Eruptive stars spectroscopy

Cataclysmics, Symbiotics, Novae, Supernovae

ARAS Eruptive Stars
Information letter n° 14 #2015-02 28-02-2015
Observations of February 2015

News

Two novae discovered in february

Nova Sco 2015 = PNV J17032620-3504140
2015 February 11.837 UT at mag 8.1
by Tadashi Kojima

Nova Sgr 2015 = PNV J18142514-2554343
2015 February 12.840 at mag 11.2
by Hideo Nishimura,
Koichi Nishiyama
and Fujio Kabashima

Contents

ARAS Spectroscopy

ARAS Web page
http://www.astrosurf.com/aras/

ARAS Forum
http://www.spectro-aras.com/forum/

ARAS list
https://groups.yahoo.com/neo/groups/spectro-l/info

ARAS preliminary data base
http://www.astrosurf.com/aras/Aras_DataBase/DataBase.htm

ARAS BeAM
http://arasbeam.free.fr/?lang=en

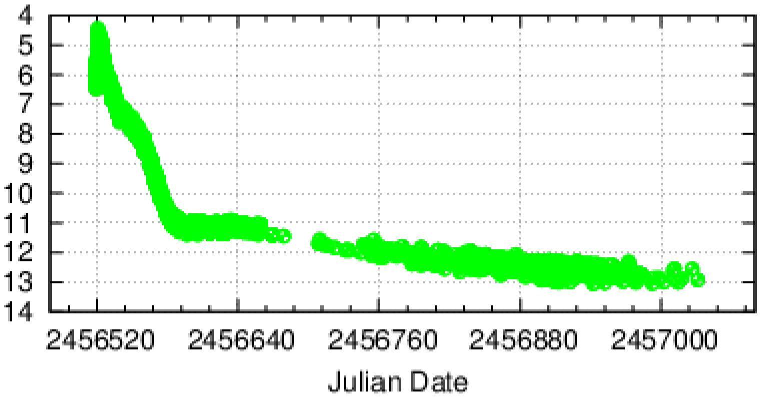
Acknowledgements :
V band light curves from AAVSO photometric data base

Authors :
F. Teyssier, S. Shore, A. Skopal, P. Somogyi, D. Boyd, J. Edlin, J. Guarro, Franck Boubault

N
O
V
A
E

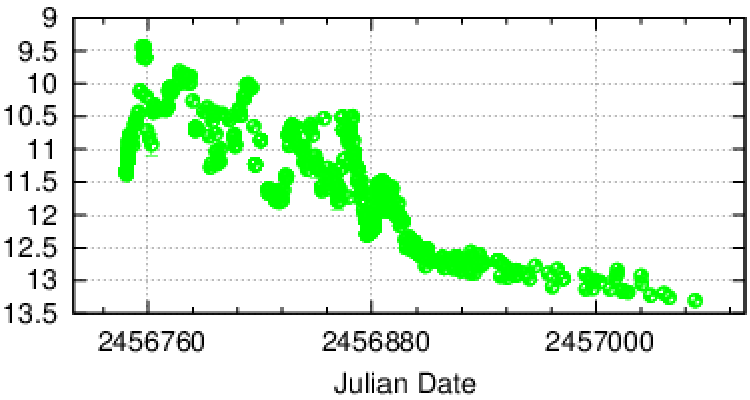
Status of current novae 1/2

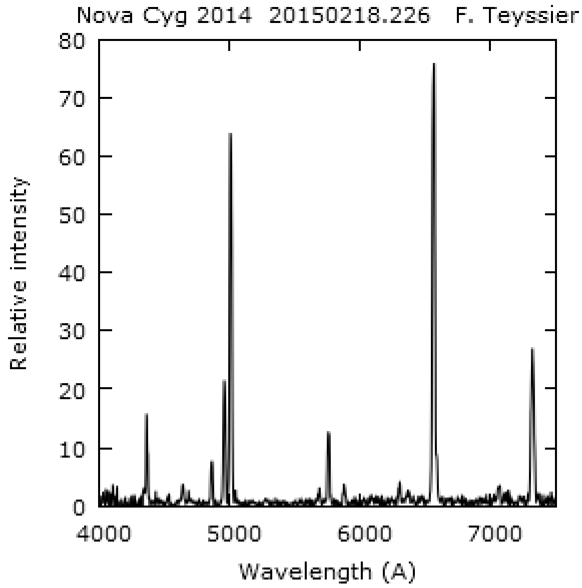
Nova Del 2013	V339 Del
Maximum	14-08-2013
Days after maximum	564
Current mag V	13
Delta mag V	8.6



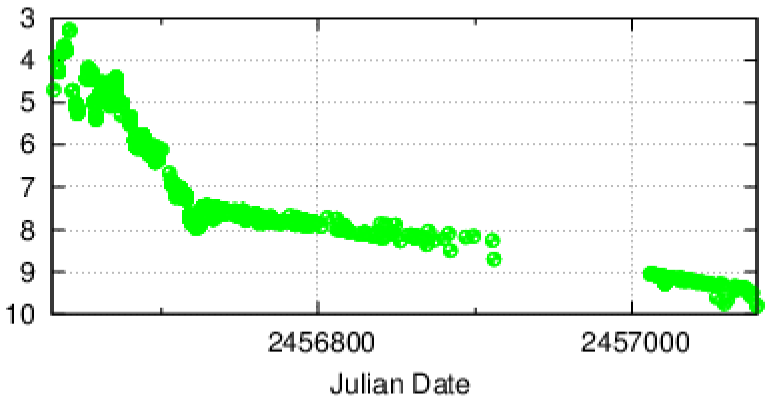
No spectrum in February

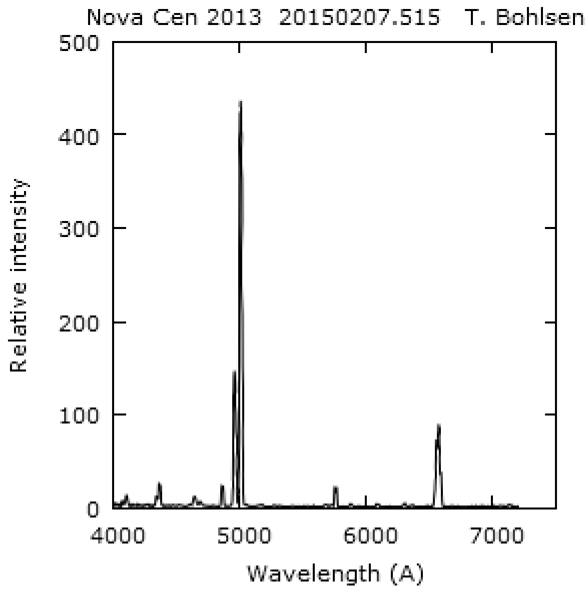
Nova Cyg 2014	V2659 Del
Maximum	09-04-2014
Days after maximum	326
Current mag V	13.3
Delta mag V	3.9





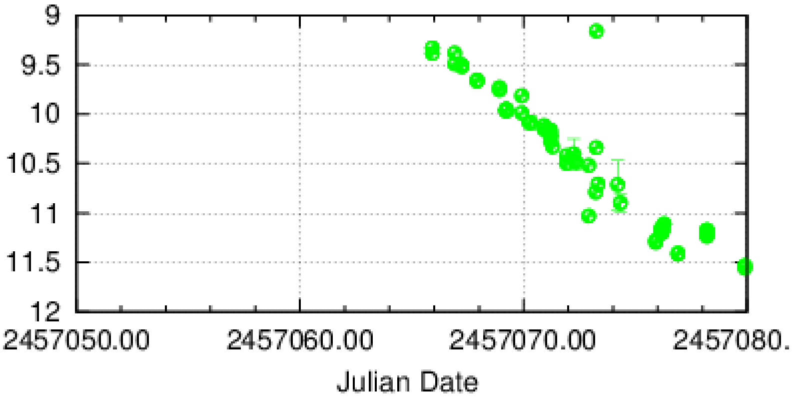
Nova Cen 2013	V1369 Cen
Maximum	14-12-2013
Days after maximum	442
Current mag V	9.5
Delta mag V	6

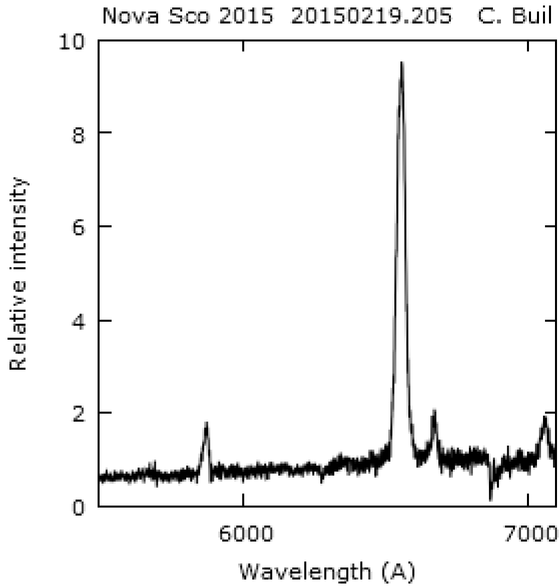




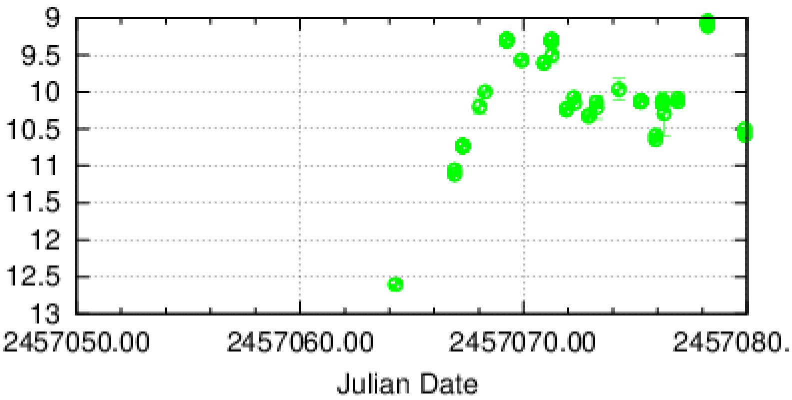
Status of current novae 2/2

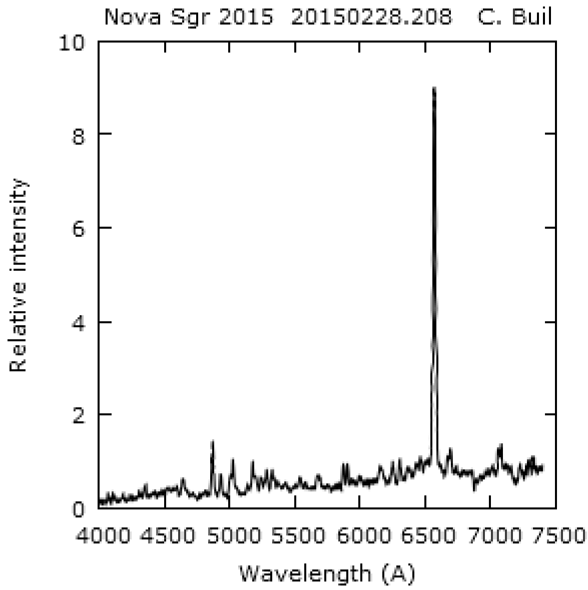
Nova Sco 2015	
Maximum	12-02-2015
Days after maximum	17
Current mag V	11.5
Delta mag V	2.2





NovaSgr 2015	
Maximum	15-02-2015
Days after maximum	14
Current mag V	10.9
Delta mag V	1.6

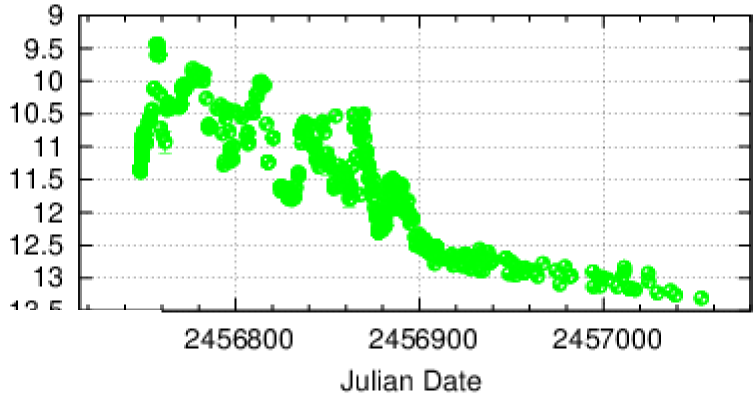




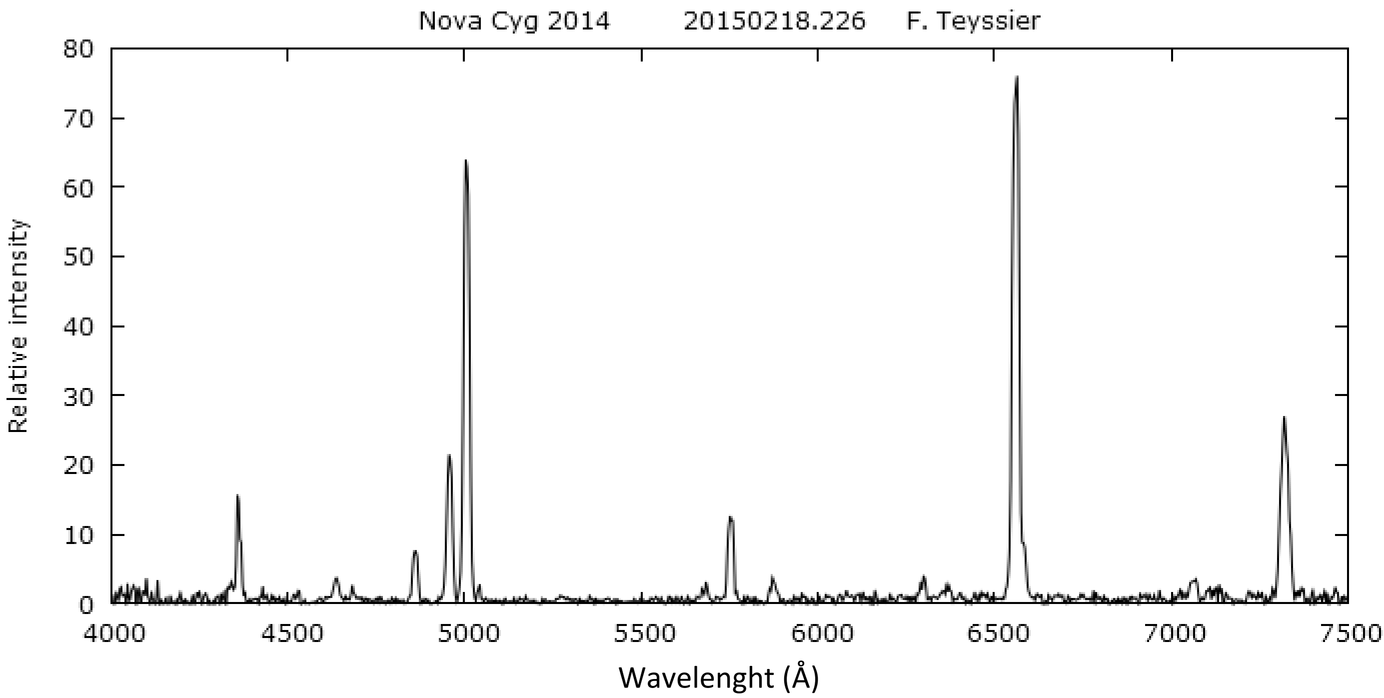
Nova Cyg 2014 = V2659 Cyg

Luminosity
Mag V = 13.3 (30-01-2015)
Slow decline

Spectroscopy
Nova Cyg in nebular phase



Spectroscopy
Nebular spectrum with noticelly [OII] still intense
See also : [N II] appears in the red part of H alpha

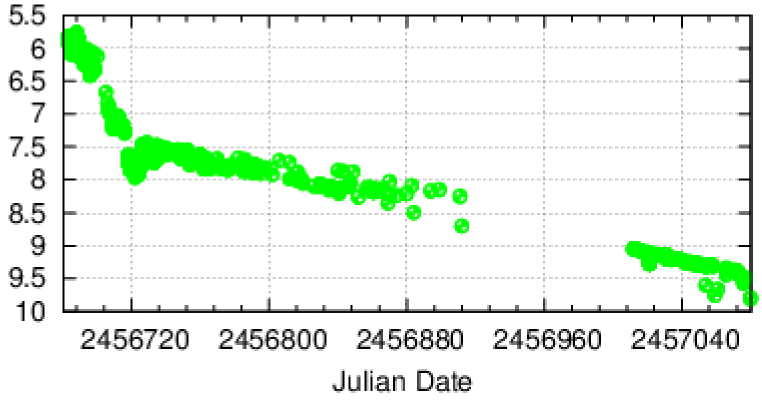


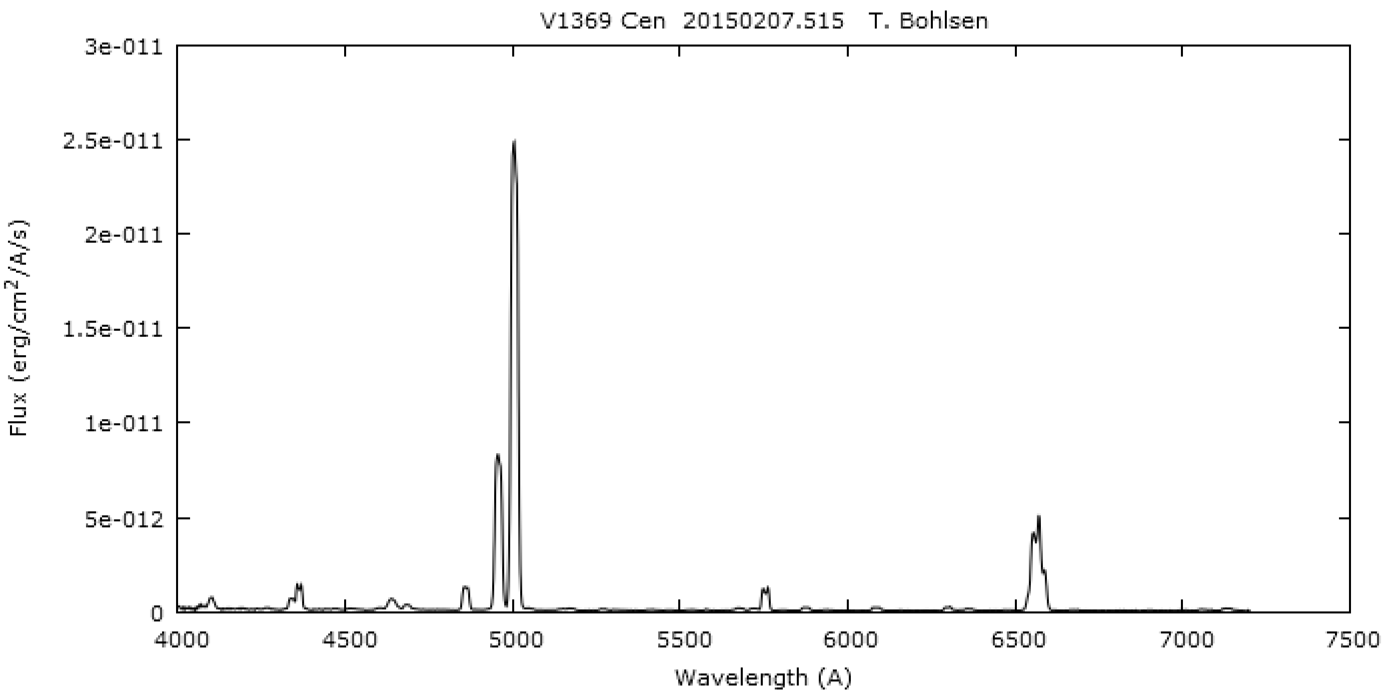
Observers : Tim Lester | Christian Buil | Paul Gerlach | Olivier Garde | François Teyssier | Jacques Montier | Antonio Garcia | Joan Guarro Paolo Berardi | Franck Boubault | Peter Somogyi | Miguel Rodriguez | F. Boubault | O. Thizy | D. Boyd | J. Edlin

ARAS DATA BASE : 210 spectra http://www.astrosurf.com/aras/Aras_DataBase/Novae/Nova-Cyg-2014.htm
Web Page : http://www.astrosurf.com/aras/novae/NovaCyg2014.html

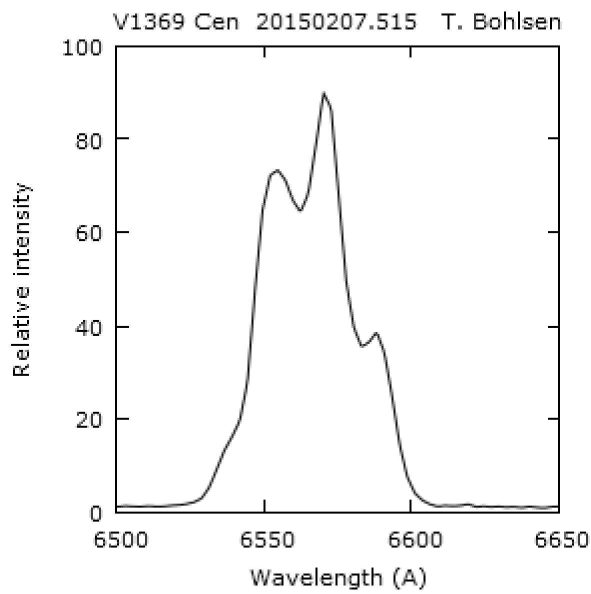
Luminosity
Mag V = 9.5 (28-02-2015)
Slow decline

Spectroscopy
Nova Cen in nebular phase





Terry Bohlsen - 07-02-2015 - LISA R = 1000

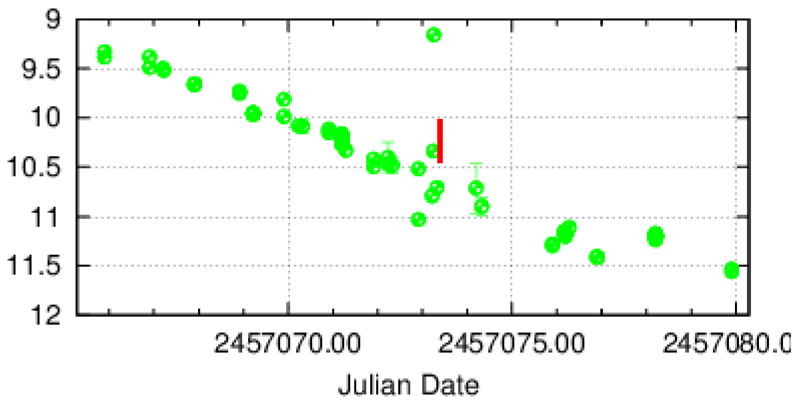


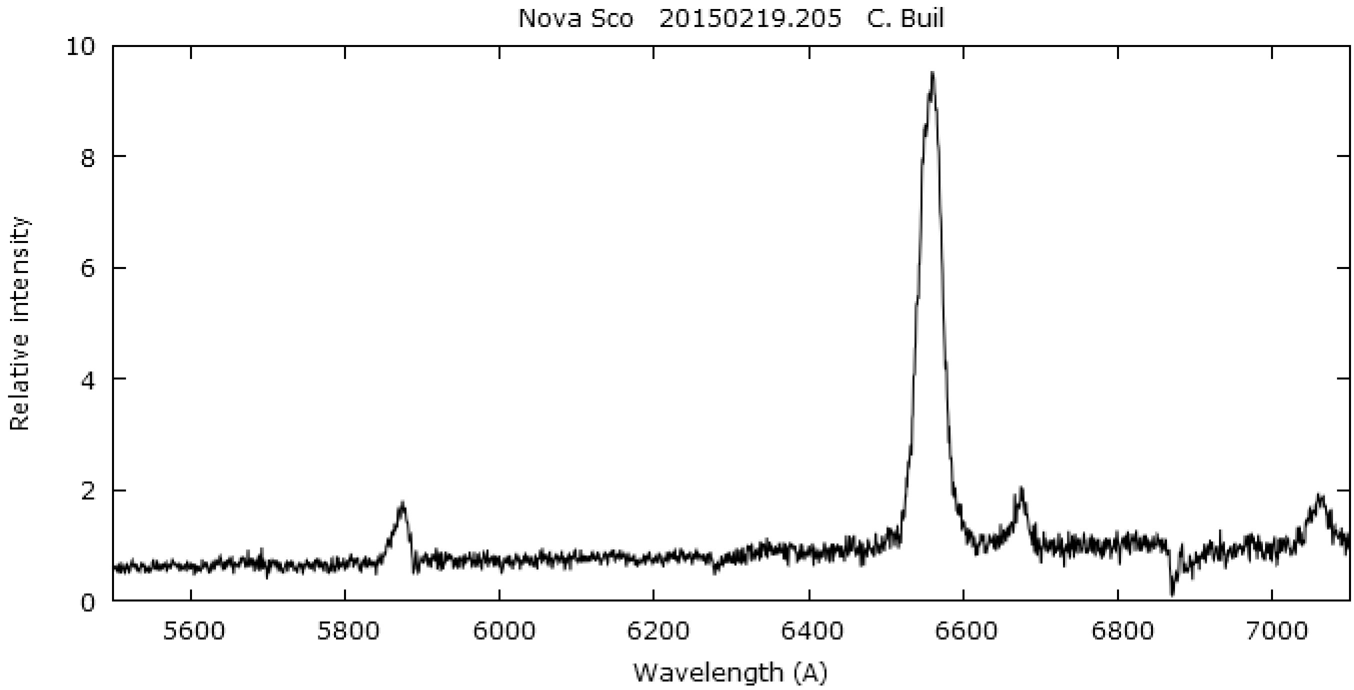
Crop on H alpha profile
Note [NII] 6548 and 6583 in the blue and red part of Ha

Luminosity

The maximum luminosity in AAVSO data base is observed on February, 12th (JD = 2457065.9) at mag V = 9.3.

t2 ~ 10 days (V = 11.3 on JD = 2457075.9)





Christian Buil
Lhires 600 l/mm - R ~ 2500

H alpha
FWHM ~ 1500 km/s
EW ~ -31 nm

Note the asymmetry of He I lines

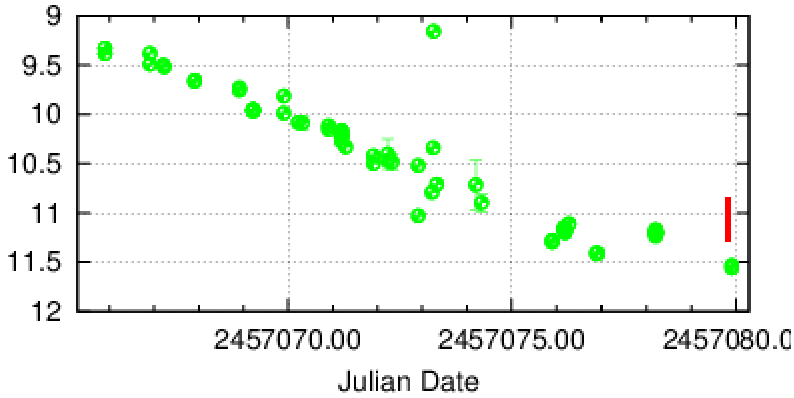
The Astronomer's Telegram # 7060
Nova Sco 2015 = PNV J17032620-3504140

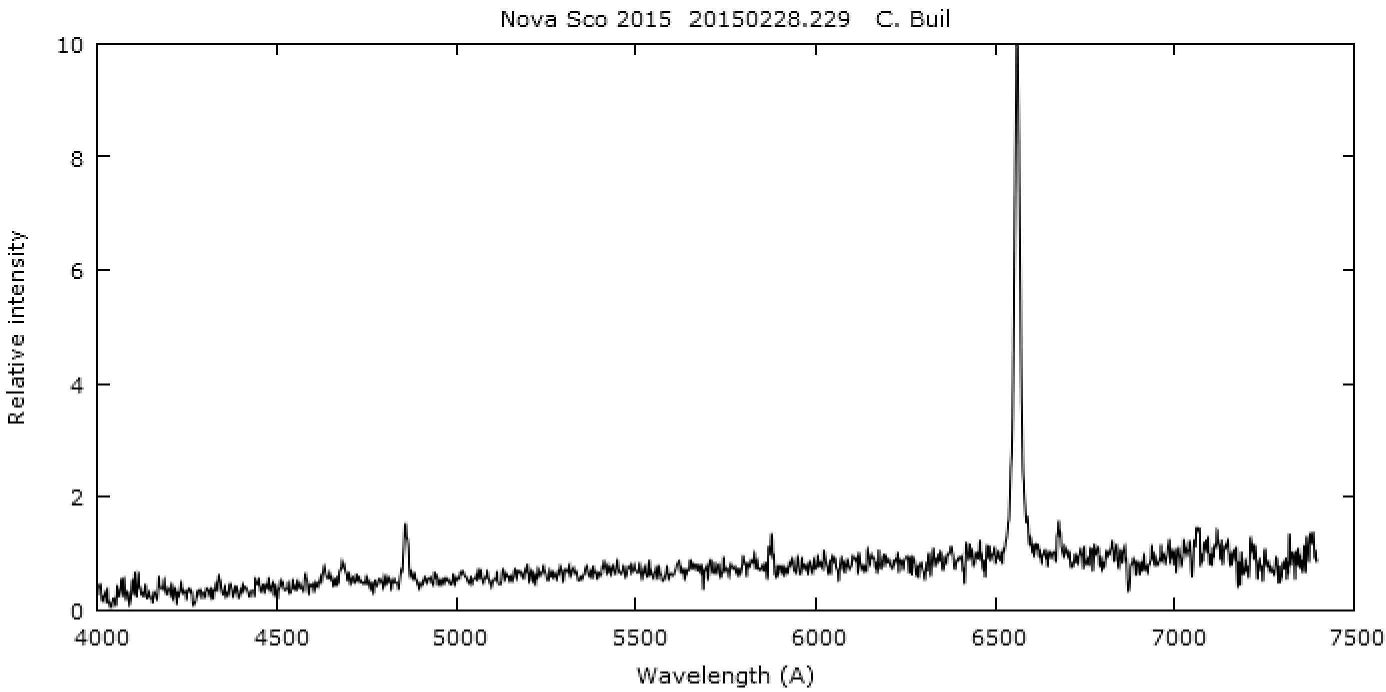
ATel #7060
Frederick Walter (Stony Brook University)
on 13 Feb 2015; 19:39 UT

An observation with the Chiron Echelle Spectrograph on the SMARTS/CTIO 1.5m on 2015 February 13 at 09:38UT confirms that this object, reported by P. Schmeer in vsnet-alert 18276 on 11 February, is a nova. H-alpha has an equivalent width of -14 nm and an FHWH ~ 2000 km/s. There are symmetrically-displaced emission features at about +/- 4500 km/s which resemble those seen in fast He-N novae. H-alpha and H-beta show P Cyg absorption features at about -4200,-3200, and -2300 km/s. O I 777 nm and 845 nm are in emission. A strong emission line at 588 nm with a prominent P Cyg absorption is either He I 587 nm or modestly blueshifted Na I. Broad (2000 km/s FWZI) He I 706 nm emission may be present. Similarly broad emission is seen in the prominent Fe II multiplet 42 lines at 492, 502, and 517 nm, though the first two may have some He I contribution. The apparently rapid fading and bright possible near-IR counterpart (P. Schmeer, followup to vsnet-alert 18276) suggest this is a system

Nova Sco 2015 also detected in X-ray
See page

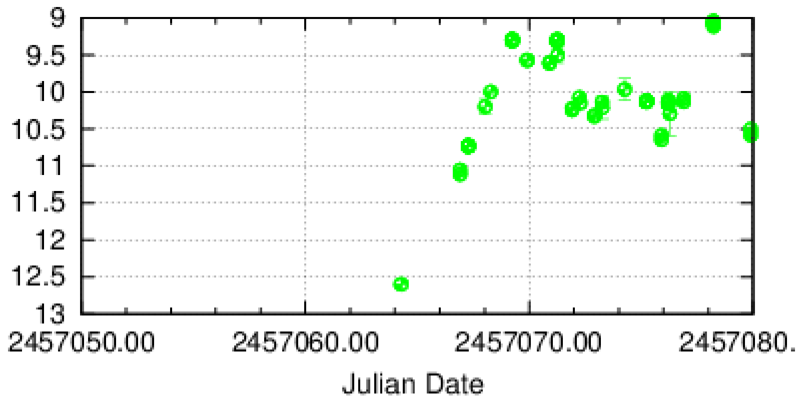
Nova Sco 2015 (Nova Sco 2015 = PNV J17032620-3504140

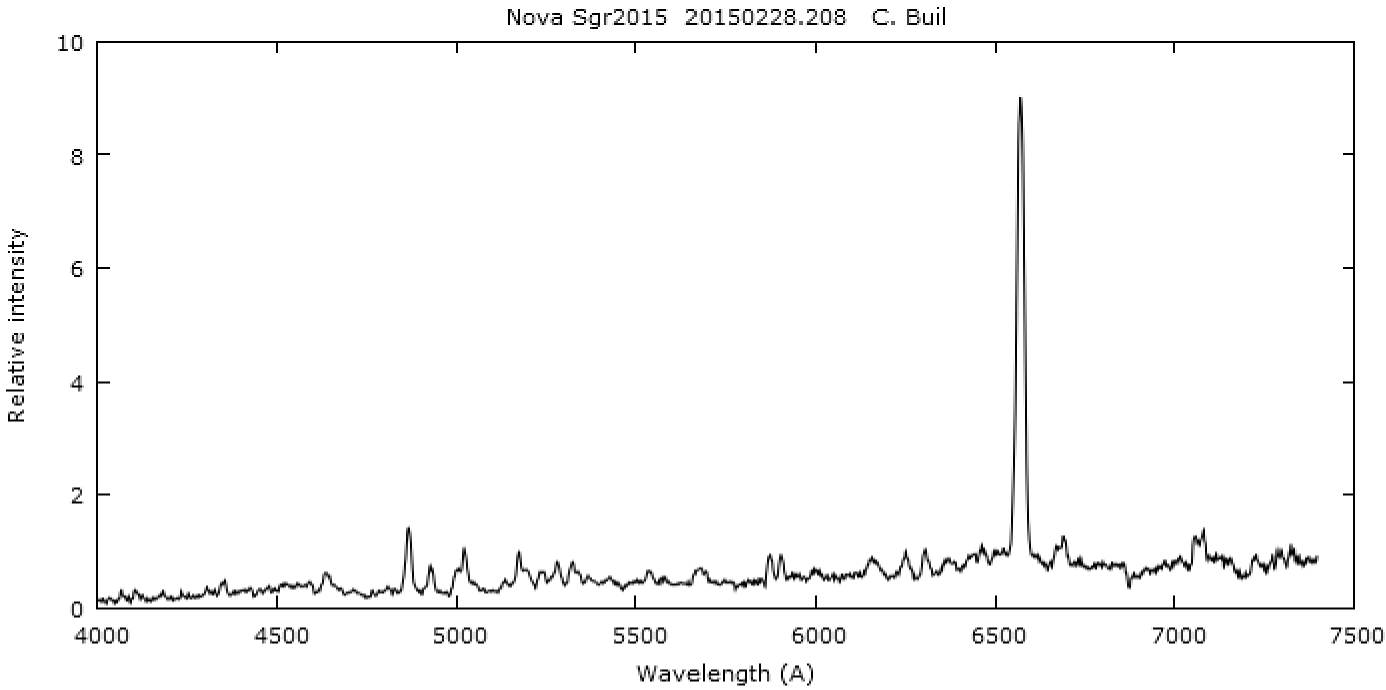




Christian Buil
Alpy 600 + T200 - R ~ 700

Nova Sgr 2015 (Nova Sgr 2015 = PNV J18142514-2554343)





Christian Buil
Alpy 600 + T200 - R ~ 700

The Astronomer's Telegram

Spectroscopic Confirmation and some Photometry of Nova Sgr 2015 = PNV J18142514-2554343

ATel #7101; Frederick Walter (Stony Brook University)

An observation with the Chiron Echelle Spectrograph on the SMARTS/CTIO 1.5m, together with SMARTS 1.3m Andicam BVRIJHK photometry indicate that this object is a classical Fe II nova near maximum. Photometry on the nights of 2015 February 13-17 shows that the brightness peaked in B (10.4) and V (9.7) between MJD 57069 and 57070, in R (9.0) and I (8.8) about MJD 57071.0, and continues to increase through MJD 57071.9 at JHK. The R=28000 spectrum, obtained 2015 February 16 at 09:40UT, shows narrow P Cyg lines of Fe II, N I, N II, O I, and H-alpha and H-beta. Assuming negligible intrinsic radial velocity, the peak absorption opacity is about -100 km/s, with maximum wind velocities near -500 km/s. At this time (pre-maximum), the H-alpha emission equivalent width was -0.7nm, with a FWHM of 300 km/s. Some plots are available on SMARTS nova atlas web page (link below).

Selected list of bright symbiotics stars of interest

Target						Refrence Star					
#	Name	AD (2000)	DE (2000)	Mag V *	Interest	Name	AD (2000)	DE (2000)	Mag V	E(B-V)	Sp Type
1	AX Per	1 36 22.7	54 15 2.5	11.6	++	HD 6961	01 11 06.2	+55 08 59.6	4.33	0	A7V
2	UV Aur	5 21 48.8	32 30 43.1	10		HD 39357	05 53 19.6	+27 36 44.1	4.557		A0V
3	ZZ CMi	7 24 13.9	8 53 51.7	10.2		HD 61887	07 41 35.2	+03 37 29.2	5.955		A0V
4	BX Mon	7 25 24	-3 36 0	10.4	+	HD 55185	07 11 51.9	- 00 29 34.0	4.15		A2V
5	V694 Mon	7 25 51.2	-7 44 8	10.5	++	HD 55185	07 11 51.9	- 00 29 34.0	4.15		A2V
6	NQ Gem	7 31 54.5	24 30 12.5	8.2		HD 64145	07 53 29.8	+26 45 56.8	4.977		A3V
7	T CrB	15 59 30.1	25 55 12.6	10.4	++	HD 143894	16 02 17.7	+22 48 16.0	4.817	0	A3V
8	AG Dra	16 1 40.5	66 48 9.5	9.7	++	HD 145454	16 06 19.7	+67 48 36.5	5.439	0	A0Vn
9	RS Oph	17 50 13.2	-6 42 28.4	10.4	++	HD 164577	18 01 45.2	+01 18 18.3	4.439	0	A2Vn
10	YY Her	18 14 34.3	20 59 20	12.9	++	HD 166014	18 07 32.6	+28 45 45.0	3.837	0.02	B9.5V
11	V443 Her	18 22 8.4	23 27 20	11.3	++	HD 171623	18 35 12.6	+18 12 12.3	5.79	0	A0Vn
12	BF Cyg	19 23 53.4	29 40 25.1	10.8	++	HD 180317	19 15 17.4	+21 13 55.6	5.654	0	A4V
13	CH Cyg	19 24 33	50 14 29.1	7	+	HD 184006	19 29 42.4	+51 43 47.2	3.769	0	A5V
14	CI Cyg	19 50 11.8	35 41 3.2	10.5	++	HD 187235	19 47 27.8	+38 24 27.4	5.826	0.02	B8Vn
15	StHA 190	21 41 44.8	2 43 54.4	10.3	+	HD 207203	21 47 14.0	+02 41 10.0	5.631	0	A1V
16	AG Peg	21 51 1.9	12 37 29.4	8.6	++	HD 208565	21 56 56.4	+12 04 35.4	5.544	0	A2Vnn
18	Z And	23 33 39.5	48 49 5.4	9.65	++	HD 222439	23 40 24.5	+44 20 02.2	4.137	0	A0V
19	R Aqr	23 43 49.4	-15 17 4.2	9.9	++	HD 222847	23 44 12.1	- 18 16 37.0	5.235	0	B9V

Mag V * : 01-04-2014

Symbiotic stars

observed in February, 2015

Star	Nb. spectra
AG Dra	2
AX Per	5
BX Mon	3
CI Cyg	2
CH Cyg	1
EG And	1
NQ Gem	3
T CrB	3
Tx CVn	1
UV Aur	2
YY Her	3
V443 Her	2
V694 Mon	17
Z And	2
ZZ CMi	2

Observing

CH Cygni campaign
Especially high resolution H alpha
See Information Letter #11

Detect high state of V694 Mon

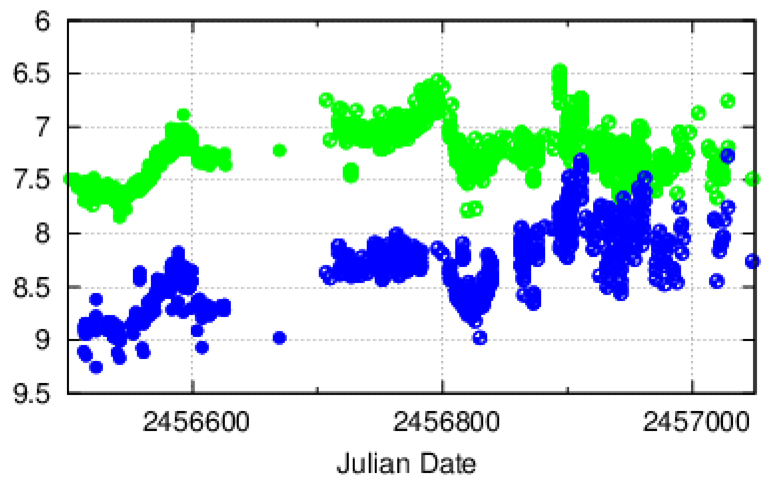
Symbiotic nova
ASAS J174600-2321.3
See AAVSO Notice page

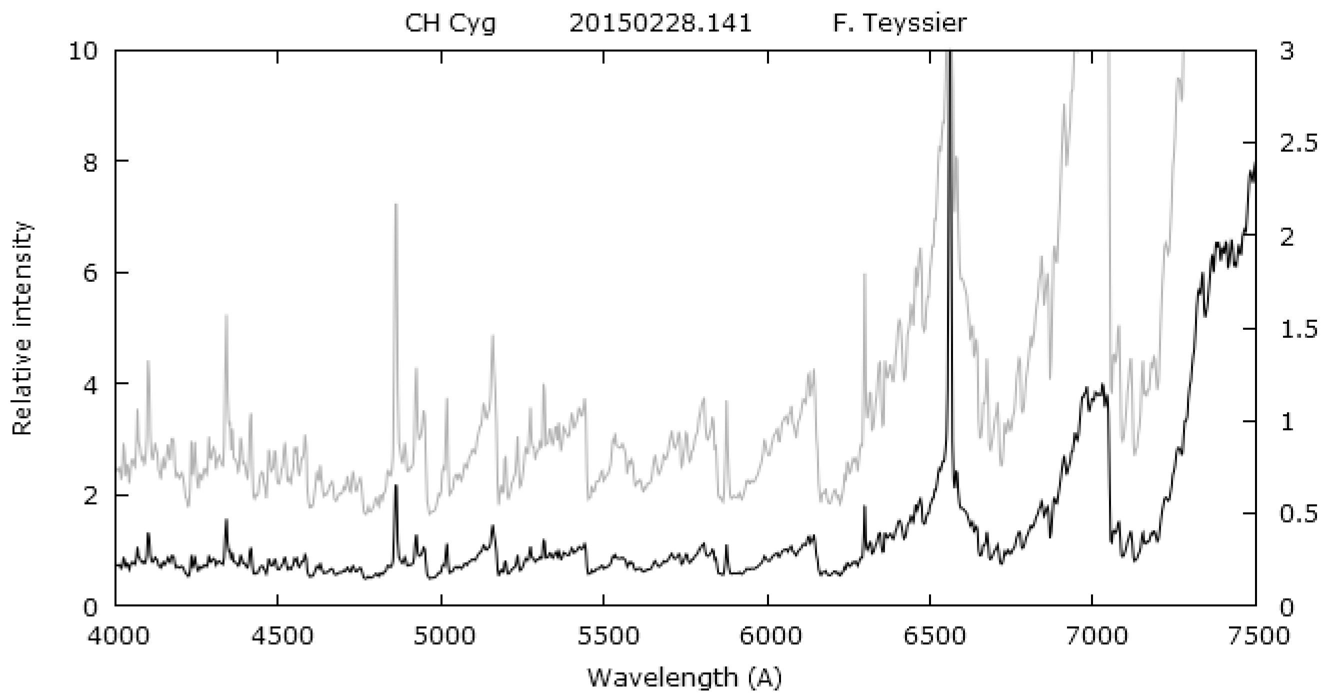
In the morning sky :
AG Dra
T CrB
YY Her
V443 Her
BF Cyg
CI Cyg

CH Cygni campaign

Coordinates (2000.0)	
R.A.	19 24 33.0
Dec.	+50 14 29.1

CH Cygni is now visible in the morning sky
The campaign is focused on Ha variations at R = 10 000
Low resolution spectra are also useful
See details for the campaign page

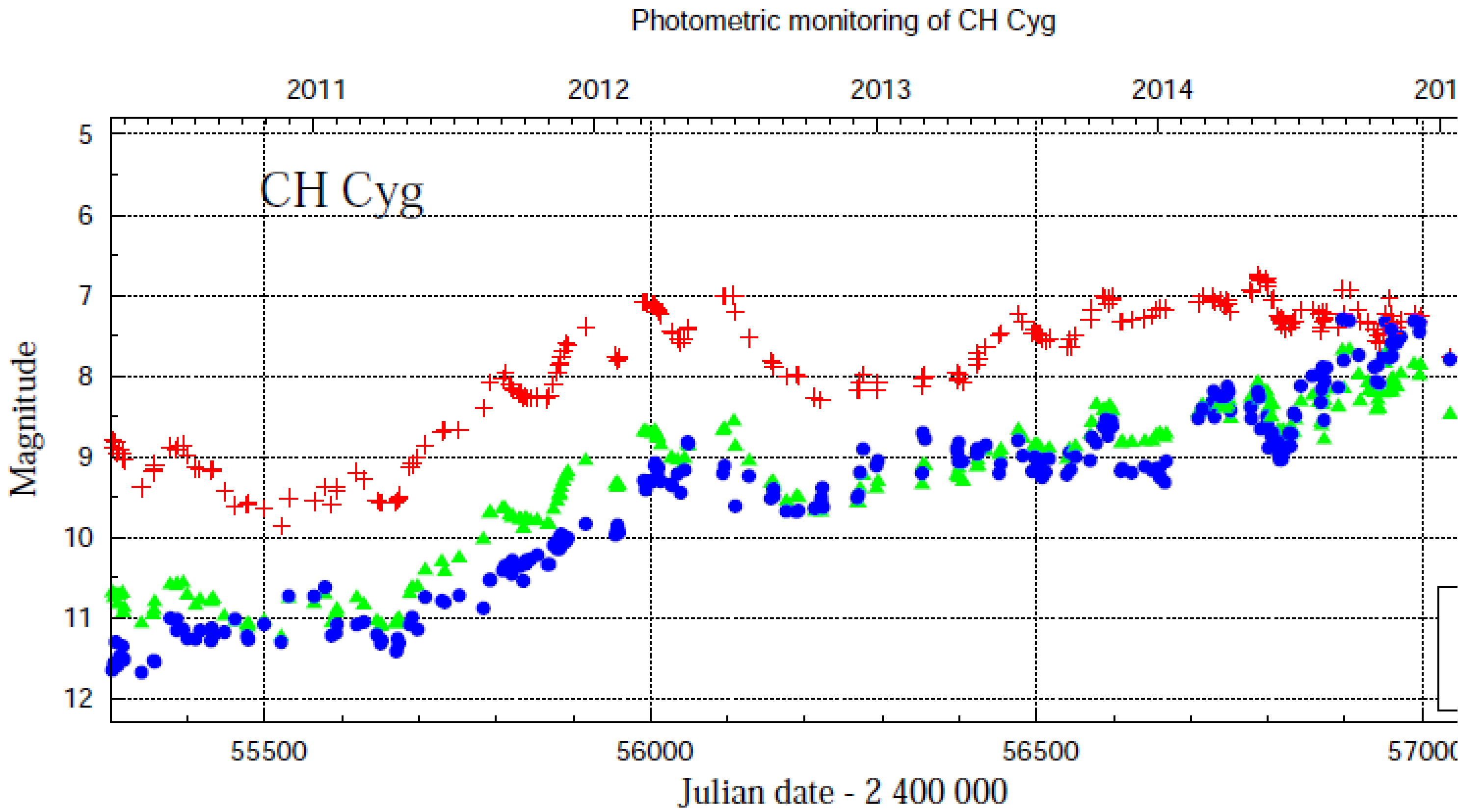




CH Cyg at low resolution - F. Teyssier - LISA R = 1000 - 28-02-2015

CH Cygni campaign

Coordinates (2000.0)	
R.A.	19 24 33.0
Dec.	+50 14 29.1



Comments from Dr Augustin Skopal

The spectrum clearly shows continuing activity of CH Cyg. A flat continuum for lambda < ~ 6000 A suggests a relative strong contribution from a warm white dwarf pseudophotosphere superposed to that from the giant. Also the emission line spectrum becomes to be gradually more pronounced, still dominated by the hydrogen Balmer emissions, well recognizable HeI lines and numerous FeII lines. This signalizes that the inner parts of the disk-like pseudophotosphere is becoming hotter, producing thus a larger flux of ionizing photons that give rise to a stronger nebular radiation.
The increase of CH Cyg activity is also demonstrated by the multicolour light curves, although that no dramatic brightening can be seen (see the figure in attachment). From_around November 2014 to the present, the U and V magnitudes vary between 7 and 8. Note, however, that U ~ V and U < B (in contrast to the behaviour until ~ Sept. 2014) which reflects a high level of the blue continuum From_the active white dwarf as confirmed by your spectroscopic observations. A transient decrease by ~0.5 mag around the middle of January 2015 was thus caused by the variable light from the giant, and has nothing in common with the active white dwarf.
What CH Cyg will show next? Nobody knows. Therefore, symbiotic stars are so exciting.

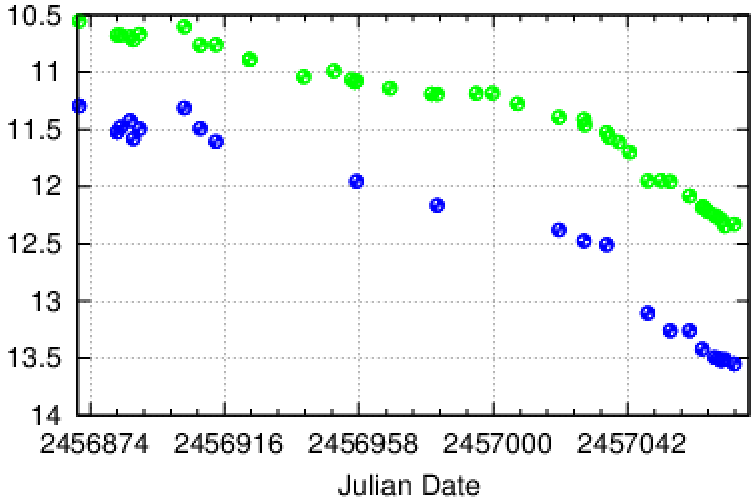
AX Per Outburst

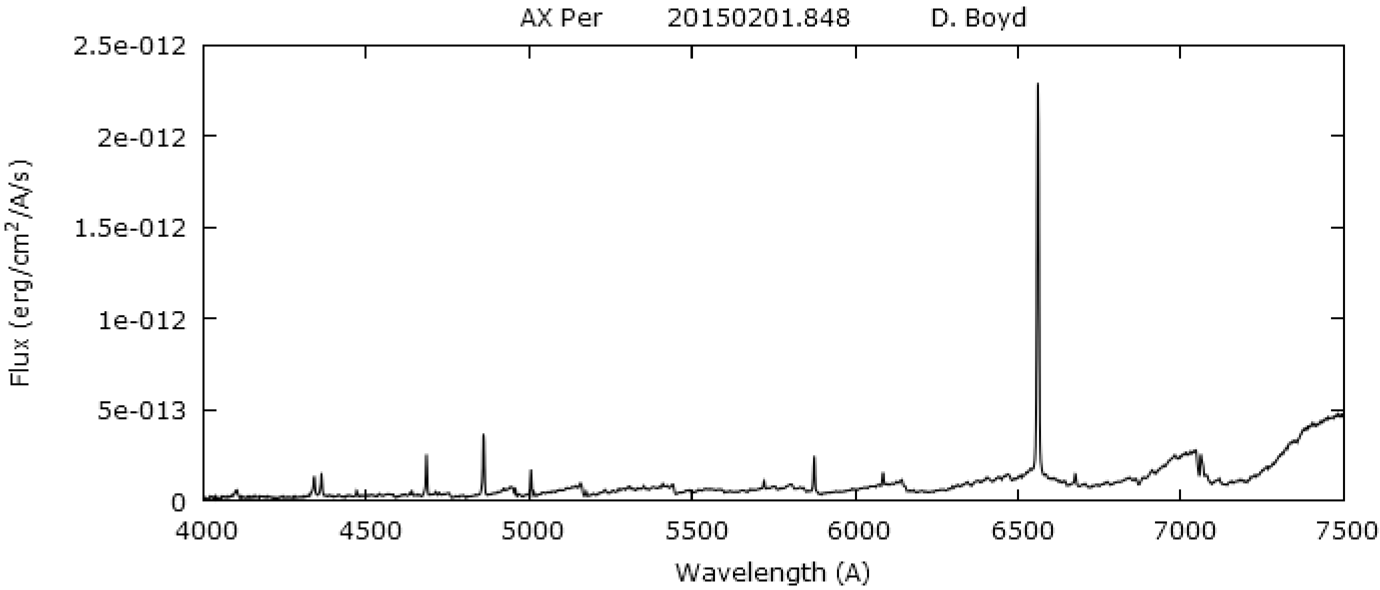
The prototype Symbiotic **AX Per** has been detected in outburst in august 2014 by ANS collaboration See ATel #6382

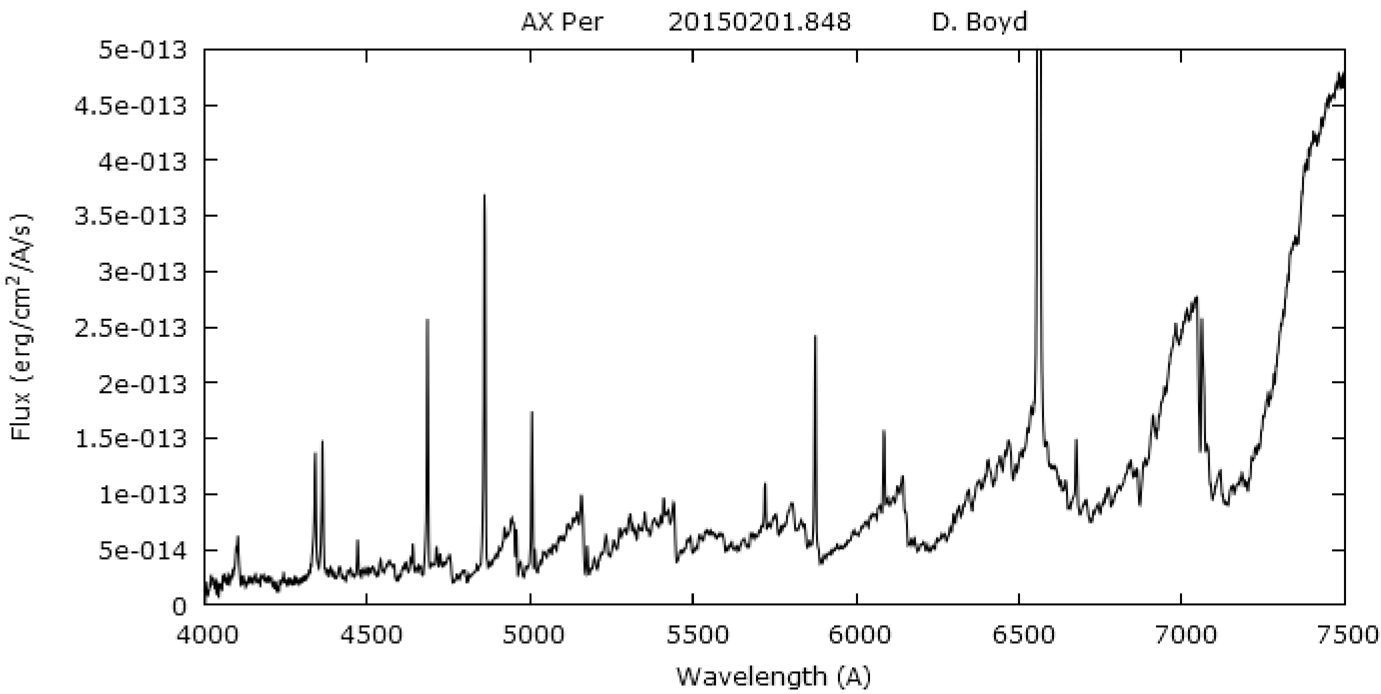
AX Per enters into eclipse of the hot component
The current V mag is about 12.5 (declining)

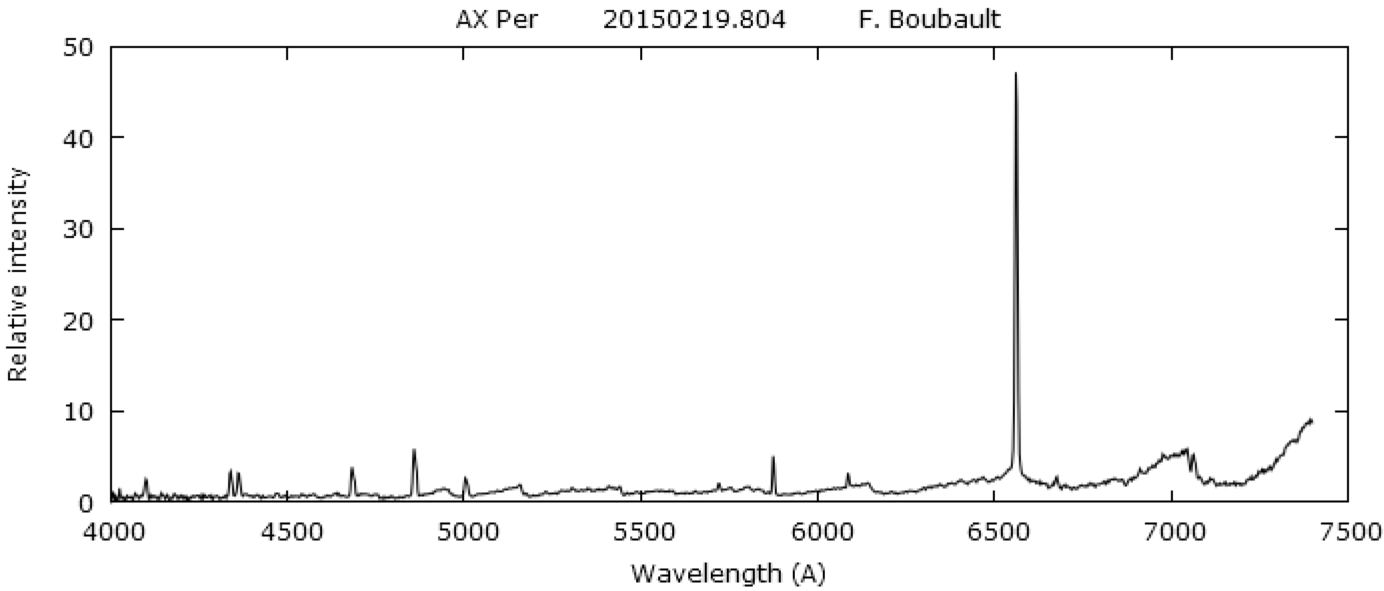
ARAS data base Data Base AX Per

Coordinates (2000.0)	
R.A.	**01 h 36 m 22.7 s**
Dec.	**+54° 15' 2.5"**



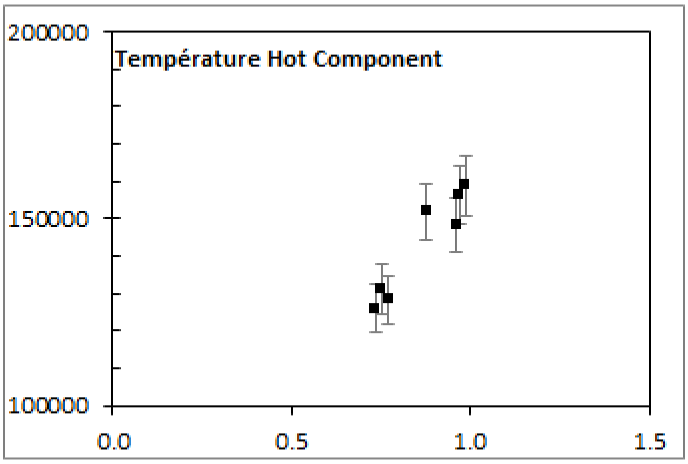




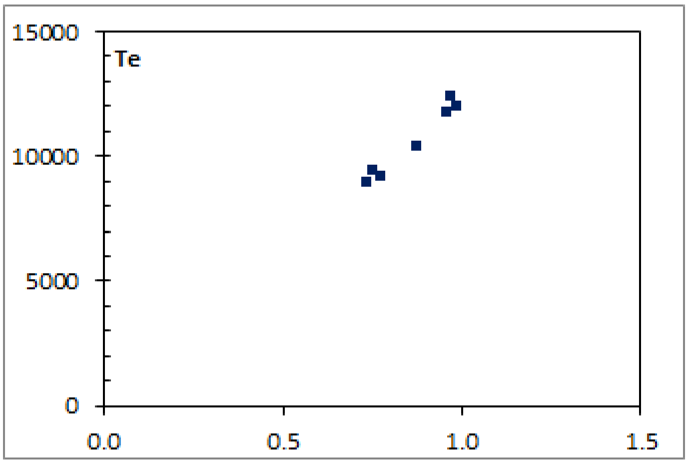


Measurements from spectra R = 1000 of the data base

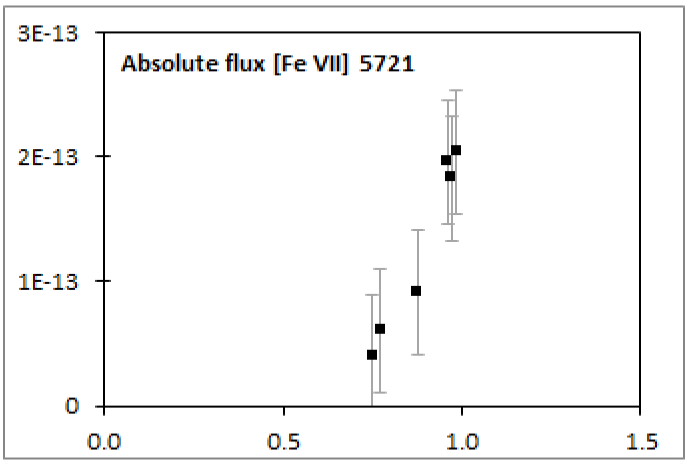
Horizontal axis = phase according to Ephemeris : Phase = 2447551.26 + 680.86 * N - 13
Data from 2014, August to 2015, February

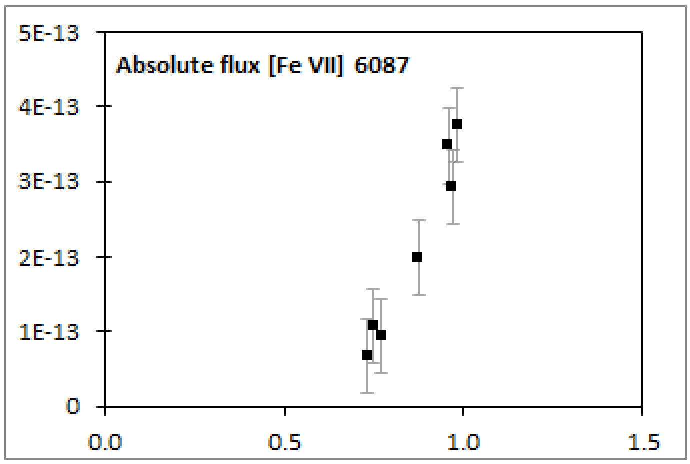


Temperature of the hot component (K)
increases as the pseudo photosphere of the white dwarf contracts



Electronic temperature(K)
using [OIII] (5007+4959)/[OIII] 4363 ratio





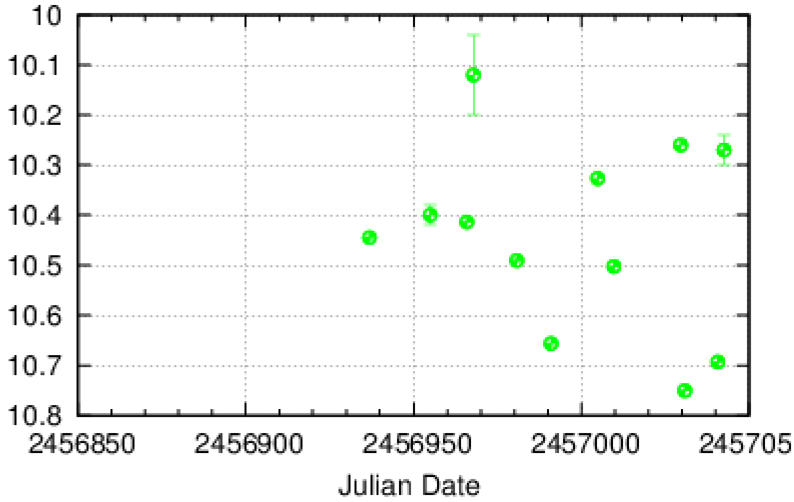
Absolute flux of Fe^{6+} lines : increasing with the hardening of the radiation from hot component

V694 Mon = MWC 560

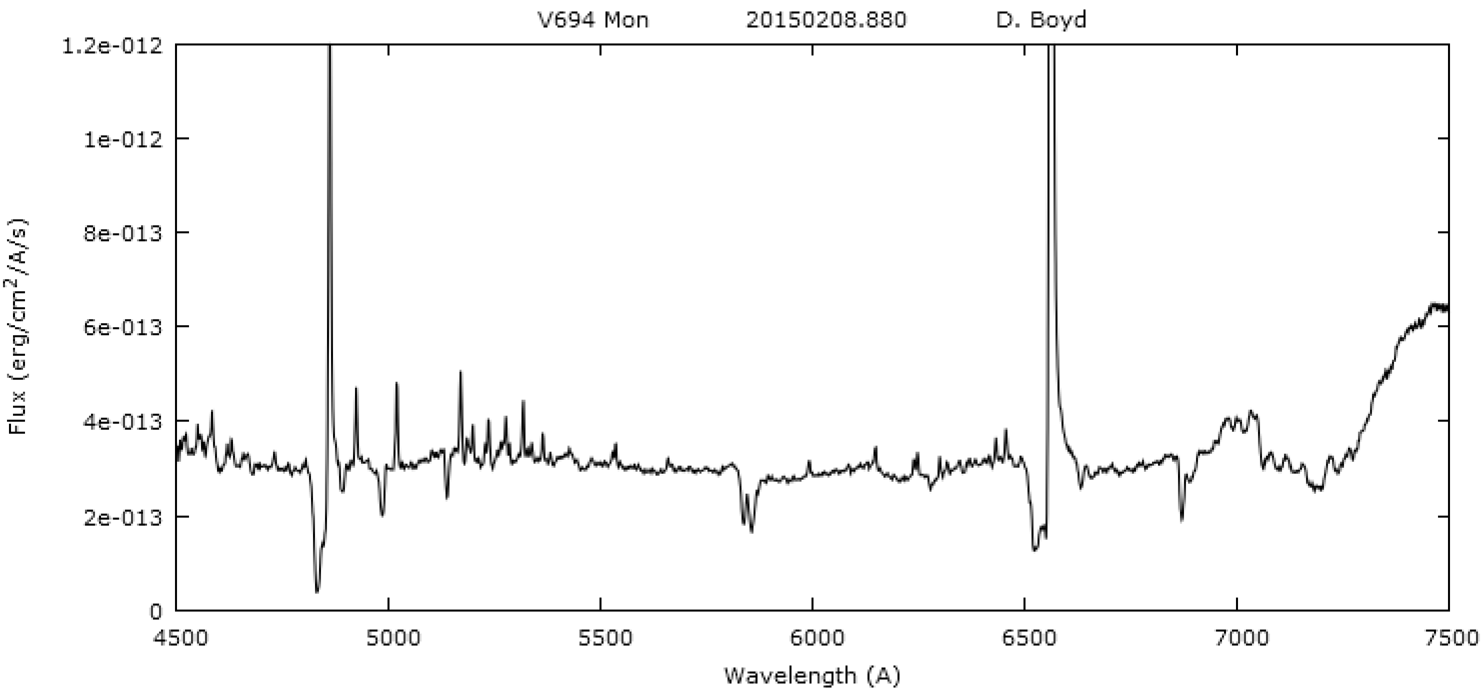
Coordinates (2000.0)	
R.A.	07 h 25 m 51.2 s
Dec.	-07° 44' 08"

Spectroscopy : ungoing high activity at the beginning of February, returns to low state mid-February

Observing : detect high state
Daily coverage should be must !

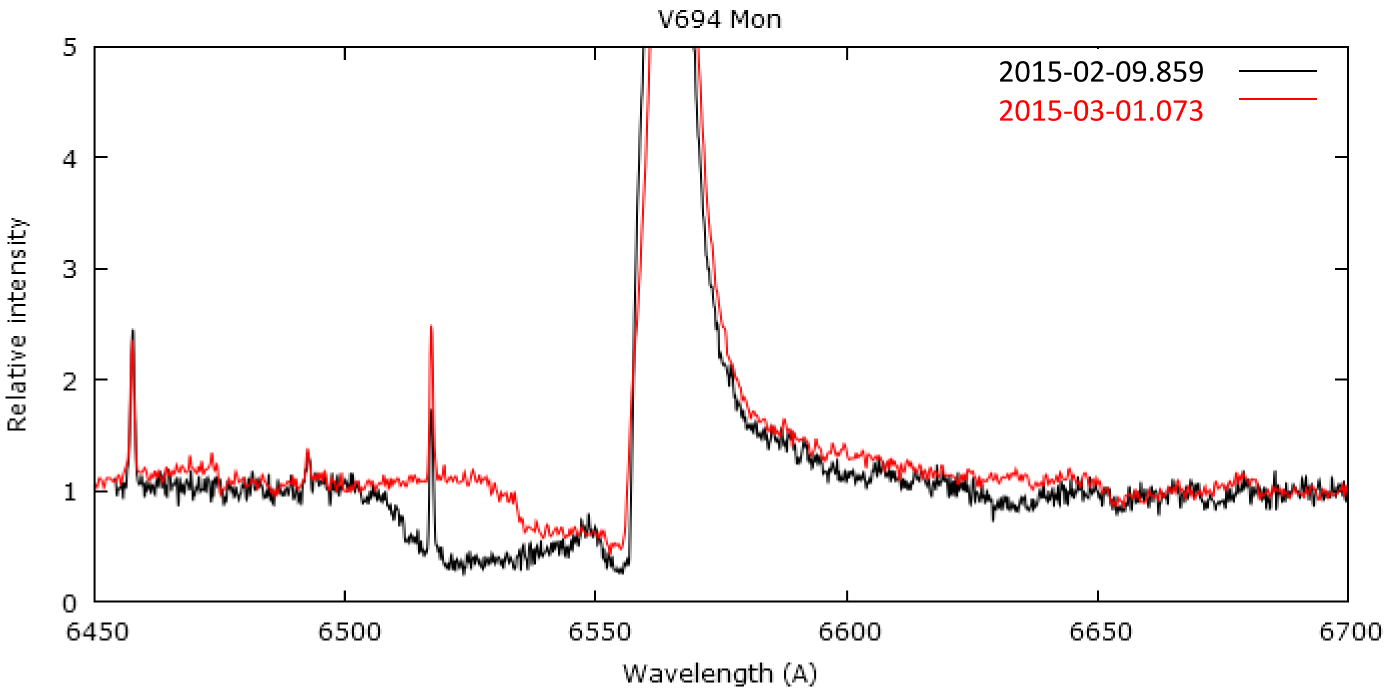


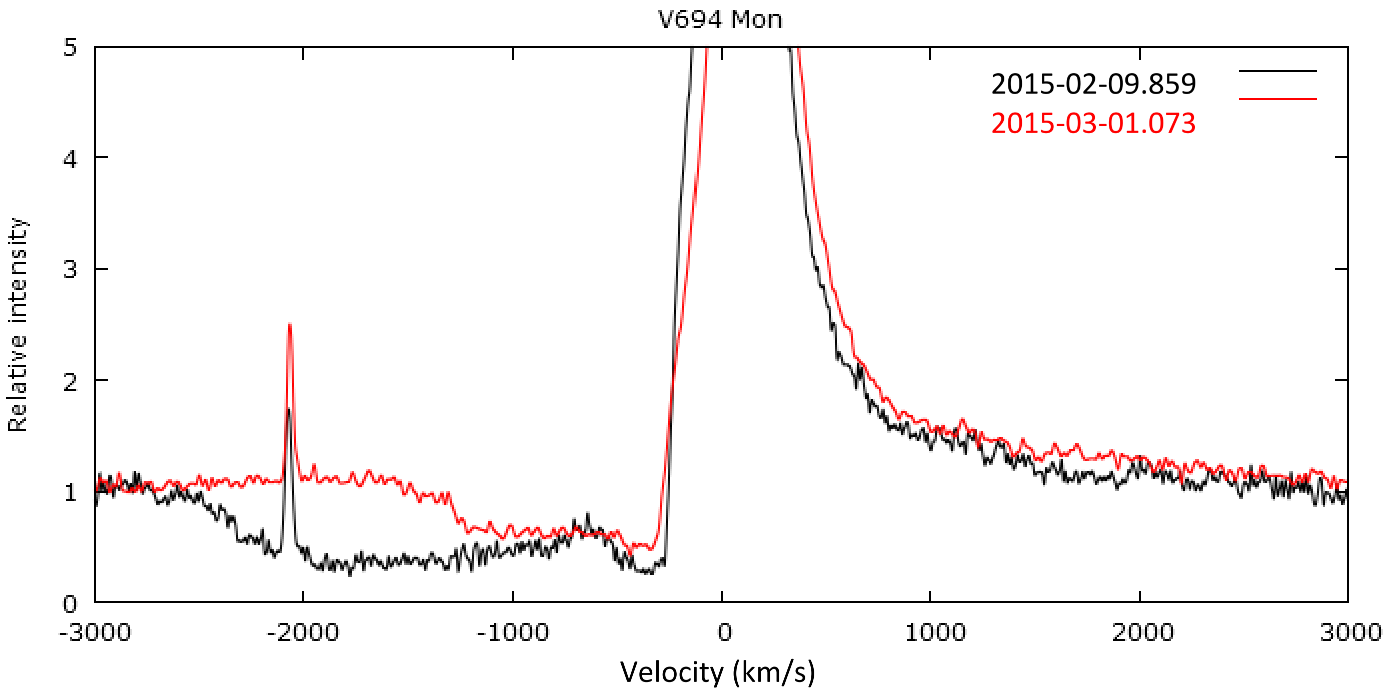
AAVSO - V band light curve



David Boyd Flux calibrated spectra LISA R = 1000

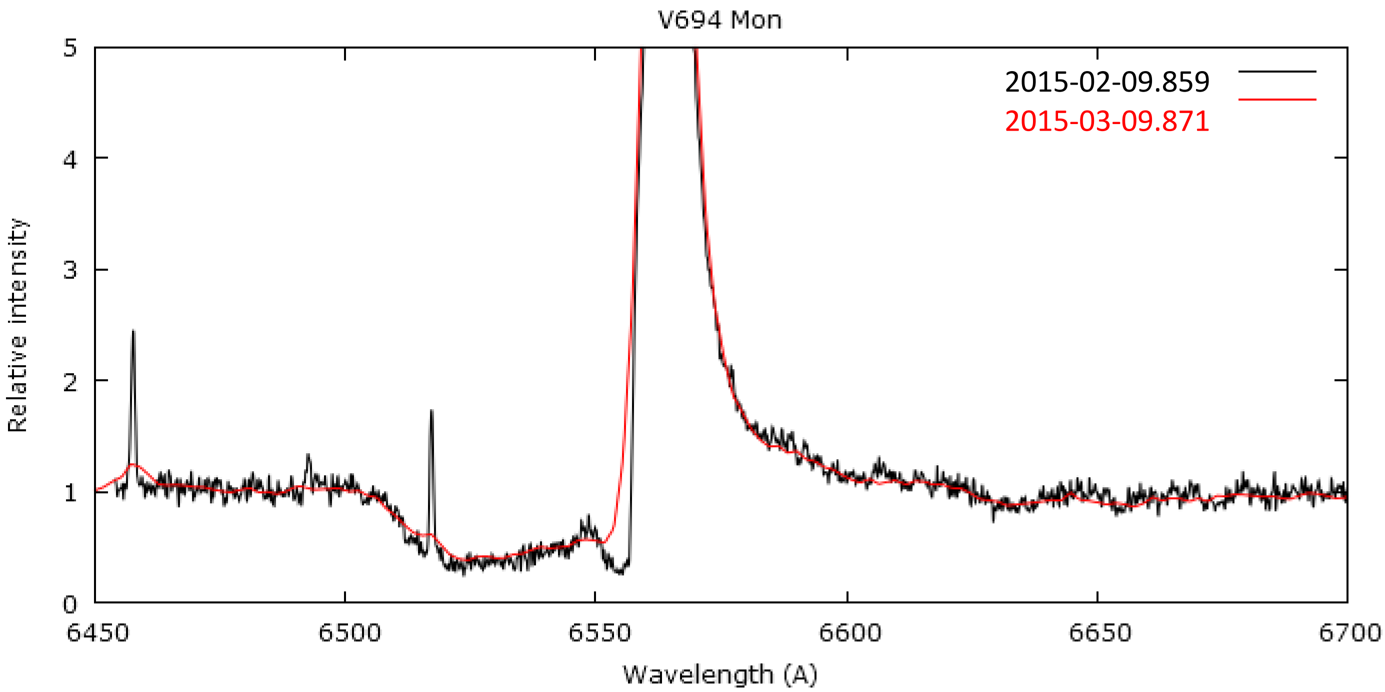
Comparison of spectra from c. Buil (2015-02-09) and T. Lester (2015-03-01) at R = 9000





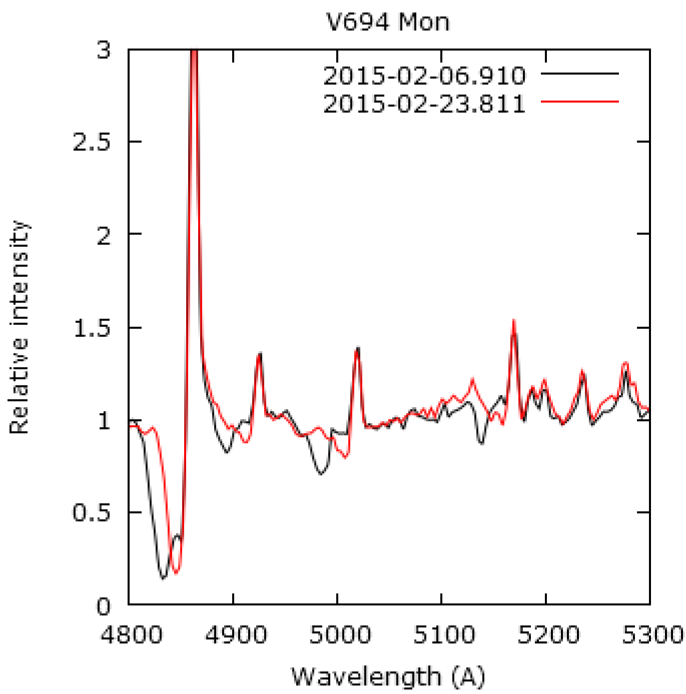
The maximum velocity declines from about 2500 to 1200 km/s
The narrow lines are Fe II 6457 and 6518 from the accretion disk

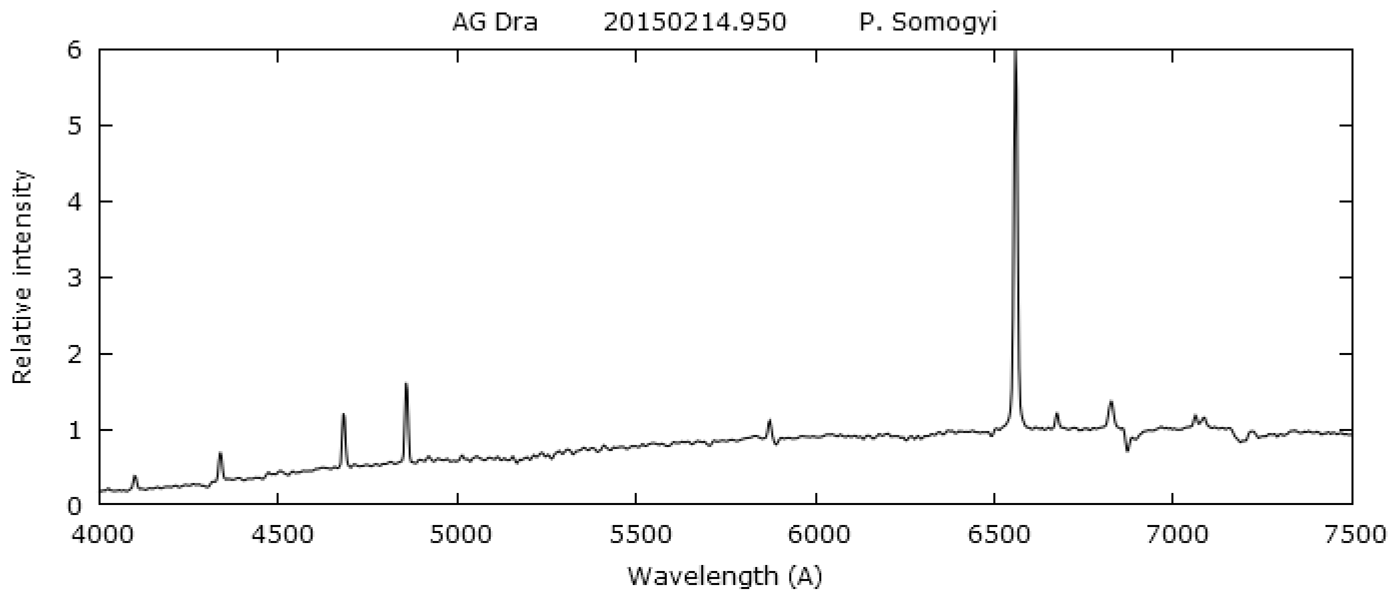
Comparison oh high resolution R = 9000 (C. Buil) and low resolution R = 1000 (D. Boyd) the same day

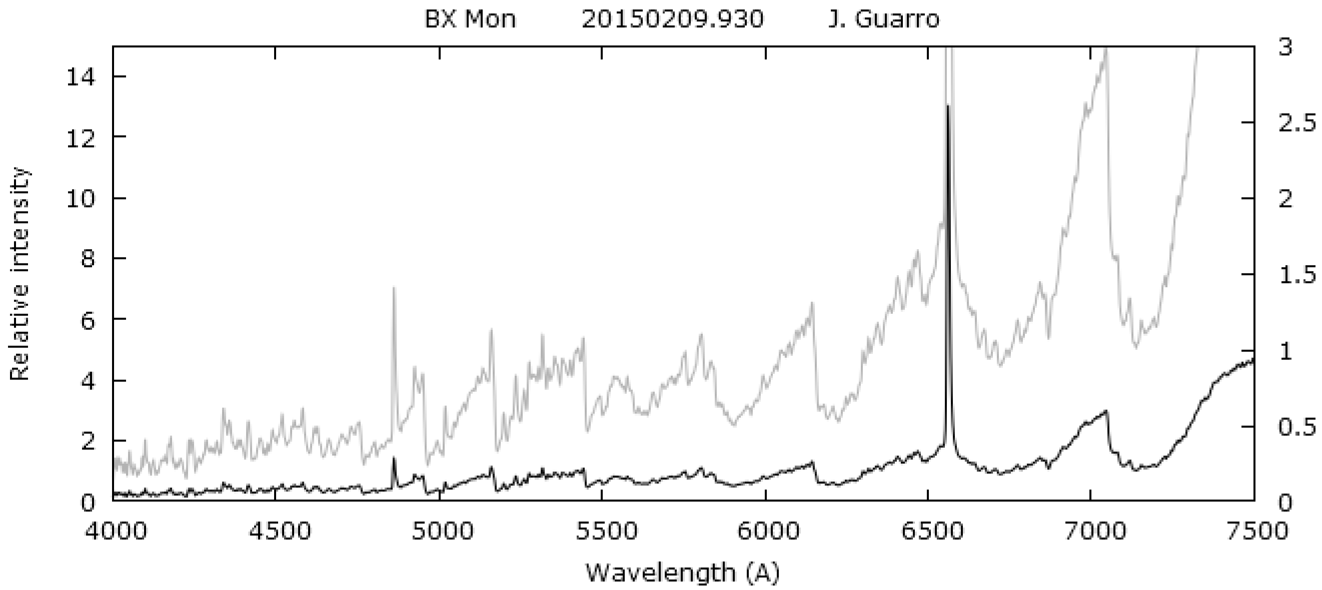


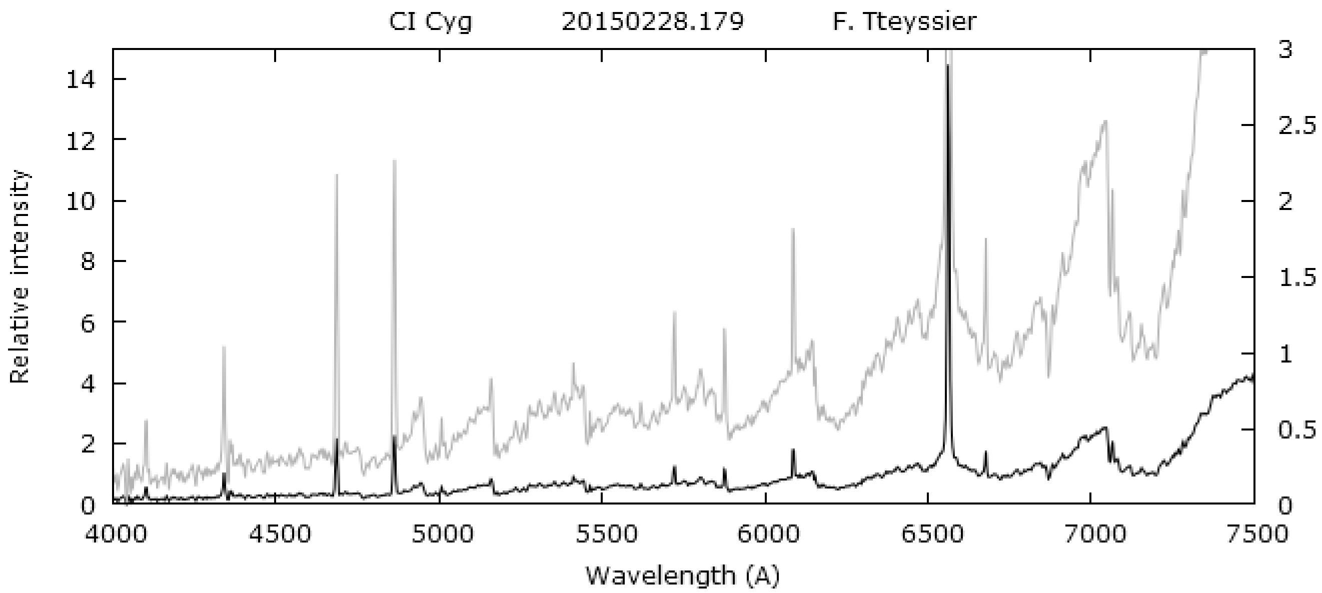
The low res. Spectra allows the measure of the maximum velocity of the absorption.

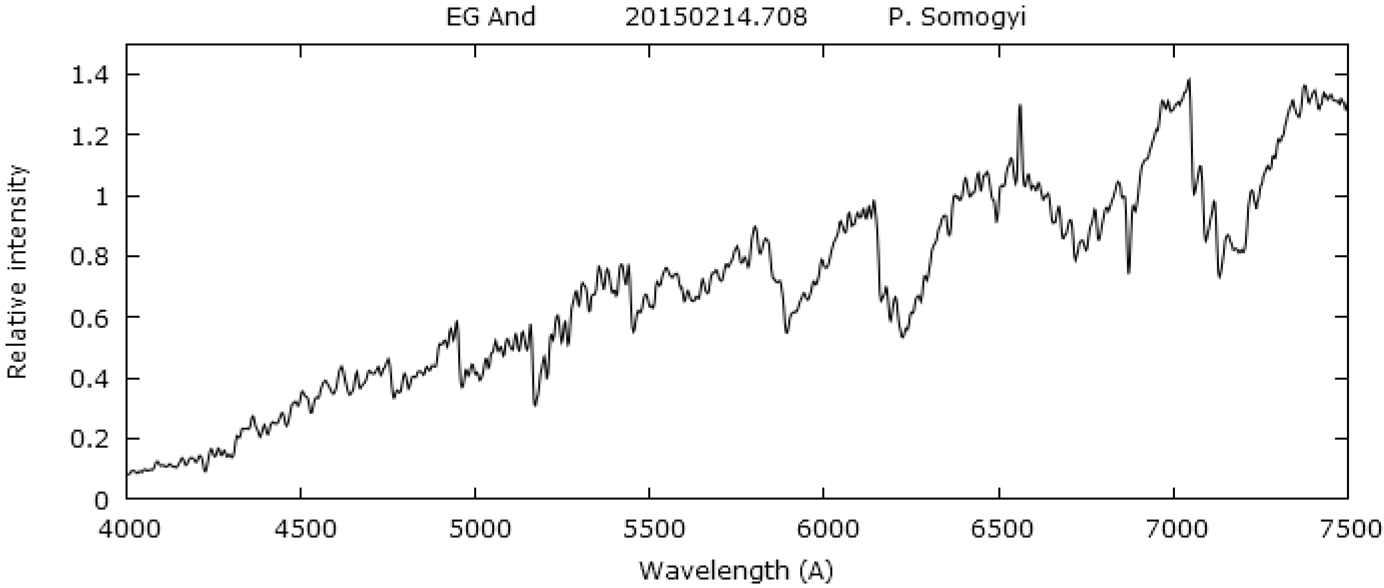
F. Teyssier LISA R = 1000
Comparison of the absorptions of Fe II (42) lines
In the 6th of February spectrum, the absorptions are well detached

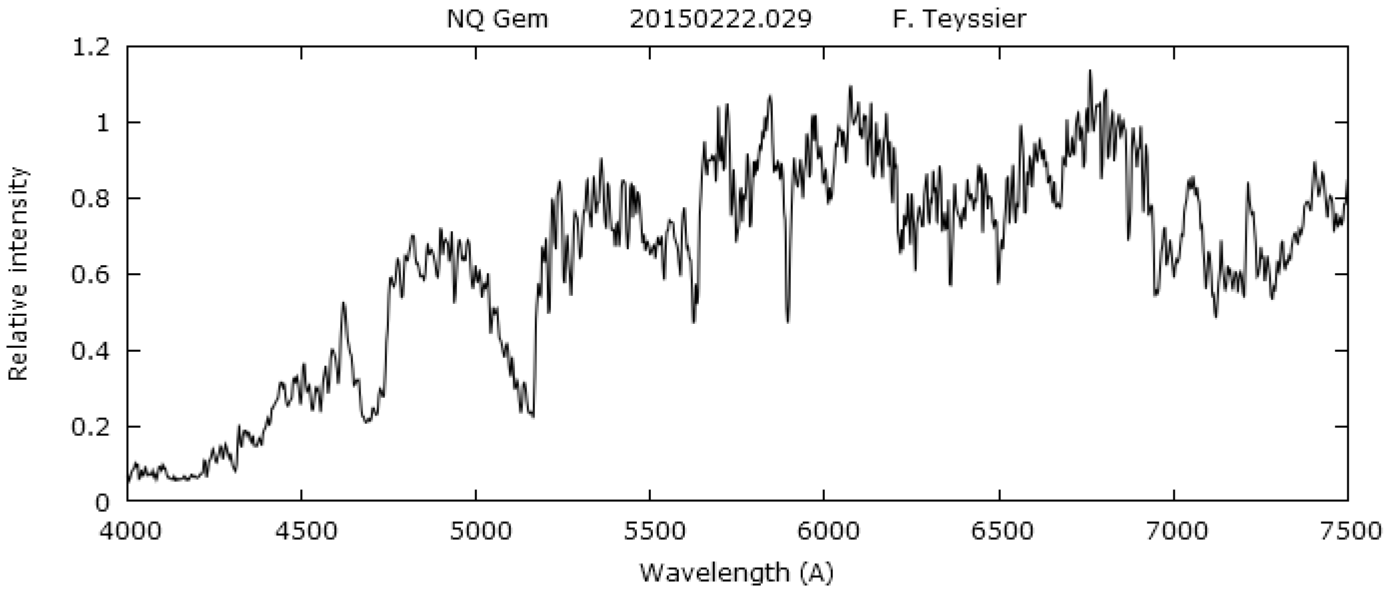


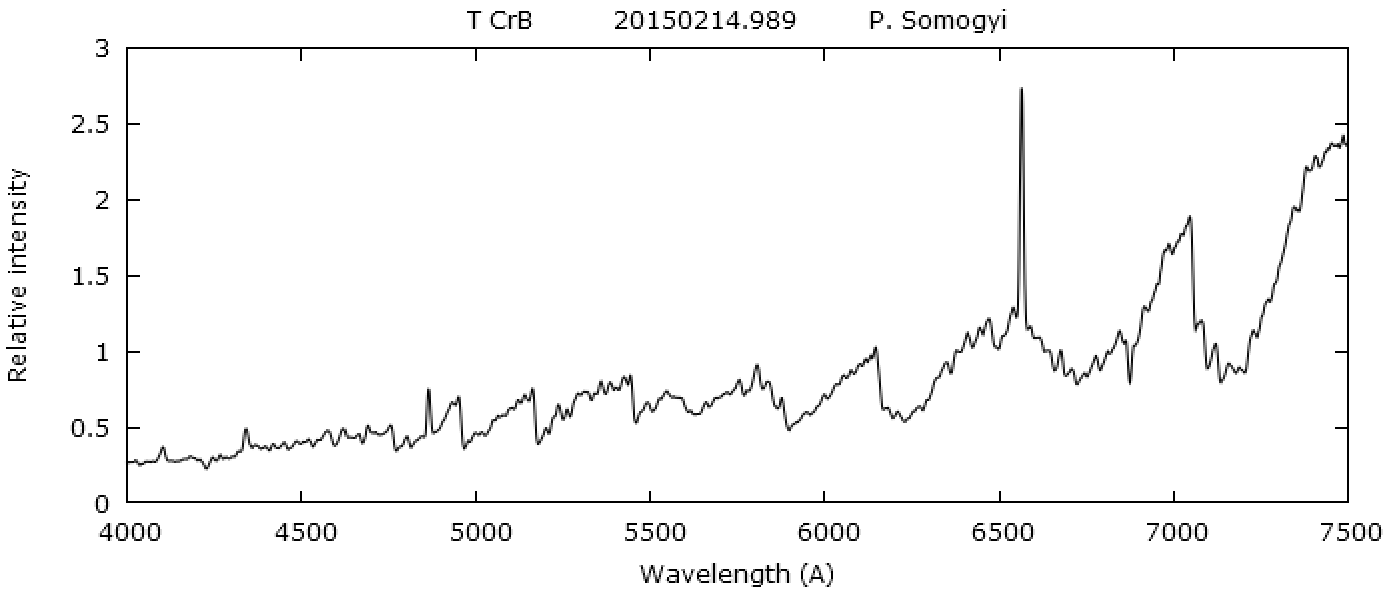

AG Dra 20150214.950 P. Somogyi
Relative intensity
Wavelength (A)

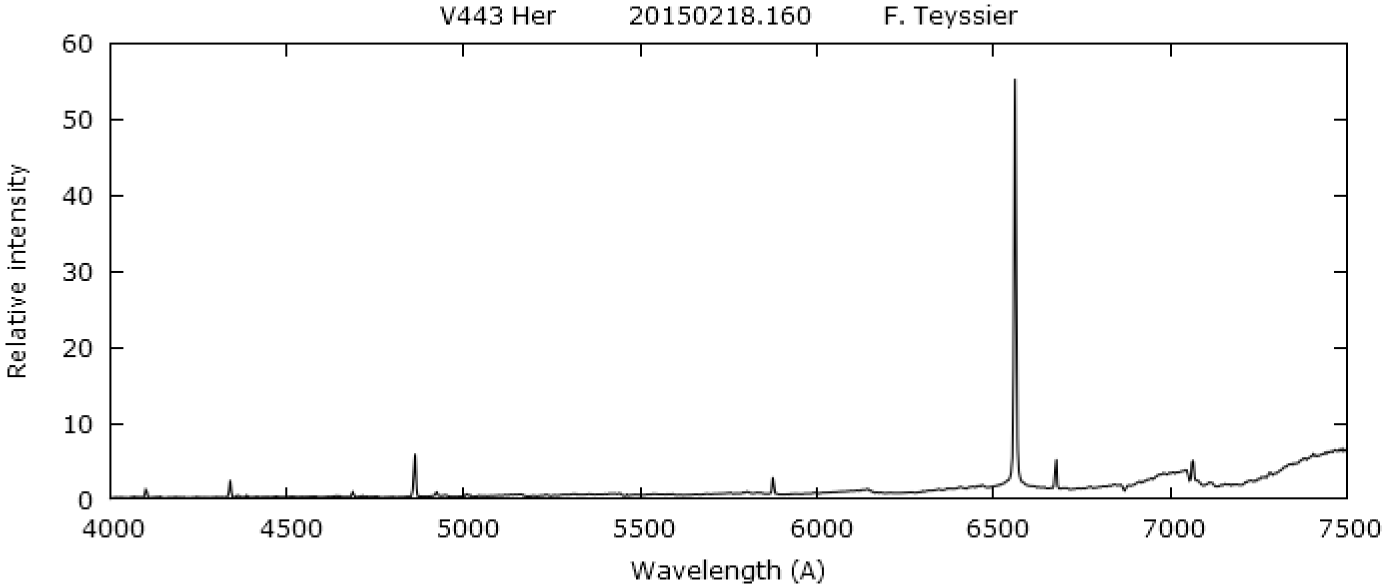

BX Mon 20150209.930 J. Guarro
Relative intensity
Wavelength (A)

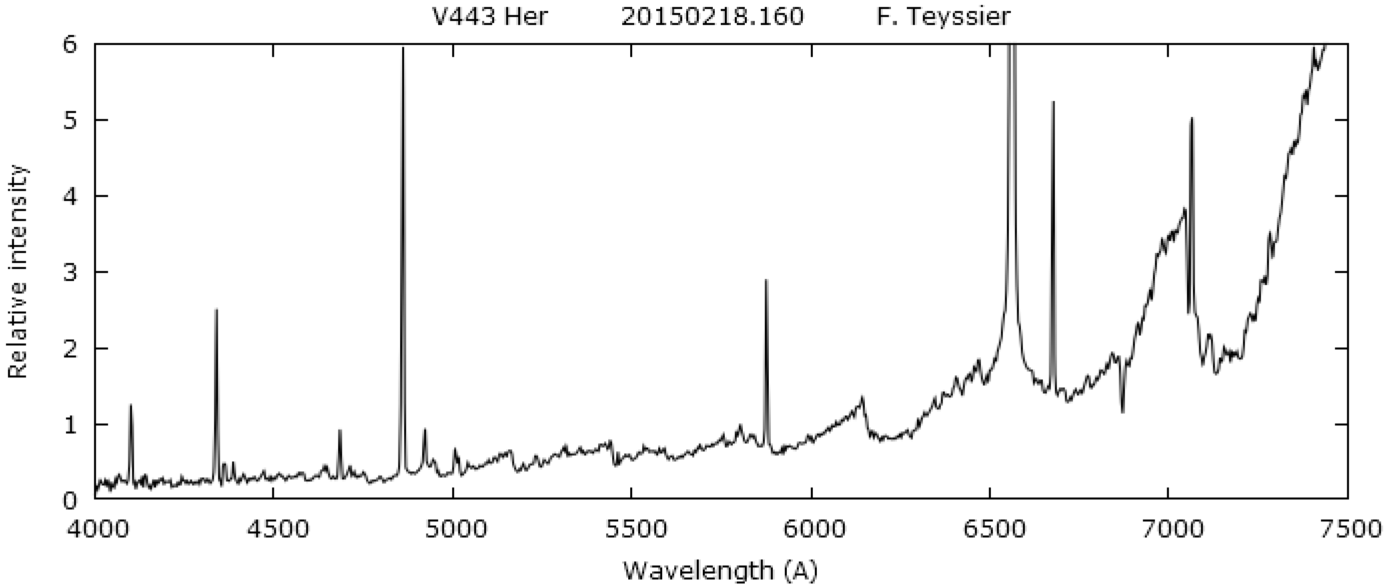

CI Cyg 20150228.179 F. Tteyssier
Relative intensity
Wavelength (A)

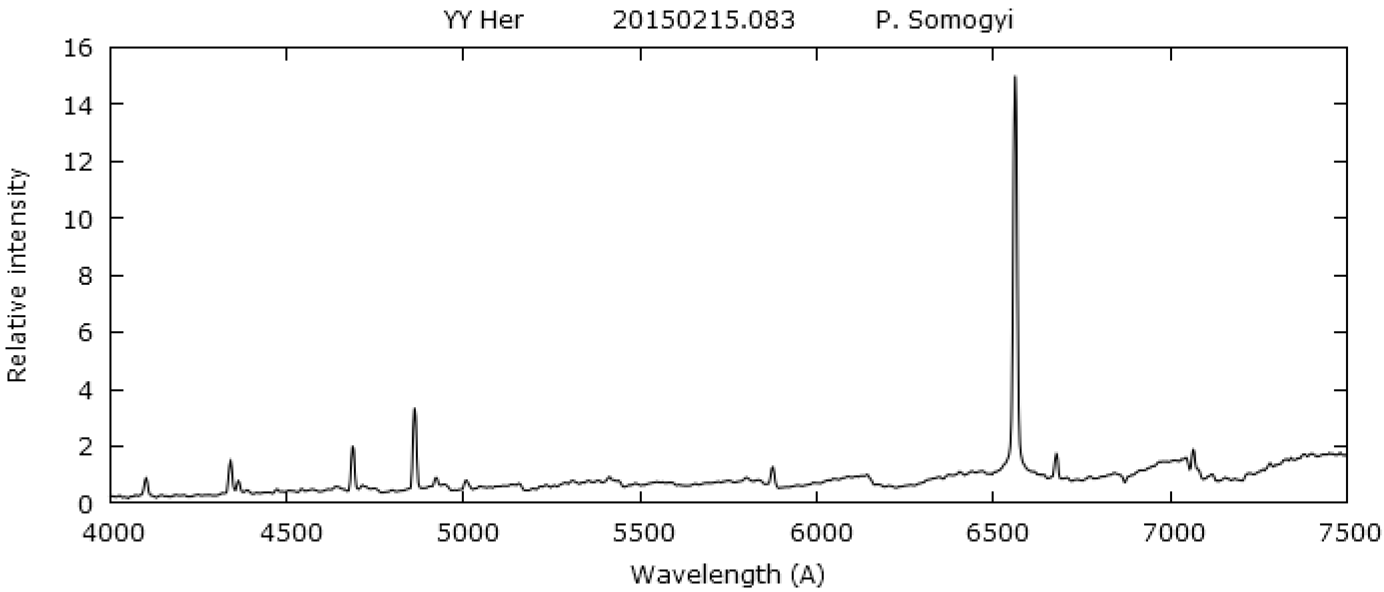

EG And 20150214.708 P. Somogyi
Relative intensity
Wavelength (A)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
4000
4500
5000
5500
6000
6500
7000
7500

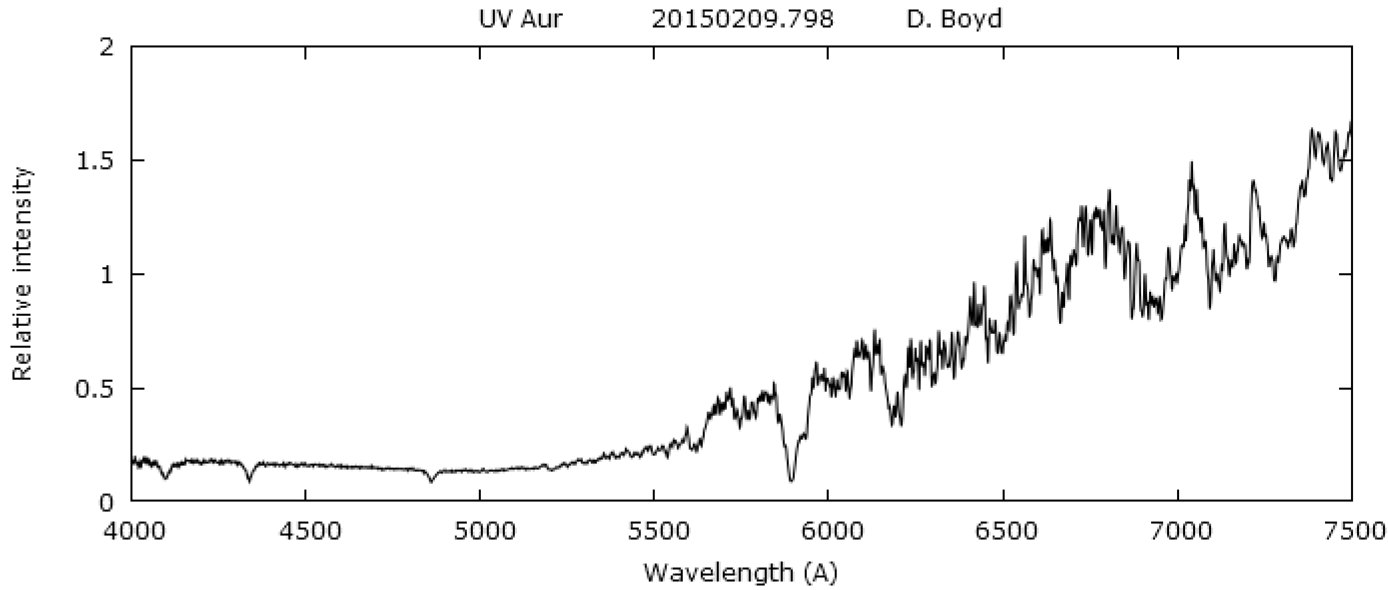

NQ Gem 20150222.029 F. Teyssier
Relative intensity
Wavelength (A)
0
0.2
0.4
0.6
0.8
1
1.2
4000
4500
5000
5500
6000
6500
7000
7500

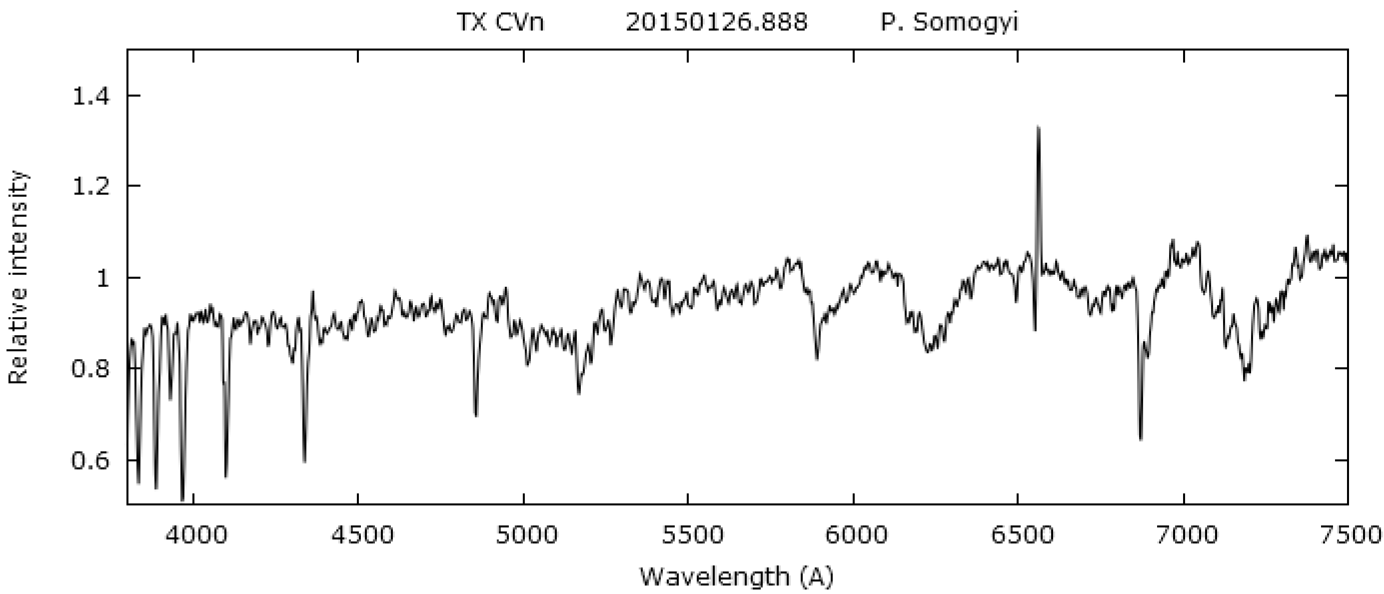

T CrB 20150214.989 P. Somogyi
Relative intensity
Wavelength (A)
0
0.5
1
1.5
2
2.5
3
4000
4500
5000
5500
6000
6500
7000
7500


V443 Her 20150218.160 F. Teyssier
Relative intensity
Wavelength (A)
0
10
20
30
40
50
60
4000
4500
5000
5500
6000
6500
7000
7500

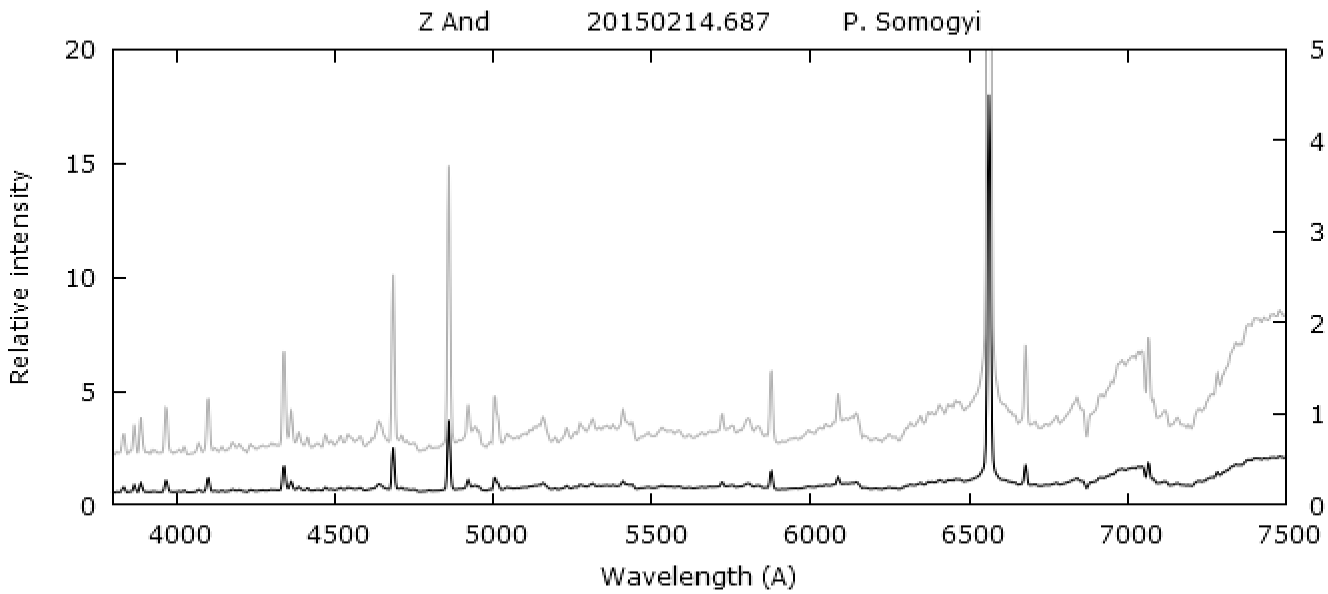

V443 Her 20150218.160 F. Teyssier
Relative intensity
Wavelength (A)
0
1
2
3
4
5
6
4000
4500
5000
5500
6000
6500
7000
7500


YY Her 20150215.083 P. Somogyi
Relative intensity
Wavelength (A)
0
2
4
6
8
10
12
14
16
4000
4500
5000
5500
6000
6500
7000
7500

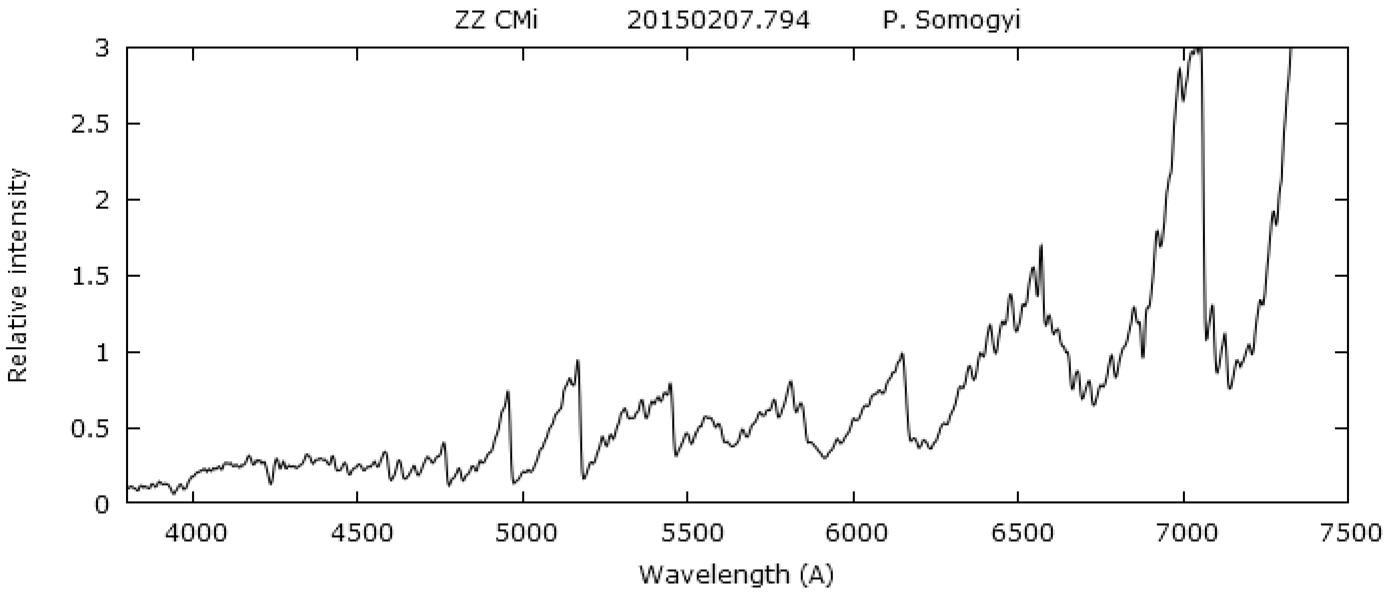




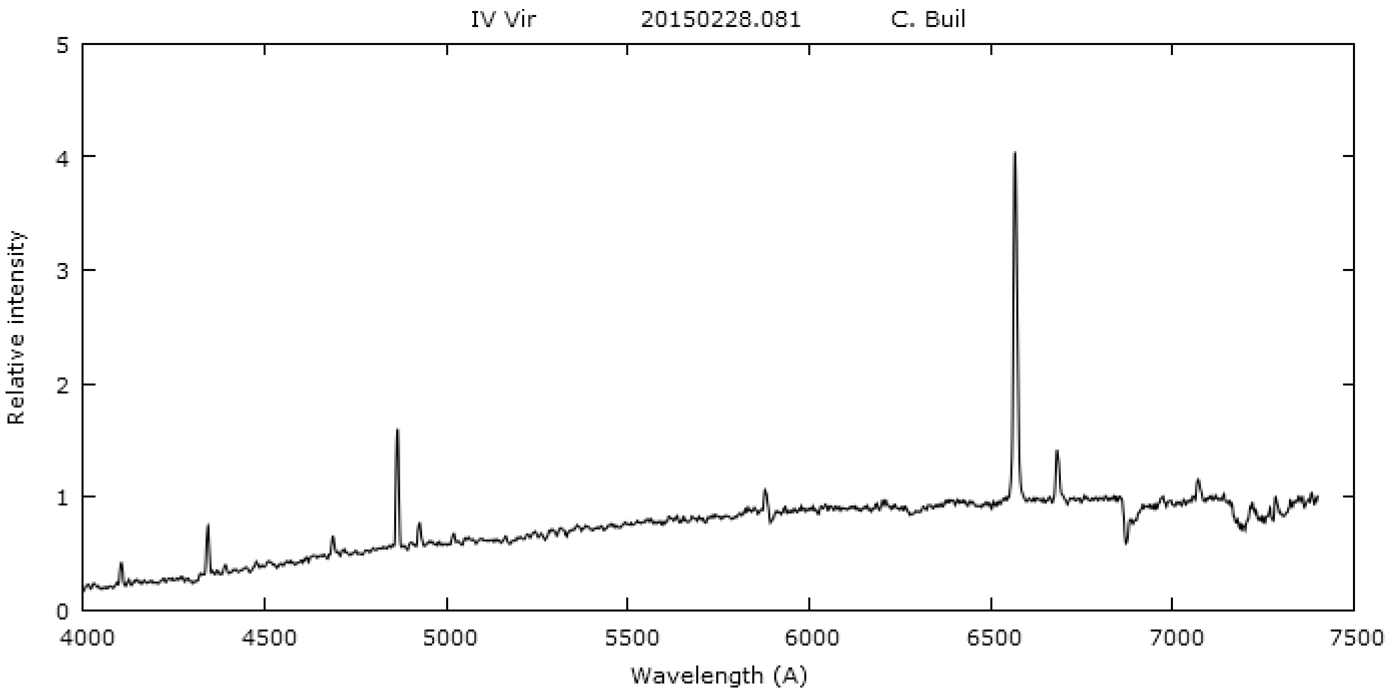
Peter Somogyi - Alpy 600 - 26-02-2015 - Note the excellent resolution in near UV



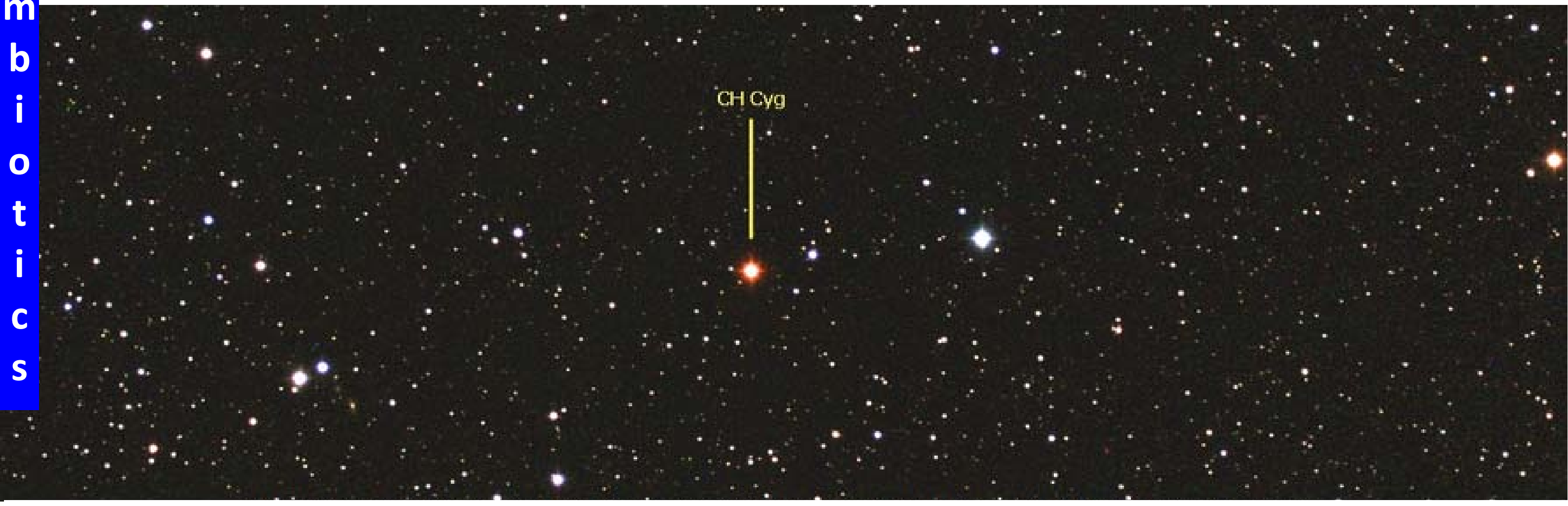
ARAS DATA BASE | http://www.astrosurf.com/aras/Aras_DataBase/Symbiotics.htm



IV Vir obtained by Christain Buil with a T200 and Alpy
A new symbiotic in the data base
The visual magnitude is about 10.8
A nice target for spring nights



Request for observations of the symbiotic star CH Cygni (Dr A. Skopal)



Field of CH Cygni - Christian Buil - 15-03-2012

CH Cygni

Coordinates (2000.0)	
R.A.	**19 24 33**
Dec.	**+54 14 29.1**

Current magnitude V = 7.4 to 7.6 (Flickering)

Reference stars

MILES Standart for high resolution spectra

Name	RA (2000)	Dec (20002)	Sp. Type	Mag. V	E_{B-V}
HD 192640	20:14:31.9	+36:48:22.7	A2V	4.96	0.026

Reference for low resolution spectra

Name	RA (2000)	Dec (20002)	Sp. Type	Mag. V	E_{B-V}
HD 183534	19:27:42	+52:19:14	A1V	5.7	0

Observing

High resolution spectra
Eshel
LHIRES III 2400 l/mm (H alpha)

Low resolution spectra (minimum R = 600)

Send spectra

To francoismathieu.teyssier at bbox.fr

File name : _chcygni_aaaammdd_hhh.fit
And _chcygni_aaaammdd_hhh.zip for eShel

ARAS Data Base for CH Cygni

http://www.astrosurf.com/aras/Aras_DataBase/Symbiotics/CHCyg.htm
See also former campaign :
www.astrosurf.com/aras/surveys/chcyg/index.html

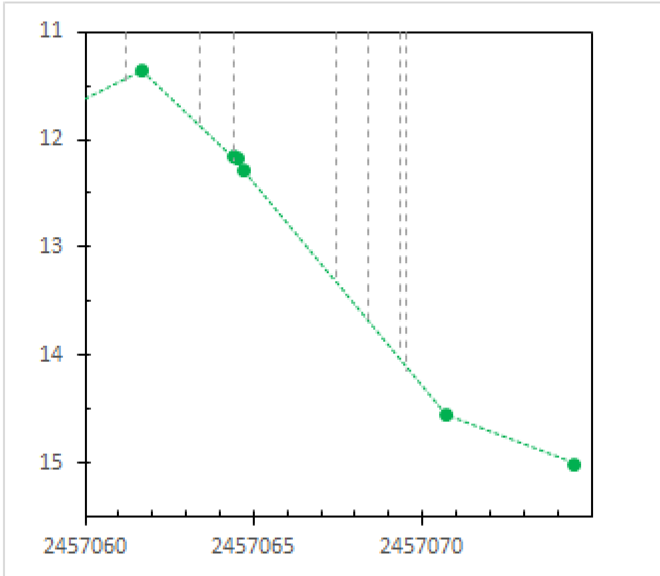
SS Aur : spectroscopic coverage along an outburst

Peter Somogyi, Joan Guarro

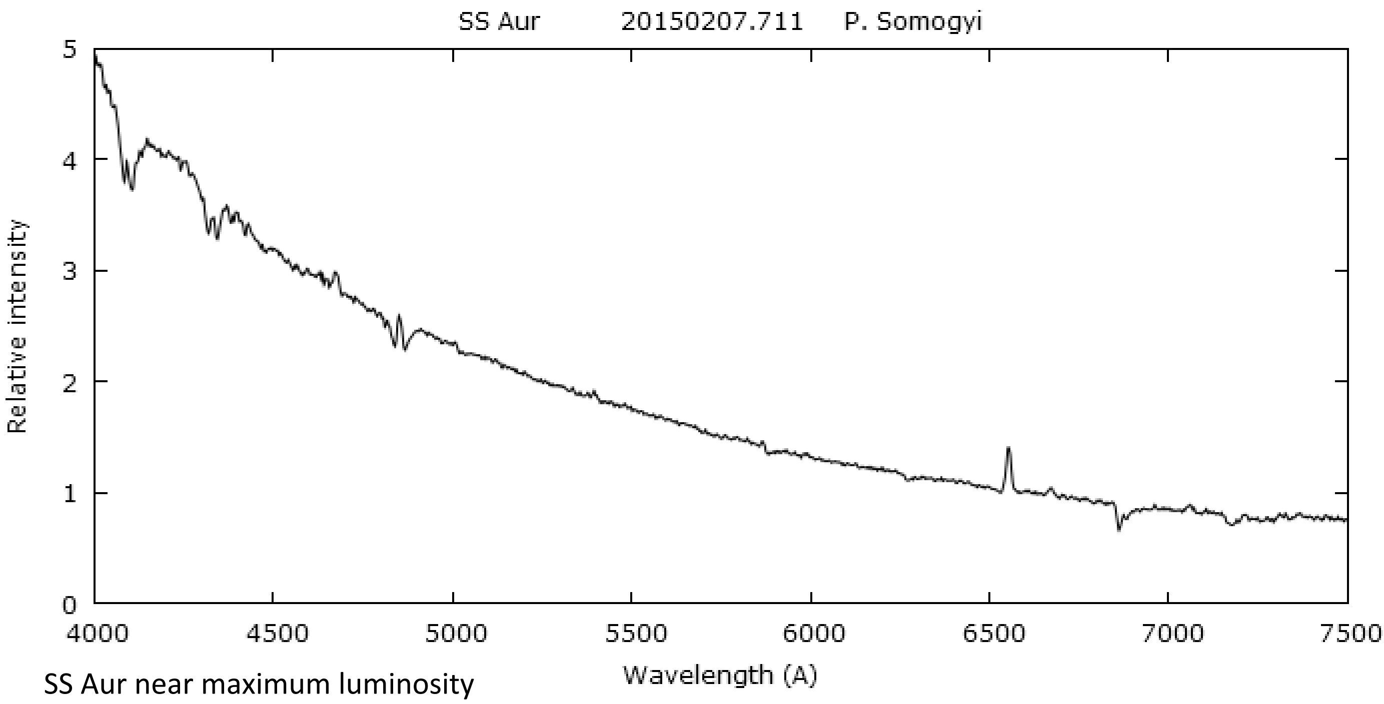
SS Aur

Coordinates (2000.0)	
R.A.	**06 13 22.4**
Dec.	**+47 44 25.4**

SS aur is a classical cataclysmic star of UG Gem type, showing outbursts of the accretion disk. Outbursts of this stars are classified as Long, Short and Anomalous.
In February, Peter Somogyi and Joan Guarro produced the **first spectroscopic evolution of an outburst** (Short outburst) for this star from maximum luminosity (Mag V ~ 11.5) to quiescent stage (Mag V ~ 15.5).



AAVSO light curve (V band) of the outburst
Dates of the spectra : dashed grey lines



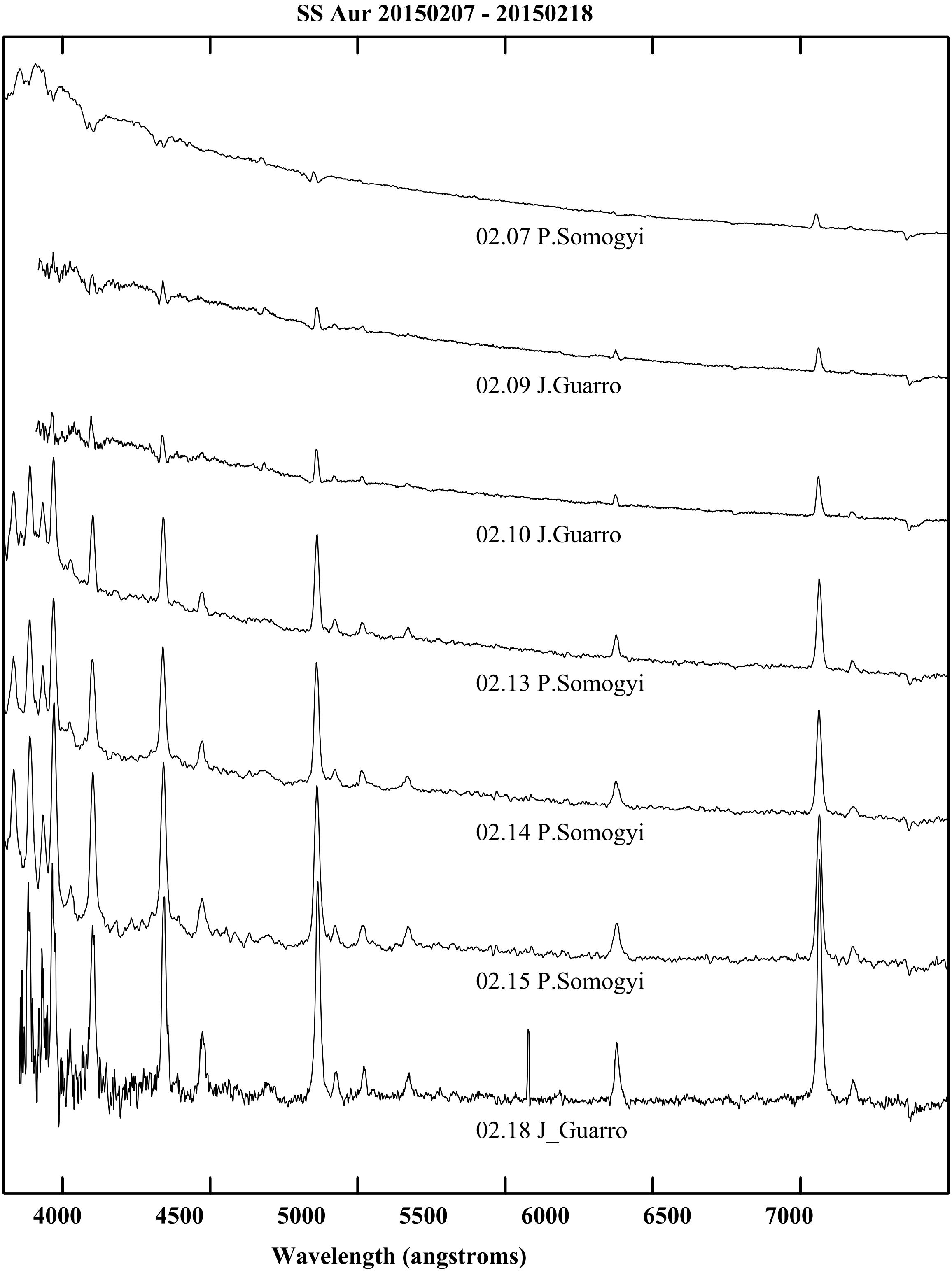
SS Aur near maximum luminosity
Peter Somogyi - Alpy R = 600

07/02/2015	17:03:09	2457061.235	psomogyi
09/02/2015	20:20:24	2457063.382	J.Guarro
10/02/2015	21:31:25	2457064.432	J.Guarro
13/02/2015	22:02:59	2457067.447	psomogyi
14/02/2015	21:25:15	2457068.413	psomogyi
15/02/2015	19:35:48	2457069.311	psomogyi
15/02/2015	22:57:02	2457069.491	J.Guarro
18/02/2015	22:03:49	2457072.454	J.Guarro
22/02/2015	20:47:41	2457076.436	J.Guarro
24/02/2015	20:17:39	2457078.422	J.Guarro

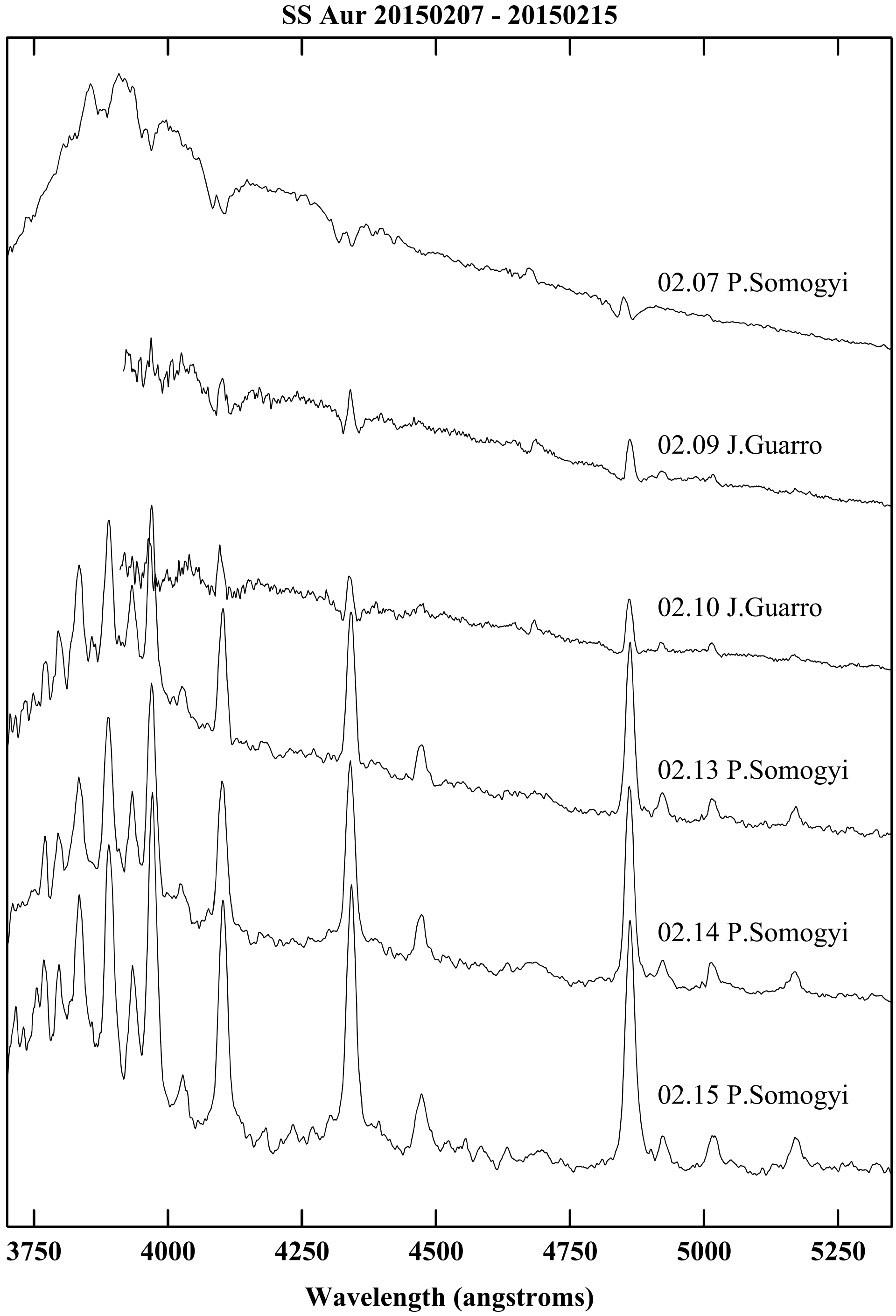
Log of observations

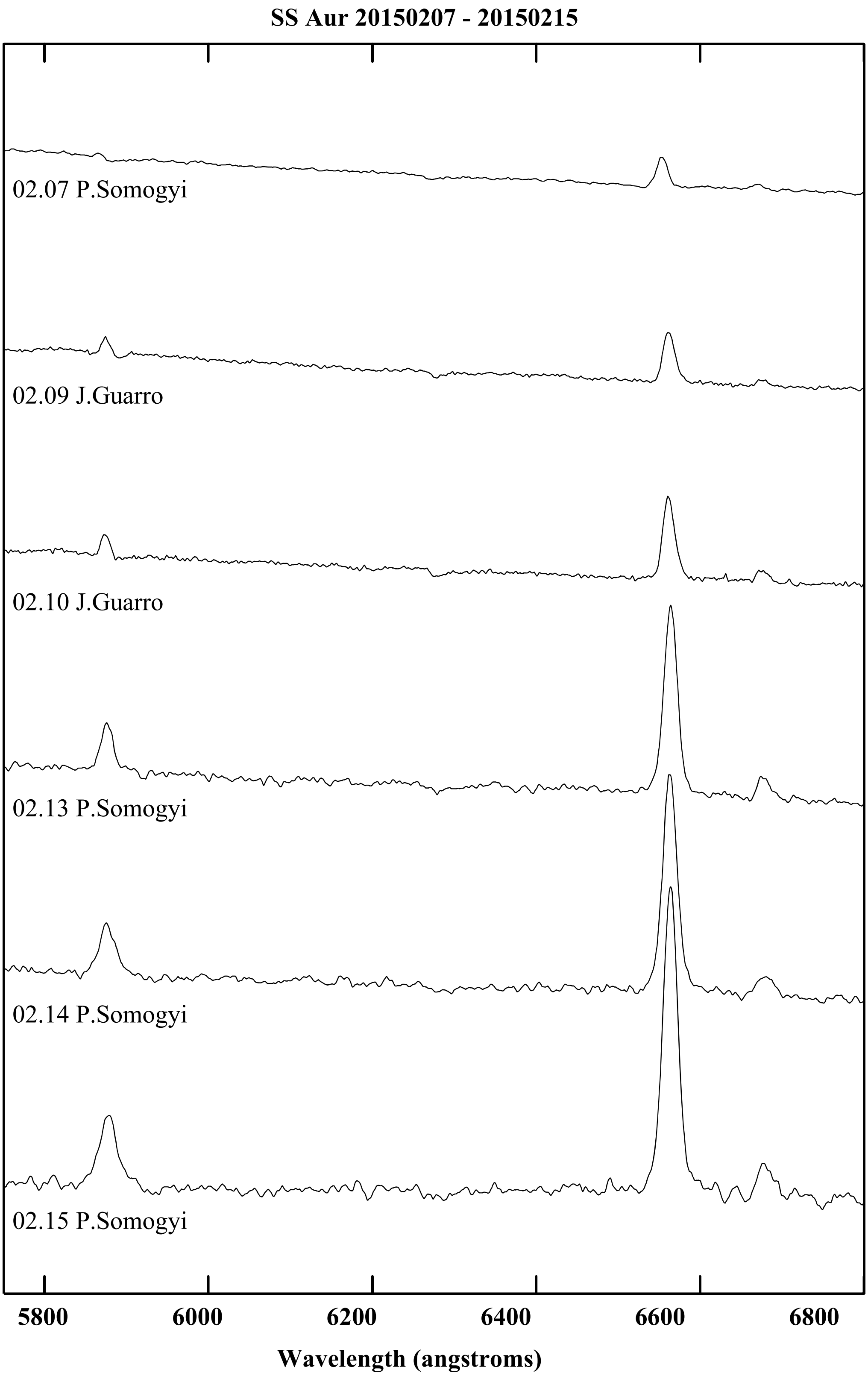
Evolution of the outburst

Graphs prepared by Peter Somogyi



SS Aur : spectroscopic coverage along an outburst




SS Aur 20150207 - 20150215
02.07 P.Somogyi
02.09 J.Guarro
02.10 J.Guarro
02.13 P.Somogyi
02.14 P.Somogyi
02.15 P.Somogyi
5800
6000
6200
6400
6600
6800
Wavelength (angstroms)

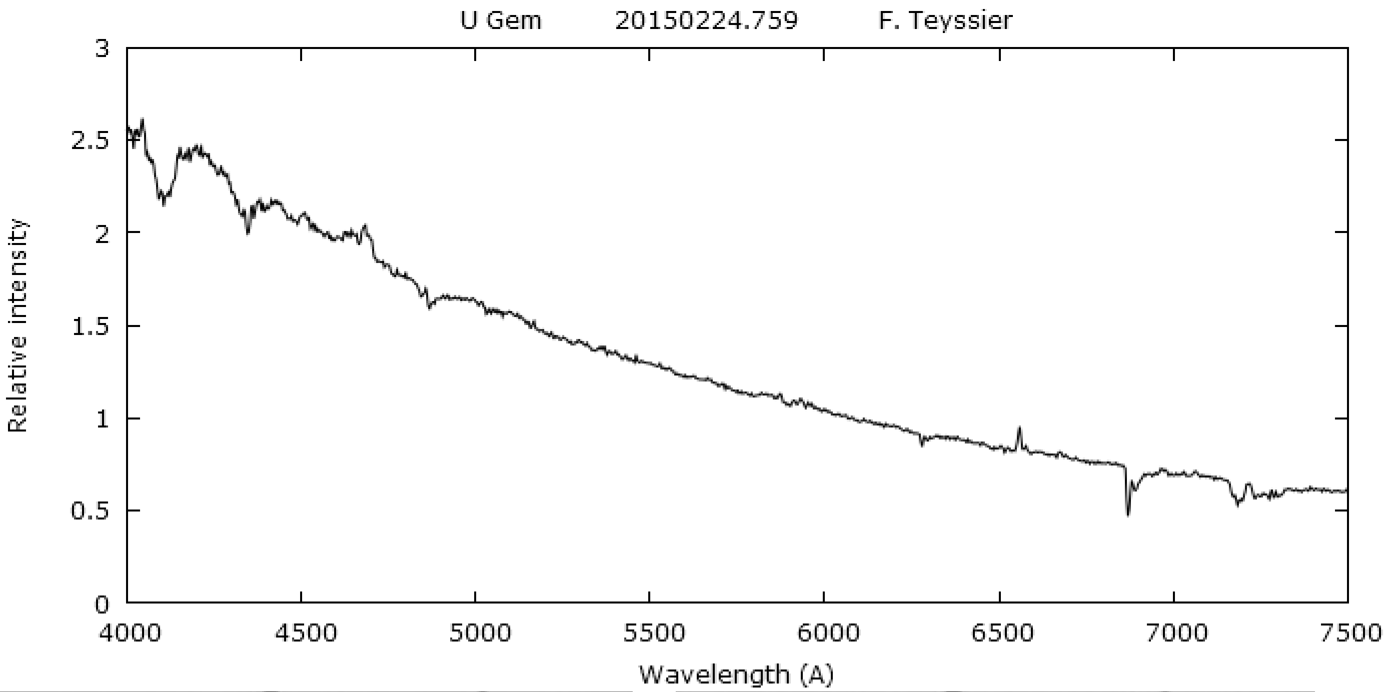
U Gem : spectroscopy at maximum

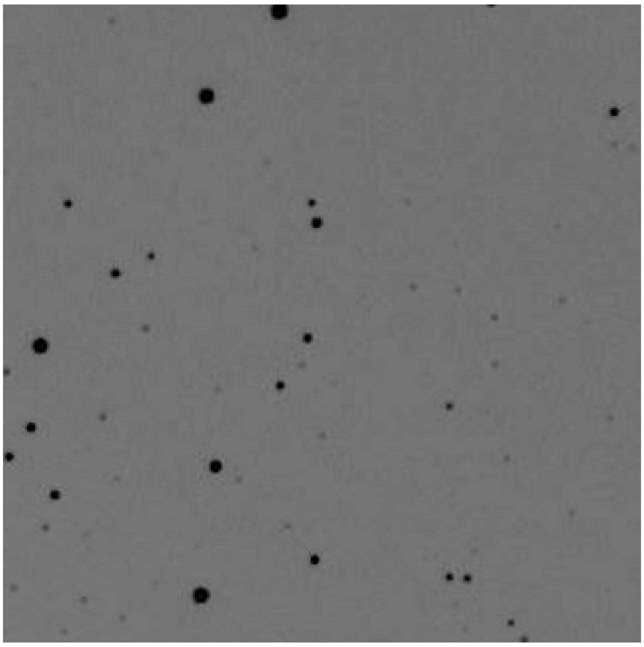
U Gem

Coordinates (2000.0)	
R.A.	07 55 05.2
Dec.	+22 00 05
V Max	9.1
V Min	15.2
Period	0.1769 d
Tn	102 d

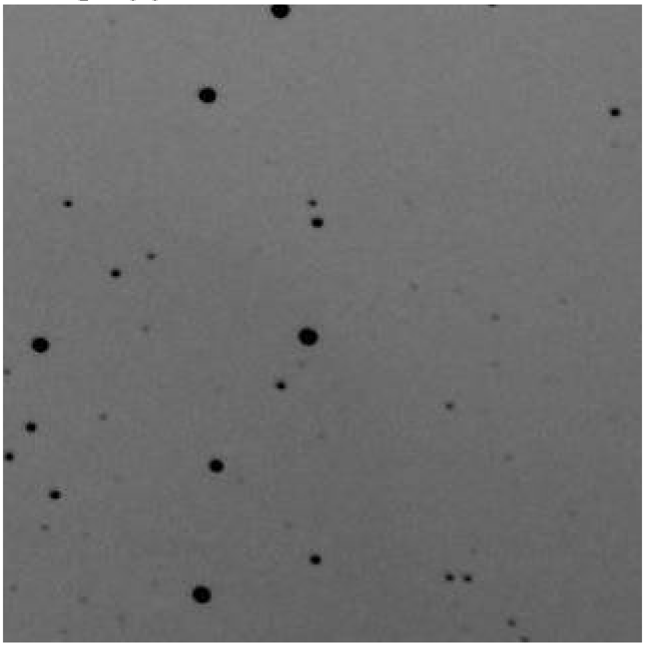
The prototype of dwarf novae in outburst late February

Spectroscopic coverage in the next issue of the letter





Quiescent state 23 11 2008 m[V]= 14.71



Decline 01 01 2009 m[V] = 11.28

Photometry of a previous outburst - F. Teyssier SC10" SX9-H9 Schuller filter V Band

Continuing the discussion from earlier issues of the *Newsletter*, I thought it would be useful to go into a bit more detail about how the different physical properties are recovered for a gas from spectroscopy. We've already discussed the line formation in expanding ejecta and some of the properties of symbiotic star winds, but not how all of this connects with the laboratory.

Take, for instance, the N IV transition at 1486 Å. This is an intercombination line, meaning it's not an electric dipole transition and has a lower transition probability than, for instance, the Balmer lines. In fact, although this is a ground state ^1S-^3P transition, and would be expected to show more than one component, it usually just shows a single line in nova ejecta. But in planetary nebulae, or symbiotics, it is accompanied by a much weaker line at 1483 Å. This is the *other* component of the multiplet whose strength is about 10^{-7} that of the main transition. The appearance is a very good indicator of density. The ratio depends, as for the [O III] lines, on the competition between collisional and radiative de-excitation so is a function of both electron density and temperature. But unlike the forbidden lines, here the two transitions are from the same state although they have very different density sensitivities. So one may appear from the denser regions while two lines are emitted at lower density. Since these regions may have different velocities, as in nova ejecta, this is another way of mapping the density structure. In symbiotics, the outer portions of the wind -- being rarefied relative to the chromosphere -- will show the doublet while the inner zones will only show the single, stronger line. Again, since the line is intrinsically weak, it's quite narrow and even small velocity differences will shift the profiles. This is illustrated in the attached showing the comparison of the N IV] 1486 Å line at two epochs for V1369 can, one near day 670 and the other -- more recent -- around day 800. Notice that in the first you see only N IV] 1486 Å, the electric quadrupole transition, while later the lower density is shown by the appearance of the 1483 Å line with the same profile.

The difference between driven and freely expanding is not that great. In a wind, matter is transported outward by some driving accelerator. If this is radiation pressure it's dependent also on the state of the gas at every radius since the only limiting velocity for acceleration is the speed of light. For anything like sound waves, instead of continuous acceleration there has to be a limit to the velocity since the acoustic speed is irrelevant once the matter is in outflow conditions. If, for instance, something ionizes the gas near the base of the wind, that state remains as the gas is advocated outward. I'm mentioning this in light of symbiotic stars. There the wind, in the broad environmental sense of the red giant outflow, envelops the system but is dynamical. So once exposed to UV photons from the white dwarf, mater that's already on the way out will preserve its ionization *despite the local temperature and density conditions*. Nothing makes the interpretation of non-local spectra more difficult, the conditions that govern the radiative and ionization state of the gas can be very distant, perhaps completely unconnected with the parcel of gas being studied, but whose effects are systematic and can be separated from the intrinsic processes of the matter.

Why this is important is that even long after an outburst, nova ejecta remain in a very high state of ionization. The same holds for the solar wind, one of those beautiful cases we can actually study up close. So to use the *corona* as an example for understanding cataclysmics and symbiotics, le's look for on moment at the lines you see in the spectrum. From S*olar Dynamics Observer* (SDO) that monitors solar activity by imaging the corona and transition region simultaneously in a set of intermediate, line dominated XR and EUV bands, we know that the lower corona is hot. The ions observed, above Fe^{+6}, that are permitted resonance transitions, demonstrate that the lower (1.5 $R_\odot$ or so) of the outer solar atmosphere has a steeply outwardly rising temperature gradient. Hence the corona requires a continual heating because otherwise conductive and additive losses would render it invisible on the conduction timescale (less than days). The kinetic temperatures are 10^6K, corresponding to some significant XR emission (as you know, the Sun was the first-discovered cosmic XR source in the early 1960's). Thus, if confined, there are only cooling and heating processes contending with magnetic confinement (gravity plays a lesser ole in the structuring of the coronal gas but not a completely negligible one).

In contrast, if the matter is also ported way from the ionizing site, it will combine. But the recombination rate depends on *both* temperature and density, so even if the gas is isothermal (that it can cool by radiative de-excitations of collisionally populated states,) the recombination rate may be low. The same, of course, for the collisional excitations so the individual lines should weaken. But since the drop in density takes place on the expansion time, f*or every ion there is a critical density, at fixed temperature, when the recombination time becomes as long as or longer than the expansion time*. This is the *freeze-out* state. It can be reached ion ejecta of novae and supernovae, or it can be seen in the outflows from stars that ave coronae and/or ionizing and radiative drivers (massive stars). The difficult part with winds such as those in symbiotic giants is that the ionization is supplied by an external agent, the accreting WD, or the pulse of hard radiation during phases of outburst (symbiotic novae). This isn't even at the base of the flow, it's offset by whatever orbit it occupies so the ionization and heating are neither steady state nor symmetric. If you look at the spectra of symbiotics, therefore, you're averaging over all this. You as optical observers have an advantage of limited information. There are things you don't have to treat because you don't see the phenomenon. For instance, the ionization state you see will be like a planetary nebula. Virtually always. The UV and XR don't vary by that much on short timescales. Now come back a decade later and the red giant star and WD may be very different, lines formed drink outburst episodes from emission in inaccessible parts of the spectrum show up.

This we've discussed in other notes. But I want to make a point here about interpretation. Since there are strong density gradients in the kinds of line forming regions you're all interested in, an since these are dynamical rather than hydrostatic columns, all of these regions appear at the same time in the same spectrum. Now to return tom the star of this discussion: different lines have different density and temperature sensitivities so *only taken together* is it possible to separate the medium into structure and understand the dynamical processes.

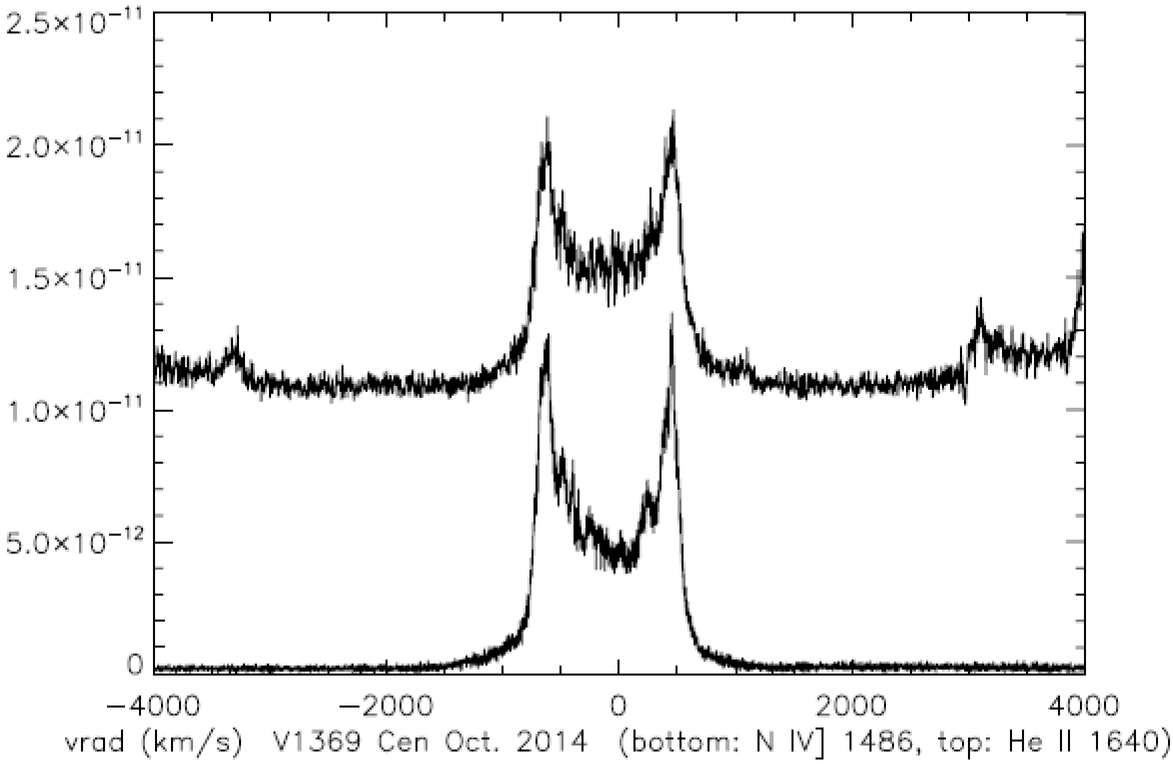
Once at freeze-out, the spectrum remains virtually invariant so you may not have an idea of the age of the ejecta from jut tho spectral morphology. If, on the other hand, you contrast *different plasma diagnostic transitions* among themselves, then you can recover density and velocity (hence radial) structural information. The lines weaken because of the decreasing rate of recombination but the profiles won't change if the matter is homogeneous.

For instance, He II 4686 Å is *purely recombination* so the decay of that line follows the electron density. If the central source is off and the number of electrons is deceasing as the ejecta neutralize, the He II lines will also get weaker but their profiles will remain invariant. A number of you had instrumental capabilities sufficient to the task. With the line profiles, you look at how different velocity intervals behave and this pas out the changes in the ionization stat of the gas and its excitation. Mainly ionization because lines formed by direct recombination are the same as a recombination flowed by emission.

For instance, in the V1369 Cen spectrum from 2014 Oct (Figure 1.) , so late and after XR turnoff, you see that the N IV] lines have a very similar, though not identical, profile compared with He II 1640 (dotted line). The same for C III] vs. N IV] (Figures 2 & 3). He II being an excited state transition you can compare it to N IV] 1718 Å and there the profiles are virtually identical. Once the ionization structure of the ejecta are fixed, it can only change by density fluctuations leading to accelerated recombination. By this I mean that once the ionizing source turns off and the recombination rate *necessarily* slows, line profiles will remain invariant unless the *local, volumetric electron density* isn't uniform. Not only depending on distance from the center, but also distributed at the same radius, we know that in winds, H II regions, and under yourbed, there are knots and filaments of matter that have a densitycontrast with their surroundings (again, think under your bed!).

So in those denser portions the relative rate of recombination will behigher, the ion will be weaker, and the profile distorted *reflecting the lack of the ion in a given velocity range*. In a wind, this won't remain fixed. Being a moving, fully dynamical environment, until the density fluctuations arrive at the terminal velocity they will continually displace in velocity (and space). In nova ejecta, and in the base of the winds of giants, features remain fixed *below* the terminal velocity. The recombination changes the relative intensity of those parts of the line profiles corresponding to the projections of the velocities along the line of sight.

Steve Shore, 13-03-2015



(Figure 1.) V1369 Cen spectrum from 2014 Oct

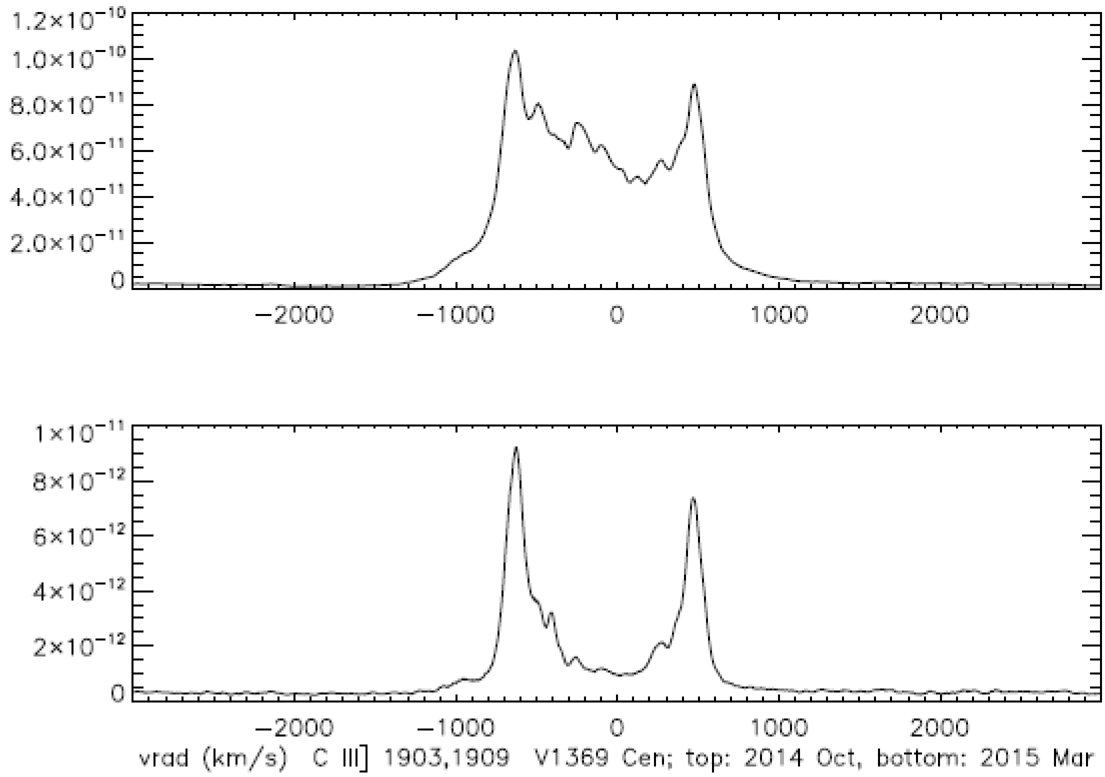


Figure 2. Comparison of C III] 1903, 1909 from 2014, Oct to 2015, March

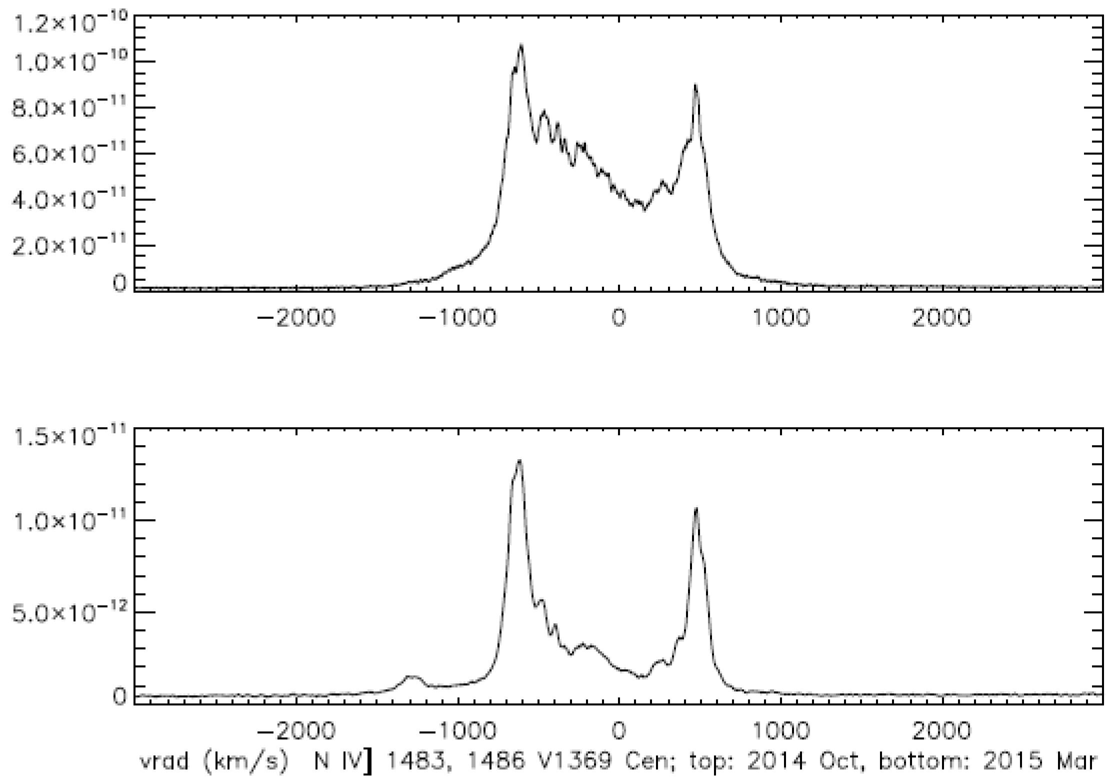


Figure 3. Comparison of N IV] 1483, 1486 from 2014, Oct to 2015, March

Novae

The slow decline of the Galactic recurrent novae T Pyxidis, IM Normae, and CI Aquilae
Andrea Caleo, Steven N. Shore
http://arxiv.org/pdf/1502.06763.pdf

Thermal radio emission from novae & symbiotics with the Square Kilometre Array
Tim O'Brien, Michael Rupen, Laura Chomiuk, Valerio Ribeiro, Michael Bode, Jennifer Sokoloski, Patrick Woudt
http://arxiv.org/pdf/1502.04927.pdf

SALT observations of southern post-novae
T. Tomov, E. Swierczynski, M. Mikolajewski, K. Ilkiewicz
http://arxiv.org/pdf/1502.03462.pdf

Difference between the optical flickering colours of cataclysmic variables and symbiotic recurrent novae
R. Zamanov, S. Boeva, G. Latev, K. A. Stoyanov, S. V. Tsvetkova
http://arxiv.org/pdf/1502.02827.pdf

The hybrid, coronal lines nova V5588 Sgr (2011 N.2) and its six repeating secondary maxima
Munari, U.; Henden, A.; Banerjee, D. P. K.; Ashok, N. M.; Righetti, G. L.; Dallaporta, S.; Cetrulo, G.
Monthly Notices of the Royal Astronomical Society, Volume 447, Issue 2, p.1661-1672
http://arxiv.org/abs/1411.6297

Symbiotics

On the diversity and similarity of outbursts of symbiotic binaries and cataclysmic variables
Augustin Skopal
http://arxiv.org/pdf/1502.04734.pdf

Characterization of the Most Luminous Star in M33: A Super Symbiotic Binary
Joanna Mikolajewska, Nelson Caldwell, Michael M. Shara, Krystian Ilkiewicz
http://arxiv.org/pdf/1412.6120v2.pdf

The Astronomer's Telegram

Early X-ray and radio observations of Nova Sco 2015 implicate strong shocks against a red giant wind

ATel #7085; T. Nelson (Minnesota), J. Linford (Michigan State), L. Chomiuk (Michigan State), J. Sokoloski (Columbia), K. Mukai (UMBC/NASA GSFC), T. Finzell (Michigan State), J. Weston (Columbia), M. Rupen (NRC-HIA) and A. Mioduszewski (NRAO)
on 16 Feb 2015; 23:22 UT

We report the first observations of Nova Sco 2015 (PNV J17032620-3504140) at X-ray, UV and radio wavelengths. The X-ray observations were carried out with the Swift satellite between 2015 February 15.5 and 16.3 UT (roughly 4 days after discovery) and resulted in a total exposure time with the XRT instrument of 4065 s. An X-ray source is clearly detected at the position of the nova with a count rate in the 0.3-10 keV range of 0.14 cts/s. The spectrum is hard and can be modeled as a highly absorbed, hot thermal plasma (N(H) ~ 6+/-1 x 10^22 cm^-2; kT > 41 keV). However, a significant excess of counts over the model prediction is observed between 1 and 2 keV, possibly indicating the presence of a second, softer emission component. The total observed flux in the 0.3 - 10 keV range is 1.9 (+1.0, -1.8) x 10^-11 erg/s/cm^2 (90% confidence).

An image of the nova in the near-UV was obtained with the UVOT instrument on Swift. The magnitude in the UVM2 filter (central wavelength 2246 Angstroms) is 13.34 +/- 0.03 in the Vega system.

We also observed Nova Sco 2015 at radio wavelengths with the Karl G. Jansky Very Large Array (VLA) on 2015 February 14.5, approximately 3 days after optical discovery. Observations were carried out in B configuration (maximum baseline of 11.1 km) at C-band and Ka-band, with a total bandwidth of 2 GHz in each band split between two sidebands. The nova was detected at frequencies from 4.55 to 36.5 GHz with a spectrum typical of non-thermal synchrotron emission (spectral index between -0.7 and -0.9). The flux densities are as follows:

Frequency	Flux density
4.55 (GHz)	4.13 +/- 0.02 (mJy)
7.38 (GHz)	2.79 +/- 0.01 (mJy)
28.2 (GHz)	0.82 +/- 0.06 (mJy)
36.5 (GHz)	0.68 +/- 0.08 (mJy)

The presence of hard, absorbed X-rays and synchrotron radio emission at this early stage of the outburst suggest that the nova-producing white dwarf is embedded within the wind of a red-giant companion, with collisions between the ejecta and this wind shock-heating plasma and accelerating particles (as in, e.g. RS Oph, V407 Cyg and V745 Sco). This interpretation supports a similar suggestion made in ATel #7060. Further X-ray

Link to AAVSO web site : http://www.aavso.org/aavso-alert-notice-510

Alert Notice 510: Observations of the symbiotic nova ASAS J174600-2321.3

March 5, 2015: The AAVSO is requesting observations of the symbiotic nova candidate ASAS J174600-2321.3 during the predicted upcoming eclipse of this system. Observers are asked to begin observing immediately (2015 March 5), and continue observations through the end of July 2015. Both visual and instrumental observations are encouraged; the object was at V=12.28 on 2015 February 6.764 (OCN; S. O'Connor, Bermuda). Filtered, transformed photometry in B, V, and Ic are especially encouraged, with several observations per night required during the ingress and egress phases. The project is being organized by S. Otero, P. Tisserand, K. Bernhard, and S. Hummerich, and is an extension of the research program discussed in Hummerich et al. (2015, AAVSO preprint (=eJAAVSO) #295, in press).

The researchers have provided the following discussion of the project:

"The deeply eclipsing system and likely symbiotic nova ASAS J174600-2321.3

RA: 17 46 00.18 , Dec: -23 21 16.4 (J2000.0)

is going to enter an eclipse in mid-March according to the published elements HJD = 2456142 + 1011.5 x E. The eclipse duration is approximately 115 days.

The system has shown a conspicuous brightening of ~4 magnitudes (V) that started in 1999 and has been in outburst since then. Recent photometry shows the system fluctuating around 12.2 mag (V) as recently as 2014 November 07 (JD 2456969.49068; HMB, J. Hambsch, Mol, Belgium, remotely from Chile). It will go fainter than 16.9 mag (V) at mid-eclipse when the red giant passes in front of the outbursting white dwarf. We might also be seeing semi-regular pulsations from the red giant during eclipse.

As no observations around mid-eclipse exist after the considerable brightening of the primary star, the exact shape of eclipse is open to conjecture. Thus, no times of second or third contact are given below, although there was a pronounced time of totality during the eclipse that has been covered before the onset of activity in the system (compare Fig. 4, JAAVSO preprint (=eJAAVSO) #295).

We encourage visual and CCD observations during the eclipse, preferably multicolour photometry to record the colour changes as the red star starts to dominate the total flux of the system. Observations in V, B and Ic would be very valuable (note, though, that the object will be very faint in B during eclipse). During the ingress and egress phases, several observations per night are advisable. During the remainder of the eclipse, one set of observations per night will be adequate due to the long period of the system. Stacking might be advisable to reach the faint magnitudes during the eclipse.

Observations should start as soon as possible to check on the brightness of the object before the eclipse sets in. Once the event is over, continued photometry with a cadence of one observation per week is encouraged to detect the start of the fading phase of this very slow nova.

Spectroscopic observations near mid-eclipse would be very desirable, too.

These are the dates observers should keep in mind:

1st contact: 2015 March 14 (JD 2457096)

Spectroscopy of planetary nebulae - 150 years later...

Olivier Thizy, François Teyssier

Introduction & historical background

In 1764, Charles Messier observed for the first time in Vulpecula constellation an object which looked like a planetary disk – Dumbbell nebula. Hundred years later, on august 29th, 1864, Sir William Huggins was the first to look at a nebula (NGC6543 in Draco) with the aid of a spectroscope behind his telescope.

He wrote himself about the event more than thirty years after the observation : « *The reader may now be able to picture to himself to some extent the feeling of excited suspense, mingled with a degree of awe, with which, after a few moments of hesitation, I put my eye to the spectroscope. Was I not about to look into a secret place of creation? I looked into the spectroscope. No spectrum such as I expected! A single bright line only! At first, I suspected some displacement of the prism, and that I was looking at a reflection of the illuminated slit from one of its faces. This thought was scarcely more than momentary; then the true interpretation flashed upon me. The light of the nebula was monochromatic, and so, unlike any other light I had as yet subjected to prismatic examination, could not be extended out to form a complete spectrum.* »

Three years before, Gustav Kirchhoff and Robert Bunsen from University of Heidelberg published their work on chemical analysis using spectroscopic observations. Kirchhoff second law of spectroscopy stated that a hot tenuous gas produces light with spectral lines at discrete wavelengths (i.e. specific colors) which depend on the energy levels of the atoms in the gas. This is certainly why Sir William Huggins wrote about his observation : *« The riddle of the nebulae was solved. The answer, which had come to us in the light itself, read: Not an aggregation of stars, but a luminous gas.* ».

August Comte, a french philosopher, wrote back in 1935 : « *Our knowledge concerning [star's] gaseous envelopes is necessarily limited to their existence, size [...], we shall not at all be able to determine their chemical composition or even their density.* »... well, he was very wrong as the light coming from celestial objects, even when they are far away and when this light tooks years to reach us, contains lot of information that astro-spectroscopists can decode, like CSI's of the sky !

Amateur spectroscopy of Cat's Eye nebula 150 year after

Sir William Huggins opened the way to planetary nebulae spectroscopy but today's amateur astronomers, using off-the-shelf modern equipment, can reproduce his first observation and even go further.

Several ARAS group members took the challenge to observe the nebula exactly 150 years (or close, depending on weather conditions) after Sir William Huggins. On August 30, Torsten Hansen had about 15 minutes before the clouds rolled in to take a visual glimpse through his 8 inch Newtonian, using a Star Analyser 100 at magnifications 140x and 240x. The nebula´s disc was not visible (only the central star), but the O-III disc showed up very prominently, beeing the most obvious feature in the field of view.

Image : visual impression of Cat's Nebula (Torsten Hansen)

On the night before, Torsten did some video work, which additionally led to about 10 minutes of observation on August 29 (UT). He processed and colorized his spectrum with VisualSpec software :

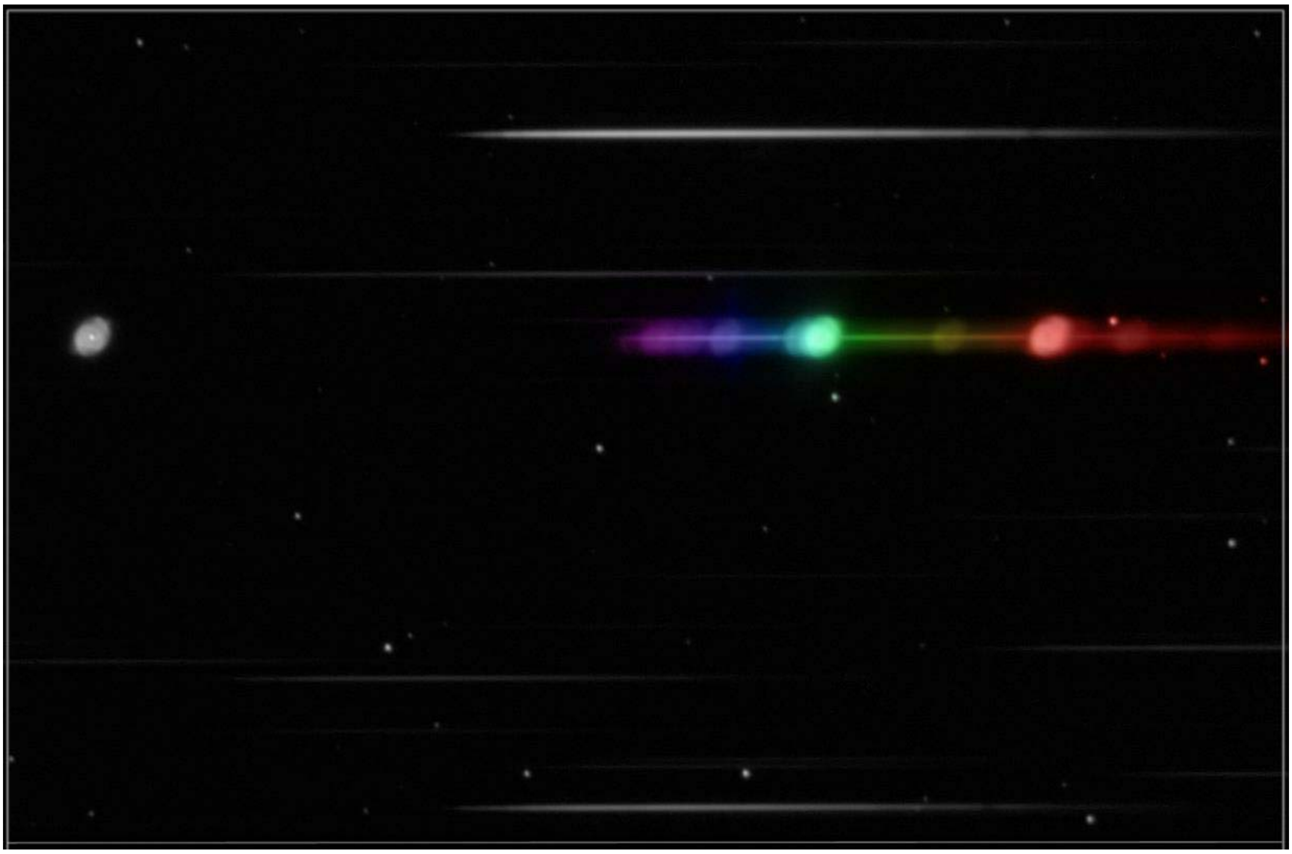


Image : Cat's Eye Star Analyser spectrum (Torsten Hansen)

The nebula on the left is the « zero order » of the spectrum, i.e. an image of the nebula itself. Most of the light (about 70%) goes into the « first order », i.e. the nebula seen at different discreet wavelengths. It is a typical exemple of astronomical spectroscopy work with a Star Analyser : simple but efficient.

Even at a very low resolution as very few details are visible, it shows the benefit of using filters in astronomy with selected spectral bandwiths to isolate the main emission lines from the nebula while removing the sky backgroung pollution of the rest of the spectral domain. This is even more efficient when the sky if luminous (bright Moon and/or light pollution from the cities).

This spectrum is also showing a very interesting feature : the central star is also broken into a spectrum also, but a continuous one. Through spectroscopic observation of the Sun, Gustav Kirchhoff and Robert Bunsen proposed a model made of a liquid and luminous core (creating a continuous spectrum as per first Kirchhoff's law of spectroscopy), surrounded by a gazeous atmosphere hot enough to contain metals in vapor state and creating selective absorptions visible as dark lines in the solar spectrum (as per third

Kirchhoff's law of spectroscopy).

On the same anniversary date, Jacques Montier recorded a spectrum of the Cat's Eye nebula with an Alpy 600 spectrograph. The resolving power R~600 and his 35cm telescope with a long focal length allowed a good resolution both in spectral and spatial domain (ie: along the nebula) showing clearly differences in emission between different region of the nebula and between different spectral lines.

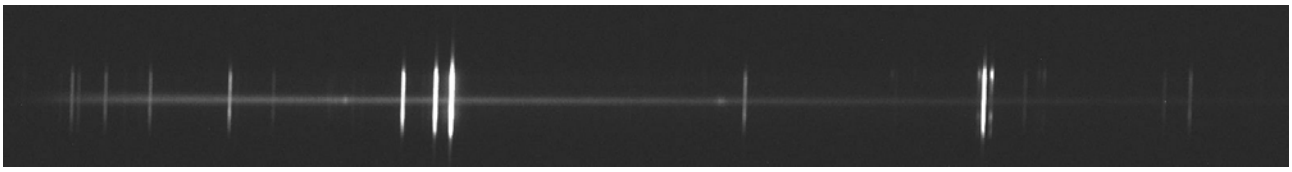


Image : NGC6543 spectrum with Alpy 600 spectrograph (Jacques Montier)

One of the author took a spectrum with a C11 and a LISA spectrograph allowing a little bit more resolving power (LISA with the large 35µm slit : R~800).

Thirty 60-sec exposures have been taken under a foggy sky. They have been, stacked together and colorized in IRIS software (RAINBOW function) using proper wavelength calibration. Sky background is well visible with sodium lamps but also some aurora lines (oxygen) which cross the full height of the slit:

Image : LISA spectrograph mounted on a C11

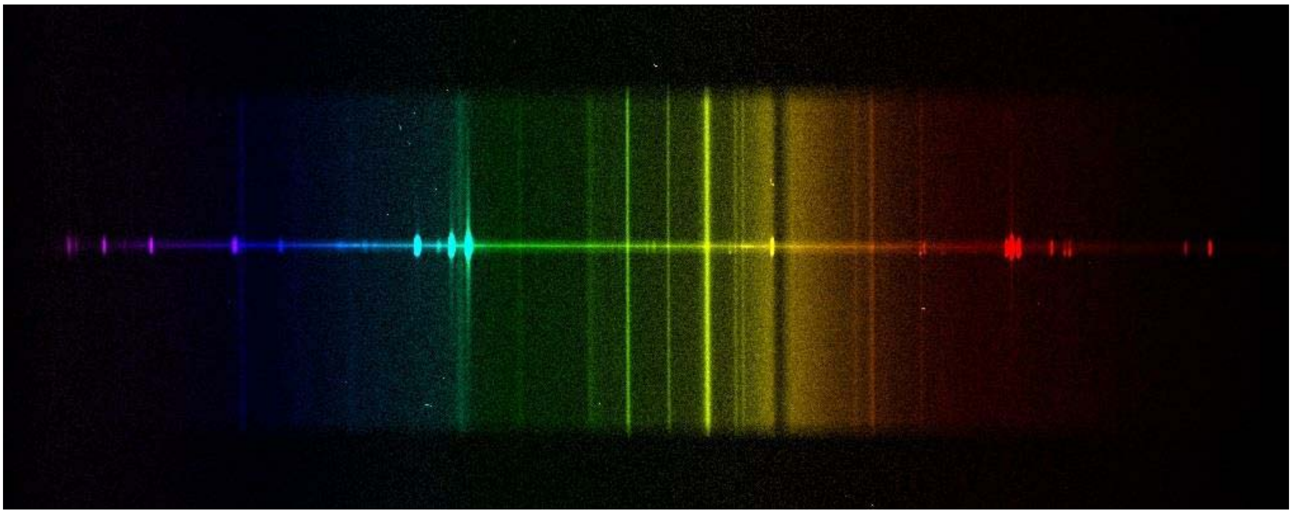


Image : NGC6543 color spectrum, C11 + LISA (35µm slit) + Atik 460 (binning 2x2) (Olivier Thizy)

The bright green lines were not identified as provoked by an element known on Earth, a « *yet undiscovered gas suggested as a principal constituent of the nebulae* » as Mary Huggins wrote in Astrophysical Journal in 1898. « *Sir William Huggins used occasionally the term* nebulum. *Independently, Miss Agnes Clerke has made a suggestion […] of* nebulium *as an appropriate term ».*

It is only in 1927 when Ira Bowen, an american physicist who later became director of Mount Wilson and

Mount Palomar observatories, suggested that those lines were forbidden transition of oxygen ionized twice (OIII) which couldn't be observed on Earth as it requires extremely low density gas environment which can only be found in space... such as in nebulae.

Some books, such as « Stars and Atoms » by Sir Arthur Eddington, had to be re-edited to correct the mistake of those line identification ! A new element wasn't discoverd by Sir William Huggins, but a new environmental condition was found... a region is space well visible through our telescope but with a density so low that it is impossible to reproduce on Earth. Space became a fantastic laboratoty for scientists to study...

Today, amateur spectra show lot of emission lines - more than the three originally observed by Sir William Huggins. It also shows more details as seen in the spectrum taken by Robin Leadbeater with a very high resolution Lhires III spectrograph, showing lot of details in hydrogen H-alpha and NII (nitrogen) lines and oh surprise – line are not simple straight lines but show some features :

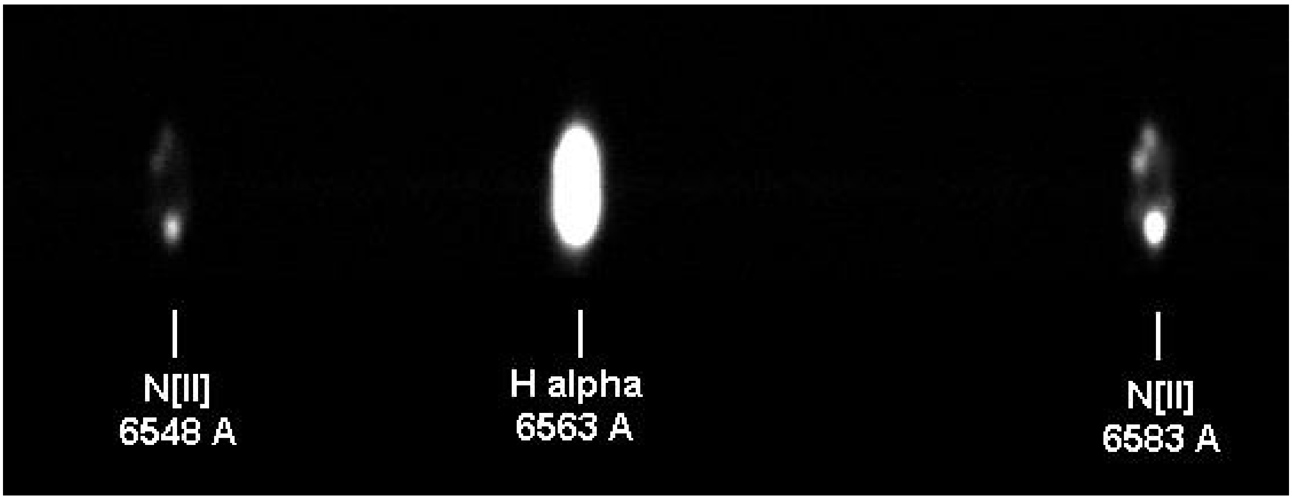


Image : Nitrogen and hydrogen lines, Lhires III spectrograph (Robin Leadbeater)

Halpha is stronger than N[II] emission lines, but it also shows some features :

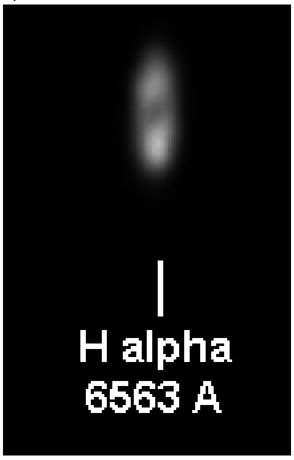


Image : Halpha line details (Robin Leadbeater)

If Sir William Huggins had such high resolution spectrograph to see those features, he could have explained them because Christian Doppler published in 1842 a key paper explaining that light was modified by the movement of the source compared to the observer. Doppler even explained, wrongly, the color of the stars by their movement.

It is because the nebula is in expansion that we do see some portion of the nebula coming toward us (line shifted toward the blue, or shorter wavelengths) while the other portion is going away from us (line shifted tward the red, or longer wavelengths). Because the nebula is not homogenous (in speed, density and temperature), the spectral emission lines have a disform shape.

The estimated radial velocity of the N[II] shell from this spectrum of ~+-20km/s seems to agree quite well with the figures for some features quoted in litterature (16.4km/s and 25 km/s).

Some physics

The end of the nineteenth century was the time of the chemist to analyse the elements on Earth (must have been a good time, burning everything they could in their laboratory!) and the time for the astronomer to observe and start to classify the celestial object with this new instrument that was the spectrograph.

George Liveing and James Dewar, from Cambridge University, classificed in 1890 the spectral emission lines of metal as « sharp » or « diffuse » while lines also view in absorption in spectra were called « principle ».

In 1895 for exemple, Johann Balmer described the hydrogen atomic spectrum with an empirical mathematical law of series. In 1897, Johannes Rydberg made a graphical representation of the spectral lines distribution for doublet and triplet for several atoms. In 1908, Walther Ritz derived a relationship (Rydberg-Ritz combination law) that could be applied to all atoms.

At the turn of the twentieth century, nuclear physics (and later astrophysics) took a leap. In 1897, Joseph Thomson discovered the electron. In 1900, Max Planck showed that the exchange of energy between atoms only occured in integer multiple of an elementary energy ; he introduced a new constant in physics : 'h', Planck constant. He also demonstrate that a black body would emit a contunuous spectrum, which is the first spectroscopy law of Kirchhoff published in 1861.

In the spectroscopy article of Encyclopedia Brittanica of year 1911, Arthur Schuster wrote « the difficulty that a number of spectroscopic lines seem to involve at least an equal number of electrons may 'be got over by imagining that the atom may present several positions of equilibrium to the electron, which it may occupy in turn. A collision may be able to throw the electrons from one of these positions to another ».

Student of Joseph Thomson and working with Lord Ernest Rutherford of Nelson (known for his work on reactivity), Niels Bohr published end of 1913 a serie of three key articles in Philosophical Magazine which definitively marked nuclear physics. His theory is an atomic nucleus aurrounded by electrons, the chemical properties of each element beeing mainly driven by the number of electrons around the nucleus. He also stated that :

- each electron can only move on an orbit whose momentum equals an integer multiple of h/2p (h beeing the Planck constant)
- an electron staying on his orbit is not emitting any light
- an electron changing to an orbit closer to the nucleus emits a quantum of discrete energy in the form of light

He introduced the « principle » quantum number 'n' to describe electron's orbits. Note that today we avoid the terminology of « orbits » of the Bohr model to only keep the quantization of the electrons energy levels and their quantum states. We talk about probability densities.

In 1915, Arnold Summerfeld introduced the notion of elliptic orbit and the azimutal quantum number 'l' , with l taking a value from 0 to 'n-1'. He later also introduced the latitude (now called « magnetic ») quantum number 'm' taking a value from 0 to +/-'l'.

In 1925, Pauli added the « spin » to specify electron orbital state. He also stated the Pauli exclusion principle : two electrons in an atom cannot have the same quantum numbers (n, l, m) and only two electrons can occupy each orbital where they must have opposite spin states.

In 1927, Friedrich Hund introduced the s (sharp), p (principle), d (diffuse) and f (fundamental) terminology which is now widely used in nuclear physics and to describe electron energy levels and transitions.
It is that same year when Ira Bowen suggested that the prominent lines in planetary nebulae were forbidden transition of oxygen ionized twice, ie an oxygen atom missing two electrons or [OIII]. But what do we mean by « [OIII] » ?

A non ionized atom is marked with a standard symbol and roman number I : HI for hydrogen, HeI for helium, NI for nitrogen, OI for oxygen, NeI for neon, SI for sulfur, ArI for argon... An atom ionized once has a roman number II : HeII for helium with a single electron instead of two, OIII for an oxygen atom with 6 electrons instead of 8 normally, etc...

Hydrogen HI is the simpliest atom with a single electron (HII is an ionized hydrogen atom, it with no electron). This electron can be at different level of energy which we quantify with n=1, n=2, n=3, n=4, etc...
Transitions from any upper level to level n=1 are called the Lyman series ; they are very energetic and visible in ultra-violet : La is the transition at 1220A from n=2 to n=1 ; Lb at 1030A from n=3 to n=1, and so on.
Transitions from any upper level to n=2 are called the Balmer series ; they are famous because they are in the visible domain : Ha at 6563A from n=3 to n=2, Hb at 4861A from n=4 to n=2, Hg at 4340A from n=5 to n=2, Hd at 4101A from n=6 to n=2 and so on...
Transition froù any uppoer level to n=3 is the Paschen series which ends in the near infra-red region around 8200A.

When an electron capture energy for exemple from a continuous spectral source, it moves from a lower level to an upper level and absorb a discreet level of energy from that source. This is why we observe absorption spectra for exemple on stellar atmospheres. This explains the third spectroscopy law published by Kirchhoff in 1861.

When an electron release that energy, by moving from this upper level to a lower and more stable level, it radiates that energy in a form of a monochromatic light. This explains the second Kirchhoff's law. Those are also the emission lines we see for exemple on planetary nebulae spectra.

For exemple, hydrogen emission line Ha comes from hydrogen atoms with electron excited at level n=3 releasing energy while transiting to level n=2. Excitation can come from previous choc with another atom or from absorption of light (usually high energy ultraviolet light) from the central star.

Note that the de-excitation takes some time to occur after the excitation is done. This time is called the radiative lifetime of the atomic level and is the inverse of the transition probability A_{ki} given by NIST atomic tables. For exemple, Ha radiative lifetime is about a millionth of a seconde and is easy to observe on Earth.

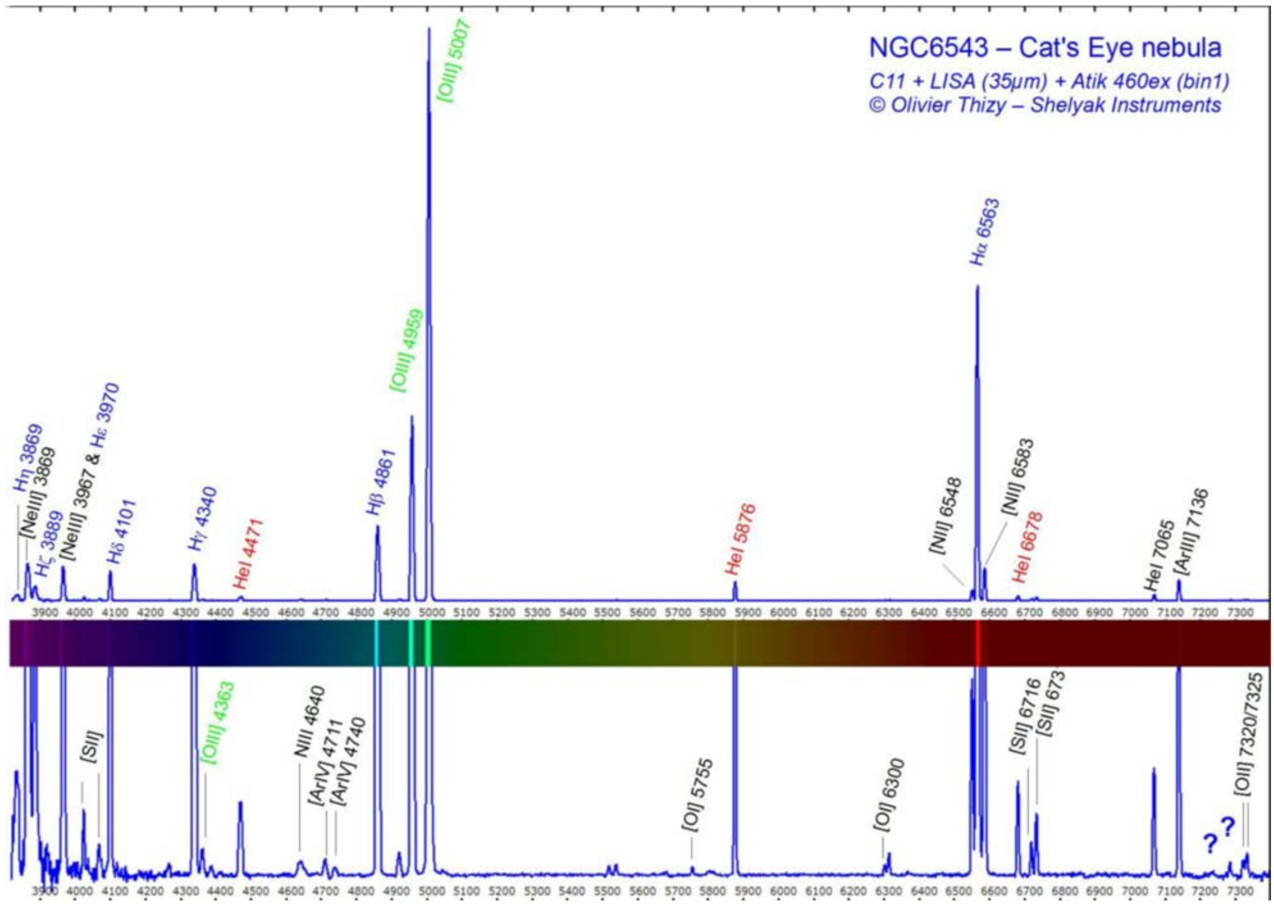
But for oxygen atom ionized two times, transitions from $2s^2 2p^2\ ^3P$ 1 to $2s^2 2p^2\ ^1D$ 2 and $2s^2 2p^2\ ^3P$ 2 to $2s^2 2p^2\ ^1D$ 2 emitting light respectively at 5007A and 4959A have radiative lifetime around 55sec and 162sec. This means that those transition can't be seen on Earth but only in very rarified environment such as in space with only a few atoms per cubic centimeter. Those transition are called forbidden transitions and are marked in brakets, in those case [OIII].

Line identification & measurements

To better look at a spectrum, astronomers usually remove the background and extract the profile by 'counting' the signal column by column. Each column is actually a specific wavelength which can be identified by properly calibrating the spectrograph with a reference spectral lamp. The official unit of measure for wavelength is the meter, or nm (nanometer) around the visible domain and µm in the infra-red but lot of astronomers continue to use the old Angstrom unit of measure (A). The visible domain is around 4000A to 7000A.
The intensity is also corrected from the instrumental response as each element on the way (atmosphere,

telescope, spectrograph, CCD camera) have a different 'transparency' depending on the wavelength of the each photon that is recorded.

Planetary nebulae line can be identified from litterature or François Teyssier « low resolution spectroscopy » booklet freely available on the web.



graph : NGC6543 spectrum line identifcation

Cat's Eye nebula shows of course prominent [OIII] lines as seen visually by Sir William Huggins in 1864 but also the Balmer series (Ha, Hb, Hg...), nitrogen[NII] lines surrounding Ha emission line, helium HeI and HeII lines, argon [ArIII] and [ArIV], neon [NeII], oxygen ionized once [OII] and sulfur [SII] lines.

Permitted lines HeI, HeII or Balmer series come from atoms ionized by radiation of the central star and recombination. Forbidden lines such as [OIII] come from collisional excitation and recombination.

We can measure the intensity of each line by measuring the area under the line and above the continuum (mostly coming from the central star). This intensity is a measure of the strength of the line, or transition. It is also a common tradition in nebulae spectroscopy to assign a value of 100 for Hb line intensity :

Element	Wavelength (A)	Intensity	Intensity (dereddenned)
He	3970	22,58	23,57
Hd	4101	29,87	30,97
Hg	4340	49,32	50,53
[O III]	4363	1,85	1,89
Hb	4861	100	100
[O III]	4959	226,73	225,78
[O III]	5007	679,6	675,37
He I	5876	17,84	17,15
[N II]	6548	10,54	9,92
Ha	6563	300,08	282,37
[N II]	6583	31,95	30,05
He I	6678	4,86	4,56
[S II]	6716	1,69	1,59
[S II]	6731	3,15	2,95

Table : line intensity on NGC6543 spectrum before anf after « dereddenning »

For exemple, the relative intensity of [OIII] 5007A compared to [OIII] 4959A line is about 2.9 - simply the ratio between those line radiative lifetime (162sec/55sec). In our spectrum, we measure this ratio at 679/226=3.0 so close to the theoritical value. Likewise, the ratio of [NII] 6548 / [NII] 6583 should be around 3.0 which is what is measured on our spectrum.

The ratio Ha/Hb should be 2.9 (2.87 to be precise). In our spectrum, it is 3.0. While very close, the reason of this discrepency in this spectrum is the interstellar material between the nebula and our solar system, reddening the spectrum by diffusion (same effect that makes the Sun redder when low on the horizon).

The first operation to do when we want to measure physical quantities in planetary nebulae across a wide spectral range is to perform a dereddenning of the spectrum. The extinction coefficient is first calculated by the formula (Acker) :

$$c(H\beta) = 3.08 \log(I(H\alpha)) - 7.55 \quad [2]$$

with $I(H\alpha)$ = observed intensity of $H\alpha$ relative to $H\beta$ = 100 (table 2)

In our case : c = 3.08 x log (300) - 7.55 = 0,08, which is compatible with published values.

This extinction coefficient allows to compute the colour excess = E(B-V) = c/ 1.46 = 0,05

Dereddening of the nebula spectrum can then be done in Christian Buil's ISIS free software which lot of amateur use to reduce their astronomical spectra, using this E(B-V) value. The line intensity can also be dereddened using the formula (with wavelength in micrometers) :

$$I_c(\lambda) = I_o(\lambda).10^{c.f(\lambda)}$$

$f(\lambda)$ is the reddening curve value for the line

An analytical estimation from values established by Kaler (1976)

$$f(\lambda) = 2.5634\,\lambda^2 - 4.8735\,\lambda + 1.7636 \quad [4]$$

Electronic temperature of NGC6543

A method to determine the electronic temperature uses the ratio of some forbidden emission lines. It is based on several approximations (low density, nebulae optically thin in forbidden radiation, isothermal. The more usual is [OIII] ratio wich gives the electronic temperature Te in a simplified form (Osterbrock & Ferland, 2006) :

$$R_{[OIII]} = \frac{I(5007) + I(4959)}{I(4363)}$$

$$R_{[OIII]} = \frac{7.90 \exp(3.29.\frac{10^4}{Te})}{1 + 4.5\,10^{-4}\,Ne.Te^{-1/2}}$$

With : Ne = electron density (particules per cm^3)
Te = electronic temperature (K)

In planetary nebulae, the term « $4.5\ 10^{-4}\ Ne.Te^{-1/2}$ » is very small, so we can approximate :

$$Te = \frac{3.29\,.10^4}{\ln(\frac{R_{[OIII]}}{7.90})}$$

In our spectrum of NGC6543, this gives us $R_{[OIII]}$=(675,4+225,8)/1,89 = 476,8

So we have our electronic temperature value of : **Te = 8027 K**

Luridiana et al (2003) find Te=7050-7950K, Hyung et al. (2000) find Te=8000-8300K, Kingsburgh et al (1996) find Te=7850-8050K, Peimbert, et al (1995) find Te=8334K. With typical amateur equipment in our backyard, we have been able to measure Cat's Eye nebula temperature within a good accuracy !

Electronic density of NGC6543

The electronic density is evaluated using the ratio of forbidden lines rather insensitive to temperature. The most common determination is from [SII] ratio (Acker & Jaschek, 1995) :

$$R_{[SII]} = \frac{I(6716)}{I(6731)}$$

$$R_{[SII]} = 1.49 \cdot \left(\frac{1 + 3.77\,x}{1 + 12.8\,x}\right) \quad \text{with } x = 10^{-2} \cdot Te^{-1/2}$$

$$Ne = 10^2\,Te^{1/2} \cdot \left(\frac{R_{[SII]} - 1.49}{5.62 - 12.8R_{[SII]}}\right)$$

In our NGC6543 spectrum, we measured R[SII]=0.54, so : **Ne = 6745 particules per cm^3**.

Luridiana et al (2003) find Ne=1260-2200 and Dinerstein et al (1985) find NE=4000-10000 particules per cm^3.

Spectro-nebulography

Because the planetary nebula is an extended object, one can scan the surface by moving the slit along the nebula and record successive spectra. This scanning method is called spectro-heliography on the Sun so maybe we can call it spectro-nebulography...

We acquired a series of 21 spectra of NGC6543. Autoguiding was done on a star in the guiding camera field of view and the consigned position for the autoguiding was shifted by 2 pixels in X direction between each spectra acquisition ; here is a subset of the serie :

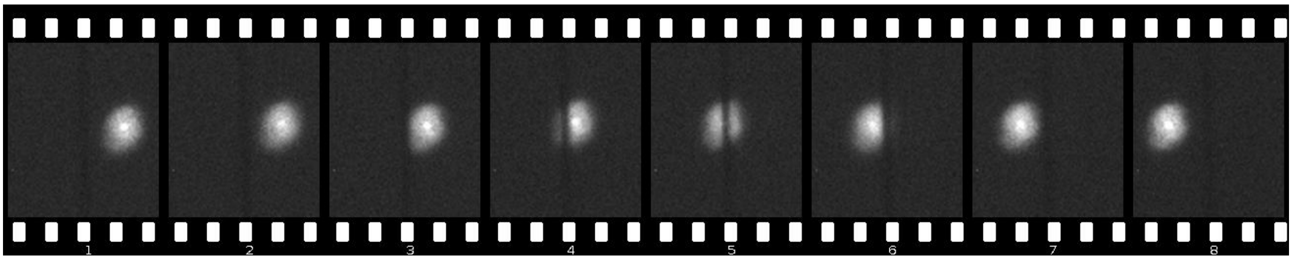
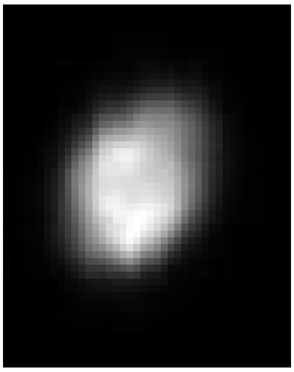
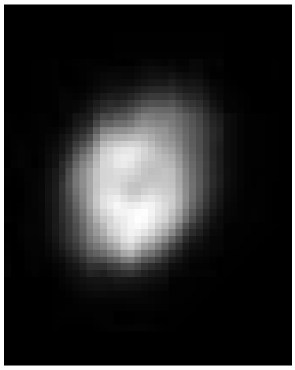
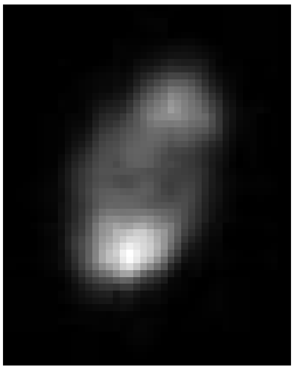
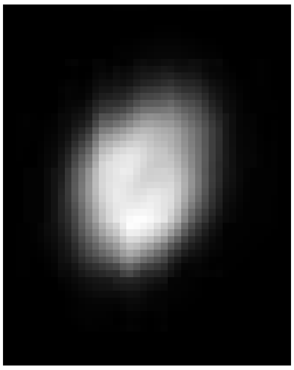
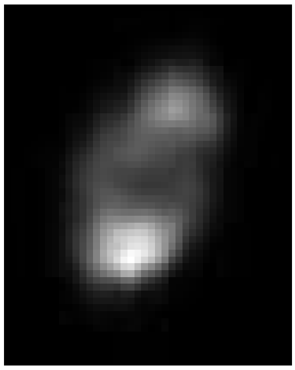
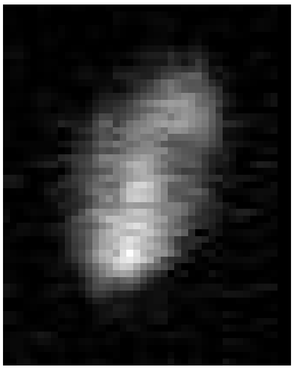
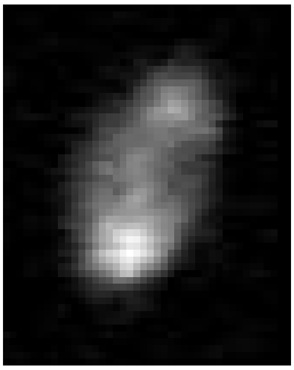


Image : guiding images with the slit passing in front of the nebula (Olivier Thizy)

Christian Buil ISIS free spectroscopy data reduction software is very convenient to process all the acquired spectra in very few operations. We reconstructed the nebula image in different wavelength : Ha, Hb, [OIII], [NII] and [SII]. We then notice a very different view between oxygen or hydrogen and nitrogen or sulfer images.

It is interesting to note that most narrow filters have a 6nm bandwidth while our spectral resolution achieved with the LISA spectrograph is around 8A. Typical narrow band filter imaging on Halpha actually combine light from hyrogen but also nitrogen emission lines. With this more complex spectro-nebulography technic, we can split those images.

	 *Hbeta (4861)*	 *OIII (5007)*
 *NII (6523)*	 *Halpha (6563)*	 *NII (6583)*
 *SII (6716)*	 *SII (6731)*	

Images: NGC6543 spectro-nebulography (scan) ; Olivier Thizy
Celestron 11 + LISA (35µm slit) + Atik 460EX (binning 1x1)

Conclusions

In 1864, Sir William Huggins was the first to look at a spectrum of Cat's Eye nebula. In 2014, amateur astronomers have now access to off-the-shelf spectrographs giving lot of details in the emission line spectra. The nebula emission, concentrated in few radiation lines, gives access to numerous astrophysical conditions of the gaz and central star.

Doing the measurement and calculation yourself is a great self-educational project by itself, it brings lot of value to high school student as science project.

But planetary nebulae sometimes vary over time (some good exemples are NGC6572, IC4997...) and monoring them can help for a better understanding of the mechanisms involved, observed in a perfect space laboratory.

We encourage you to make your first steps in astronomical spectroscopy and look at the sky with a different eye... the Cat's Eye !

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* Shelyak Instruments spectrographs : http://www.shelyak.com/

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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!

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Andrew Smith and Thierry Lemoult
New ARAS Page
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T Tauri observations upon the request of Henz Moritz Guenther

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http://www.spectro-aras.com/forum/viewtopic.php?f=5&t=1033
New spectra
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spectra gathered in ARAS data base
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Contribution to ARAS data base

From 01-02 to 28-02-2015

F. Boubault
D. Boyd
C. Buil
J. Edlin
J. Guarro
P. Somogyi
F. Teyssier

Submit your spectra

Please :
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Resolution should be at least R = 500
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