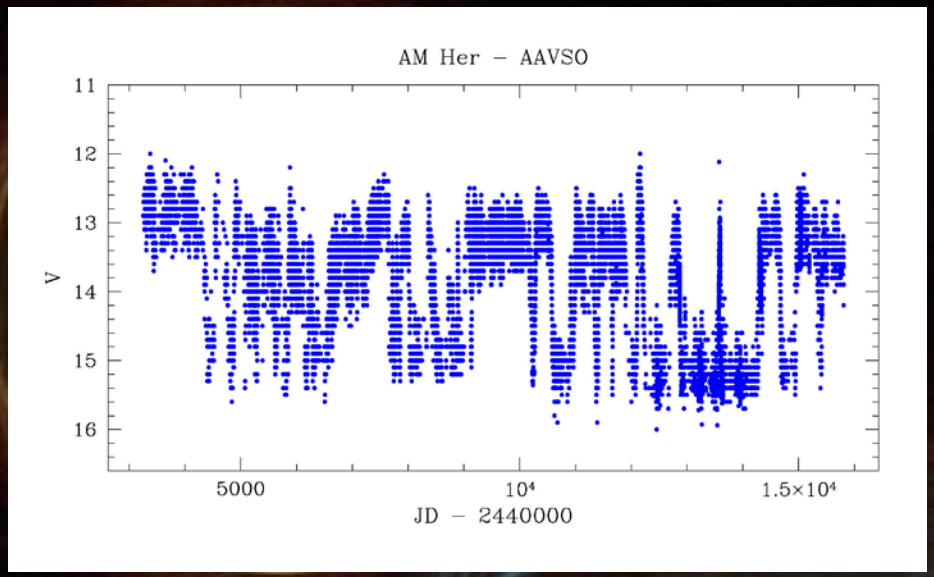
ANTI-NOVAE: PROBING THE INVISIBLE

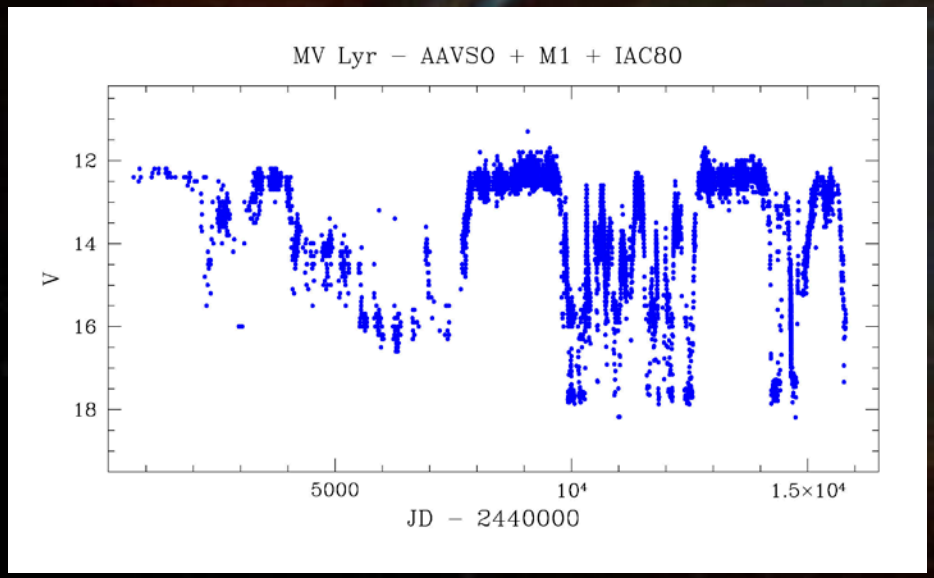
Pablo Rodríguez-Gil

Hernanzfest – Tossa de Mar – 2017 Jun 16

Low states in CVs: the donor star rules



AM Her: the polar prototype
P = 3.09 h
(34-year coverage)



MV Lyr: a well-known nova-like
P = 3.18 h
(37-year coverage)

CV evolution in a nutshell

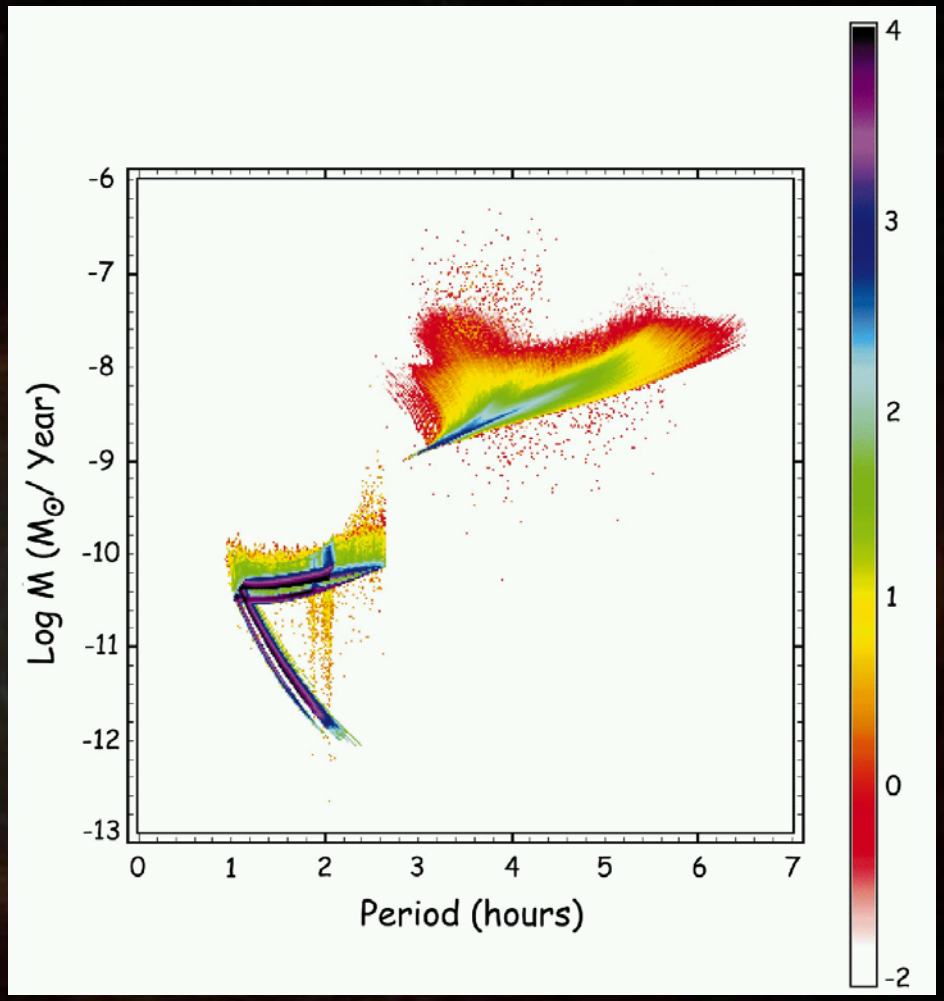
AML: Magnetic wind braking + gravitational radiation

$\tau_J << \tau_{KH}$ or τ_{nuc} above the gap.

MB disruption at the upper edge of the gap (P ≈ 3 h).

$M_2 \leq 0.35\ M_\odot$: (bloated) donor star almost totally or fully convective.

Thermal relaxation of the donor: mass transfer ceases at $M_2 \approx 0.20\ M_\odot$



Howell et al., 2001, ApJ, 550, 897

What would your neighbours be like?

THE ASTRONOMICAL JOURNAL VOLUME 102, NUMBER 1 JULY 1991

PG0027+260: AN EXAMPLE OF A CLASS OF CATACLYSMIC BINARIES WITH MYSTERIOUS, BUT CONSISTENT, BEHAVIOR[1]

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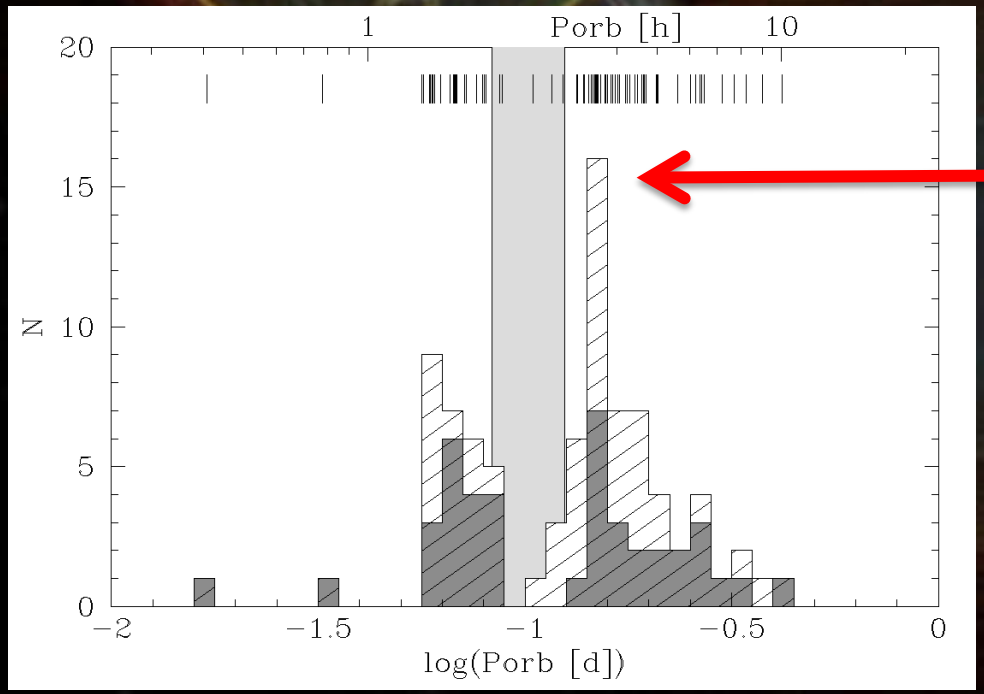
Received 30 November 1990; revised 25 March 1991



HQS “SW Sex spike”

54% of the new HQS nova-likes are SW Sex stars

Rodríguez-Gil et al., 2007, MNRAS, 377, 1747

What would your neighbours be like?

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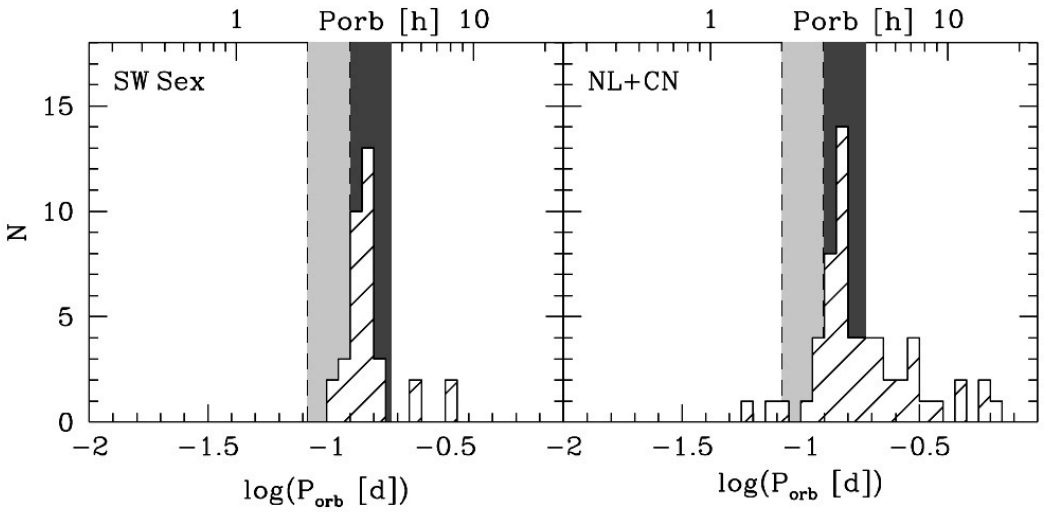
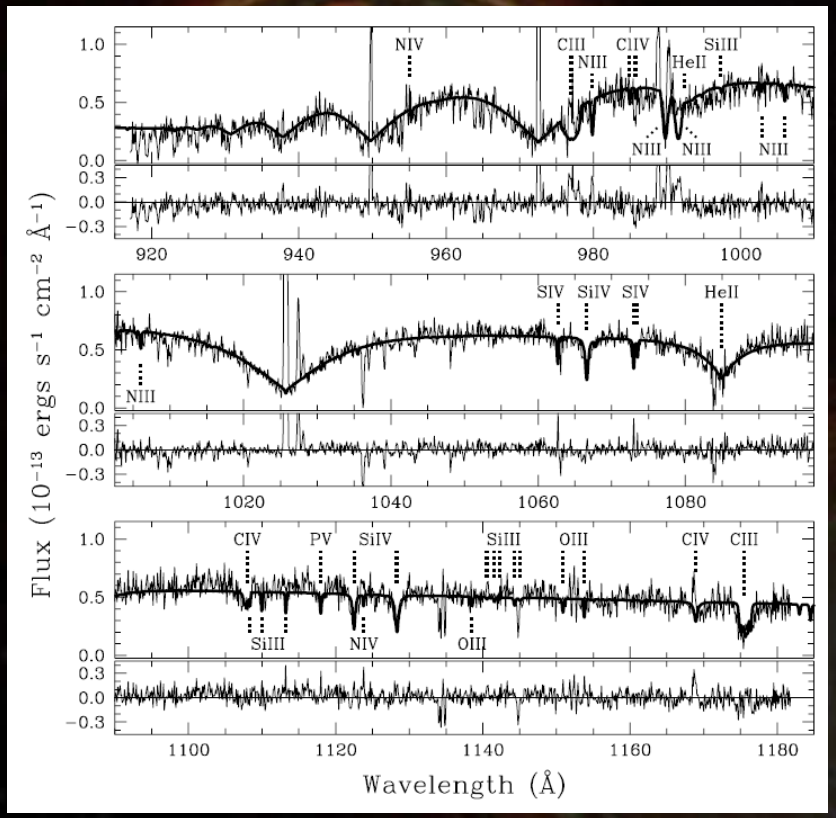


At least half of the CVs in the 3-4 h period interval are SW Sextantis stars.

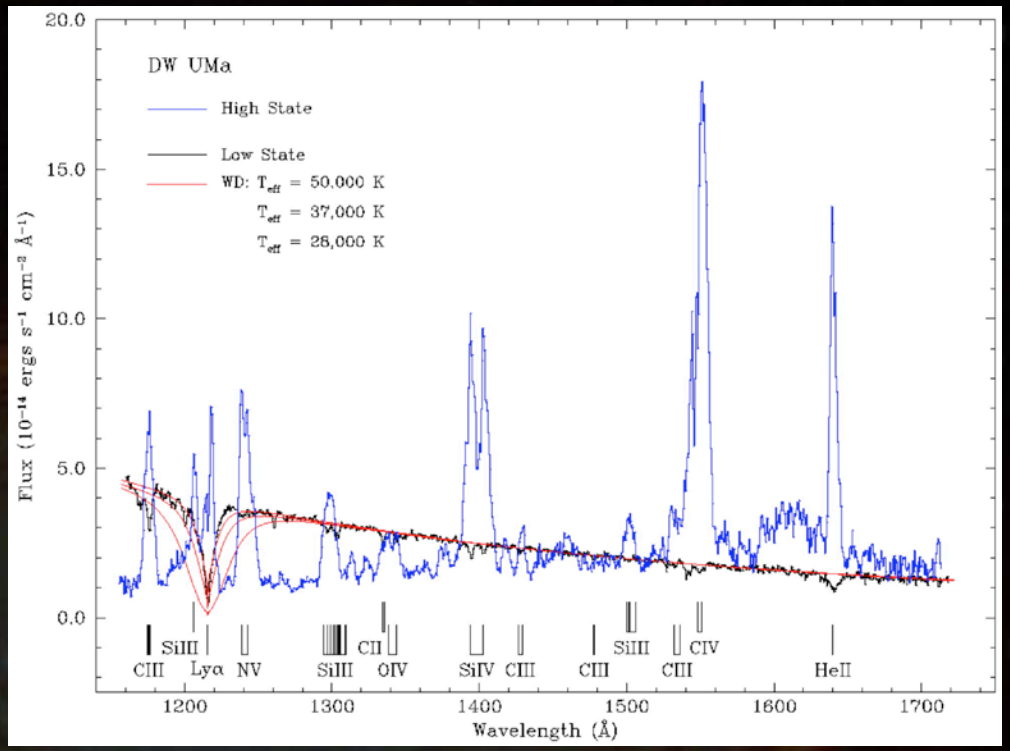
Rodríguez-Gil et al., 2007, MNRAS, 377, 1747

Mysterious, weird… and hot



MV Lyr: T_1 = 47000 K

Hoard et al., 2004, ApJ, 604, 346



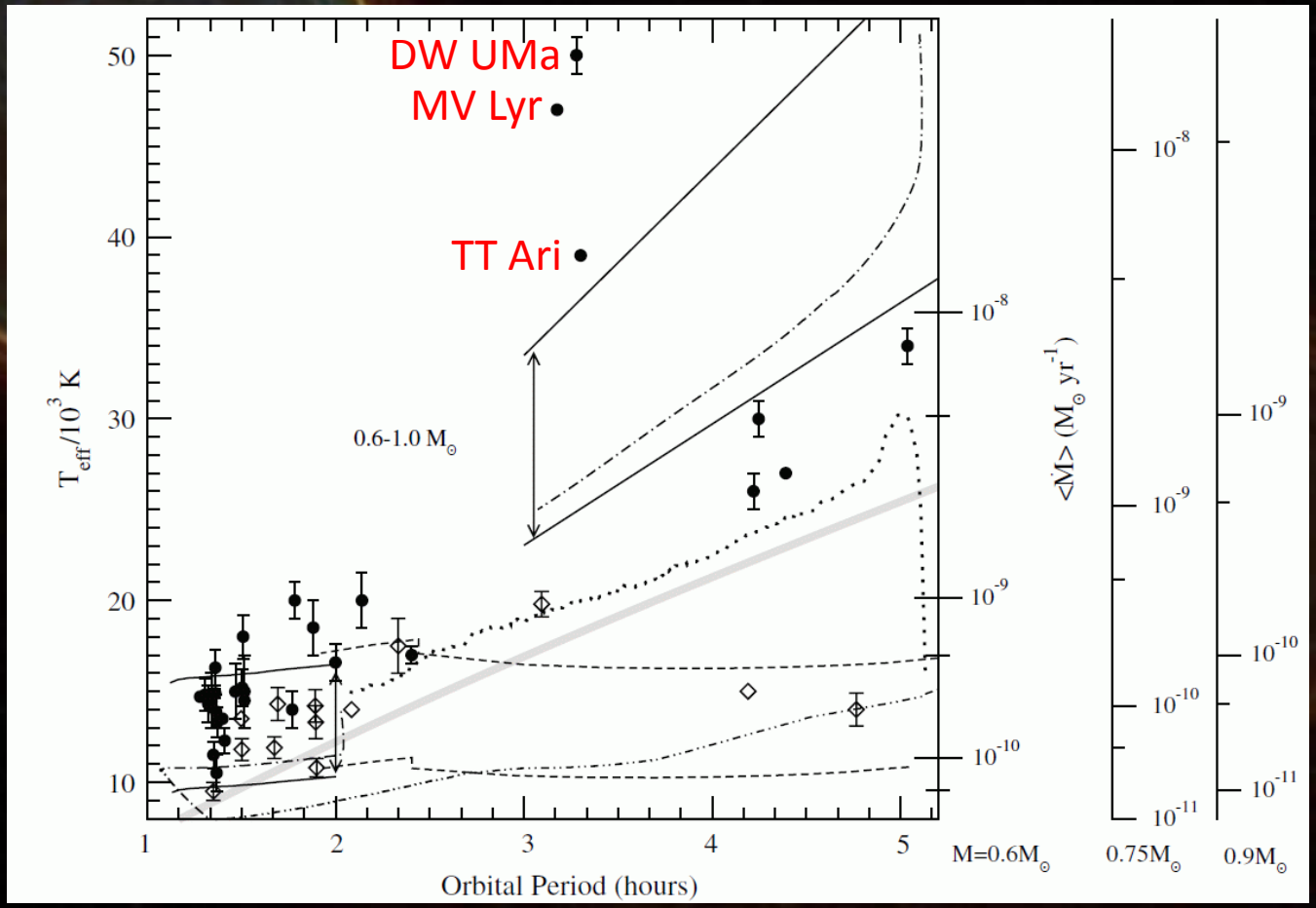
DW UMa: T_1 = 50000 K

Araujo-Betancor et al., 2003, ApJ, 583, 437

Knigge et al., 2004, ApJ, 615, L129

Mass transfer rates ($\dot{M}$) from T_1

$$T_{\rm eff} = 1.7 \times 10^4\ {\rm K} \left(\frac{\langle \dot{M} \rangle}{10^{-10}\ M_\odot\ {\rm yr}^{-1}} \right)^{1/4} \left(\frac{M}{0.9\ M_\odot} \right)$$



Townsley & Gänsicke, 2009, ApJ, 693, 1007

Dynamical mass measurements: do we have (m)any?

BELOW the gap:

$\langle M_1 \rangle = 0.81 \pm 0.04\ M_\odot$ ($\sigma_{int} = 0.13\ M_\odot$)
$M_2 = 0.18 - 0.22\ M_\odot$ (just below)

Savoury et al., 2011, MNRAS, 415, 2025

$\langle M_1 \rangle = 0.73 \pm 0.07\ M_\odot$ ($\sigma_{int} = 0.19\ M_\odot$).

Knigge, 2011, ApJS, 194, 28

ABOVE the gap:

$\langle M_1 \rangle = 0.77 \pm 0.06\ M_\odot$ ($\sigma_{int} = 0.15\ M_\odot$).

Knigge, 2011, ApJS, 194, 28

JUST ABOVE the gap: Mass estimates involving a variety of assumptions; e.g. DW UMa (Araujo-Betancor et al. 2005) or UU Aqr (Díaz & Steiner 1991; Baptista, Steiner & Cieslinski 1994). **WHY?**

This is what we see in the high state…

Open questions

What's going on at P ~ 3-4 h?
Were they born there?
Are they about to enter the gap?

WE NEED ACCURATE MASSES AT THE UPPER EDGE OF THE GAP

Low states: measuring the invisible

Long-term photometric monitoring of 60 systems in the north (SW Sex, candidates and other VY Scl stars including classical novae).

Effort of a big number of Spanish amateur astronomers + IAC80.

1.3-m SMARTS photometric monitoring of 7 southern systems.

+

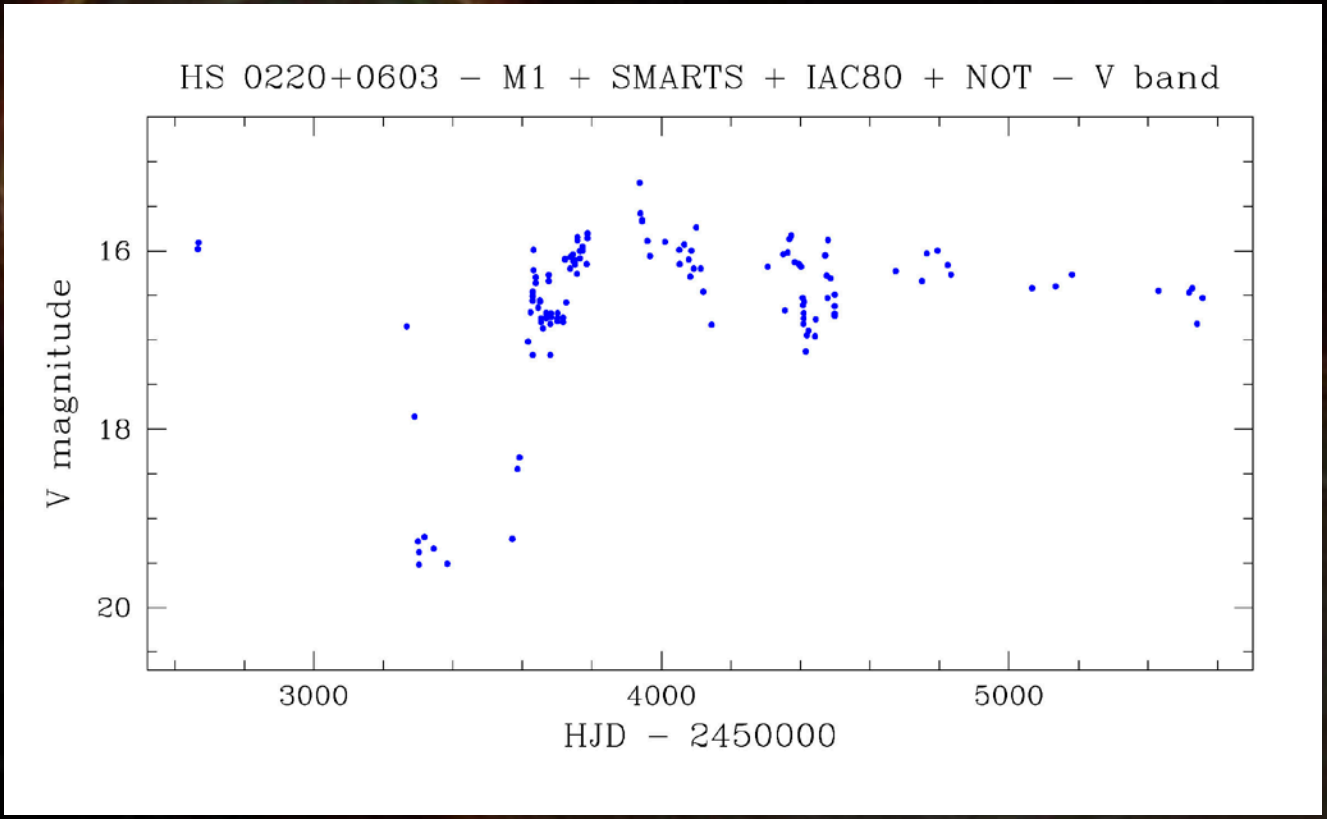
ToO time-resolved spectroscopy: VLT, Gemini, WHT, and 10-m GTC.

Time-resolved (mainly I-band) photometry: NOT, WHT, INT.

=

Sp(1), Sp(2), T_1, log g, d, K_{abs}, K_{em}, K_2, v sin i, q, K_1, M_1, M_2, (R_1, R_2)

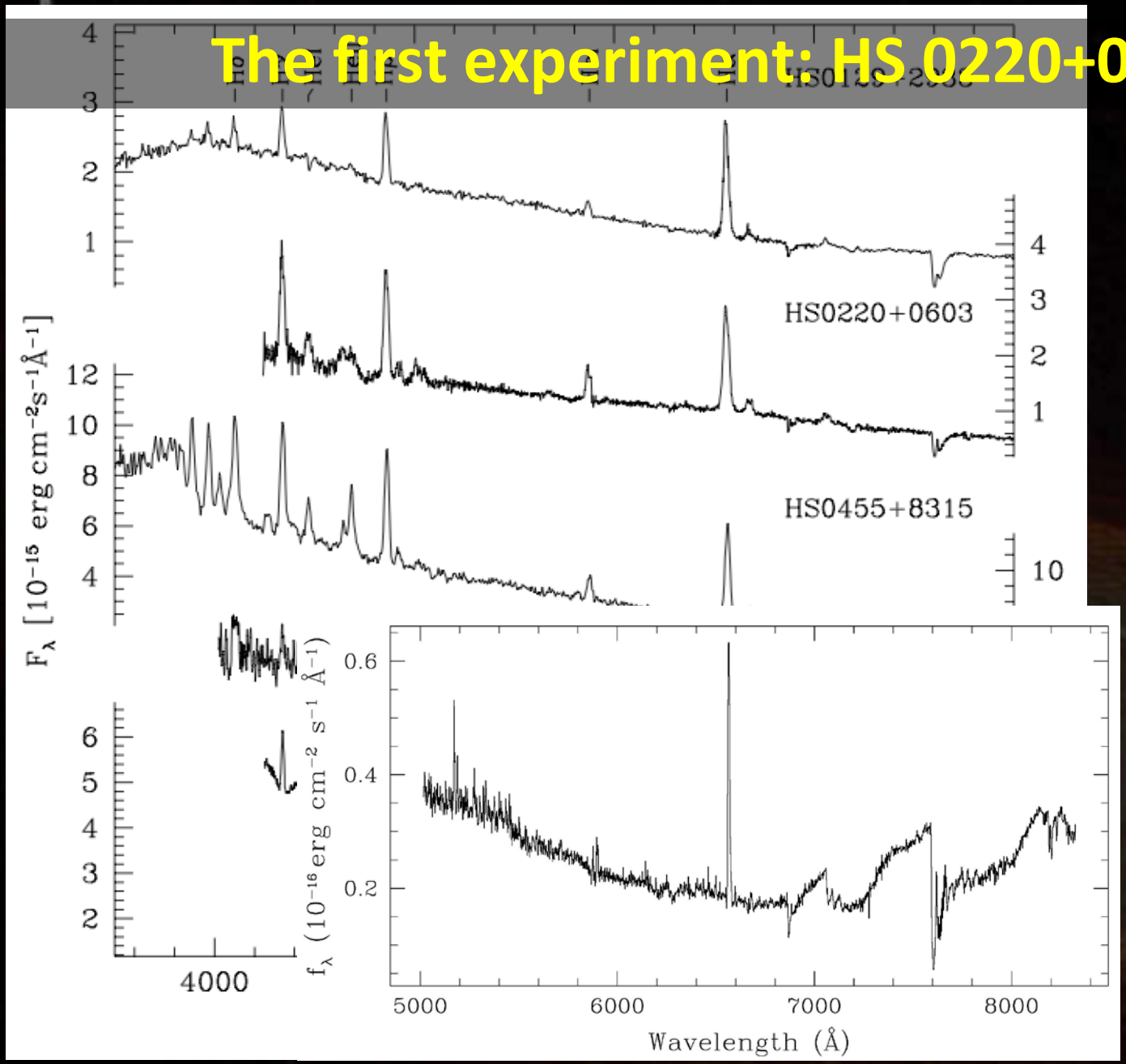
The first experiment: HS 0220+0603



P = 3.58 h

Rodríguez-Gil et al., 2015, MNRAS, 452, 146

The first experiment: HS 0220+0603



Rodríguez-Gil et al., 2007, MNRAS, 377, 1747

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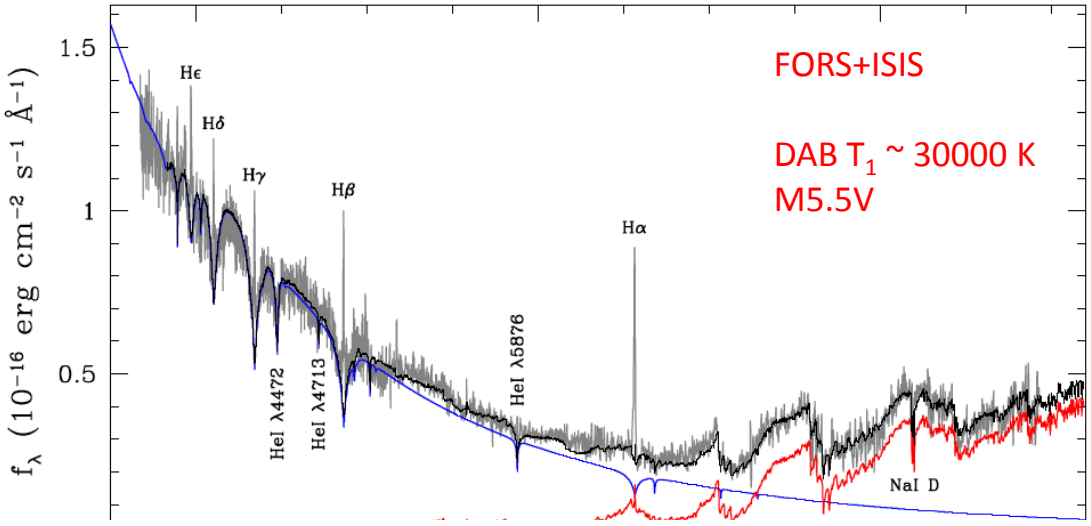
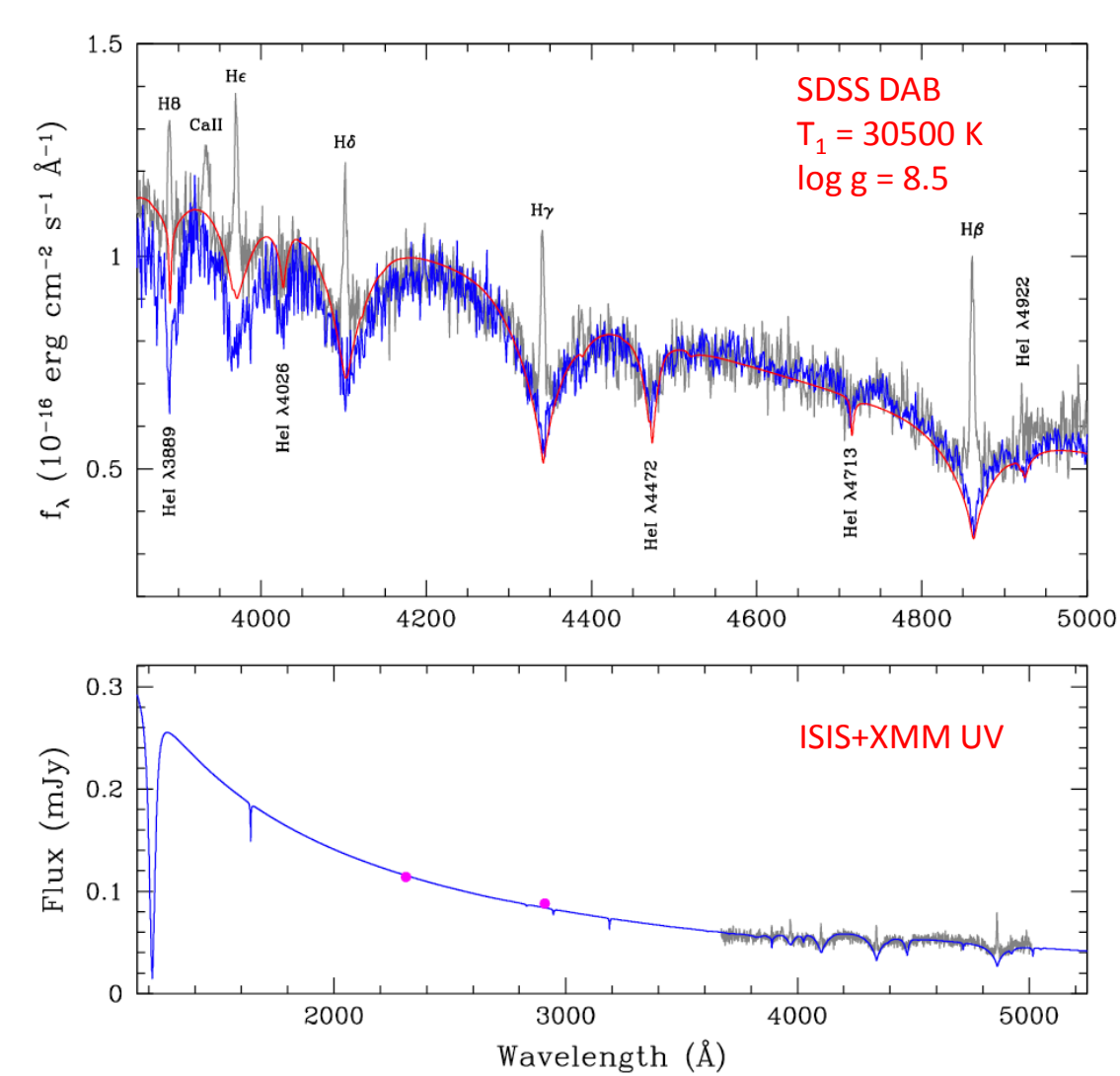


Table 3. Molecular band-head indices.

Star	VO1	VO2	TiO7
HS 0220+0603	0.875	0.649	0.756
M2 V	0.947	0.899	0.956
M3 V	0.920	0.821	0.914
M4 V	0.904	0.758	0.876
M5 V	0.874	0.654	0.791
M6 V	0.851	0.601	0.762
M7 V	0.829	0.537	0.703
M8 V	0.799	0.443	0.626

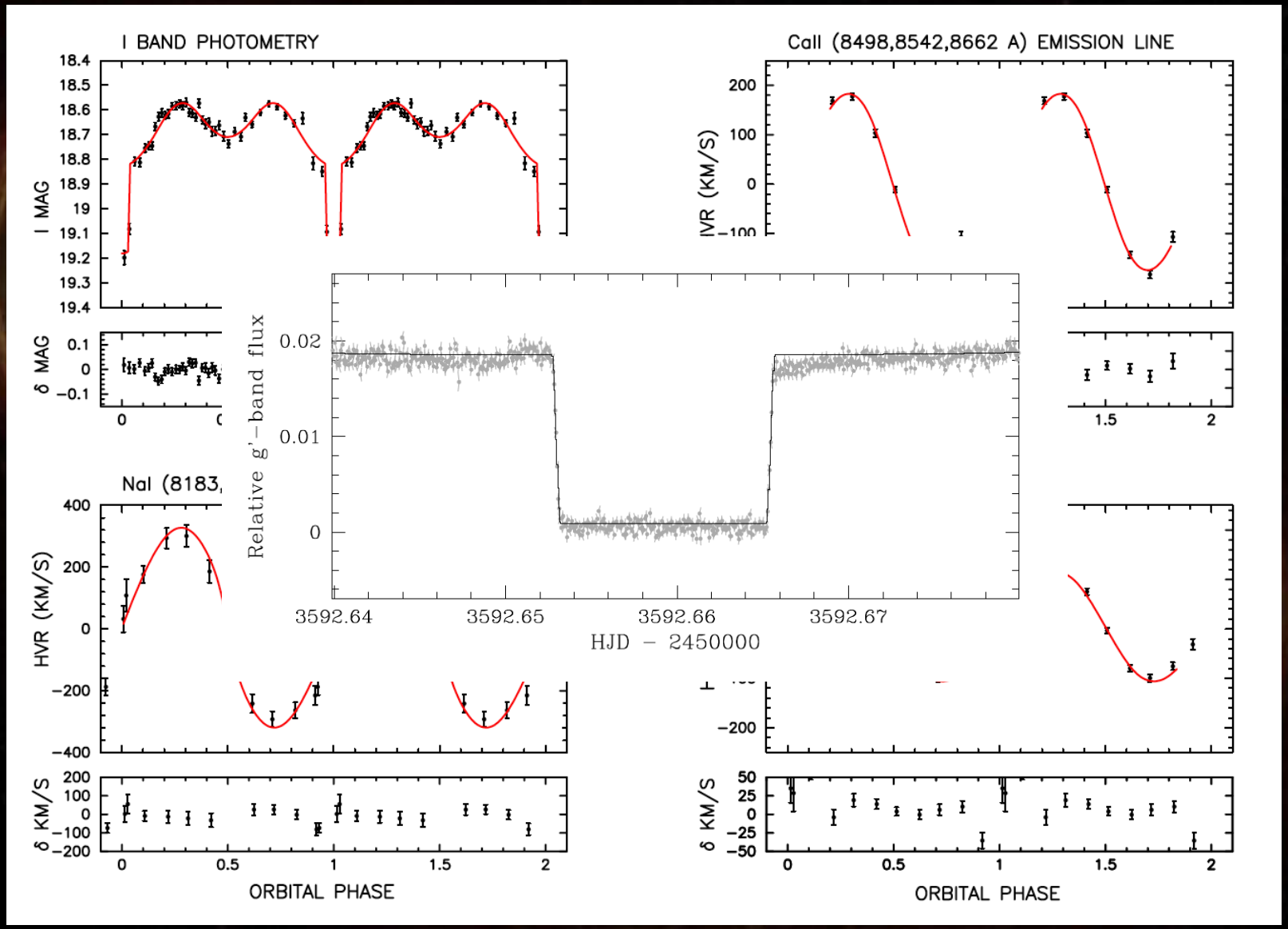
Rodríguez-Gil et al., 2015, MNRAS, 452, 146

The first experiment: HS 0220+0603



Rodríguez-Gil et al., 2015, MNRAS, 452, 146

The first experiment: HS 0220+0603



Rodríguez-Gil et al., 2015, MNRAS, 452, 146

The first experiment: HS 0220+0603

Table 7. System parameters for HS 0220+0603. R_2 is the volume radius of the secondary star's Roche lobe as defined by Eggleton (1983).

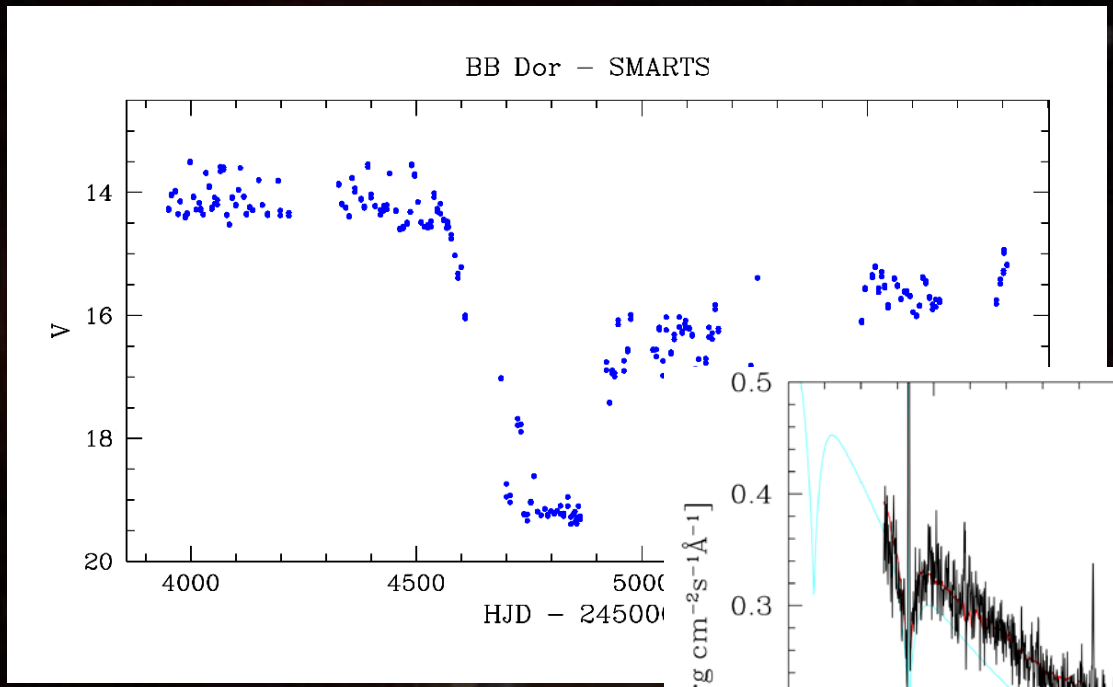
Parameter	Value
q	0.54 ± 0.03
a ($R_\odot$)	1.31 ± 0.03
M_1 ($M_\odot$)	0.87 ± 0.09
R_1 ($R_\odot$)	0.0103 ± 0.0007
T_1 (K)	$30\,000 \pm 5\,000$
M_2 ($M_\odot$)	0.47 ± 0.05
R_2 ($R_\odot$)	0.43 ± 0.03
K_2 ($km\,s^{-1}$)	284 ± 11
i (°)	~ 79
d (pc)	740 ± 26

Rodríguez-Gil et al., 2015, MNRAS, 452, 146

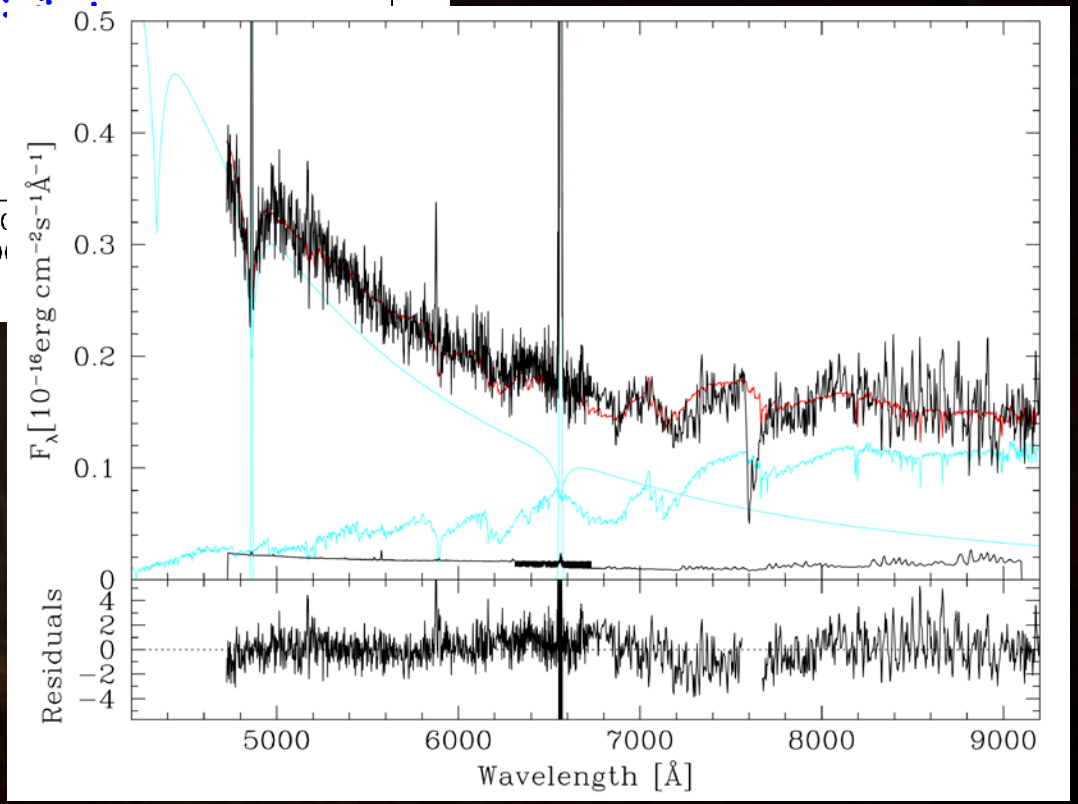
$M_1 = 0.87\ (\pm\ 0.09)\ M_\odot$

$M_2 = 0.47\ (\pm\ 0.03)\ M_\odot$

The low state of BB Doradus



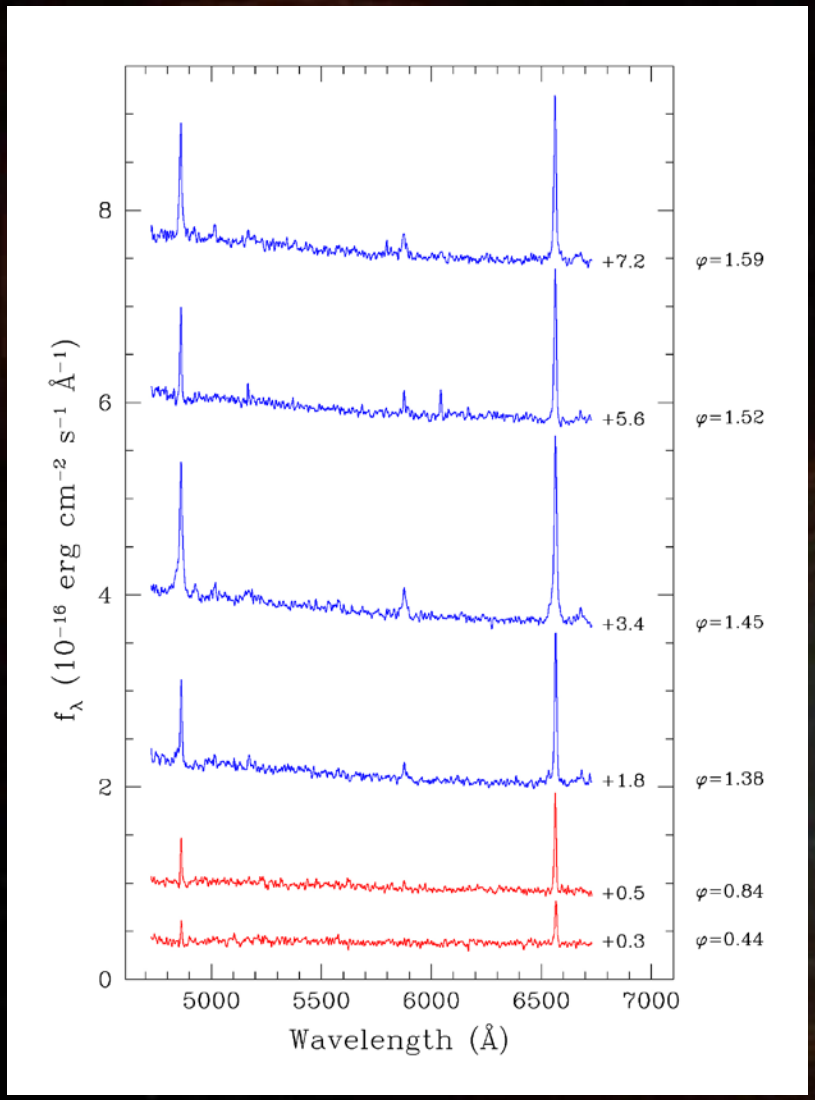
P = 3.70 h
(5-year coverage)

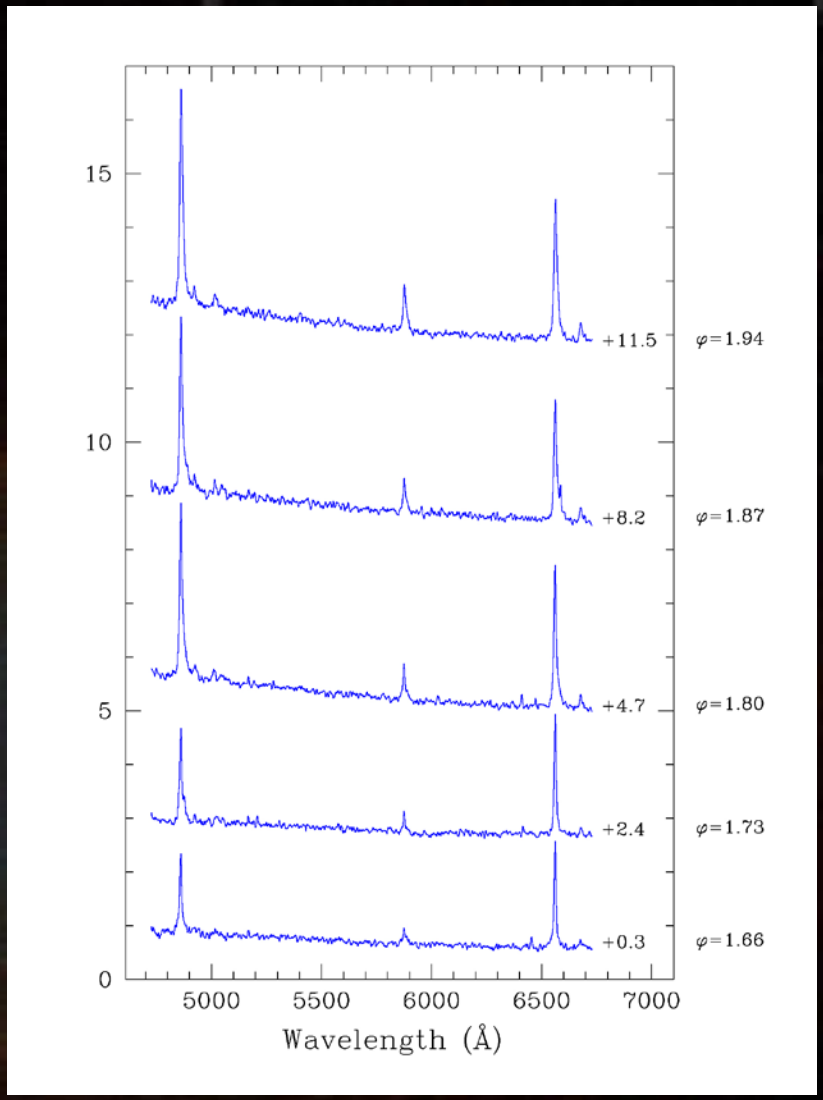


T_1 > 25 000 K
Sp(2) >~ M4 V

Rodríguez-Gil et al., 2012, MNRAS, 422, 2332

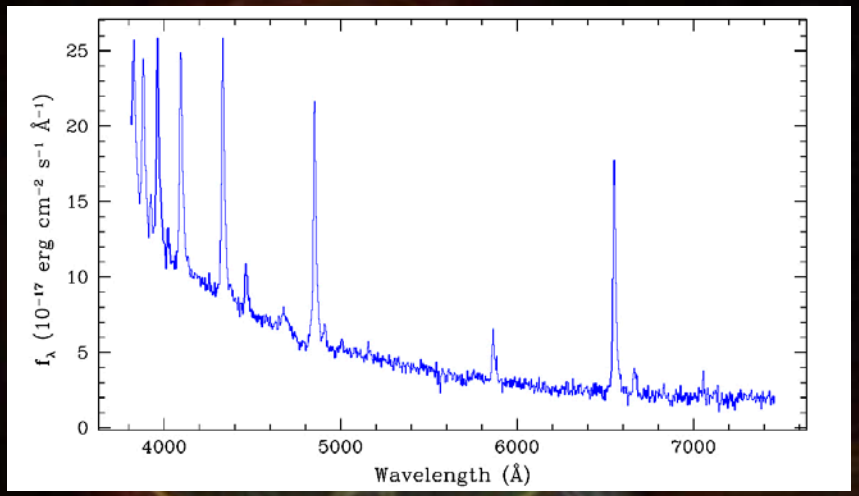
Sporadic mass transfer in BB Doradus

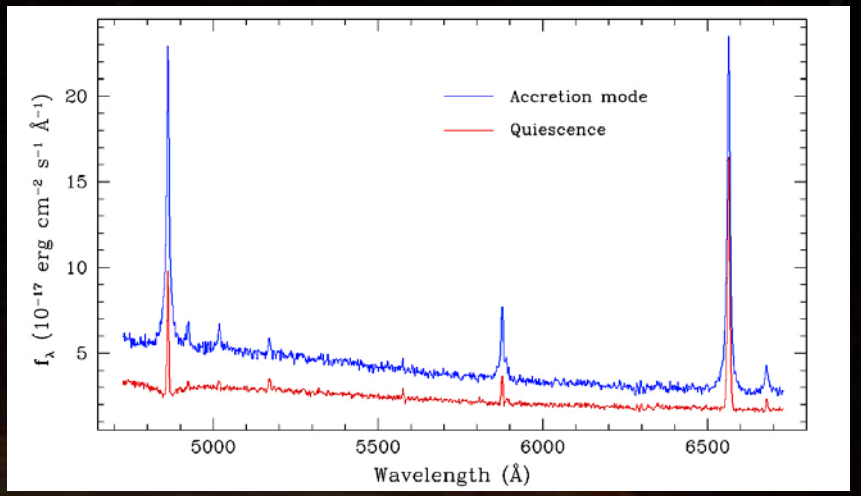


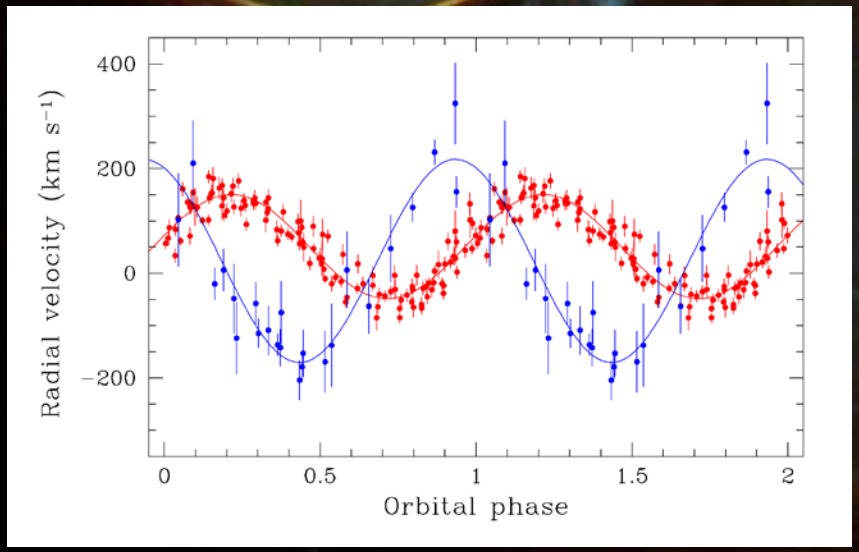


Rodríguez-Gil et al., 2012, MNRAS, 422, 2332

Sporadic mass transfer in BB Doradus...







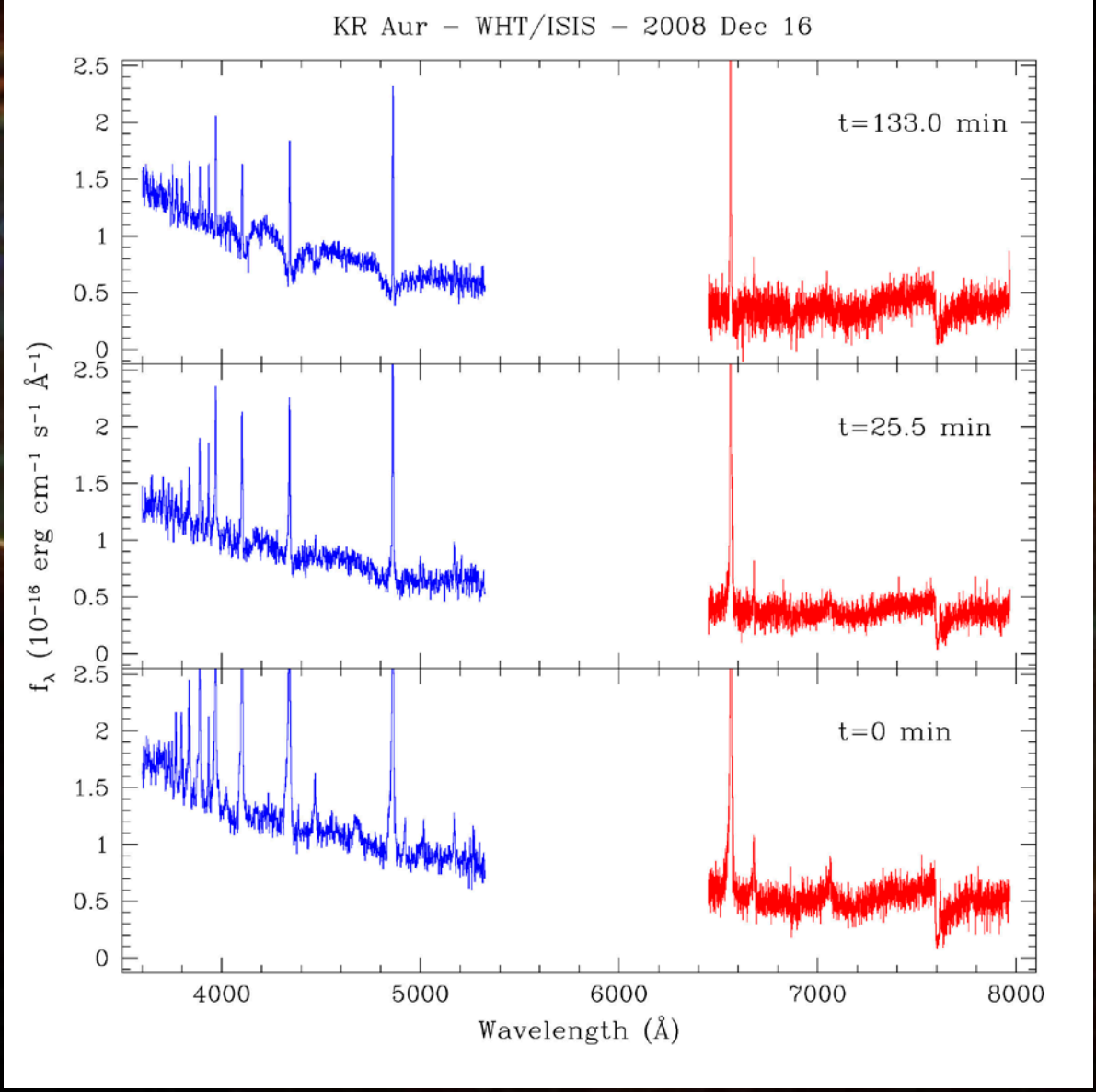
Typical 0.2-cycle phase delay of SW Sex stars in the high state.

Impact on a cold disc?

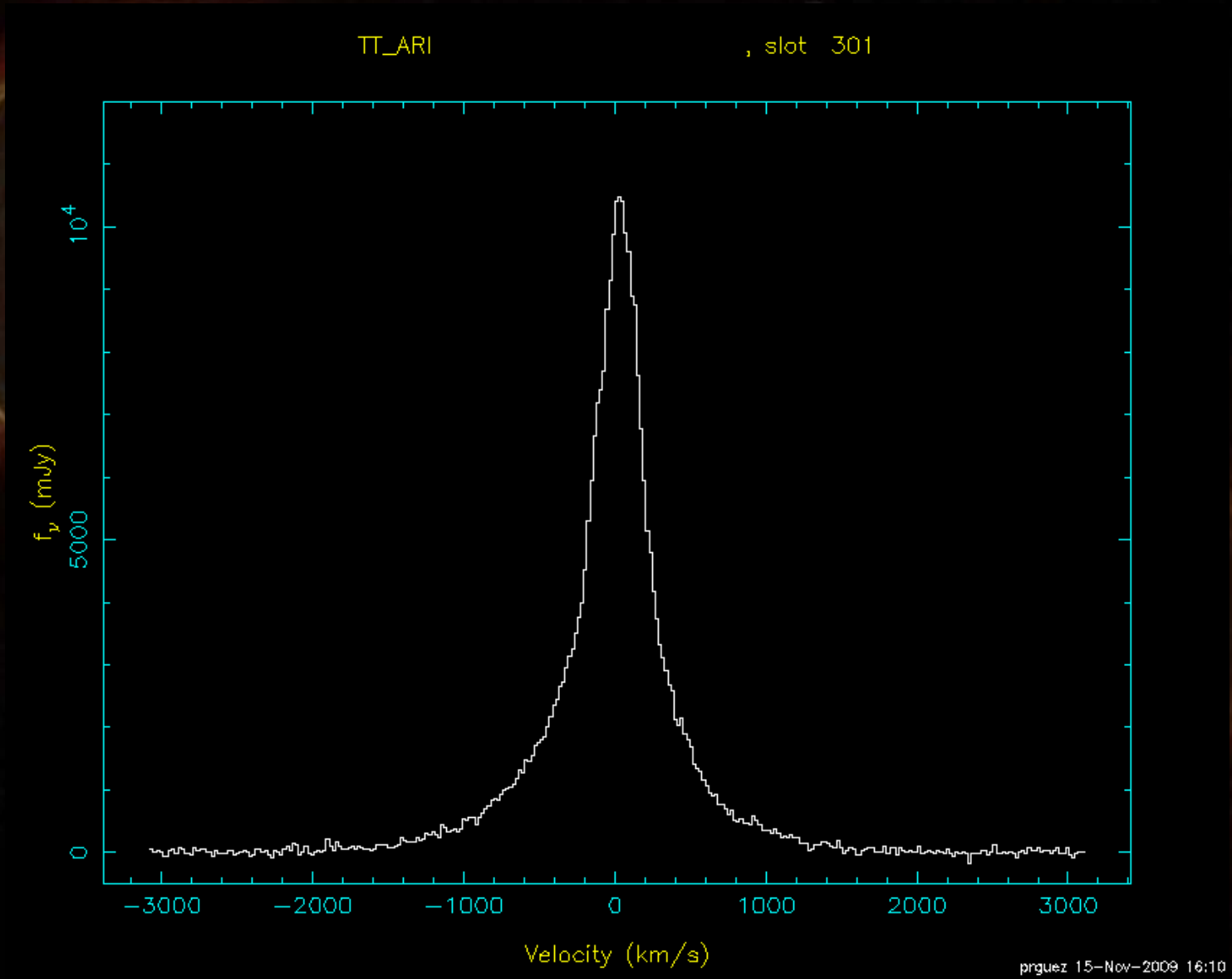
Stream-field coupling?

Rodríguez-Gil et al., 2012, MNRAS, 422, 2332

…and in other VY Scl stars

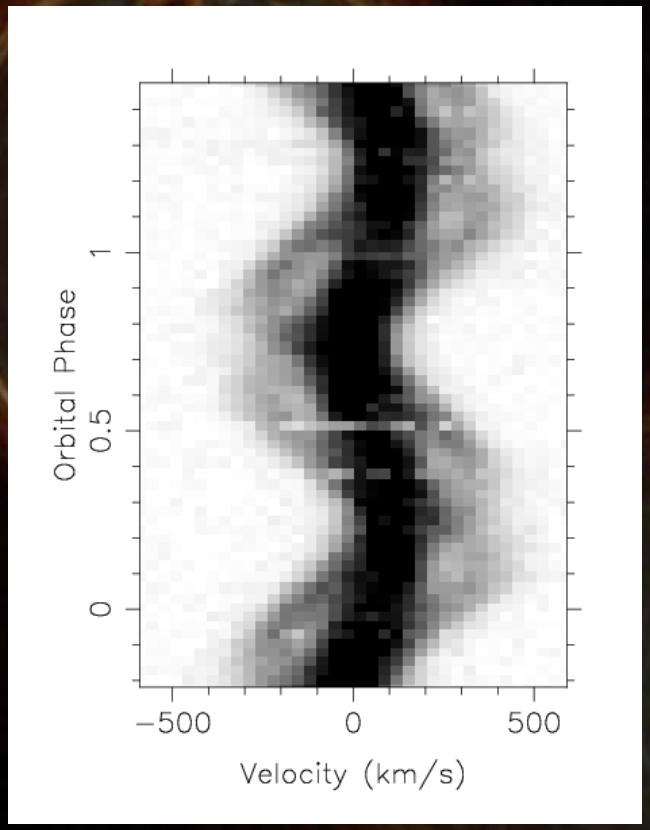


…and other VY Scl stars

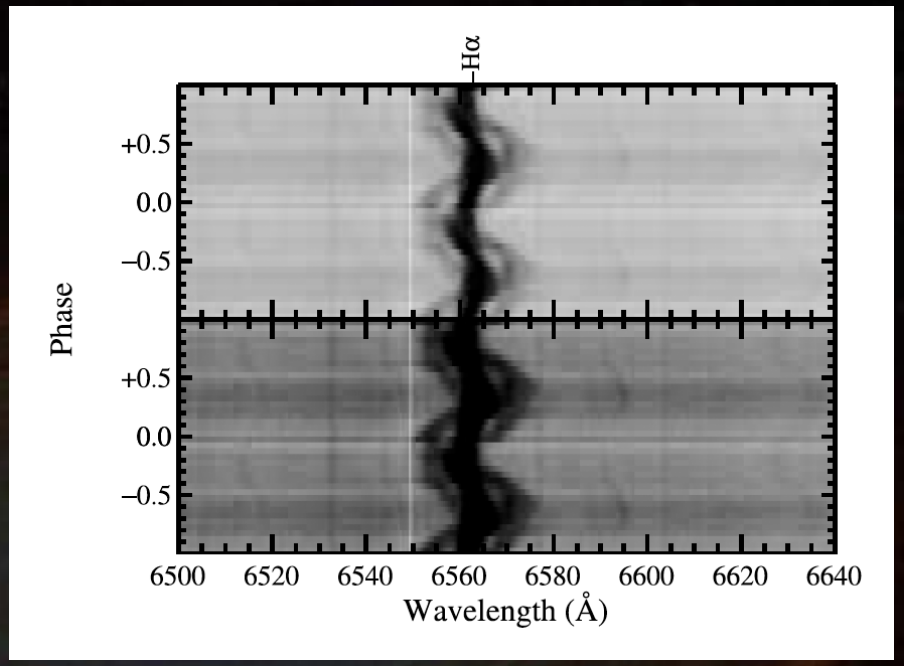


The unexpected: BB Dor *vs* AM Her

VLT/FORS



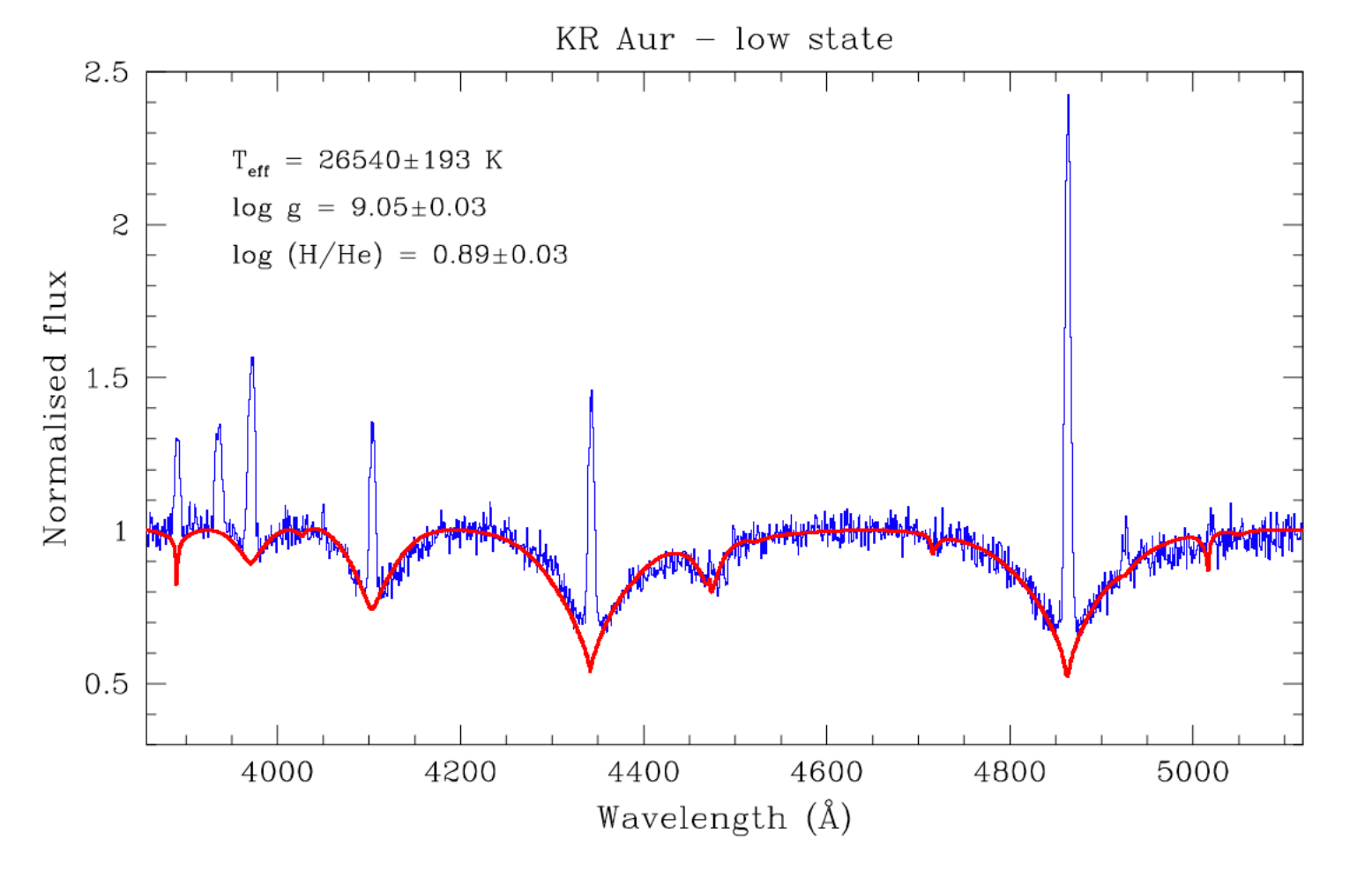
Schmidtobreick et al., 2012, MNRAS, 422, 731



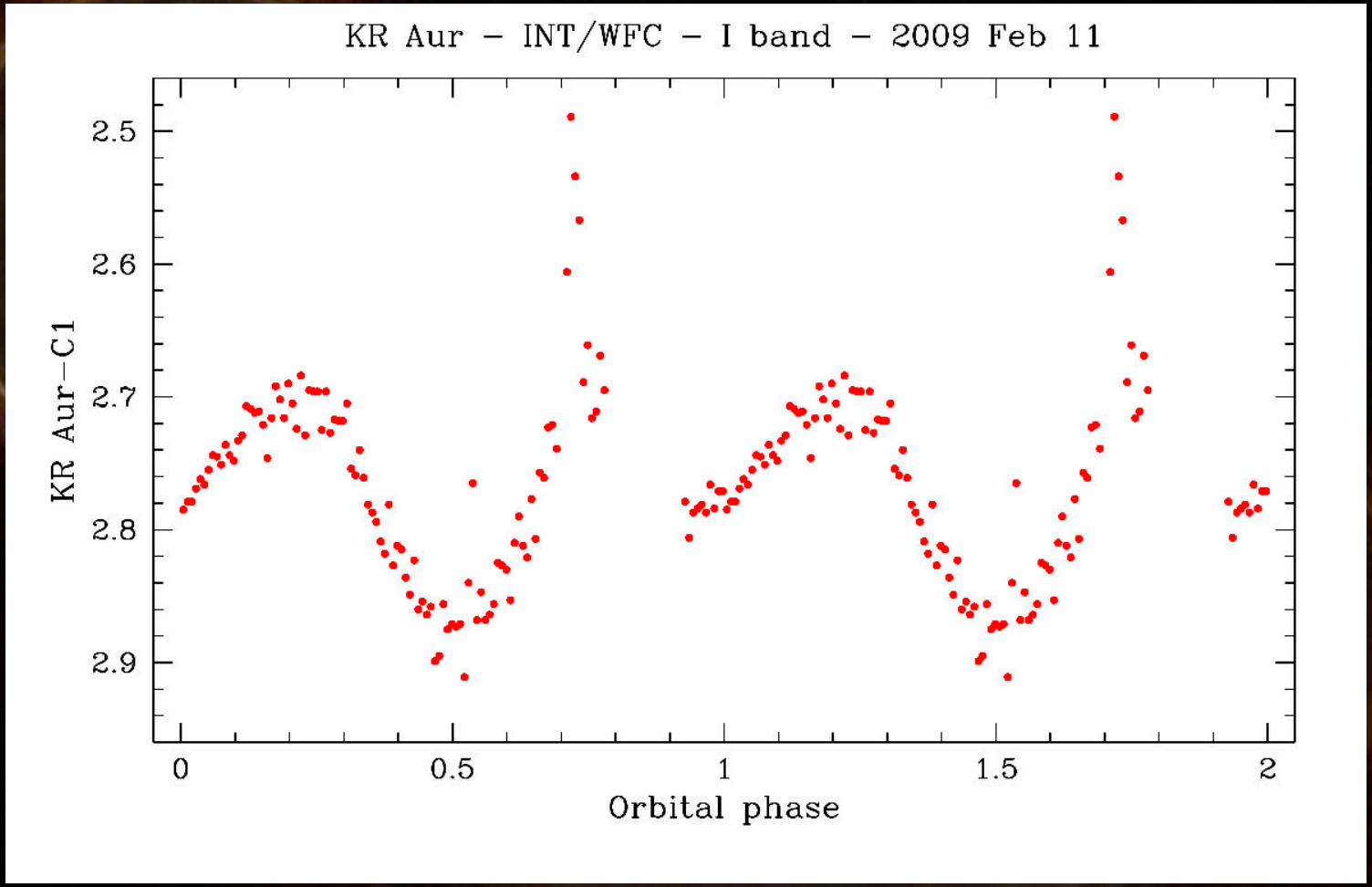
Kafka et al. 2008, ApJ, 688, 1302

Prominences on the donor star coupled to the magnetic field?

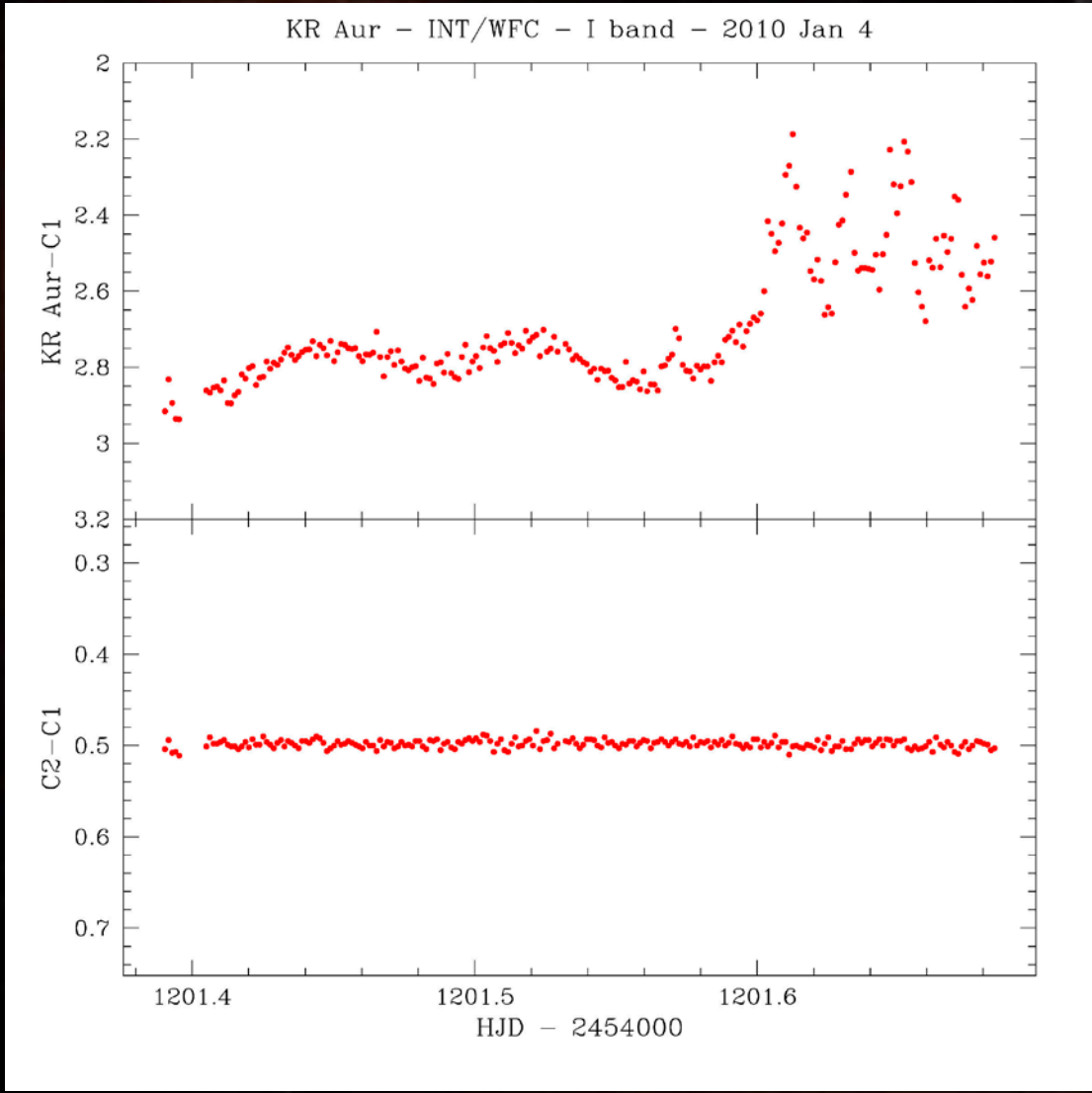
KR Aurigae


KR Aur – low state
T_{eff} = 26540±193 K
log g = 9.05±0.03
log (H/He) = 0.89±0.03
Normalised flux
2.5
2
1.5
1
0.5
4000
4200
4400
4600
4800
5000
Wavelength (Å)

KR Aurigae


KR Aur – INT/WFC – I band – 2009 Feb 11
KR Aur−C1
2.5
2.6
2.7
2.8
2.9
0
0.5
1
1.5
2
Orbital phase

KR Aurigae

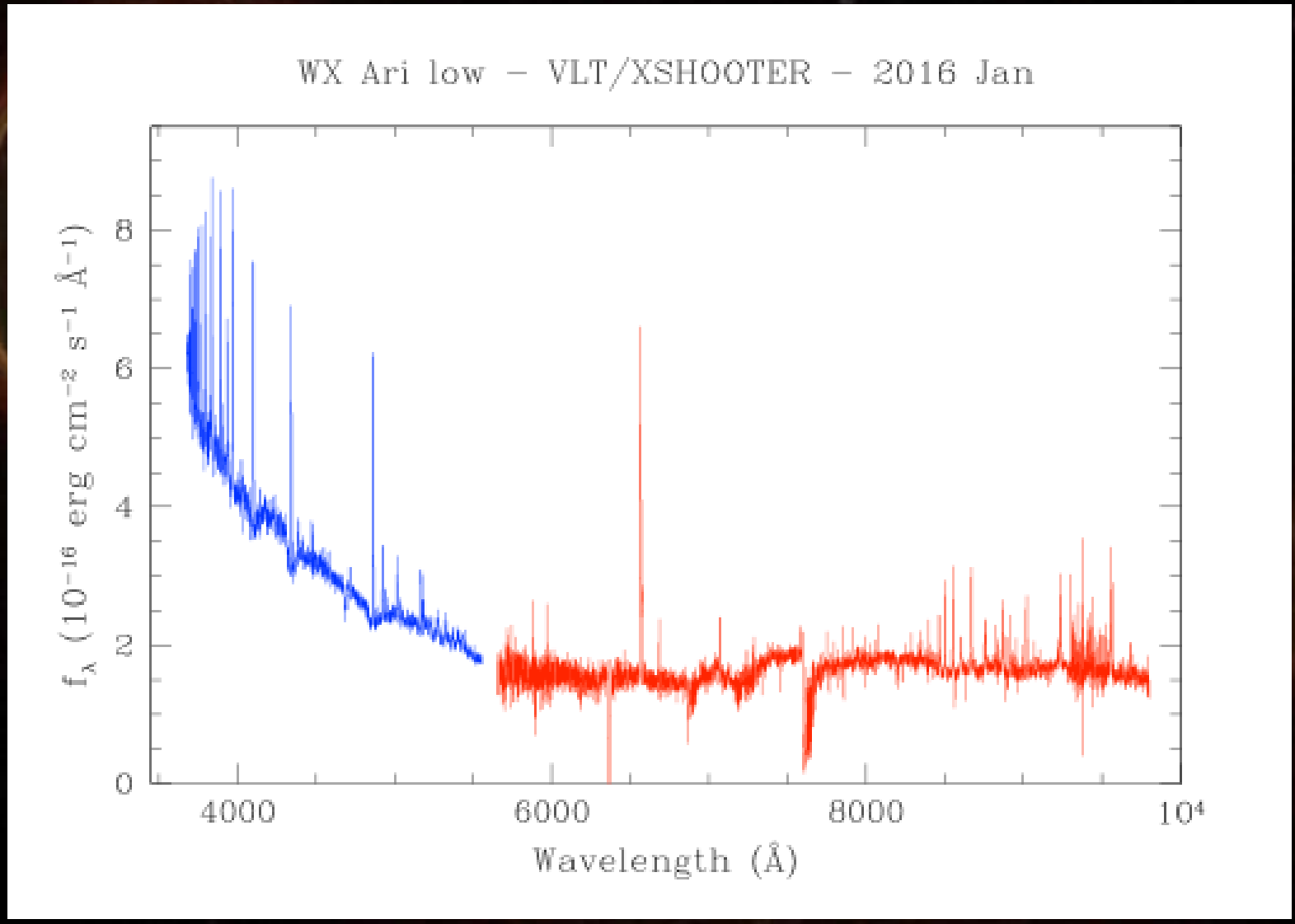


P = 3.91 h

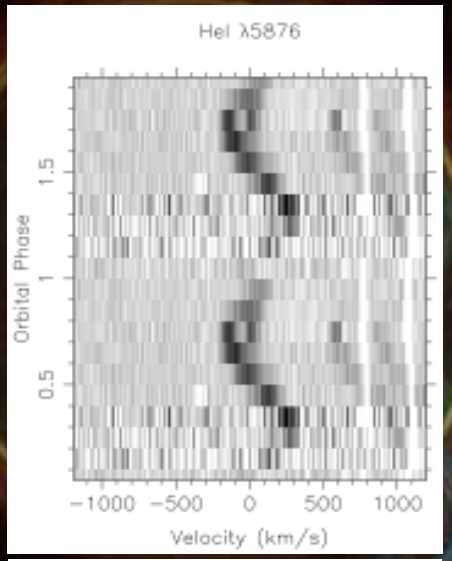
Flare

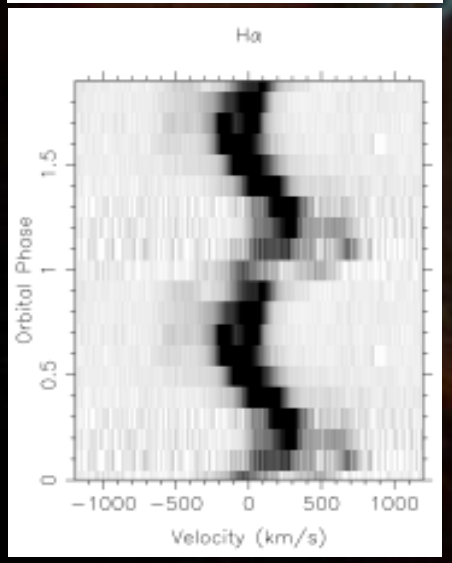
Oscillation at ~ 27 min

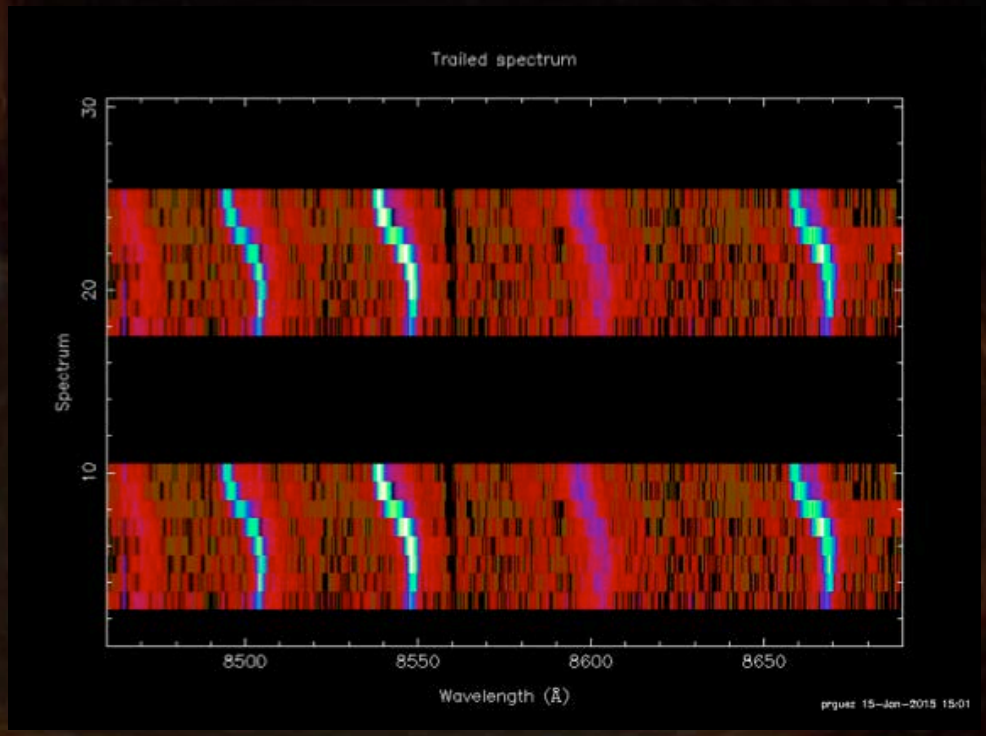
WX Arietis: the low state



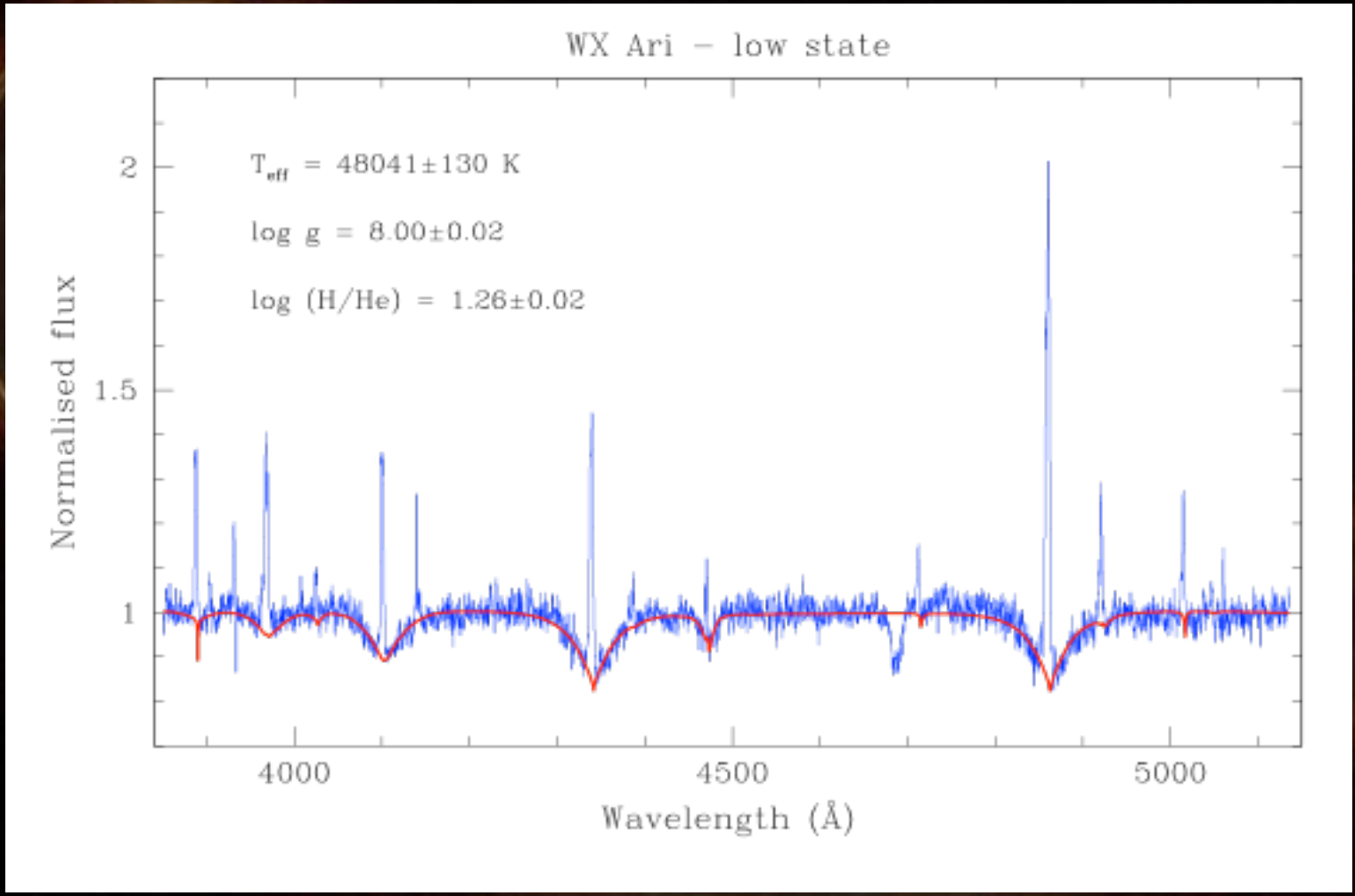
WX Arietis: the low state





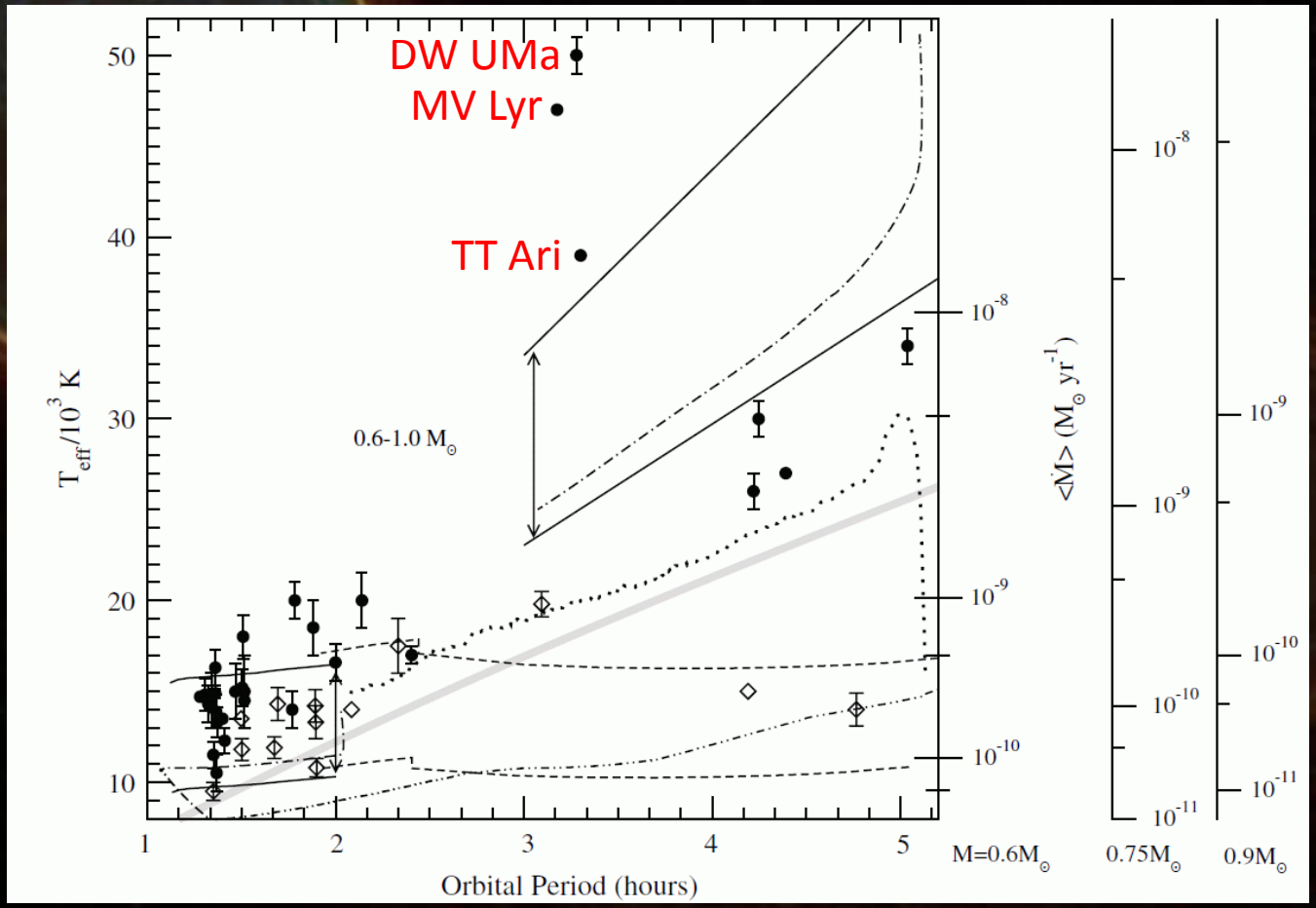


WX Arietis: the low state



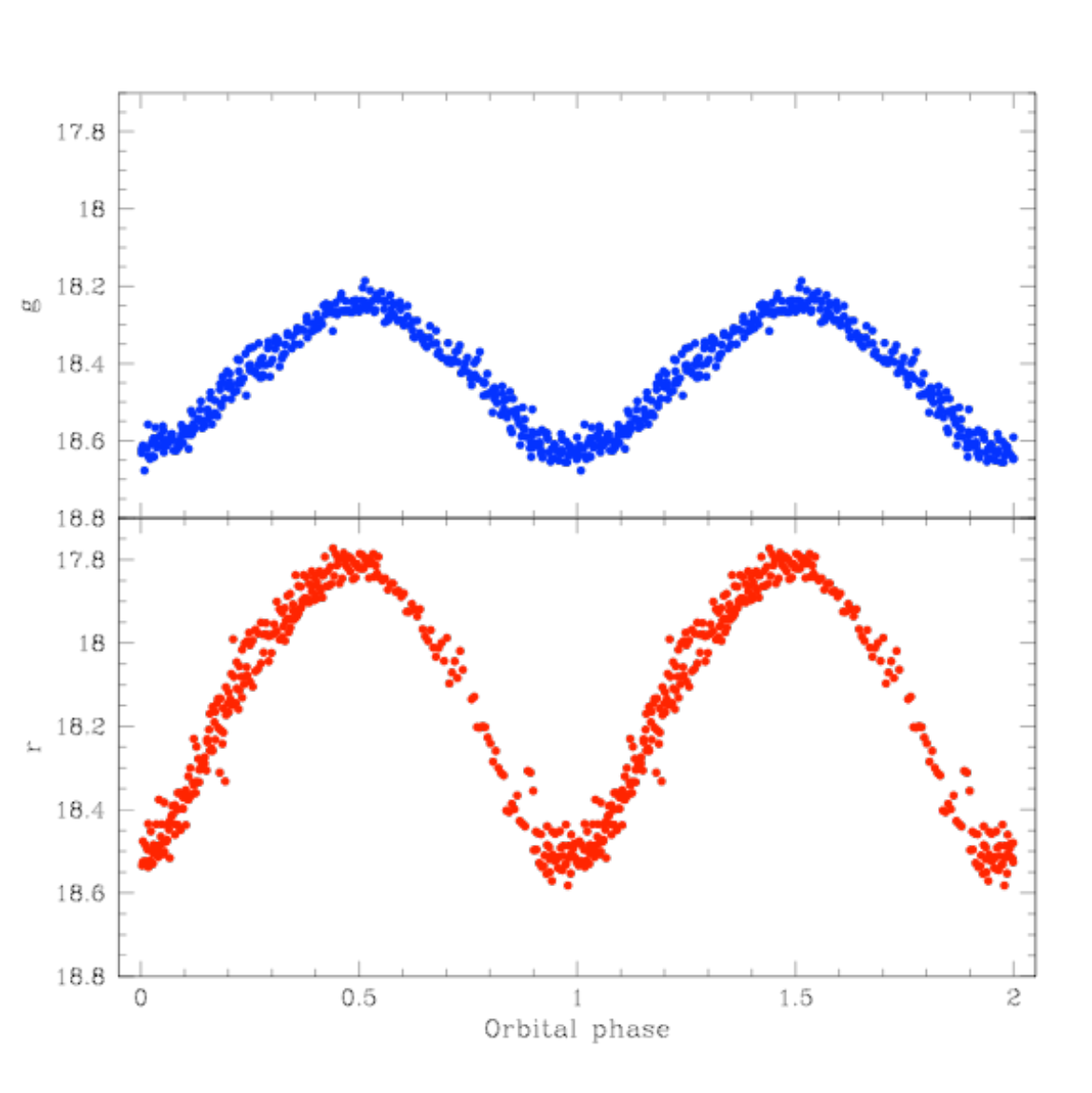
Mass transfer rate ($\dot{M}$) from T_1

$$T_{\rm eff} = 1.7 \times 10^4 \ {\rm K} \left(\frac{\langle \dot{M} \rangle}{10^{-10} \ M_\odot \ {\rm yr}^{-1}} \right)^{1/4} \left(\frac{M}{0.9 \ M_\odot} \right)$$

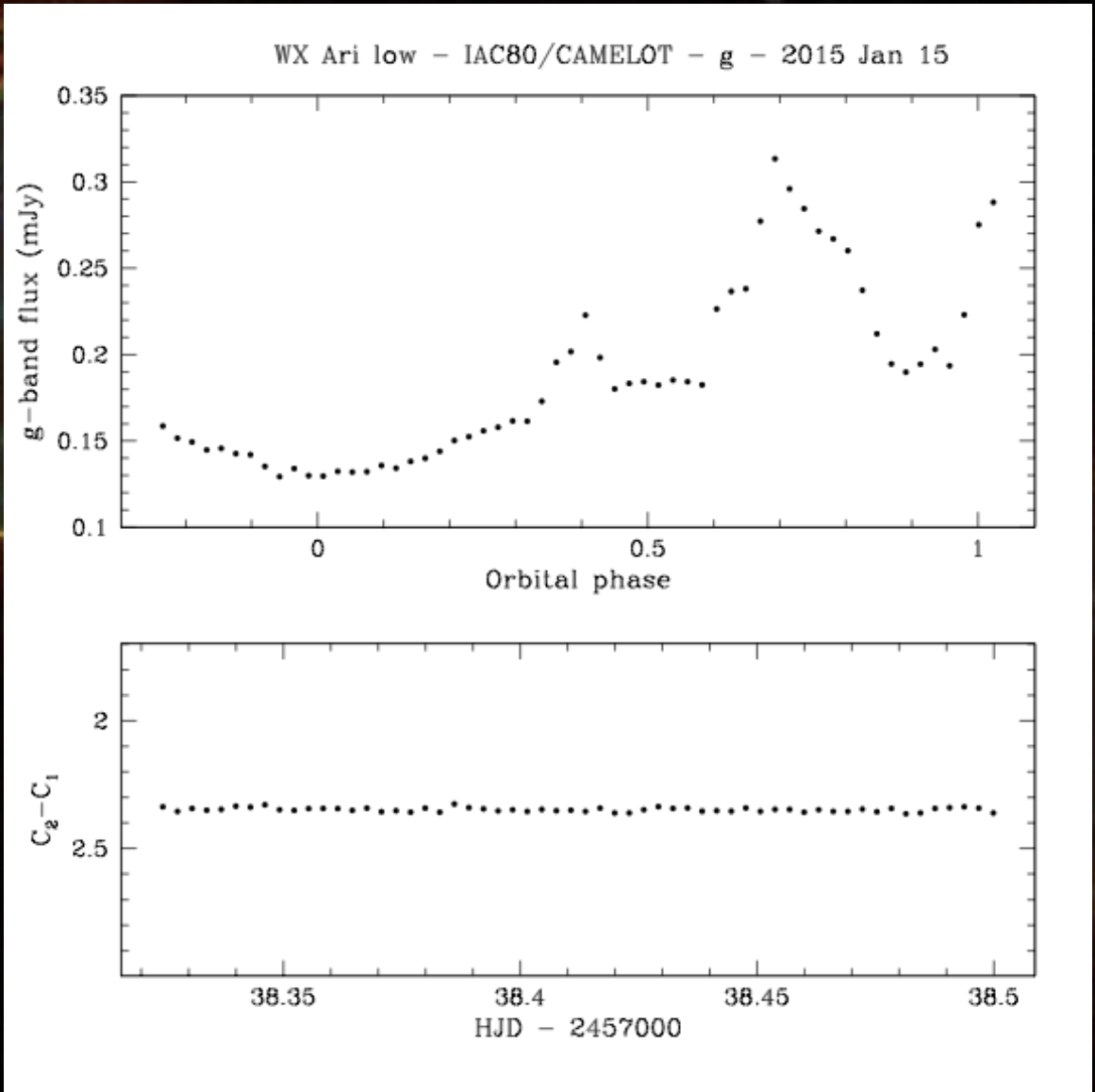


Townsley & Gänsicke, 2009, ApJ, 693, 1007

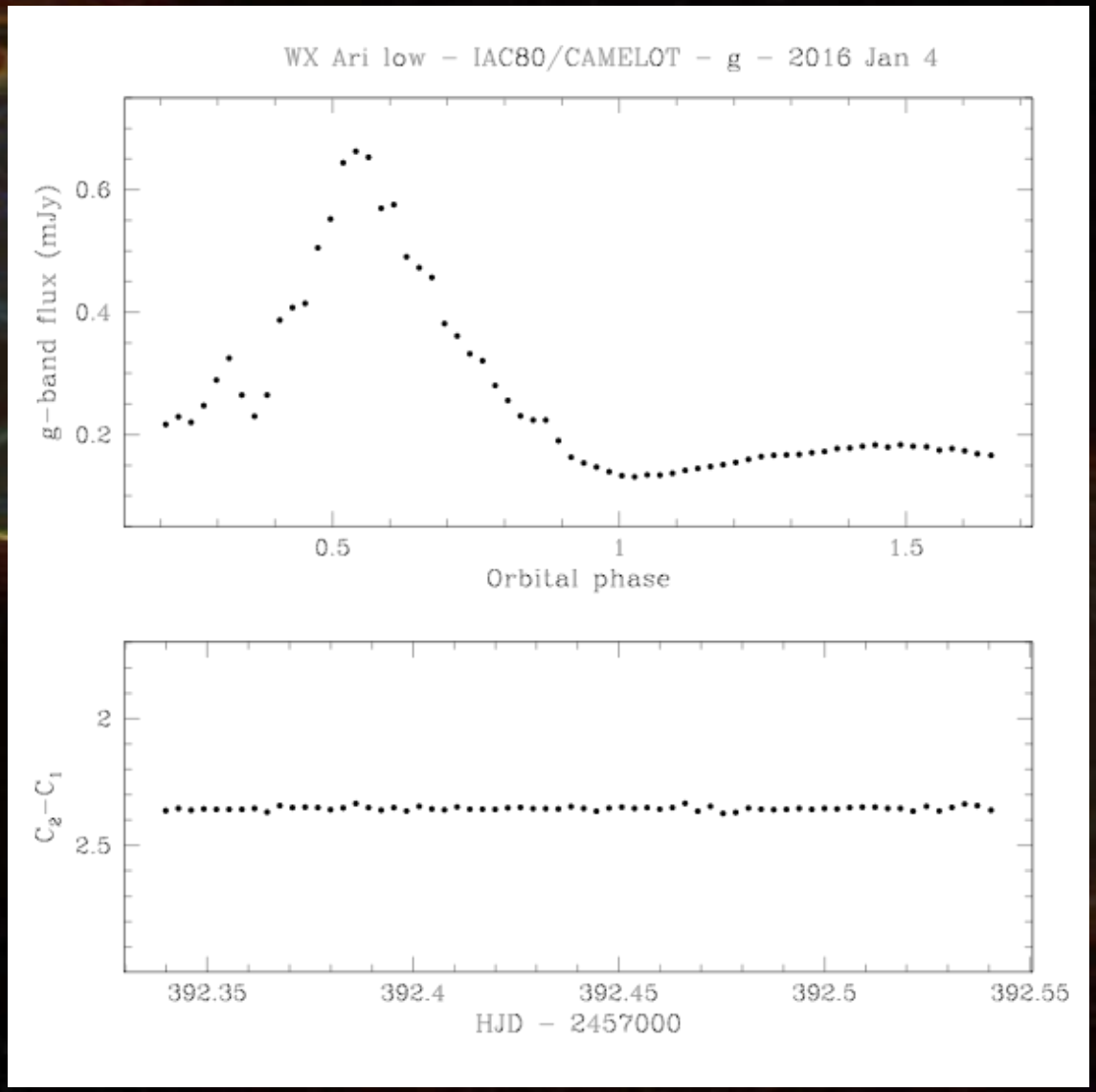
WX Arietis: the low state



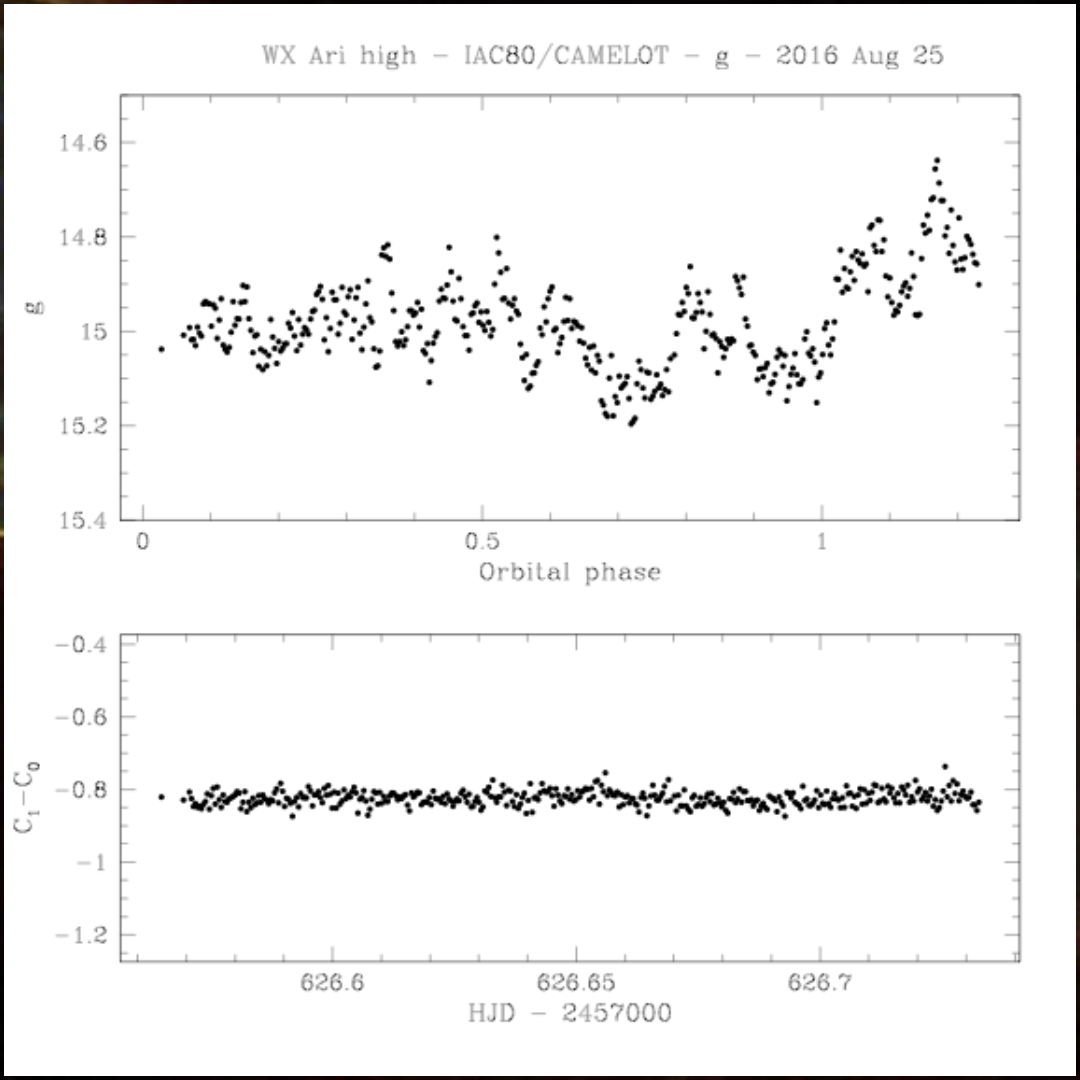
WX Arietis: any ideas?



WX Arietis: any ideas?



WX Arietis: back to the high state!



Thanks!

Linda Schmidtobreick (ESO)

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Knox Long (STScI)

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Detlev Koester (Kiel)

Mattias Schreiber (Valparaíso)