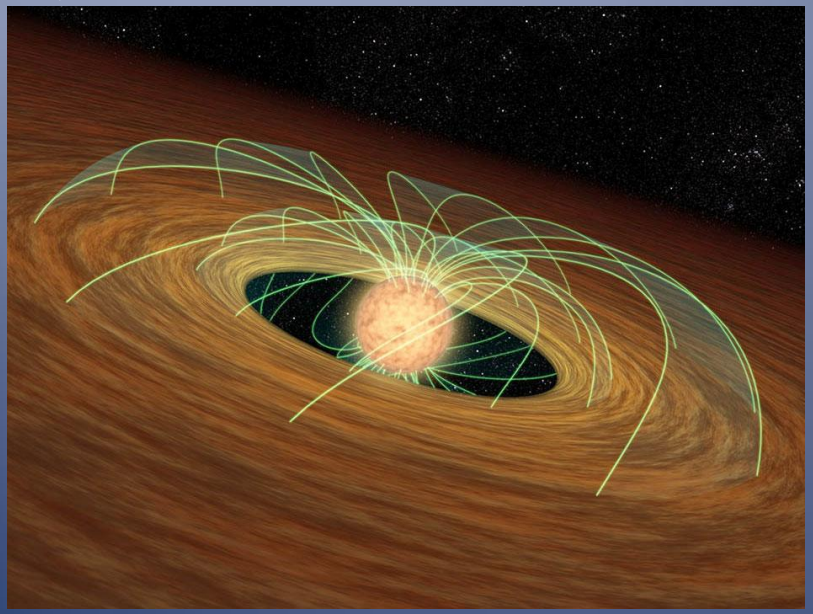
- What causes the γ Cas behaviour?

1. Accretion onto a compact companion (White et al. 1982, ApJ 263, 277)?



Neutron star companions were considered unlikely. White dwarfs are possible, but evolution would be very peculiar.

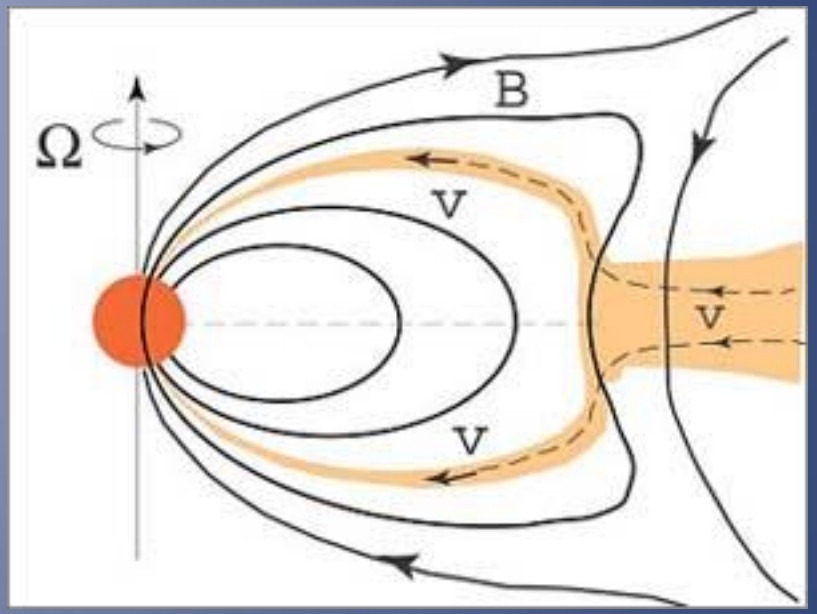
2. Wind-disk interactions via magnetic fields (Smith et al. 2012, A&A 540, A53)?



No evidence for global stellar B-field. Why would this mechanism only affect a subset of the Be stars?

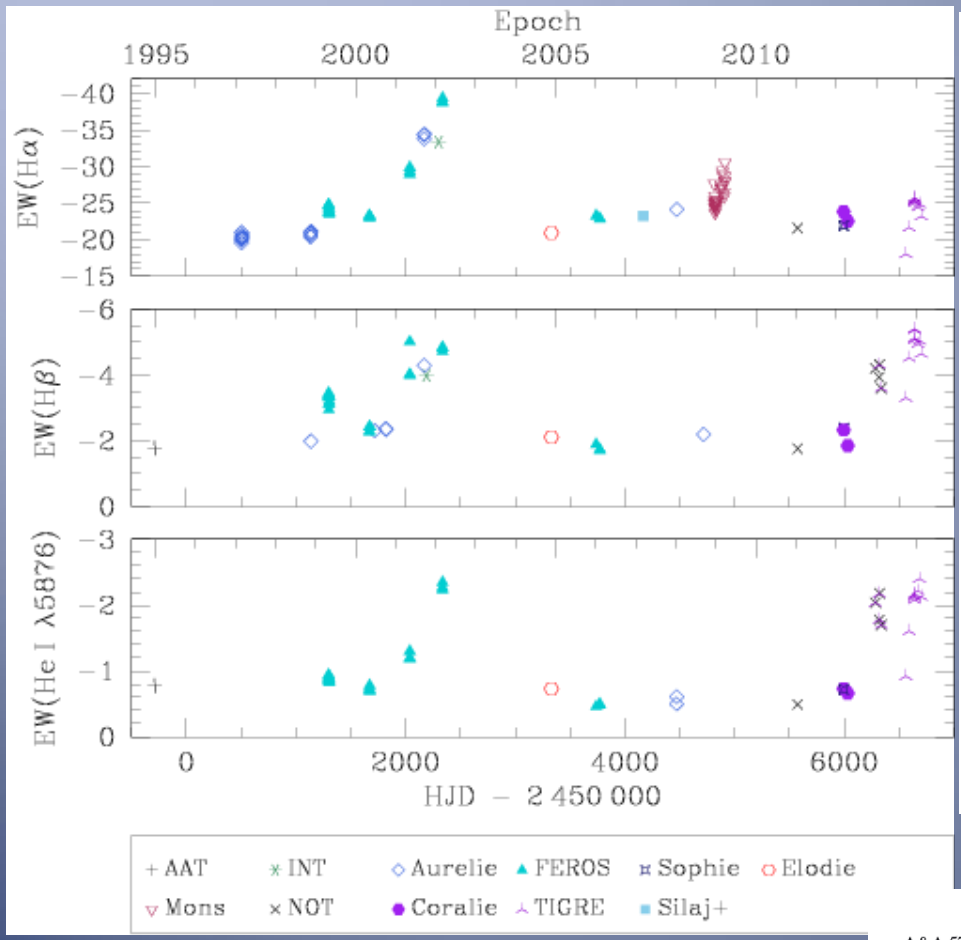
- What causes the γ Cas behaviour?

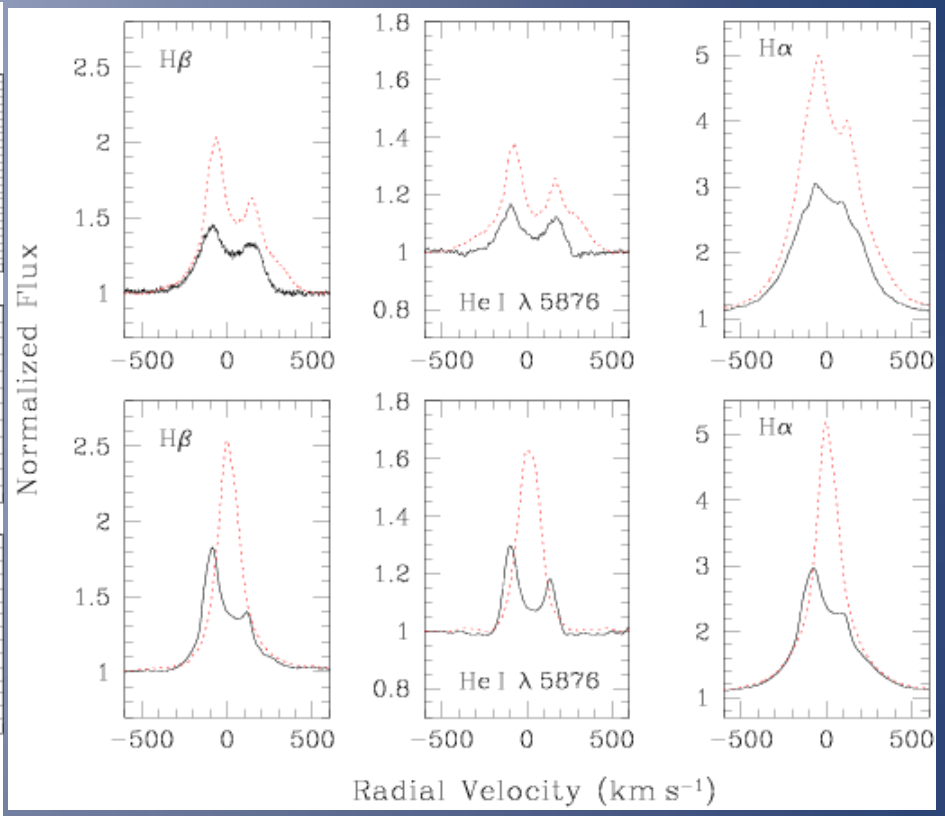
3. Return of the binary scenario with a fast-spinning neutron star in the propeller regime as compact companion (Postnov et al. 2016, MNRAS 465, L119).



- A way to test these scenarios: observe a γ Cas analog in X-rays when the Be star is in optical eruption or in a very low state.
- We obtained a ToO program on XMM-Newton to perform such a study for HD45314.

- The emission lines in HD 45314 display long-term variations that we have previously monitored:





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Spectroscopic variability of two Oe stars

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Conclusions

- TIGRE studies of IC1805 shed new light on the O-stars in this cluster.
- Additional studies are needed to investigate the apsidal motion of BD+60° 497, to establish the orbital solution of BD+60° 498 and search for the signature of its companion, and to solve the mystery of HD 15558.
- TIGRE monitoring of the Oe star HD 45314 allowed us to catch the X-ray emission of a γ Cas star while it is a low emission state and to trigger an XMM-Newton ToO (analysis is under way).
- It is crucial to resume our monitoring as soon as possible (next XMM visibility window opens in March 2017 and then again in September 2017).