




***Introduction to astronomical spectroscopy
through the eyes of an Alpy 600 spectrograph in Cygnus constellation***

Olivier THIZY
Webb Society annual meeting
Cambridge, 20 June 2015

 UNIVERSITY OF
CAMBRIDGE
Maddingley Rise

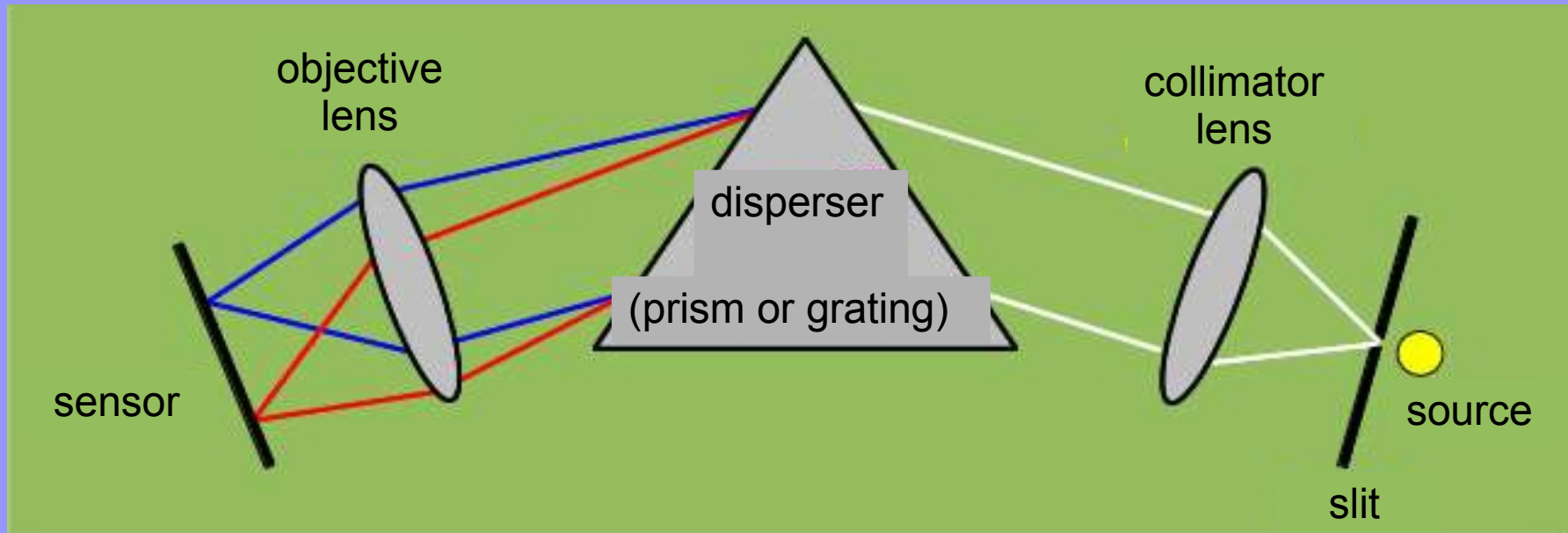
Institute of Astronomy

Agenda

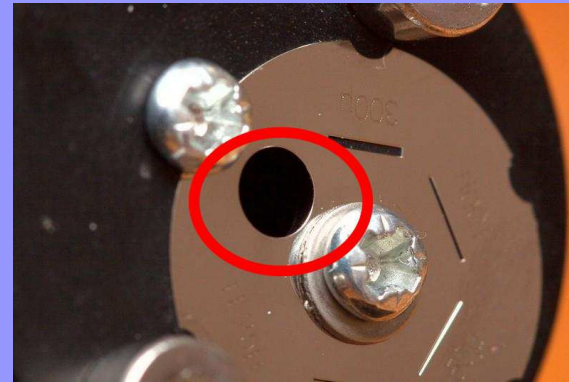
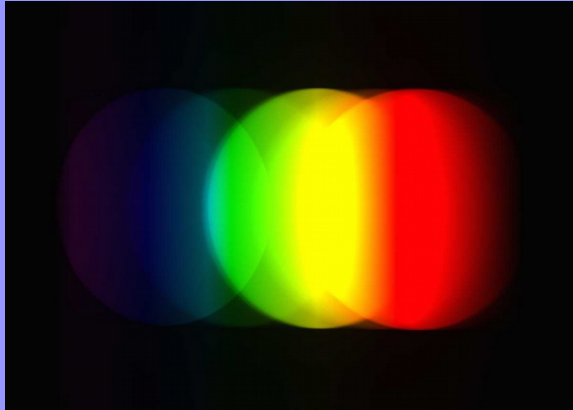
- How does a slit spectroscope works?
- Kirchhoff's law through Albireo exemple
- P Cygni: Doppler Fizeau effect
- Nova Del 2013: Spectro-photometry, pro/am
- Pulsating stars: quest for higher resolution
- Some other variable stars
- Conclusions



Inside the Alpy 600 spectroscope



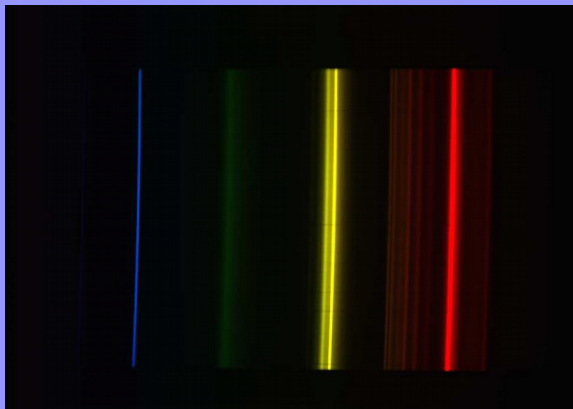
Importance of the slit



3mm slit (hole)

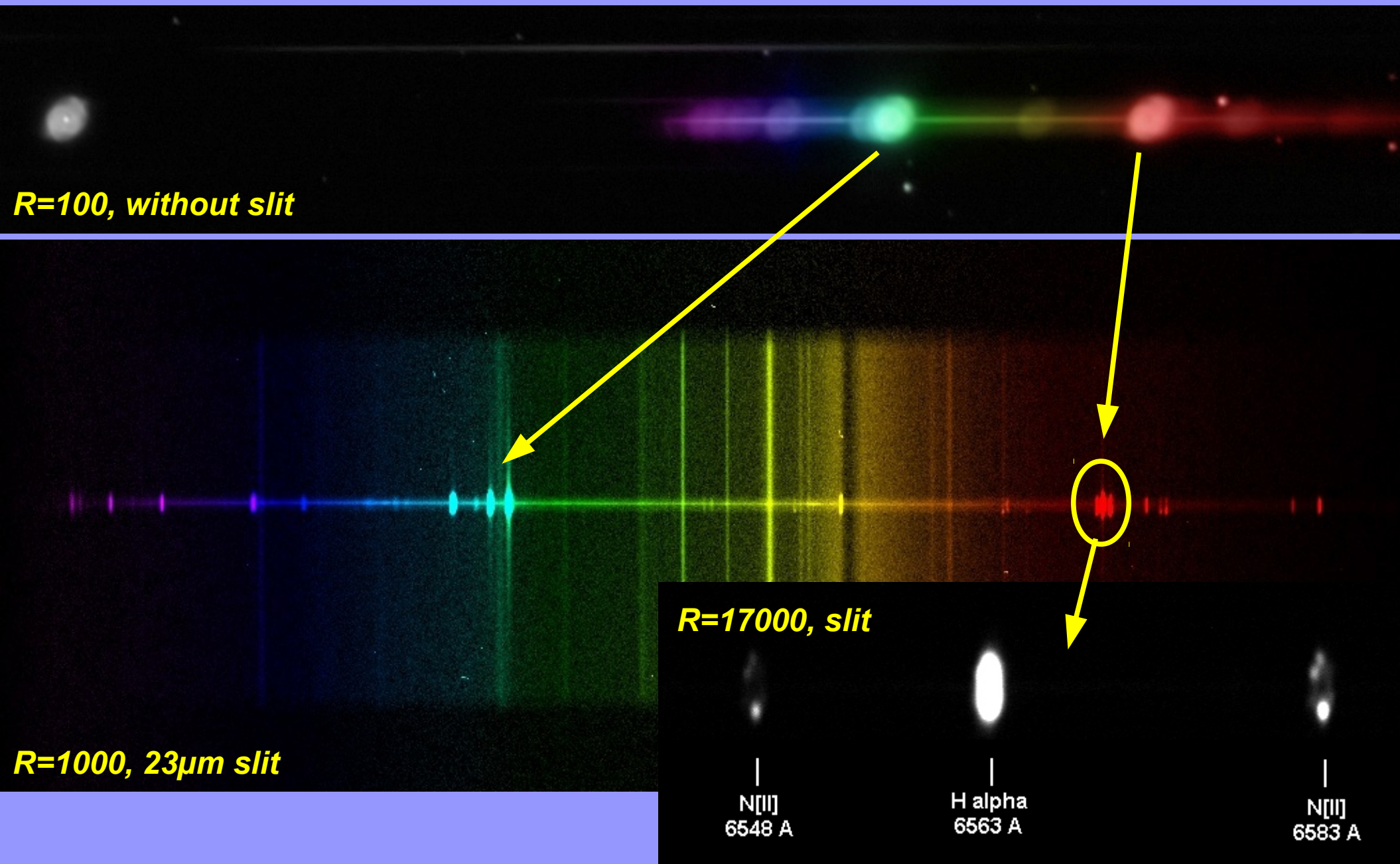


300µm slit



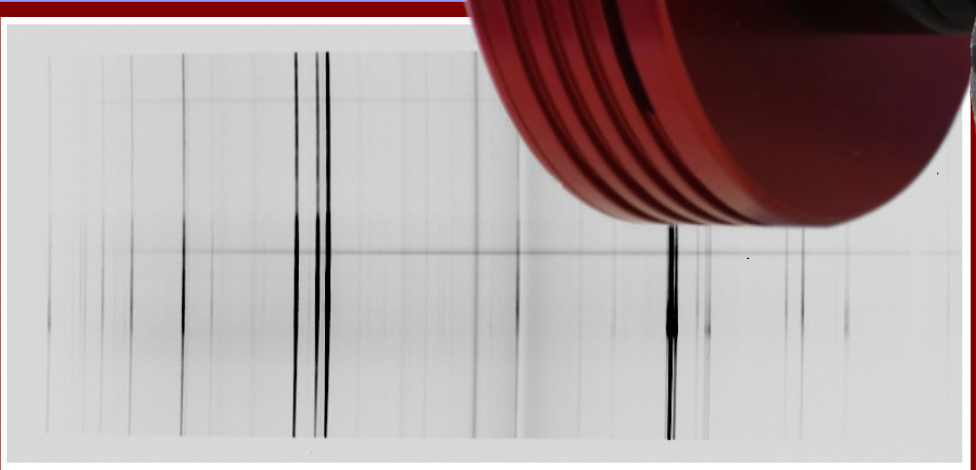
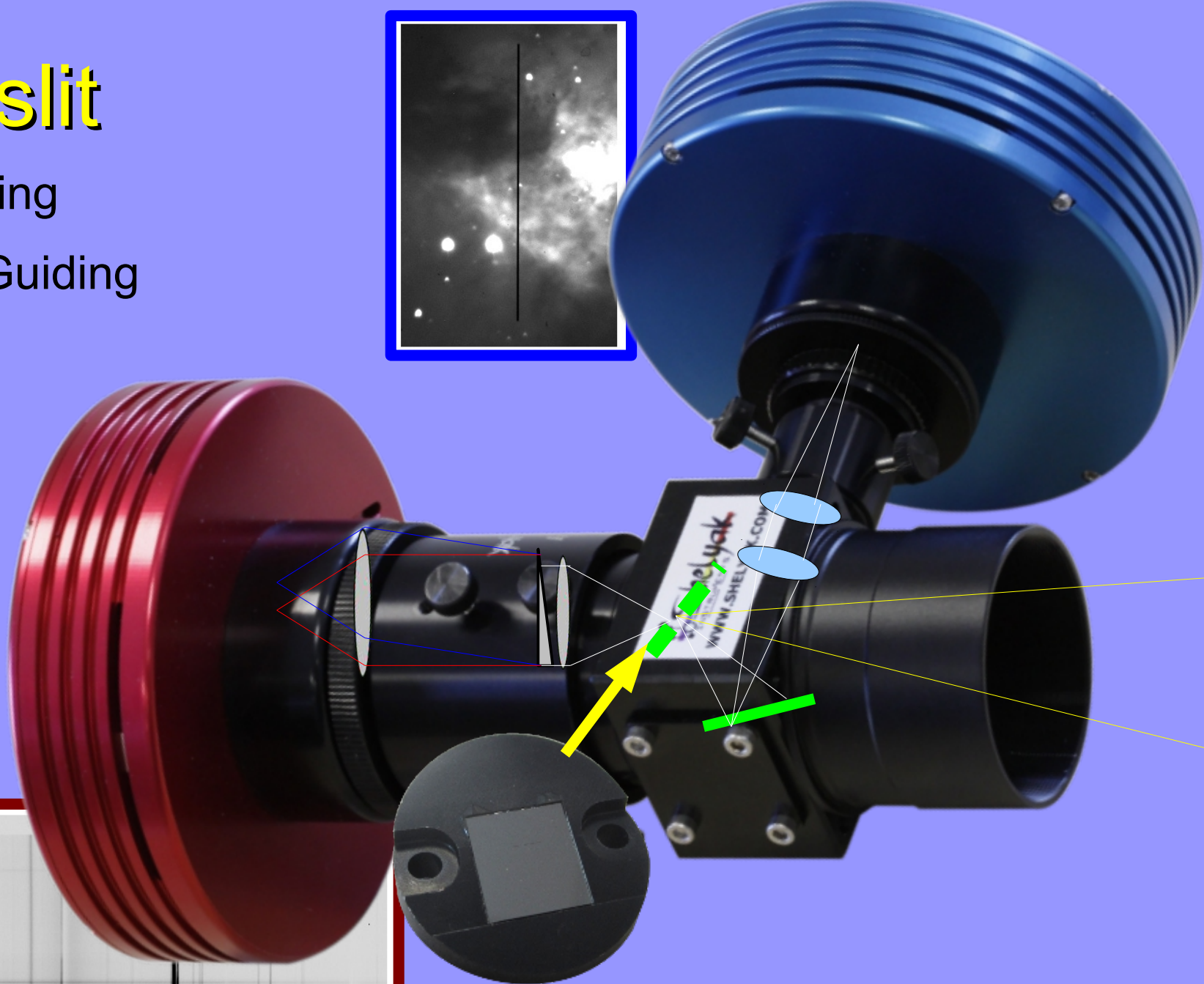
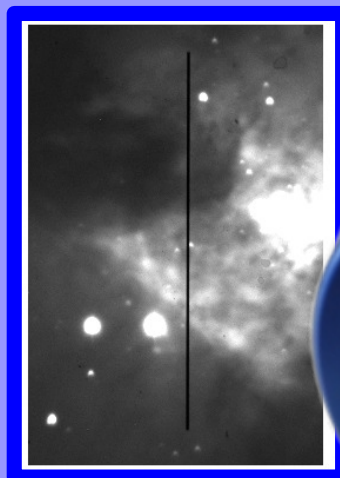
25µm slit

Cat's eye nebula / no slit Vs slit

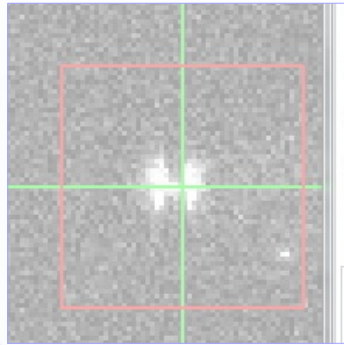


Mirror slit

- Centering
- (auto)Guiding



The Alpy 600 system on a scope



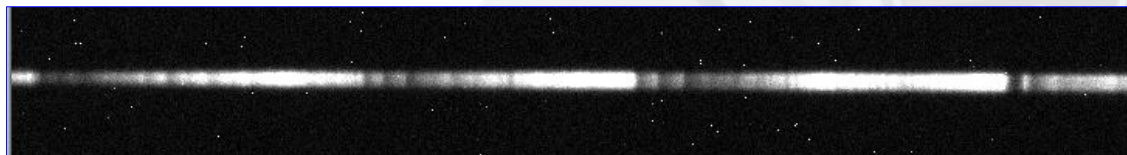
Guiding camera

a *spectrum* is an *image* that can be also displayed as a spectral *profile*

Alpy 600 spectrograph



Acquisition camera



Kirchhoff's law's through Albireo

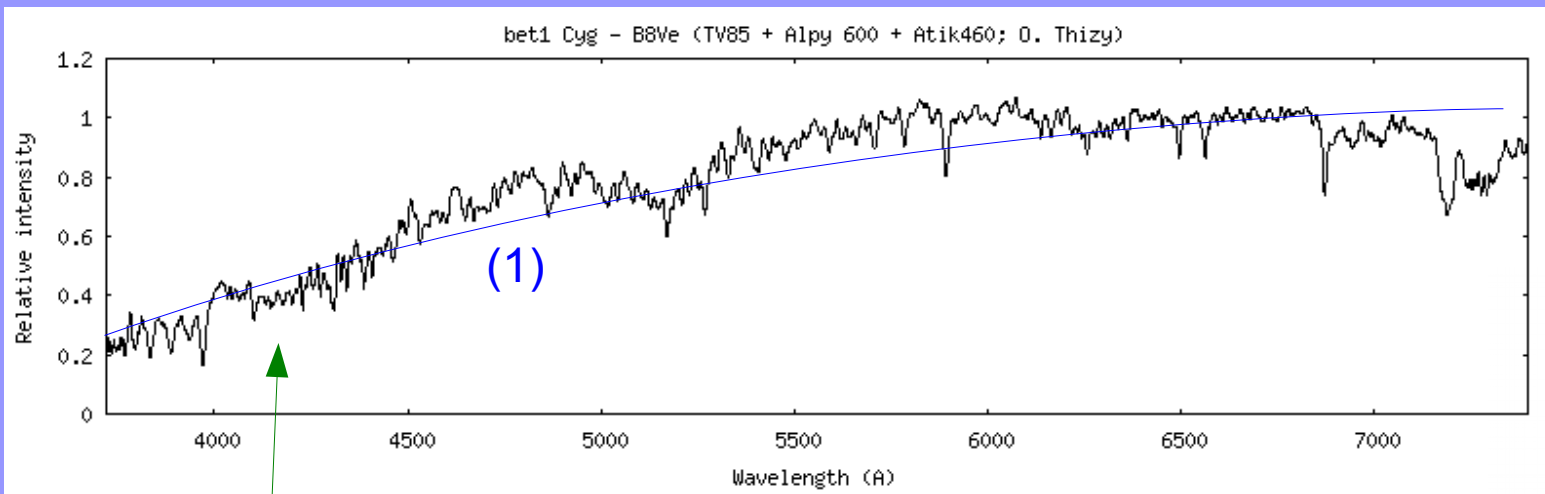
beta Cygni
(Albireo)



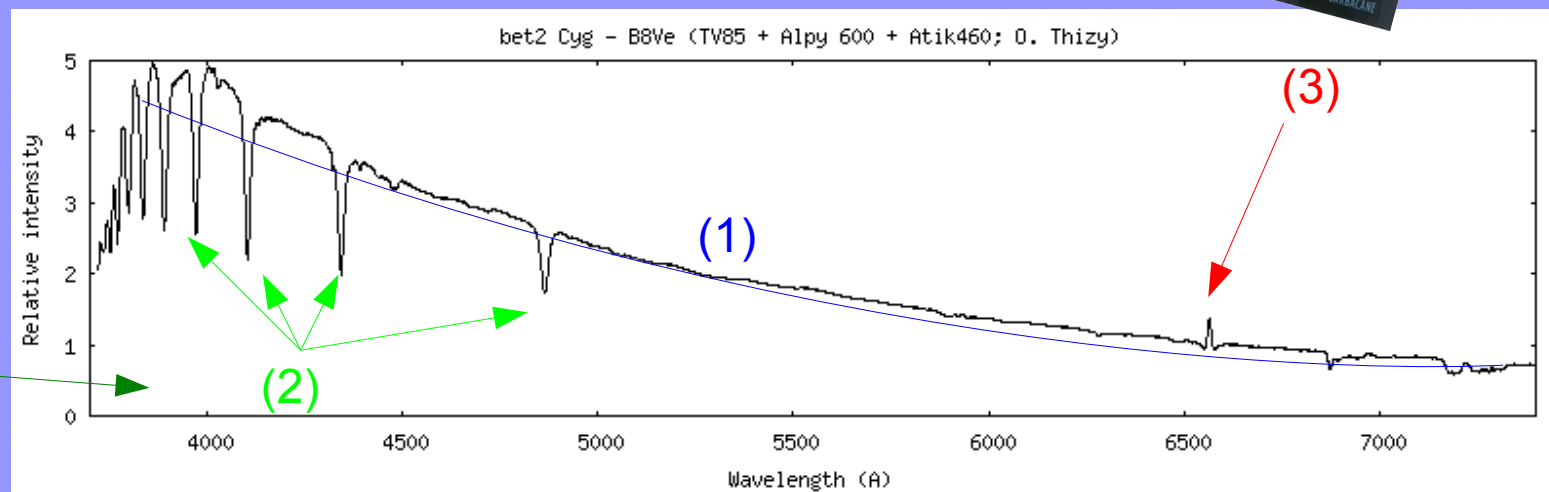
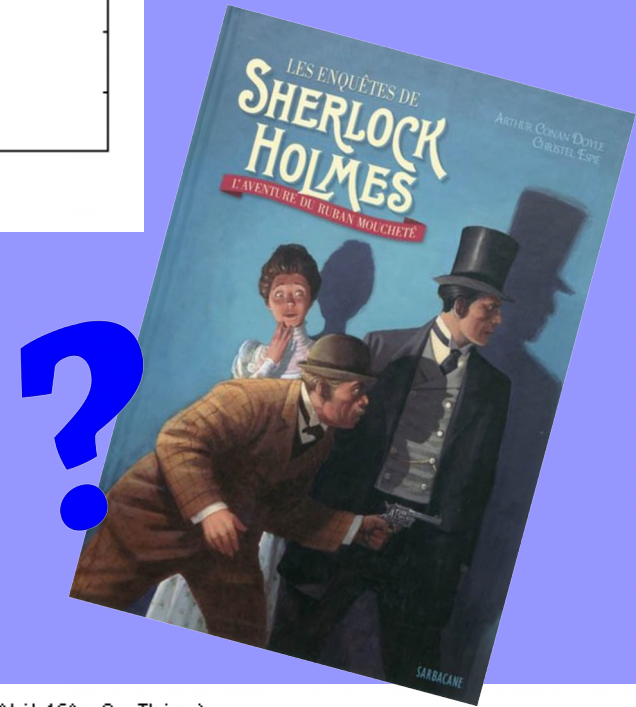
Stars won't
look the same!



Albireo



- (1) Overshape profile
- (2) Absorption lines
- (3) Emission line

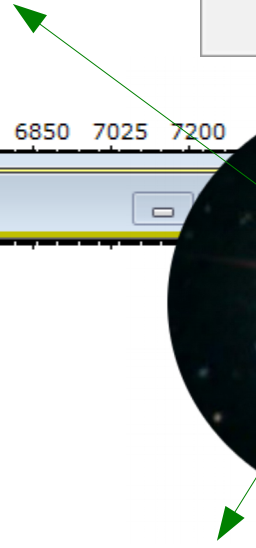
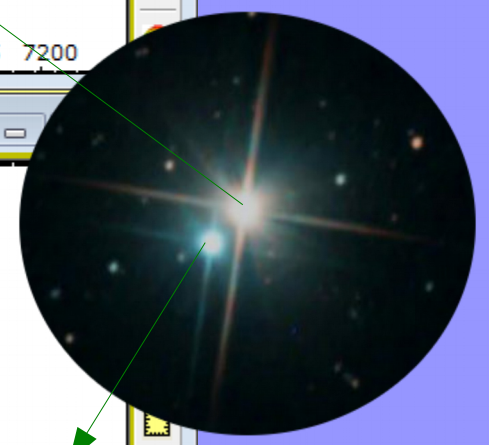
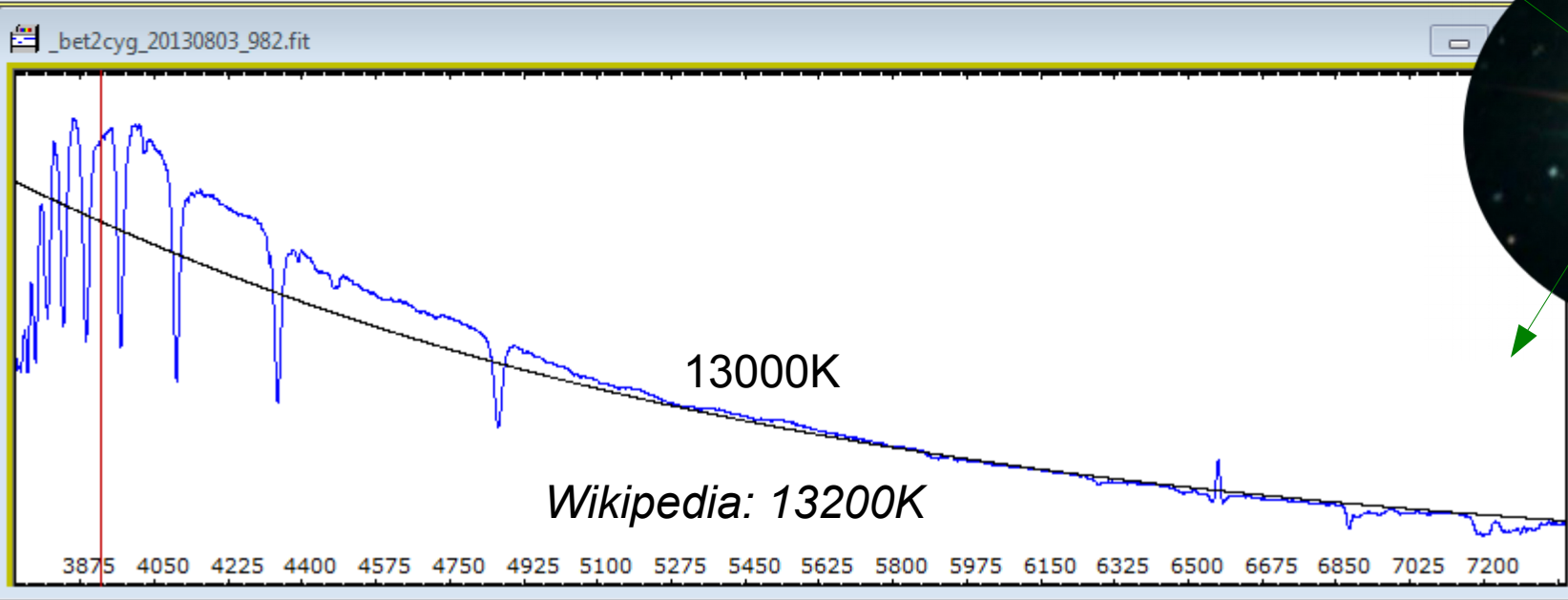
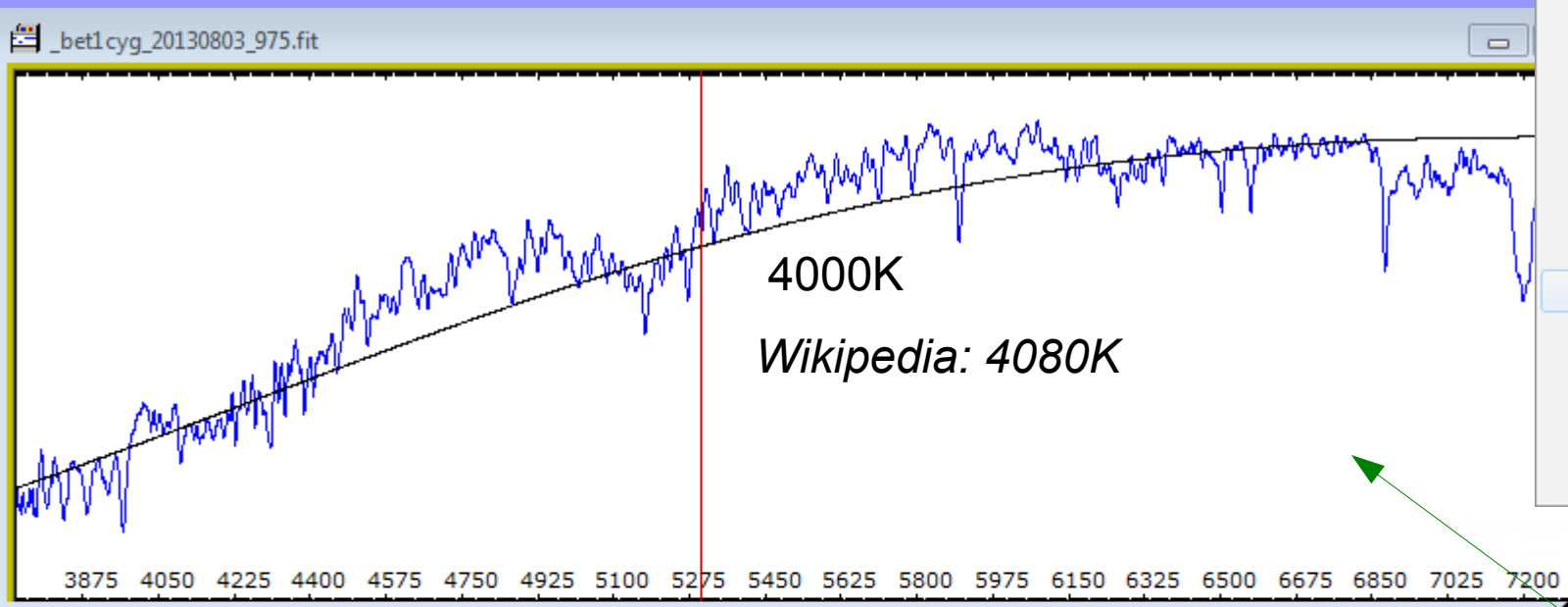


Perfect exemple of Kirchhoff's laws...

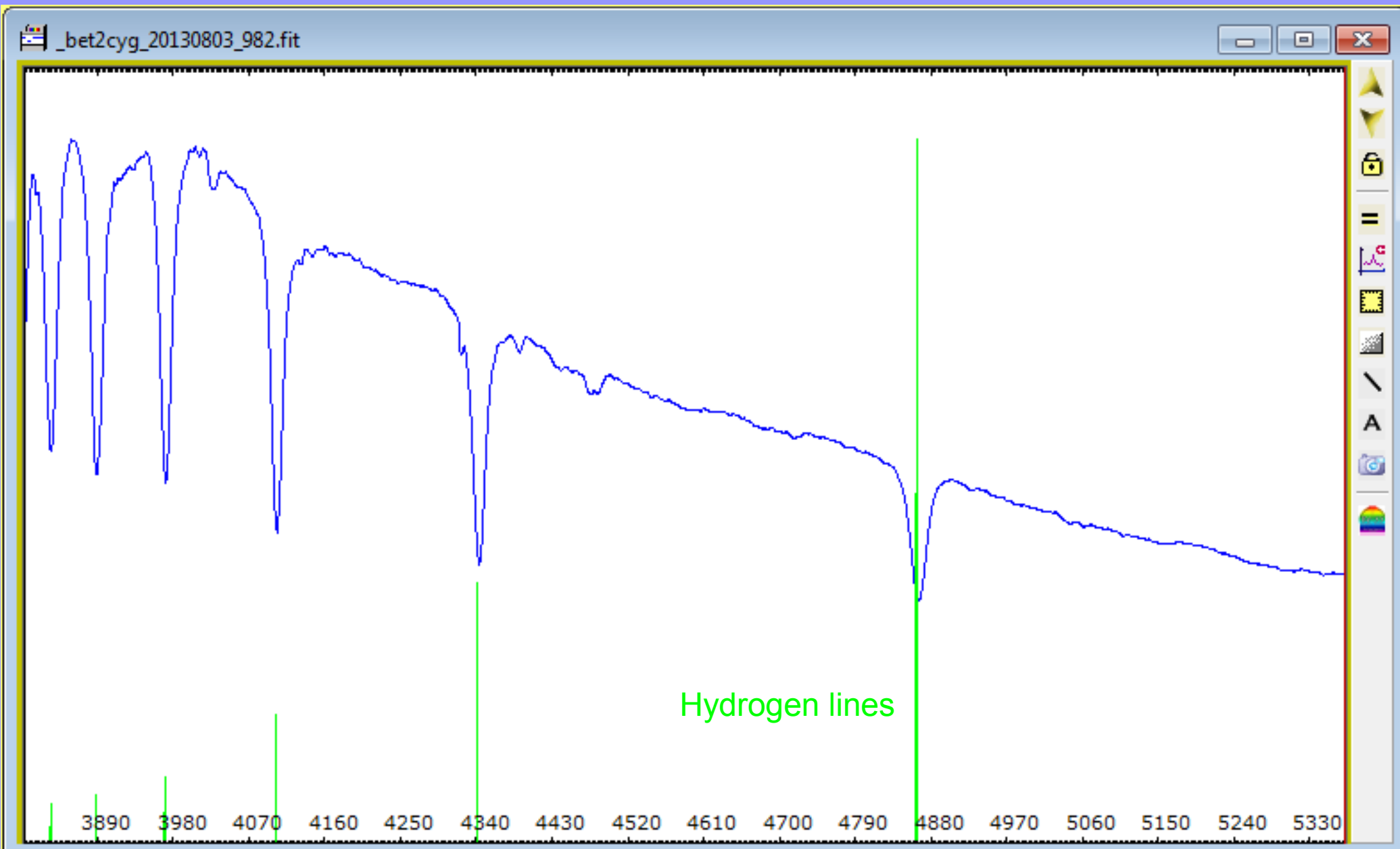


1: overall profile --> Temp.

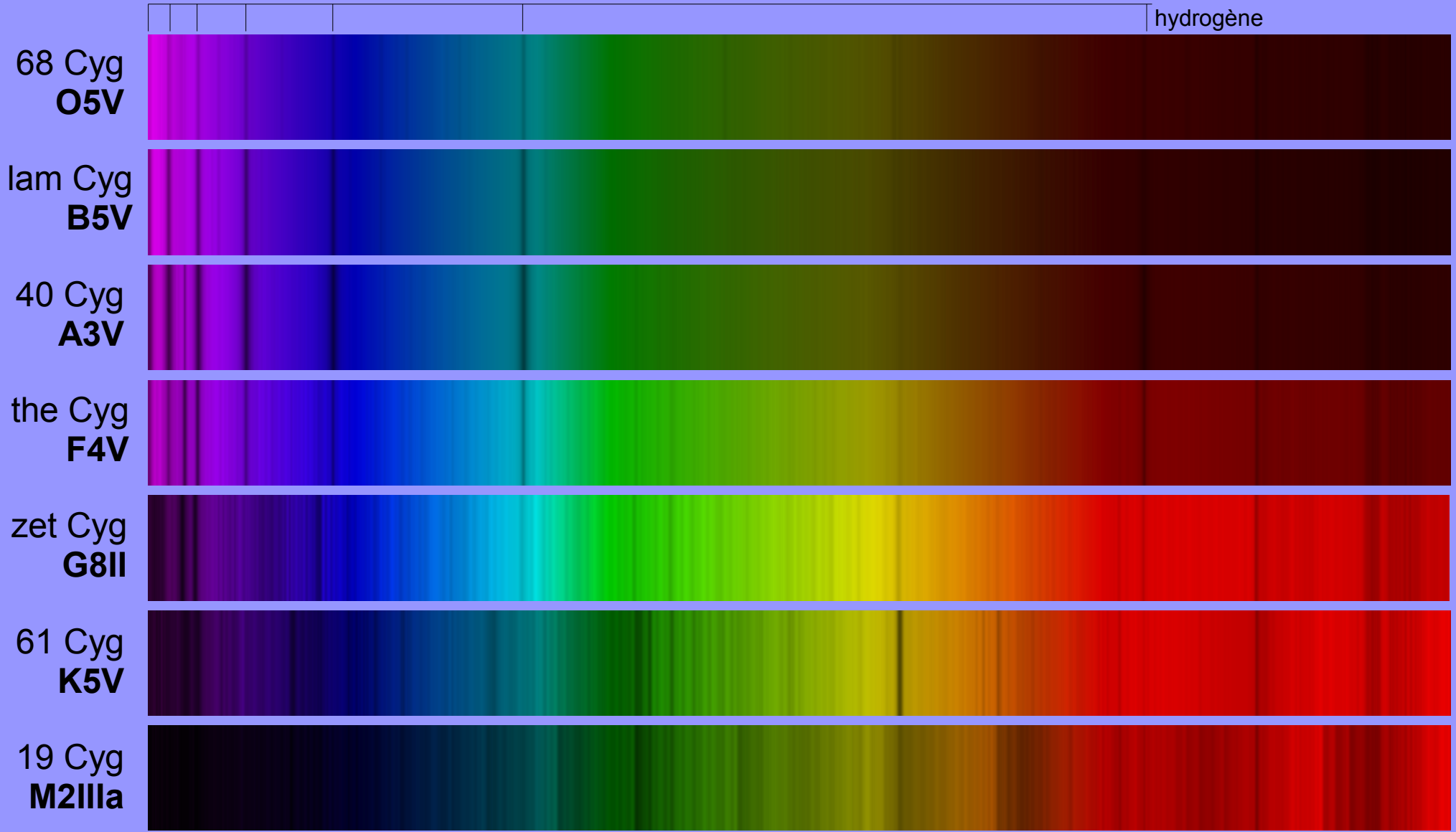
- Radiometry
- Tools
- Assistant
- Window
- Op
- Compute Continuum...
- Extract...
- Extract from zone list
- Automatic continuum
- Continuum Division
- Continuum Subtraction
- H2O correction...
- H2O correction real spectrum...
- Auto H2O correction
- Verif Cal Atm
- Auto Planck...**
- Planck...
- Extinction...
- Compute flux of reference star...
- Compute absolute flux..



2: stellar atmosphere

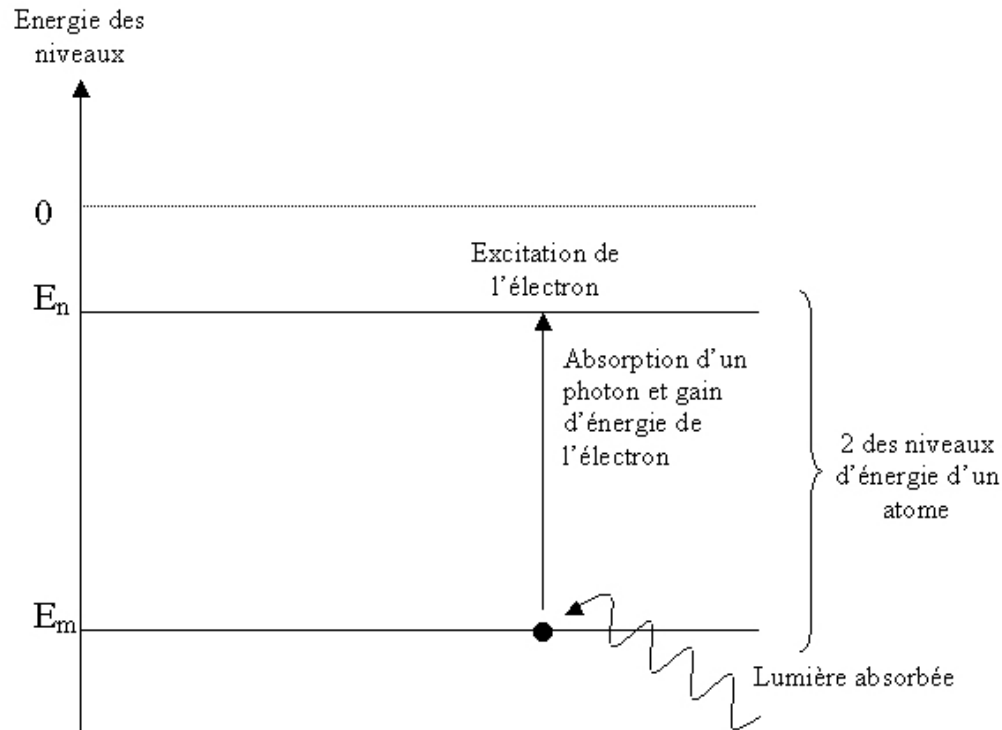
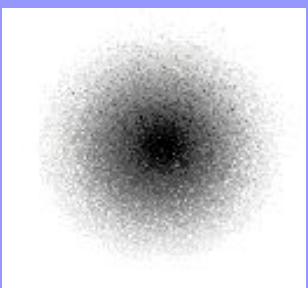


Spectral classification

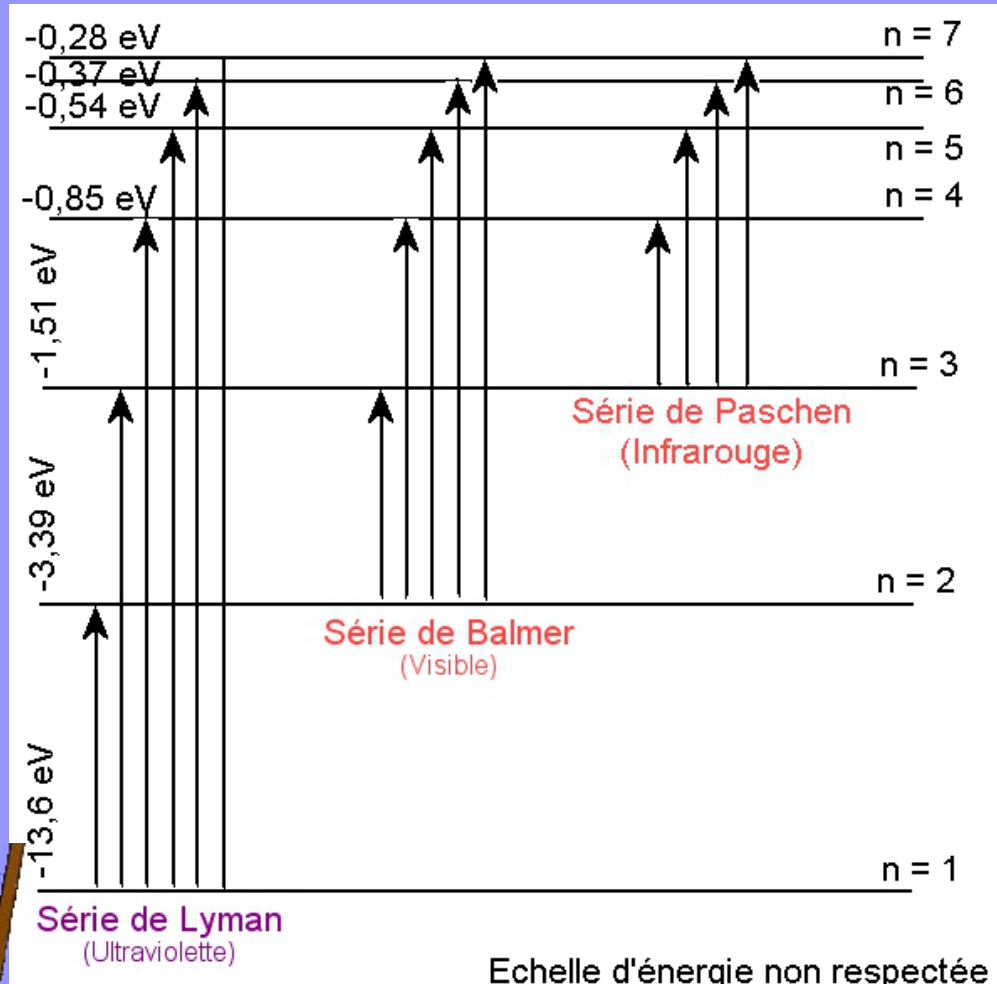


O_h, **B**_e **A****F**_{ine} **G**_{irl}/**G**_{uy}... **K**_{iss} **M**_e!

Absorption lines physics



$$\Delta E = |E_n - E_m| = h\nu = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{\Delta E}$$



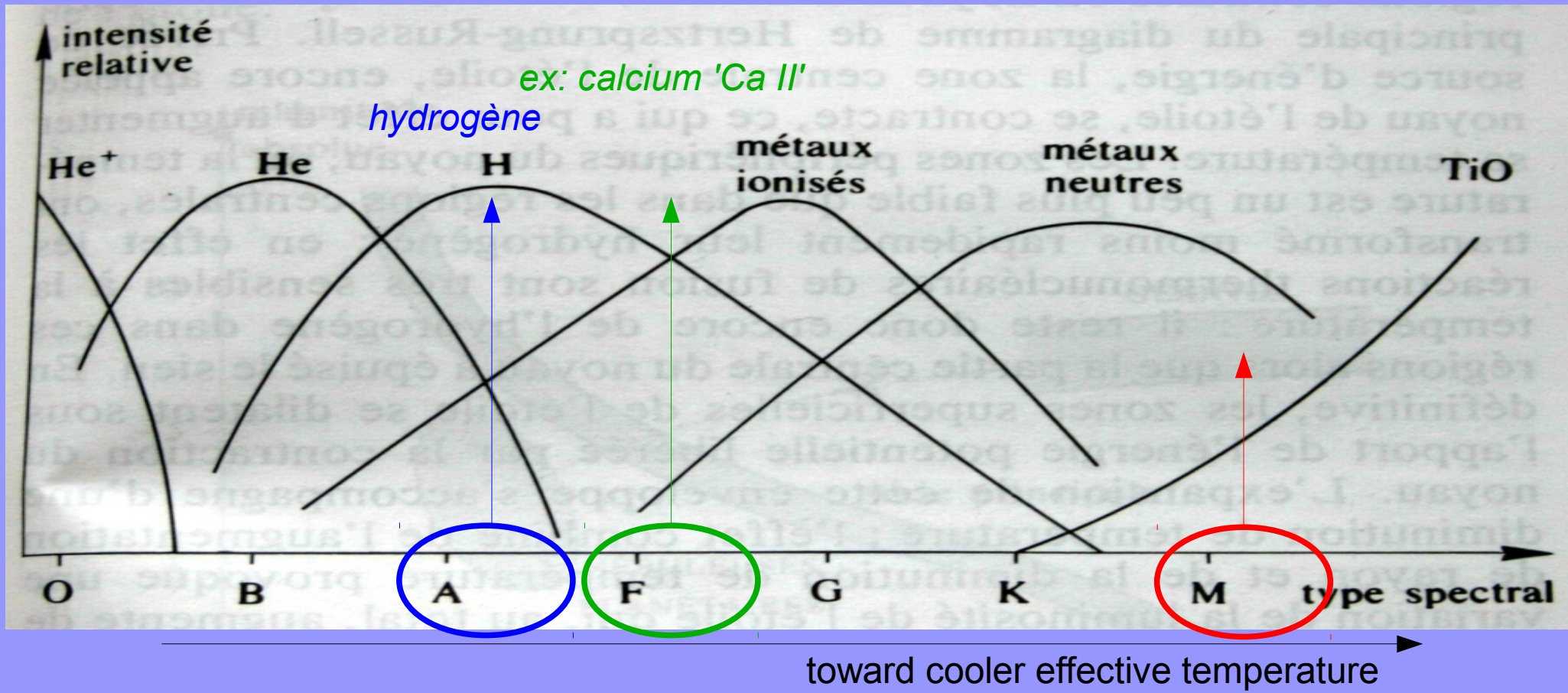
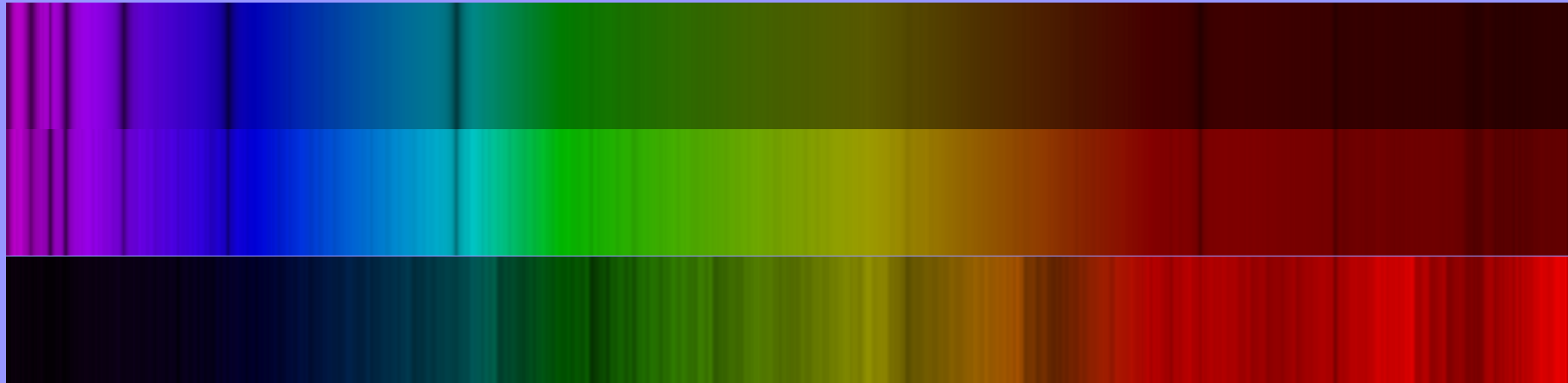
Exemple for the hydrogen atom

Temperature Vs line strength

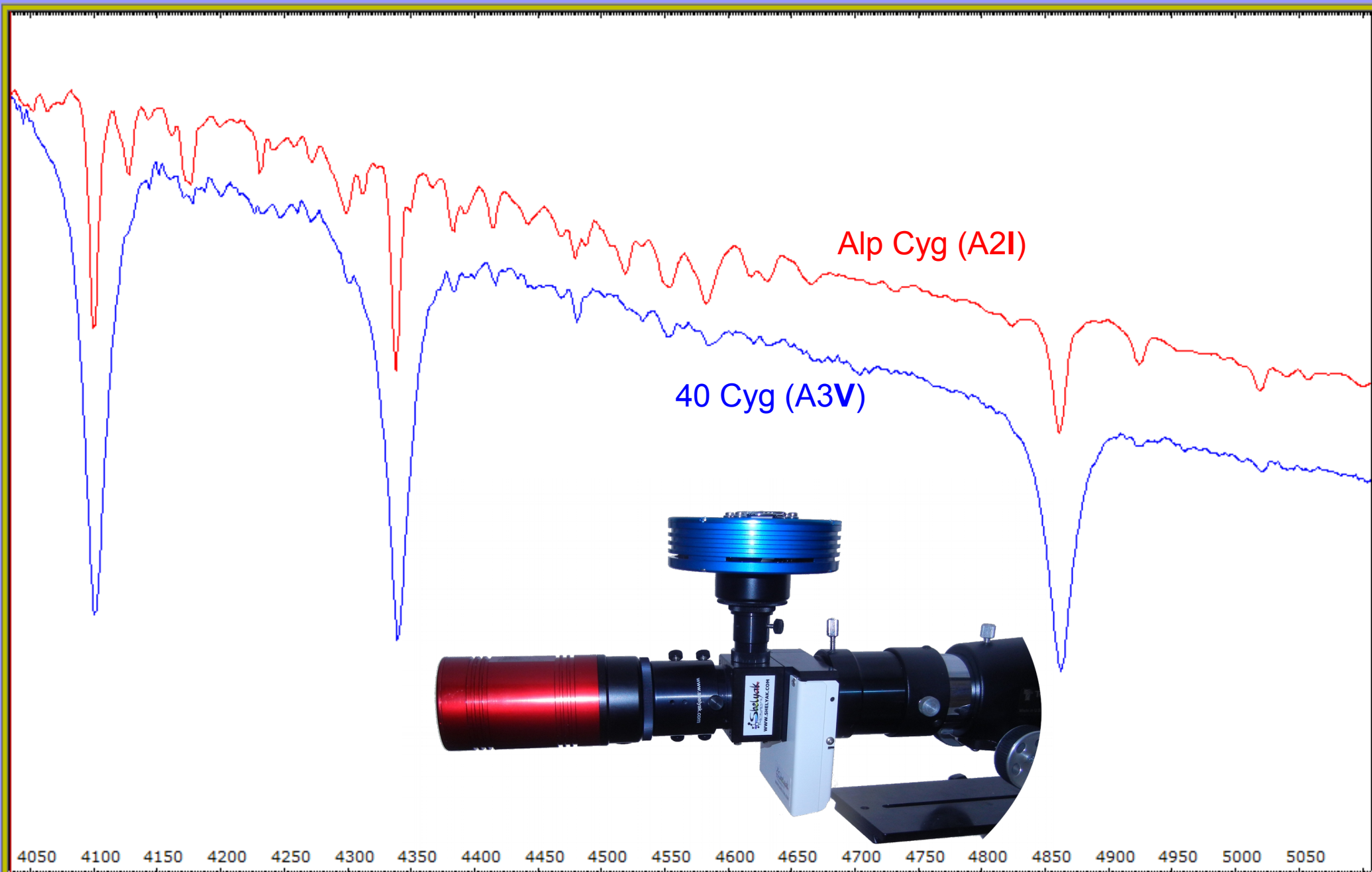
40 Cyg
A3V

the Cyg
F4V

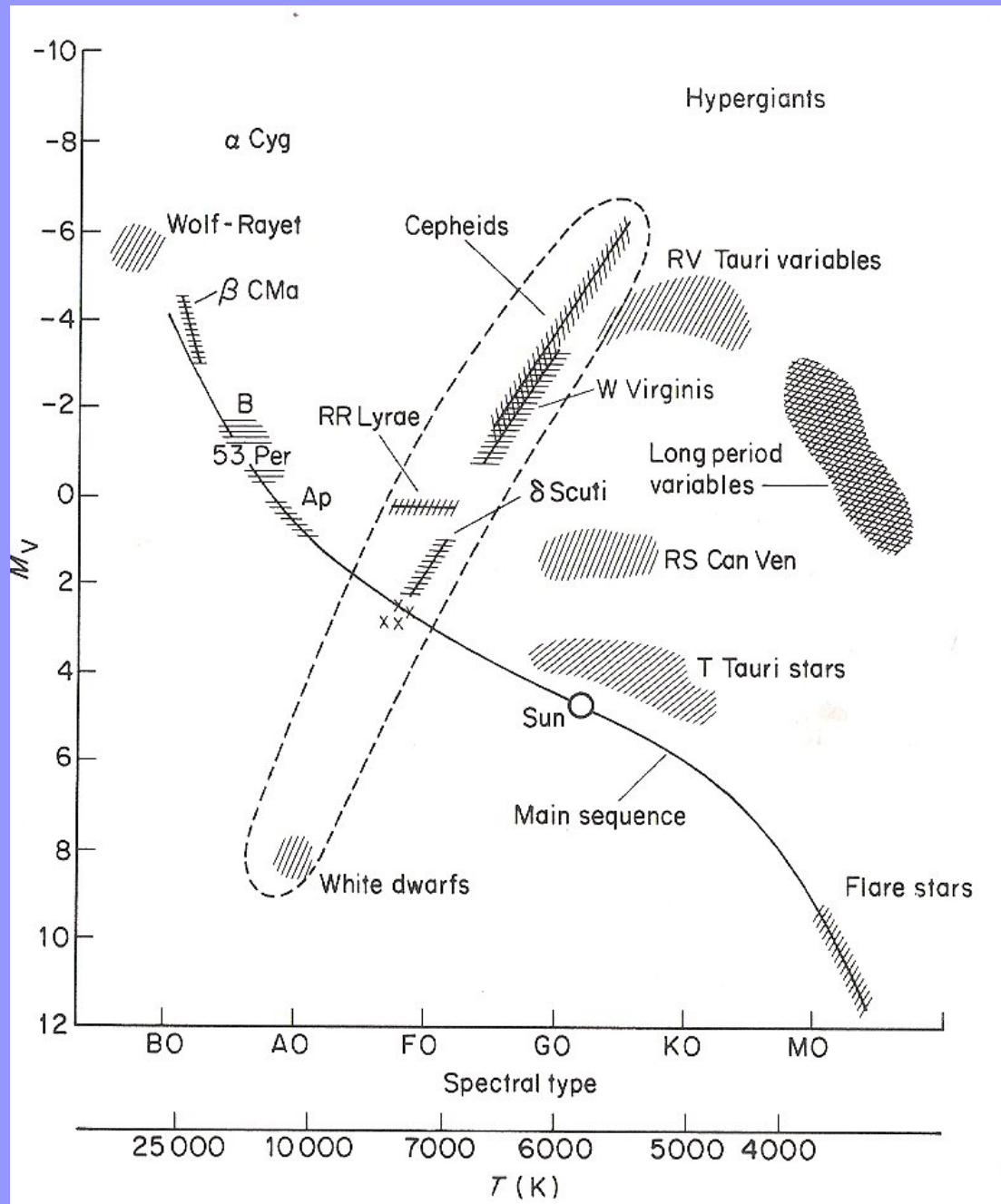
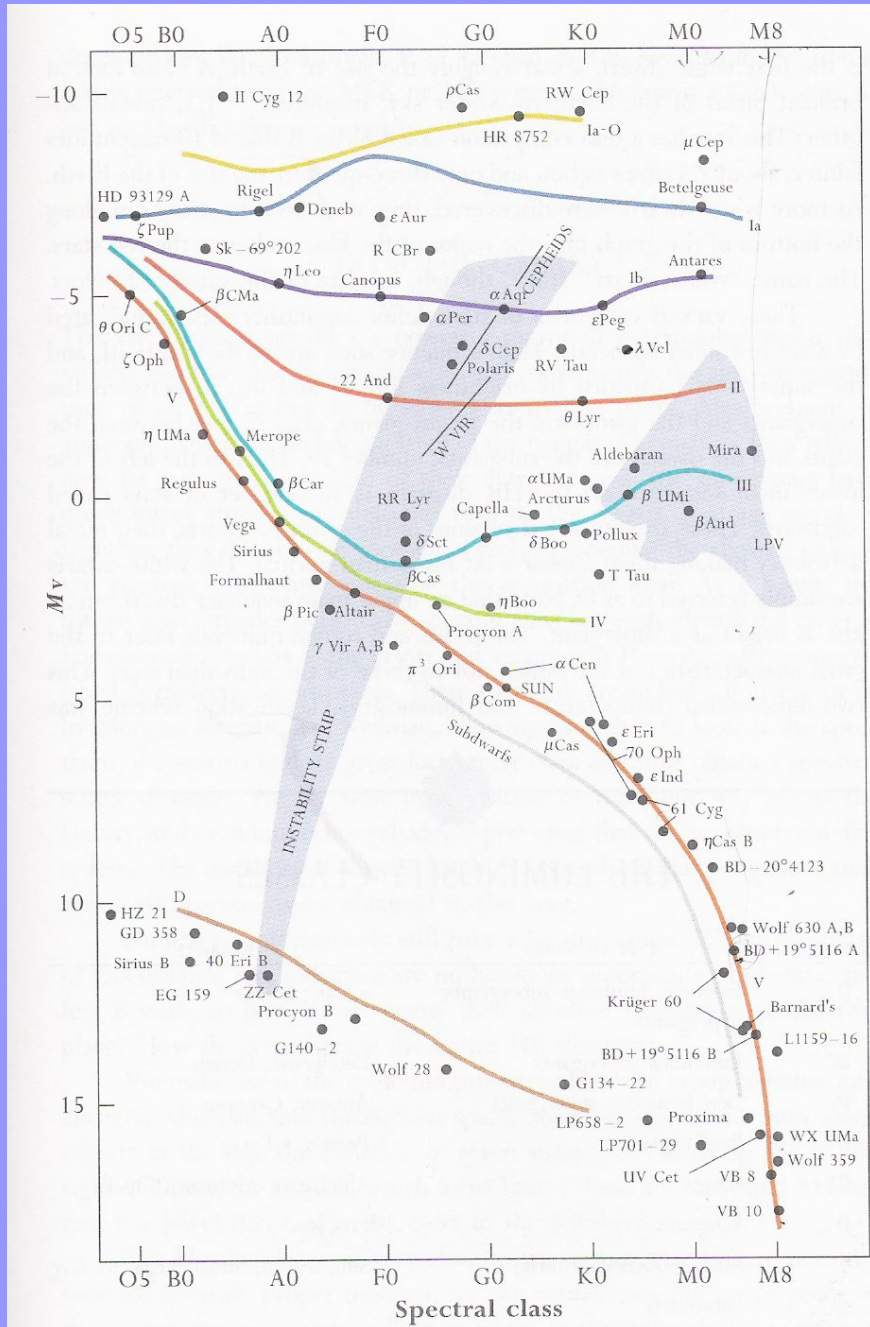
19 Cyg
M2IIIa



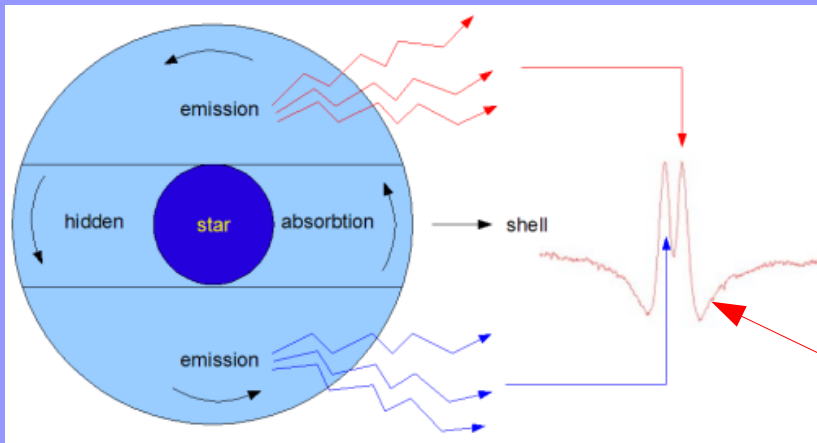
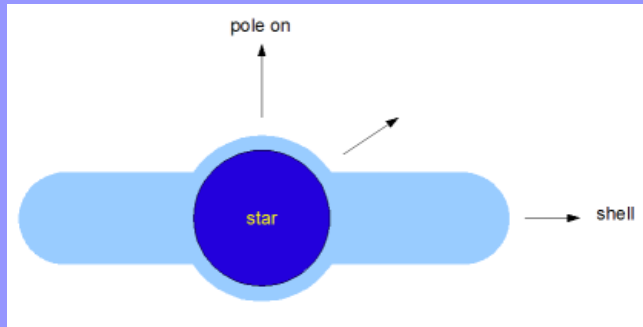
Luminosity class



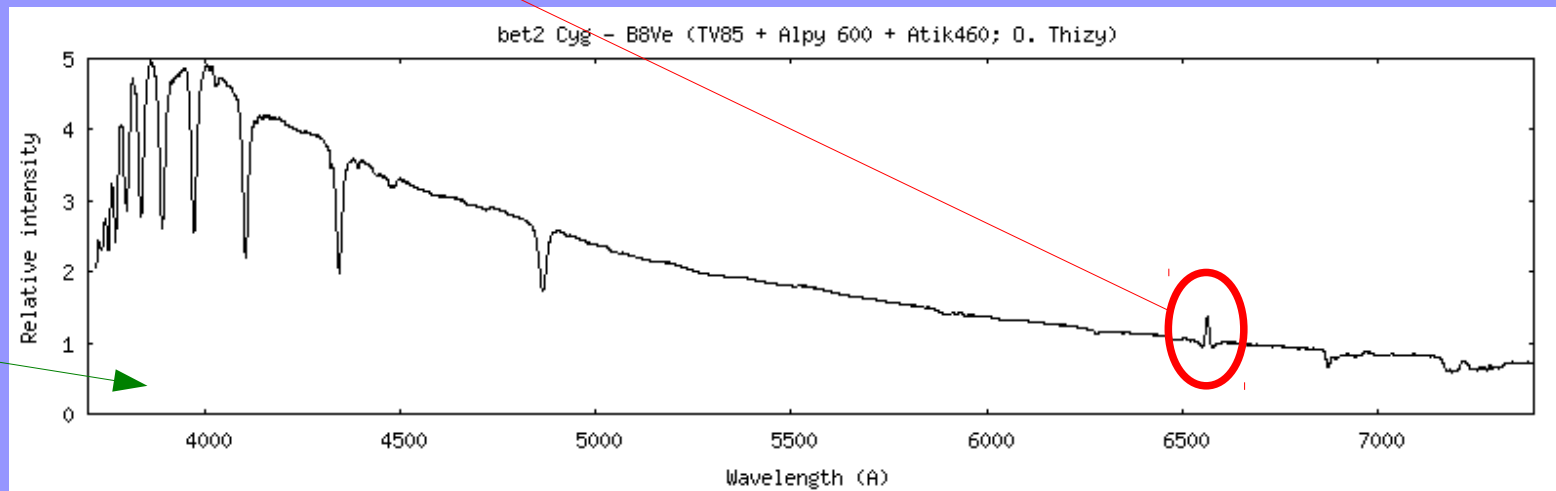
Hertzspring-Russell diagram



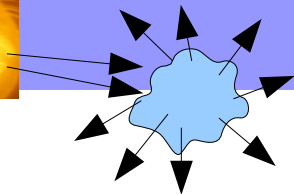
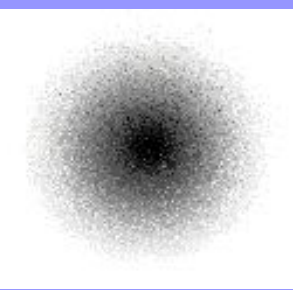
3: emission lines



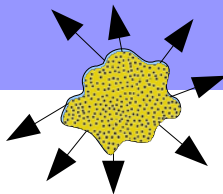
- non super-giant B type star showing or having shown a Balmer line in emission
- Discovered in 1866 by father Secchi: gamma Cas, beta Lyrae...
- Disk of matter ejected from the star and re-emitting energy through emission line



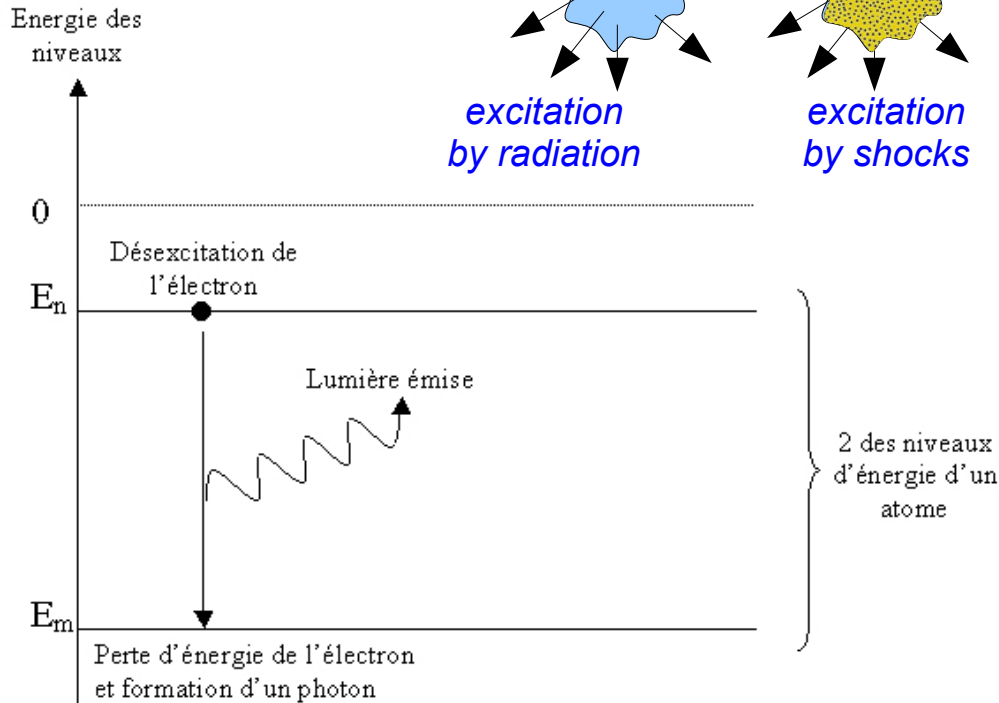
Emission lines physics



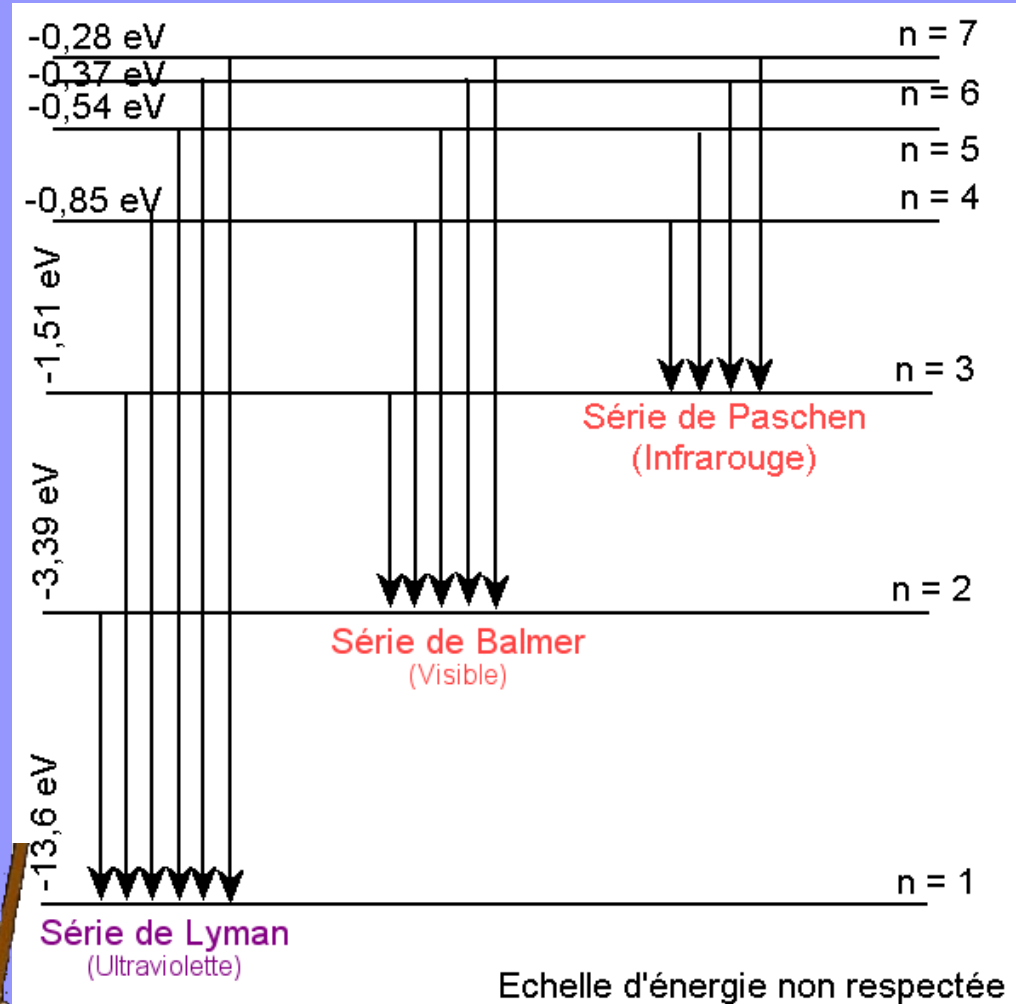
*excitation
by radiation*



*excitation
by shocks*



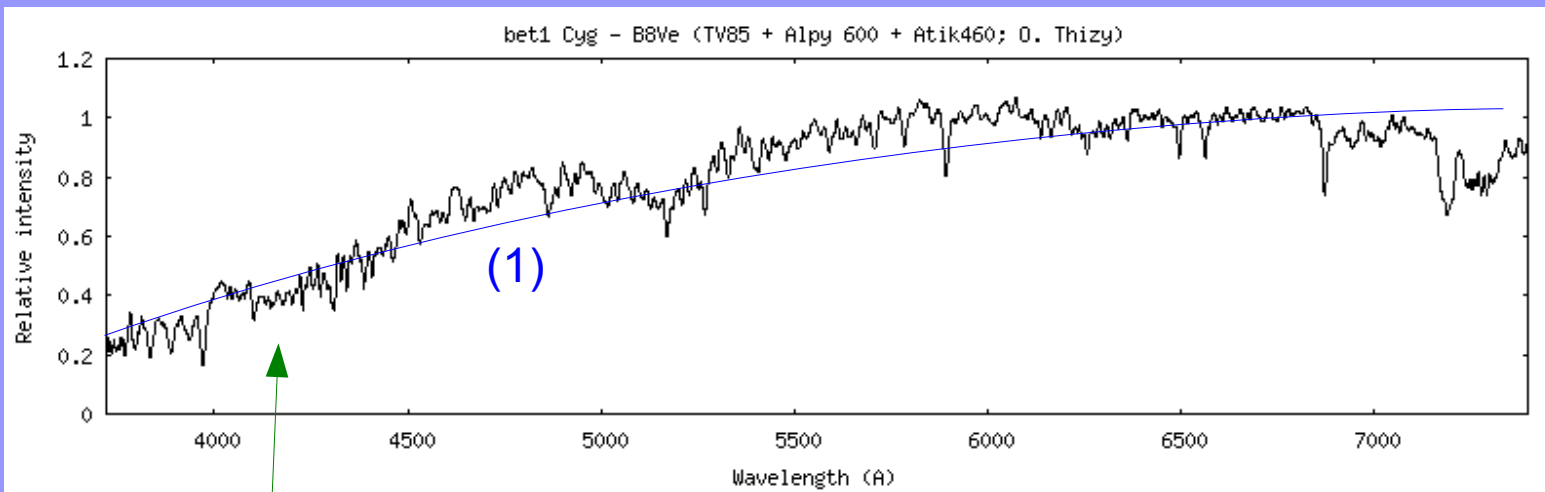
$$\Delta E = |E_n - E_m| = h\nu = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{\Delta E}$$



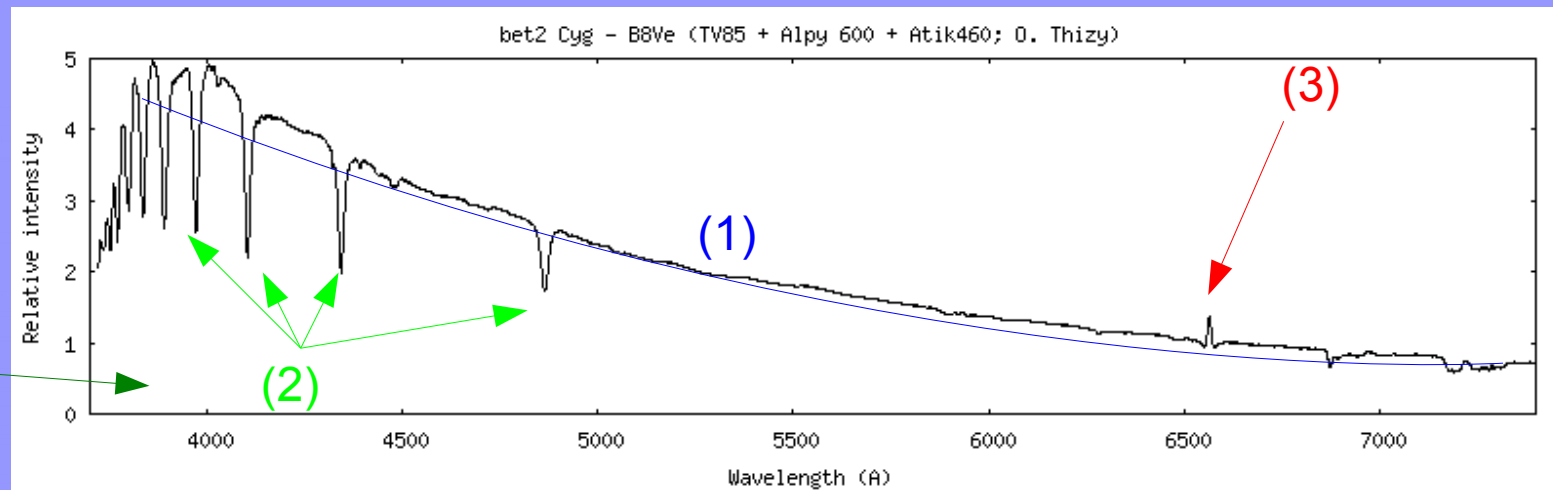
Exemple for the hydrogen atom



Albireo summary



- (1) Overall profile = effective Planck temperature
- (2) Energy absorption (photons) = stellar atmosphere
- (3) Energy emitted = circumstellar disk



...thanks Mr Kirchhoff !

Where is Charly ?

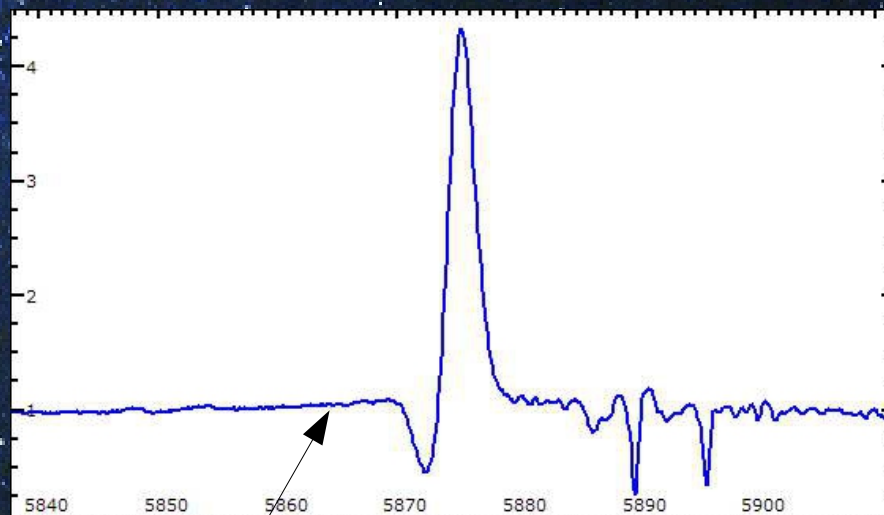
...or how the Doppler-Fizeau effect is important...

...and why photometry & spectroscopy are complementary...

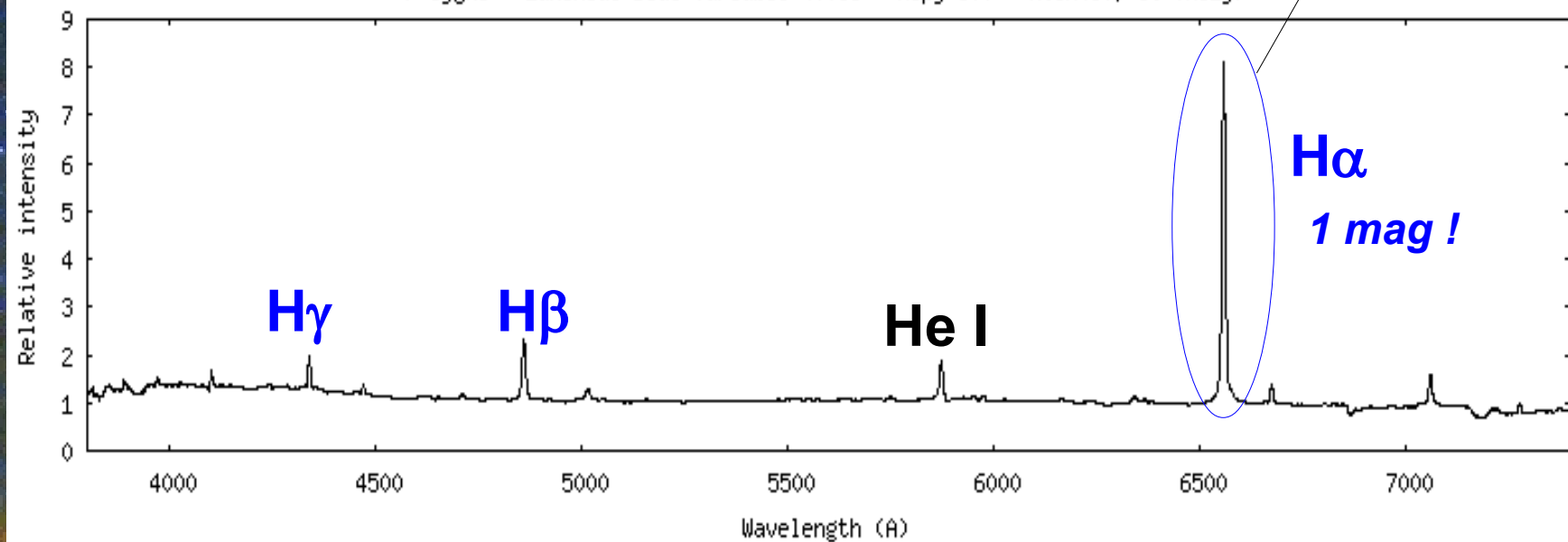
...and why high resolution is fun...

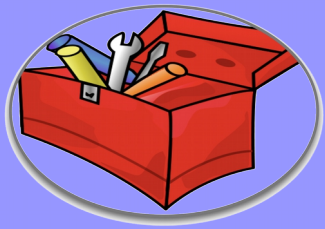
P Cygni Luminous Blue Variable

P Cygni

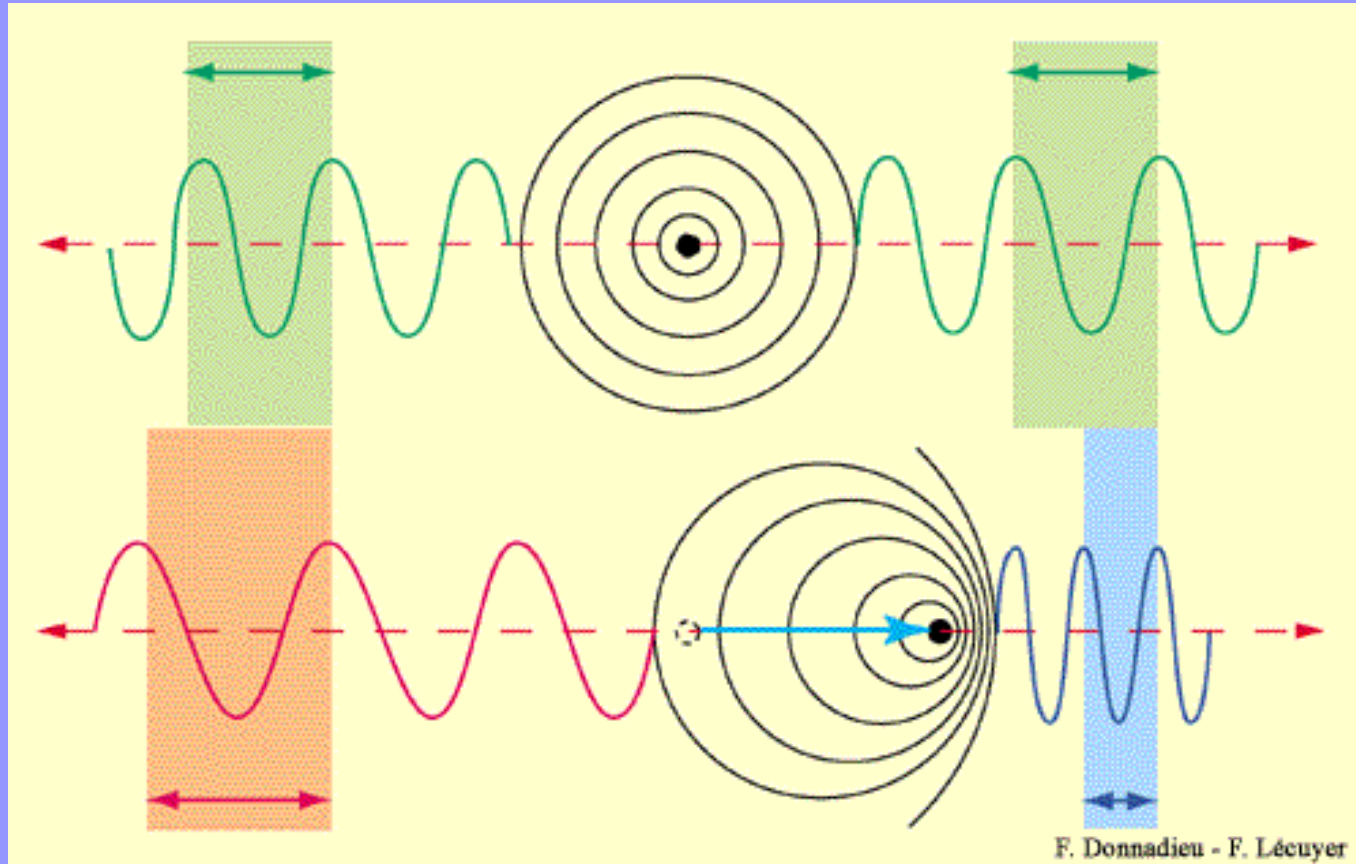


P Cygni - Luminous Blue Variable (TV85 + Alpy 600 + Atik460; O. Thizy)





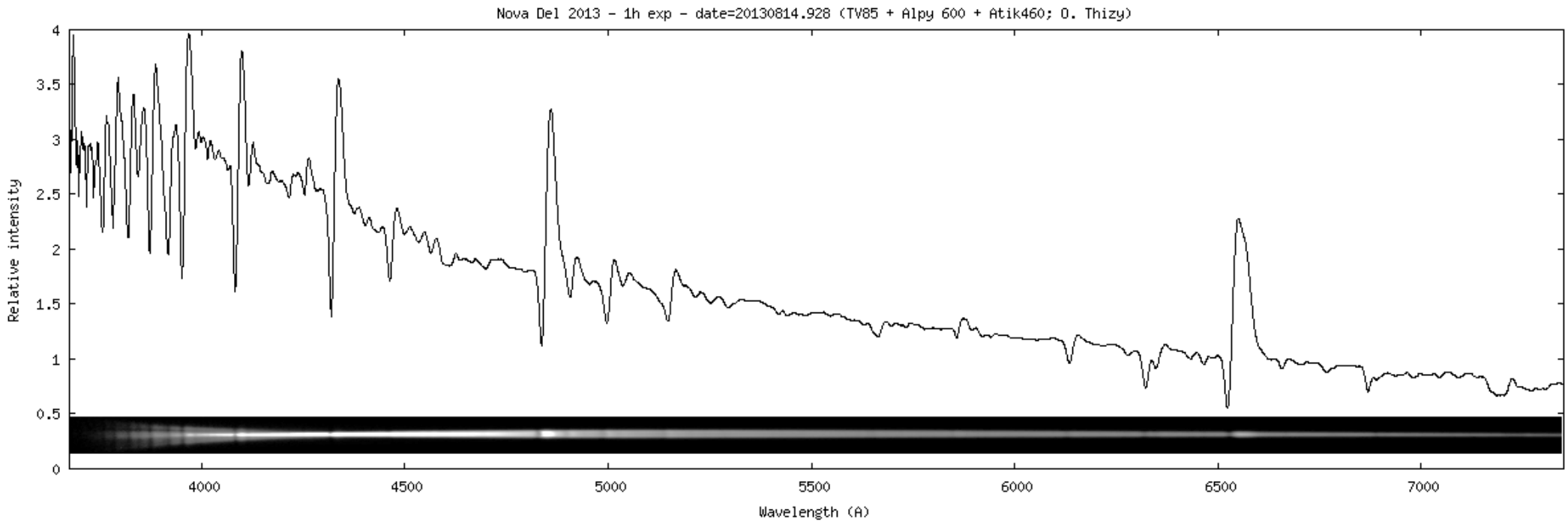
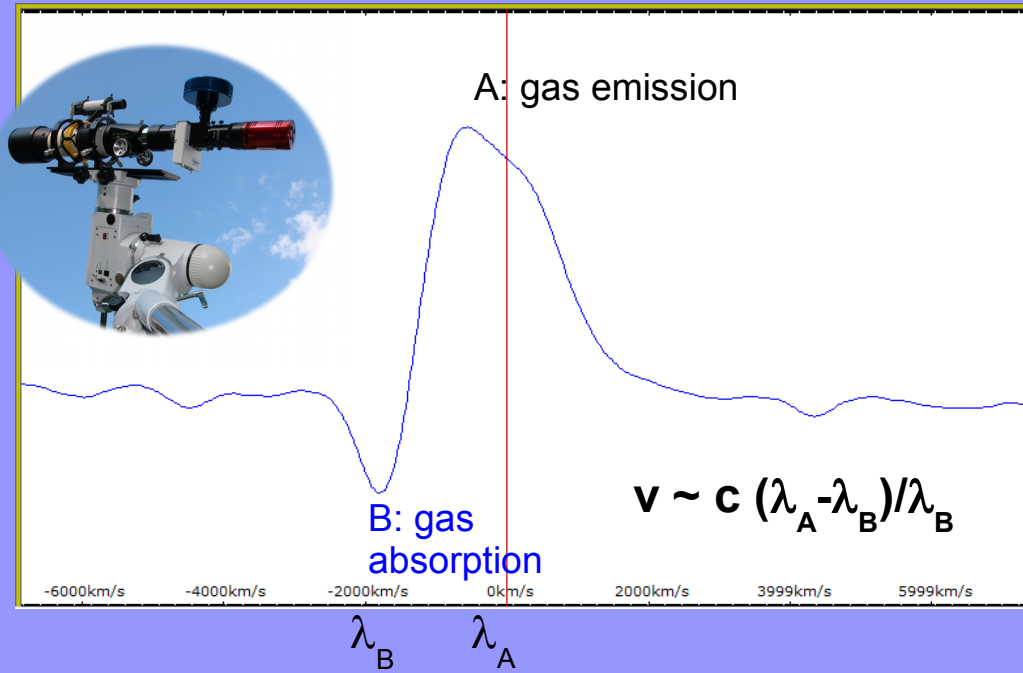
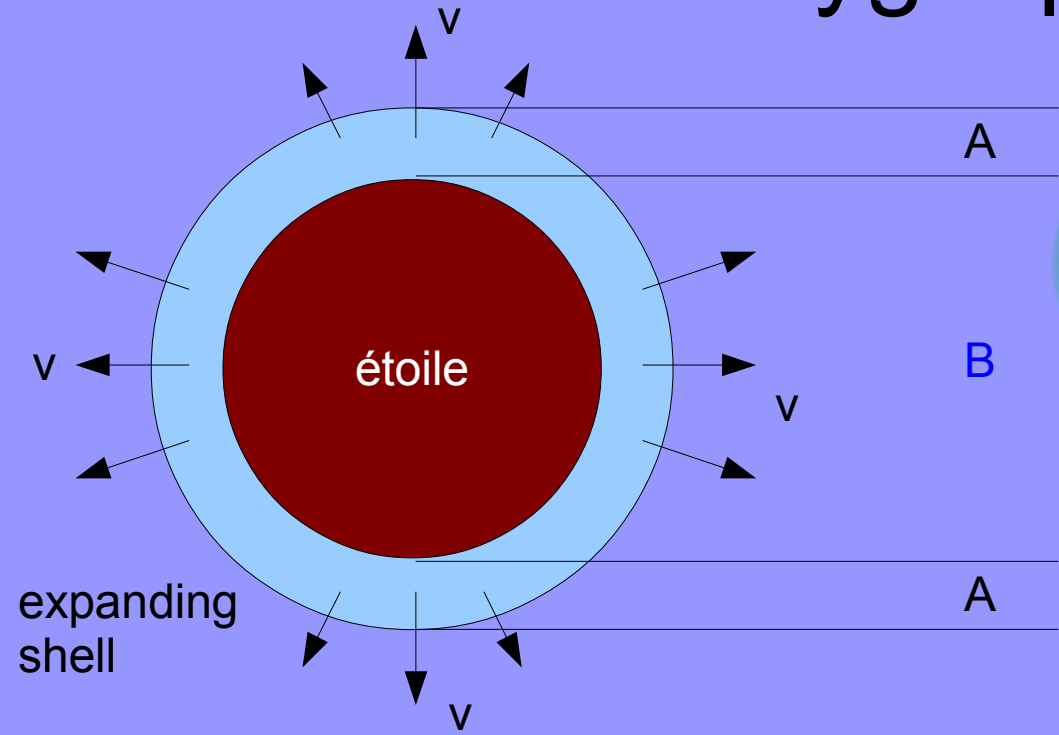
Doppler – Fizeau effect



Universe expansion
=
red shift

$$\frac{(\Delta \lambda)}{\lambda} = \frac{v}{c}$$

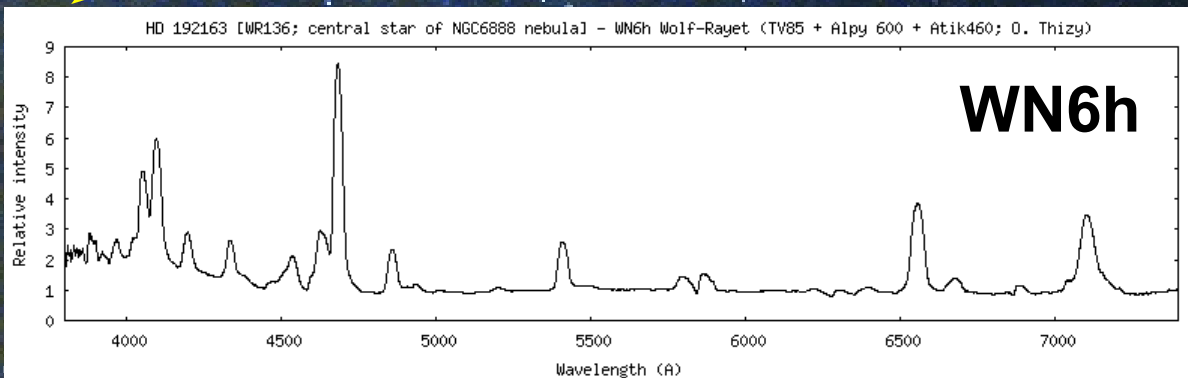
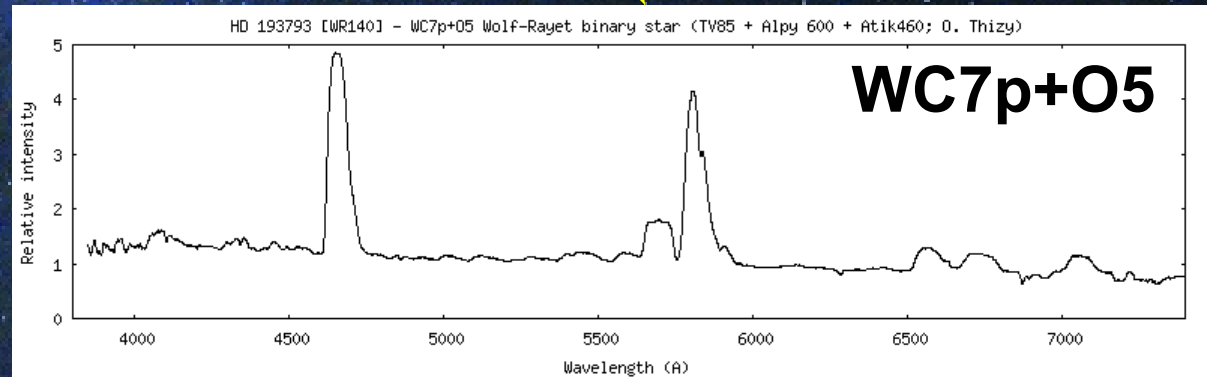
P Cygni profile / Doppler effect



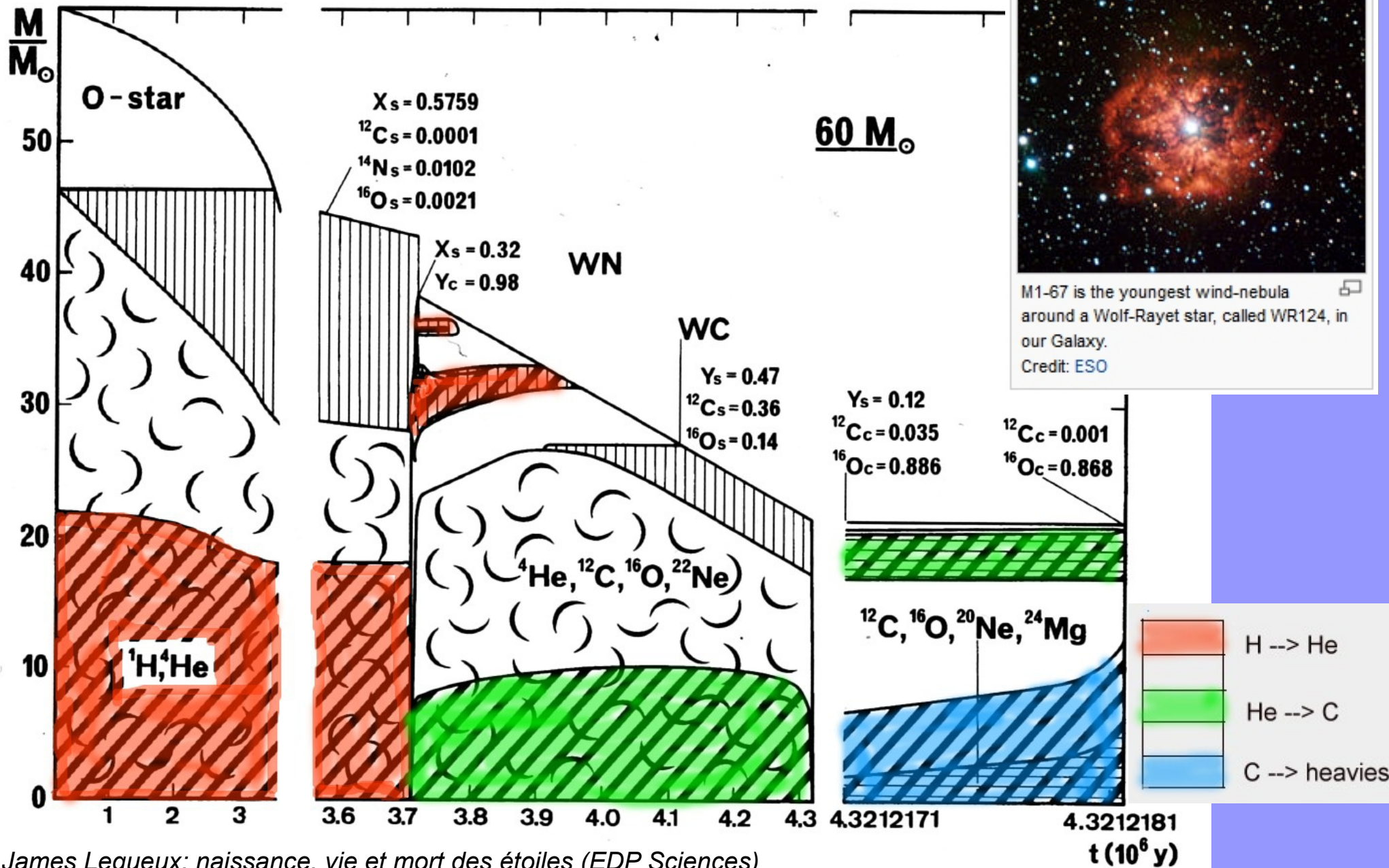
Wolf Rayet stars

WR 136

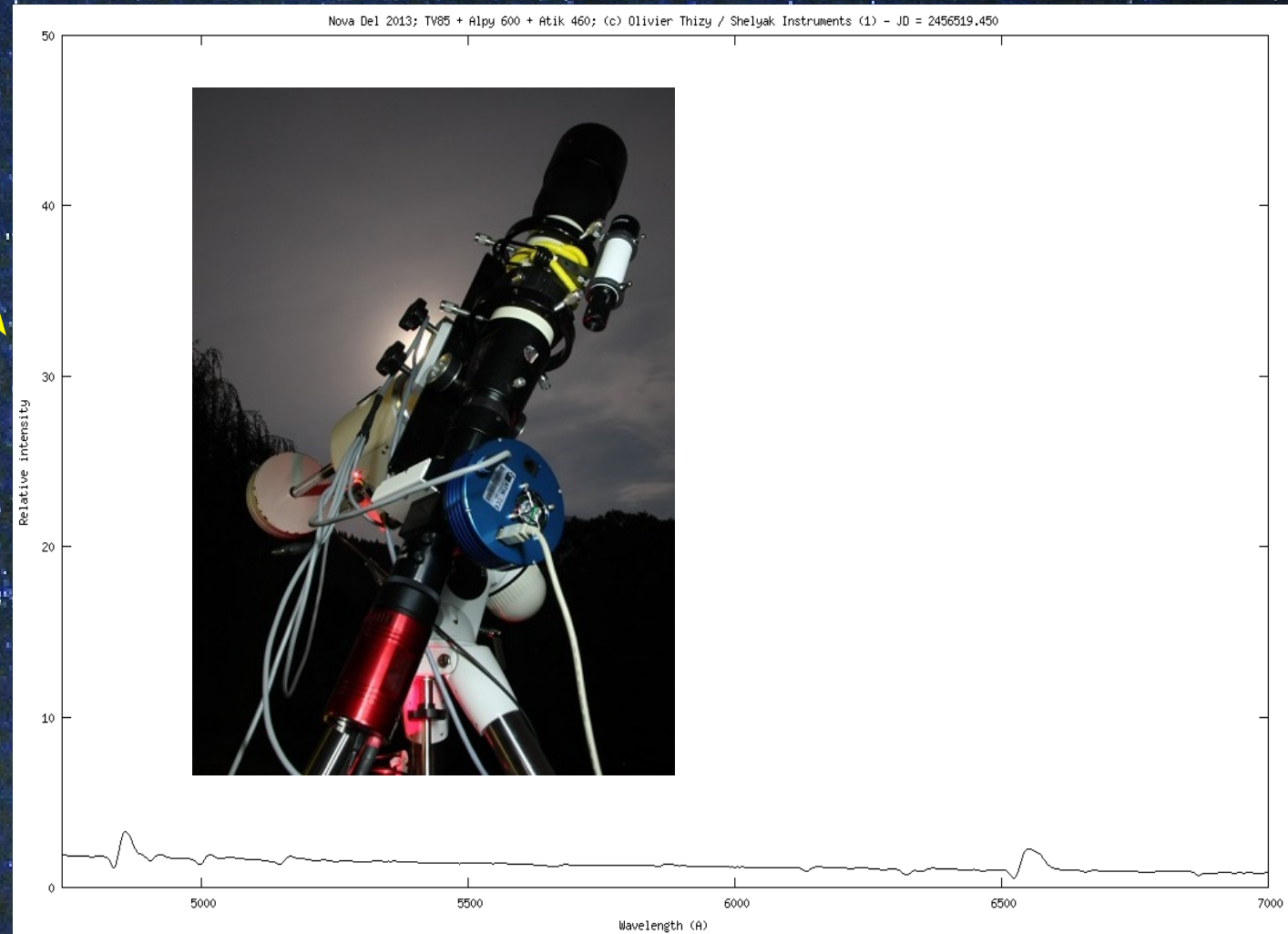
WR 140



Wolf Rayet – massive stars evolution

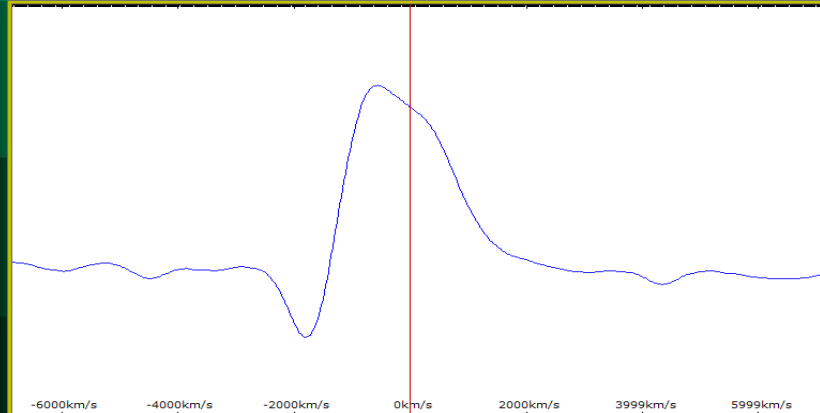


Nova Del 2013



Nova Del 2013

„P Cygni“ profile



20130814.928

20130815.865

20130816.862

20130817.838

20130818.874

20130819.985

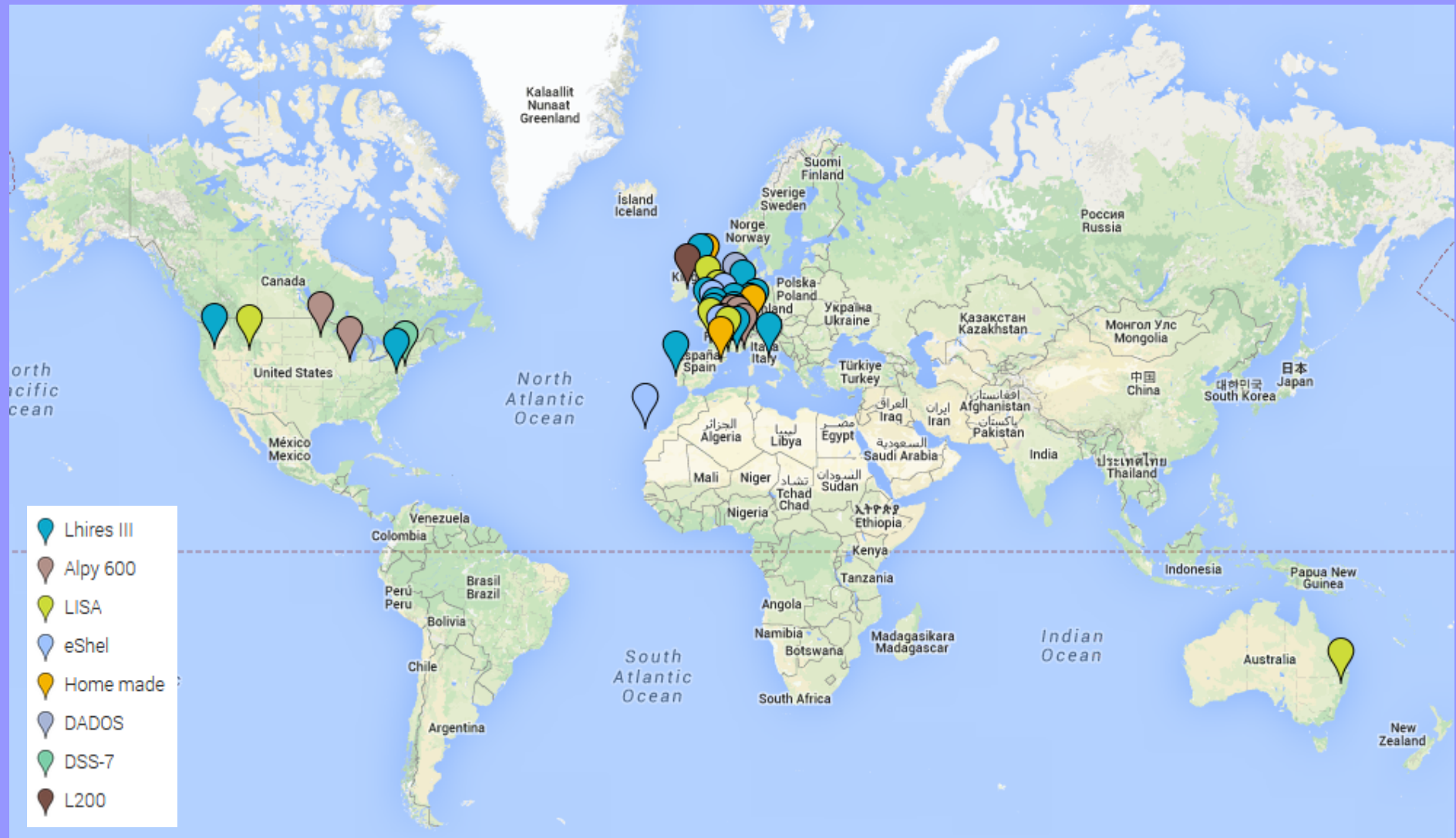
20130820.829

20130821.814

20130822.848

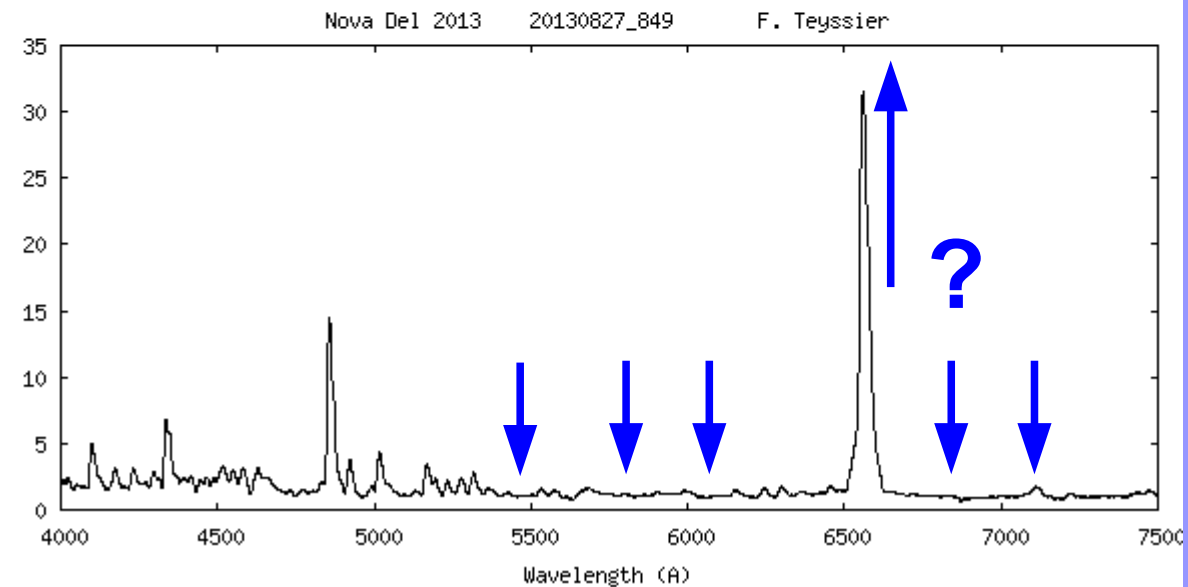
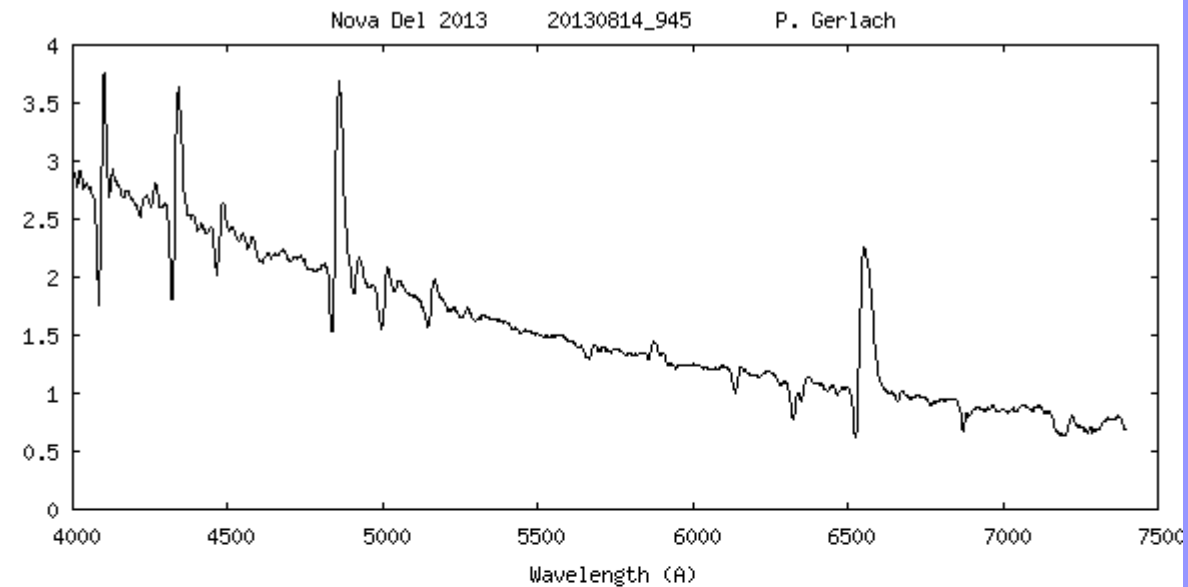
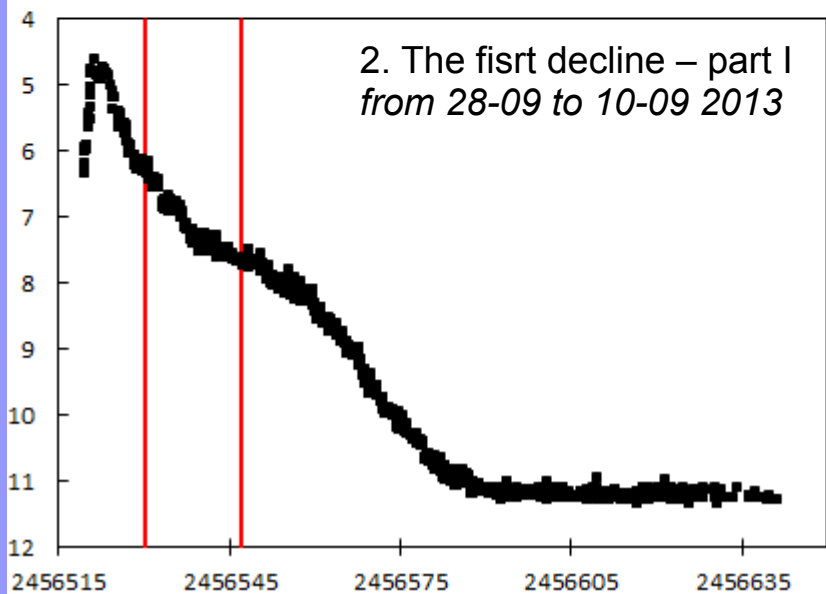
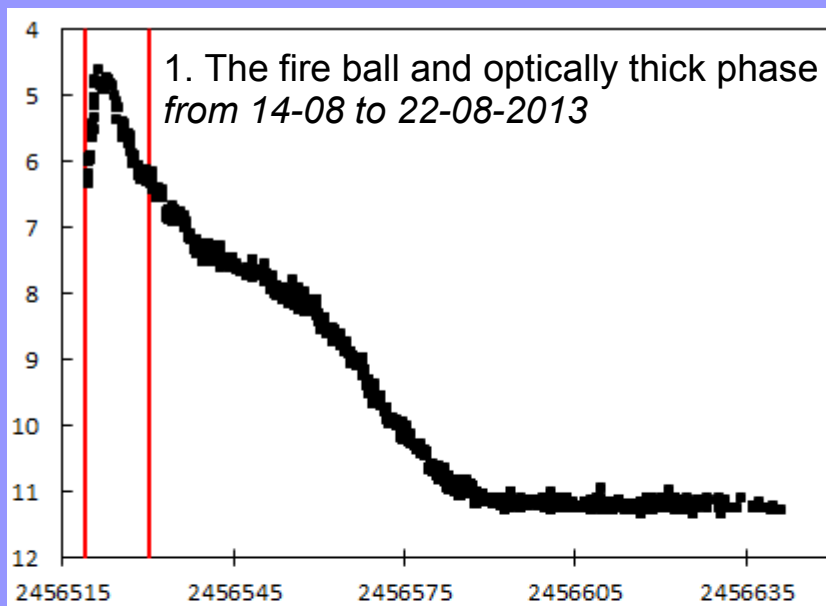
20130823.806

Nova Del 2013: Pro-Am campaign



- Over 1100 spectra, 40 people active for the nova spectral follow up
- An excellent collaboration with a professional astronomer - Steve Shore
- A structured campaign: <http://www.astrosurf.com/aras/novae/Nova2013Del.html>

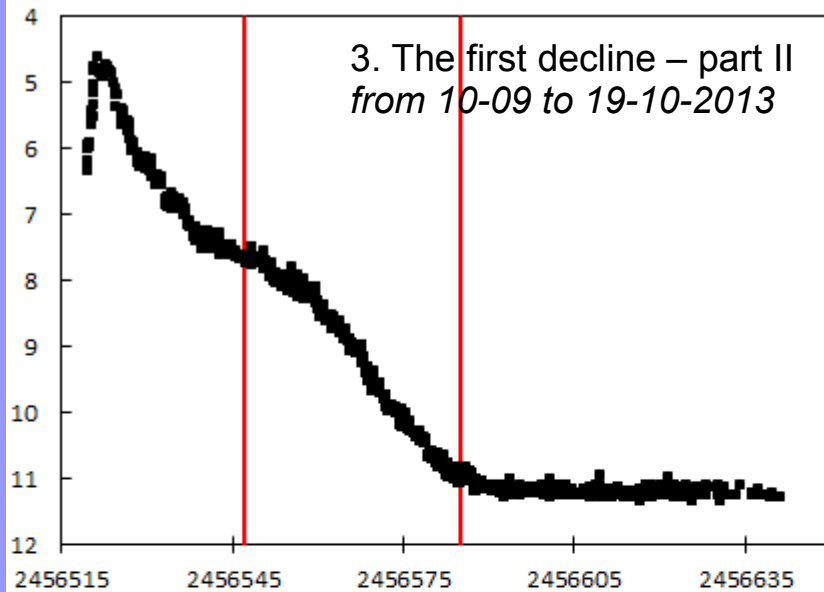
Photometry or Spectroscopy?



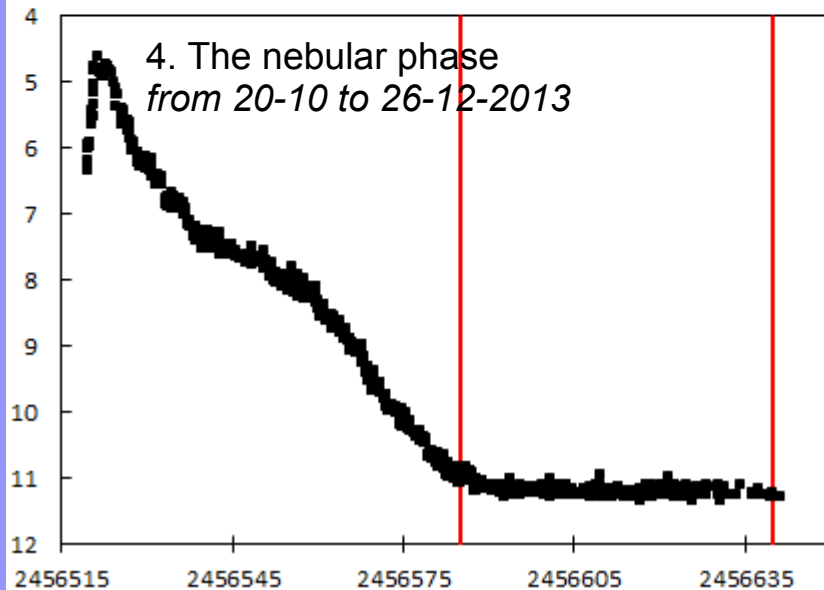
⇒ BOTH ARE IMPORTANT AND COMPLEMENTARY !!!

Photometry or Spectroscopy?

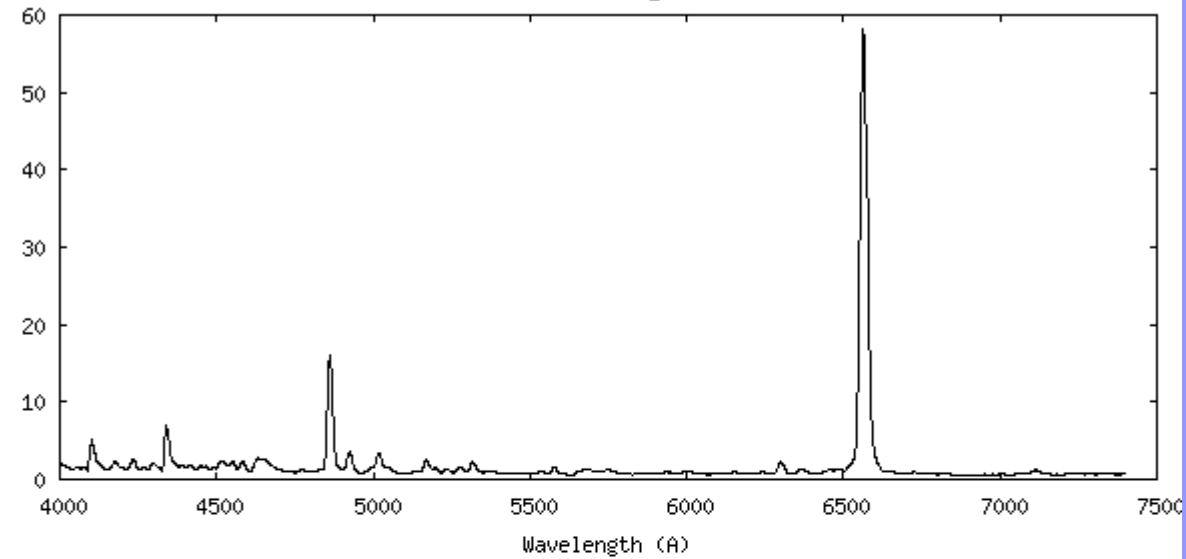
3. The first decline – part II
from 10-09 to 19-10-2013



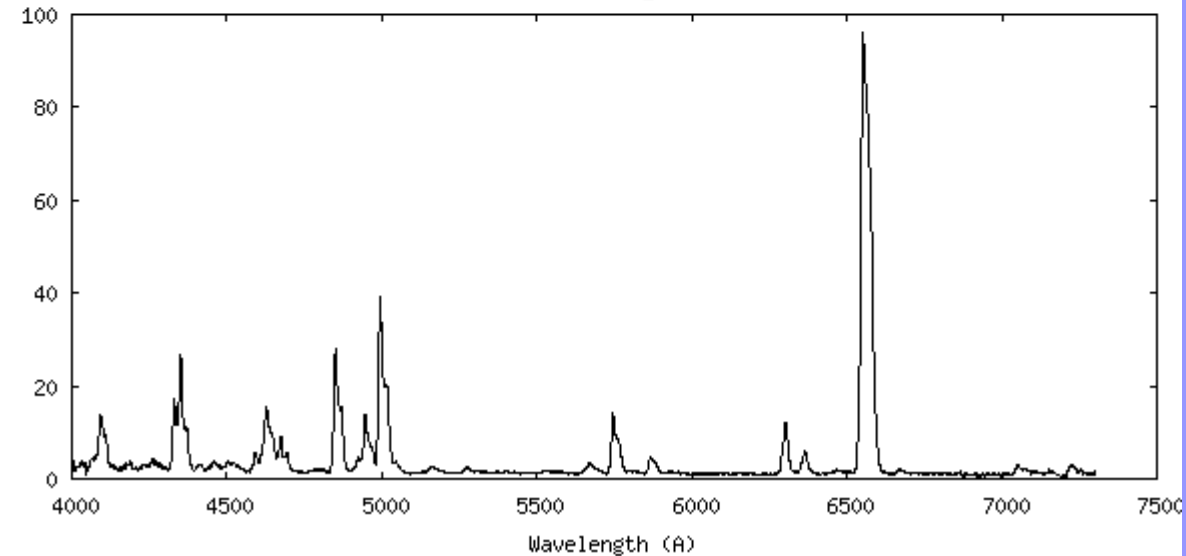
4. The nebular phase
from 20-10 to 26-12-2013



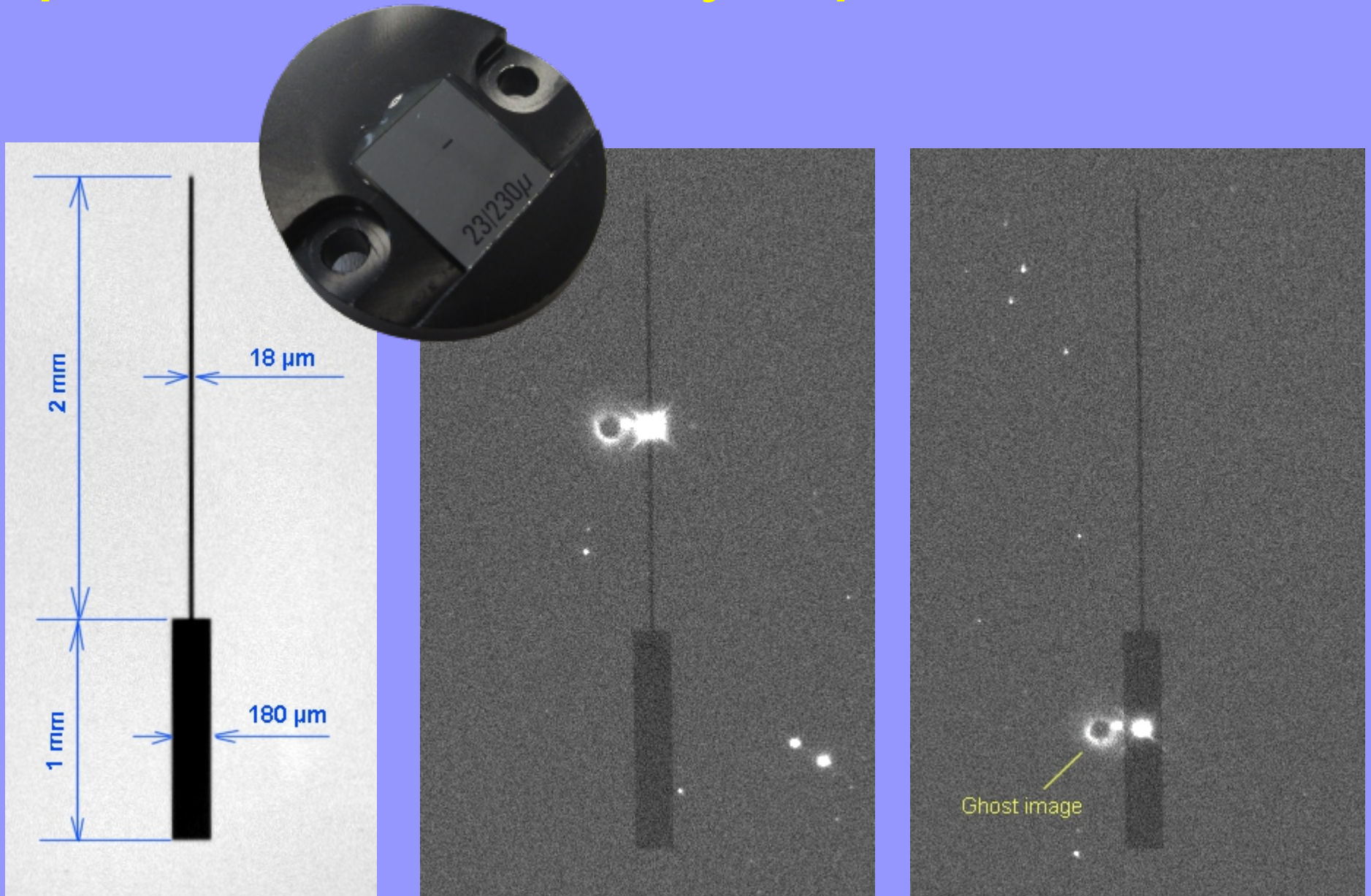
Nova Del 2013 20130910_120 J. Edlin



Nova Del 2013 20131112_412 T. Bohlsen

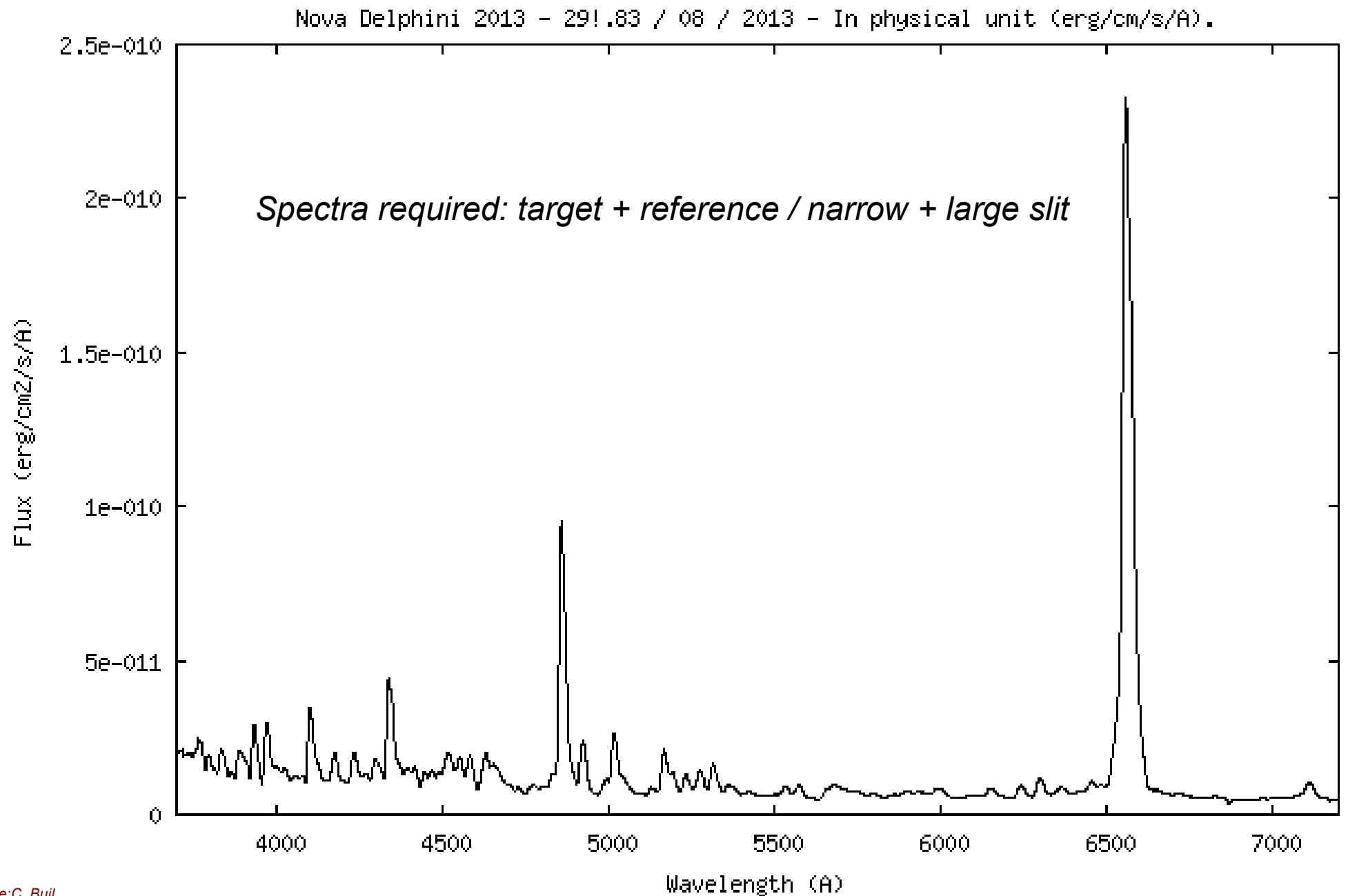


Spectro-Photometry: special slit

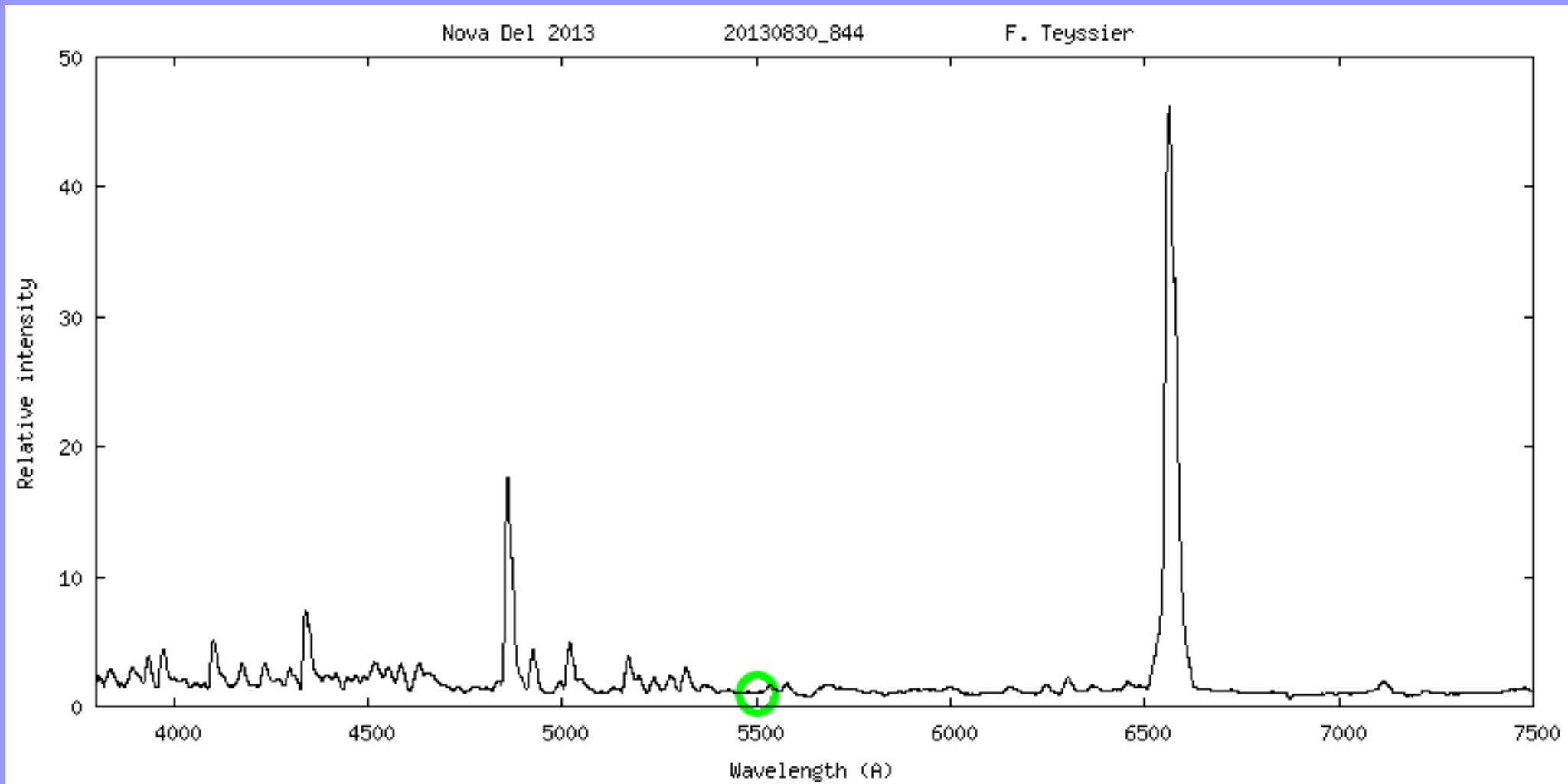


HD180163

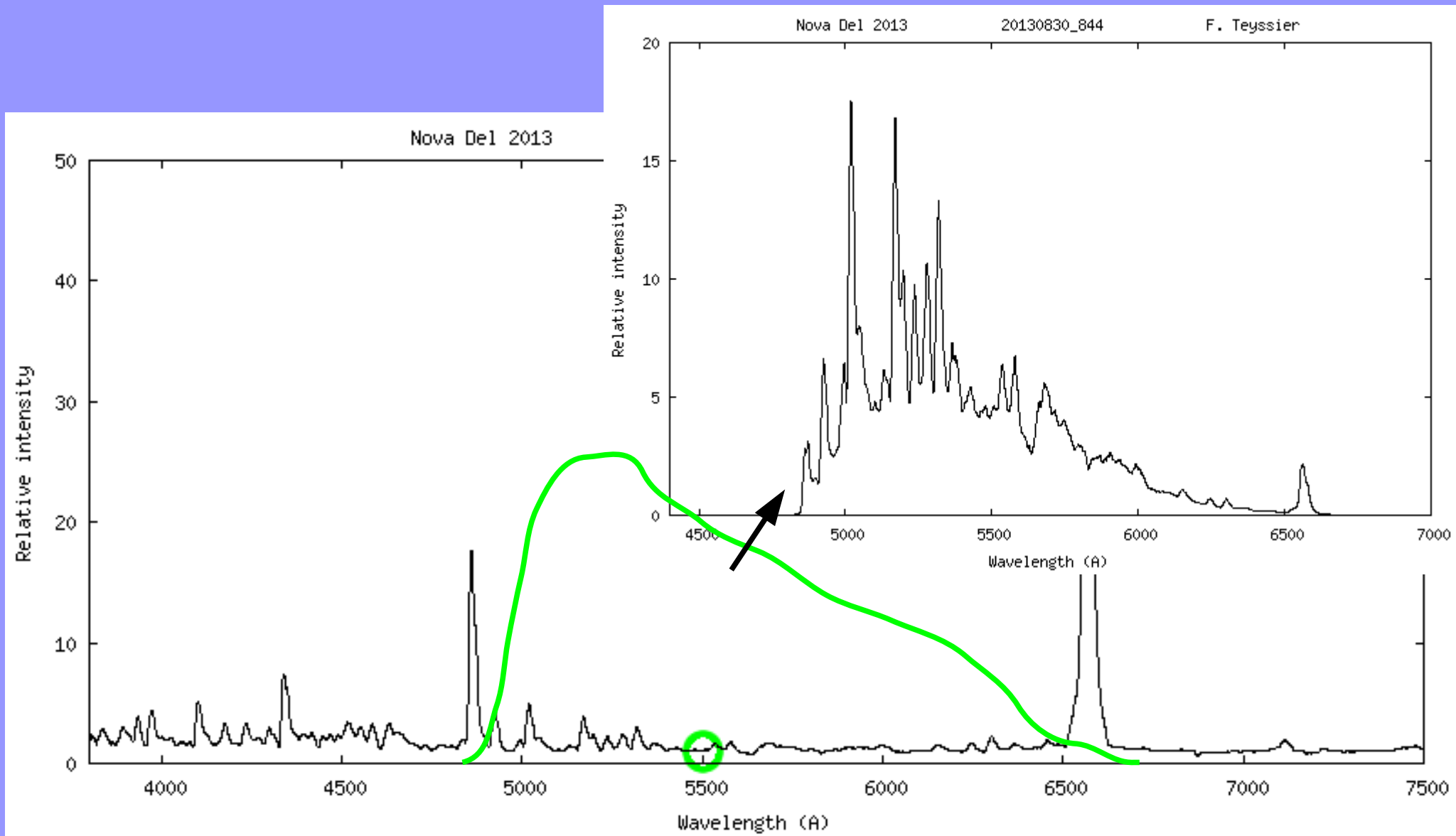
Absolute spectrophotometry #1



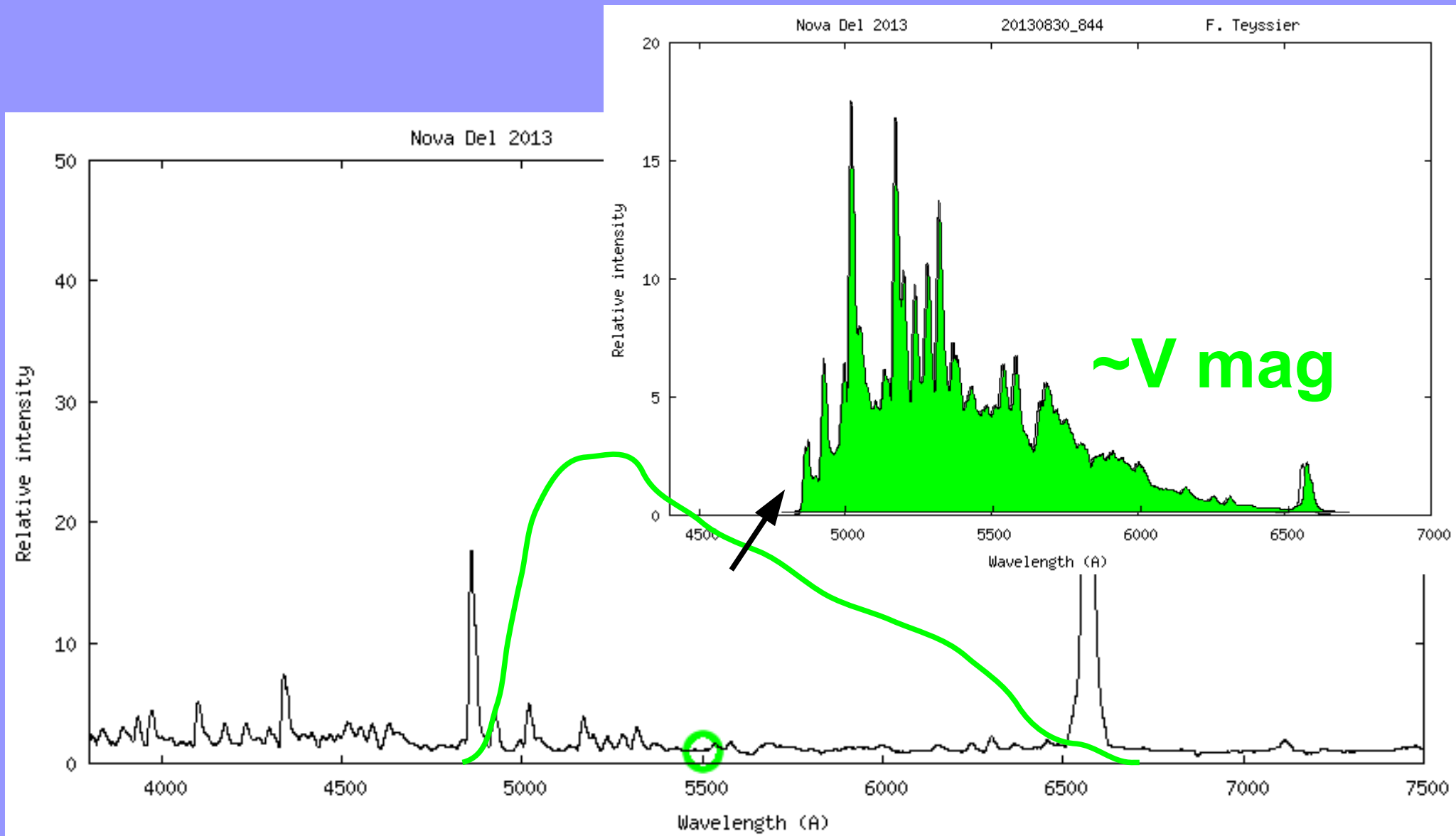
Absolute spectrophotometry #2



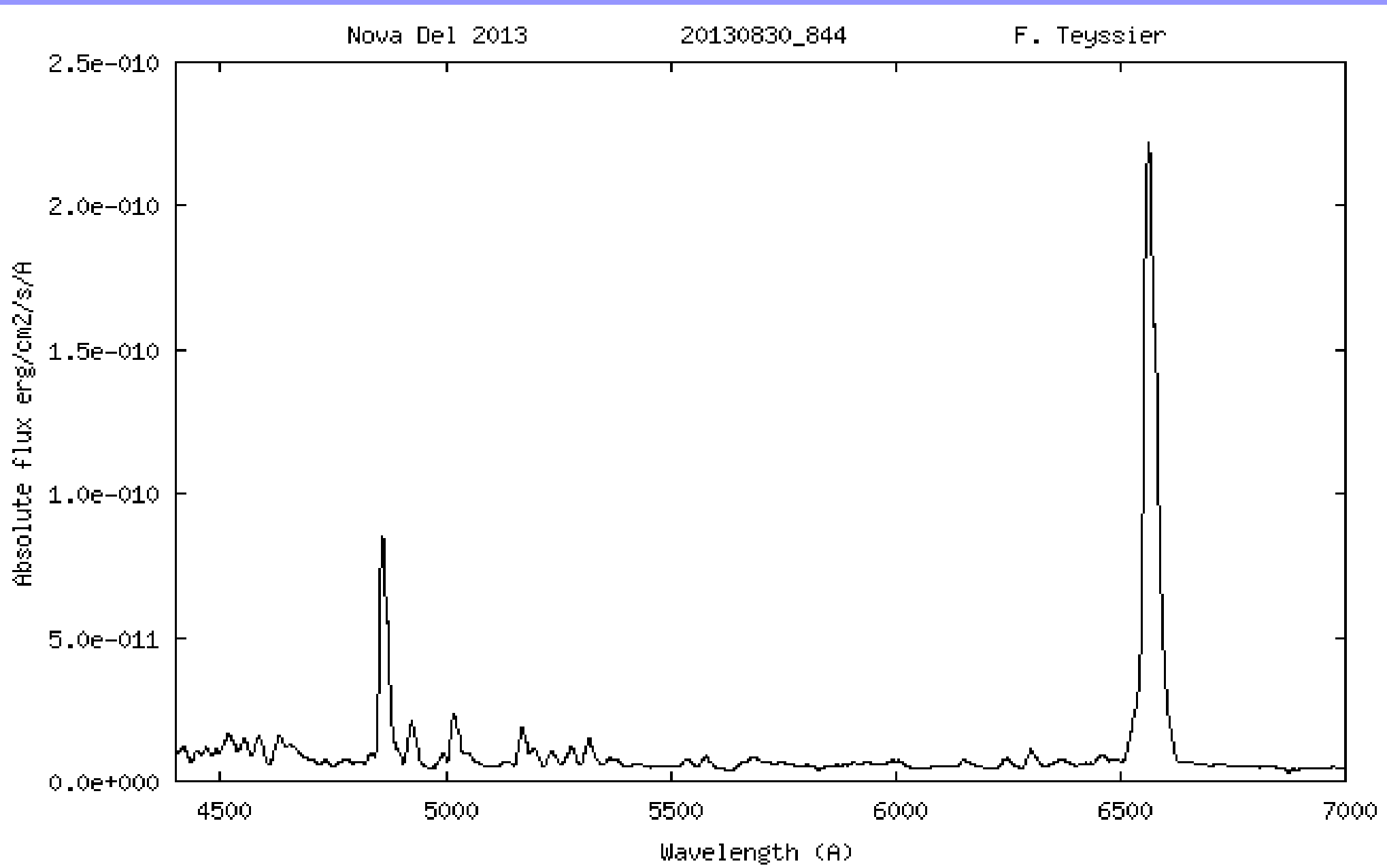
Absolute spectrophotometry #2



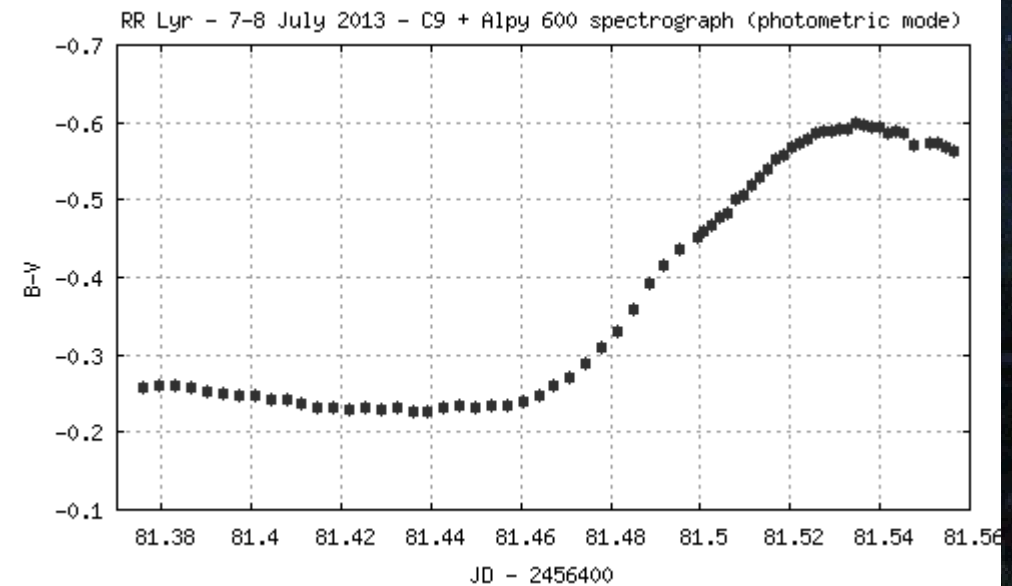
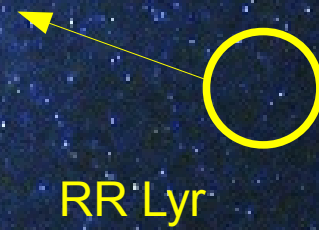
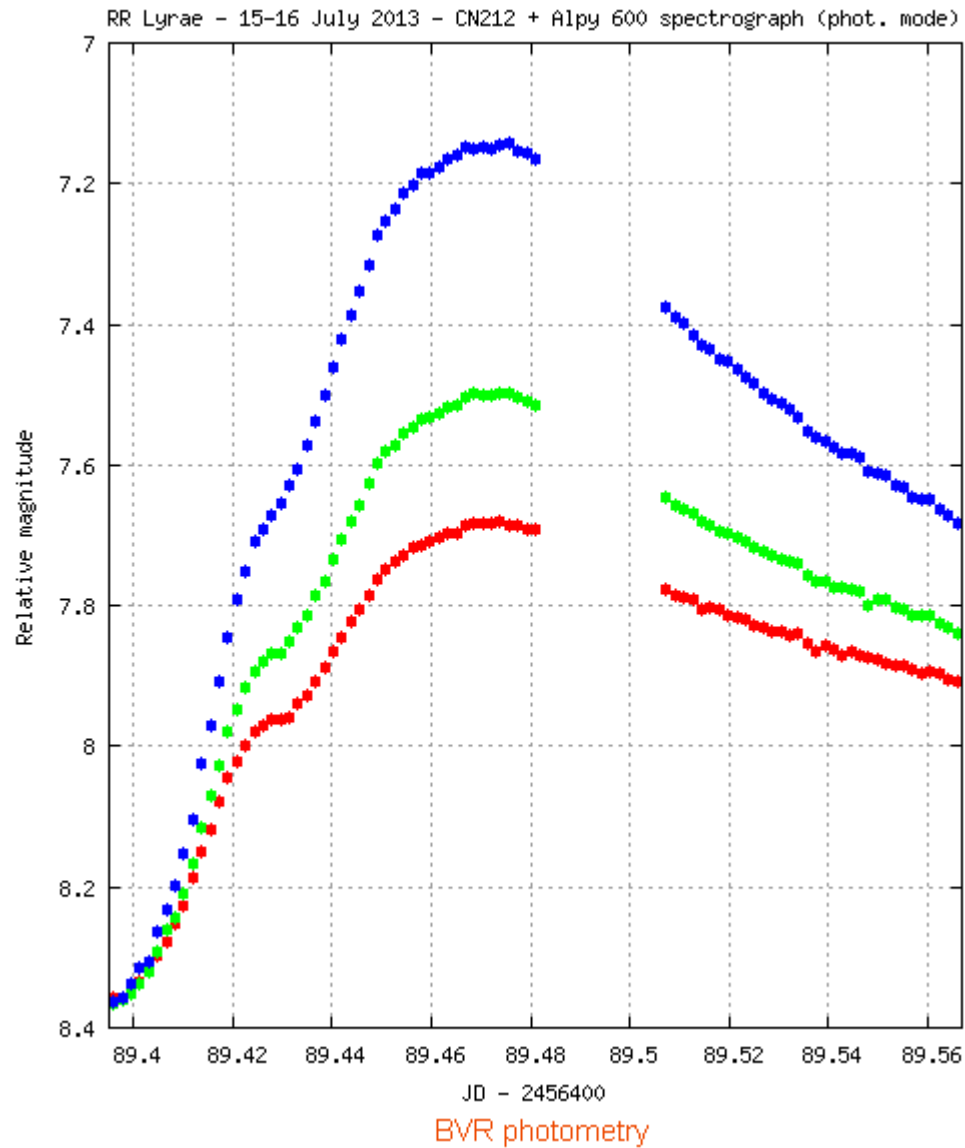
Absolute spectrophotometry #2



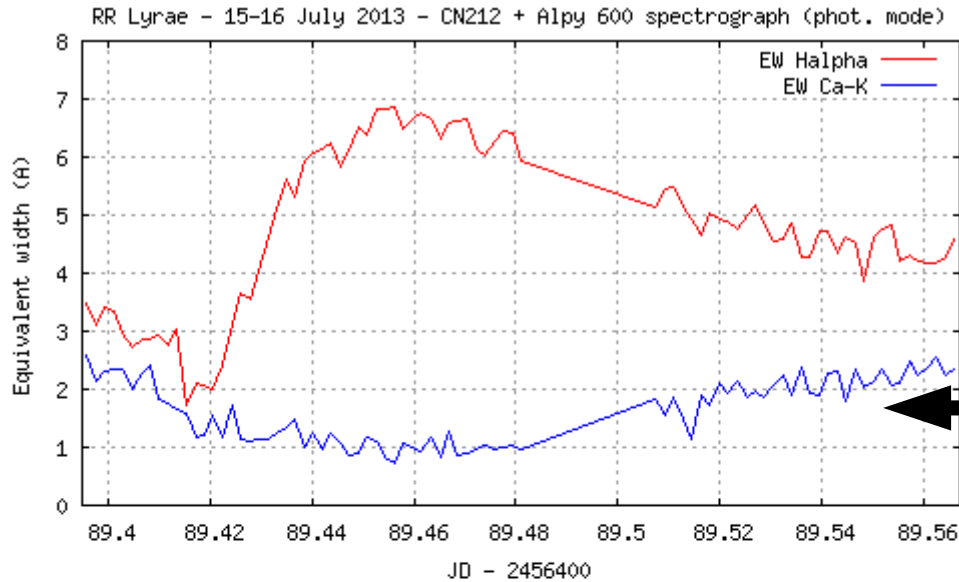
Absolute spectrophotometry #2



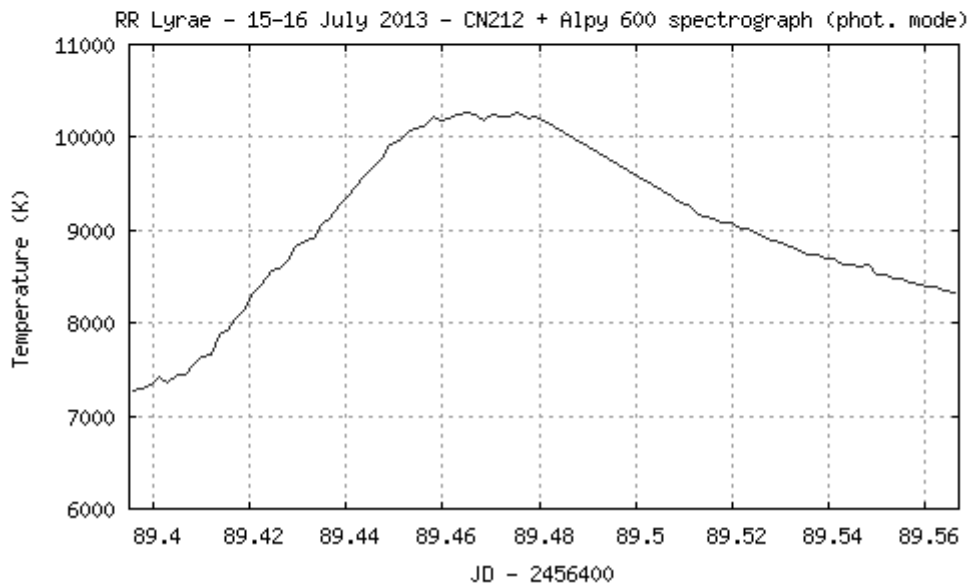
Pulsating stars: RR Lyrae



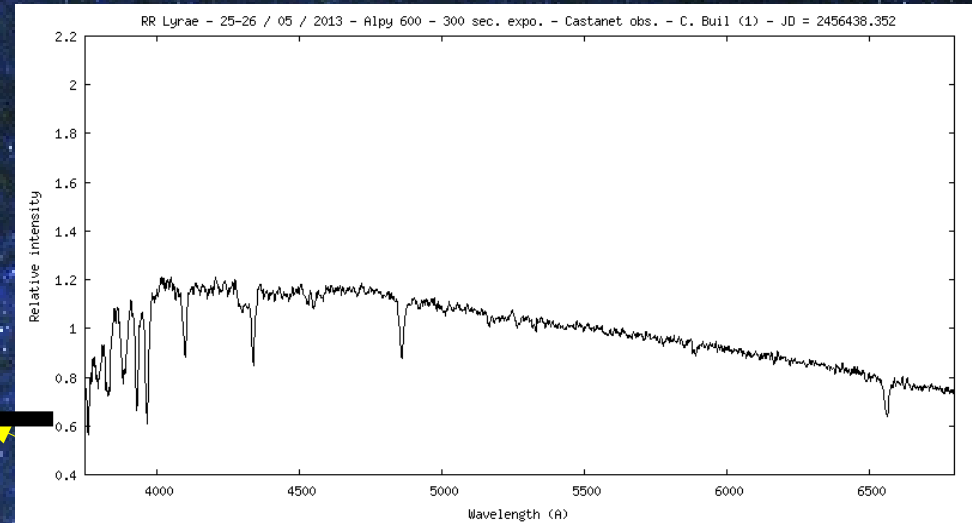
Pulsating stars: RR Lyrae



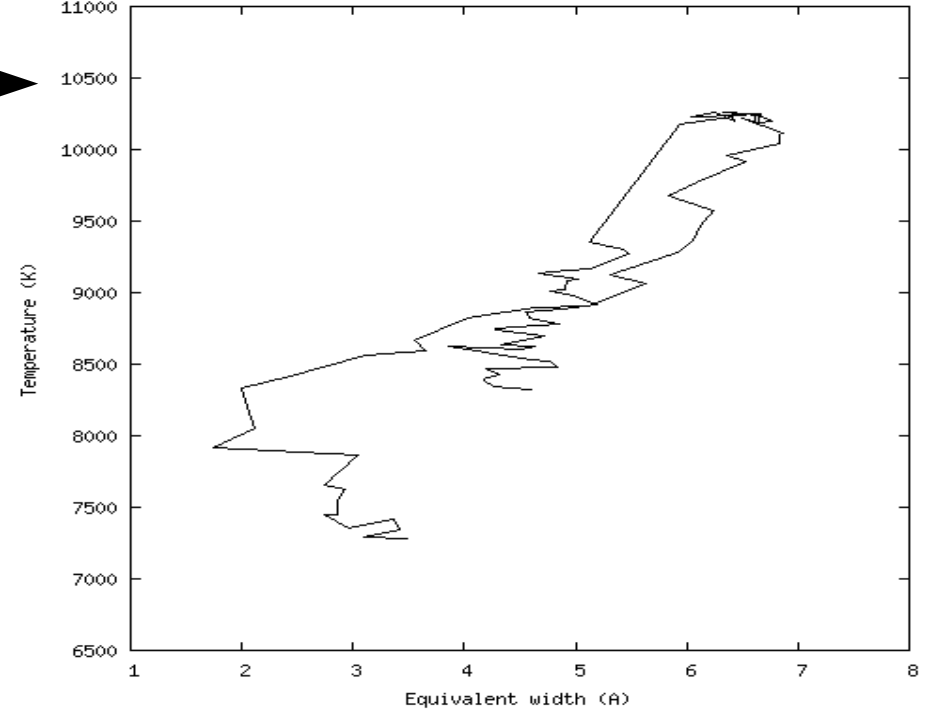
Halpa and Ca K lines equivalent width in Angstroms



Photospheric temperature (K)

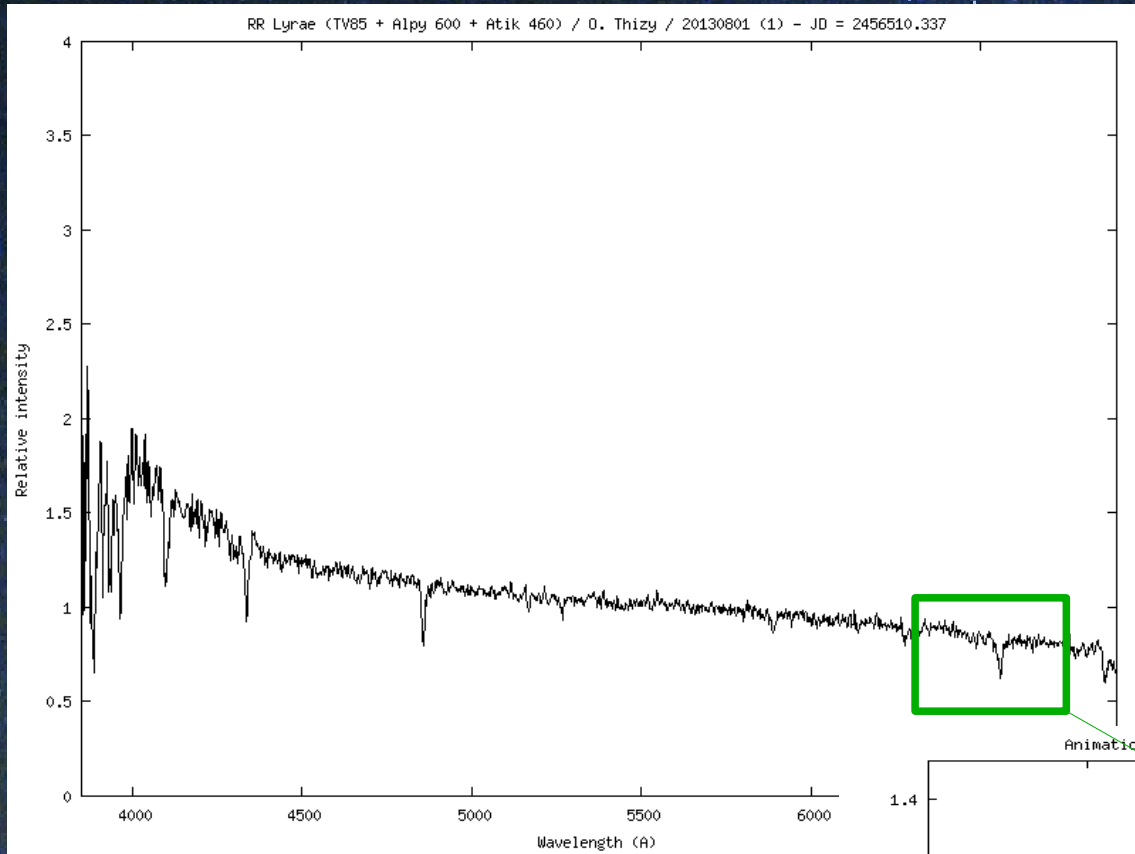


RR Lyrae - 15-16 July 2013 - CN212 + Alpy 600 spectrograph (phot. mode)

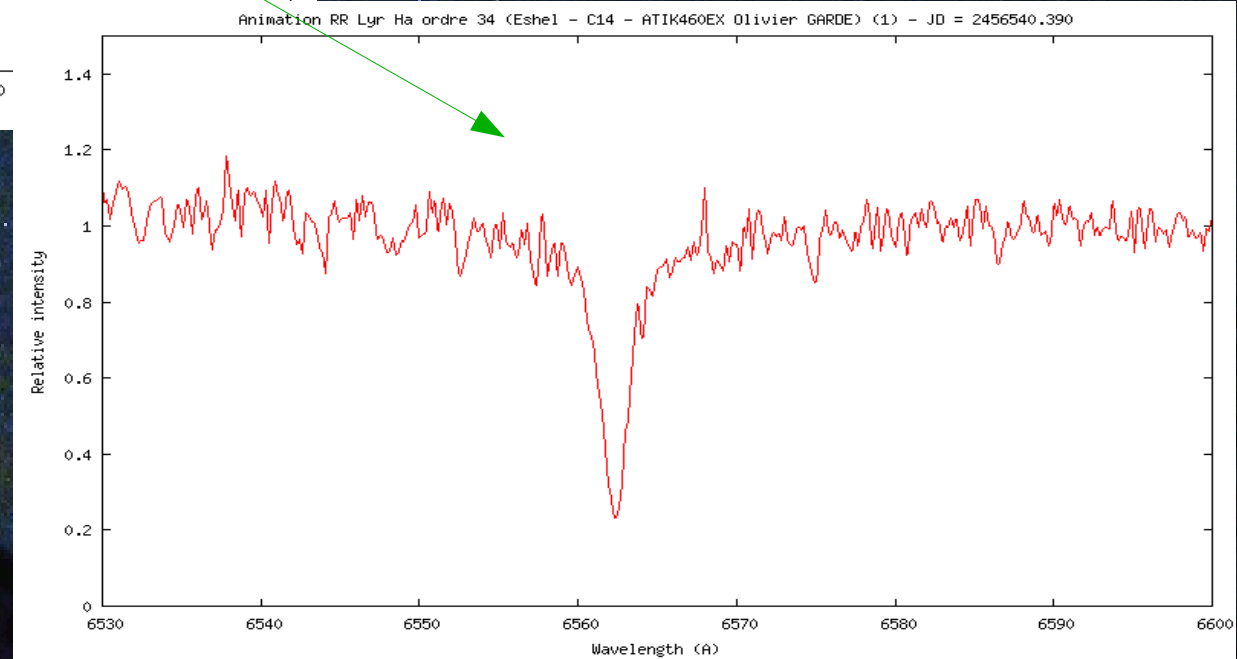


Halpa equivalent width vs Temperature diagram

Pulsating stars: RR Lyrae

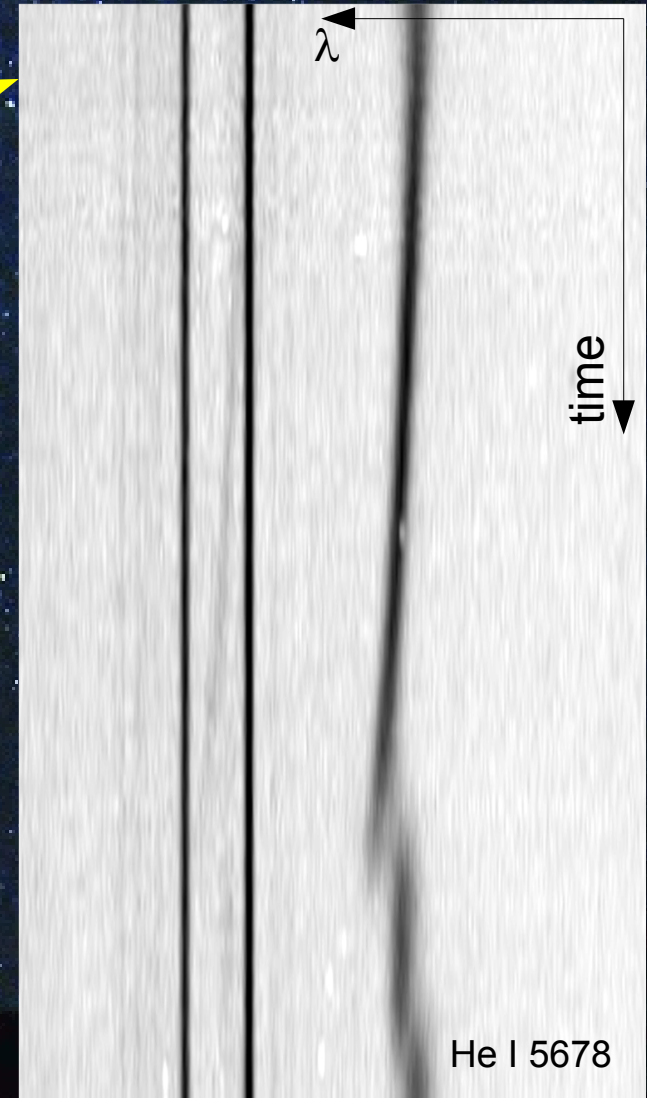
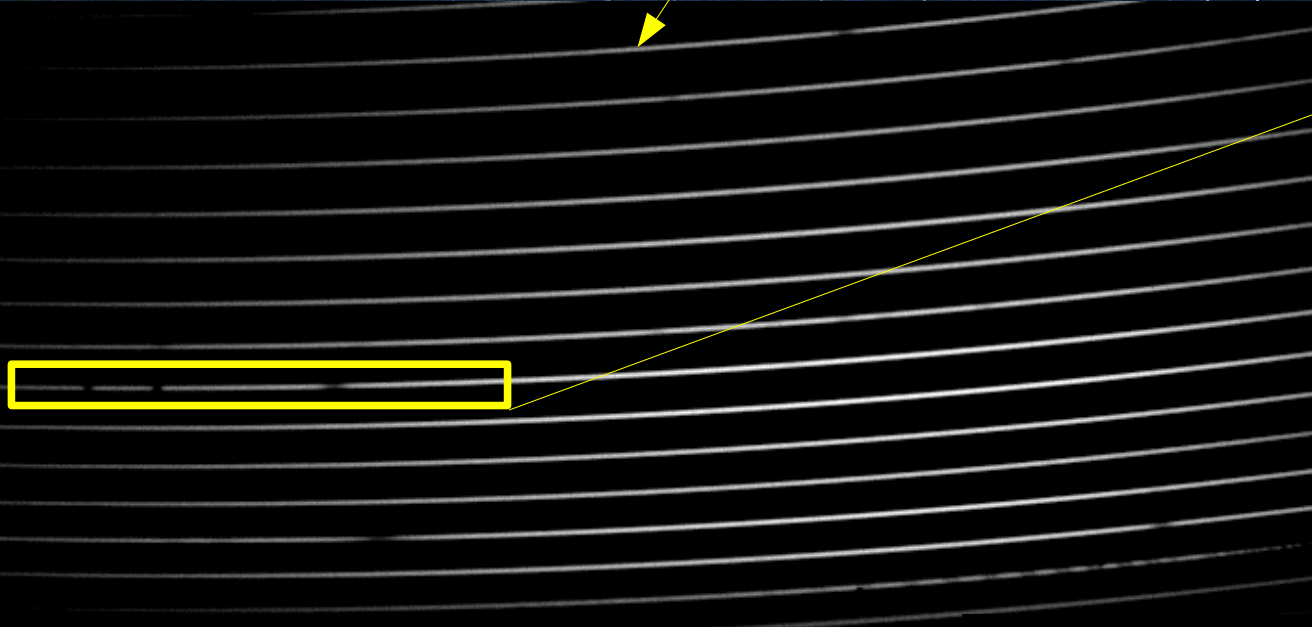


RR Lyr



Pulsating stars: quest for higher resolution

BW Vul



Christian Buil
Valérie Desnoux
Michel Pujol
Olivier Thizy

He I 5678

Where is Charly ?

...or how the Universe can very diverse...

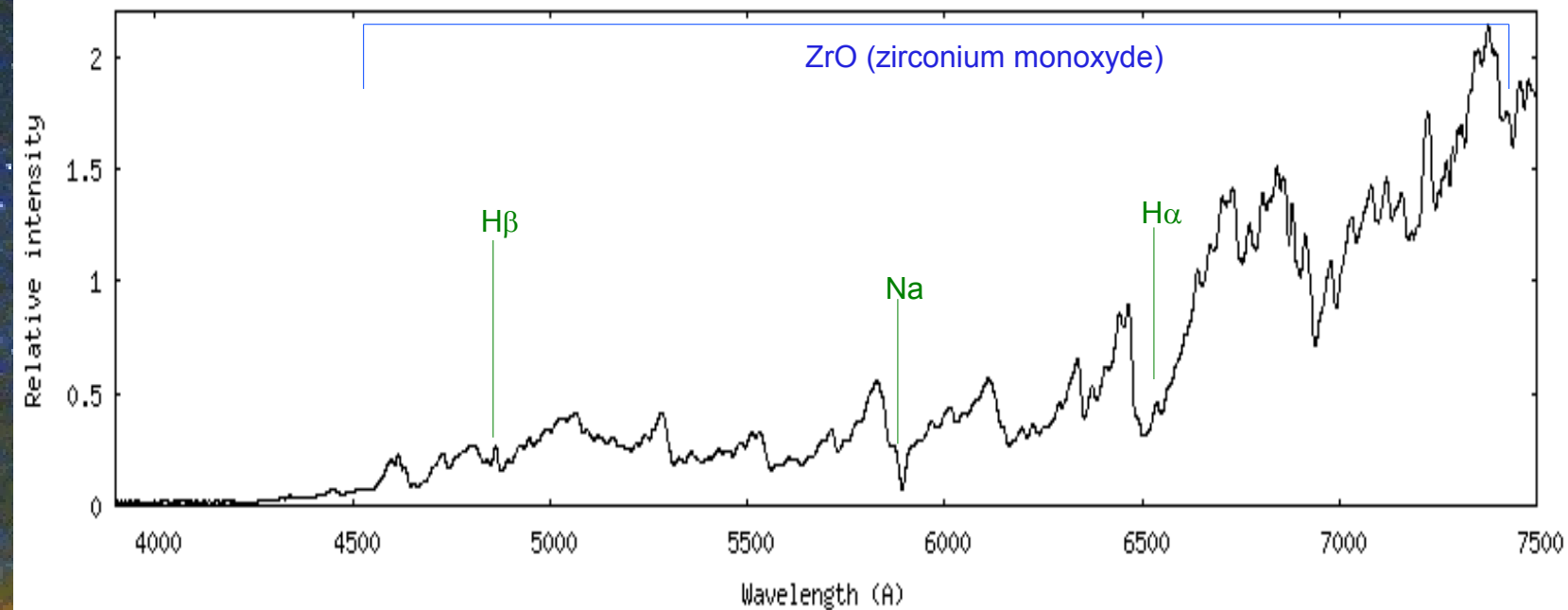


R Cyg: S type, near maximum

- S-type: red giant at end of life, between M-type and Carbon stars
- Mira variable stars

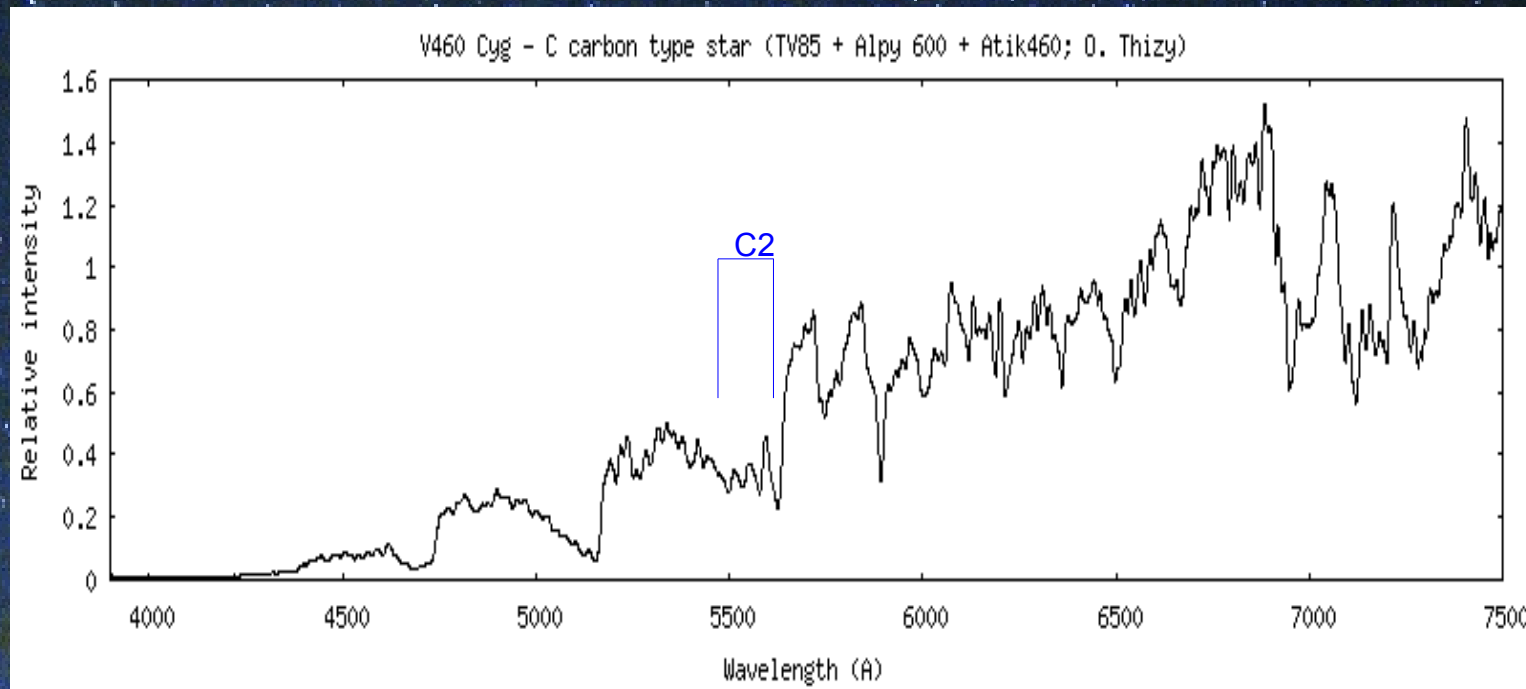
R Cyg

R Cyg - S type star; Mira variable star close to maximum (TV85 + Alpy 600 + Atik460; O. Thizy)



V460 Cyg

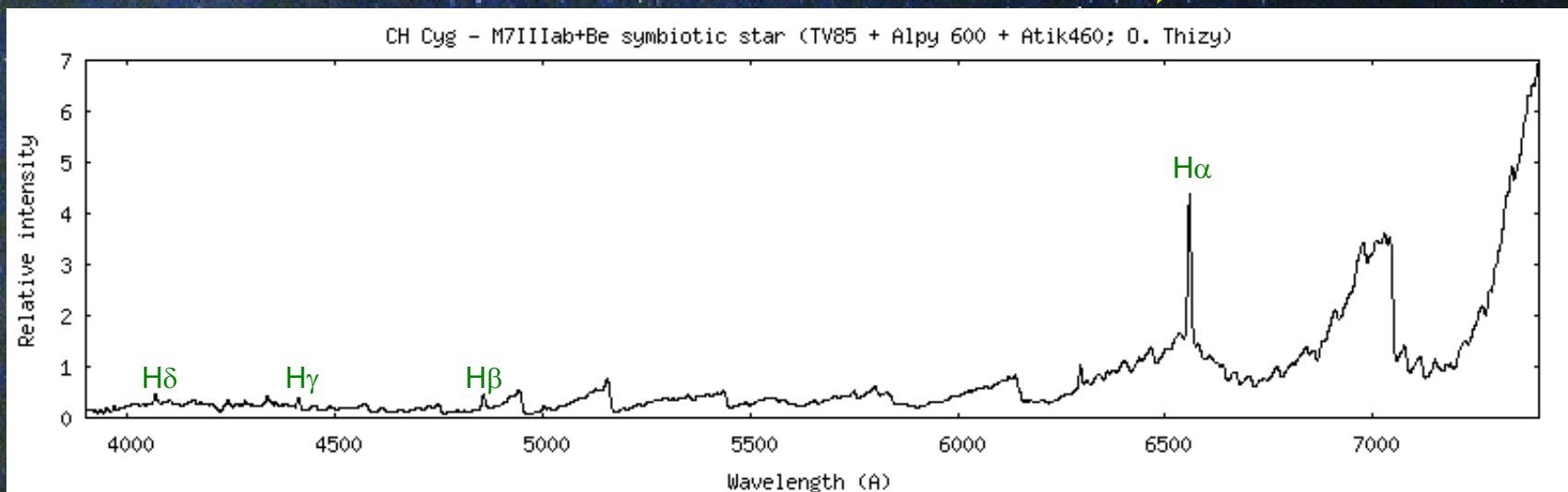
V460 Cyg: type C6,3



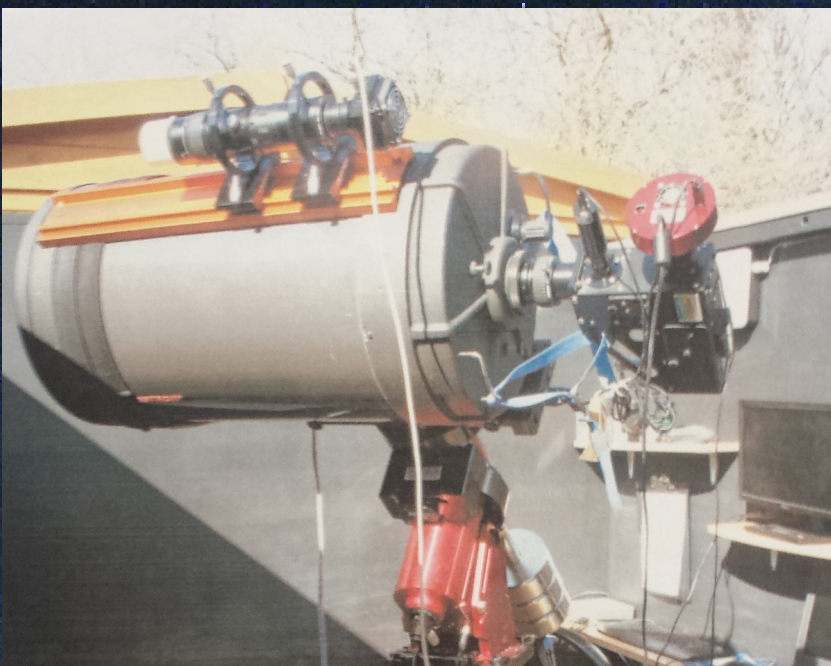
- C6,3 spectral type : Carbon stars
 - $T_{\text{eff}} \sim 3200\text{K}$
 - Measure the C2 bands variations

Symbiotic star: CH Cyg

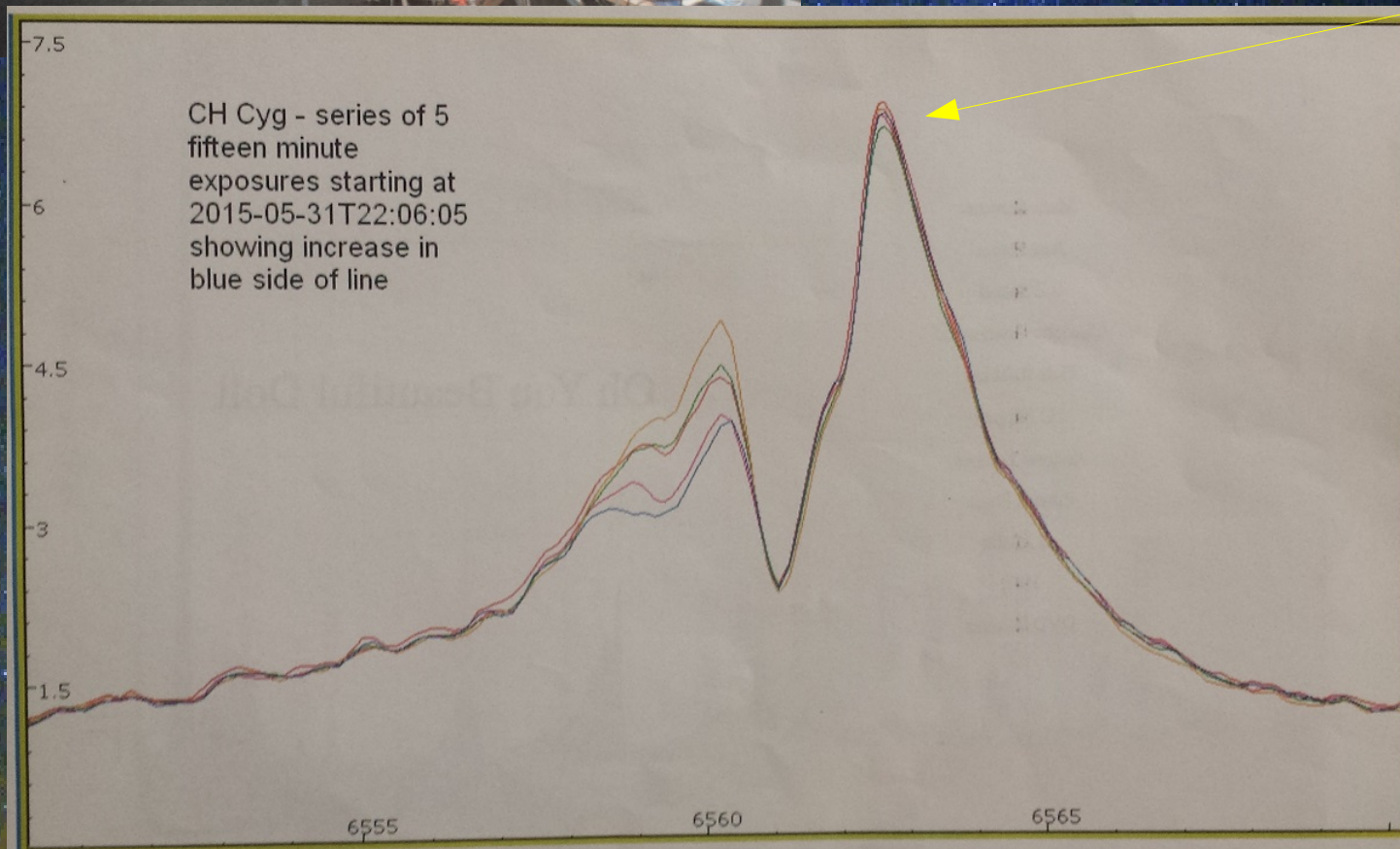
- Red Giant + white dwarf
- Mass transfer



Star of the moment !!!

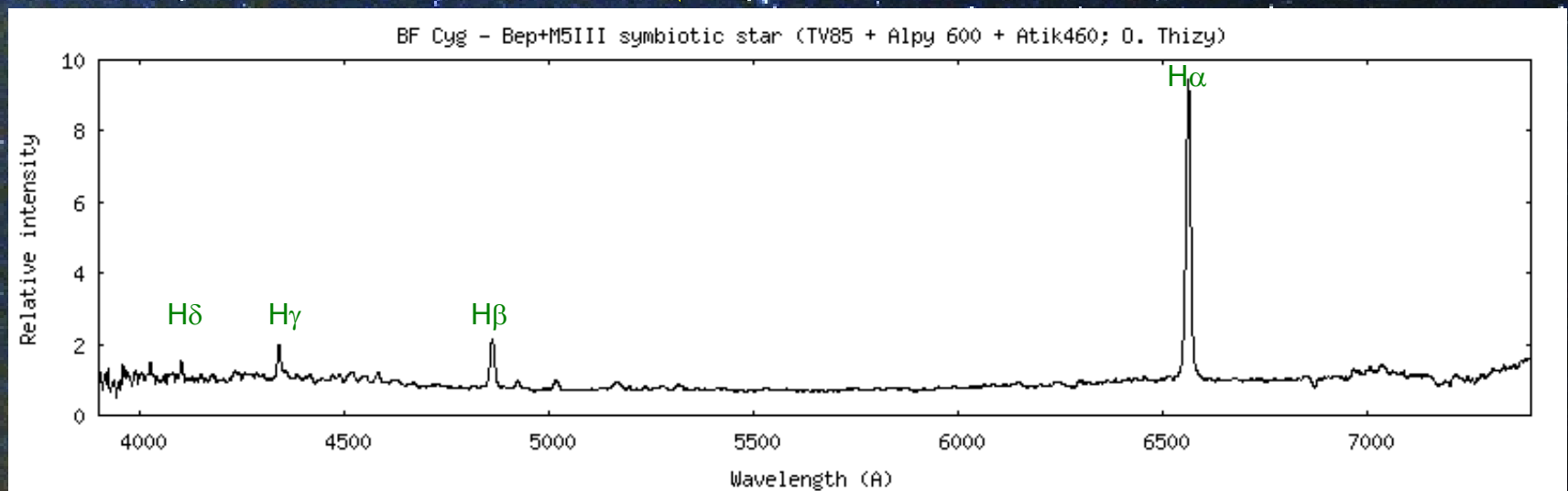


CH Cyg

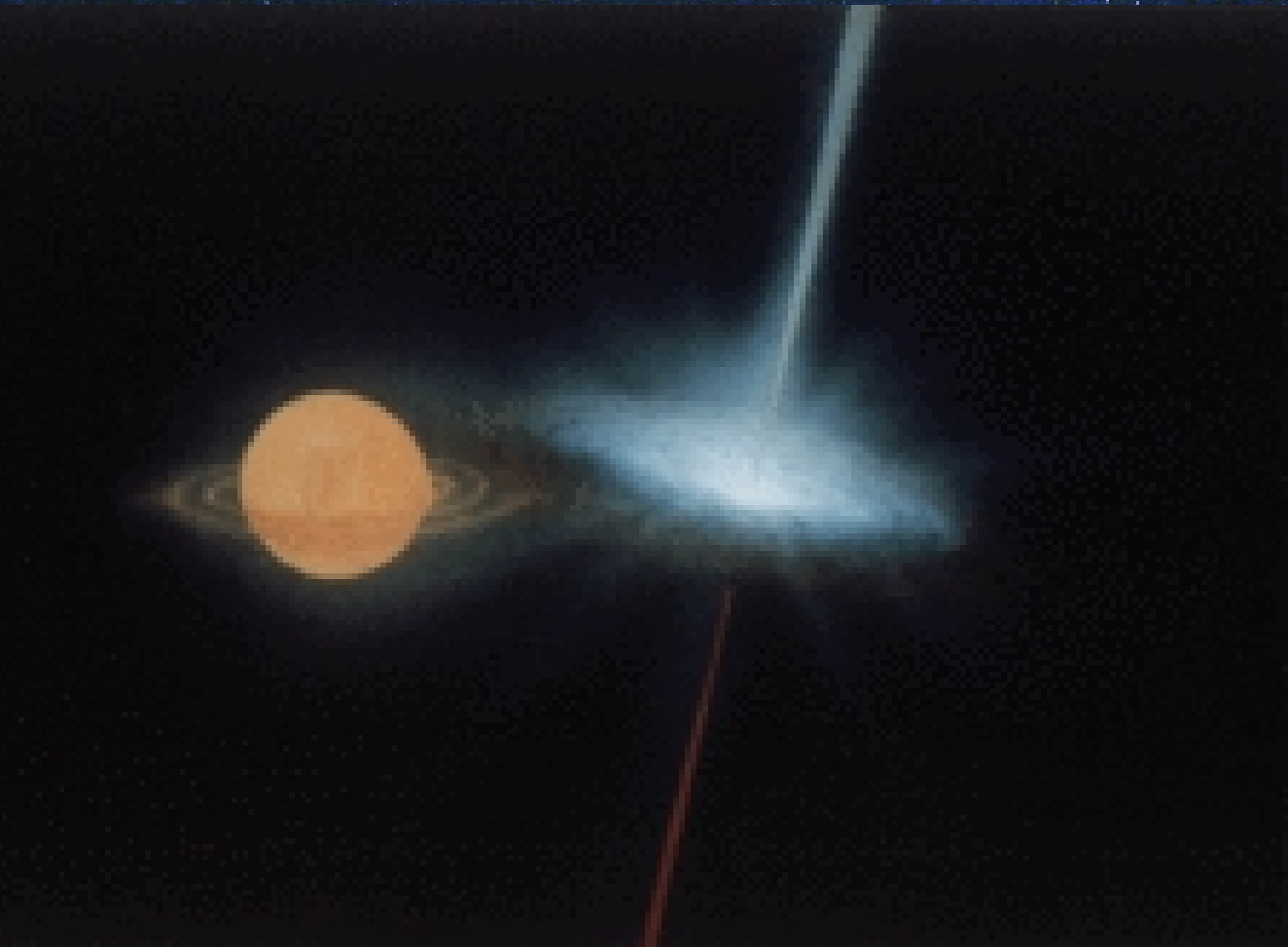


another Symbiotic star: BF Cyg

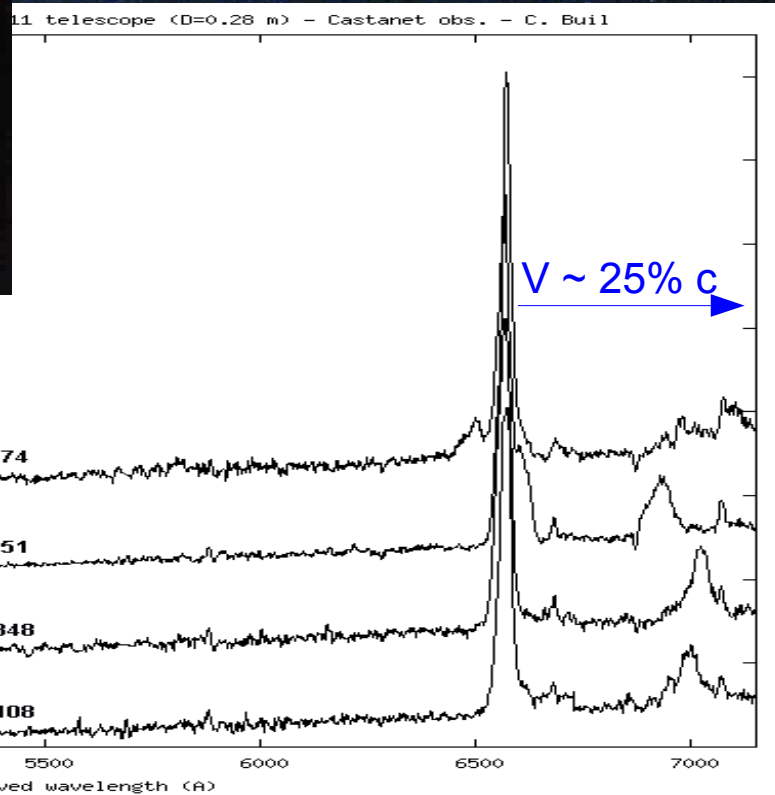
BF Cyg



Microquasars



-1



SS 433

The future: robotic observations!

The screenshot displays a web application interface for robotic observations. The browser window shows the URL `192.168.0.103`. The interface includes a navigation bar with **PLAYBACK**, **SETUP**, and **LOG OUT** options. The main area is divided into four camera channels:

- CH1**: Shows a close-up of a robotic arm with a timestamp of `12/09/2014 22:40:46`.
- CH2**: Shows a different angle of the robotic arm with a timestamp of `12/09/2014 22:40:46`.
- CH3**: Shows a dark view with a timestamp of `12/09/2014 22:40:46`.
- CH4**: Shows a dark view with a timestamp of `12/09/2014 22:40:45`.

On the right side, there are control panels:

- PLAY CONTROL**: Includes icons for home, camera, and video, a grid of numbered buttons (1, 4, 9, 16), and a volume control slider.
- PTZ CONTROL**: Features a circular PTZ control pad with directional arrows and a central **PTZ** label. Below it are buttons for **ZOOM**, **FOCUS**, and **IRIS**, each with minus and plus controls. There is also a **SET** button, a numeric input field with **START**, **STOP**, and **RECALL** buttons, and a row of **LOAD**, **SAVE**, and **CLEAR** buttons.

The Windows taskbar at the bottom shows various application icons and the system tray with the date `12/09/2014` and time `23:44`.

The future: robotic observations!

The screenshot displays the PRISM software interface (Version 9.0.2) running on a Windows system. The main window shows a monochrome astronomical image of SX-LODESTAR (752x580 pixels, 32-bit). The image is a dark field with numerous bright stars and a prominent dark, curved feature. Below the image, a status bar indicates parameters: 10 s, Bin: 1x1, 0.0°C, MX=0 MY=0, Fit=-, Foc=135.0 mm, sca=13.14 "/pixel, R.

A terminal window titled "Run: SPECTROAUTO.PGM" displays the following text:

```
soleil ne nous gene pas encore elevation=-31.036158
est de visibilité de REF HD129174 Sp=B9p+...
-angle horaire= 6.70144 heures
-hauteur = 5.6090517 degre
*** La cible REF HD129174 Sp=B9p+... est trop basse
esse a la cible suivante

soleil ne nous gene pas encore elevation=-31.036267
est de visibilité de HR 5931 Sp=B8III typ* * B=06.17 V=06.25 R=
-angle horaire= 6.48280 heures
-hauteur = 19.242941 degre
*** La cible HR 5931 Sp=B8III typ* * B=06.17 V=06.25 R=
esse a la cible suivante

soleil ne nous gene pas encore elevation=-31.036399
est de visibilité de 16 Oph Sp=B9.5III typ* * B=06.00 V=06.02 R=
-angle horaire= 4.62202 heures
-hauteur = 14.212249 degre
*** La cible 16 Oph Sp=B9.5III typ* * B=06.00 V=06.02 R=
esse a la cible suivante

soleil ne nous gene pas encore elevation=-31.036542
est de visibilité de HD 162365 Sp=B2IV typ* * B=07.90 V=08.02 R=
-angle horaire= 3.84484 heures
-hauteur = 35.830748 degre
Cible suivante HD 162365 Sp=B2IV typ* * B=07.90 V=08.02 R=
Telescope côté WEST
Objet pointé vers EAST
Retournement de monture nécessaire
spectroire de travail : Z:\2014-9-12 19h12m15 LISA_RACINE\2014-9-12 21
Pointage sur le telescope sur 18h22m49.160s +45°00'00.00"
Pointage termine
Pointage sur le telescope sur 17h50m07.610s +15°29'43.31"
Pointage termine
Orientation des cameras suivant position du telescope
Telescope côté EAST
Attente 1 minute max que le dome arrive
Fin d'attente: duree: 1 sec
Extinction de toutes les lampes.
C'est le premier pointage ou on vient de se retourner
chercheur: Procedure Astrometrie allsky
-Pose d'astrometrie sur le ciel pendant 10 secondes
-debut astrometrie ALLSKY
```

The interface also includes a "Graphiques" panel with "Reset" and "Sauver" buttons, a "Positions Axe DEC" panel showing -0.53 Pix and +46ms, and a "Décalage [Pixels, angle]" panel showing 0.56 -70.75°. A "Champ" panel displays 180°00'00"x180°00'00" and "Az IZ Tpc". The bottom status bar shows "Format 695x519x1 [Réels 32bits] Zoom = 1". The Windows taskbar at the bottom shows the system time as 23:46 on 12/09/2014.

The future: robotic observations!

The screenshot displays the PRISM software interface, version 9.0.2, running on a Windows operating system. The main window shows a monochrome astronomical image of HD 162365, with a zoom level of 1. The image is split into two panels, showing the star and its surrounding field. A status bar at the bottom of the image window indicates a 18-second exposure, binning of 2x2, a temperature of -10.0°C, and a focal length of 2153.5 mm.

Overlaid on the image is a 'Run: SPECTROAUTO.PGM' window, which displays a log of the observation process. The log includes details such as the telescope's orientation (WEST and EAST), the target star's coordinates, and the results of the astrometric measurements. A 'Seuils' (Thresholds) dialog box is also open, showing a histogram of the image data with a red cursor indicating a threshold value of 9522.643. The dialog also shows a 'Seuil Bas' of 327.6262 and a 'Palettes' section with 'Max, Min' values of 65535 and 213.

At the bottom of the interface, there is a 'Contrôle Dome' (Dome Control) section with a 'Focuser: ASCOM,Optec...' dropdown menu. The system tray at the bottom right shows the date and time as 23:47 on 12/09/2014.

Format 695x519x1 [Réels 32bits] Zoom = 1

The future: robotic observations!

The screenshot displays the PRISM software interface, version 9.0.2, running on a Windows operating system. The main window shows a grayscale CCD image of a star field with a zoom level of 1. The image is labeled 'ARTEMIS CCD ATIK-314L | 695x519 - Monochrome - Réels(32bits) [Zoom = 1]'. Below the image, technical parameters are displayed: 90.0 ms, Bin:2x2, -10.0°C, MX=0 MY=0, Fil=, and Foc=2147.8 mm sca=1.24".

On the right side, a log window titled 'Run: SPECTROAUTO.PGM' displays the following text:

```
Repertoire de travail : Z:\2014-9-12 19h12m15 LISA_RACINE\2014-9-12 21
pointe le telescope sur 19h22m49.160s +45°00'00.00"
Pointage termine
pointe le telescope sur 17h50m07.610s +15°29'43.31"
Pointage termine
Orientation des cameras suivant position du telescope
Telescope côté EAST
attente 1 minute max que le dome arrive
Fin d attente: duree: 1 sec
Extinction de toutes les lampes.
c est le premier pointage ou on vient de se retourner
Chercheur: Procedure Astrometrie allsky
- Pose d astrometrie sur le ciel pendant 10 secondes
- debut astrometrie ALLSKY
- reconnaissance reussie, recalage telescope
pointe le telescope sur 17h50m07.557s +15°29'43.97"
Pointage termine
Champ: Procedure Astrometrie
Premiere Astrometrie precise
- Pose sur le ciel pendant 10 secondes
- debut calcul astrometrie precise:
- resultat_astrometrie_absoelue=1
- position fente: 17h50m11.103s +15°32'03.72" X=348 Y=233
- position aux coordonnees de la cible: 17h50m07.61s +15°29'43.31"
- distance fente-cible dX=40 dY=114
- deplace cible sur la fente
attente rattrage entrainement horaire
Deuxieme Astrometrie precise
- Pose sur le ciel pendant 10 secondes
- debut calcul astrometrie precise:
- resultat_astrometrie_absoelue=1
- position fente: 17h50m06.990s +15°29'45.78" X=348 Y=233
- position aux coordonnees de la cible: 17h50m07.61s +15°29'43.31"
- distance fente-cible dX=-7 dY=2
demi taille de la fenetre de recherche de l'etoile guide= 30
La cible est l'etoile de guidage on va guider doucement
Determine le temps de pose pour le guidage
pose de 0.01 secondes donne un max ADU etoile=543
pose de 0.03 secondes donne un max ADU etoile=1423
pose de 0.09 secondes donne un max ADU etoile=3583
On choisit un temps de pose de guidage de =0.09 secondes
autoguidage
lance centrage
```

At the bottom of the interface, there are control panels for 'Positions Axe RA' (set to -1.46 Pix, +61ms) and 'Positions Axe DEC' (set to -0.64 Pix, -54ms). A 'Répartition' panel shows a bar graph and a 'Délaiage (Pixel, angle)' panel shows '1.60 -155.47°'. The bottom status bar indicates 'Format 695x519x1 [Réels 32bits] Zoom = 1' and 'Contrôle Dome'.

The future: robotic observations!

The screenshot displays the PRISM software interface, version 9.0.2, running on a Windows operating system. The main window shows a dark astronomical image with a bright horizontal line across the center, likely representing a star or a spectral feature. The interface includes a menu bar (Fichier, Edition, Prétraitement, Visualisation, Transformations, Trichromie, Traitements, Caméras, Telescope/observatoire, Fenêtre, Options, Aide) and a toolbar with various icons for file operations and image processing.

Key components of the interface include:

- ARTEMIS CCD ATIK-460ex [1] | 1374x1099 - Monochrome - Réels(32bits) [Zoom = 1/2]**: The main image window showing the astronomical data.
- Run: SPECTROAUTO.PGM**: A terminal window displaying the execution log of the spectroscopy automation script. The log includes details about the observation setup, such as the target star (HD 162365), the slit position, and the resulting spectrum.
- ARTEMIS CCD ATIK-314L**: A panel on the right side of the interface, likely used for selecting and configuring different camera modules.
- SX-LODESTAR**: A panel on the right side, possibly used for selecting and configuring different filter sets.
- Positions Axe DEC: 1.07 Pix +94ms**: A panel at the bottom left showing the current position and timing of the observation.
- Décalage (Pixels, angle) 2.34 152.71°**: A panel at the bottom center showing the offset of the observation.
- Champ=180°00'00"x180°00'00" Az IZ Tpc**: A panel at the bottom center showing the field of view and other parameters.

The terminal window output includes the following text:

```
Run: SPECTROAUTO.PGM
PARAMETRES PREDEFINIS
-Pose sur le ciel pendant 18 secondes
-debut calcul astrometrie precise:
-résultat_astrometrie_absoelue=1
-position fente: 17h50m11.103s +15°32'03.72'' X=348 Y=233
-position aux coordonnées de la cible: 17h50m07.61s +15°29'43.31''
-distance fente-cible dX=40 dY=114
-deplace cible sur la fente
attente rattrage entrainement horaire
Deuxieme Astrometrie precise
-Pose sur le ciel pendant 18 secondes
-debut calcul astrometrie precise:
-résultat_astrometrie_absoelue=1
-position fente: 17h50m06.990s +15°29'45.78'' X=348 Y=233
-position aux coordonnées de la cible: 17h50m07.61s +15°29'43.31''
-distance fente-cible dX=-7 dY=2
demi taille de la fenetre de recherche de l'etoile guide= 30
La cible est l'etoile de guidage on va guider doucement
Determine le temps de pose pour le guidage
pose de 0.01 secondes donne un max ADU etoile=543
pose de 0.03 secondes donne un max ADU etoile=1423
pose de 0.09 secondes donne un max ADU etoile=3583
On choisit un temps de pose de guidage de =0.09 secondes
autoguidage
lance centrage
centrage OK
centrage stop
Pose sur le champ pour sauvegarde
lance autoguidage final Agressivite RA=0.2 DEC=1
autoguidage definitif en cours
determination du temps de pose et nb de pose optimum
pose evaluation spectre dure:1 secondes
Flux= 362
pose evaluation spectre dure:10 secondes
Flux= 2776
La pose unitaire choisie est de 60 secondes
Temps total exposition necessaire 109 secondes, pour obtenir un flux
La pose d evaluation de 10 secondes donne un max ADU=2776
On choisit de realiser 3 poses unitaires exposees pendant 36.333333
Soit un total de 109 secondes
Pose Photometrie au Chercheur
commence l acquisition de 1 objet=HD 162365
Extinction de toutes les lampes.
spectre de HD 162365 ,debut de la pose 1/3 duree 36.333333 secondes
```

The future: robotic observations!

PRISM Version 9.0.2 build 2717 27/06/2014 (TU:12/09/2014 21:51:24) Alloué > 37 722 176 -> Log désactivé, Processus 0x0000E60 [39,20]

Fichier Edition Prétraitement Visualisation Transformations Trichromie (imagerie couleur) Traitements Caméras Telescope/observatoire Fenêtre Options Aide

ARTEMIS CCD ATIK-460ex [1] | 1374x1099 - Monochrome - Réels(32bits) [Zoom = 1/2]

Run: SPECTROAUTO.PGM

```

ATTENTE RATTRAGE ENTRAINEMENT HORS-HEURE
Deuxieme Astrometrie precise
- Pose sur le ciel pendant 10 secondes
- debut calcul astrometrie precise:
- resultat_astrometrie_absolue=1
- position_fente: 17h50m04.990s +15°29'45.78'' X=348 Y=233
- position aux coordonnees de la cible: 17h50m07.61s +15°29'43.31''
- distance_fente-cible dX=-7 dY=2
Demi taille de la fenetre de recherche de l'etoile guide= 30
La cible est l'etoile de guidage on va guider doucement
Determine le temps de pose pour le guidage
pose de 0.01 secondes donne un max ADU etoile=543
pose de 0.03 secondes donne un max ADU etoile=1423
pose de 0.05 secondes donne un max ADU etoile=3683
On choisit un temps de pose de guidage de =0.05 secondes
autoguidage
lance centrage
centrage OK
centrage stop
Pose sur le champ pour sauvegarde
lance autoguidage final Agressivite RA=0.2 DEC=1
autoguidage definitif en cours
determination du temps de pose et nb de pose optimum
pose evaluation spectre dure:1 secondes
Flux= 362
pose evaluation spectre dure:10 secondes
Flux= 2776
La pose unitaire choisie est de 60 secondes
Temps total exposition necessaire 109 secondes, pour obtenir un flux
La pose d evaluation de 10 secondes donne un max ADU=2776
On choisit de realiser 3 poses unitaires exposees pendant 36.333333
Soit un total de 109 secondes
Pose Photometrie au Chercheur
commence l acquisition de l objet=HD 162365
Extinction de toutes les lampes.
spectre de HD 162365 ,debut de la pose 1/3 duree 36.333333 secondes
spectre de HD 162365 ,debut de la pose 2/3 duree 36.333333 secondes
spectre de HD 162365 ,debut de la pose 3/3 duree 36.333333 secondes
Arrêt de l'autoguidage sur Consigne
Allume la lampe Neon
attente apres manipulation lampe 5 secondes
Neon de HD 162365 ,debut de la pose 1/1 duree 5 secondes

```

Positions Axe RA : -0.95 Pix +16ms Répartition

Positions Axe DEC : 0.25 Pix +22ms

Décalage (Pixels,angle) 0.00 100.50°

Champ=180°00'00"x180°00'00" Az/El Tpc

Contrôle Dome

23:51 12/09/2014

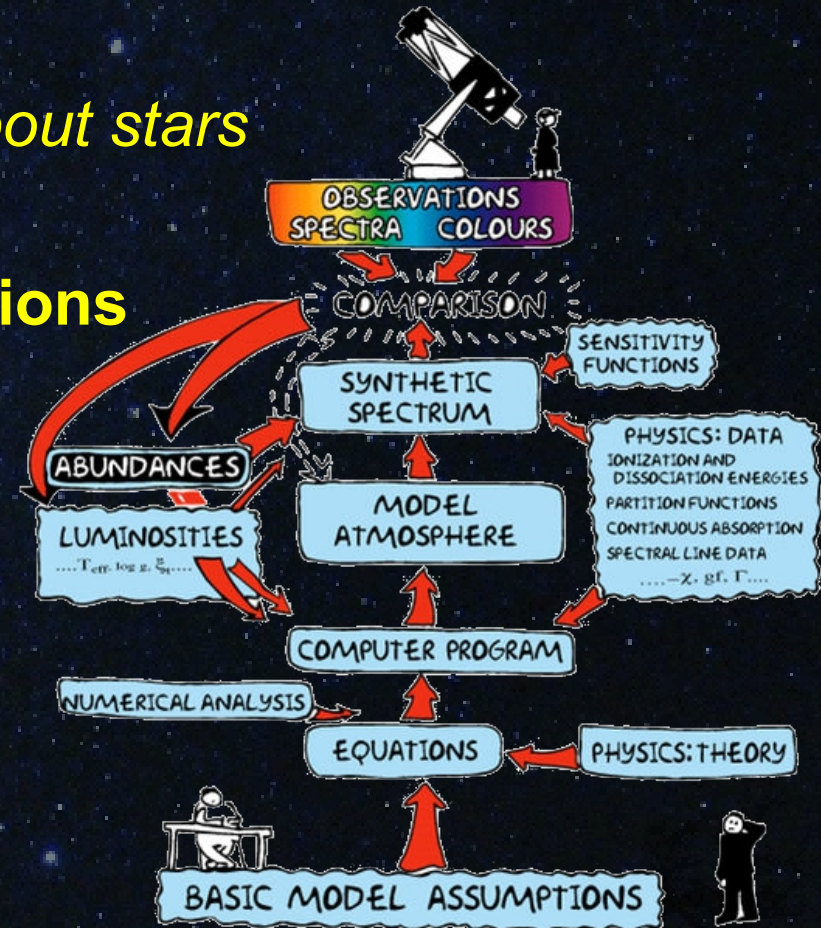
Conclusions

Spectroscopy teaches lot of information about stars

- their **temperature** [overall profile]
- their **composition and physical conditions**
- **abondance, pressure, gravity**
- their **movements** [Doppler effect]

*Spectroscopy is an additional **tool** for variable stars study*

- complementary to photometry
- main tool for professional astronomers
- off-the-shelf equipment & software now available
- more and more amateur are doing spectroscopy
- active Pro/Am community – **Join Us**



OHP Spectroscopy workshop

13-18 august 2015

<http://www.astrosurf.com/thizy/ohp2015/>





Merci...

<http://www.shelyak.com/>