SALT spectroscopic observations of supersoft Be binaries in the Magellanic Clouds

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SuperSoft Be binaries

– 30% of Be are binary systems (Oudmaijer & Parr, 2010)

– thin viscous **truncated** Keplerian disk of gas in the equatorial plane of the B star

– **higher density** disk than in isolated Be (Reig+2016)

– variability of emission lines (H, He, Fe) on **shorter time scales** (1-5 yrs, Reig 2011) than isolated Be (2-11 yrs, Okazaki 1997)

– **double spiral arms** caused by the binarity (Panoglou+ 2016, 2018)

– very soft X-ray spectrum $L_{SX} \leq 10^{38}$ erg s^{-1} caused by accretion onto a compact object (WD, BH?)

Targets

XMMU J010147.5-715550
Recurrent SSS, $L_{SX} \geq 10^{35}$ erg s^{-1}, V = 14.47±0.04, SpType = O7IIIe – B0Ie (Sturm+ 2012)

SUZAKU J0105-72 (1E0102.2-7219, Takei+ 2008; 2dFS 2064, Evans+ 2004)
Transient SSS in a SNR, $L_{SX} = 2 \times 10^{37}$ erg s^{-1}, V = 14.64 (Evans+ 2004), SpType = B0 IV (Evans+ 2004), O9.3 III/Ve (Lamb+ 2016)

MAXI J0158-744
Transient SSS, $L_{0.2\text{-}2\ keV} \sim 2 \times 10^{37}$ erg s^{-1} , $L_{2\text{-}4\ keV} \sim 1.6 \times 10^{39}$ erg s^{-1} , I = 14.82, SpType = B1/2 IIIe (Li+ 2012)

XMMU J052016.0-692505 (LMCV 2135)
SSS, $L_{SX} = 5.5 \times 10^{36}$ erg s^{-1}, V = 15.45±0.05, SpType = B0-3e (Kahabka+ 2006)

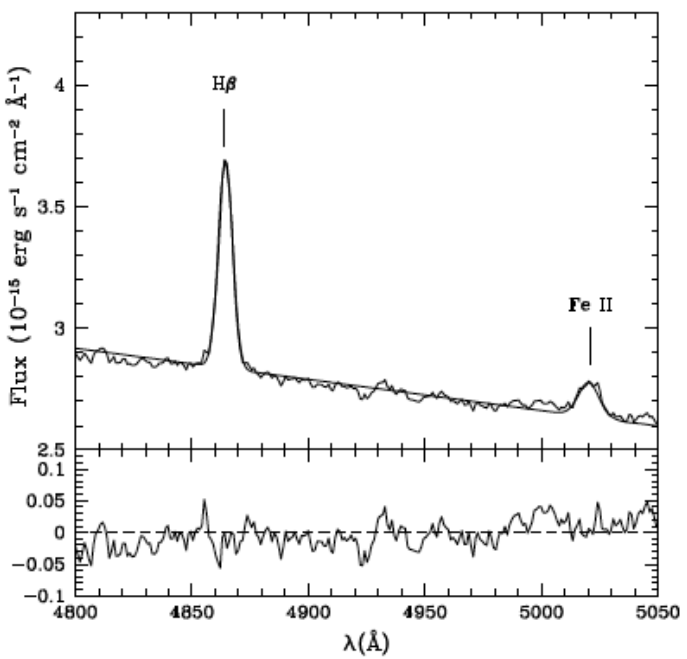
RX J0527.8-6954
Transient SSS, $L_{SX} \sim 0.4\text{-}0.9 \times 10^{37}$ erg s^{-1} (Oliveira+ 2010), V = 17.3 (Cowley+ 1997), SpType = B8 IV (Oliveira+ 2010)

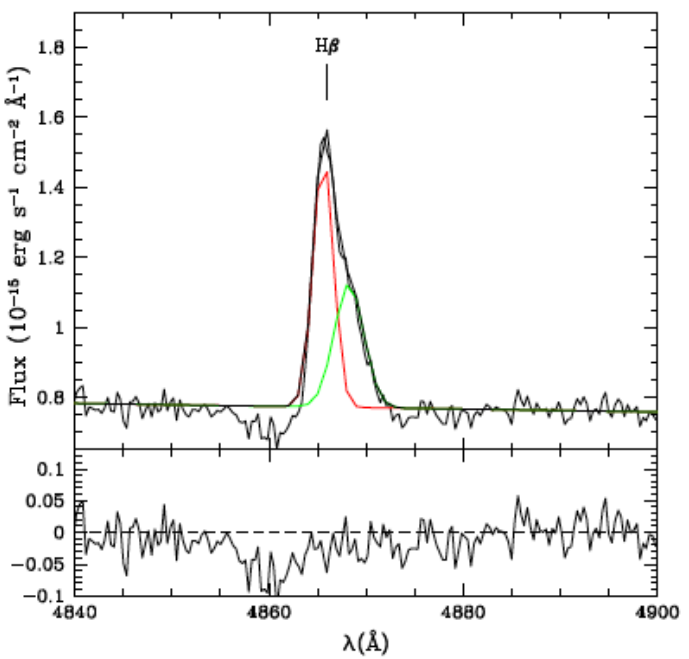
SALT Observations

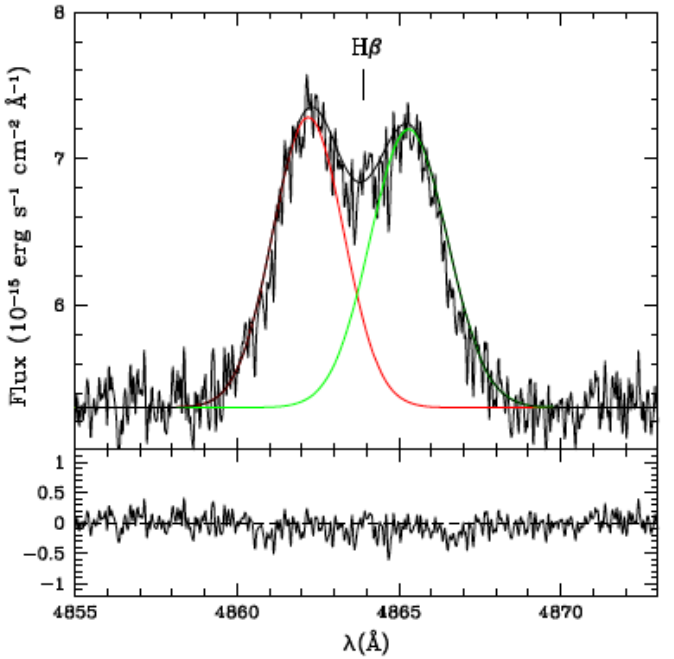
Object	Date	Instrument	Grating	Grating Angle (deg)	Spectral Range (Å)	R ($\lambda/\Delta\lambda$)	$\delta\lambda$ (Å pixel^{-1})	T_{exp} (s)
XMMU J010147.5–715550	2016 Sep 07	RSS	PG0900	14.75	4063–7113	1100	0.96	900
	2016 Sep 29	RSS	PG0900	14.75	4062–7137	1100	0.96	900
	2017 Jun 17	HRS	LR	···	3702–8870	15000	0.024–0.045	1700
	2017 Jul 30	HRS	LR	···	3702–8870	15000	0.024–0.045	1700
	2017 Oct 26	HRS	LR	···	3702–8870	15000	0.024–0.045	1400
SUZAKU J0105–72	2016 Sep 20	RSS	PG0900	14.75	4061–7132	1100	0.97	900
	2016 Oct 19	RSS	PG0900	14.75	4063–7130	1100	0.97	700
	2017 Jul 14	HRS	LR	···	3702–8870	15000	0.024–0.045	1900
	2017 Aug 26	HRS	LR	···	3702–8870	15000	0.024–0.045	1900
	2017 Oct 26	HRS	LR	···	3702–8870	15000	0.024–0.045	1600
XMMU J052016–692505	2016 Sep 20	RSS	PG2300	35.00	4443–5463	2900	0.32	960
	2016 Oct 20	RSS	PG2300	35.00	4442–5462	2900	0.32	960 + 669
	2016 Oct 25	RSS	PG0900	14.75	4062–7131	1100	0.97	870
	2017 Sep 17	HRS	LR	···	3702–8870	15000	0.024–0.045	1575
	2017 Oct 22	HRS	LR	···	3702–8870	15000	0.024–0.045	1575
	2017 Oct 29	HRS	LR	···	3702–8870	15000	0.024–0.045	1400
MAXI J0158–744	2016 Oct 10	RSS	PG2300	35.00	4443–5463	2900	0.32	900
	2016 Oct 23	RSS	PG2300	35.00	4443–5462	2900	0.32	900
	2017 Aug 13	HRS	LR	···	3702–8870	15000	0.024–0.045	1750
	2017 Sep 17	HRS	LR	···	3702–8870	15000	0.024–0.045	1750
	2017 Oct 26	HRS	LR	···	3702–8870	15000	0.024–0.045	1350

(Cracco+ 2018)

Analysis and Results

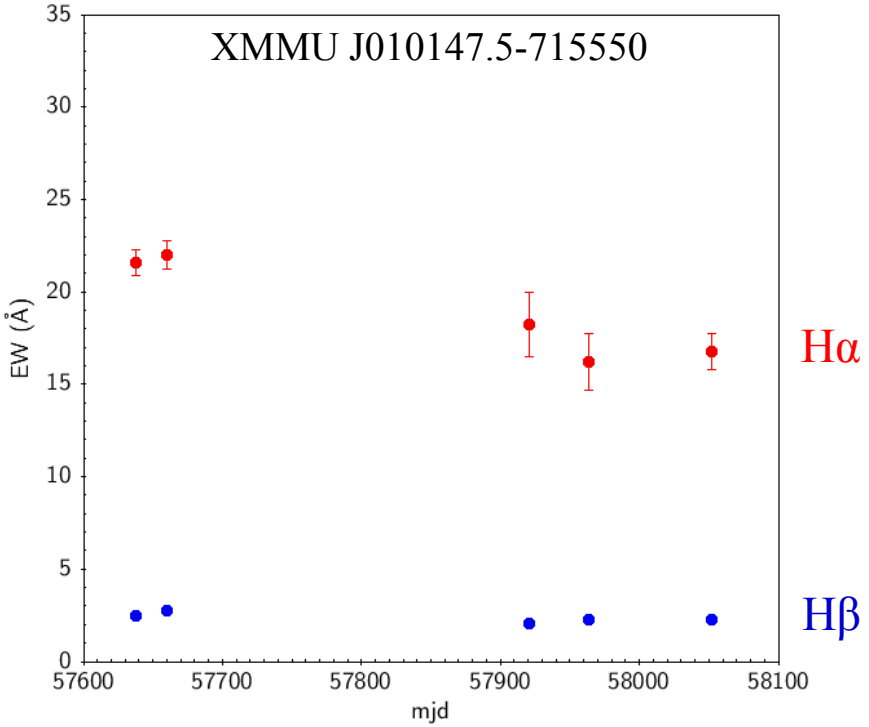


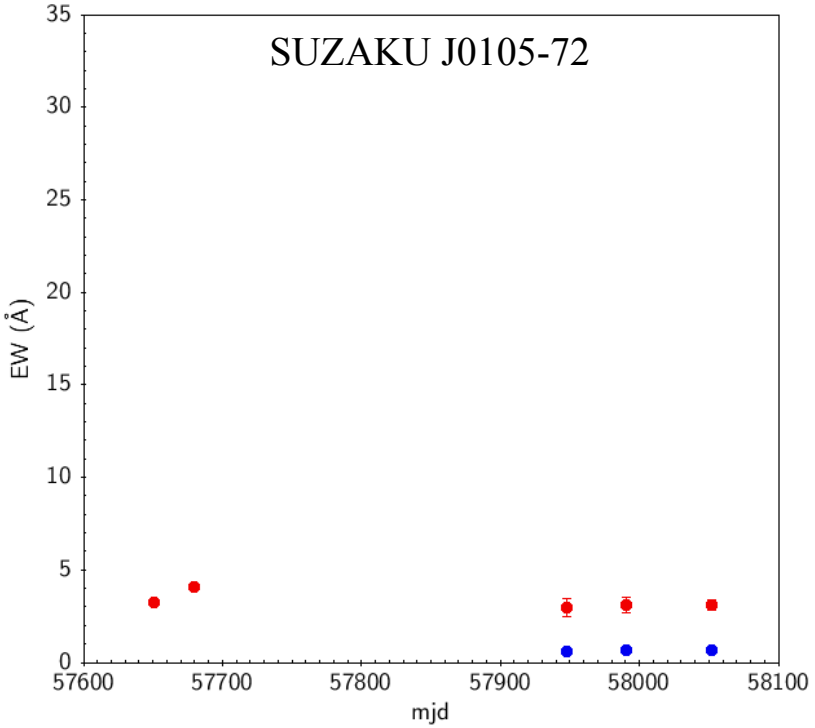


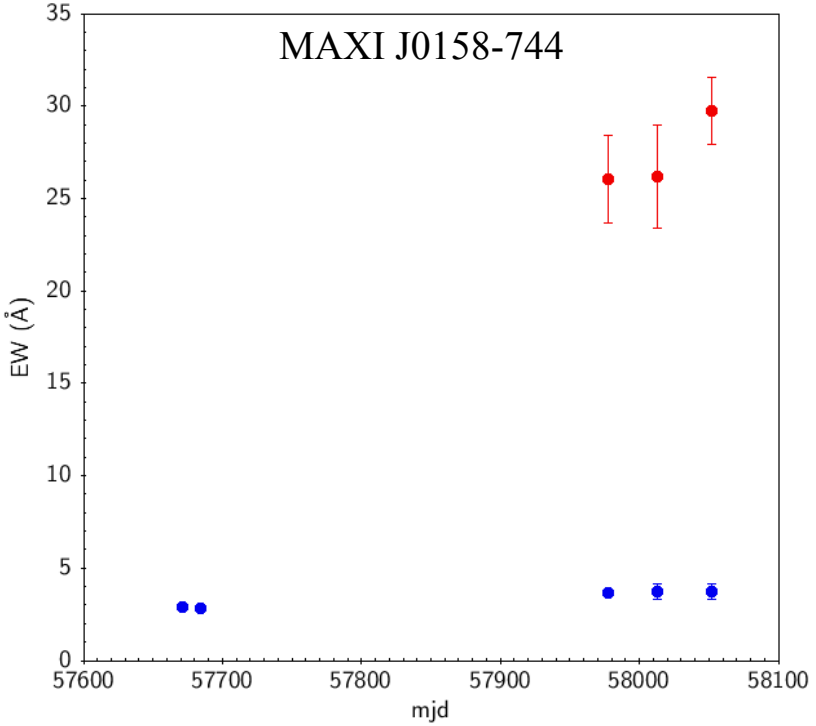


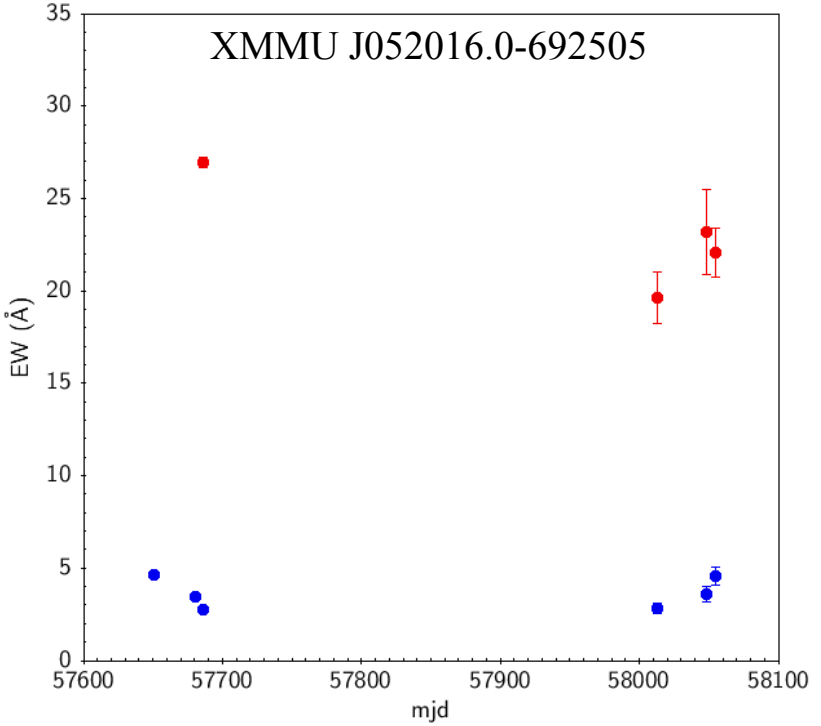
Equivalent width
Radial velocity
$\Delta v = v_V - v_R$ (peak separation or σ of the profile)
V/R

(Cracco+ 2018)

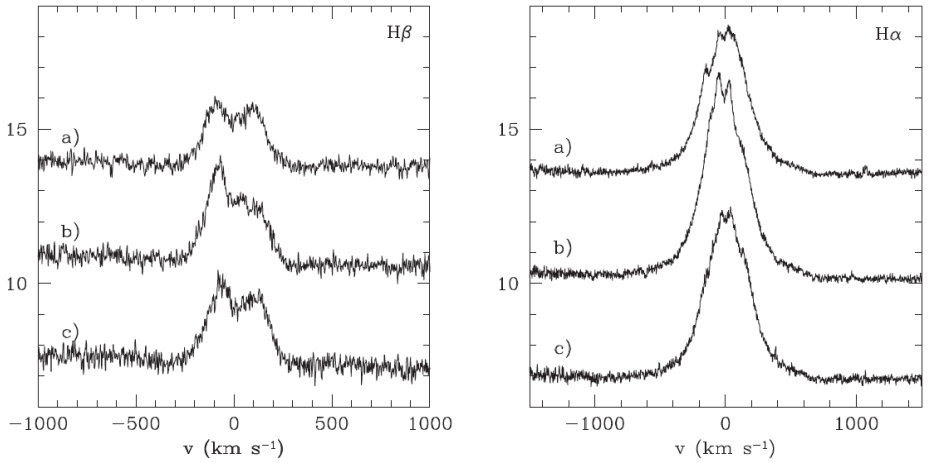

XMMU J010147.5-715550
EW (Å)
mjd
Hα
Hβ


SUZAKU J0105-72
EW (Å)
mjd


MAXI J0158-744
EW (Å)
mjd


XMMU J052016.0-692505
EW (Å)
mjd

XMMU J010147.5-715550



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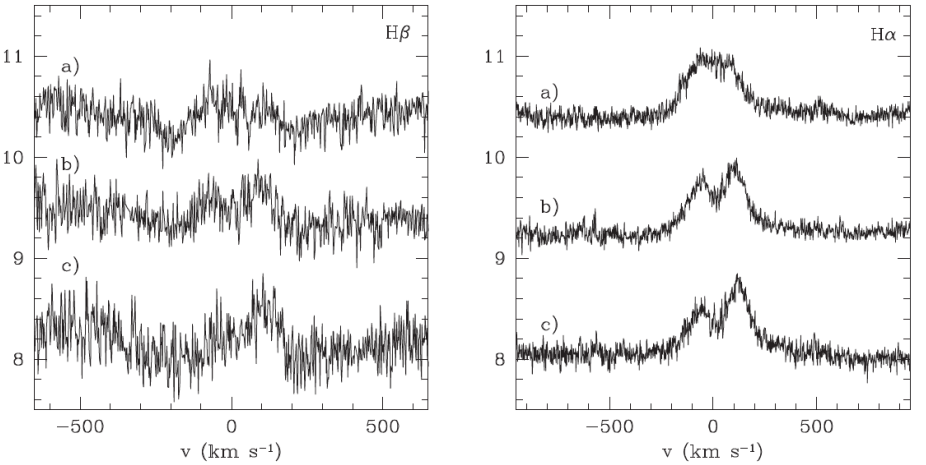

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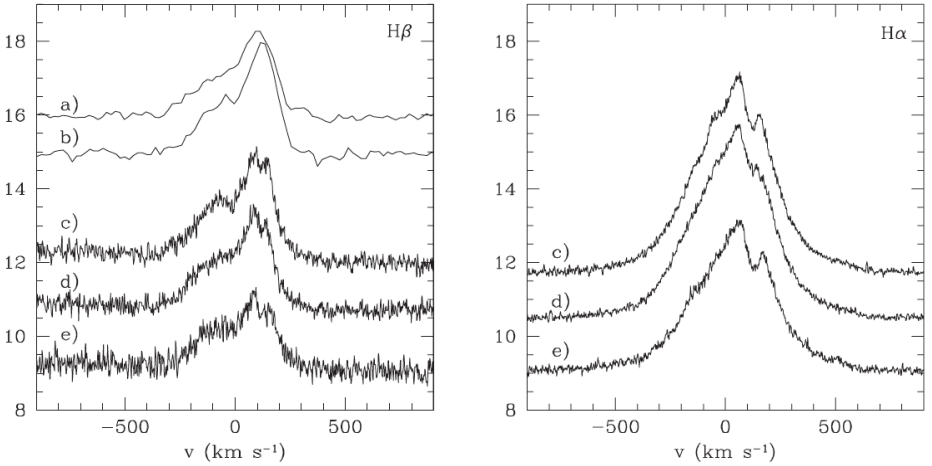

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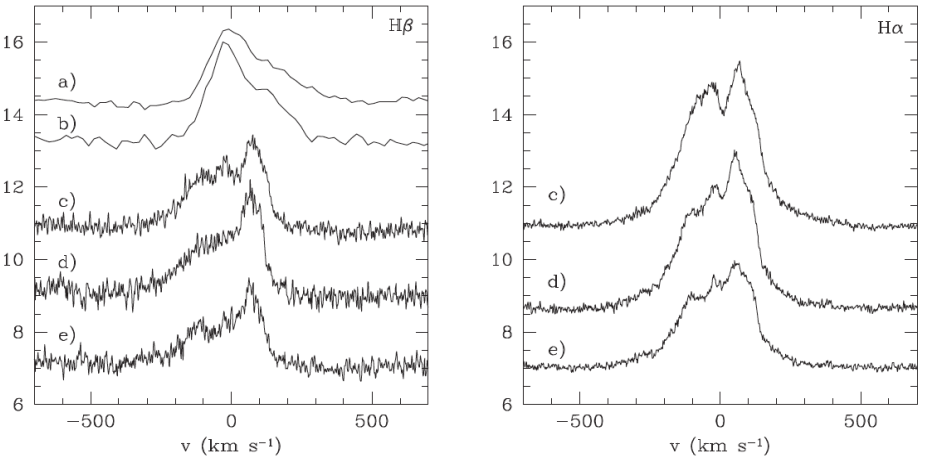


(Cracco+ 2018)

Results

– no one is a shell Be

– no He II 4686 → no accretion disk

– accretion
  - WD crosses the disk of the Be
  - Be increases the disk size

– disk radius lower than the average in normal Be

– V/R variations indicate disk perturbations induced by the binary system (Panoglou+ 2016, 2018)

$$\frac{r_d}{R_{star}} = \left(\frac{2\, v_{star} \sin i}{\Delta v} \right)^2$$

$\Delta v \sim 150$ km s^{-1}
$v_{star} \sin i \sim 250$ km s^{-1}

$r_d \sim 10\ R_{star}$

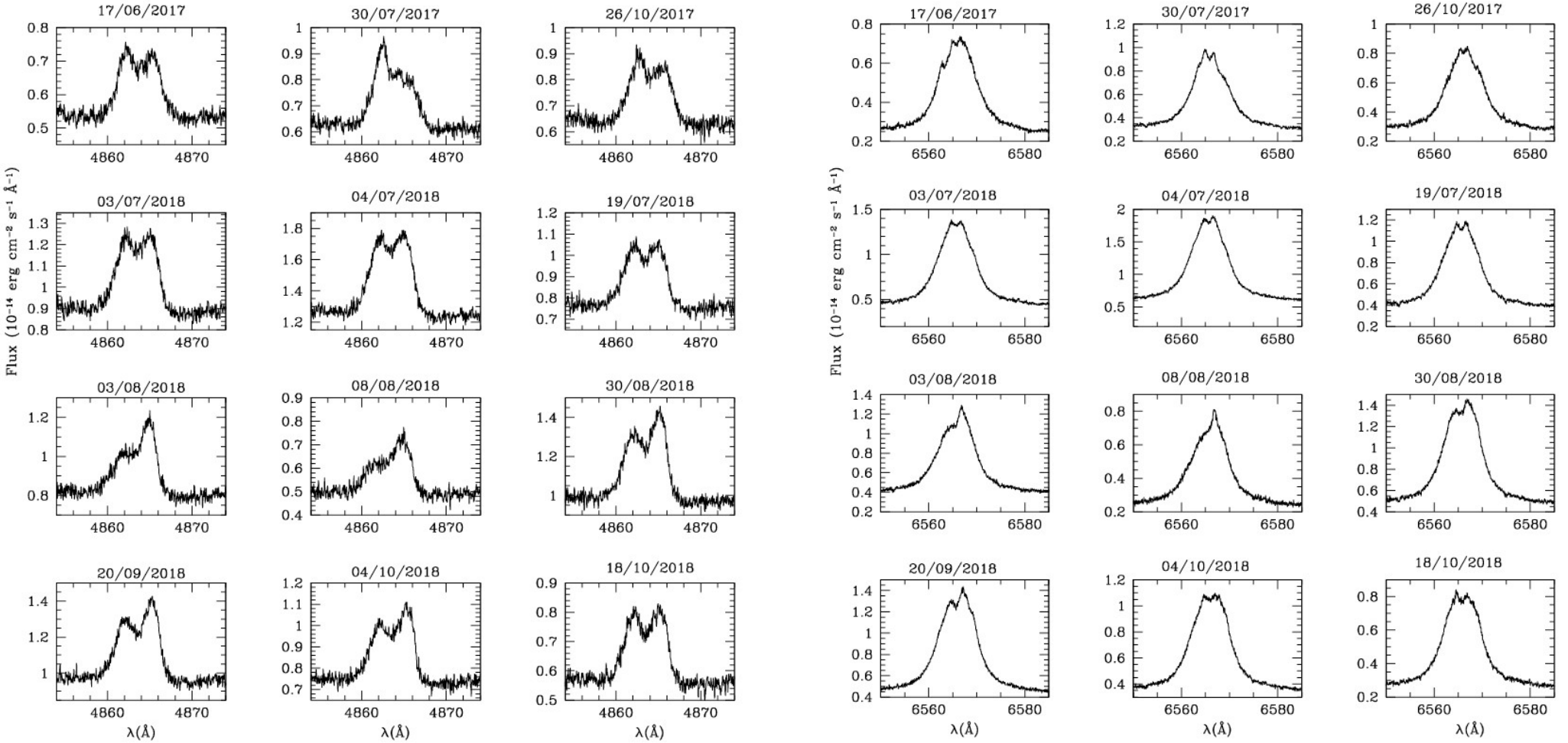
$< r_d > \sim 14\text{-}22\ R_{star}$ (Reig 2016)

(Cracco+ 2018)

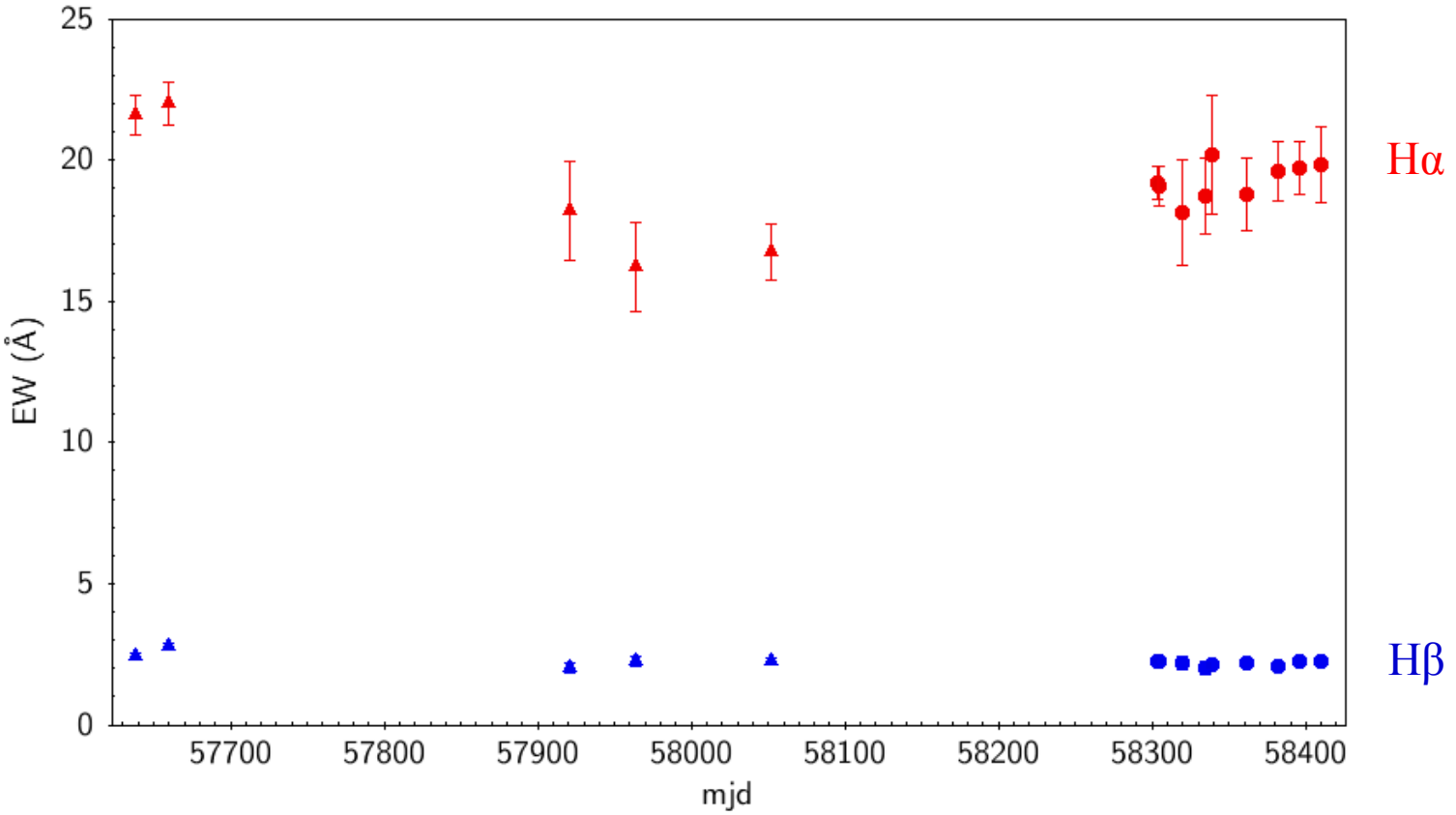
New Observations

Target	Date-obs	T_{exp}	S/N_{4600}	S/N_{7100}	seeing	
XMMU J010147.5-715500	2018-07-04	1700	39	43	1.5	
	2018-07-05	1700	47	55	n/a	
	2018-07-20	1700	40	37	1.7	
	2018-08-04	1700	37	35	3	
	2018-08-09	1700	27	25	2	
	2018-08-30	1700	46	38	1.5	clouds
	2018-09-20	1700	49	47	1.3	
	2018-10-05	1700	38	37	1.6	thin clouds
	2018-10-18	1700	35	30	1.6	
XMMU J052016-692505	2018-08-31	1700	28	16	1.3	clouds
	2018-09-15	1700	17	10	1.1	thin clouds
	2018-09-29	1700	19	14	1.9	
	2018-10-14	1700	12	8	1.2	thin clouds

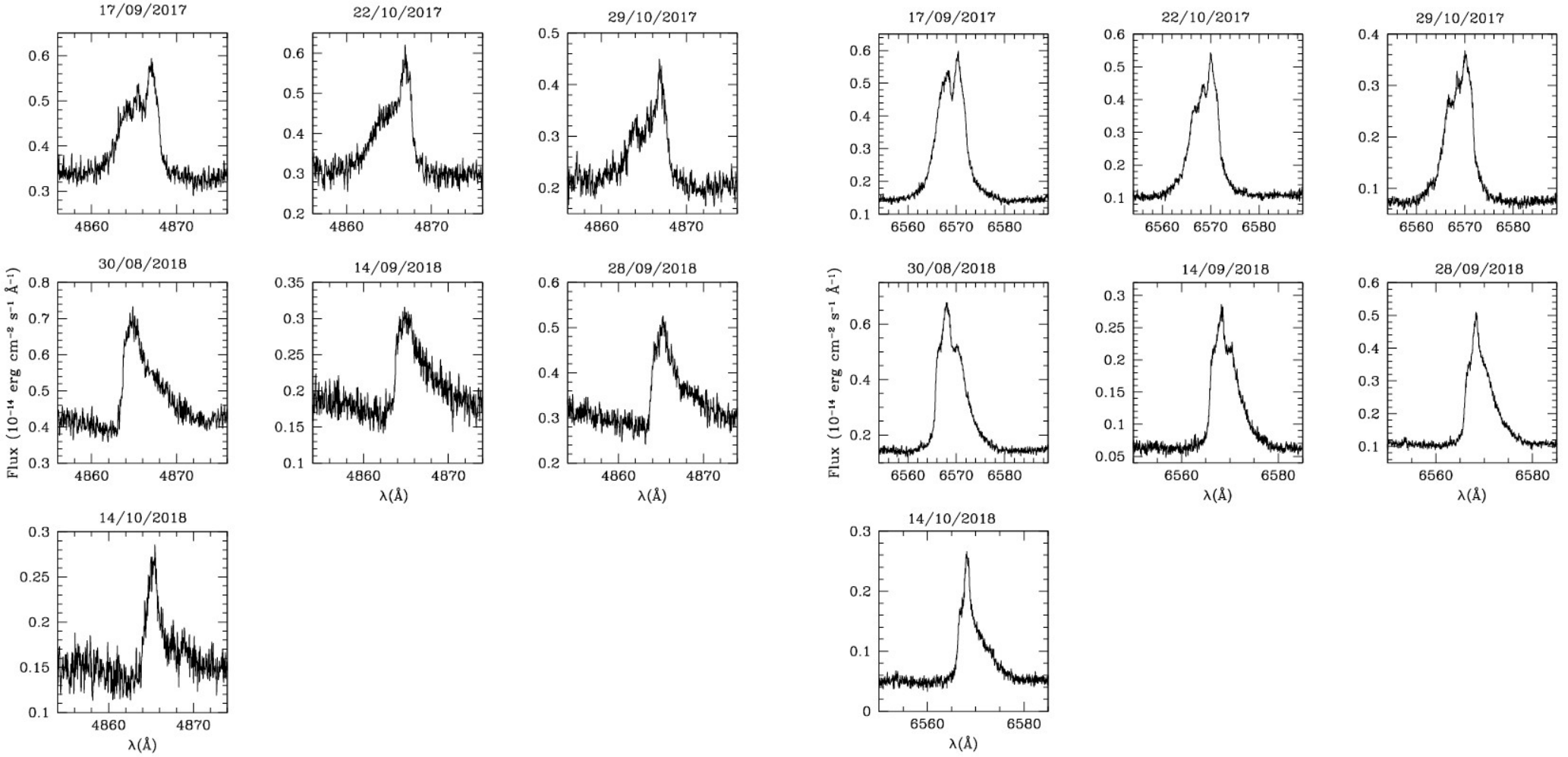
Monitoring of XMMU J01



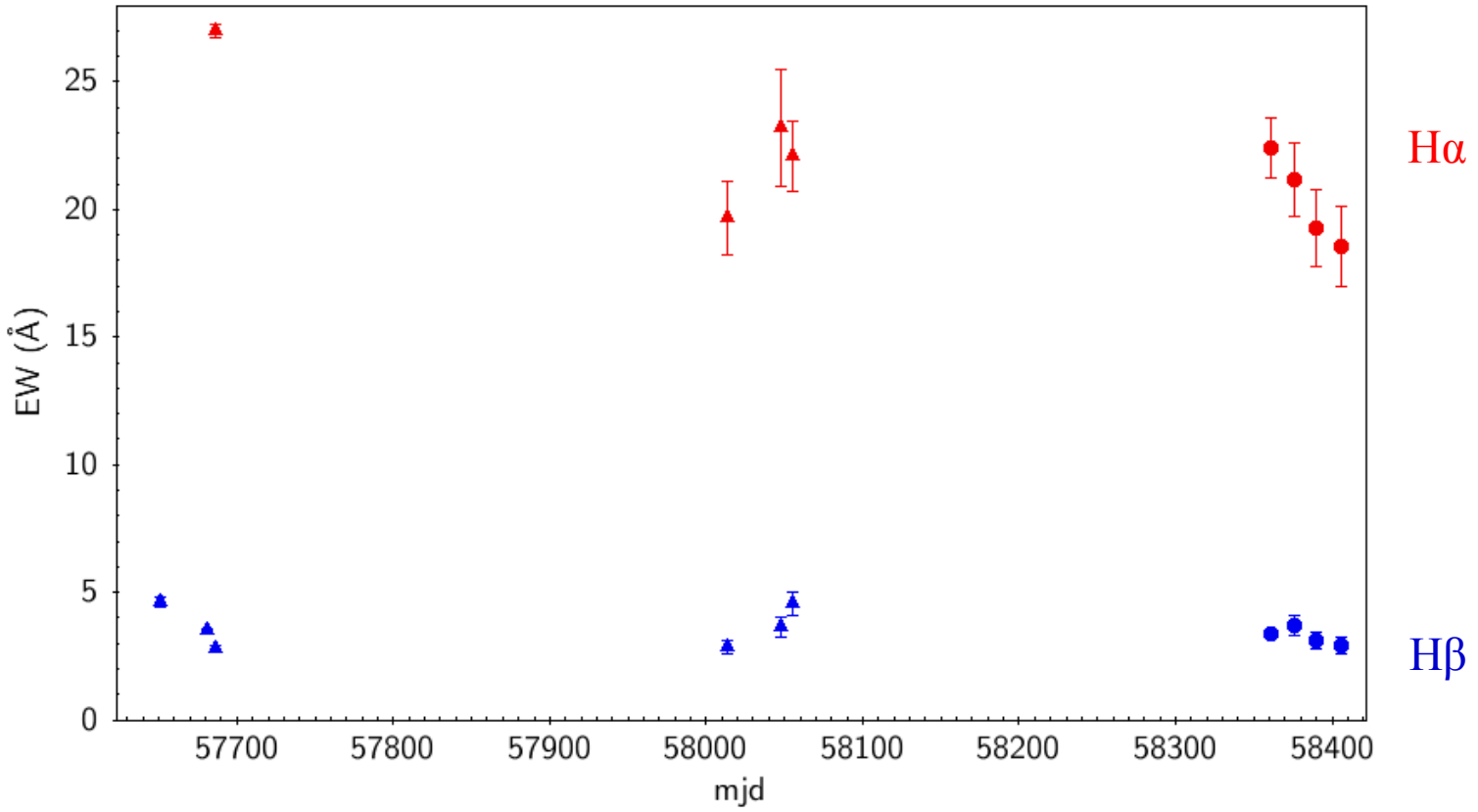
Monitoring of XMMU J01



Monitoring of XMMU J05



Monitoring of XMMU J05



$$\langle f_\lambda \rangle = \frac{\sum f_\lambda}{N}$$

mean spectrum

$$\sigma_\lambda = \sqrt{\frac{\sum (f_\lambda - \langle f_\lambda \rangle)^2}{N-1}}$$

rms spectrum

(Peterson+ 2004)

$$\lambda_0 = \frac{\int \lambda f_\lambda d\lambda}{\int f_\lambda d\lambda}$$

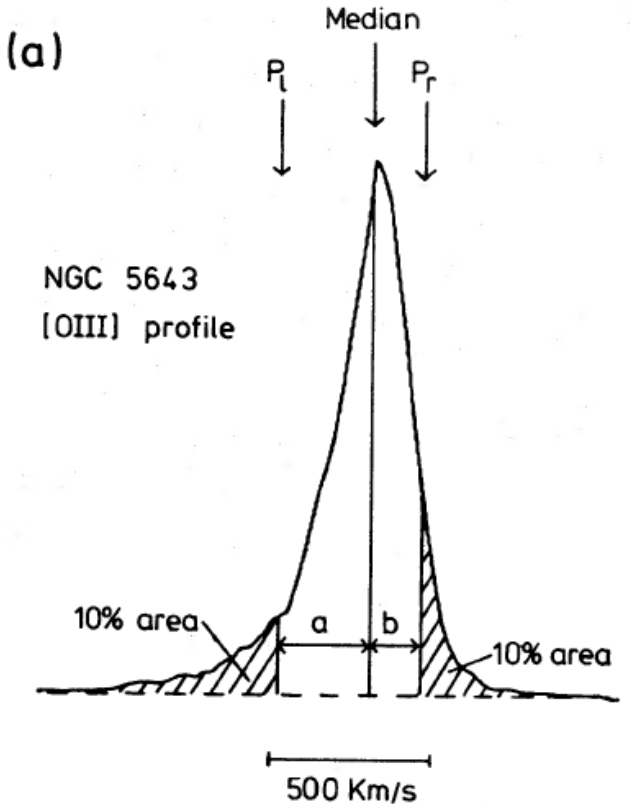
first moment
of the line profile

$$\sigma_{\rm line}^2 = \frac{\int \lambda^2 f_\lambda d\lambda}{\int f_\lambda d\lambda} - \lambda_0^2$$

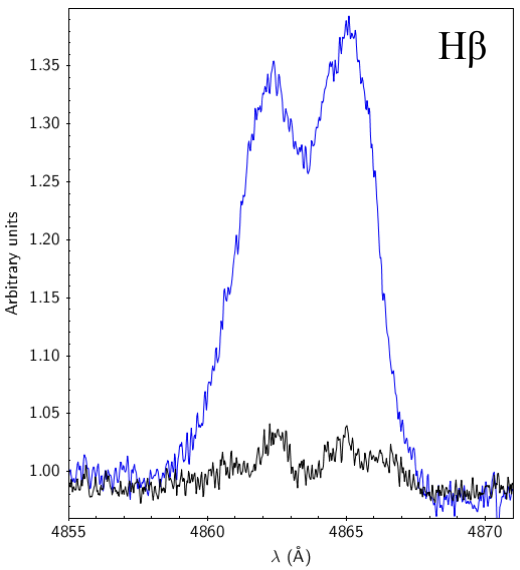
second moment
of the line profile

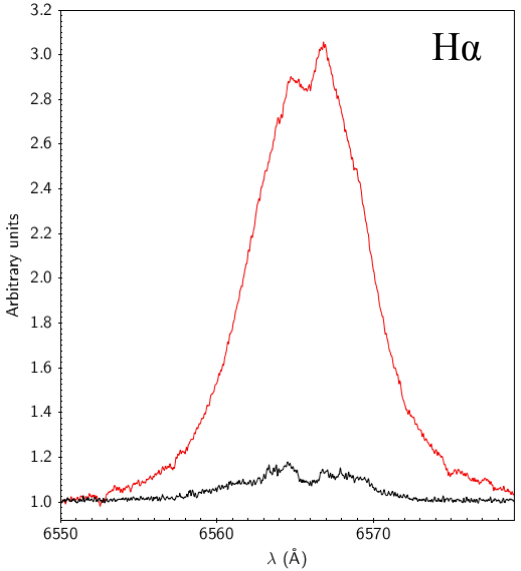
asymmetry (Whittle 1985)

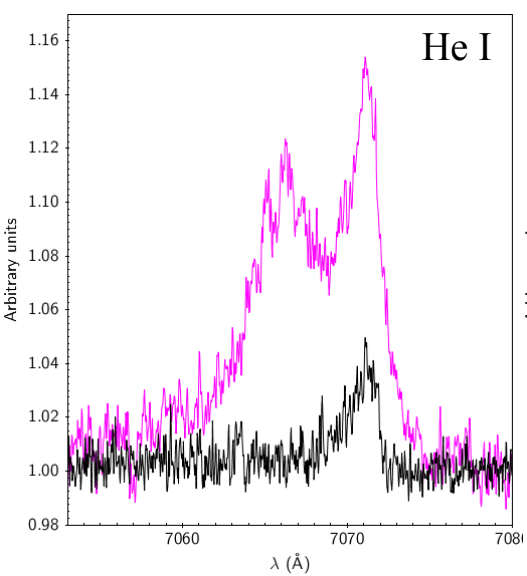
$$A = \frac{a-b}{a+b}$$

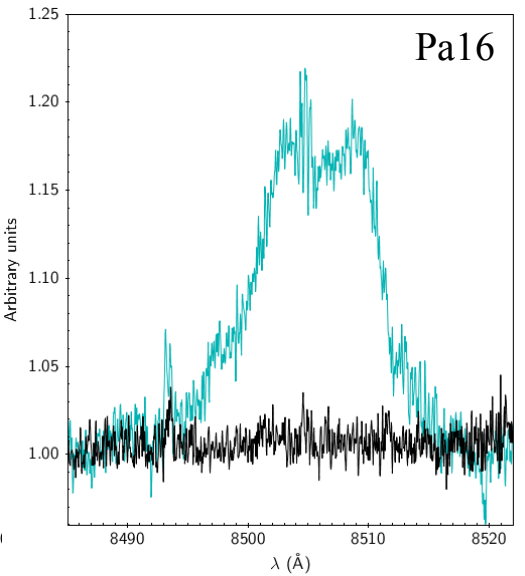


XMMU J010147.5-715550 (T_{exp} = 20100 s)

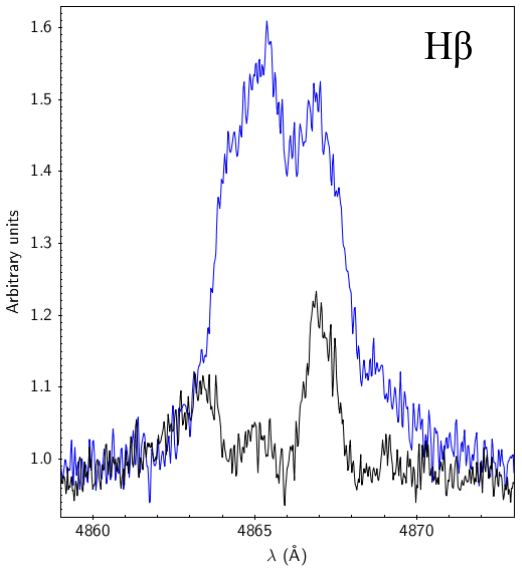


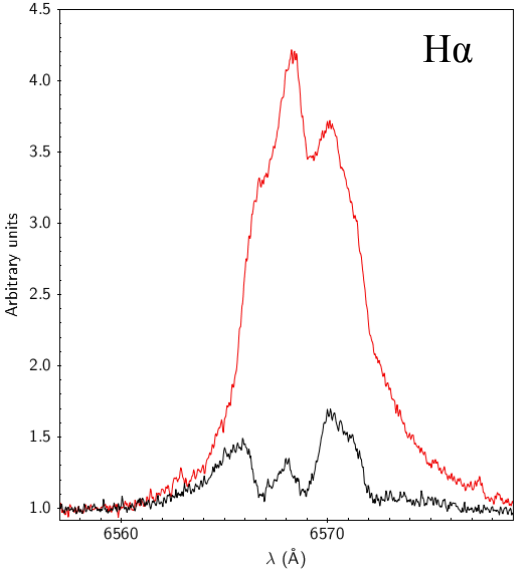


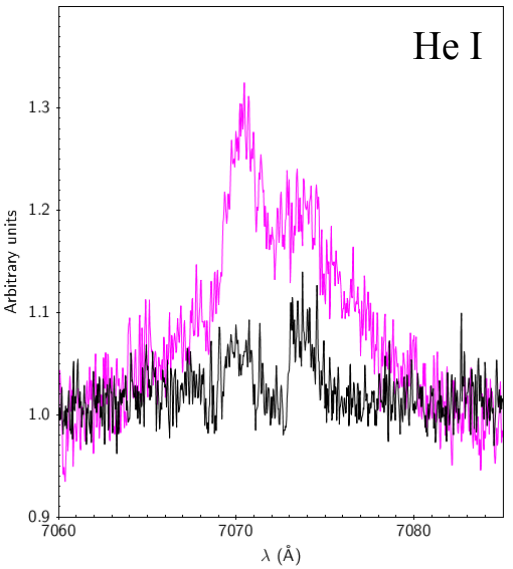




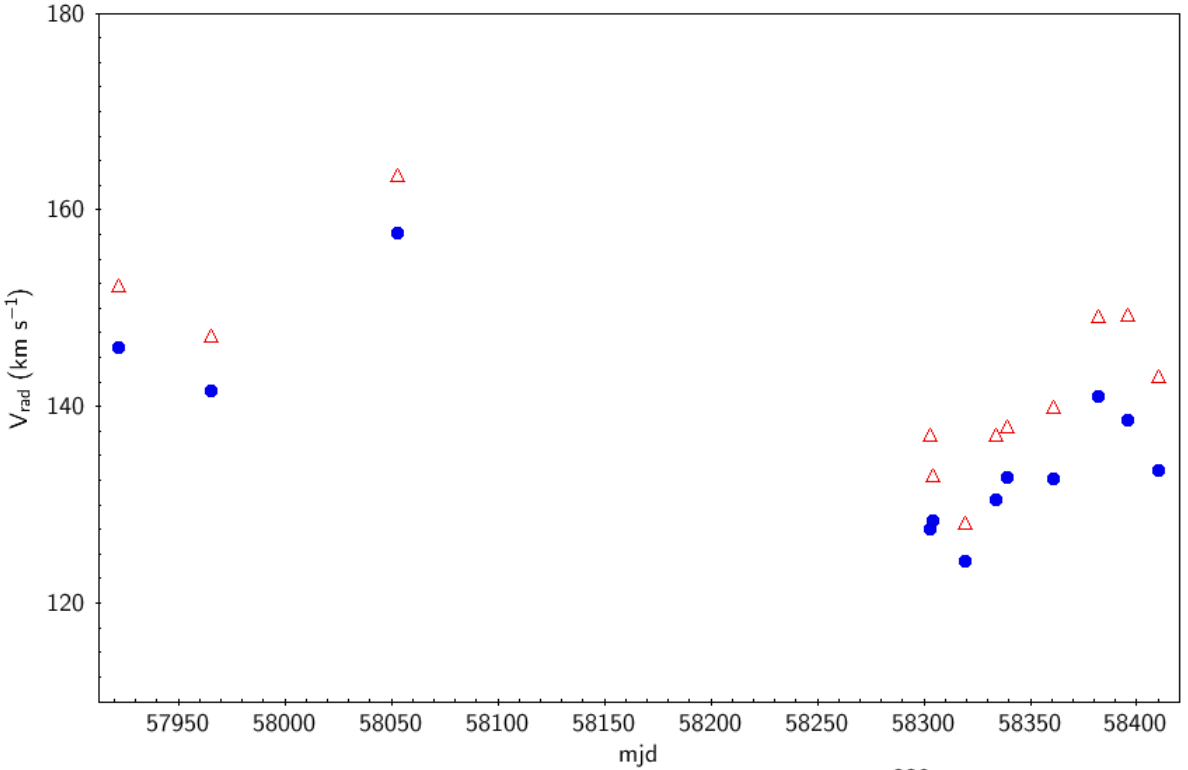
XMMU J052016.0-692505 (T_{exp} = 11350 s)





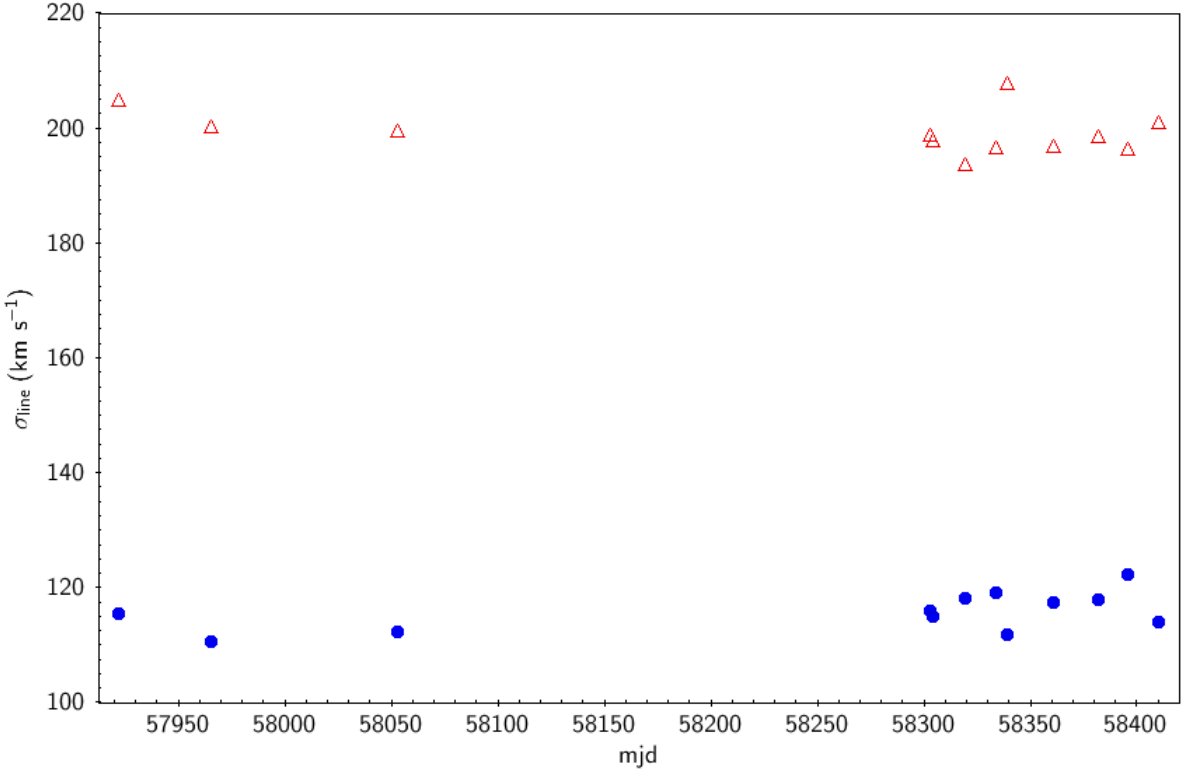


XMMU J010147.5-715550



Hα

Hβ



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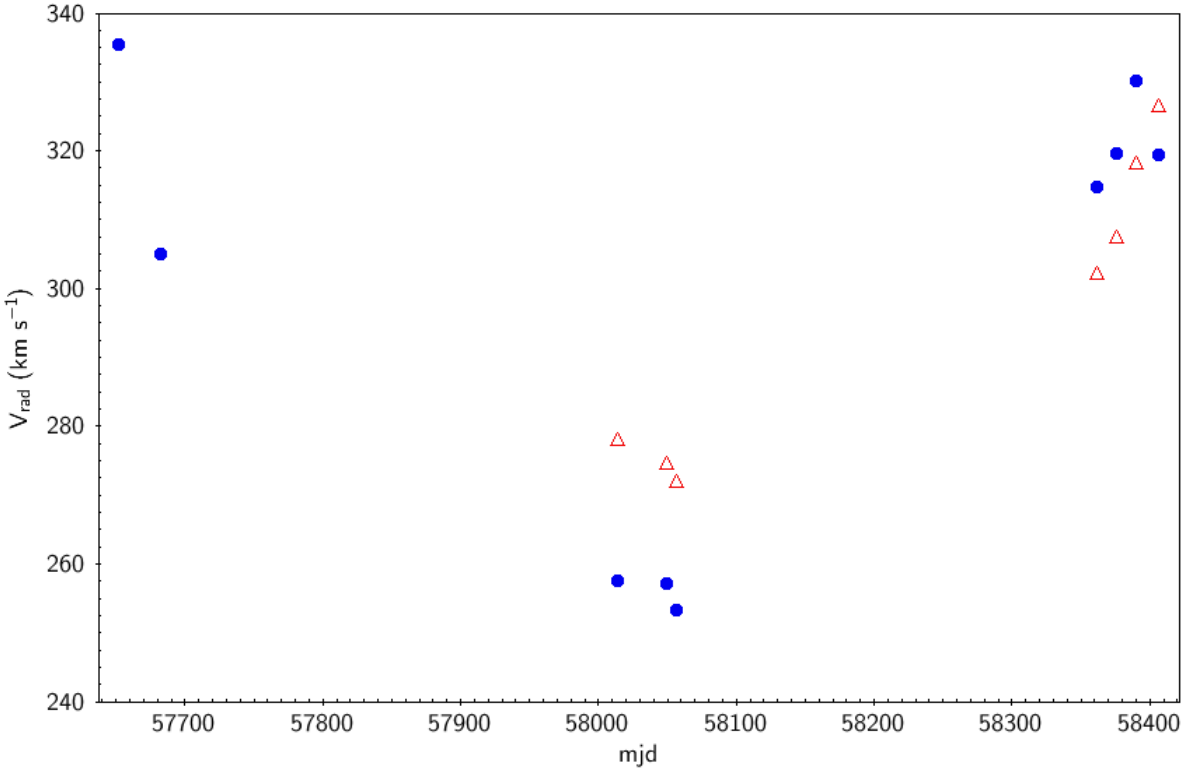
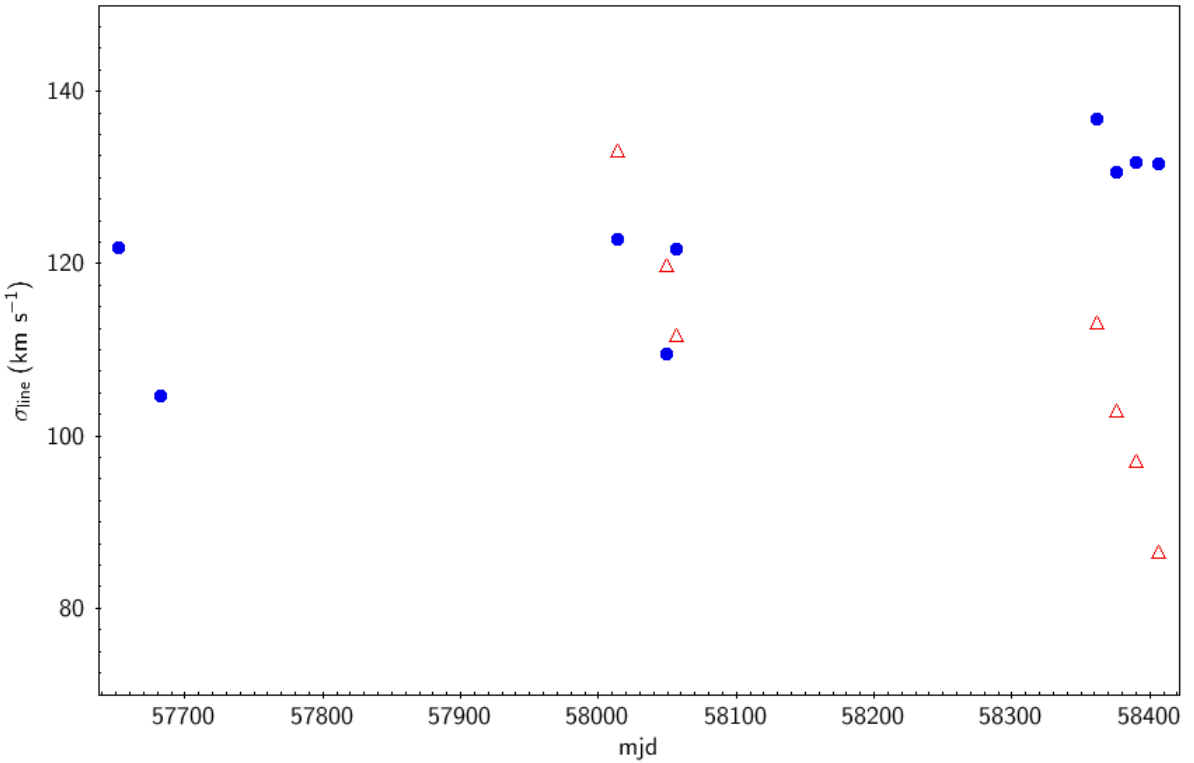
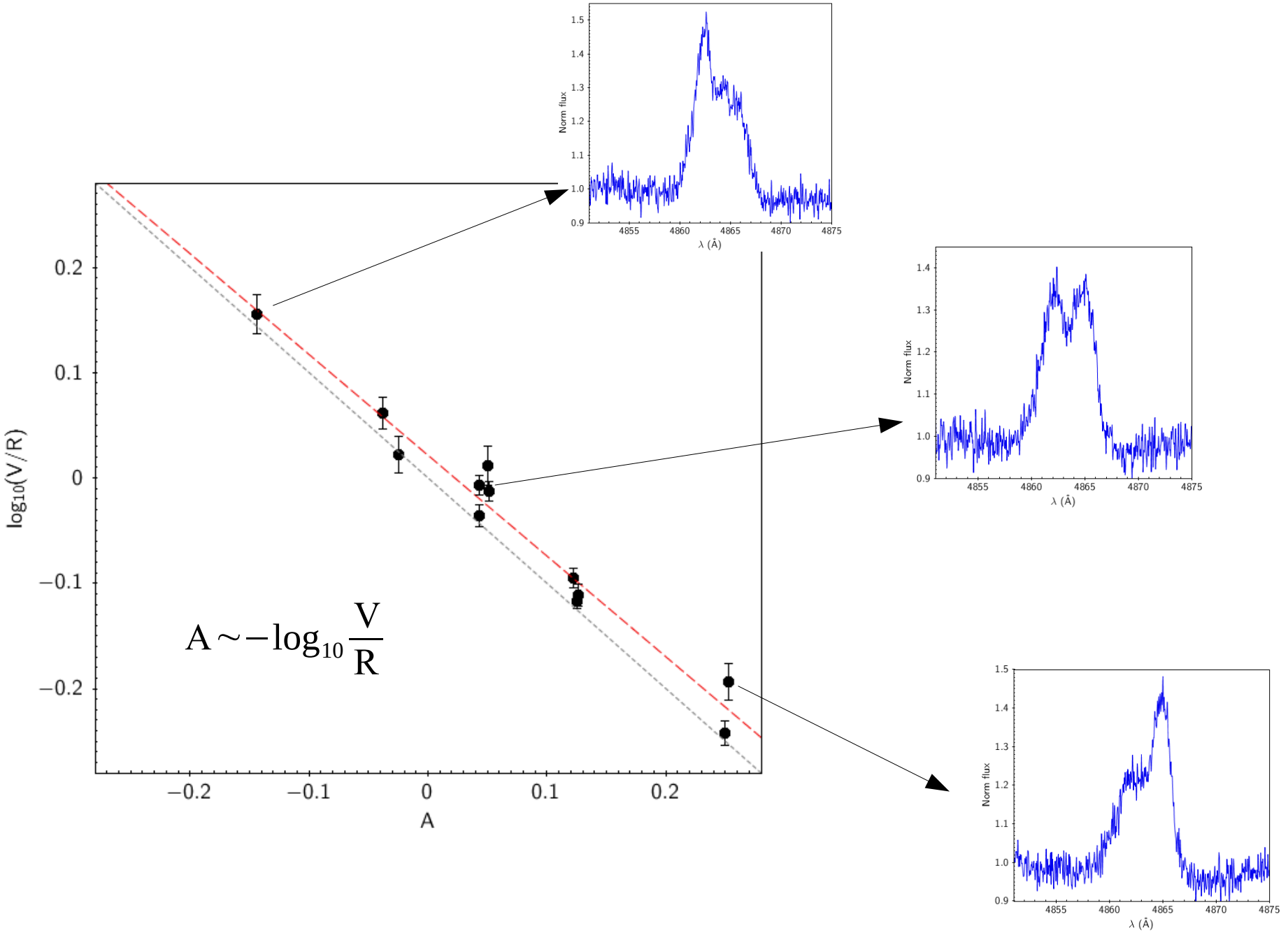
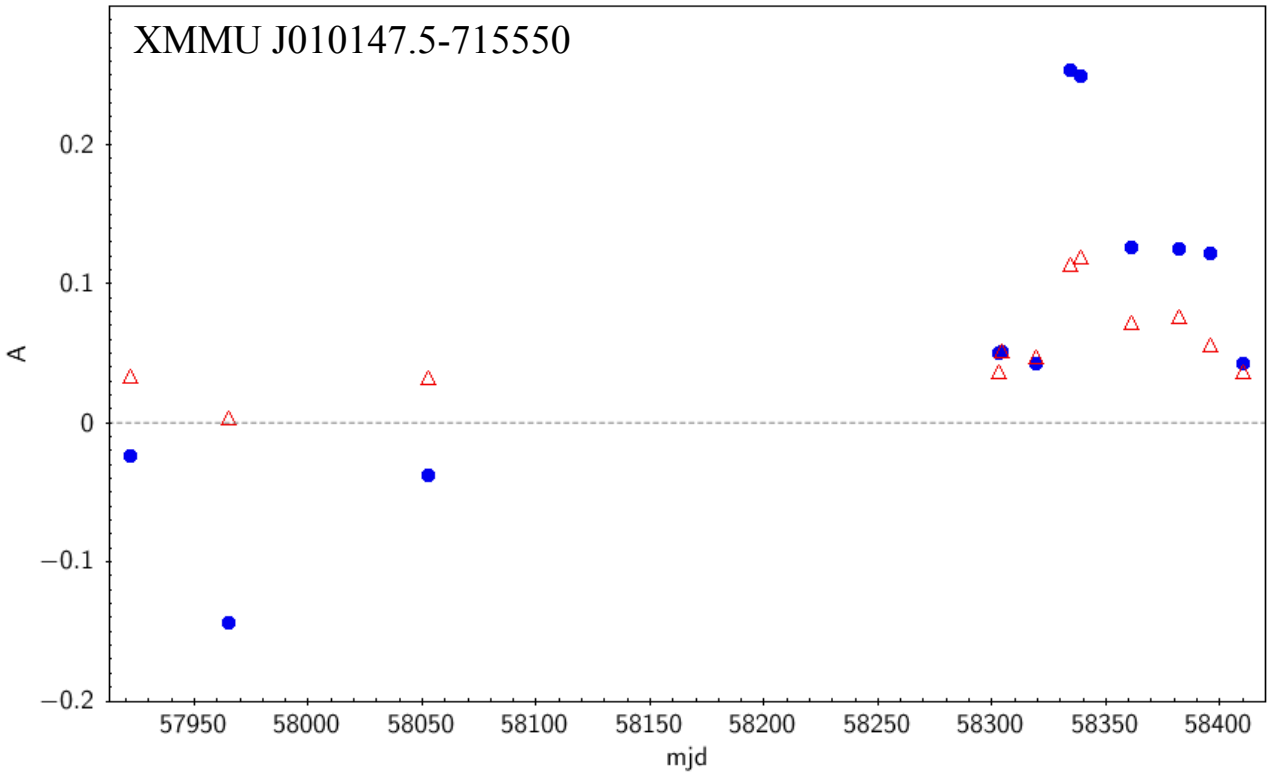


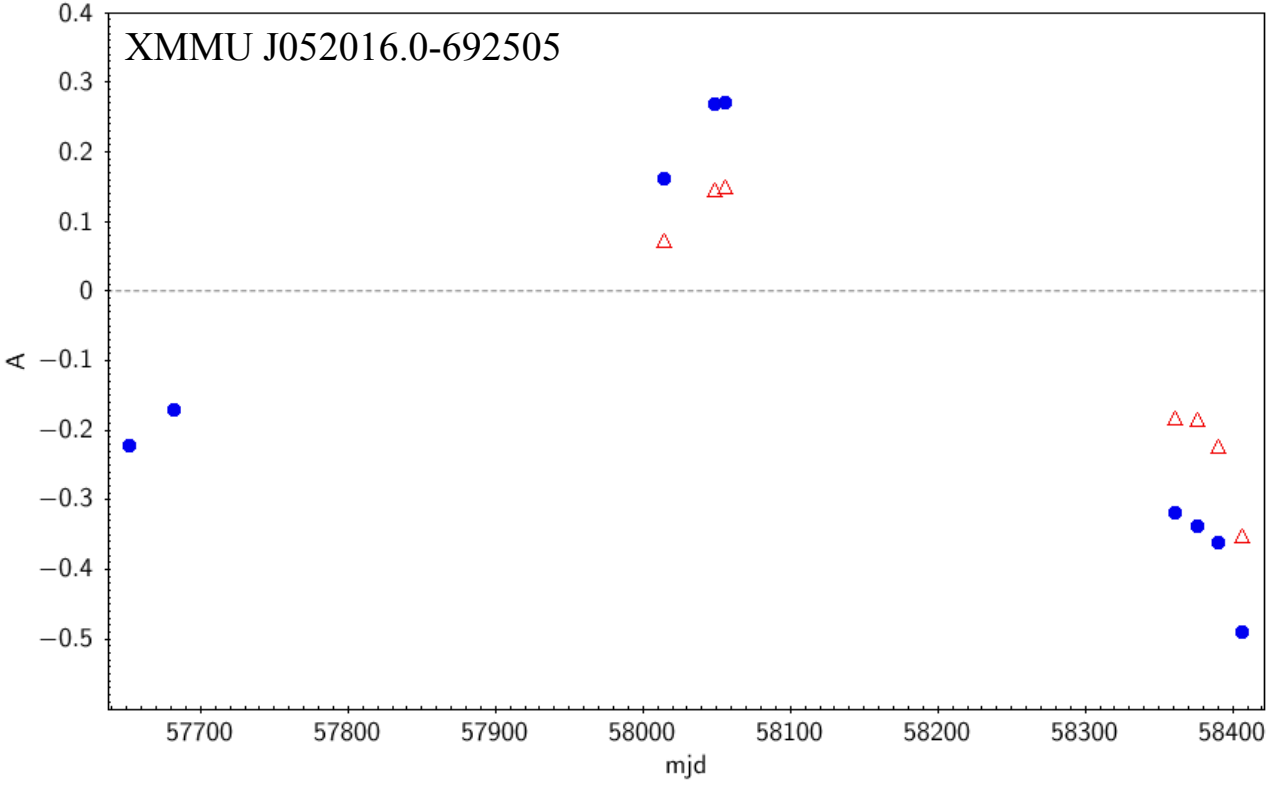



log10(V/R)
A
A ~ −log10 V/R
Norm flux
λ (Å)


XMMU J010147.5-715550
A
mjd
0.2
0.1
0
−0.1
−0.2
57950
58000
58050
58100
58150
58200
58250
58300
58350
58400

V/R < 1

V/R > 1


XMMU J052016.0-692505
A
mjd
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
57700
57800
57900
58000
58100
58200
58300
58400