TIGRE and the γ Cas phenomenon

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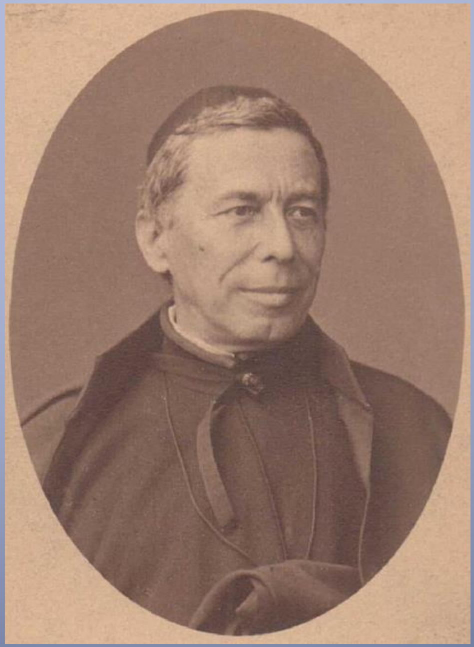
γ Cas stars

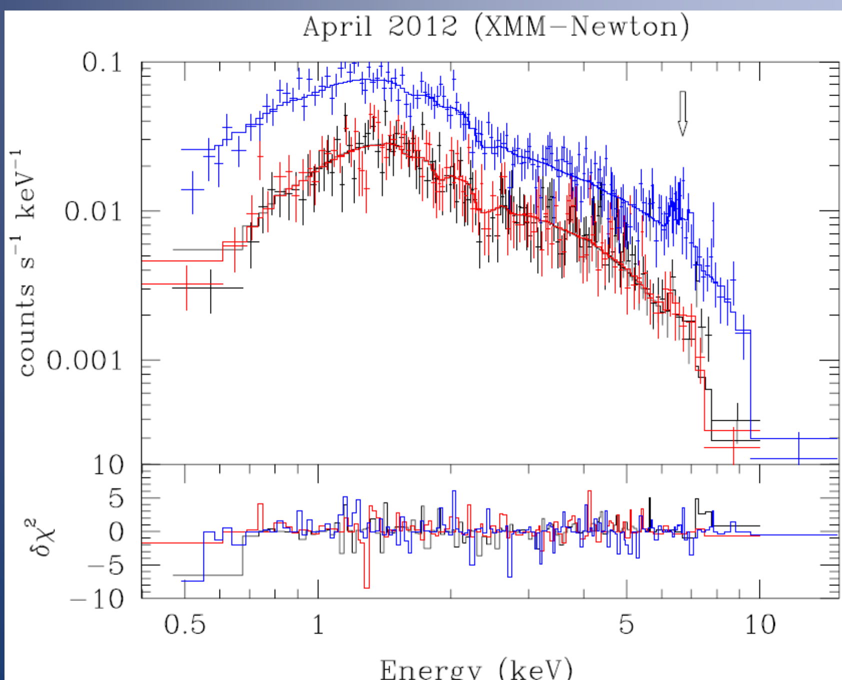
- In 1866 Angelo Secchi discovered that γ Cassiopeia displays the Hβ line in emission.
- γ Cassiopeia became the prototype of so-called Be stars.
- Nowadays the emission lines are interpreted as arising from a Keplerian “decretion” disk.

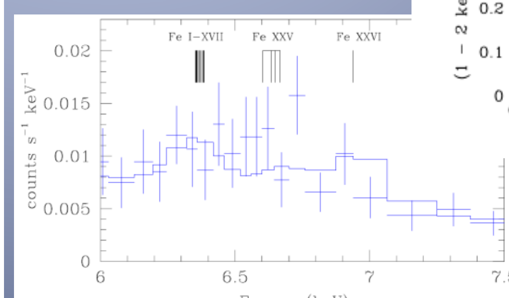


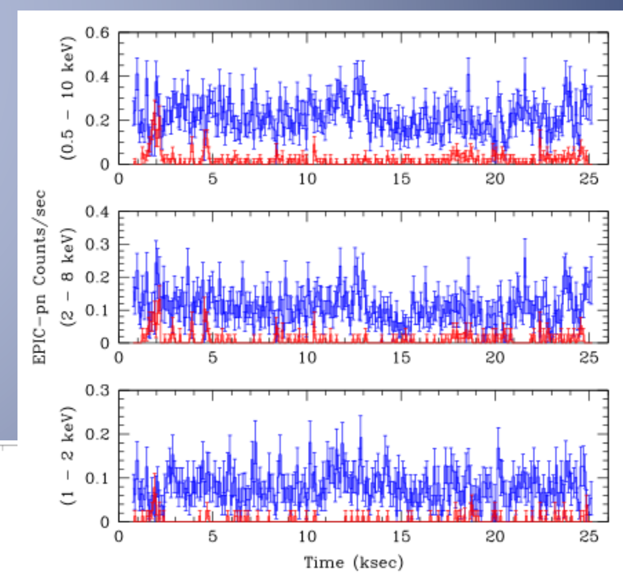
- SAS-3 revealed that γ Cas displays an unusual X-ray emission (Jernigan 1976, IAU Circ. 2900 #2):

1. 10 L_X (OB stars) ≤ L_X (γ Cas) ≤ 0.1 L_X (Be HMXBs)
2. Thermal X-rays with kT ~ 10 keV.

- Modern X-ray telescopes: ~ a dozen Be stars with similar X-ray properties → new class of X-ray sources = γ Cas stars (Smith et al. 2016, AdSpR 58, 782)

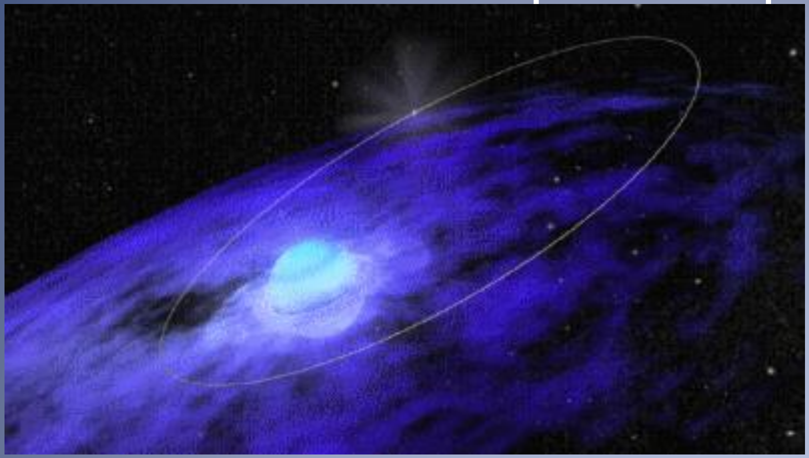






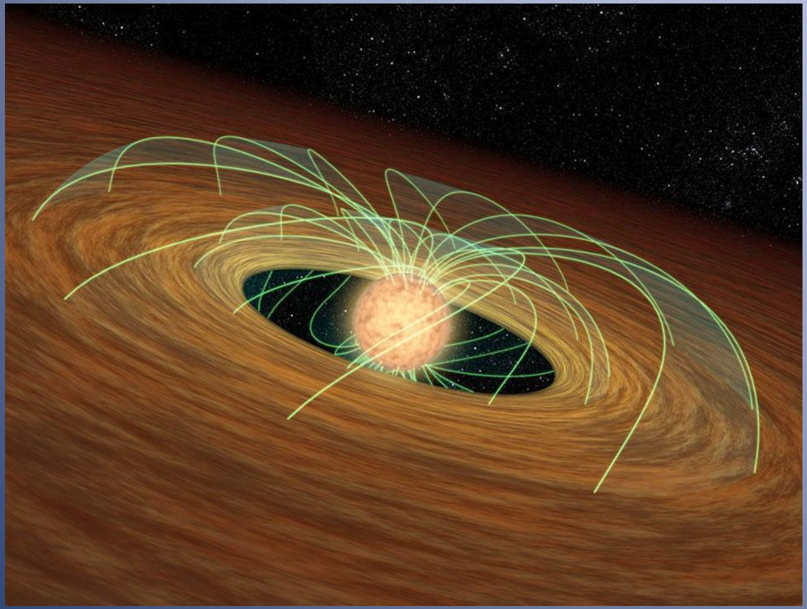
- Origin of the γ Cas phenomenon?

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



Neutron star companions considered unlikely. White dwarfs possible, but peculiar evolution required.

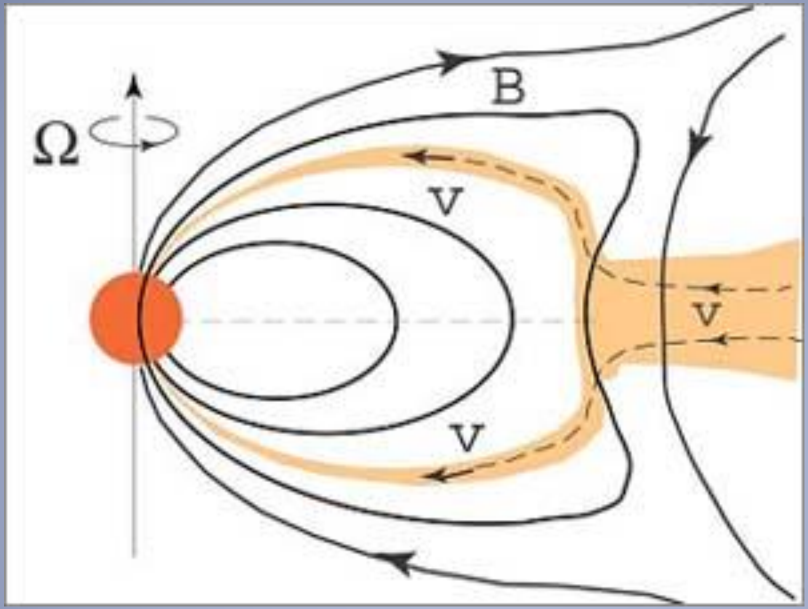
2. Wind-disk interactions via magnetic fields (Smith et al. 2012, A&A 540, A53)?



Global stellar B-field > 10 G inconsistent with disk (ud-Doula et al. 2018, MNRAS, in press, arXiv:1805.0300).

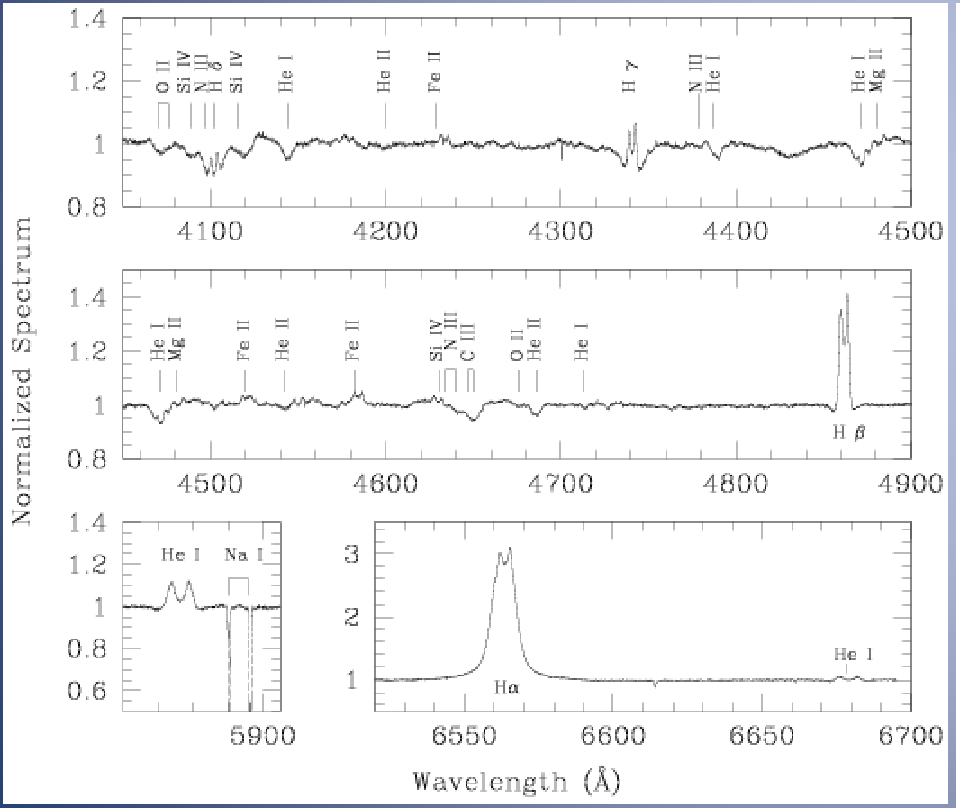
Why would this mechanism only affect a subset of the Be stars?

3. Come-back of the compact companion scenario: fast-spinning neutron star in the propeller regime (Postnov et al. 2016, MNRAS 465, L119).

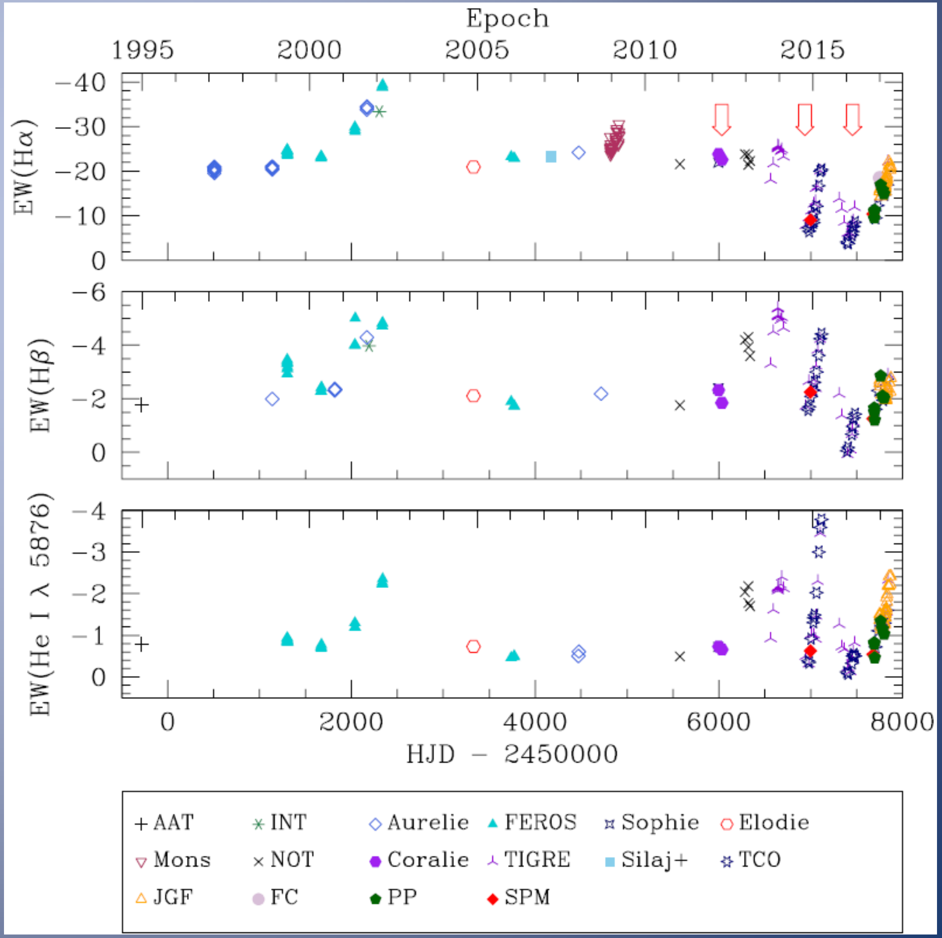


HD 45314: the disk connection…

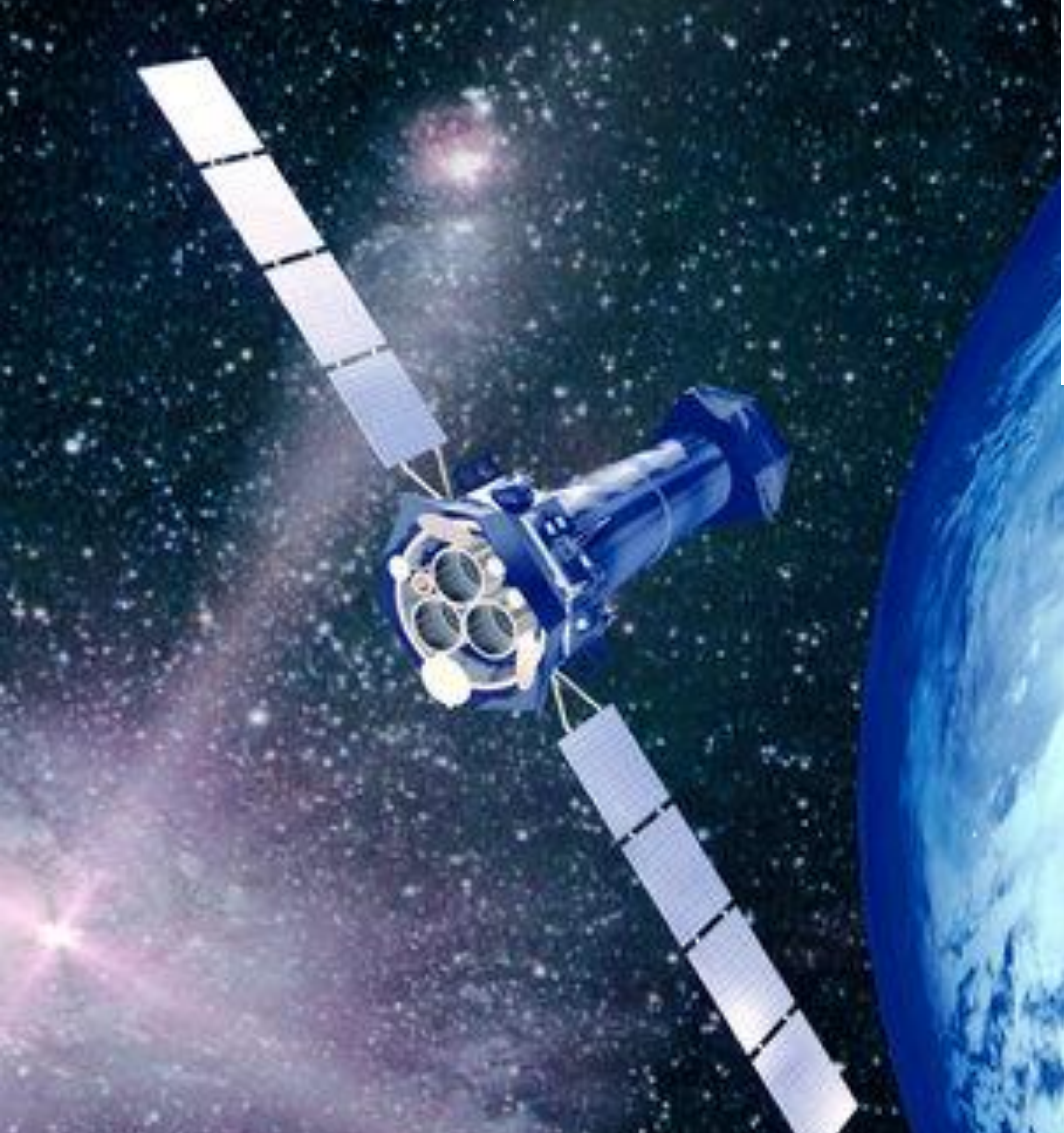
- HD 45314 O9.7e star with strong spectral variability (Rauw et al. 2007, IBVS 5773).
- TIGRE monitoring initiated in 2013 (Rauw et al. 2015 A&A 575, A99).

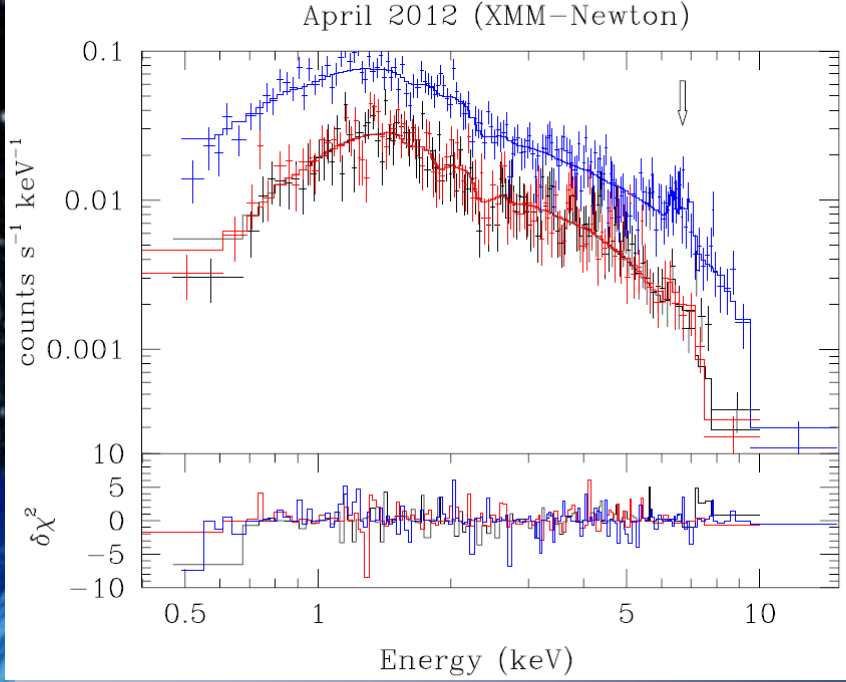


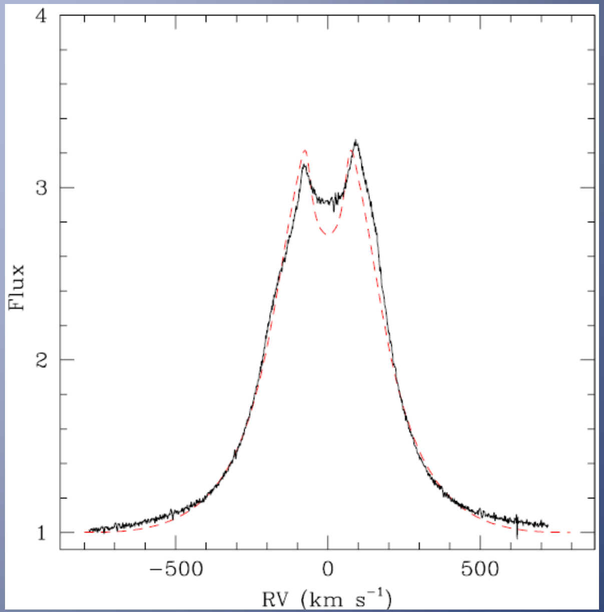
HD 45314



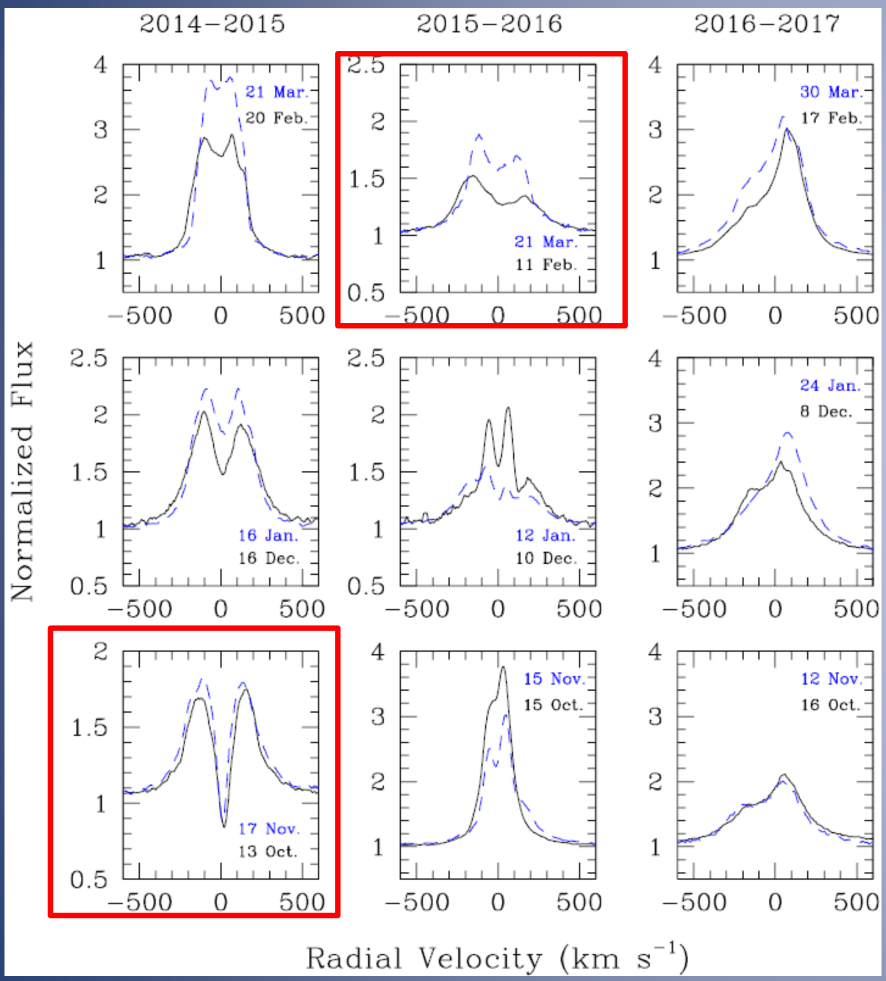
- XMM-Newton revealed γ Cas nature of HD 45314 (Rauw et al. 2013 A&A 555, L9).

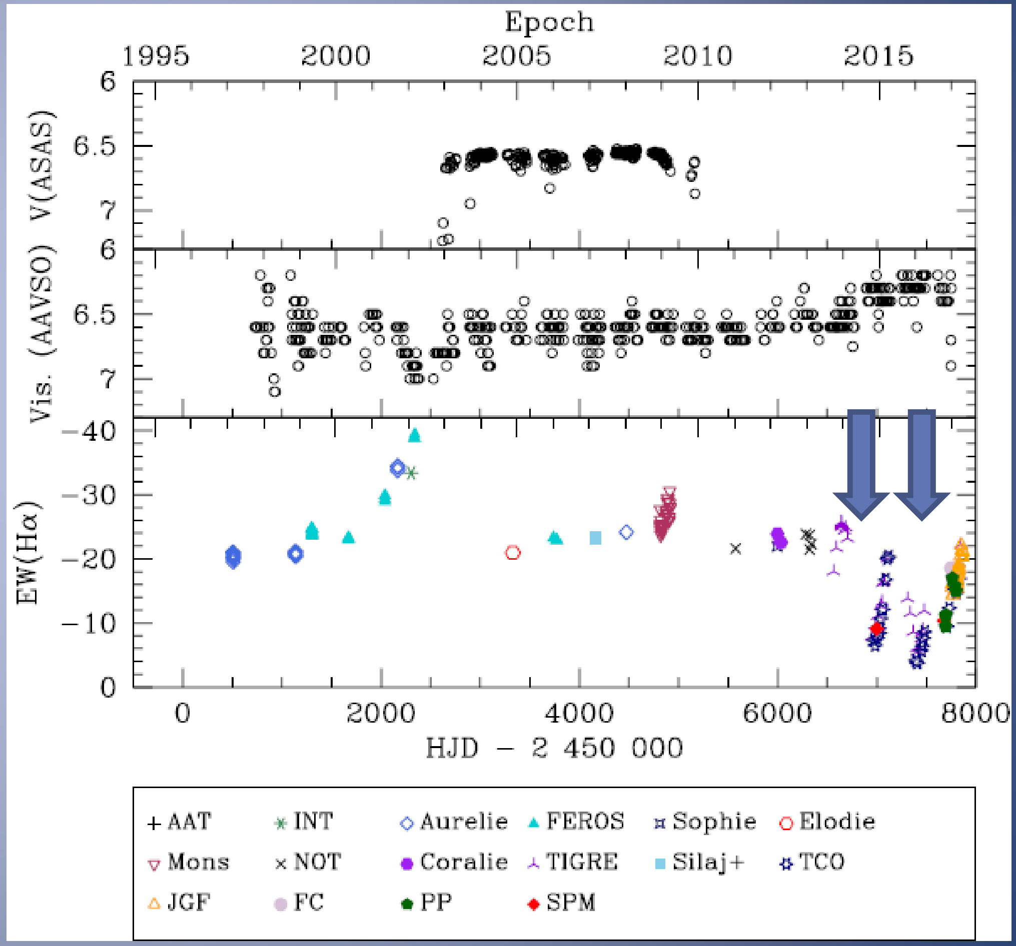






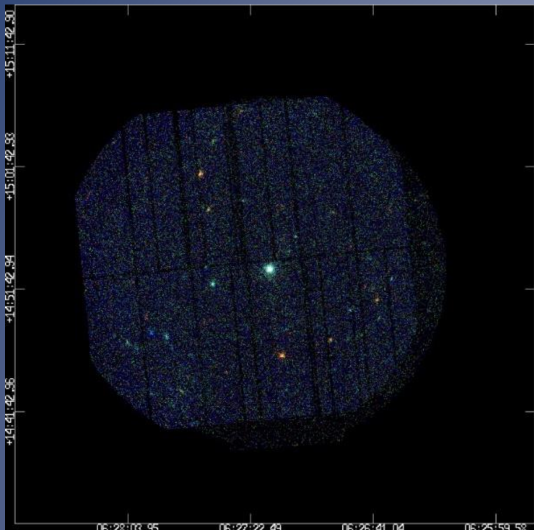
- In 2014, HD 45314 entered an episode of "spectacular variations" including a shell phase and a near-clearing of the disk.

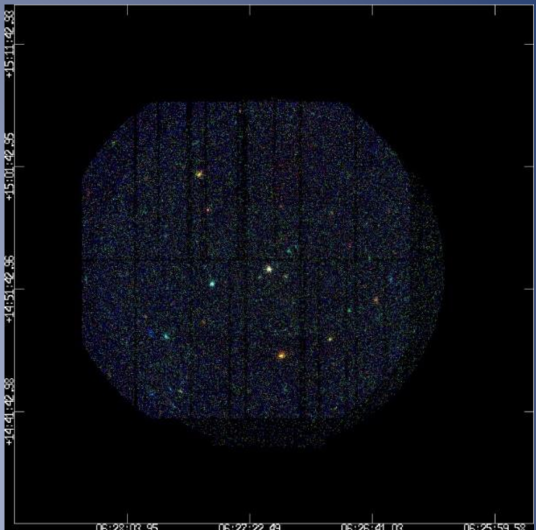


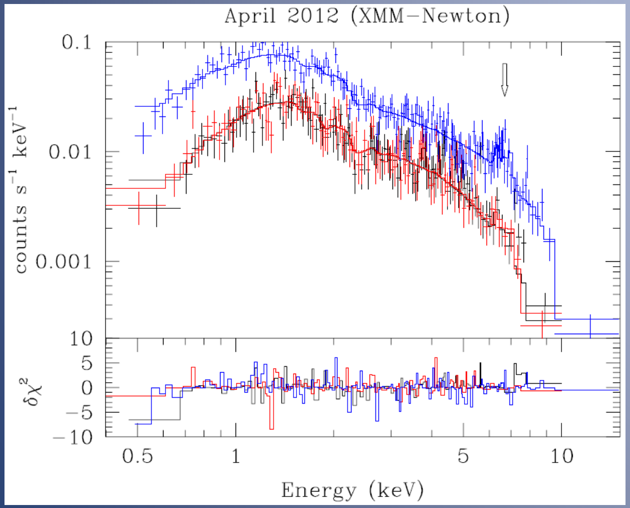


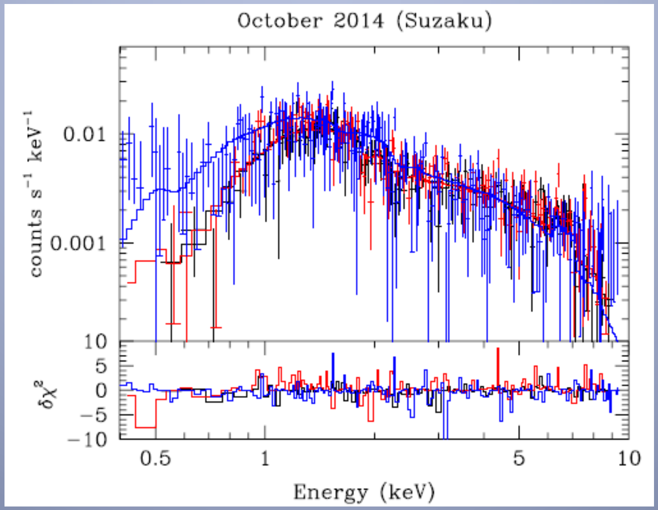
❑ XMM-Newton and Suzaku observed HD 45314:

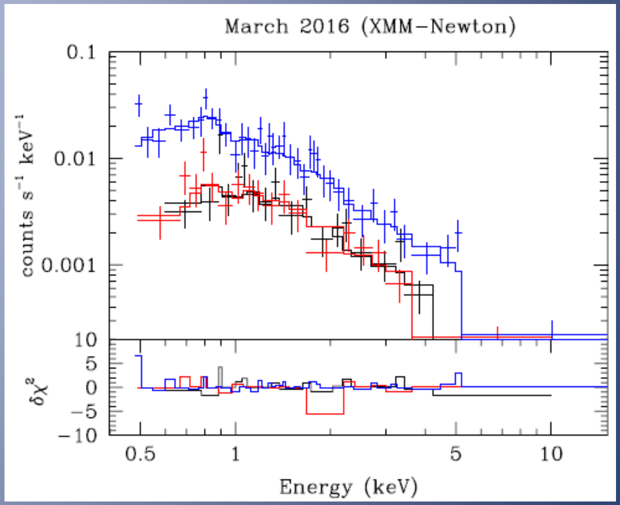
14/4/2012 6/10/2014 8/3/2016



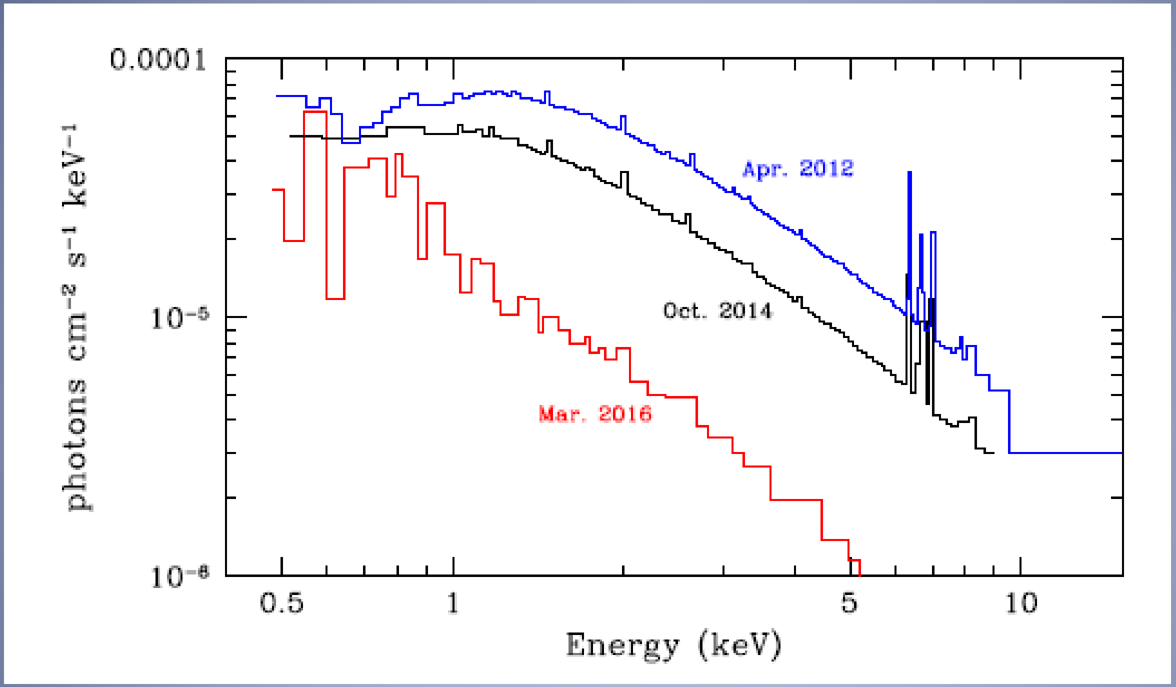




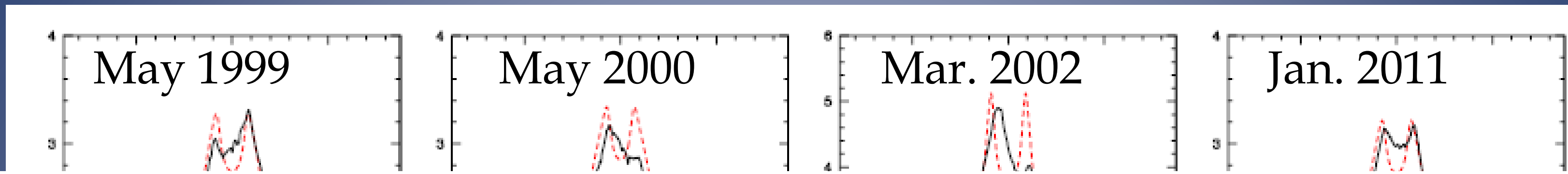




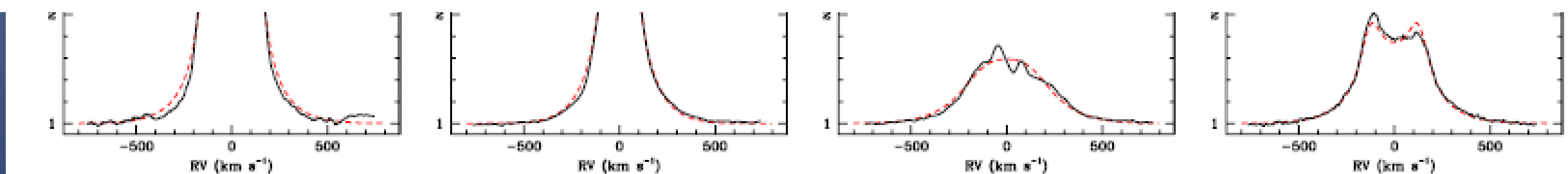
- The X-ray flux was a factor 10 lower and softer in March 2016 than in April 2012.
- γ Cas emission present during shell phase though weaker.



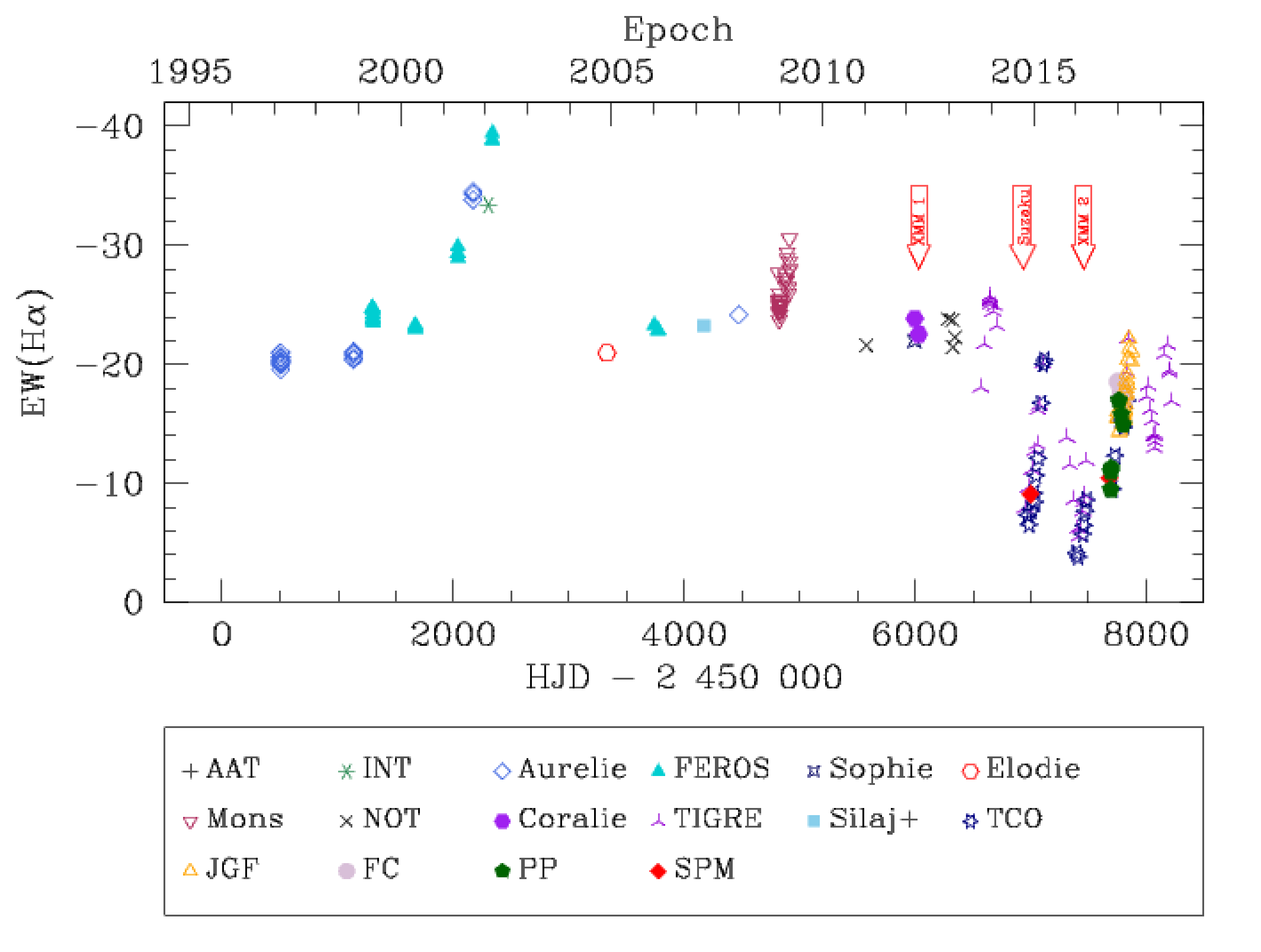
- Results (Rauw et al. 2018, A&A in press, arXiv:1802.05512) suggest that X-ray emission scales with "instantaneous" Be disk-density.
- Complex behavior of disk during "spectacular variations"



Epoch	i_{disk} (°)	R_{disk} R_*	n_0 (cm^{-3})	α	$v_{extra,0}$ ($km\ s^{-1}$)
May 1999	43.3 ± 3.4	48.5 ± 9.8	1387 ± 84	3.5	238 ± 21
May 2000	43.4 ± 6.6	50.8 ± 14.4	1408 ± 80	3.4 ± 0.3	218 ± 37
Mar. 2002	59.0 ± 2.1	49.9 ± 3.9	930 ± 20	3.0	250
Jan. 2011	38.2 ± 5.9	47.2 ± 15.8	1396 ± 81	3.1 ± 0.6	222 ± 37
Apr. 2012	38.5 ± 5.7	43.3 ± 14.1	1353 ± 88	3.0 ± 0.6	240 ± 20
Dec. 2013	≤ 15.0	13.5 ± 1.5	1200 ± 36	3.5	250
Oct. 2014	80.0	31.7 ± 4.7	1156 ± 115	3.5	30 ± 24
Dec. 2014	45.5 ± 16.3	29.6 ± 12.9	956 ± 362	3.1 ± 0.4	118 ± 92
Feb. 2015	20.0	4.5 ± 0.5	851 ± 253	2.8 ± 0.5	210 ± 38
Oct. 2015	18.6 ± 2.3	41.6 ± 17.6	914 ± 97	3.5	222 ± 25
Jan. 2016	32.9 ± 10.8	31.0 ± 22.2	573 ± 232	3.3 ± 0.4	193 ± 71
Mar. 2016	29.0 ± 5.2	25.2 ± 17.5	763 ± 310	3.1 ± 0.4	195 ± 49

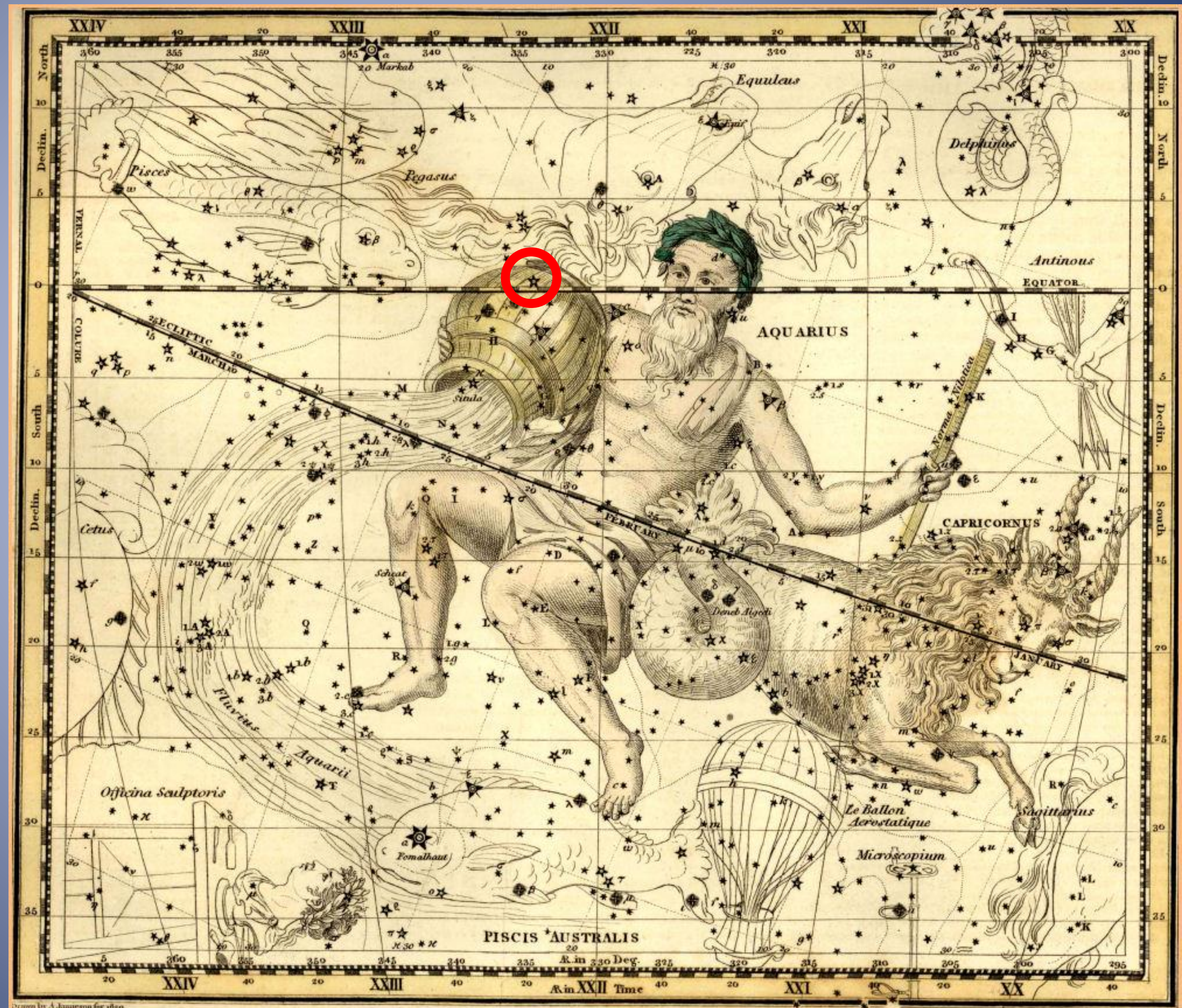


- Monitoring continues, awaiting for next "outburst".

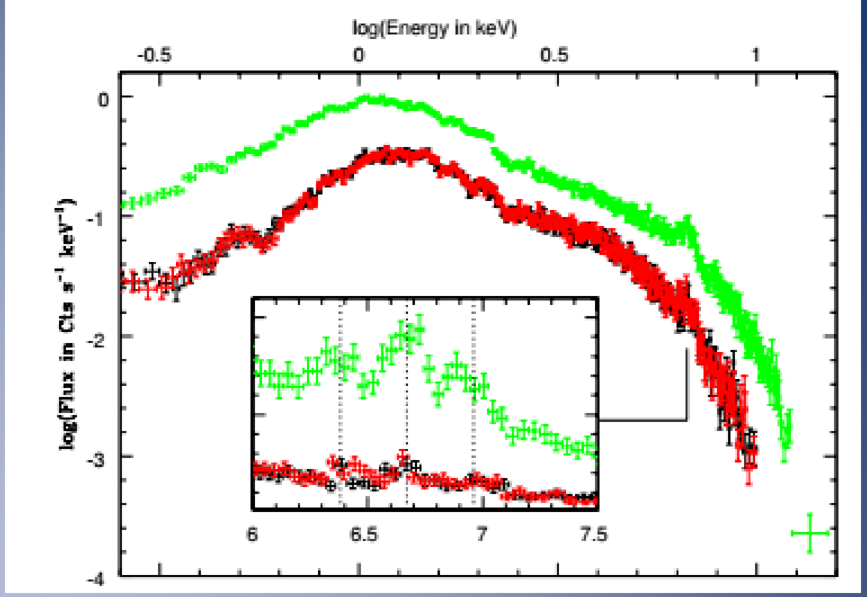


π Aqr – another γ Cas analog…

- Be star
- V=4.64
- d=241pc
- $\Omega/\Omega_c \sim 0.5$
- with UV peculiarities

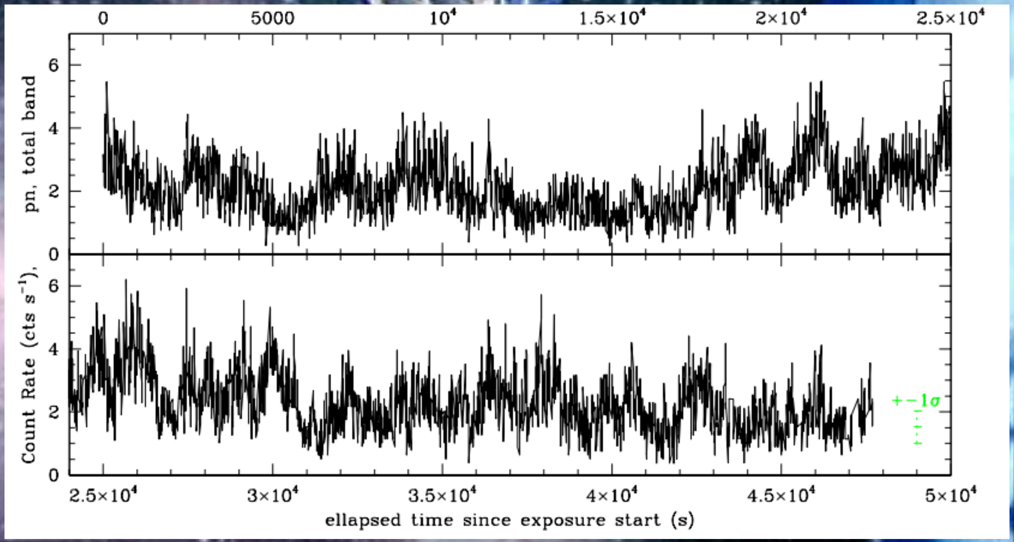


- May 2004: XMM-Newton during a slew: 2.8 ± 1.1 ct/s (SL2)
- Nov. 2013: dedicated 50 ks obs.



- Hard spectrum (kT~11keV), Fe K fluorescent line, L_X~7e31 erg/s, $\log(L_X/L_{bol})$ ~ -5.6
- Short and long-term variability (e.g. 50% brightening XMM vs ROSAT)

⇒ new γ Cas star (Nazé et al. 2017, A&A 602, L5)



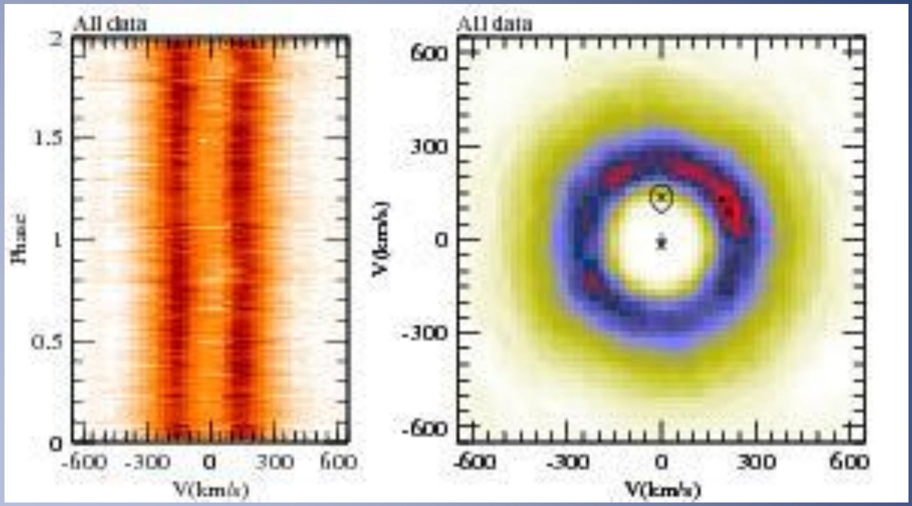
So, what's special?

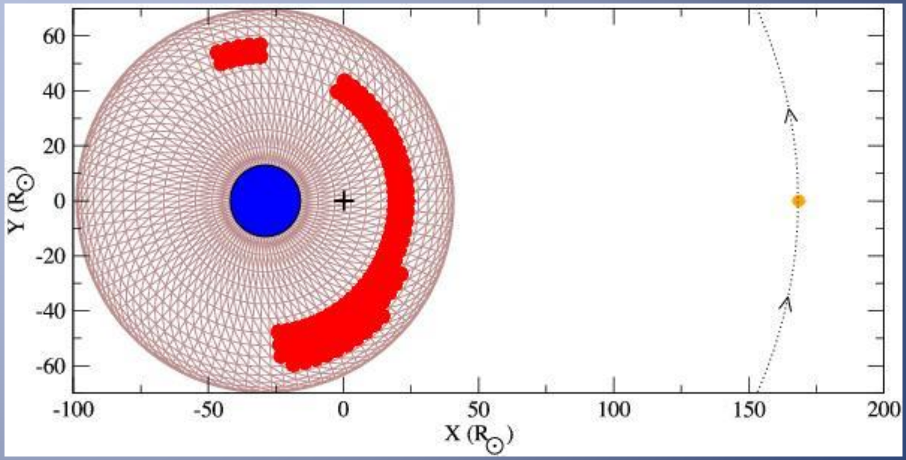
π Aqr is a binary (Bjorkman et al. 2002, ApJ 573, 812) with RV variations of abs/em in Hα: ~12+2.5 Msol + non-compact companion!

Zharikov et al. (2013, A&A 560, A30):

- Disk << orbital separation
- V/R variations locked to P_{orb}, disk over-density facing companion

⇒ Accretion scenario unlikely

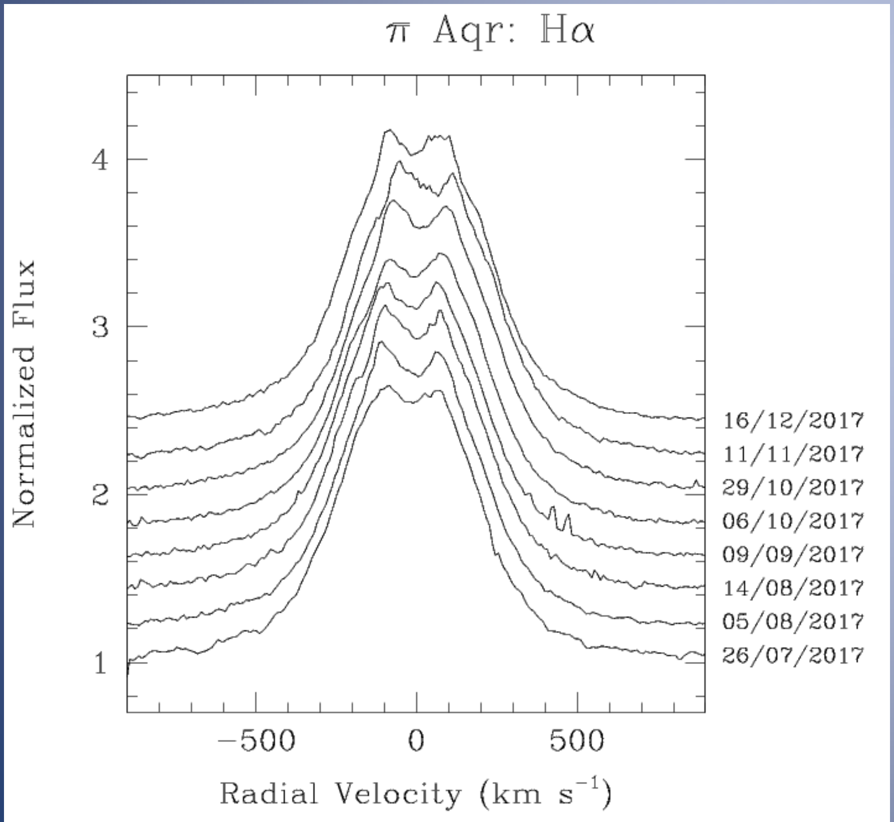


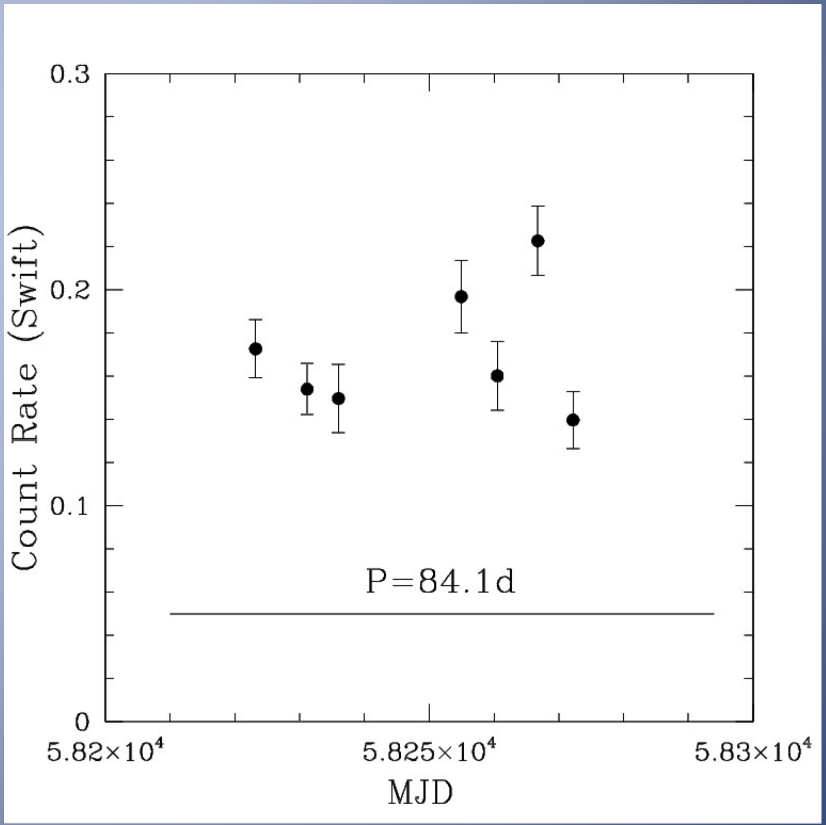


Multi-wavelength monitoring:

- 1 ks snapshots with Swift XRT-WT
- TIGRE+HEROS, 5 min snapshots
- Amateur spectroscopists (Malin Moll + Christoph Quandt)

Aim : to cover 3 cycles during visibility period, ~1 obs/week





Conclusions

- Coordinated TIGRE and XMM-Newton observations established a connection between the properties of the disk and the X-ray emission.
- The binary Be star π Aqr was found to be a γ Cas star.
- Both results favour the magnetic interaction scenario.
- Future steps:

1. Monitor the orbital variations of the X-ray emission of π Aqr.
2. Observe HD 45314 in X-rays during its next outburst.
3. Enlarge the sample of γ Cas stars with X-ray and optical monitoring (BROSIT! Be with eROSIta and Tigre).