



# Small Telescope Spectroscopy

— NEAIC —  
18 april 2013

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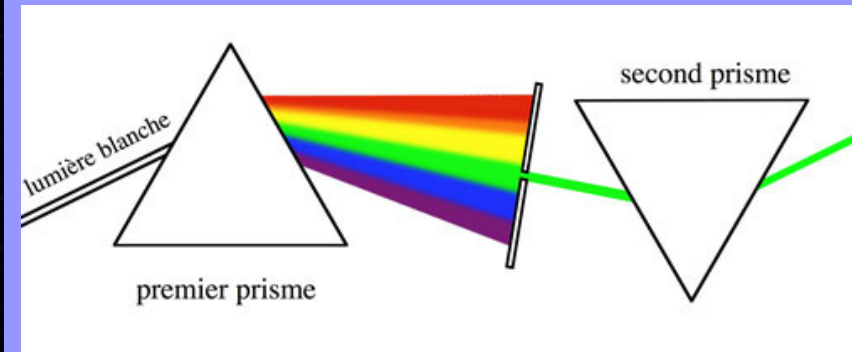


# my "friend" Isaac Newton



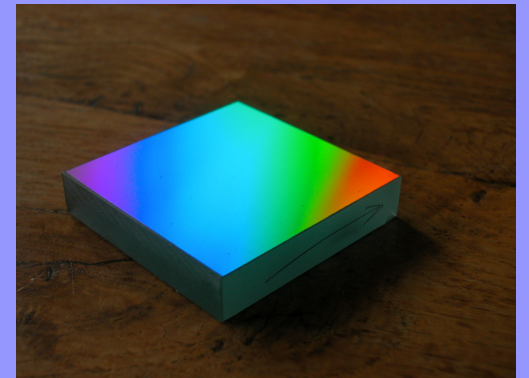
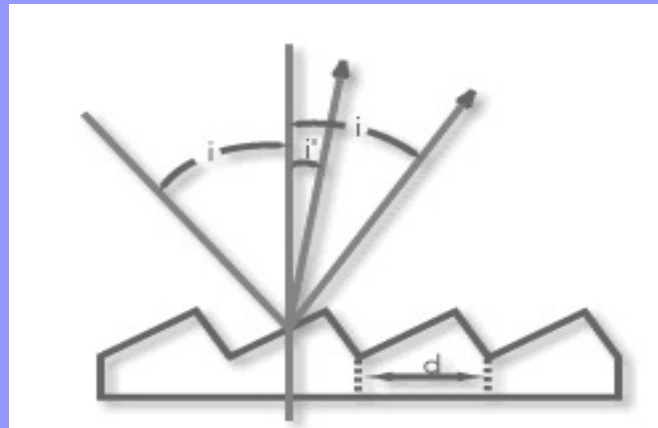
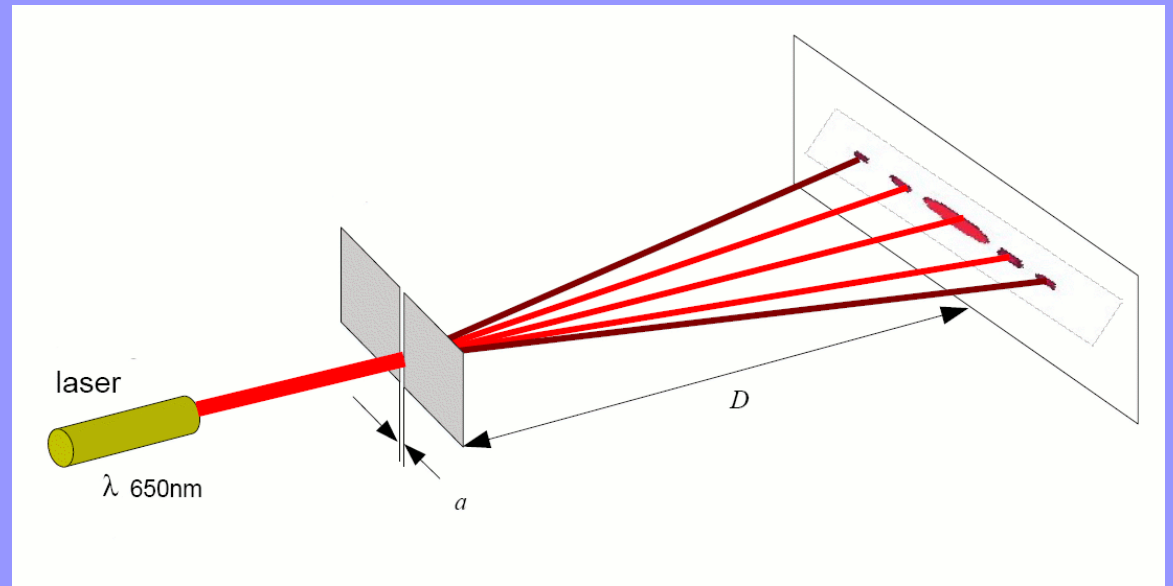
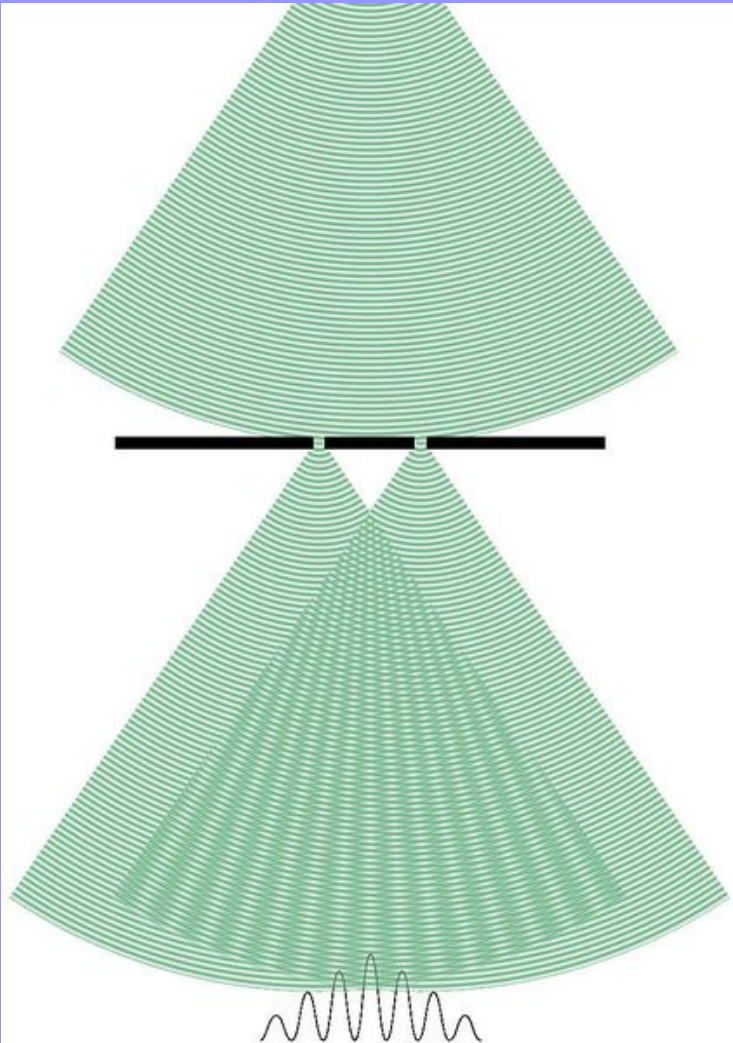
Isaac Newton (1642-1726) ; Mme Tussaud museum / London

# Light & Colors



- Isaac Newton : a pionneer
- 1670: experience with a prism
- Circular “slit” ~6mm:  $\lambda/\Delta\lambda \sim 10$  !

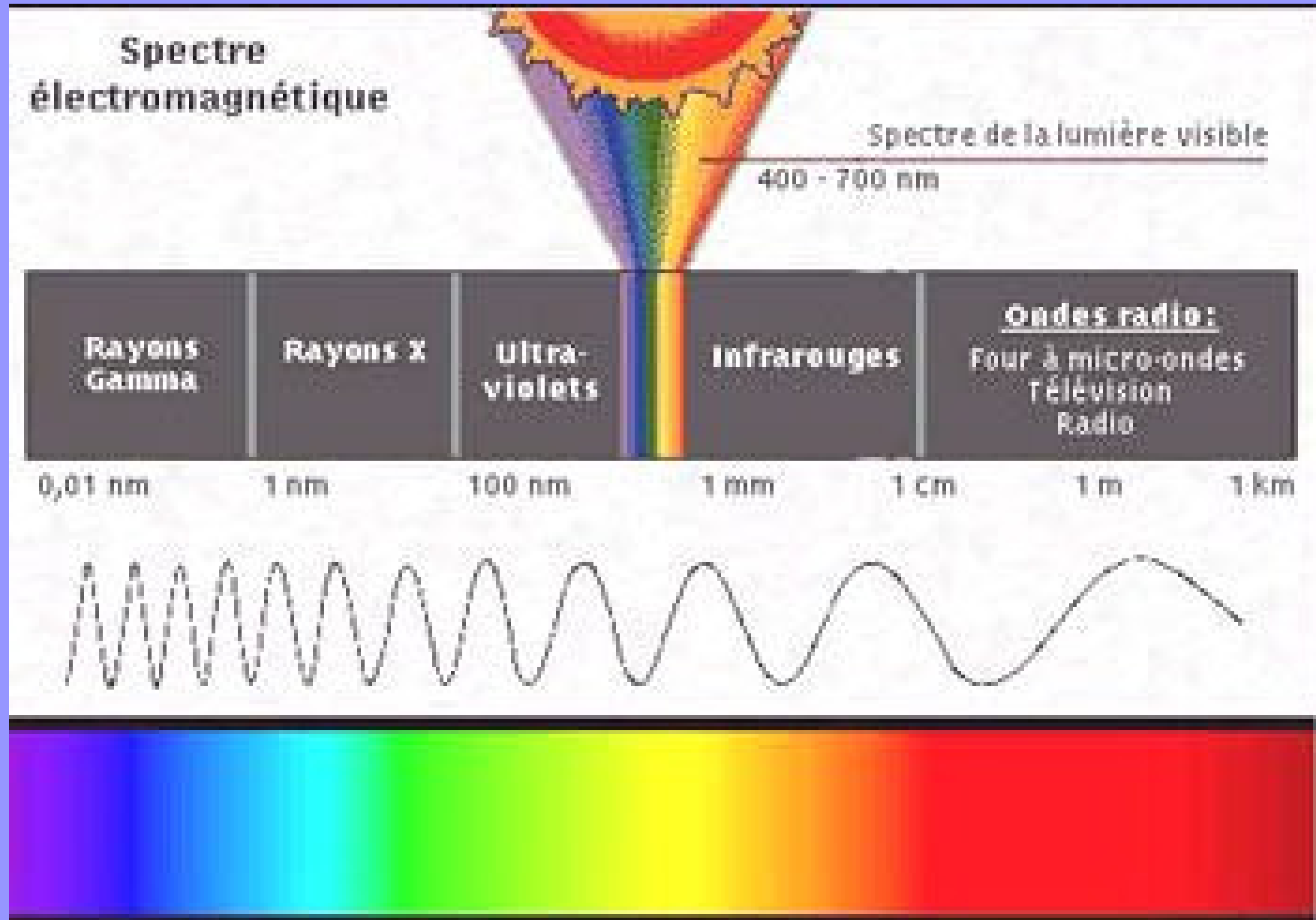
# Light is a wave



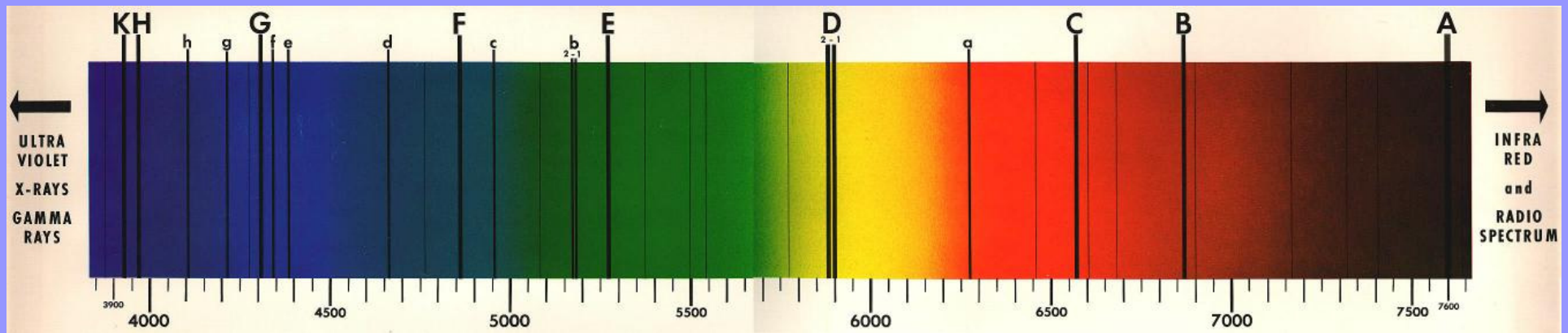
- Thomas Young (1773-1829)
  - Wave interpretation of light (1801)
  - Worked with grating with 20 grooves/mm



# Electromagnetic spectrum



# Solar spectrum

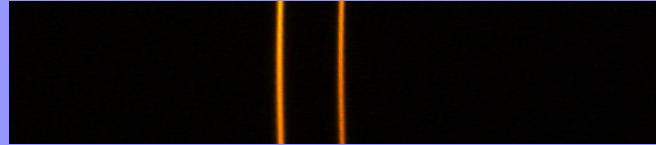


- **William Wollaston (1766-1828)**
  - ~150 years after Newton !
  - First observation (in 1802) of dark lines
  - Demonstrated the importance of the slit width
- **Joseph Fraunhofer (1787-1826)**
  - Manufacturer of high quality glasses
  - A, B ( $H\alpha$ ), C, D (sodium doublet)... H, K (Calcium) lines
  - Catalog of ~600 raies in 1814
  - Also observed planets and some stars !
- **Edmon Becquerel (1820-1891)**
  - First photography of the solar spectrum (June 13th, 1842)

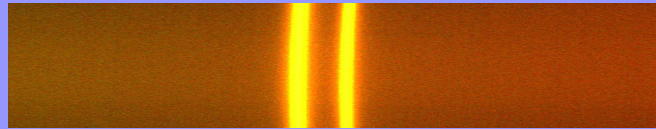


# Sodium in all shape !

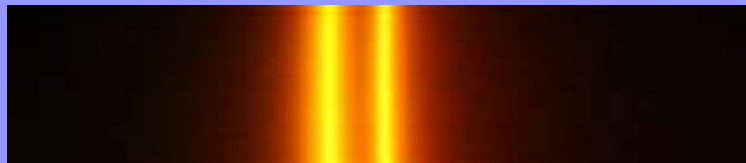
Salt



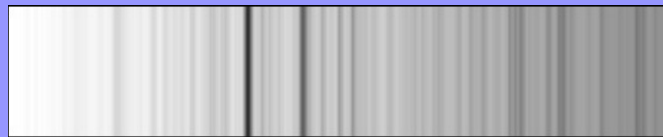
Match



Pickel !



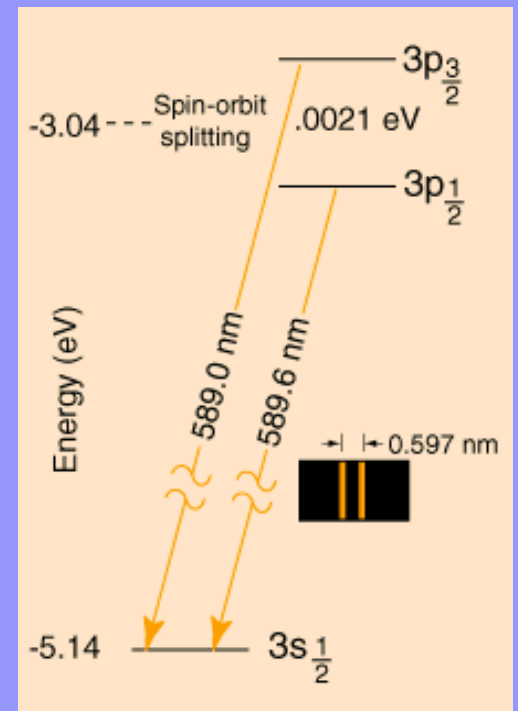
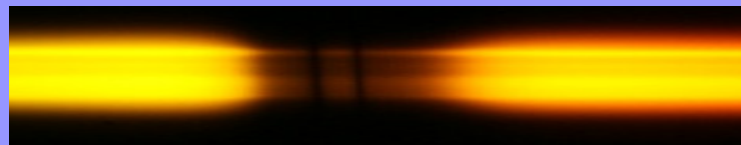
Sirius



Sun

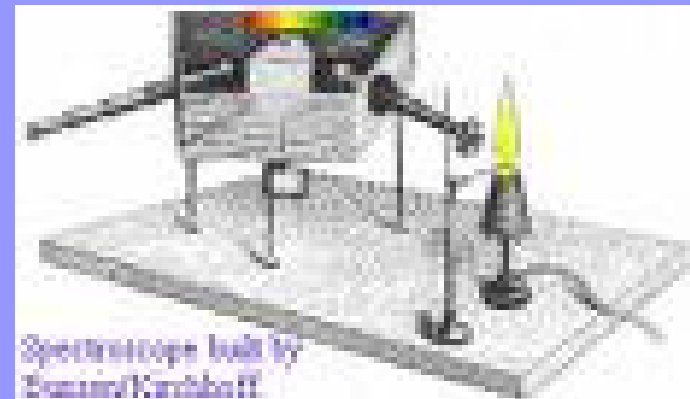


Street lamp



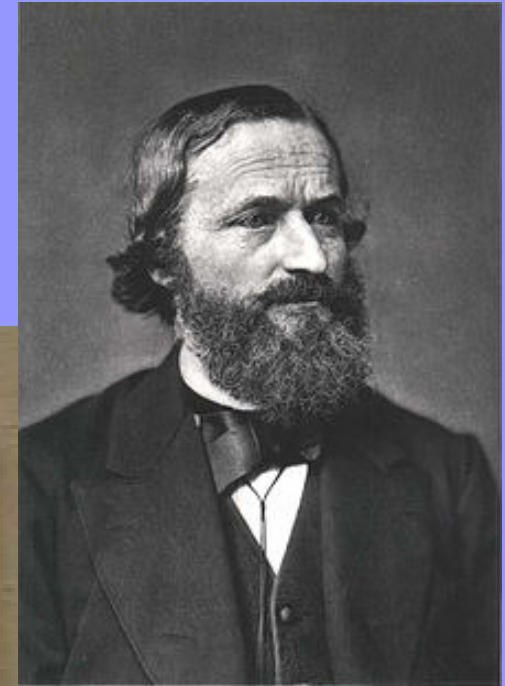
# Chemical analysis & spectroscopy

- **Léon Foucault (1819-1868)**
  - **Comparison between spectra on Earth and solar spectrum (sodium lines, 1849)**
- **Gustav Kirchhoff**
  - **In parallel, he made the experiment with salt and published in 1859 that sodium should exist on solar atmosphere!**
  - **A key theoretical result: Kirchhoff laws**
- **Robert Bunsen (1811-1899)**
  - **Heidelberg university like Kirchhoff**
  - **Together, they published in 1860 a paper on « chemical analysis by spectroscopic observation », then in 1861-1863 the analysis of several chemical elements and their work on the solar spectrum**
- **...Spectroscopy was born...**





# Spectroscopie is born !



IN DIESEM HAUSE HAT  
KIRCHHOFF  
1859 SEINE MIT BUNSEN BEGRÜNDETE  
SPEKTRALANALYSE  
AUF SONNE UND GESTIRNE GEWANDT  
UND DAMIT DIE CHEMIE DES WELTALLS  
ERSCHLOSSEN

# Let's play with a grating...

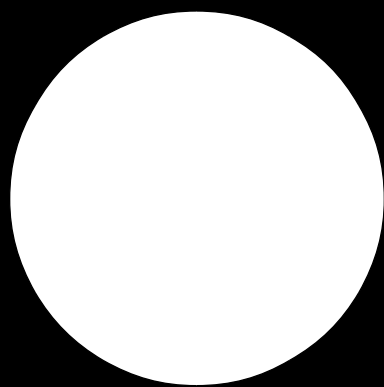




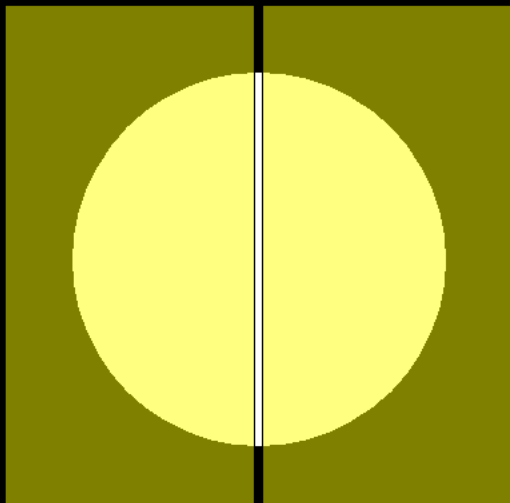
# Star Analyser, the simplest (astro) spectroscope ( $R \sim 100$ )



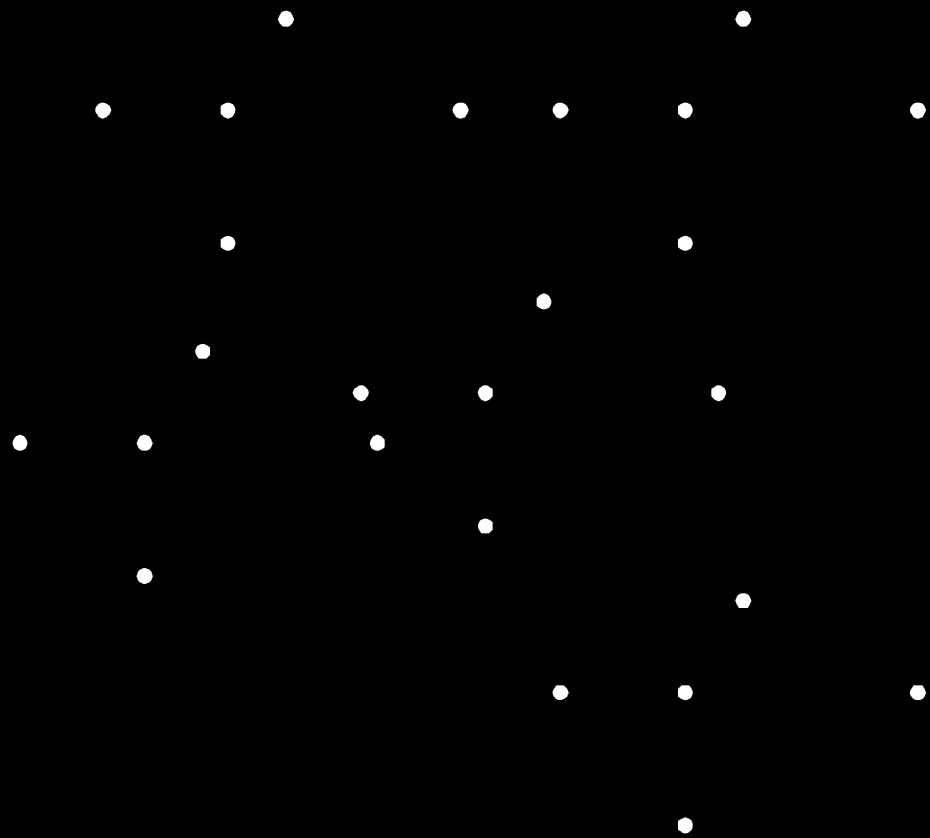








1





# Multiple way to setup



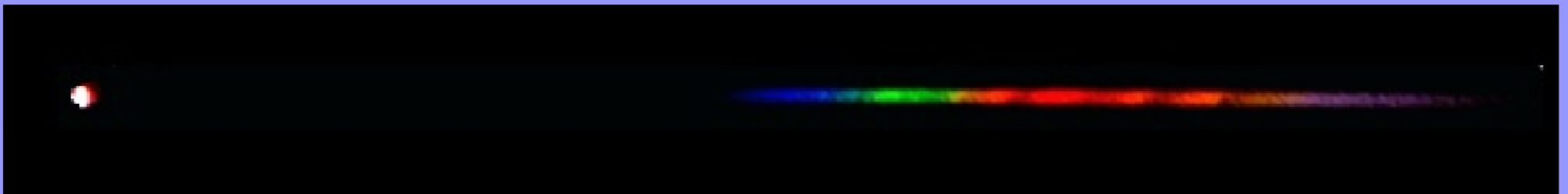
Like a filter  
(webcam)



Like a filter  
(CCD camera)



In front of a lens



(R.Leadbeater)

# CCD vs APN ?



0.1 sec

1 sec

- › **Dynamic: 16-bits**
- › **Monochrome**
- › **Sensitivity, temp. control**

- › **Dynamic: 12-bits**
- › **Color (Bayer matrix → Problem)**
- › **Noisy**



# 4-steps astronomical spectroscopy

## 1 / Acquisition

*Prepare your equipment before the night !*

*Acquire a reference (A-type) star, then your targets*

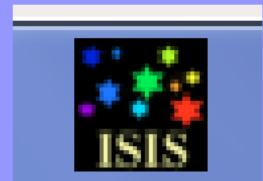


## 2 / Process reference star (ex: Vega)

*Geometry + extract signal column by column (binning)*

*X axis calibration: wavelength calibration / dispersion*

*Y axis calibration: instrumental response*



## 3 / Reduce all your spectra

*As above using:*

*-wavelength calib. Law (or Zero order + dispersion)*

*-divide intensities by your instrumental response*

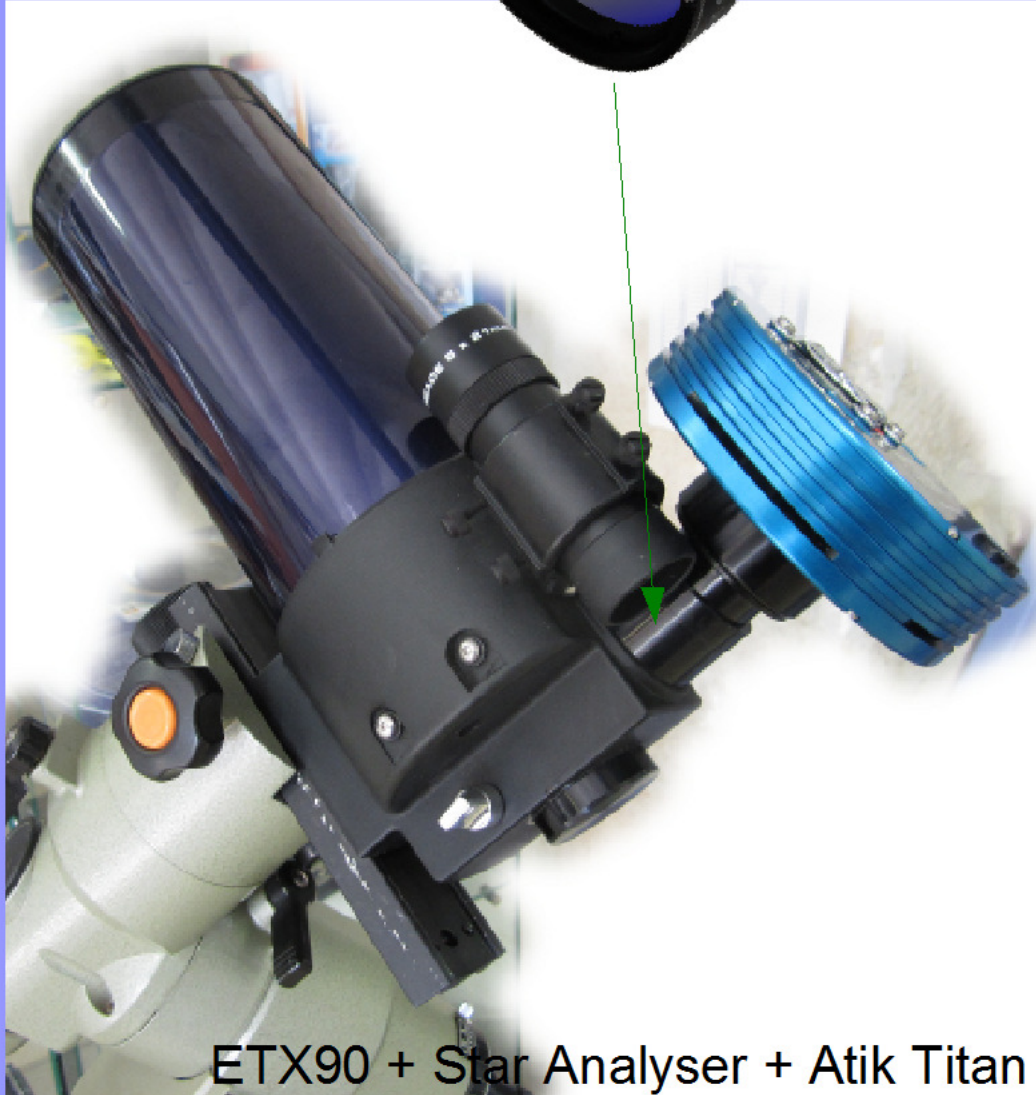
## 4 / Analyse & publish your spectra (ex: VisualSpec)

*Measure astrophysical data from your profiles: line intensity, wavelength shift...*

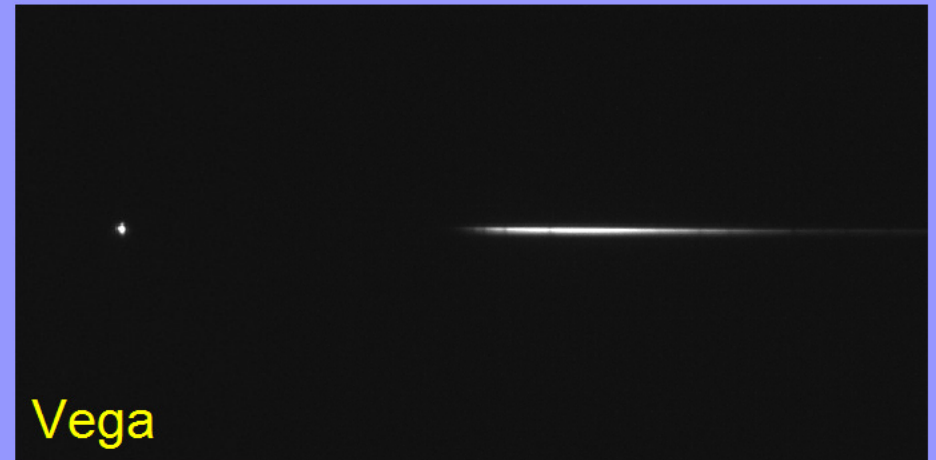




# 1/ Acquisition



ETX90 + Star Analyser + Atik Titan



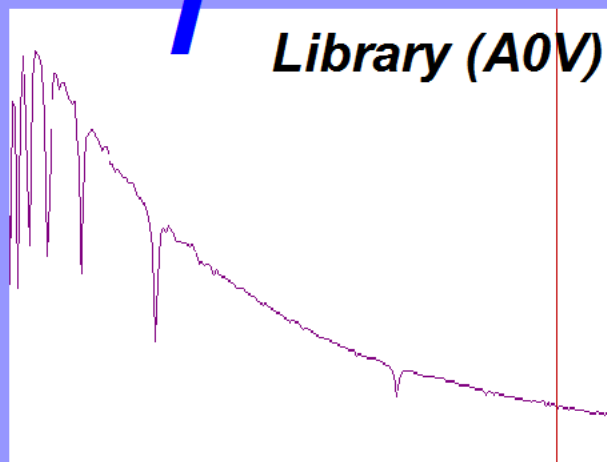
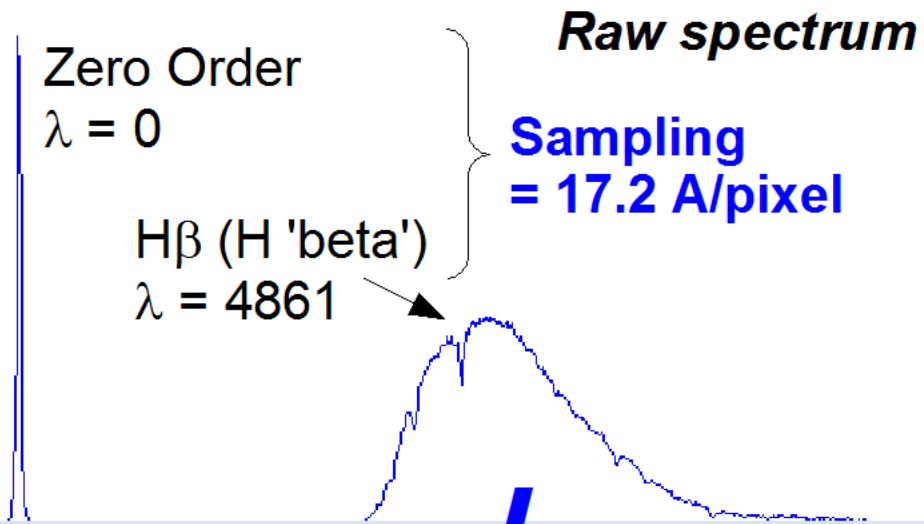
Vega



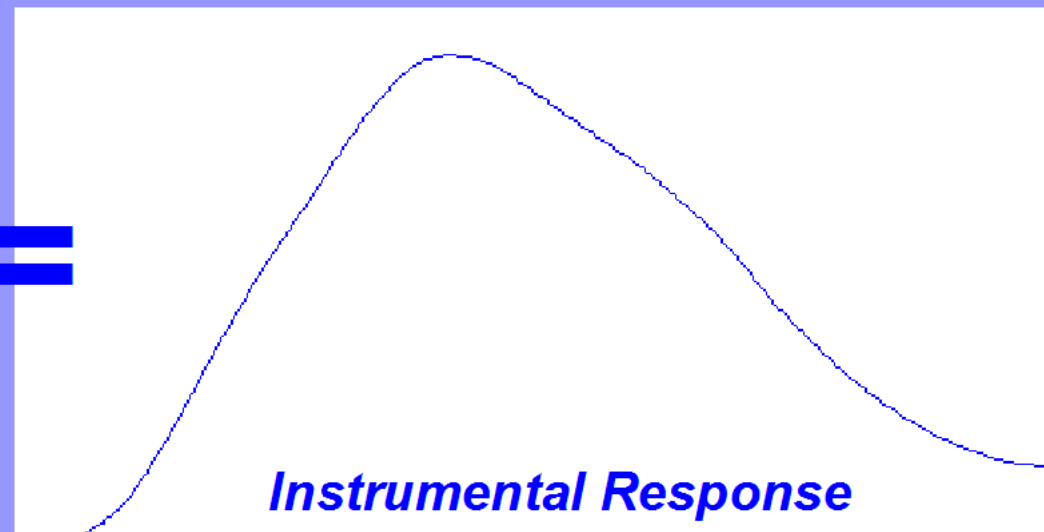
Aldebaran



## 2/ Process reference star



=



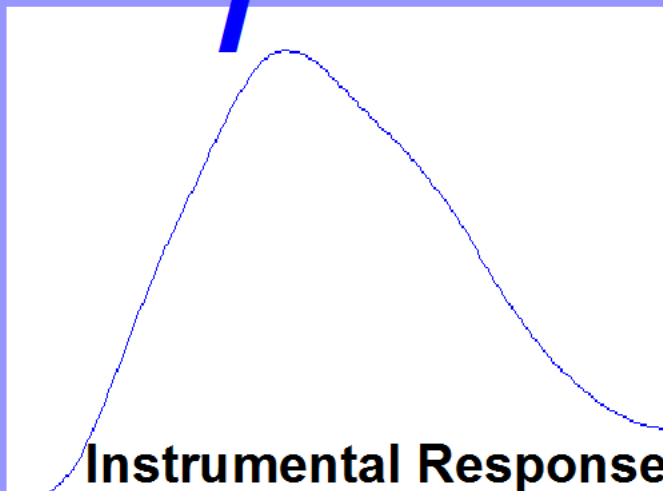
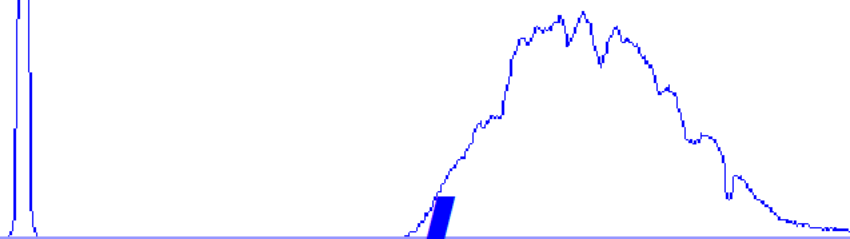




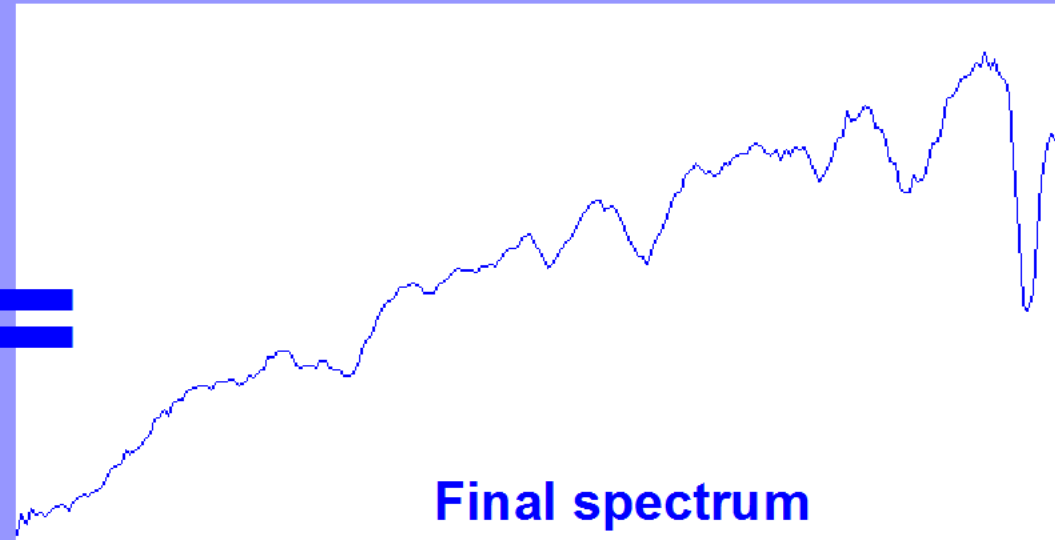
# 3/ Reduce (process) your other spectra

Ordre Zéro  
 $\lambda = 0$   
Sampling / Dispersion = 17.2 Å/pix

Raw spectrum



Instrumental Response

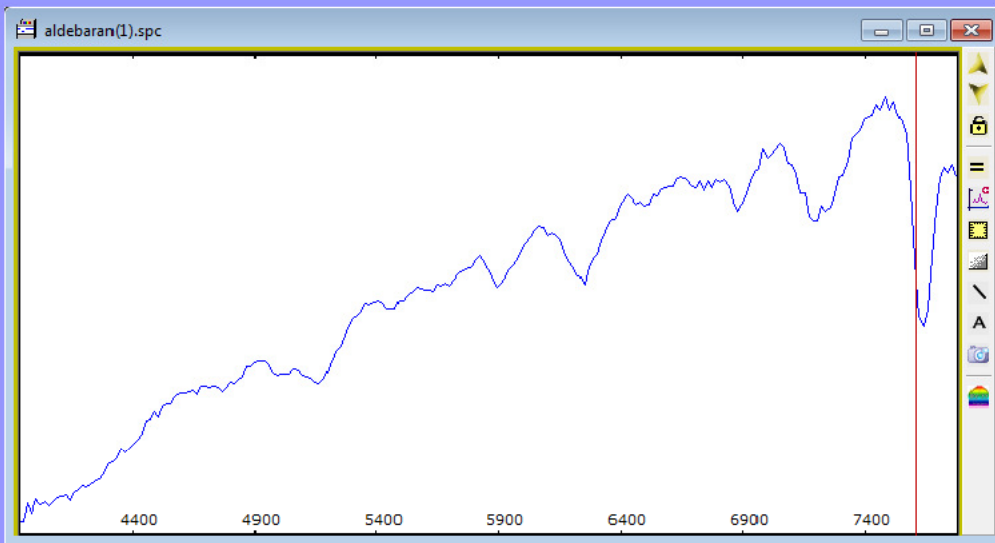
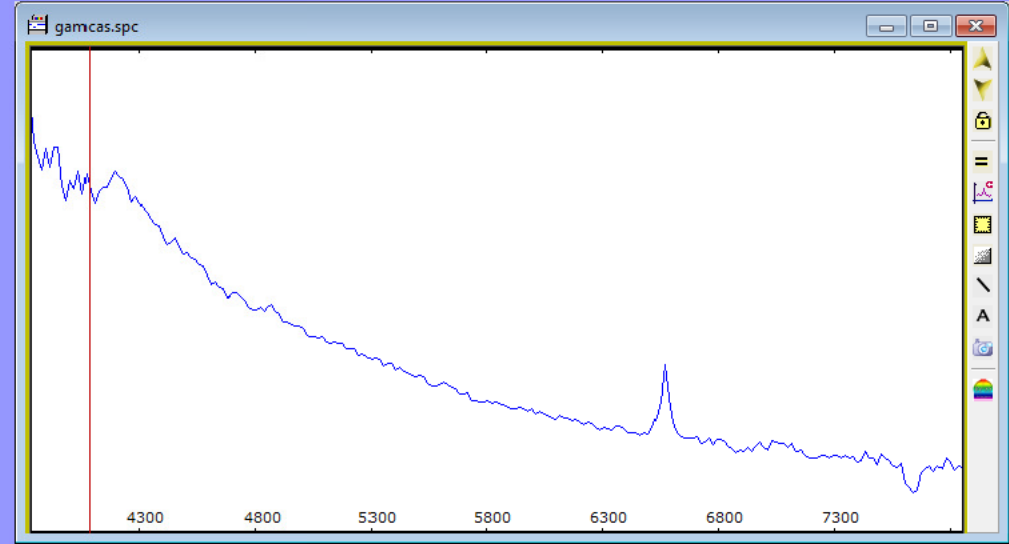
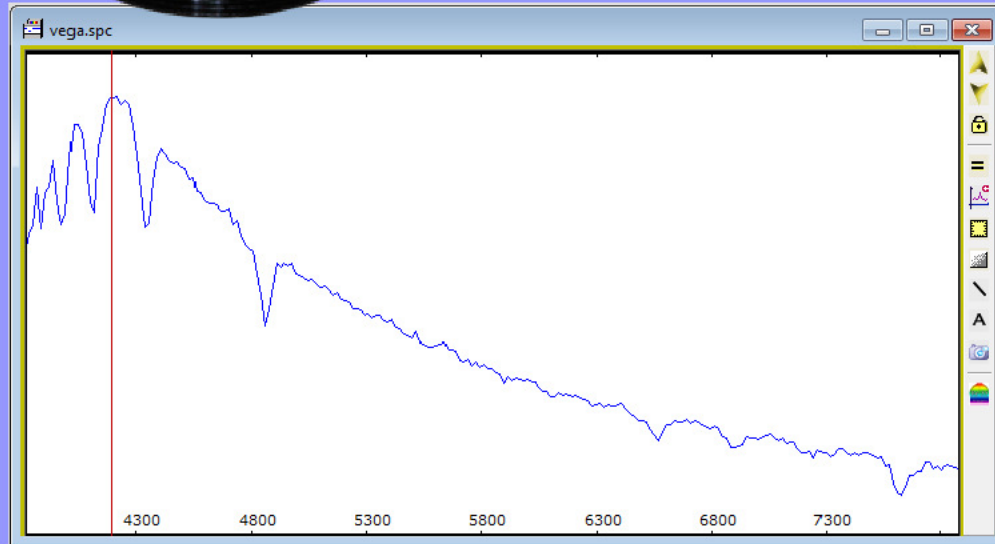


Final spectrum

**Note:**  
Crop your spectra within the  
meaningful spectral domain  
~ 3800-7000 Å



# 4/ Compare your spectra



***What do we see?***

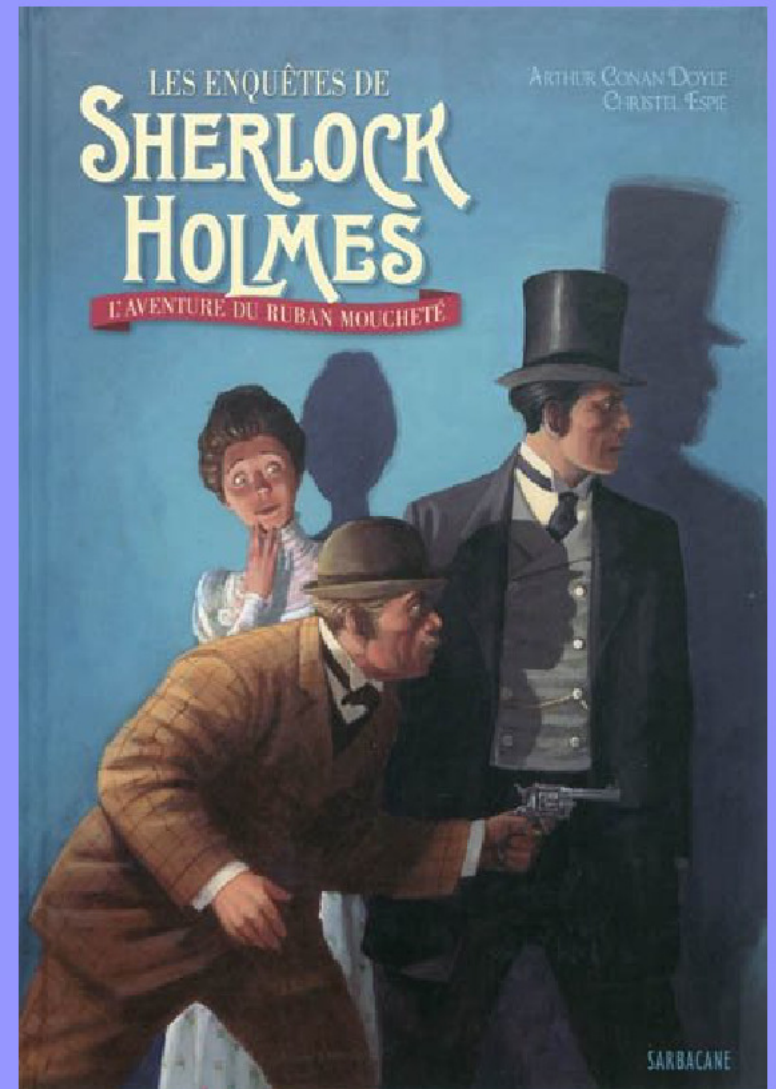
***1/ overall profile varies***

***2/ absorption lines***

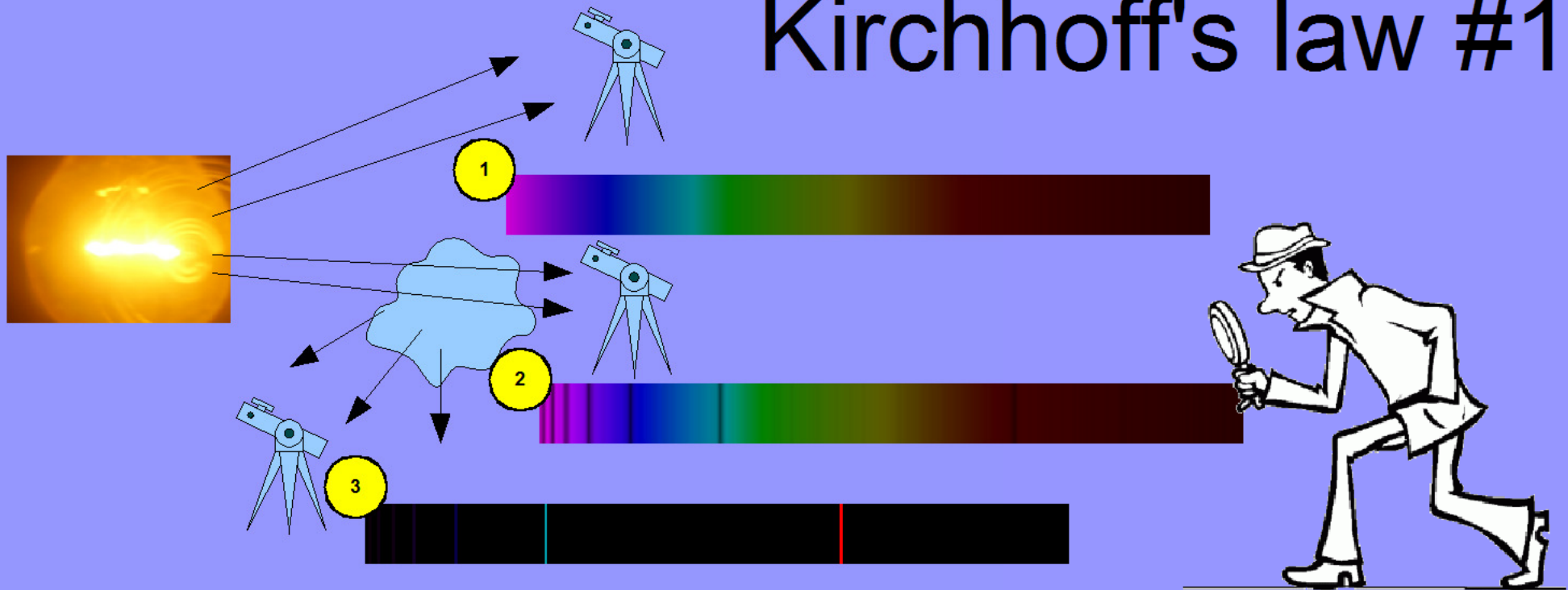
***3/ emission lines***

***→ WHY ???***

# Spectroscopy is first a game !



# Kirchhoff's law #1



1

**A continuous spectra** is emitted by any solid or gaseous body under high pressure and high temperature. Stars are, under first approximation, like black body whose continuous spectra has a shape which depends on its surface temperature;

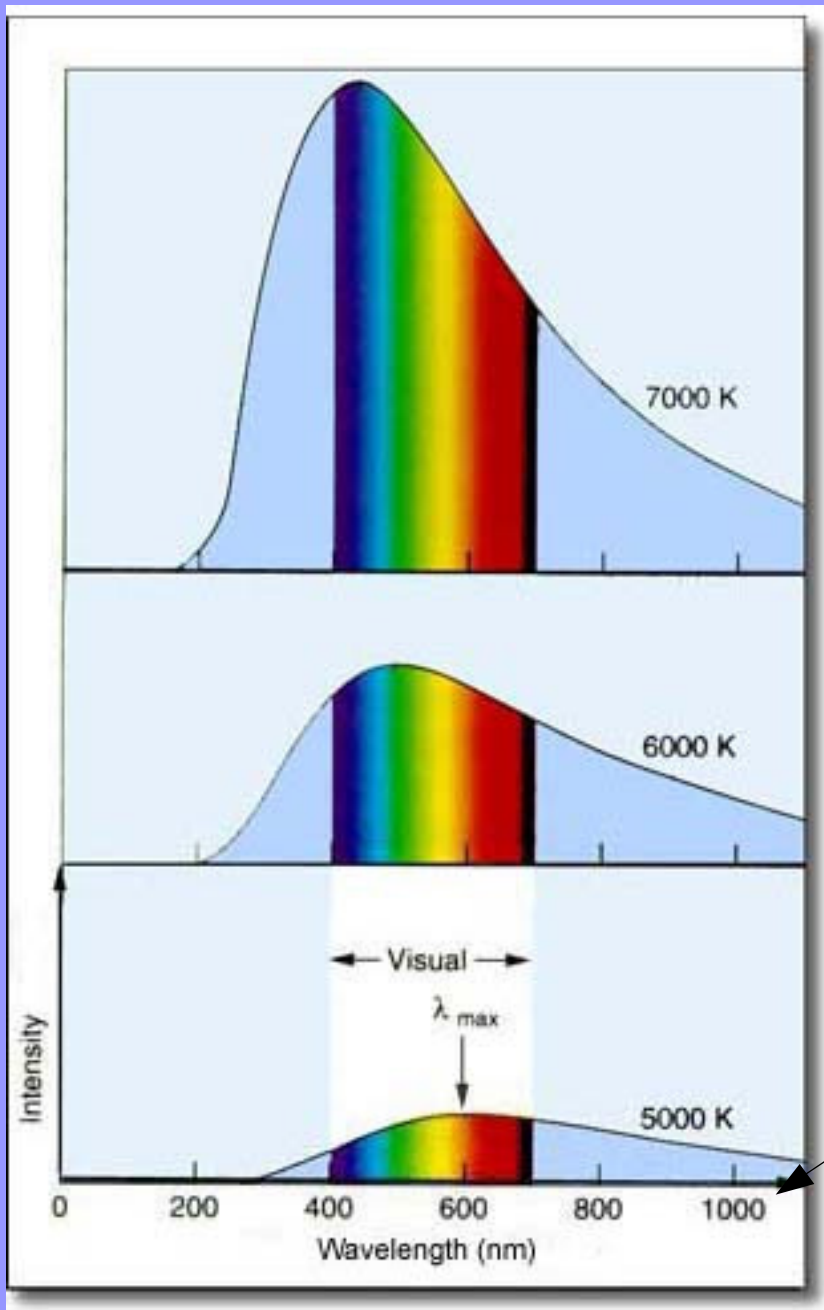
2

**Absorption line spectra:** a low pressure low temperature gas crossed by a continuous light absorbs some photons. Spectra then shows dark lines in front of the continuous spectra;

3

**Emission line spectra:** a low pressure high temperature gas emits a light made of few radiations, characteristics of the atoms that constitutes this gas. Each chemical element has its own line spectra, true identity card of its composition and state.

# Informations from Planck profile



➤ **Stefan's law:**

Intensity (below the curve) =  
Constant \*  $T^4$

➤ **Wien's law:**

$\lambda_{max}$  \* Temperature = Constant  
(2900  $\mu\text{m.K}$ )

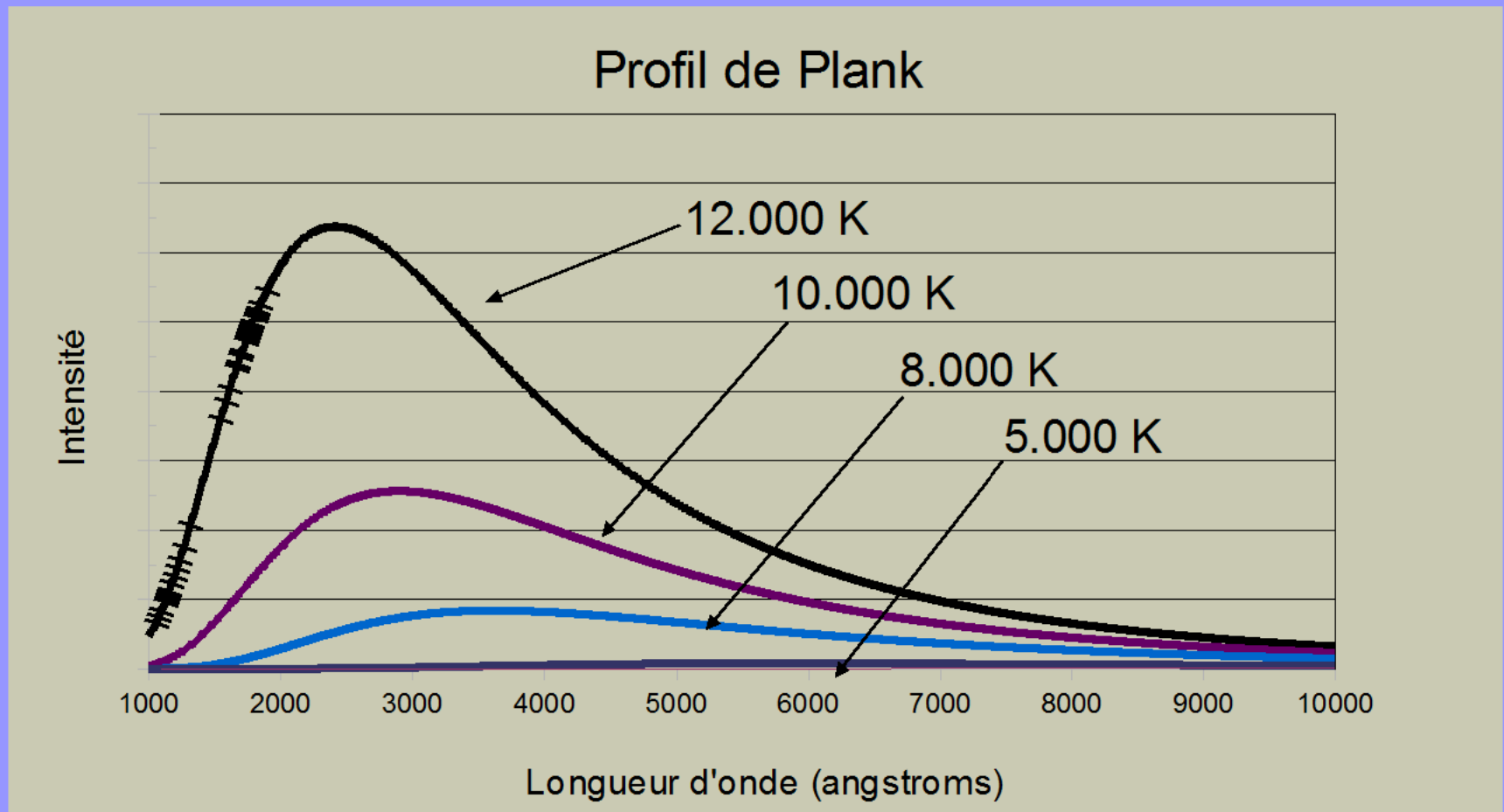
==> Temperature = Color !!!

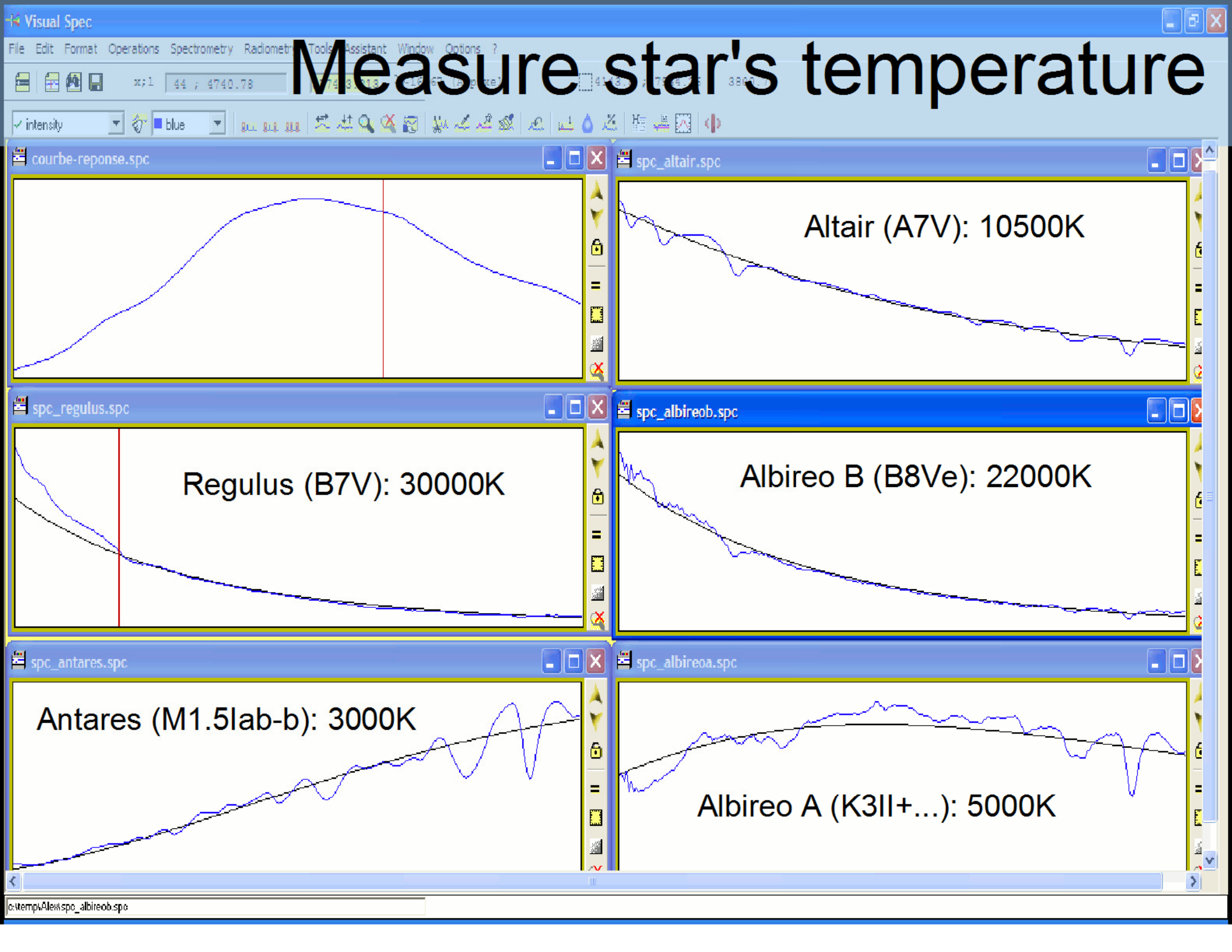
**Visible domain**

**= 400-700nm (4000A-7000A)**

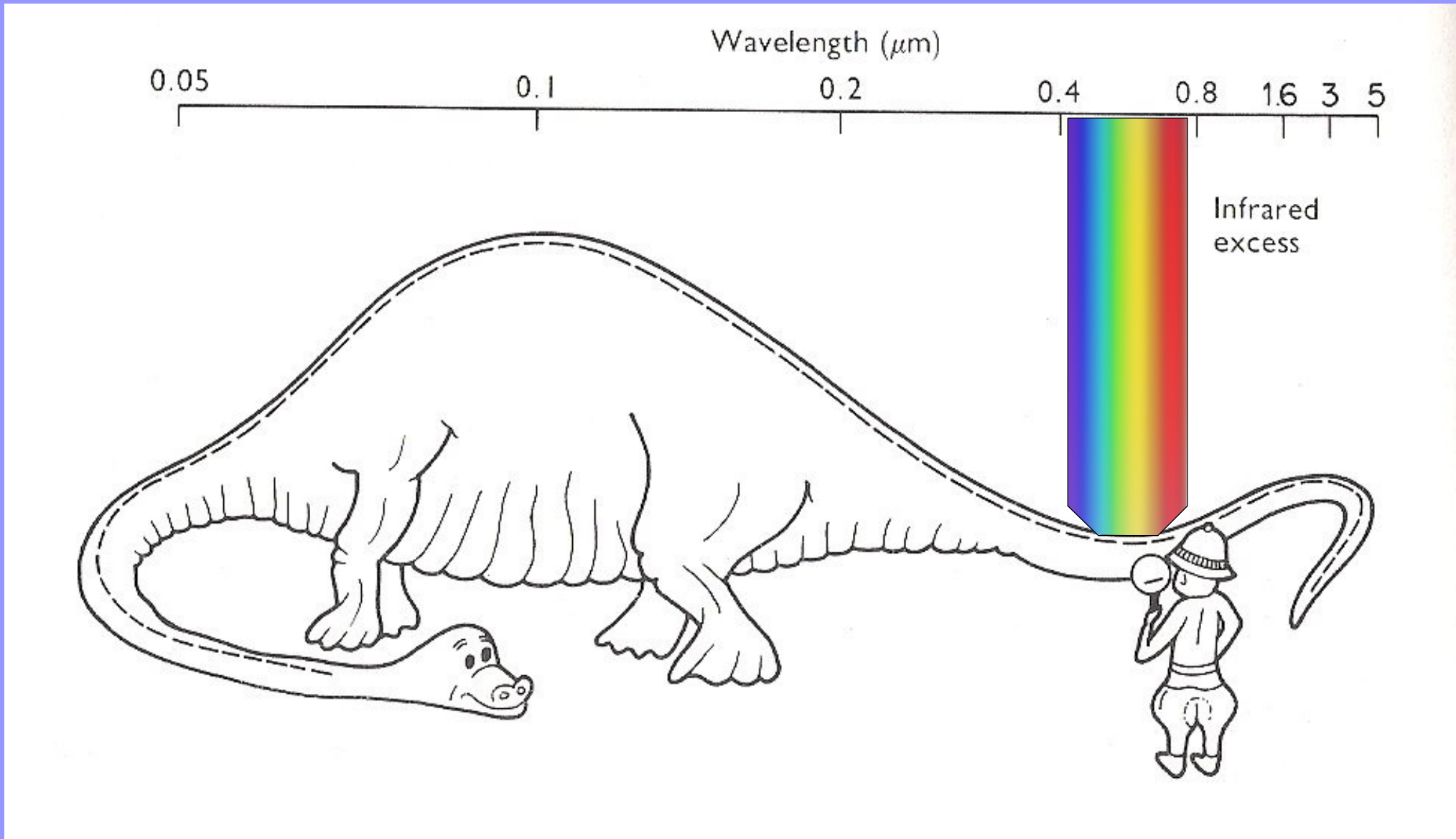


# Black body profile

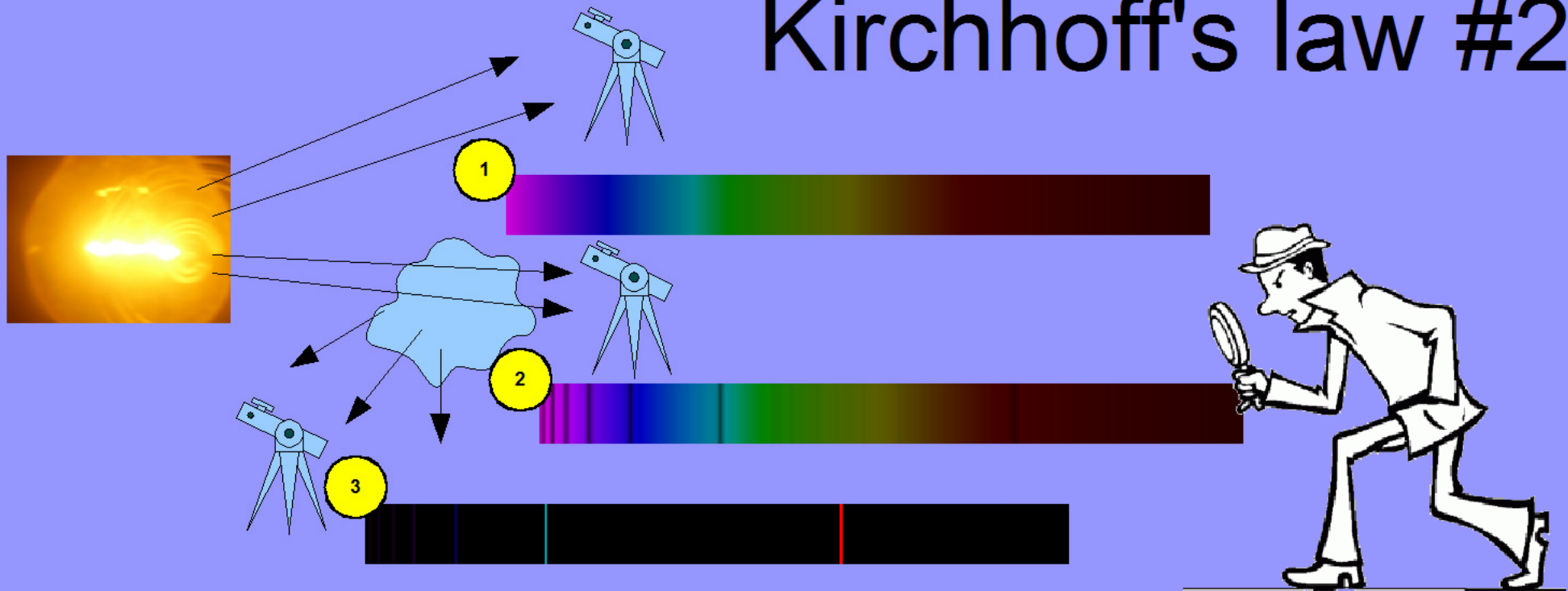




# Be aware: Visible = partial view



# Kirchhoff's law #2



1

A **continuous spectra** is emitted by any solid or gaseous body under high pressure and high temperature. Stars are, under first approximation, like black body whose continuous spectra has a shape which depends on its surface temperature;

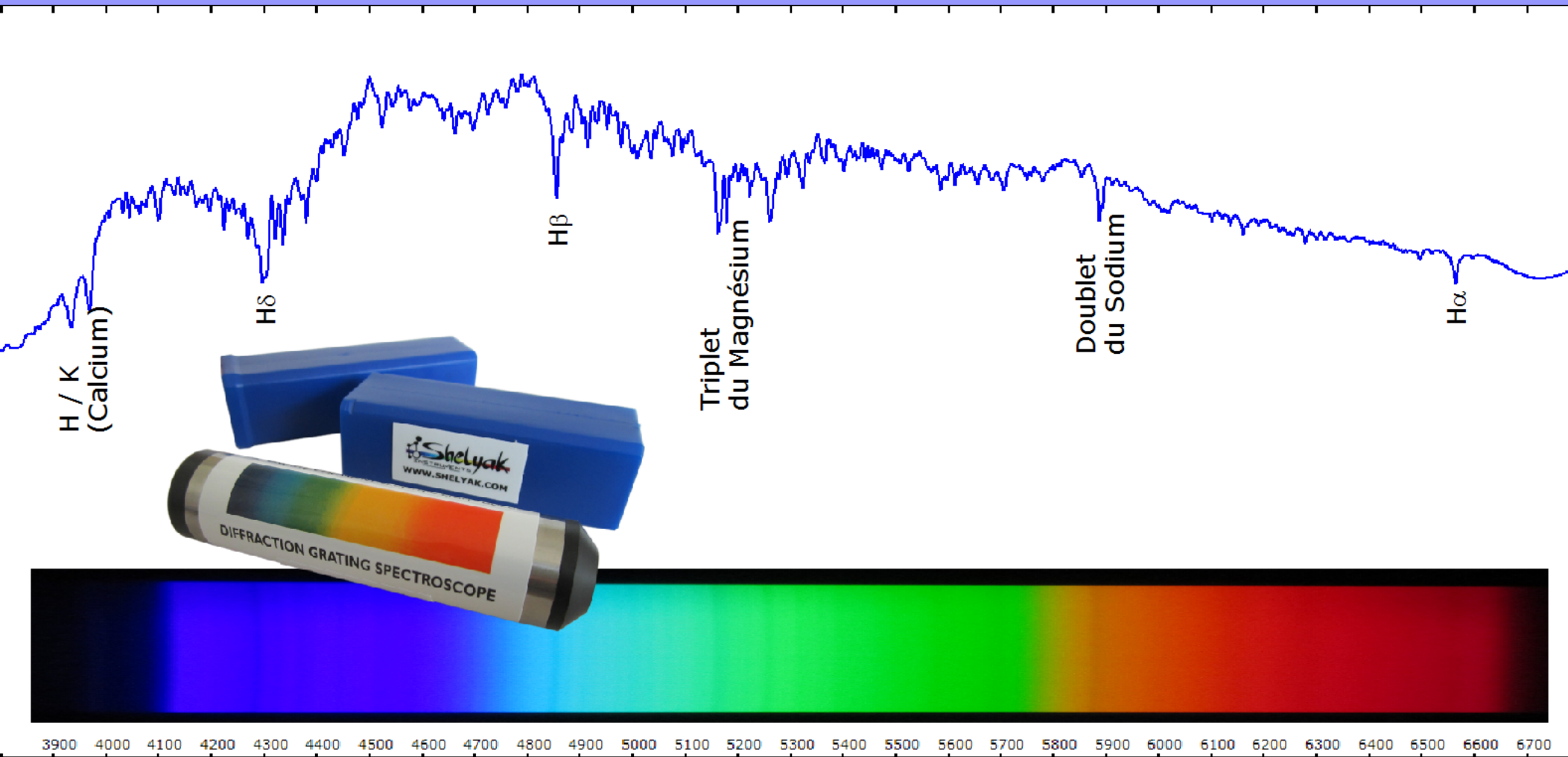
2

**Absorption line spectra:** a low pressure low temperature gas crossed by a continuous light absorbs some photons. Spectra then shows dark lines in front of the continuous spectra;

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**Emission line spectra:** a low pressure high temperature gas emits a light made of few radiations, characteristics of the atoms that constitutes this gas. Each chemical element has its own line spectra, true identity card of its composition and state.

# Solar spectrum absorption lines

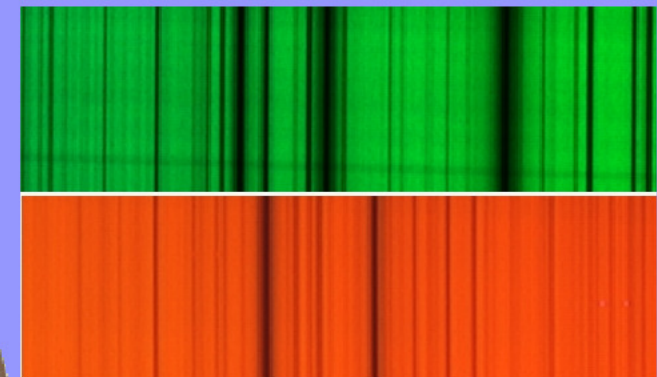
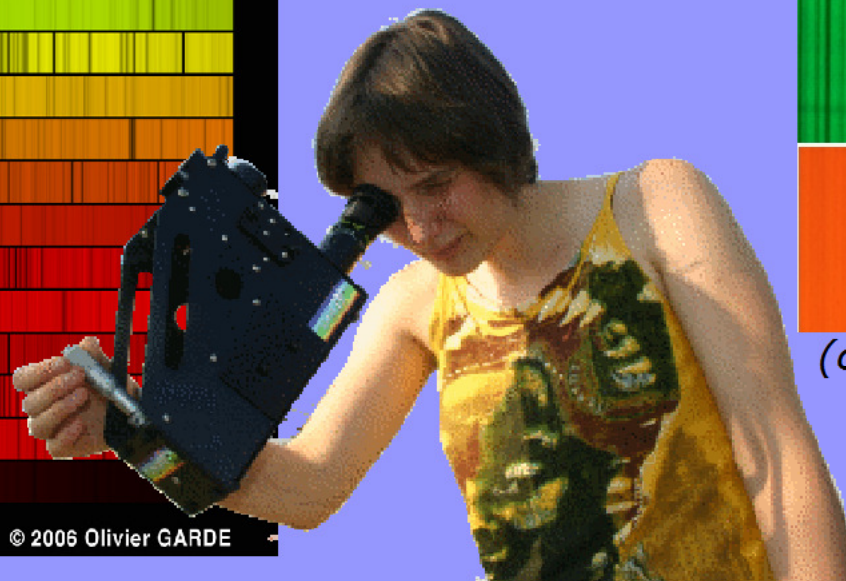
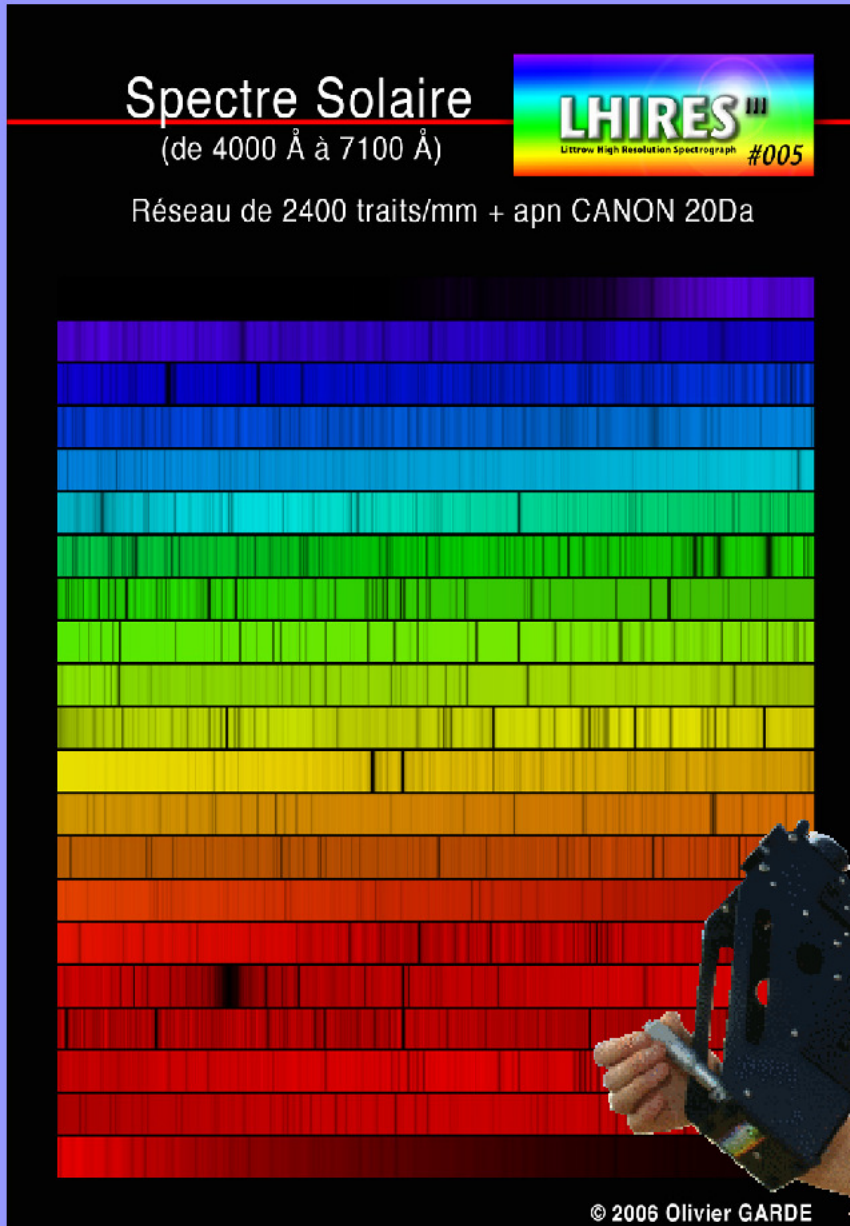


Profil : O. Thizy, janvier 2007 ; Lhires III – 300tt/mm; Digital Rebel / EOS300D  
Pic du Midi (ie: no telluric lines)

Spectrum : recorded with the handheld spectroscope.

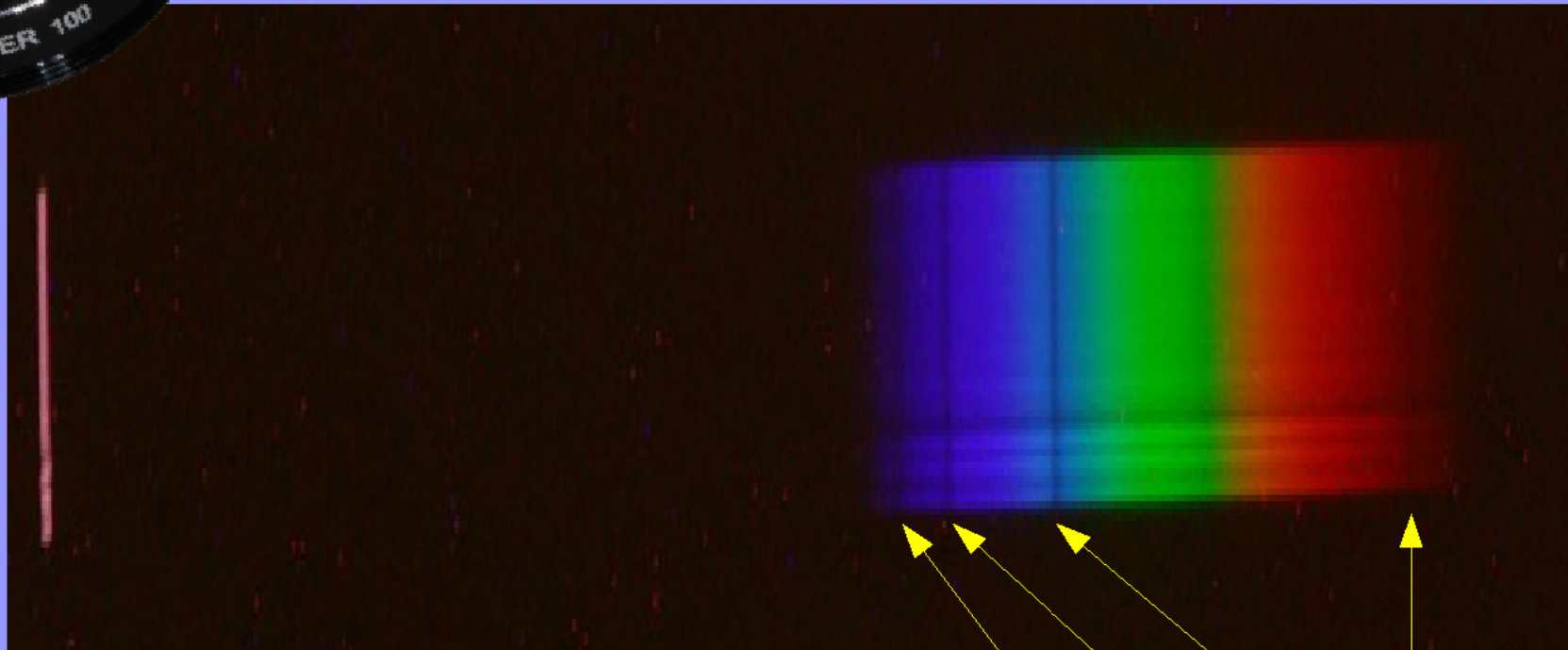


# Solar spectrum (visual)



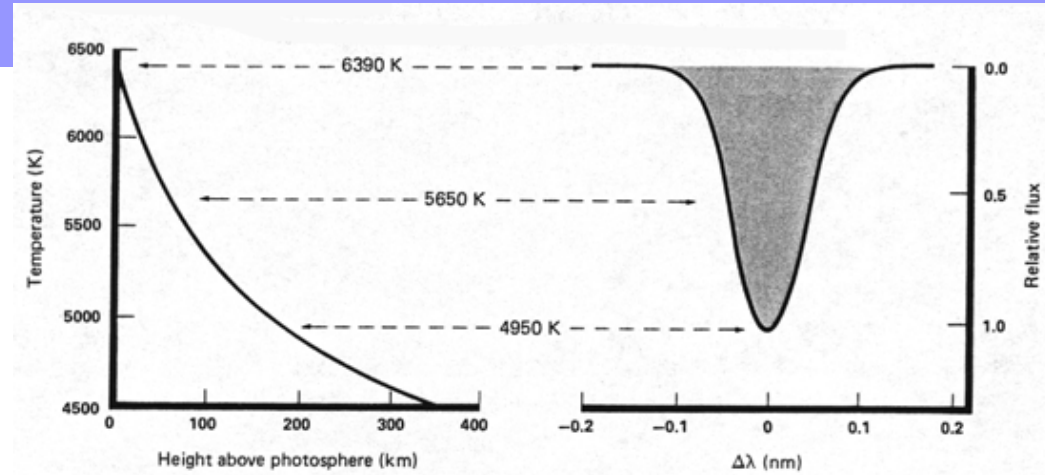
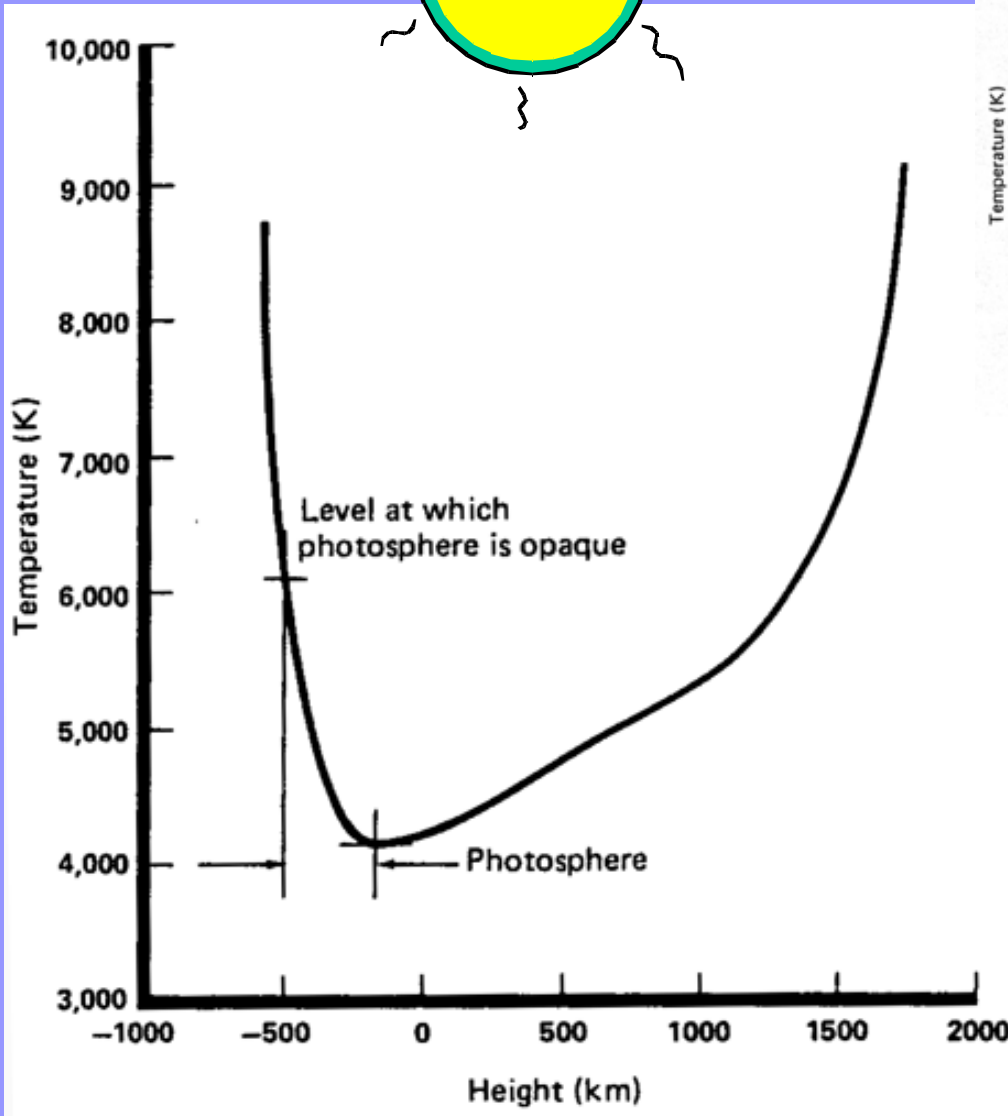
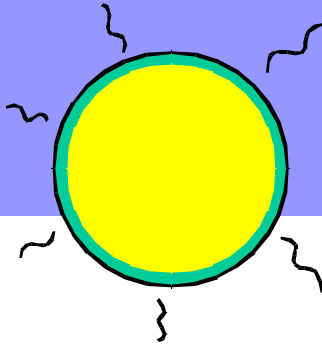
(c) Robin Leadbeater

# Absorption lines ?



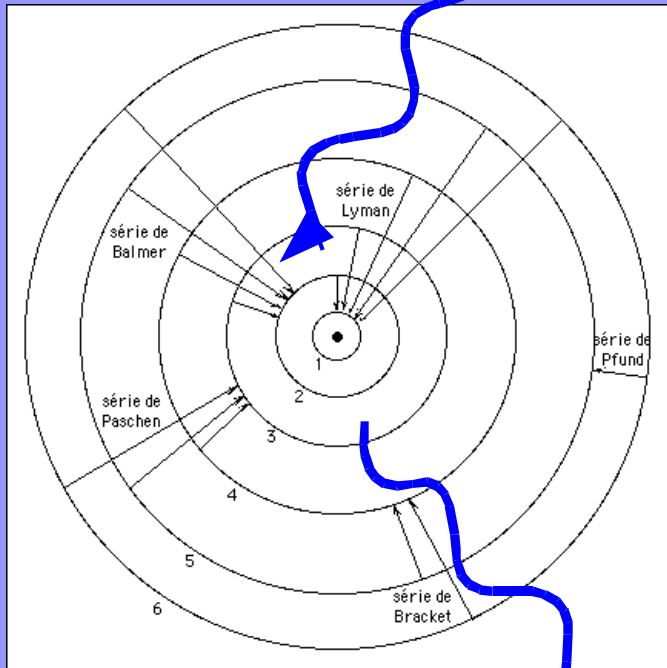
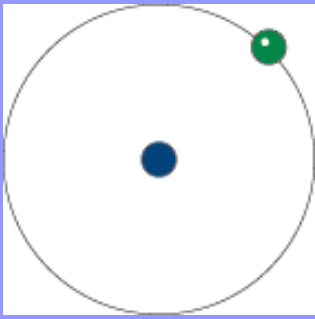
Hydrogen lines (Balmer serie : ...H $\delta$ , H $\gamma$ , H $\beta$ , H $\alpha$ )

# Photospheric line

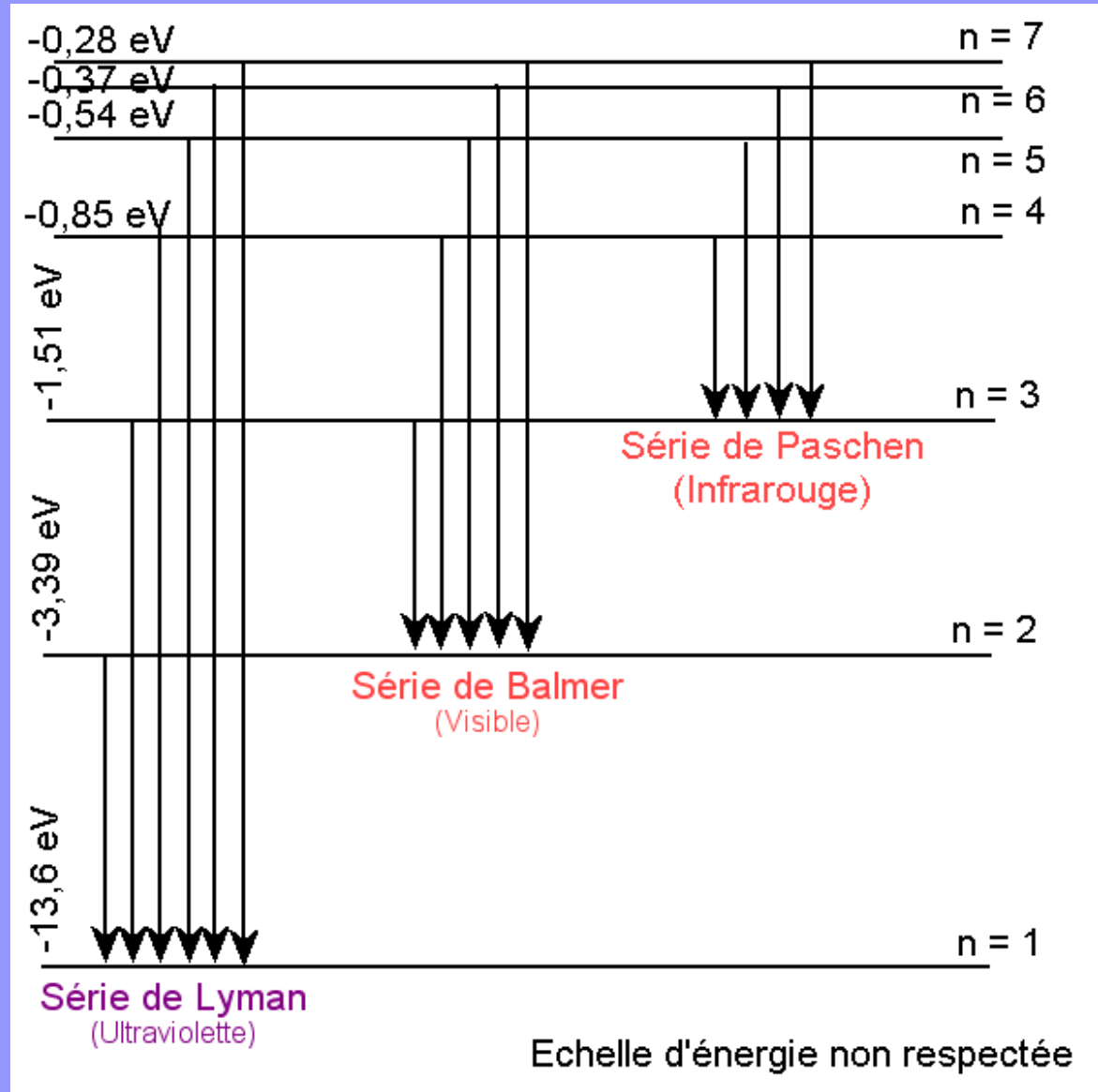


- *Photosphere is a very very thin layer*
- *'Wings' of the line come from deeper layers than the center of the line*

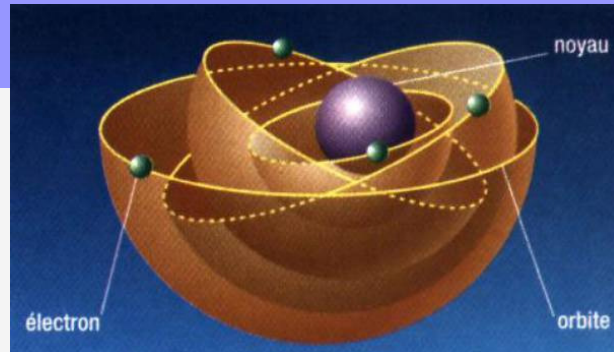
# Absorption/Emission lines



$$\Delta \text{Energy} = h * \nu = h * c / \lambda$$



# Table of elements



	IA																	0	
1	1 <b>H</b>	IIA																	2 <b>He</b>
2	3 <b>Li</b>	4 <b>Be</b>										5 <b>B</b>	6 <b>C</b>	7 <b>N</b>	8 <b>O</b>	9 <b>F</b>	10 <b>Ne</b>		
3	11 <b>Na</b>	12 <b>Mg</b>	IIIB	IVB	VB	VIB	VIB	VII	IB	IIB	13 <b>Al</b>	14 <b>Si</b>	15 <b>P</b>	16 <b>S</b>	17 <b>Cl</b>	18 <b>Ar</b>			
4	19 <b>K</b>	20 <b>Ca</b>	21 <b>Sc</b>	22 <b>Ti</b>	23 <b>V</b>	24 <b>Cr</b>	25 <b>Mn</b>	26 <b>Fe</b>	27 <b>Co</b>	28 <b>Ni</b>	29 <b>Cu</b>	30 <b>Zn</b>	31 <b>Ga</b>	32 <b>Ge</b>	33 <b>As</b>	34 <b>Se</b>	35 <b>Br</b>	36 <b>Kr</b>	
5	37 <b>Rb</b>	38 <b>Sr</b>	39 <b>Y</b>	40 <b>Zr</b>	41 <b>Nb</b>	42 <b>Mo</b>	43 <b>Tc</b>	44 <b>Ru</b>	45 <b>Rh</b>	46 <b>Pd</b>	47 <b>Ag</b>	48 <b>Cd</b>	49 <b>In</b>	50 <b>Sn</b>	51 <b>Sb</b>	52 <b>Te</b>	53 <b>I</b>	54 <b>Xe</b>	
6	55 <b>Cs</b>	56 <b>Ba</b>	*La	72 <b>Hf</b>	73 <b>Ta</b>	74 <b>W</b>	75 <b>Re</b>	76 <b>Os</b>	77 <b>Ir</b>	78 <b>Pt</b>	79 <b>Au</b>	80 <b>Hg</b>	81 <b>Tl</b>	82 <b>Pb</b>	83 <b>Bi</b>	84 <b>Po</b>	85 <b>At</b>	86 <b>Rn</b>	
7	87 <b>Fr</b>	88 <b>Ra</b>	+Ac	104 <b>Rf</b>	105 <b>Db</b>	106 <b>Sg</b>	107 <b>Bh</b>	108 <b>Hs</b>	109 <b>Mt</b>	110 <b>Ds</b>	111 <b>Rg</b>	112 <b>Uub</b>	113 <b>Uut</b>	114 <b>Uuq</b>	115 <b>Uup</b>	116 <b>Uuh</b>	117 <b>Uus</b>	118 <b>Uuo</b>	

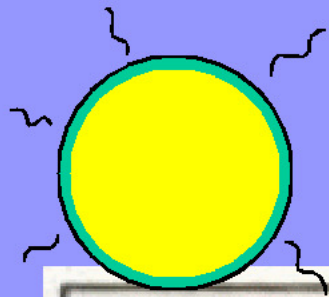
\*Lanthanide

+Actinide

58 <b>Ce</b>	59 <b>Pr</b>	60 <b>Nd</b>	61 <b>Pm</b>	62 <b>Sm</b>	63 <b>Eu</b>	64 <b>Gd</b>	65 <b>Tb</b>	66 <b>Dy</b>	67 <b>Ho</b>	68 <b>Er</b>	69 <b>Tm</b>	70 <b>Yb</b>	71 <b>Lu</b>
90 <b>Th</b>	91 <b>Pa</b>	92 <b>U</b>	93 <b>Np</b>	94 <b>Pu</b>	95 <b>Am</b>	96 <b>Cm</b>	97 <b>Bk</b>	98 <b>Cf</b>	99 <b>Es</b>	100 <b>Fm</b>	101 <b>Md</b>	102 <b>No</b>	103 <b>Lr</b>



# Absorption lines



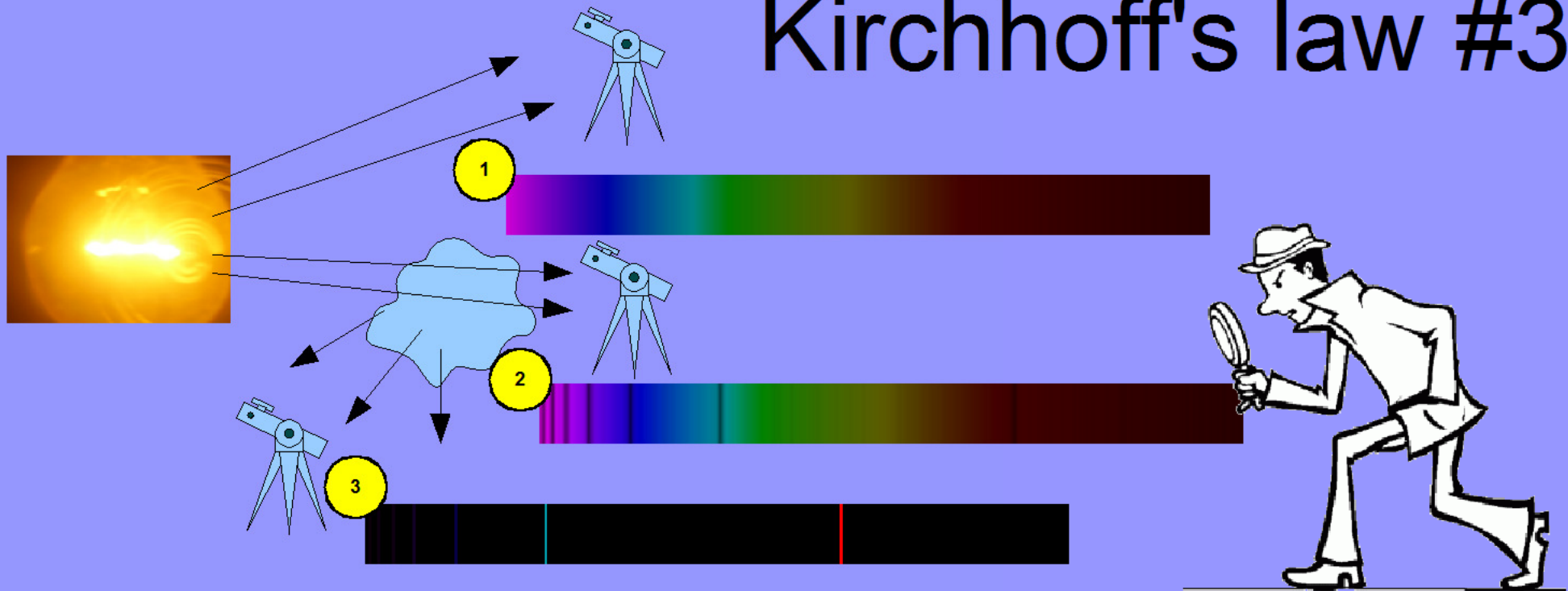
You've heard of the spectroscope. It's the instrument that enables us to discover elements in stars, elements not yet isolated here on the earth. This is a spectroscopic photograph of the meteor which brushed past us today. Each of these lines, or each group of lines is characteristic of a metal. Those lines in the centre represent an unknown metal, which exists in the meteor. You follow me?

Er... more or less ...





# Kirchhoff's law #3



1

A **continuous spectra** is emitted by any solid or gaseous body under high pressure and high temperature. Stars are, under first approximation, like black body whose continuous spectra has a shape which depends on its surface temperature;

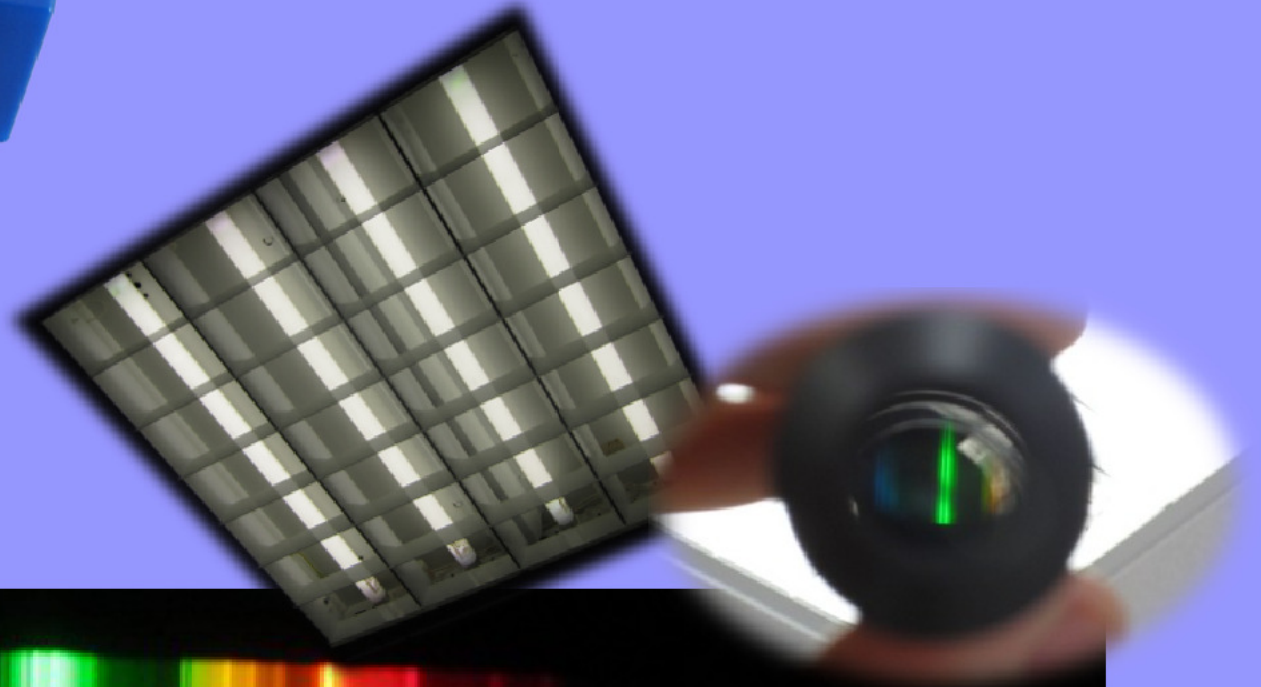
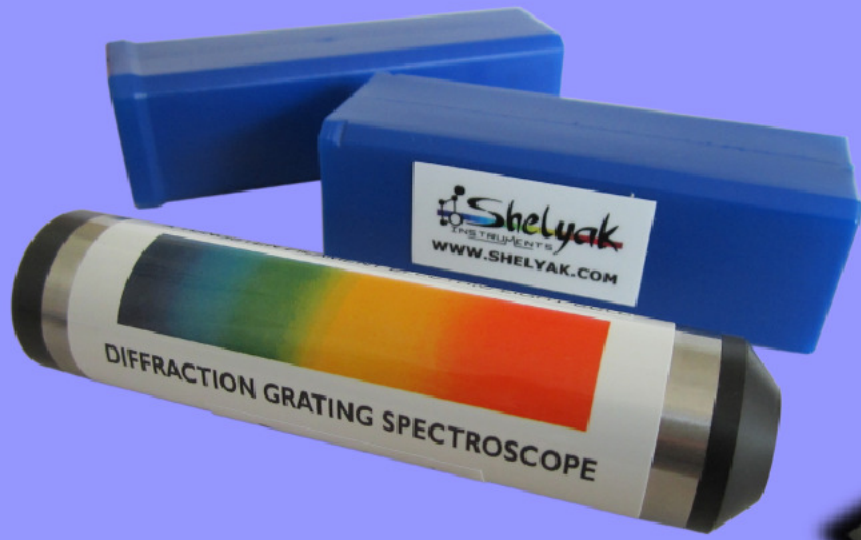
2

**Absorption line spectra:** a low pressure low temperature gas crossed by a continuous light absorbs some photons. Spectra then shows dark lines in front of the continuous spectra;

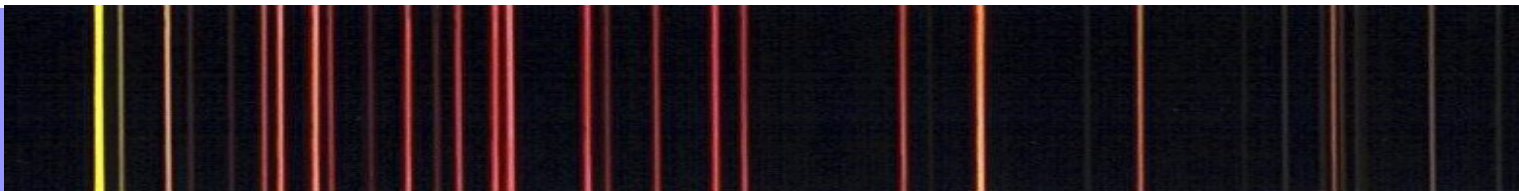
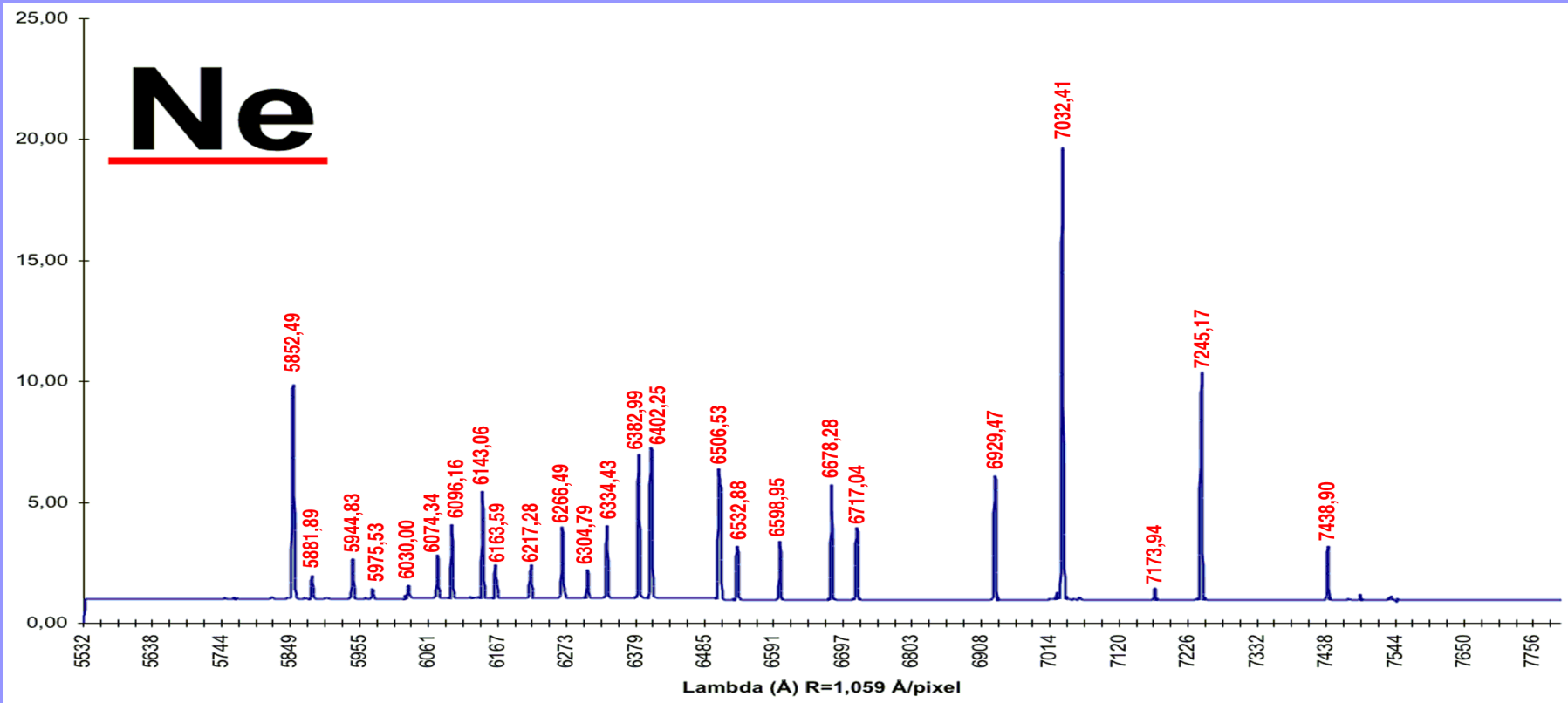
3

**Emission line spectra:** a low pressure high temperature gas emits a light made of few radiations, characteristics of the atoms that constitutes this gas. Each chemical element has its own line spectra, true identity card of its composition and state.

# Economy saving lamp (handheld spectroscope)

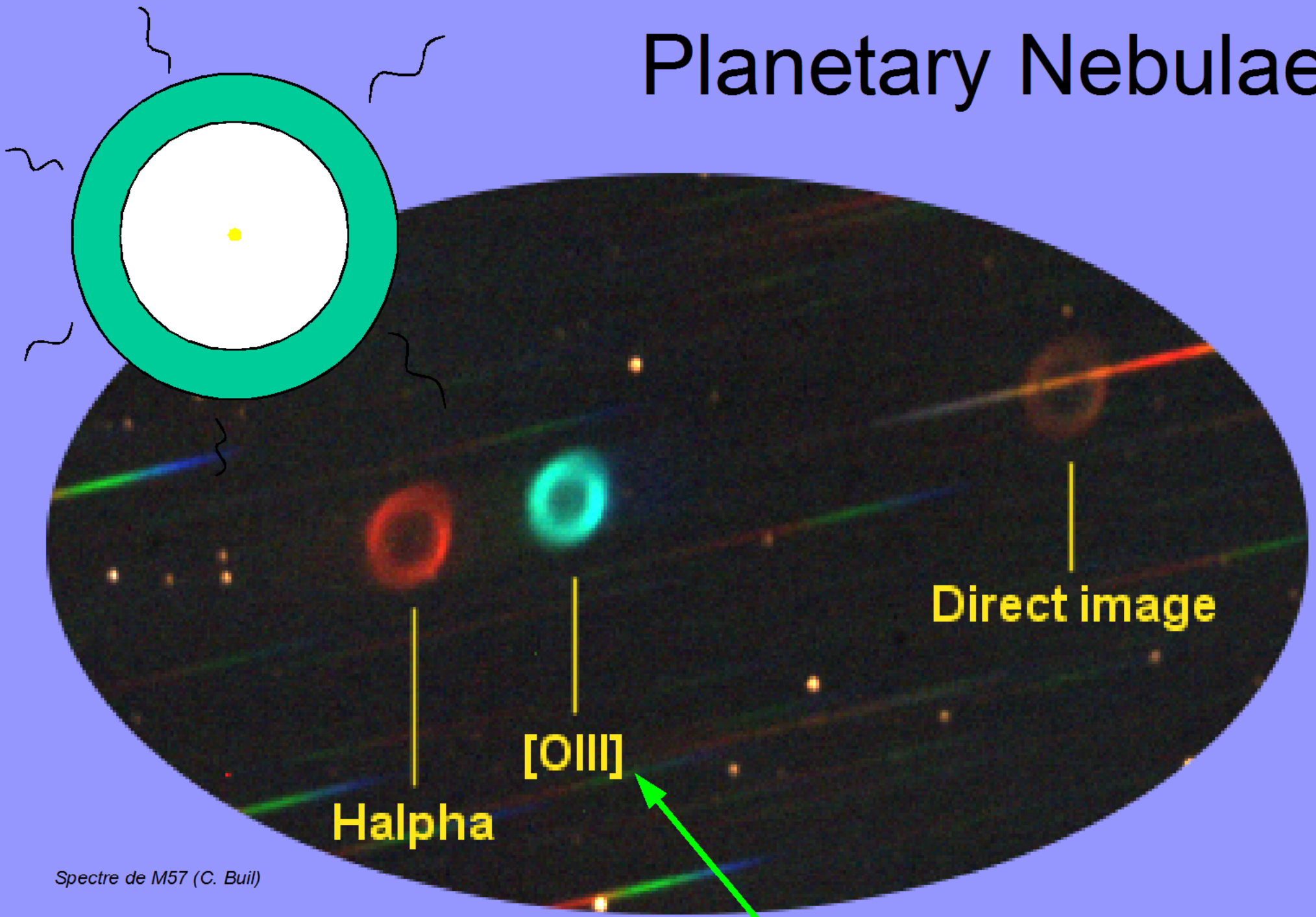


# Emission lines → calibration



- *Calibration lamps (ex: internal Lhires III neon) → critical !*

# Planetary Nebulae



*Spectre de M57 (C. Buil)*

**Halpha**

**[OIII]**

**Direct image**

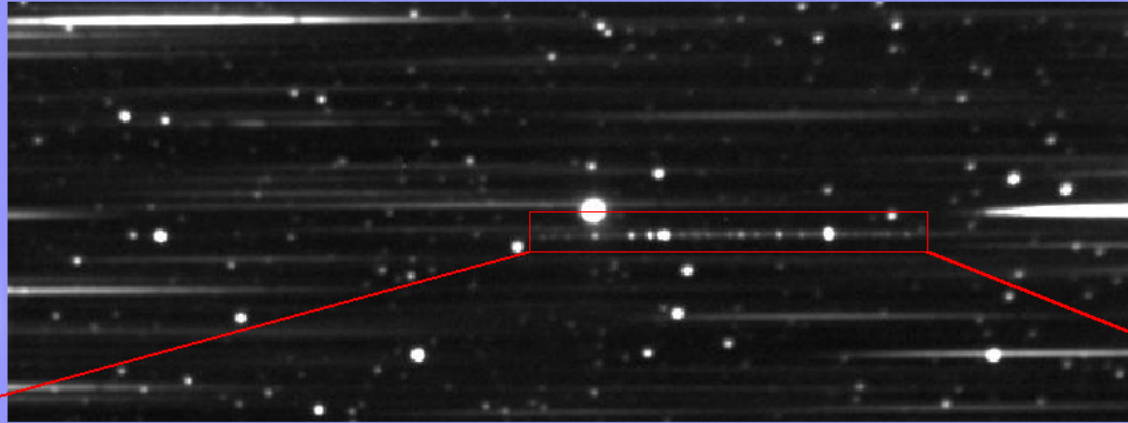
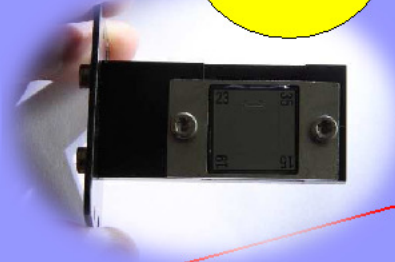
Forbidden lines  
Names 'nebulium' originally !



# Slitless Vs slit spectroscopy

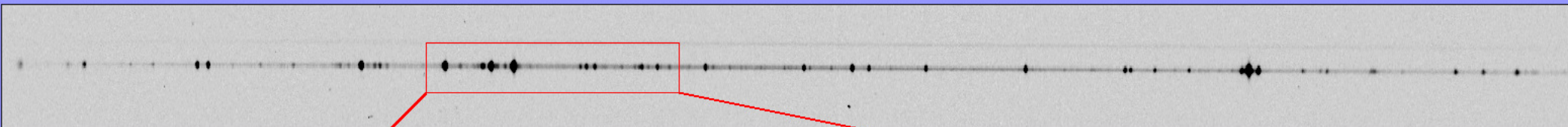
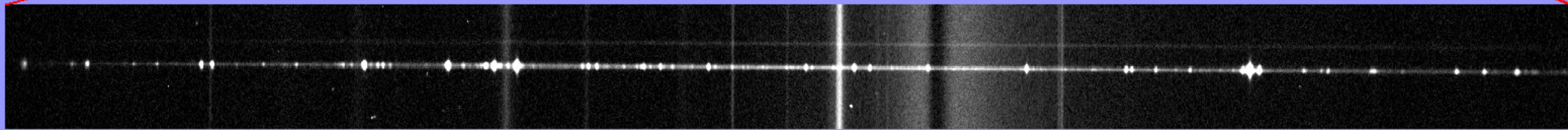
*ex: symbiotic star V1016 Cyg*

Slit !

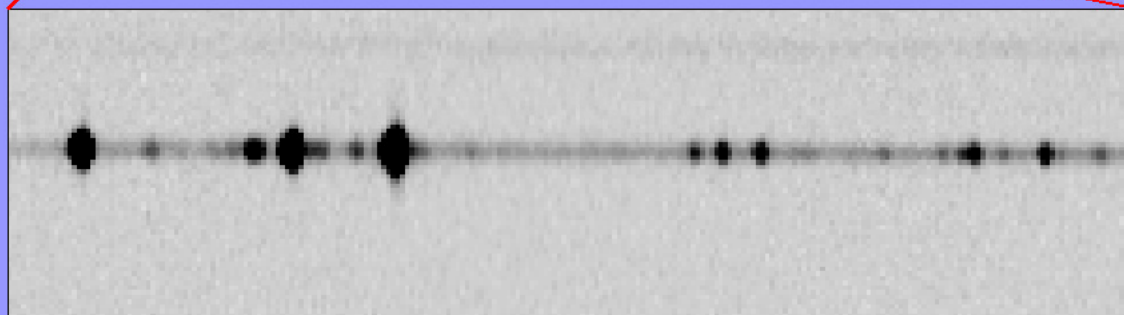


Star Analyser

2D spectrum before sky subtraction (23 $\mu$ m slit)



2D spectrum after sky subtraction

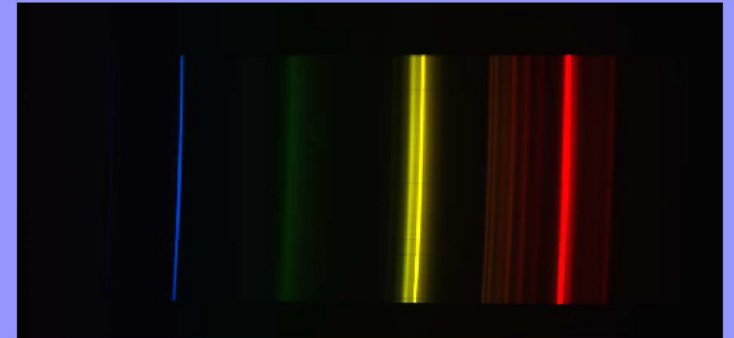




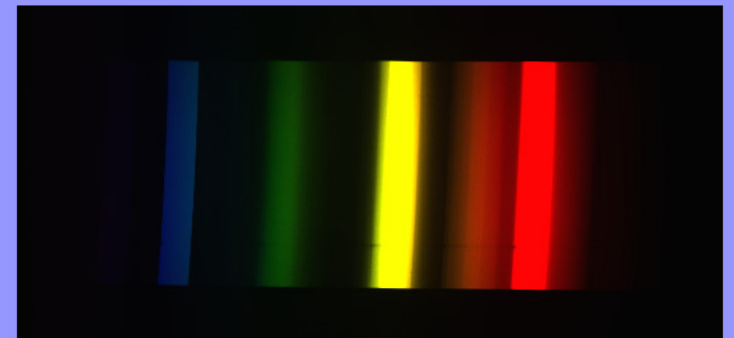
# new *Alpy 600* modular spectrograph

Slit

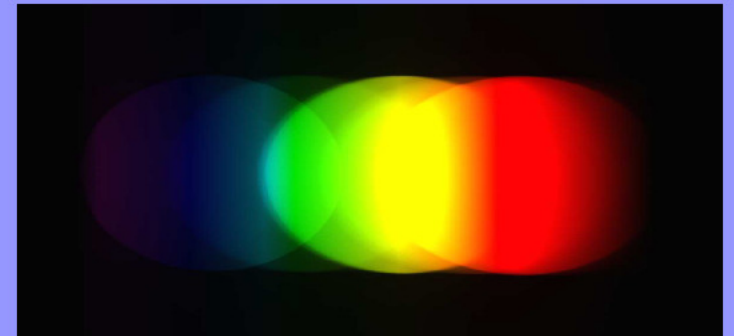
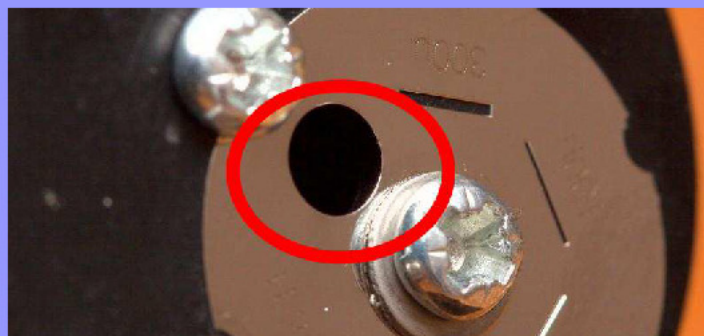
➤ 25 $\mu$ m



➤ 300 $\mu$ m



➤ 3mm





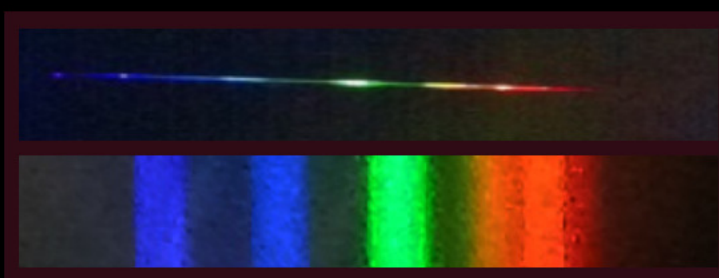


# iSpectroscopy...



[Back](#) **Analyze**

For best results, crop and rotate your photo so the emission lines are aligned with the colors in the full spectrum. Go back to the calibrate screen to fine tune.



**← Compact Florescent White →**

Compact Fluorescent Lights primarily rely on the discharge of mercury gas and various phosphors to produce light. When combined with other noble gases, mercury discharges can produce a variety of visible light.

iPhone application : SpectraSnapp

# Alpy 600 & CCD simple setup

Shelyak Instruments ALPY 600 spectrograph with PL1M (QHY5) CMOS camera



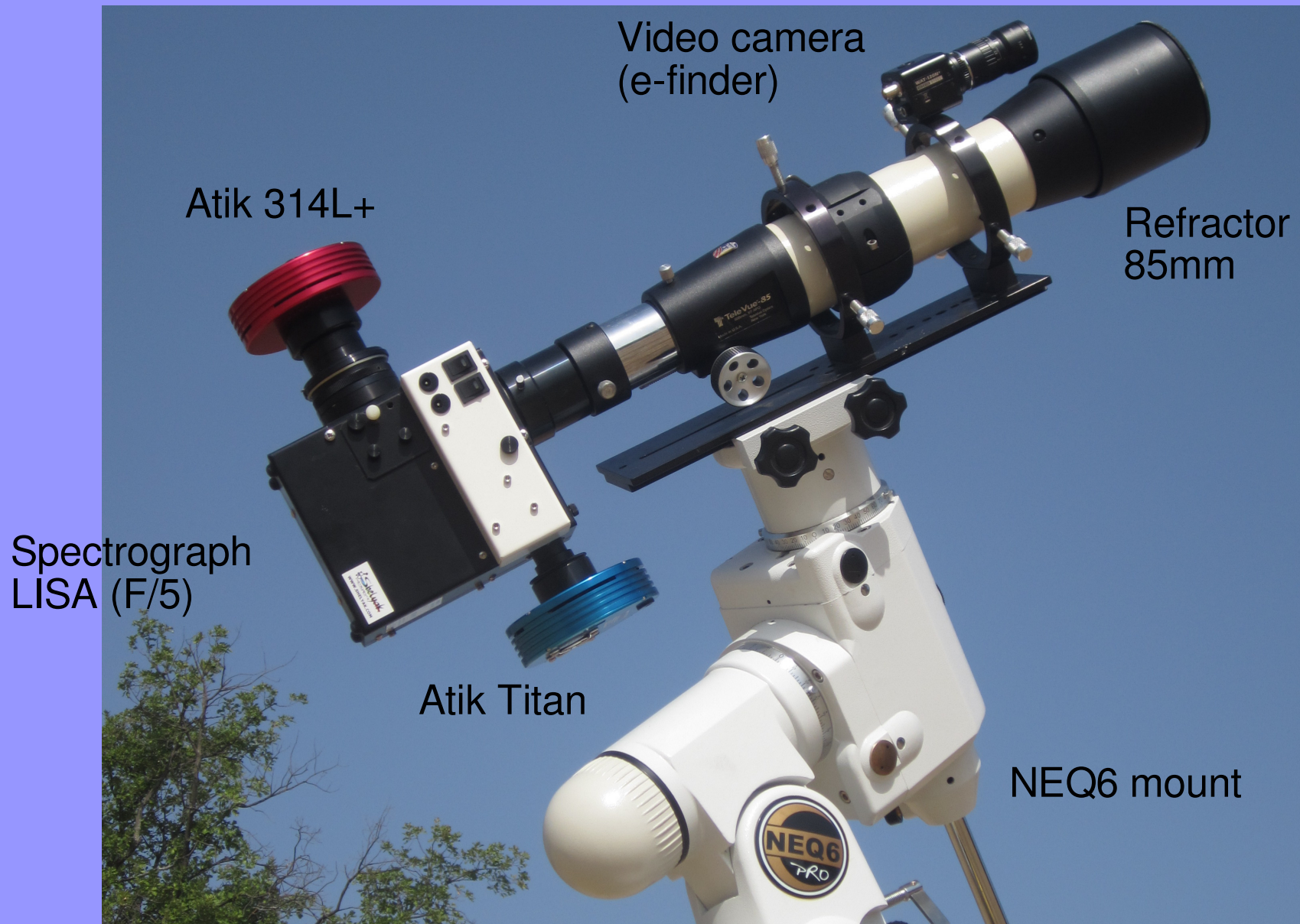
Solar spectrum

neon spectrum

energy saving lamp spectrum



# Gain resolution: LISA Pack (R ~1000)





# In the field: acquisition w/ a LISA

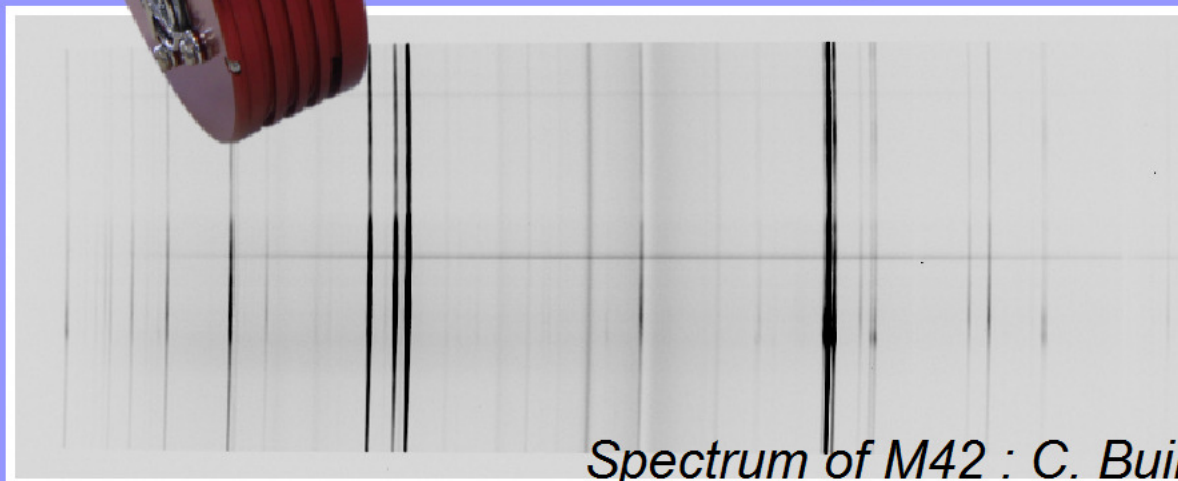
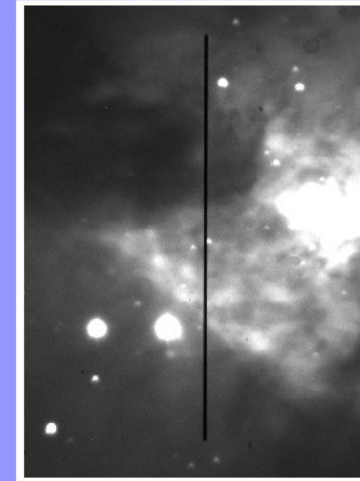
	Slit 23 $\mu\text{m}$ R = 1100	Slit 50 $\mu\text{m}$ R = 600	Slit 100 $\mu\text{m}$ R = 290
D = 12.8 cm F/D = 8	12.5	13.1	13.4
D = 28 cm F/D = 6.8	13.6	14.6	15.0
D = 35 cm F/D = 6.8	13.9	14.9	15.4
D = 50 cm F/D = 6.0	14.4	15.5	16.2
D = 100 cm F/D = 6.0	15.2	16.3	17.2

## Limit magnitude :

- A0V type star
- 1h exposure (KAF8300)
- Signal/Noise = 10 (H $\alpha$ )
- Altitude 0, near city



# Alpy modular system



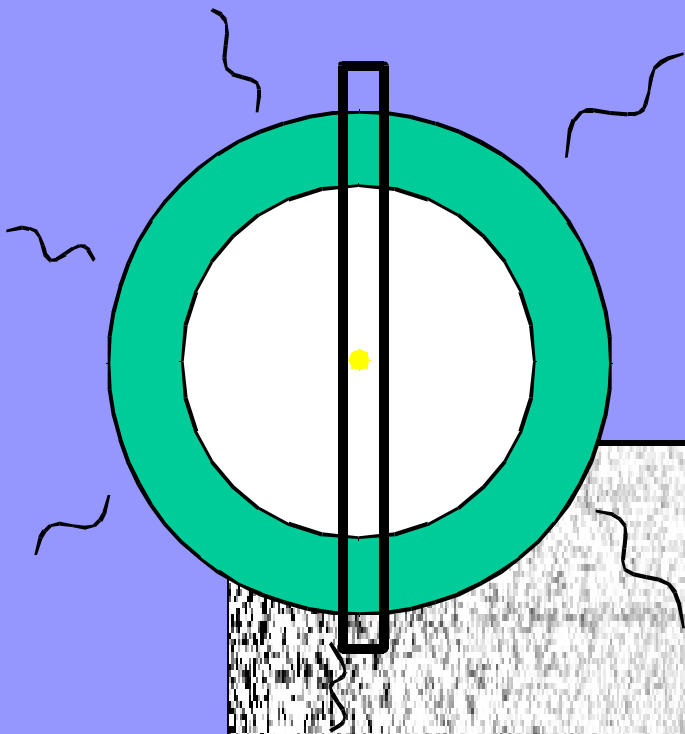
*Spectrum of M42 : C. Buil*

Diameter	S/N=10 @650nm	S/N=10 @ 450nm
85mm	12,9	14,3
200mm	14,6	16,0
280mm	15,1	16,5
350mm	15,4	16,8
940mm	17,0	18,4

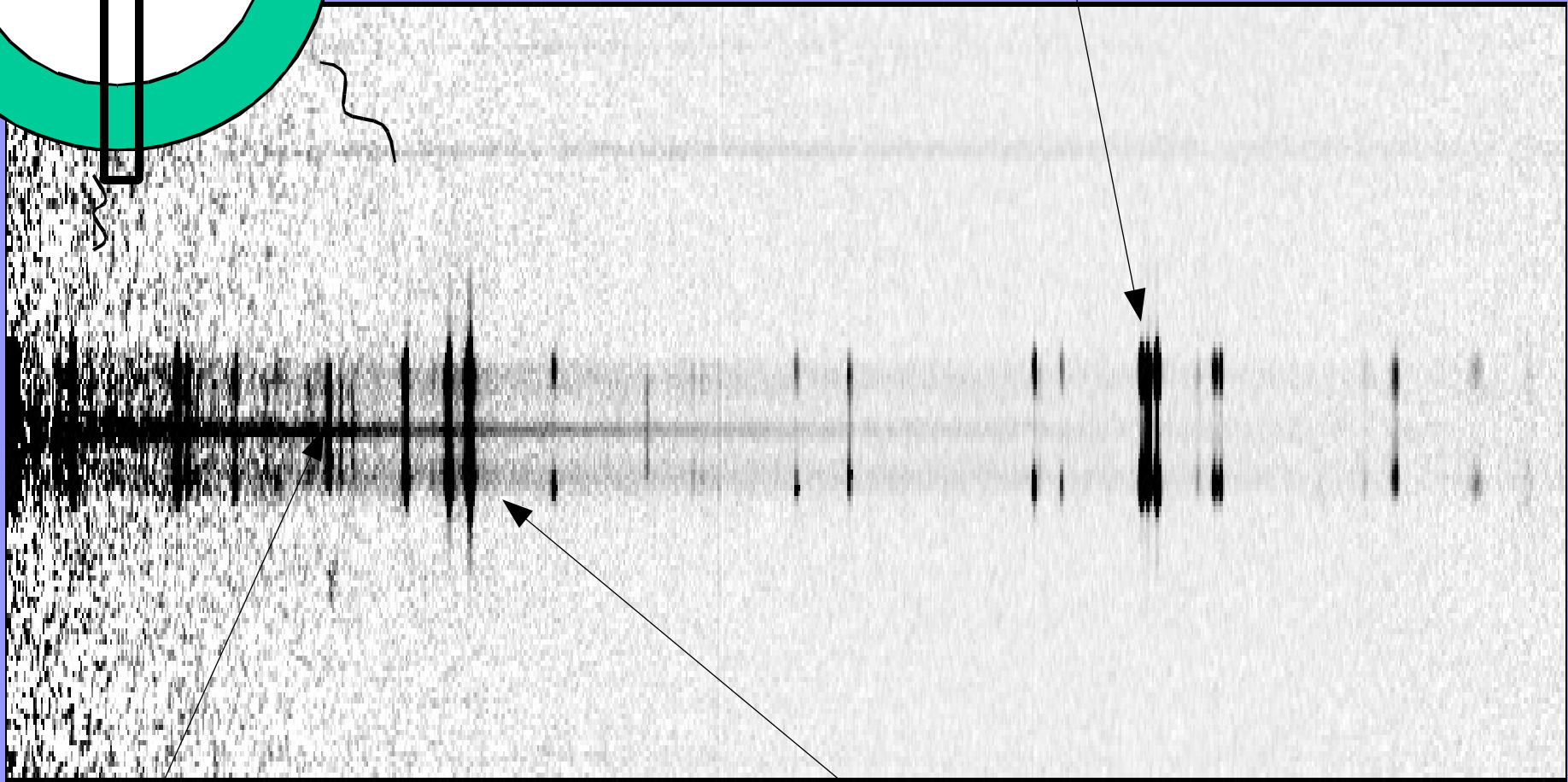
***Limit magnitude :***

- A0V type star
- 1h exposure (Atik 460EX)

# Planetary Nebulae



Emission lines (nebula)

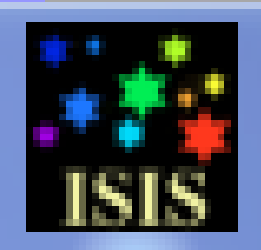
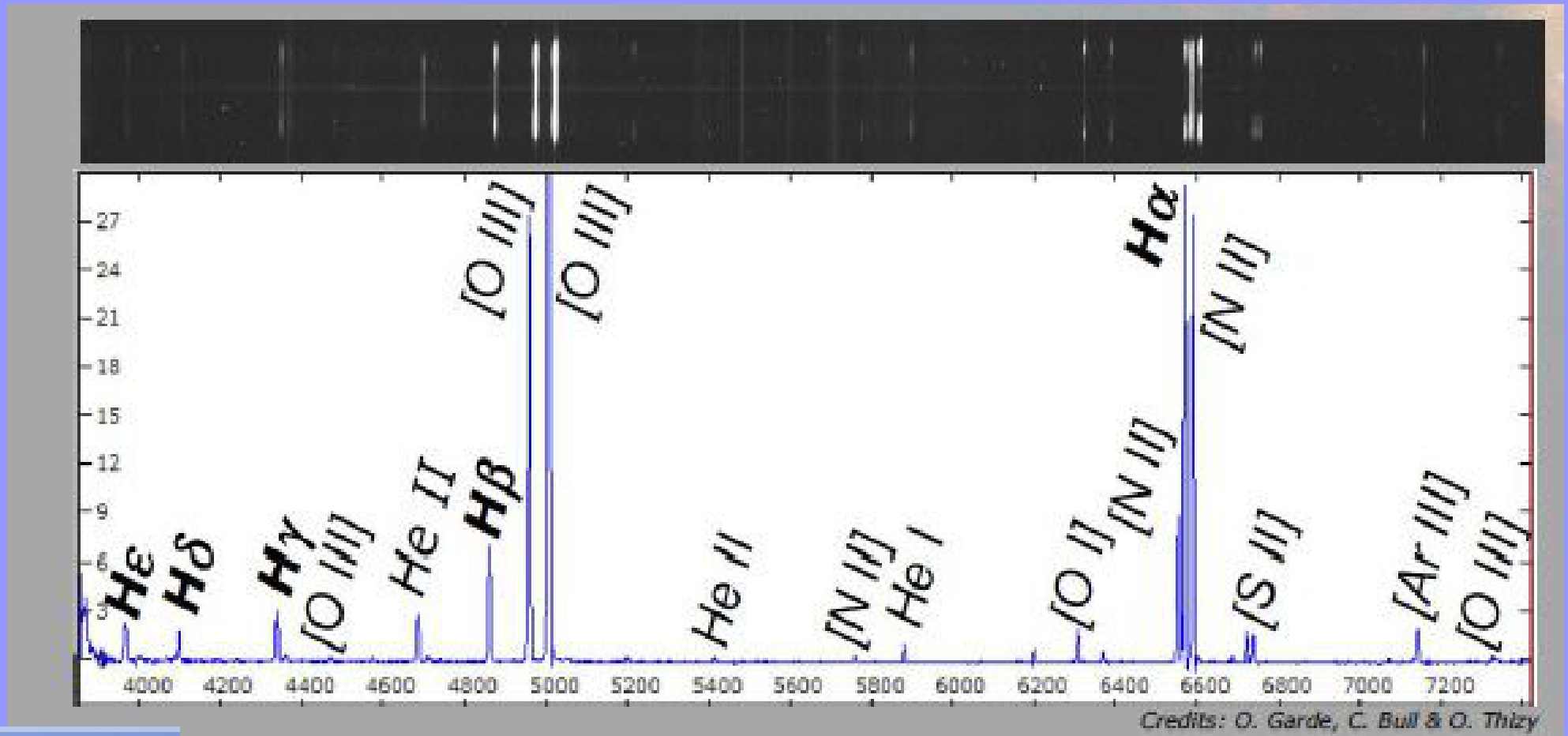


Central star spectrum

Nebula continuous spectrum

*M57 spectrum (C. Buil; LISA, C9, QSI583, 70min)*

# In practice: data reduction



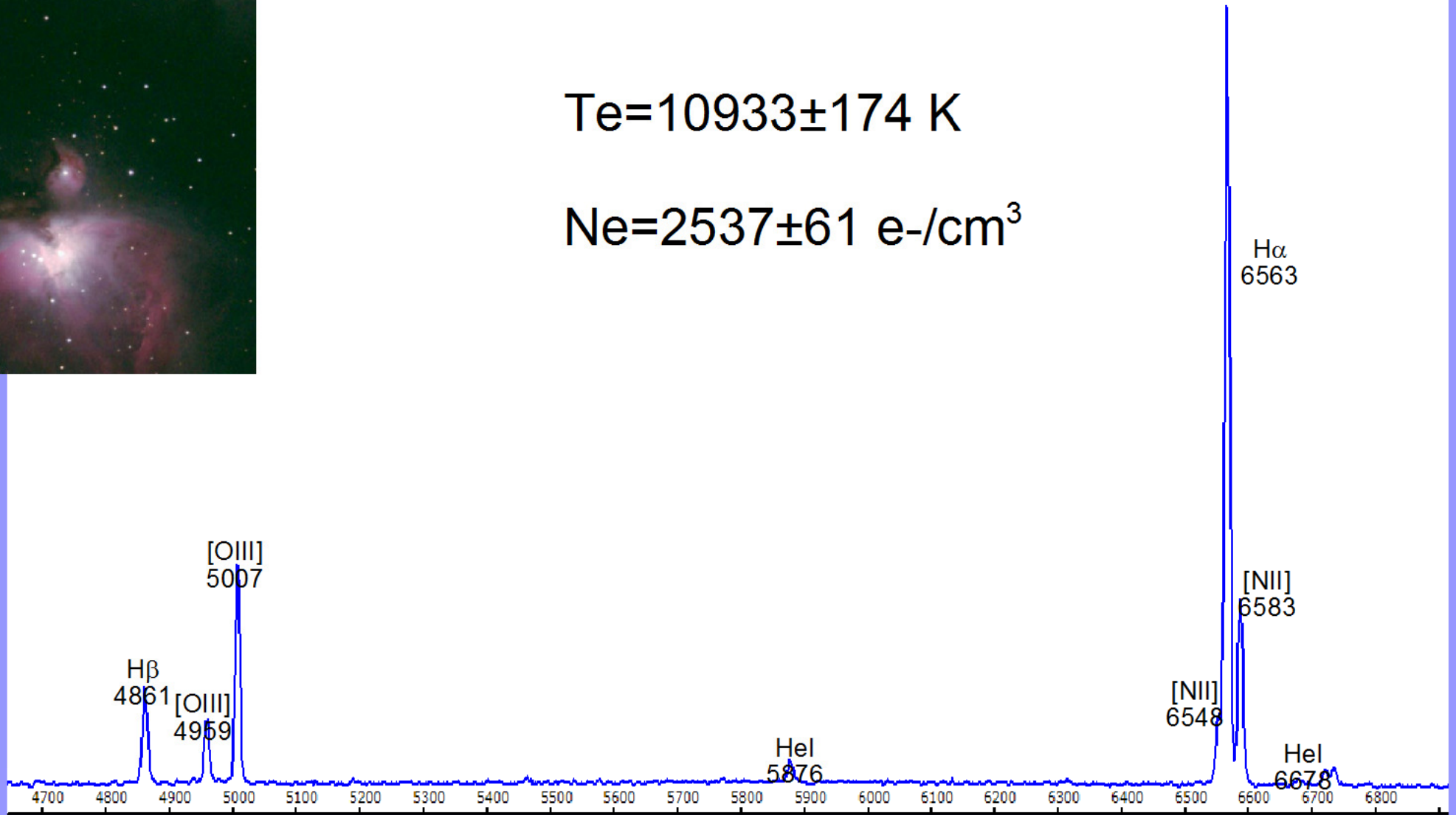
<http://www.astrosurf.com/buil/isis/isis.htm>

# Nebulae: measure electronic temperature et density



$T_e = 10933 \pm 174$  K

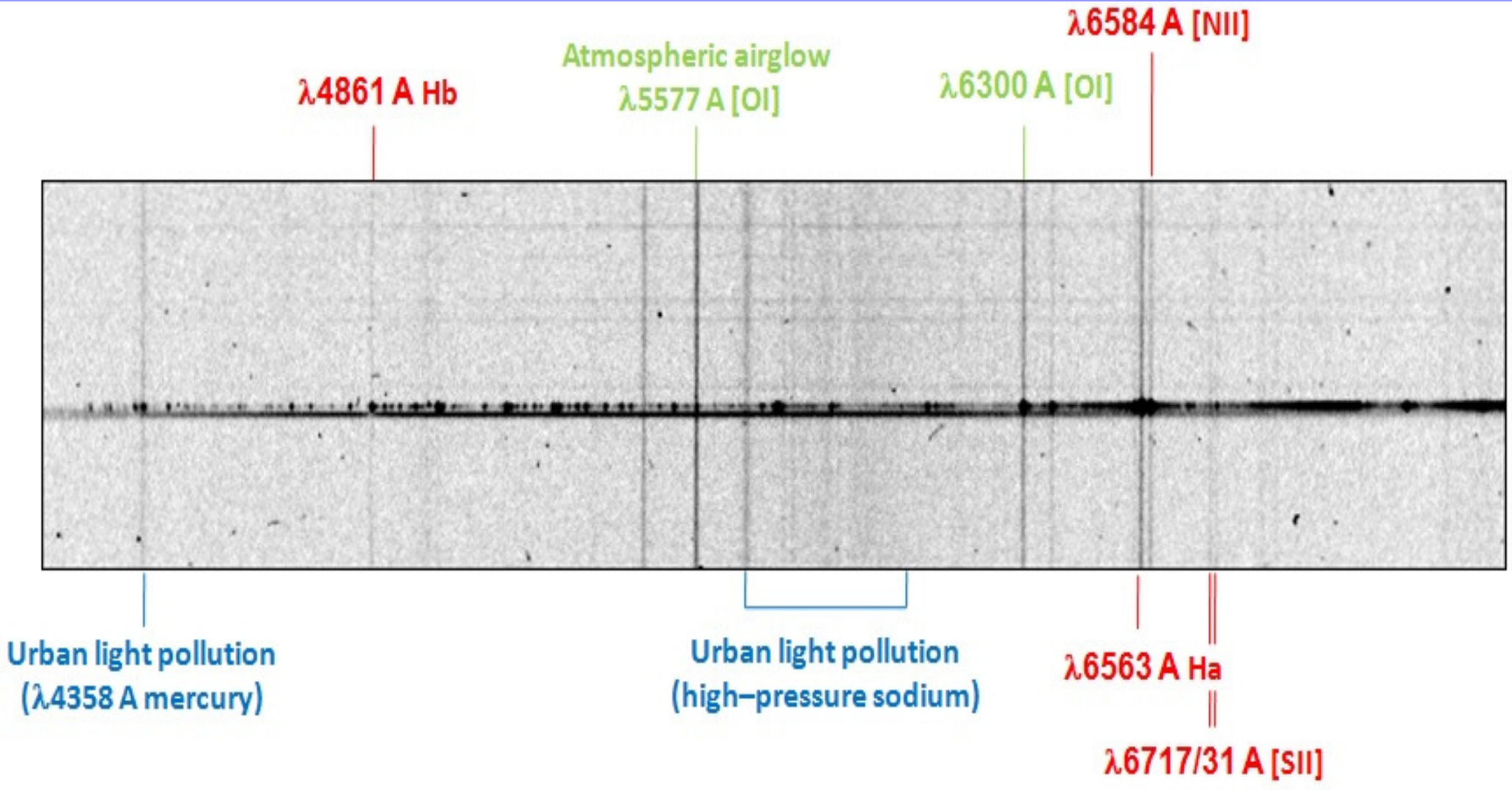
$N_e = 2537 \pm 61$  e-/cm<sup>3</sup>



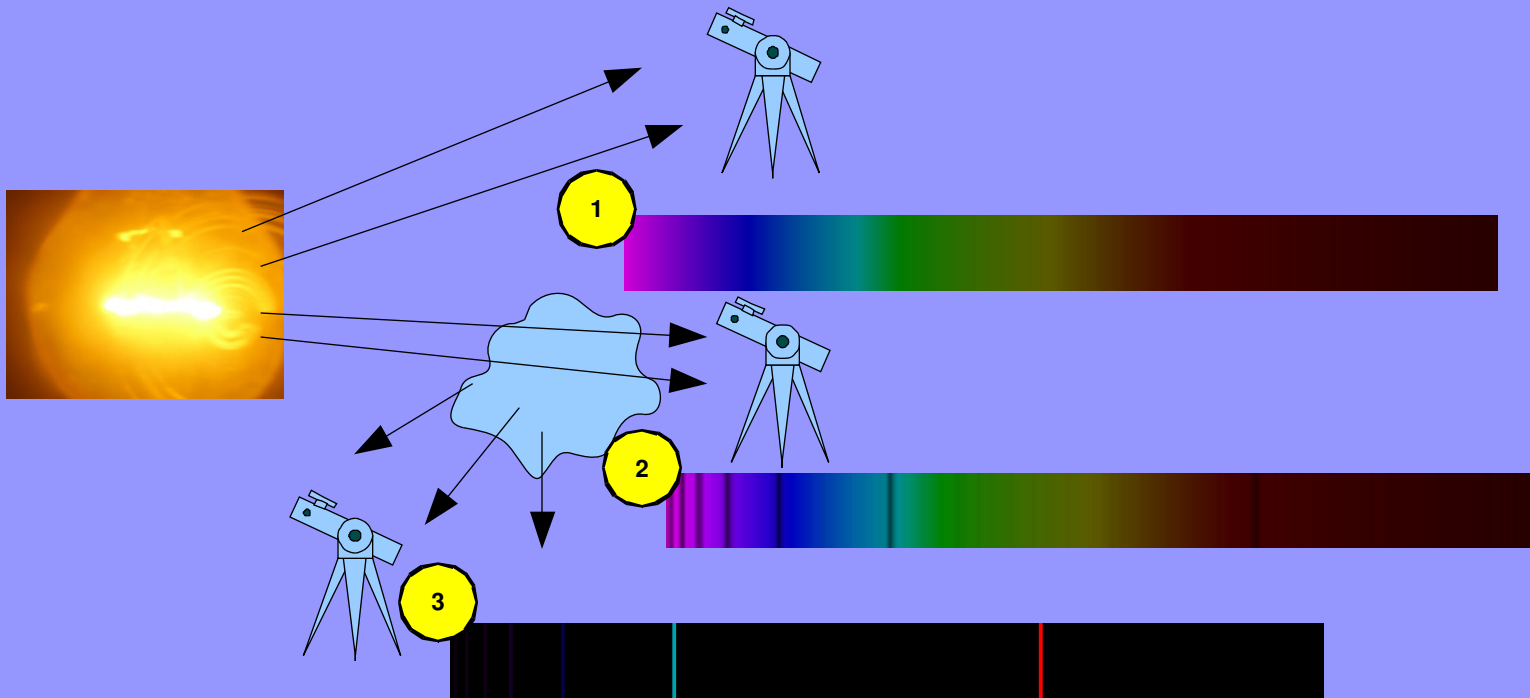
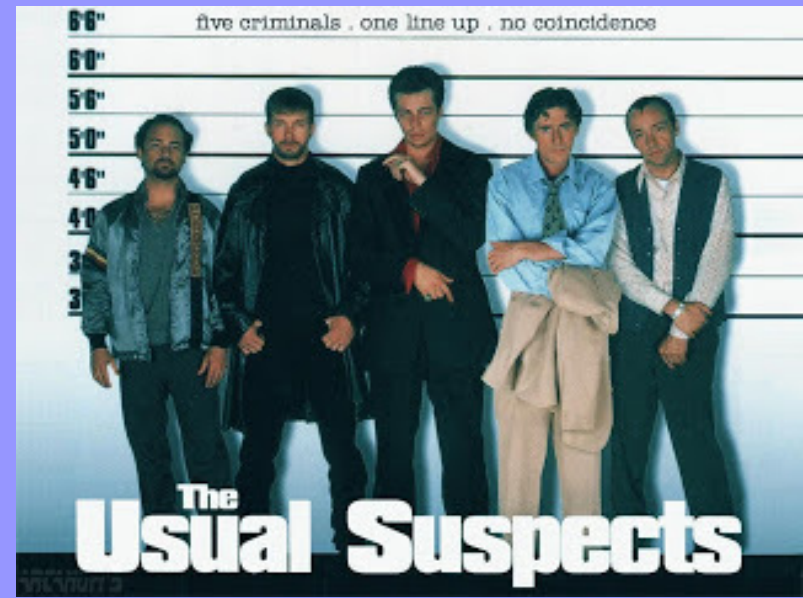
**Spectre de M42** - Lhires III (150tt/mm) + KAF1600 / Acquisition: Benjamin Mauclaire / Traitement: Olivier Thizy  
Cf: <http://bmauclaire.free.fr/astronomie/spectro/atlas/nd/m42/>  
Image de M42: Olivier Garde & Adrien Viciano (CALA)



# Sky “pollution” !



# Kirchhoff's law summary



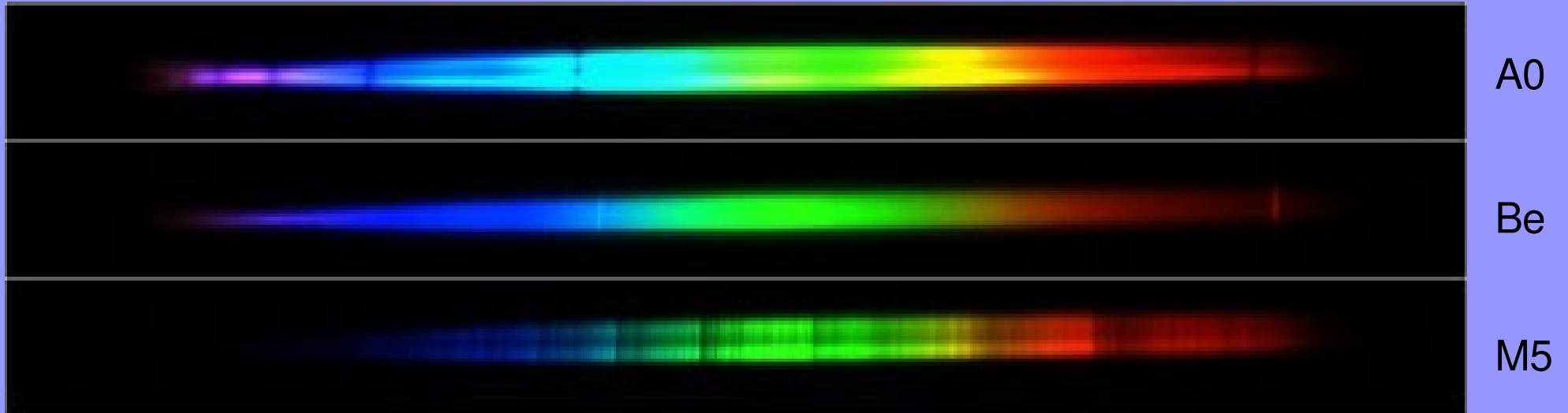
# Stellar classification

- **Some pioneers: Lewis Rutherfurd (1816-1892), Angelo Secchi (1818-1878), William Huggins (1824-1910), Hermann Carl Vogel (1841-1907)**
- **A key work: Henry Drapper catalog from Harvard**
  - **Edward Pickering (1846-1919) and his team (of women!); created AAVSO**
  - **Williamina Fleming (1857-1911): type A...Q; 26000 spectra**
  - **Antonia Maury (1866-1952): type I...XX; first to put O type before A type in Flemming classification**
  - **Annie Cannon (1863-1941)**
    - **“OBAFGKM” types**
    - **sub-divisions (B0..9)**
    - **~400000 spectra of her own !!!**



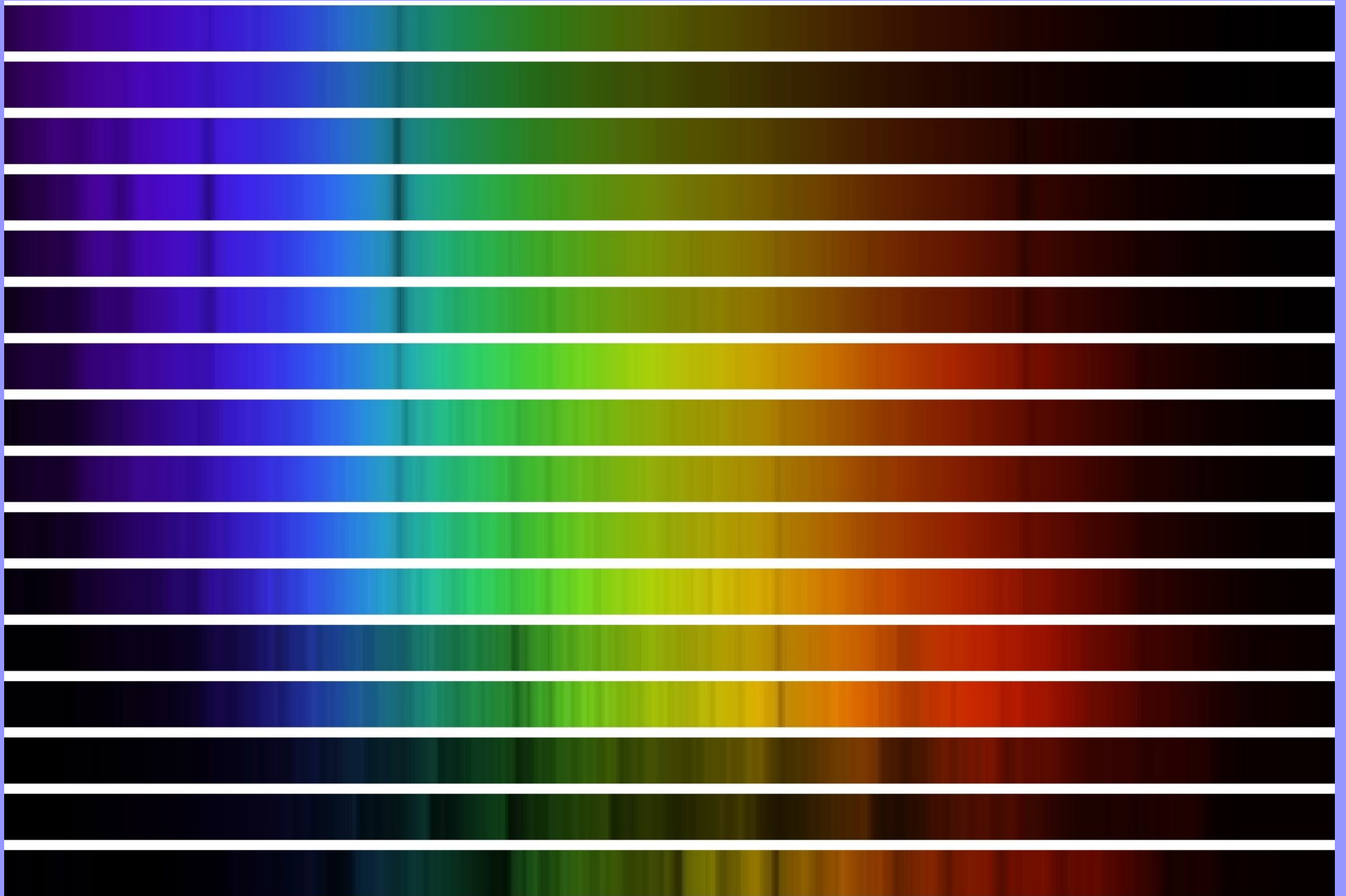
*A.J. Cannon*

# Spectral Classification (Low Res.)



C8 – Lhires III (150tt/mm) – EOS 300D – 30 sec – no computer !

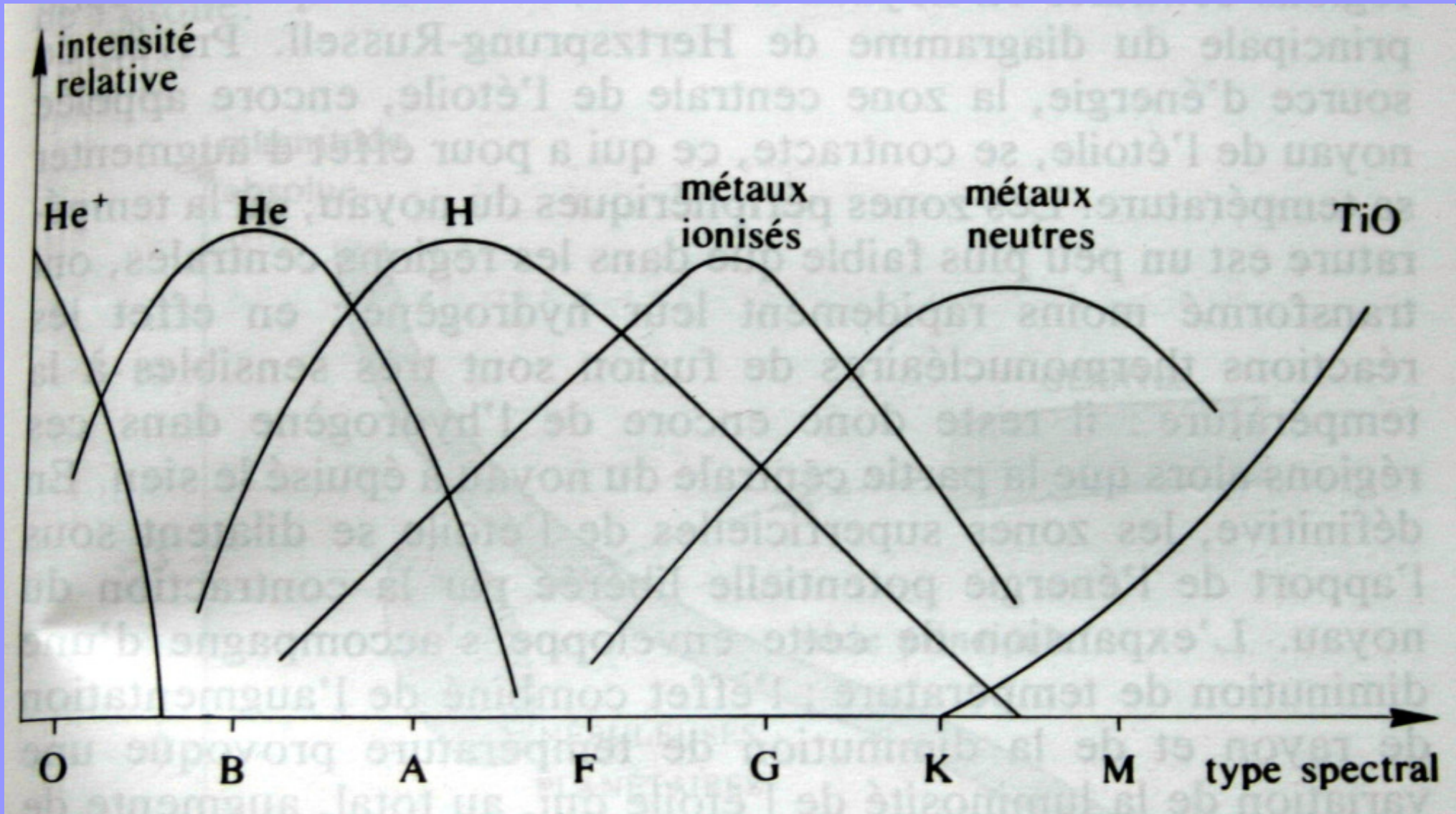
# From ABC... to OBAFGKM !



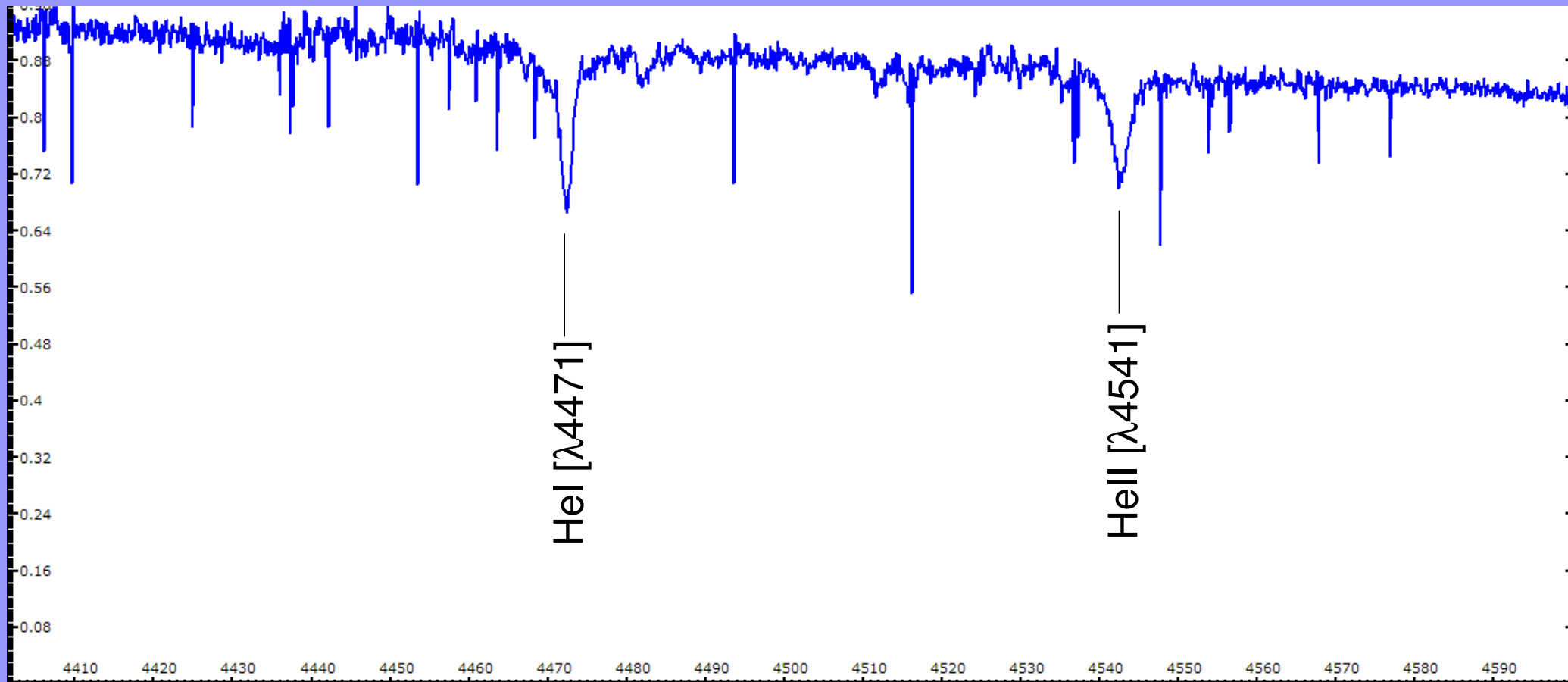




# Relative intensity per elements



# A more precise classification's method



*Measuring Equivalent Width of He I [λ4471] & He II [λ4541] ==> precise spectral type*

*HD 47839: He I [λ4471] = 0.799 et He II [λ4541] = 0.533 ==> type = O8*

*eShel Shelyak Instruments echelle spectrograph ( $R \sim 11000$ )  
T0.28m f/6.3; Observatoire de Haute Provence – 2009, february 27*

# Stellar classification

- **1890: Drapper catalog of stellar spectra**
- **1911-1915: 225300 stars reviewed by A.J. Cannon**
- **1918-1924: HD (Henry Drapper) catalog published**
- **1949: HDE: HD catalog extension**
- **1943: “Atlas of Stellar Spectra” by William Morgan, Philip Keenan, & Edith Kellman [MKK]**
  - **Spectral type from HD catalog (Temperature): OBAFGKM**
  - **Introduced class of luminosity I...V**

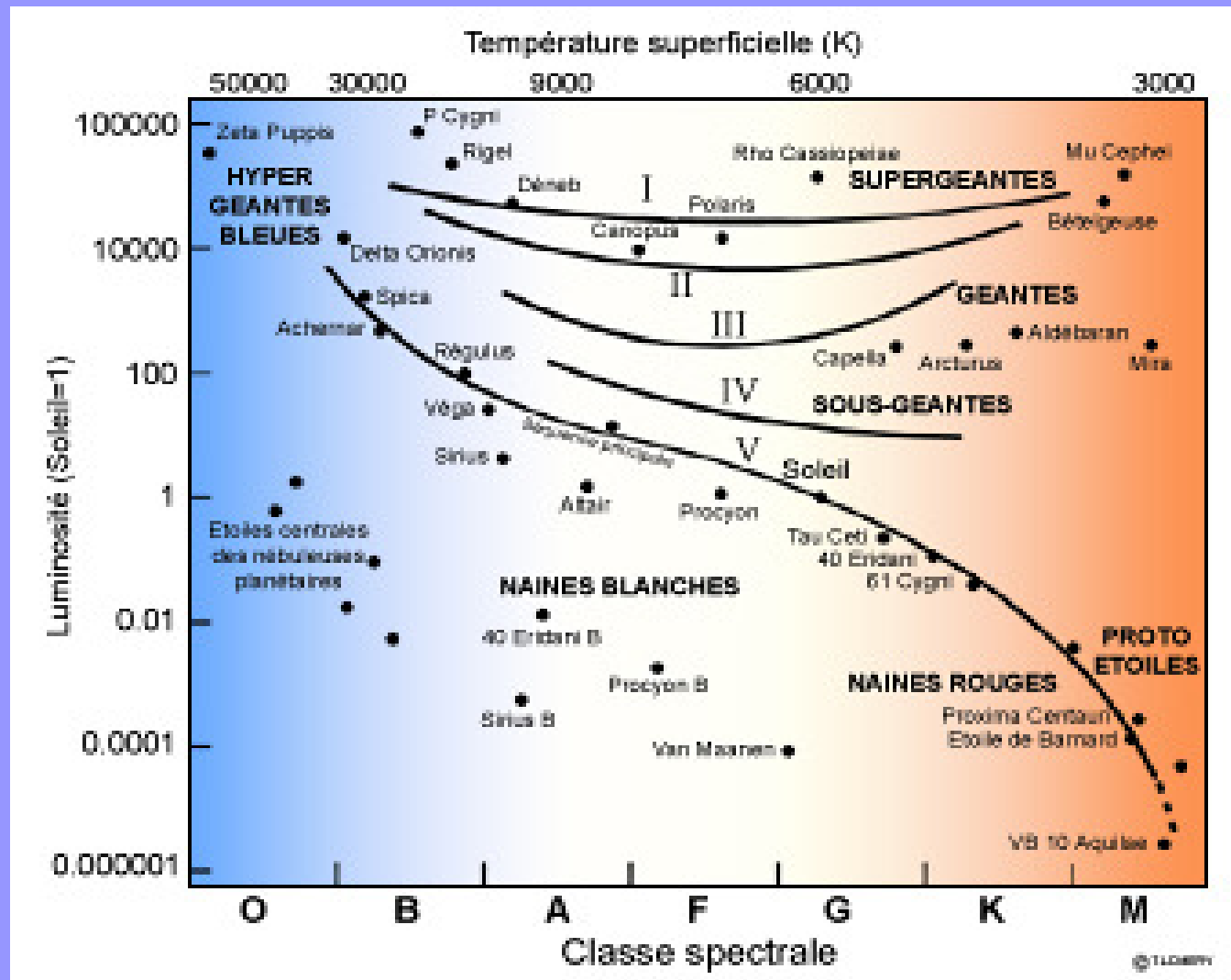


*E. Pickering team (all women!) in 1913.*



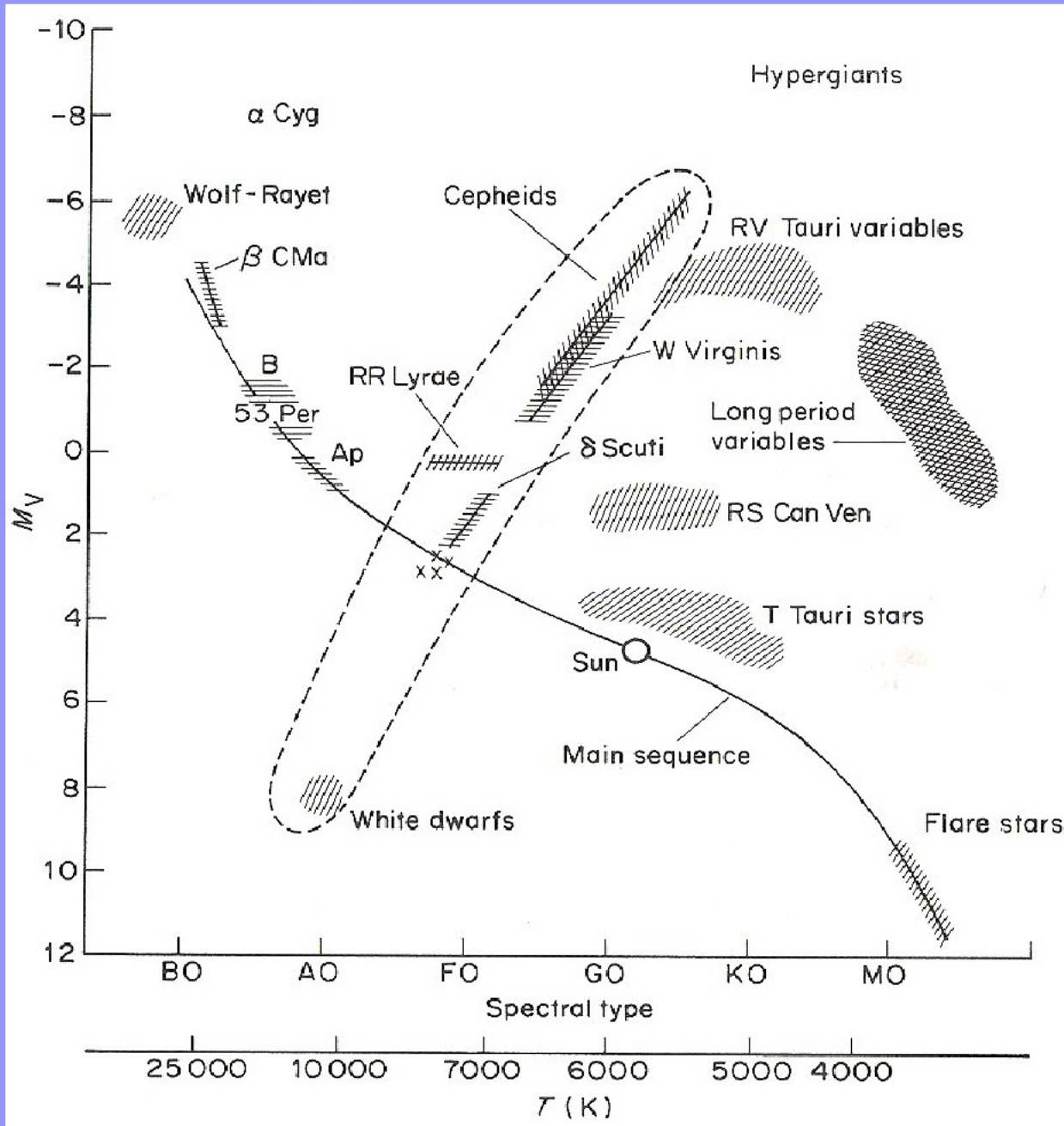
# Beginning of Astrophysics

- Einar Hertzsprung (1873-1967) & Henry Russell (1877-1957)
- Color/Luminosity (first published in 1911)

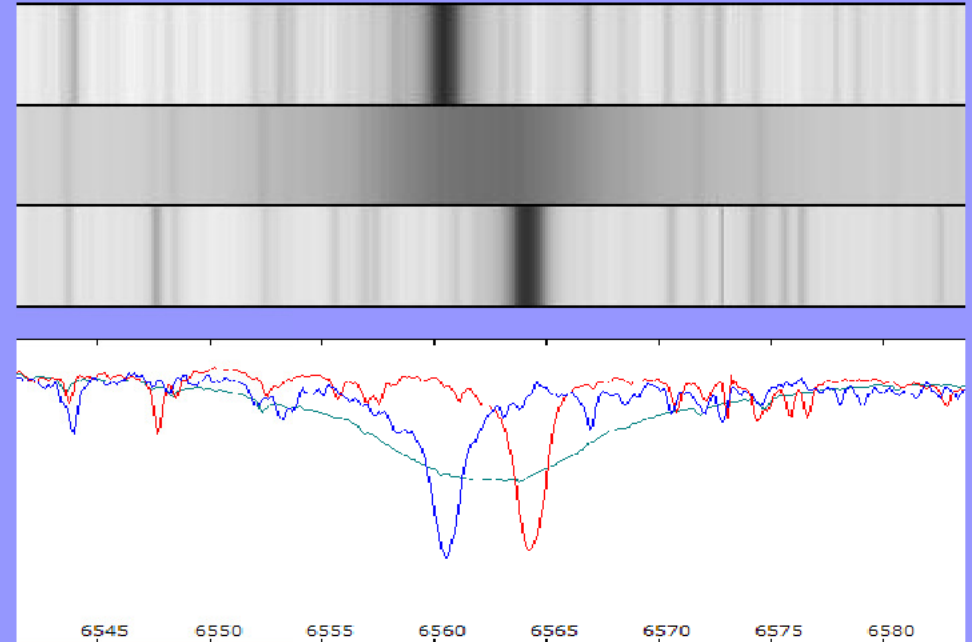
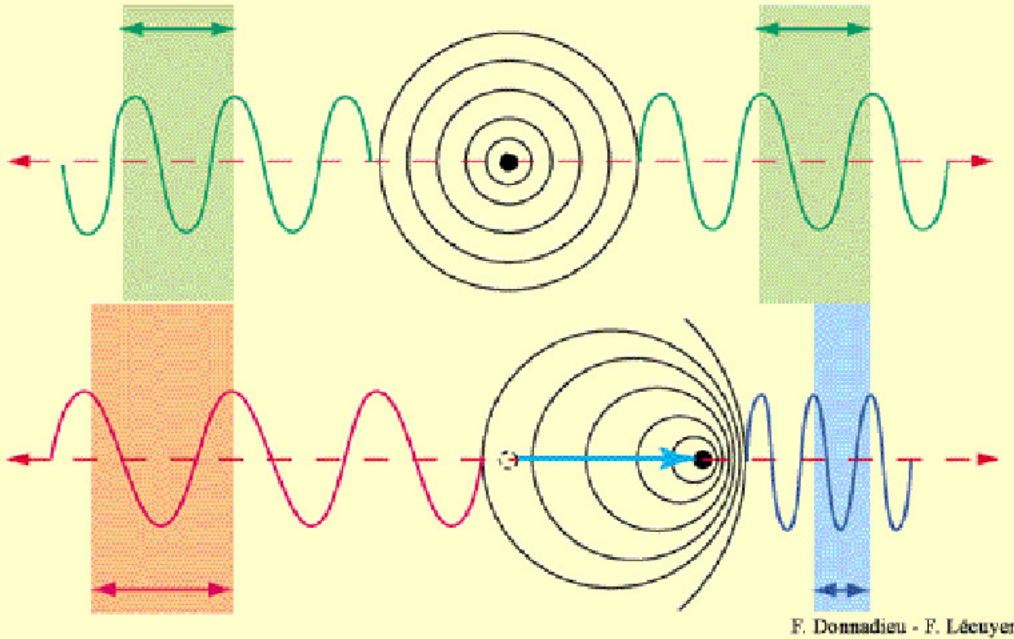
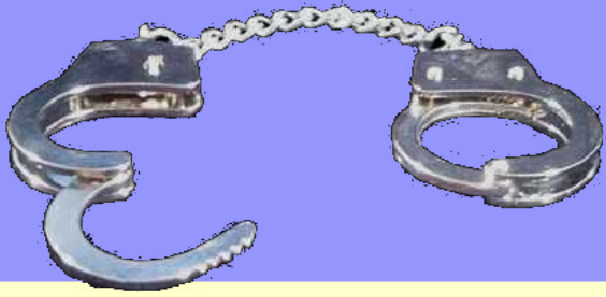




# Variables stars (cf AAVSO)



# Doppler-Fizeau: the ideal suspect !



Galaxies redshift

=

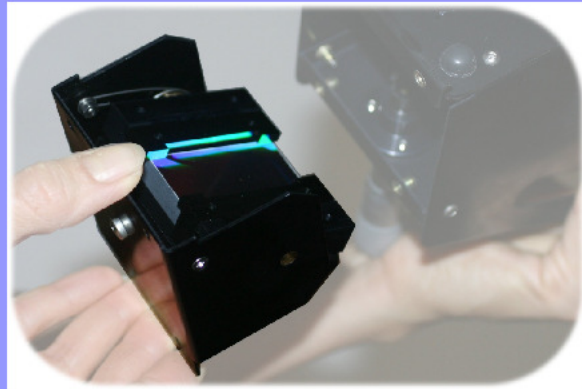
Expansion of our Universe !

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

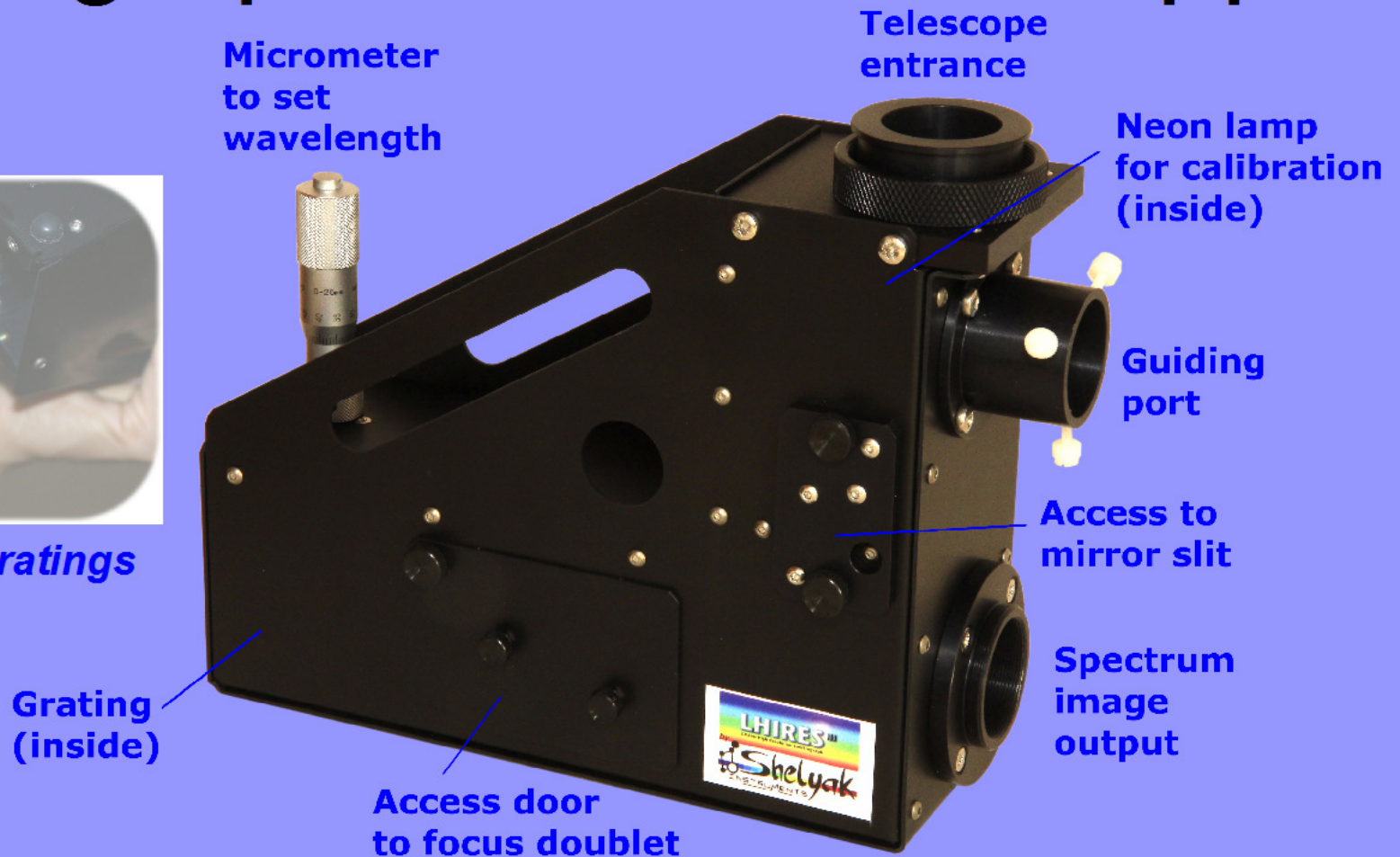




# Lhires III : high-resolution spectrograph to measure Doppler

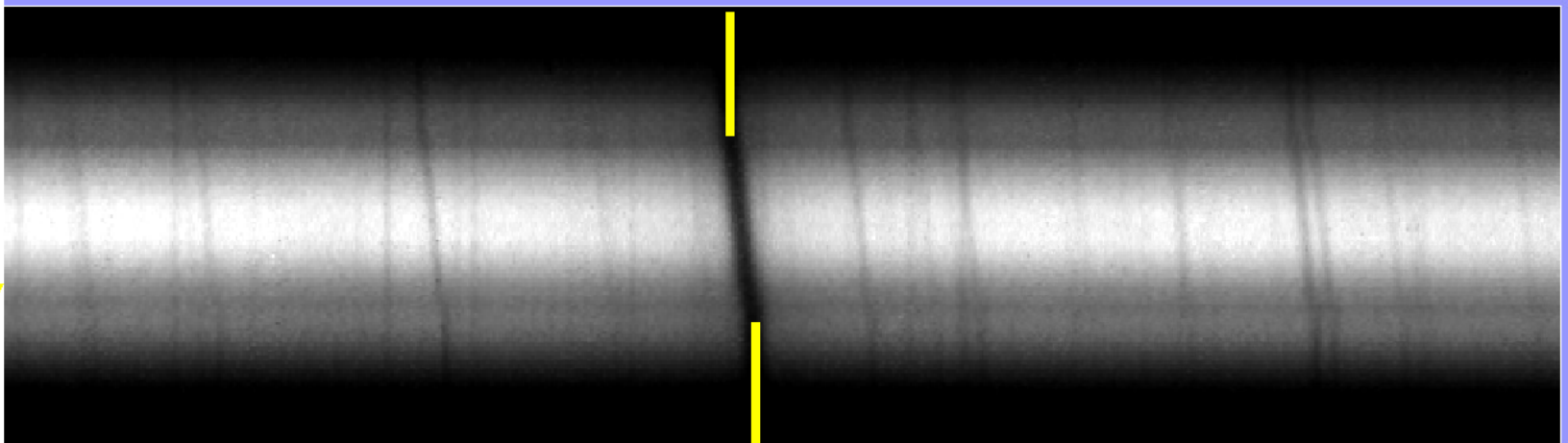
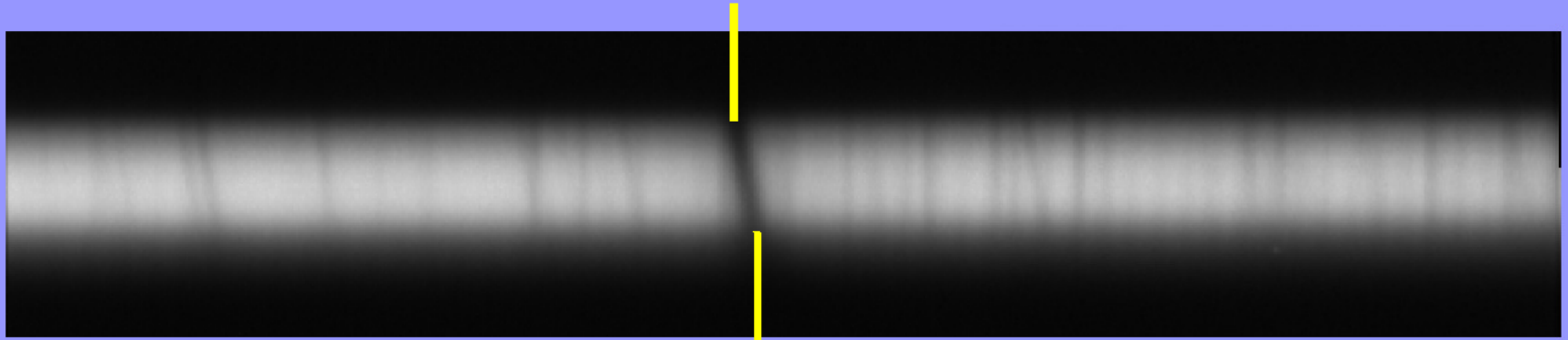


Interchangeable gratings



		2400	1200	600	300	150
Resolution	Å	0,3	1	2,5	5	11
	km/s	18	50	110	230	500
Power of Resolution (R)		17000	6000	2700	1300	600
Spectral domain		Å	85	250	550	2300
Limiting magnitude		5	6	7	8	9

# Planet's rotation



Saturn:

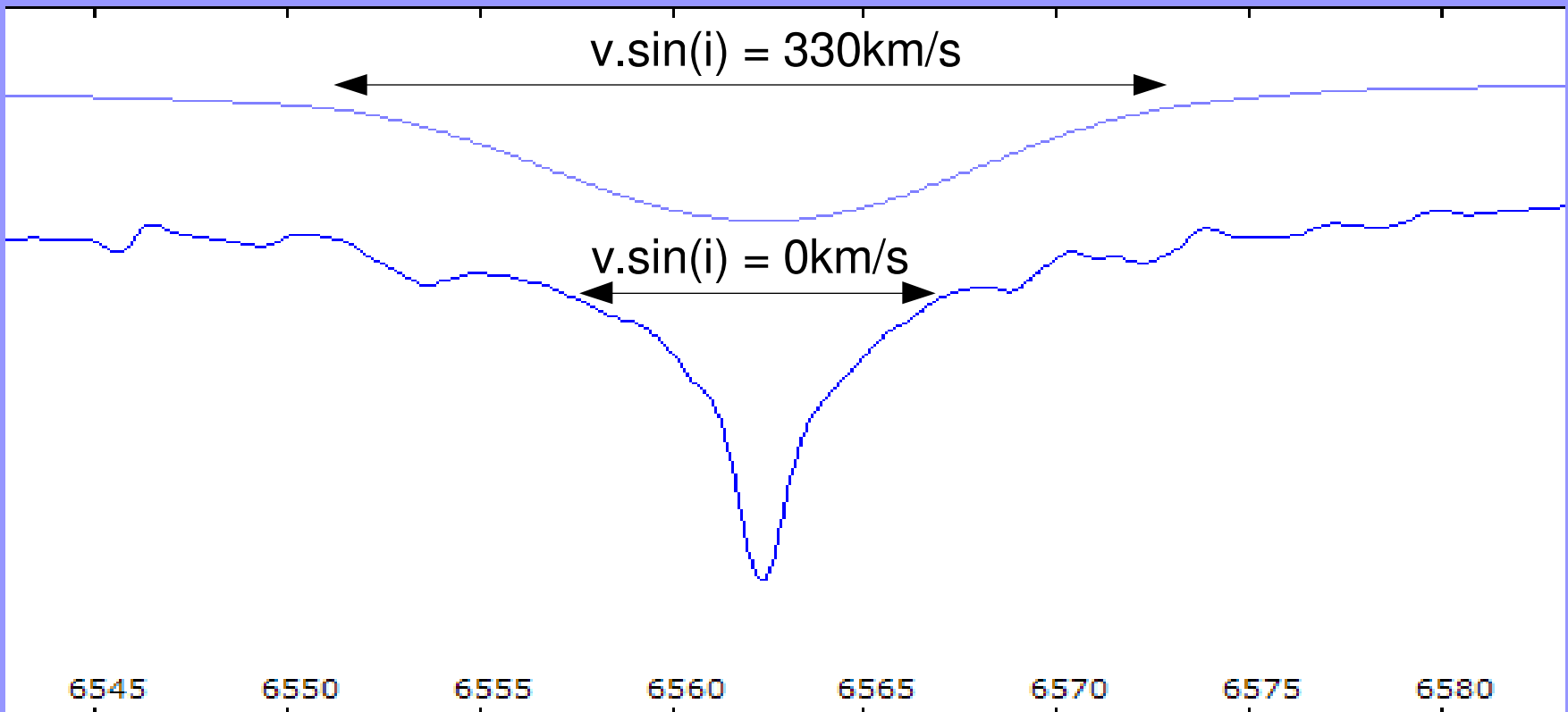
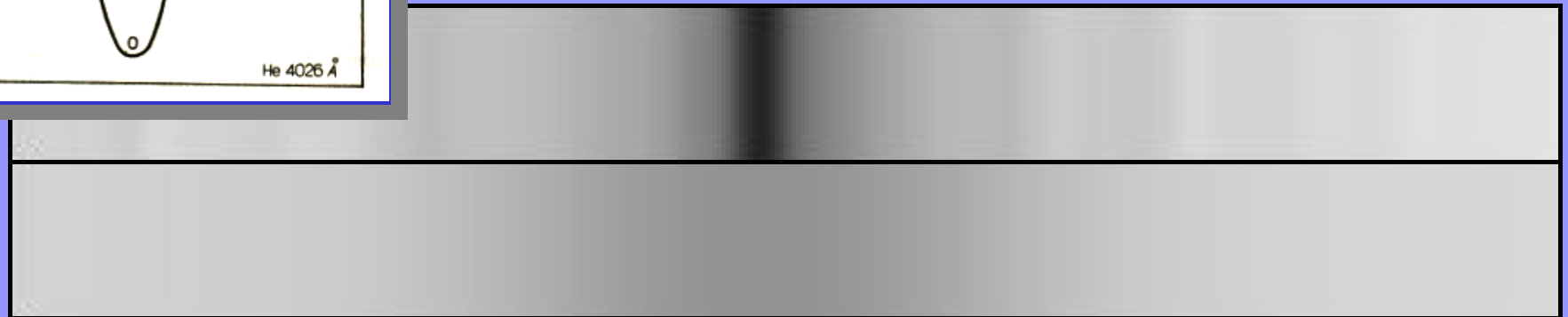
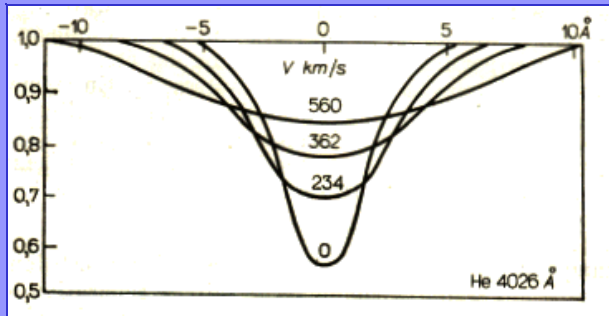
Shift = 7 pixels = 8,8 km/s

Period of 10,6 h  $\gg$  R = 107511 km

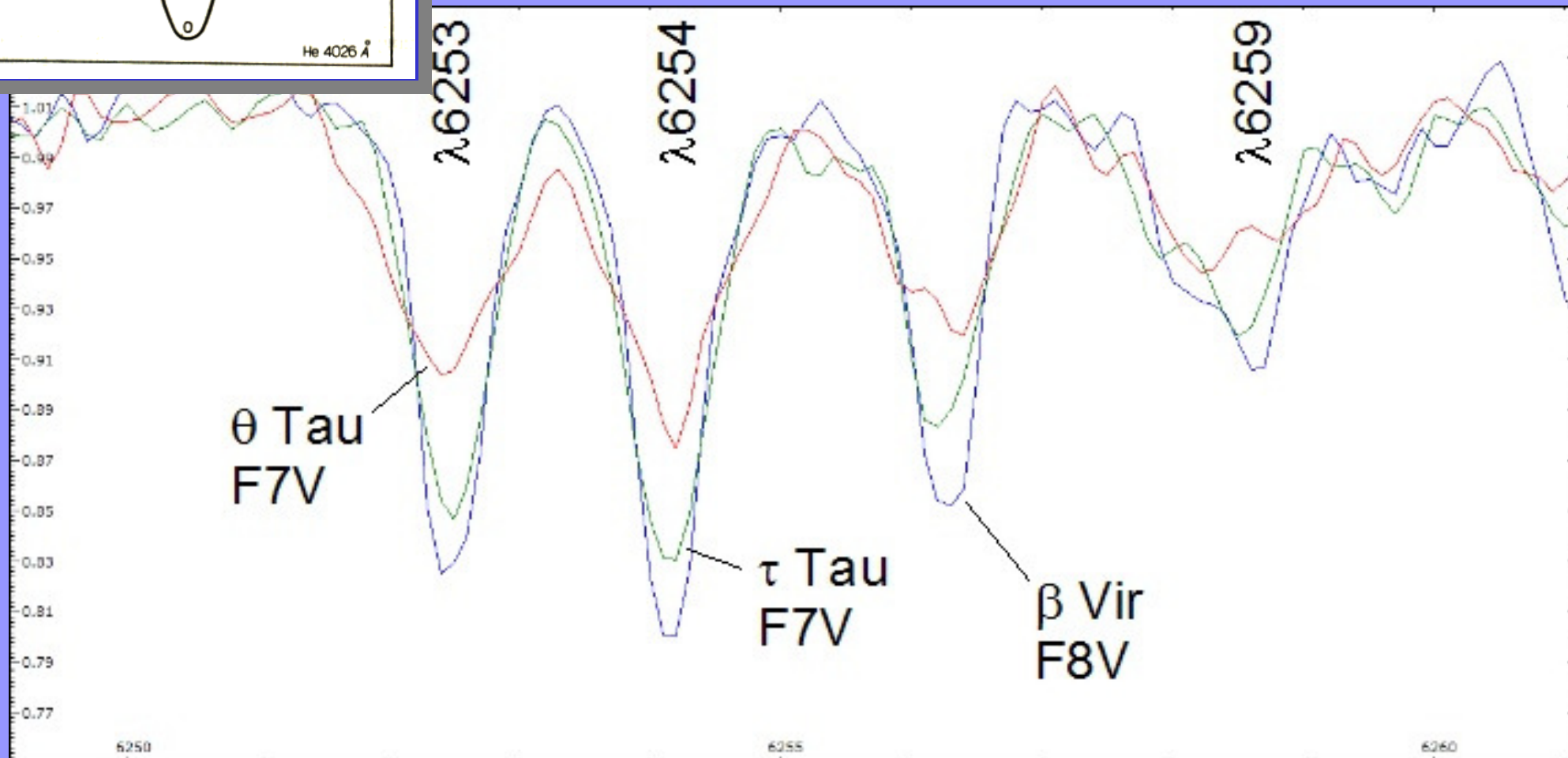
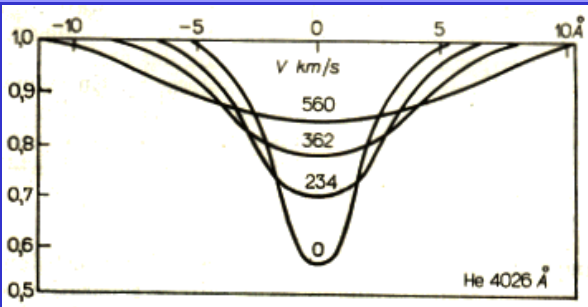
$$T^2 = \frac{(4\pi^2)}{(G(m_1 + m_2))} a^3$$

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

# Stellar Rotation: $v \cdot \sin(i)$



# Rotation stellaire : $v \cdot \sin(i)$

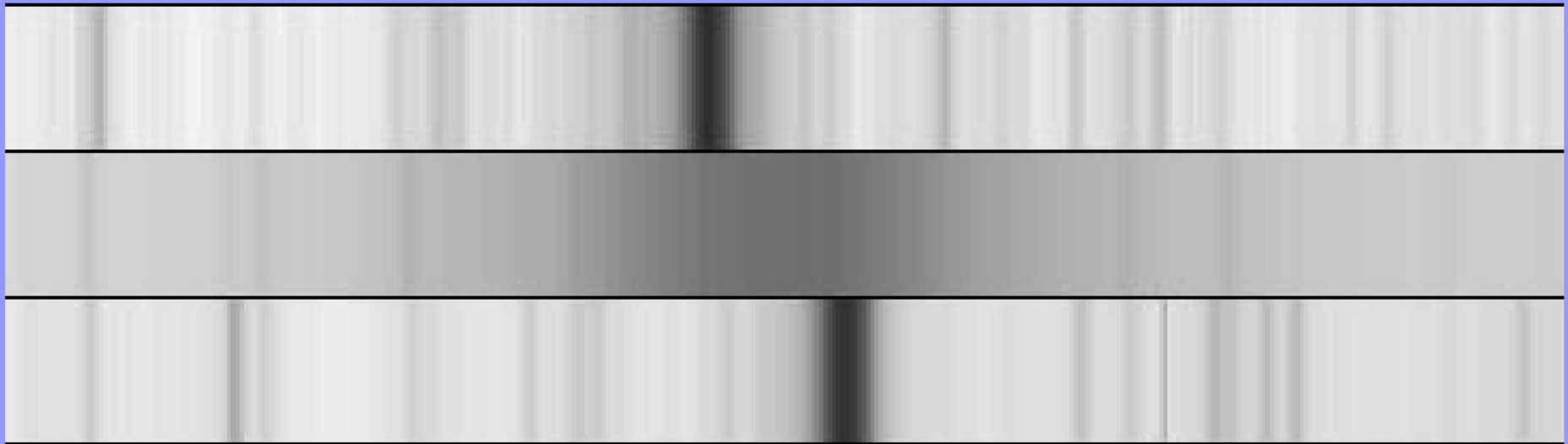


*Effet de la rotation sur l'élargissement de raies spectrale.  
eShel Shelyak Instruments echelle spectrograph ( $R \sim 11000$ ).  
T0.28m f/6.3; Observatoire de Haute Provence – 27 février 2009.  
Idée de D. Gray (observation and analysis of stellar photosphere).*

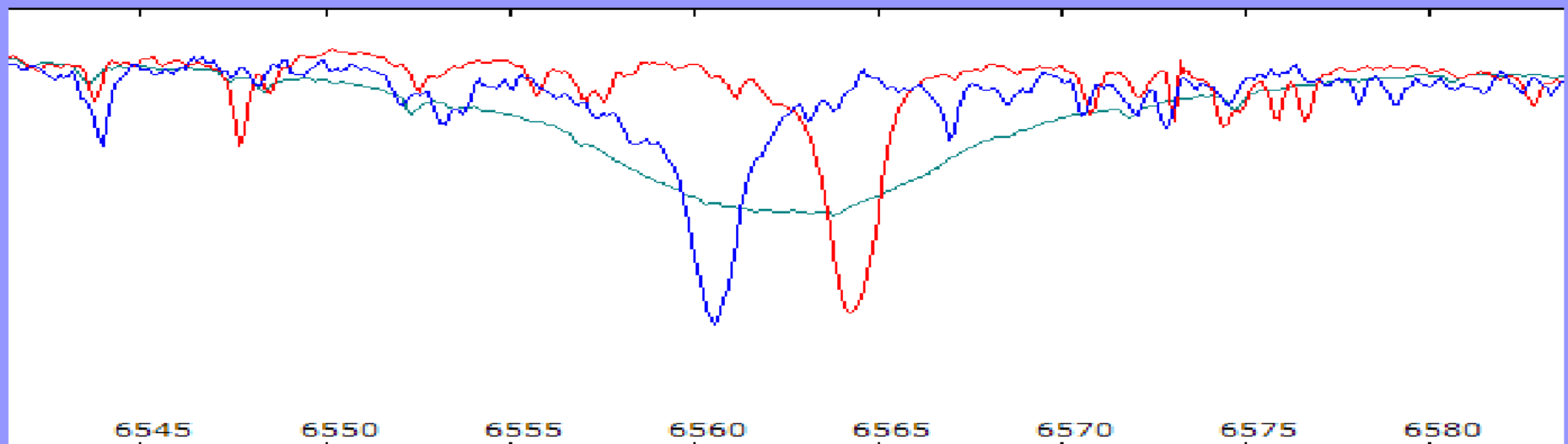


$$\frac{(\Delta\lambda)}{\lambda} = \frac{v}{c}$$

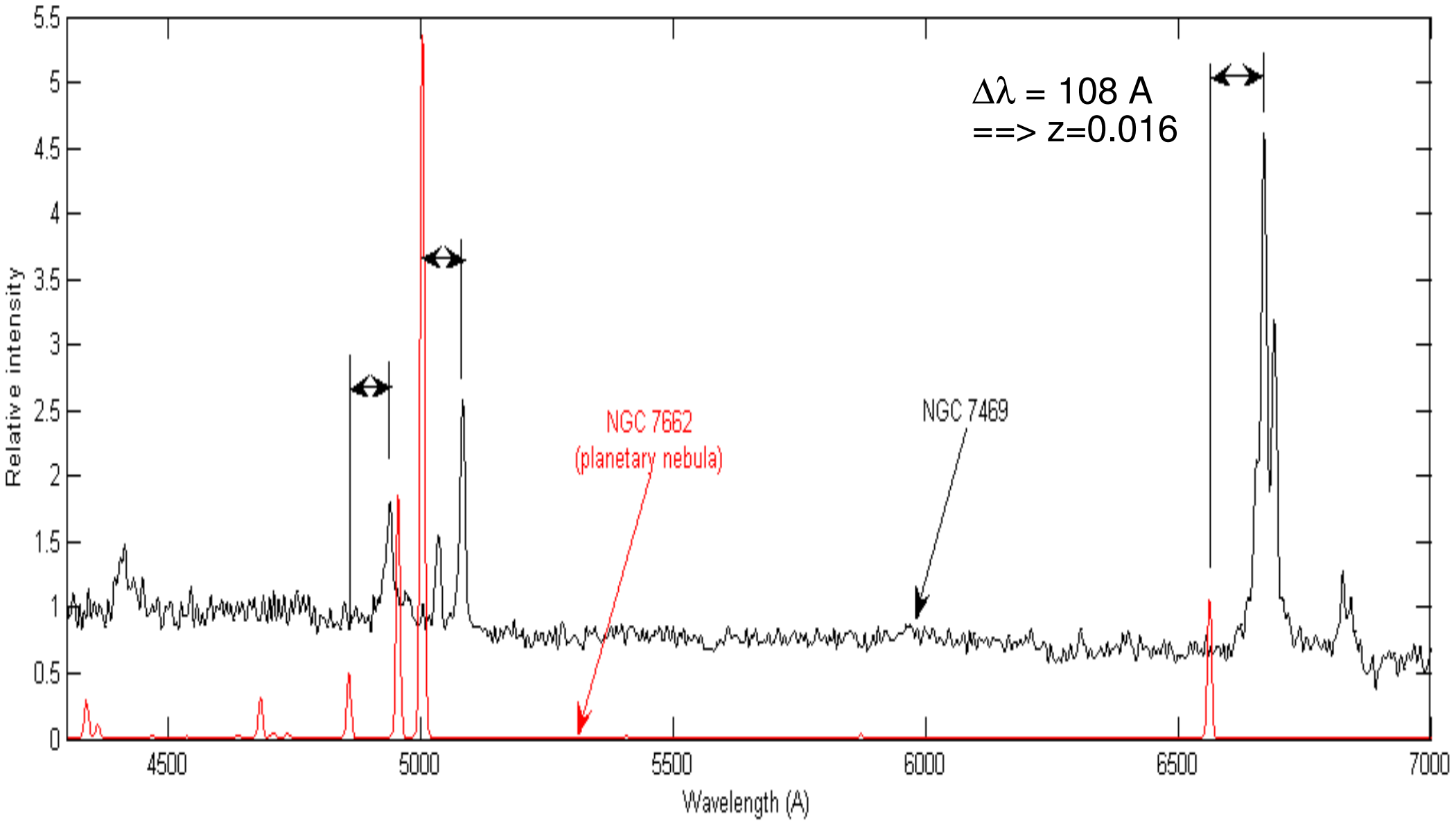
# Stellar Radial Velocities



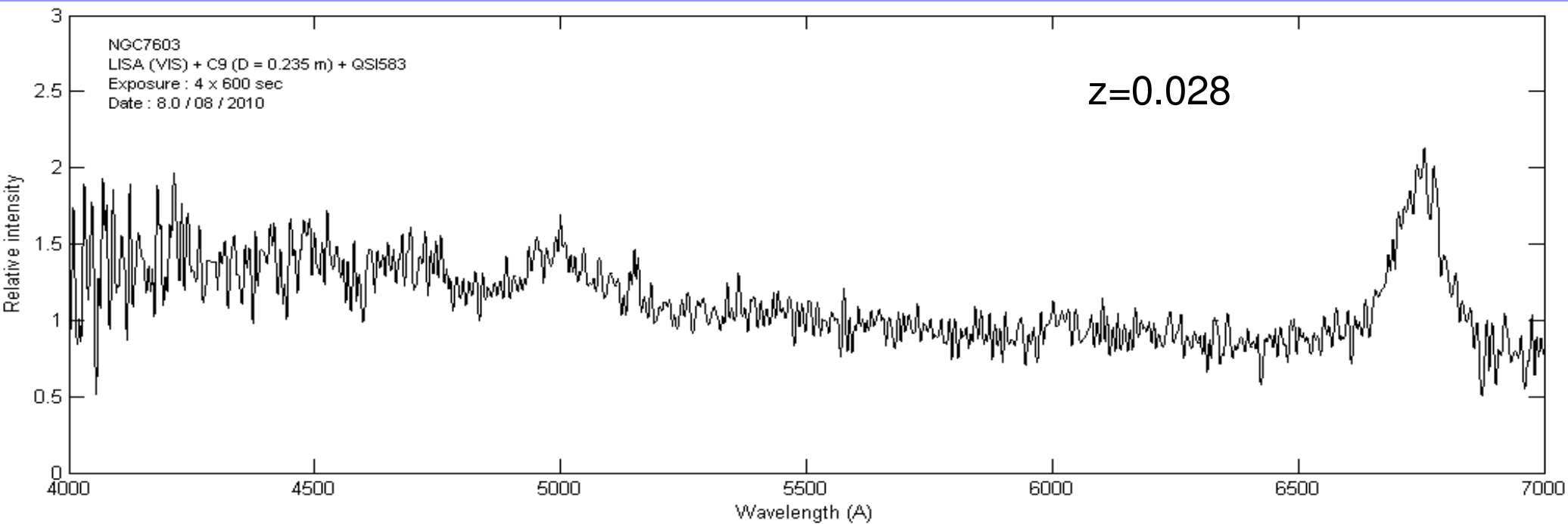
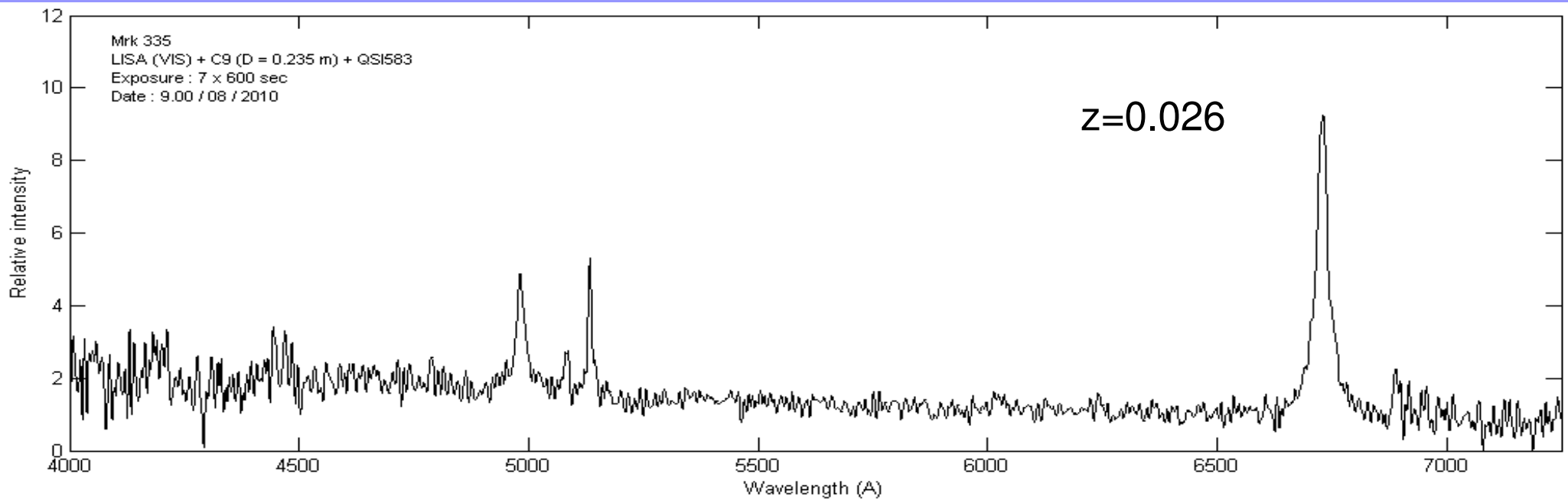
*SAO104807, Altair, & SAO112958*



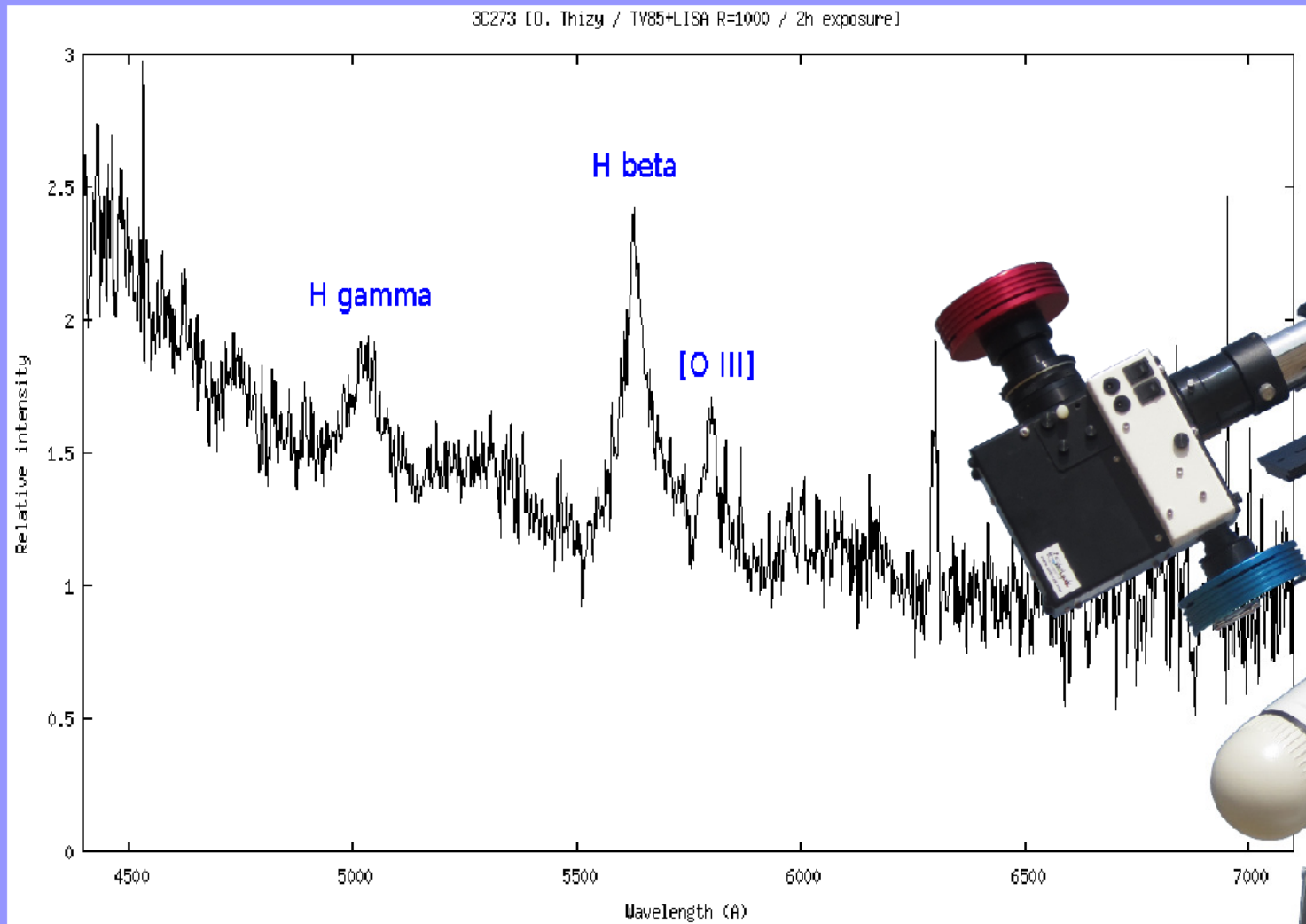
# Galaxies redshift



# Galaxies redshifts



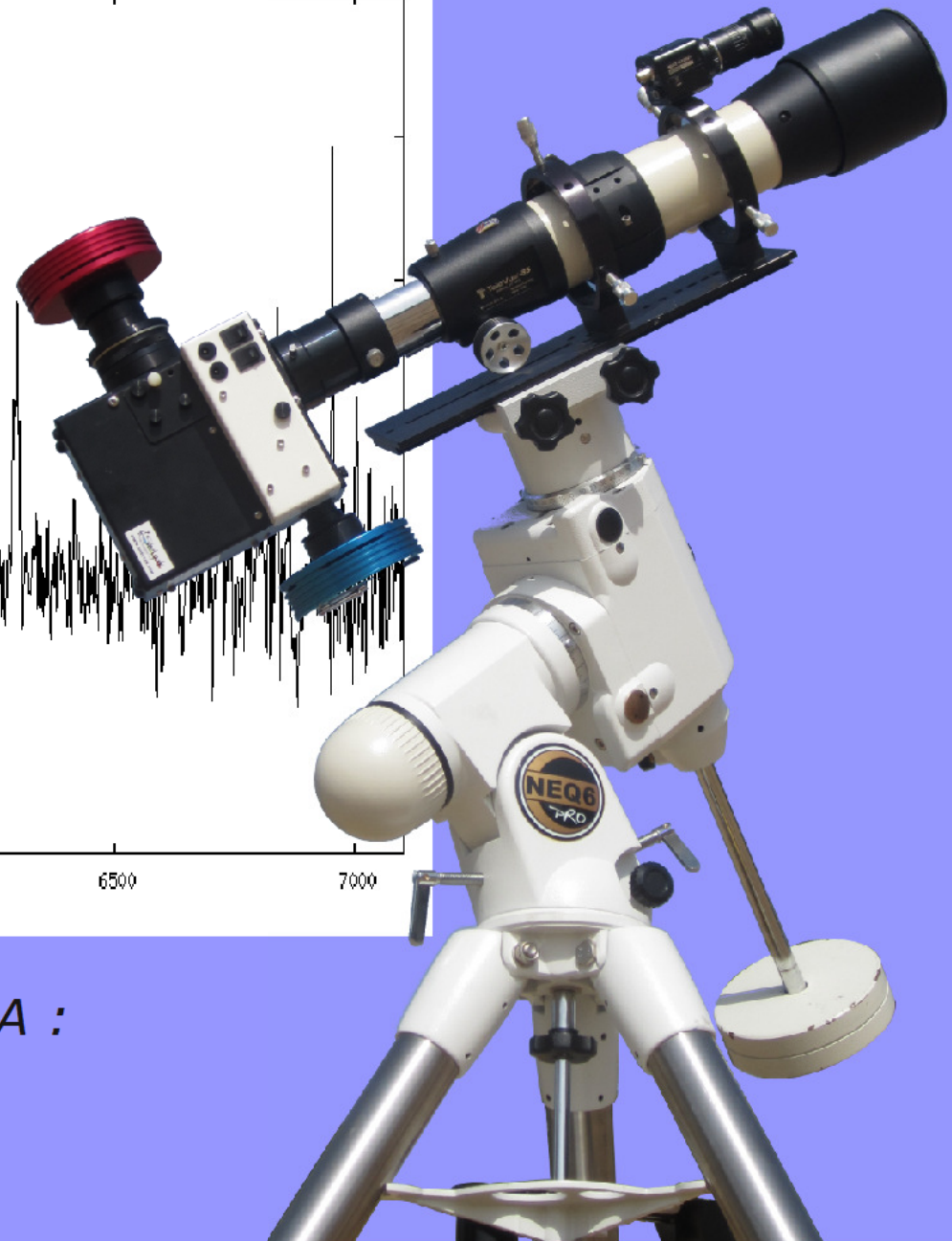
# 3C273 quasar



*Hbeta red-shifted from 4861Å to 5629Å :*

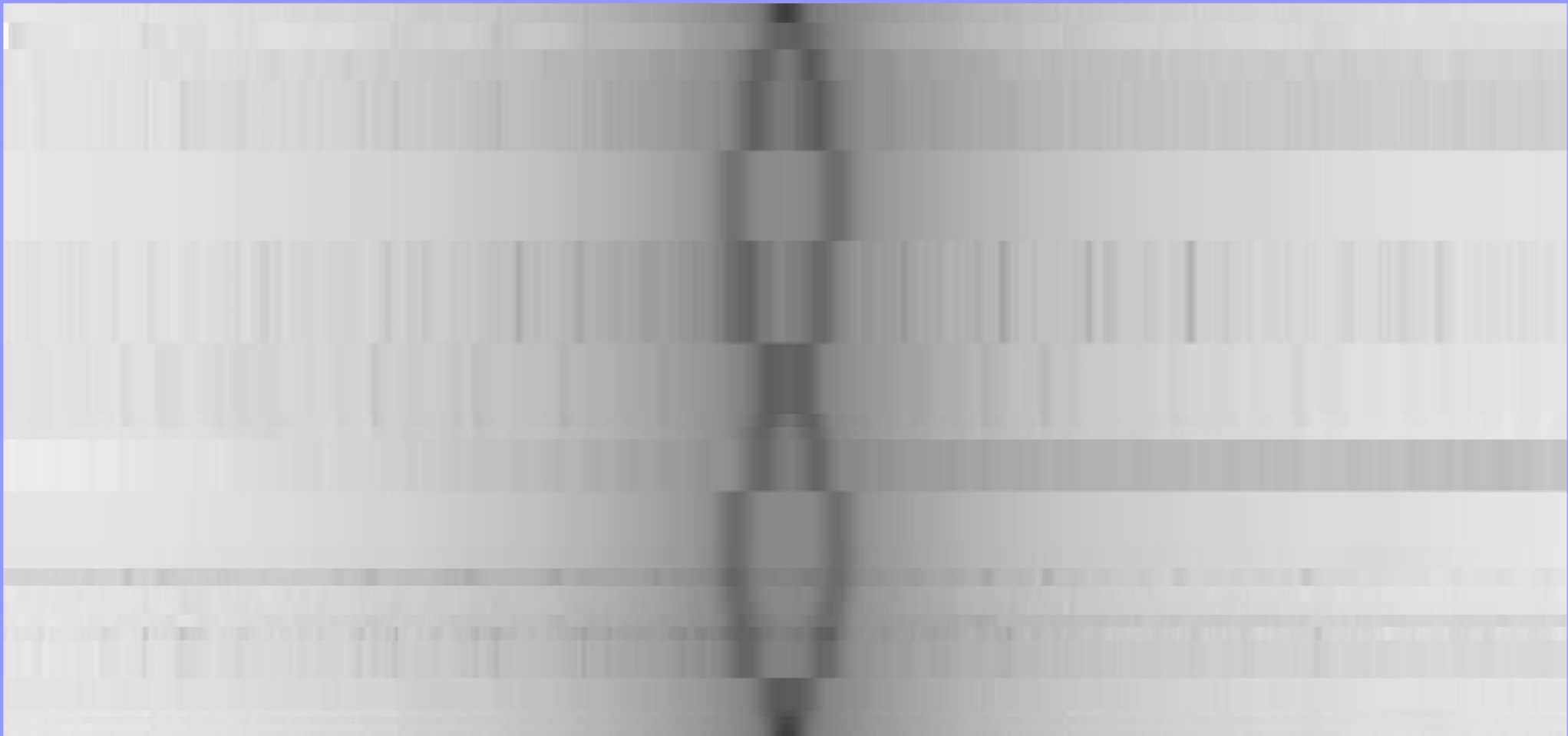
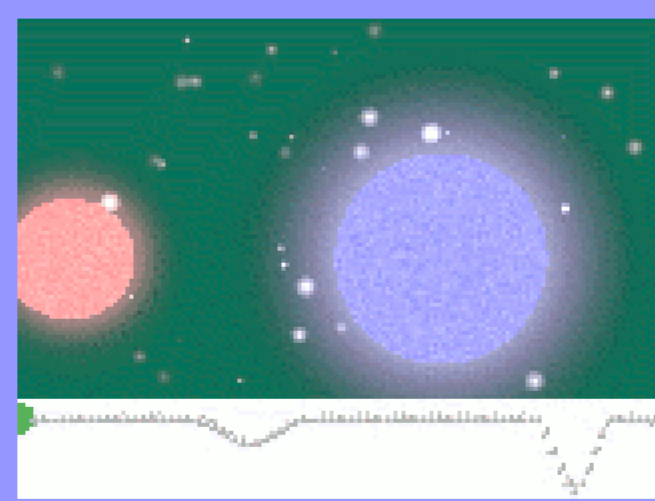
$$z = (5629.27/4861.32) - 1$$

$$z = 0.158$$

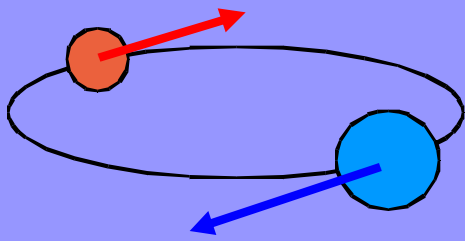




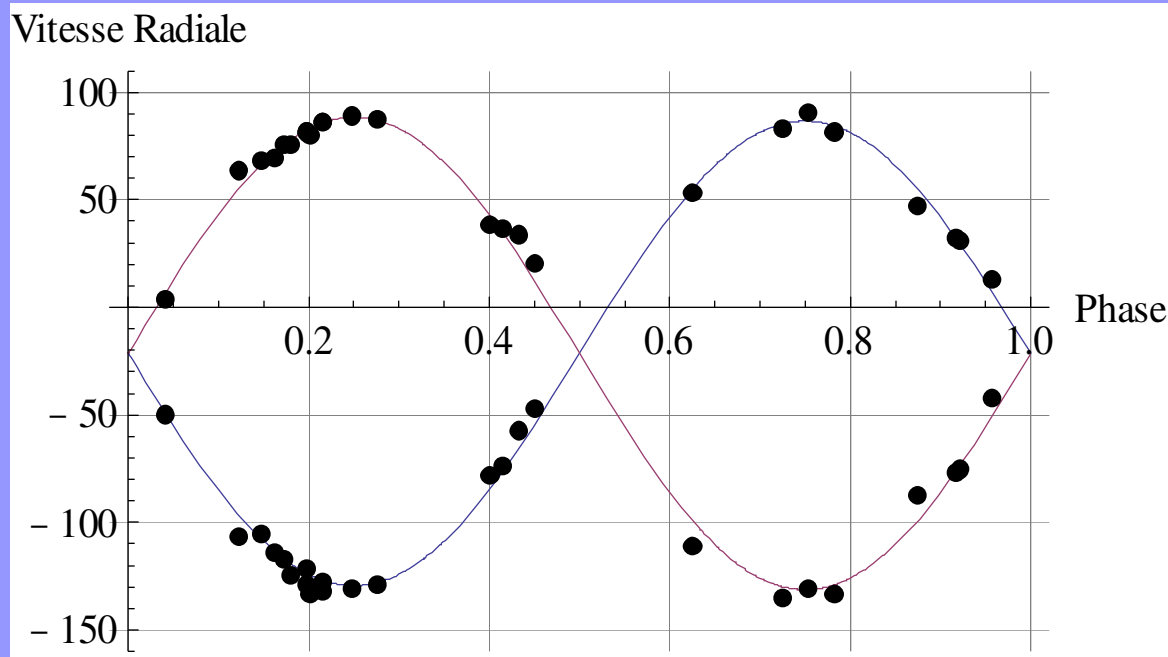
# Spectroscopic binaries



*Spectrogrammes de Beta Auriga (30 spectres sur 2006/2007) / O. Thizy et al.*



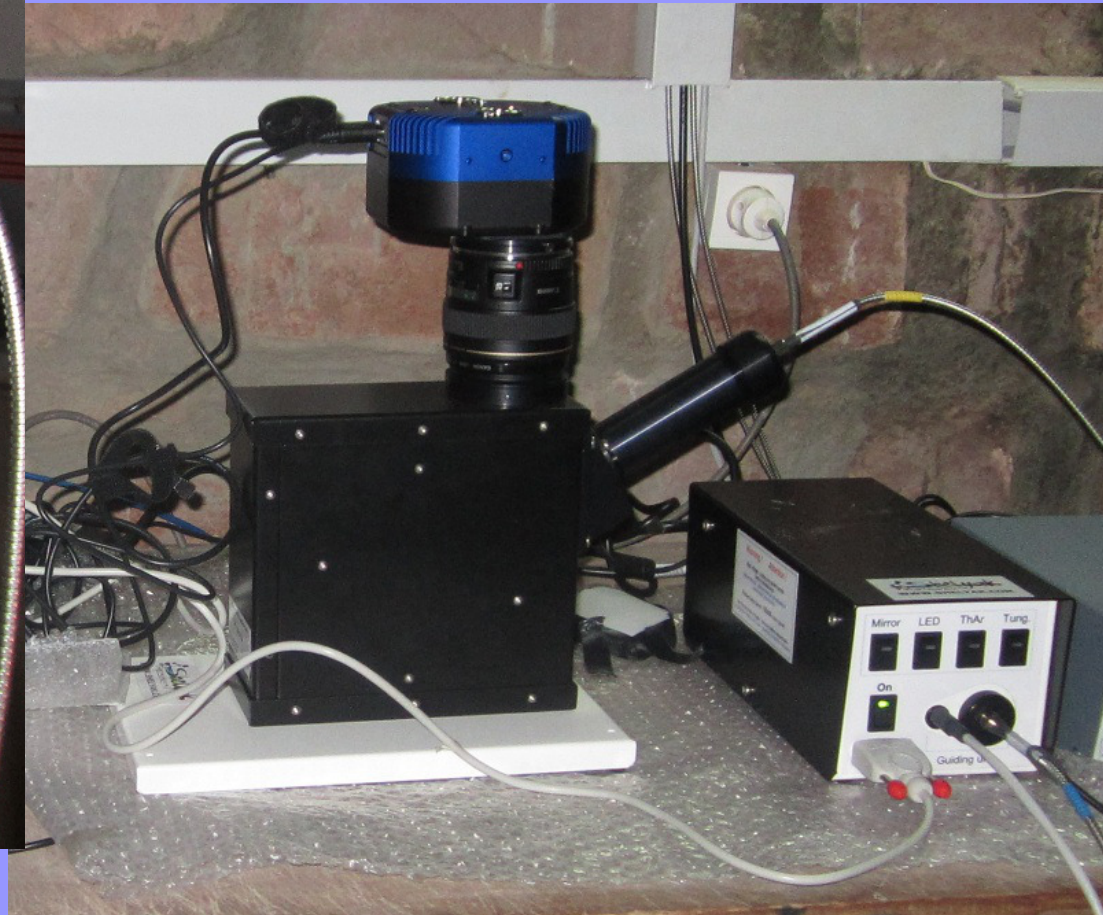
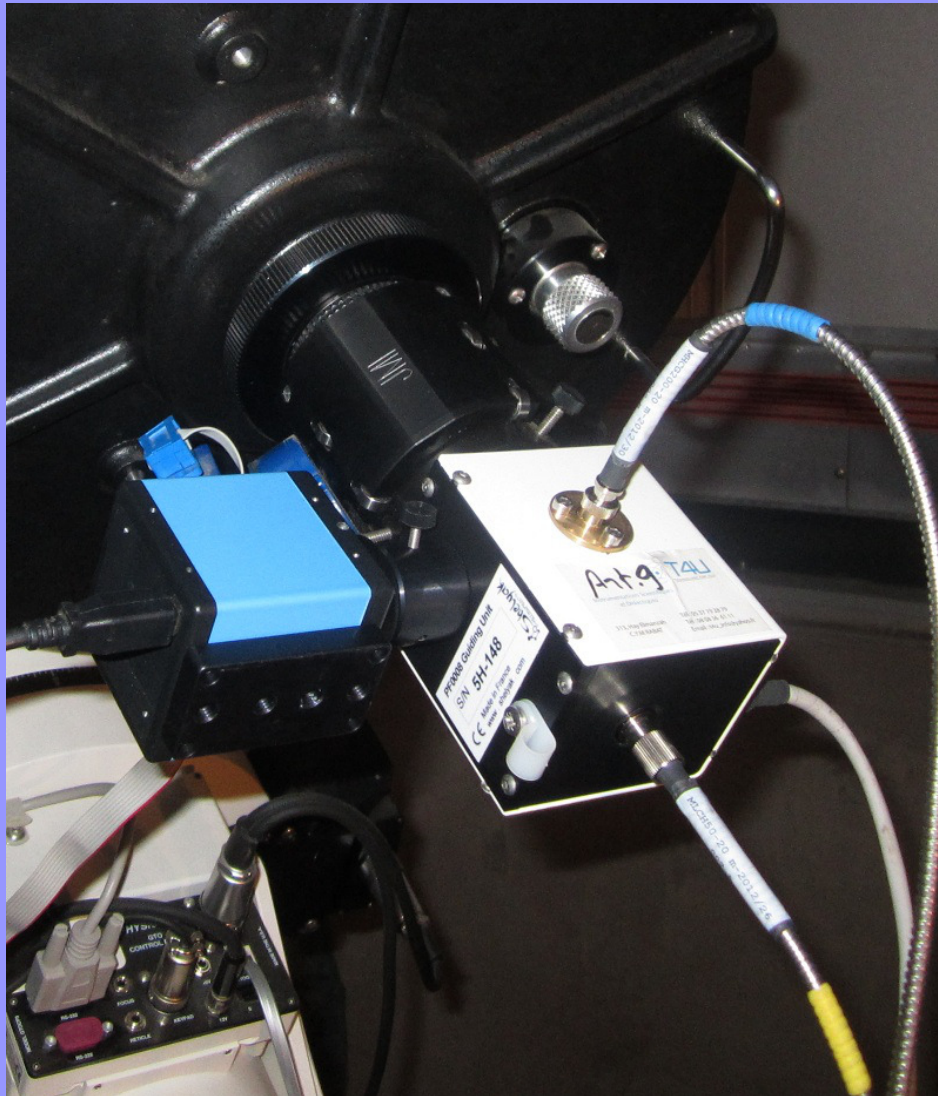
# Spectroscopic binaries

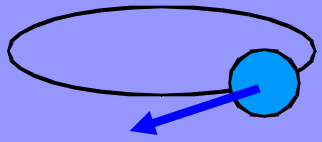


Paramètres orbitaux	Cette étude (VSpec)	Cette étude (PeakFit)	Nordström (1994)
$K_1$ (km.s <sup>-1</sup> )	106 ± 3	108 ± 3	107.75 ± 0.40
$K_2$ (km.s <sup>-1</sup> )	108 ± 3	110 ± 3	111.25 ± 0.40
$M_1/M_2$	0.98 ± 0.06	0.98 ± 0.06	0.97 ± 0.01
$V_\gamma$ (km.s <sup>-1</sup> )	-20 ± 2	-21 ± 2	-17.0 ± 0.4
$a.\sin(i)$ (R <sub>sol</sub> )	16.7 ± 0.5	17.1 ± 0.6	17.13 ± 0.04
$m_1.\sin^3(i)$ (M <sub>sol</sub> )	2.02 ± 0.06	2.15 ± 0.06	2.19 ± 0.02
$m_2.\sin^3(i)$ (M <sub>sol</sub> )	1.99 ± 0.06	2.11 ± 0.06	2.12 ± 0.02

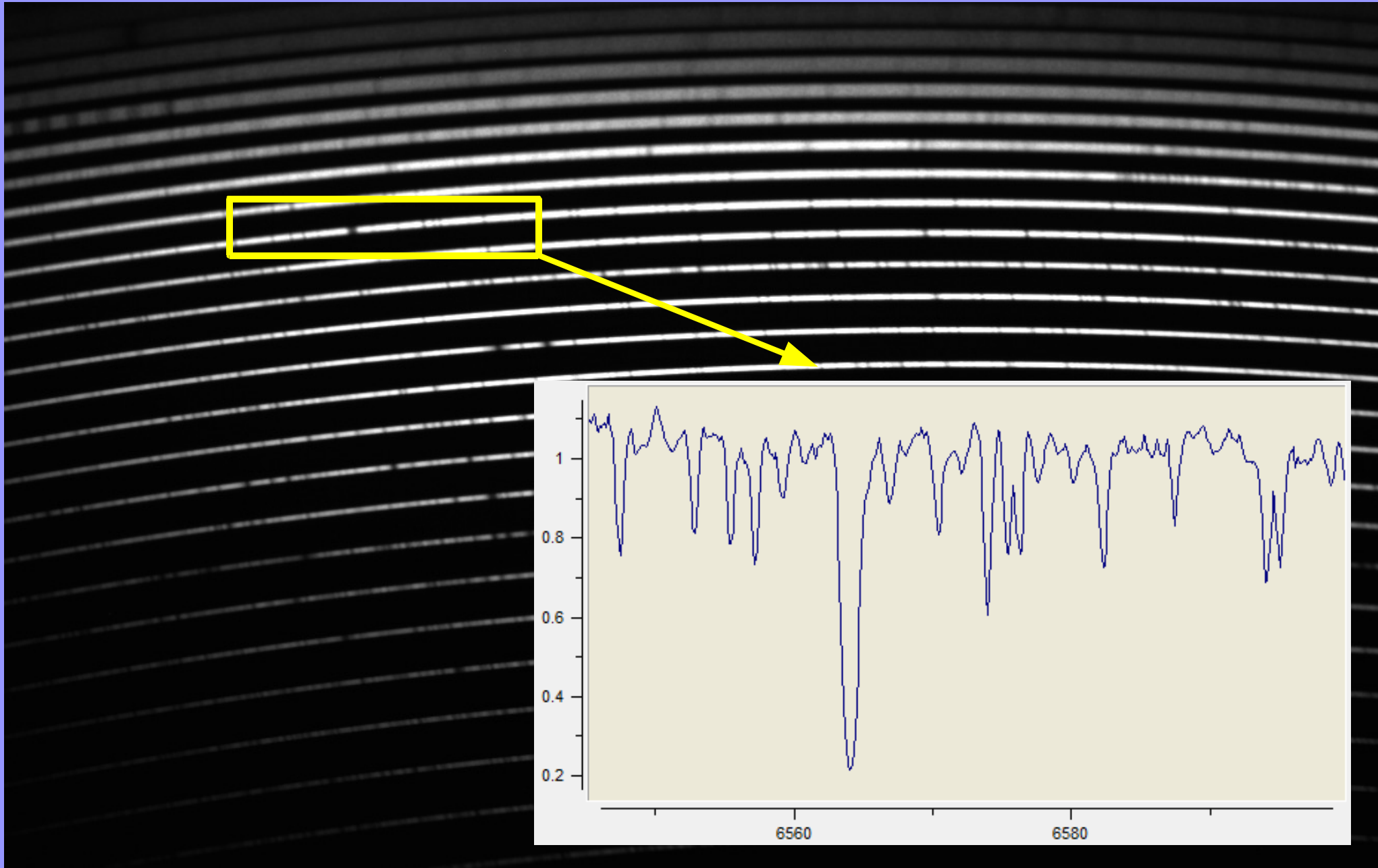


# eShel optical fiber fed spectrograph : a tool for Radial Velocities



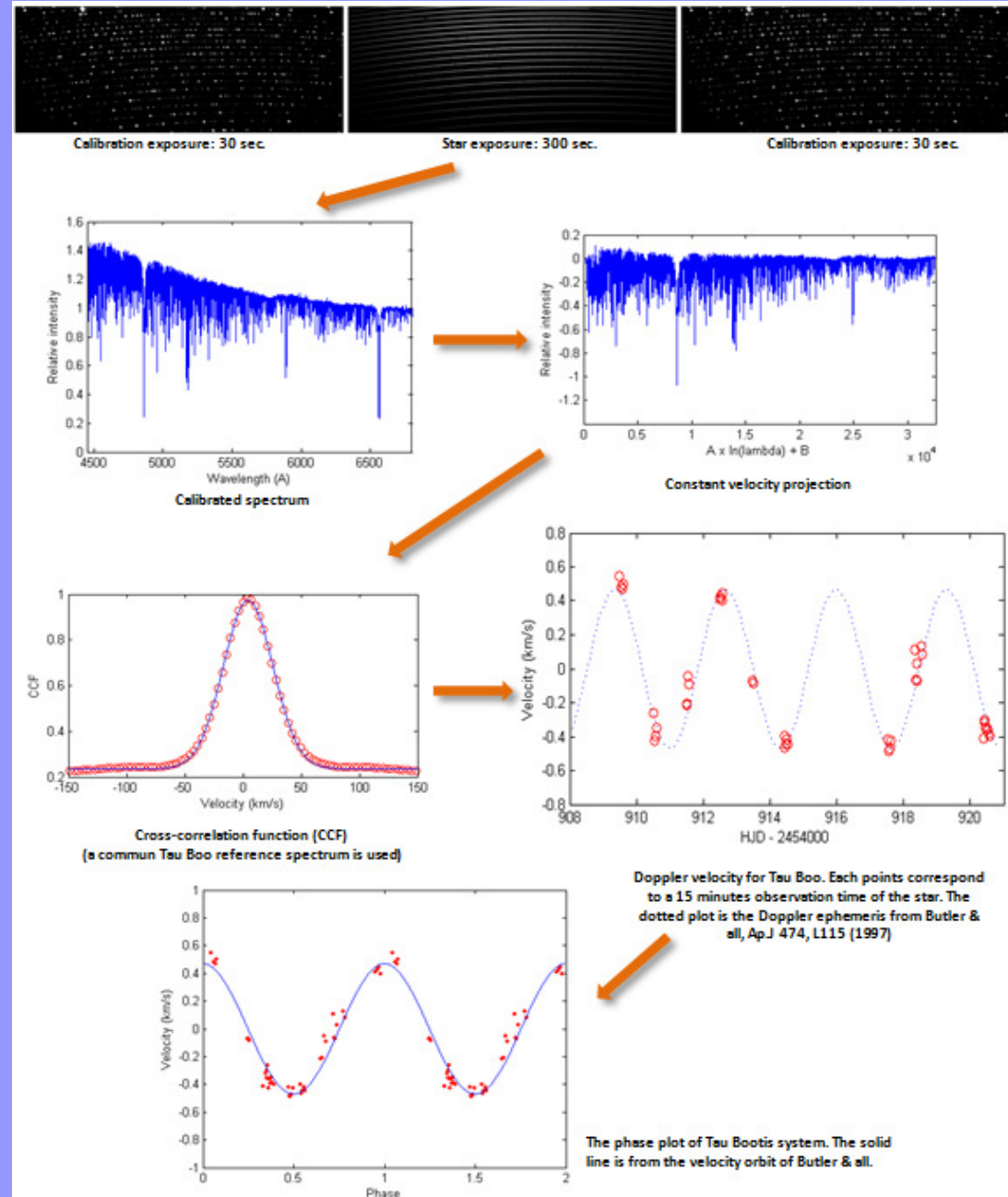
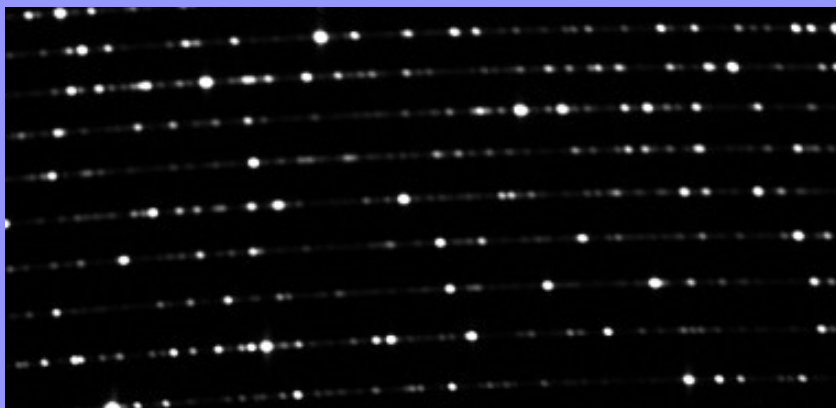
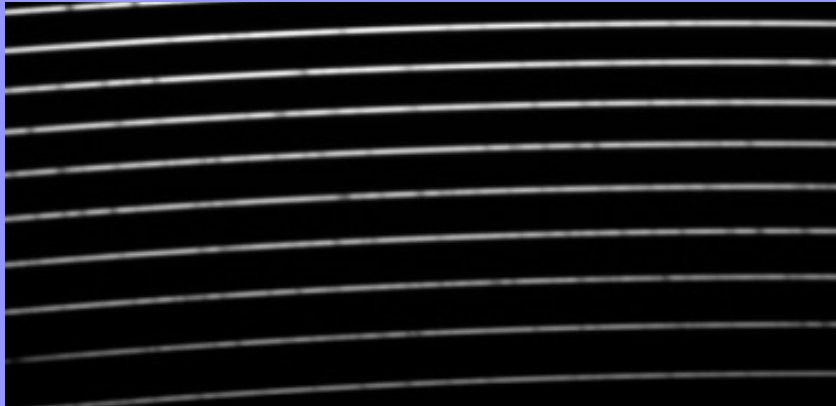
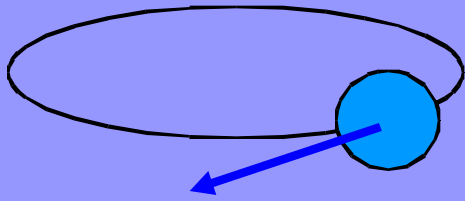


# Eshel spectrum of Aldebaran





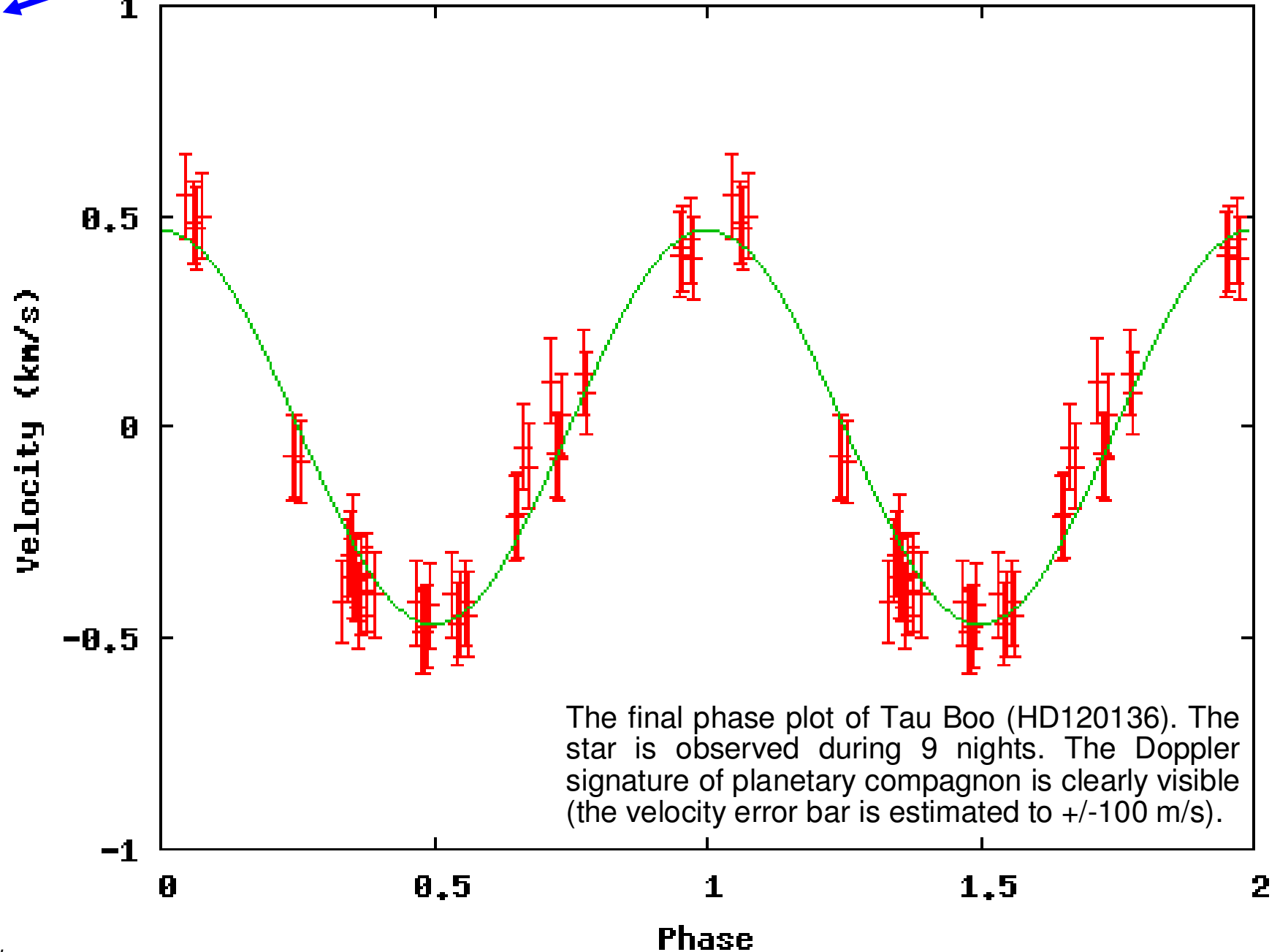
# Exoplanet: tau Boo



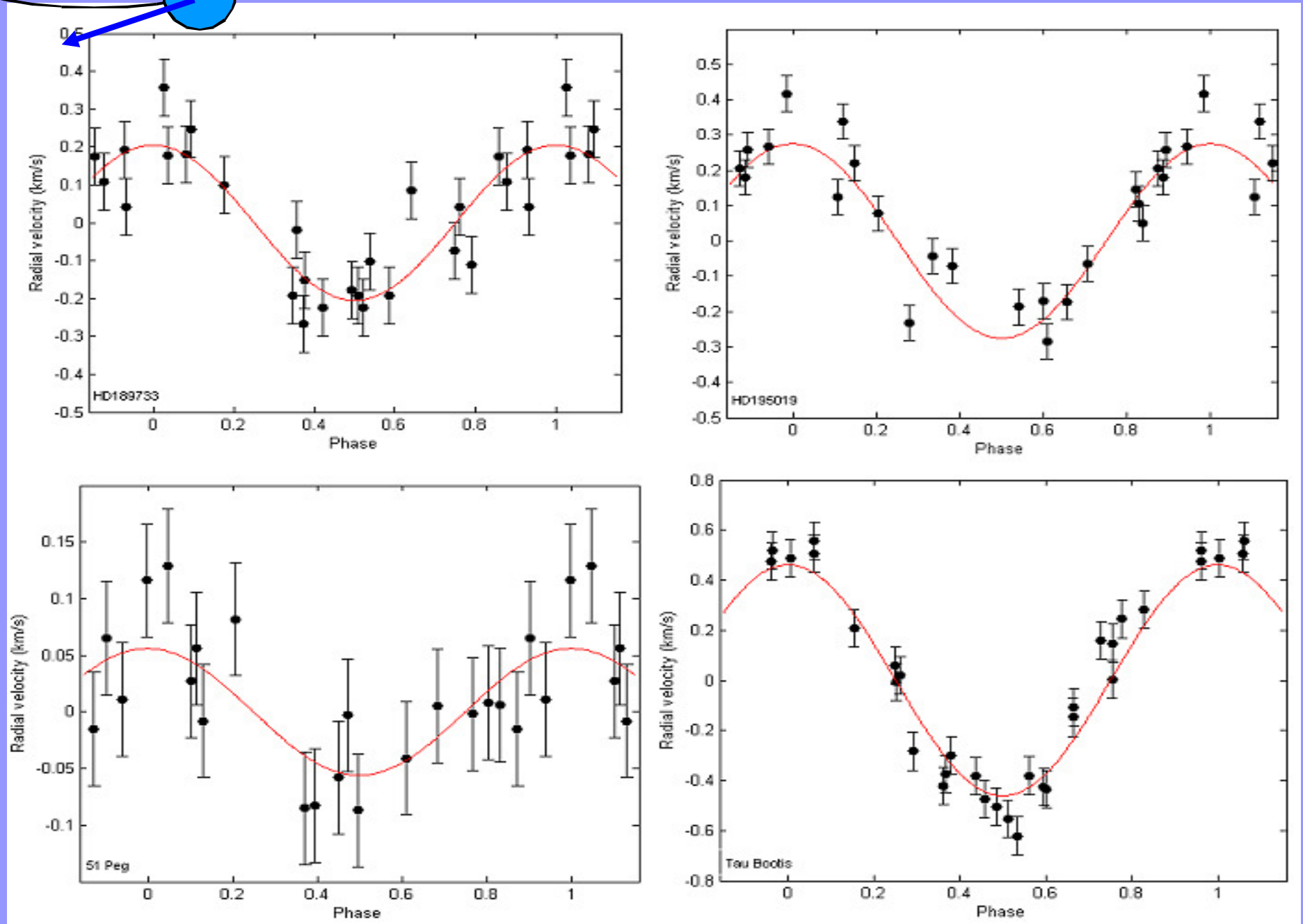
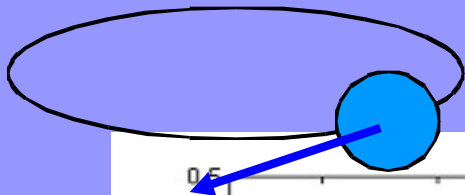
The CCF is computed by using the spectral range 4400-6445 Å (the H $\alpha$  line is excluded).

The total velocity Doppler spectral amplitude shift represents only 1/25th part of the spectrograph resolution. The data are collected between March 19-March 29, 2009.

# Exoplanet: tau Boo



# Exoplanets: 4 done so far



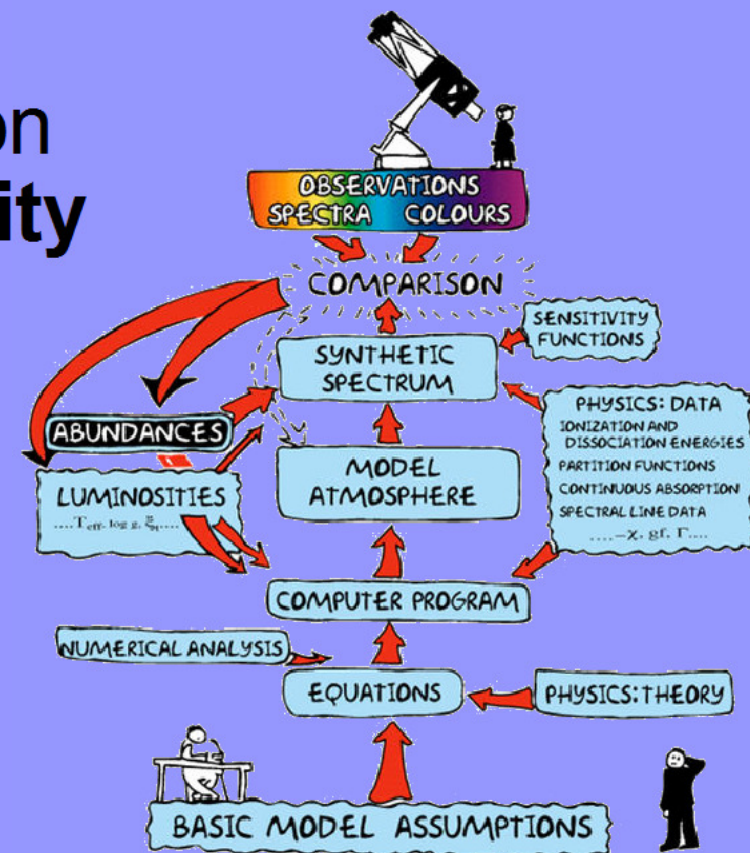
# Summary...

*Light from the stars provides information on :*

- their **temperature** [overall profile]
- their **composition** and **physical conditions** of excitation or ionisation (ie temperature) [visible lines]
- a quantitative chemical composition (**abundance**), **pressure** and **gravity** [intensity and line shape]

*But also on :*

- their **movements** [Doppler effect]
  - *radial velocity*
  - *rotation*
  - *expansion*

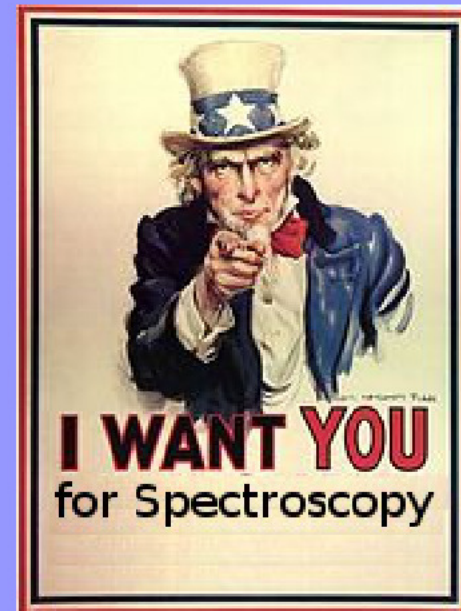




# Conclusion



- Spectroscopy a «scientific game»
- It's a booming area
  - *material is available off-the-shelf*
  - *software solutions are growing and getting simpler to use*
  - *tutorials & projects are available on the web*
  - *litterature will follow*
  - *community is active & helping*
- Become an *investigator of a night...*
- ...and join the *Pro/Am* community !



# Useful links



ARAS group

<http://www.astrosurf.com/aras/>

ARAS forum

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

Spectro-L discussion

<http://groups.yahoo.com/group/spectro-l/>

Shelyak Instruments

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







**Back-Up Slides**



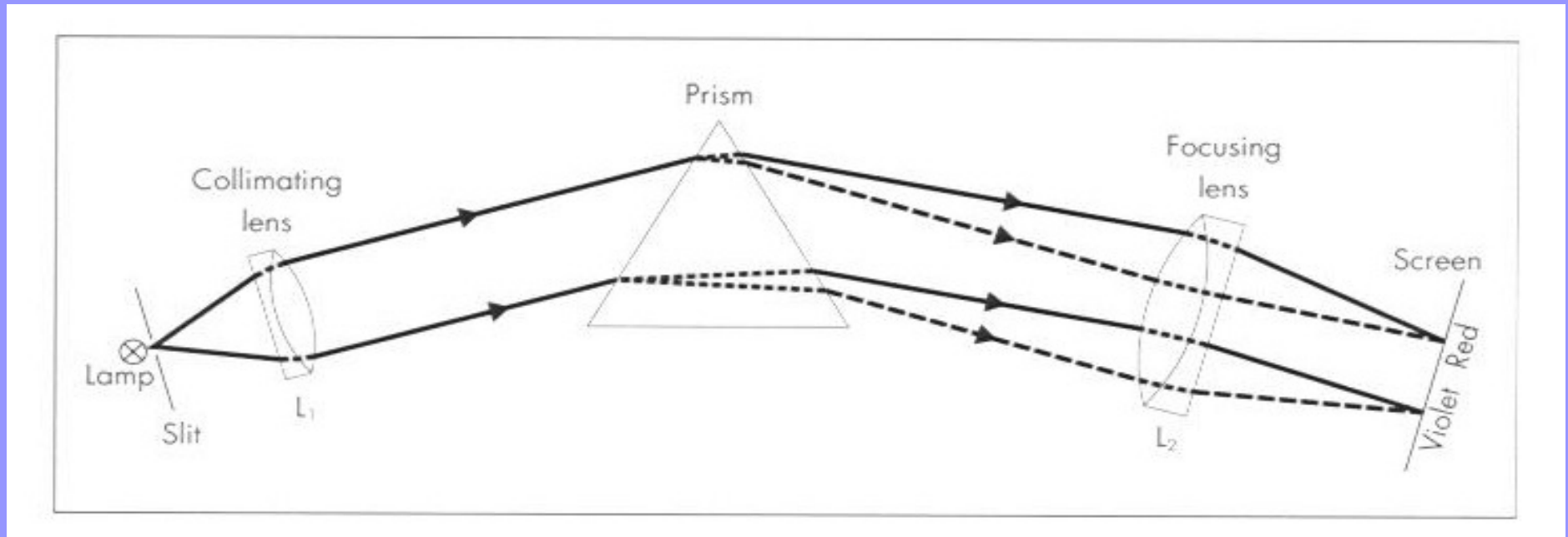


# Equipment



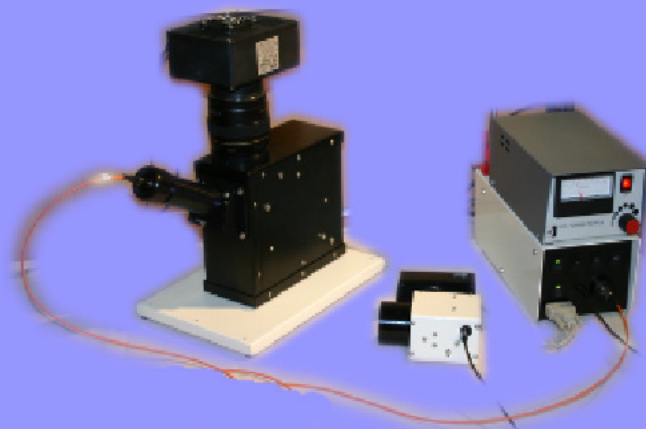


# How does a spectrograph works?

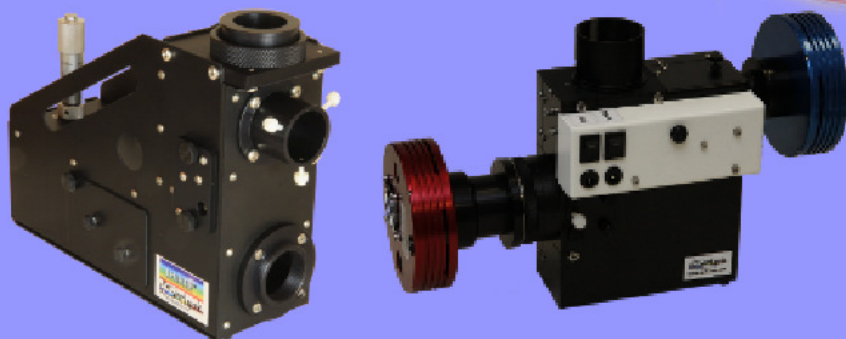


- › **Dispersion can be done by a prism or a grating**
- › **Slit is one key element for high resolution resolution**
- › **Littrow: collimator = objective**
- › **Professional astronomers also use 'echelle' spectrographs with cross dispersing**

# Equipment



**Professional:**  
eShel is an off-the-shelf optical fibre fed echelle spectrograph for higher RV accuracy and productive spectroscopy



**Study:**  
Lhires III (high resolution) and LISA Pack (high luminosity) are exploration tool allowing pro/am collaboration



**Alpy:**  
Our new modular instrument for educational and scientific (astronomical) spectroscopy



**Discover spectroscopy:**  
The Star Analyser is the simplest spectroscope, ideal to get started in this field with limited budget

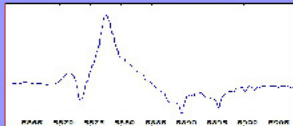


**Share your passion:**  
Handheld spectroscope and Lhires Lite visual spectroscope for public outreach

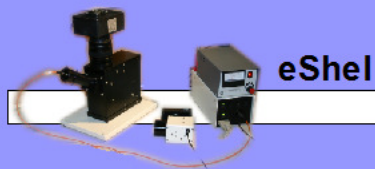
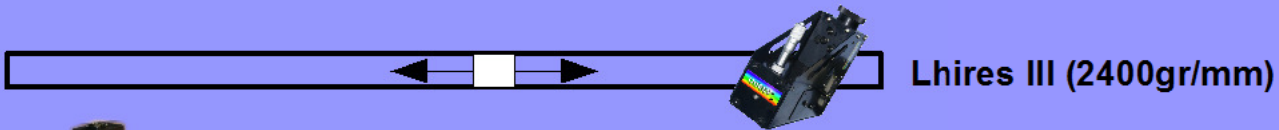
# Product overview

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

20000



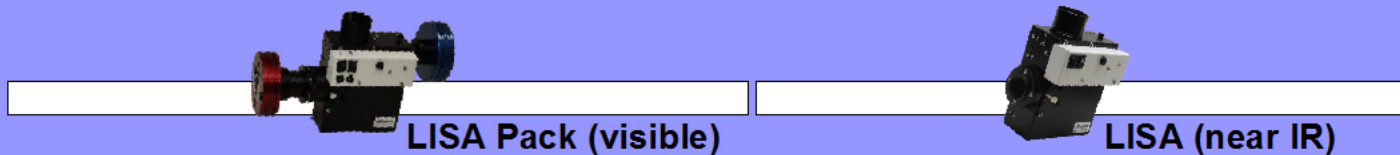
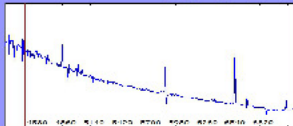
10000



eShel



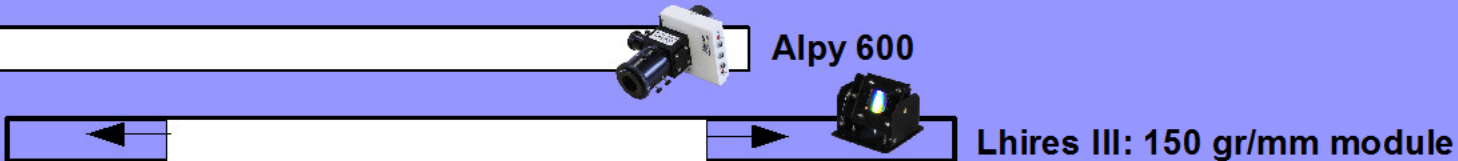
1000



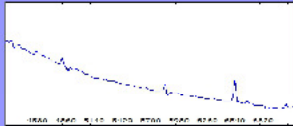
LISA Pack (visible)

LISA (near IR)

Alpy 600



100



Star Analyser


4000 5000 6000 7000 8000 9000 10000

Spectral Domain (nm)

# Take some good Resolutions !





	Spectral Domain	Resolving Power R	Resolution (500nm)	Slit	RV	Limit mag
<b>eShel</b> 	430-710nm	>10000	0.5 Å	50µm F/6	50 m/s	~10
<b>Lhires III</b> 	Visual (window of ~10nm)	~17000 with 2400 gr/mm grating	0.3 Å	15- 35µm F/10	~3 km/s	~10
<b>LISA</b> 	390nm- 1µm	600-1000	5 Å	15- 35µm F/5	n/a	~16
<b>Alpy 600</b> 	370-720nm	~600	10 Å	multiple slits	n/a	~15
<b>Star Analyser</b> 	Visual	~100	50 Å	No slit	n/a	~15

## Applications

### eShel



High level education  
Bright stars line profile (Be stars, pulsations...)  
Abundances, classification  
Spectroscopic binaries & exoplanets

### Lhires III



(self) education with low / medium / high resolution modes  
Stellar classification  
Bright stars line profile (Be stars, eps Aur, Wolf-Rayet, Slow Pulsating B stars, Herbig Ae/Be...)

### LISA



Education: lamp, classification, nebulae, galaxie redshift...  
Faint variable stars: cataclysmics, novae, mira...  
Comets classification  
Asteroids classification  
...

### Alpy 600



Step by step educational spectroscopy on bench : lamps, Sun...  
Planet composition, nebulae, galaxie redshift...  
Faint variable stars: cataclysmics, novae, mira...  
Comets classification  
...

### Star Analyser



Education: star temperature & classification  
Novae  
Faint variable stars  
Supernovae





# Some steps back...



# Oleron 2003

## ➤ The situation

- Very few pro/am collaboration (but some, see **Buil Be star atlas**), done with custom designed spectrograph.

## ➤ Oleron 2003

- **AUDE/CNRS pro/am official school**
- **Proceedings book to be published soon**
- **Kick off for Lhires III design**
- **Kick off Spectro-L list**
- **Kick off ARAS website front-end**





# La Rochelle: 2006

- **Be Stars Spectra (BeSS) database kick off**
  - **Structuring spectra collection & archiving**
  - **Defining a spectra file format (FITS based)**
- **Workshop on Lhires III (AUDE first kits just received !)**



# La Rochelle: 2009

- **10000 amateur spectra in BeSS...**
- **Exoplanet newly observed: pushing the limits...**
- **Dozen of active amateur spectroscopists...**
  
- **==> More professional astronomers looking for help and support from amateurs !**





# OHP practical workshops

- **2004, 2005, 2007, 2008, 2009, 2010: a growing interest ! International attendance.**
- **30-40 instruments, all with spectrographs !**
- **Different style**
  - **workshop Vs talks, need for some theory**
  - **structured project Vs autonomous groups**
  - **courses Vs star party**
- **... the optimal format is hard to find !**



# OHP ambiance...



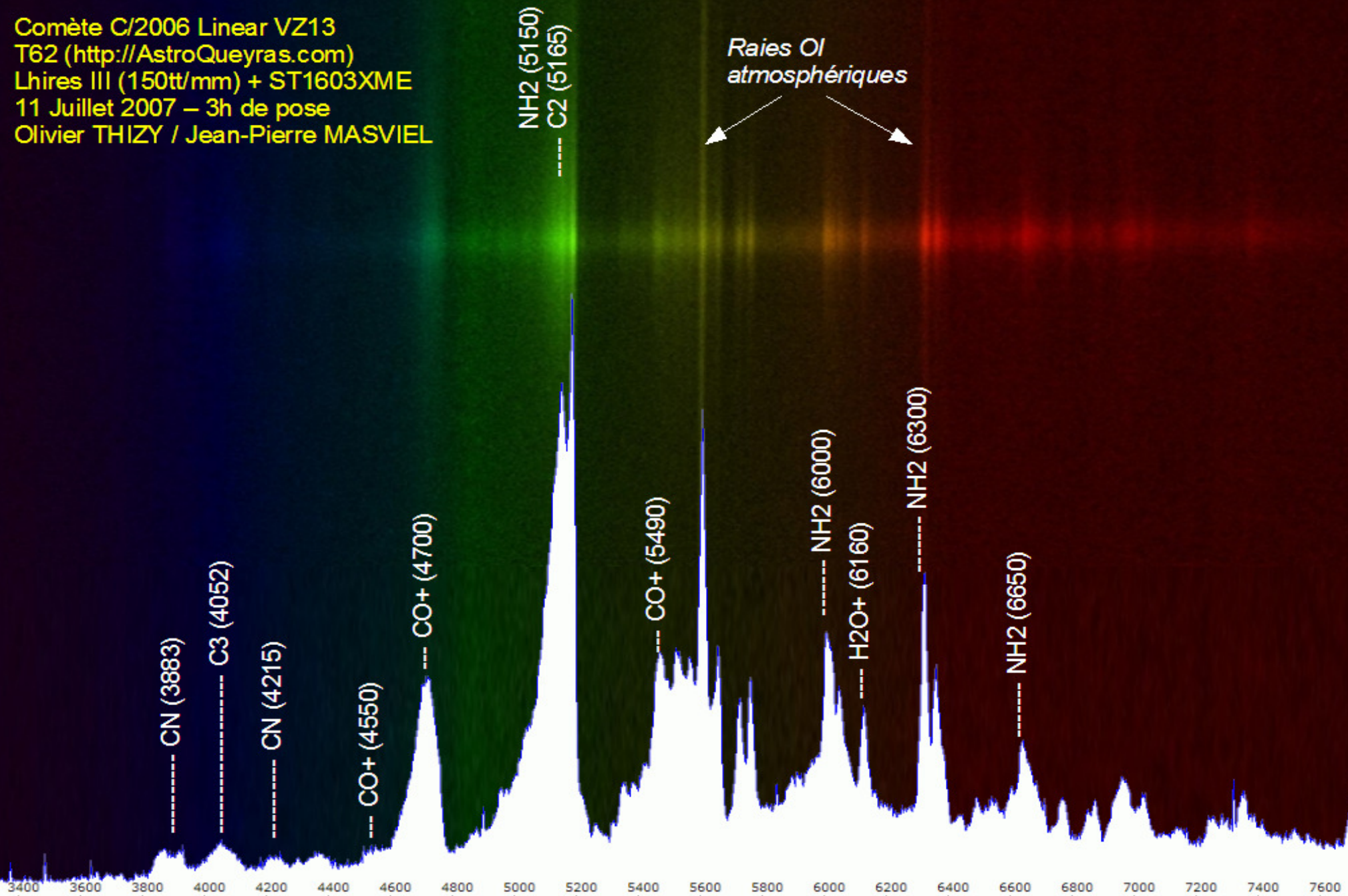


# Pro/Am projects

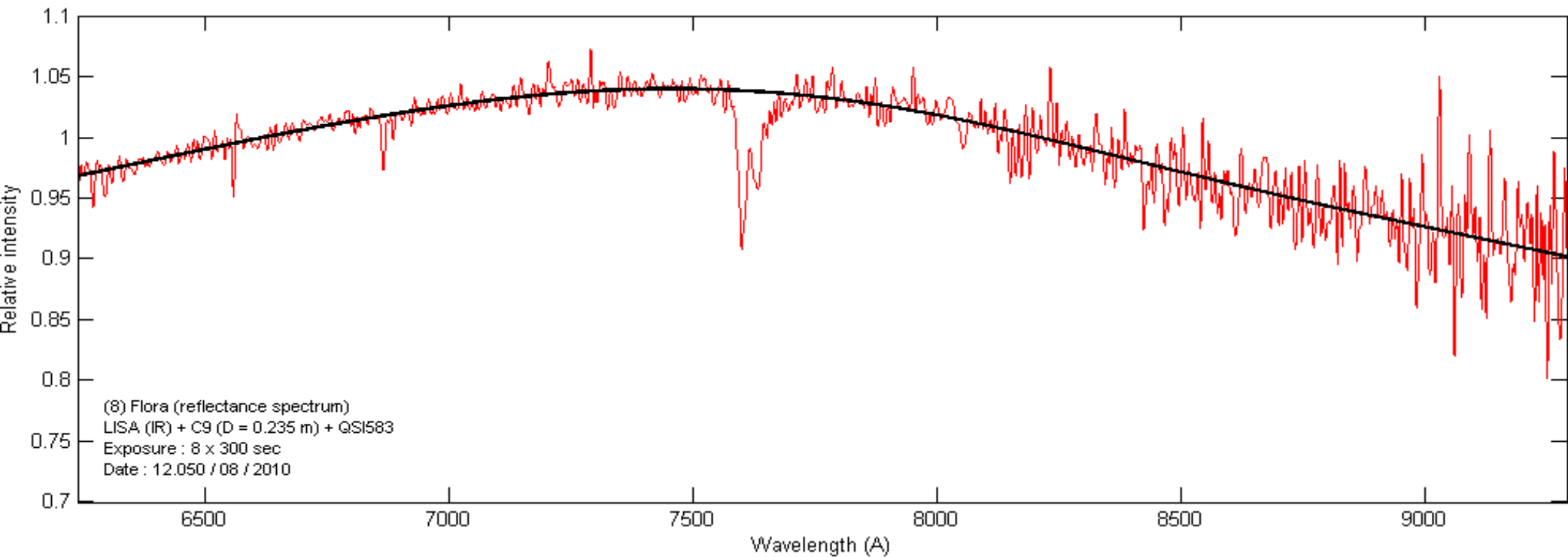
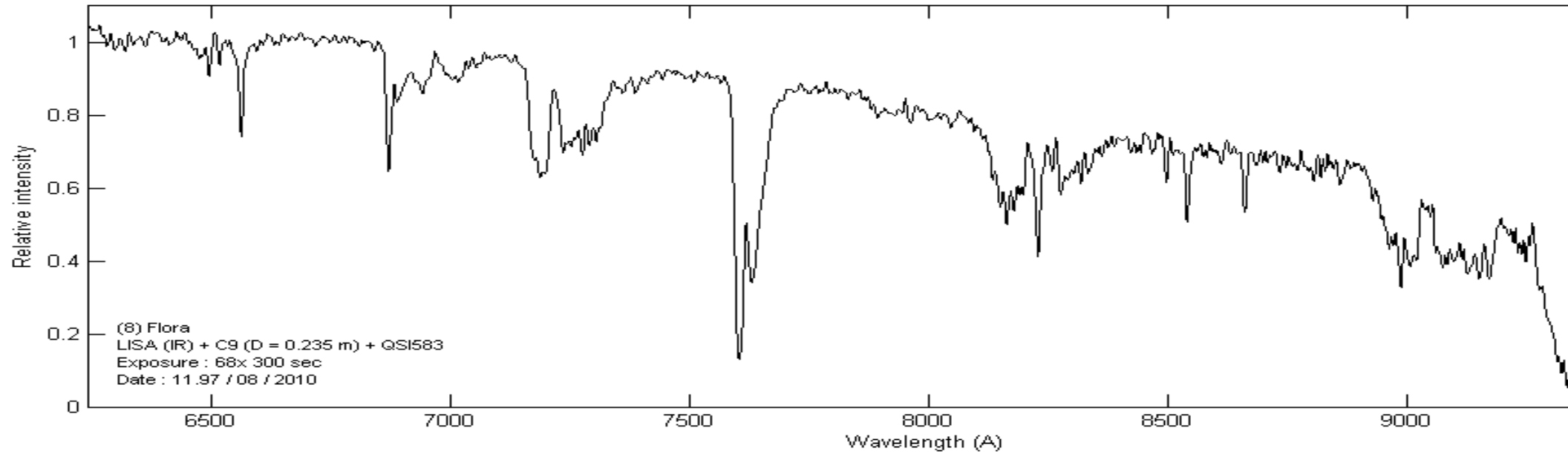


# Comets

Comète C/2006 Linear VZ13  
T62 (<http://AstroQueyras.com>)  
Lhires III (150tt/mm) + ST1603XME  
11 Juillet 2007 – 3h de pose  
Olivier THIZY / Jean-Pierre MASVIEL

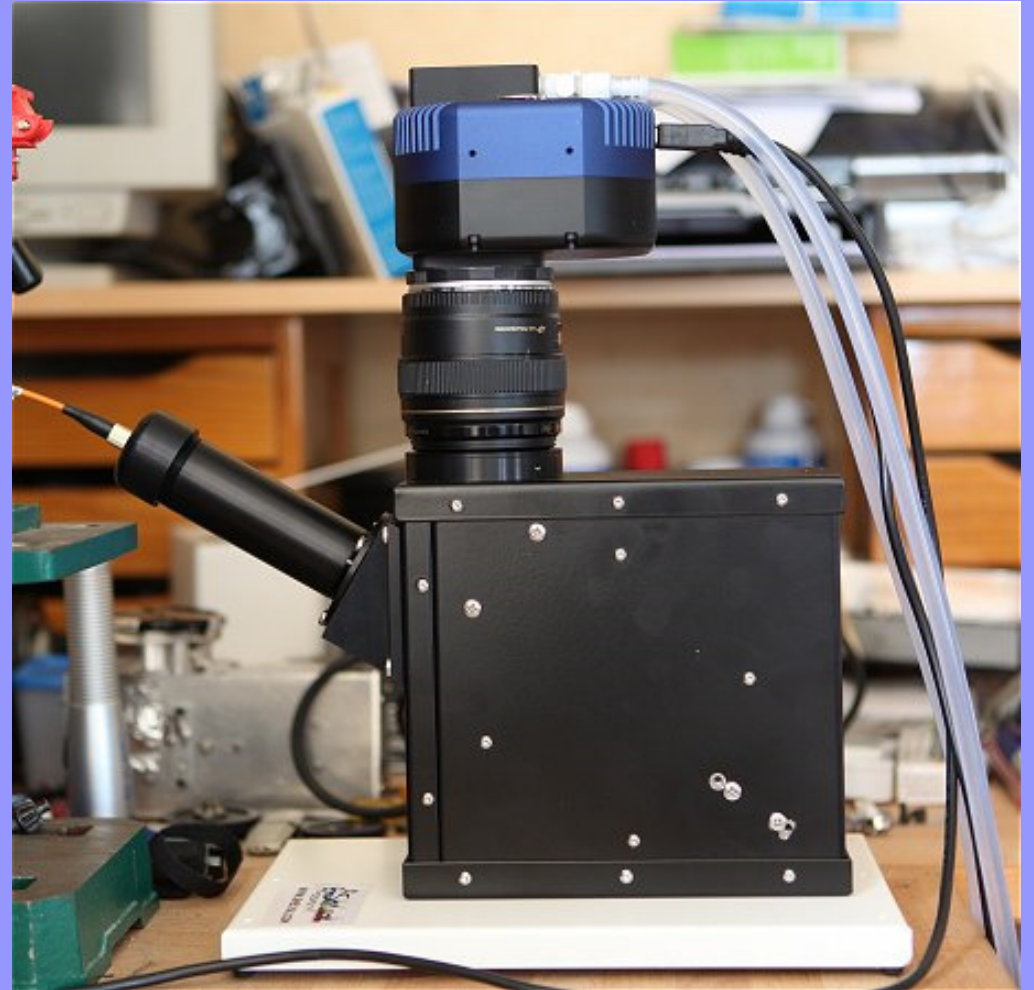
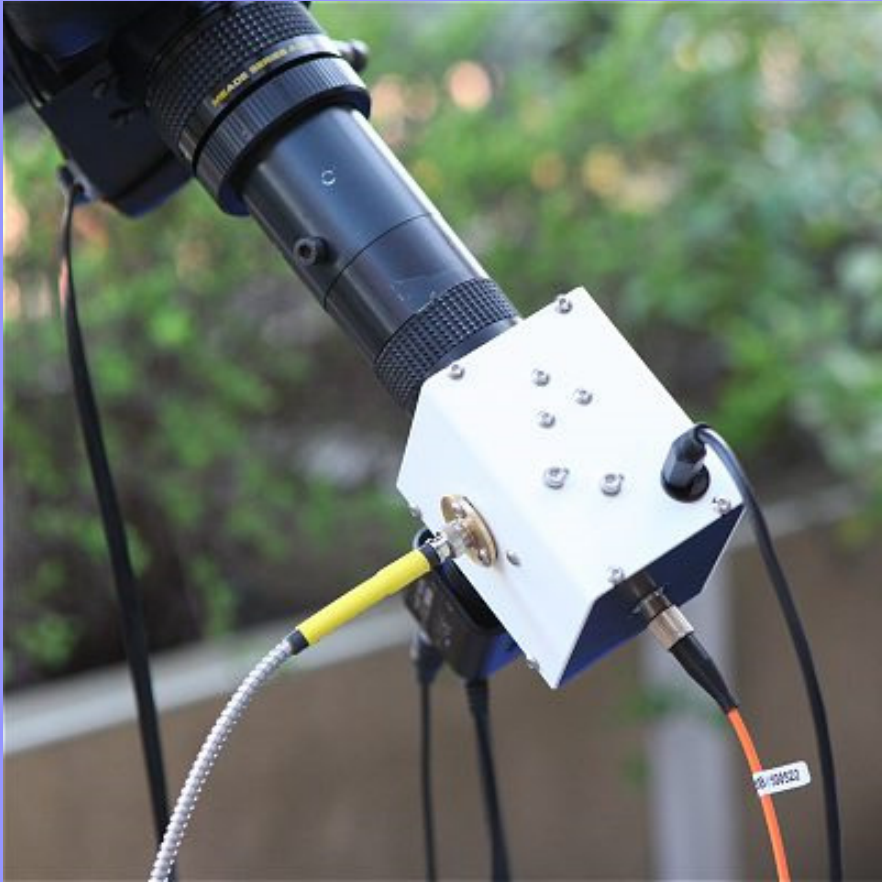
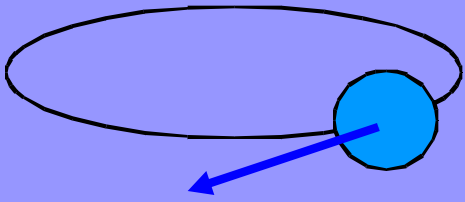


# Asteroids classification



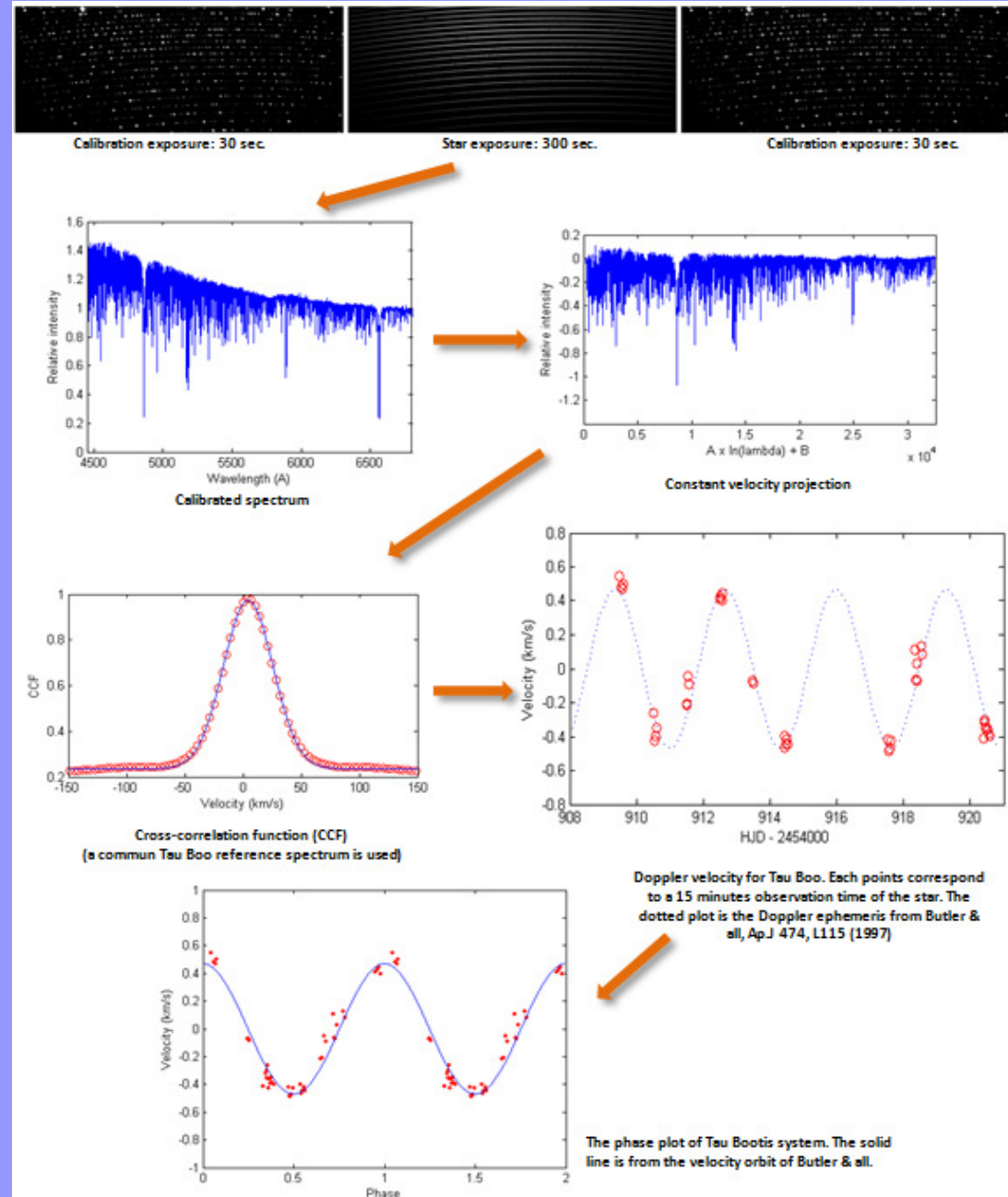
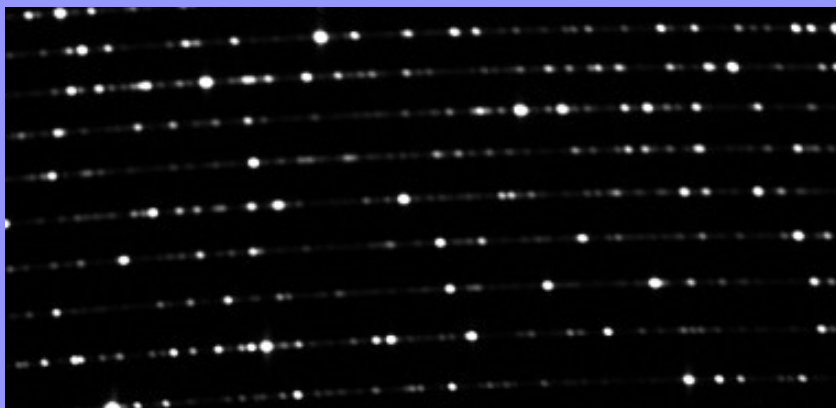
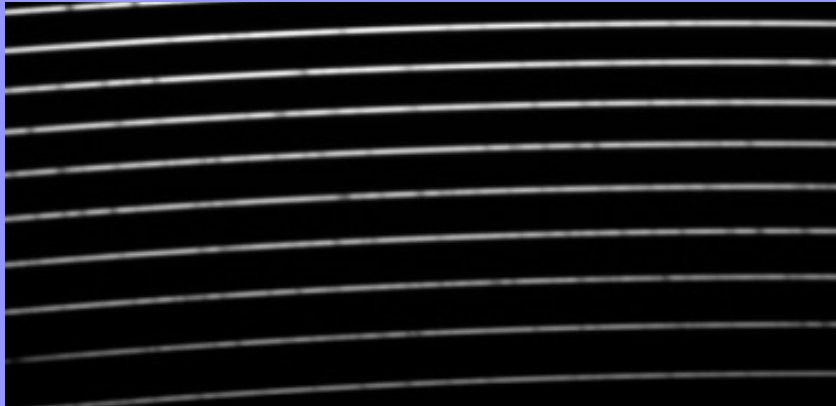
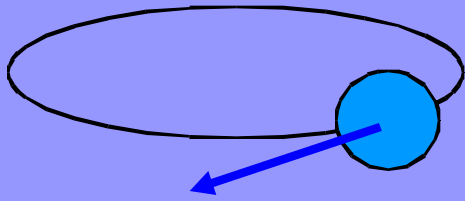


# exoplanets !





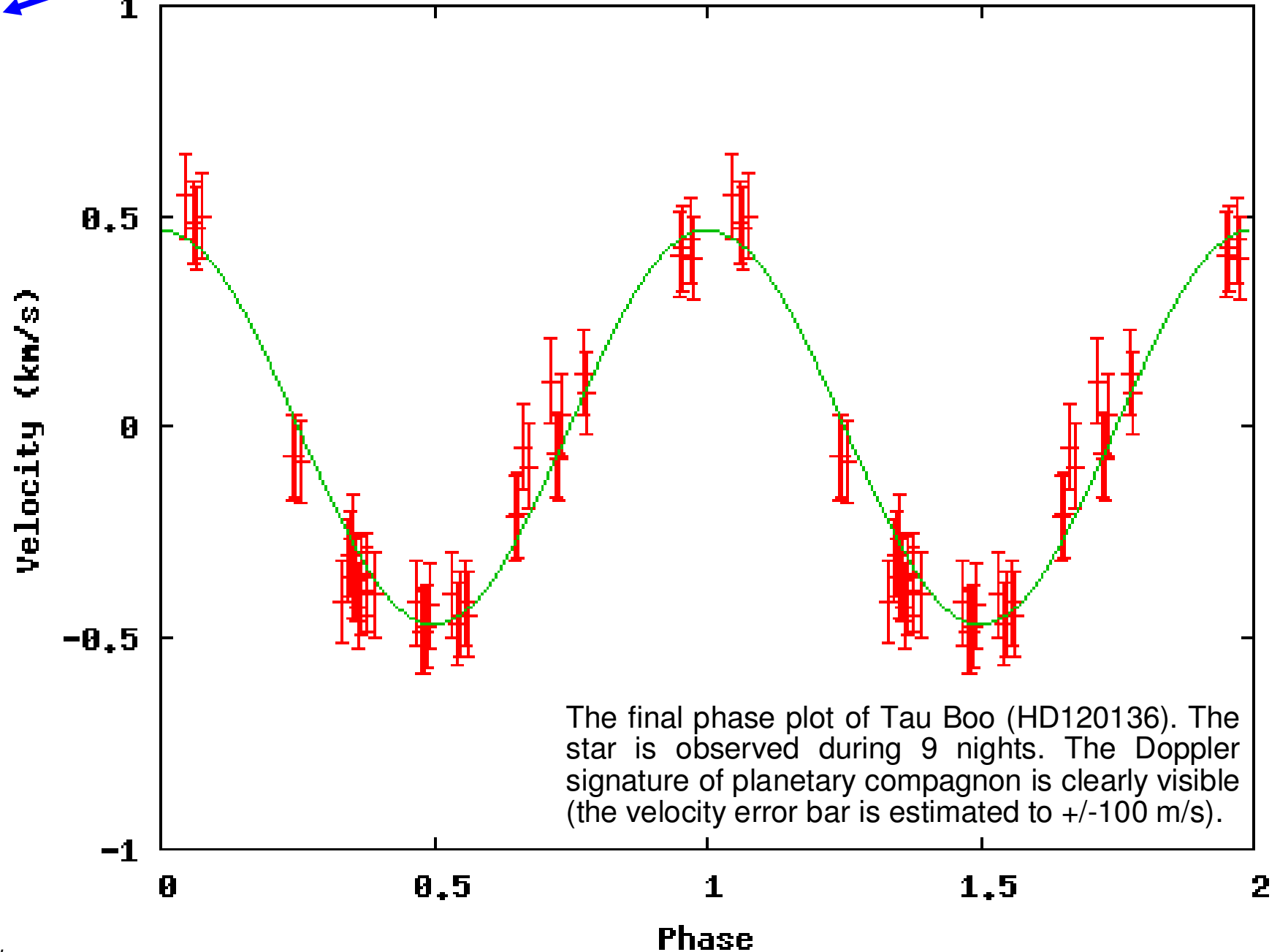
# Exoplanet: tau Boo



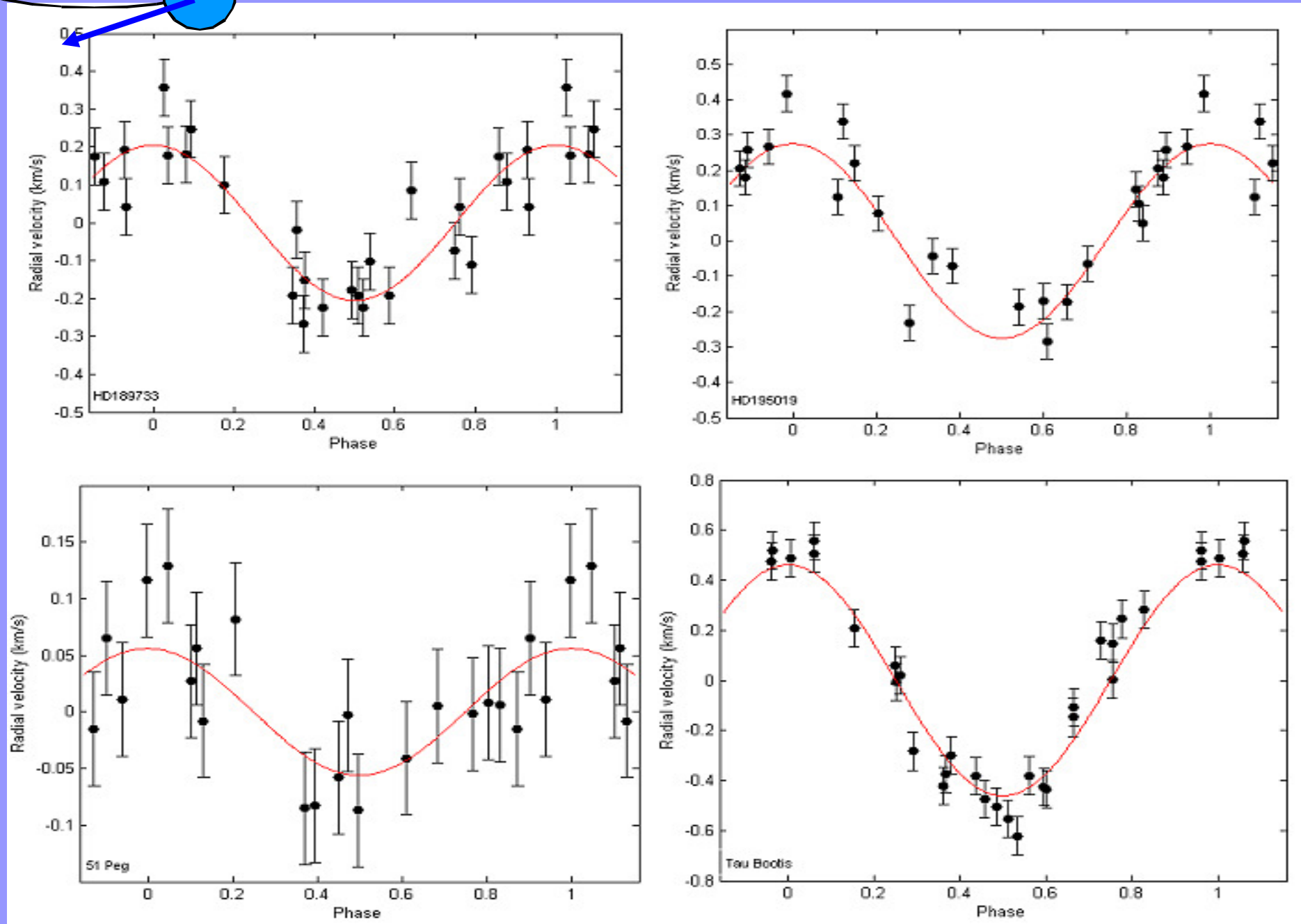
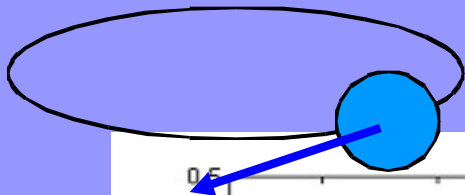
The CCF is computed by using the spectral range 4400-6445 Å (the H $\alpha$  line is excluded).

The total velocity Doppler spectral amplitude shift represents only 1/25th part of the spectrograph resolution. The data are collected between March 19-March 29, 2009.

# Exoplanet: tau Boo



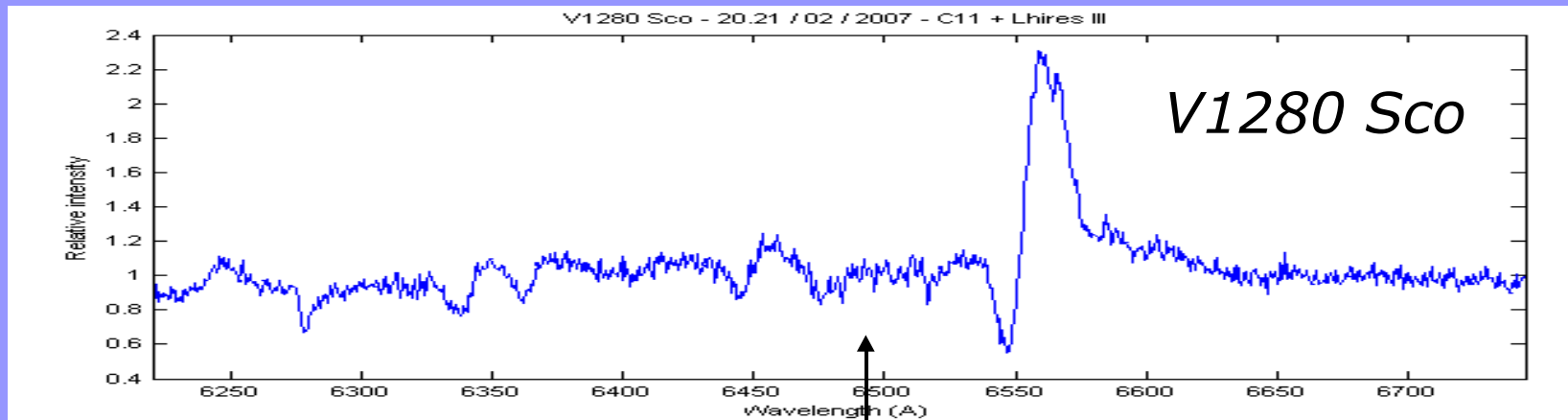
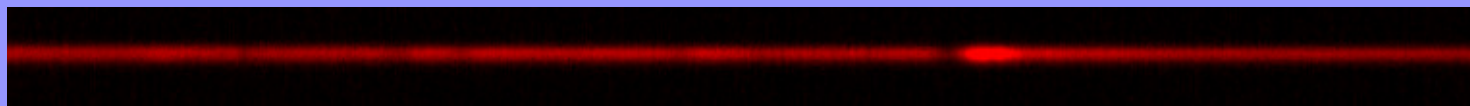
# Exoplanets: 4 done so far





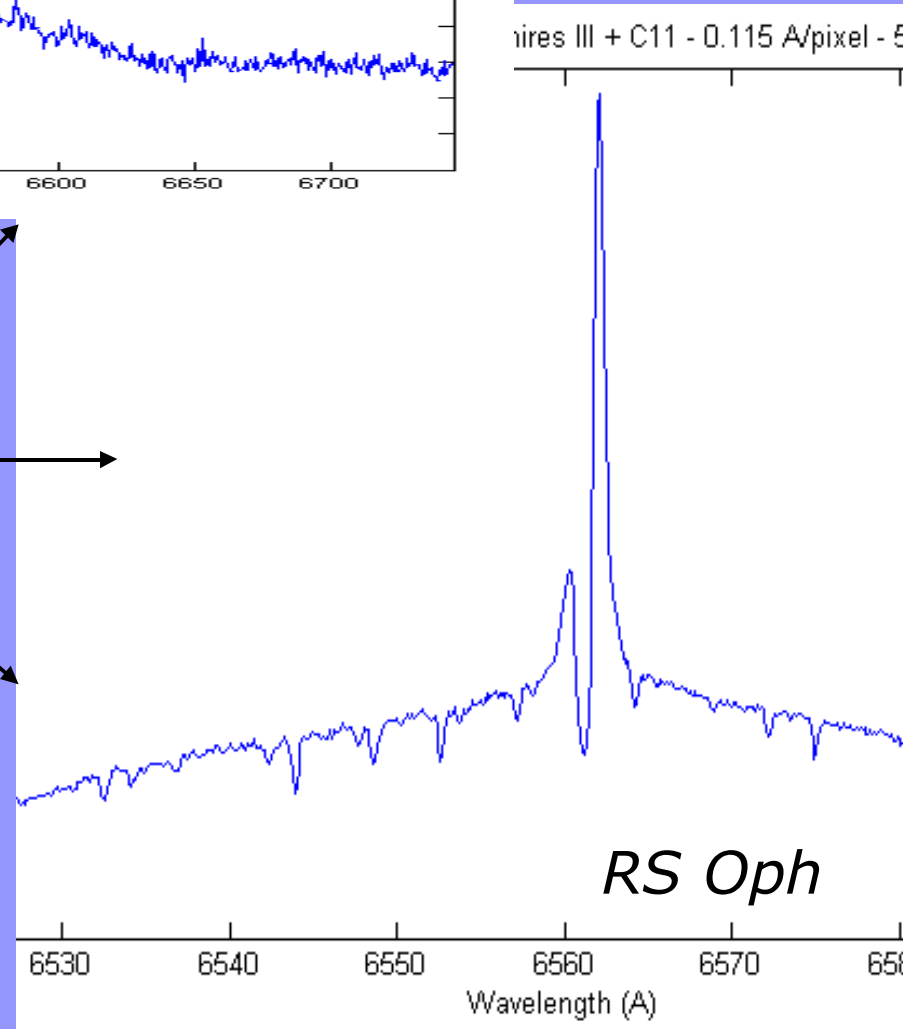
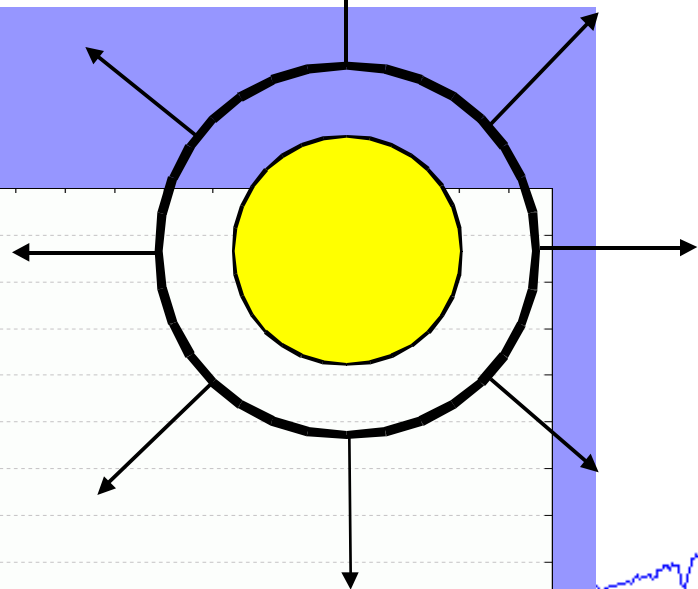
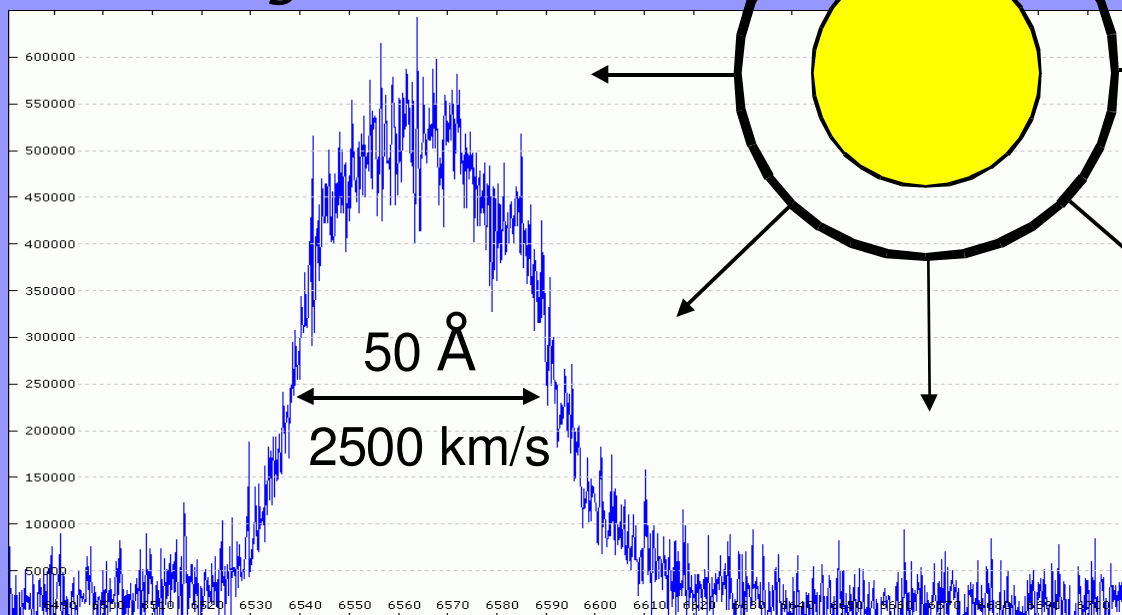


# Novae



Lhires III + C11 - 0.115 Å/pixel - 5

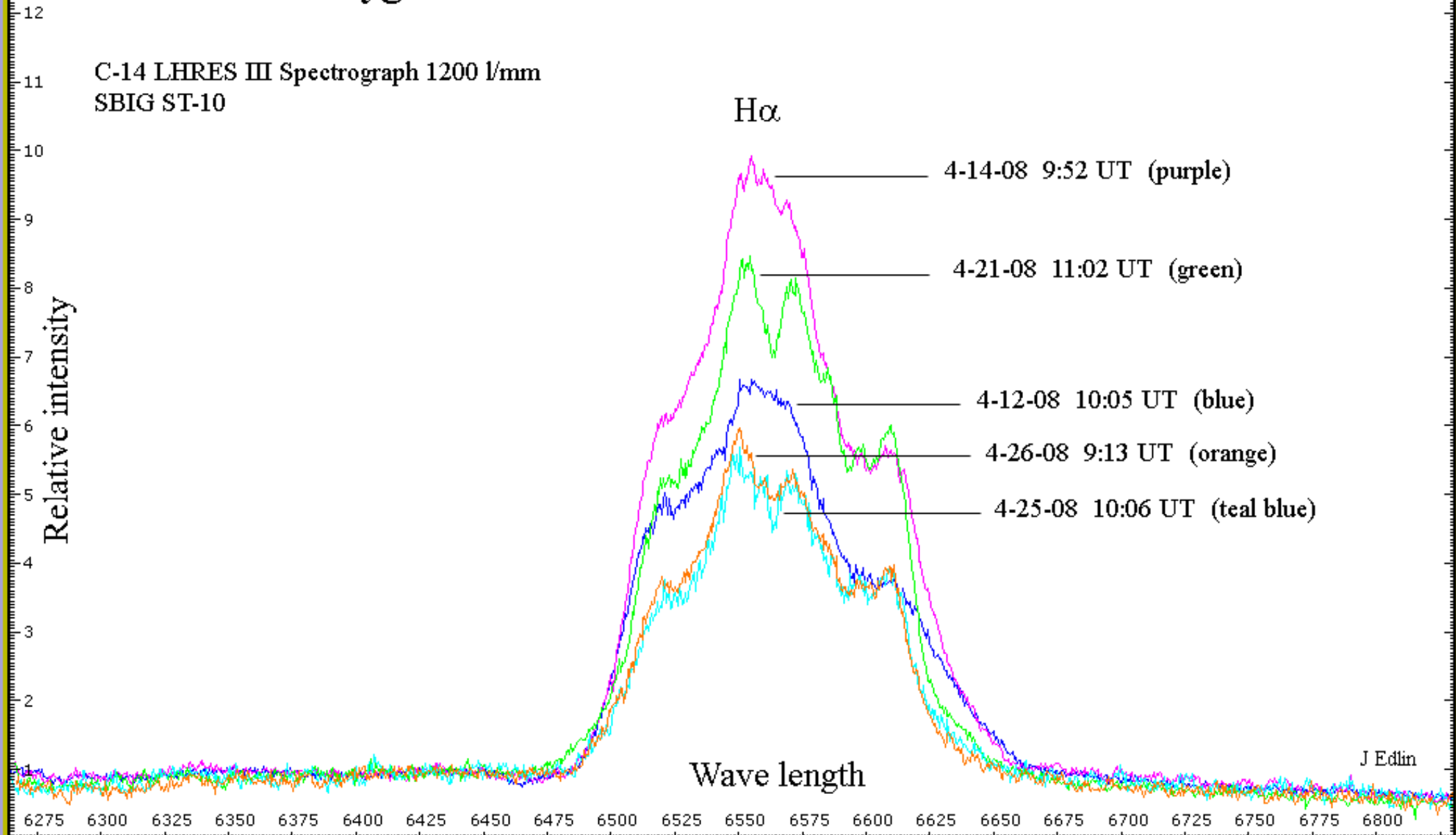
V4743 Sgr



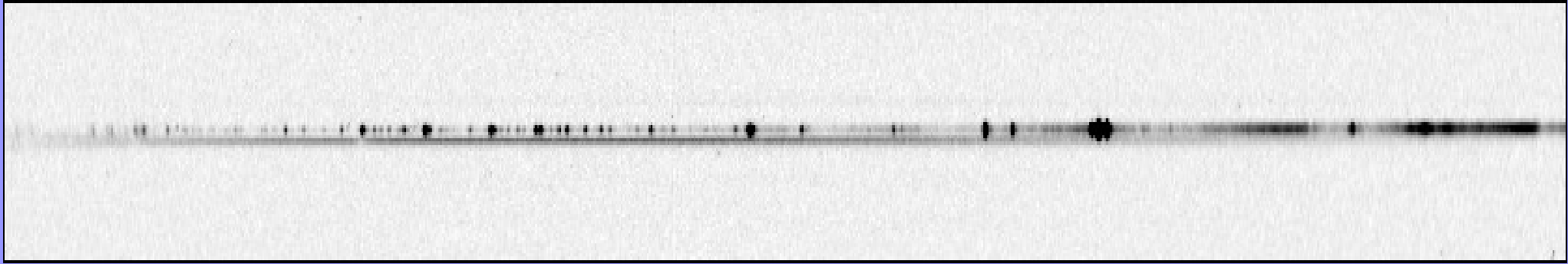
# Novae

## V2491 Nova Cyg 2008 #2

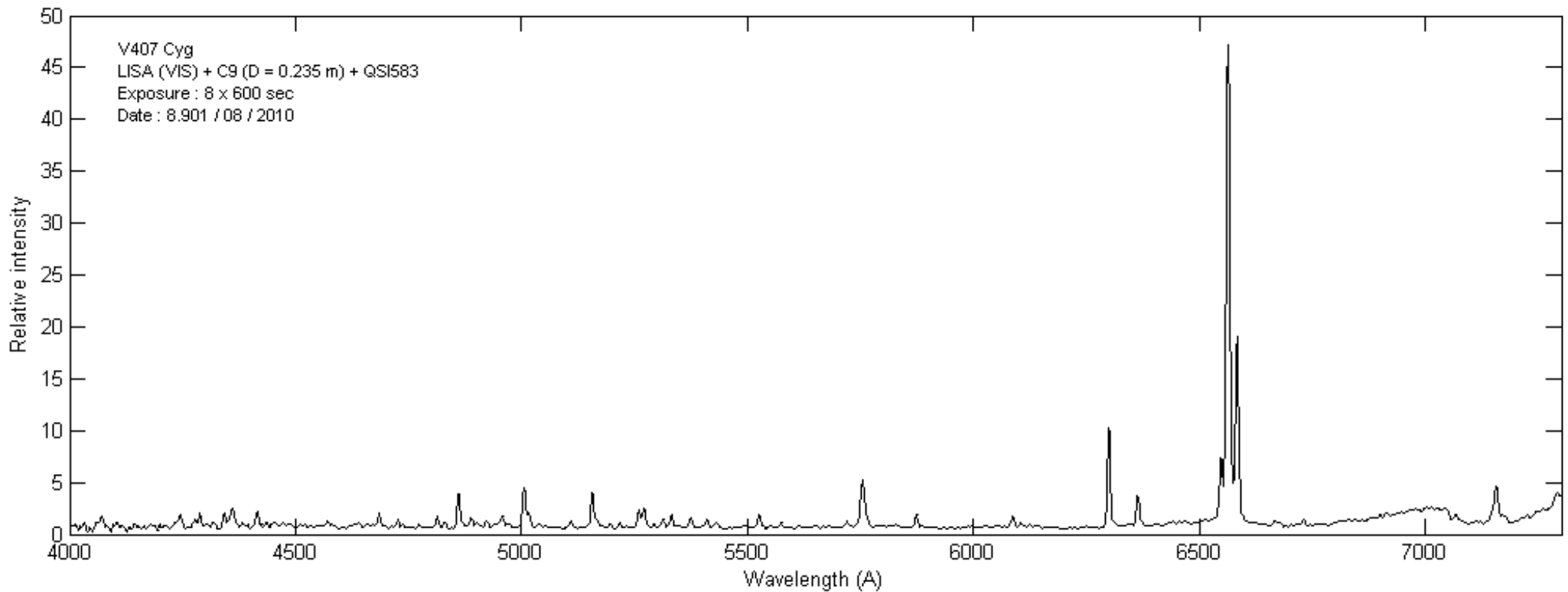
C-14 LHRES III Spectrograph 1200 l/mm  
SBIG ST-10



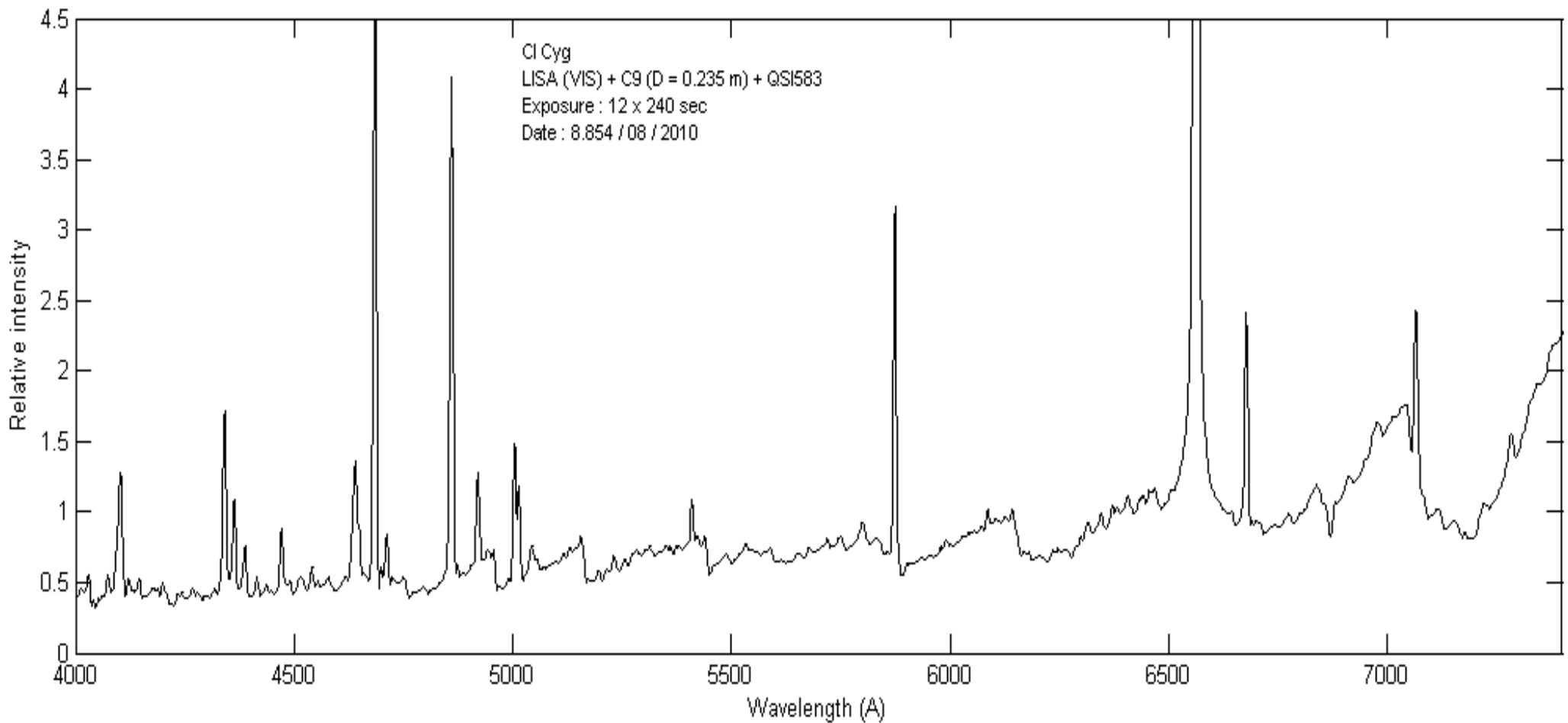
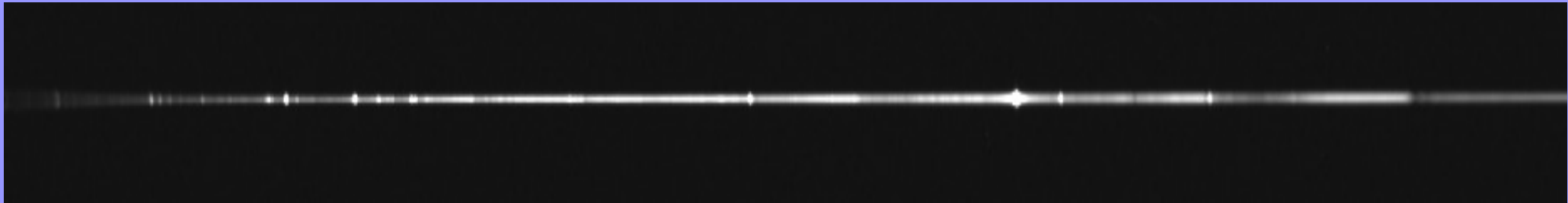
# Symbiotic stars: V407 Cyg



*Note: another star spectrum is closed to V407 Cyg spectrum...*

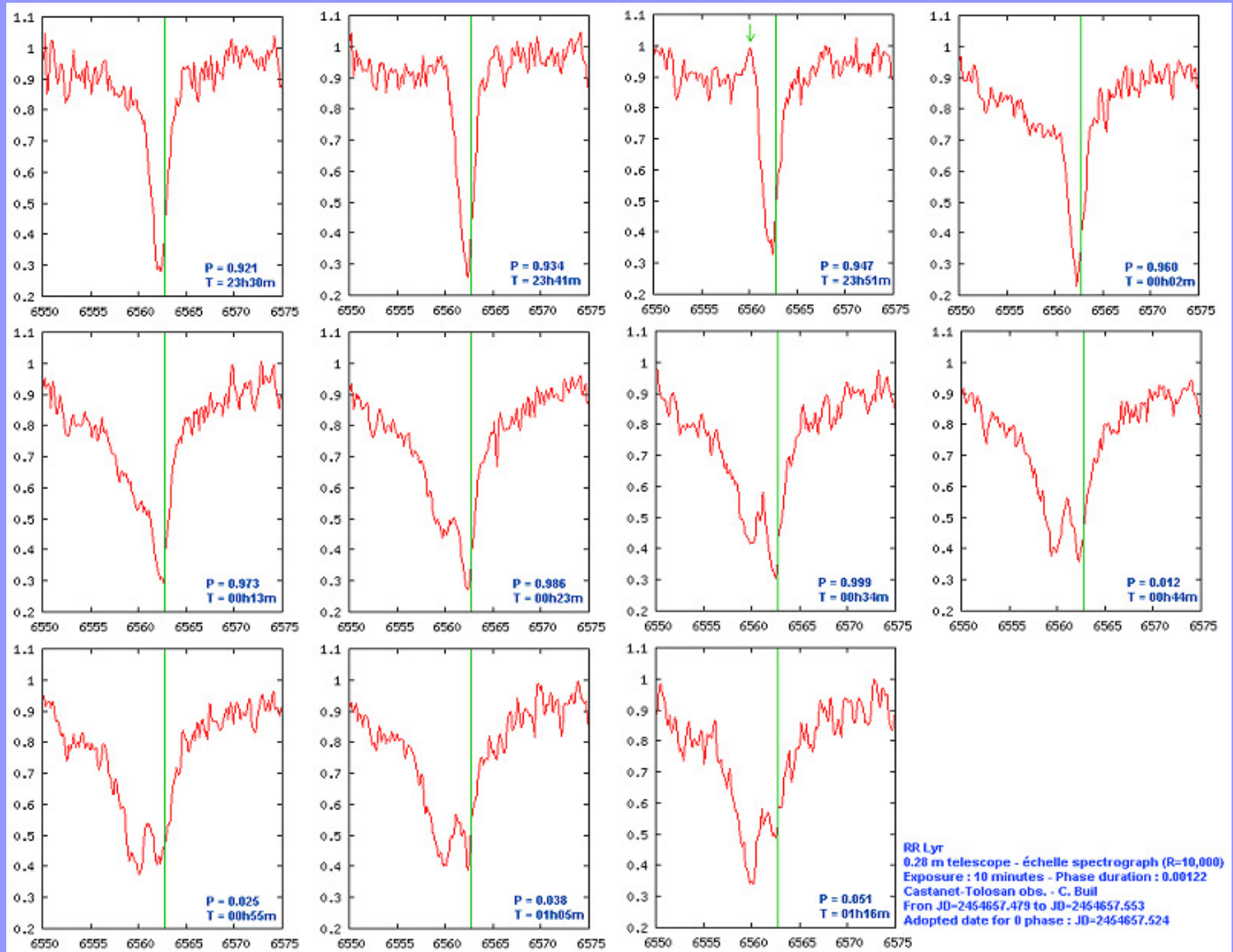


# Symbiotic stars: CI Cyg

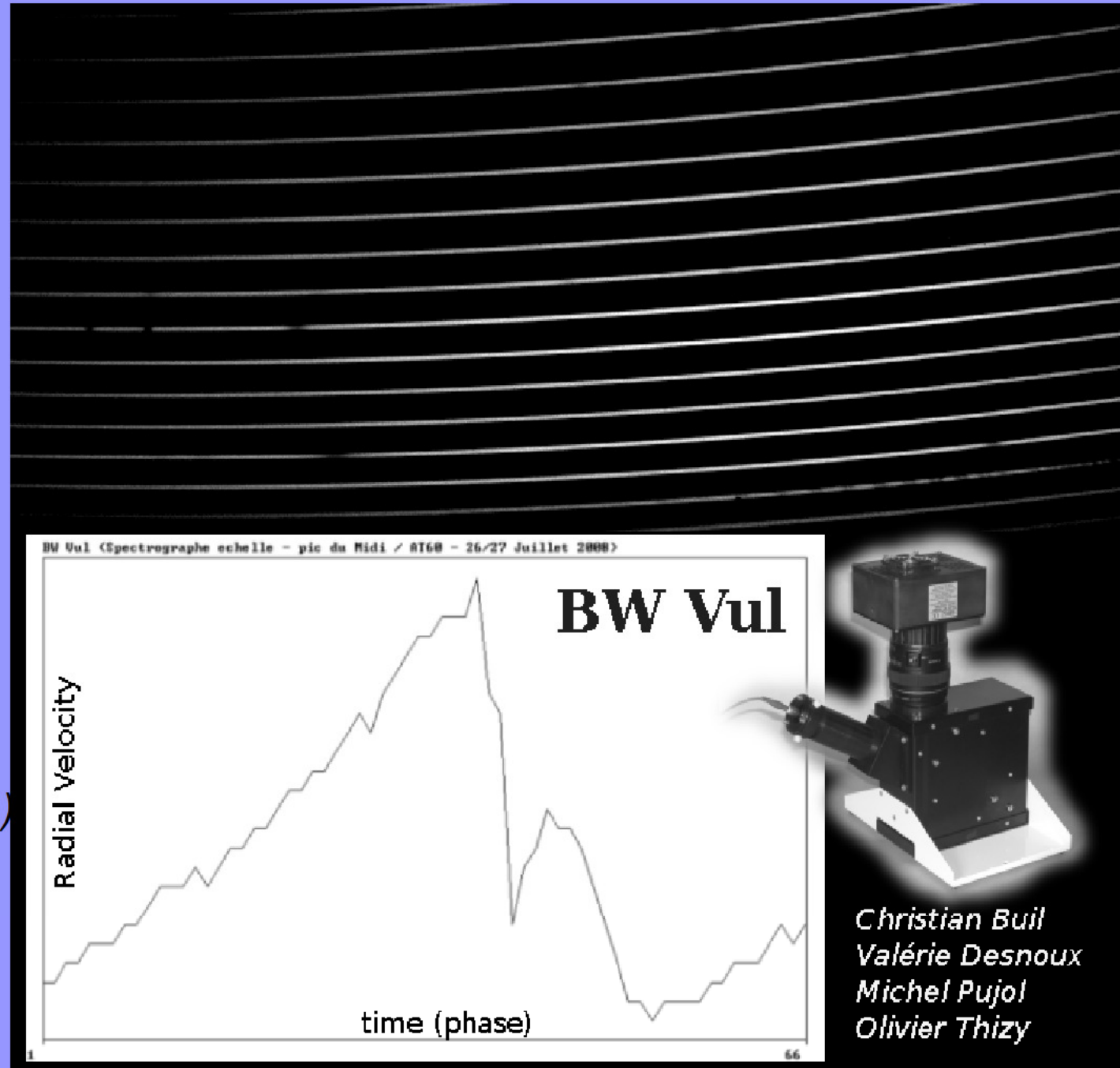
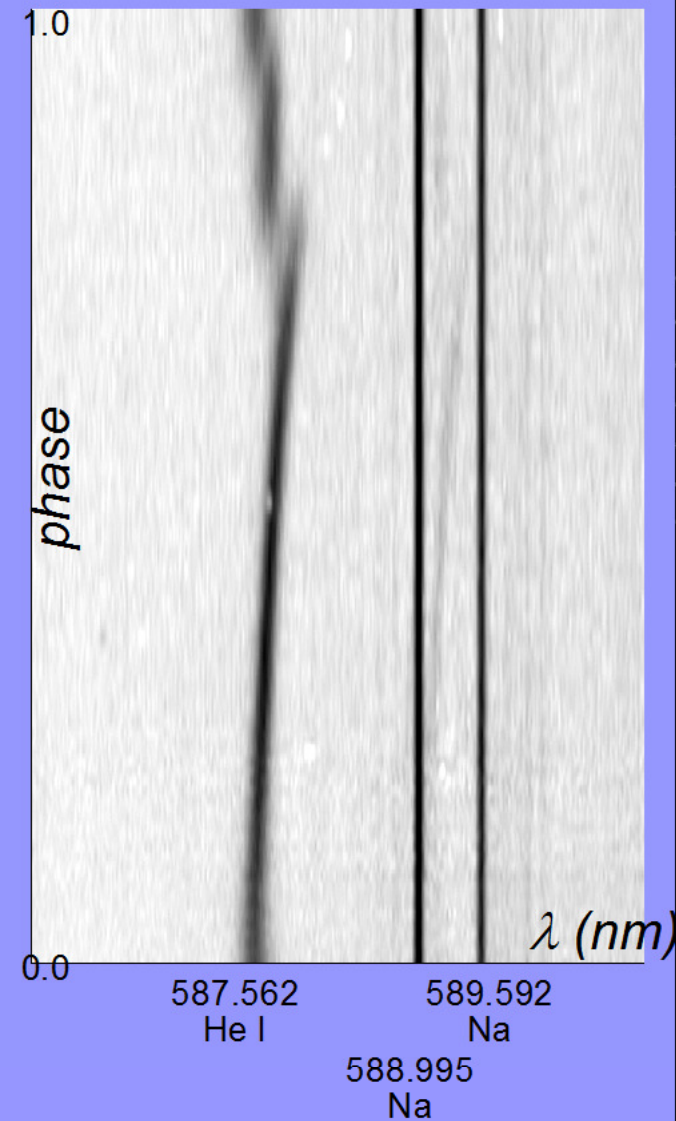




# RR Lyrae: seeing stars pulsating live !

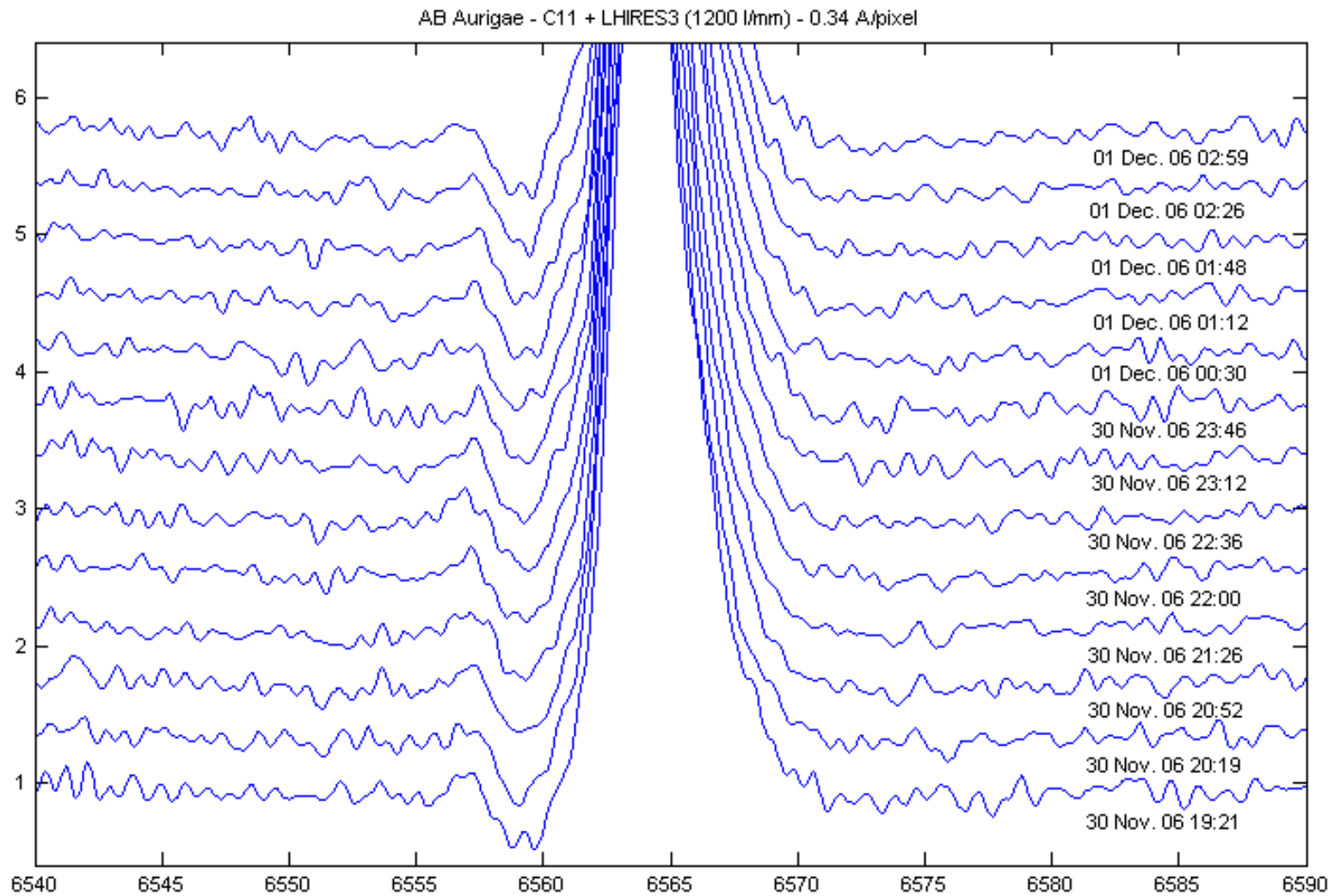


# BW Vul: at the heart of a star !!!

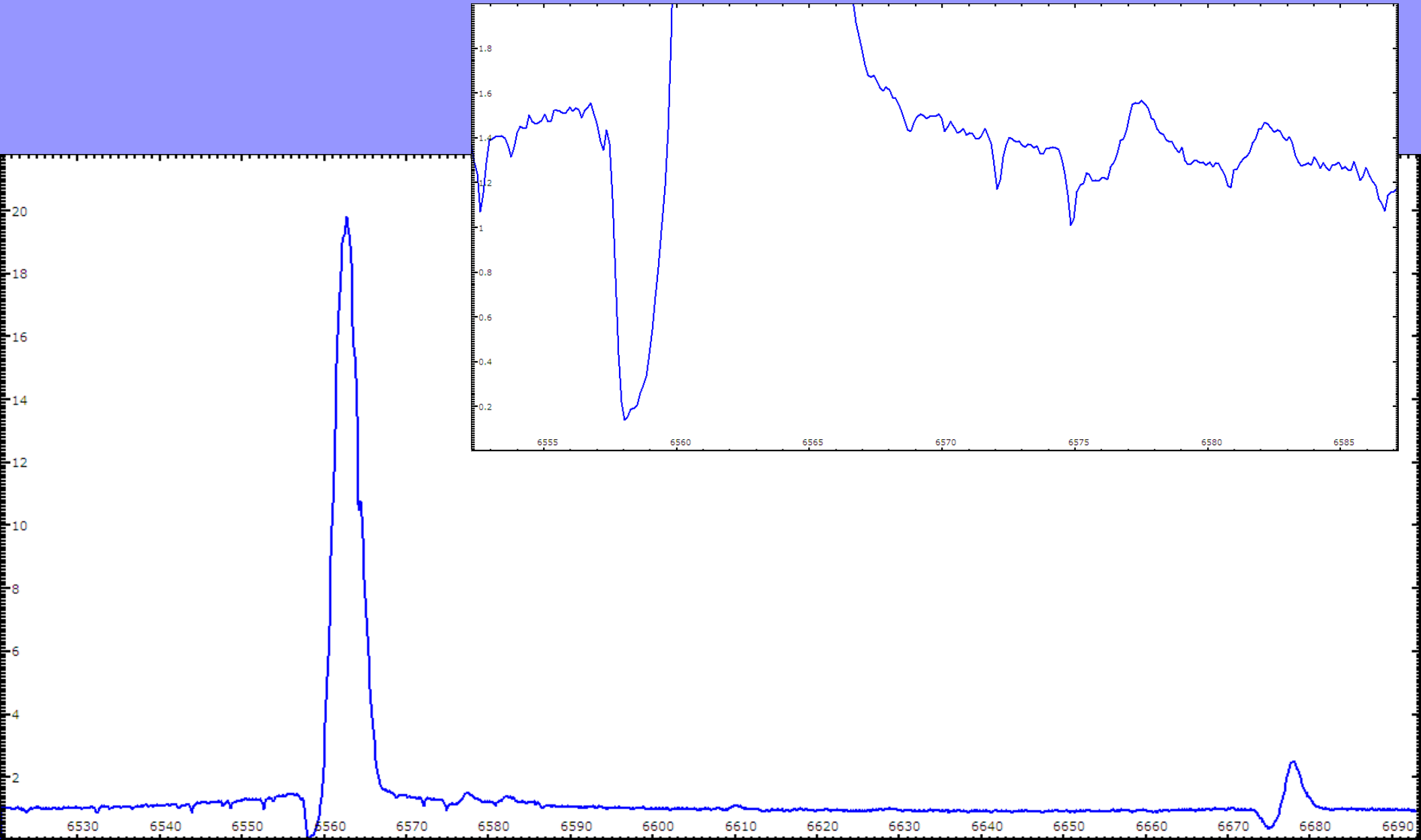


*Spectrogram of HeI/Sodium doublet of BW Vul  
(5min expoure, 60cm f/3.5 telescope at pic du Midi)*

# Herbig Ae/Be stars



# P Cygni

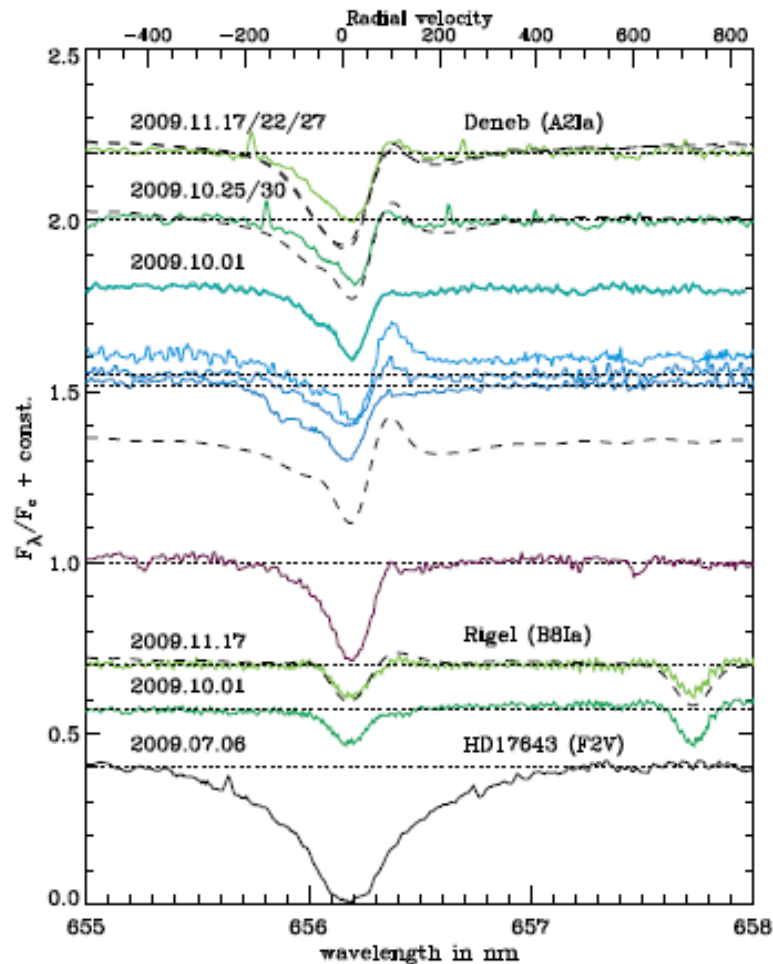




# other Active Hot Stars: Rigel, Deneb

4

O. Chesneau et al.: The H $\alpha$  line-formation region of Deneb and Rigel



tion about the spectral FWHM and position of the interferometric signal. The spectral location of the differential visibility and differential phase dips are stable at a level of 0.005 nm ( $\sim 3 \text{ km s}^{-1}$ ). Information from the blue camera was also used, as some important lines, e.g. Si III 6343–6371 Å can be investigated (see Fig. 3 and Sect. 3.3).

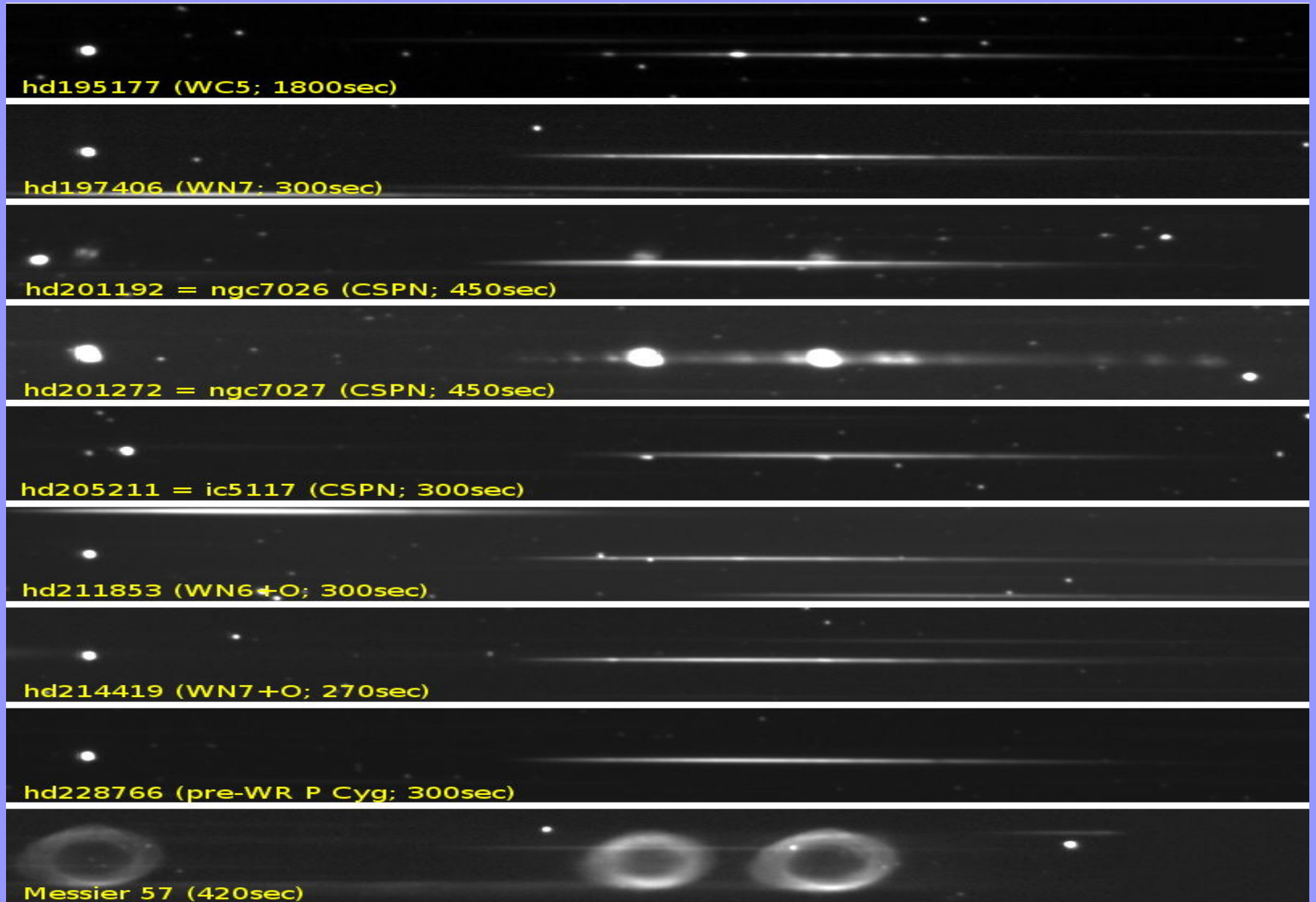
## 2.2. Spectroscopy from amateur astronomers

Several H $\alpha$  spectra were obtained during the same period with the 0.28 m amateur telescope (Celestron 11) located in Castanet-Tolosan (France) equipped with the eShel spectrograph and a QSI532 CCD camera (CCD KAF3200ME). These spectra were used in this study as an indication of the emission level and variability of the stars. The typical resolution of these spectra is  $\sim 11\,000$ .

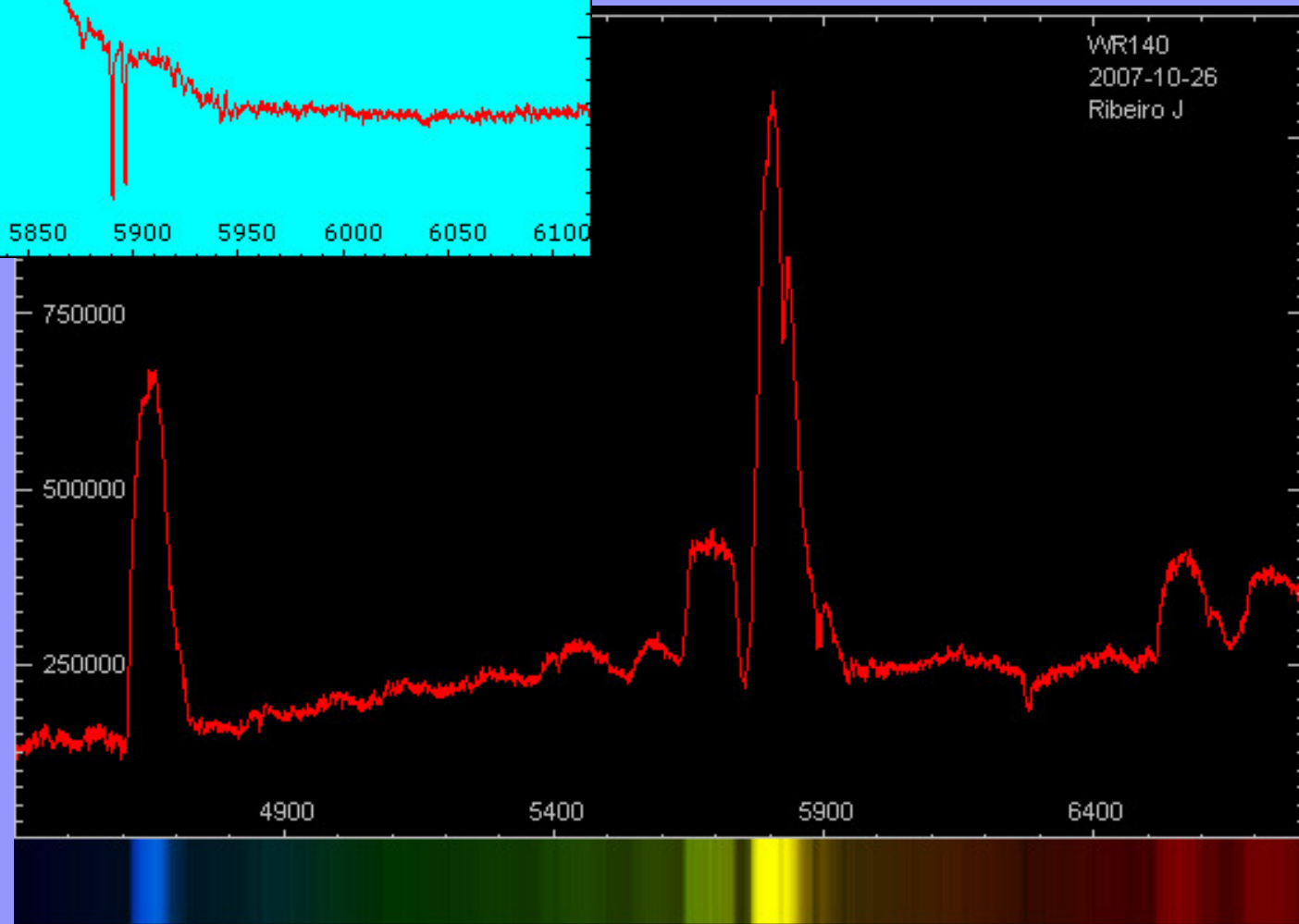
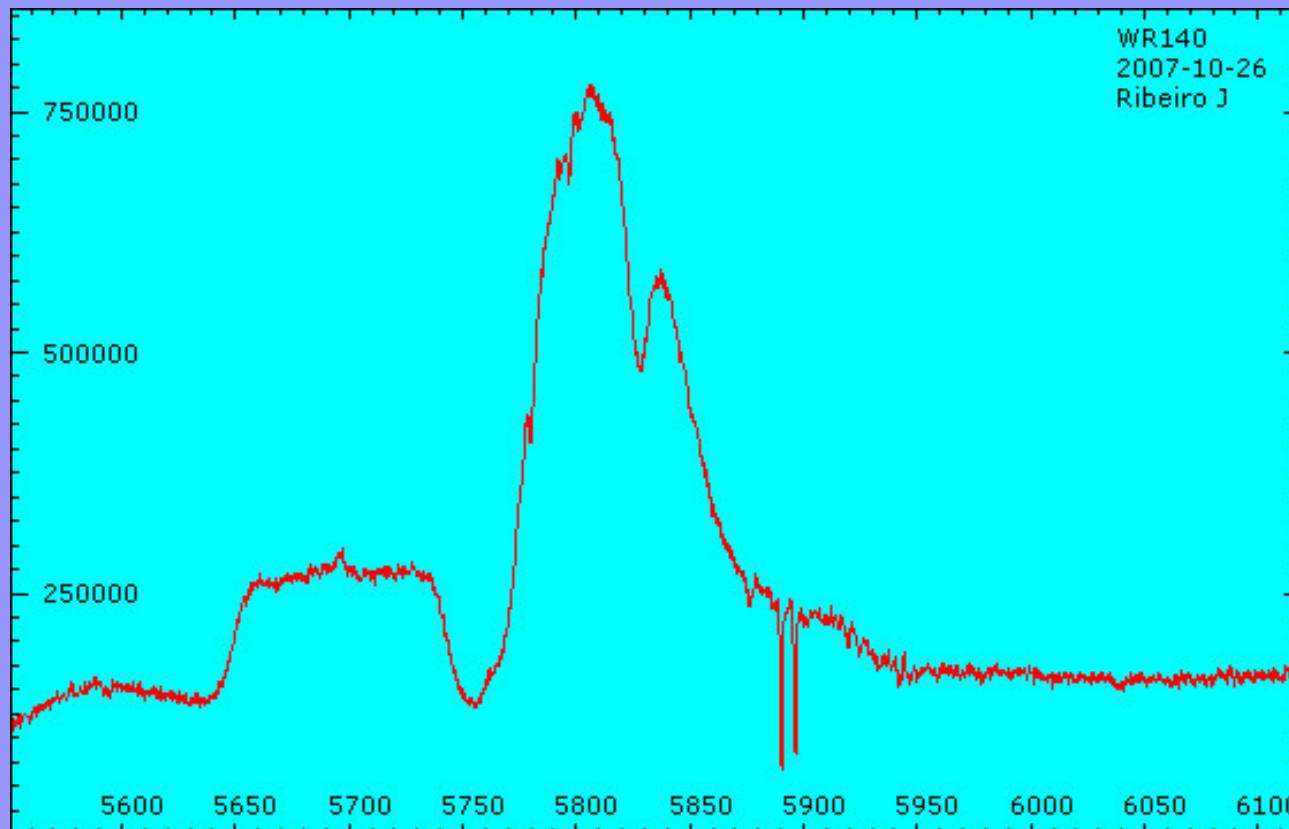
The reduction of these data was performed using the standard echelle pipeline (Reshel software V1.11). H $_2$ O telluric lines are removed by means of division by a synthetic H $_2$ O spectrum using Vspec software - the telluric-line list was taken from GEISA database (LMD/CNRS). We corrected for the diurnal and annual earth velocity are corrected for (spectral wavelengths are given in an heliocentric reference for a stan-

➤ **Ref:** arXiv:1007.2095v1 : Time, spatial, and spectral resolution of the H $\alpha$  line-formation region of Deneb and Rigel with the VEGA/CHARA interferometer

# Wolf-Rayet

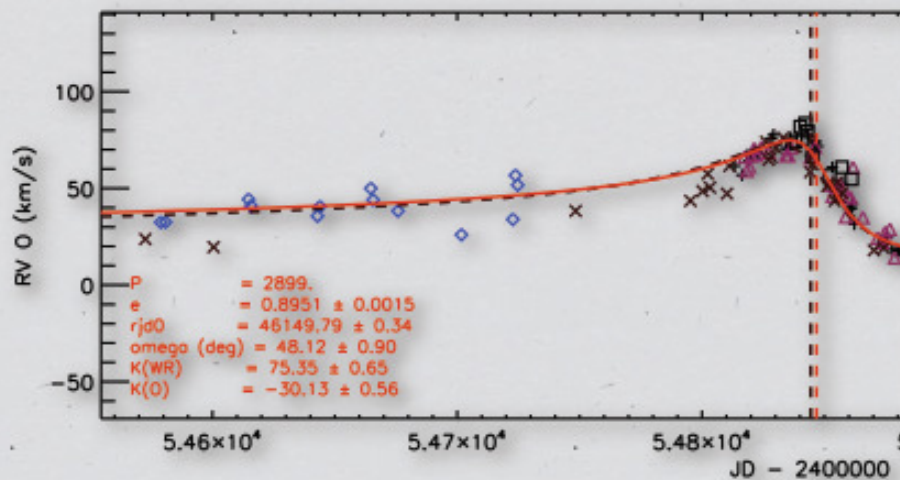
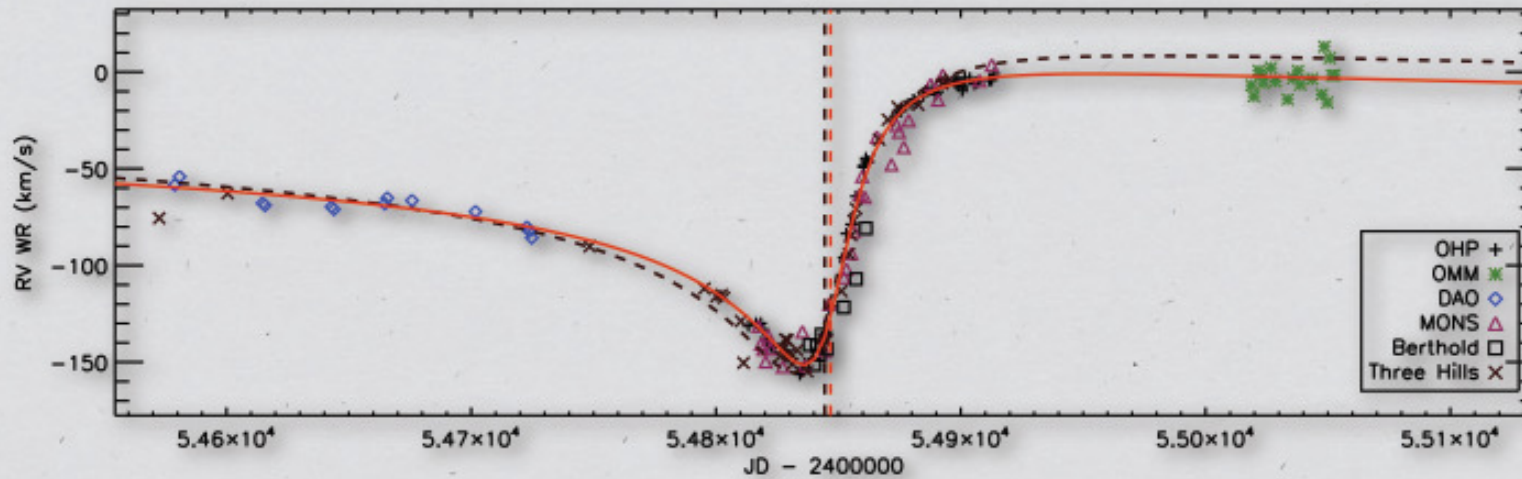


# WR140



# WR140 / 2009 periastron

## Radial Velocities

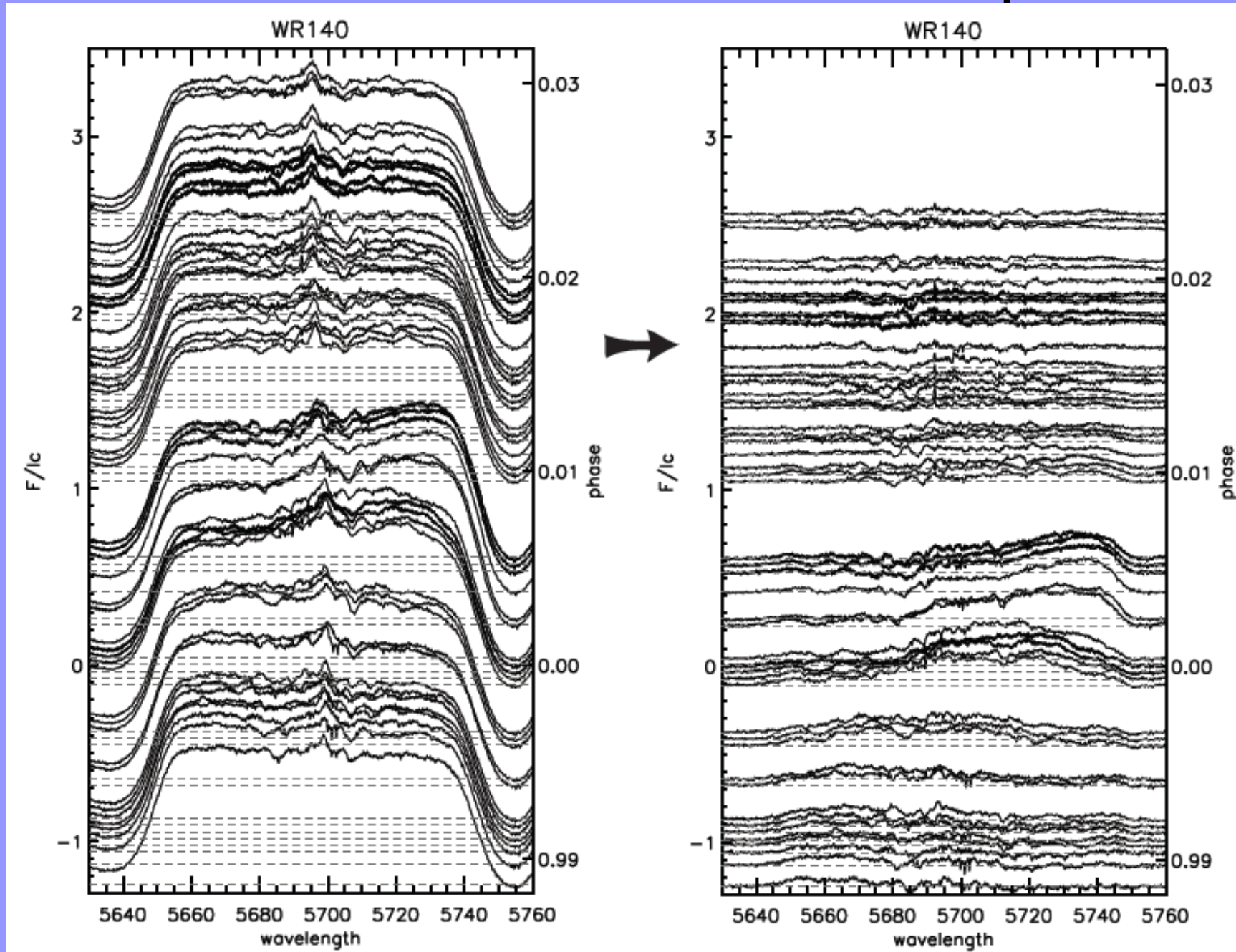


ORBITAL ELEMENTS OF WR 140

Element	WR	O
$K$ (km s <sup>-1</sup> )	$82.0 \pm 2.3$	$30.5 \pm 1.9$
$a \sin i$ (10 <sup>10</sup> km)	$0.154 \pm 0.007$	$0.057 \pm 0.004$
$\gamma$	assumed: 0.0	$3.1 \pm 1.0$
$P$ (days)	$2899.0 \pm 1.3$	...
$e$	$0.881 \pm 0.005$	...
$T_0$ (HJD 2,440,000+)	$6147.4 \pm 3.7$	...
$\omega$	$46.7 \pm 1.6$	...



# WR140 / 2009 periastron



*Rémy Fahed et al.: C III 5696 flat top line as function of phase / excess emission (right)*

# Eps Aurigae eclipse

B star ?  
~15000K  
5.9 Msol

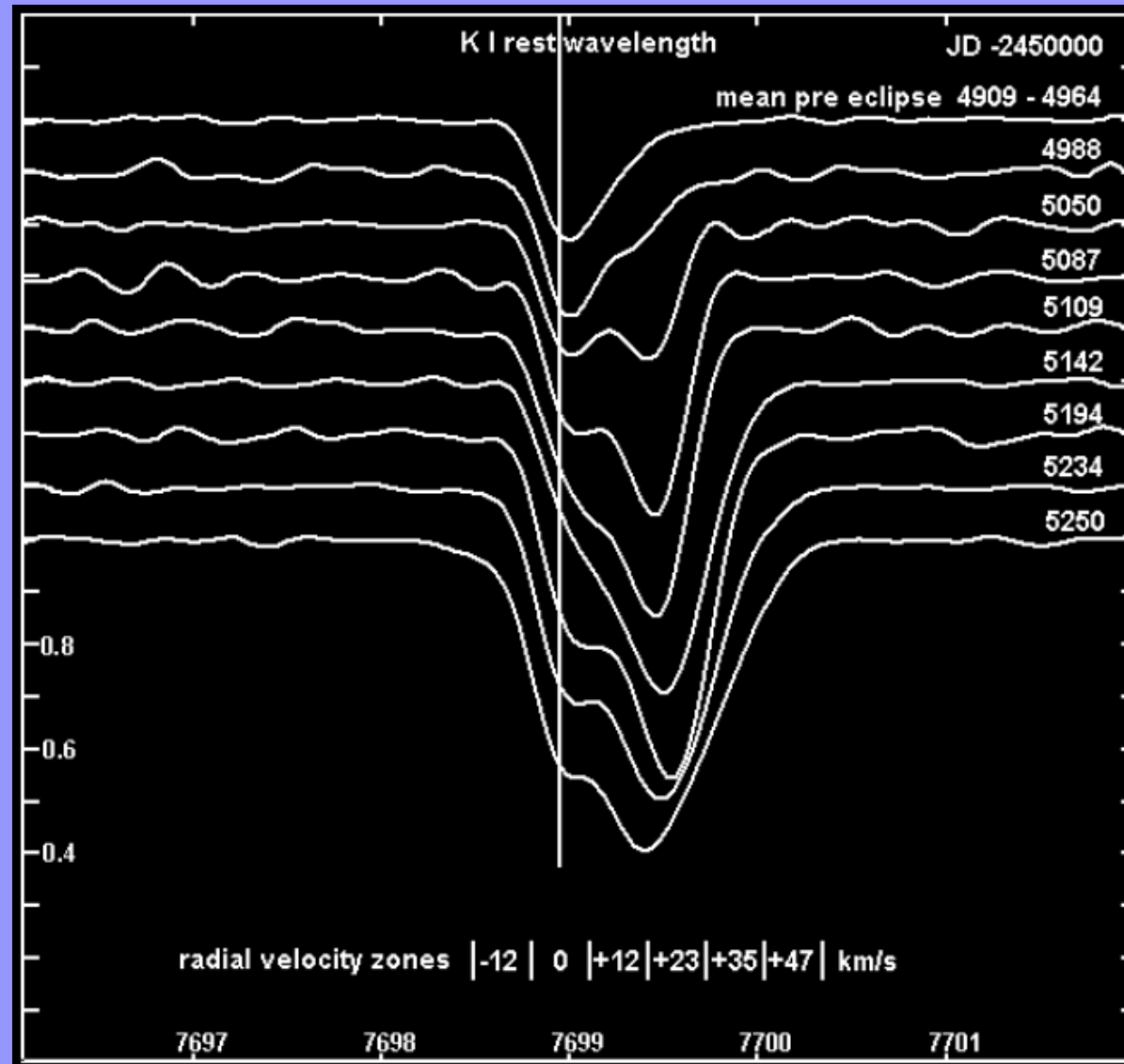
F type  
star ?  
~7000K  
2.7 Msol ?

Disk  
~500K

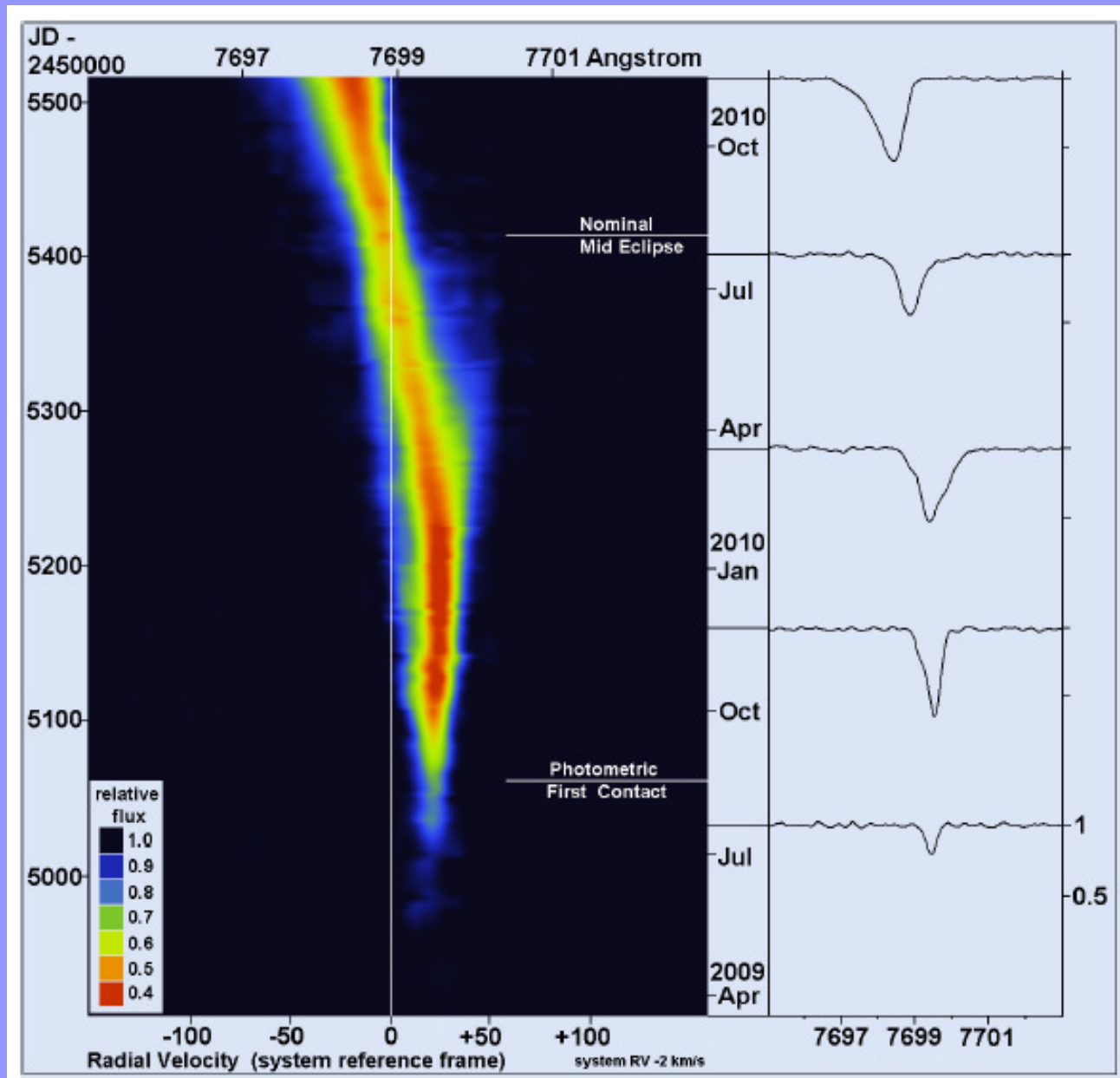


- Eclipse every 27 years !!!
- ~15 amateurs contributing
- Over 130 spectra to date ?

# Eps Aurigae eclipse : KI 7699 line



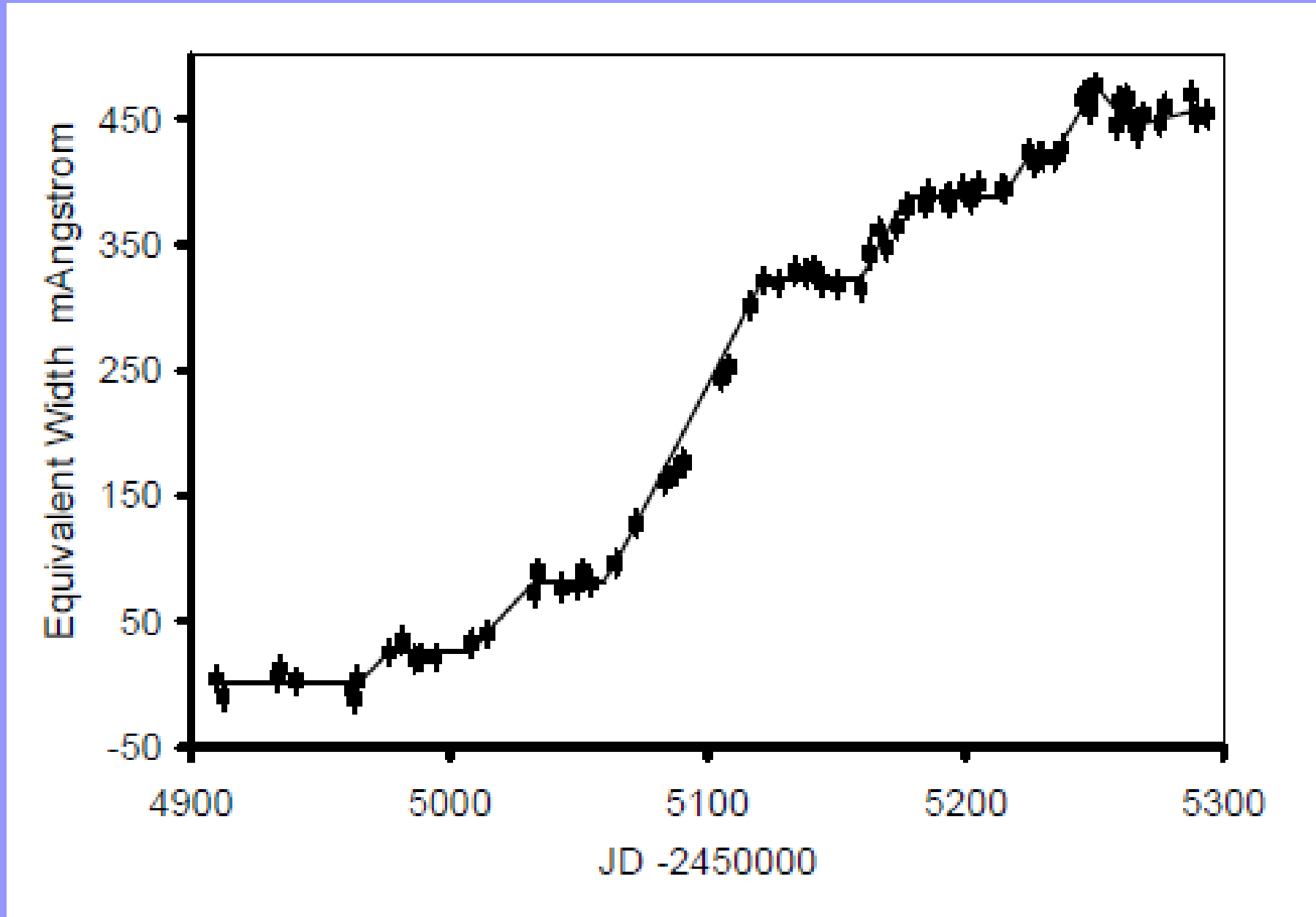
- New absorption line appearing !



*Robin Leadbeater (Lhires III), Bob Stencel: Contour plot showing the evolution of the 7699A neutral potassium line after removal of the interstellar component seen outside eclipse. Coverage is 140 days before first contact to 100 days after predicted mid eclipse.*

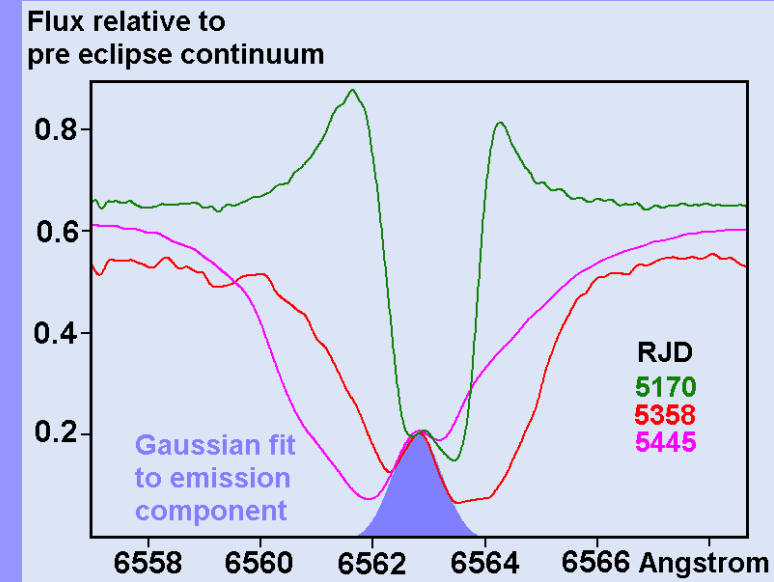
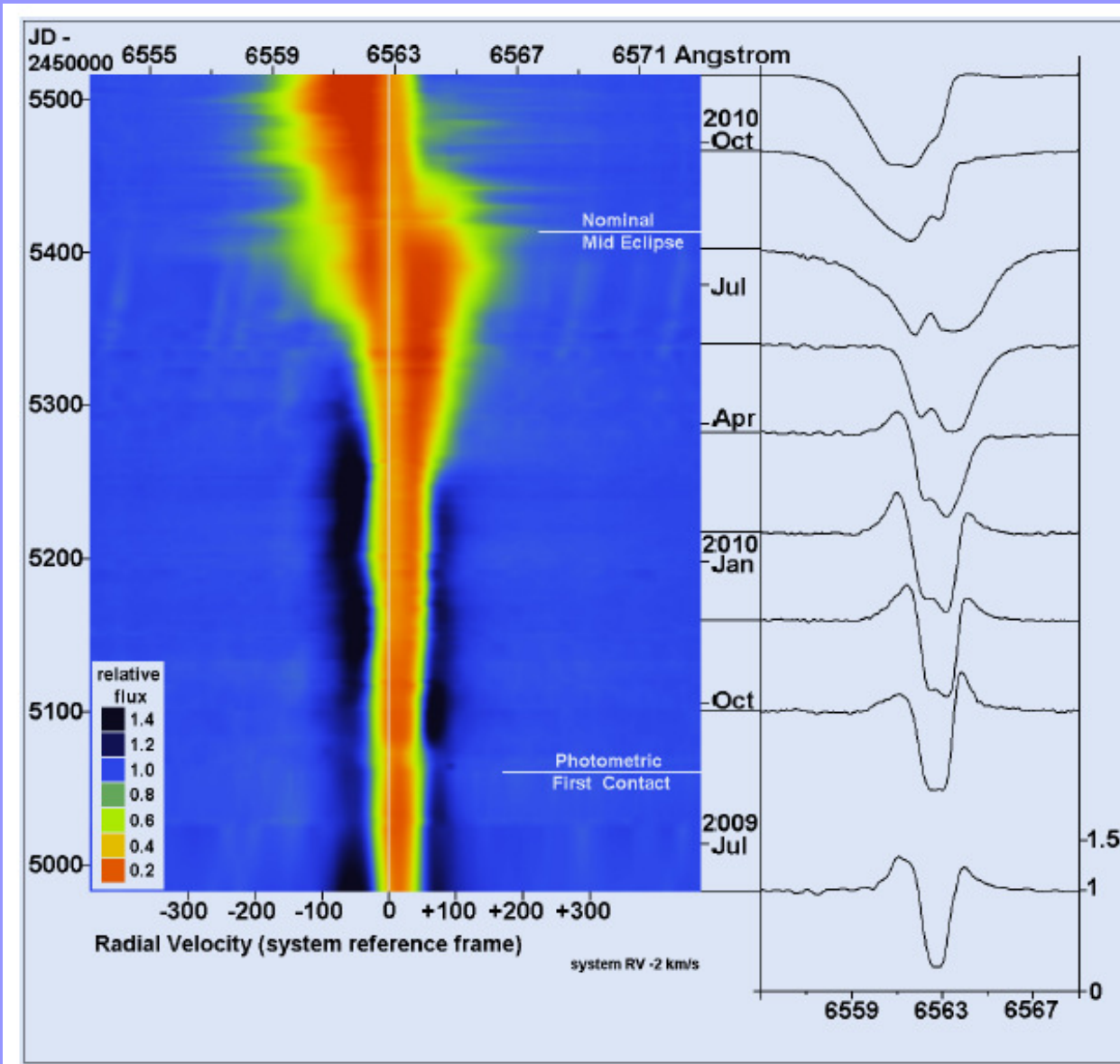


# Eps Aurigae eclipse : KI 7699 line



• Disk structures in « rings » ?

# Eps Aurigae eclipse : Halpha line



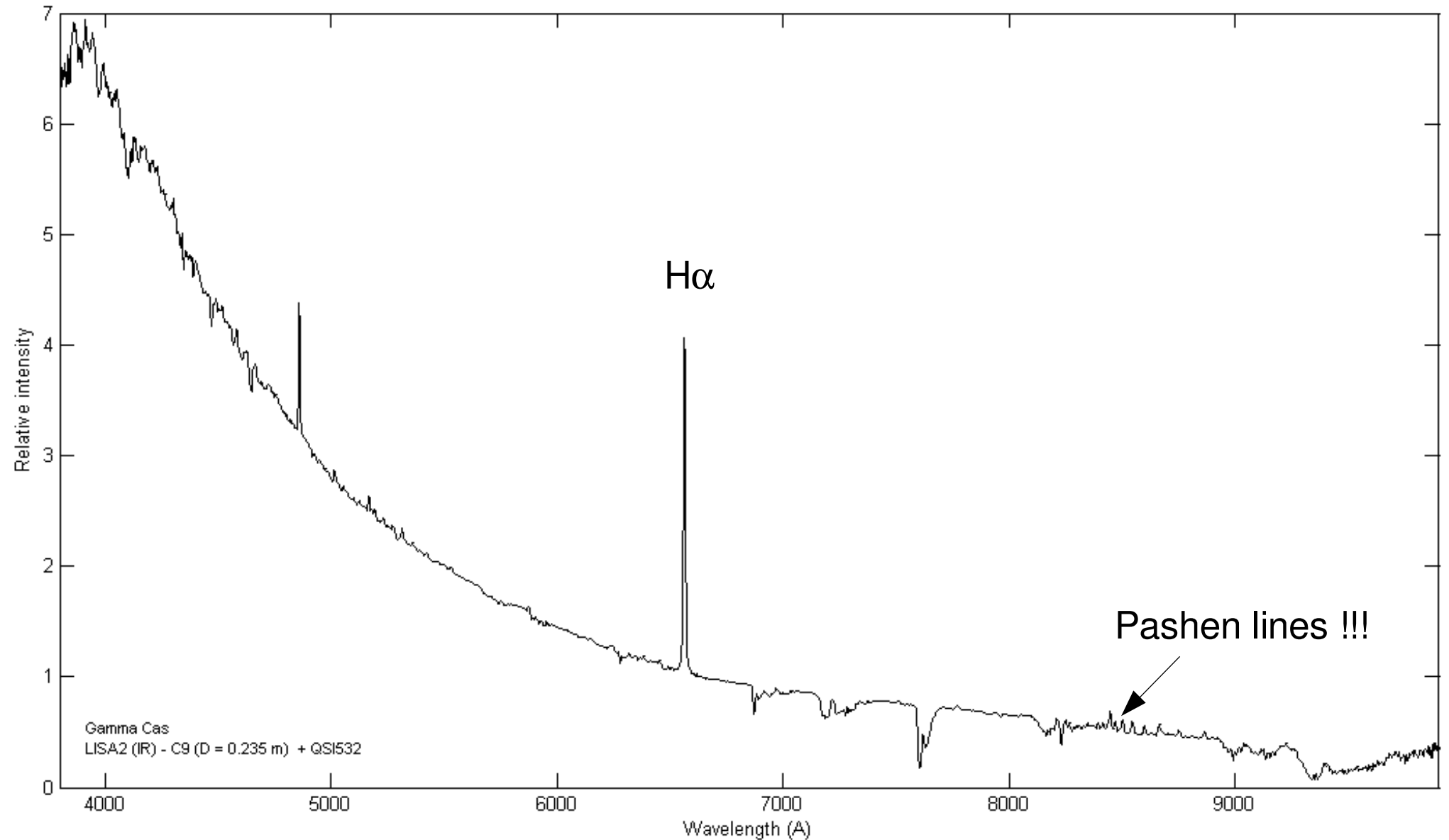
*A hidden emission component  
An emission component appeared in the core of the H alpha line close to the rest wavelength.*

*Robin Leadbeater, Bob Stencel: Contour plot showing the evolution of the H alpha line from pre first contact to approximately 100 days after predicted mid eclipse. It is generated from 159 spectra from all observers.*

# eps Aurigae pro-am campaign

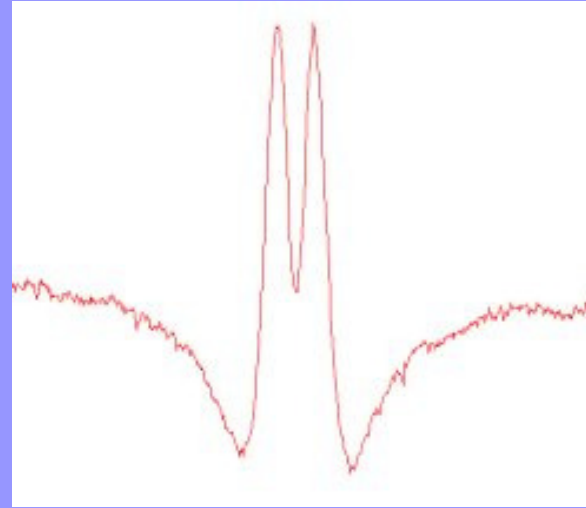
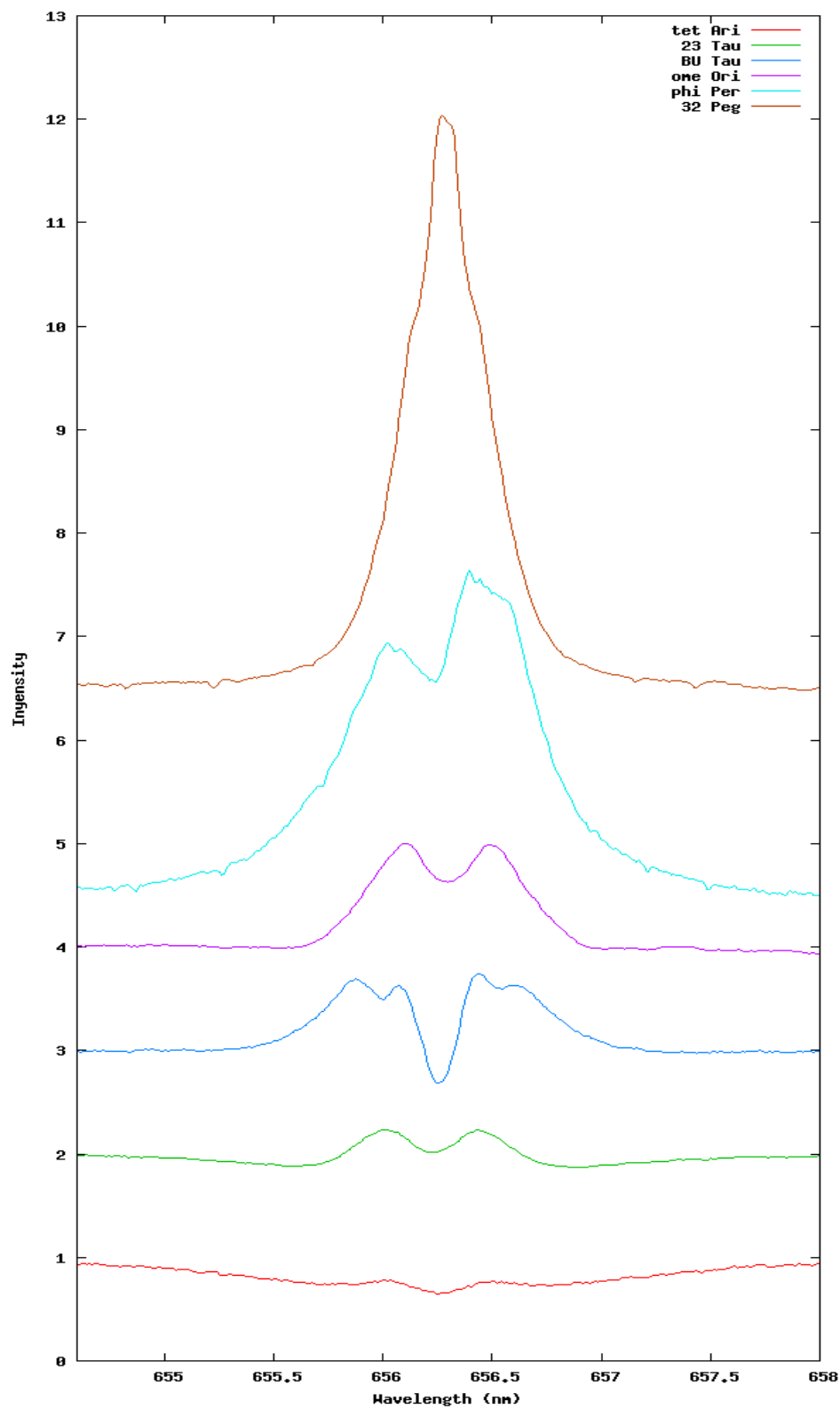
- **Complementary photometry / spectroscopy campaign**
- **Over 600 spectra collected (and increasing) !**
  
- **Contacts: Robert 'Bob' Stencel (Denver, USA)**  
*Jeff Hopkins (amateur; photometry lead)*  
*Robin Leadbeater (amateur; spectroscopy lead)*
  
- **Publications:**
  - [http://www.threehillsobservatory.co.uk/astro/spectra\\_40.htm](http://www.threehillsobservatory.co.uk/astro/spectra_40.htm)
  - arXiv:0807.2855v1 : Gearing Up for Epsilon Aurigae's First Eclipse of the Millennium
  - 2009SASS...28..157H : Epsilon Aurigae Hydrogen Alpha Emission Line Variation: The Horn Dance
  - 2009CBET.1885....1W : Epsilon Aurigae (first detection !)
  - arXiv:1003.3617v2 : Structure in the disc of epsilon Aurigae: Spectroscopic observations of neutral Potassium during eclipse ingress
  - arXiv:1101.1435v1 : The International Epsilon Aurigae Campaign 2009-2011. A description of the campaign and early results to May 2010
  - Article in Sky & Telescope magazine !

# A *state-of-the-art* pro/am project: Be stars

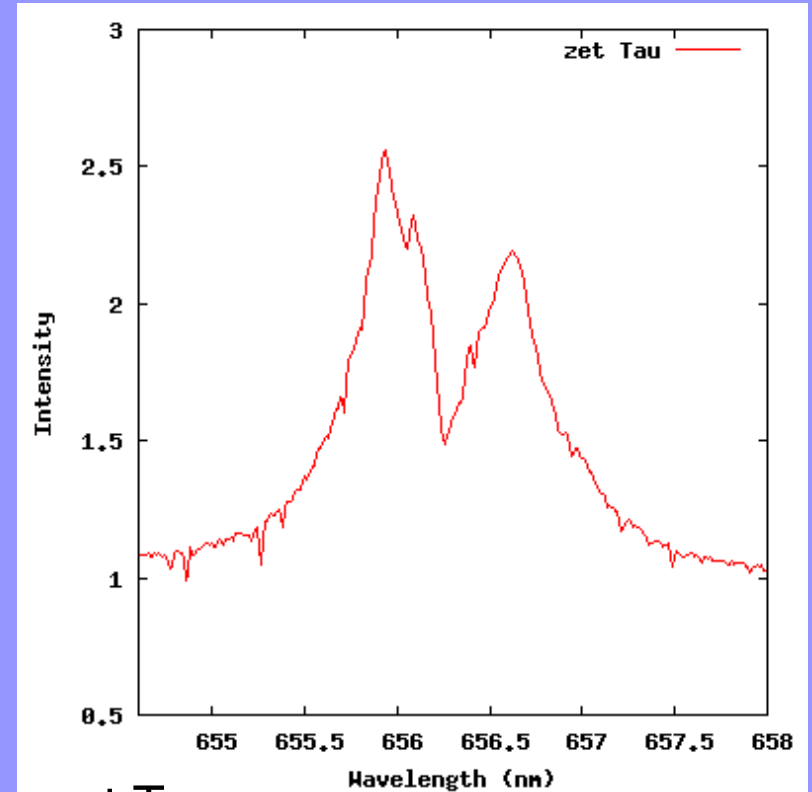
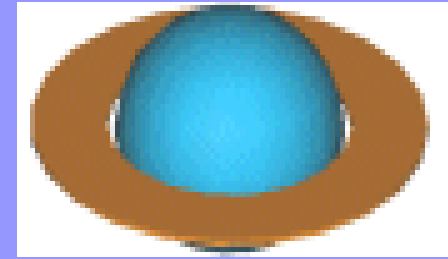




# Be stars

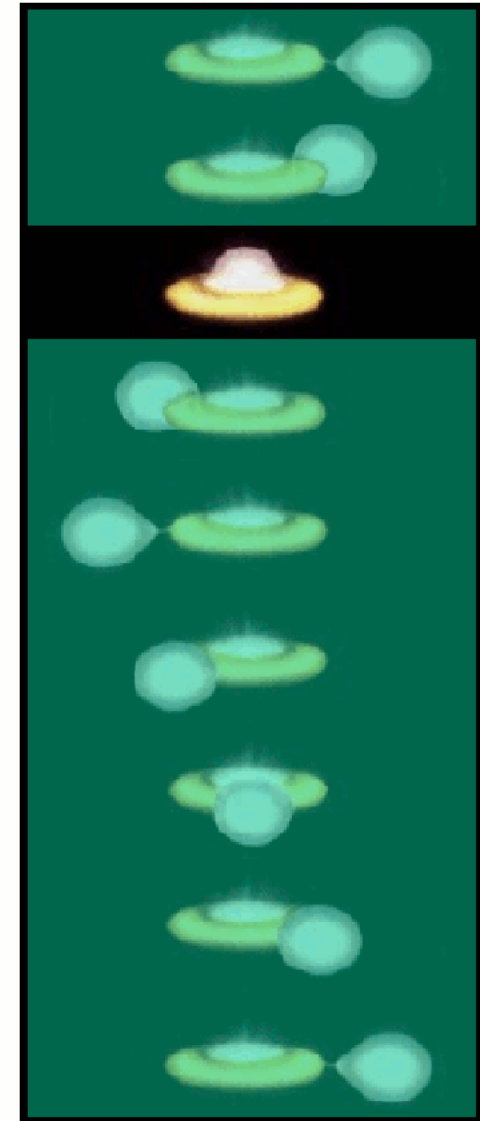
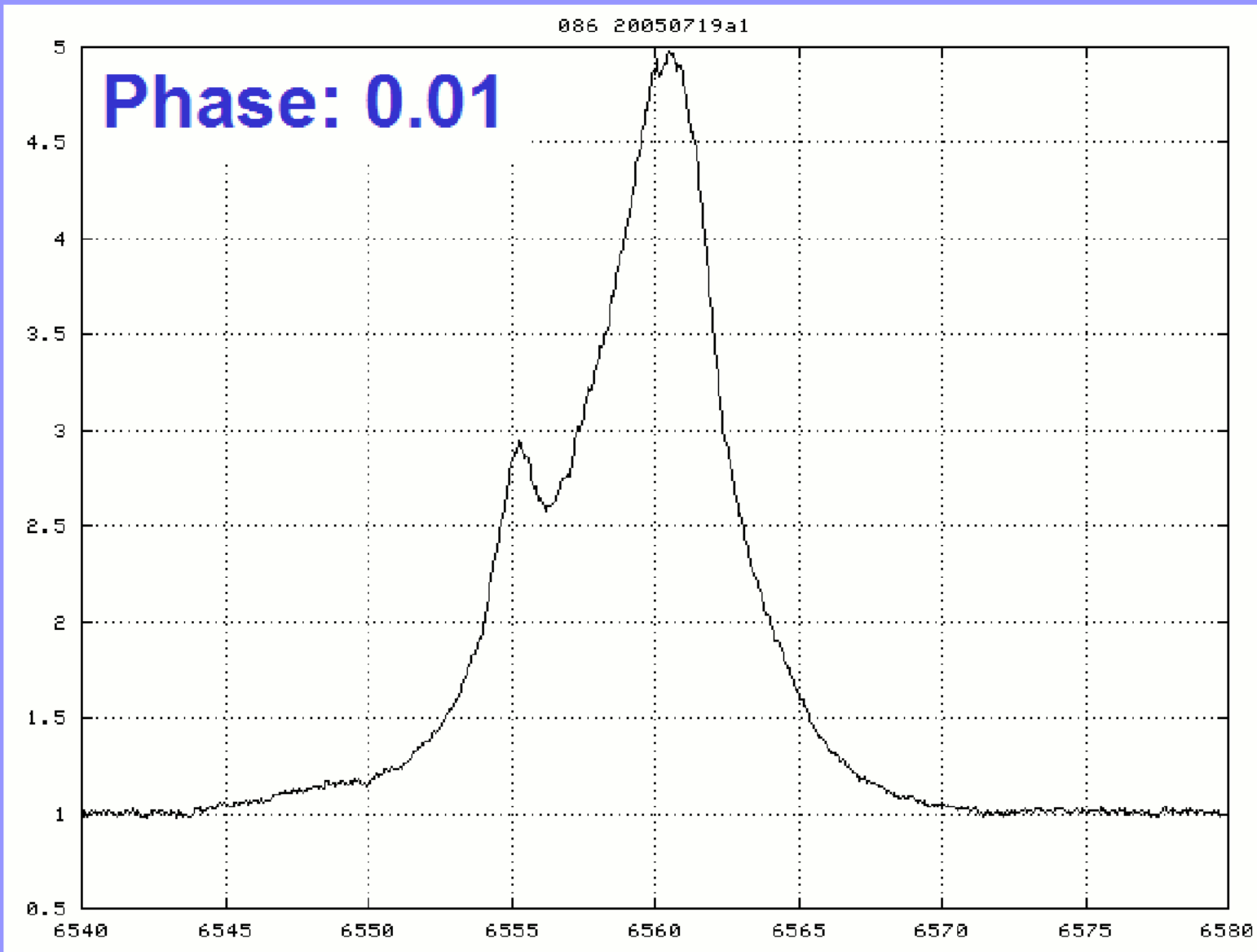
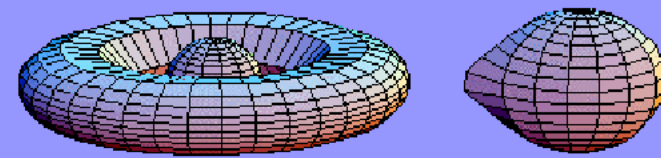


23 Tau

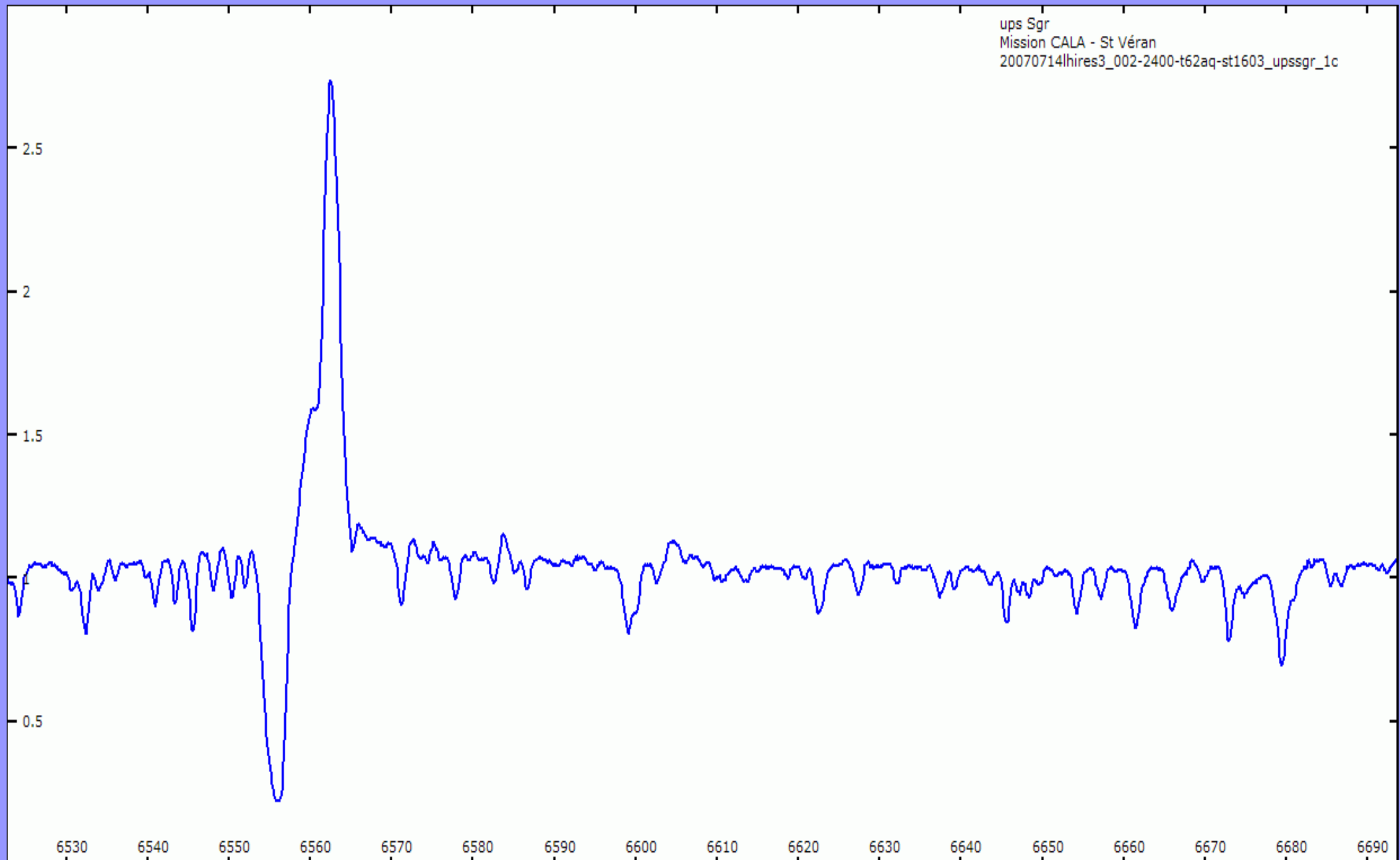


zet Tau

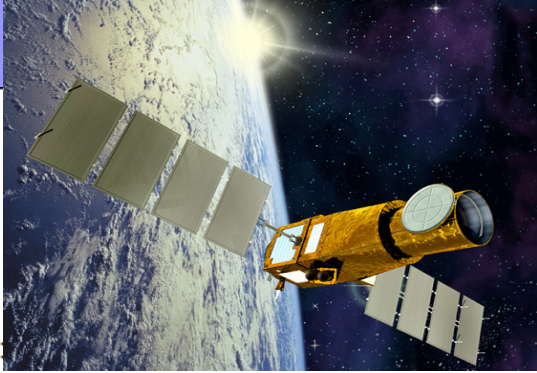
# H $\alpha$ - time evolution $\beta$ Lyr



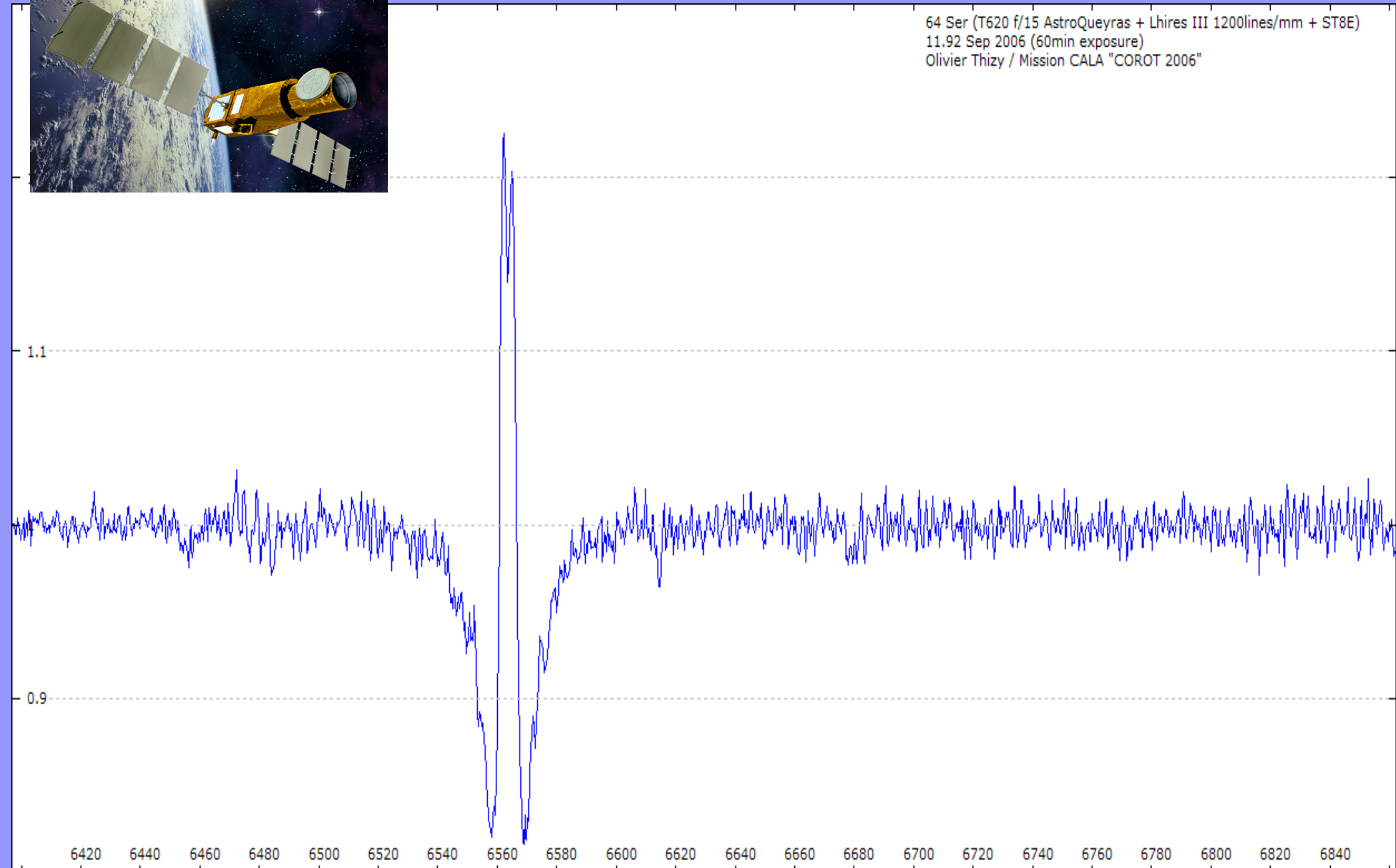
# Example of Be targets: $\upsilon$ Sgr



# COROT targets: 64 Ser

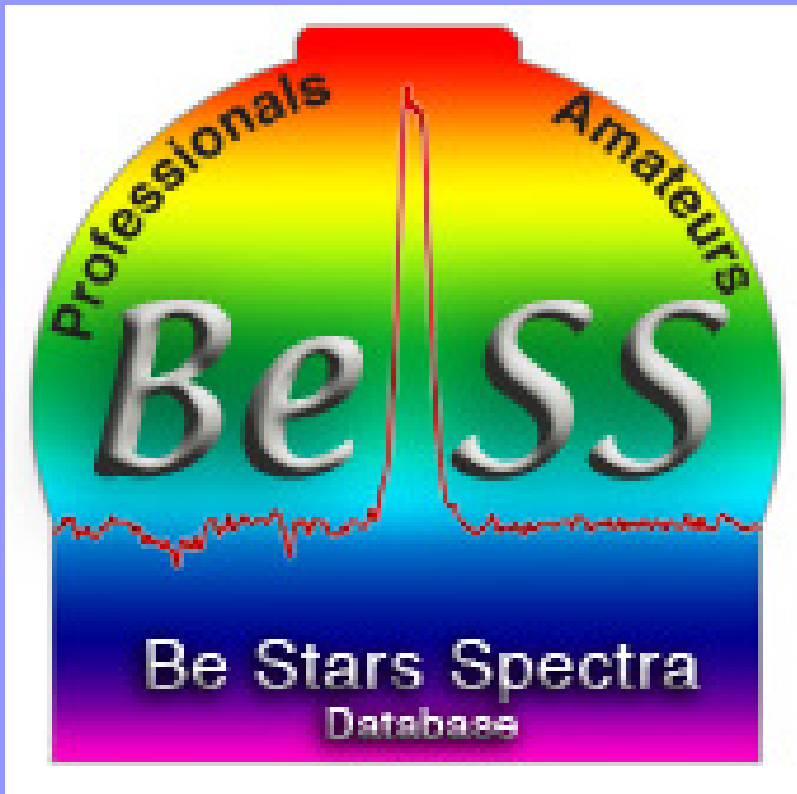


64 Ser (T620 f/15 AstroQueyras + Lhires III 1200lines/mm + ST8E)  
11.92 Sep 2006 (60min exposure)  
Olivier Thizy / Mission CALA "COROT 2006"





# BeSS database

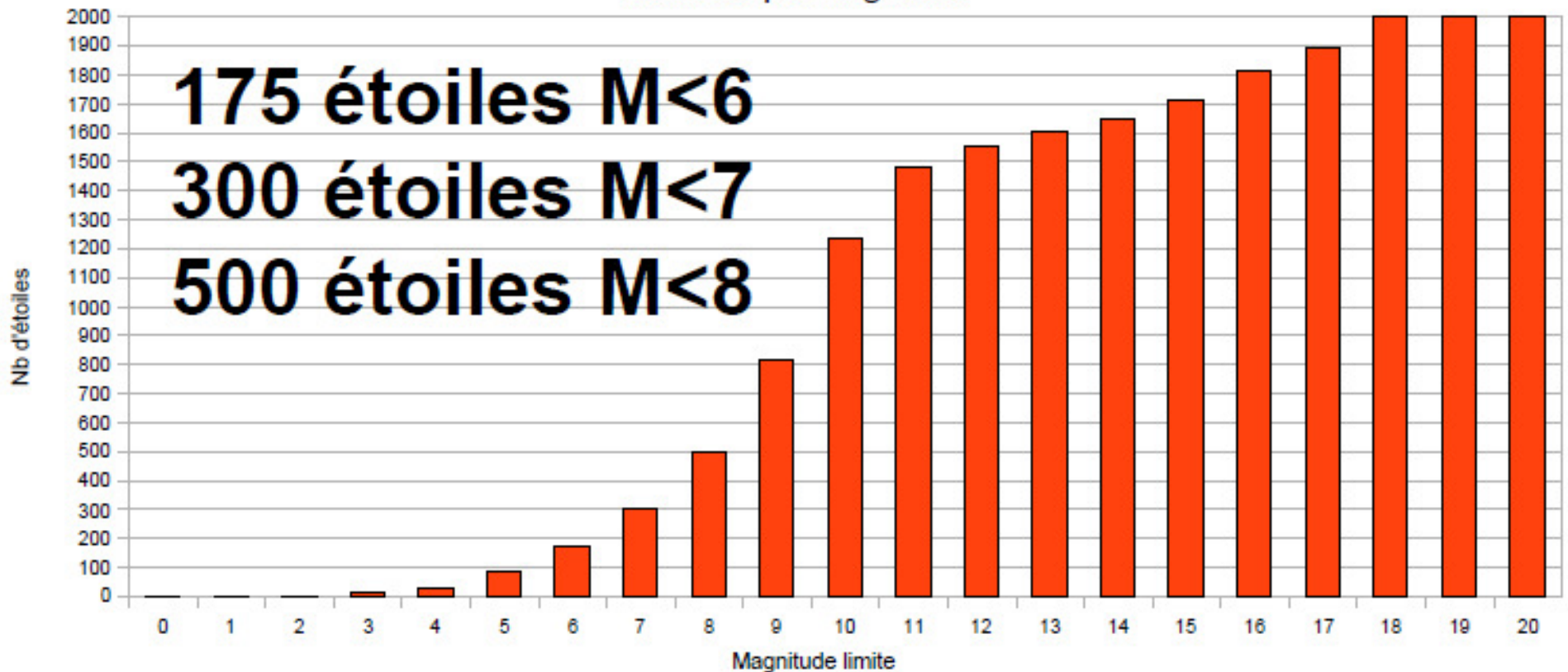
A screenshot of a web browser showing the registration page for the BeSS database. The browser's address bar shows the URL 'http://basebe.obspm.fr/basebe/PageV6/Accueil.php'. The page features a navigation menu on the left with options like 'Aide', 'Accueil', 'Requête', 'Verification', 'S'enregistrer', 'Listes', and 'Statistiques'. The main content area contains a registration form titled 'Formulaire OBSERVATEUR'. The form includes fields for 'Nom', 'Prénom', 'Adresse Electronique', 'Statut' (with a dropdown menu set to 'Amateur'), 'Adresse', 'Telephone', 'Nationalite', 'Photo', 'URL site WEB', 'Langue(s) pratiquée(s)', and 'Alias d'observateur'. There are also dropdown menus for 'Public' and 'Parcourir'. At the bottom of the form are buttons for 'Envoyer', 'Effacer', and 'Abandonner'. A note at the bottom states: '(\*) : Les champs marqués d'une \* sont obligatoires'.

URL: <http://basebe.obspm.fr>

# BeSS catalog

2026 étoiles Be

Nb de Be par magnitude



F. Cochard / V. Desnoux

- Plenty of BRIGHT stars to work on !!!

# BeSS database

## Top ten de tous les insomniaques Top ten des amateurs insomniaques Top ten des pros insomniaques

Spectres	Observateur
37180	Coralie Neiner
34940	Bertrand de Batz
31153	archive ELODIE
7823	Christian Buil
5292	Claude Catala
3978	Olivier Thizy
3015	Huib Henrichs
2650	Anne-Marie Hubert
2601	database INES
1876	Philippe Mathias

Spectres	Observateur
7823	Christian Buil
3978	Olivier Thizy
839	Joan Guarro Fló
575	Valerie Desnoux
467	Thierry GARREL
370	Michel Pujol
358	Ernst Pollmann
240	Benjamin MAUCLAIRE
176	José Ribeiro
169	Jean-Noël TERRY

Spectres	Observateur
37180	Coralie Neiner
34940	Bertrand de Batz
31153	archive ELODIE
5292	Claude Catala
3015	Huib Henrichs
2650	Anne-Marie Hubert
2601	database INES
1876	Philippe Mathias
1186	database GAUDI
871	Pascale Ehrenfreud

- >11000 amateur spectra from over 30 different users

# Equipment used

Type	
Lhires III	42
Pro	13
Other	6
eShel	5
<b>Total Résultat</b>	<b>66</b>



- Amateur telescope size: 12cm to 62cm
- Mainly Lhires spectrographs used by amateurs
- eShel echelle spectrograph is new but provides larger spectral coverage



# ArasBeAm “amateur” front end

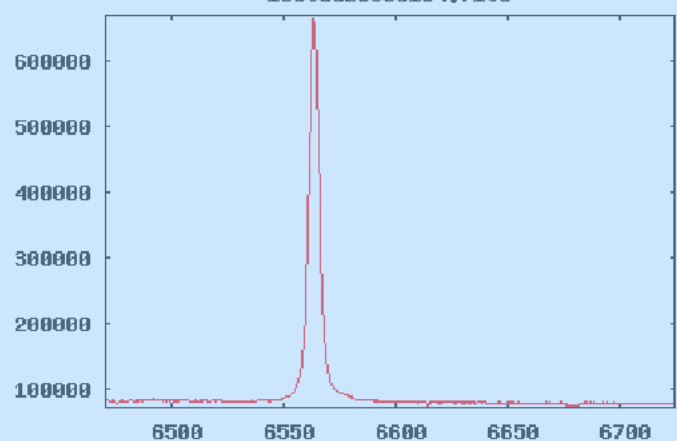
Spectras - Mozilla Firefox

http://arasbeam.free.fr/spip.php?page=lastspectres&lang=en

AGENDA nos LIENS Revel Caisse d'Epargne Crédit Agricole Yahoo! Groups Blog Famille AstroSurf Spectro Futura CloudyNight Simbad ADS Query Page Wikipedi

Observe the current Corot Be targets HD51193 & HD51452  
QR Vul  
Updated expected period for several stars  
2 BeSS Data  
Be list  
Last spectra in BeSS  
Spectrum of a Be star  
3 Links

**105tau20090104.fits**



Star : 105 Tau

Obs. date 2009-01-04 21:00:28

Instrument : NOU 16

Observation duration : 1531 s.

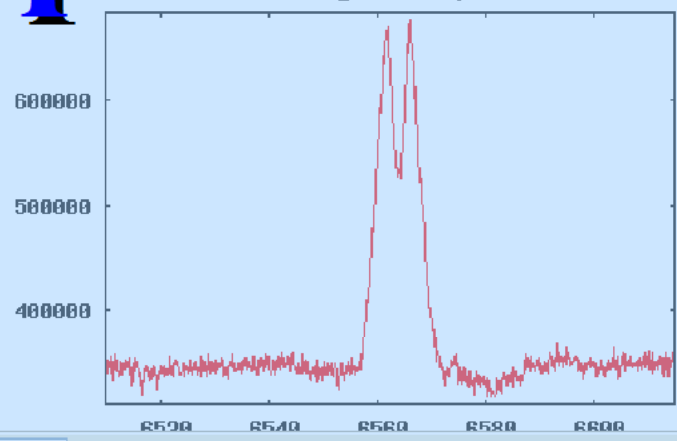
Resolution : 6000

Observation site : PIERA

Observer : Joan Guarro Fló

Wavelength range : 6470.89 - 6711.54 ang.

**oneur1\_20090110.fits**



Star : oneur1

Obs. date 2008-01-10 20:54:44

Instrument : STC 254 LHIRES#129 Sbig ST8

Observation duration : 2878 s.

Resolution : 0

Observation site : Observatoire du Pilat

Observer : Jean-Noël TERRY

Rechercher : qr

Terminé

# http://arasbeam.free.fr

# ARAS BeAm « to do » list

Resultats - Mozilla Firefox

Fichier Édition Affichage Historique Marque-pages Outils ?

http://arasbeam.free.fr/spip.php?page=listebe&lang=en

AGENDA nos LIENS Revel Caisse d'Épargne Crédit Agricole Yahoo! Groups Blog Famille AstroSurf Spectro Futura CloudyNight Simbad ADS Query Page Wikiped

QR Vul  
Updated expected period for several stars  
2 BeSS Data  
Be list  
Last spectra in BeSS  
Spectrum of a Be star  
3 Links

**List of Be stars with Magn lower than 6**  
**Limit Declination : -25**

105 objects

Star	HD #	RA	DEC	Magn.	Tot. nb	1 year	2 months	Last	Obs Period
<input type="checkbox"/> + <input type="checkbox"/> -	<input type="checkbox"/> + <input type="checkbox"/> -	<input type="checkbox"/> + <input type="checkbox"/> -	<input type="checkbox"/> + <input type="checkbox"/> -	<input type="checkbox"/> + <input type="checkbox"/> -	<input type="checkbox"/> + <input type="checkbox"/> -	<input type="checkbox"/> + <input type="checkbox"/> -	<input type="checkbox"/> + <input type="checkbox"/> -	<input type="checkbox"/> + <input type="checkbox"/> -	<input type="checkbox"/> + <input type="checkbox"/> -
del Sco	143275	+16 00 20.0	-22 37 18.2	2.29	141	89	0	2008-08-30 19:30:41	7
zet Tau	37202	+05 37 38.7	+21 08 33.2	3.03	343	43	9	2009-01-15 17:07:19	60
14 Lac	216200	+22 50 21.8	+41 57 12.2	5.93	178	40	1	2008-11-22 20:33:19	90
QR Vul	192685	+20 15 15.9	+25 35 31.0	4.76	1890	28	3	2008-12-07 17:25:36	5
ups Sgr	181615	+19 21 43.6	-15 57 17.7	4.58	76	27	0	2008-10-26 18:06:47	15
pi Aqr	212571	+22 25 16.6	+01 22 38.6	4.79	99	25	0	2008-11-06 19:50:00	60
4 Aql	173370	+18 44 49.9	+02 03 36.1	5.01	129	22	0	2008-09-27 18:47:35	365
12 Vul	187811	+19 51 04.1	+22 36 36.2	4.89	33	22	0	2008-08-09 20:41:15	365
31 Peg	212076	+22 21 31.1	+12 12 18.7	4.81	168	22	1	2009-01-07 18:29:07	30
phi Per	10516	+01 43 39.6	+50 41 19.4	4.09	195	22	1	2008-11-22 23:07:54	90
zet Oph	149757	+16 37 09.5	-10 34 01.5	2.58	811	22	0	2008-07-26 20:22:14	365
bet Psc	217891	+23 03 52.6	+03 49 12.2	4.49	304	22	0	2008-11-06 20:56:54	365
tet Ari	14191	+02 18 07.5	+19 54 04.2	5.58	89	21	0	2008-11-14 21:22:34	365
lam Cyg	198183	+20 47 24.5	+36 29 26.6	4.56	164	21	4	2008-12-21 19:20:57	15
16 Peg	208057	+21 53 03.8	+25 55 30.5	5.08	166	21	1	2008-12-02 18:19:11	365
eps Cap	205637	+21 37 04.8	-19 27 57.6	4.50	48	21	0	2008-08-30 21:59:13	365
8 Lac A	214167	+22 35 52.3	+39 38 03.6	5.73	89	21	1	2008-11-26 20:26:32	365
gam Cas	5394	+00 56 42.5	+60 43 00.3	2.39	2727	20	2	2009-01-15 18:30:45	180

Terminé

# ArasBeAm: detecting outburst

Spectras - Mozilla Firefox

Echier Édition Affichage Historique Marque-pages Outils ?

http://arasbeam.free.fr/spip.php?page=spectres&etoile=169&lang=en

AGENDA nos LIENS Revel Caisse d'Épargne Crédit Agricole Yahoo! Groups Blog Famille AstroSurf Spectro Futura CloudyNight Simbad ADS Query Page Wikip

lan\_eri20090104.fits

600000  
580000  
560000  
540000  
520000  
500000

6500 6550 6600 6650 6700  
Angstrom

Obs. date : 2009-01-04 21:35:59

Instrument : NOU 16

Observation duration : 1531 s.

Resolution : 6000

Observation site : PIERA

Observer : Joan Guarro Fló

Wavelength range : 6470.14 - 6729.08 ang

# 37790

lan\_eri20080223.fit

36000  
34000  
32000  
30000  
28000

6500 6550 6600 6650 6700  
Angstrom

Obs. date : 2008-02-23 20:05:16

Instrument : NEWTON 254 - LHIRES-B12t - AUDINE 403

Observation duration : 4496 s.

Resolution : 7000

Observation site : STA. MARIA DE MONTMAGASTRELL

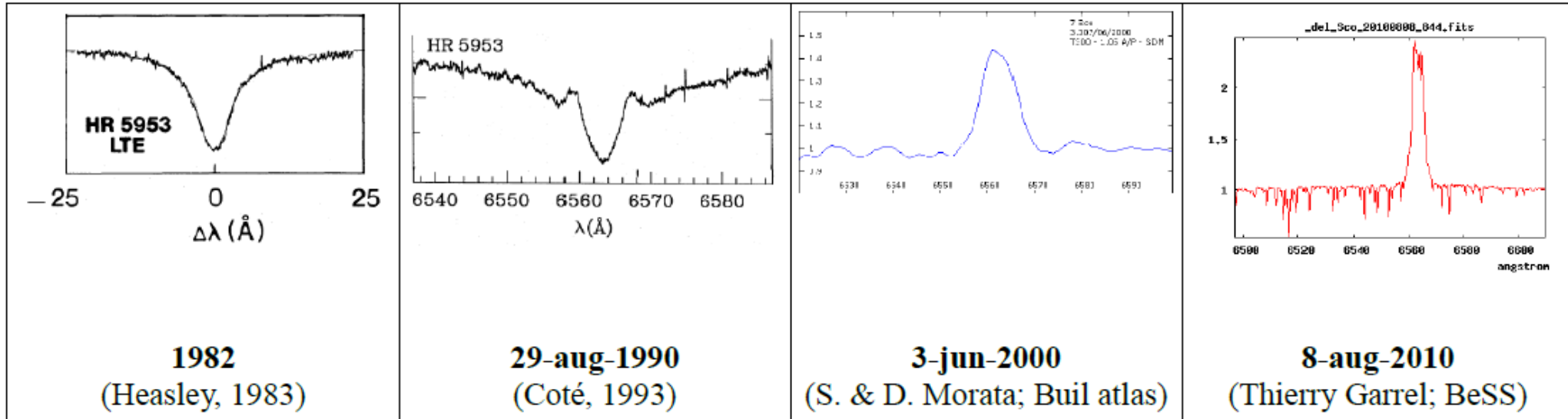
Observer : Joan Guarro Fló

Wavelength range : 6482.04 - 6715.96 ang

several outbursts discovered

Terminé

# delta Sco : 2011 periastron !!!

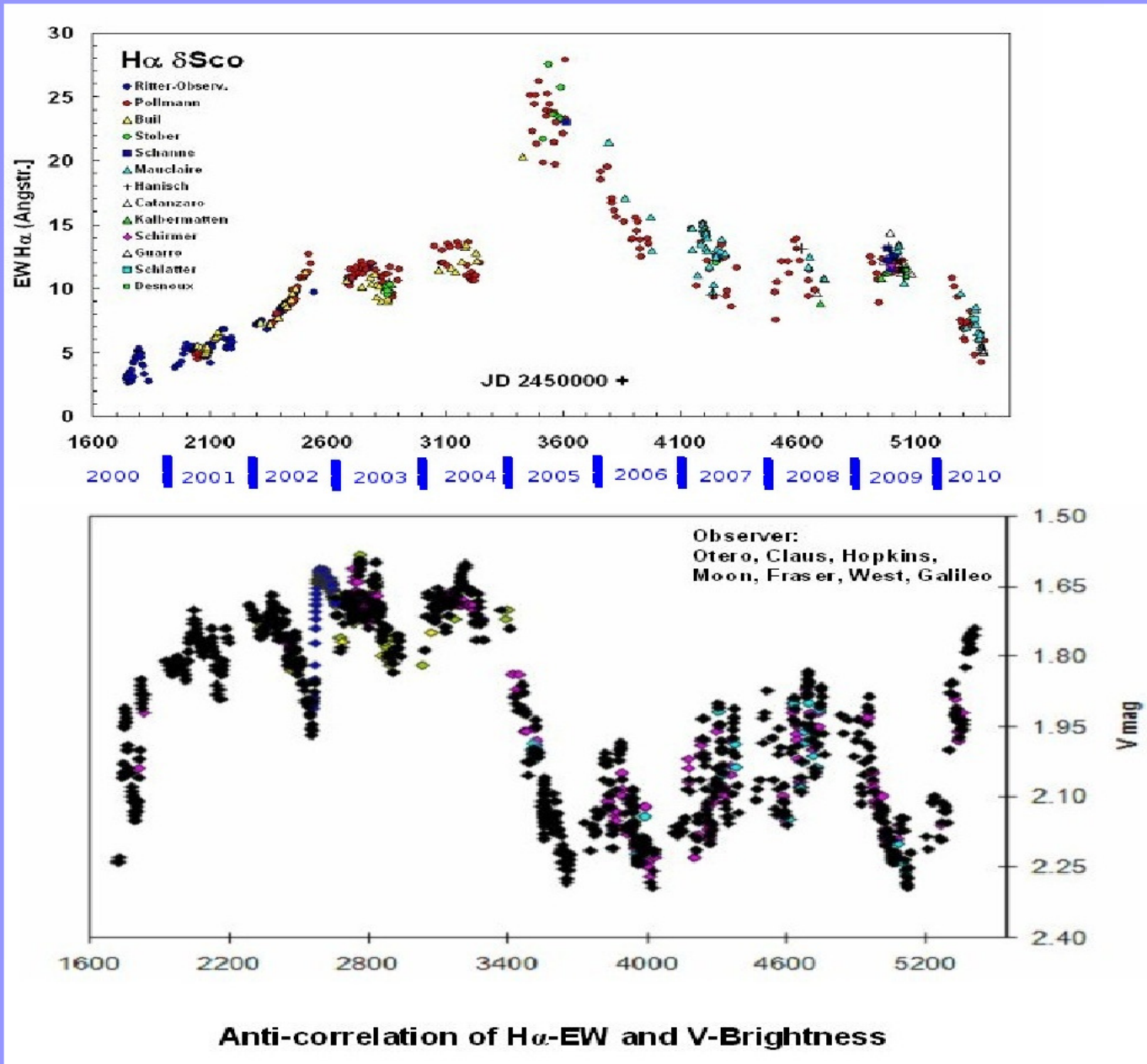


*snapshots of delta Sco spectrum (H-alpha) through the years...*

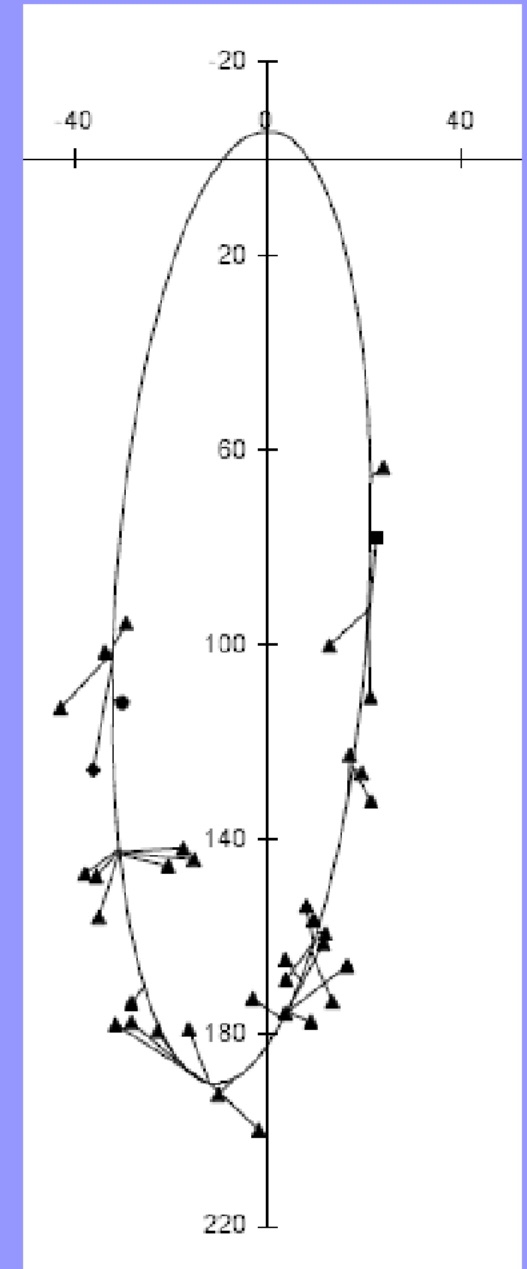
- Be stars identified as such in 1993
- Outburst in 2000 with sudden increase of visual brightness



# delta Sco : 2011 periastron !!!

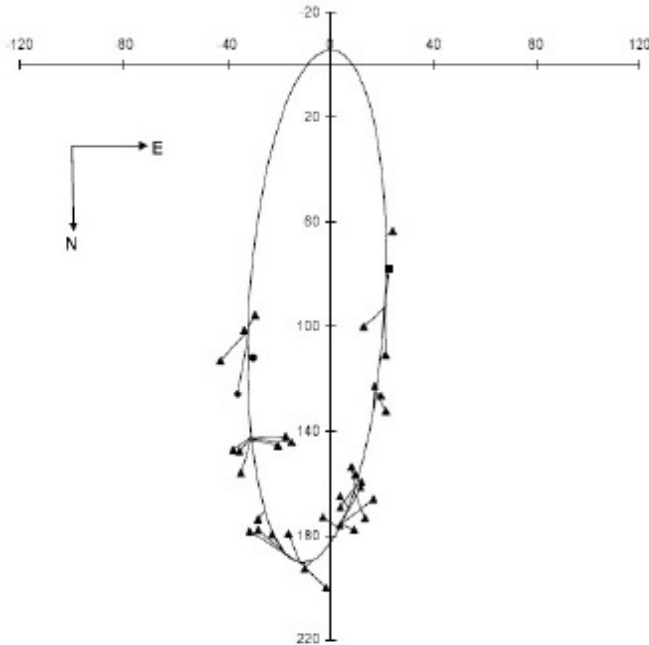


Ernst Pollmann



Tango et al. 2009

# delta Sco : 2011 periastron !!!



The orbital elements for  $\delta$  Sco

Element	Ref. <i>a</i>	Ref. <i>b</i>	This Work
Period $P$ (yr)	$10.58 \pm 0.08$	$10.58^c$	$10.74 \pm 0.02$
Epoch of periastron $T$	$B1971.41 \pm 0.14$	$J2000.693 \pm 0.008$	$J2000.69389 \pm 0.00007$
Eccentricity $e$	$0.92 \pm 0.02$	$0.94 \pm 0.01$	$0.9401 \pm 0.0002$
Semimajor axis (mas) $a''$	$107 \pm 7$	$107^c$	$98.3 \pm 1.2$
Inclination $i$	$48^\circ 5 \pm 6^\circ 6$	$38^\circ \pm 5^\circ$	$38^\circ \pm 6^\circ$
Long. periastron $\omega$	$24^\circ \pm 13^\circ$	$-1^\circ \pm 5^\circ$	$1^\circ 9 \pm 0^\circ 1$
Long. of asc. node $\Omega$	$159^\circ 3 \pm 7^\circ 6$	$175^\circ$	$175^\circ 2 \pm 0^\circ 6$
Systemic RV $V_\gamma$ ( $\text{km}\cdot\text{s}^{-1}$ )		$-6 \pm 0.5$	$-6.72 \pm 0.05$
RV amplitude $K_A$ ( $\text{km}\cdot\text{s}^{-1}$ )			$23.84 \pm 0.05$
Semimajor axis of primary $a_A$ (km)			$(7.1 \pm 0.1) \times 10^8$
Mass function $M_B^3 / (M_A + M_B)^2$ ( $M_\odot$ )			$0.9 \pm 0.4$

Ref. *a* [Hartkopf et al. \(1996\)](#)

Ref. *b* [Miroshnichenko et al. \(2001\)](#)

<sup>c</sup> Value assumed from Ref. *a*

*interferometric orbit for delta Sco and orbital elements (Tango et al., 2009)*

Recent interferometric observations (Tango et al., 2009) led to new orbital elements and masses estimation:  $M_1 = 15 \pm 7 M_\odot$  and  $M_2 = 8.0 \pm 3.6 M_\odot$

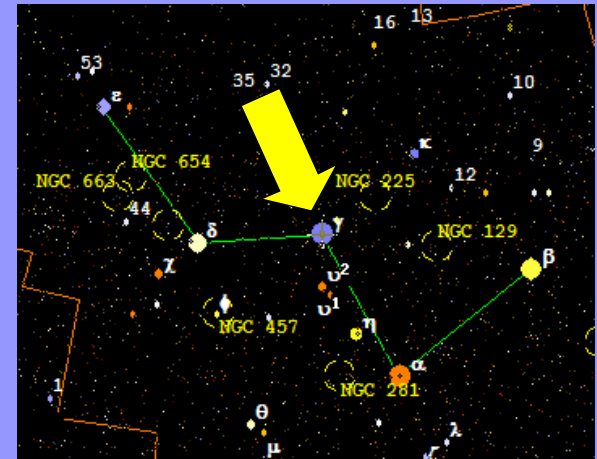
# delta Sco : 2011 periastron !!!

- Exact periastron date unknown (around beginning of July 2011)
- Radial Velocity will change drastically few weeks before
- Monitoring of H alpha is key
- Monitoring of He I 6678 is very interesting too

**==> amateur Spectroscopy  
is required !!!**

# Telegram... from this morning !

----- Message original -----  
**Sujet:** [spectro-l] gamma Cas [1 Attachment]  
**Date :** 15 Apr 2011 08:09 GMT  
**De :** Ernst Pollmann <ernst-pollmann@t-online.de>  
**Répondre à :** spectro-l@yahoogroups.com  
**Pour :** Gruppe ARAS <spectro-l@yahoogroups.com>



Dear colleagues !

Myron Smith, Computer Sciences Corporation, Space Telescope Science Institute and my mentor in issues of gamma Cas, is asking for Halpha-EW observations during the coming observation season.

He and his colleague Greg Henry are very interested in correlation between Halpha-EW and photometric brightness within the UBV-system. Meanwhile they monitored the star in this way for 13 years (see fig. 3).

Actually, I gave him the attached compiling plots (fig. 1 & 2) of Halpha EW and visual brightness observations of my colleagues in Hungaria and Germany.





It would be great, if interested observers could measure the Halpha EW for the coming months of visibility.

Ernst Pollmann

-----  
Active Spectroscopy in Astronomy  
<http://www.astrospectroscopy.de>






**==> mag 2 star !**



Spectrograph	Star Analyser	LISA	Lhires III	eShel
				
Resolving Power	R ~ 100	R ~ 1000	R ~ 600 – 17000	R ~ 11000

Solar System				
Earth atmosphere		Aurora spectra.	150: Aurora spectra.	
Meteors	Meteor spectra: how useful ???			
Moon		Geology changes during impact.	150: Geology changes during impact.	
Planet atmosphere		Spectra of atmospheric features (near IR ?)		
Comets		Composition, classification.	150-300: Composition, classification.	Bright comets ?
Asteroids		Classification.		

Binaries				
Spectroscopic binaries			2400: bright binaries period/orbit follow up	Binaries period and orbital elements improvements.
Exoplanets				Orbital elements follow up. Discoveries around A-type stars?

Variable Stars				
 <b>Be Stars</b>		Monitoring, outburst detection, Survey/Discovery, classification.	2400: pulsations (hours) ? 1200-2400: Line profile changes (days/years) 150-600: Monitoring, outburst detection, Survey/Discovery, classification.	Line profile changes (days/years).
 <b>Binary Be Stars:</b> <i>delta Sco, VV Cep, zeta Tau, ups Sgr...</i>		Monitoring, Outburst detection.	1200-2400: RV measurement (ex: delta Sco) 1200-2400: Line profile changes: delta Sco, zeta Tau...	RV measurement (ex: delta Sco) Line profile changes: delta Sco, zeta Tau...
<b>Herbig Ae/Be</b>			1200: spectral changes in few hours. 300-600: changes over the years / outburst	Changes over the years / outburst
<b>LBV (P Cygni)</b>			1200-2400: line profile changes (years)	Line profile changes (years)
<b>Active hot stars (Rigel, Deneb...)</b>			1200-2400: line profile changes (years ?)	Line profile changes (years ?)
<b>Wolf-Rayet</b>		Classification.	1200-2400: line profile changes (years ?) 150-300: classification	
 <b>Binary Wolf-Rayet:</b> <i>WR 140...</i>			1200-2400: periastron studies	Periastron studies; orbital elements; spectral changes.
 <b>epsilon Aurigae (every 27 years !)</b>			2400: line profile change, KI line change (modified Lhires III)... eclipse follow up.	Line profile changes.
 <b>Cataclysmic variables</b>	Outburst monitoring	Initial classification, monitoring. Line profile changes. Expansion speed.	1200: Line profile changes at initial stage. Expansion speed. 150-600: Initial classification, monitoring.	Line profile changes at initial stage. Expansion speed measurement.
<b>Novae</b>	Initial classification, monitoring	Initial classification, monitoring. Line profile changes. Expansion speed.	1200: Line profile changes at initial stage. Expansion speed. 150-600: Initial classification, monitoring.	Line profile changes at initial stage. Expansion speed measurement.
<b>Mira</b>		Monitoring during all period.	1200: at maximum brightness. 150: follow up. during (almost) all period.	At maximum brightness.
<b>Pulsating stars (RR Lyrae, BW Vul, SPB...)</b>			600-1200: RV of absorption lines.	RV changes of absorption lines.
<b>Supernovae</b>	Initial classification (SN type)	Initial classification (SN type)		

# in summary...

- Spectroscopy reveal hidden details from the stars
- Equipment is available off-the-shelf
- Educational projects are numerous and fun
- Pro/Am collaboration is increasing  
*with more amateur contributing  
with more professionals requesting support*

**==> join us !!!**





# Some books...



More on [www.Shelyak.com](http://www.Shelyak.com) (bibliography)

# Some useful links

Groupe ARAS: <http://www.astrosurf.com/aras/>

Liste Spectro-L: <http://groups.yahoo.com/group/spectro-l/>

SAS: <http://www.socastrosci.org/>

CDS Strasbourg <http://cdsweb.u-strasbg.fr/>

ADS (articles) [http://adsabs.harvard.edu/abstract\\_service.html](http://adsabs.harvard.edu/abstract_service.html)

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



Stars won't  
look the same ◊

**Thank You !!!**



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