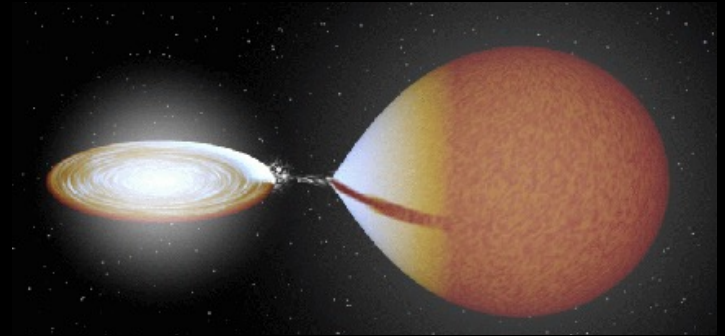



Puzzles and Promise of Accreting, Pulsating White Dwarfs



Paula Szkody, Keaton Bell, Jan van Roestel, Boris Gaensicke, Odette Toloza, Patrick Godon, Paul Chote, Zach Vanderbosch, Dean Townsley

Important Points to Keep in Mind about Accreting Pulsating WDs vs ZZ Ceti:

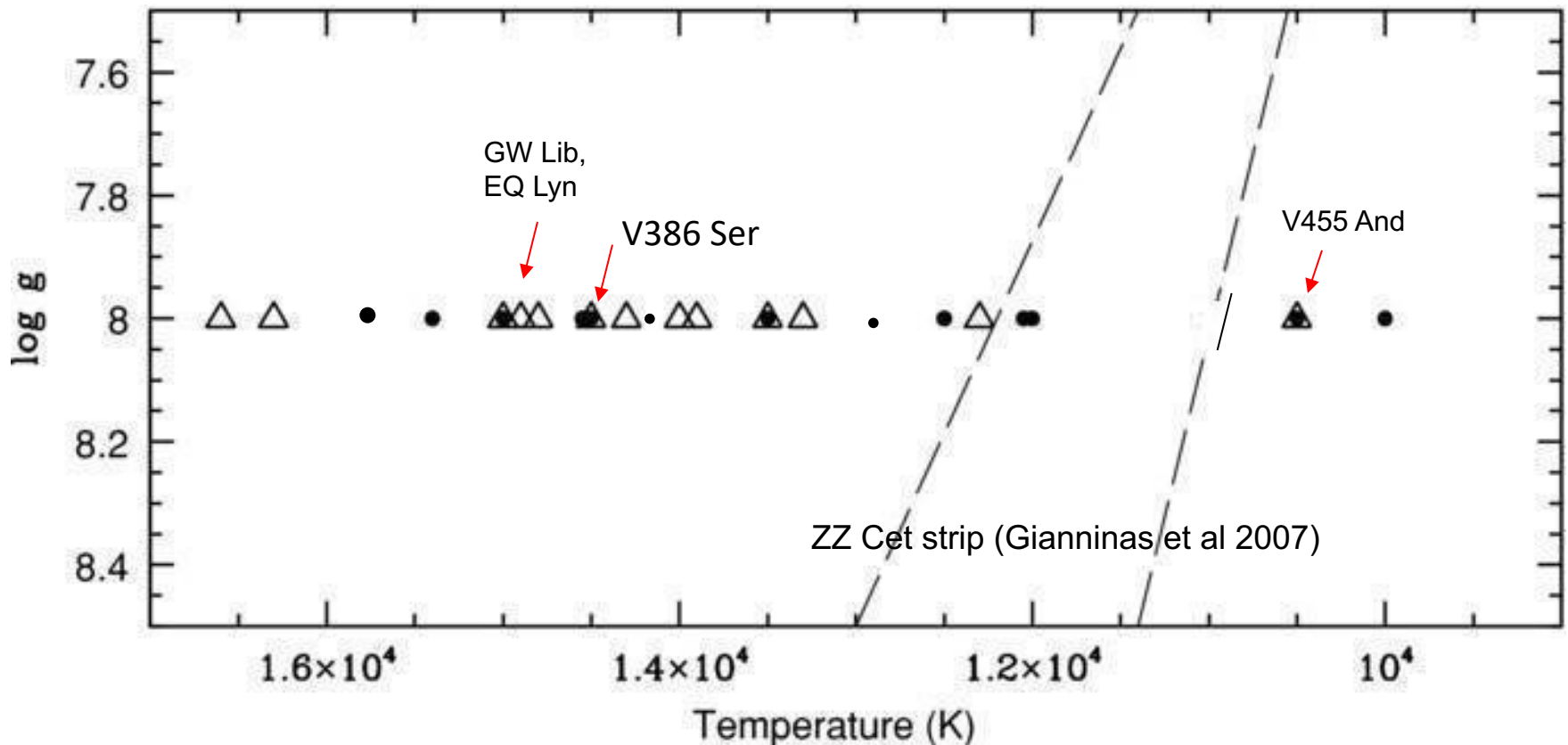
- They rotate faster - 200 sec vs hrs-days
- They are hotter due to accretion - 11-16,000K
- They are mixed composition - 0.1 solar vs H
- They are more massive - $0.8M_{\text{sun}}$ vs $0.6M_{\text{sun}}$
- They are heated by outbursts and cool on
 timescales of only years vs millions of years

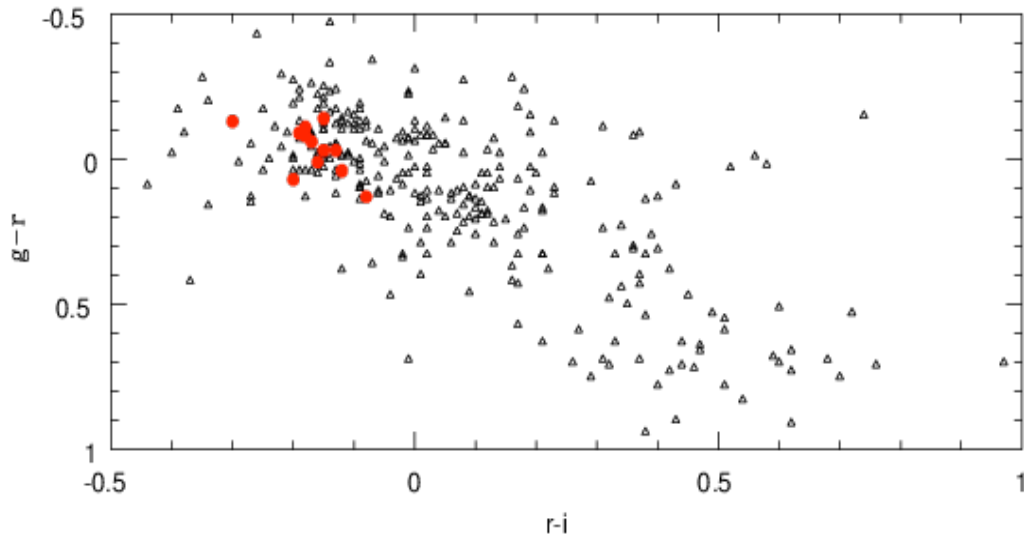


		P _{orb}	T _{wd}	P _{pulse}	
★	GW Lib	1998	76.8min	15,000K	236,376,648 sec
★	V455 And	2004	81.1	10,500	320-370
	GY Cet SDSS0131-09	2004	81.5	14,500	335,581-595
★	V386 Ser SDSS1610-01	2004	80.5	14,500	609
	SDSS2205+11	2004	82.8	15,000	330,475,575
	EQ Lyn SDSS0745+45	2005	77.8	15,100	1192-1230
	PQ And	2005	80.6	12,000	1358,1967,1988
	LV Cnc SDSS0919+08	2005	81.3	13,500	214,260
	MT Com RE1255+266	2005	119.5	12,000	668,1236,1344
	V355UMa SDSS1339+48	2006	82.5	12,500	641,1065
	PP Boo SDSS1514+45	2006	88.8	10,000	559
	OV Boo SDSS1507+52	2008	66.6	14,200	500,660,1140
	EZ Lyn SDSS0804+51	2008	85.0	13,000	256,756
	DY CMi SDSS0747+06	2011	85.6		238,684
	BW Scl	2012	78.2	14,800	618,1242
	SDSS1457+51	2012	77.9		582,642,1200
	SDSS0755+14	2017	84.8	15,900	257-262
	RXJ0232-37	2017	95.3	13,200	267

Location for Accreting Pulsators:

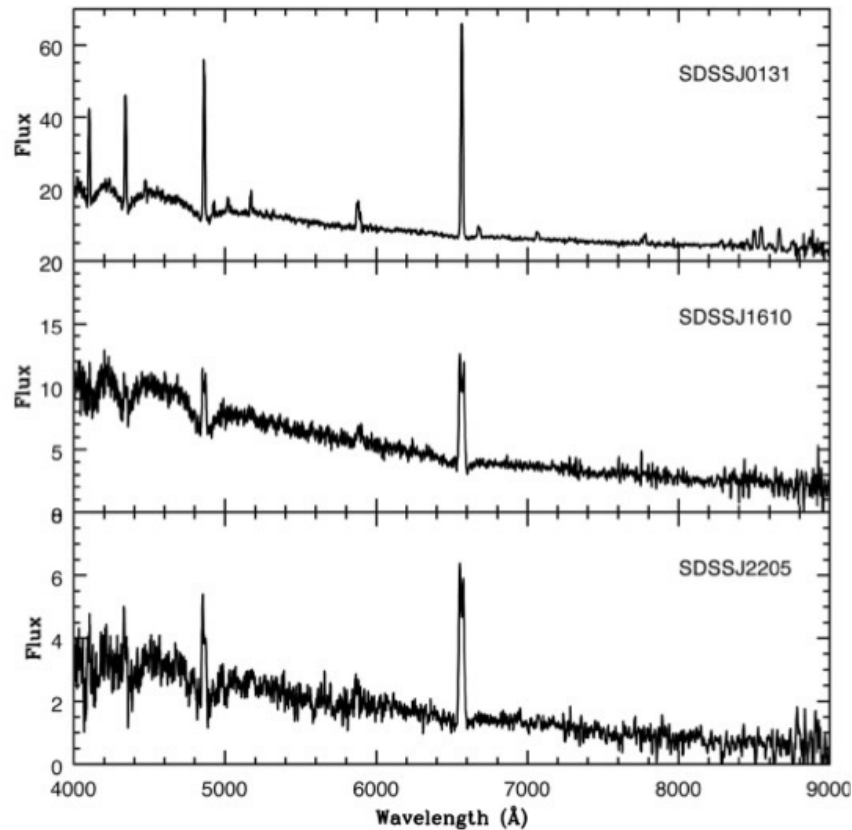
Instability strip is wider than ZZ Ceti (He- Arras et al. 2006, ApJL)



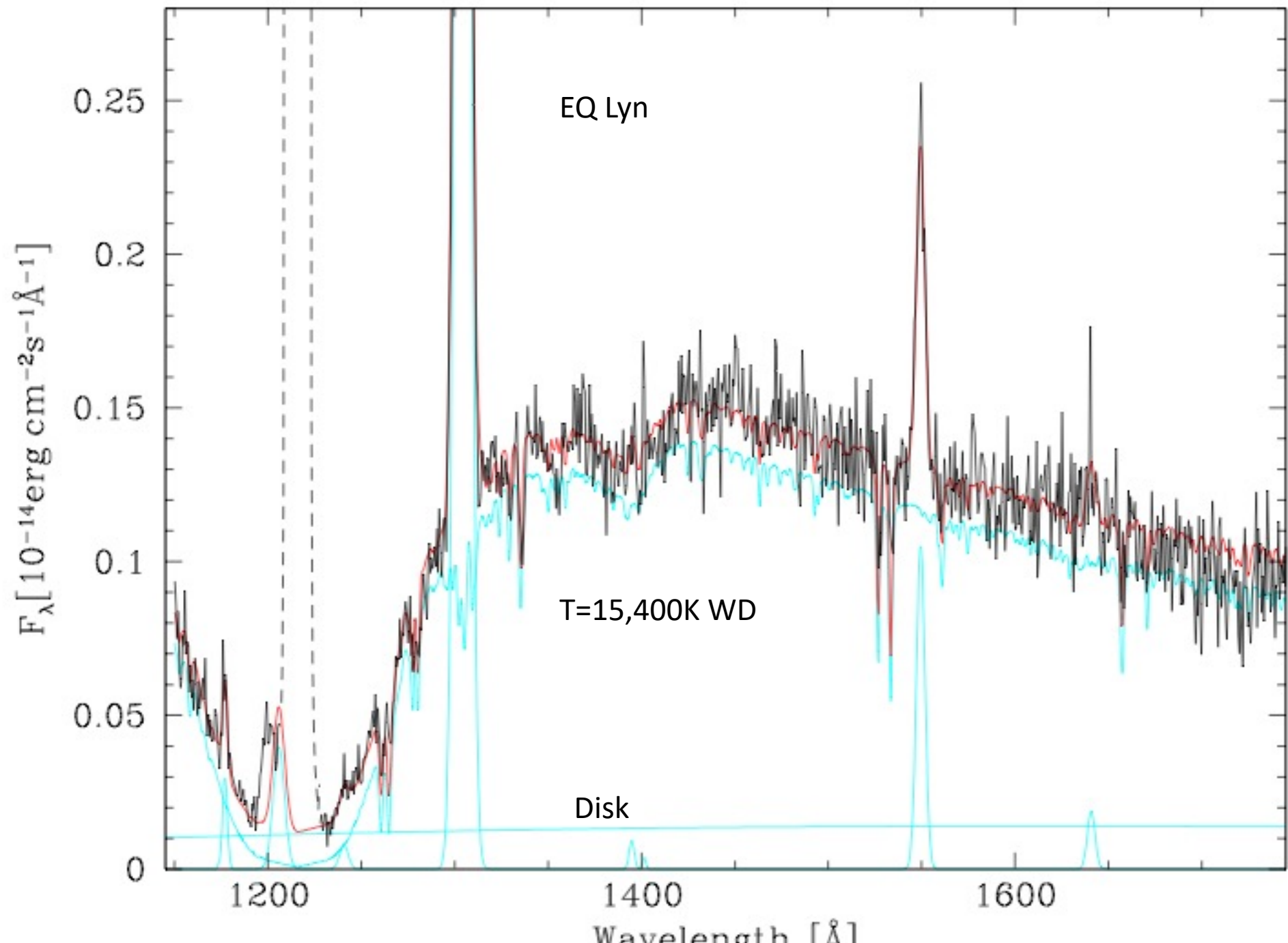


Accreting
pulsators are
clustered in blue
colors

All SDSS CVs



Spectra are best (show
Balmer abs from WD)



Known Outbursts of Accreting Pulsators:

- PQ And (1938, 1967, 1988, 2010, 2020) – 8 mag



- GW Lib (1983, 2007) – 9 mag



- V455 And (2007) – 8 mag -an IP

- REJ1255+26 MT Com (1994)



- SDSS0745+45 EQ Lyn (2006, 2019) – 5-8 mag

- SDSS0804+51 EZ Lyn (2006, 2010) – 5 mag

- SDSS1339+48 V355 UMa (2011)

- SDSS2205+11 (2011)

- BW Scl (2011)

- SDSS1507+52 OV Boo (2017)



- V386 Ser (2019)- 8 mag

Theoretical Prediction

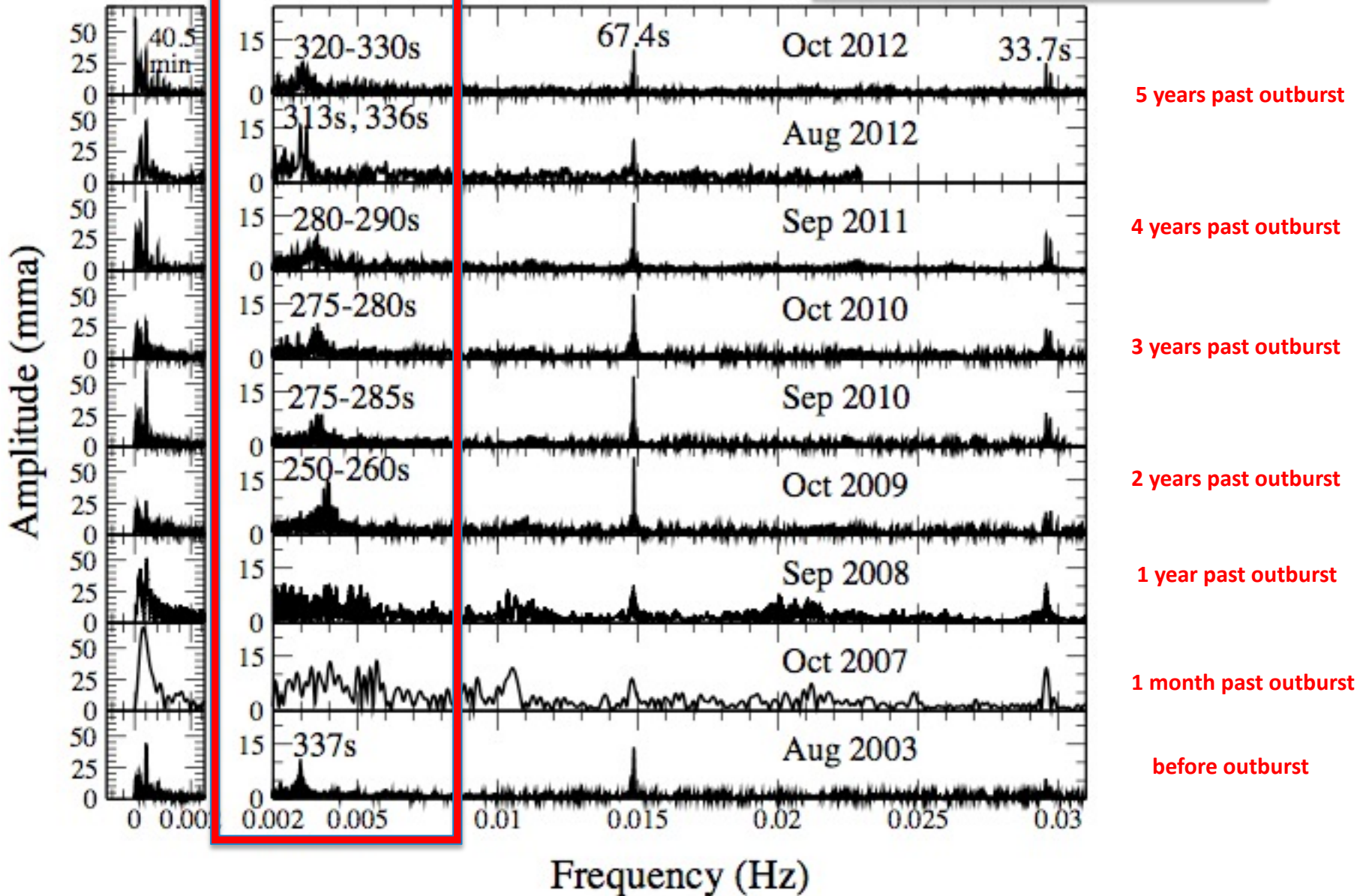
As white dwarf is heated by outburst, it moves out of instability strip and pulsations cease

As white dwarf cools and reenters strip, pulsation periods should scale with the thermal timescales (shorter when outer layers of WD are heated, longer when cooler)

V455 And $T_{wd} = 10,500K$

Follows expectation despite magnetic nature but pulse mostly in emission lines in UV

Optical DFTs



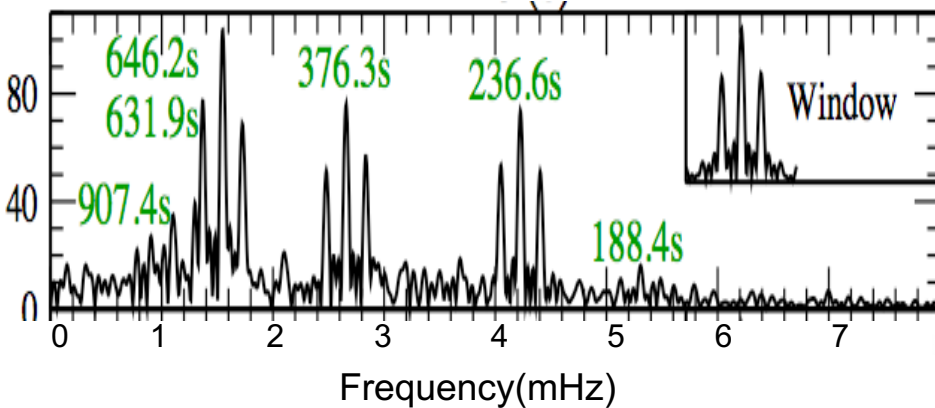
GW Lib 6-10 yrs pre-outburst

$$P_{\text{pulse}} = 650, 376, 236\text{s}$$

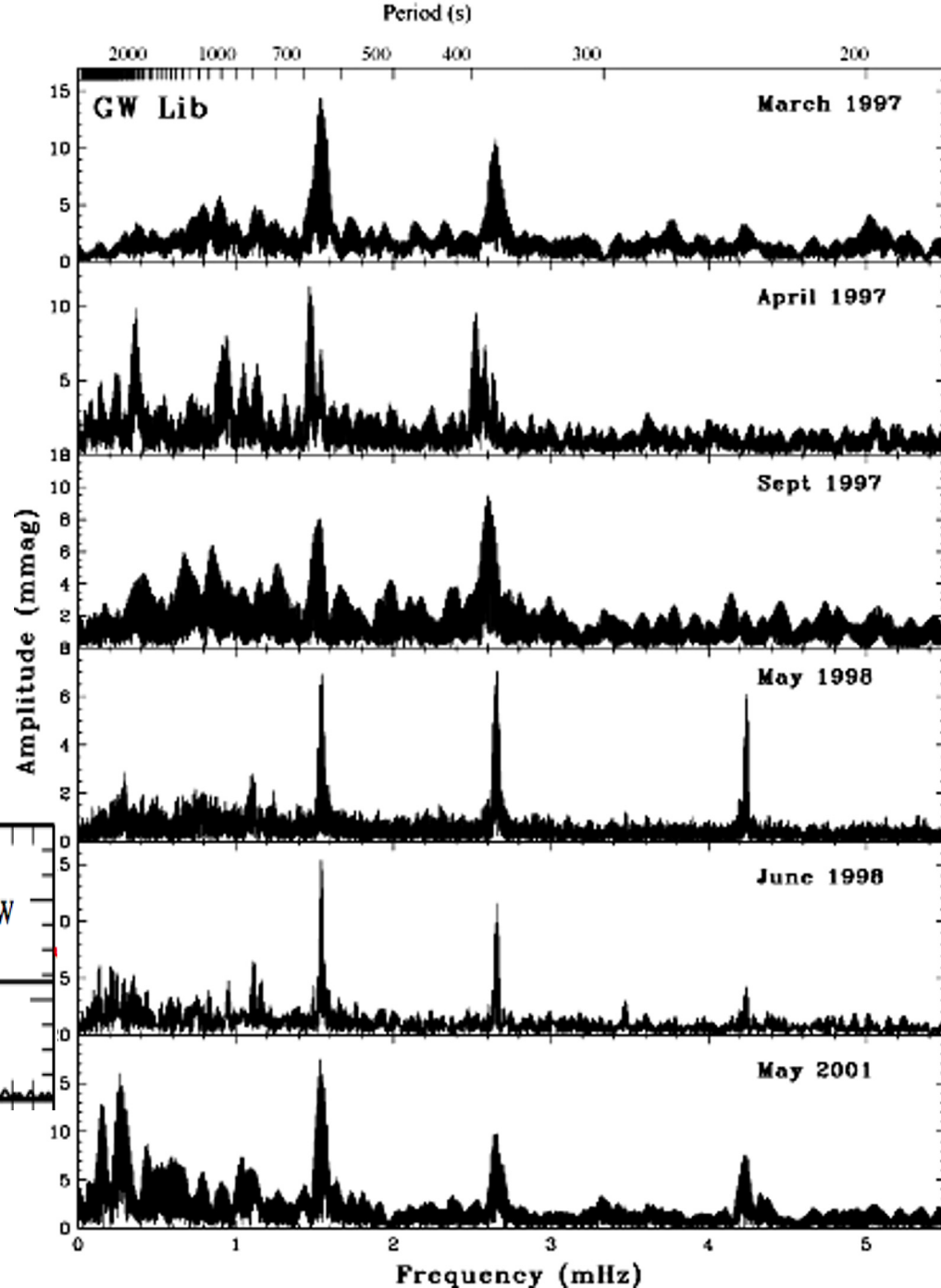
$$P_{\text{long}} = 2.1 \text{ hrs}$$

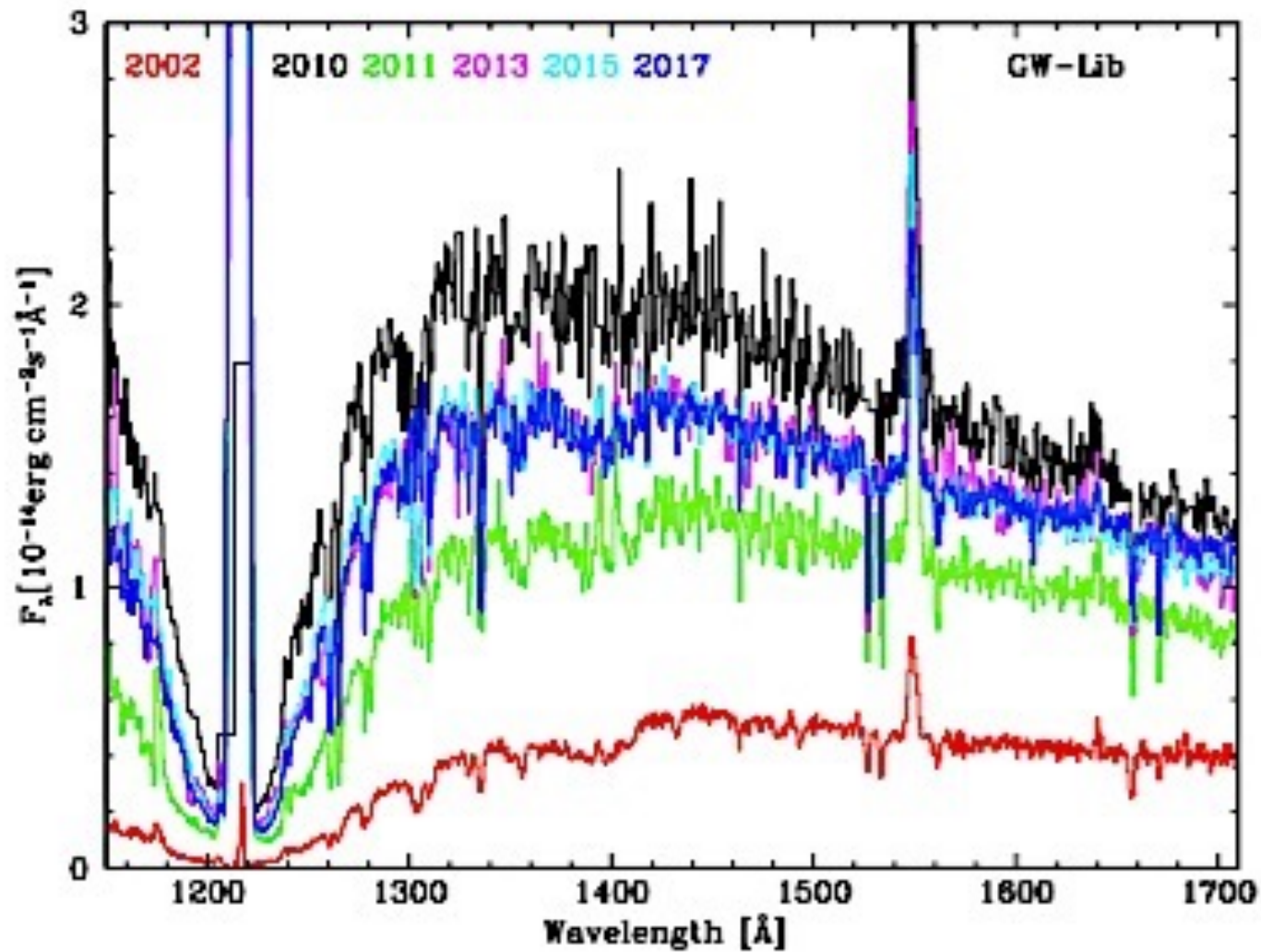
(Van Zyl et al 2004, MNRAS)

UV/opt amp ~ 10



UV STIS 2002 (Szkody et al. 2002)





GW Lib
HST FUV

18,000K-3 yrs after

6,8,10 yrs after

16,000K-4 yrs after

14,700K

quiescence

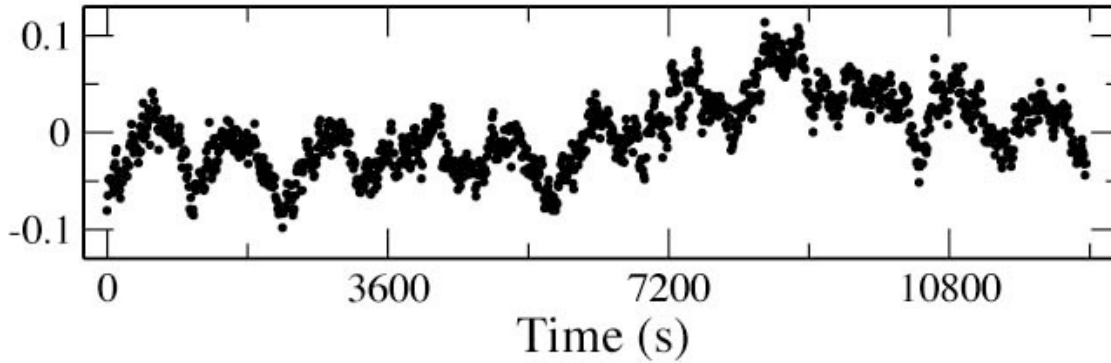
5 yrs prior to outburst

Not monotonic cooling!

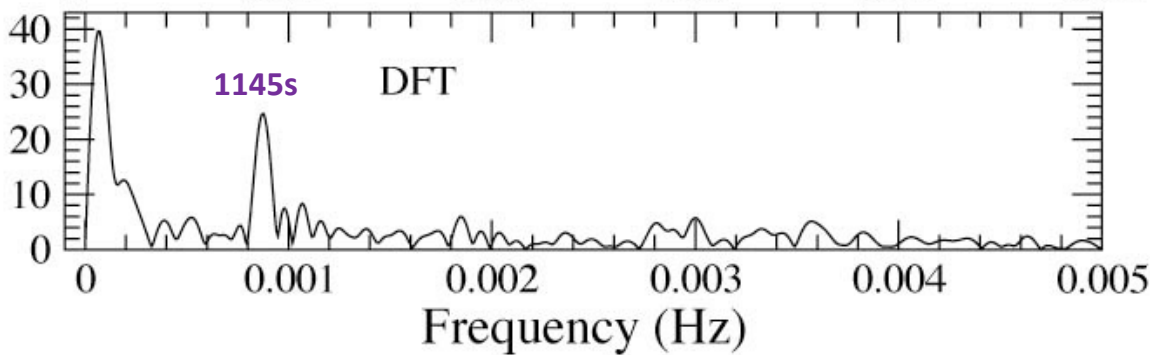
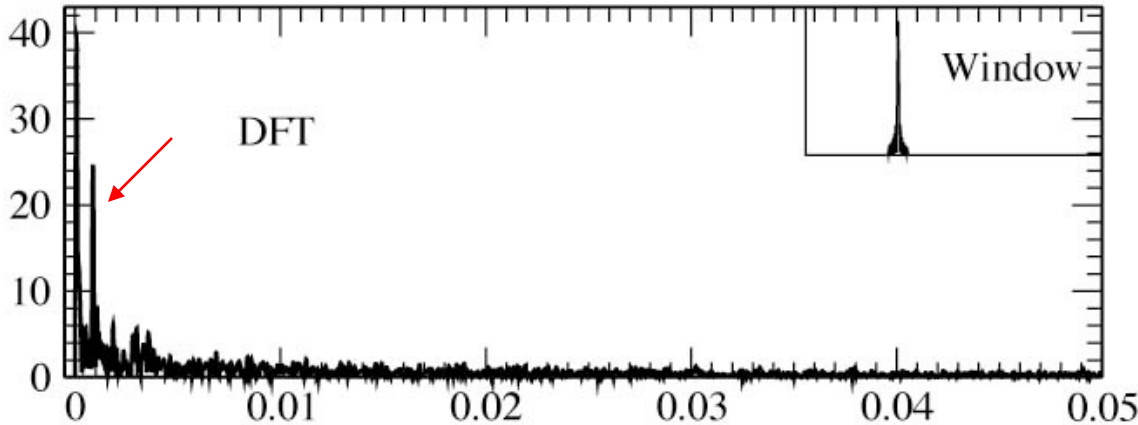
GW Librae (29 March 2008)

APO 3.5m, Agile, 10s exp, BG40 filter, high airmass, 2.7" seeing

Fractional Intensity



Amplitude (mma)



optical

1 yr after outburst

**a new 19 min
periodicity is
apparent**

**not seen in UV
(GALEX)**

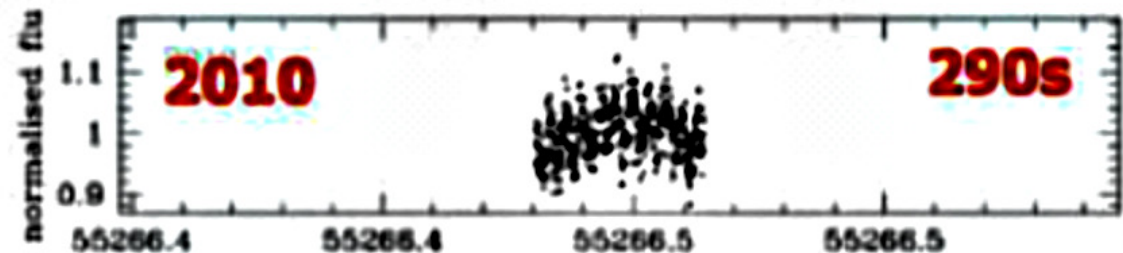
Copperwheat et al. 2009
MNRAS

Schwieterman et al.
2010, JSARA

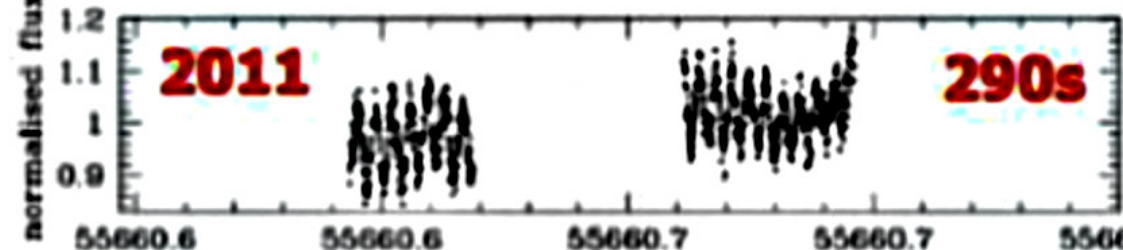
Bullock et al. 2011, AJ

HST FUV Light curves

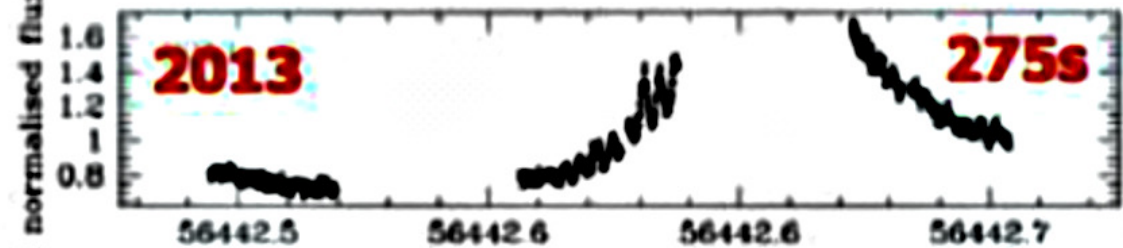
3 yrs after



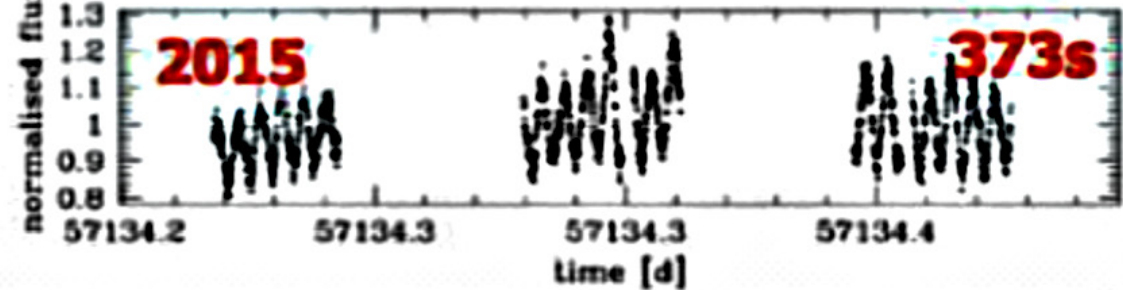
4 yrs after



6 yrs after



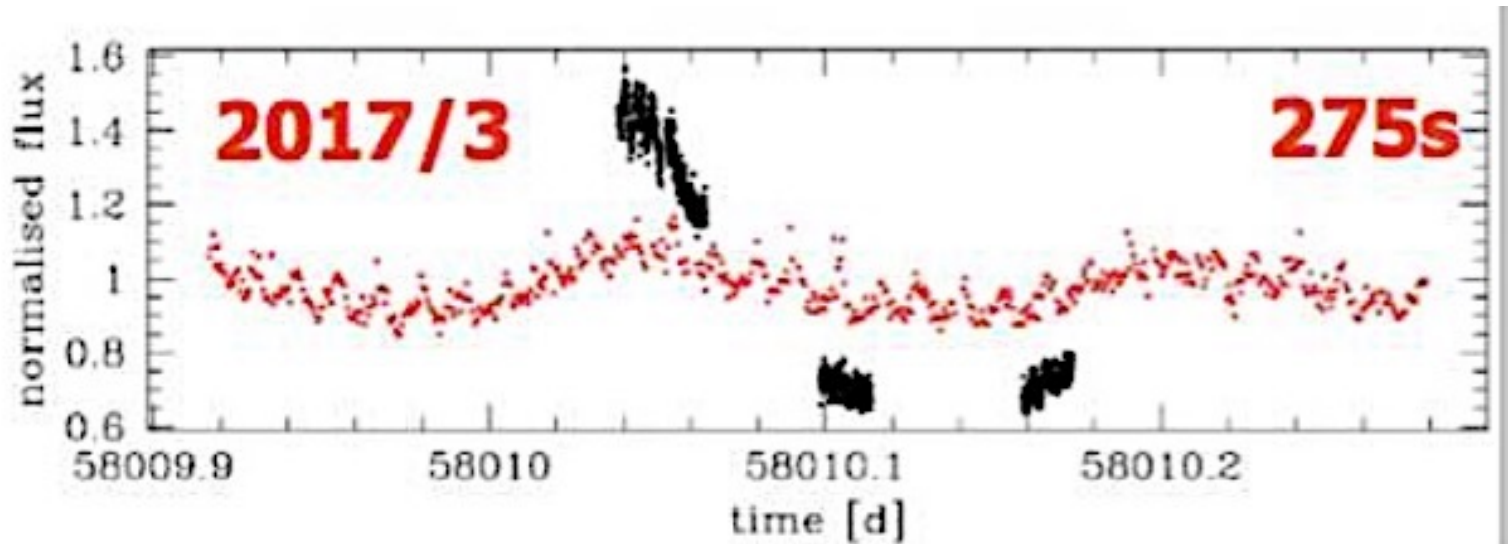
8 yrs after



(Quiescence were 650, 376, 236s)

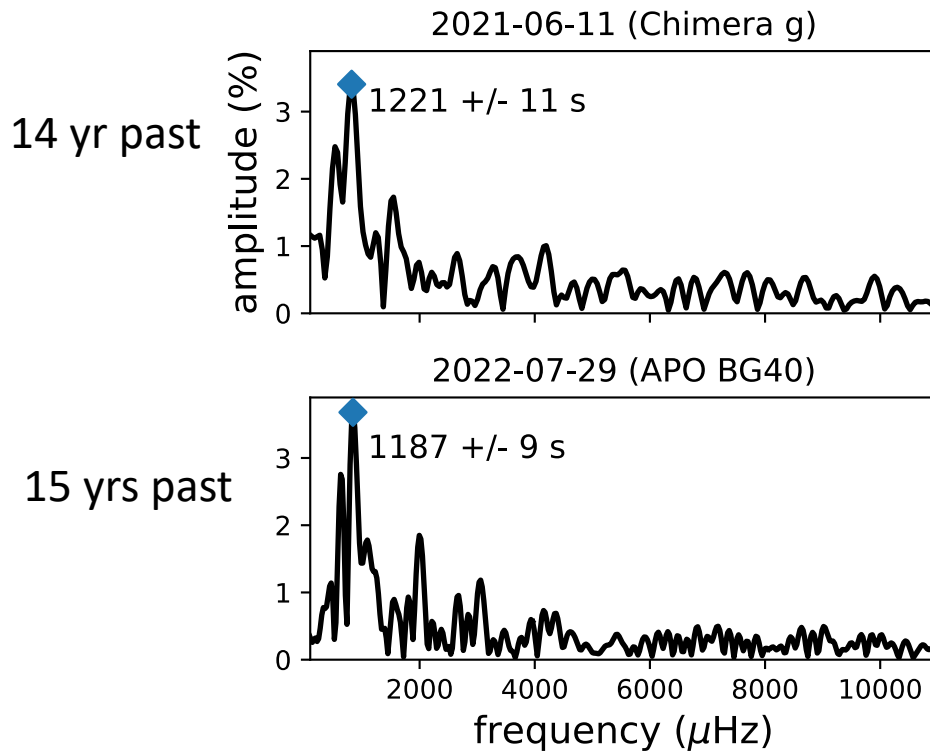
Black is HST FUV (275s only during 4 hr P)

Red is K2 (shows 19 min P) on 4 hr Period



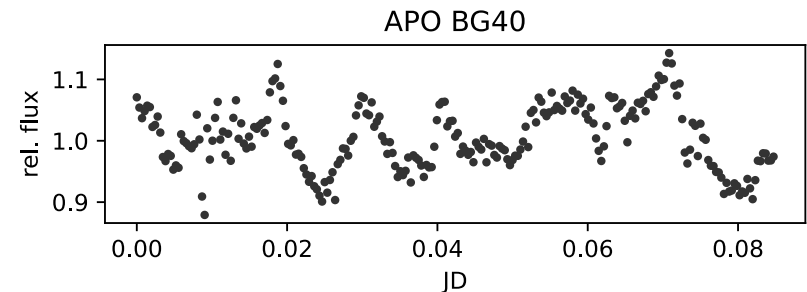
GW Lib

GW Lib does not follow expectations!



19 min period still there.

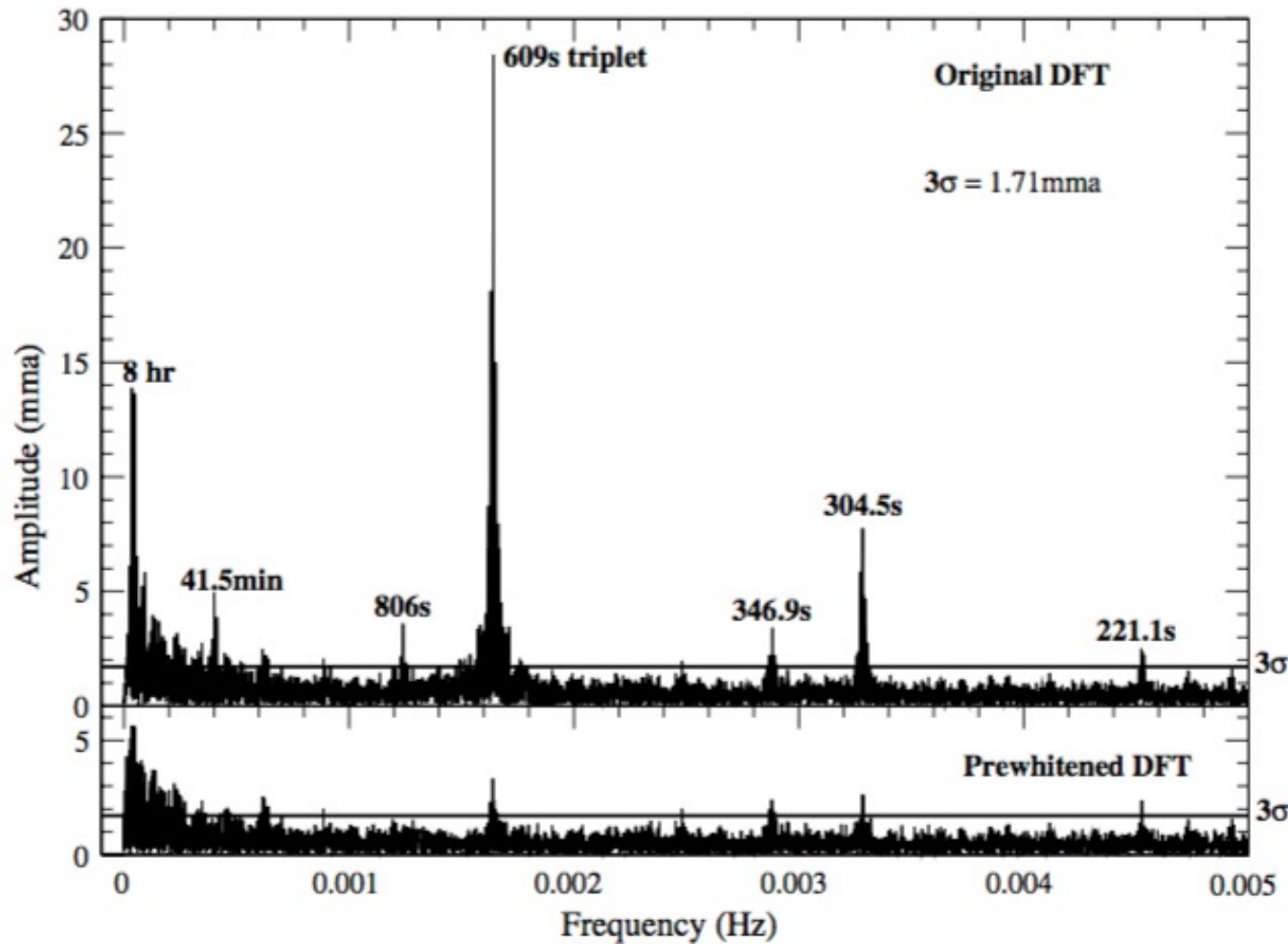
If $P_{\text{out}} = 24$ yrs, this is same epoch as van Zyl data prior to 2007 outburst!



WD has not yet returned to pre-outburst state and this quiescence is different than that preceding the 2007 outburst!

V386 Ser at Quiescence

- 2004-2014 pulsation $P=609$ sec

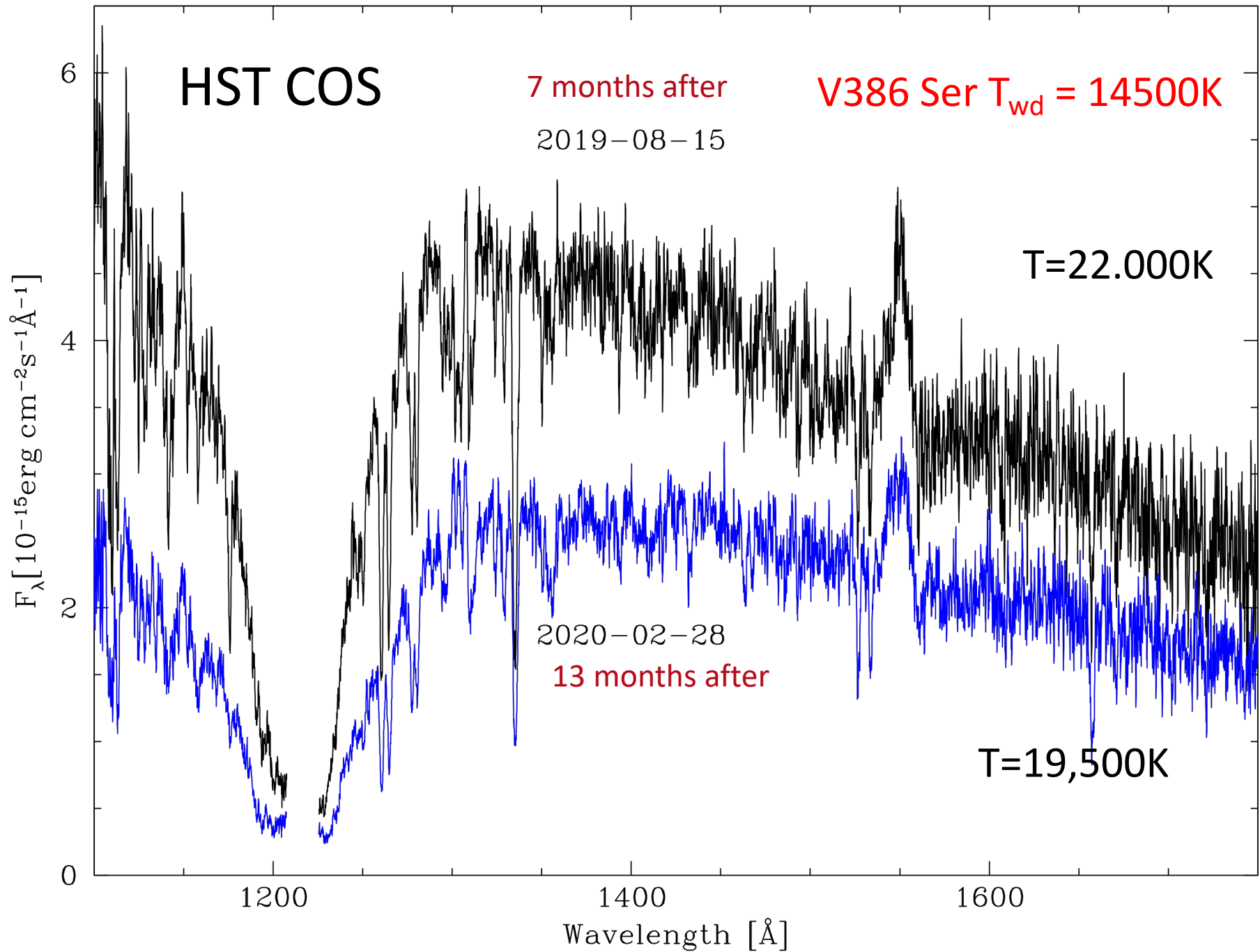


11 day campaign

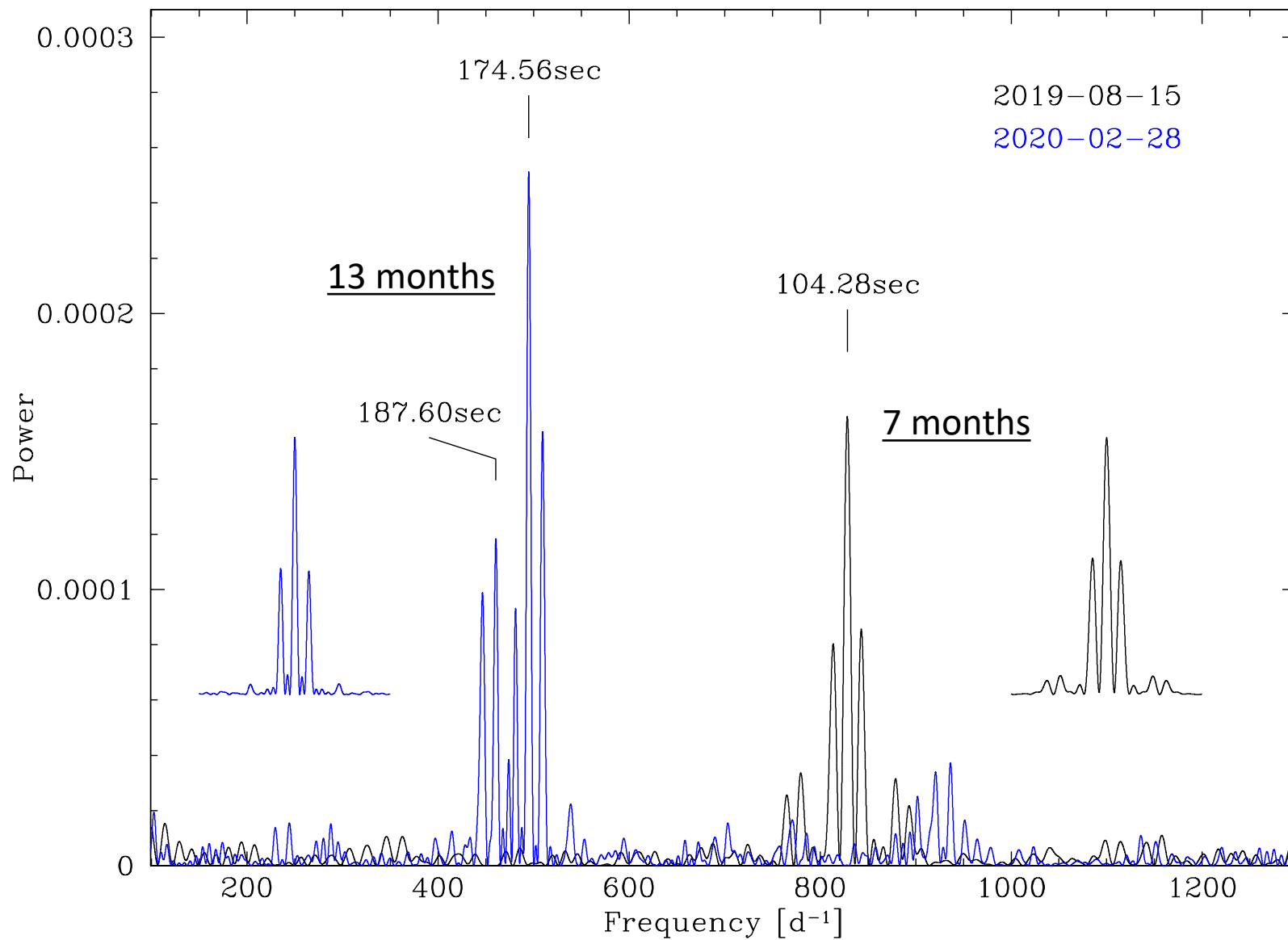
609 s is triplet,
spacing gives
 $P_{\text{rot}}=4.8$ days!

346, 221sec
periods are
linear
combinations
with orbital
harmonic

Mukadam et al.
2010, ApJ

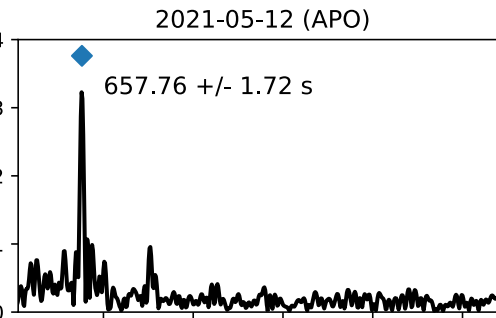
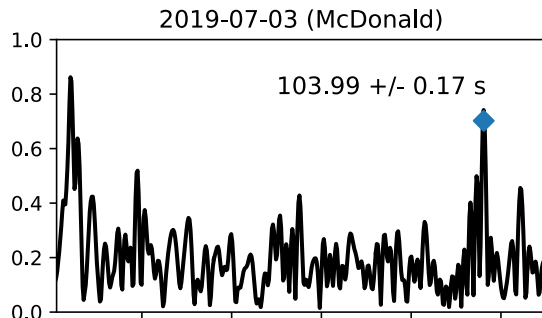


V386 Ser HST post 2019 outburst



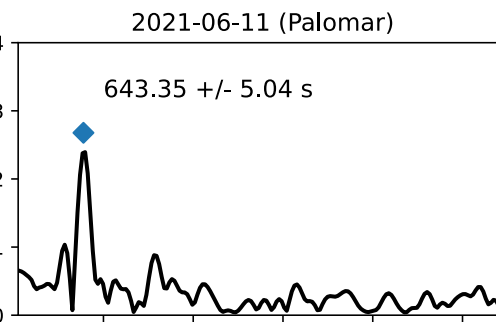
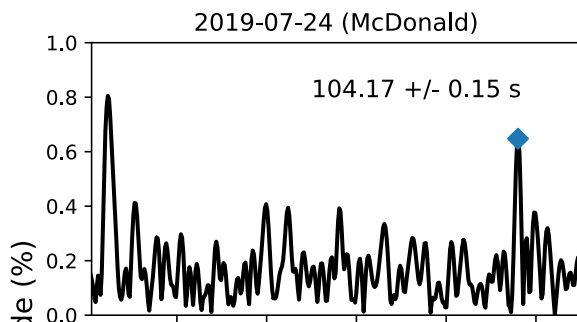
Optical

6 months



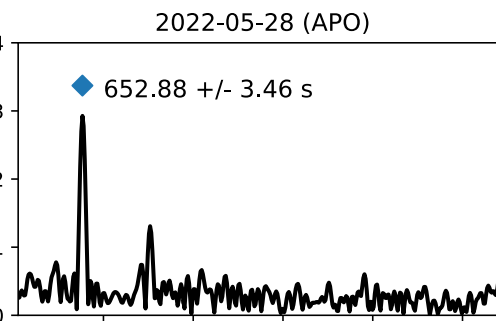
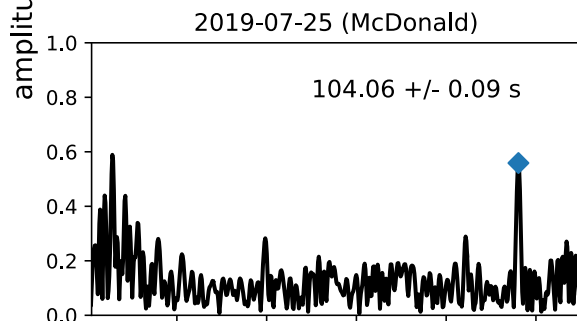
2.3 yrs

6 months



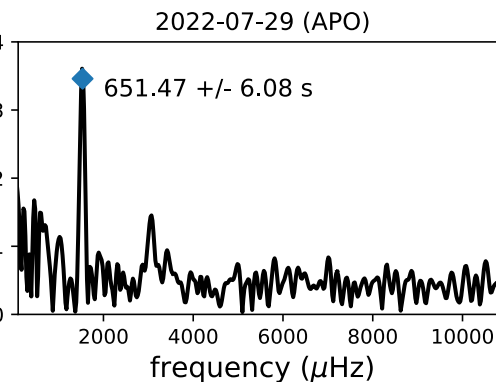
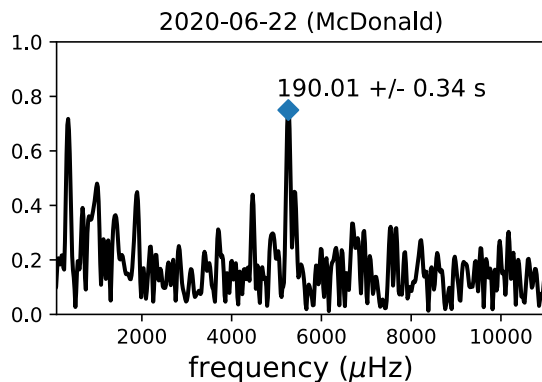
2.4 yrs

6 months



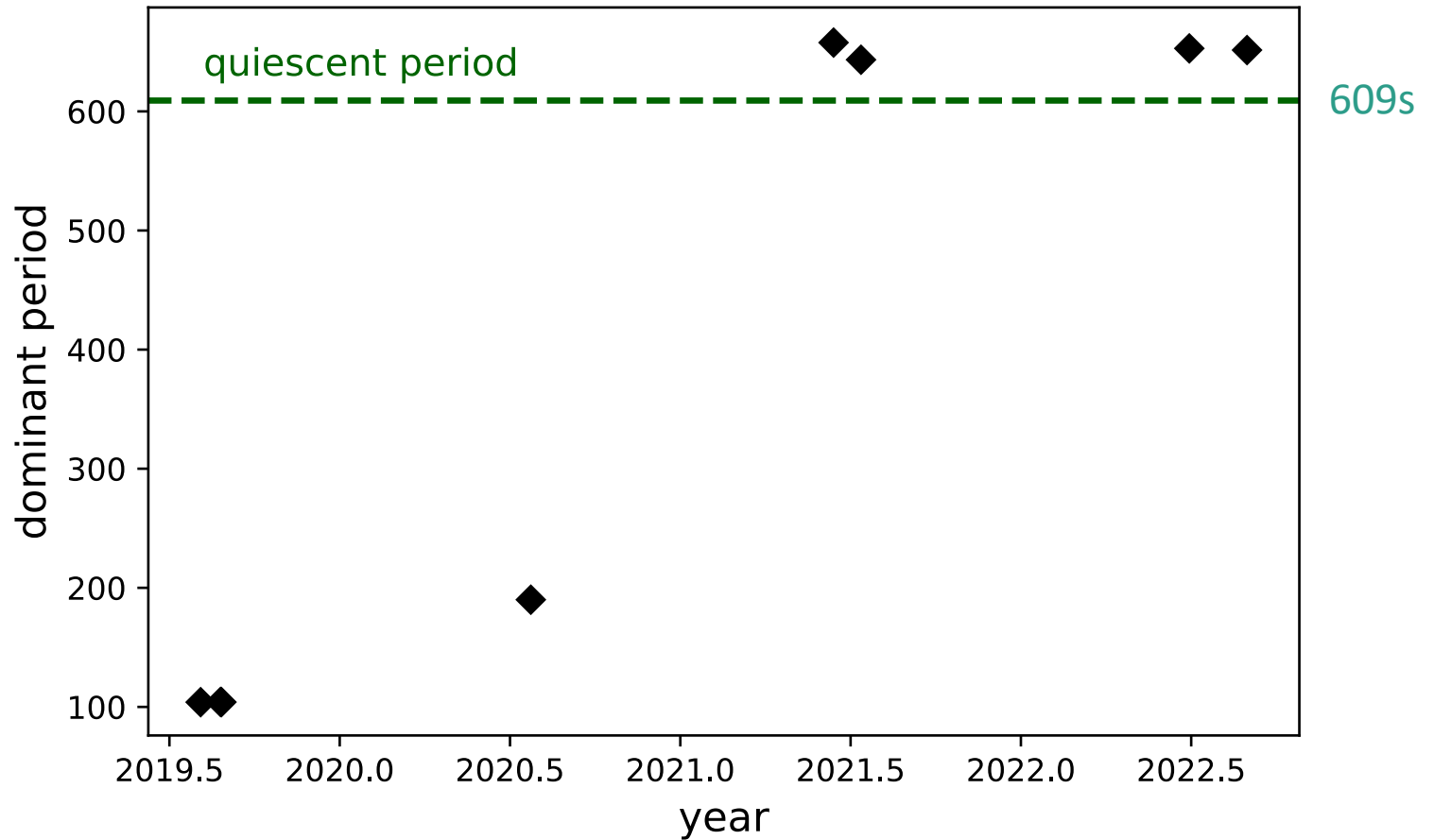
3.3 yrs

1.5 yrs



3.5 yrs

V386 Ser Period Evolution



Summary of the 3:

- V455 And, cool magnetic WD, pulse migrates to same quiescent P over 5 yrs
- GW Lib, hot WD, cools as expected for first 4 yrs, then non-monotonic over next 6+ yrs, 19 min + 4hr + SH periods appear, short pulse P only during 4 hr modulation, state not same as prior to outburst
- V386 Ser, hot WD, cools as expected over first yr, migrates toward quies P over 1.5 yrs but overshoots in years 2-3

What is the “normal” behavior following outburst heating?