Eruptive stars spectroscopy

Cataclysmics, Symbiotics, Nova Supernovae

ARAS Eruptive Stars

Information Letter n° 24 #2016-02 20-03-2016

Observations of February 2016

Contents

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“We acknowledge with thanks the variable star observations from the AAVSO International Database contributed by observers worldwide and used in this letter.”
Kafka, S., 2015, Observations from the AAVSO International Database, http://www.aavso.org

Symbiotics in February

CH Cygni : ongoing campaign upon the request of Augustin Skopal

AG Peg : declining during the secondary outburst.

V694 Mon : strong luminosity outburst. 42 spectra in February
AX Per : in outburst

T CrB : superactive phse

Observing : main targets

V694 Mon : the more spectra as possible (low and high resolution) of the extraordinary star during its strong visual outburst

AX Per in outburst

Ungoing campaign : **CH Cygni** for A Skopal (low resolution and H alpha profile at R > 10000)
Now, in the morning sky. Almost one spectrum a month.
CI Cygni, also in the morning sky

T CrB : high cadency coverage should be welcome until the next nova outburst (could take afew years)

SYMBIOTICS

Symbiotics in ARAS Data Base Update : 20-03-2016

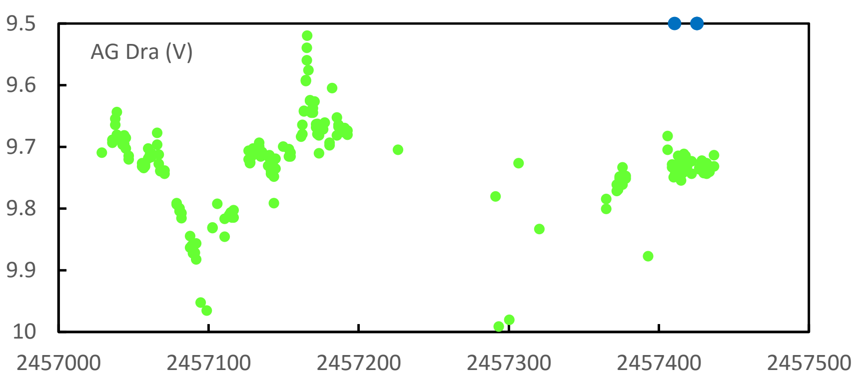
#	Name	AD (2000)	DE (2000)	Nb. Of spectra	First spectrum	Last spectrum	Days Since Last
1	EG And	0 44 37.1	40 40 45.7	44	12/08/2010	24/02/2016	25
2	AX Per	1 36 22.7	54 15 2.5	95	04/10/2011	07/03/2016	13
	V471 Per	1 58 49.7	52 53 48.4	3	06/08/2013	04/02/2016	45
3	o Ceti	2 19 20.7	-2 58 39.5	6	28/11/2015	20/02/2016	29
4	BD Cam	3 42 9.3	63 13 0.5	15	08/11/2011	06/03/2016	14
5	UV Aur	5 21 48.8	32 30 43.1	38	24/02/2011	07/03/2016	13
6	V1261 Ori	5 22 18.6	-8 39 58	5	16/01/2016	20/02/2016	29
7	StHA 55	5 46 42	6 43 48	2	17/01/2016	25/01/2016	55
8	ZZ CMi	7 24 13.9	8 53 51.7	29	29/09/2011	12/03/2016	8
9	BX Mon	25 24	-3 36 0	36	04/04/2011	12/03/2016	8
10	V694 Mon	7 25 51.2	-7 44 8	133	03/03/2011	17/03/2016	3
11	NQ Gem	7 31 54.5	24 30 12.5	36	01/04/2013	06/03/2016	14
12	GH Gem	7 4 4.9	12 2 12				
13	CQ Dra	12 30 06	69 12 04	3	11/06/2015	08/03/2016	12
14	TX CVn	12 44 42	36 45 50.6	26	10/04/2011	12/03/2016	8
15	IV Vir	14 16 34.3	-21 45 50	2	28/02/2015	09/05/2015	316
16	T CrB	15 59 30.1	25 55 12.6	70	01/04/2012	14/03/2016	6
17	AG Dra	16 1 40.5	66 48 9.5	67	03/04/2013	17/03/2016	3
18	V503 Her	17 36 46	23 18 18	1	05/06/2013	05/06/2013	1019
19	RS Oph	17 50 13.2	-6 42 28.4	16	23/03/2011	16/09/2015	186
20	V934 Her	17 6 34.5	23 58 18.5	9	09/08/2013	20/06/2015	274
21	AS 270	18 05 33.7	-20 20 38	2	01/08/2013	02/08/2013	961
22	AS 289	18 12 22	-11 40 13				
23	YY Her	18 14 34.3	20 59 20	17	25/05/2011	07/09/2015	195
24	FG Ser	18 15 6.2	0 18 57.6	3	26/06/2012	24/07/2014	605
25	StHa 149	18 18 55.9	27 26 12	3	05/08/2013	14/10/2015	158
26	V443 Her	18 22 8.4	23 27 20	21	18/05/2011	07/02/2016	42
27	FN Sgr	18 53 52.9	-18 59 42	4	10/08/2013	02/07/2014	627
28	V335 Vul	19 23 14.2	24 27 40.2				
29	BF Cyg	19 23 53.4	29 40 25.1	71	01/05/2011	07/11/2015	134
30	CH Cyg	19 24 33	50 14 29.1	325	21/04/2011	15/03/2016	5
31	V919 Sgr	19 3 46	-16 59 53.9	2	10/08/2013	10/08/2013	953
32	V1413 Aql	19 3 51.6	16 28 31.7	5	10/08/2013	26/09/2015	176
33	HM Sge	19 41 57.1	16 44 39.9	7	20/07/2013	11/11/2015	130
34	QW Sge	19 45 49.6	18 36 50				
35	CI Cyg	19 50 11.8	35 41 3.2	103	25/08/2010	17/02/2016	32
36	StHA 169	19 51 28.9	46 23 6				
37	V1016 Cyg	19 57 4.9	39 49 33.9	7	15/04/2015	01/11/2015	140
38	PU Vul	20 21 12	21 34 41.9	14	20/07/2013	23/11/2015	118
39	LT Del	20 35 57.3	20 11 34				
40	ER Del	20 42 46.4	8 40 56.4	3	02/09/2011	05/11/2014	501
41	V1329 Cyg	20 51 1.1	35 34 51.2	4	08/08/2015	26/09/2015	176
42	V407 Cyg	21 2 13	45 46 30				
43	StHA 190	21 41 44.8	2 43 54.4	14	31/08/2011	08/11/2015	133
44	AG Peg	21 51 1.9	12 37 29.4	160	06/12/2009	13/01/2016	67
45	V627 Cas	22 57 41.2	58 49 14.9	12	06/08/2013	18/02/2016	31
46	Z And	23 33 39.5	48 49 5.4	58	30/10/2010	05/02/2016	44
47	R Aqr	23 43 49.4	-15 17 4.2	27	25/09/2010	25/01/2016	55

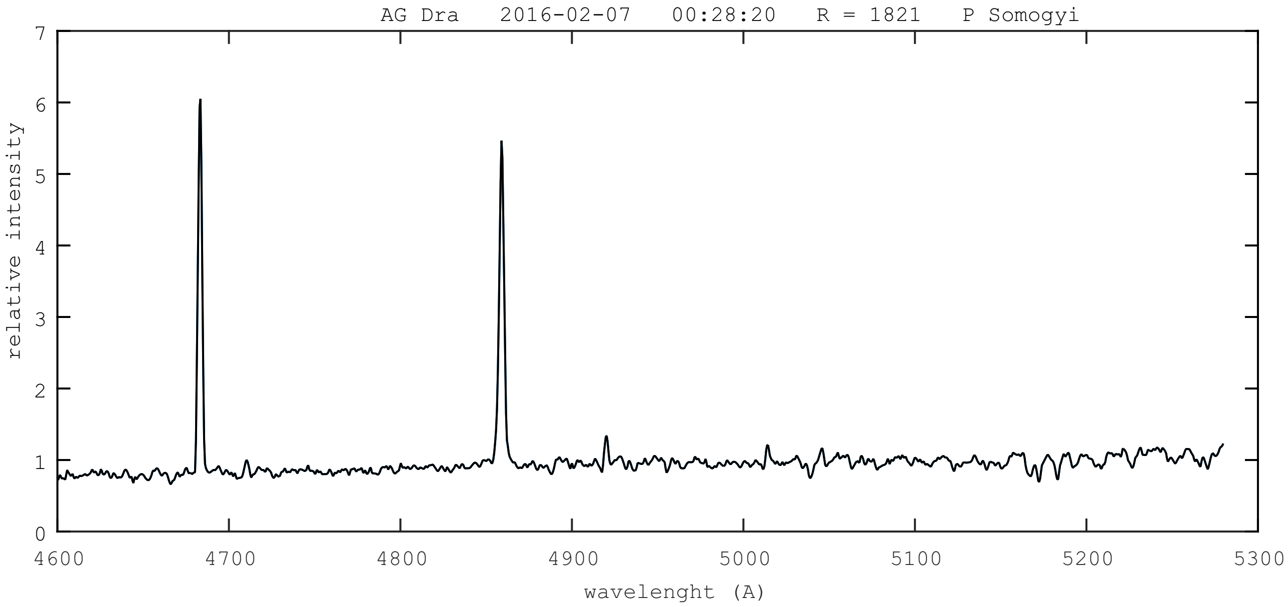
ARAS Data Base Symbiotics : http://www.astrosurf.com/aras/Aras_DataBase/Symbiotics.htm

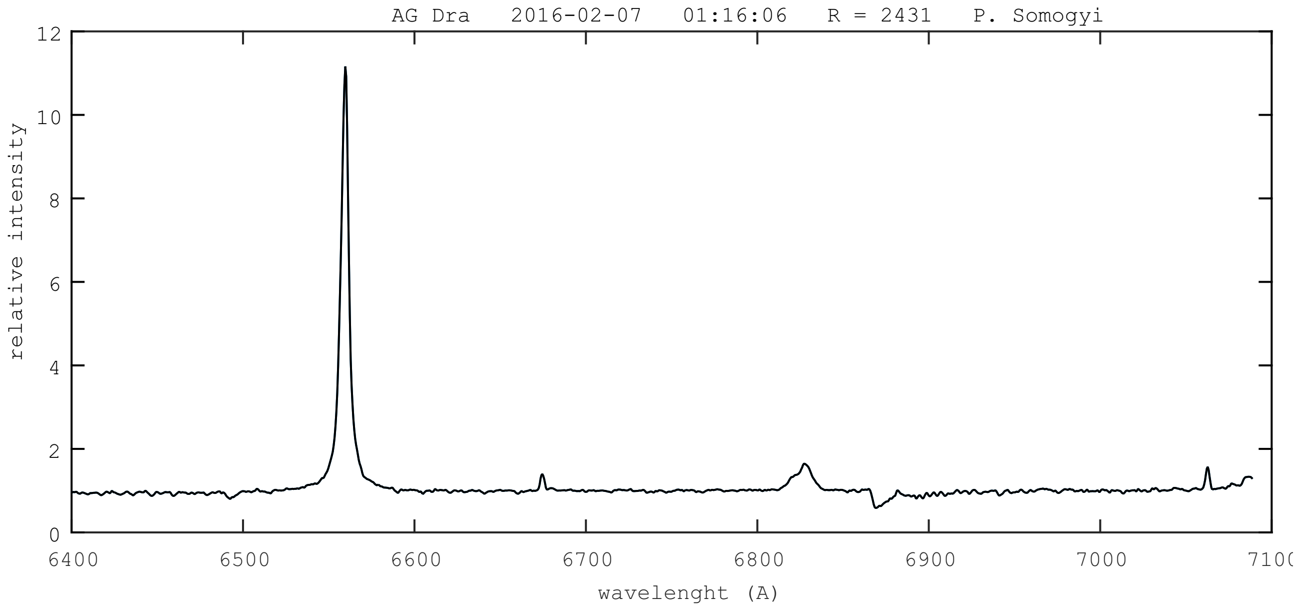
SYMBIOTICS

AG Dra

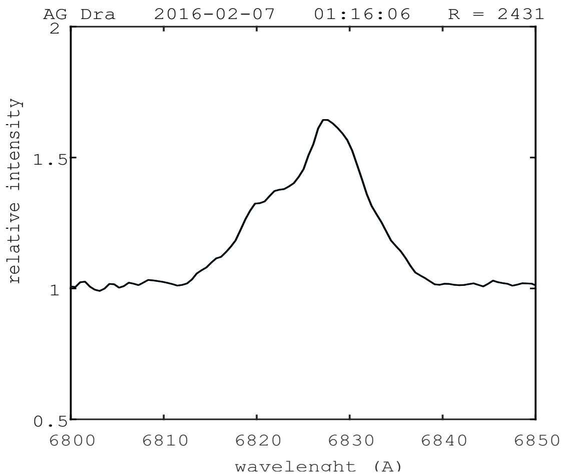
Coordinates (2000.0)	
R.A.	16 01 41.0
Dec	+66 48 10.1





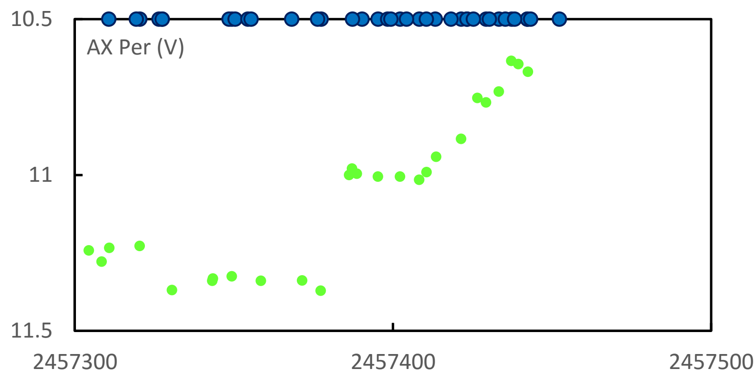


Peter Somogyi
Lhires III 600 l/mm
Top : H beta range
Bottom : H alpha range
Right : Raman OVI

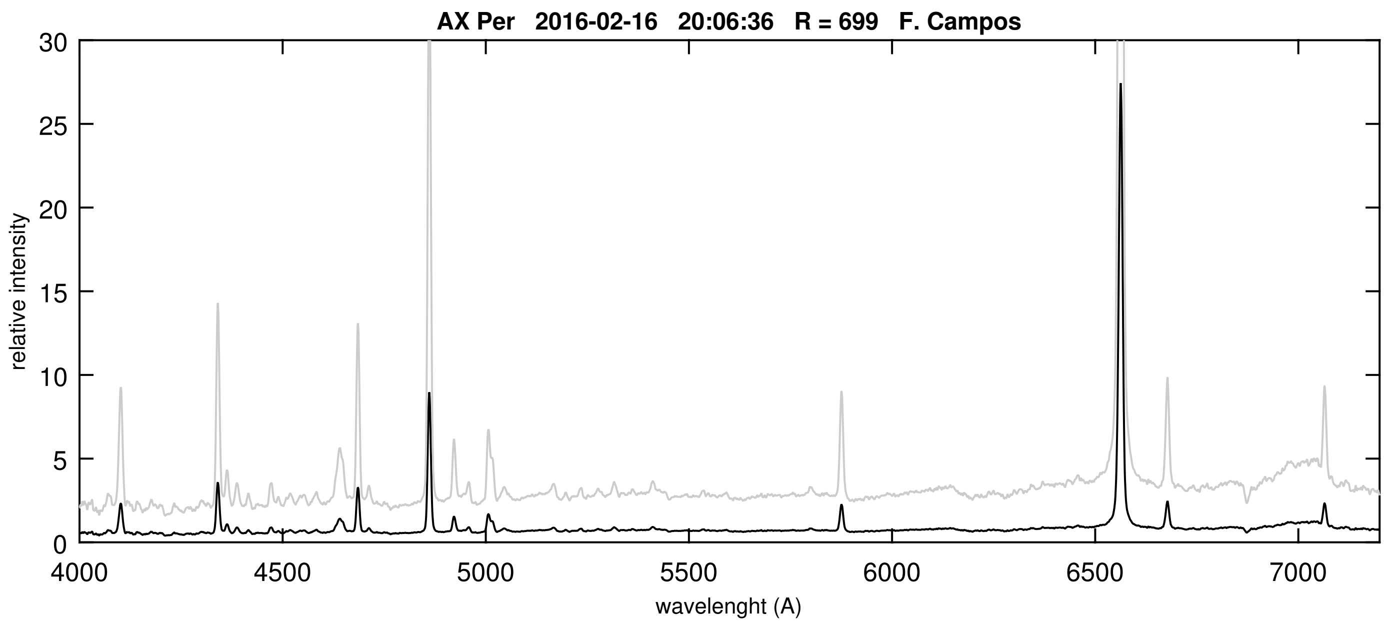


AX Per

Coordinates (2000.0)	
R.A.	1 36 22.7
Dec	54 15 2.5
Mag	11.3 (V)

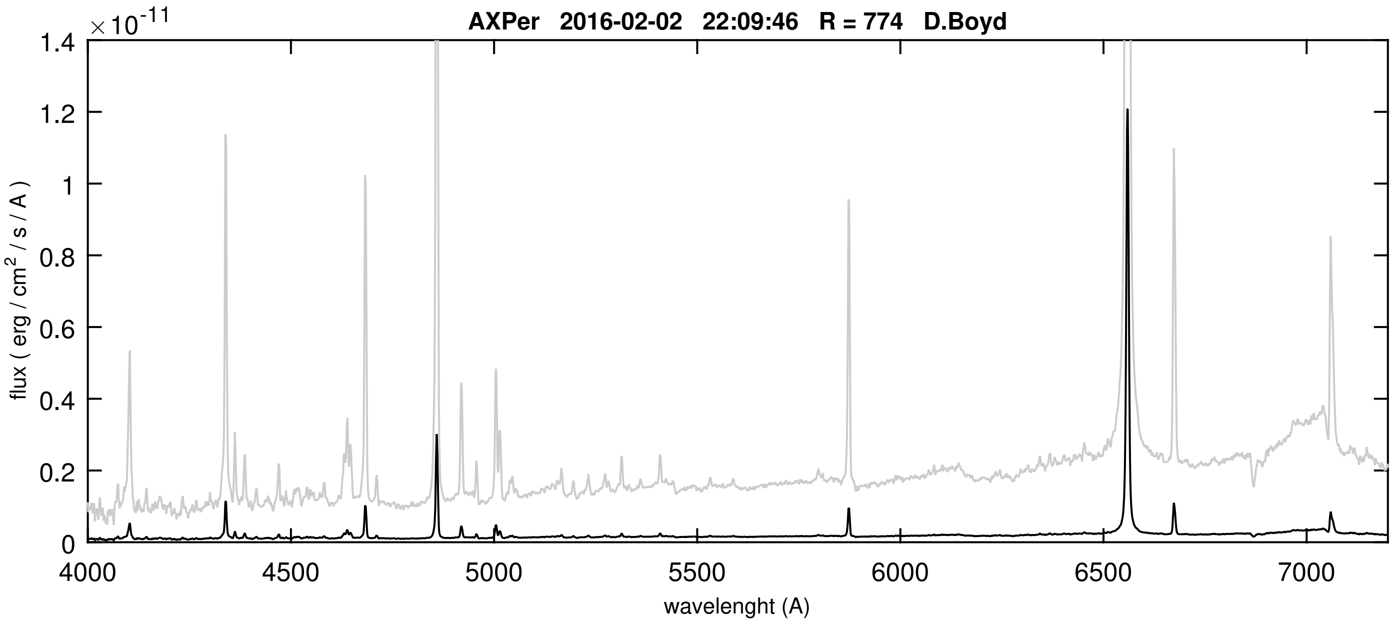


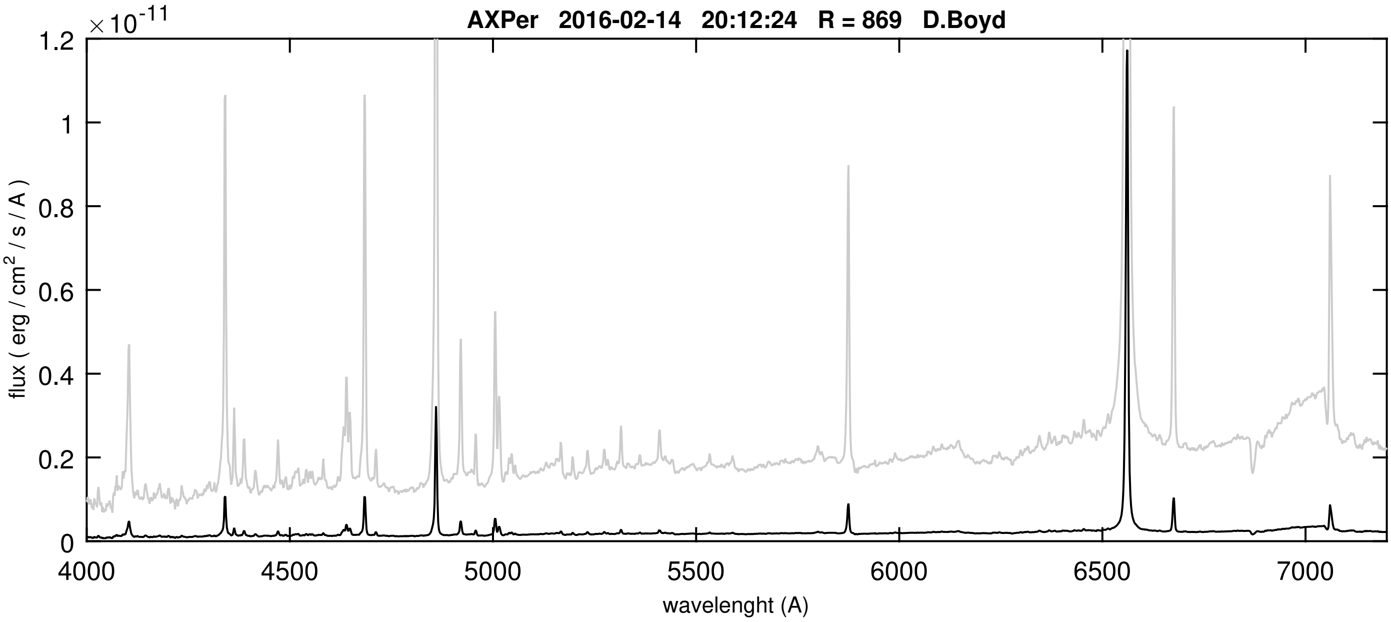
Increasing luminosity (V)
AX Per reaches mag V = 10.7 on February, 18
ARAS observers obtained a good coverage of the classical symbiotic outburst of AX Per

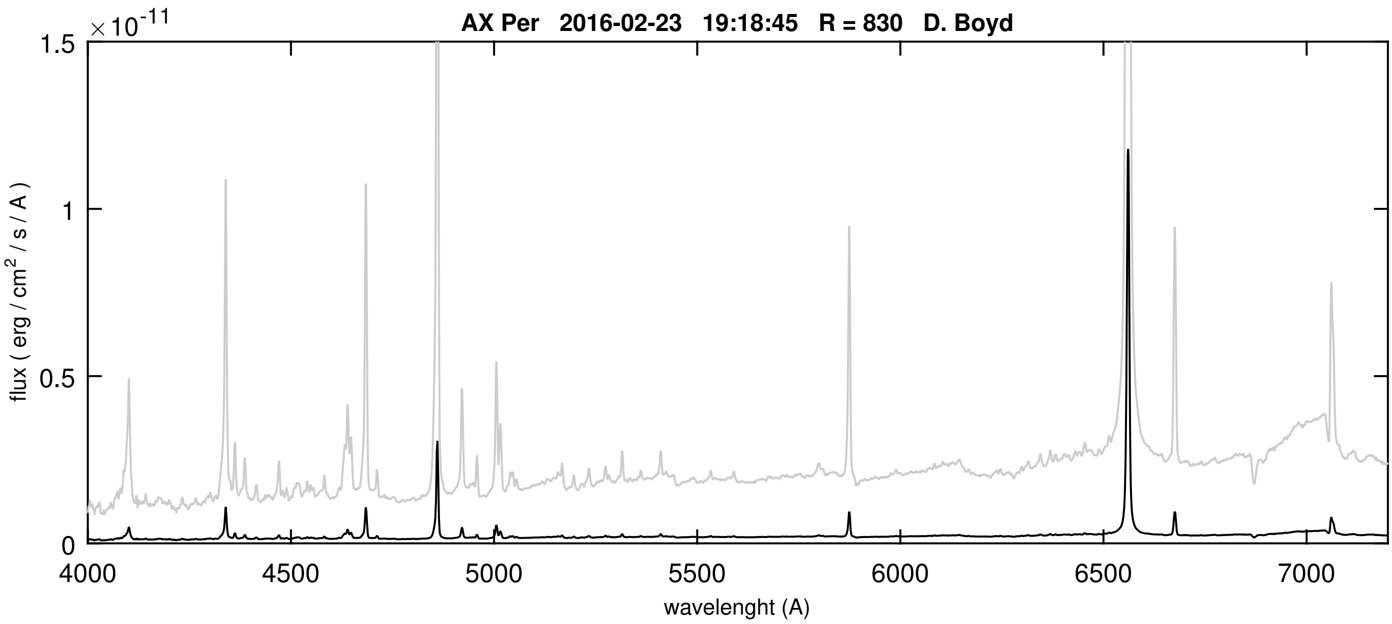


AX Per

AX Per in February : flux calibrated spectra
obtained bt D. Boyd

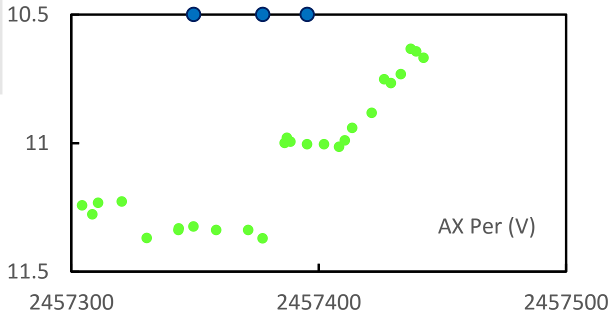


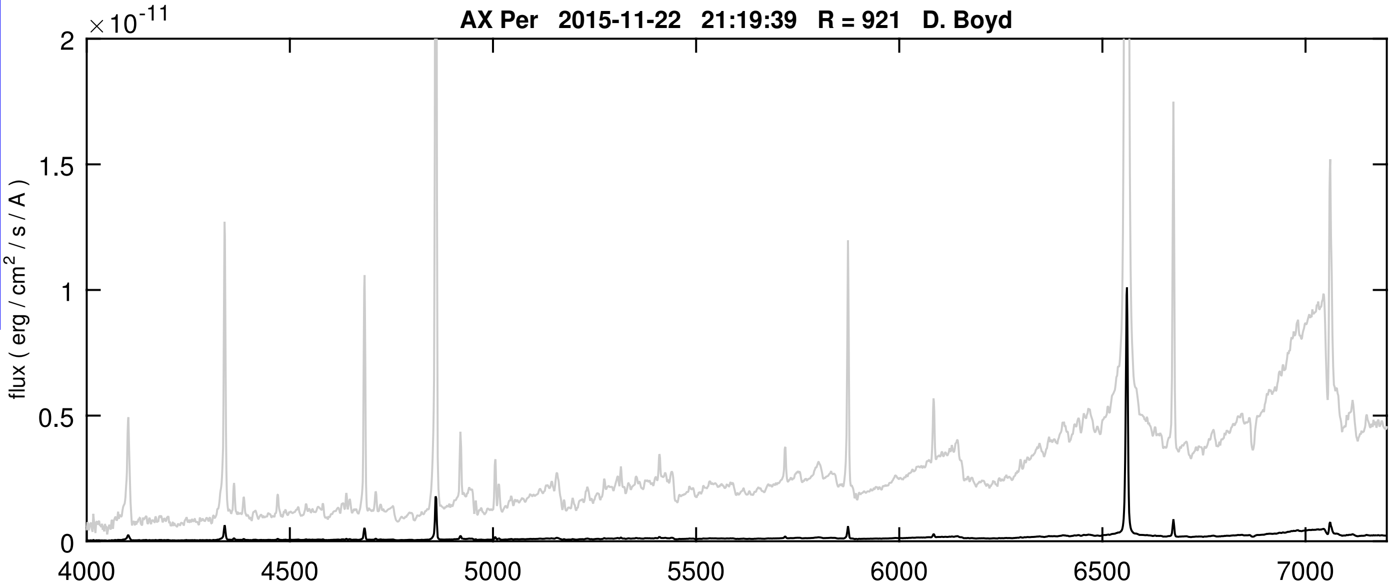


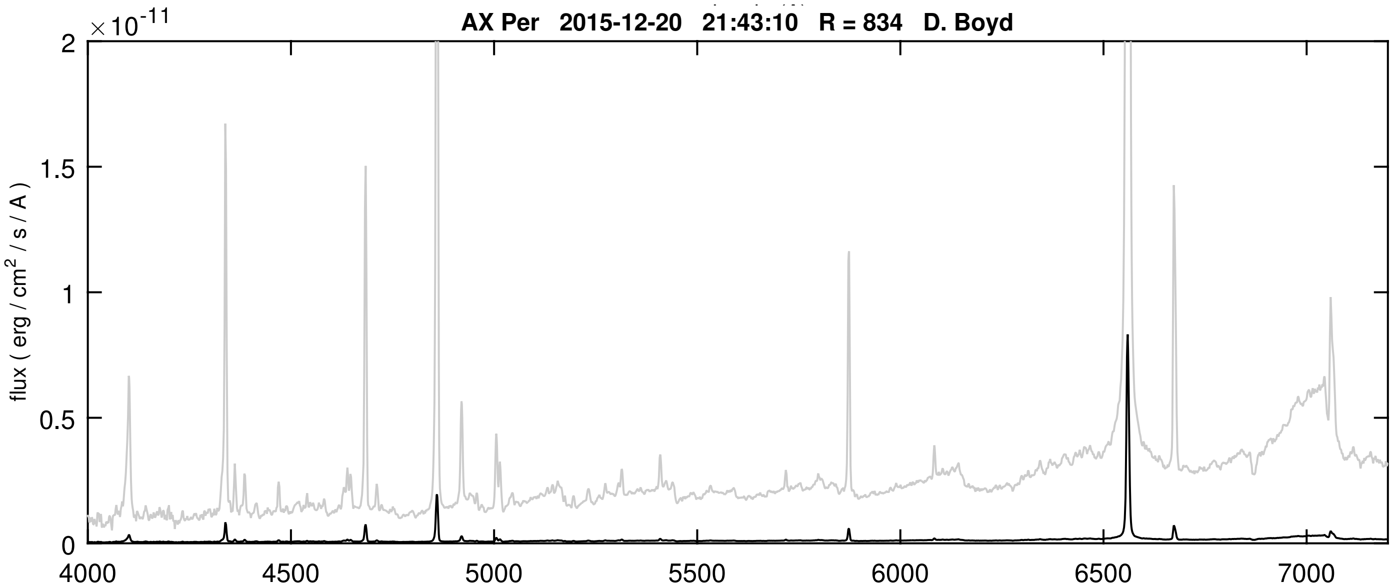


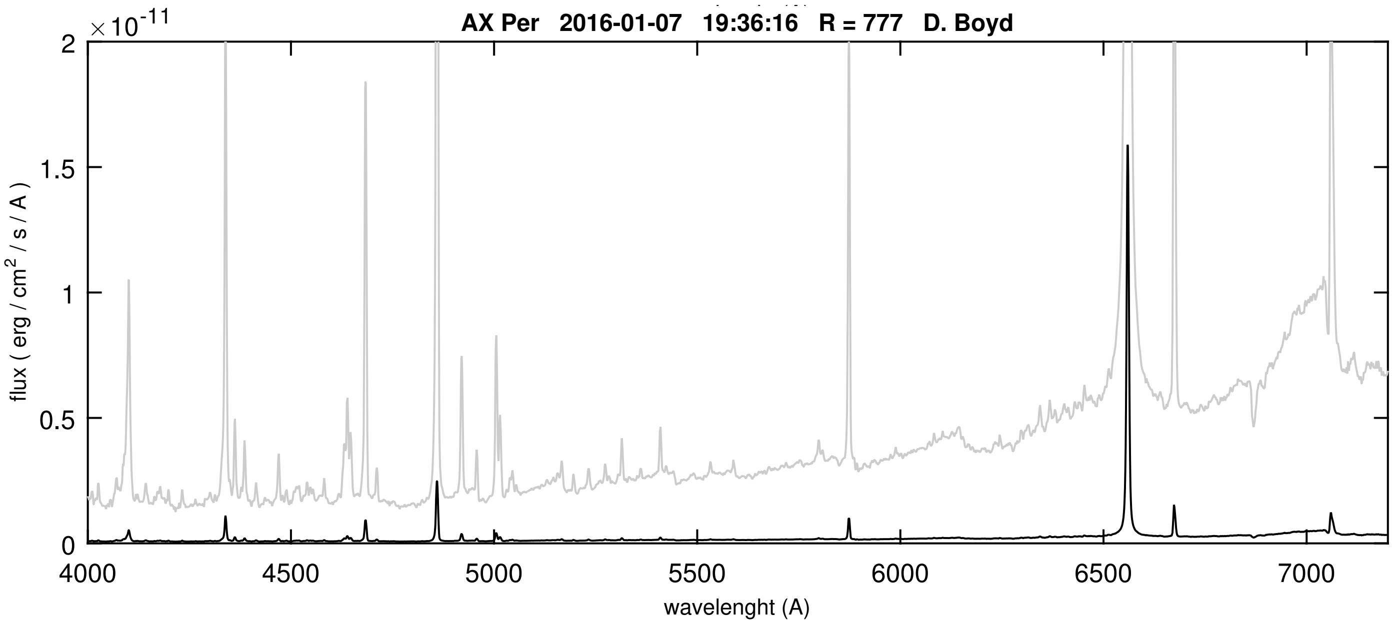
SYMBIOTICS

AX Per





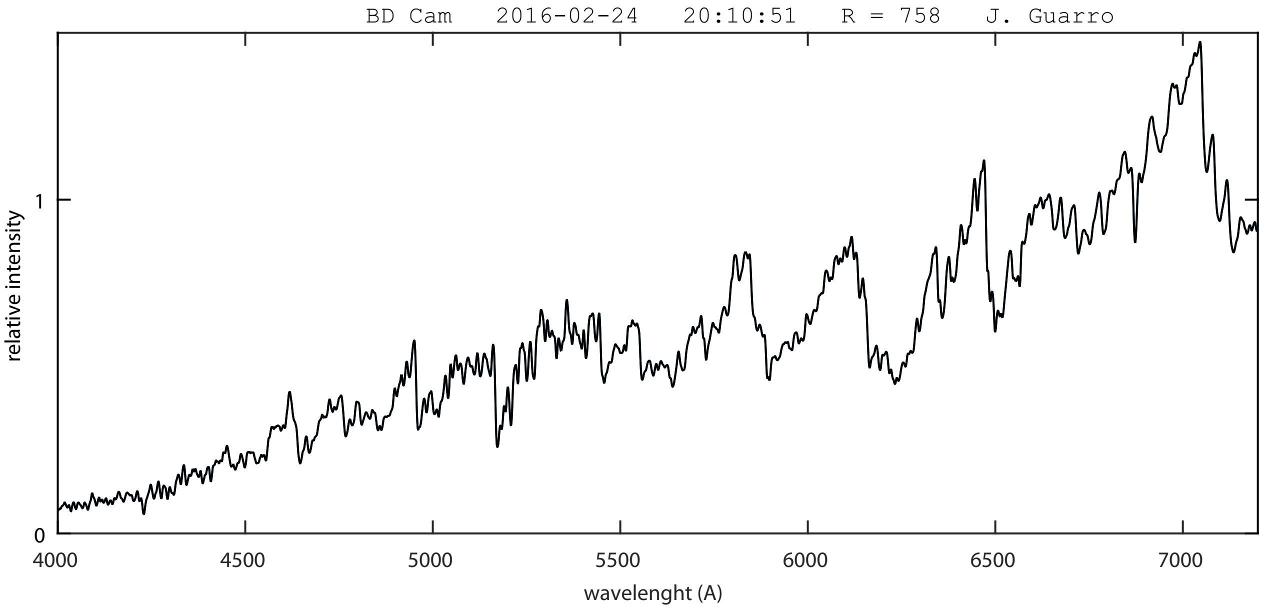


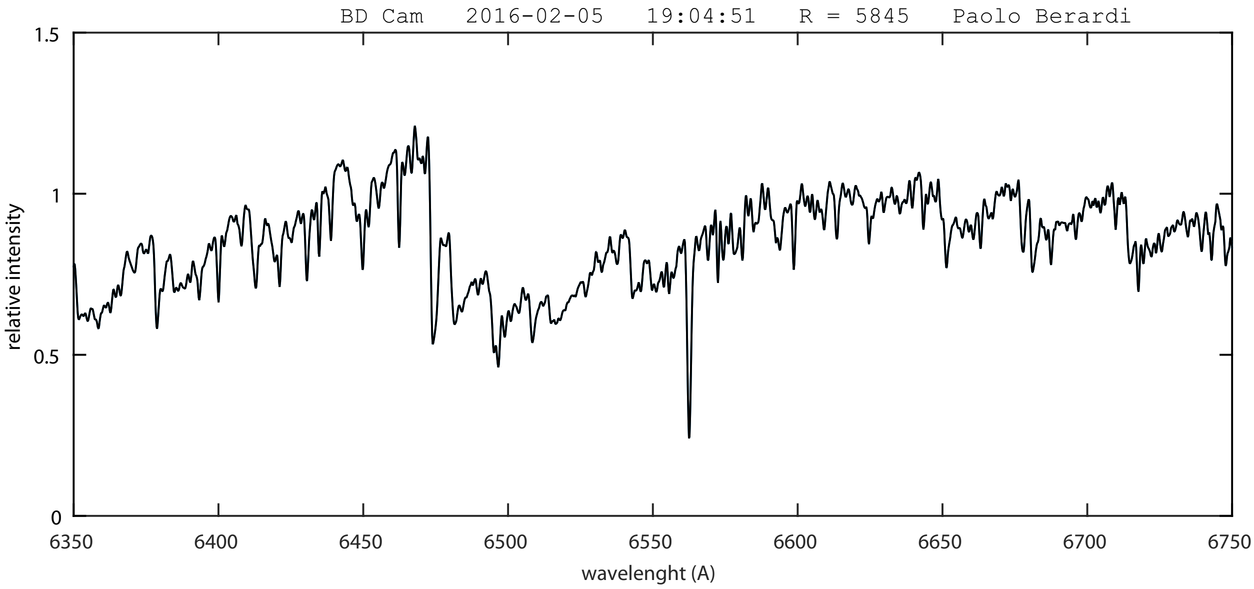


S Y M B I O T I C S

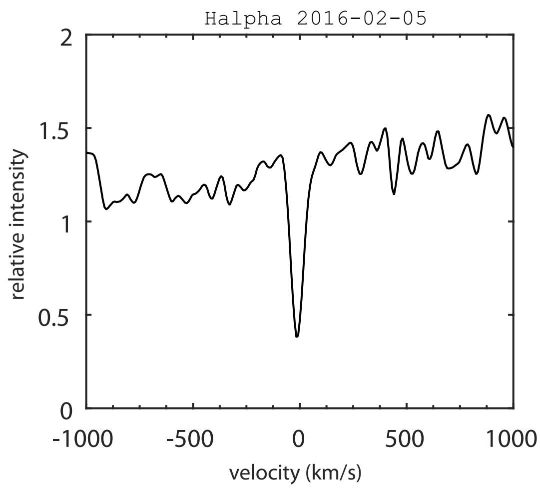
BD Cam

Coordinates (2000.0)	
R.A.	03 42 09.3
Dec	+63 13 00.5
Mag	~ 5





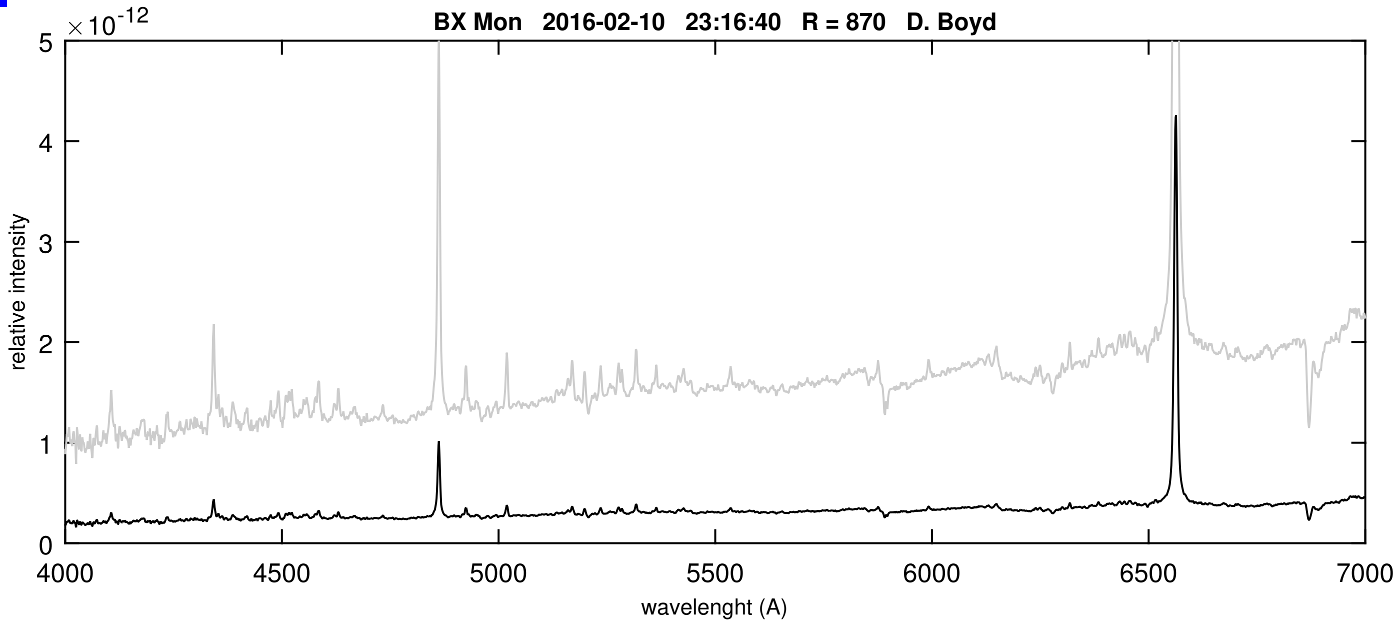
Paolo Berardi
Lhires III 600 l/mm
H alpha in absorption

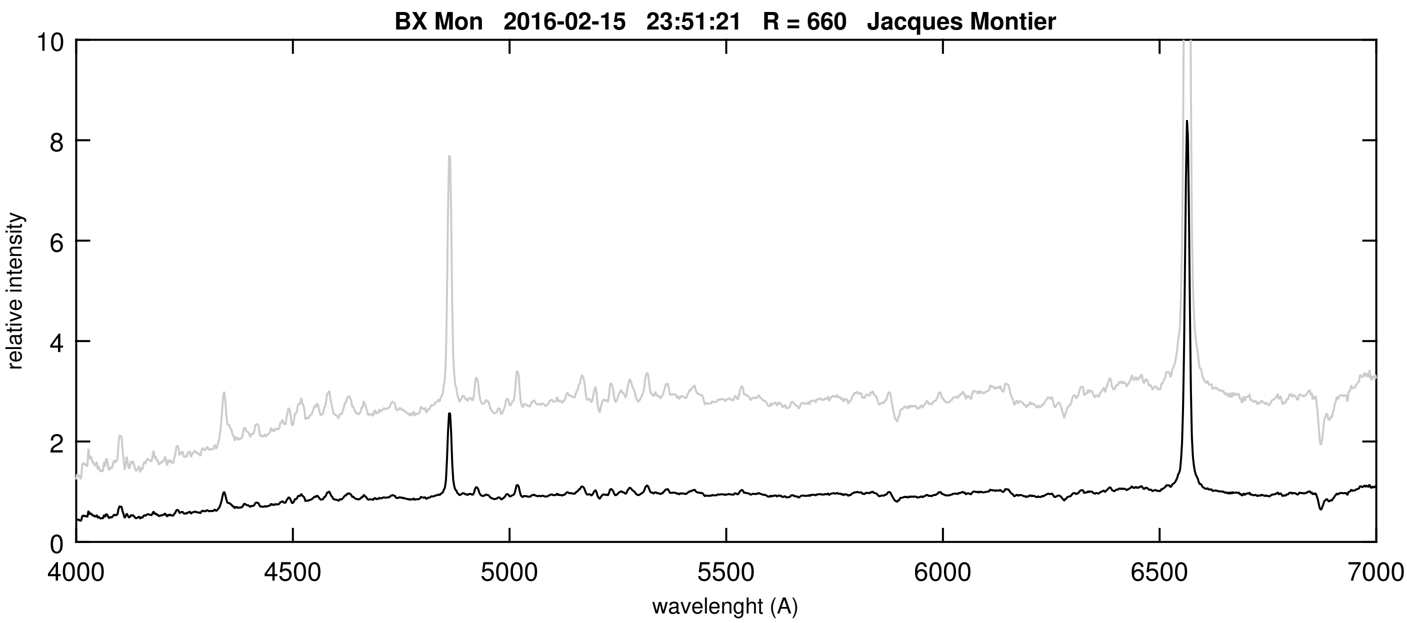


S Y M B I O T I C S

BX Mon

Coordinates (2000.0)	
R.A.	07 25 22.8
Dec	-03 35 50.8
Mag	10.2 (01-2016)



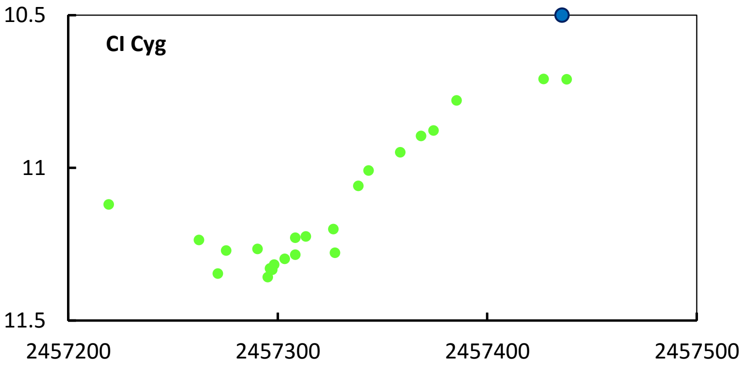


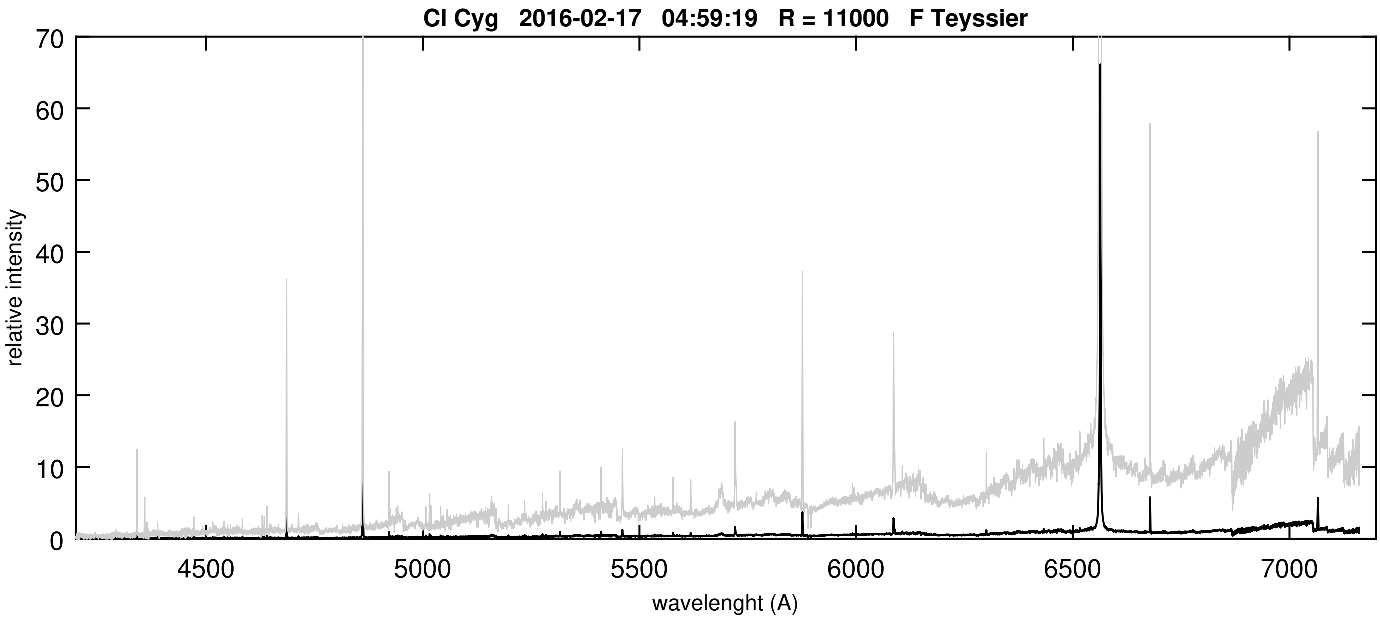
SYMBIOTICS

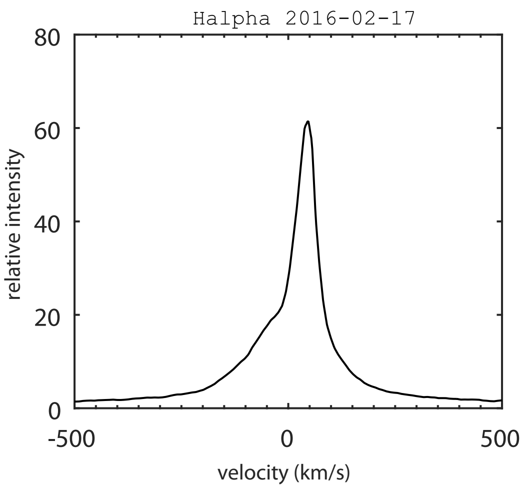
CI Cyg

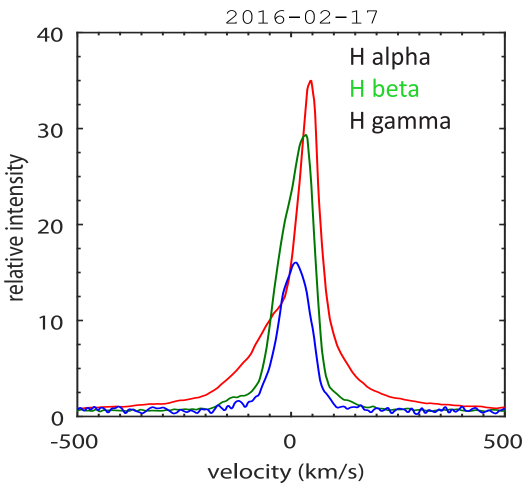
Coordinates (2000.0)	
R.A.	19 50 11.8
Dec	+35 41 03.0
Mag	

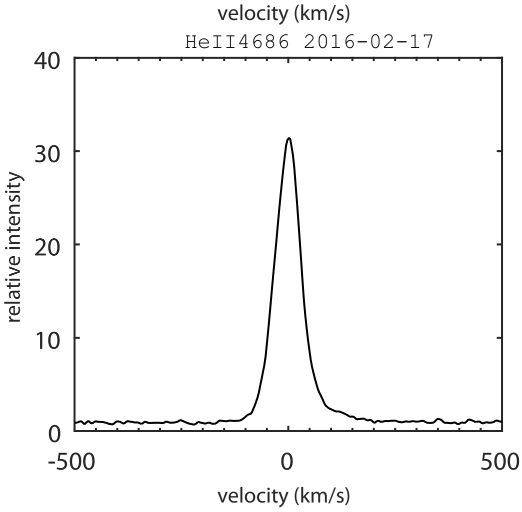
In the morning sky

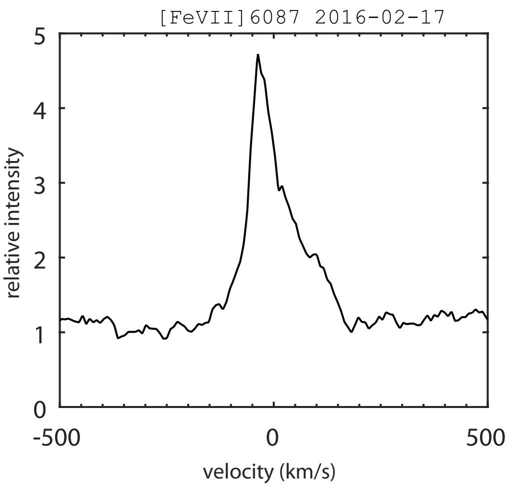








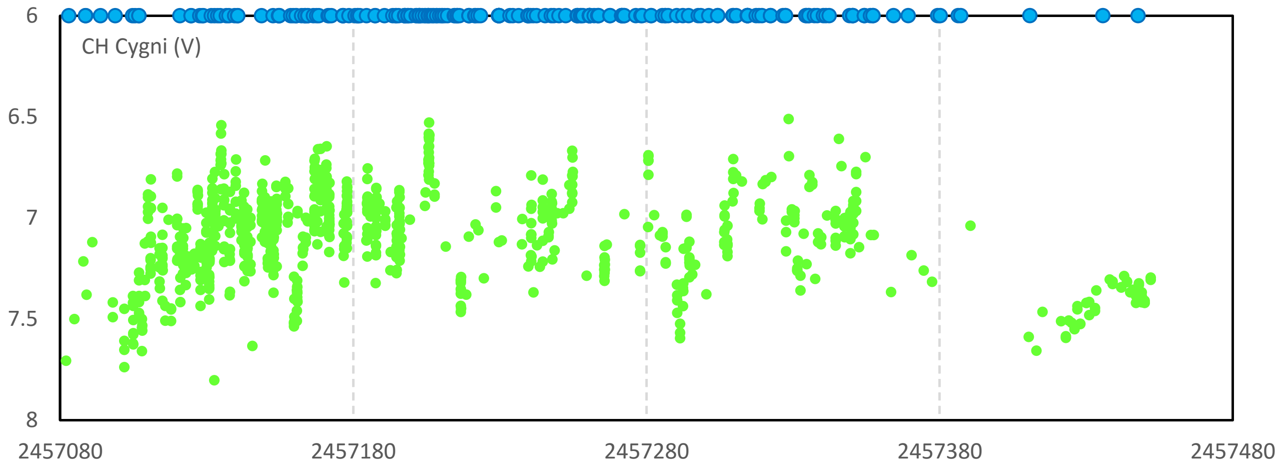




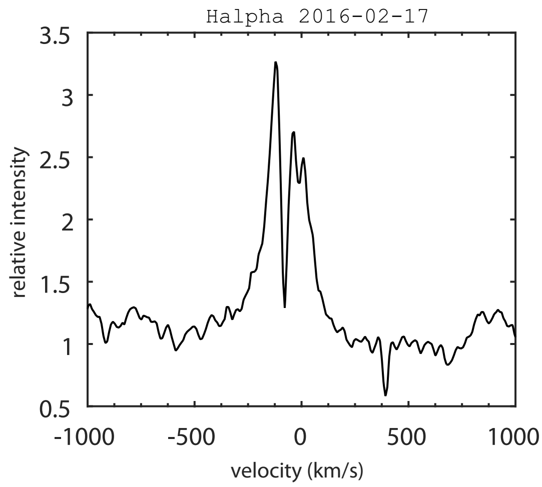
S Y M B I O T I C S

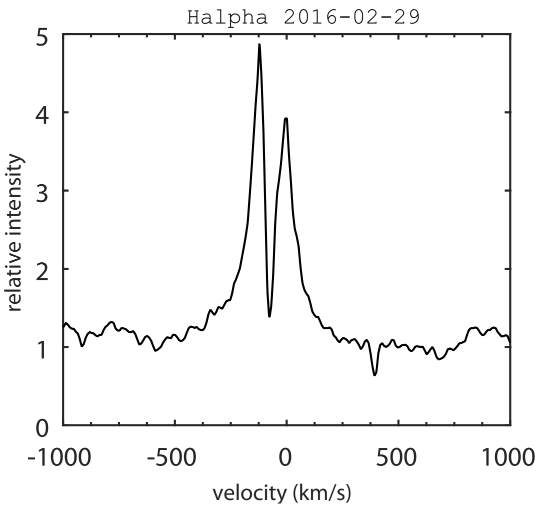
CH Cyg

Coordinates (2000.0)	
R.A.	19 24 33.1
Dec	+50 14 29.1
Mag	

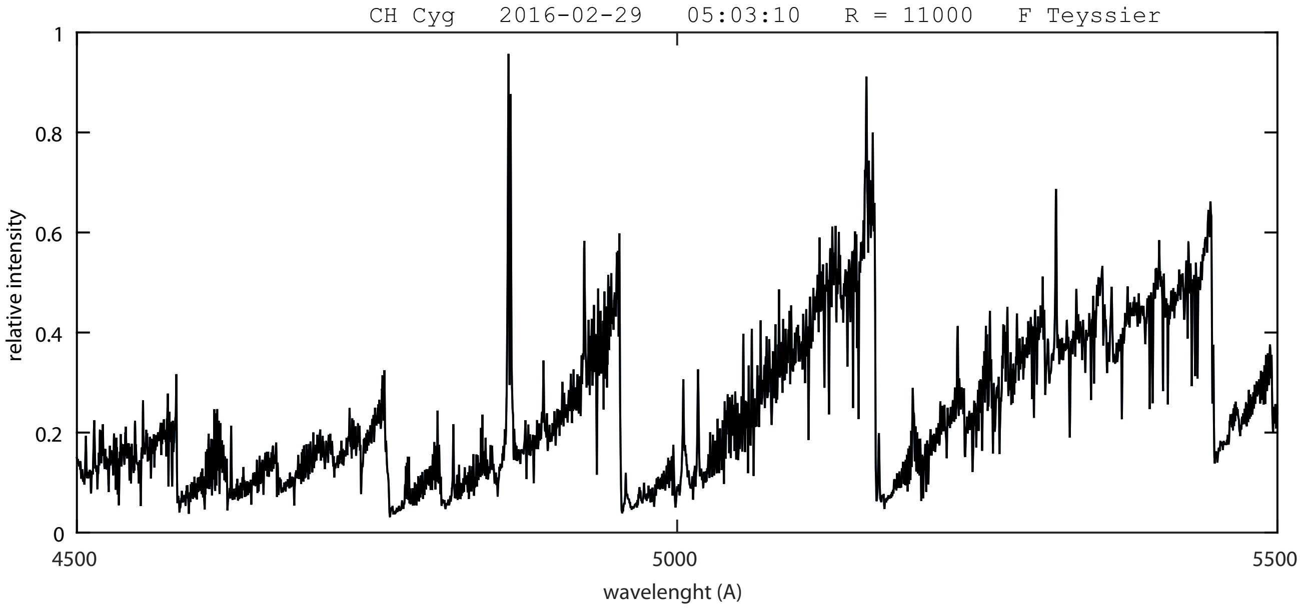


AAVSO light curve V in 2015-2016
ARAS Spectra blue dots

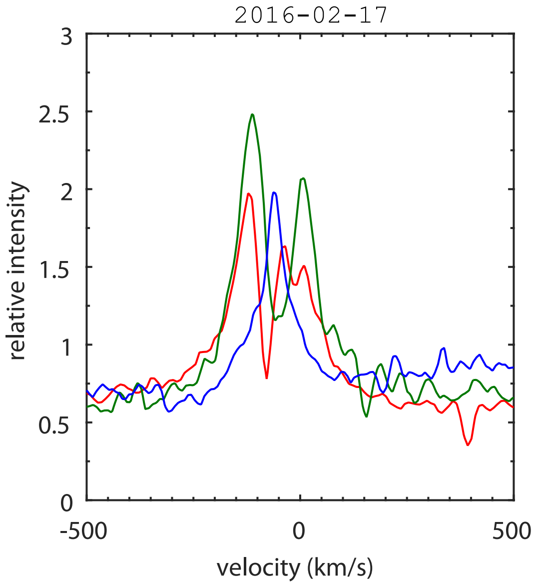




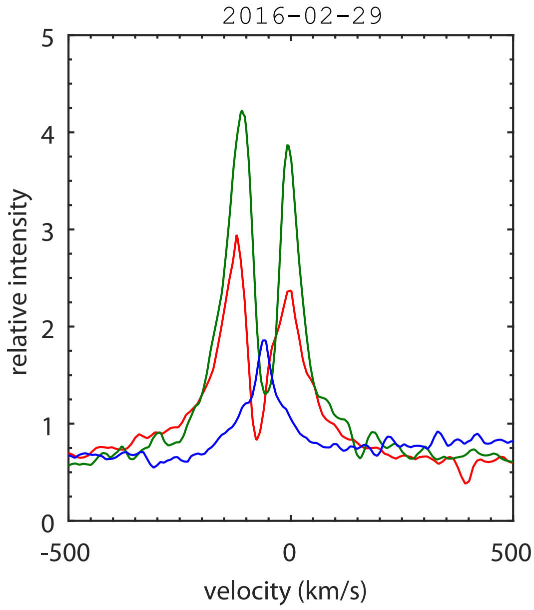
CH Cyg



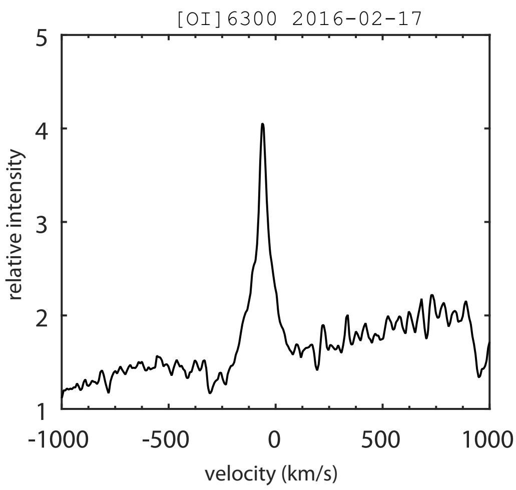
CH Cyg 2016-02-29 05:03:10 R = 11000 F Teyssier
relative intensity
wavelenght (A)
4500
5000
5500
0
0.2
0.4
0.6
0.8
1



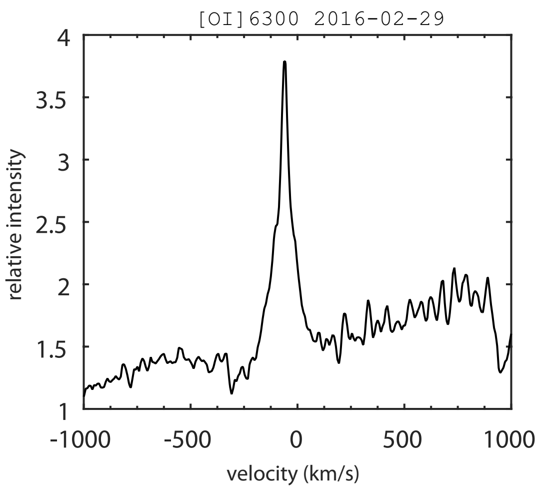
2016-02-17
relative intensity
velocity (km/s)
-500
0
500



2016-02-29
relative intensity
velocity (km/s)
-500
0
500



[OI]6300 2016-02-17
relative intensity
velocity (km/s)
-1000
-500
0
500
1000



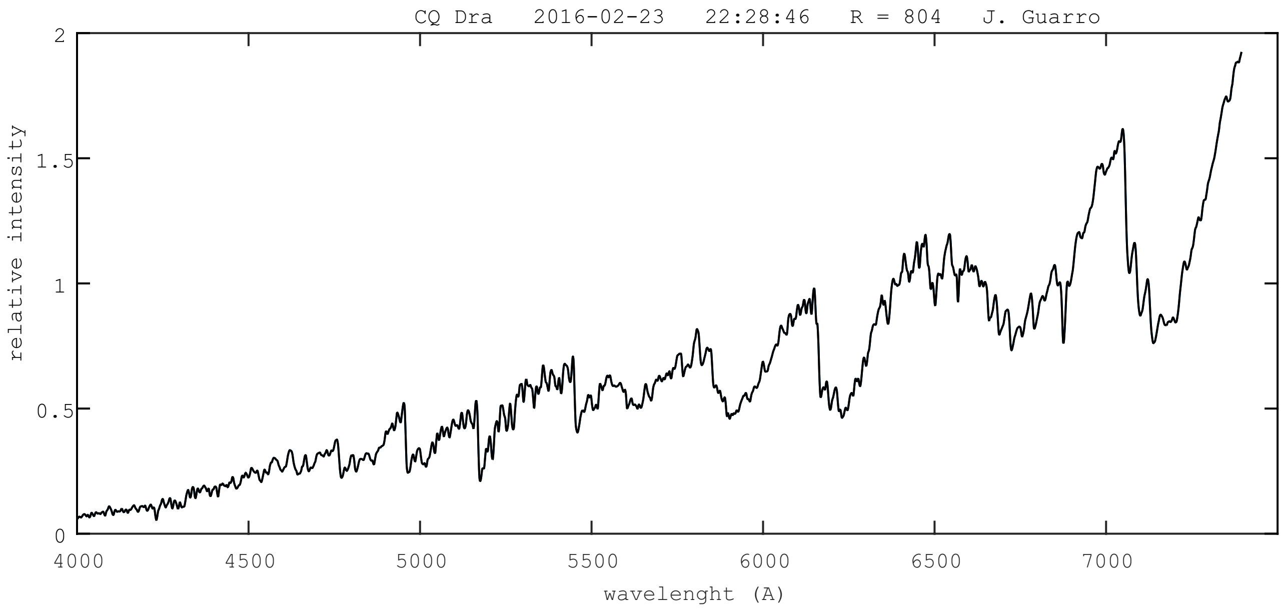
[OI]6300 2016-02-29
relative intensity
velocity (km/s)
-1000
-500
0
500
1000

S Y M B I O T I C S

CQ Dra

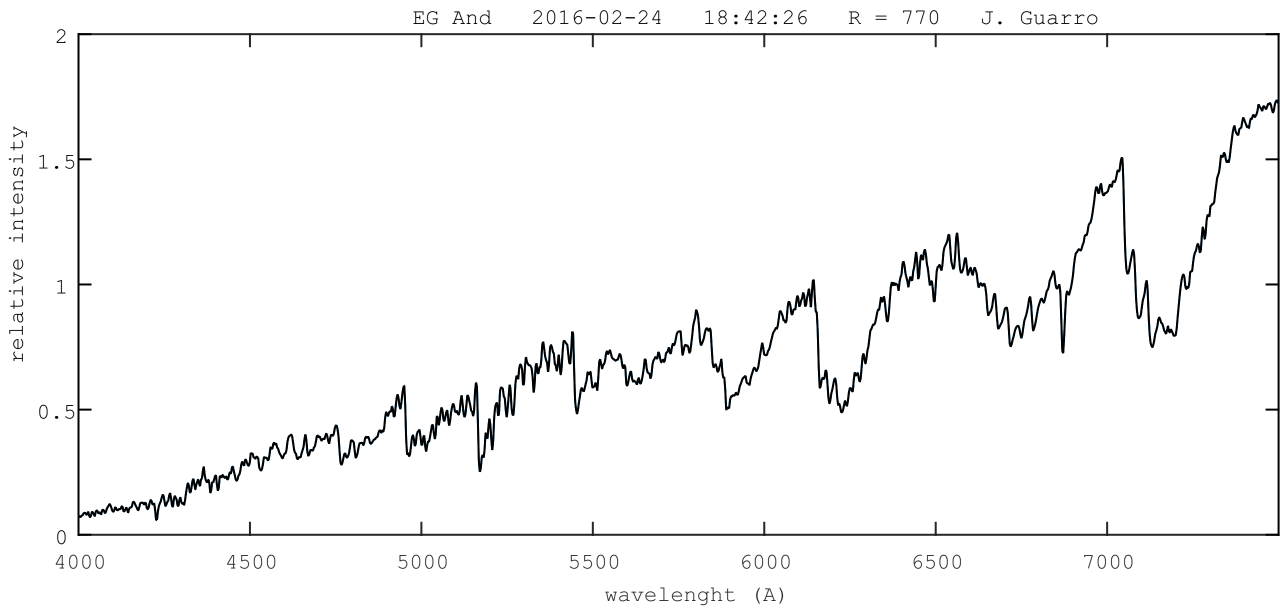
Coordinates (2000.0)	
R.A.	12 30 06.65
Dec	+69 12 04.0
Mag	5

CQ Dra = 4 Dra mag 5

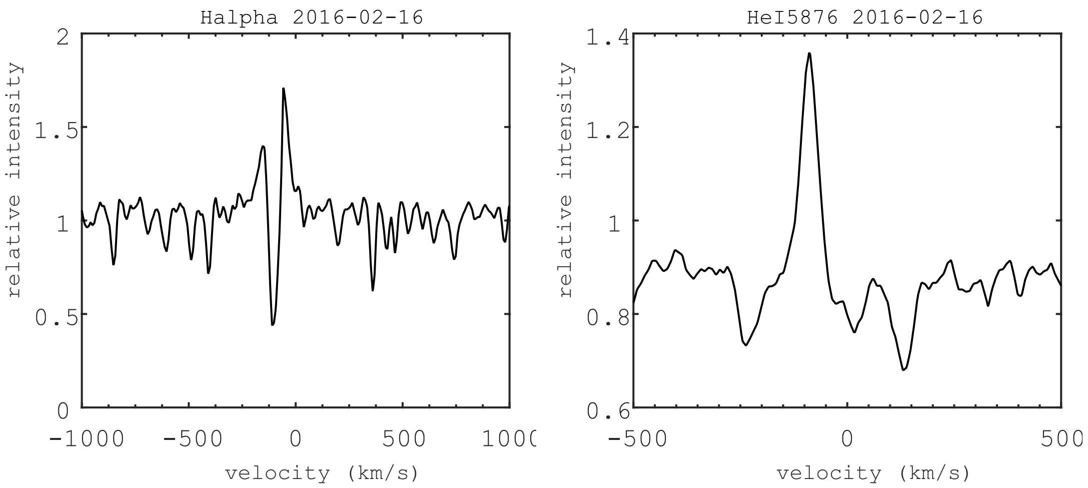


EG And

Coordinates (2000.0)	
R.A.	0 44 37.1
Dec	40 40 45.7
Mag	7.4



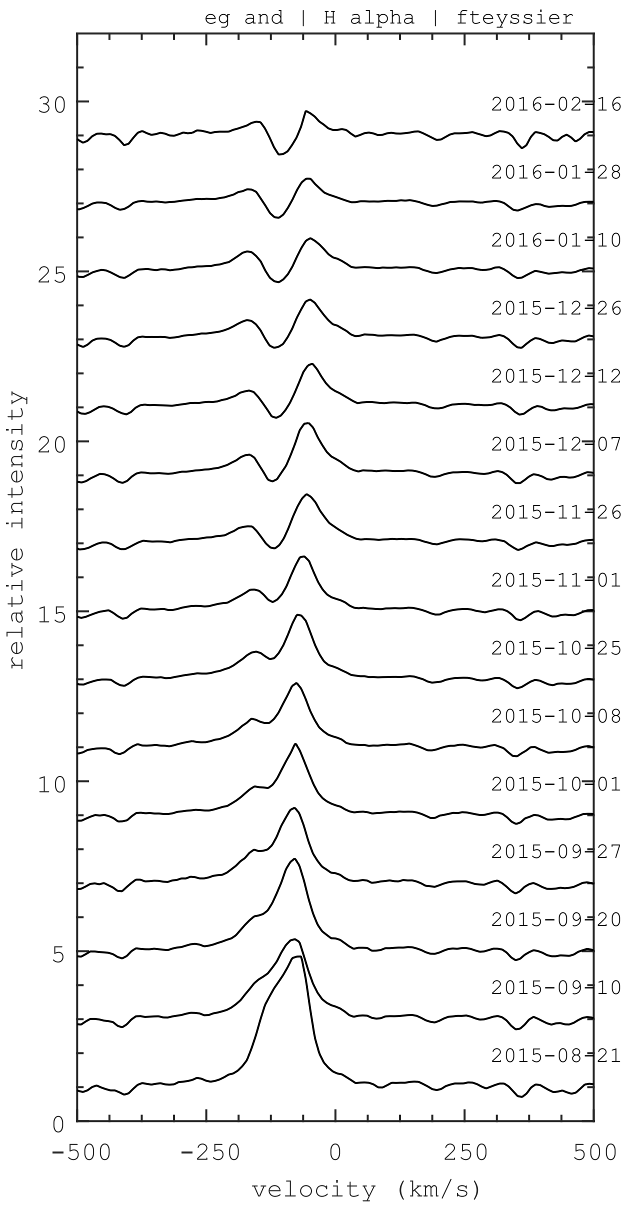
Flux calibrated spectrum - David Boyd - LISA R= 1000

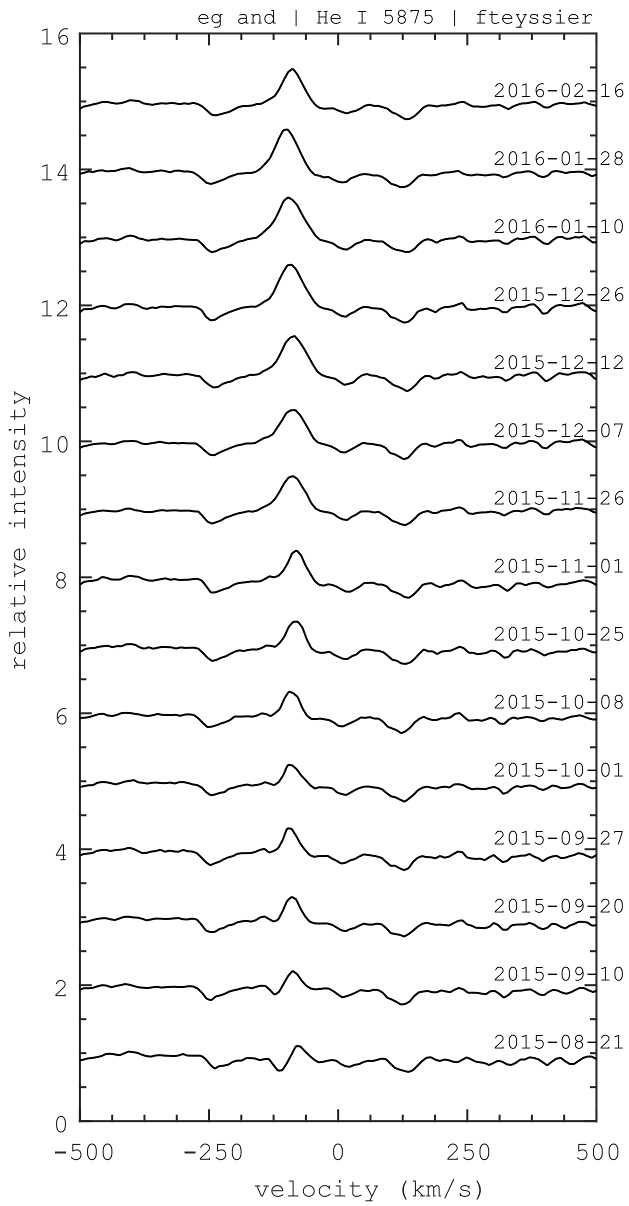


eShel spectrum R = 11000 F. Teyssier

EG And

H alpha and He I 5876 evolution in 6 months,
from late August,2015 to January, 2016
eShel spectra R = 11000 F. Teyssier



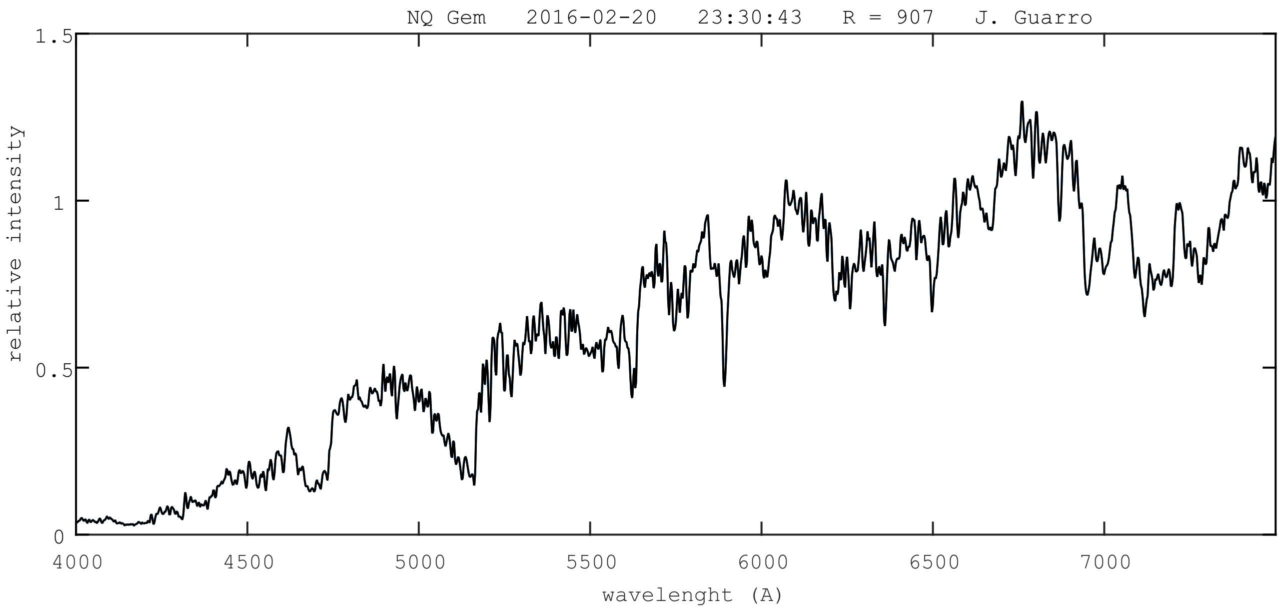


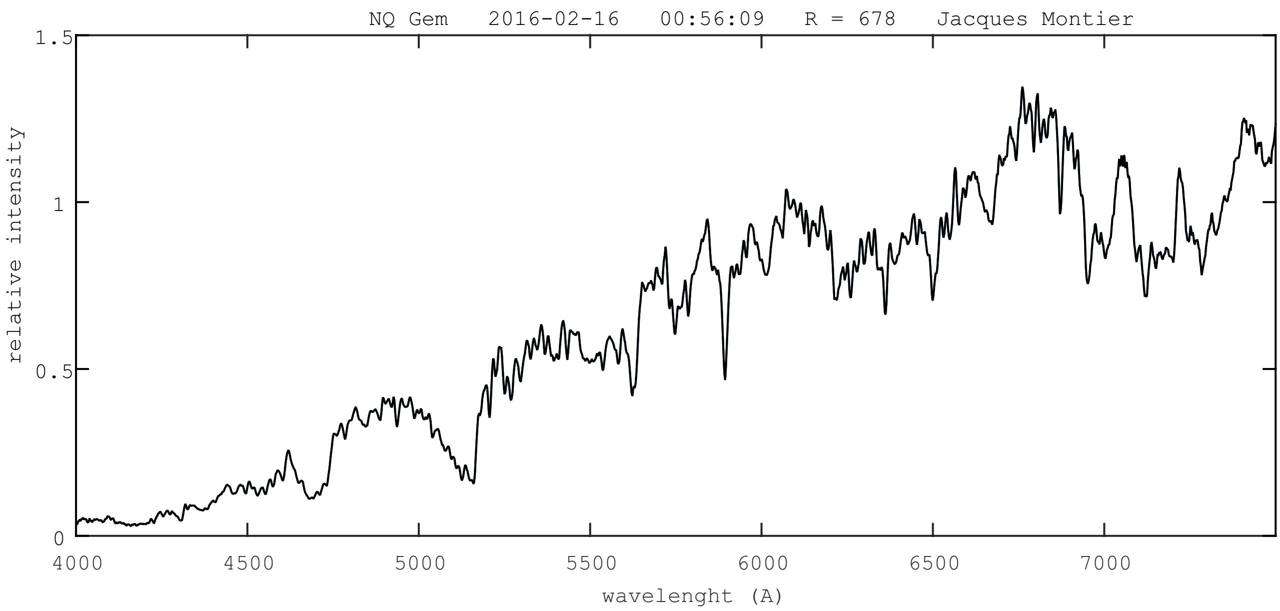
Note the inverse correlation between Ha and He I intensities

SYMBIOTICS

NQ Gem

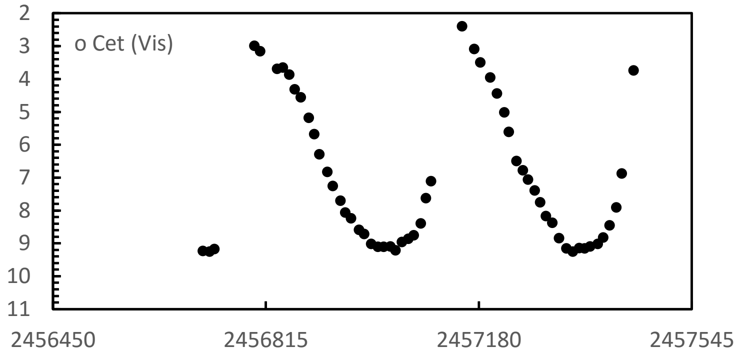
Coordinates (2000.0)	
R.A.	07 31 54.5
Dec	+24 30 12.5
Mag	7.9



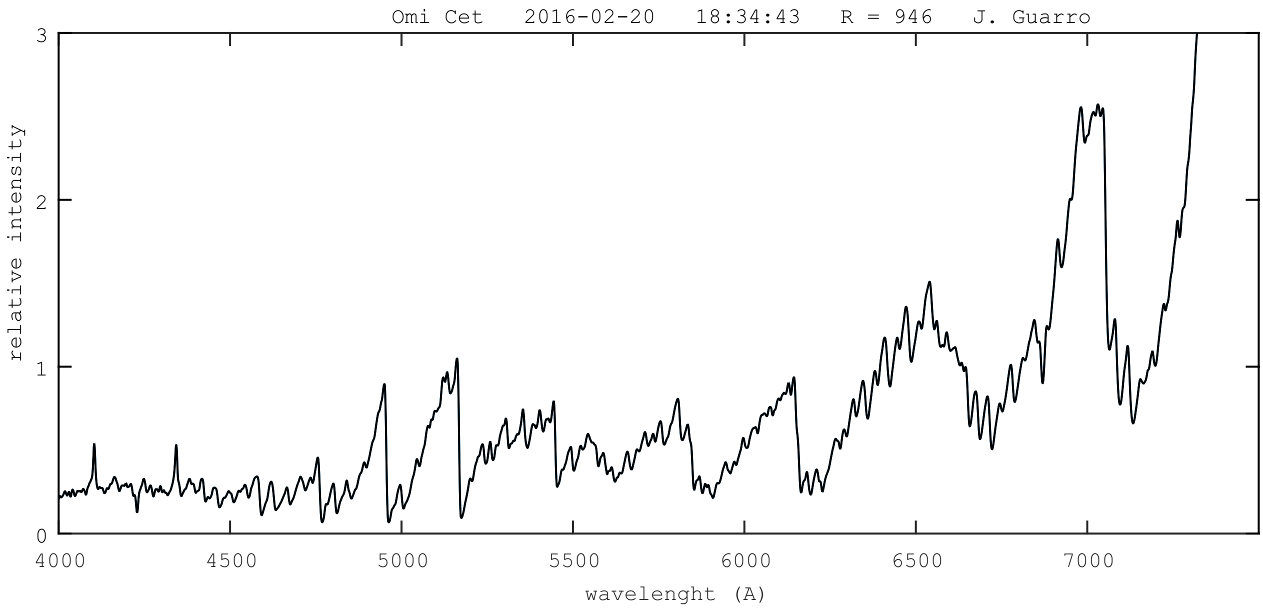


o Cet

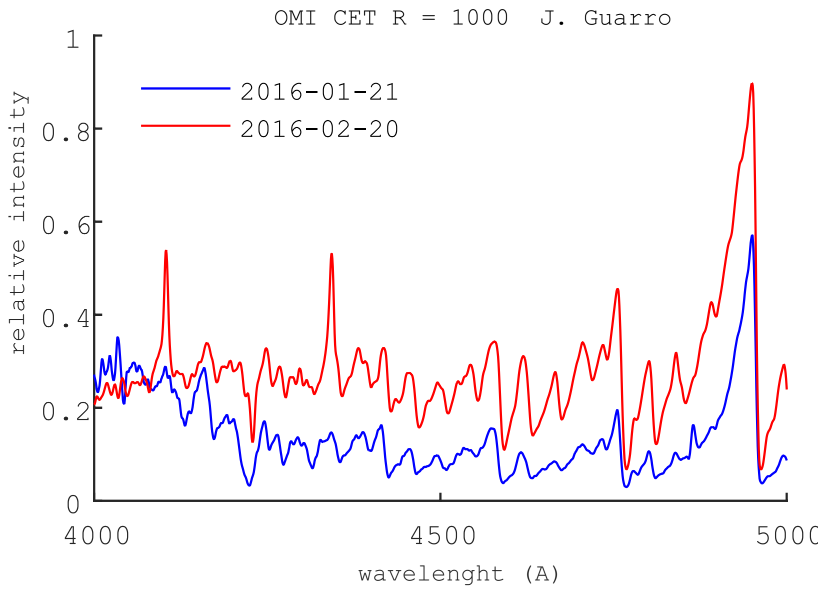
Coordinates (2000.0)	
R.A.	02 19 20.8
Dec	-02 58 39.5
Mag	7.4



Mira near its maximum luminosity

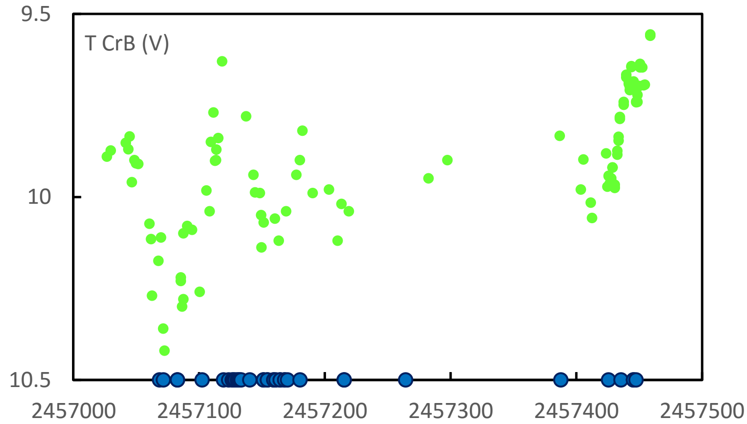


Comparison of Joan's spectra during the rise
In February, Hγ and Hδ appears in emission, a classical behavior for Mira Stars near their maximum



T CrB

Coordinates (2000.0)	
R.A.	15 59 30.2
Dec	+25 55 12.6
Mag	



AAVSO V Band lightcurve 2015-2016
ARAS Spectra blue dots

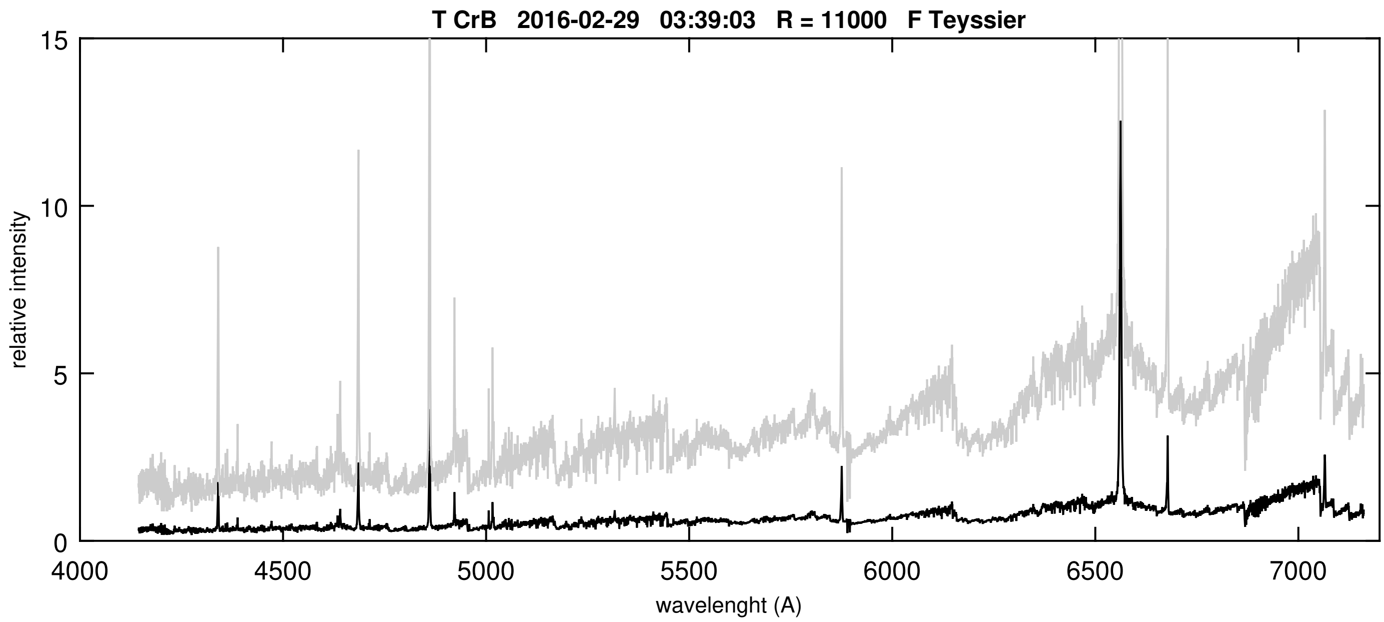
The recurrent nova T CrB has entered in 2015 a phase of unprecedented high activity. To trace something equivalent, it is necessary to go back to 1938, before the last nova eruption in 1946. The 2015 super-active state is characterized by: a large increase in the mean brightness (Delta B =0.72 mag over the uderlying secular trend), vanishing of the orbital modulation from the B-band lightcurve, and appearance of strong and high ionization emission lines, on top of a nebular continuum that overwhelms at optical wavelengths the absoption spectrum of the M giant. Among the emission lines, HeII 4686 attains a flux in excess of Hgamma, the full set of OIII and NIII lines involved in the Bowen fluorescence mechanism are strong and varying in intensity in phase with HeII 4686, and OIV and [NeV] are present

The recurrent nova T CrB has entered in 2015 a phase of unprecedented high activity.

Is therefore everything in place for a new nova outburst in 2026, again 80 years past the last eruption ?

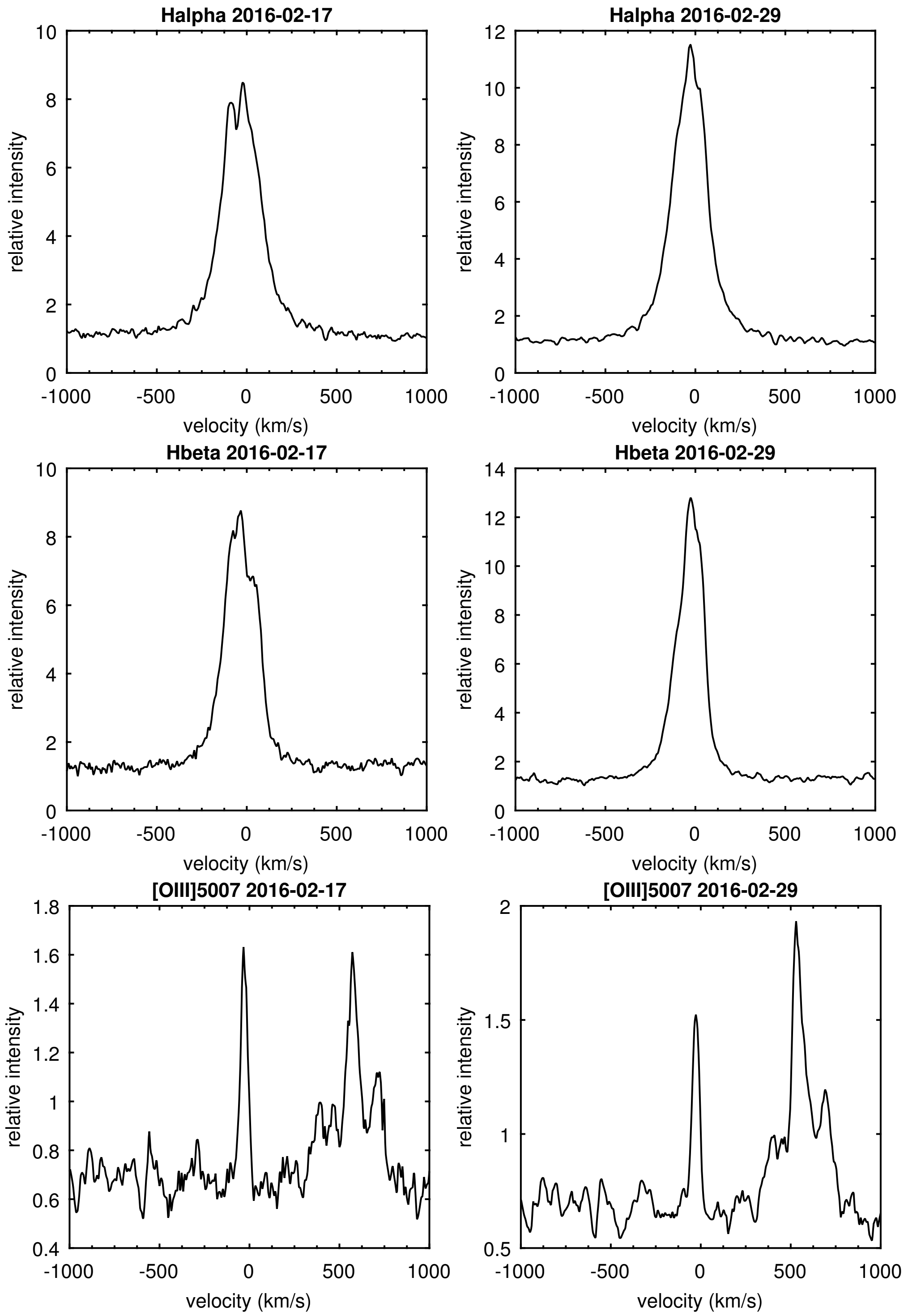
See Munari & al., 2016

U. Munari, S. Dallaporta, G. Cherini
The 2015 super-active state of recurrent nova T CrB and the long term evolution after the 1946 outburst
http://arxiv.org/abs/1602.07470

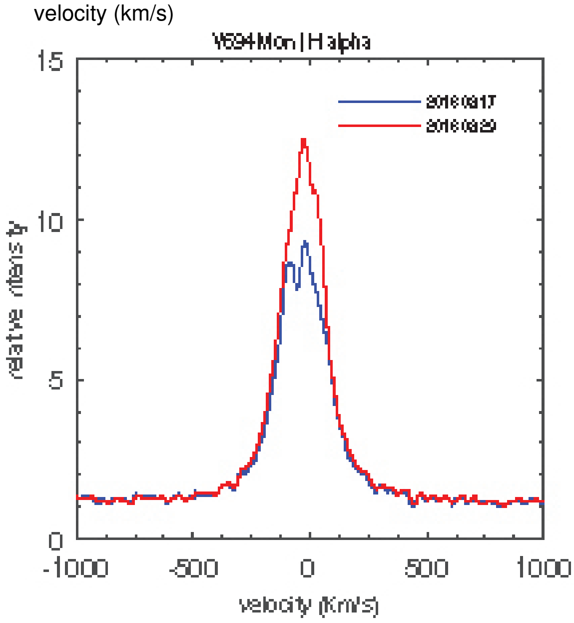


T CrB

Comparison of profiles 17-02 and 29-02-2016 F. Teyssier eshel R = 11000

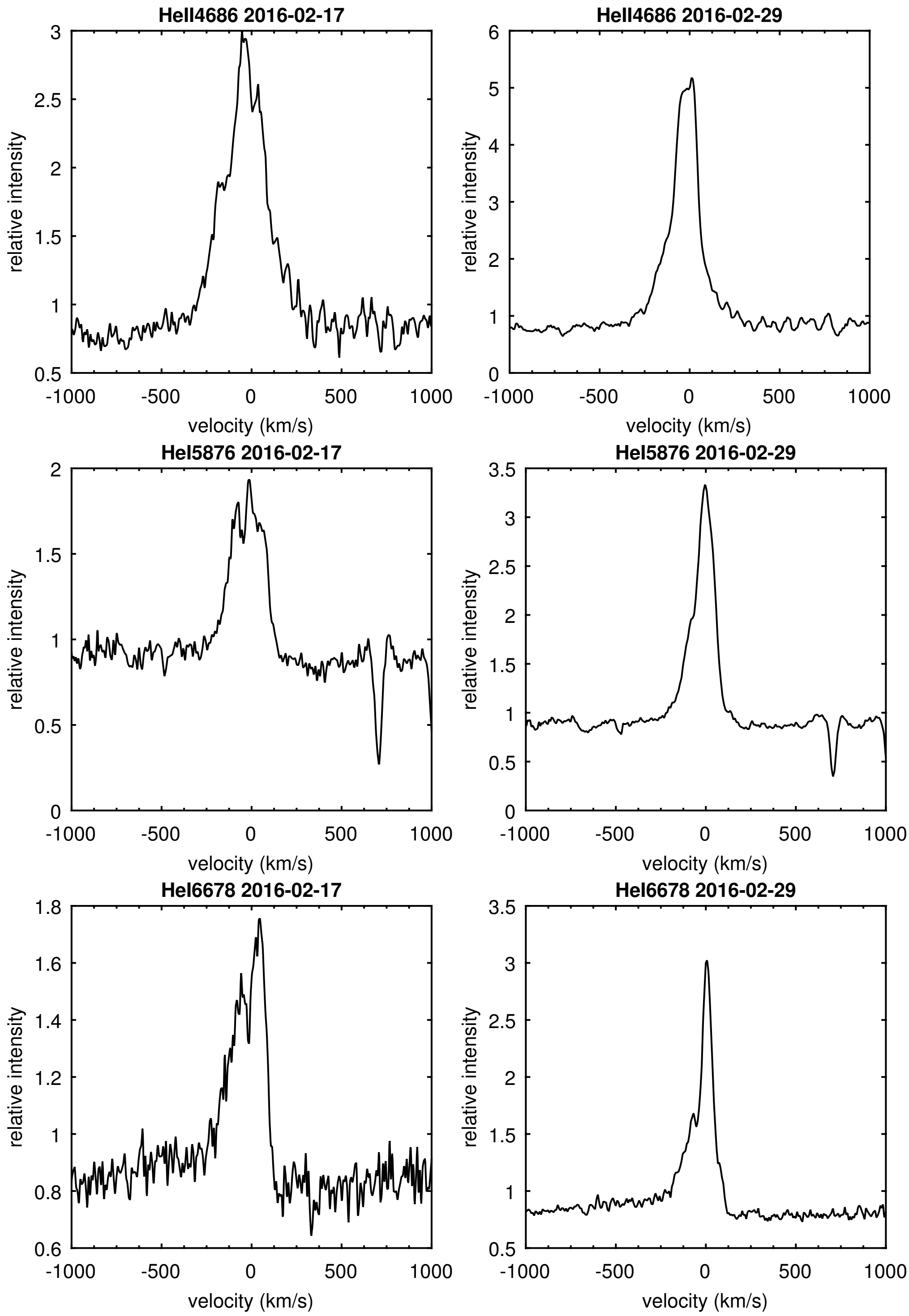


Comparison of Hα and He II for the two dates Note the changes of profiles, especially the central absorption:



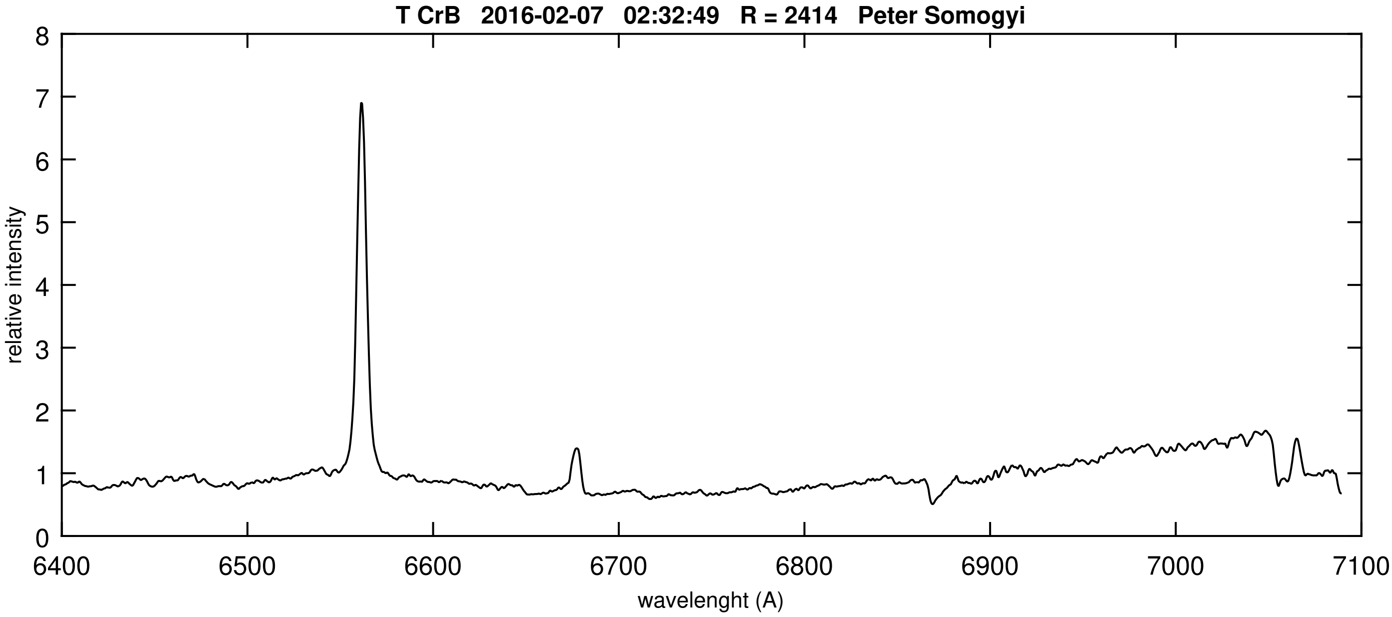
T CrB

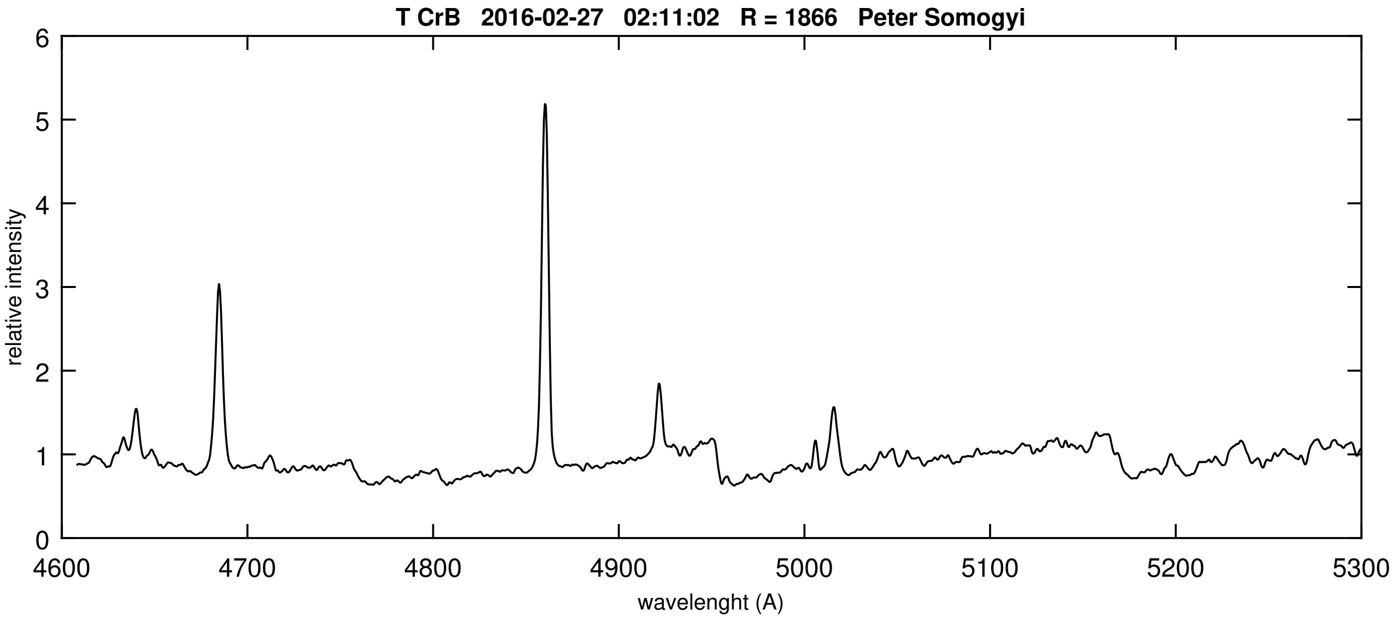
Comparison of profiles 17-02 and 29-02-2016 F. Teyssier eshel R = 11000



T CrB

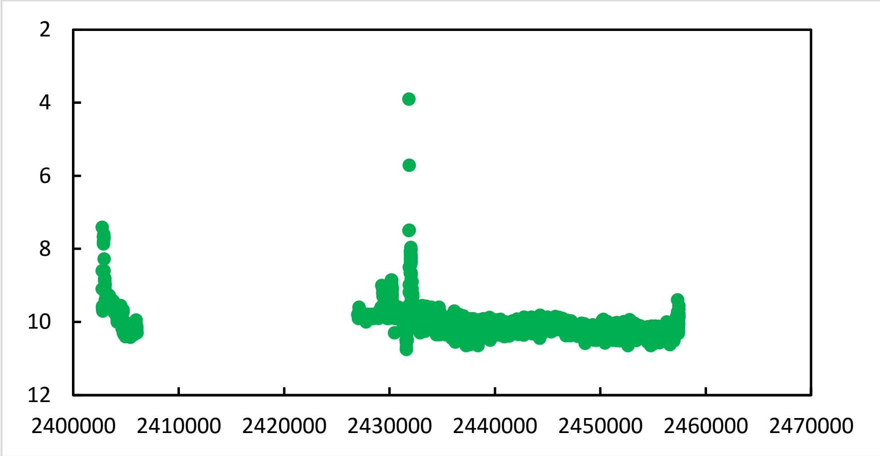
Hα and Hβ regions by Peter Somogyi Lhires III 600 l/mm R = 2500



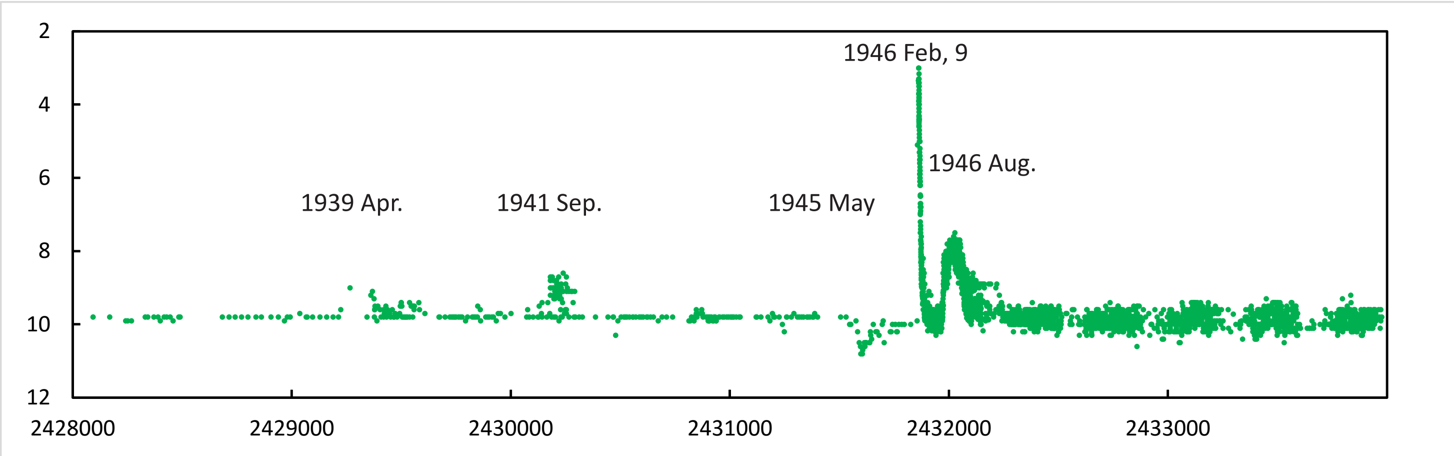


T CrB

T CrB is a symbiotic star consisting of a MIII3 giant filling its Roche lobe and a massive (M= 1.4 $M_{\odot}$ white dwarf.
T CrB shows flickering at a time scale of hour (ΔV = 0.5).
T CrB is one the rare known recurrent novae with two outbursts raising mag 2 detected in 1866 and 1946.



AAVSO historical light curve (Visual, Mean on 3 days) showing the two nova-type events in 1866 and 1946

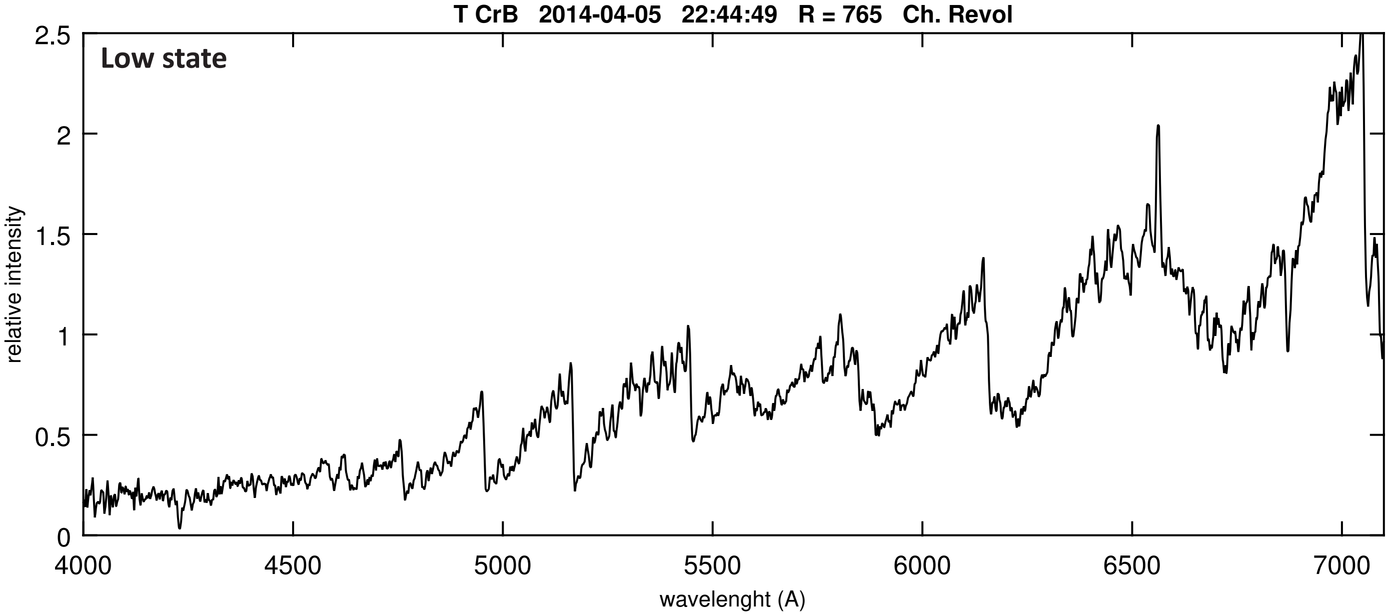


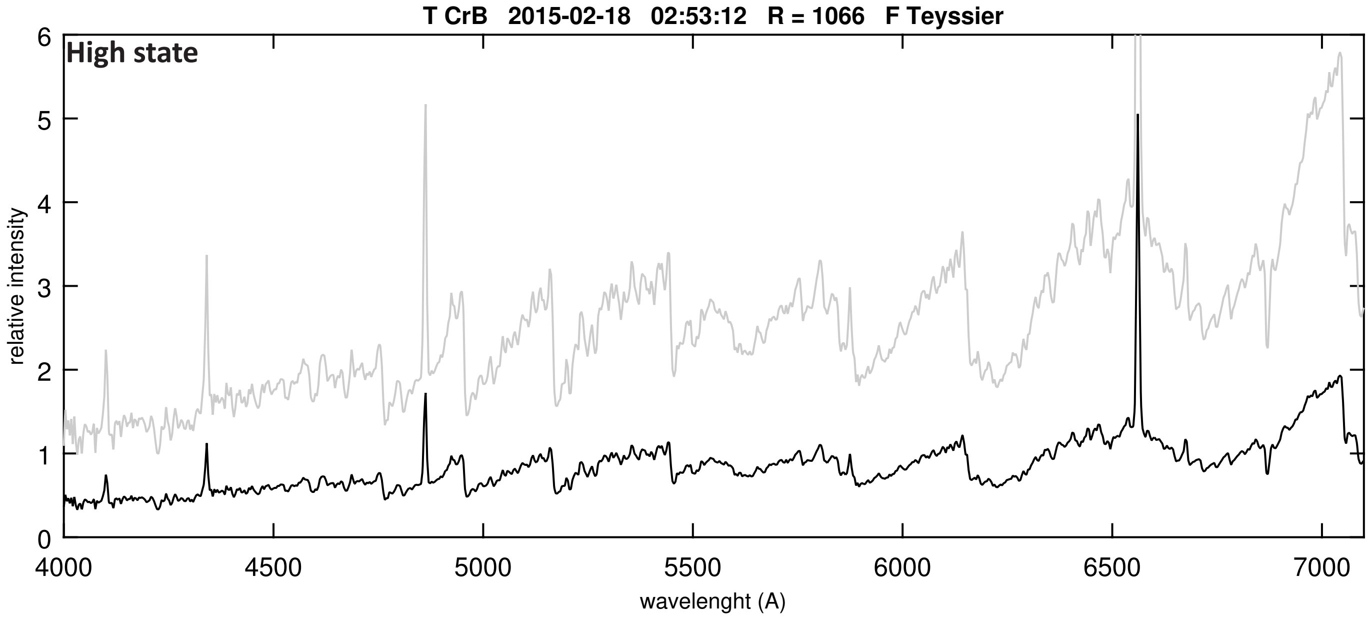
1946 nova event

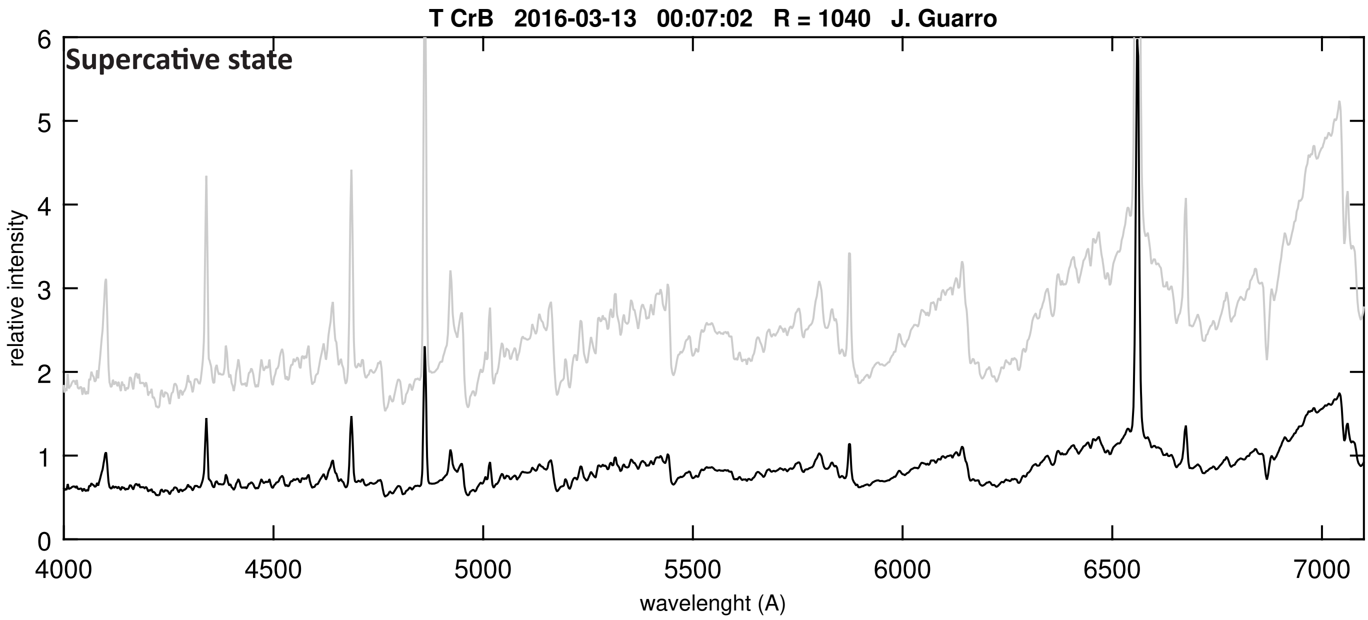
Two outbursts mag ~ 9 in 1939 and 1941. Luminosity declining in May 1945
Nova outburst Peak = mag 2 (1946 Feb, 9)
Secondary outburst (mag ~ 8) in August 1946 about 6 months after the principal outburst

T CrB

Three states according to Iijima (1990) and Munari & al. (2016)
- low state : weak H alpha line on the giant M3III continuum
- high state : strong Balmer and He I emission lines
- superactive state : strong He II, [O III], Bowen fluorescence blend 4640 (N III)







T CrB

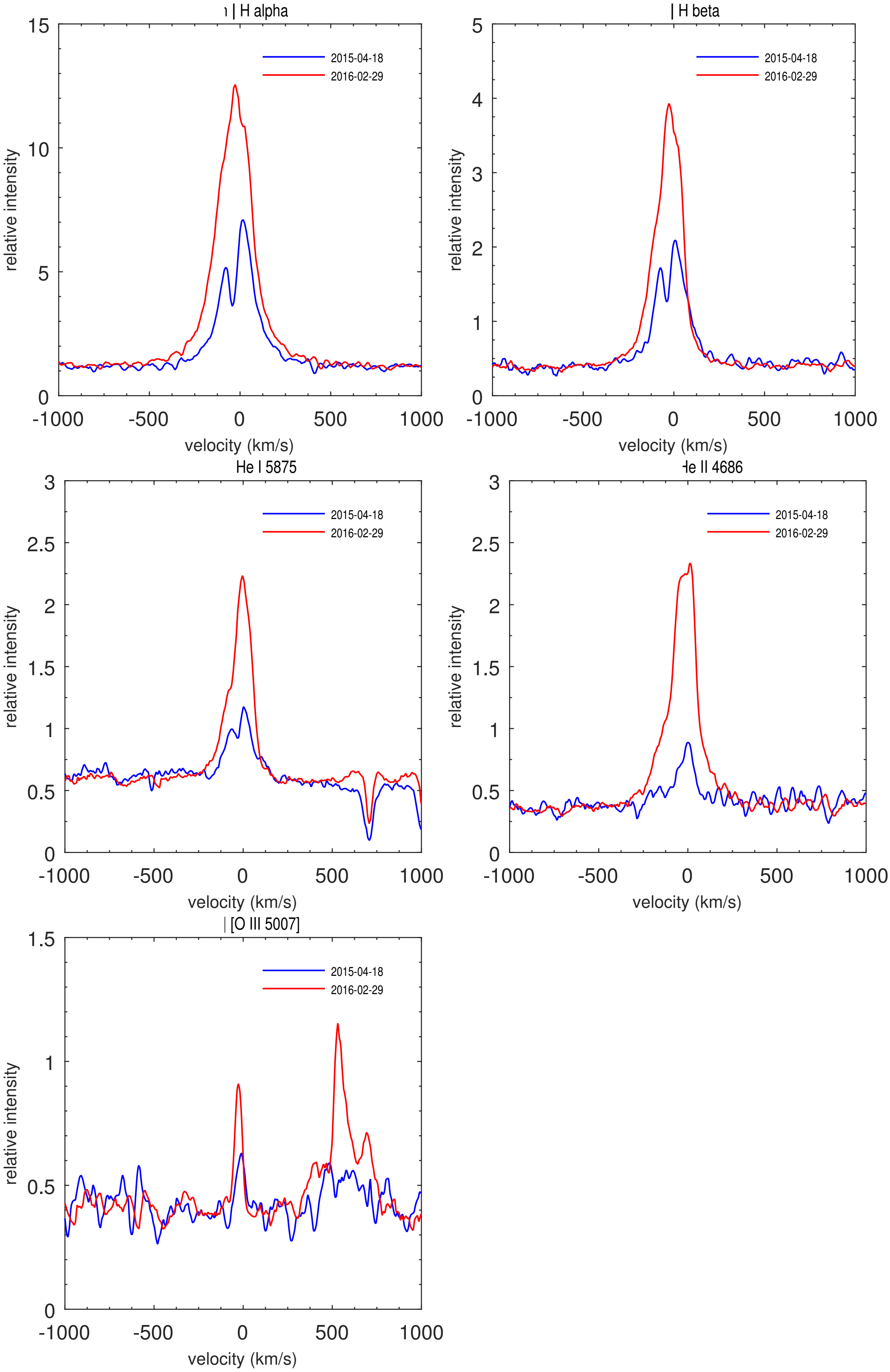
Comparison of lines profiles obtained at R = 11000 with an eshel spectroscop (F. Teyssier) in 2015 and 2016.

18-04-2016 : orbital phase = 0.730

29-02-2016 : orbital phase = 0.123

Ephemeris : Min I = 2431933.83 + 227.55 × E primary minima (Passage of the M3III companion at inferior conjunction)

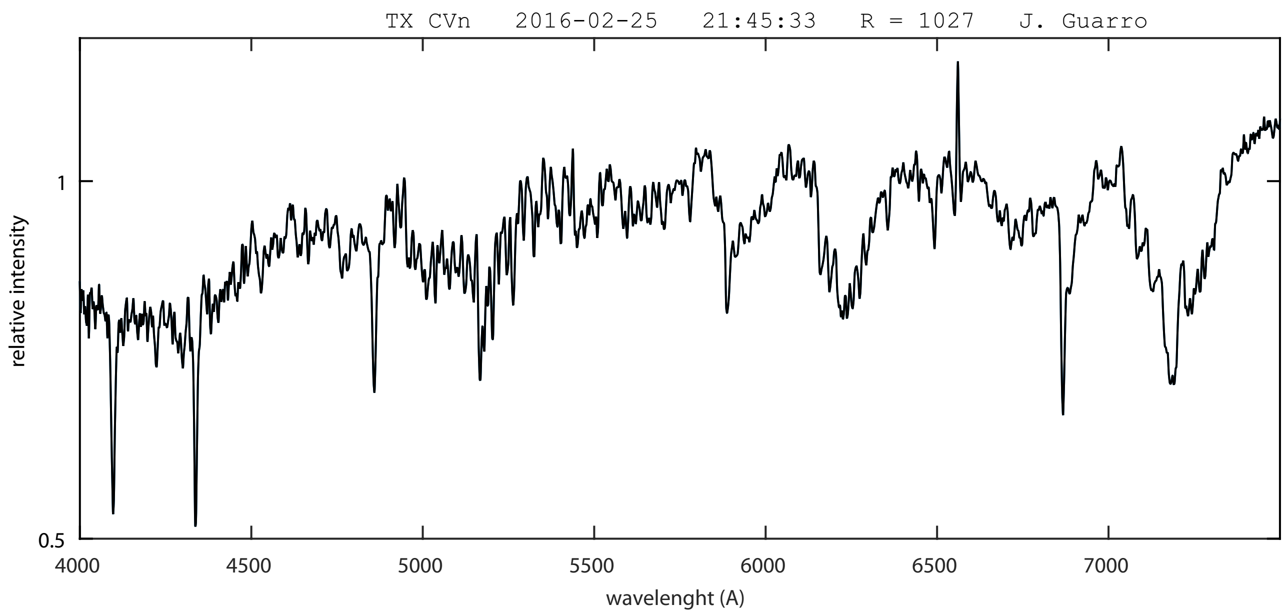
Note that the typical absorption in Balmer and He lines which originates in the outflowing wind of symbiotics has vanished (all the nebula is ionized)



S Y M B I O T I C S

TX CVn

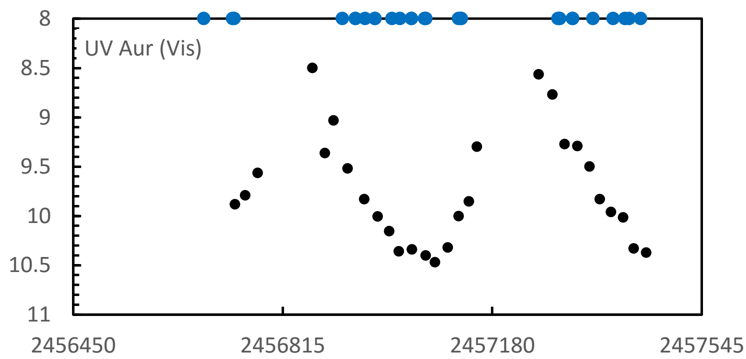
Coordinates (2000.0)	
R.A.	12 44 42.0
Dec	+36 45 50.7
Mag	



SYMBIOTICS

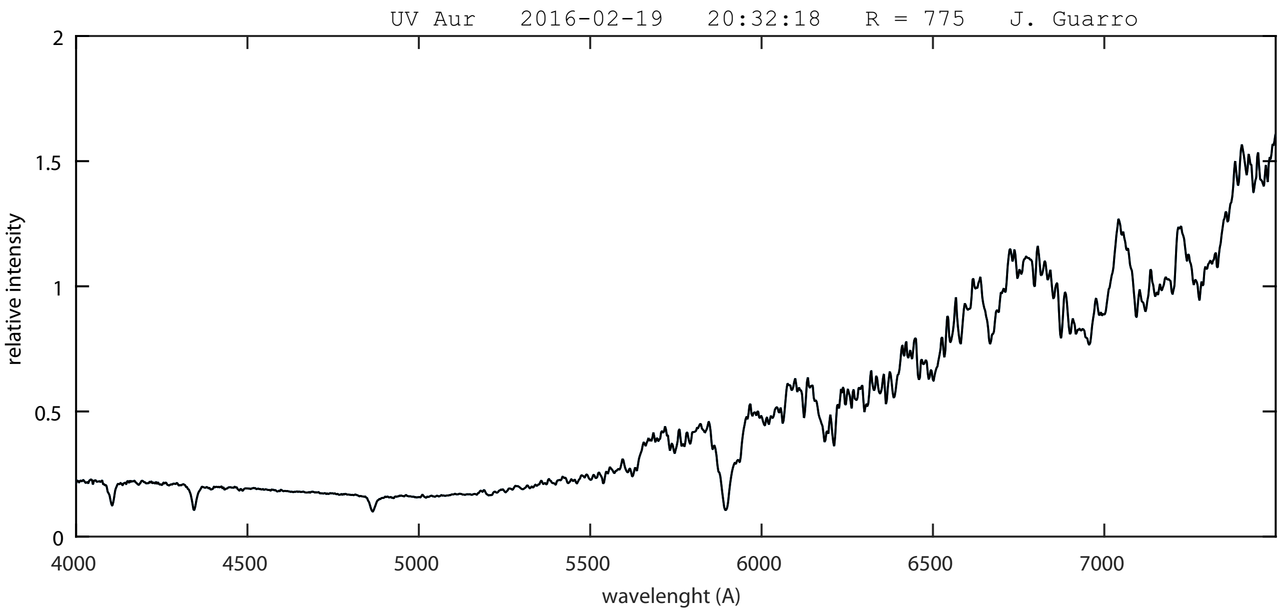
UV Aur

Coordinates (2000.0)	
R.A.	5 46 42.1
Dec	+06 43 47.1
Mag	10.2 (01-2016)



AAVSO light curve (visual, mean values)
from 2014 to 2016
ARAS spectra : blue dots

S

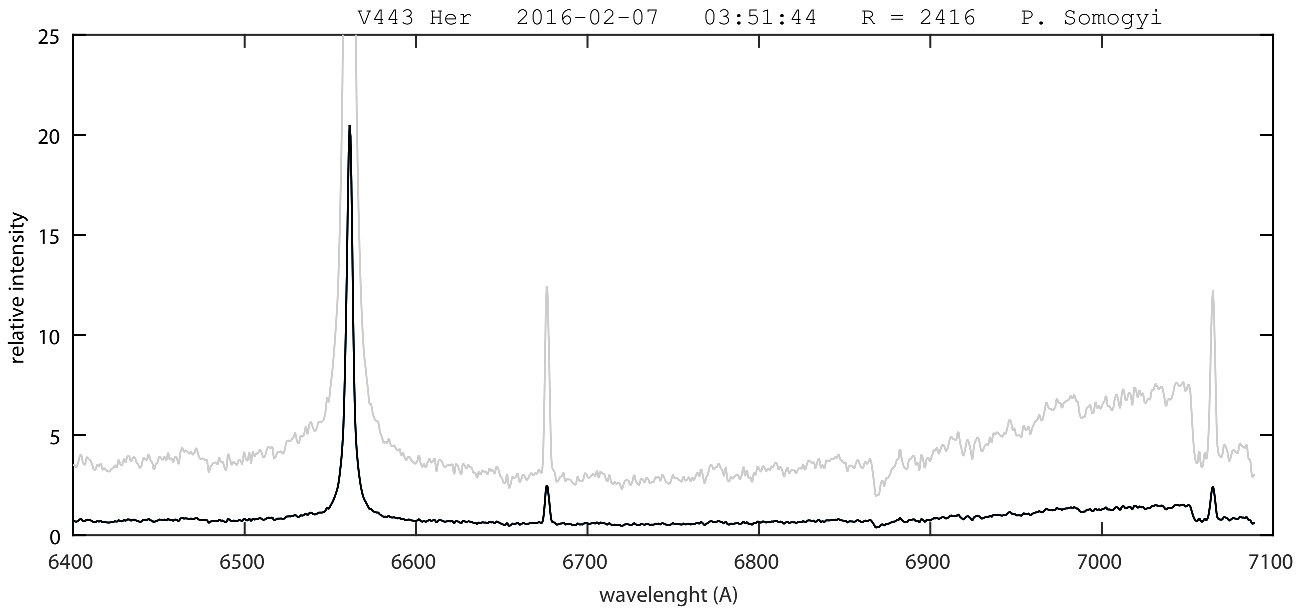


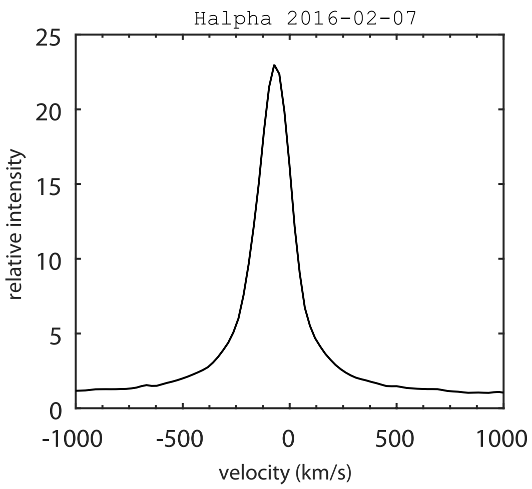
S Y M B I O T I C S

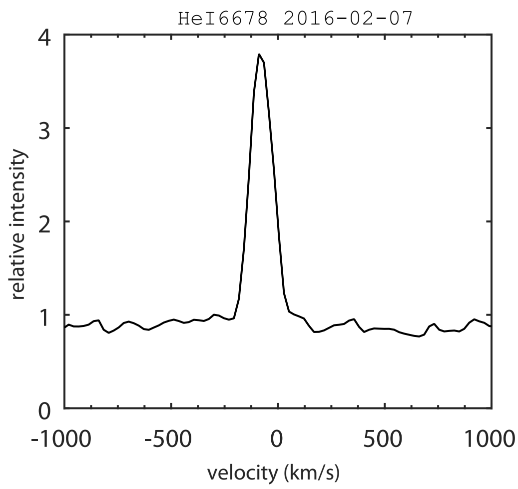
V443 Her

Coordinates (2000.0)	
R.A.	18 22 07.8
Dec	+23 27 20.0
Mag	11.7

The classical symbiotic V443 Her
now in the morning sky

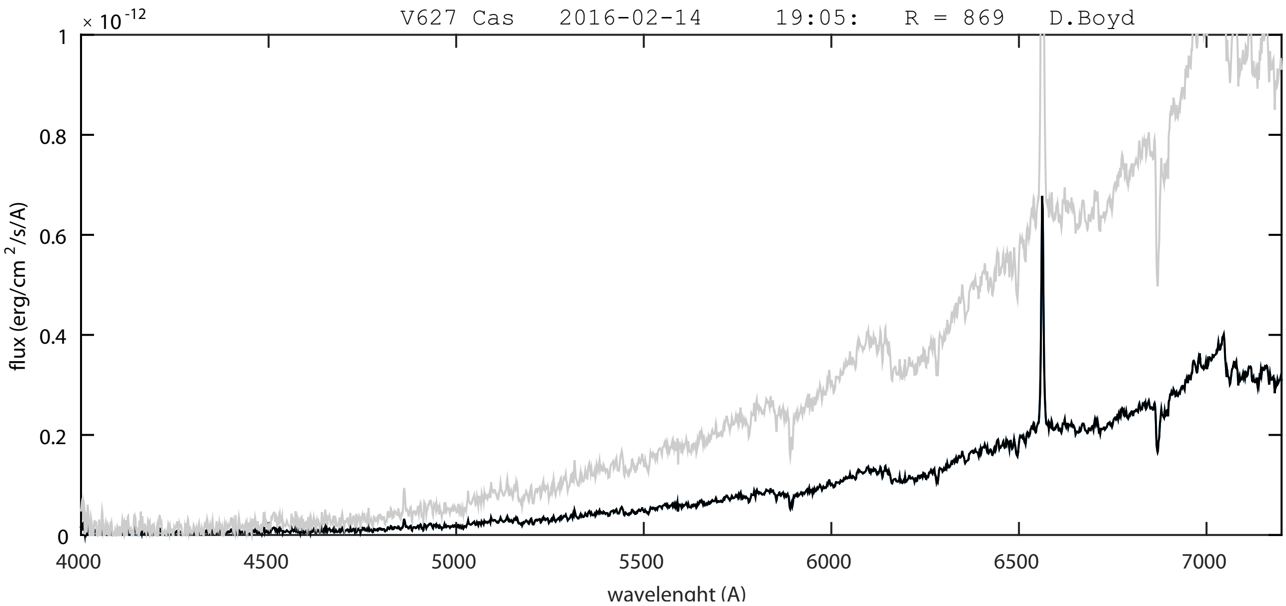


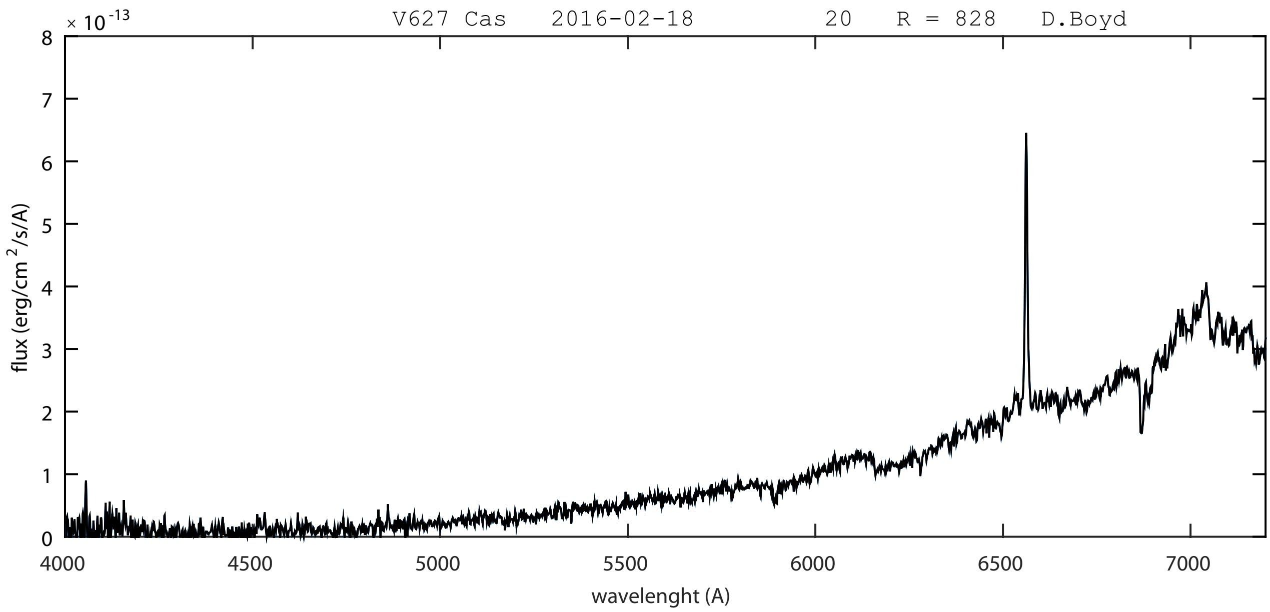




V627 Cas

Coordinates (2000.0)	
R.A.	22 57 41.2
Dec	58 49 14.9
Mag	12.7 (V)

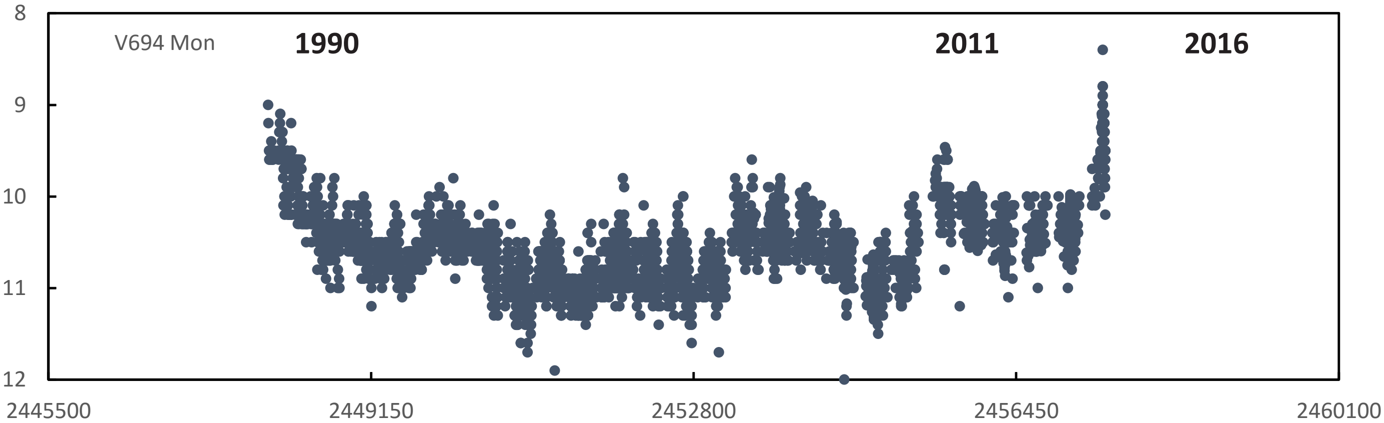




V694 Mon

Coordinates (2000.0)	
R.A.	07 25 51.3
Dec	-07 44 08.1
Mag	9.8 (12-2015)

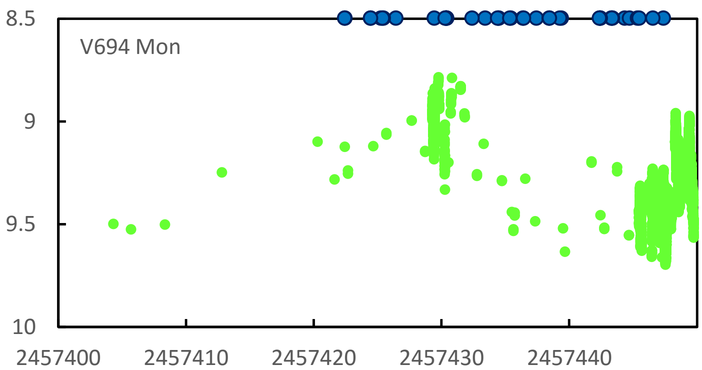
V694 Mon Field
18th Feb., 2016
David Boyd

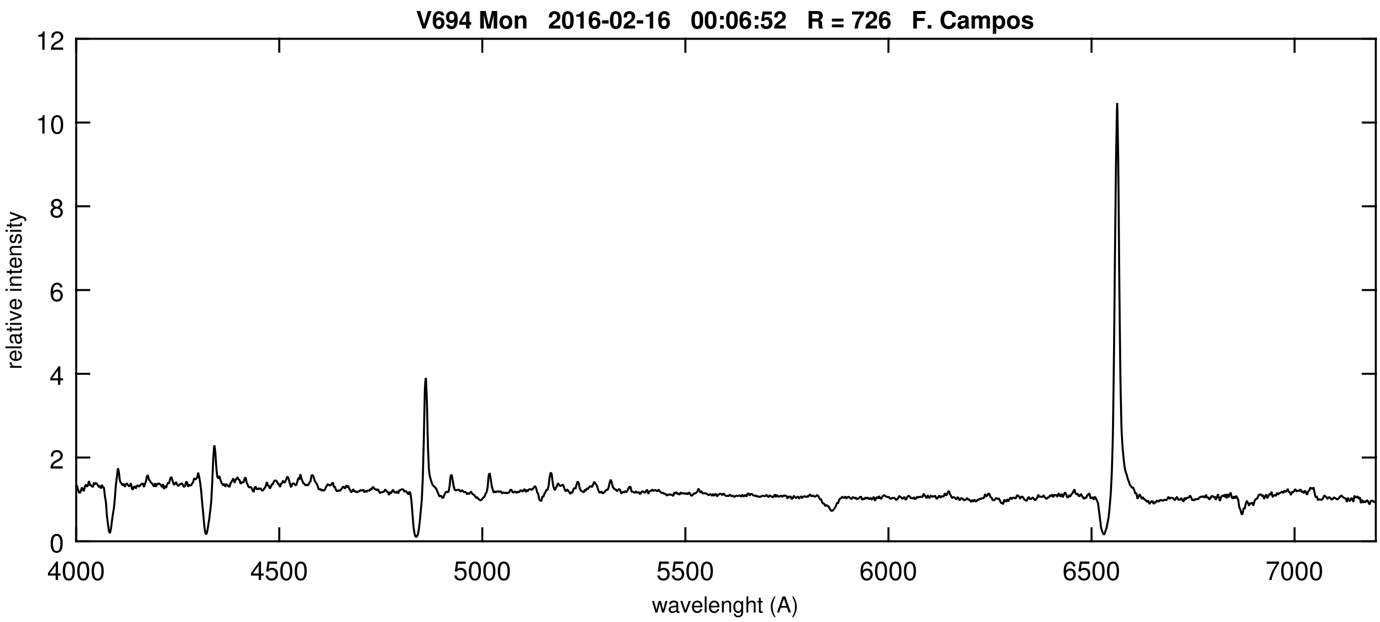


Long term AAVSO light curve in V and Visual. 2016 outburst brighter than 1990

AAVSO V band database
ARAS Spectra in February (48): blue dots
V mag (max) declined from ~ 8.7 to ~9.2.
0.5 mag flickering at time scale ~ 1 hour

At date, the maximum velocity of absorptions remains at about 2000 km/s. No plateau detected between absorption and emission



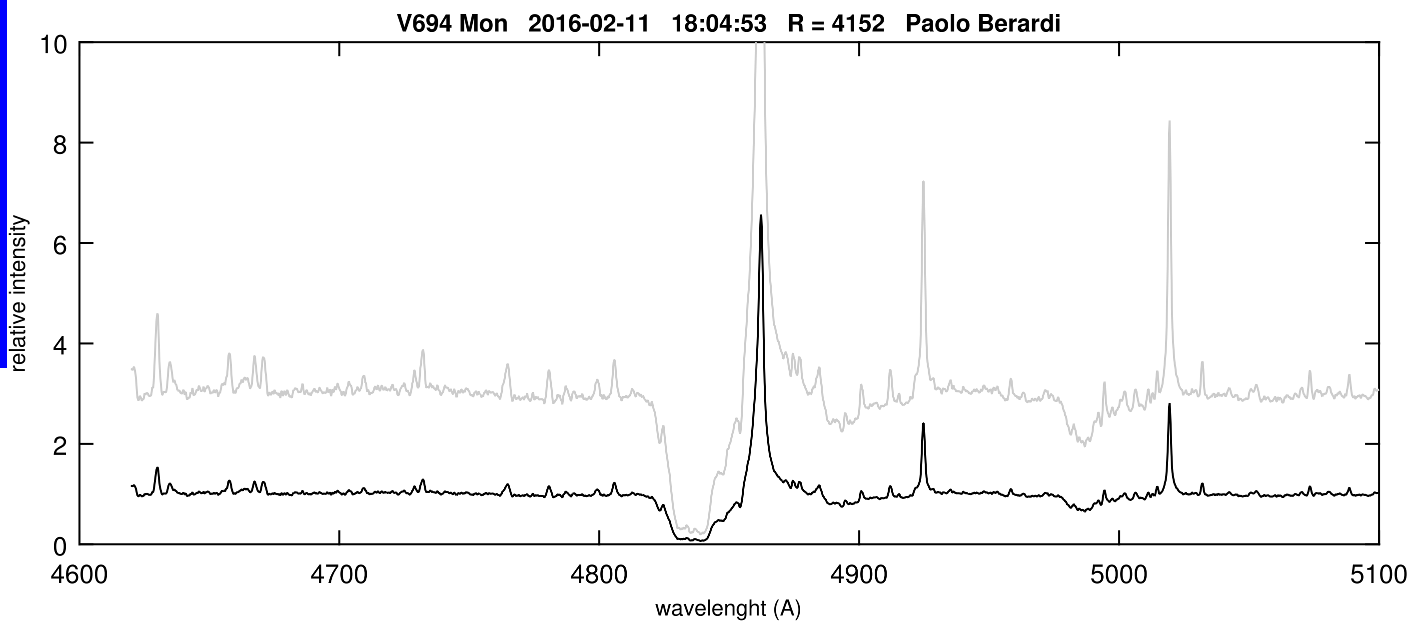


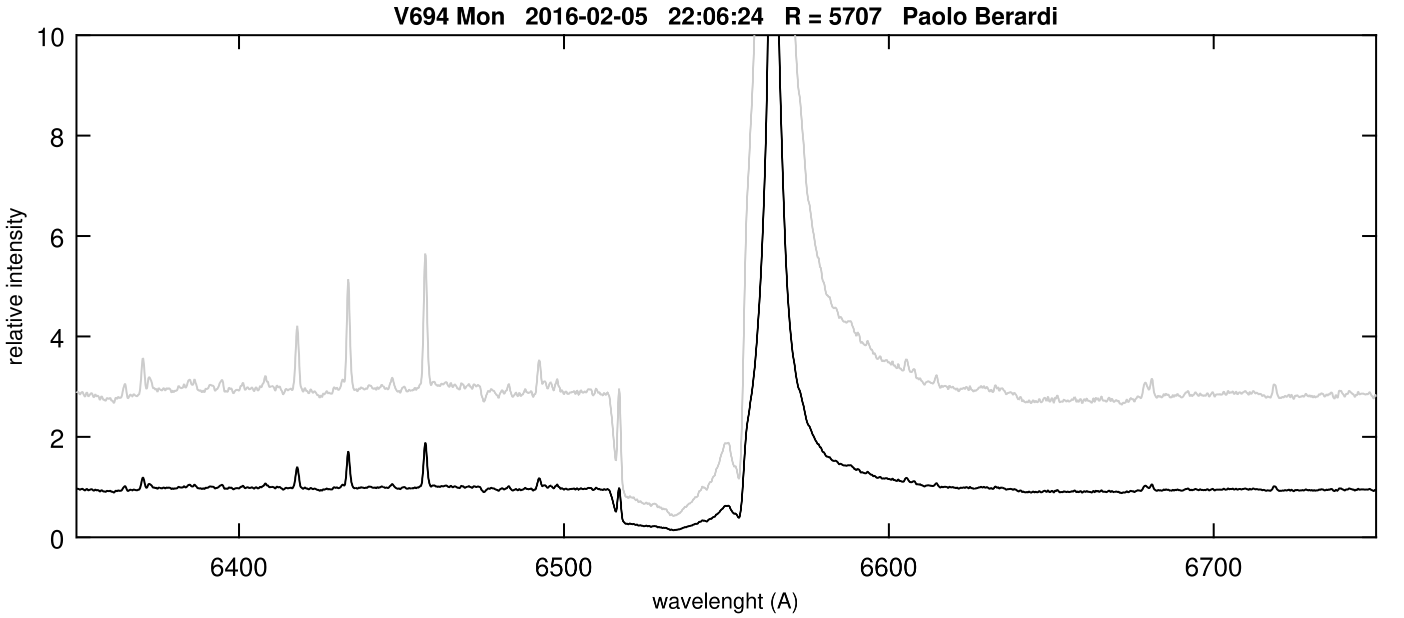
Frederico Campos Dados spectrograph

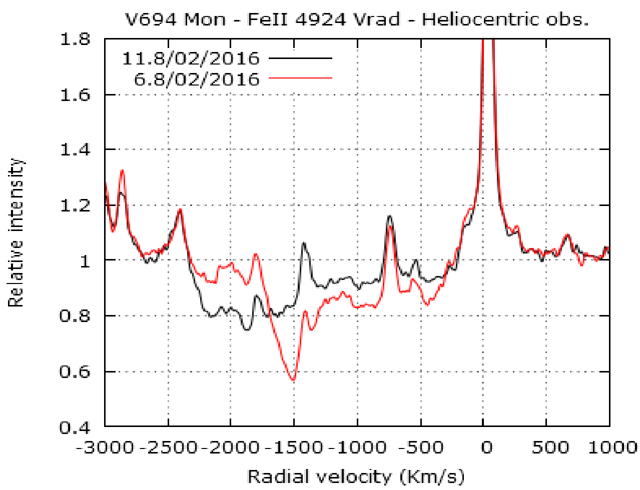
SYMBIOTICS

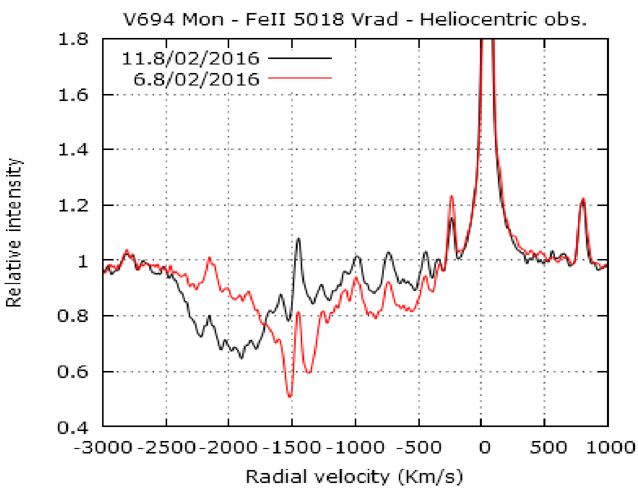
V694 Mon

Paolo Berardi
Lhires III (1200 l/mm) R = 5000



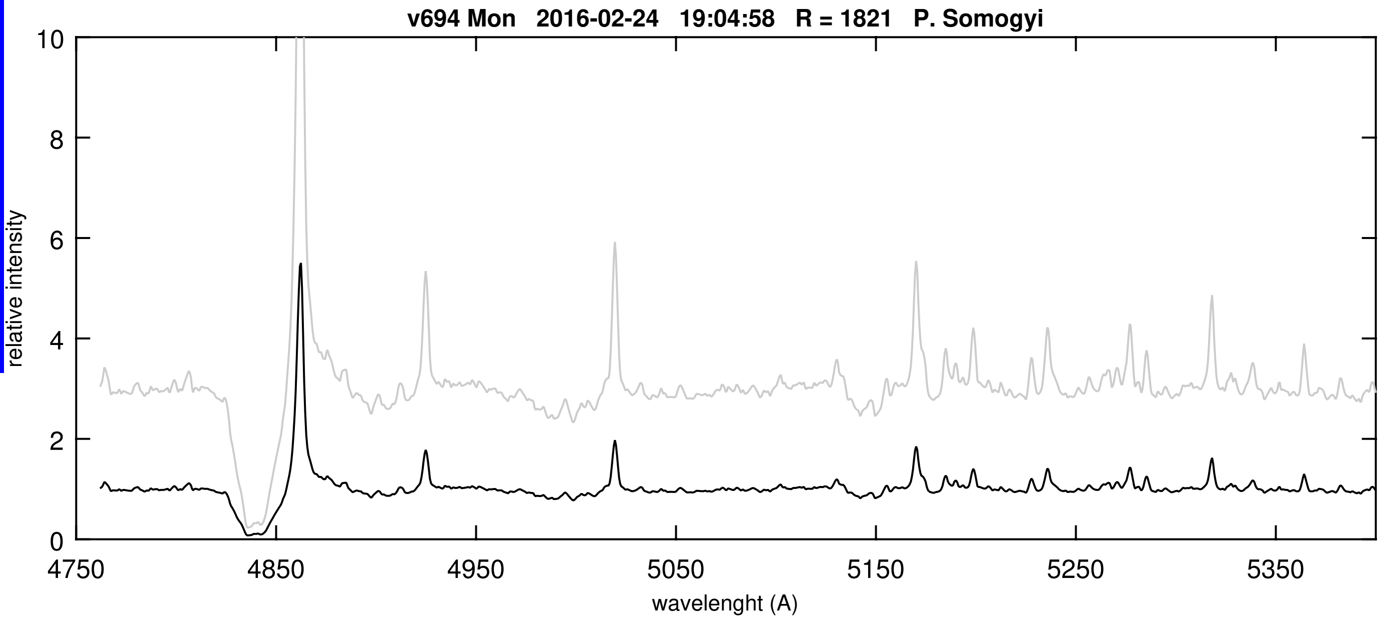


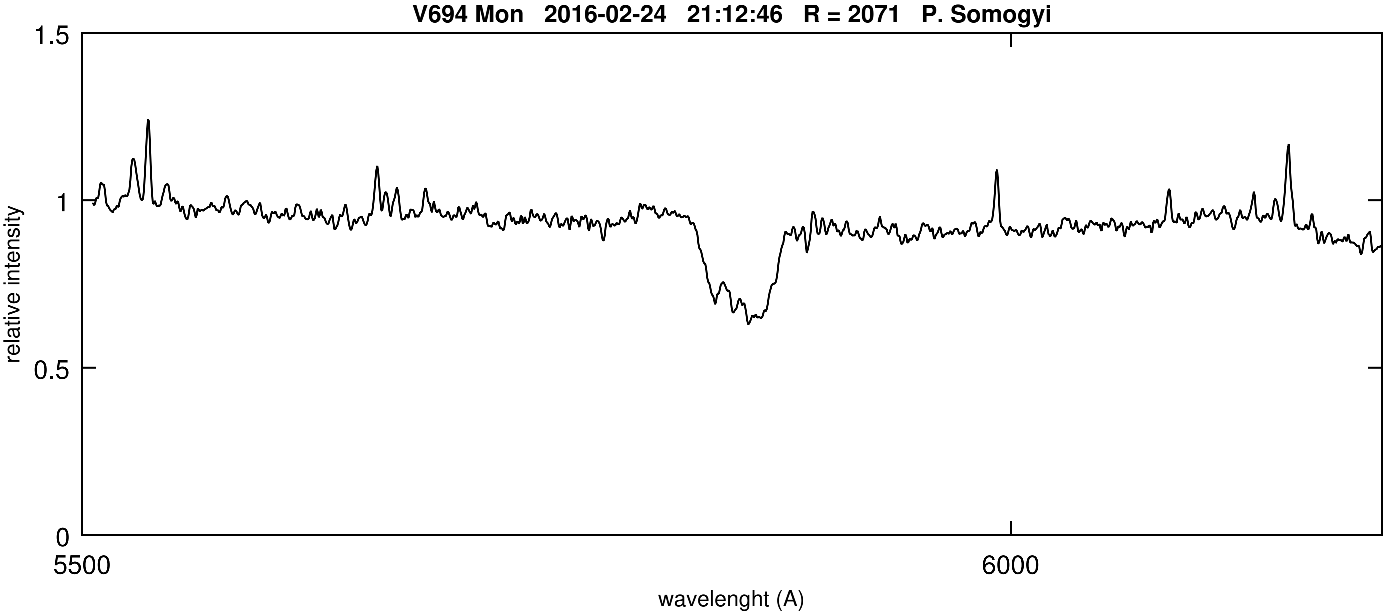


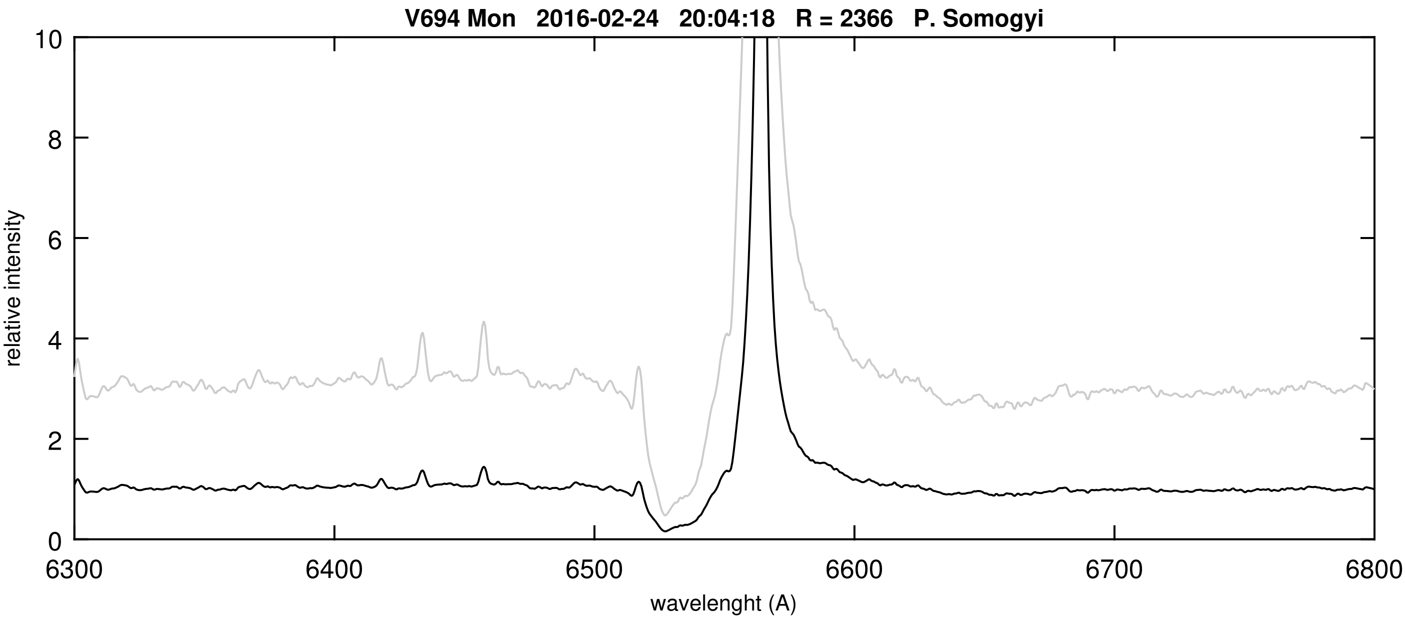


V694 Mon

R= 2500 Lhires III 600 l/mm Peter Somogyi

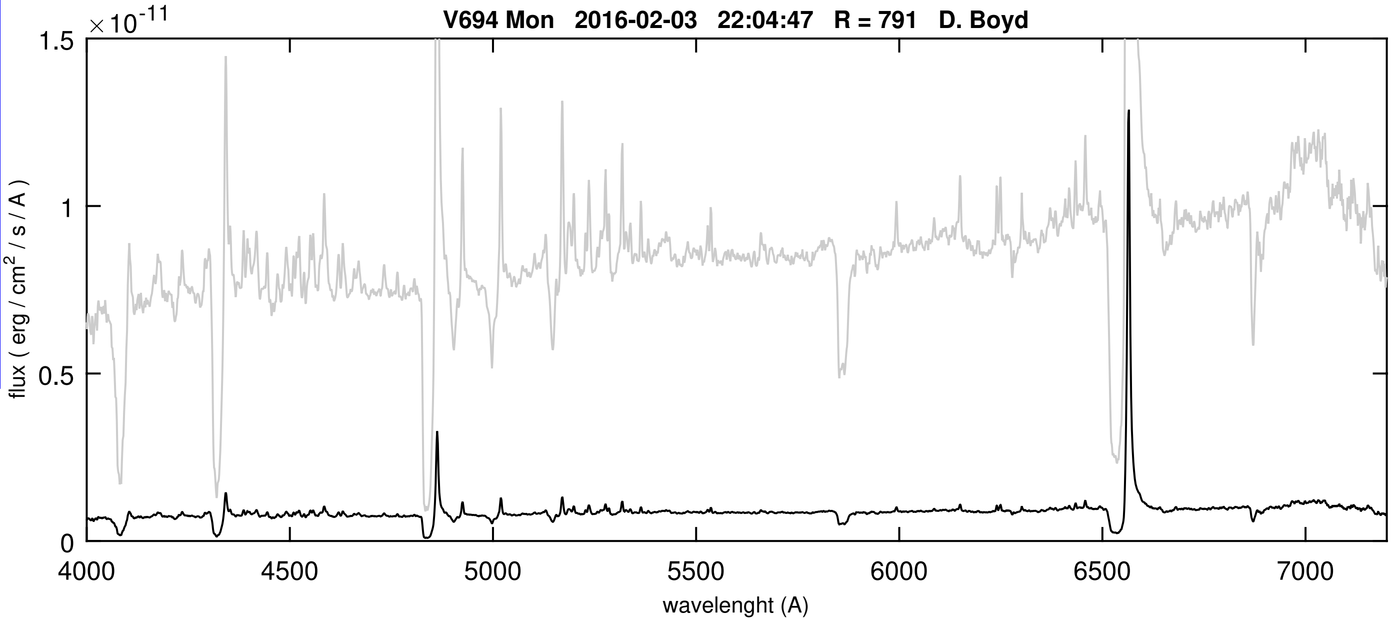


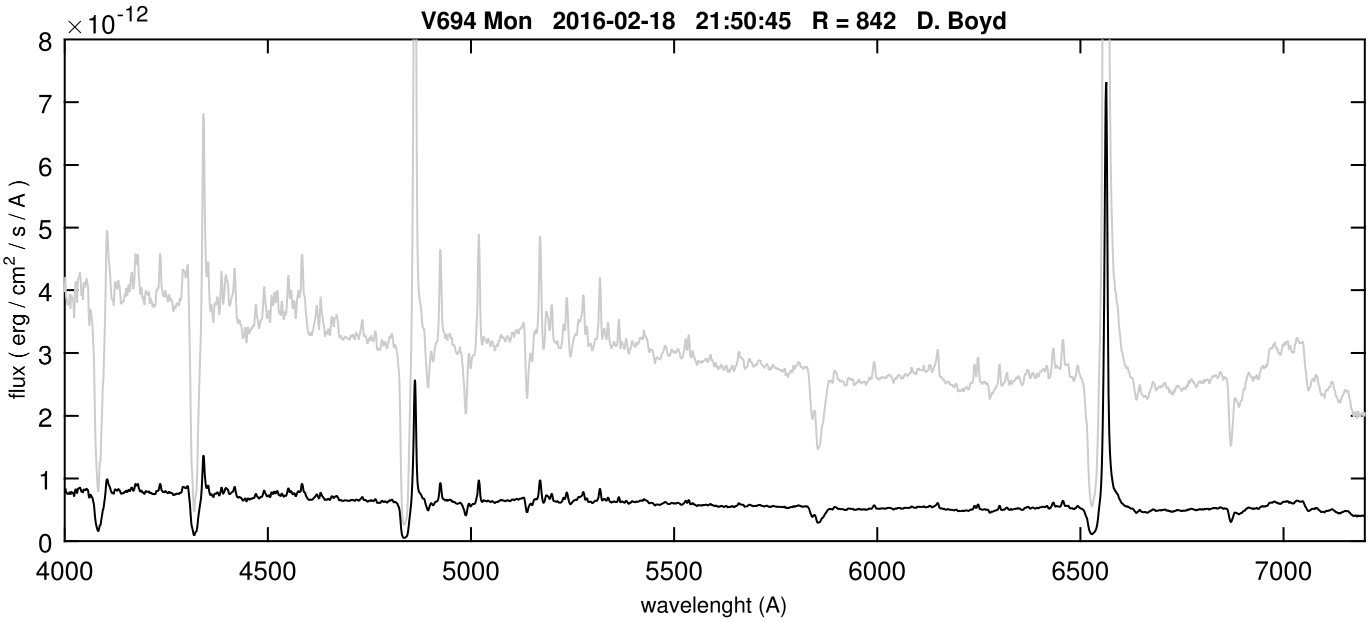


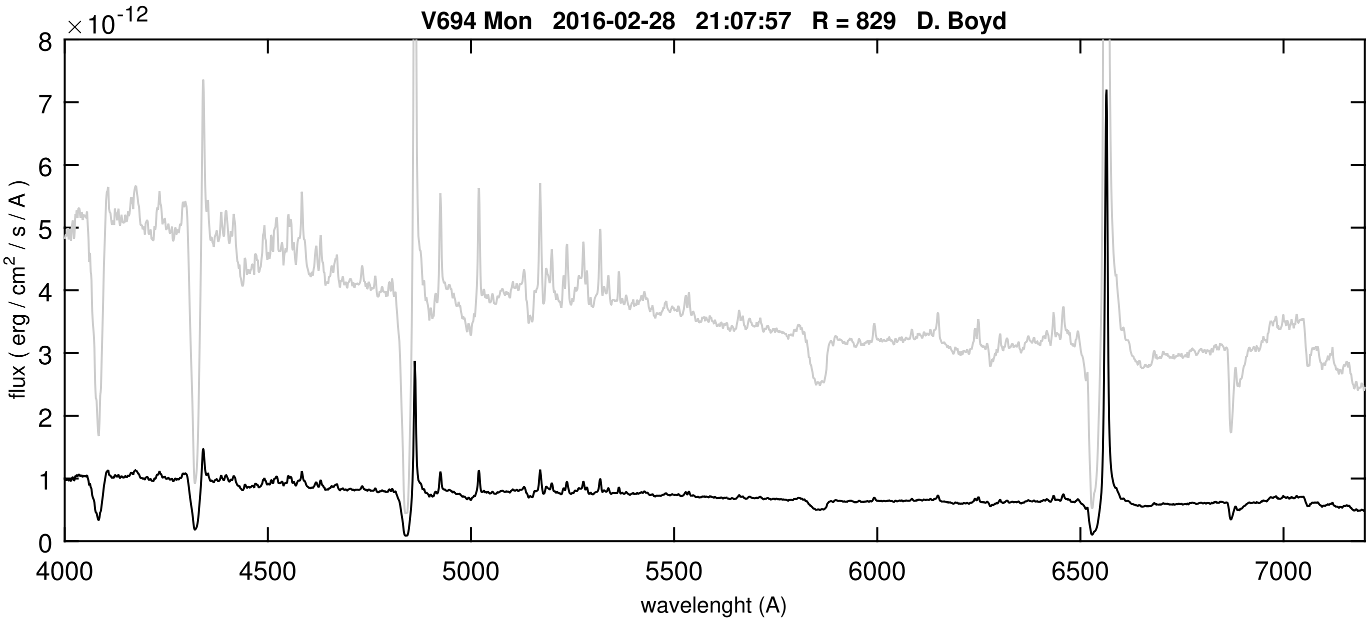


V694 Mon

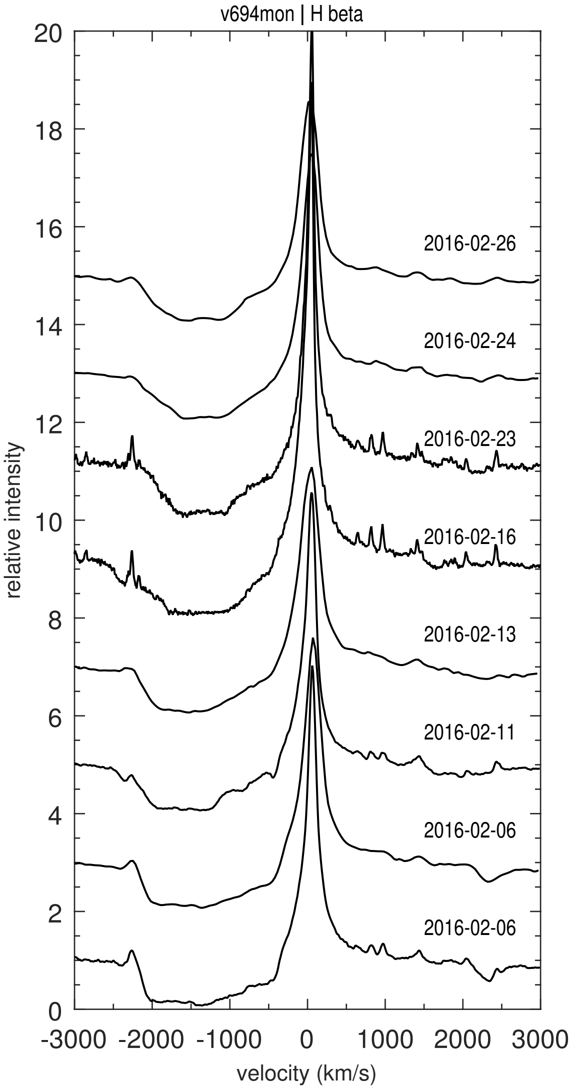
Flux calibrated spectra obtained by David Boyd witha a LISA (R = 1000)

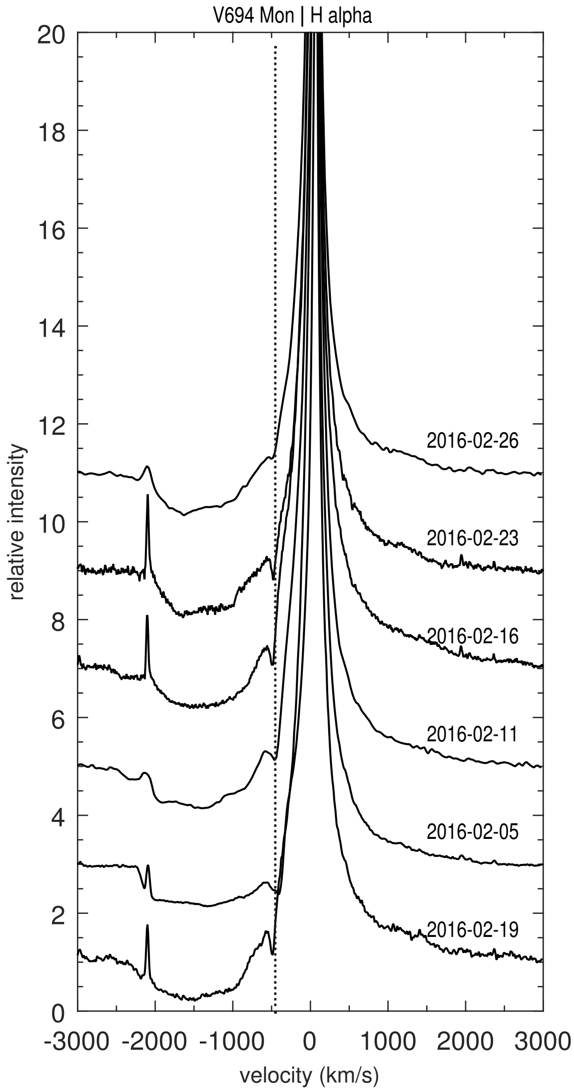






V694 Mon

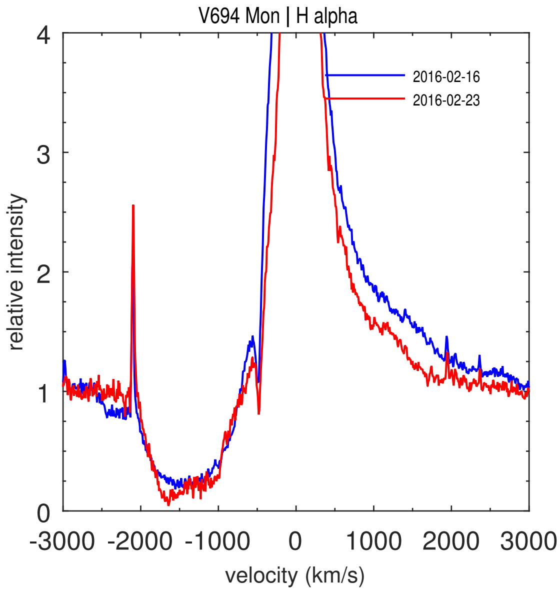


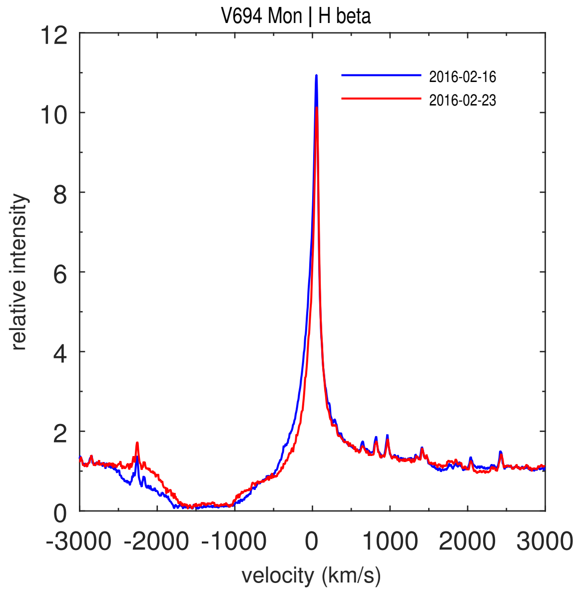


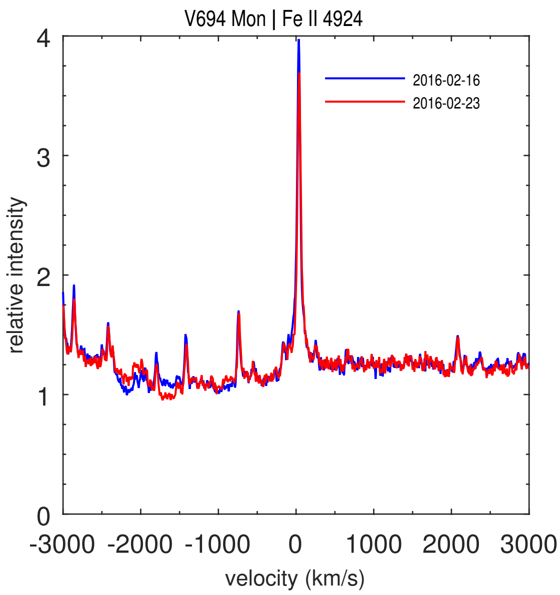
Balmer lines Hα and Hβ (radial velocity) in February
Spectra obtained by
P. Somogyi (Lhires III 600 l/mm R = 2500)
P. Berardi (Lhires III 1200 l/mm)
T. Lester (Home made Spectrograph, R = 9000)
R = 6000 F. Teyssier (Eshel R =11000)

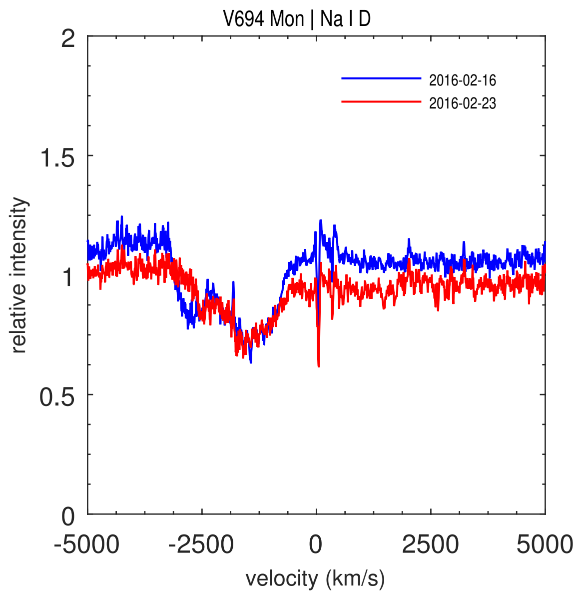
V694 Mon

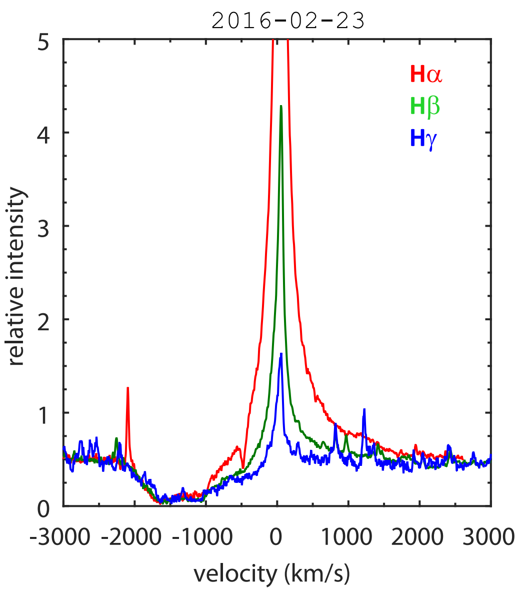
Eshel spectra (R = 11000) obtained on 16-02 and 23-02-2016 F. Teyssier

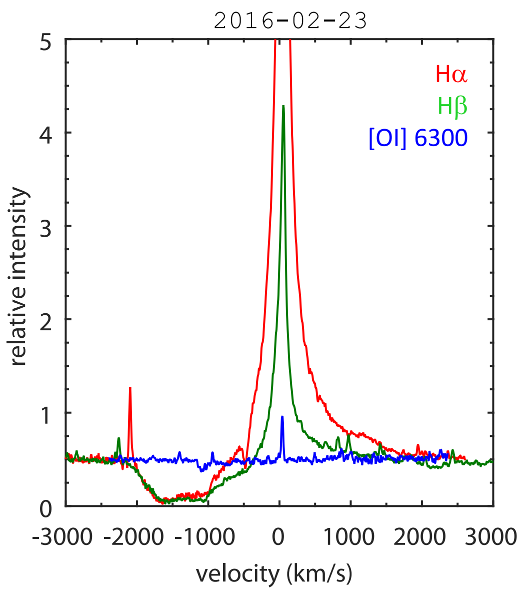






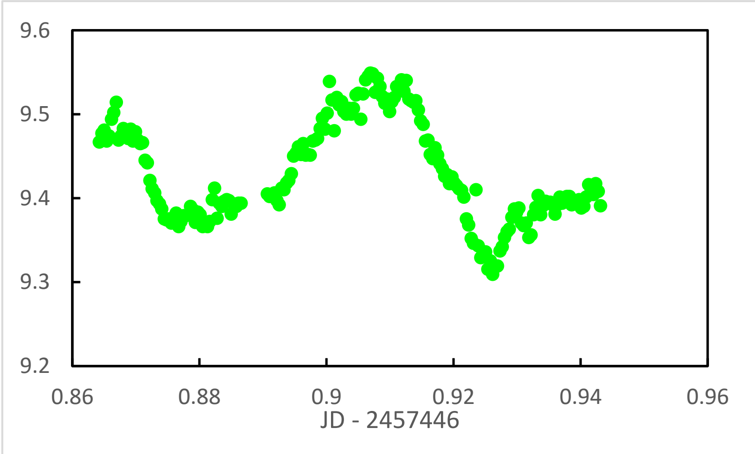


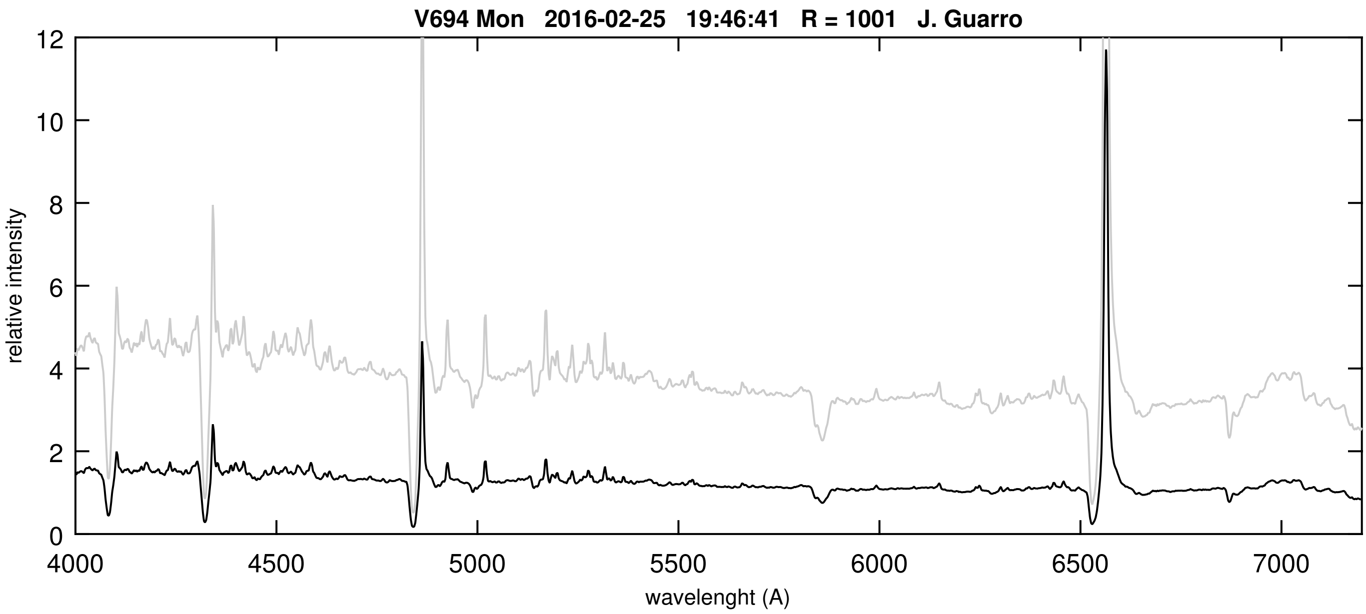


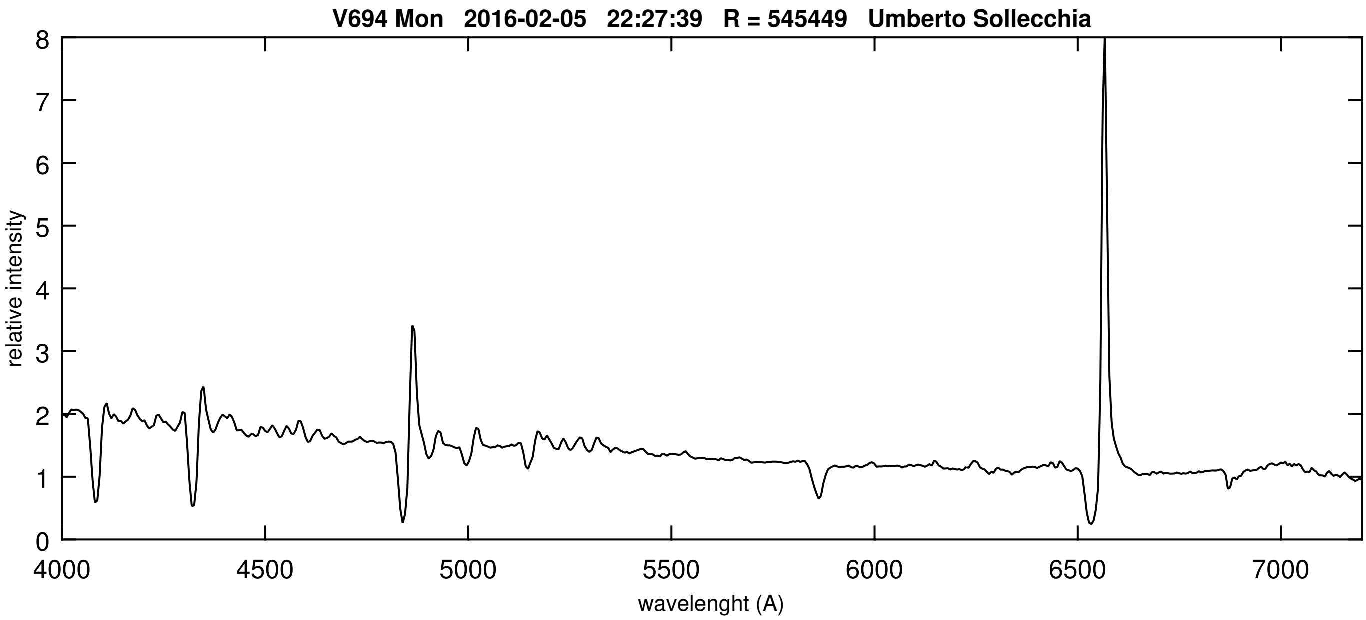


V694 Mon

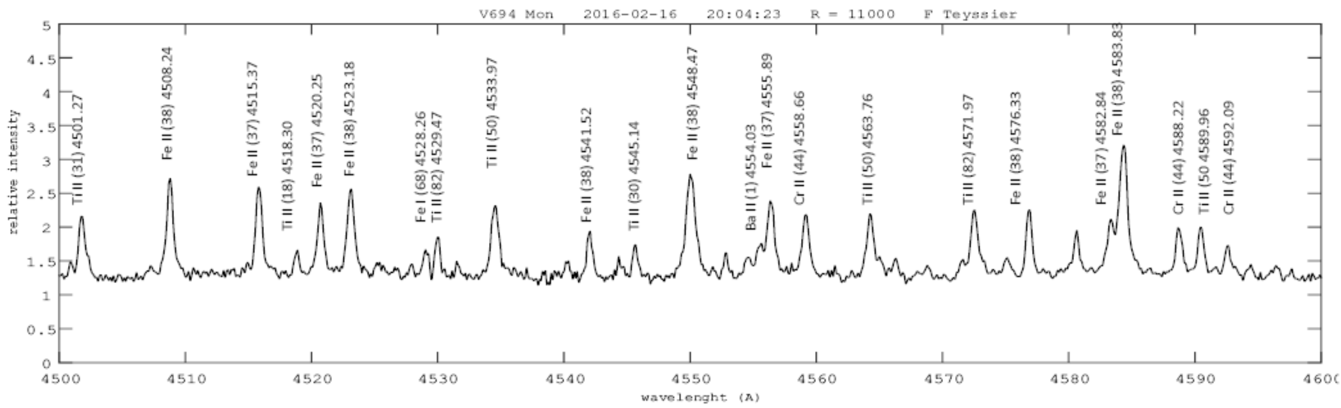
V Band photometry
28-02-2016
(Keith Graham) showing the
flickering at time scale ~ 1 mag



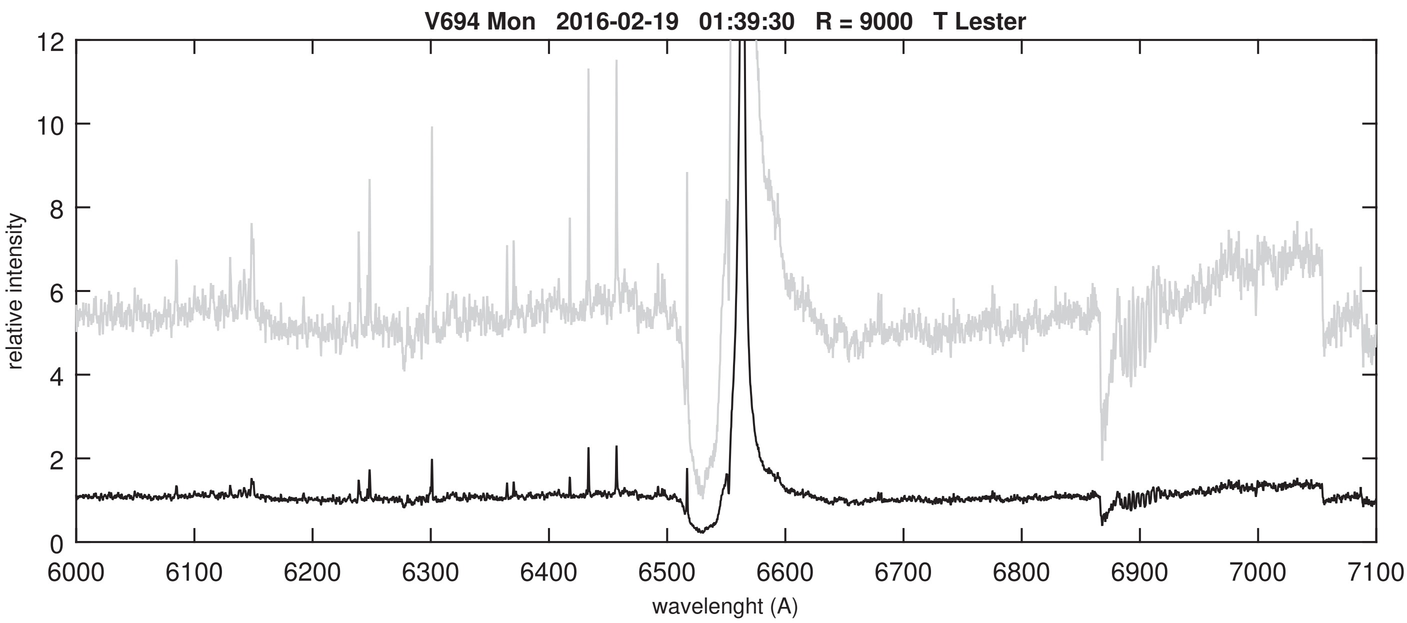




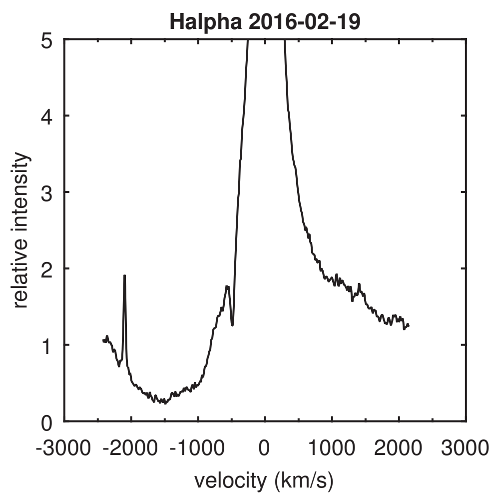
V694 Mon



Lines Identification Range 4500-4600 F. Teyssier
Lines : Fe II, TiII, Ba II, Cr II



Tim Lester
Home Built spectrograph R = 9000



V694 Mon by P. Somogyi

Compilation of spectra R = 500 to 2500 by P. Somogyi
U. Sollecia - Frederico Campos : Alpy 600 - R = 500/600
David Boyd : LISA - Joan Guarro : Home made spectrograph - R = 1000
Peter Somogyi : Lhires III (600 l/mm) - R = 2500

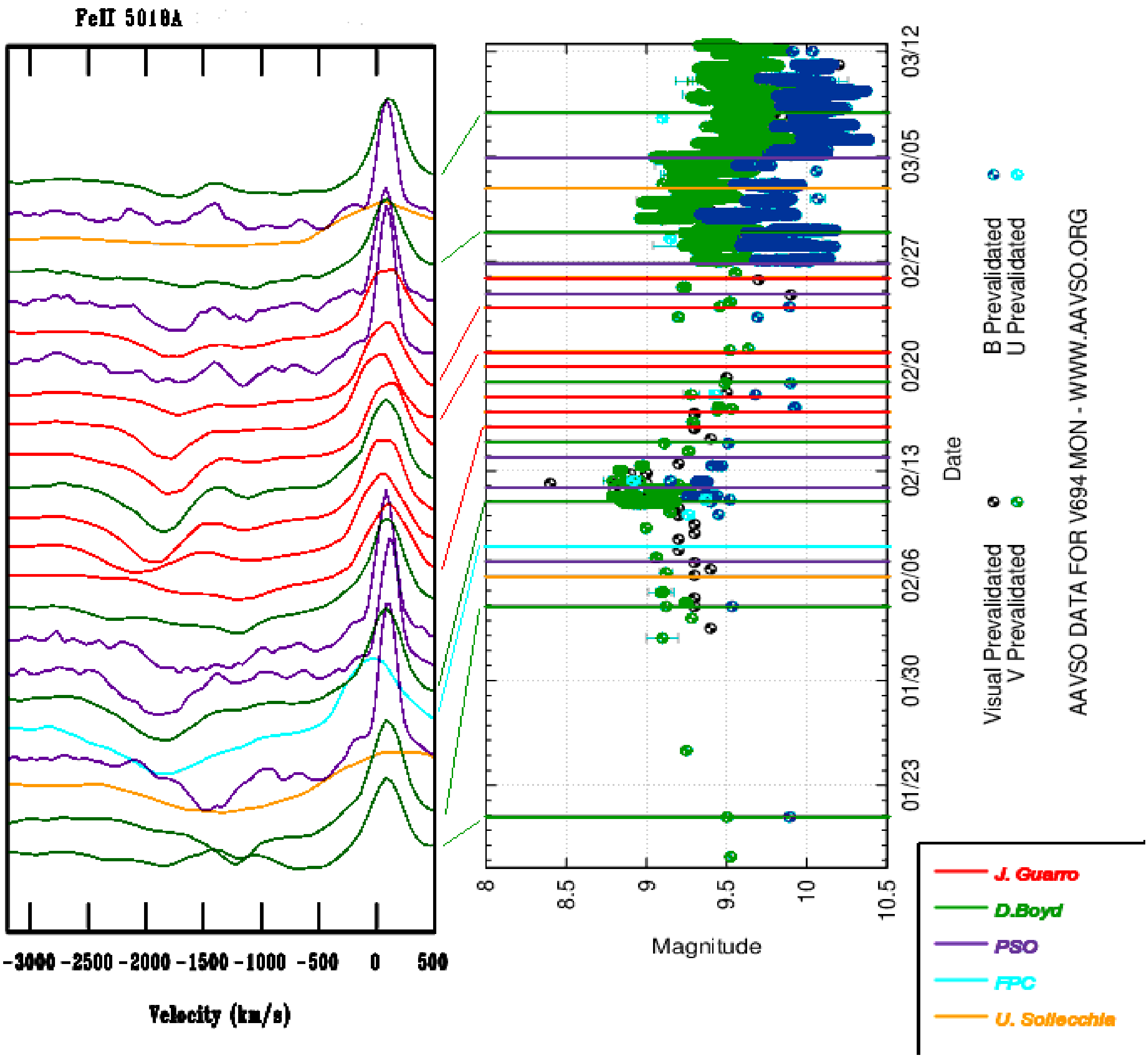


Table V694 Mon FeII:

This graph was meant to summarize last month v694 Mon most prominent changes in the absorption of Fe II 5018A (the 5169A and 4924A just followed it by changes).
Spectral data has been downloaded from ARAS. For spacing reasons, a special Ymin=0.6, Ymax=6.4 has been chosen, shifting each spectra upwards by 0.2 as time increasing. All spectra are rectified to continuum=1.
The AAVSO graph has the interval between JD: 2457405 and 2457460.
At peak magnitude (02/11 - 02/12) I could measure of -1900 km/sec the center on my (obs.code: PSO) graph seen in purple. That spectrum has a very low noise, and the hole is real at this resolution.
Later on, surpisingly J. Guarro catched a maximal velocity of -2125 km/sec at the center (date: 2016.02.16) not correlating with any AAVSO trend.
Compilation: Peter Somogyi

V694 Mon

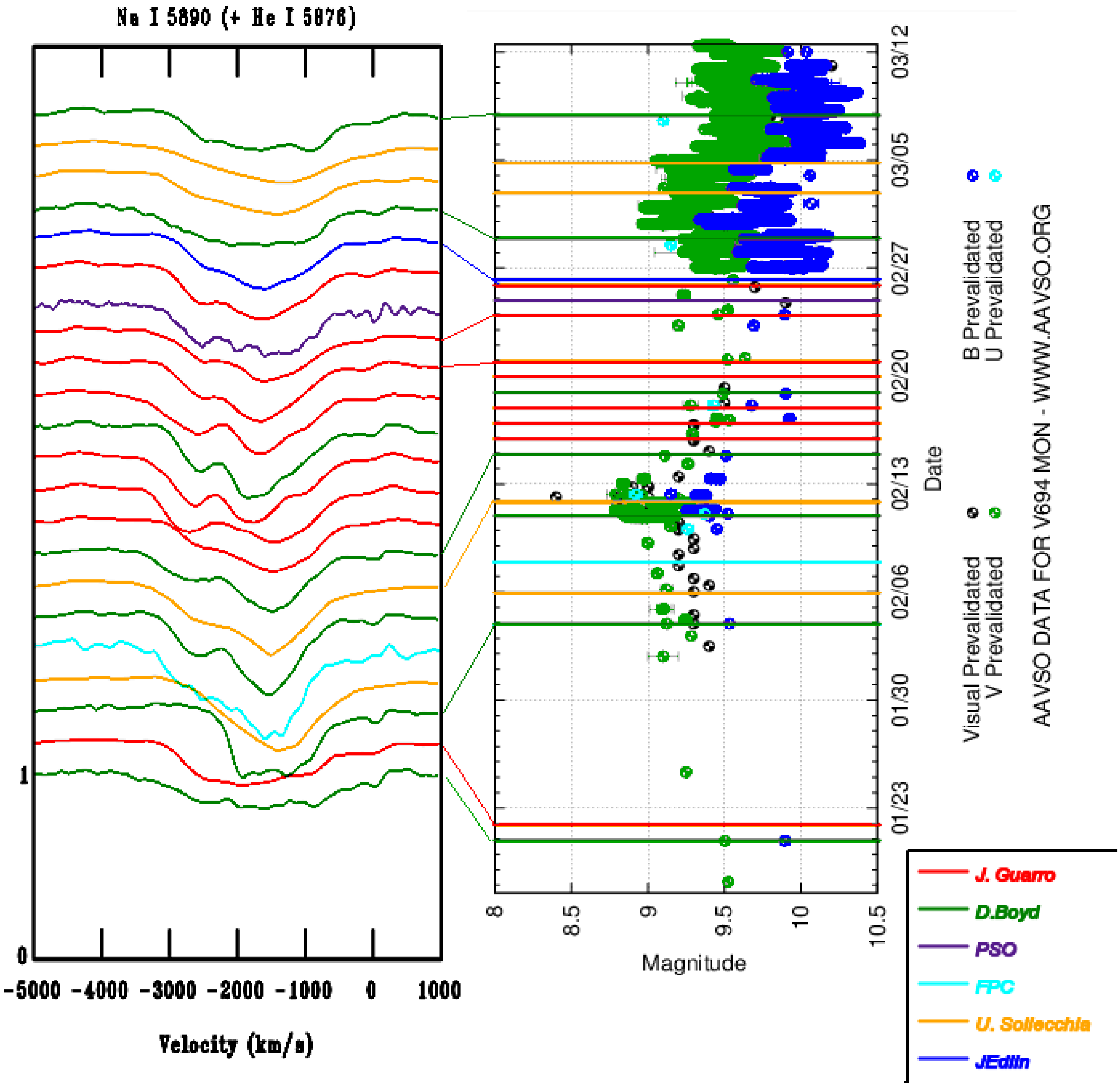


Table v694 Mon Na I 5890 (+ He I 5876):

This graph was produced in order to show correlation with the outburst event of v694 Mon. Low resolution spectra brought the possibility to detect interesting variations.

All spectra are rectified to have continuum=1.

To show the real ratios, scaled to Ymin=0 and Y(first spectra)=1 by intention.

The AAVSO graph has the interval between JDp2457405 and 2457460.

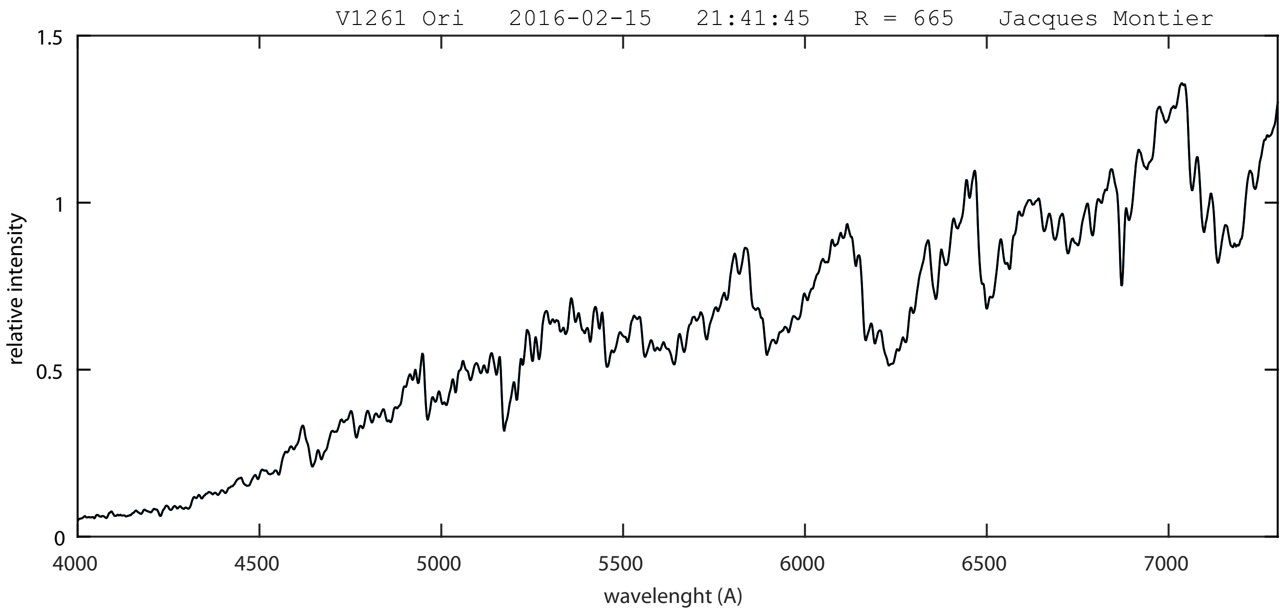
Velocity zero point has been set to 5890A, however the feature is blended by the absorption of He I 5876 (that should be the blue part), according to arxiv 9808226 (1998 A.A. Panferova , S.N. Fabrikaa , T. Tomov).

It is hard to identify any correlation with peak magnitudes, however before and after a few days of maximum brightness, the optical depth of this feature had a minimum slightly above 0.5 continuum (2016.02.03 - 02.11). It has had a return on 02.16-18 and then it went back to its original shape (of 0.75 continuum).

Compilation: Peter Somogyi

V1261 Ori

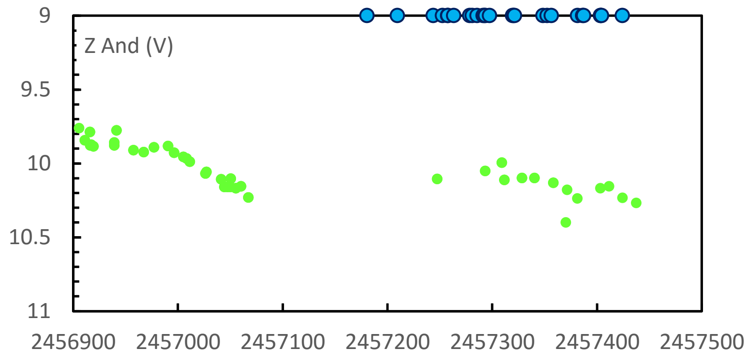
Coordinates (2000.0)	
R.A.	05 22 18.6
Dec	-08 39 58.0
Mag	6.9

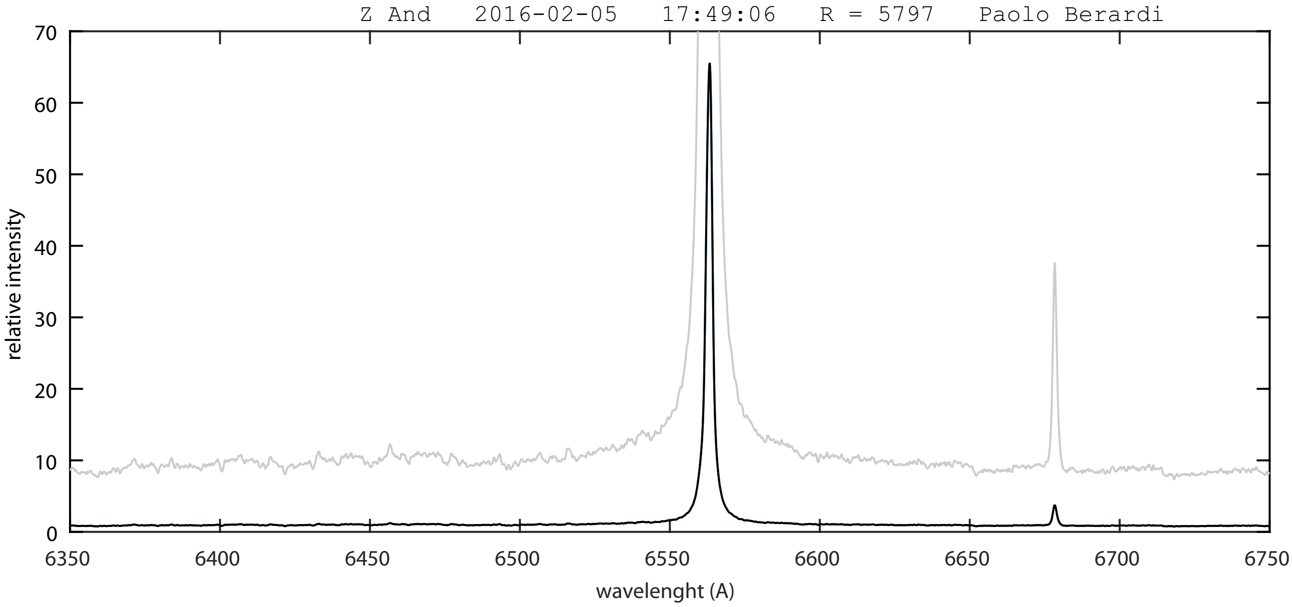


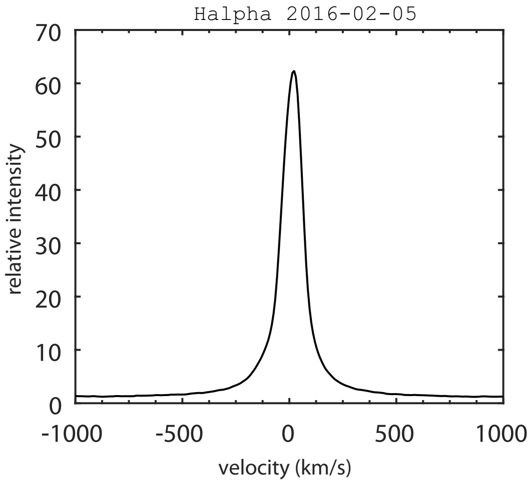
Z And

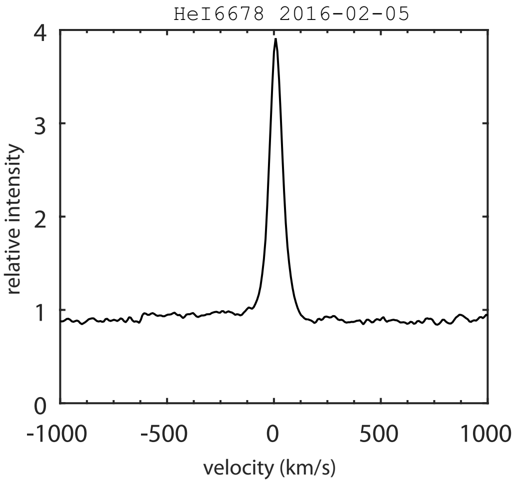
Coordinates (2000.0)	
R.A.	23 43 49.4
Dec	48 49 5.4
Mag	10.1

Z And in quiescent state at mag V ~ 10.2



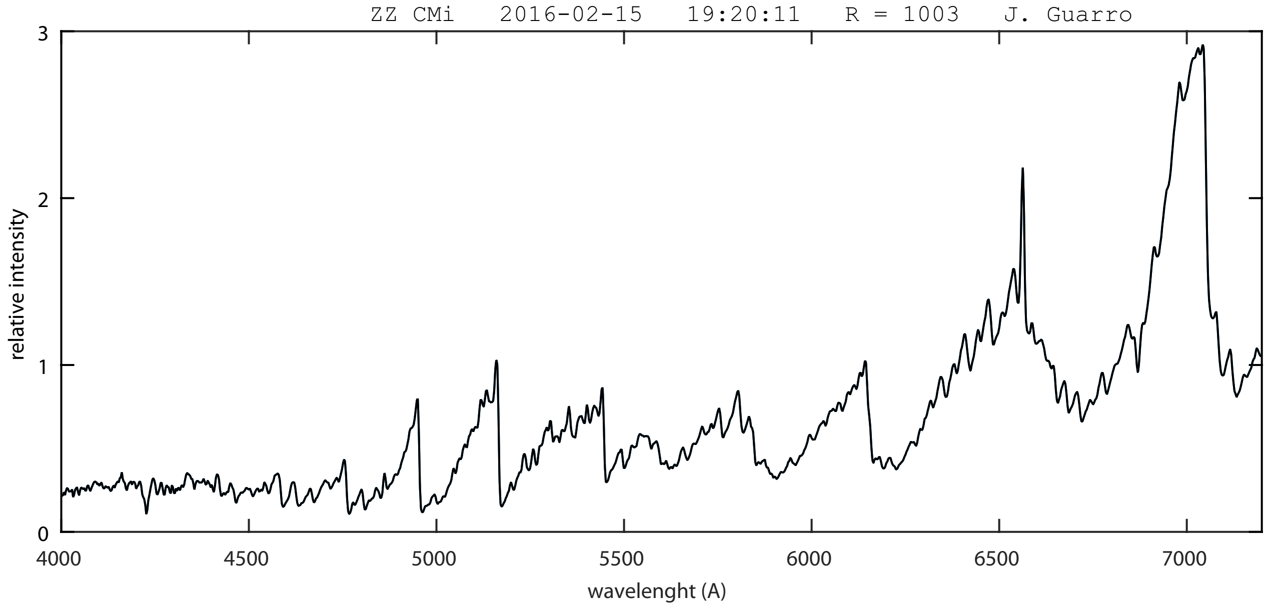






ZZ CMi

Coordinates (2000.0)	
R.A.	07 24 14.0
Dec	+08 53 51.8
Mag	10.2



Large More on interactions of flows and environment

Steve Shore

This month's installment follows from further discussions with Francois and also the hope that it will spur you to think about new physical processes.

1. Shocks

Having discussed steady outflows, whether winds or jets, it's now time to cover the dynamical, time dependent observational consequences of a very ``normal'' cosmic condition, shocks. Let's start with some of the basics and then move to the things you're able to distinguish -- and analyze -- spectroscopically.

Sound waves and beyond

Gases are different from liquids in one property, compressibility. Squeeze a liquid and the pressure seems to increase instantly without, it seems, producing a change in the density. Recalling the moment when Archimedes jumped out of the bath and ran through Syracuse yelling ``eureka'', the pressure is directly proportional to the weight of the overlying material with the density remaining constant. The deeper the layer, the higher the pressure. Another way of saying is is that in any perturbation in the pressure, the flow velocity increases in direct proportion to the change in the velocity. Yet another is to say that the flow is ***divergenceless***, meaning the disturbance is only in a change in the depth of the layer and not in the density. Think of wind blowing over a lake. This doesn't create internal waves along the direction of the wind, the surface ripples and there's a vertical change in the displacement that propagates like a membrane having been hit at some point. The motion is locally a small circulation around the horizontal direction, like an ensemble of springs that are coupled elastically. The velocity of the wave depends on the depth of the channel.

Instead, in a gas, the pressure change in one place forces a compression (a ***longitudinal*** change in the density changes and this causes a periodic displacement along the propagation direction. It's like an internal piston: the high density part expands, the density internally drops but the surroundings are compressed, and so on. In one dimension, along a tube (like a trombone) the wave maintains its amplitude. In free propagation in three dimensions, it's intensity remains the same but its flux falls like any wave from an impulse. Now make the amplitude of the pressure kick so large that the expansion becomes asymmetric, that an internal pressure gradient within the wave is so large that the front is an outward accelerator. That is how a shock develops. The greater the difference within a few mean free paths, the more kick is given to the affected gas. Now, for the last step, if the energy that drives the expansion is supplied so quickly that the gas can't mechanically adjust to find (by expansion) an equilibrium, it explodes. And that explosion is supersonic so is also relative to the surroundings. Using the language of kinetics (the microscale picture of gases) If this change in density or pressure happens on a scale much smaller than the mean free path, there's a sudden, impulsive change in the momentum of the upstream particles when this compression passes. The gas can't respond on the sound travel time since collisions can't happen before the front hits.

View on the microscopic scale

To simplify matters, I'll use an atomic gas as the model, but any mixture is possible. The average distance between collisions, the ***mean free path***, is the length scale over which the atoms are coupled. This depends on the temperature and density, and the collisional cross section. But in a simple (ideal) gas the atoms have a range of velocities (this is what the temperature measures), the average over all possible microscopic velocities gives the pressure and the distance over which the collisions are balanced. A small change in the density, one that happens on a length scale greater than a mean free path, will seems to be continuous. This is a sound wave, a region of locally higher density that expands and compresses adjacent parts of the medium. The propagation speed of this disturbance depends only on the temperature for a simple gas, and the sound speed for a small perturbation, c_s is the same as the compressibility, the change of the pressure with density. For an ideal gas this depends only on the temperature and is independent of the density. A small increase in density, balanced by a small decrease, move through the gas at constant speed.

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Let me connect this with our previous discussions. In novae, at the start of the event the thermonuclear runaway drives mixing and heating but little expansion. The length scale over which the temperature changes is about one pressure scale height, a very large distance relative to molecular collision lengths. But when the produced ^{15}O and other radionuclides decay, they input energy so rapidly that the gas can't physically redistribute it. That's the explosive part of the event. To complete the picture, since we've discussed it at length last year, the nova ejecta are not uniform and this could be the effect of a range of times of ejection during the TNR. If so, the individual pieces of the ejecta will not have the same velocities and on colliding will emit and merge and split, a mess (see below for more on the spectral signatures).

As you'd have in the collision between two hard spheres, there's a ballistic transfer of momentum from the over-pressured side of the front to the gas immediately at the boundary and the fluid, even if initially at rest, is accelerated. In contrast, a sound wave transfers energy but not mean motion, the density oscillates at some point but there's no net displacement of the gas. This impulse, moving faster than the sound speed, is something that doesn't happen to photons so the upstream medium can remain stationary when absorbing photons but now when the gas hits.

Now put yourself on the front of the shock and look upstream, the the direction of its propagation. It looks like the background fluid os coming toward you at supersonic speeds but on passing through the front, on the downstream side it seems to be moving away from the front having been slowed down. But to the gas through which the shock moves, the front arrives at some speed *V* and the gas, after being accelerated, moves along with but at a lower speed than the front (think of the difference between being on the TGV when it passes through a station and being on the platform; after the train passes it looks like the junk lifts and follows the train but to the passenger, the stuff is being left behind). In steady state, the flow satisfies the usual conditions of conservation of mass, momentum, and energy. But now, because this is an extended region (the front), mass conservation requires that the flux of matter through the surface be the same entering as leaving. Since the velocity is slower than the front, the post-shocked gas has a higher density that depends on the velocity of the shock that, in turn, depends on the over-pressure. The same for momentum, the flux of momentum across the front is constant, and the same for the energy current.

Why this matters is that if a gas is compressed and has no time to radiate the excess energy, the post-shock will have both higher densities and temperatures but a lower speed of advance than the shock front. If the gas can radiate, it can lose the excess energy generated by the compression (work done by the shock, but it depends on the efficiency of the emission). In the shock frame, the gas behind the front is also over-pressured relative to the post-shocked gas and the sound speed is higher so the flow is subsonic. That's why collisions and radiative losses can be important. For astrophysical shocks, the comparatively low density also means the front is very likely not optically thick. Let me explain this for a bit because it's not hard but it's very rich in different phenomena.

Dimensional scaling for fun

Since shocks are completely outside equilibrium, we can use simple dimensional analysis to describe many of their properties. You might want to try this based on data sometimes provided in ATel's for novae and supernovae. Imagine an explosion with a kinetic energy, *E*, in a medium of constant density ρ (mass/volume) expands in such fashion that *E* is constant. Then the dimensions of *E* are L^2/t^2 where L is a length and T is an expansion time (you'll recognize the dimensions of mass times v^2 for a velocity v. The front is the velocity of the shock and the internal pressure drops like an energy density. In time, when the internal pressure balances the external medium, the (not degraded) front propagates as a strong sound wave and eventually dissipates. So when the internal energy density (a.k.a. pressure) balances that of the external medium(P_0), the shock stalls. This is when $P_0 = E/R^3$, the internal pressure balances the external pressure. hen the radius of the expanding

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gas is the same as the length L so the radius scales as L ~ $(E/\rho)^{1/5}.t^{2/5}$. It grows but *much* different than free expansion (in this case the shock velocity is always inferred to be smaller than any inferred fro the spectra).

The radiative precursor, supernova ejecta as examples

To be technical for a moment, the emitted spectrum of the shocked gas depends on its temperature. A way of thinking about this is a simple scaling: for 10 km s^{-1}, the gas has a temperature of about 10^4 K and the scaling is that T ~ v^2. So at 100 km.s^{-1}, the expected temperature is closer to a few million K. In other words, the gas emits X-rays. This radiation escapes ***through*** the front and ionizes (and excited) the gas ahead of the shock, becoming an ionized zone that expands far faster than the material blast front, at the speed of light. But how far ahead of the front it gets depends, exactly as for an H II region, on the luminosity of the shock and the density of the upstream gas. So there's a pre-ionization of the matter in front of the shock even before the physical impact is felt from the shock's passage. This ***precursor*** is the true novelty of very high velocity phenomena. In nuclear blasts, you've seen this many times (too many, I suspect), the formation of a vapor sphere surrounding the bom site that appears almost instantly. It then disappears and you see the inner cloud of debris and damage. Now imagine a supernova remnant that expands into the ISM. It can be though of as a ball of hot gas, with velocities of 10^4 km.s^{-1} or higher, impacting the cold, stationary gas of the surroundings. This velocity is typically so high that even γ-rays are emitted (above a few MeV) and certainly a lot of UV and XR. The neutral upstream hydrogen is overwhelmed by the ionization front (again, expanding at light speed) long before the powering shock arrives so the gas is pre-heated and pre-ionized. But it's still static, no momentum transfer has yet occurred. Even if the emitted energy is enormous in the external world frame, the fraction of the original blast energy may be almost negligible and that means the expansion is legitimately treated as ***adiabatic*** (i.e., with no loss of energy). Then the original energy of the explosion (for N this is of order 10^{51} erg but may be more) remains constant but the overpressure drops as the hot bubble expands. This radiates according to the shock velocity, the velocity of the boundary of the hot gas. But the light emitted travels ahead of the shock by parsecs. This can be resolved well at distances below that of the LMC (at 50 kpc, 1 arcsec is about 1 pc). The ``mother of all supernovae'' SN 1987A (sorry for the gendered terminology) displayed emission lines from the illuminated pre-SN old supergiant wind that produced the now famous linked-ring structure (later hourglass) when the [N II], [O III], and Balmer lines emitted on recombination from the precursor. More dramatic effects may be hidden in the spectra of extragalactic SN that affect the spectral evolution, the SN Ib and Ic may be this type. They show narrow emission lines above the broad ejecta lines. Perhaps this is an unresolved composite of the two regions? It remains an open question but some SN start out looking rather normal and end up looking almost like AGNs.

Wind bubbles

A wind freely expands until something slows it down. Imagine, as last time, a WR star losing matter in a strong wind (about 10^{-5} M yr^{-1} moving with a terminal speed of a few thousand km.s^{-1}). This packs internally an enormous amount of gas and momentum so in its expansion matter will be swept up and the flow will gradually slow down. But matter will have been accelerated and compressed by the passage of the strong boundary shock. At the front any wriggling or distortion immediately breaks into smaller shocks that are also unstable to forming substructures- filaments and knots-- whose densities vary but all of which will have been heated. So they, in turn, collide at supersonic speed and a hard XR source is born. As long as the wind is supplied, the further the wind will expand. The wind is already photoionized in these stars. This shields the surrounding gas from the direct effects of the hot photospheres of these stars. The wind largely self-absorbs (the driving is by radiation pressure) but the precursor produced by the front further ionizes the gas and that only stops when the shock has slowed to the sound speed of the ambient gas. So you'd expect the boundaries of WR winds to have structure, that these (and other massive winds) shoujd be XR sources, and that the radiative contribution from the WR itself doesn't suf-

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fice to account for the high quantities of ionized local gas, perhaps an order of magnitude. Note: as the shock slows, its internal temperature drops toward ambient (which only (!) happens when the shock stalls, when the front descends to the sound speed.

So what will you see?

The answer depends on the density and temperature of the post-shocked gas, hence on the energy of the shock. The stronger the compression ratio, the greater the heating so for very strong fronts the gas may collisionally ionize. This follows from the compression ratio and whether the gas can lose energy quickly enough to maintain constant temperature. In the strongest shocks, the UV and XR emission (from lines, recombination continuum or high ionic states, and thermal bremsstrahlung from the plasma) power emission lines that you'll see as time variations in lines that (in planetary nebulae) are stationary. An example of the precursor effects is easily seen in symbiotic-like recurrent novae, such as RS Oph and V407 Cyg. The early appearance of He II, for example, is from the precursor. The lines are initially very narrow and appear after the explosion; it's only when the matter of the ejecta sweep up the wind gas that the lines suddenly broaden. In symbiotics with jets, in principle the same thing should happen. The jet is a narrowly conical moving shock front so it has a front (called the ``working surface'') whjere the compression happens. The radiation is produced from a smaller area but is no less penetrating. The emission of even highly ionized species, such as N V and [Fe VII], show up relatively without either broadening. The lower density stuff remains emitting for longer (the gas in the peripheral parts of any pre-SN wind), but in a uniform medium some of the more density sensitive lines may also appear. In the diffuse ISM, explosions look almost like scaled up thermonuclear explosions. So you will also see all of the strong ionization states, and recombination from the He series. The velocity you observe is, however, not the front. Using the ***measured*** velocity to get the kinetic energy of the blast, without taking account of where the gas emits (behind the shock and at an expansion that follows, rather than overtakes, the front) will give the ***wrong*** result and you'll have a missing energy problem.

Final comments

I'm writing this from the Onsala Space Observatory while performing mm radio observations wit the 20 meter of molecular line emission from diffuse, turbulent interstellar clouds under a sky that any optical astronomer would think hopeless. We've observed through fog, clouds, mist, rain, and with luck starry skies. As I wish for you all. Thanks for putting up with this, we're almost done with the story.

Recent publications

Symbiotics

The 2015 super-active state of recurrent nova T CrB and the long term evolution after the 1946 outburst
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Monthly Notices of the Royal Astronomical Society, Volume 455, Issue 2, p.1282-1293
http://arxiv.org/abs/1412.7596

About ARAS initiative

Astronomical Ring for Access to Spectroscopy (ARAS) is an informal group of volunteers who aim to promote cooperation between professional and amateur astronomers in the field of spectroscopy.

To this end, ARAS has prepared the following roadmap:

• Identify centers of interest for spectroscopic observation which could lead to useful, effective and motivating cooperation between professional and amateur astronomers.
• Help develop the tools required to transform this cooperation into action (i.e. by publishing spectrograph building plans, organizing group purchasing to reduce costs, developing and validating observation protocols, managing a data base, identifying available resources in professional observatories (hardware, observation time), etc.
•Develop an awareness and education policy for amateur astronomers through training sessions, the organization of pro/am seminars, by publishing documents (web pages), managing a forum, etc.
• Encourage observers to use the spectrographs available in mission observatories and promote collaboration between experts, particularly variable star experts.
• Create a global observation network.

By decoding what light says to us, spectroscopy is the most productive field in astronomy. It is now entering the amateur world, enabling amateurs to open the doors of astrophysics. Why not join us and be one of the pioneers!

Be Monthly report

Previous issues :
http://www.astrosurf.com/aras/surveys/beactu/index.htm

VV Cep campaign

http://www.spectro-aras.com/forum/viewforum.php?f=19

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Please :
- respect the procedure
- check your spectra BEFORE sending them

Resolution should be at least R = 500
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SA spectra at R = 100 are welcome

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2/ name your file with:
_ObjectName_yyyymmdd_hhh_Observer

Exemple: _chcyg_20130802_886_toto.fit

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