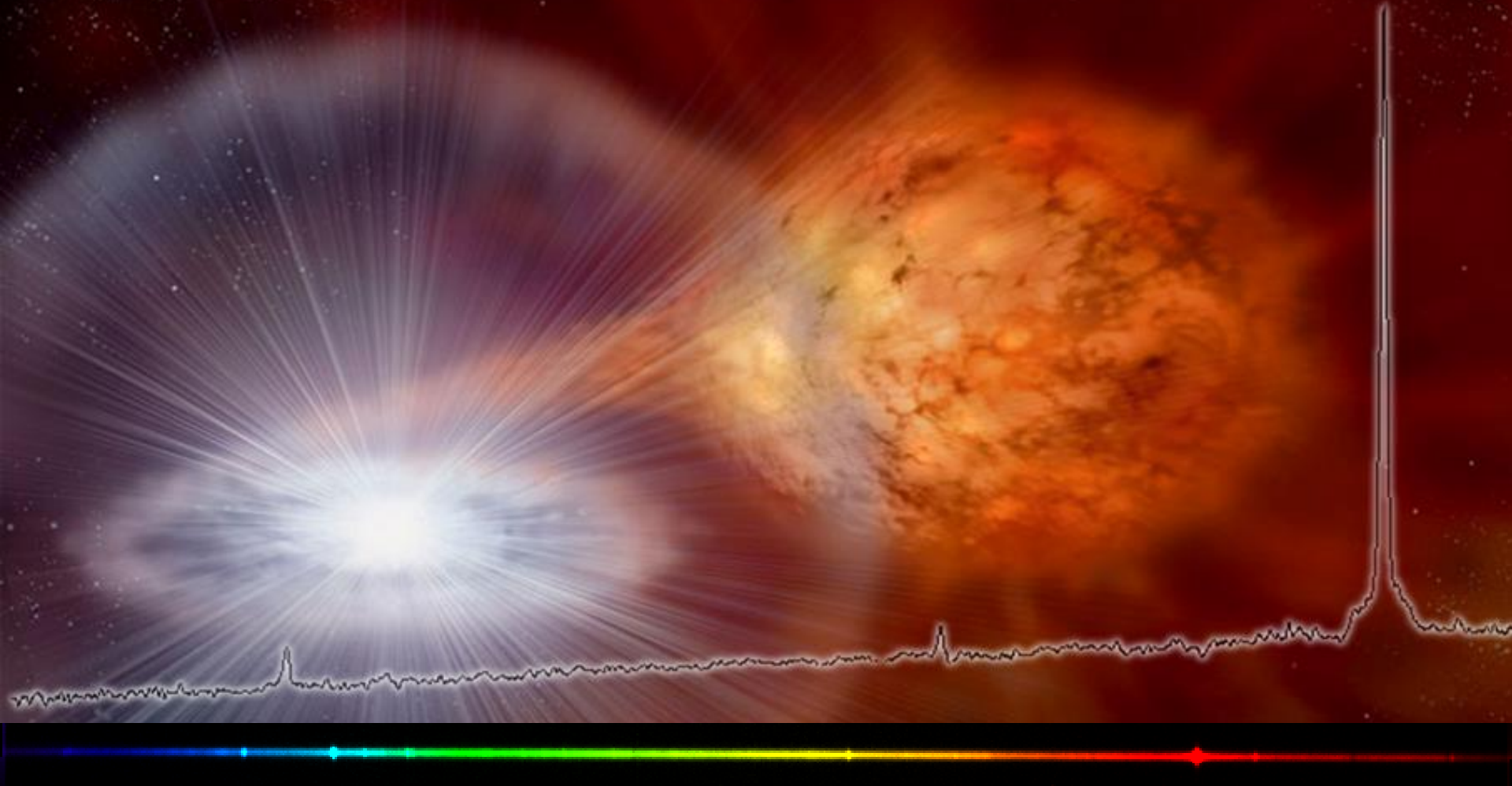


Symbiotic Stars



1 Symbiotic stars

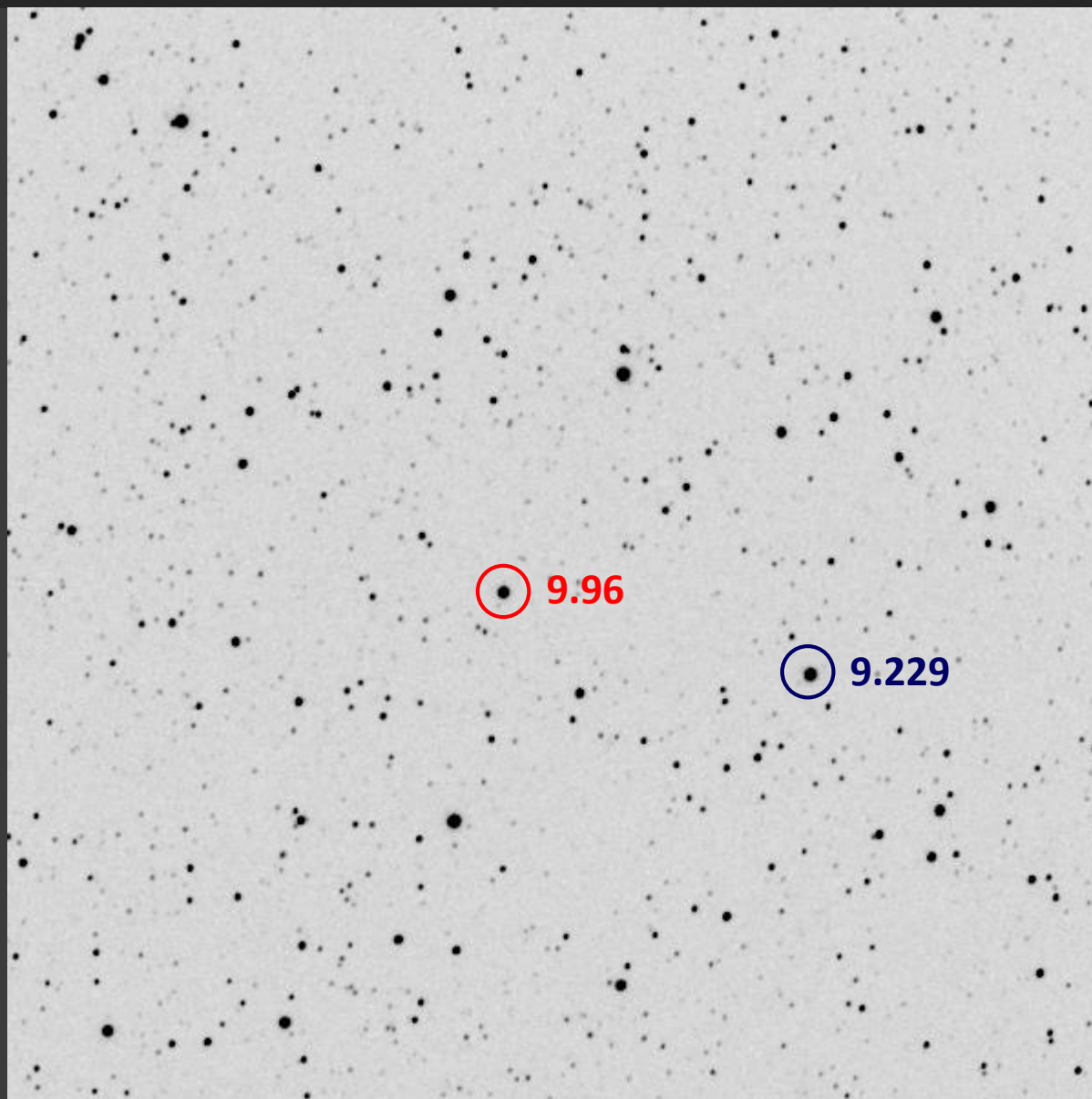
2 Symbiotics in quiescent state

3 Outbursts

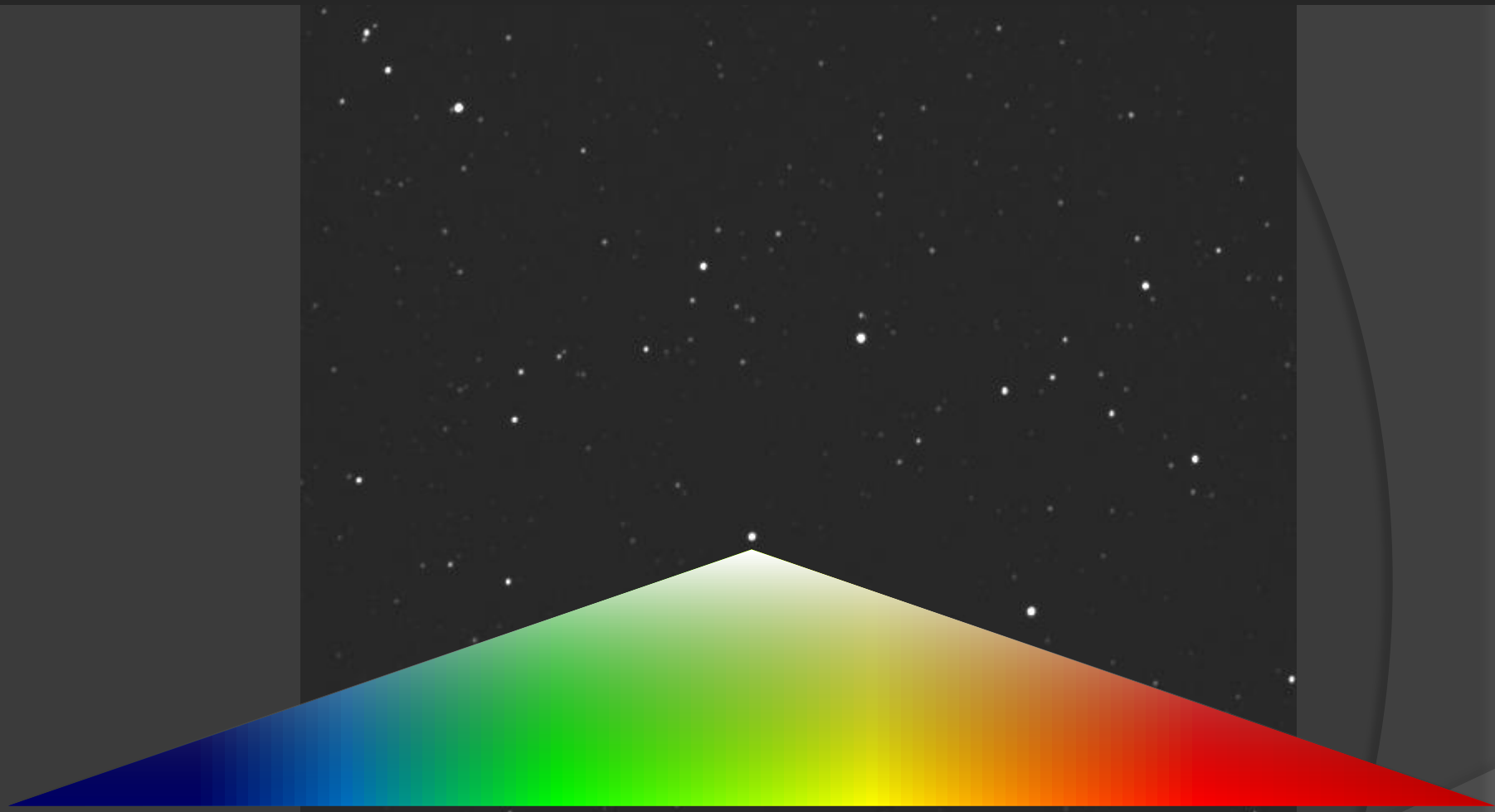
4 Amateur contribution

Z And

V filter
13-08-2016
22:06 UT
OHP (FR)



... to Spectroscopy

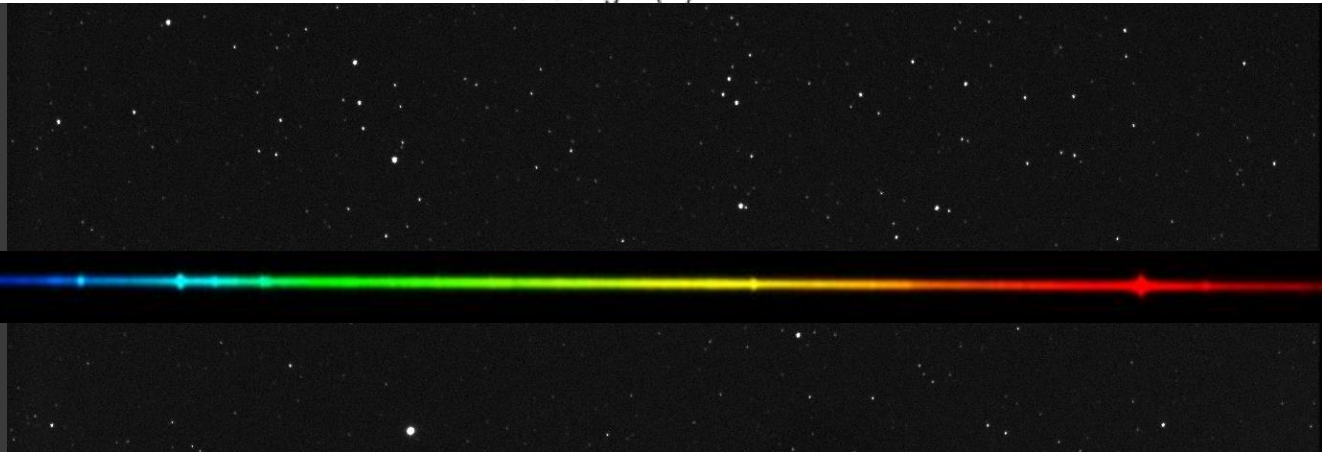
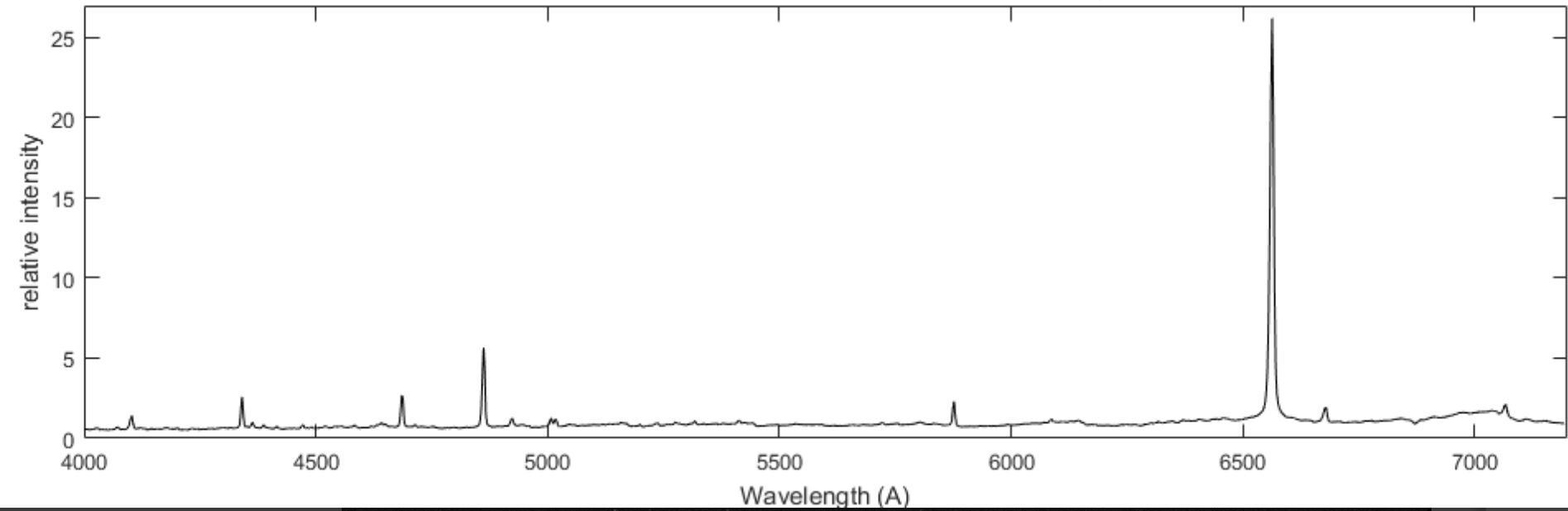


4000 Å

7500 Å

Spectroscopie

Z And 2012-09-08 21:28:03 R = 1000 François Teyssier

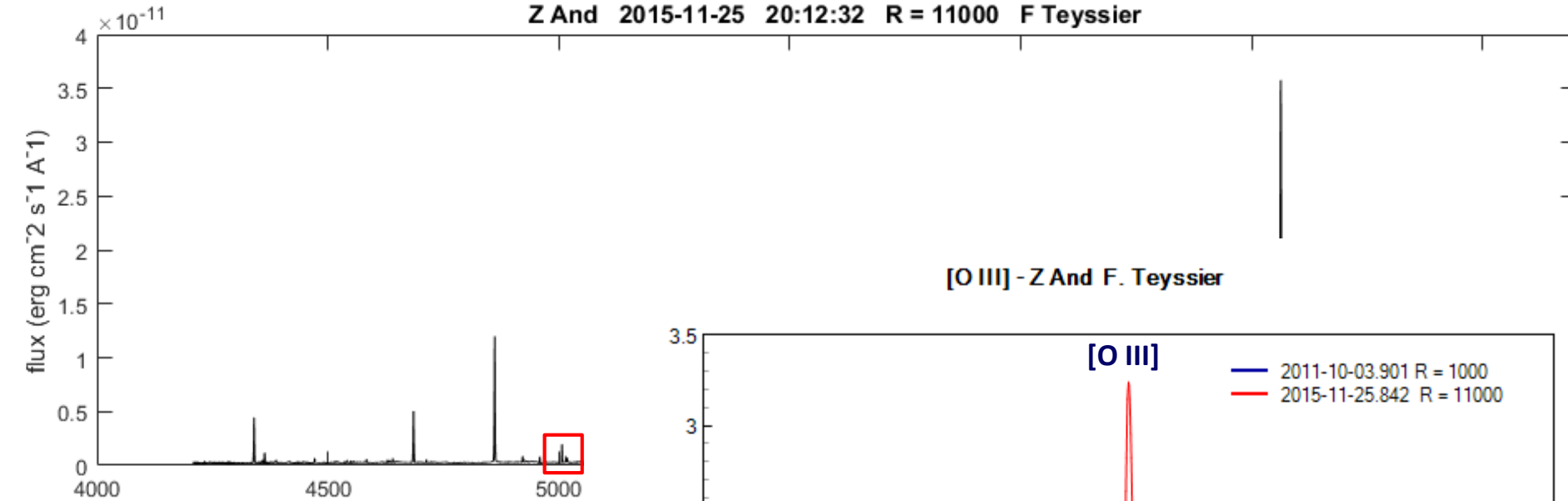


4000 Å

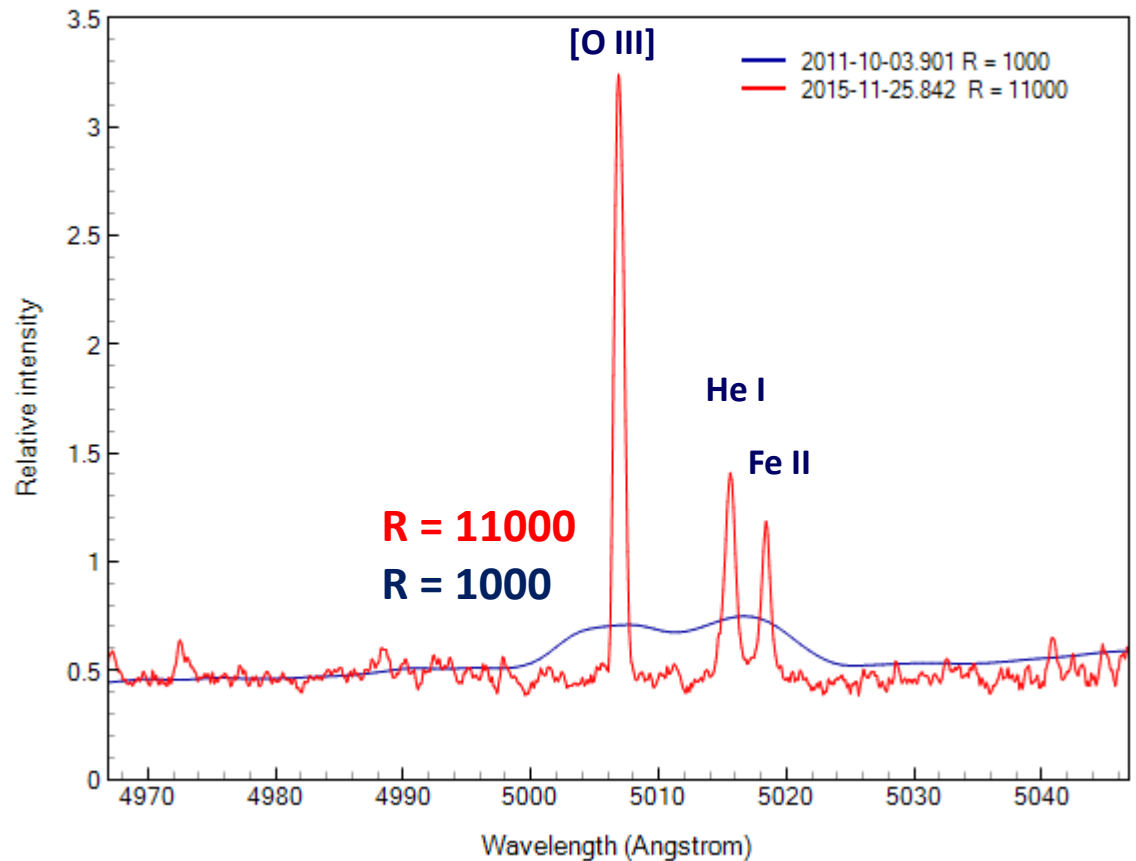
7500 Å

Spectroscopy

Z And 2015-11-25 20:12:32 R = 11000 F Teyssier



[O III] - Z And F. Teyssier



Resolution

$$R = \lambda / \Delta\lambda$$

Low	500-1000
Medium	2000-5000
High	10000-15000

Spectral classification: peculiar satrs

R Aqr

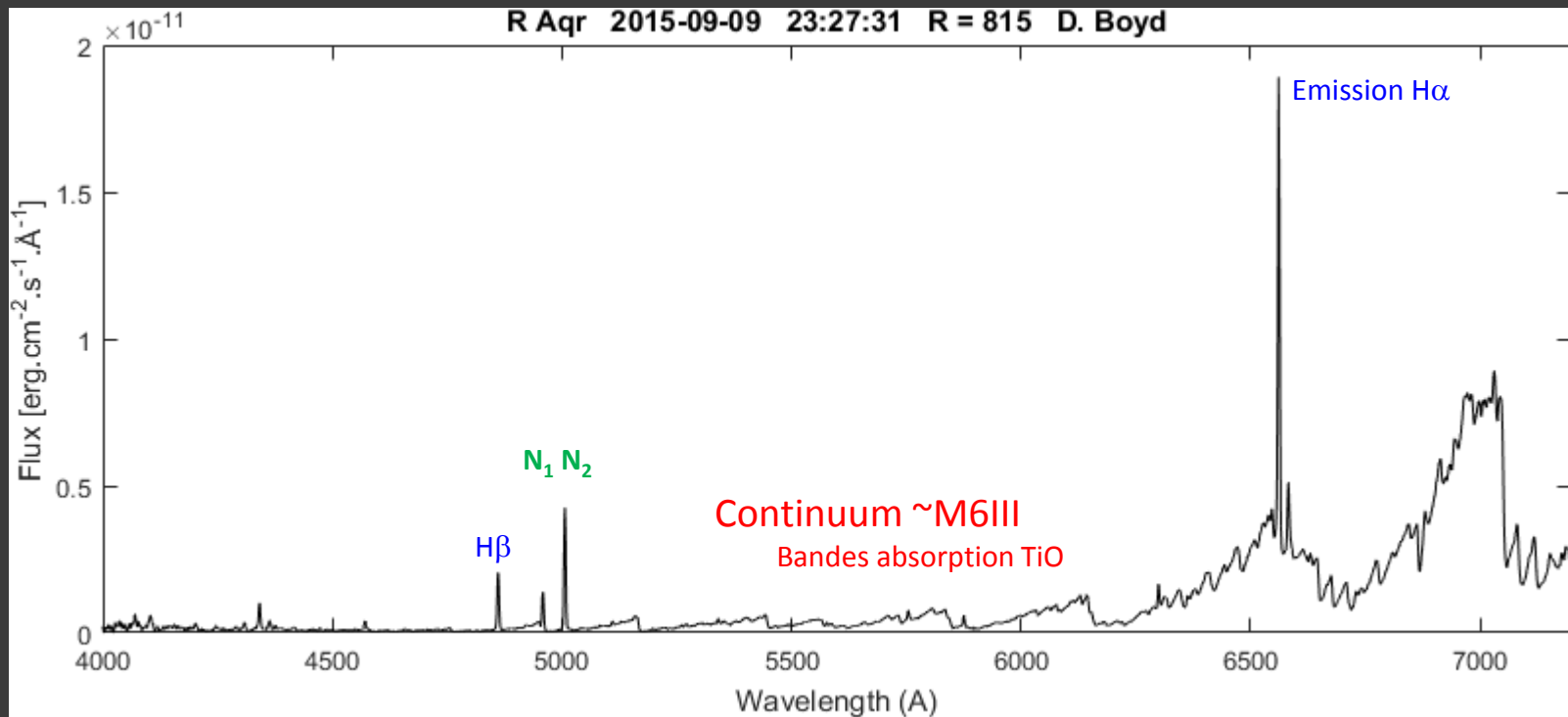
The « platypus »

Merrill, 1919

A VARIABLE STAR WITH A PECULIAR SPECTRUM

The long-period variable star R *Aquarii* 233815 has been found recently to possess a very peculiar spectrum. The data concerning

On the first three plates the chief nebular lines N₁ and N₂, and λ_{4363} are very conspicuous. On the later plates they are relatively



N₁ N₂ : raies « interdites » O²⁺ [O III] 5007, 4959 Å

Symbiotic stars

Z And

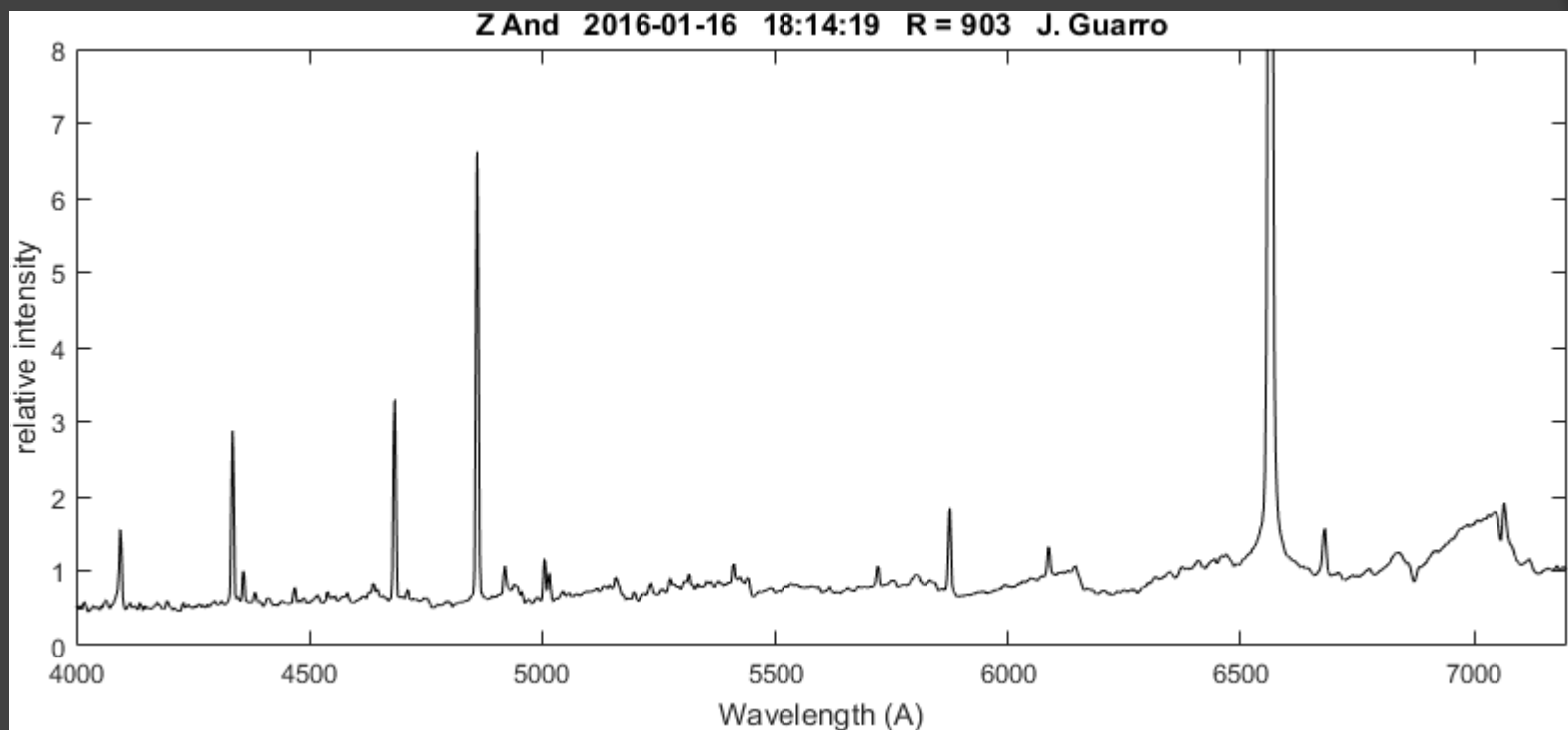
As a prototype of Symbiotic Stars

Combination of a late type continuum (K to M giant)
High excitation emission lines

Merrill, 1958 *Symbiotic phenomemon*

51 — SYMBIOSIS IN ASTRONOMY: INTRODUCTORY
REPORT

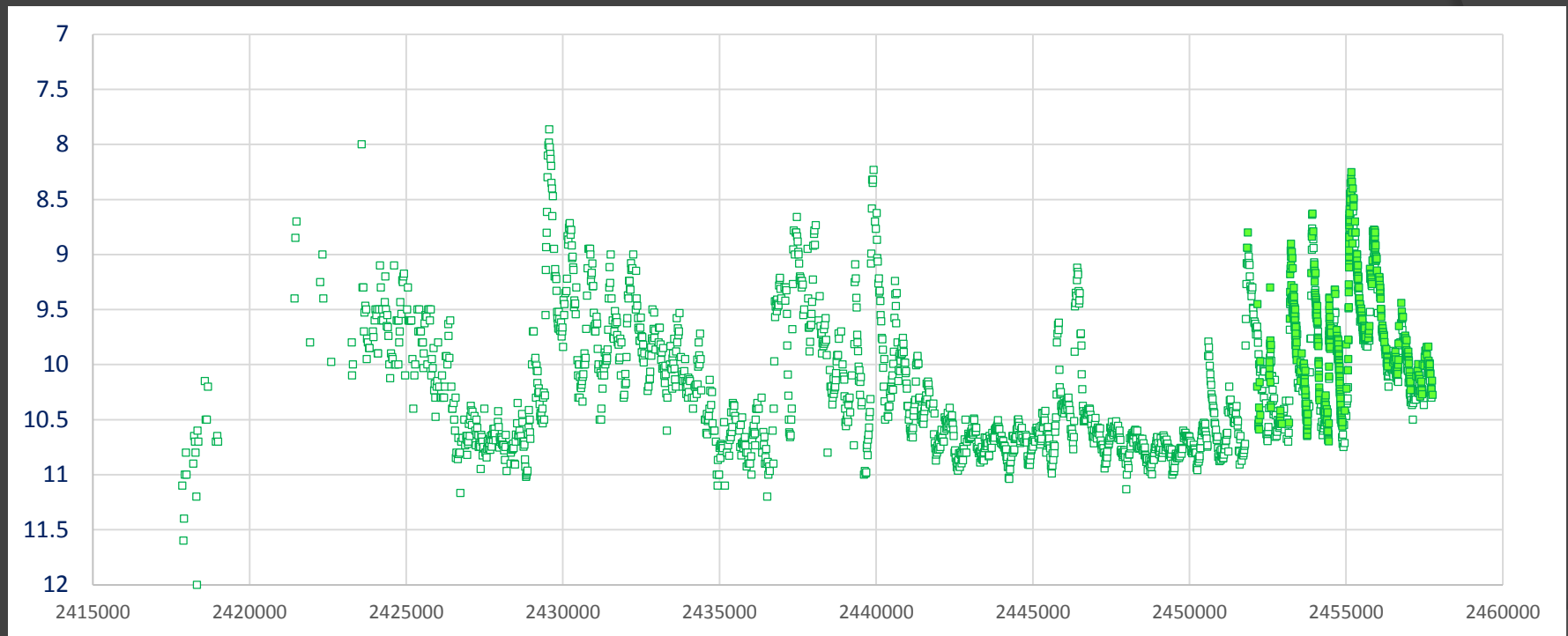
spectrograms. Thus Z Andromedae has become the prototype for those anomalous «symbiotic» stars in which high-excitation emission lines are superposed on a low-temperature absorption spectrum, usually of type M.



Symbiotic stars

Z And Prototype in the GCVS

Luminosity curve (Visible) – AAVSO – since 1907



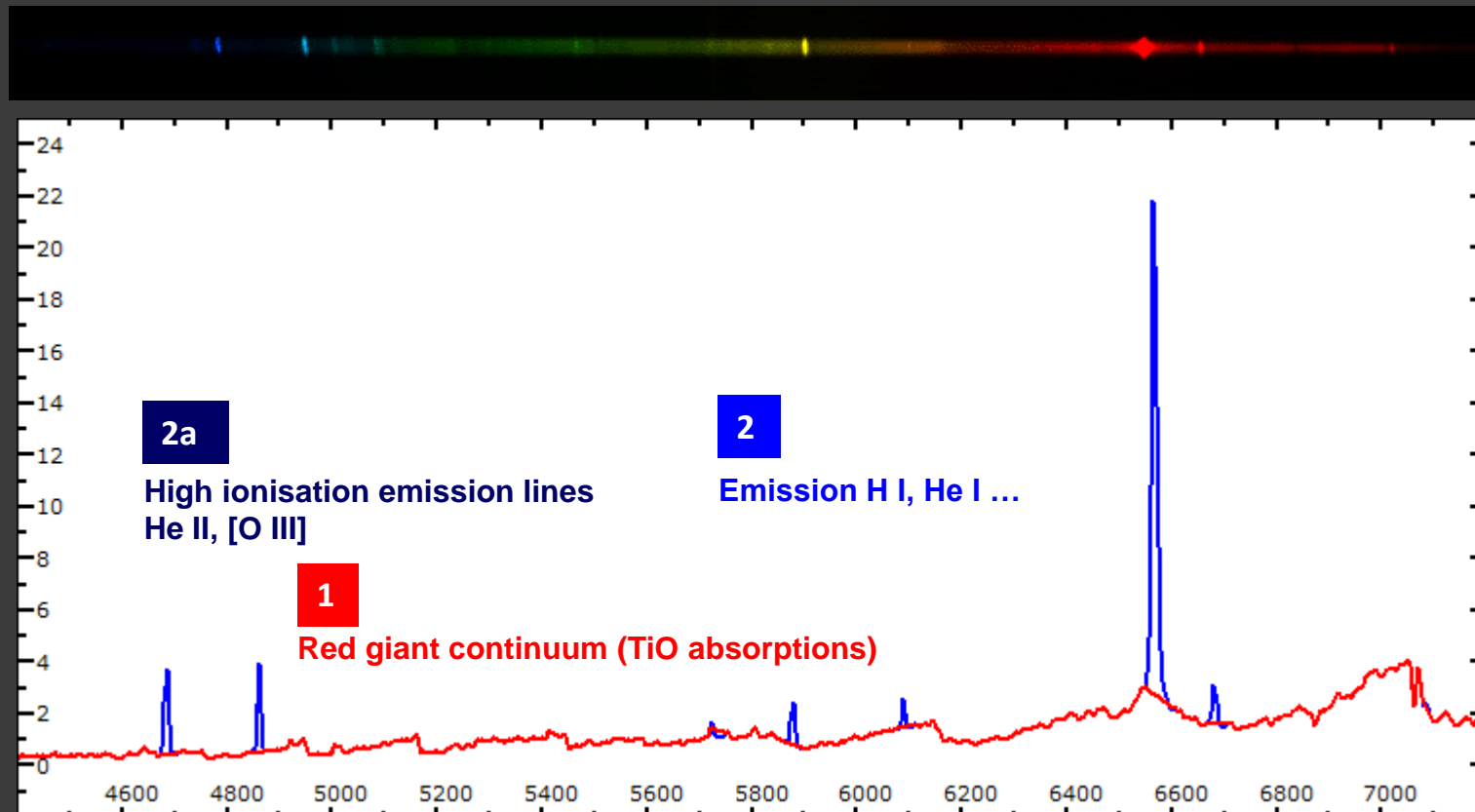
Outburst (High state) - 1 à 3 magnitudes
Quiescent state: Orbital variations

Symbiotic star: a spectroscopic definition

Belczinski & al., 2000

1. Présence de bandes d'absorption caractéristiques d'une géante de type tardif (late-type giant), parmi lesquelles TiO, H₂O, CO, CN, VO ainsi que des lignes d'absorption telles que CaI, CaII, FeI, NaI
2. Présence de fortes raies d'émission H I, He I et ...
 - raies d'émission d'ions tels [O III] (potentiel d'ionisation > 35 eV)
 - [...]

Composite spectrum



Symbiotic Stars as interacting binaries

1000 L_☉

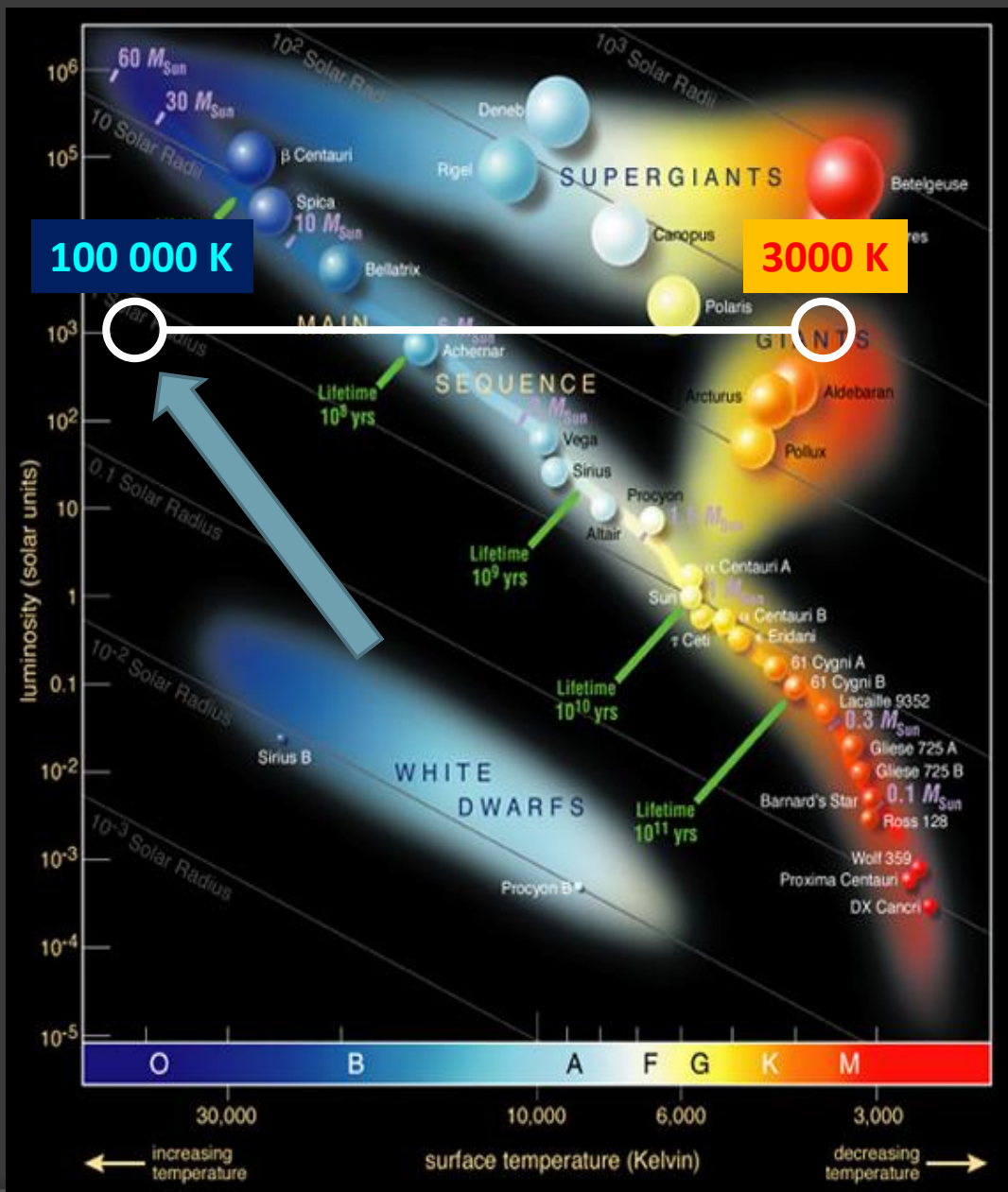
100 000 K

3000 K

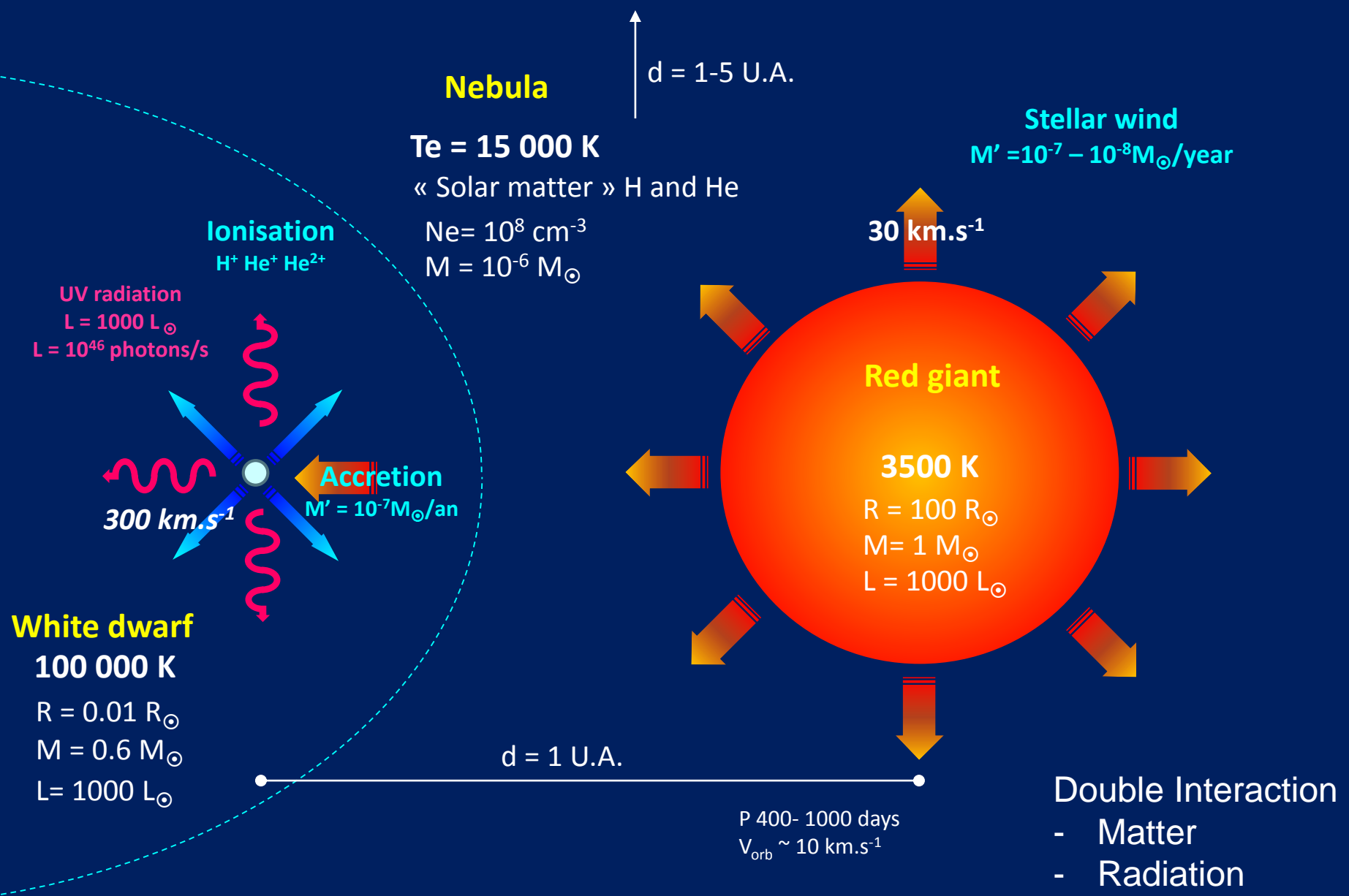
1000 L_☉

Symbiotics

Interacting binaries
red giant transferring material to a hot and luminous white dwarf via a stellar wind.



Model of a classical symbiotic



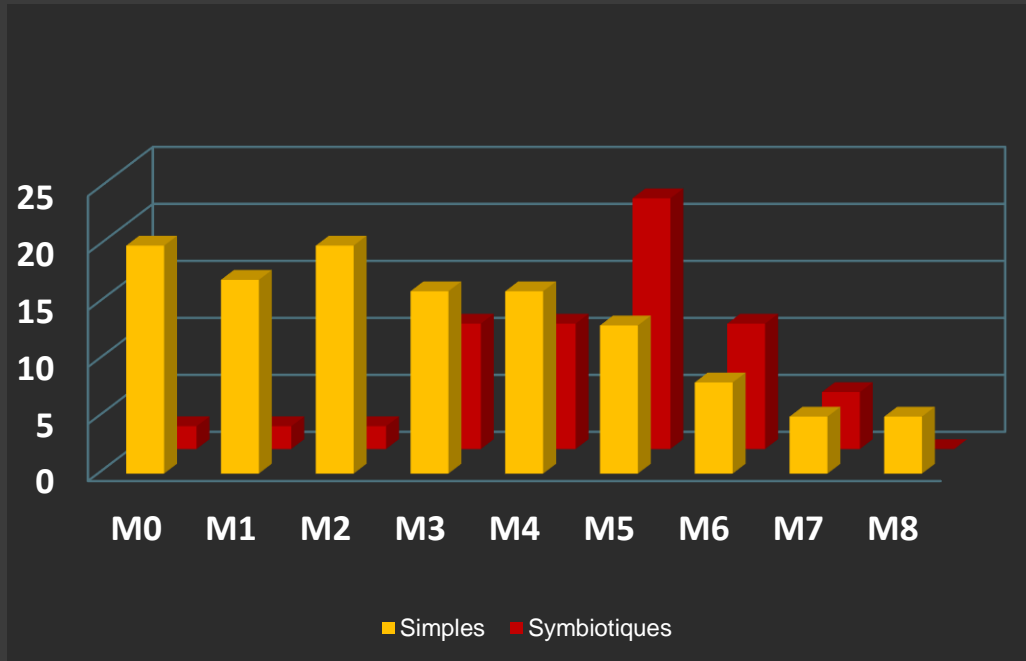
Red giant

Spectral type distribution for single red giant and symbiotic stars

Later type of the RG

= Condition for symbiotic phenomenon?

→ High loss mass



Keyes 2004

AG Dra	< K4
AG Peg	M1.7 III
EG And	M2.4 III
BF Cyg	M4.2 III
T CrB	M4.4 Ib-II
Z And	M4.4 III
AX Per	M4.8 III
CI Cyg	M4.8 III
V443 Her	M4.9 III

[Mürset & Schmid, 1999]

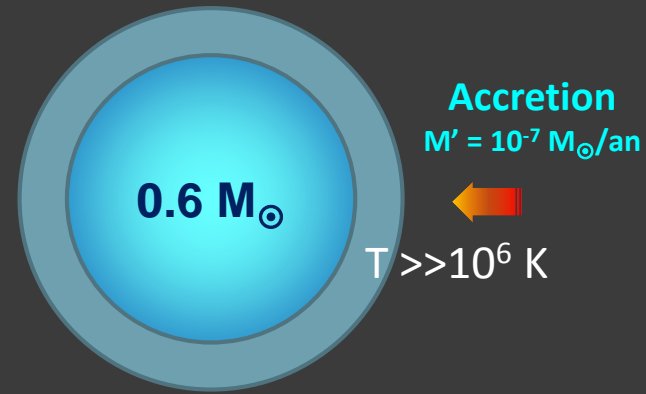
Spectral Classification
Cool star

Keyes 2004
Mürset 1999
Kenyon 1987

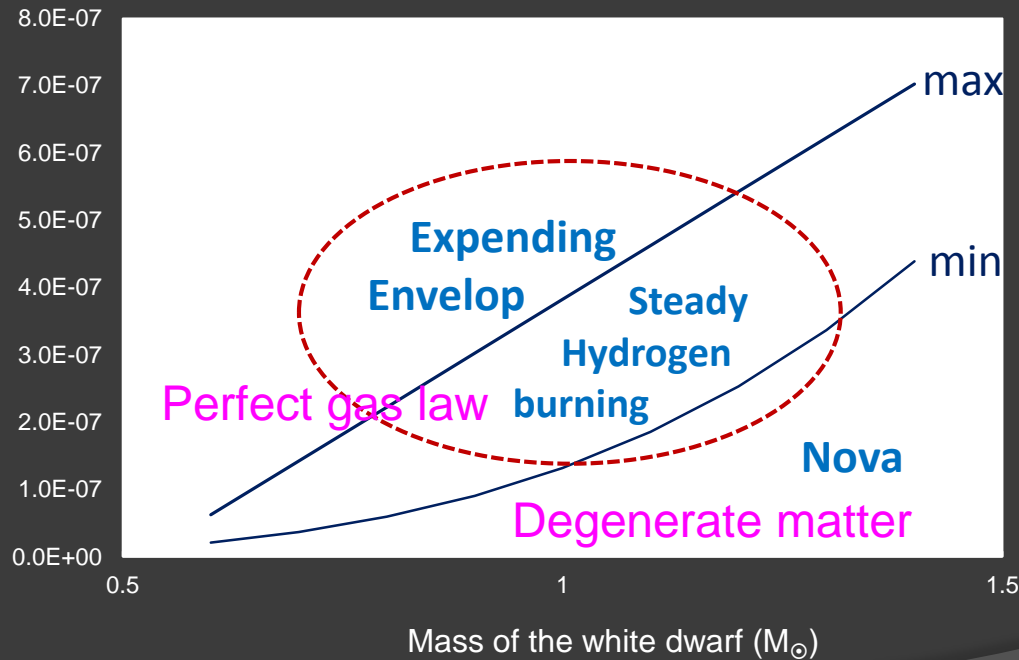
White dwarf + Steady nuclear burning Envelop = « Hot Component »

Steady hydrogen burning in the envelop
(non degenerated matter)

(Novae : thermonuclear runaway in a degenerate envelop with ejecta)



Accretion rate (M_⊙/an)



Minimum accretion rate:
Iben, 2002
 $M' = 1,32 \cdot 10^{-7} M_{\odot}/\text{an} \cdot M_{\text{wd}}^{3.57}$

Maximum accretion rate
Paczynski, 1970
 $\text{Max} = 8 \cdot 10^{-7} M_{\odot}/\text{an} \cdot (M_{\text{wd}} - 0,522 M_{\odot})$

Hot compent = Dwarf nova and envelop

High dispersion

	T [K]	R [R_{\odot}]	L [L_{\odot}]	Date
EG And	70 000	0.02	7.5	Oct. 82
AG Dra	130 000	0.01	19	Jun. 83
AX Per	105 000	0.08	710	Oct. 84
CI Cyg	115 000	0.06	560	Aug. 83
Z And	130 000	0.08	1600	Sep. 84
YY Her	100 000	0.11	1100	Aug. 80

Low luminosity:
Accretion
(Gravitationnal energy)

High luminosity:
Thermonuclear energy

Mürset 1991

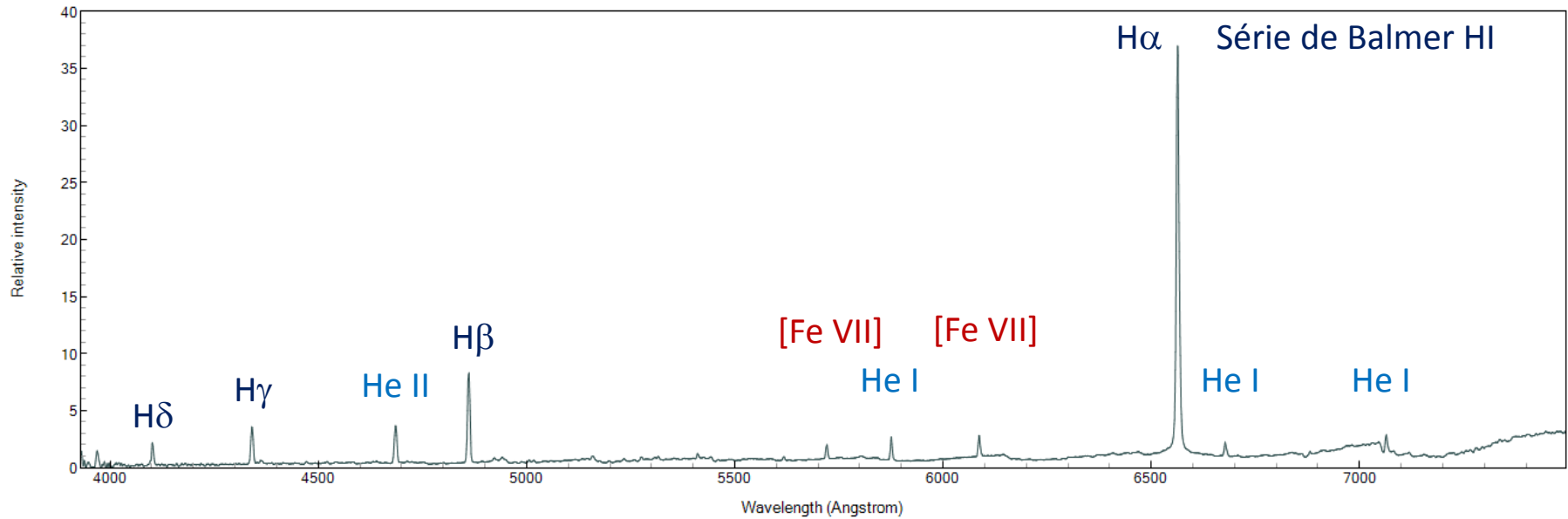
Highly variable

Z And

T [K]	L [L_{\odot}]	Date
110 000	620	07-79
105 000	620	05-80
110 000	860	08-80
105 000	720	01-81
130 000	1600	09-84
125 000	1600	10-84

Typical spectrum of a classical symbiotic

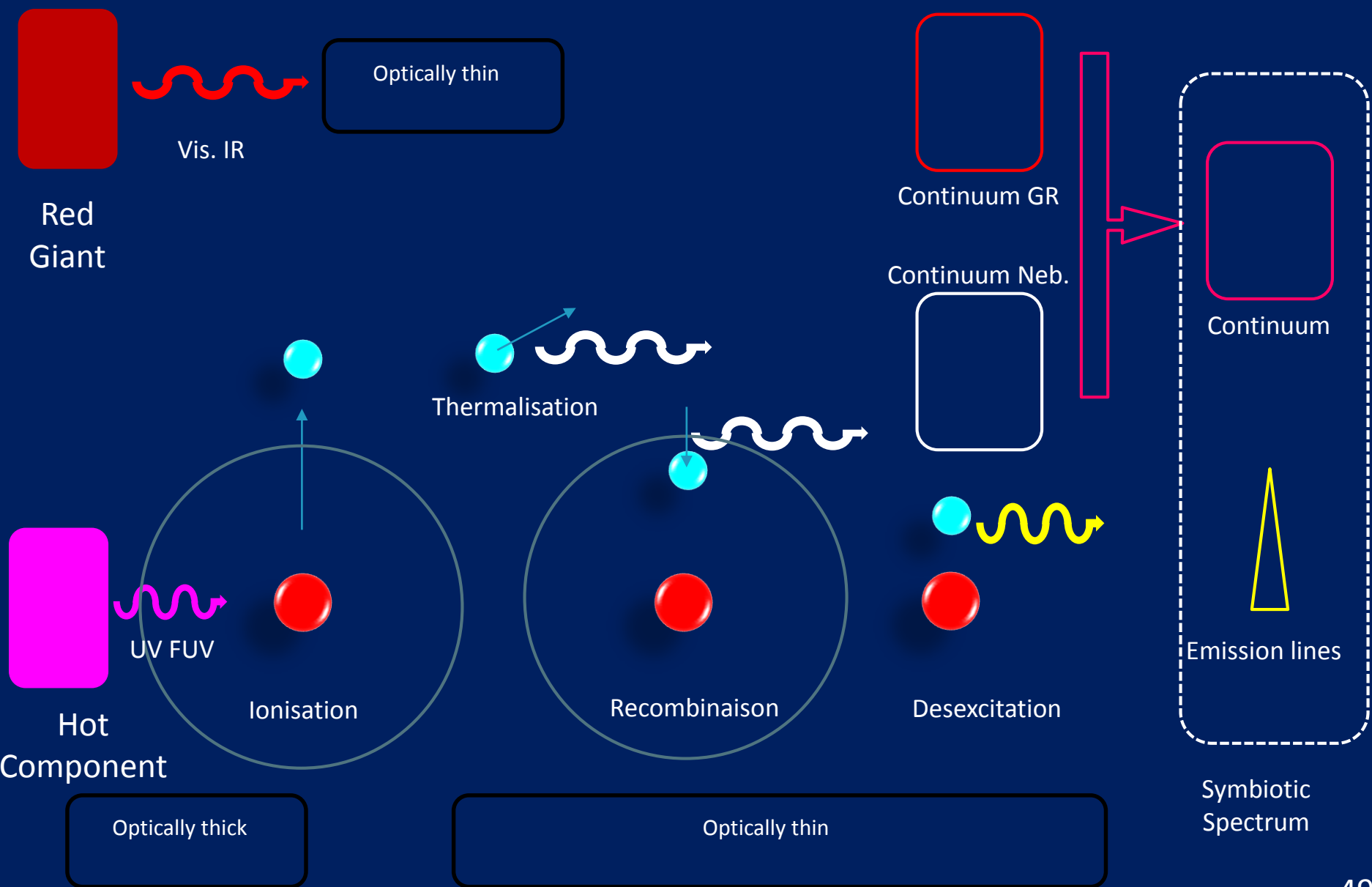
CI Cyg 2011-08-28.859 François Teyssier



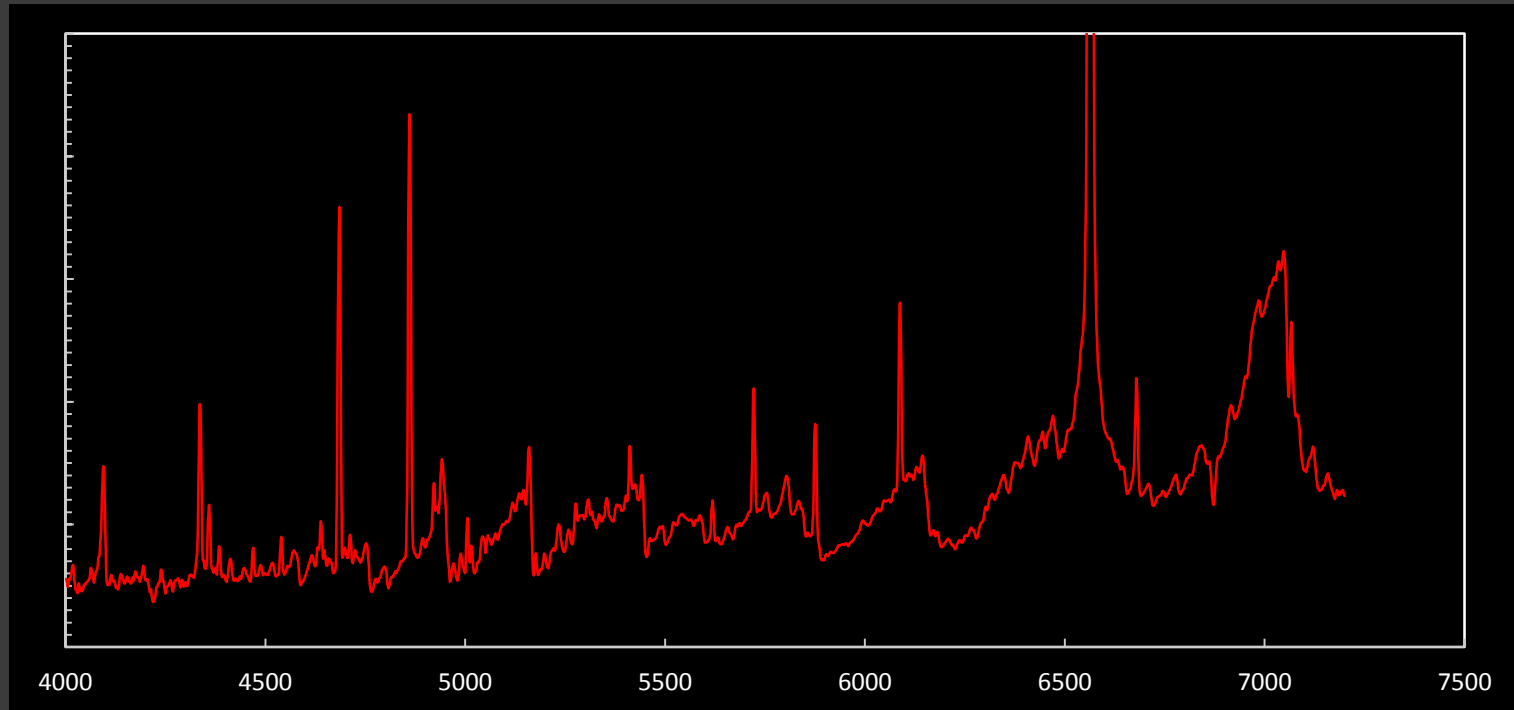
Recombinaison lines

Collisionnally excited lines (« *Forbidden* » lines)

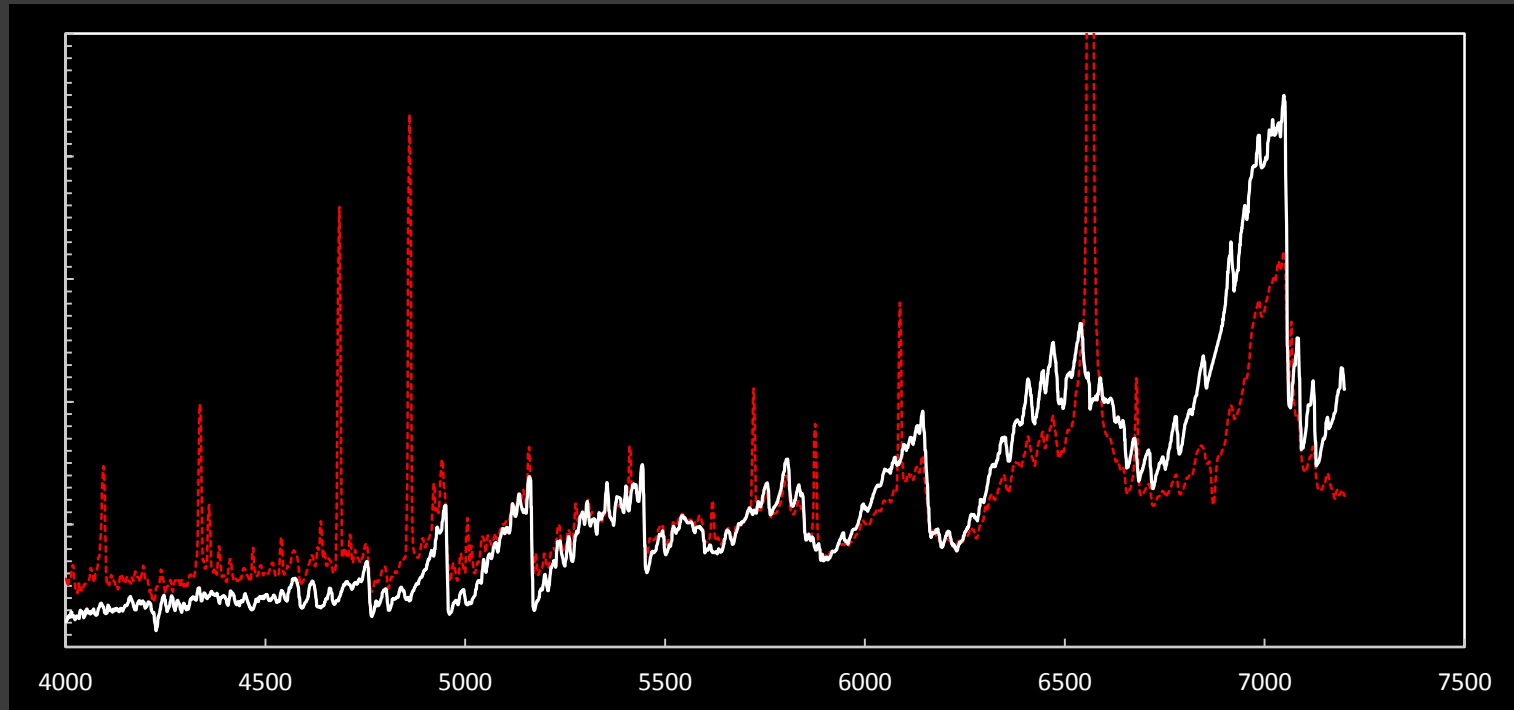
Formation of the symbiotic spectrum



CI Cygni 08-11-2015

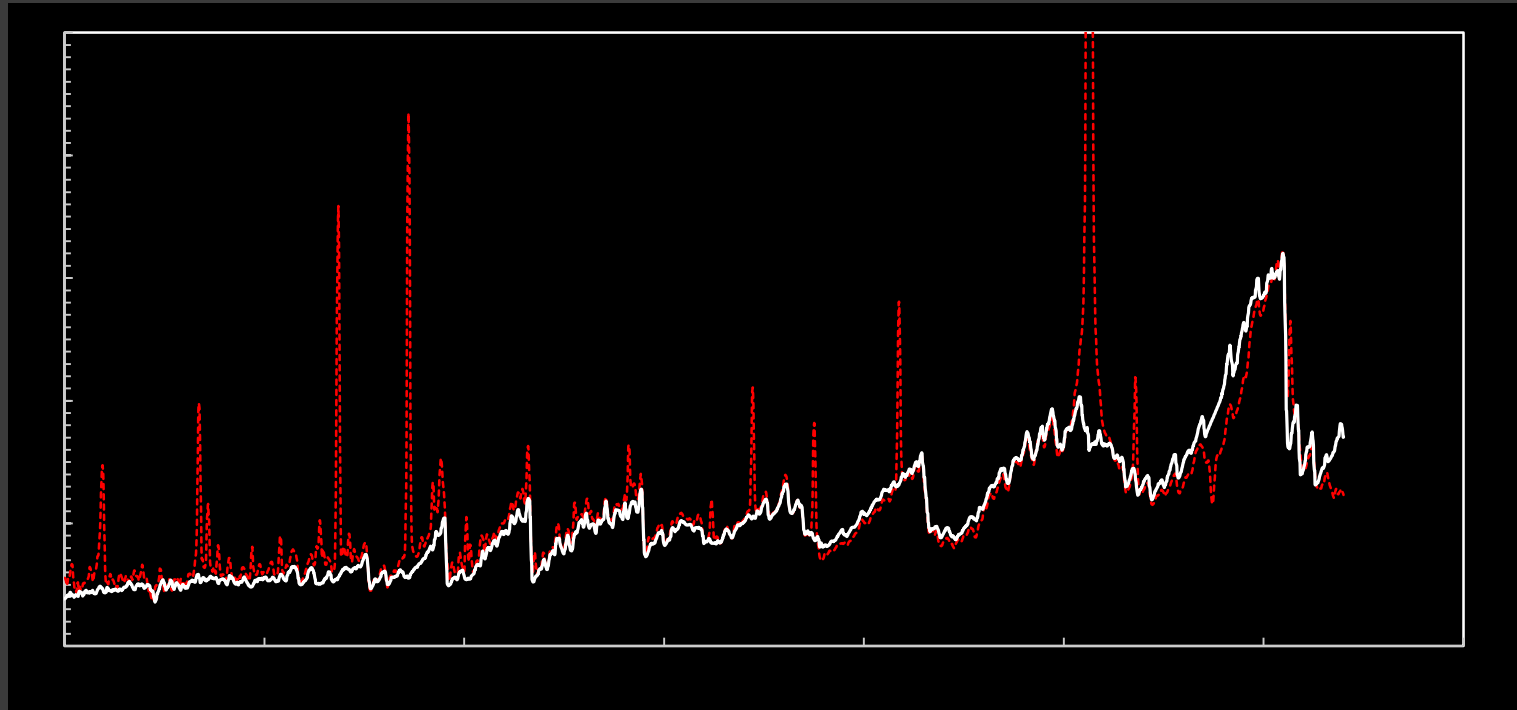


CI Cygni 08-11-2015



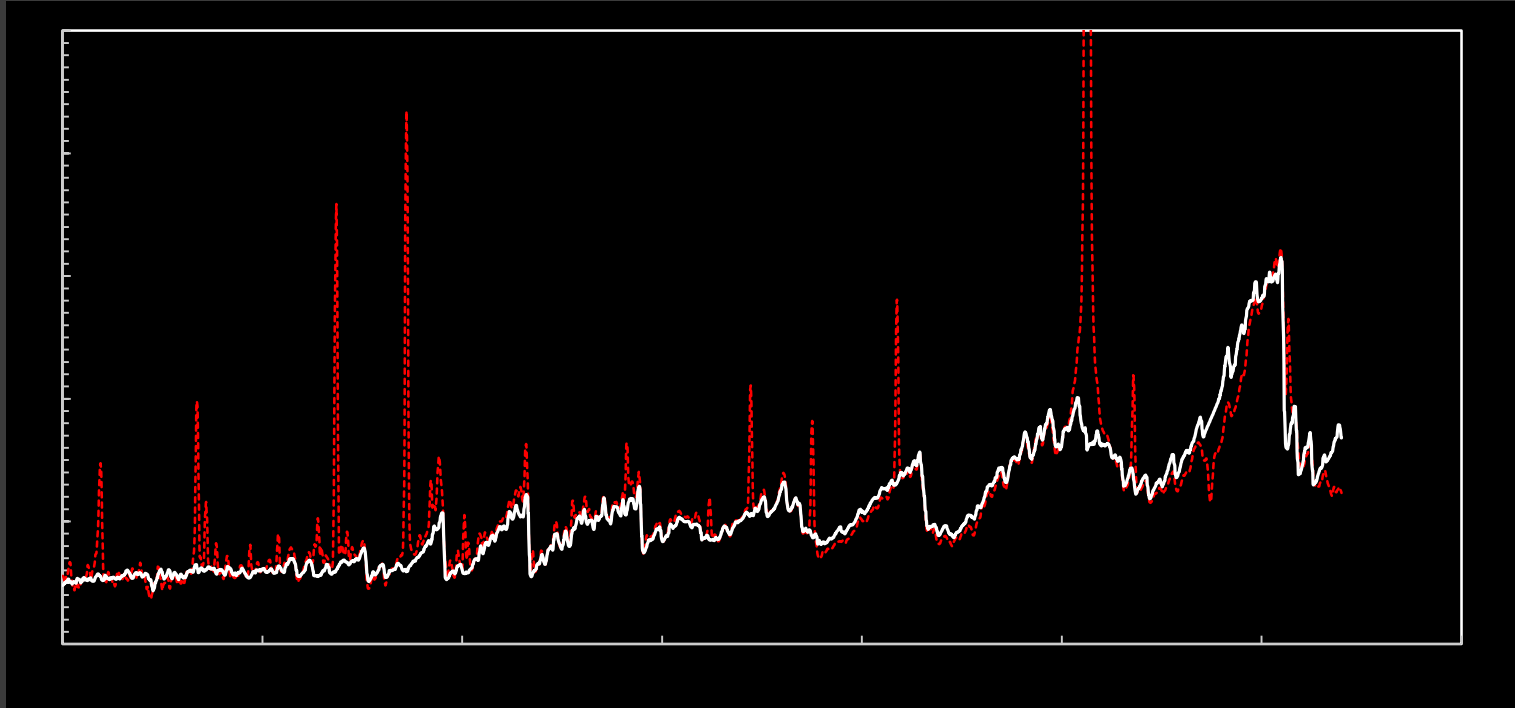
Comparaison avec spectre M5III (Fluckes)

CI Cygni 08-11-2015



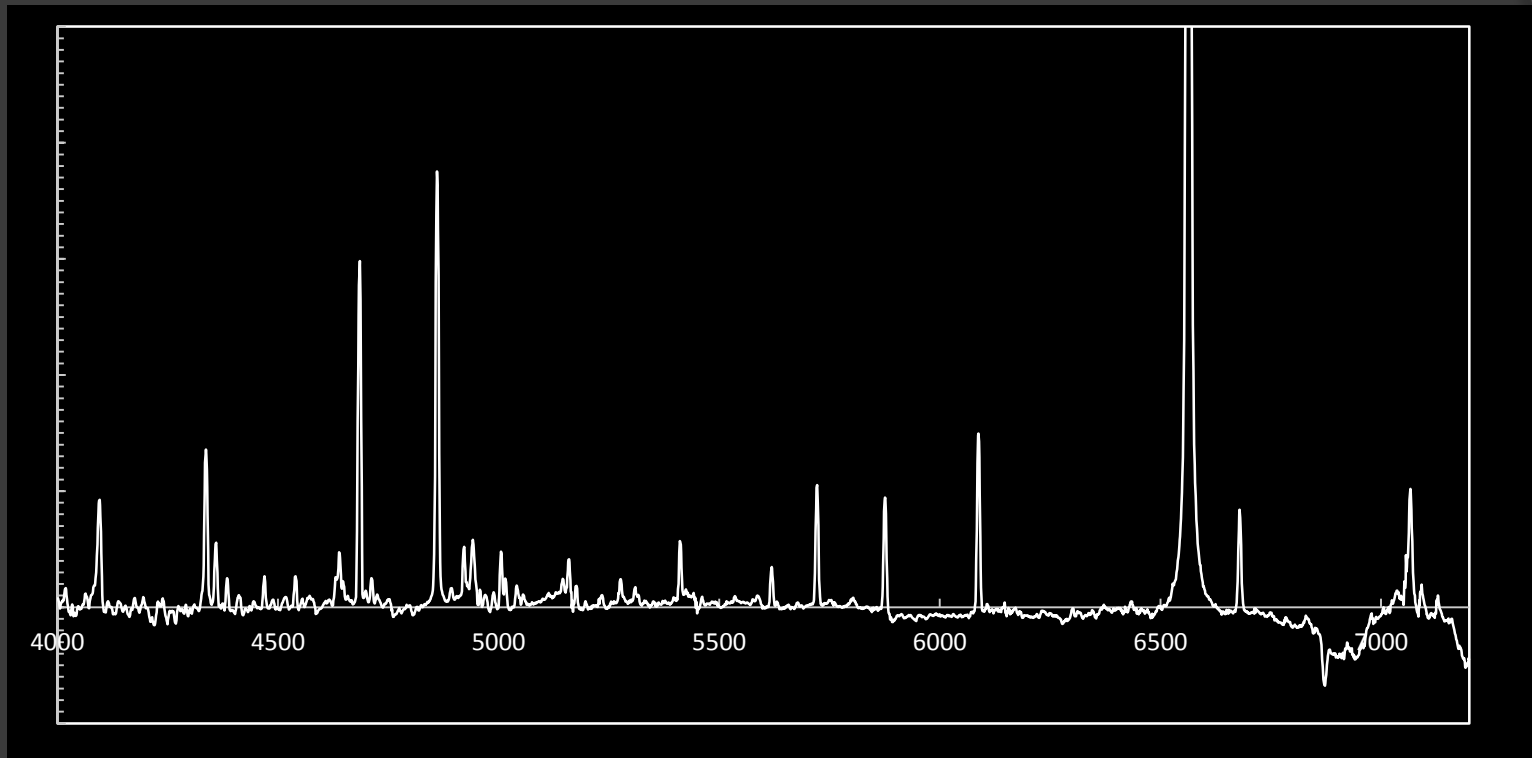
Spectre M5III (Flukes) + Recombinaison H (15 000 K)

CI Cygni 08-11-2015



Spectre M5III (Flukes) + Recombinaison H (15 000 K) + Hot Star (125 000 K)

CI Cygni 08-11-2015

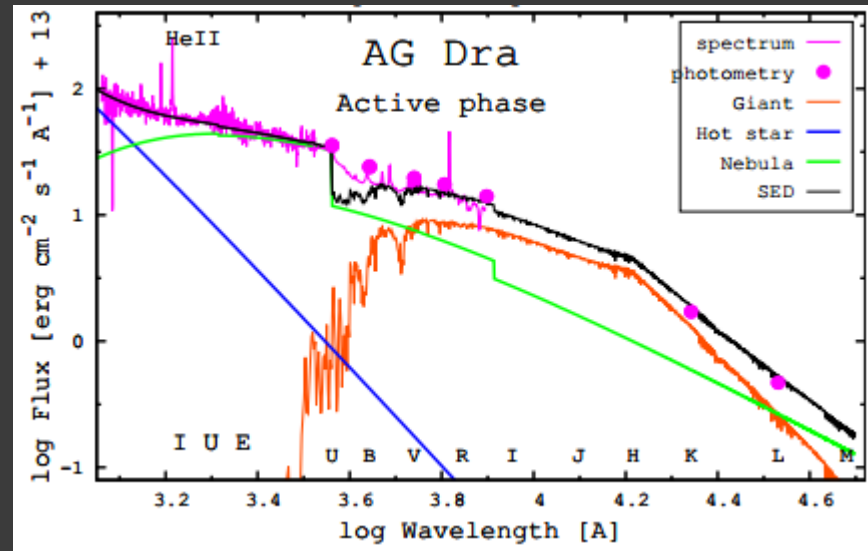


Substraction of the composite continuum (M5III+Continuum 15000 K + Hot Star 125000

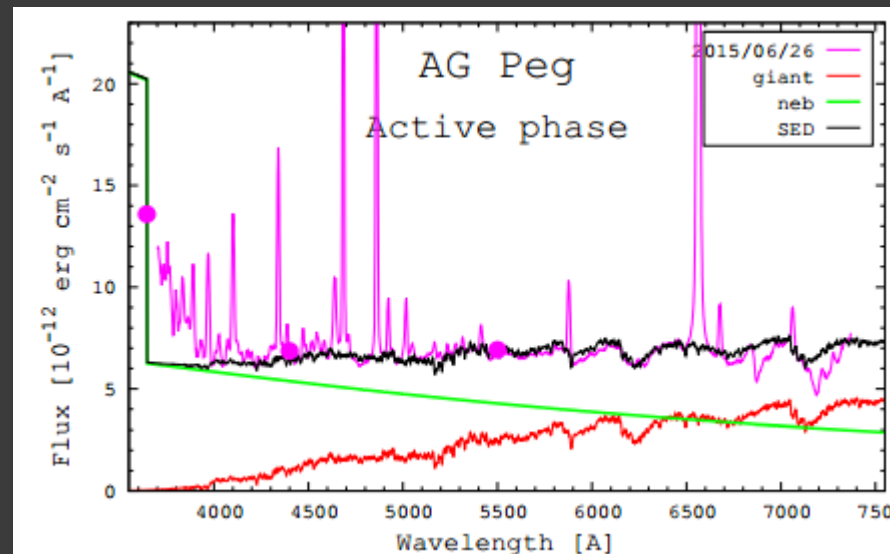
→ Emission Lines

Reconstitution du spectre composite

A. Skopal
in ARAS Eruptive Stars
Information Letter n°23
01-2016

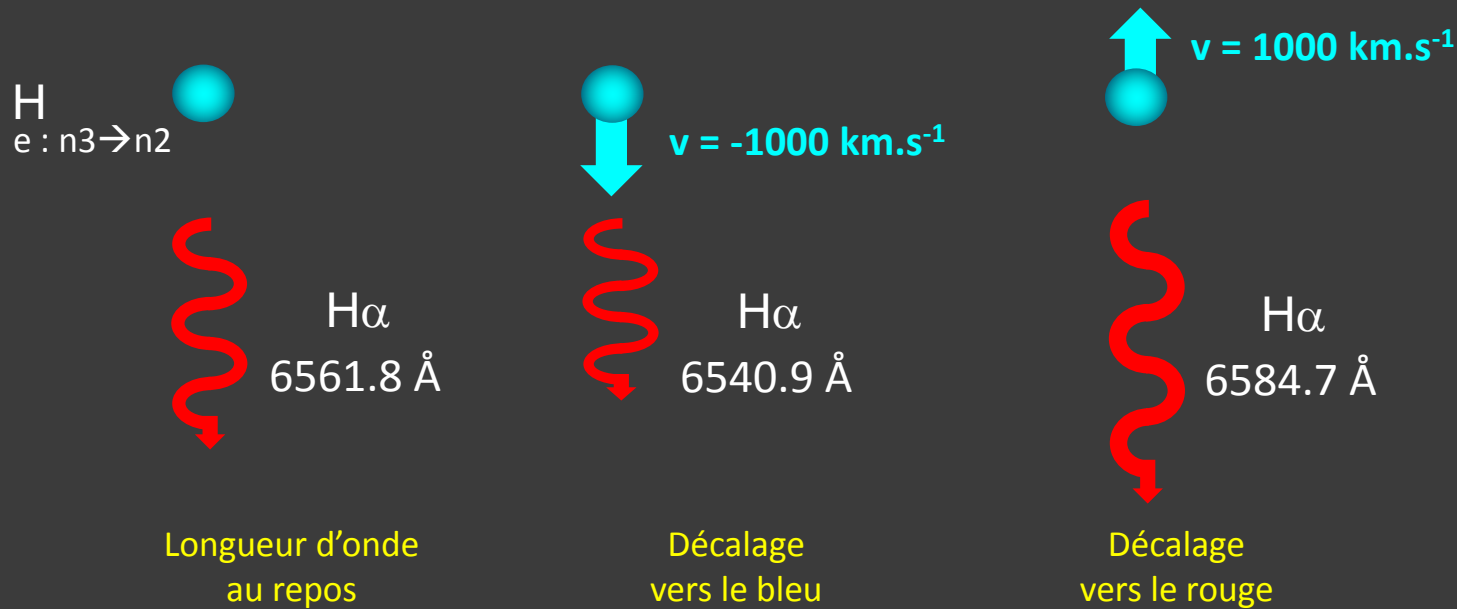


Spectre
Géante
Nébuleuse
Composant Chaud
Continuum composite



Spectre U. Sollecchia

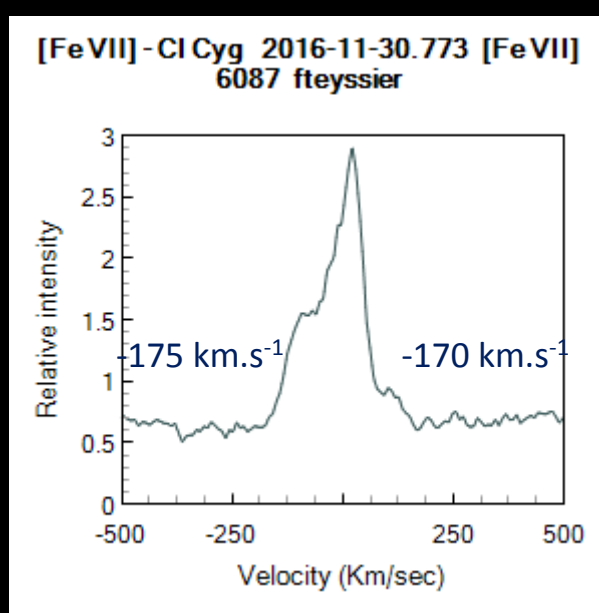
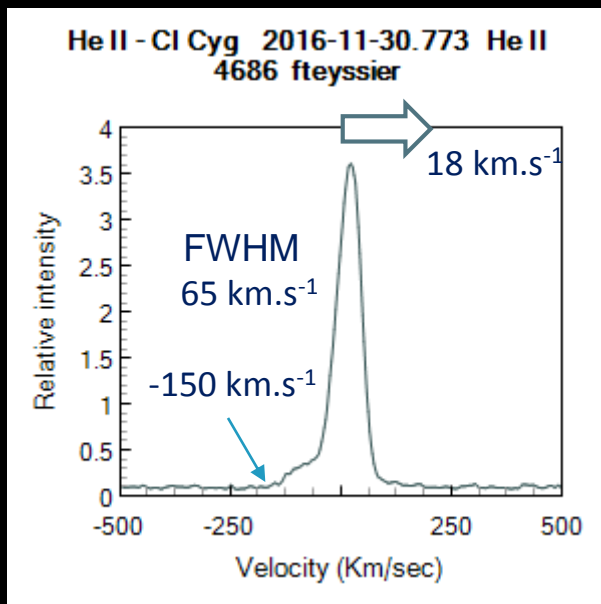
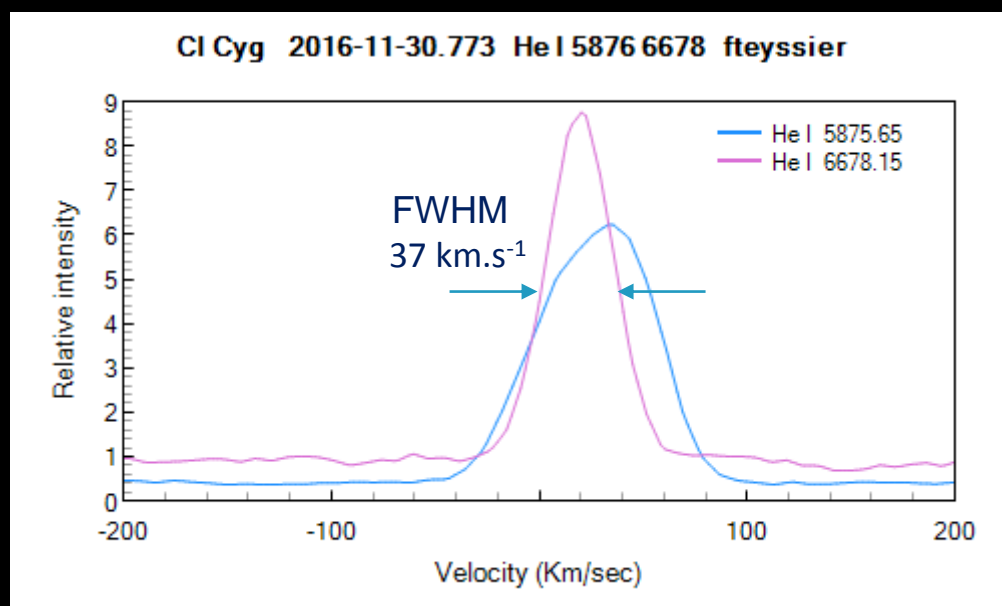
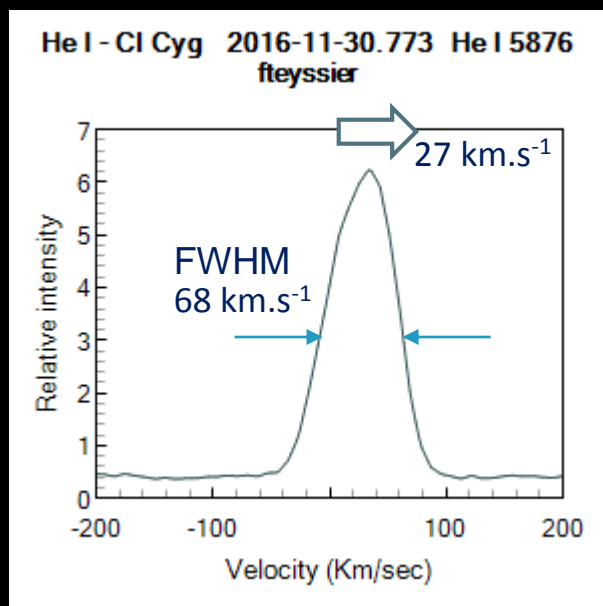
Effet doppler



La vitesse d'une électron émettant un photon
Modifie la longueur d'onde du photon

$v \text{ (km.s}^{-1}\text{)}$	$\lambda \text{ (Å)}$
-2000	6519.1
-1000	6540.9
-500	6551.9
-200	6558.4
-100	6560.6
100	6565.0
200	6567.2
500	6573.8
1000	6584.7
2000	6606.6

Line profile: Doppler effect

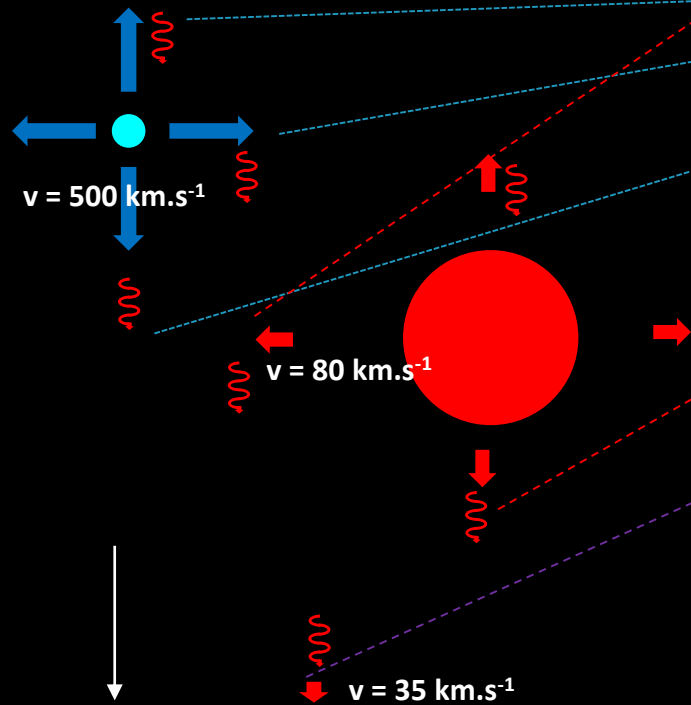
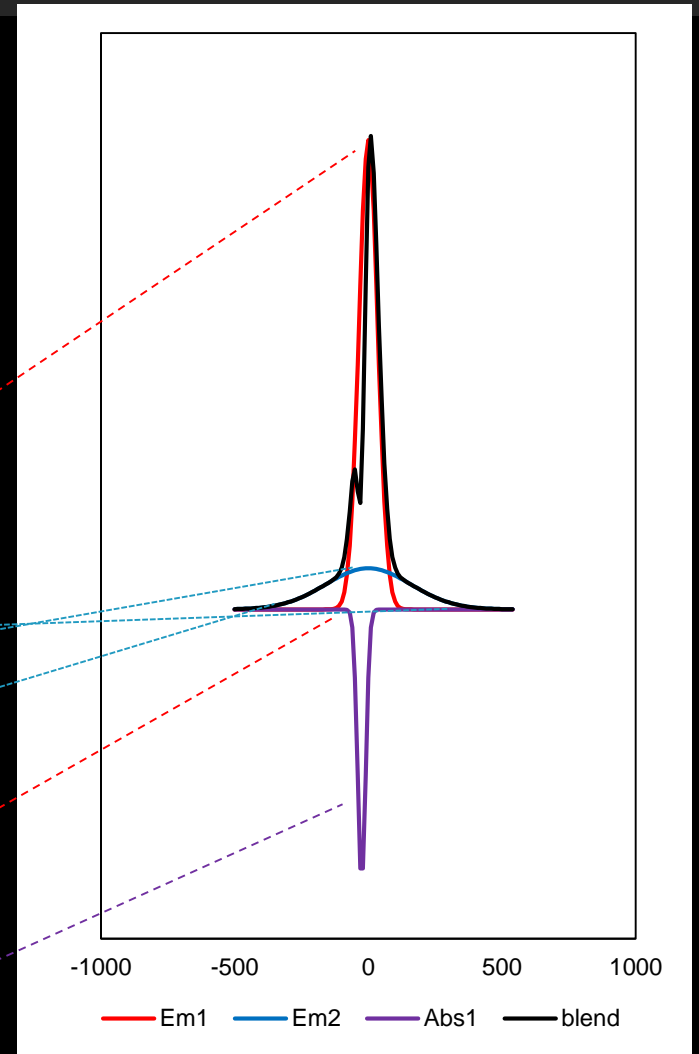
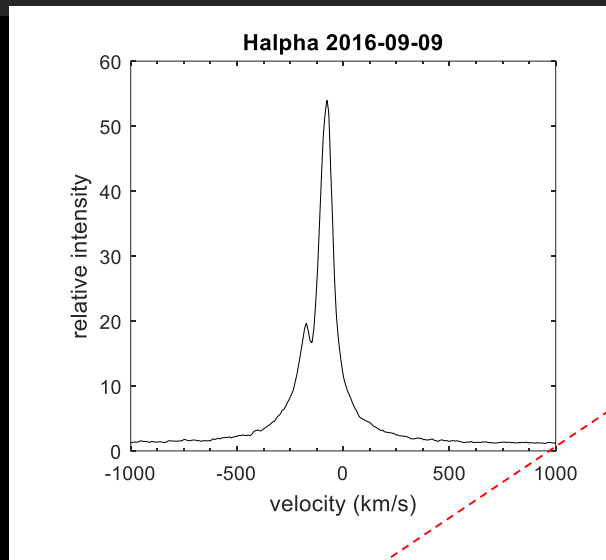


Conversion
Longueur d'onde
→ Vitesse radiale
Par rapport à la longueur d'onde
au repos

$$V_r = \Delta\lambda/\lambda * c$$

Line profiles

Cl Cyg
Raie H α



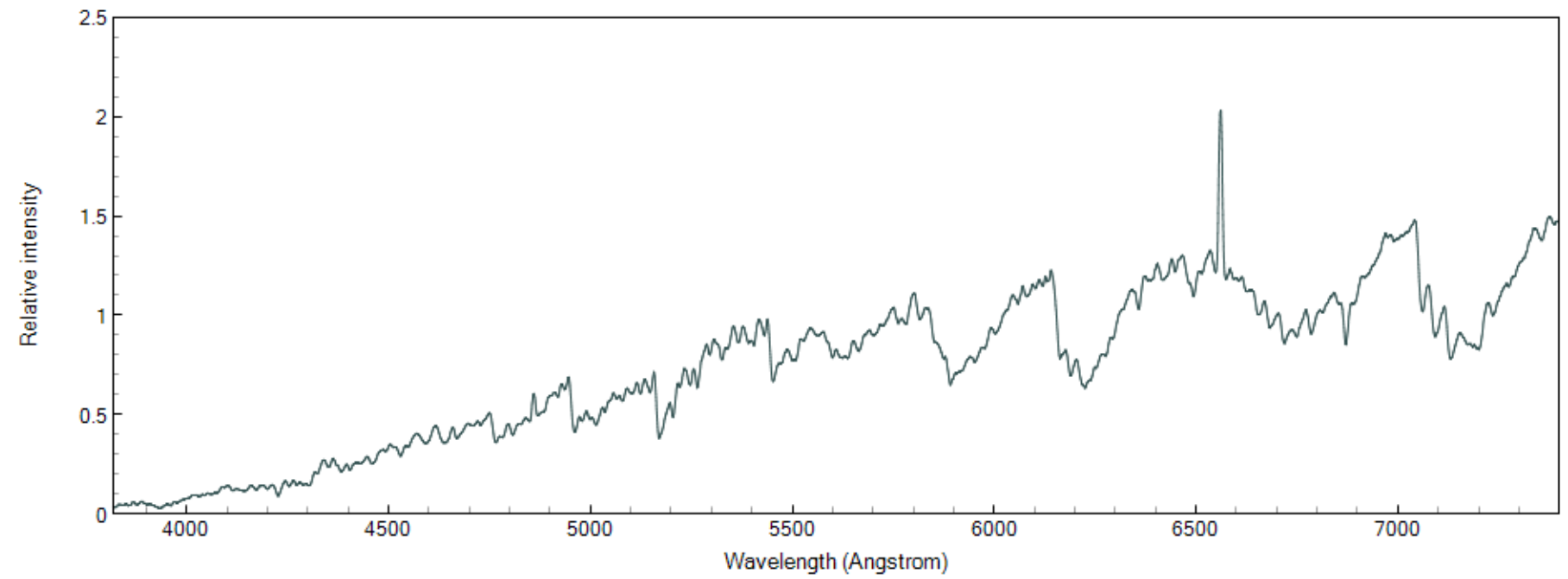
1 Symbiotic stars

2 Symbiotics in quiescent state

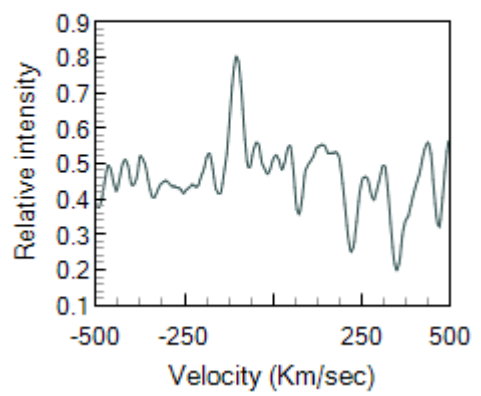
3 Outbursts

4 Amateur contribution

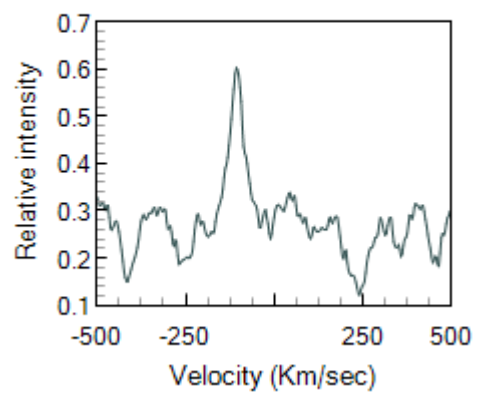
EG And 2016-10-22.958 Jacques Montier



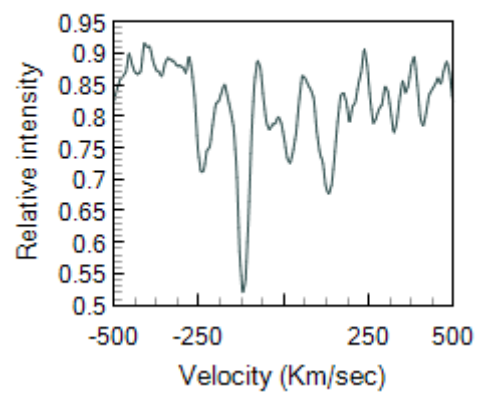
[OIII]-EGAnd 2016-10-30.813 fteyssier



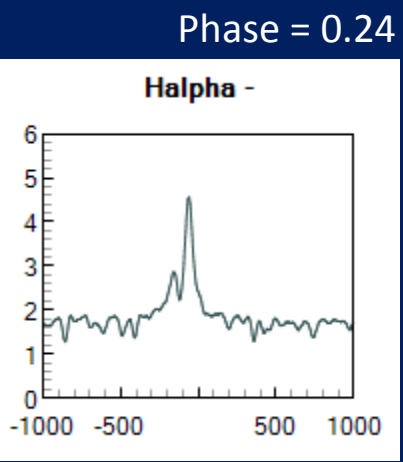
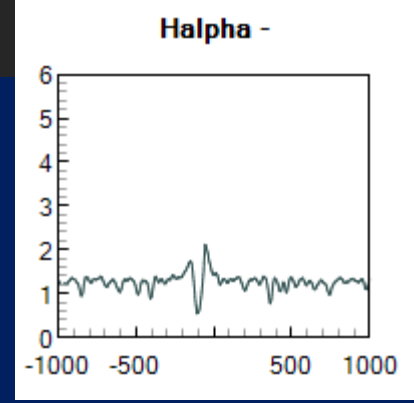
[OIII]-EGAnd 2016-10-30.813 fteyssier



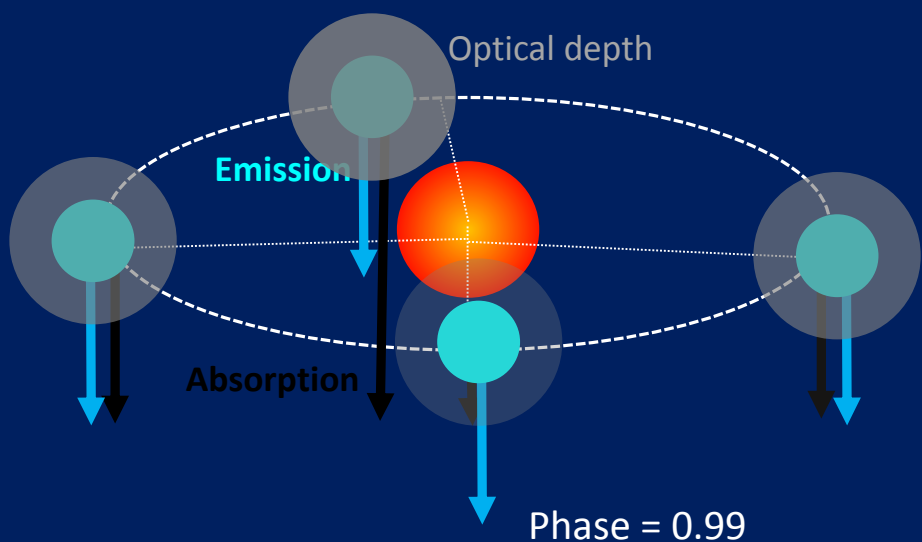
HeI-EGAnd 2016-10-30.813 fteyssier



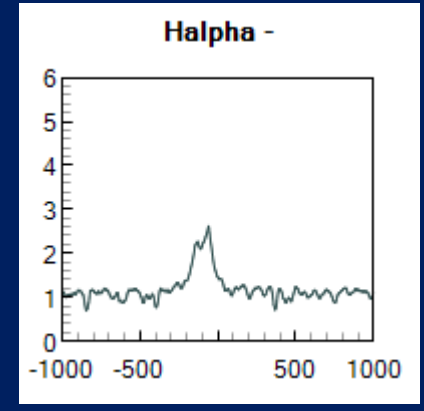
Orbital variation
H α Profile



01-11-2015

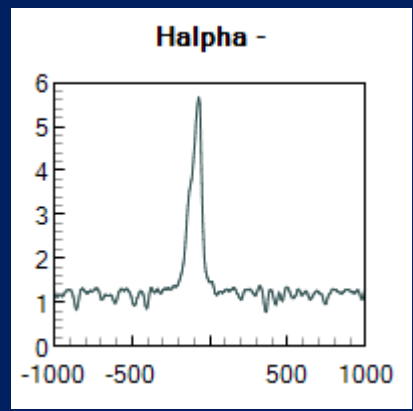


Phase = 0.78



22-07-2016

Note Profile $\phi(0.78) \neq \phi(0.24)$



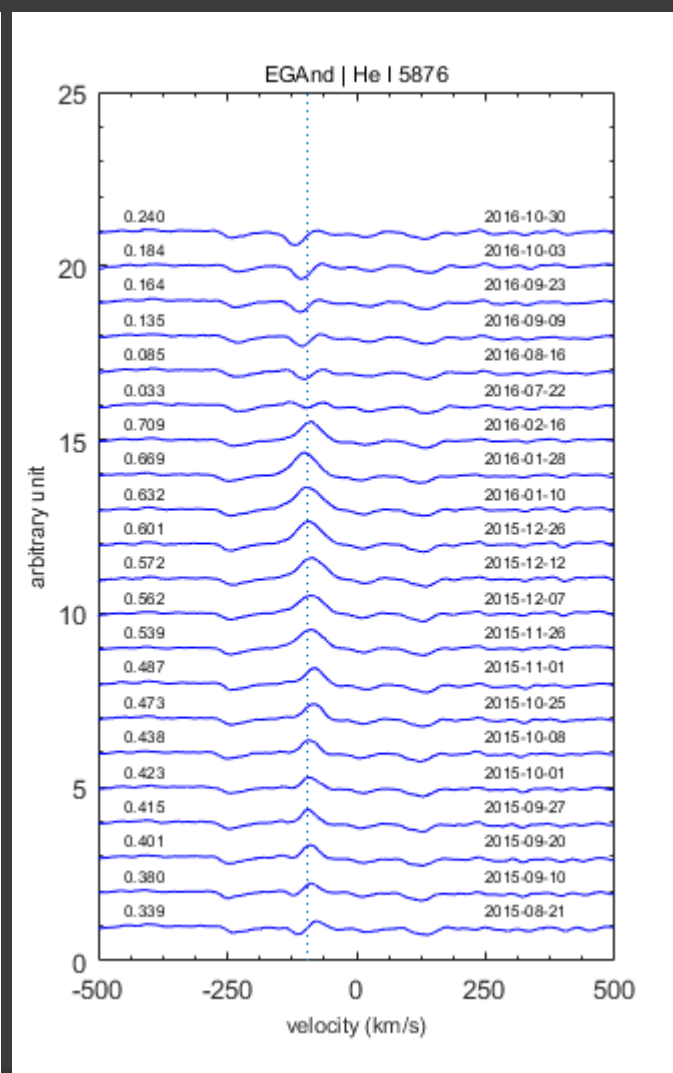
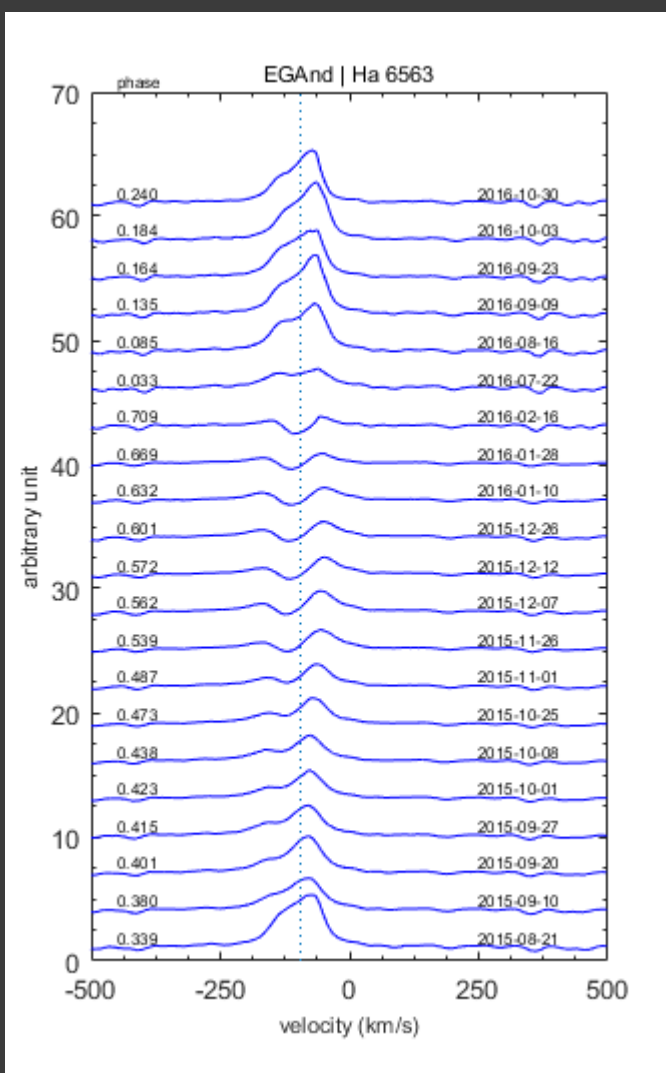
30-10-2016

EG And

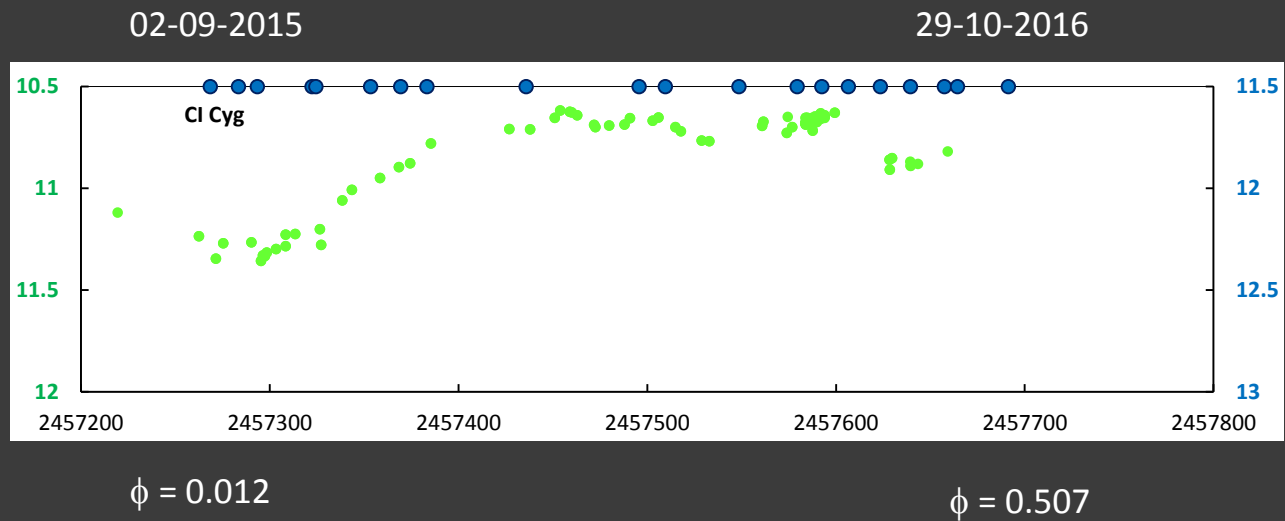
Série temporelle

H α He I

21-08-2015 au 30-10-2016



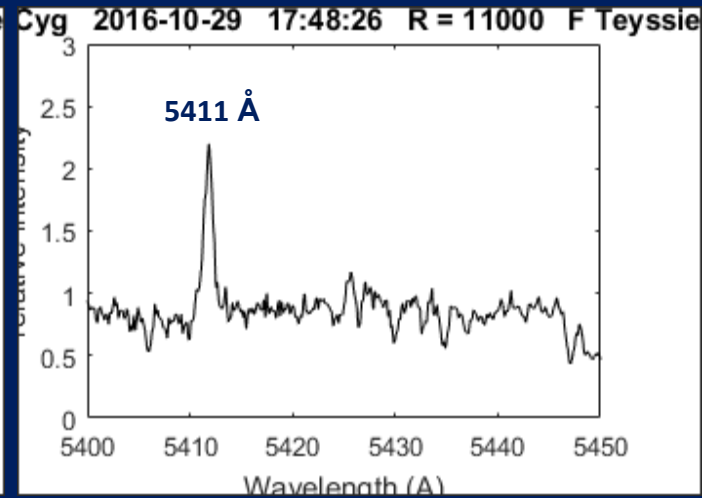
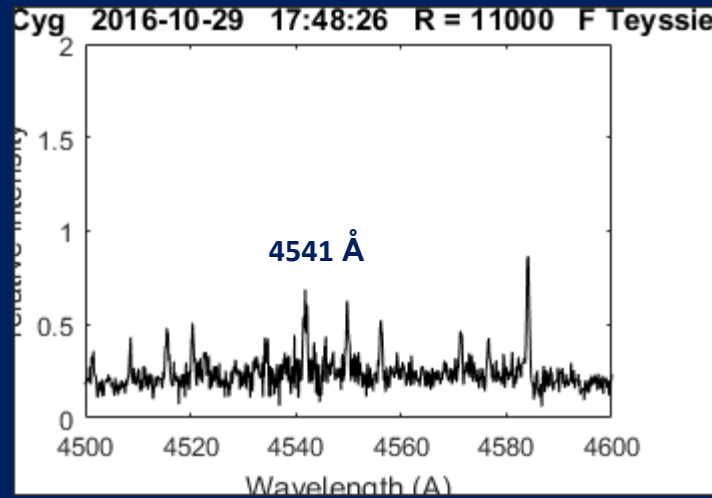
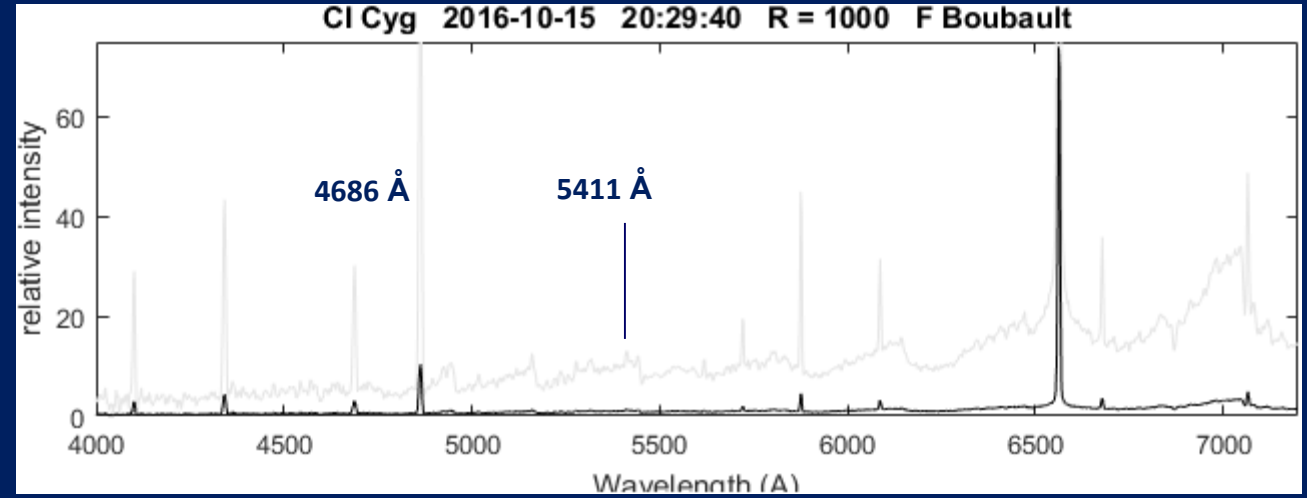
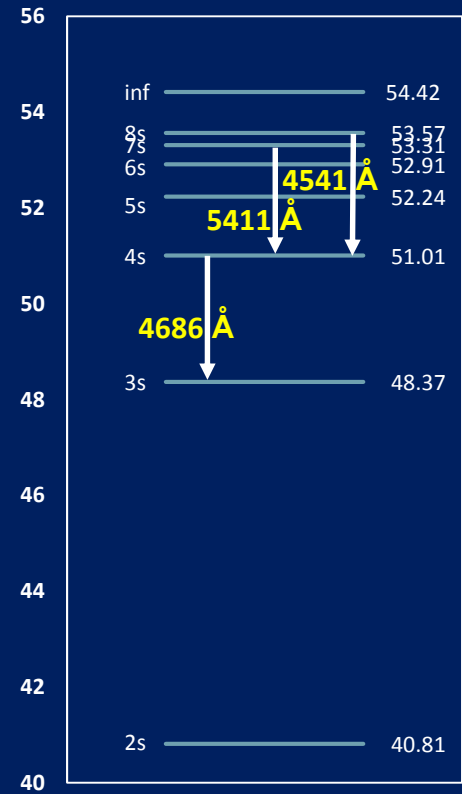
Variations orbitales : CI Cygni



E0 = 2442690
P = 853.8 jours
Fekel & al., 2000

Spectres eshel
F. Teyssier

Recombinaison



Physical conditions from lines: Helium He II

He II / H β ratio

Proxi of the temperature
of the hot component T*

$$T_4 = 19.38 K^{1/2} + 5.13$$

$$K = 2.22 F(\text{He II } 4686) / [4.16 F(\text{H}\beta) + 9.94 F(\text{He I } 4471)]$$

$$T_4 = T / 10\,000$$

$$K \sim 0.53 F(\text{He II } 4686) / F(\text{H}\beta)$$

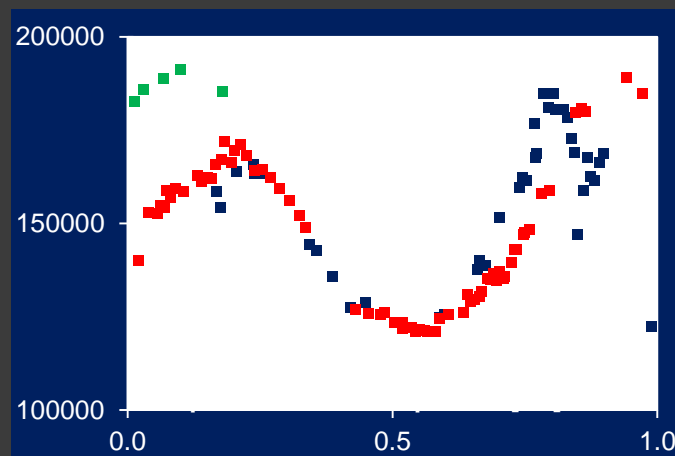
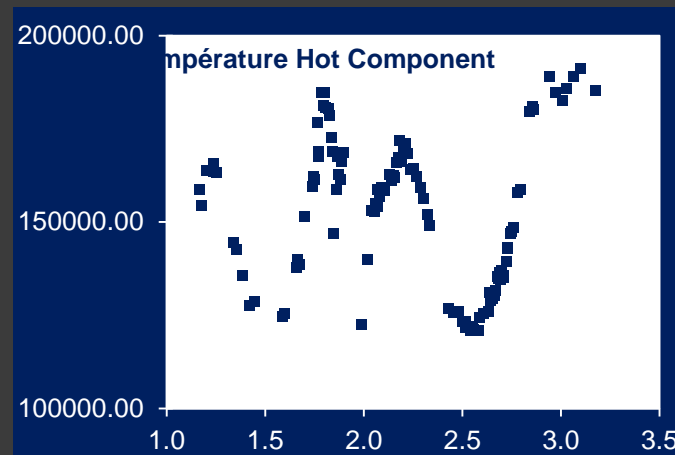
Spectres R = 1000

F. Teyssier

D. Boyd

J. Guarro

CI Cygni 2011-03-19 _ 2015-11-30



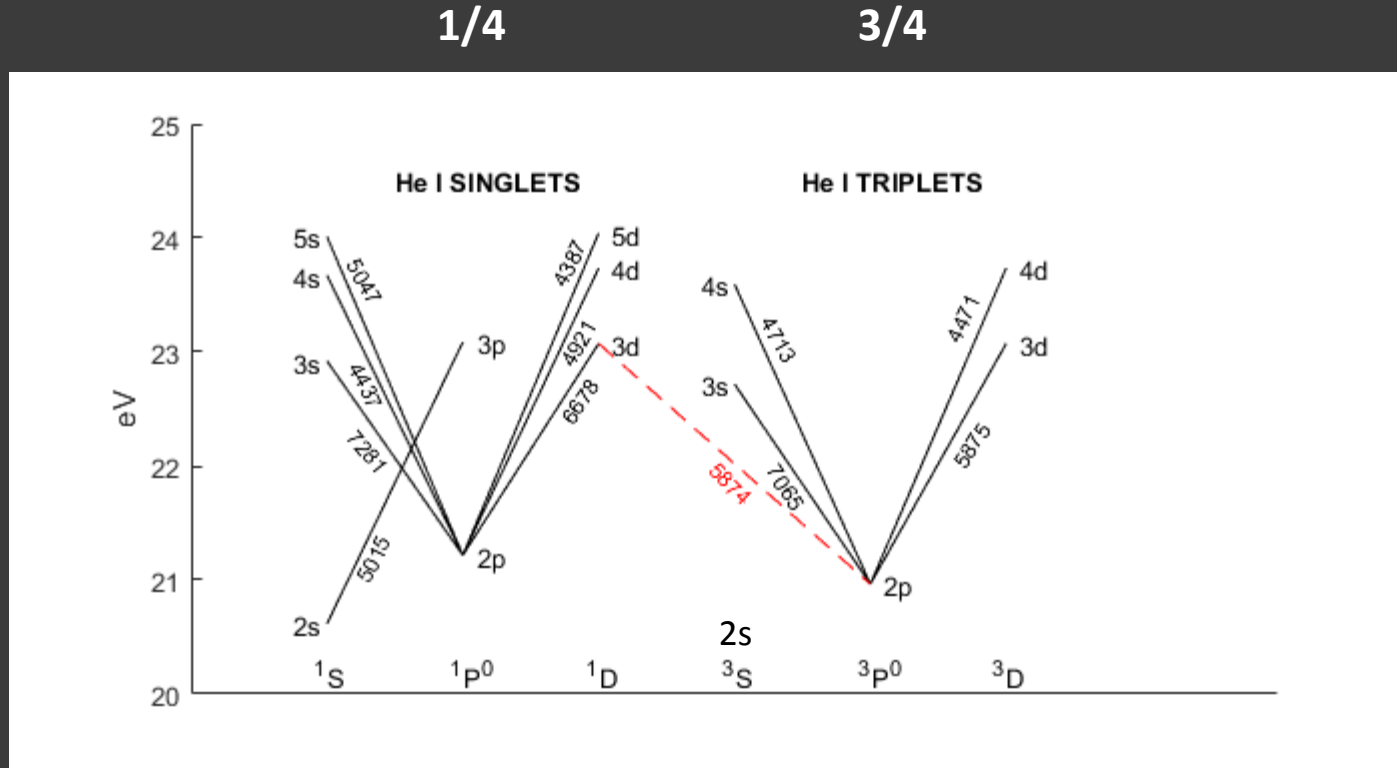
Phase orbitale

P = 853.8 jours

[Fekel & al., 2000]

Diagramme de Grotrian HeI singlets et triplets

Principales raies He I dans le domaine visible



Helium He I

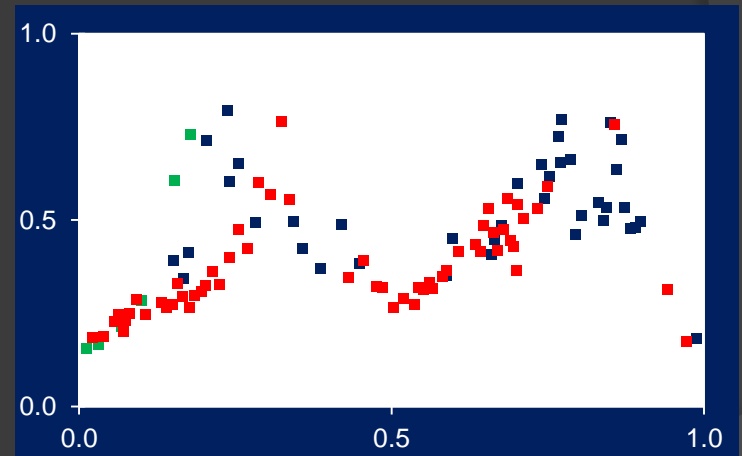
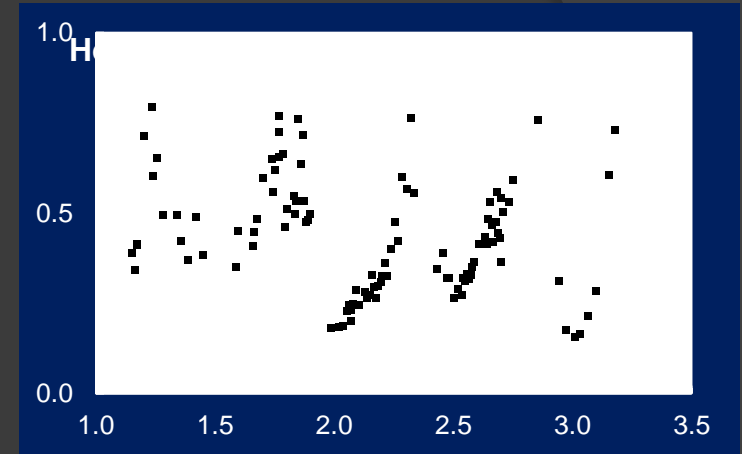
	$\frac{I(6678)}{I(5876)}$	$\frac{I(7065)}{I(5876)}$
Z And	0.57-1.00	0.89-1.07
BF Cyg	0.56-0.95	0.75-1.23
CI Cyg	0.54-0.88	1.00-1.43
AG Dra	0.65-1.14	0.78-0.79
V443 Her	0.86-1.15	0.93-1.20
AG Peg	0.89-1.09	0.73-1.09
AX Per	0.98-1.12	0.80-0.93

Proga & al., 1994

Symbiotiques classiques : $r > 0.5$
Mesure de la densité électronique

CI Cygni

He I 5876 / He I 6678



Phase orbitale

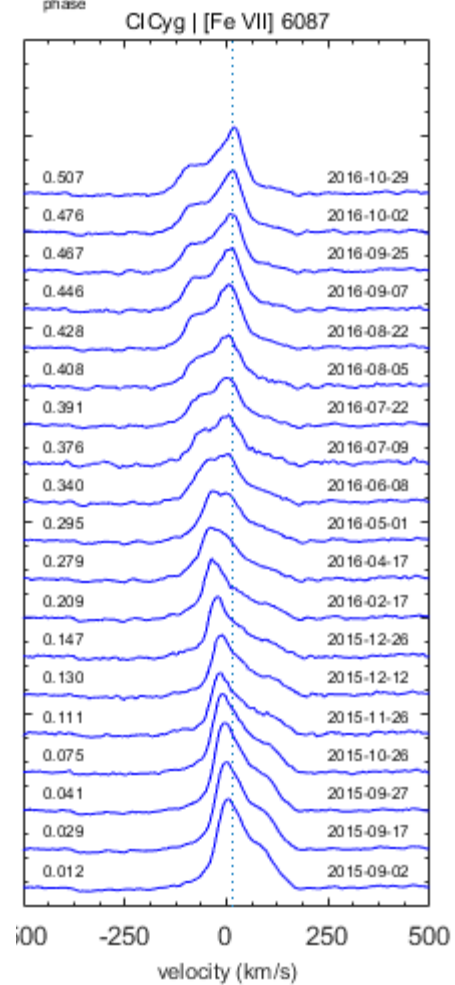
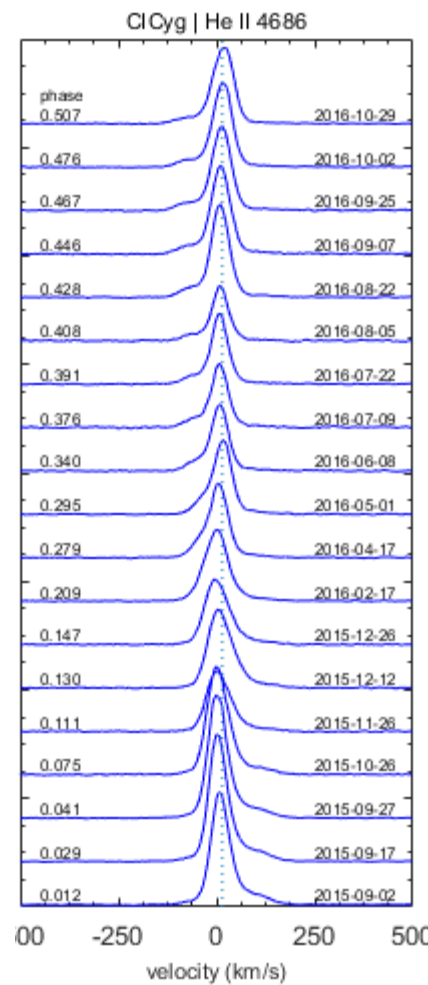
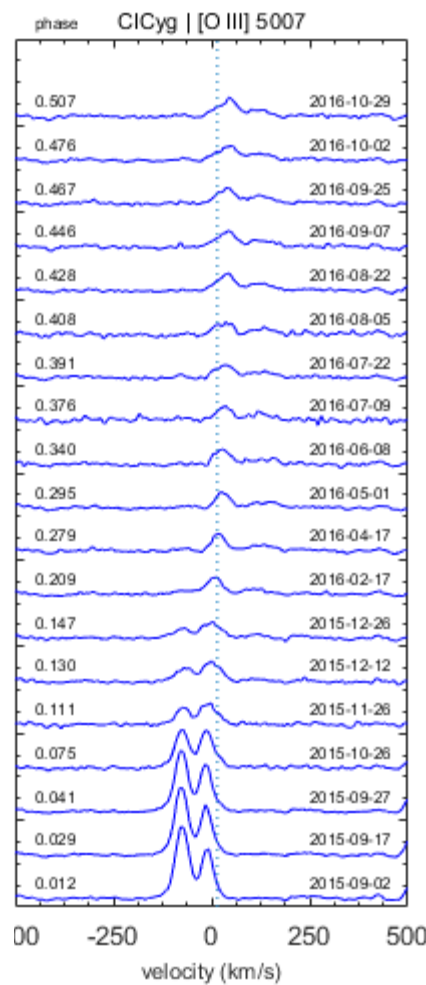
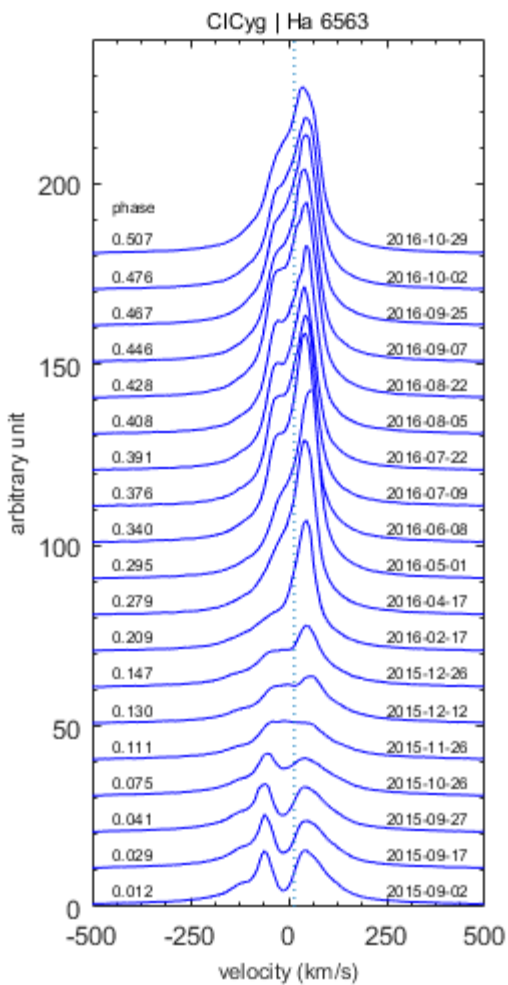
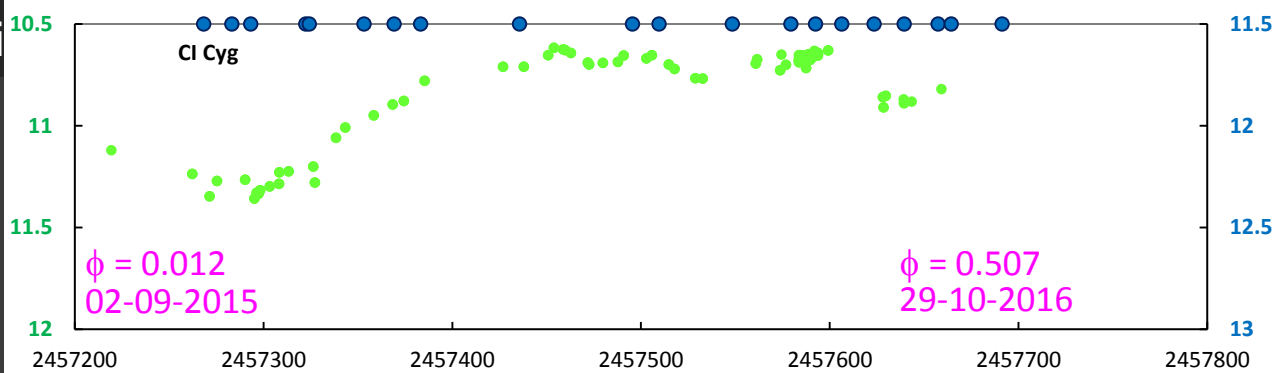
Siviero & Munari, 2003

Proga & al., 1994

Schmid, 1989

Osterbrock, 1989

Variations orbitales : CI Cygni



1 Symbiotic stars

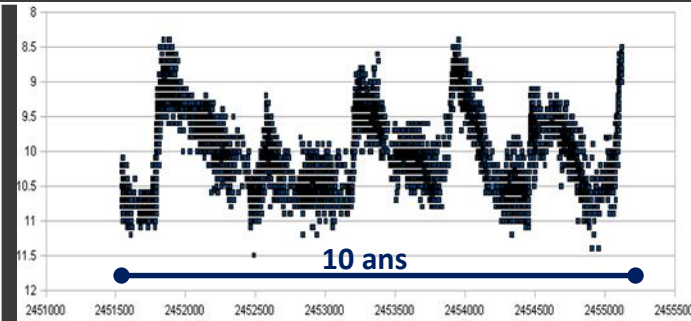
2 Symbiotics in quiescent state

3 Outbursts

4 Amateur contribution

2 types of outbursts

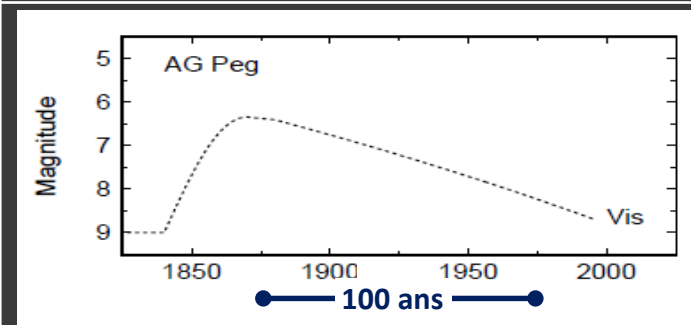
Symbiotic
outburst



Type Z And
Classical symbiotic outburst
Z And, CI Cyg

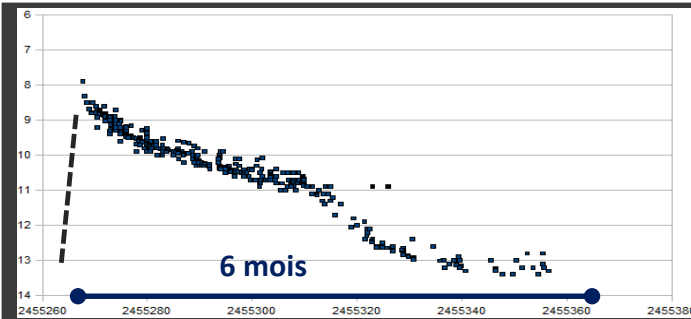
Outbursts d'amplitude moyenne (2-3 mags) parfois en série, espacés de périodes calmes

Nova event



Symbiotic nova
AG Peg, V1016 Cyg, HM Sge

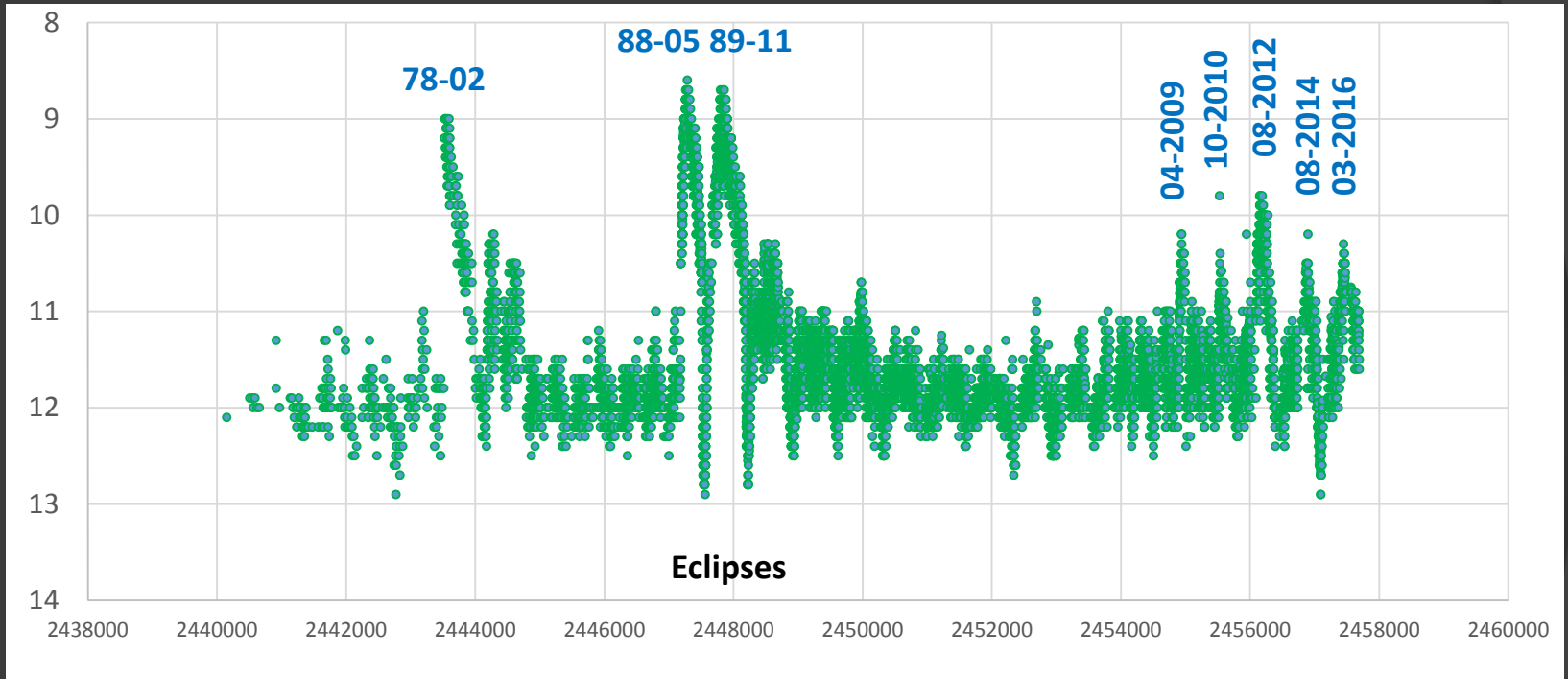
Nova event with ejecta, very slow (tens of years)



Recurrent symbiotic novae
RS Oph, T CrB
Several nova events observed

Symbiotic outburst: AX Per

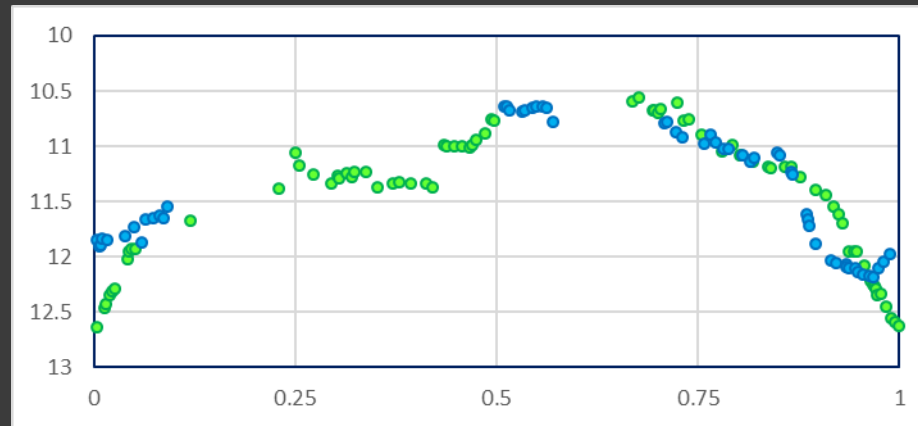
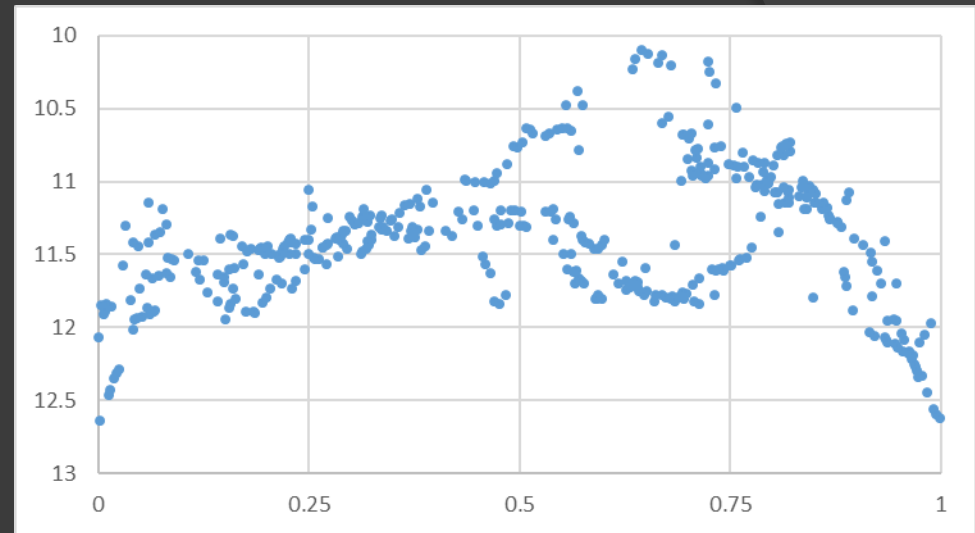
AX Per Luminosity curve V+Vis 1968-2016 – AAVSO (17000 observations)



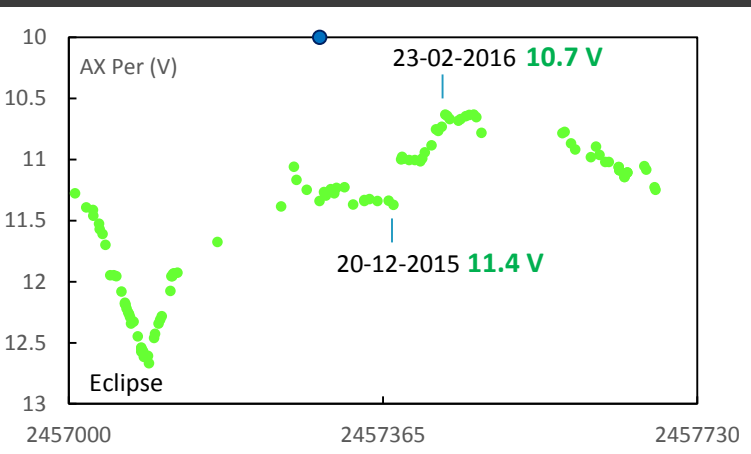
AX Per: Orbital variations

AAVSO
Visual Lightcurve
Since 2002

Ephemeris : Fekel & al., 2000
 $P = 680.8$ days



Outburst AX Per 2015-2016

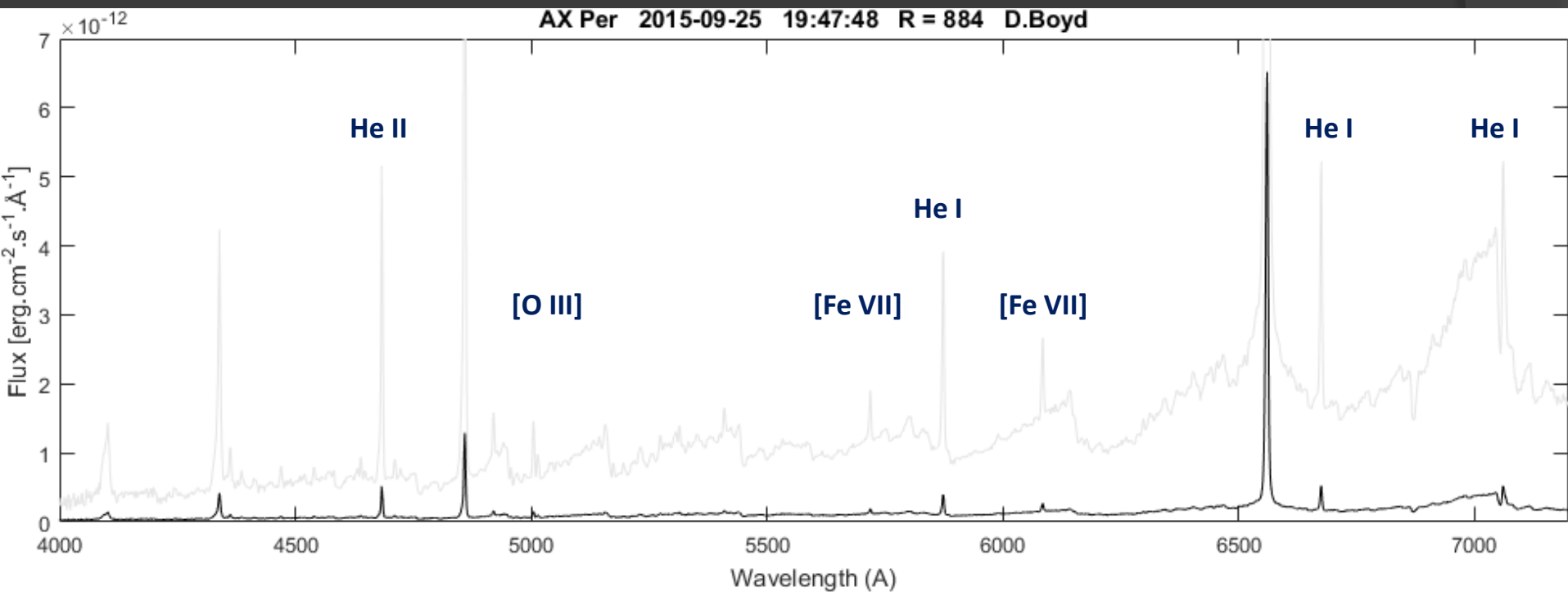


AX Per Quiescent state

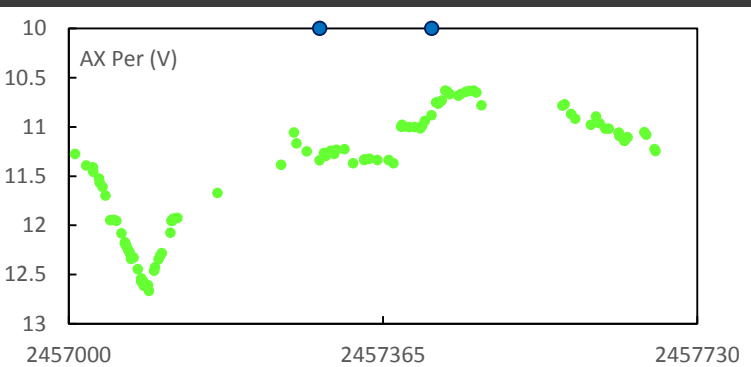
D Boyd

25-09-2016

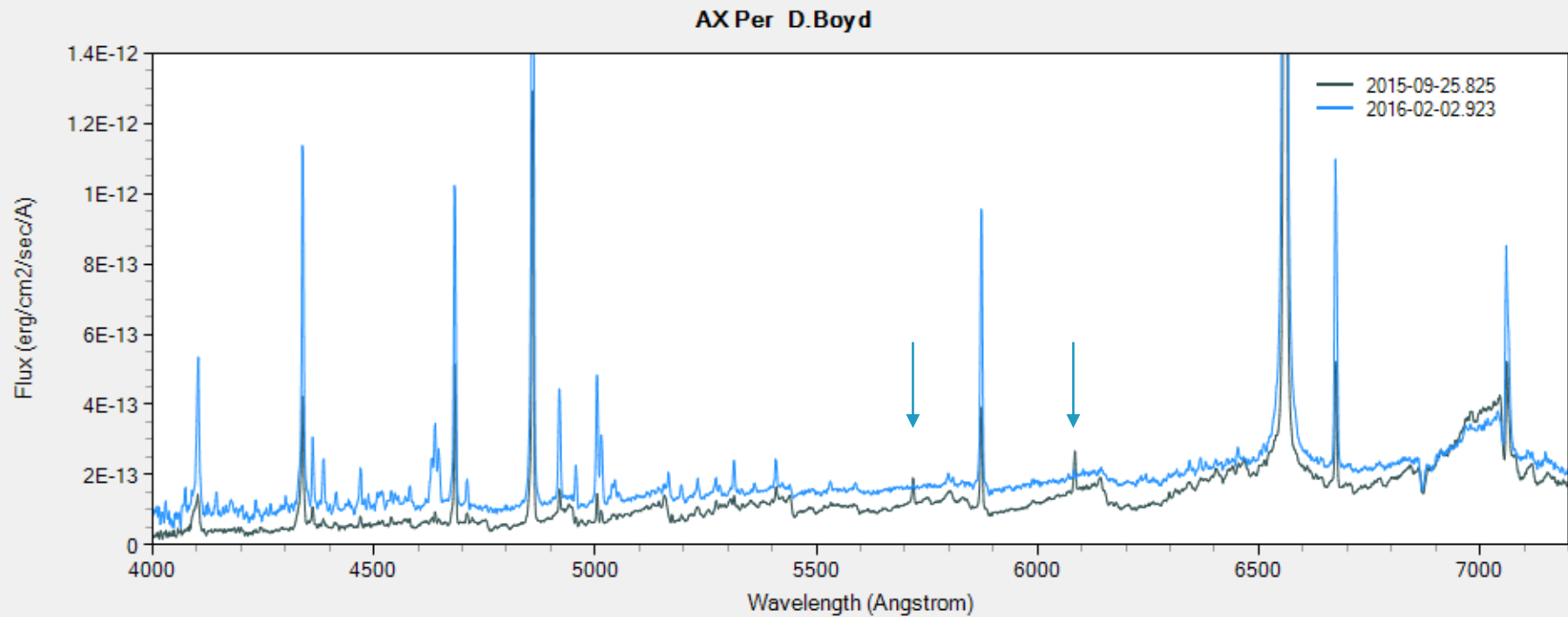
R = 1000 (LISA)



Outburst AX Per 2016



TiO absorption bands ↓
Intensity of emission lines ↑
High ionisation lines ↓



- Decrease of the temperature of the hot component
- Increase of the ionized volume of the nebula

Outbursts of symbiotics are not well understood

Two theories,

- Expansion and cooling of the envelop of the compact star
- Formation of a disk, increasing temperature of the disk

And

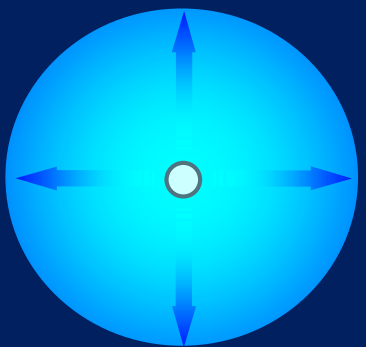
- Combination of the two, for several objects (Example: Z And)
- Cool and hot outburst for other ones (such as AG Dra)

Un modèle
Expansion enveloppe

Naine Blanche

Etat calme

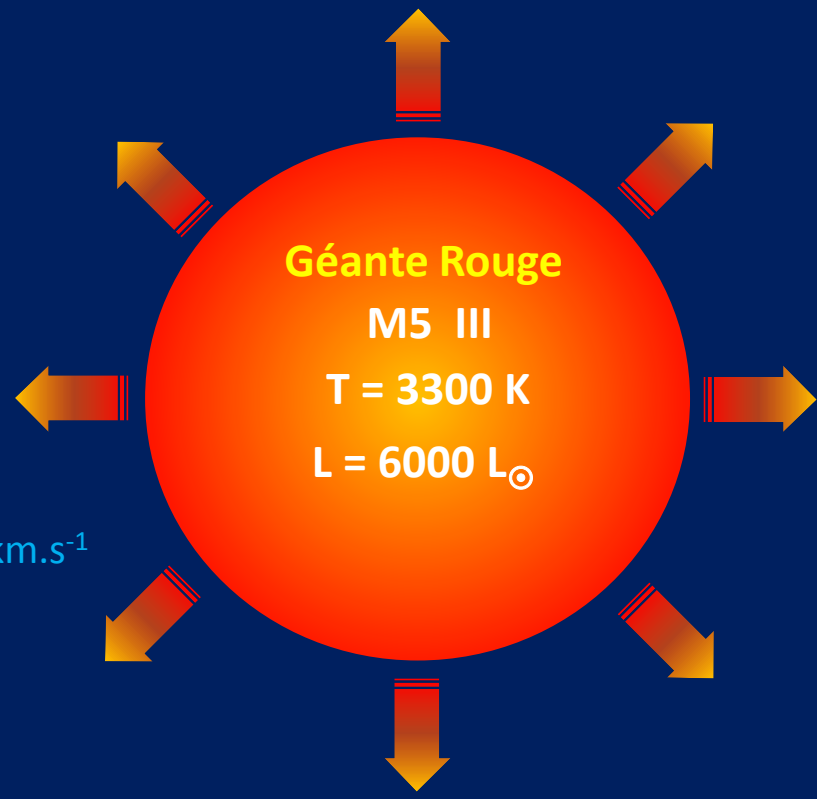
125 000 K
 $R = 0.06 R_{\odot}$
 $L = 560 L_{\odot}$



Outburst

6900 K
 $R = 28 R_{\odot}$
 $L = 15000 L_{\odot}$

$V_r = +15 \text{ km.s}^{-1}$
 $E_{B-V} = 0.4$



Géante Rouge
M5 III
T = 3300 K
L = 6000 L_⊙

P = 855 jours

Un modèle
Formation d'un disque d'accrétion

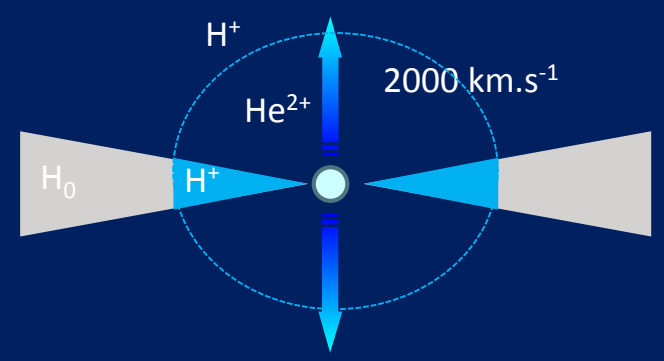
Nébuleuse

$T_e = 15\ 000\ K$
 $N = 6-9 \cdot 10^9\ cm^{-3}$

$d = 1-5\ U.A.$

Vent Stellaire
 $\dot{M}' = 3 \cdot 10^{-6}\ M_{\odot}/an$

$\dot{M}' = 2-3 \cdot 10^{-6}\ M_{\odot}/an$



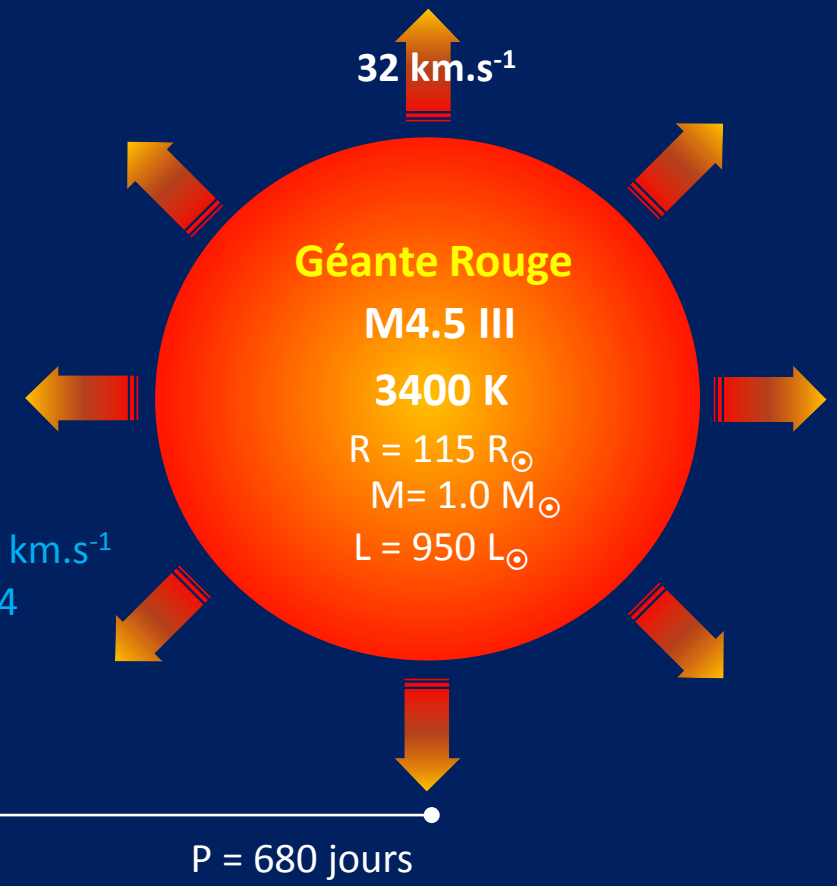
Naine Blanche

$110\ 000\ K$
 $R = 0.018\ R_{\odot}$
 $M = 0.4\ (0.1)\ M_{\odot}$
 $L = 314\ L_{\odot}$

$V_r = -110\ km.s^{-1}$
 $E_{B-V} = 0.24$

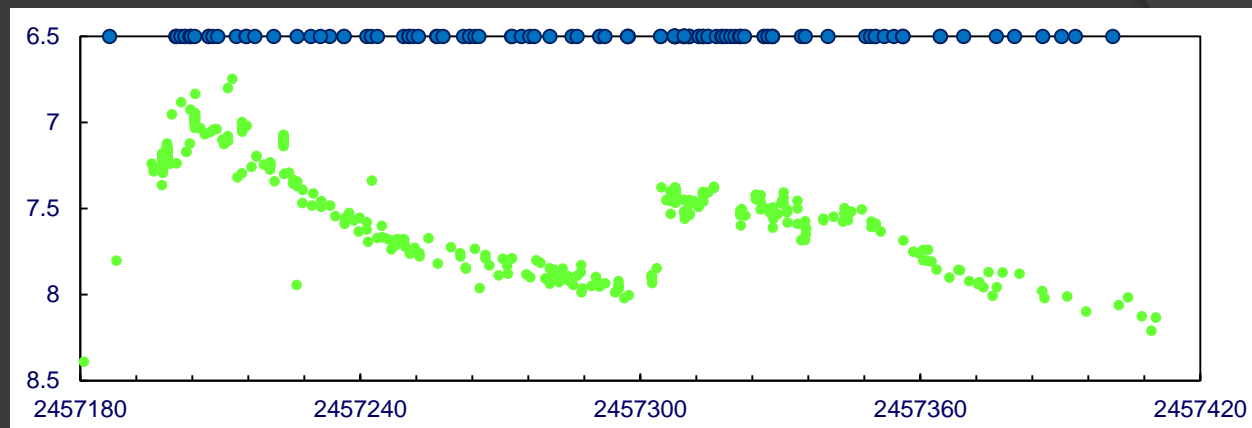
$d = 3.6\ RG$

$d = U.A.$



$P = 680\ jours$

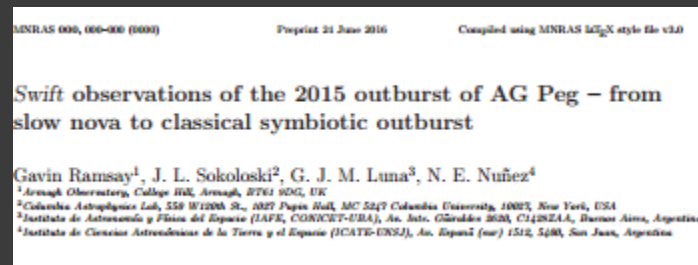
Outbursts symbiotiques AG Peg 2015



Many groups, including amateur astronomers³, have made spectroscopic observations of AG Peg over its outburst. These observations show strong emission lines, including the Balmer series plus He I (6678) and He II (4686), [O III] (4363) and the O vi emission band at 6825 Å, which is due to Raman scattering. A full analysis of the optical spectra made over the course of the outburst is beyond the scope of this work, but we were able to estimate the effective temperature of the ionizing source using the He II (4686) and H β lines and the formula of Iijima (1981) (quoted in Sokoloski et al. 2006) which derives the effective temperature using the equivalent width (EW) of these lines (we ignore the He I (4471) line since it is much weaker than He II and H β). We used spectra taken by amateur astronomers⁴ which covered the He II (4686) and H β lines to derive their EW (we estimated that the error on the EW measurements was ~ 10 percent by making a number of measurements of the same line).

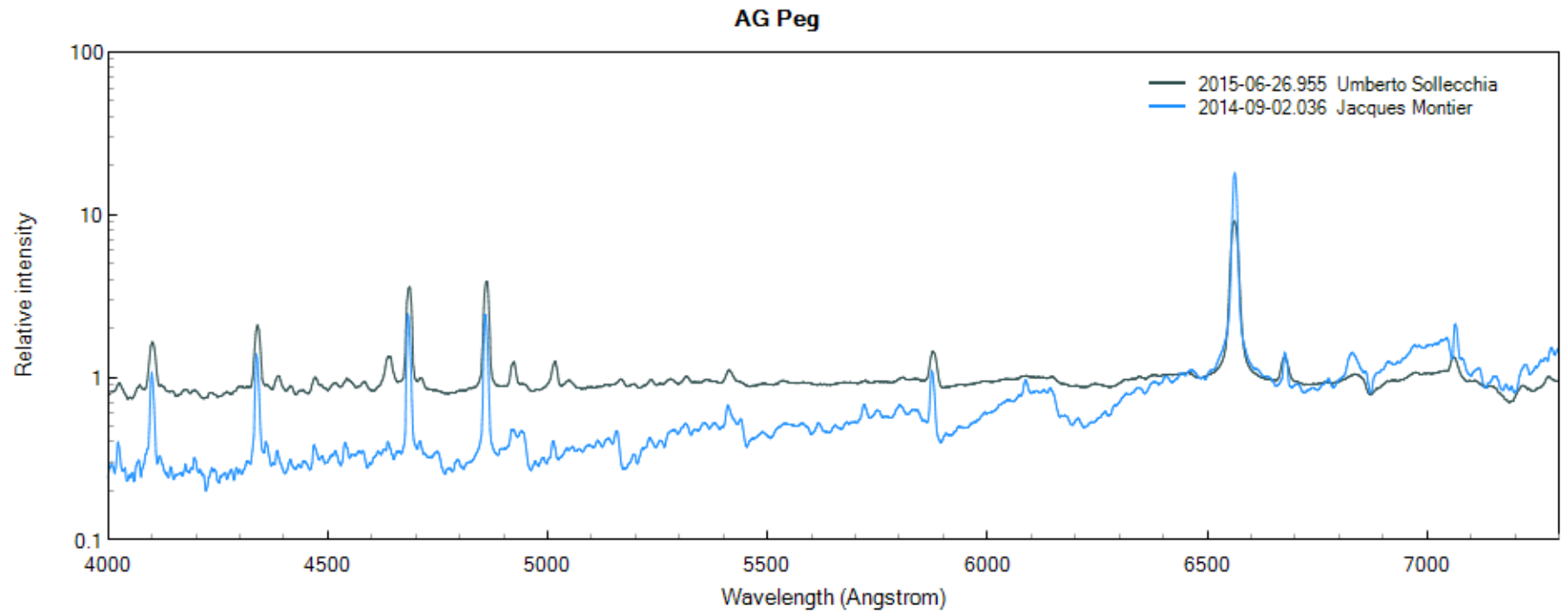
³ e.g. <http://www.astronomie-amateur.fr>

⁴ http://www.astrosurf.com/aras/Aras_DataBase/Symbiotics/AGPeg.htm

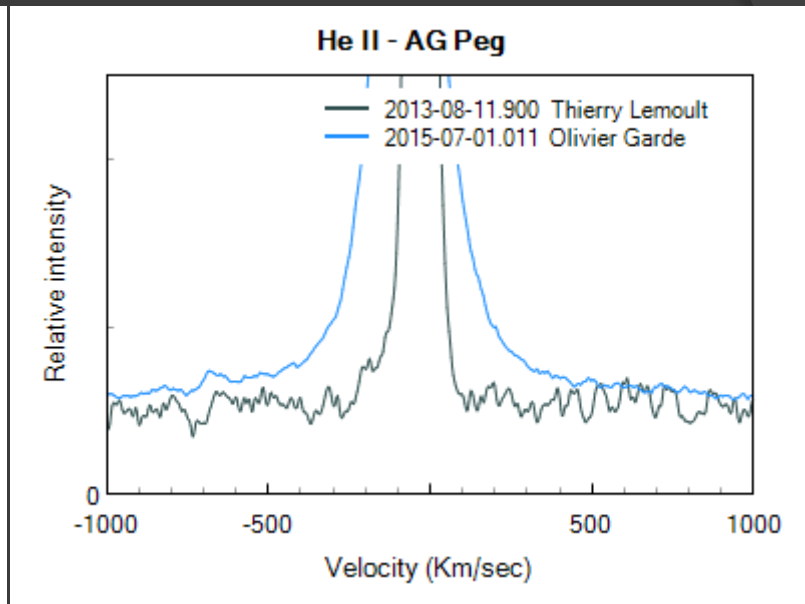
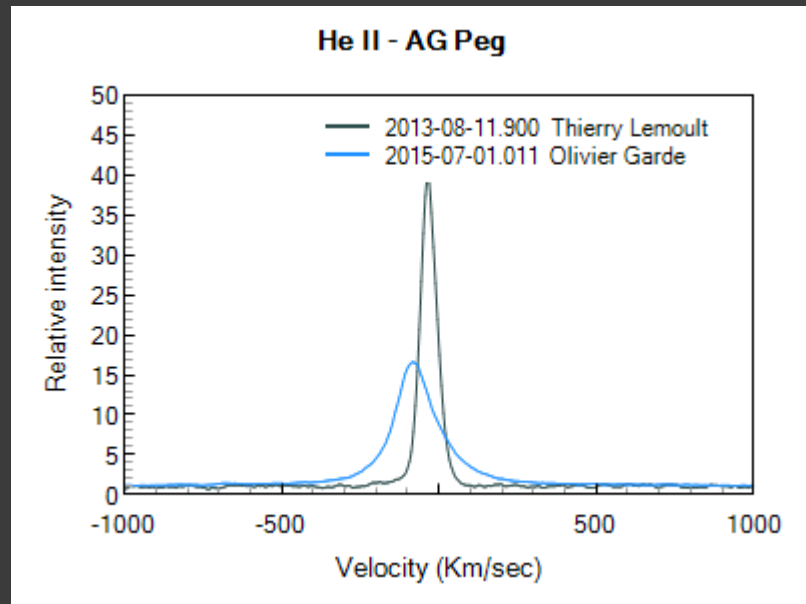


. We also thank François Teyssier for altering us to the many amateur spectroscopic observations which have been made and we acknowledge and thank François Teyssier, Umberto Sollecchia, Joan Guarro Flo, Jacques Montier, Peter Somogyi, Keith Graham and V Bouttard for use of their spectra.

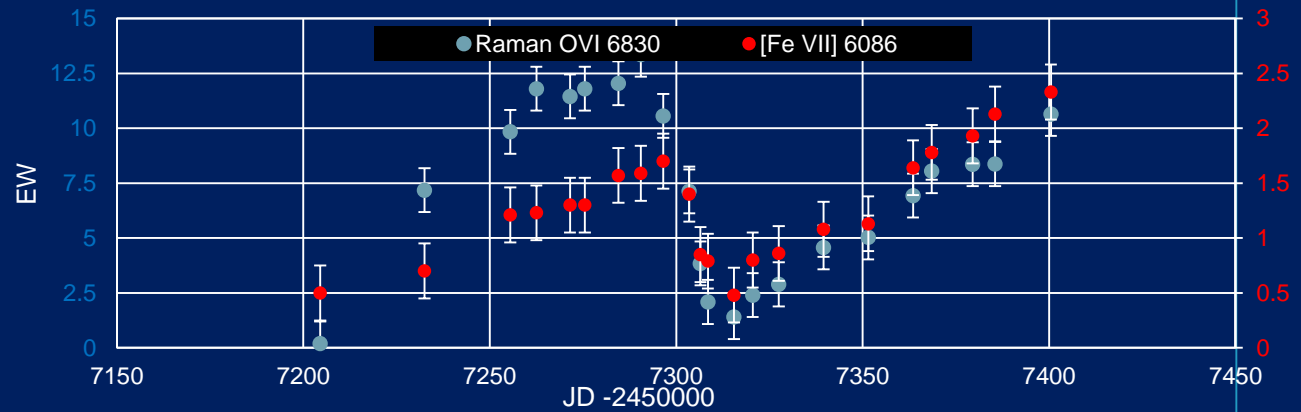
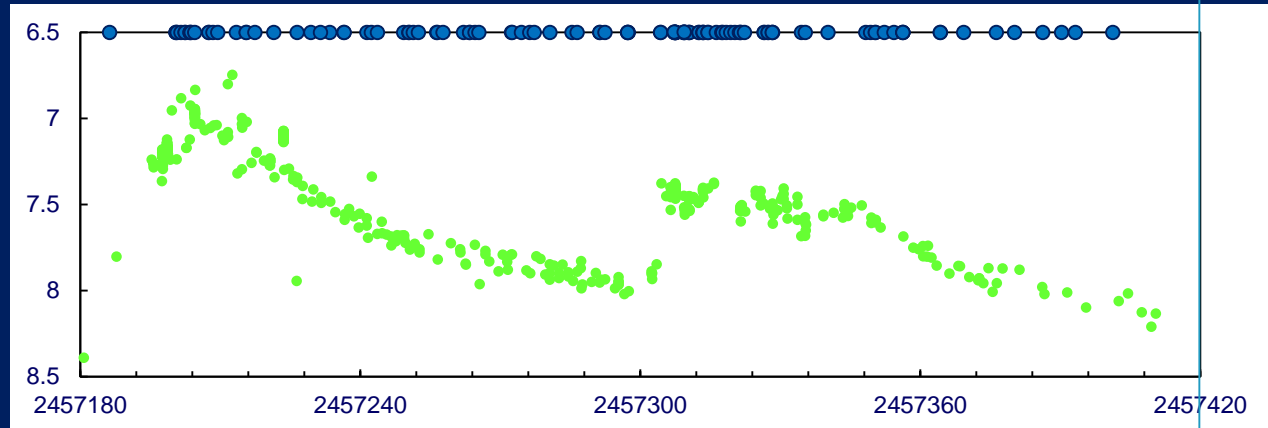
Outbursts symbiotiques AG Peg 2015



Outbursts symbiotiques AG Peg 2015



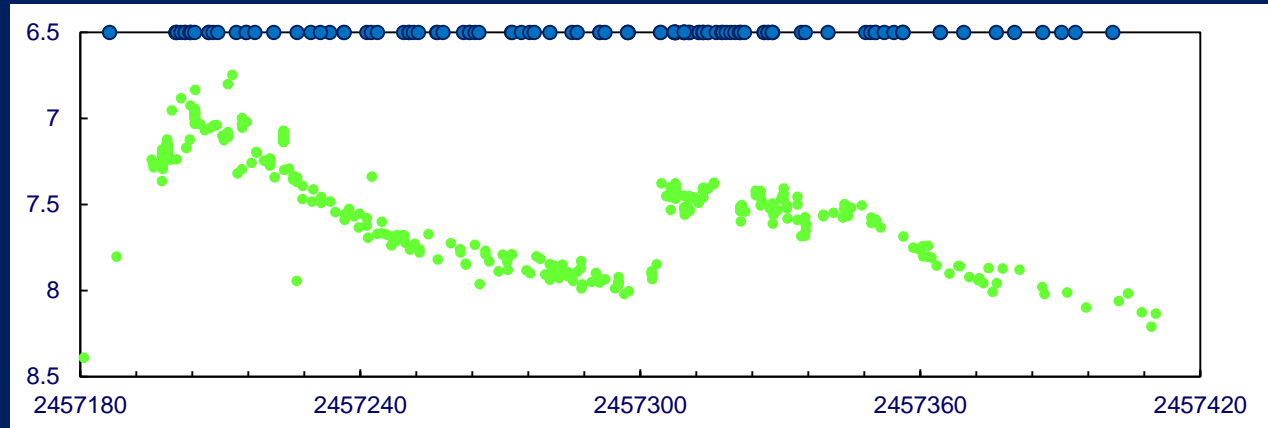
Outbursts symbiotiques AG Peg 2015



F. Teyssier
J. Guarro
O. Garde
K. Graham
T. Lester
V. Bouttard
T. Lemoult
U. Sollecchia
J. Montier
D. Boyd

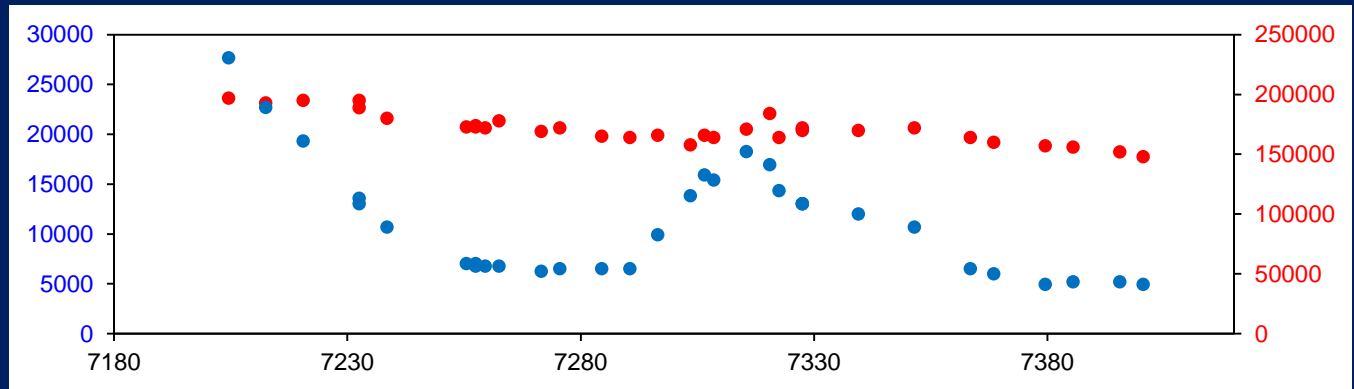
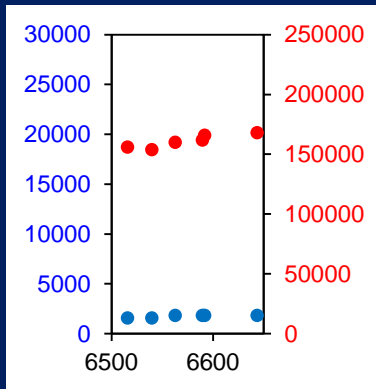
Outbursts symbiotiques AG Peg 2015

AAVSO V band light curve
And ARAS Observations



Luminosity [L_{\odot}]

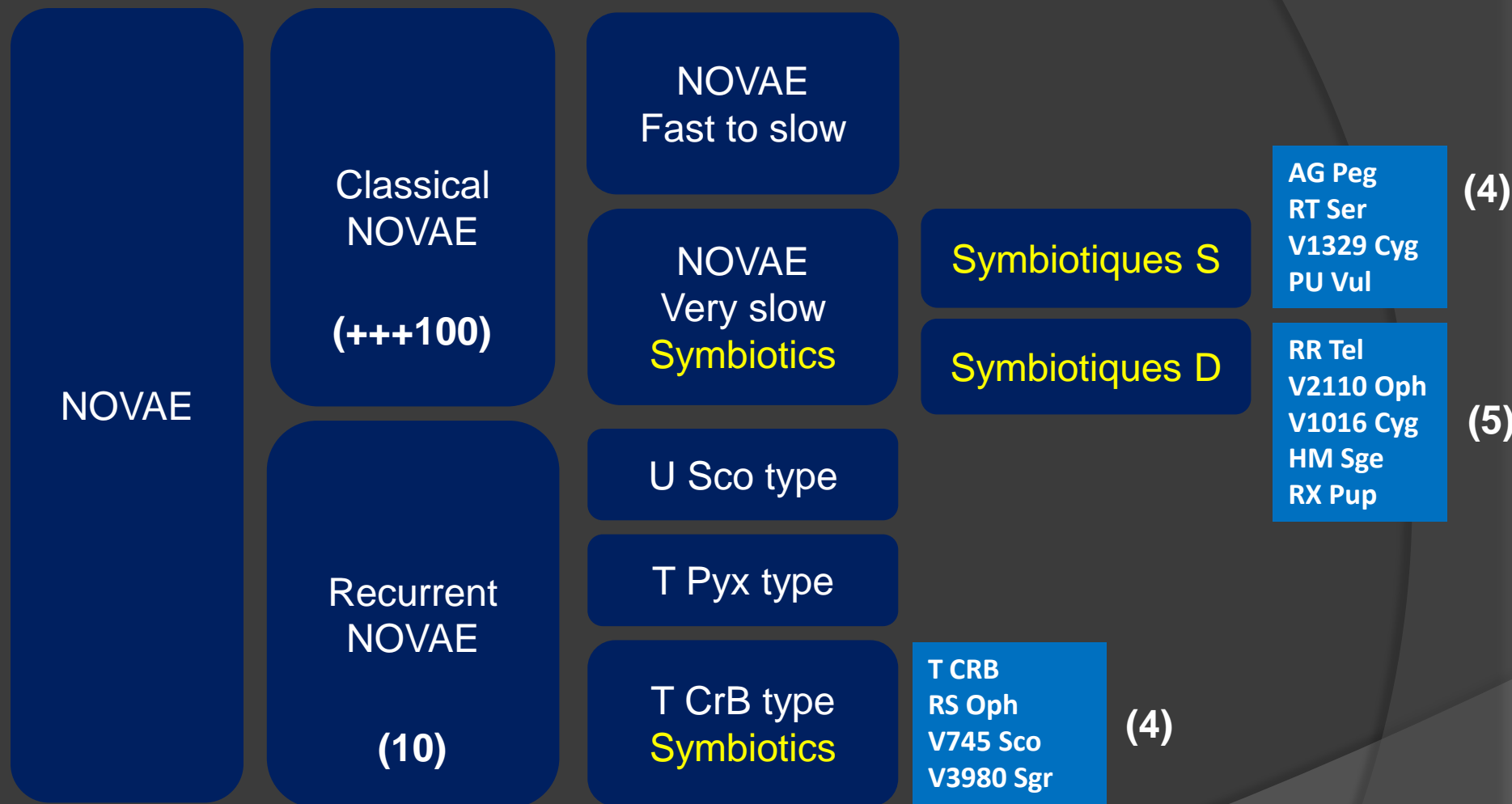
Température [K]



Accepted in Astronomy and Astrophysics

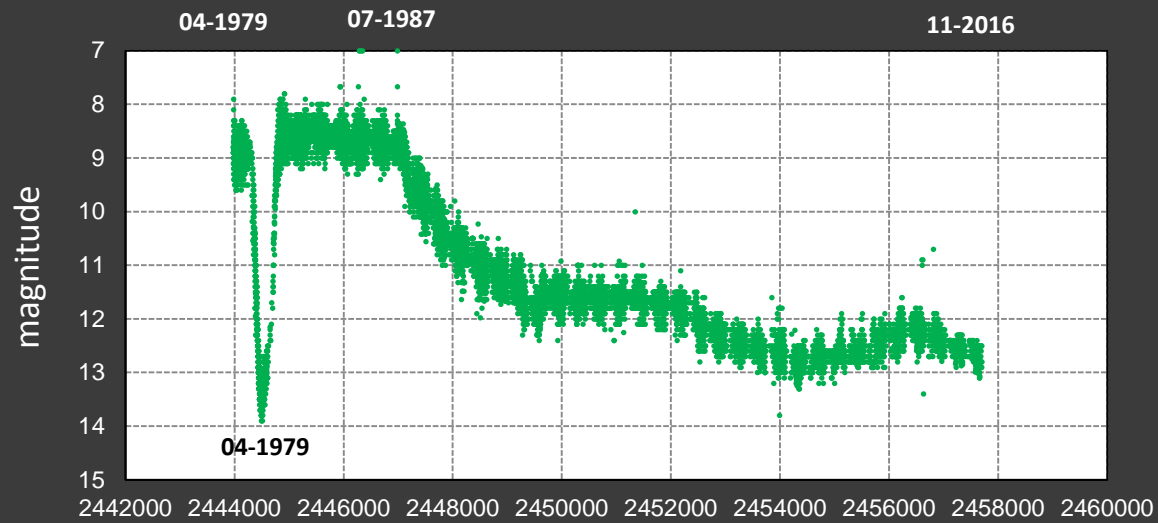
New outburst of the symbiotic nova AG Peg after 165 years

A. Skopal¹, S. Yu. Shugarov^{1,2}, M. Sekeráš¹, M. Wolf³, T. N. Tarasova⁴, F. Teyssier⁵, M. Fujii⁶, J. Guarro⁷, O. Garde⁸,
K. Graham⁹, T. Lester¹⁰, V. Bouillard¹¹, T. Lemoult¹², U. Solliecchia¹³, J. Montier¹⁴, and D. Boyd¹⁵

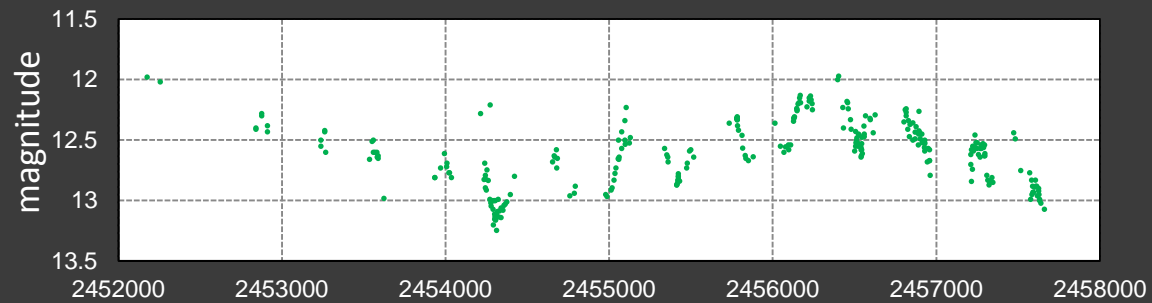


Références Allen 1980
Mürset & Nussbaumer 1994
Munari 1997
Mikolajewska 201

Novae Symbiotiques PU Vul



AAVSO
V + Vis.
LightCurve

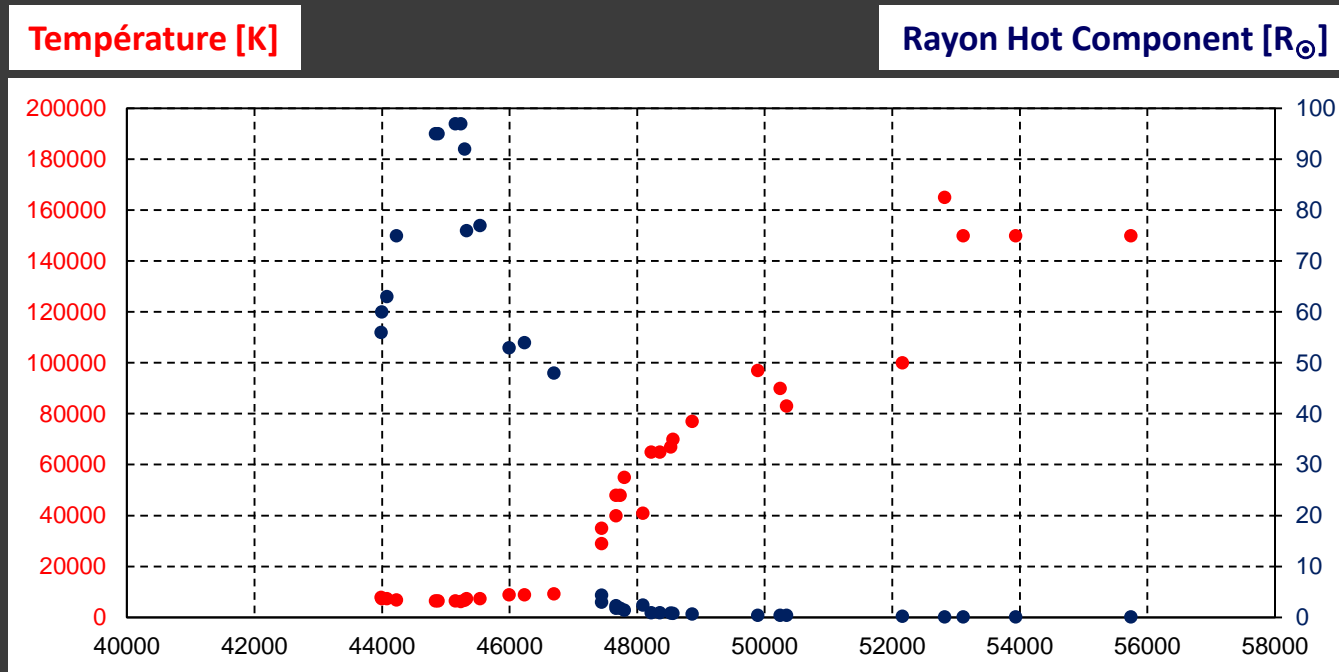


Variations orbitales AAVSO V

Novae Symbiotiques PU Vul

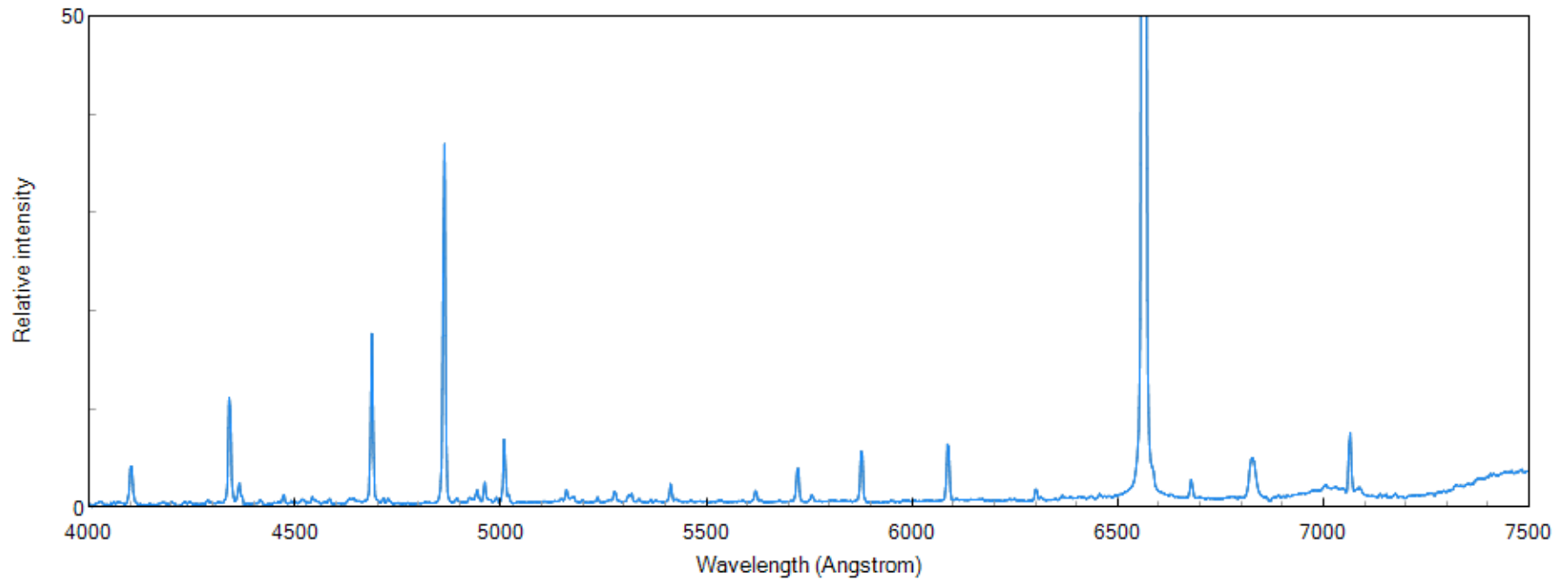
Evolution of the Symbiotic Nova PU Vul

Kato & al., 2012

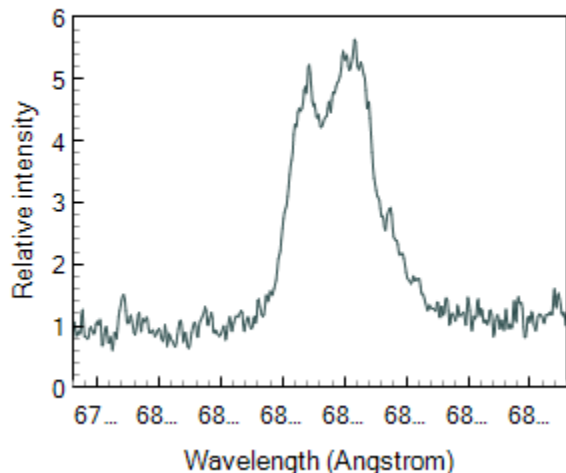


Novae Symbiotiques PU Vul

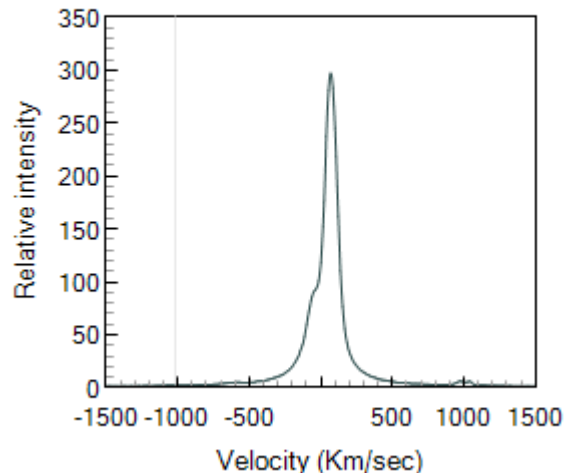
PUVul 2014-11-05.877 R = 1000 D.Boyd



Raman OIV - PUVul 2016-09-03.041 T Lester



Halpha - PUVul 2016-09-03.041 T Lester



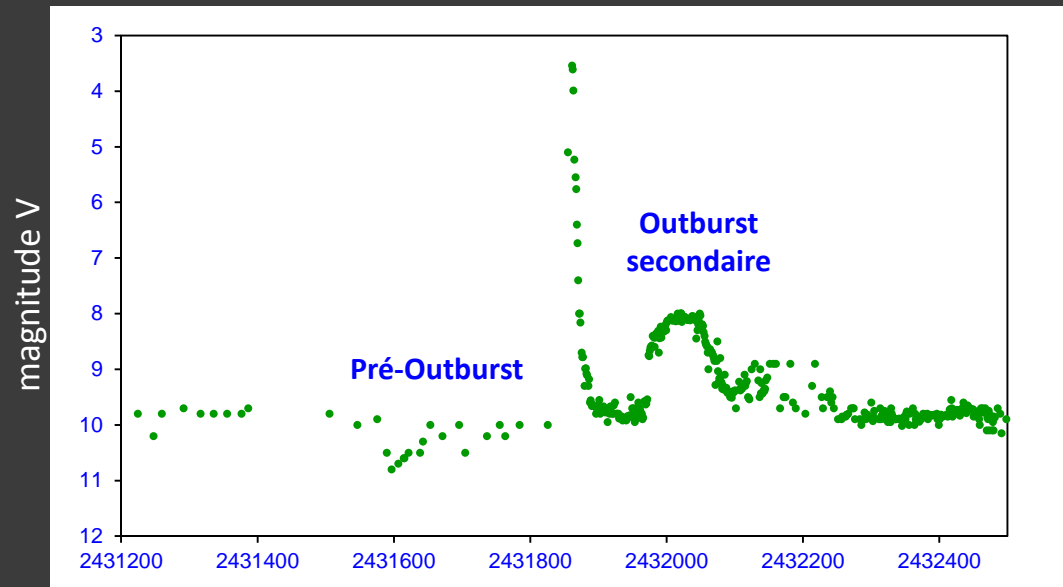
T CrB Eruptions

1866

1946

2026 ?

1946



Active phases and flickering of a symbiotic recurrent nova T CrB

Krystian Bkiewicz,^{1*} Joanna Mikolajewska,¹ Kiril Stoyanov,²
Antonios Manousakis³ and Brent Miszalski^{3,4}

¹Nicolaus Copernicus Astronomical Center, Barteldo 18, 00716 Warsaw, Poland

²Institute of Astronomy and National Astronomical Observatory, Bulgarian Academy of Sciences, Tsingardzha Street 72, 800-1794 Sofia, Bulgaria

³South African Astronomical Observatory, PO Box 9, Observatory, 7935, South Africa

⁴Southern African Large Telescope Foundation, PO Box 9, Observatory, 7935, South Africa

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We are grateful to all of the amateur astronomers that contributed their observations to this paper. In particular, we are thankful to members of the ARAS group for their wonderful work. We acknowledge with thanks the variable star observations from the AAVSO International Database

S. Charbonnel
F. Teyssier
C. Buil
T. Lester
C. Revol
JP Masviel
J. Montier
D. Boyd
J. Guarro
K. Graham
M. Rodriguez
P. Somogyi
O. Garde
P. Berardi
D. Li
V. Bouttard

Spectroscopic observations were obtained from the Astronomical Ring for Access to Spectroscopy database (ARAS). A log of observations is presented in Table A1. The data include mainly low resolution spectra covering a wide spectral range.

Voir aussi :

The 2015 super-active state
of recurrent nova T CrB
and the long term evolution after the 1946 outburst
Munari & al., 2016

Active phases and flickering of a symbiotic recurrent nova T CrB

Krystian Bkiewicz,^{1*} Joanna Mikolajewska,¹ Kiril Stoyanov,²
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¹Nicolaus Copernicus Astronomical Centre, Bartyla 18, 80716 Warsaw, Poland

²Institute of Astronomy and National Astronomical Observatory, Bulgarian Academy of Sciences, Tsarigradsko Shosse, Sofia, Bulgaria

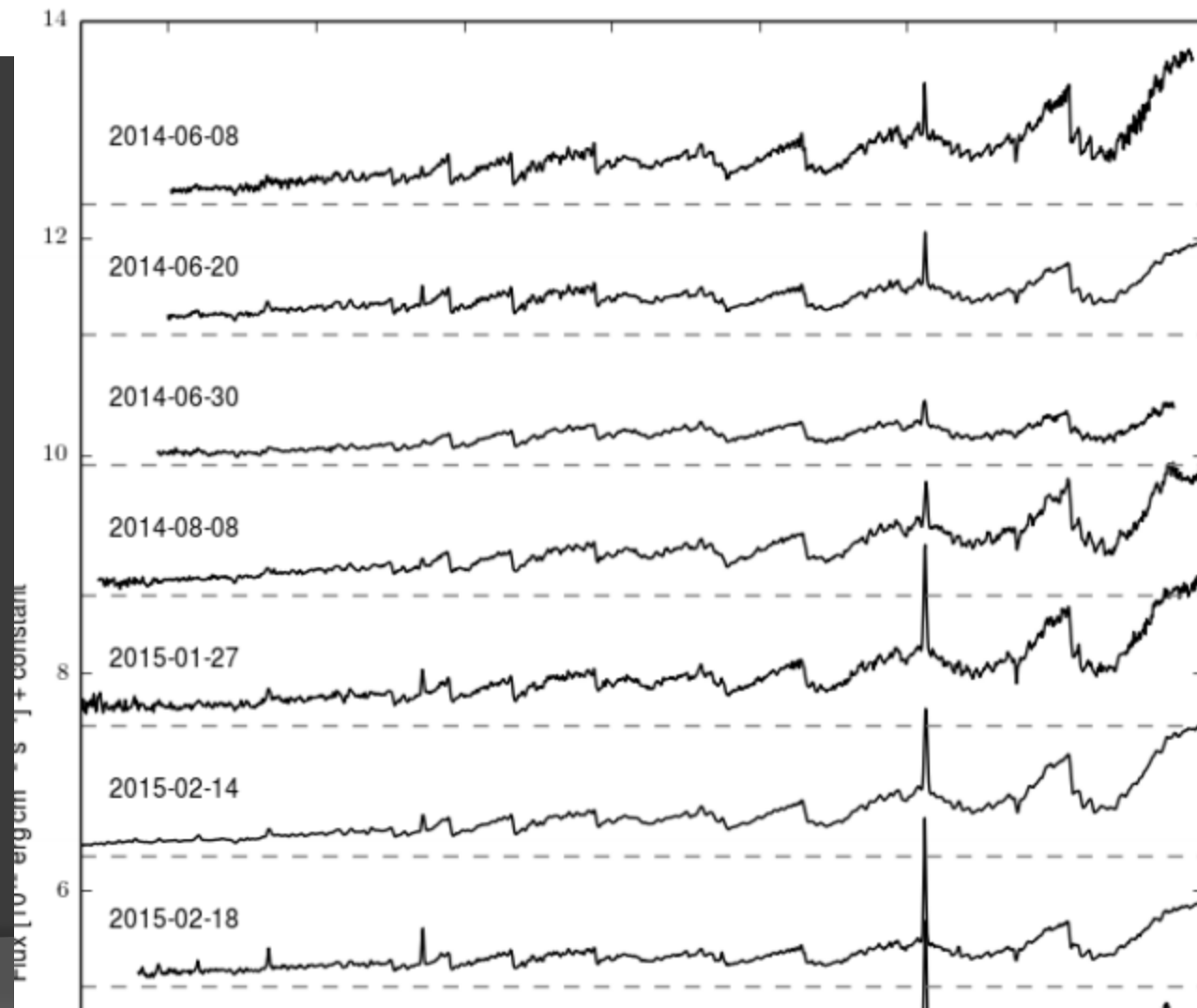
³South African Astronomical Observatory, PO Box 9, Observatory, 7935, South Africa

⁴Southern African Large Telescope Foundation, PO Box 8, Observatory, 7935, South Africa

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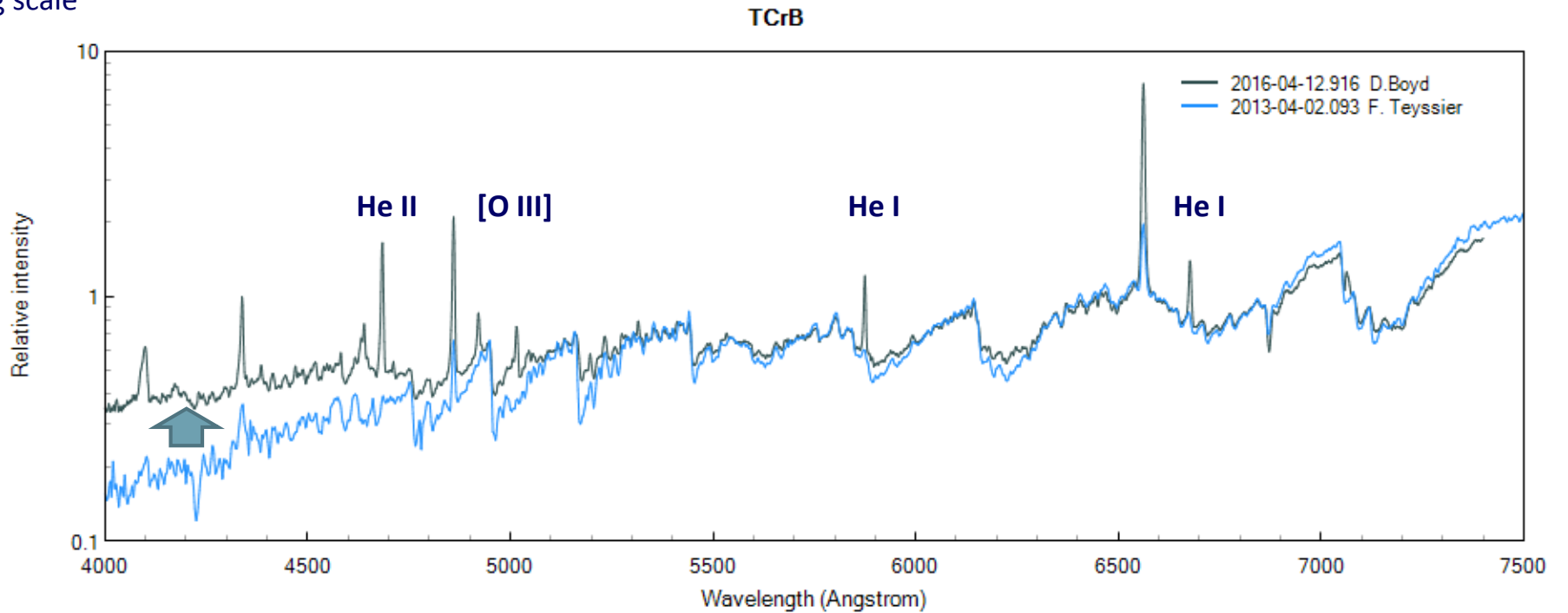
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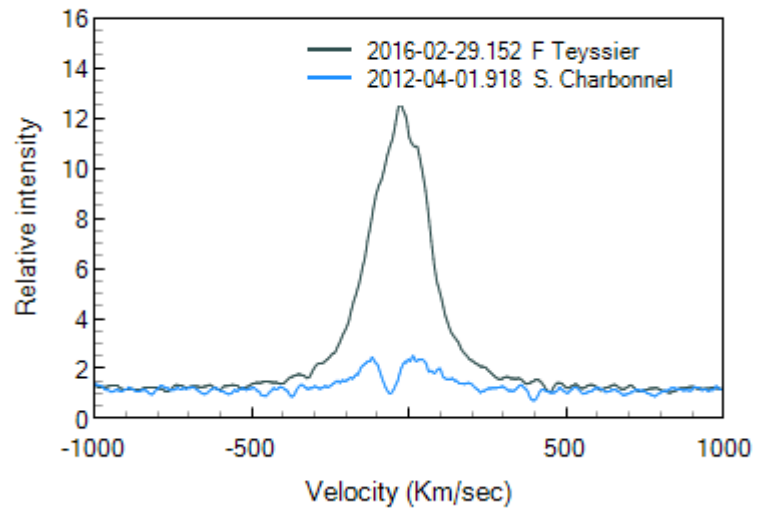
Novae Récurrentes Symbiotiques T CrB

Log scale

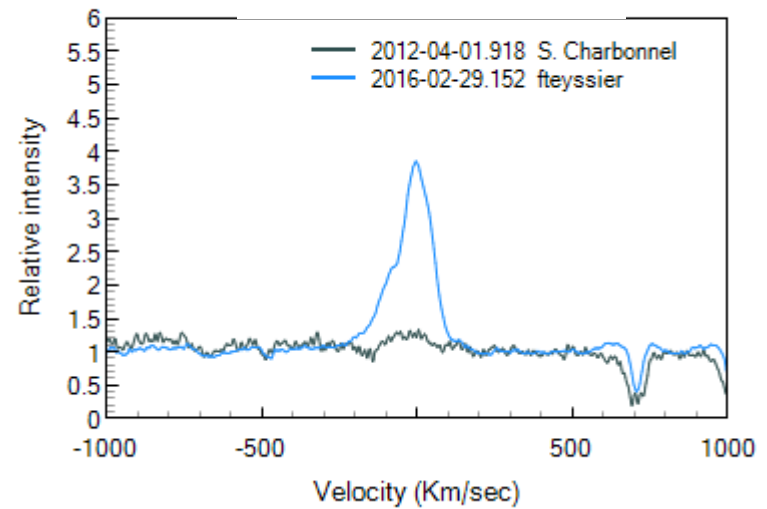


Novae Récurrentes Symbiotiques T CrB

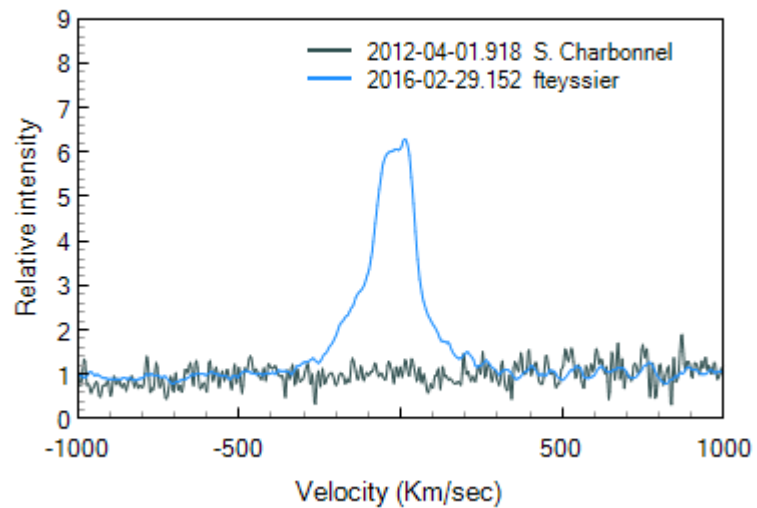
TCrB H alpha



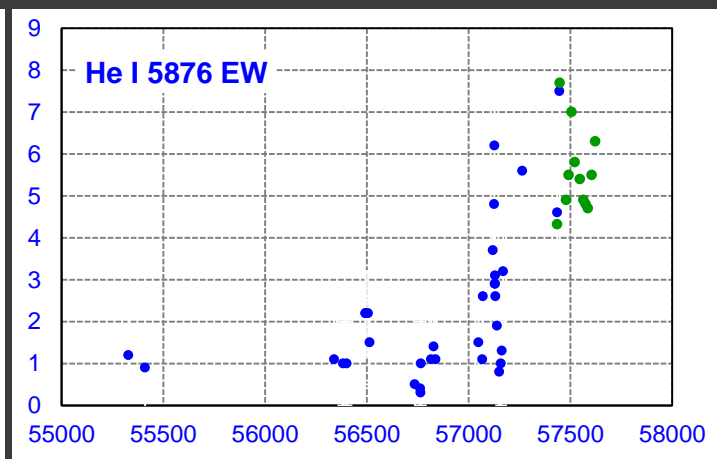
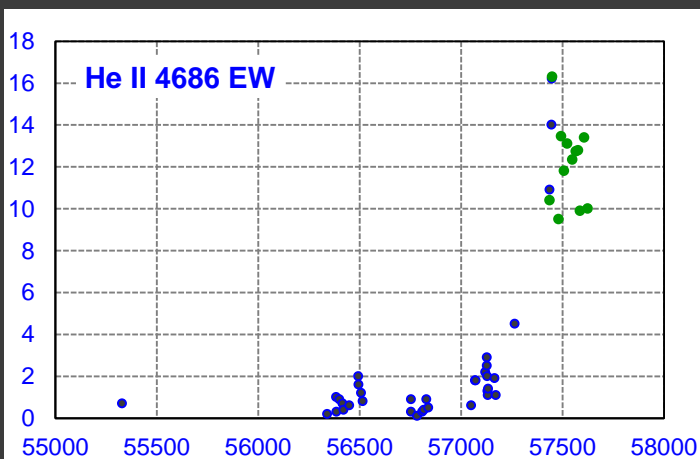
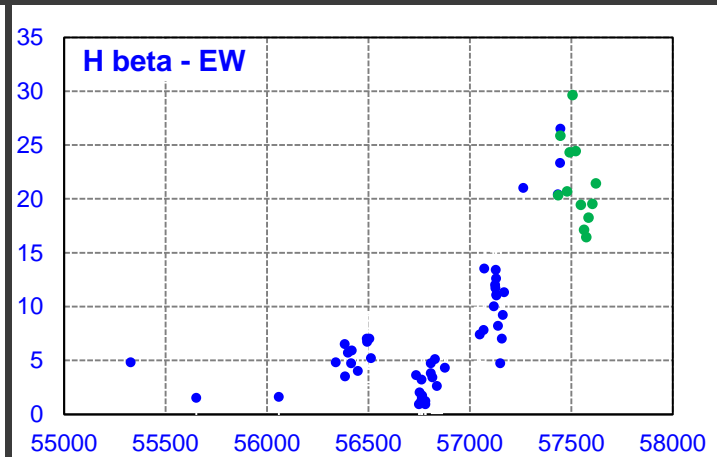
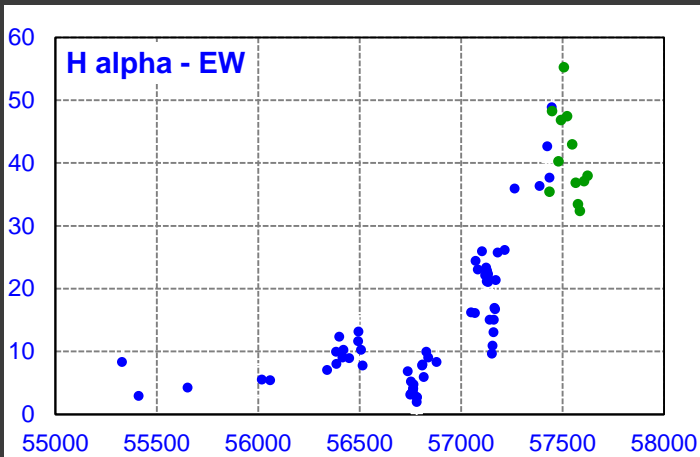
TCrB HeI 5876



TCrB HeII 4686



Novae Récurrentes Symbiotiques T CrB



Blue : mesures publiées (Liliczki & al., 2016)

Vert : mesures ARAS 2016

1 Symbiotic stars

2 Symbiotics in quiescent state

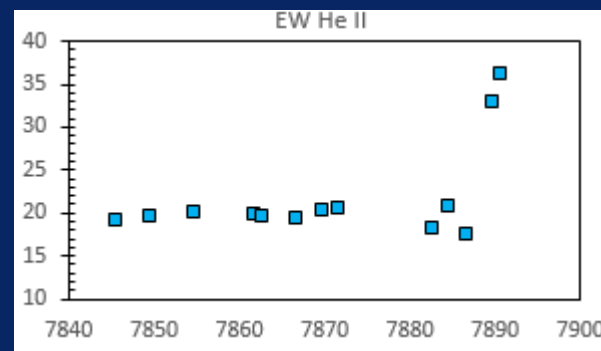
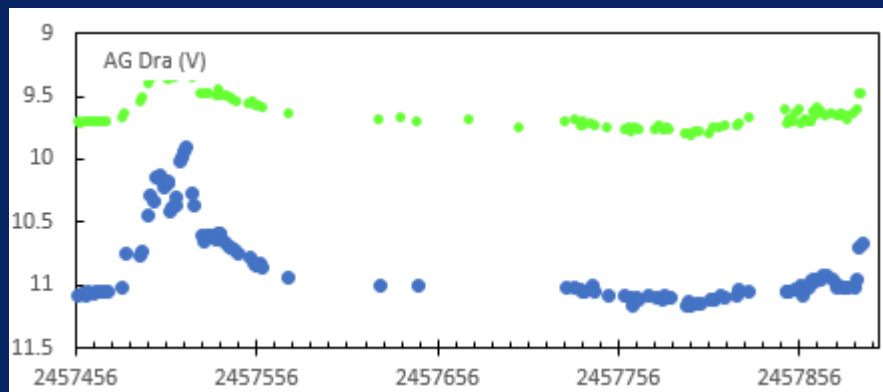
3 Outbursts

4 Amateur contribution

AG Dra

Monitoring of an outburst (ongoing)

R. Gàlis, L. Leedjarv, J. Merc



CH Cygni

Long term monitoring of a complex symbiotic
(Disk activity)

A. Skopal
M. Karaskova

SU Lyn

Study of a bright newly discovered symbiotic
(Orbital variations)

K. Drozd

T CrB

Monitoring of the recurrent nova in high state
Before the next nova event

Merrill, 1958

L. H. Aller has made a suggestion which I heartily endorse, namely, that important information could be obtained from systematic series of measurements of *absolute* intensities of certain spectral features. This is not easy in observations through a slit, but with normal photometric precautions useful accuracy could doubtless be achieved on slitless spectrograms. Accurate photometric measures of integrated brightness and color also would be highly useful and could easily be made with small telescopes.

Persistent observations, both spectroscopic and photometric, for 5 or 10 years of the brighter symbiotic stars would surely help us understand their mysterious behaviour and might develop ideas of considerable general interest.

Reactivity

Long term monitoring at high cadency

... more data are needed, both photometry and spectroscopy

You're welcome!

[www.astronomie-amateur.fr/Projets Spectro1 SySt.html](http://www.astronomie-amateur.fr/Projets_Spectro1_SySt.html)

Eruptive stars information letter

<http://www.astrosurf.com/aras/novae/InformationLetter/InformationLetter.html>

Forum ARAS

<http://www.spectro-aras.com/forum/>



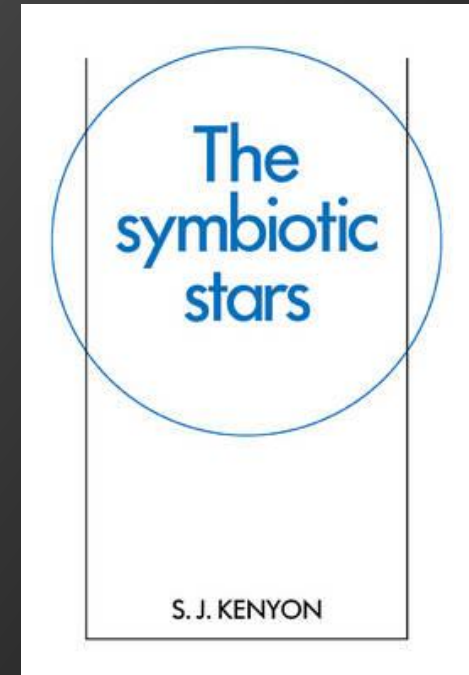
Spectral data base

http://www.astrosurf.com/aras/Aras_DataBase/Symbiotics.htm

A.R.A.S Spectral Data Base - Eruptive stars section

Symbiotic stars

More than 2000 spectra



Seul livre existant
Réédition en 2008 de l'édition 1986,
sans mise à jour



Merci pour votre attention
Danke für Ihre Aufmerksamkeit.