Parameters of 2MASS J16211735+4412541 in quiescent state

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Observing techniques, instrumentation and science for metre-class telescopes II
Stara Lesna, Sep 24-28th

JAGIELLONIAN UNIVERSITY IN KRAKOW

Mt. Suhora Observatory
Cracow Pedagogical University

Talk layout

- J16211735+4412541 a cataclysmic binary in disguise
- Outburst in 2016 – revealing its true nature
- Follow-up LCs in quiescence
- Primary and accretion disk parameters in quiescent state
- Conclusions

2MASS J16211735+441254

other query modes : Identifier query | Coordinate query | Criteria query | Reference query | Basic query | Script submission | TAP | Output options | Help

Available data : Basic data • Identifiers • Plot & images • Bibliography • Measurements • External archives • Notes • Annotations

Basic data :

2MASS J16211735+4412541 -- Eclipsing binary of W UMa type

Other object types: EB? (Ref), WU* (Ref), EB* (Ref), V* (1SWASP), * (Gaia), IR (2MASS)

ICRS coord. *(ep=J2000)* : 16 21 17.3558270836 +44 12 54.125151508 (Optical) [0.0194 0.0243 90] A 201

FK4 coord. *(ep=B1950 eq=1950)* : 16 19 42.6402205924 +44 19 56.330183751 [2.5001 1.8501 0]

Gal coord. *(ep=J2000)* : 069.4949893981366 +44.9610631566595 [0.0243 0.0194 0]

Proper motions *mas/yr* : 6.602 -15.507 [0.037 0.050 90] A 2018yCat.1345....0G

Parallaxes *(mas)*: 3.7643 [0.0260] A 2018yCat.1345....0G

Fluxes (10) :

V 15.03 [~] V3 D 2014ApJS..213....9D
G 15.0349 [0.0116] C 2018yCat.1345....0G
J 13.462 [0.027] C 2003yCat.2246....0C
H 12.875 [0.023] C 2003yCat.2246....0C
K 12.763 [0.025] C 2003yCat.2246....0C
u (AB) 17.538 [0.010] B 2012ApJS..203...21A
g (AB) 15.759 [0.003] B 2012ApJS..203...21A
r (AB) 14.921 [0.003] B 2012ApJS..203...21A
i (AB) 14.563 [0.003] B 2012ApJS..203...21A
z (AB) 14.372 [0.004] B 2012ApJS..203...21A

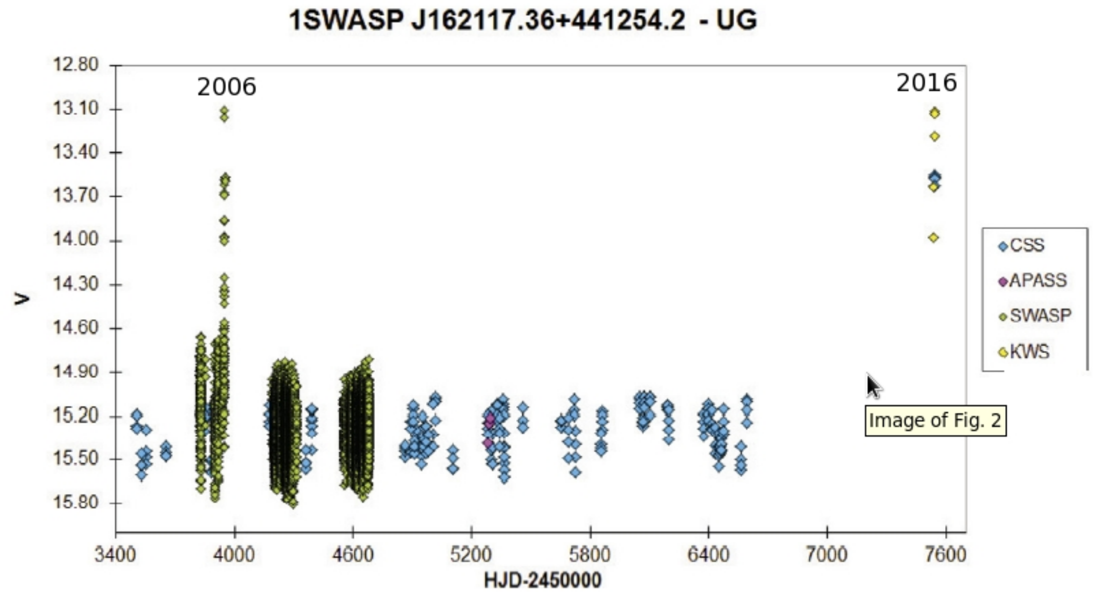
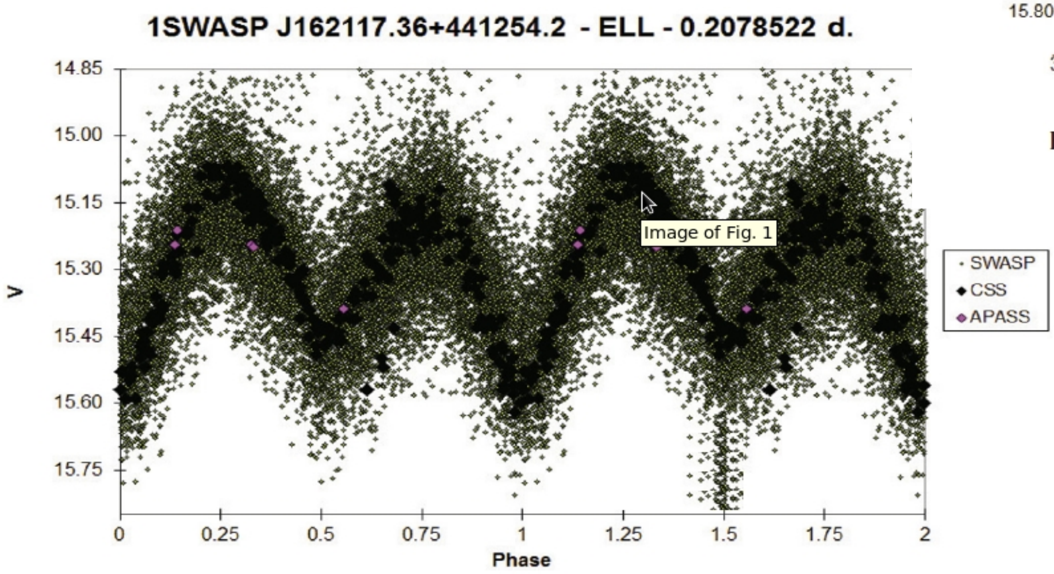


Fig. 2. Two outbursts of J1621 (from the VSX database, https://www.aavso.org/vsx/).

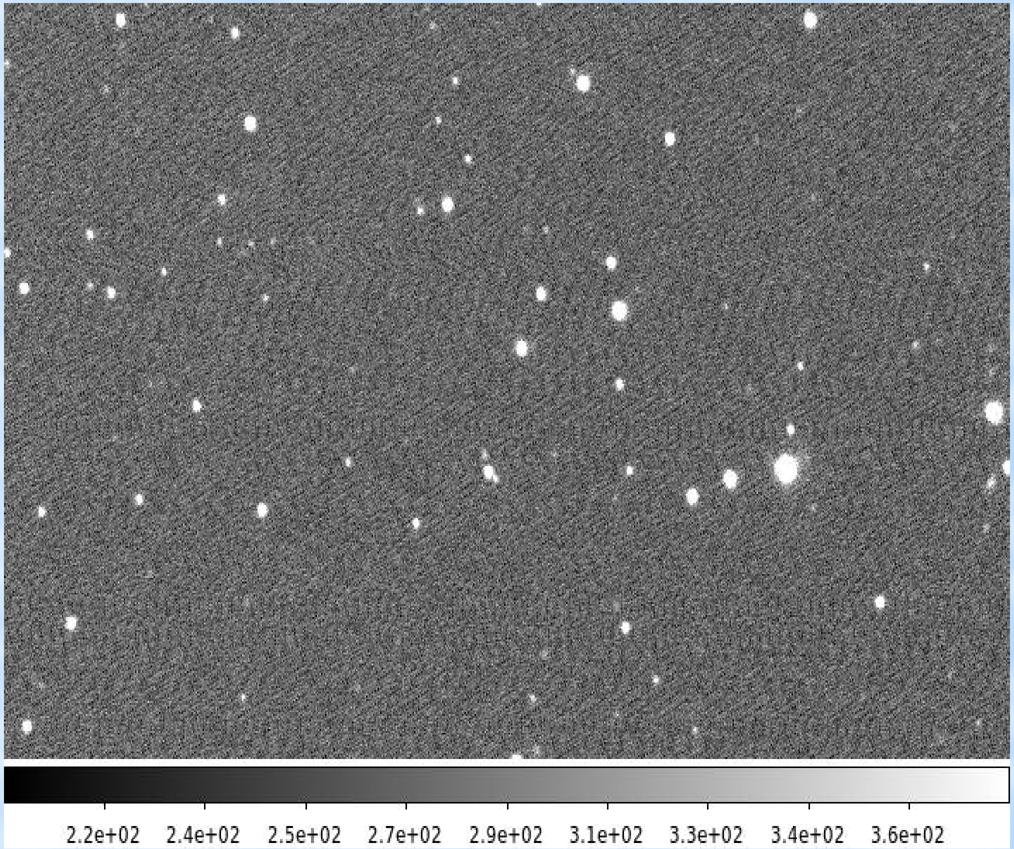
D.P. Kjurkchieva et al. / New Astronomy 52 (2017) 8–13



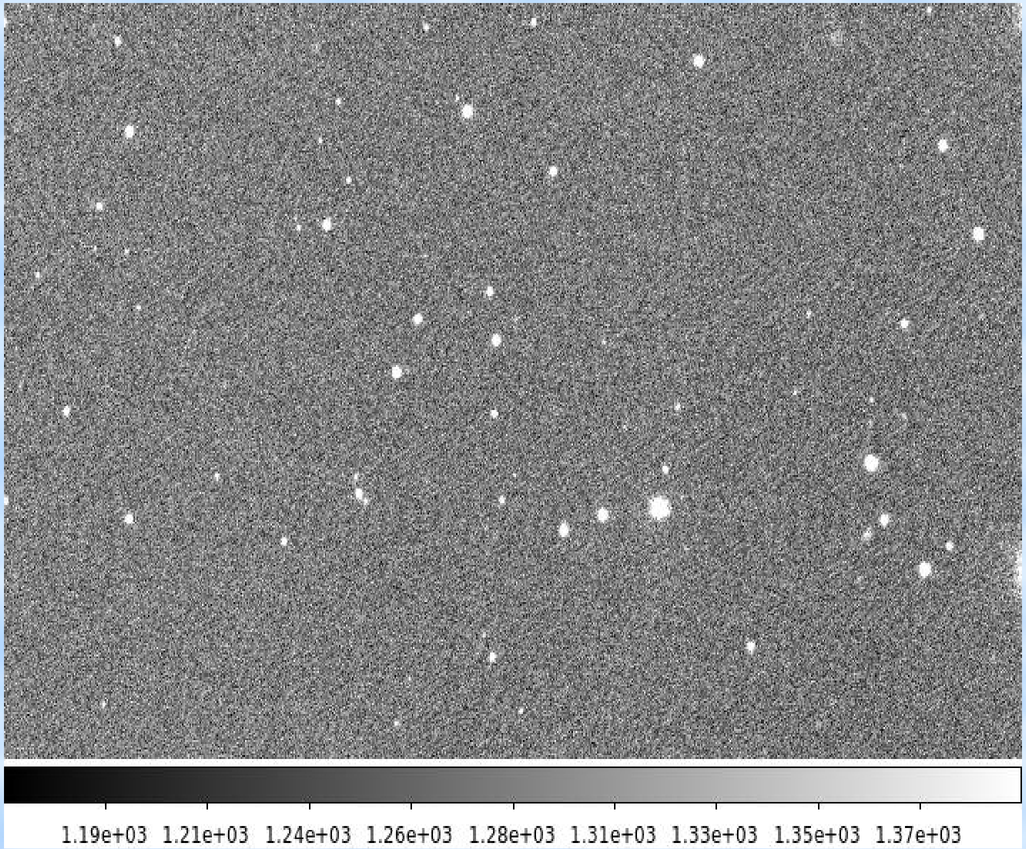
SDSS colors consistent with MS+MS binary (Drake et al. 2016)

2MASS J16211735+4412541

Outburst (June 2016)



Quiescence (July 2016)



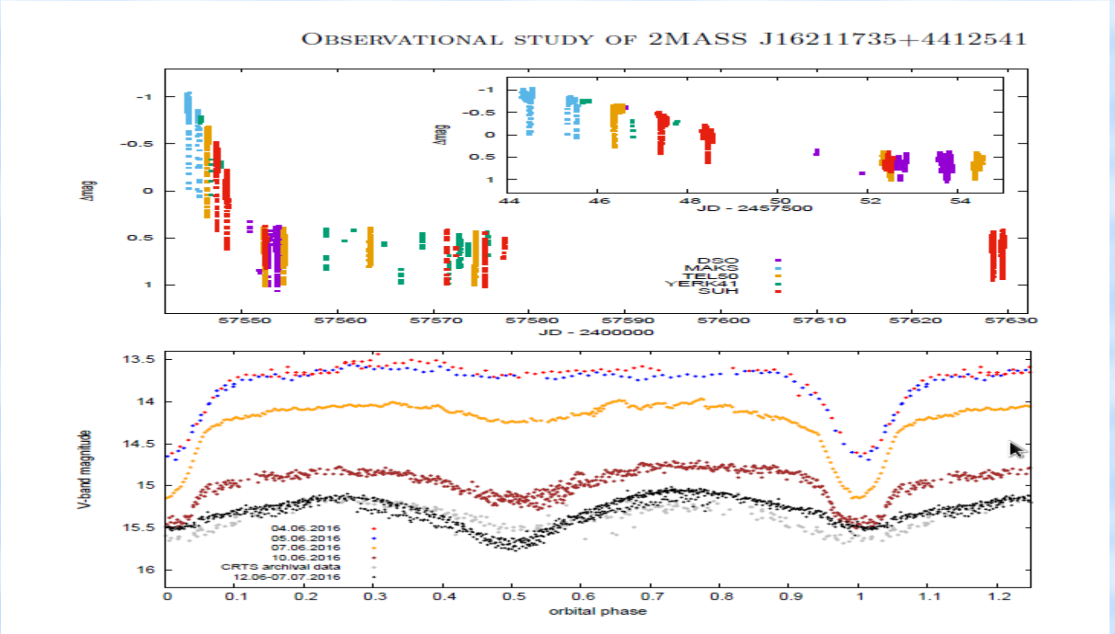
Observations
Outburst ground photometry

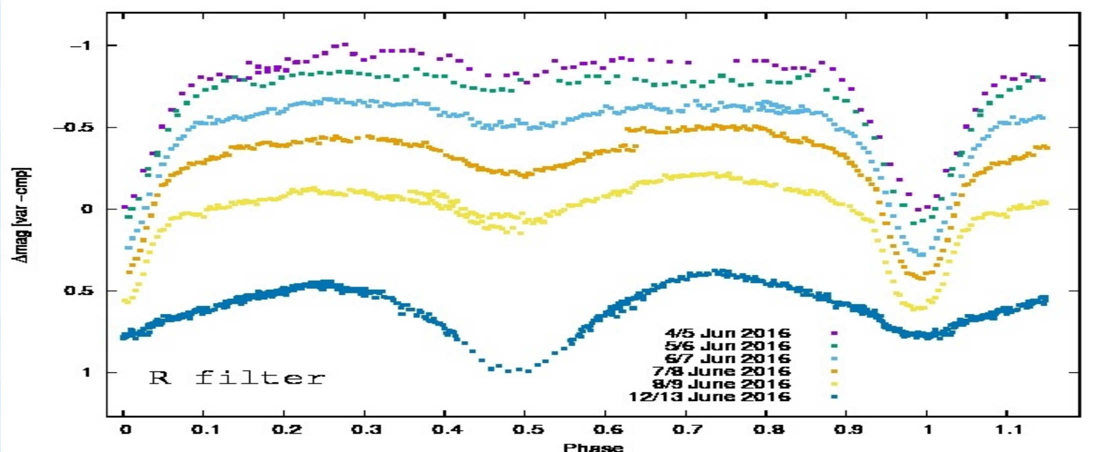
On June 4th an outburst detected by the Catalina Sky Survey

This was ~2 mags rise in brightness in the R filter (Drake at al. ATEL # 9112)

followed by a drop to pre-outburst level after less than 2 weeks since brightening detection

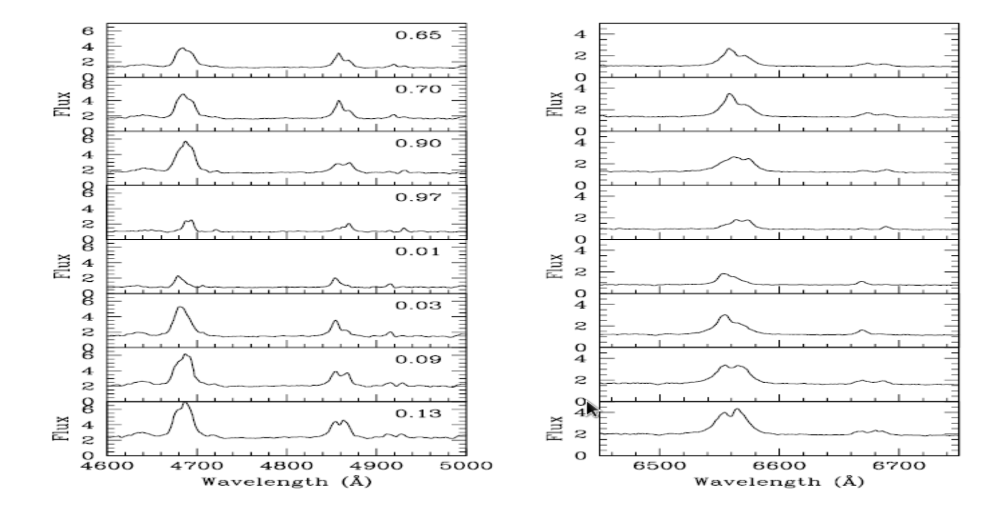
Several observers reported data:
Meahara et al. #9113, Scaringi et al. #9122, Zejda&Pejcha #9132, Thorstensen #9141 (RV), Zola et al. #9161 (end of outburst)

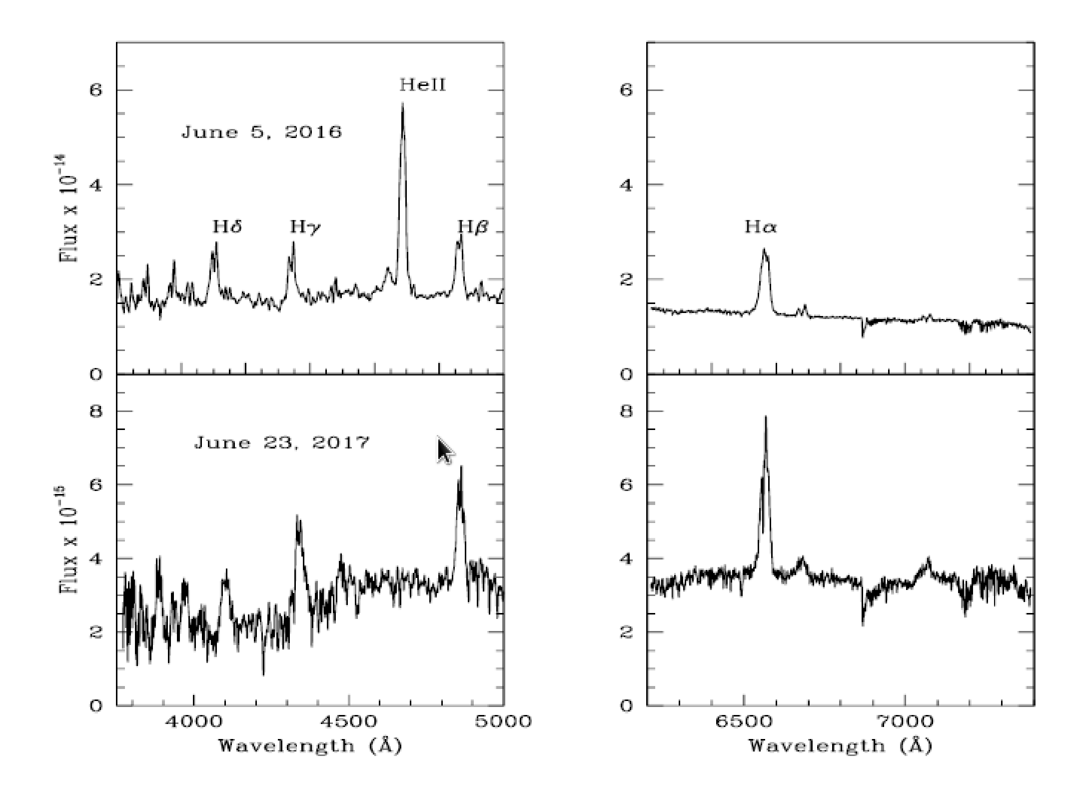




Observations
high resolution spectroscopy

Spectra taken with 3.5m telescope at APO (NM, USA)





double-peaked emission lines seen

(Zola et al 2017)

Observations
Swift X, UV

Swift observed this binary on June 10 and 14 (dedicated ToO program, XRT and UVOT), follow up observations taken in January 2017 (13, 16 & 19)

- Positive detection in X-rays
- Brightness measured in UBV as well as UVW1 and UVW2 filters

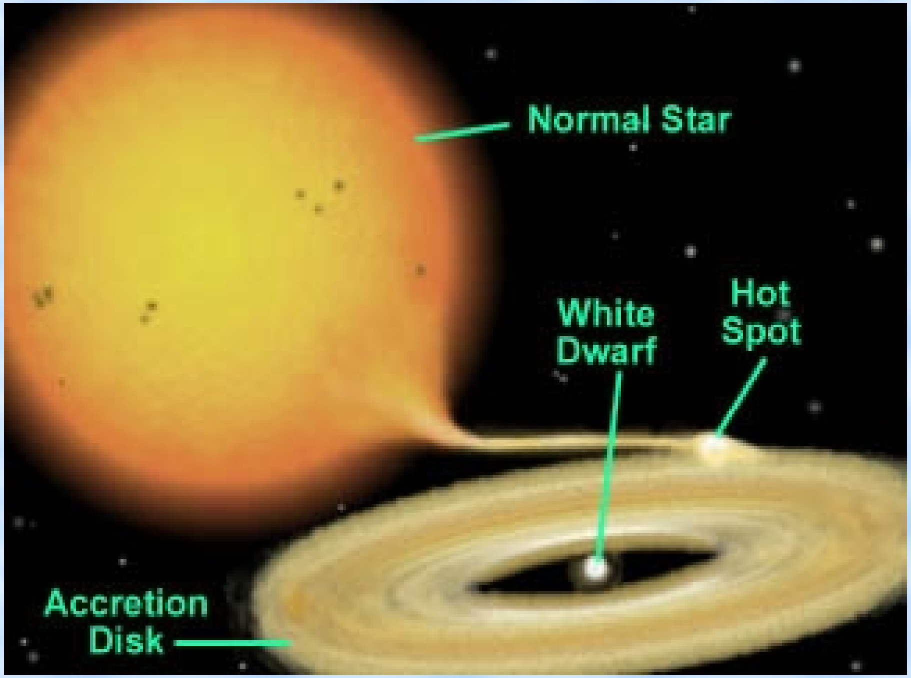
Table 1. Summary of the *Swift* UVOT observations of 2MASS J16211735+4412541. Fν given in units of erg cm^{-2} s^{-1} Hz^{-1}.

Date	UT	Band	Exp. [s]	Mag	de-reddened Mag	F(ν)	$\log_{10}\nu$
2016.06.10	10:24:56	UVW2	75.939	16.05	15.97 ± 0.09	$(3.01 \pm 0.24) \times 10^{-27}$	15.169
2016.06.10	10:31:55	UVM2	1283.49	16.07	15.99 ± 0.04	$(3.10 \pm 0.12) \times 10^{-27}$	15.129
2016.06.10	10:17:29	UVW1	75.946	16.12	16.06 ± 0.09	$(3.35 \pm 0.26) \times 10^{-27}$	15.063
2016.06.10	10:19:57	U	75.9439	15.42	15.38 ± 0.04	$(1.02 \pm 0.04) \times 10^{-26}$	14.933
2016.06.10	10:27:24	V	75.9438	15.05	15.02 ± 0.04	$(3.56 \pm 0.14) \times 10^{-26}$	14.744
2016.06.10	10:22:26	B	76.0405	15.62	15.58 ± 0.04	$(2.36 \pm 0.08) \times 10^{-26}$	14.840
2016.06.14	19:51:40	UVW2	147.305	17.43	17.35 ± 0.10	$(8.50 \pm 0.80) \times 10^{-28}$	15.169
2016.06.14	19:59:17	UVM2	147.311	17.68	17.60 ± 0.15	$(7.00 \pm 1.00) \times 10^{-28}$	15.129
2016.06.14	20:03:07	UVW1	147.312	17.01	16.95 ± 0.09	$(1.48 \pm 0.12) \times 10^{-27}$	15.063
2016.06.14	20:06:55	U	115.704	16.32	16.28 ± 0.05	$(4.45 \pm 0.22) \times 10^{-27}$	14.933
2016.06.14	19:55:28	V	147.312	15.21	15.18 ± 0.04	$(3.08 \pm 0.12) \times 10^{-26}$	14.744
2017.01.13	01:35:52	UVW2	477.292	17.81	17.73 ± 0.08	$(5.96 \pm 0.42) \times 10^{-28}$	15.169
2017.01.16	18:39:48	UVW2	541.186	17.46	17.38 ± 0.07	$(8.22 \pm 0.51) \times 10^{-28}$	15.169
2017.01.19	11:49:10	UVW2	519.371	17.76	17.68 ± 0.08	$(6.24 \pm 0.44) \times 10^{-28}$	15.169

A cataclysmic variable or a red dwarf nova?

SWIFT (and GALEX) magnitudes indicate WD+MS system

A semi-detached configuration system pretends to be a contact configuration one



credit: K. Smale

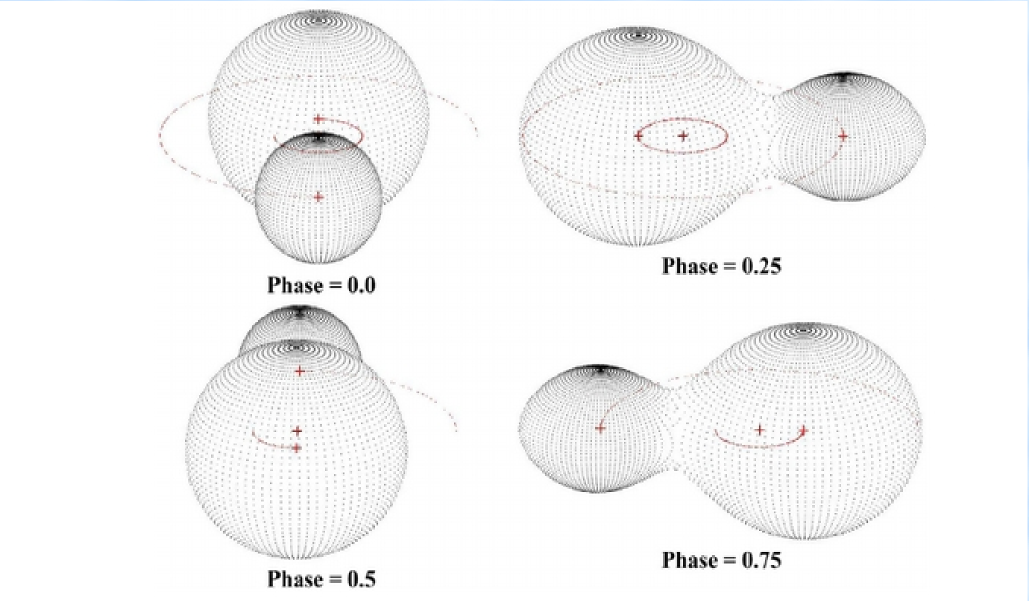
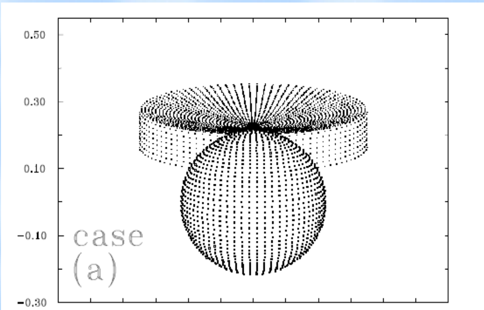


Fig. 7 The shape of the system GSC 1283-53 at phases 0.0, 0.25, 0.50, and 0.75 in *V*-band.

Essam et al. 2013

(Very old) Light curves simulations



High inclinations: Zola, A&A (1995)

contact configuration obtained as best fit if disk light contribution is low

parameters spurious

Table 1. Input values of parameters used to calculate the light curves

parameter	case (a)	case (b)	case (c)
Ω_2	2.2327	2.2327	2.2327
L_2	11.3683	9.8651	8.1045
Disk parameters			
T_{out}	1900K	3000K	3600K
l_d	2%	15%	30%

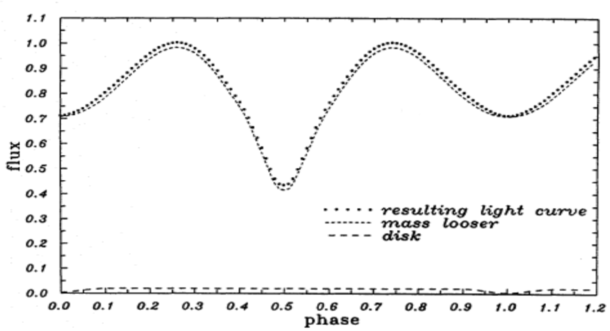


Fig. 1. Light curve in case (a)

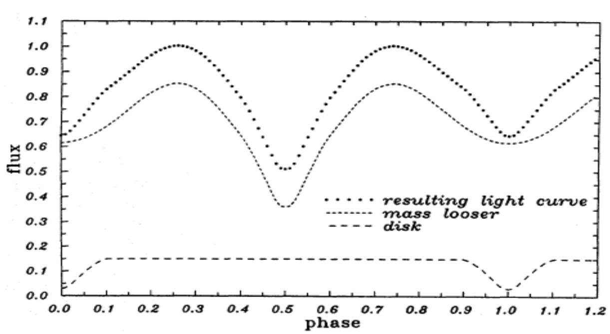


Fig. 2. Light curve in case (b)

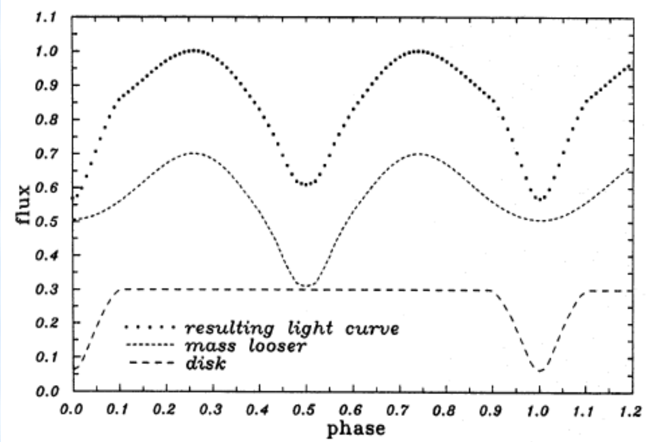


Table 2. Parameters derived from modeling

	case (a)	case (b)	case (c)
configuration	contact	contact	semidetached
i	78°	76°	75°
$g_1 = g_2$	0.888	* 0.320	* 0.320
$A_1 = A_2$	* 0.50	* 0.50	* 0.50
T_1	* 3900K	* 3900K	3950K
T_2	2840K	3540K	* 3900K
q	0.49	0.59	1.02
Ω_1	2.81	2.98	3.86
Ω_2	* 2.813	* 2.980	* 3.782
L_1	11.615	8.809	5.749
L_2	* 0.528	* 2.845	* 5.930

* - not adjusted

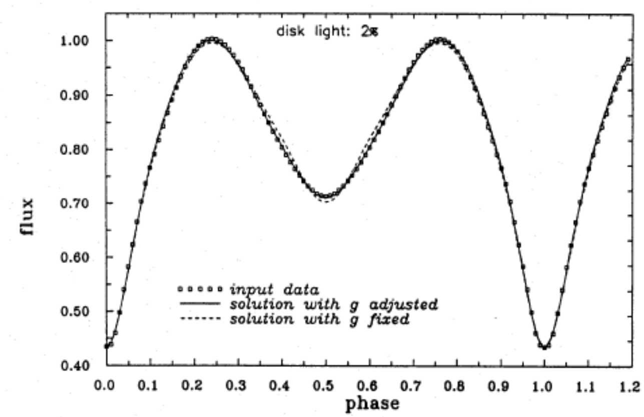
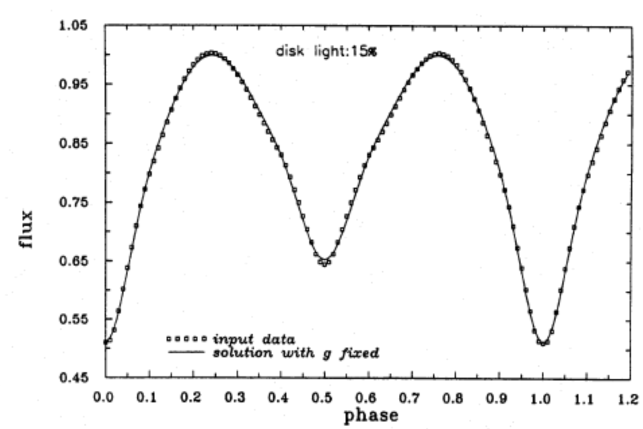


Fig. 4. Input data (squares) and light curves obtained from modeling in case (a)



Proposed models

Kjurkchieva et al. 2017

Archival and 2016 photometry analyzed with

the W-D code

Models for outburst and quiescence proposed:

a very large (0.1 R☼), cool WD (~4000K) + K-type MS star

No accretion disk at quiescence

Qian et al. 2017

outburst are caused by burst on the surface

of white dwarf due to increased mass transfer

cool spot on the secondary to cause

the deeper minimum

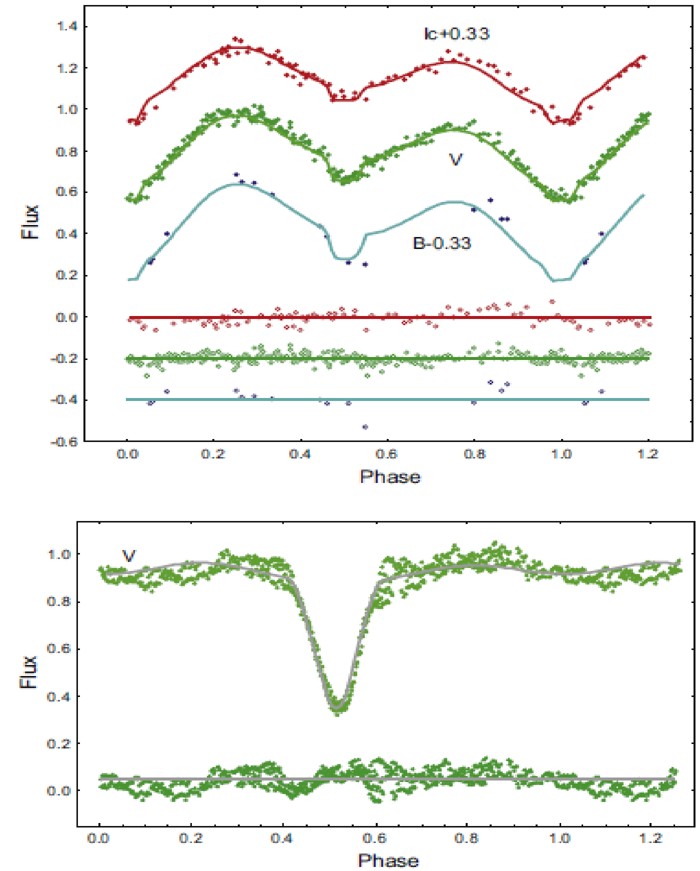
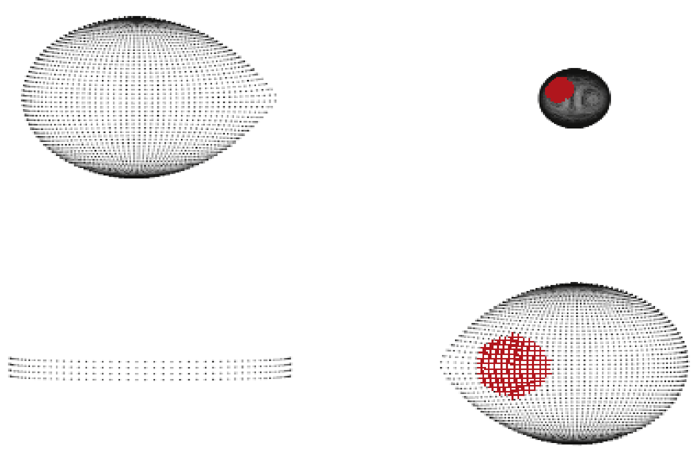


Fig. 6. Top: the IRIDA multicolor curves of J1621 at quiescence and their fits; bottom: the AAVSO light curve at outburst and its fit. The corresponding residual curves are shifted vertically by different amount for a good visibility. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)



Models

Kimura et al. 2018

Slow rise recorded

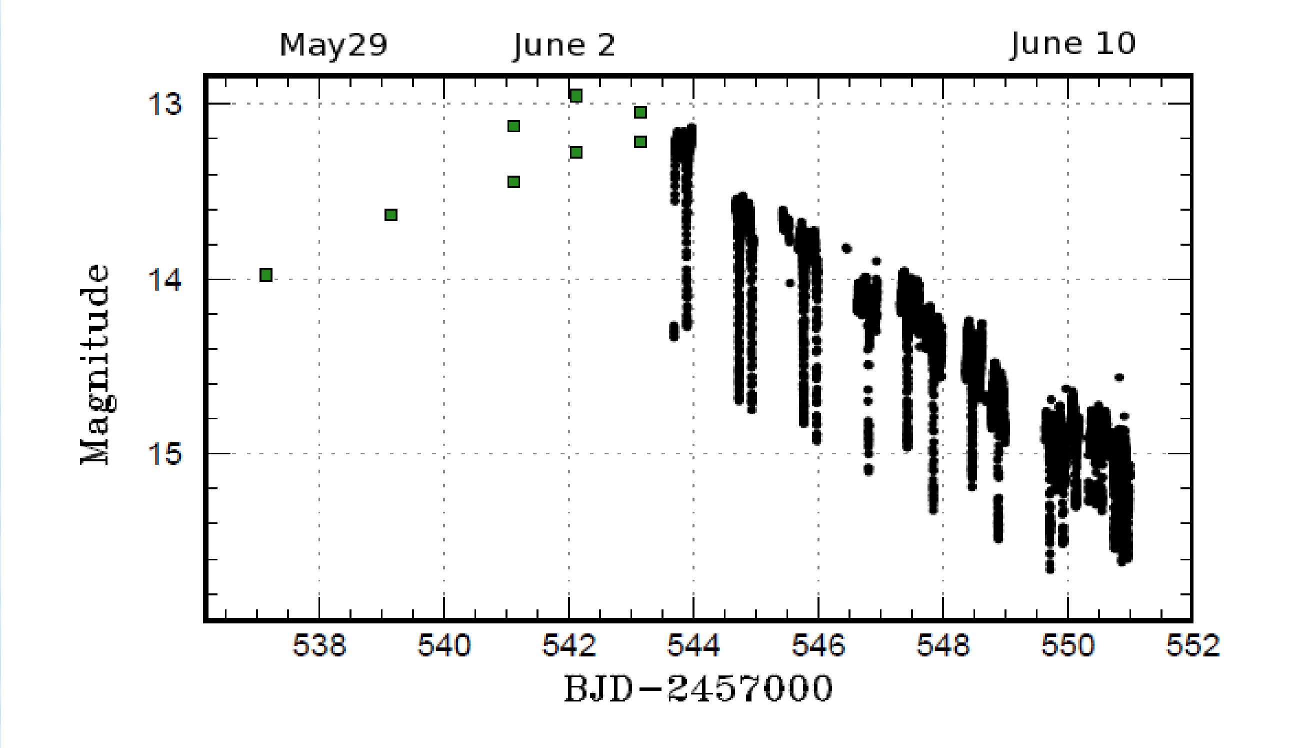
Cataclysmic variable with

an accretion disk

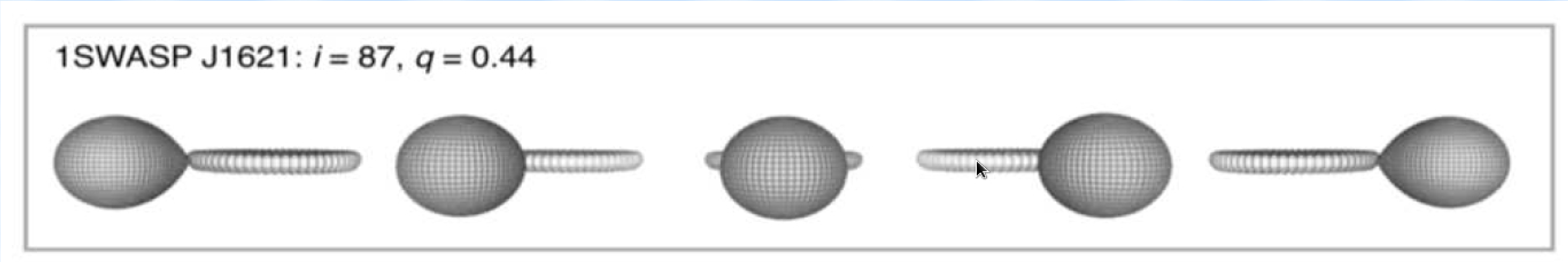
white dwarf + K star

high inclination: system

seen almost edge-on

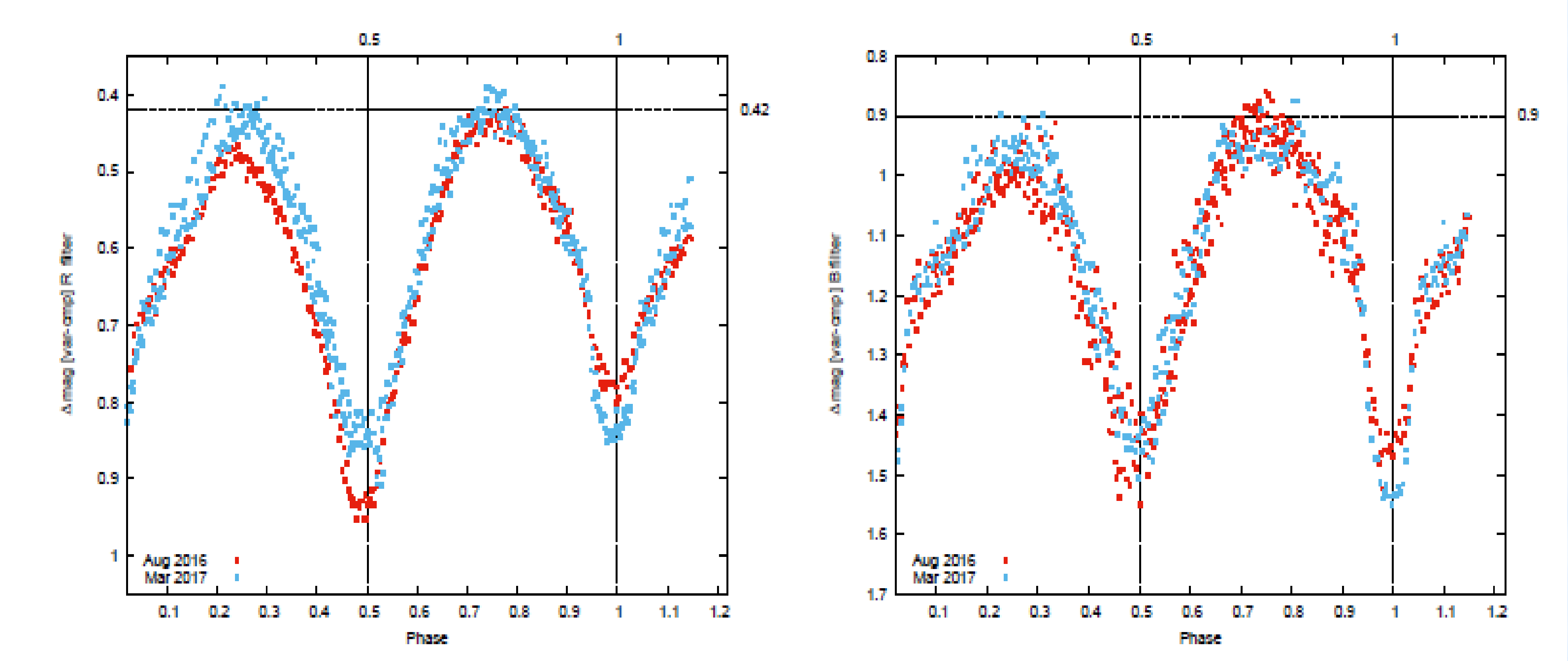


outburst of relatively low amplitude, low mass accretion rate leading to accumulation of mass in the disk –> instability triggered in the disk inner parts



Trial model – stars only

- Wilson-Devinney code with Monte Carlo search
- A spot must be introduced to account for different maxima heights in Aug 2016 (hot or cool?)



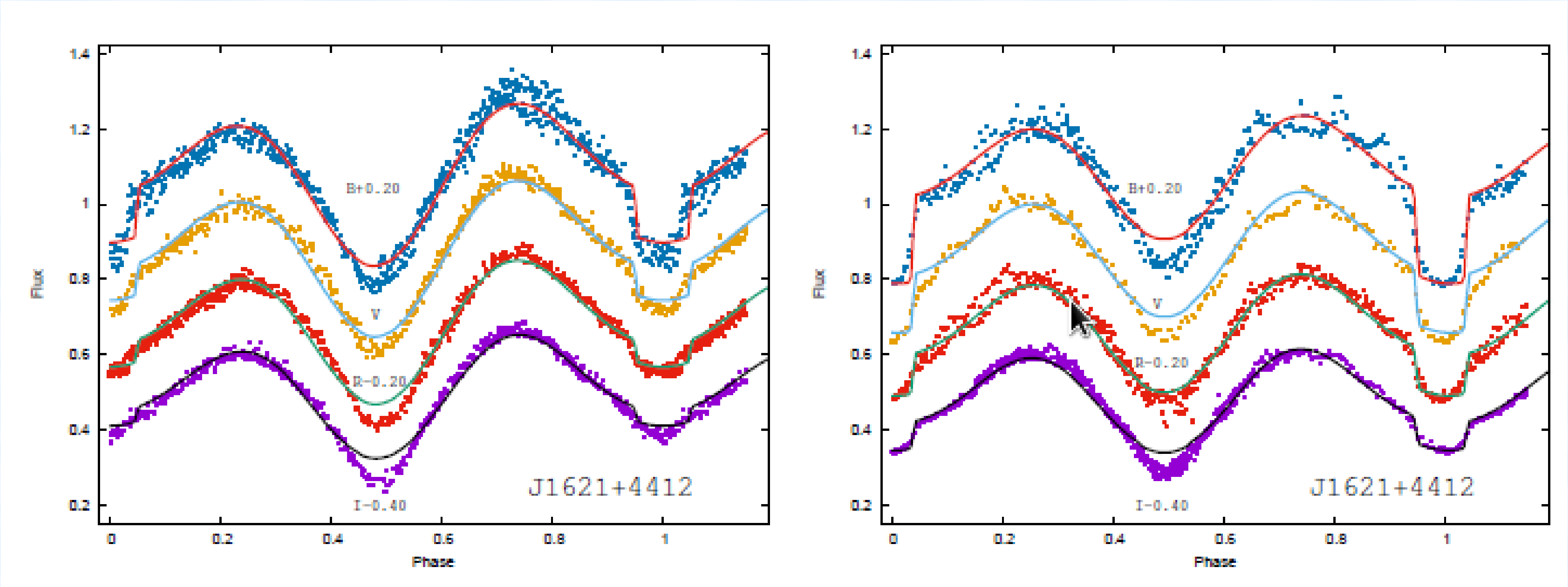
Cool spot (on the secondary) dominates but also a hot spot is present (likely on disk rim)

Trial model: results

S-D configuration with large primary, the secondary minimum depth too shallow

Component that obscures the other one at the secondary minimum (phase 0.5) must be flattened (Zola et al. 2017)

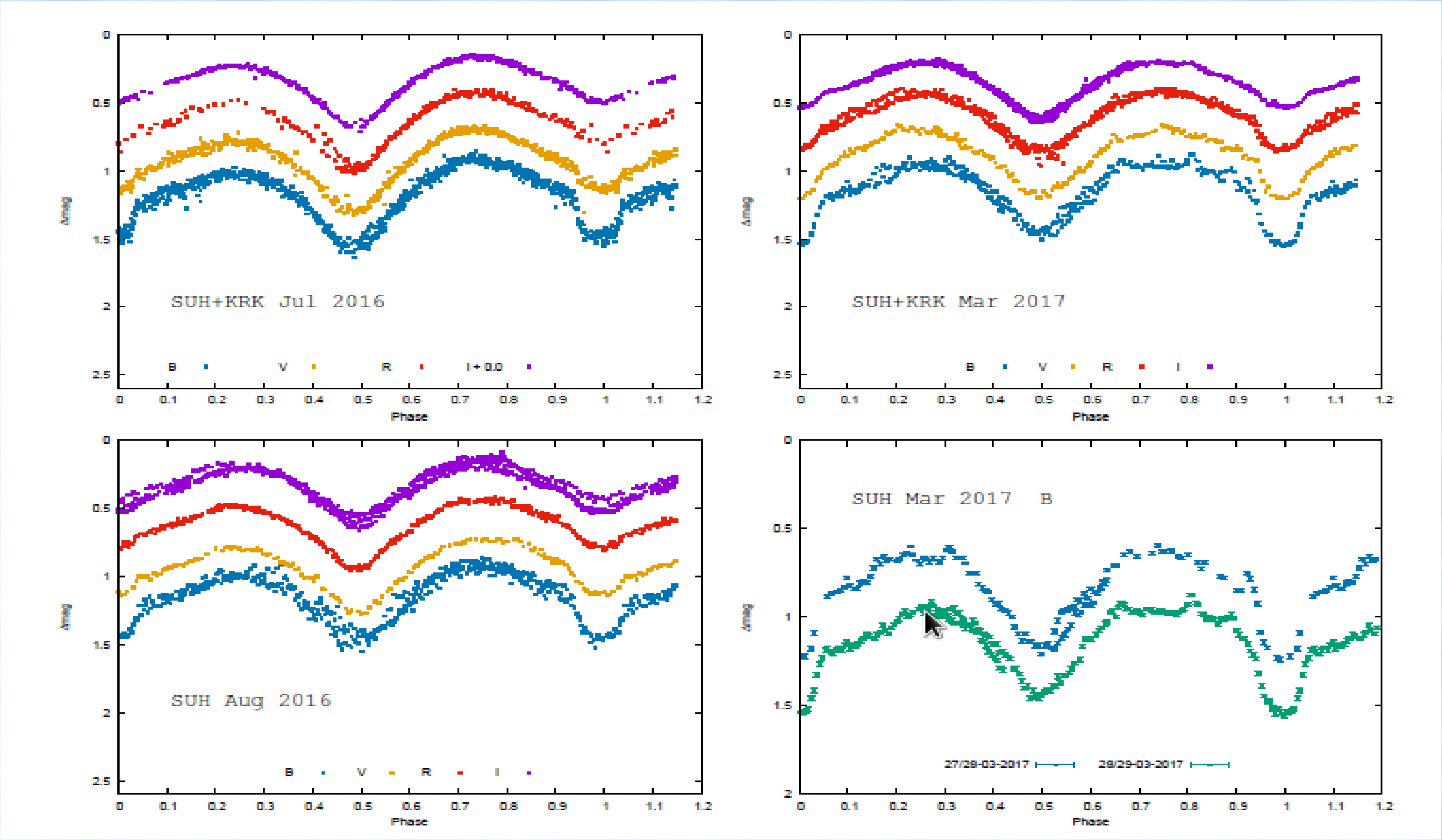
August 2016 March 2017



Follow-up observations
quiescent state photometry

Several complete BVRI light curves taken at the Mt. Suhora Observatory (Pedagogical Univ.) and Krakow (Jagiellonian Univ.) at least twice a year

2016: light curves taken ~2 and 3 month after outburst, next 9 month later



primary minimum

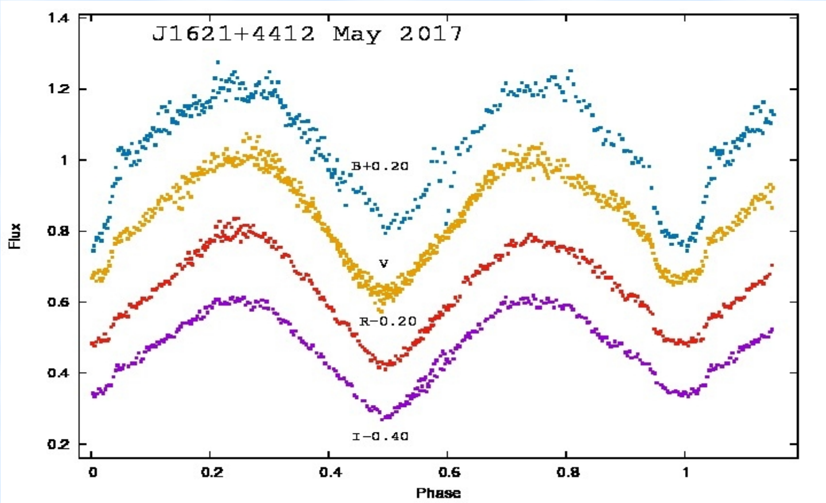
clearly visible

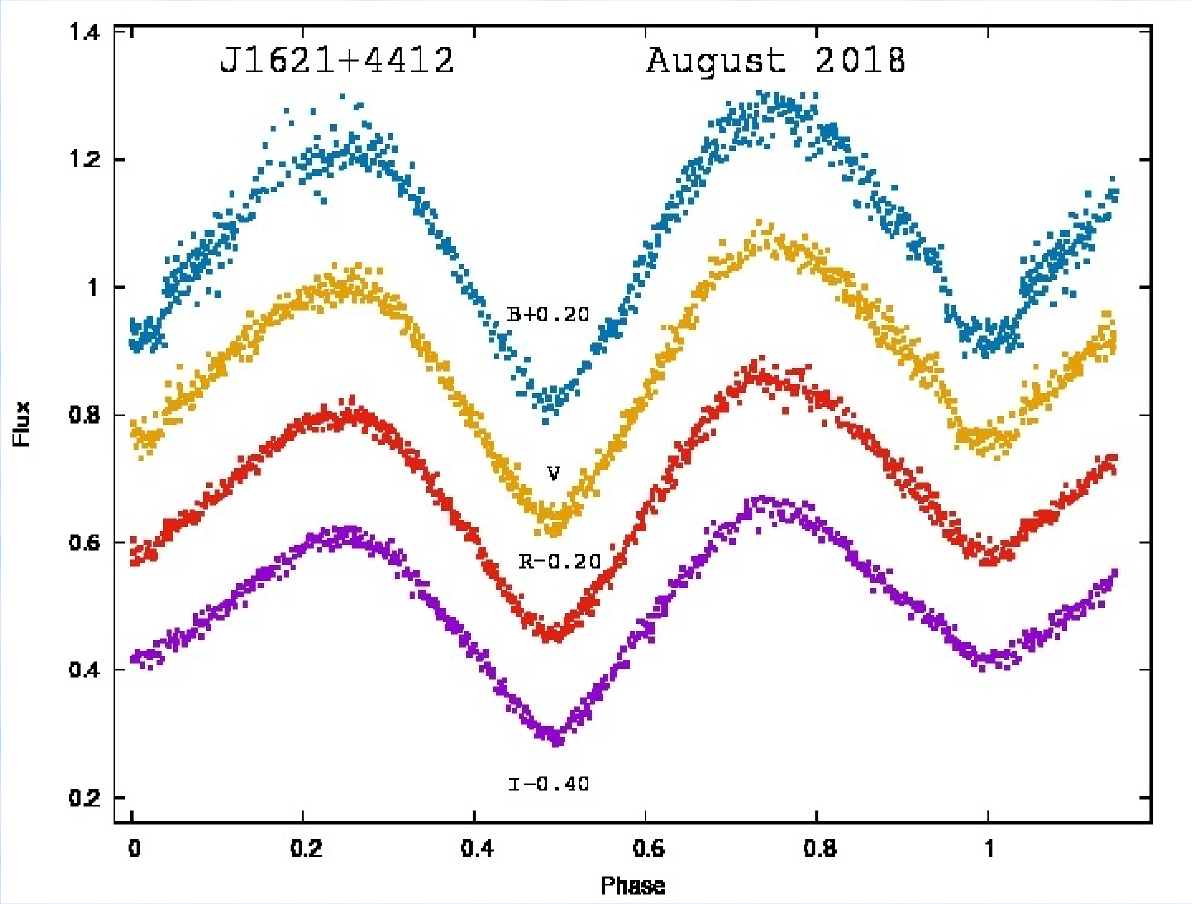
variable LC shape

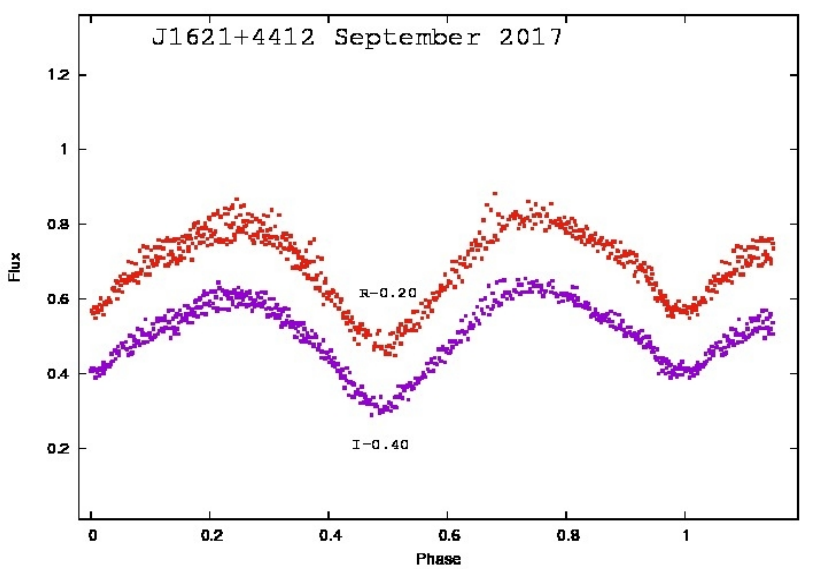
flickering

Observations
quiescent state photometry

Observations extended to 2018 (most recent LC taken in August)

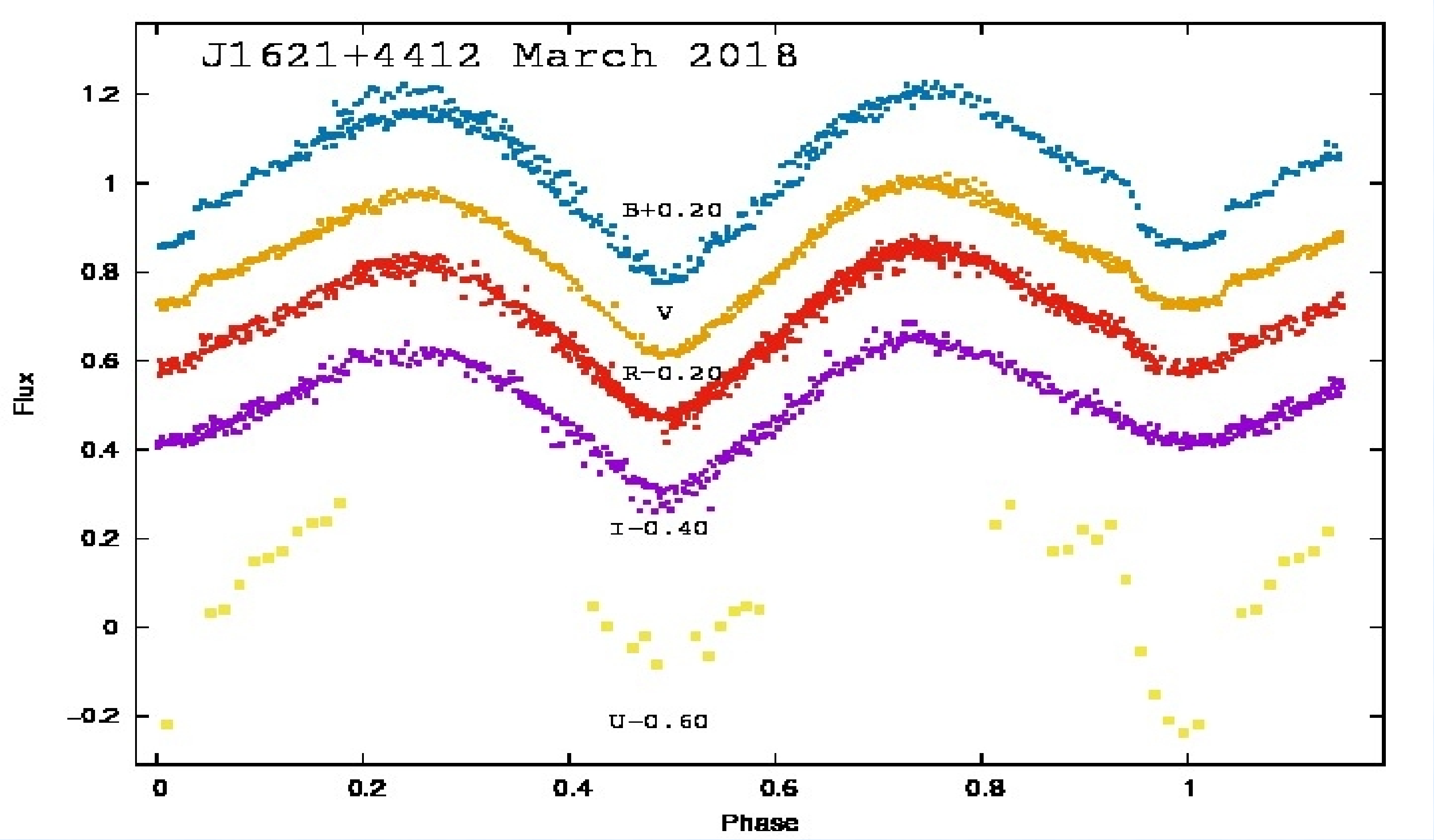






Observations
quiescent state photometry

In Mach 2018 we took data also in U filter

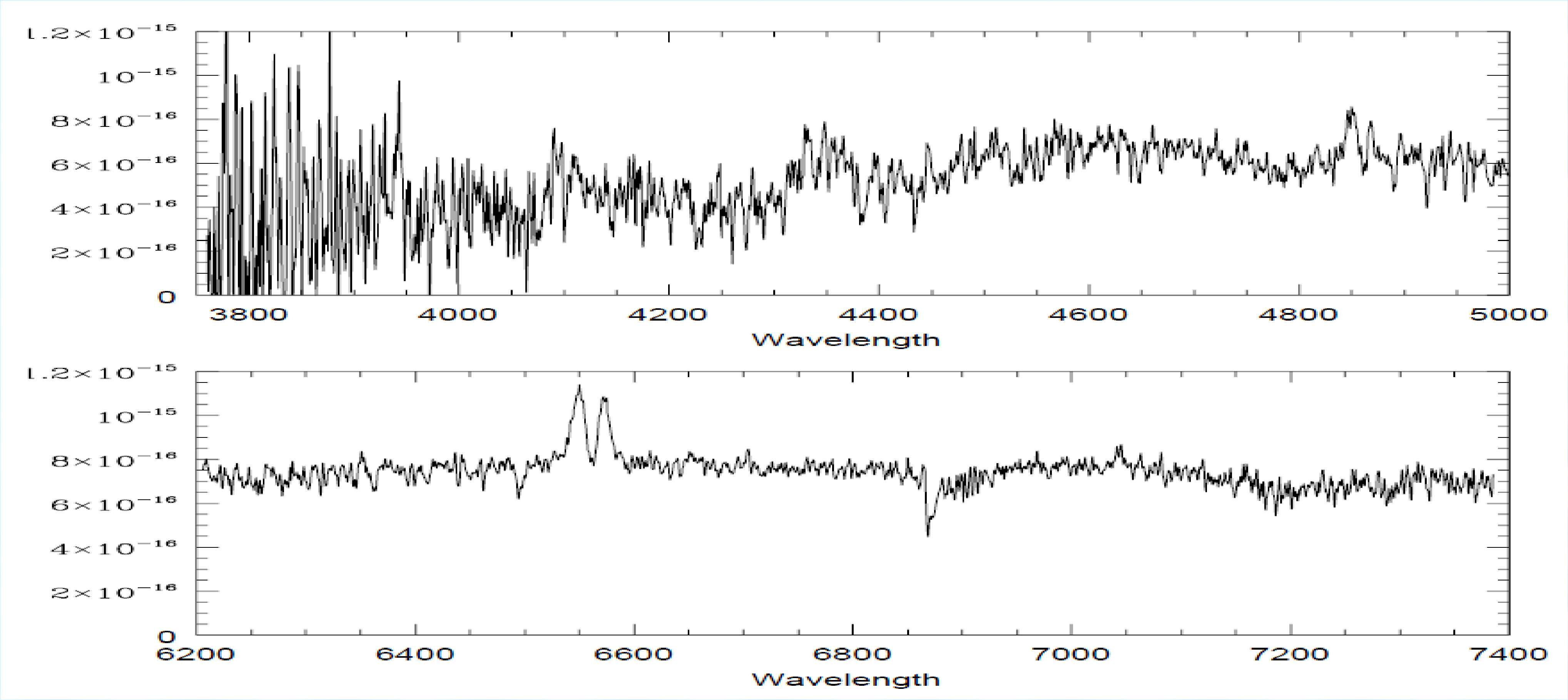


Pre-outburst BVR light curve taken in April 2016 available too (Qian et al. 2017)

Follow-up spectroscopy

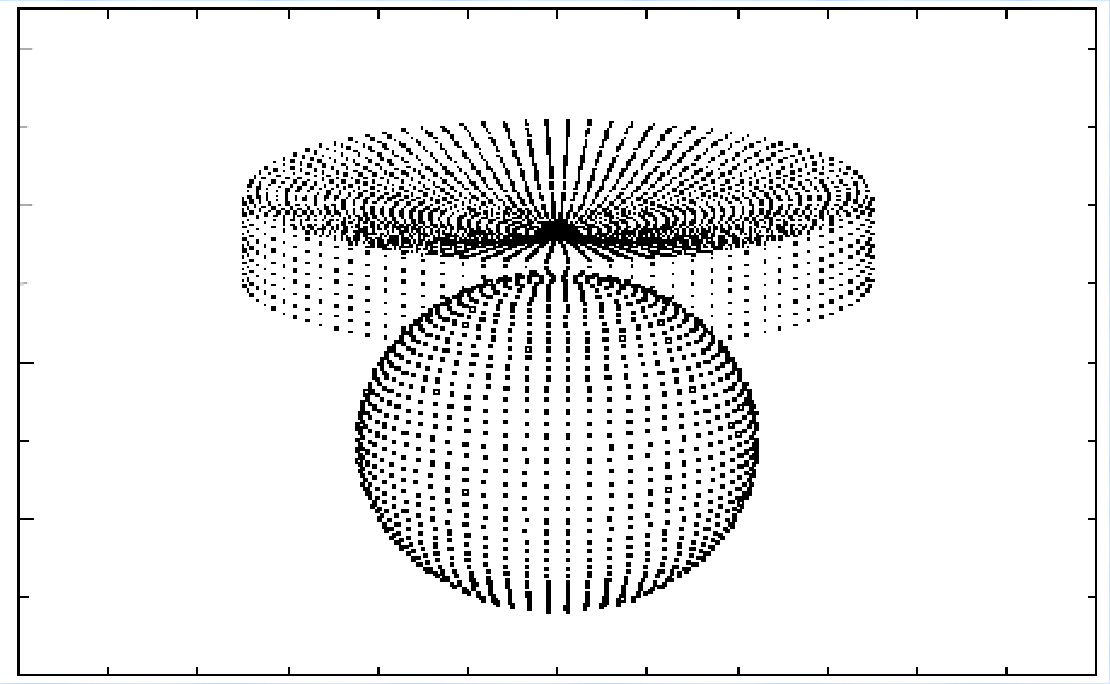
APO spectrum from June 2018

double peaked Balmer lines in emission → clear evidence for the disk presence



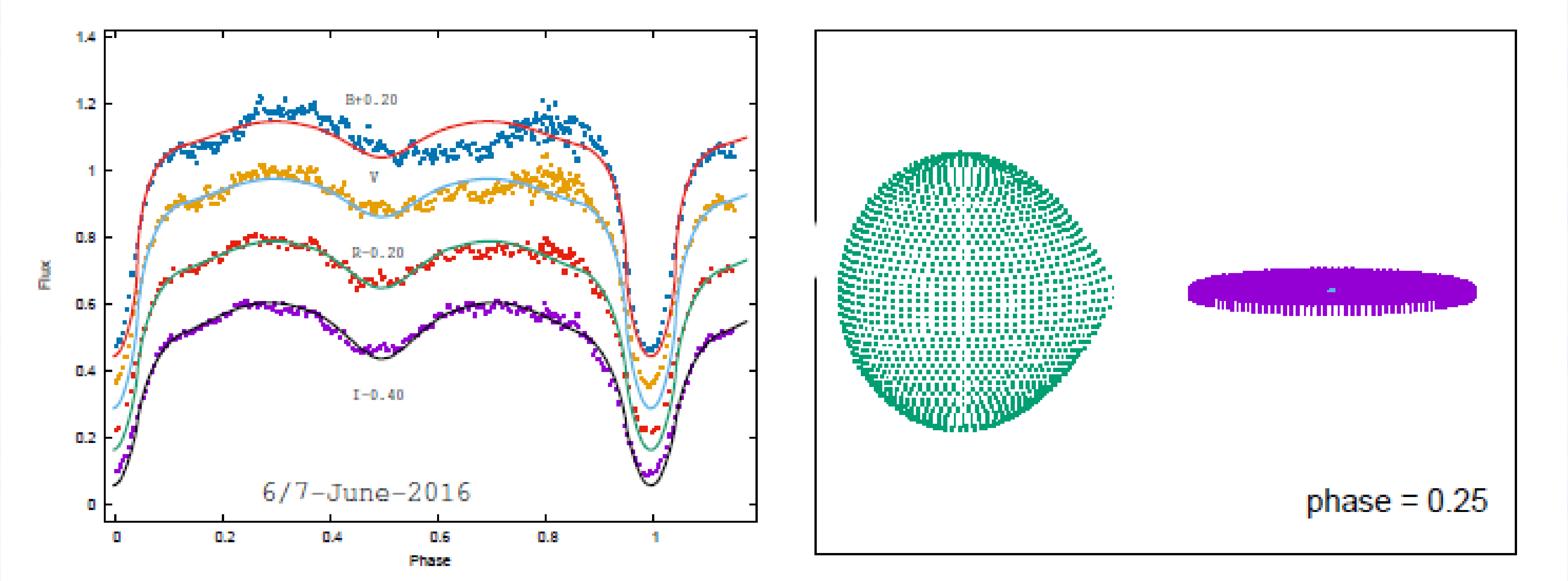
LC Model: W-D code + accretion disk built-in

- Light from stars computed with the W-D code.
- Accretion disk surrounds star #1
- Phenomenological model of the disk (rdisk,Tdout, thickness, steady state accretion temperature distribution)
- Mass gainer and the disk eclipsed at phase 0
- Disk circular in shape and optically thick
- No spots



Accretion disk model at outburst

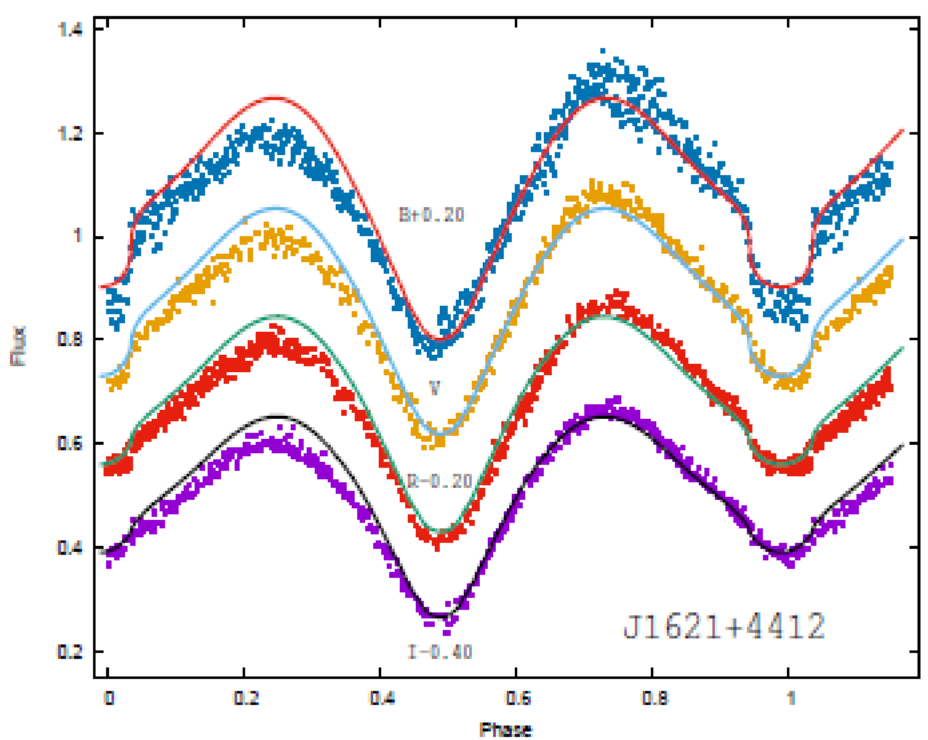
- Beginning of outburst – the disk model also gives a reasonable fit (Zola et al. 2017)
- WD temperature ~44 600K



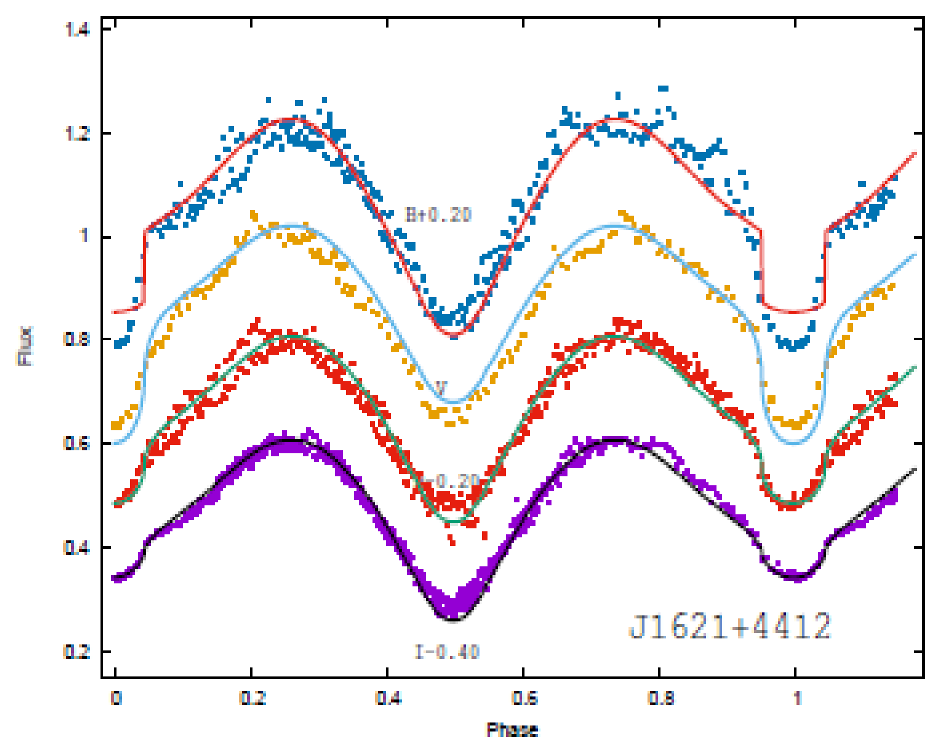
Accretion disk models at quiescence

- Parts of LCs around the quadrature with lower height removed
- Disk model gives a better fit, hot WD required, normal size

August 2016

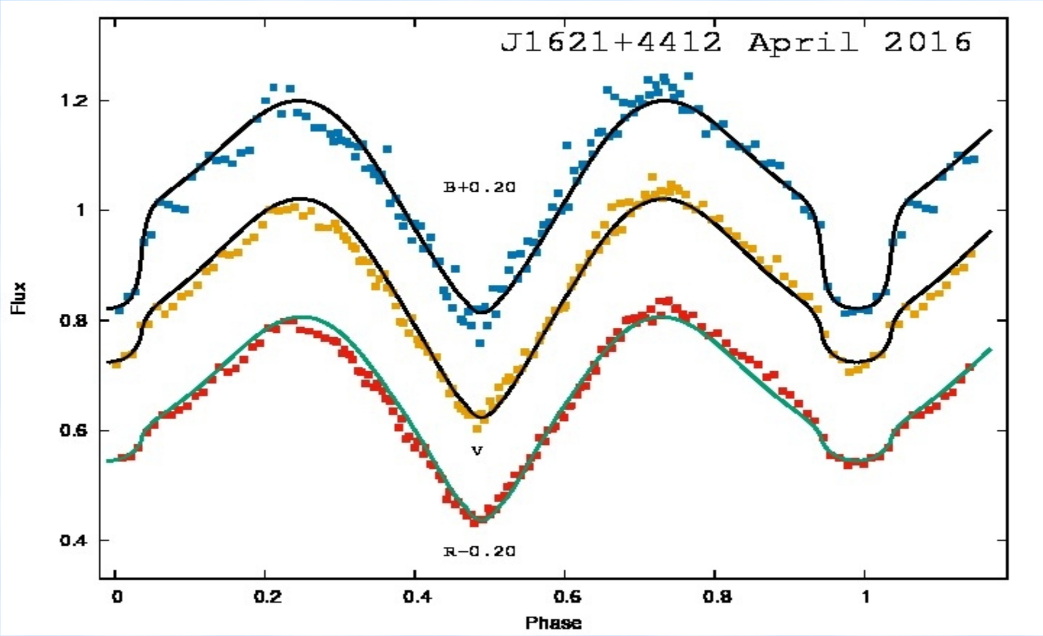


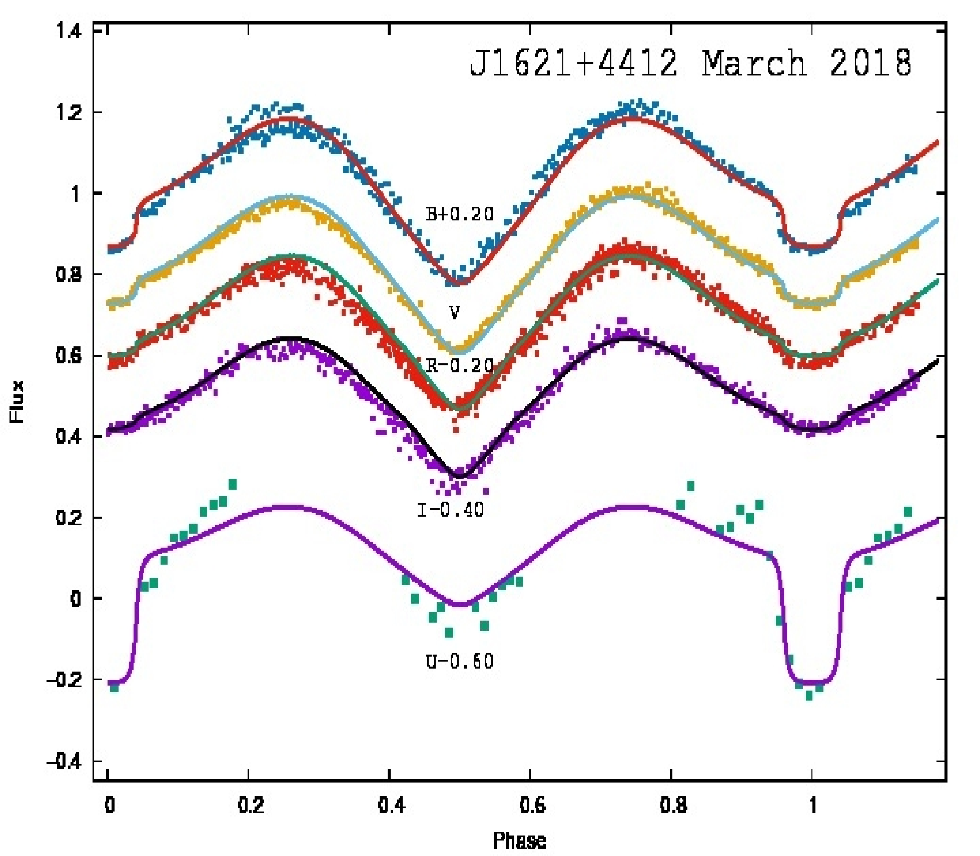
March 2017

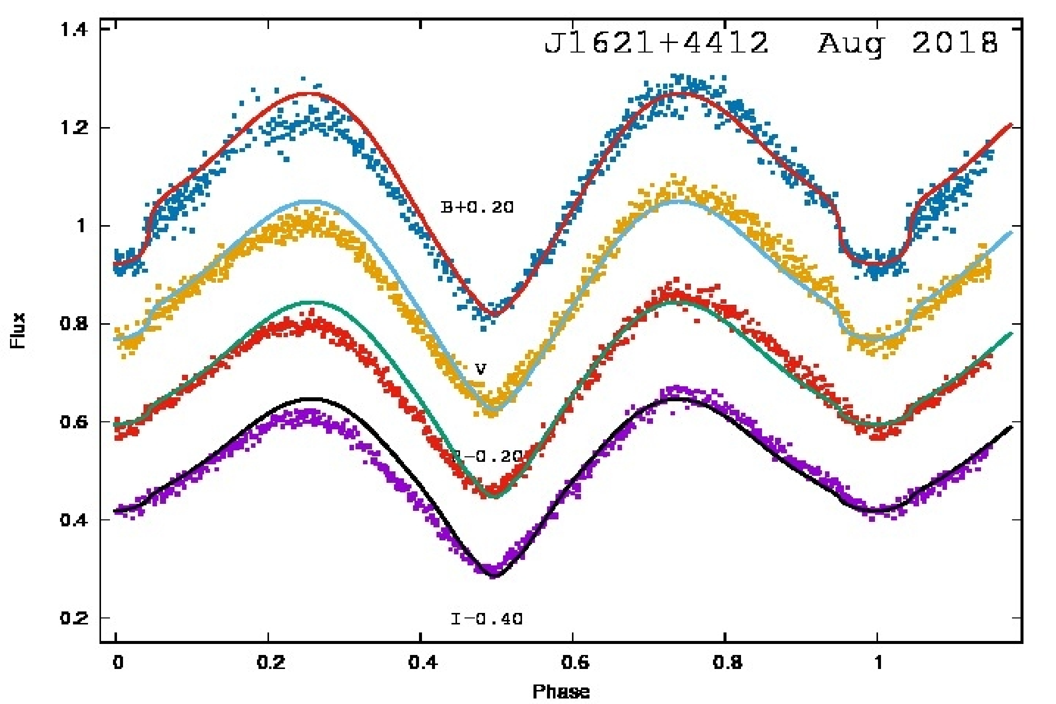


Accretion disk models at quiescene

Depths of both minima reproduced within the disk model







Very preliminary results: WD and accretion disk parameters

TABLE 1. White dwarf temperature, the size of an accretion disk and the disk light contribution in B and R filters.

Date	T_1 [K]	r_d	l_d [B]	l_d [R]	remarks
Apr 2016	11 360	0.32	16%	5%	this work
Jun 6 2016	44 600	0.39	53%	44%	Zola et al. 2017
Aug 2016	14 350	0.45	10%	7%	Zola et al. 2017
Mar 2017	28 180	0.44	5%	10%	this work
May 2017	16 830	0.34	16%	6%	this work
Sep 2017	11 440	0.28	–	4%	this work
Mar 2018	16 850	0.29	4%	1%	this work
Aug 2018	11 430	0.33	9%	2%	this work

Conclusions from observational evidence and preliminary LC modeling

J1621+4412 is a high inclination cataclysmic binary: i=86 (±3),

consists of a massive WD and a K-type dwarf

Infrequent inside-out outbursts are due to disk instability

The accretion disk present at all epochs after the outburst. Temperature of the disk and its radius vary in the quiescent state → non-uniform mass transfer rate

J1621+4412 may belong to the same class as BD Pav and V364 Lib (Kimura et al. 2018), V1129 Cen (Walter et al. 2006)

How many of such objects are lurking among systems that are classified as contact binaries?

Thank you !