Small Telescope Spectroscopy

– NEAIC –
18 april 2013

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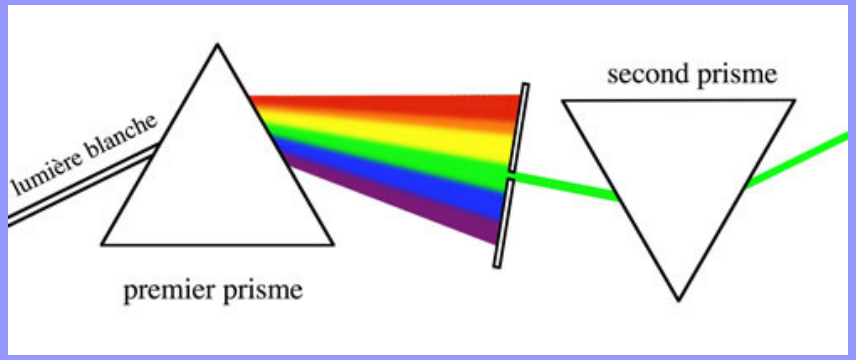
my “friend” Isaac Newton

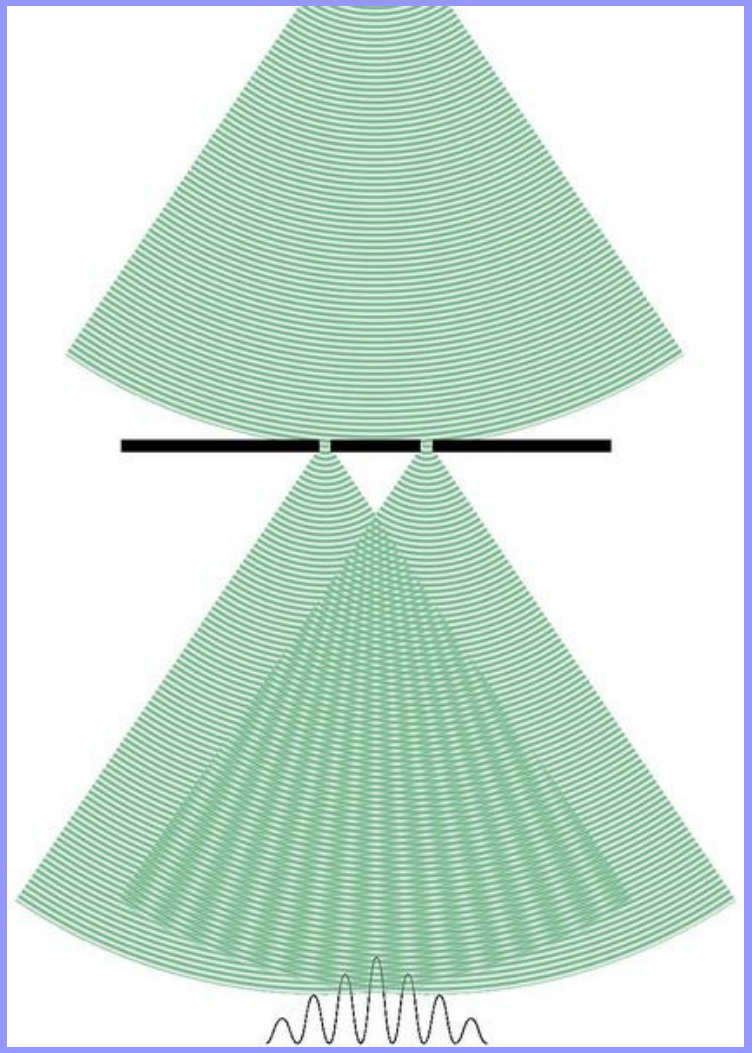
Isaac Newton (1642-1726) ; Mme Tussaud museum / London

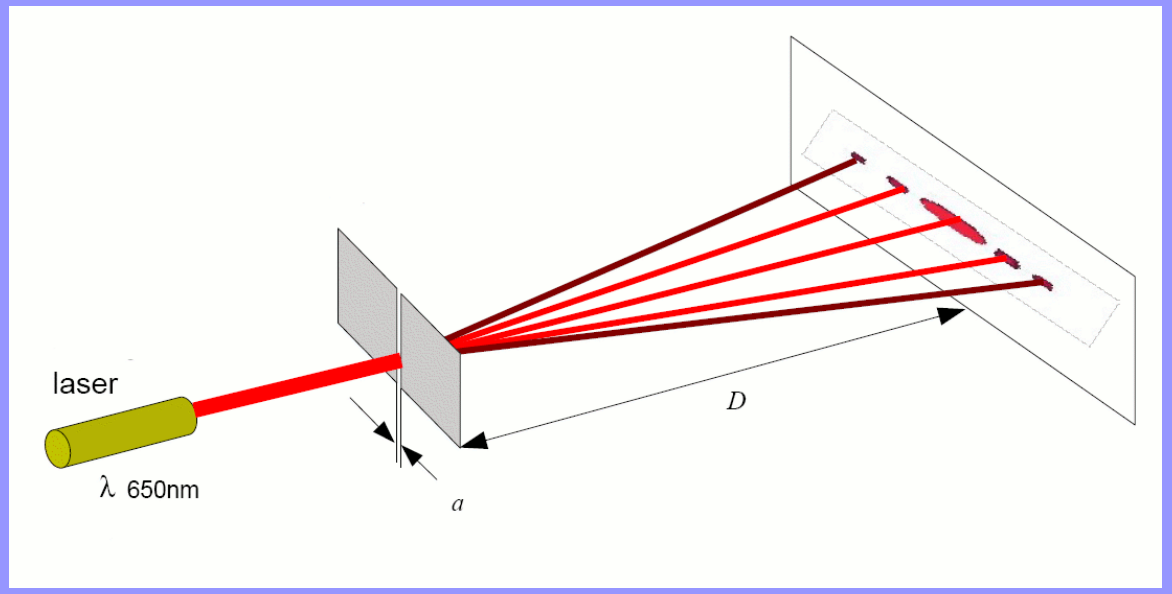
Light & Colors

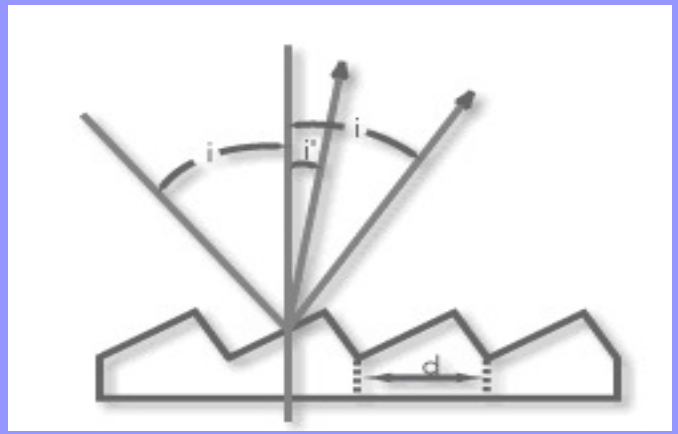


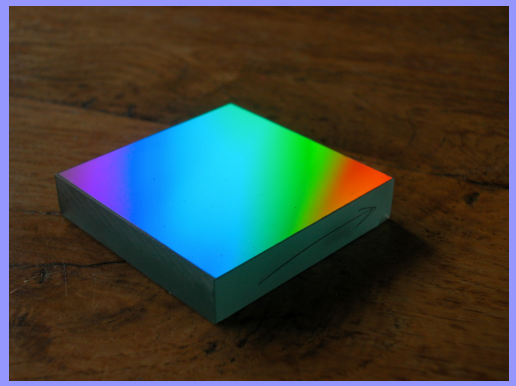
- **Isaac Newton : a pionneer**
- **1670: experience with a prism**
- **Circular “slit” ~6mm: $\lambda/\Delta\lambda$ ~10 !**

Light is a wave



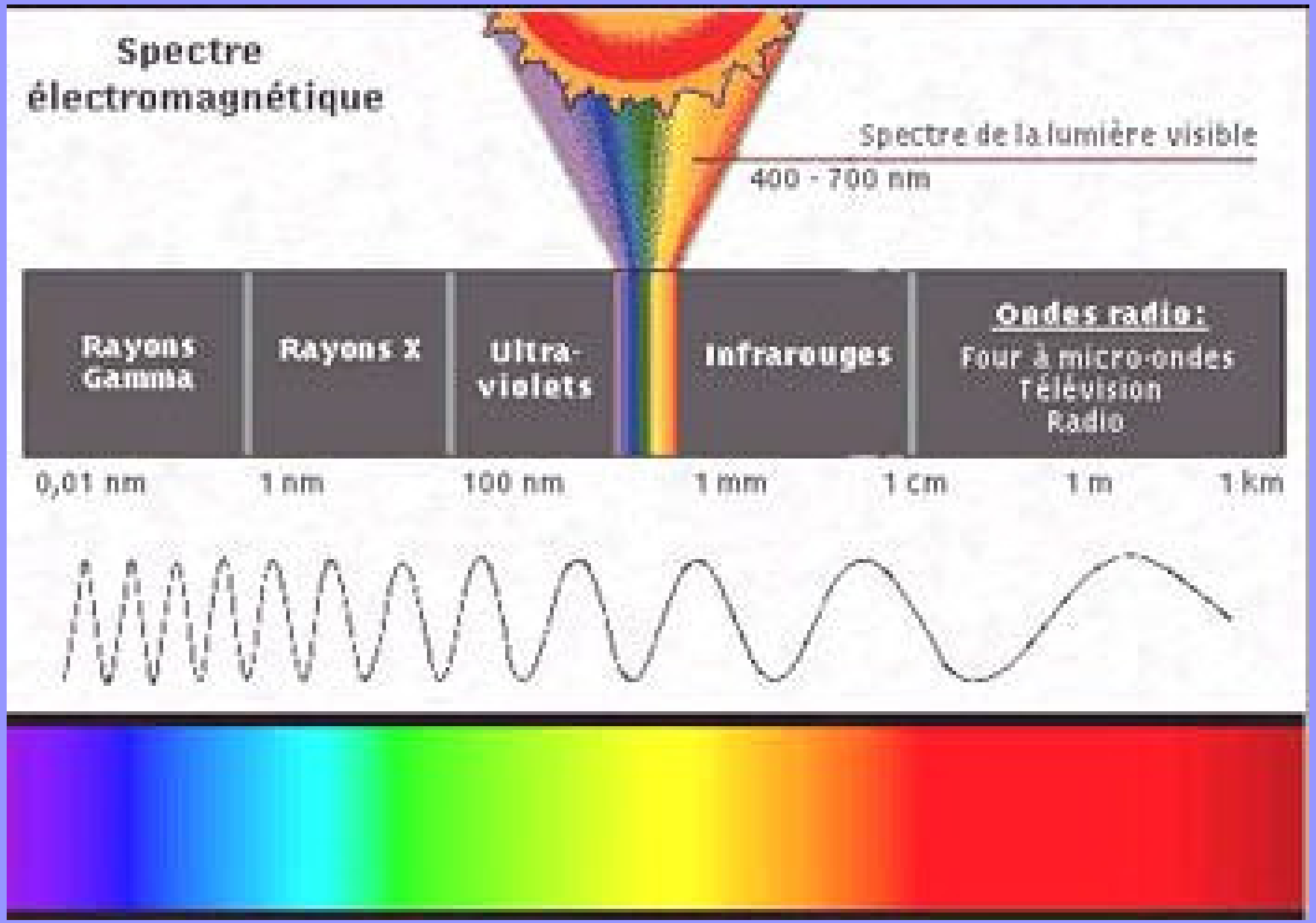




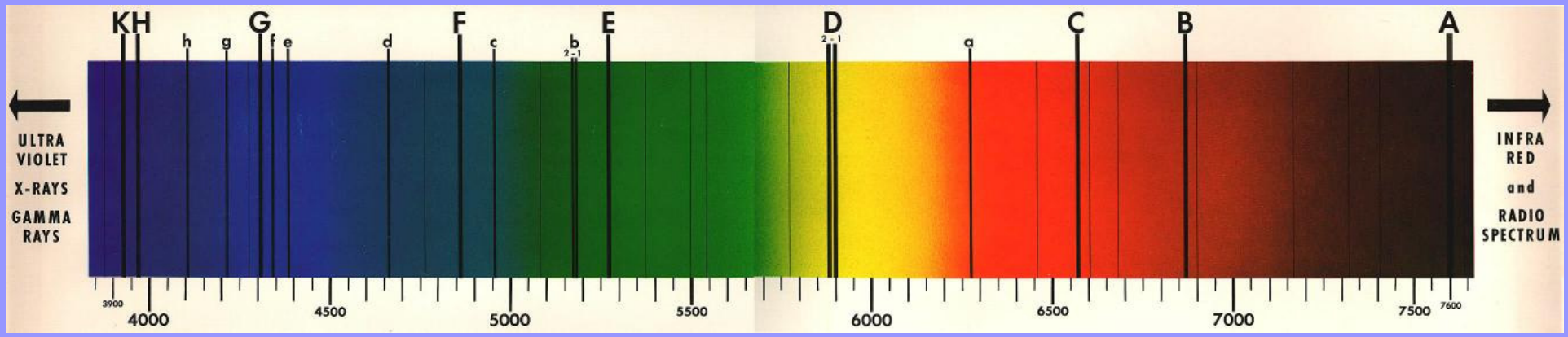


- **Thomas Young (1773-1829)**
  - **Wave interpretation of light (1801)**
  - **Worked with grating with 20 grooves/mm**

Electromagnetic spectrum



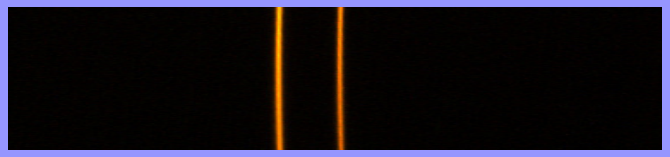
Solar spectrum



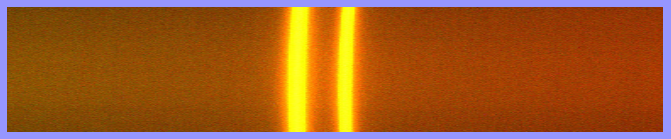
- **William Wollaston (1766-1828)**
  - **~150 years after Newton !**
  - **First observation (in 1802) of dark lines**
  - **Demonstrated the importance of the slit width**
- **Joseph Fraunhofer (1787-1826)**
  - **Manufacturer of high quality glasses**
  - **A, B (Hα), C, D (sodium doublet)... H, K (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 !

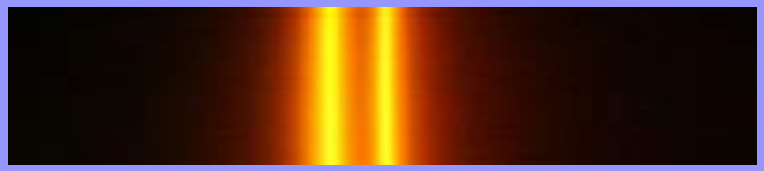
Salt



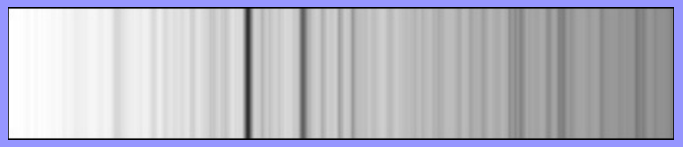
Match



Pickel !

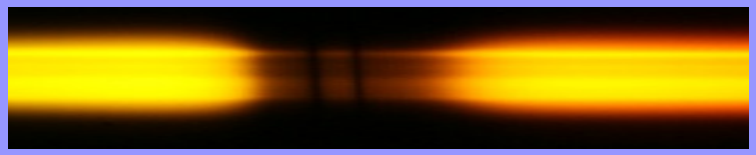


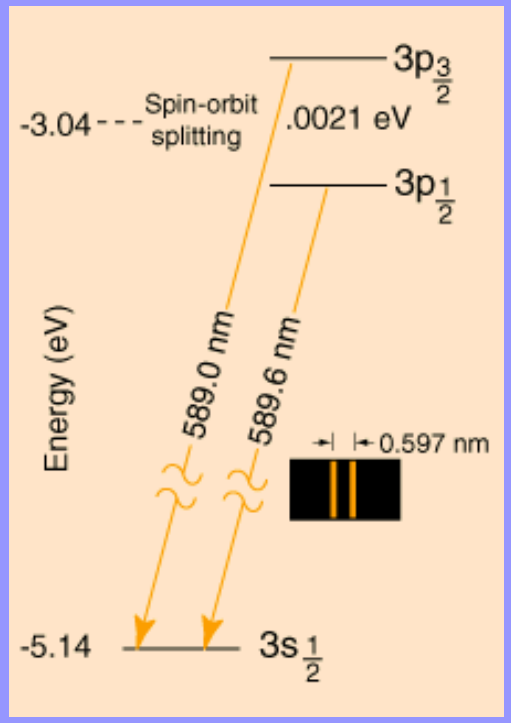
Sirius



Sun

Street lamp



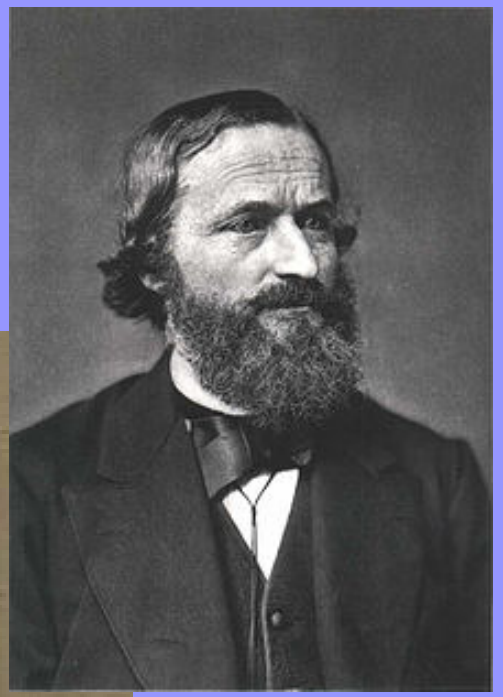


Chemical analysis & spectroscopy

- **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 theoritical 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 !



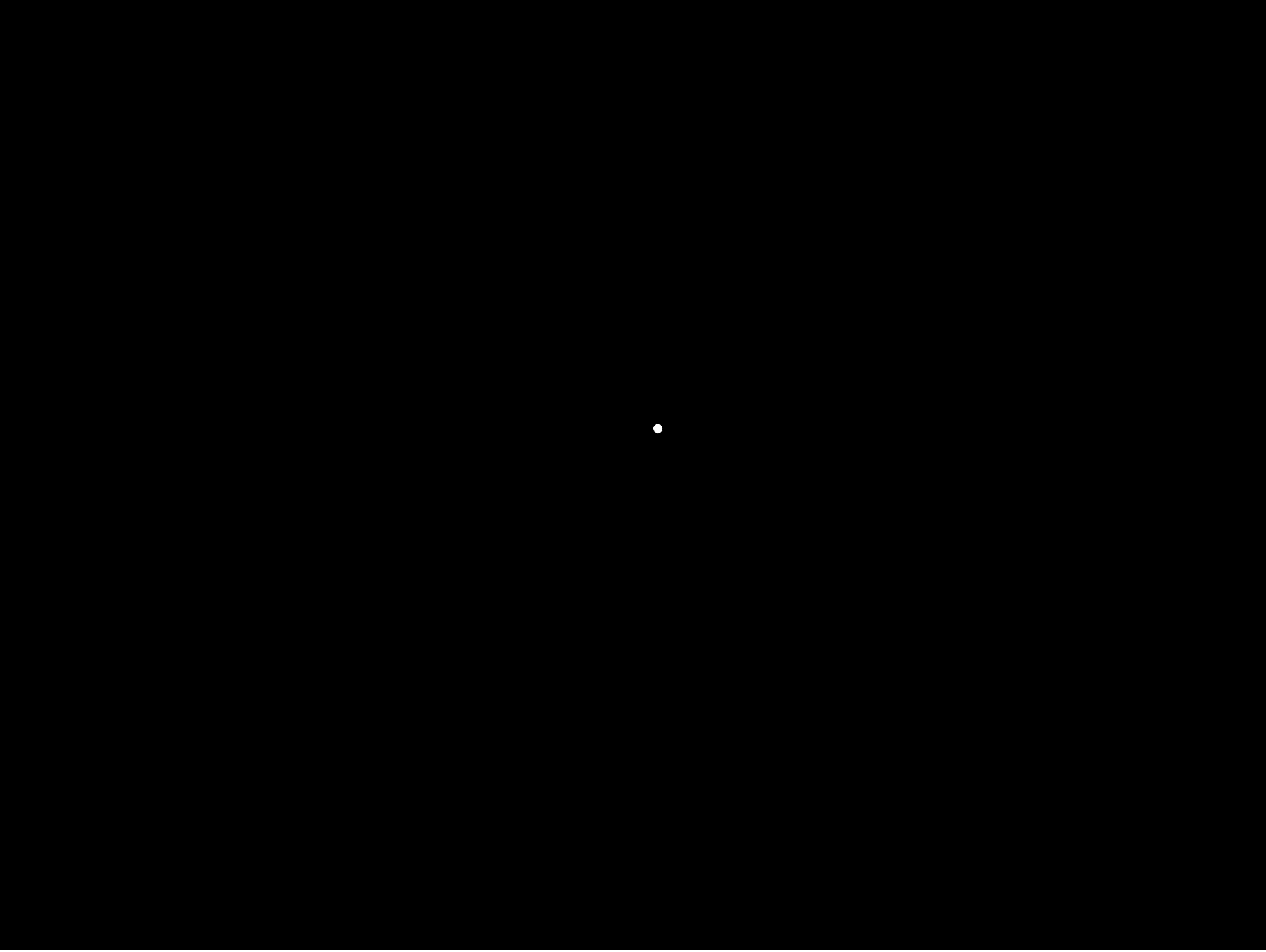
Photos : Wikipedia / O. Thizy

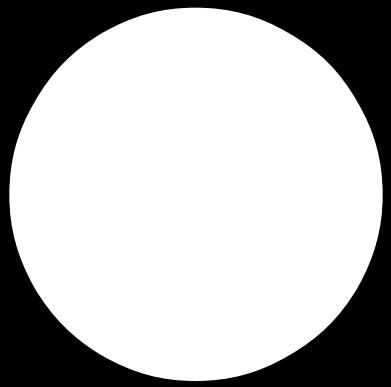
Let's play with a grating...

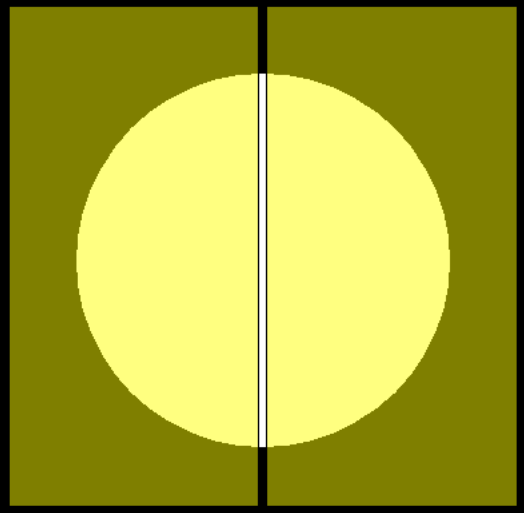
Images : C. Buil / O. Thizy

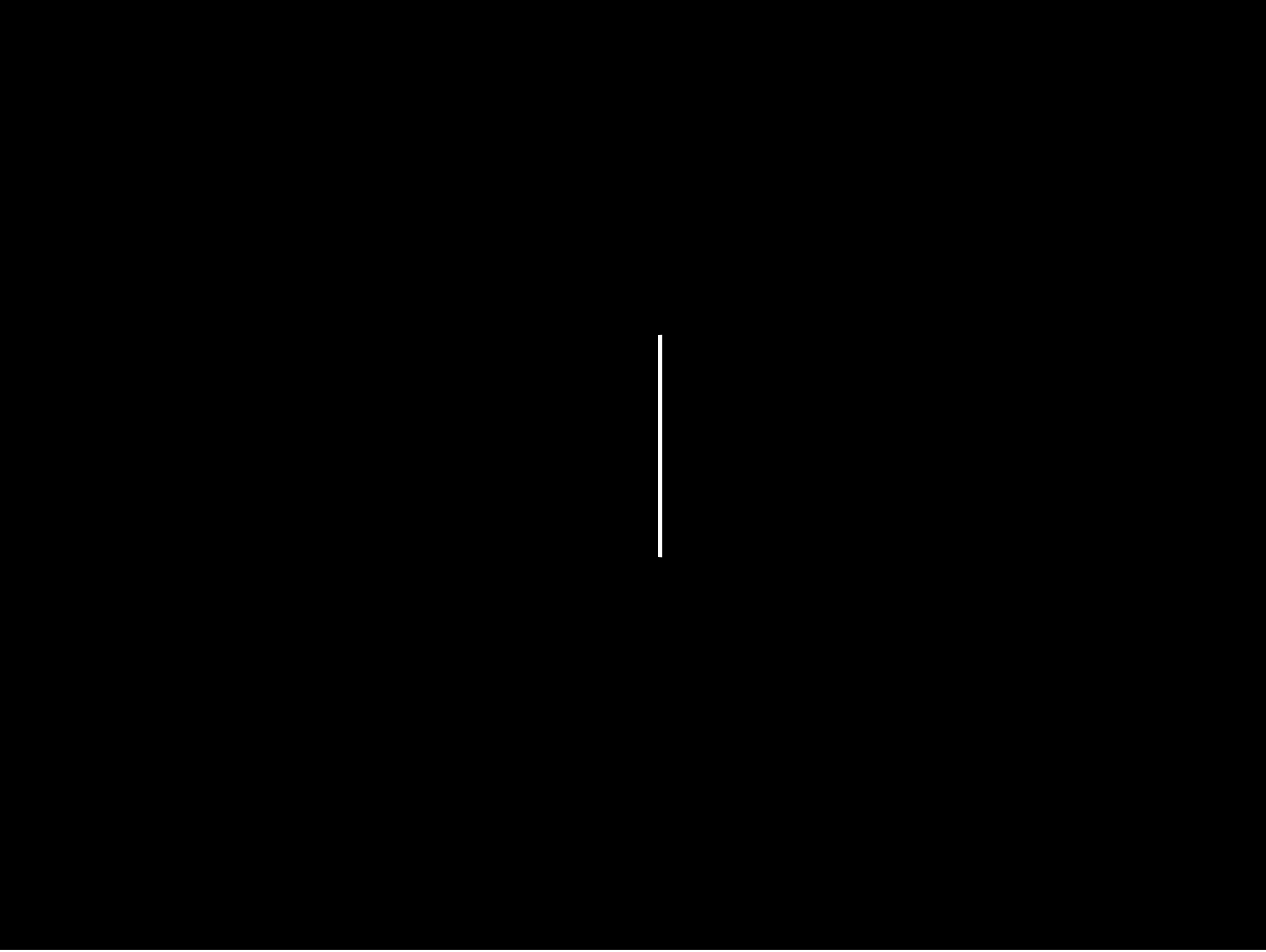
Star Analyser, the simplest (astro) spectroscope (R ~100)

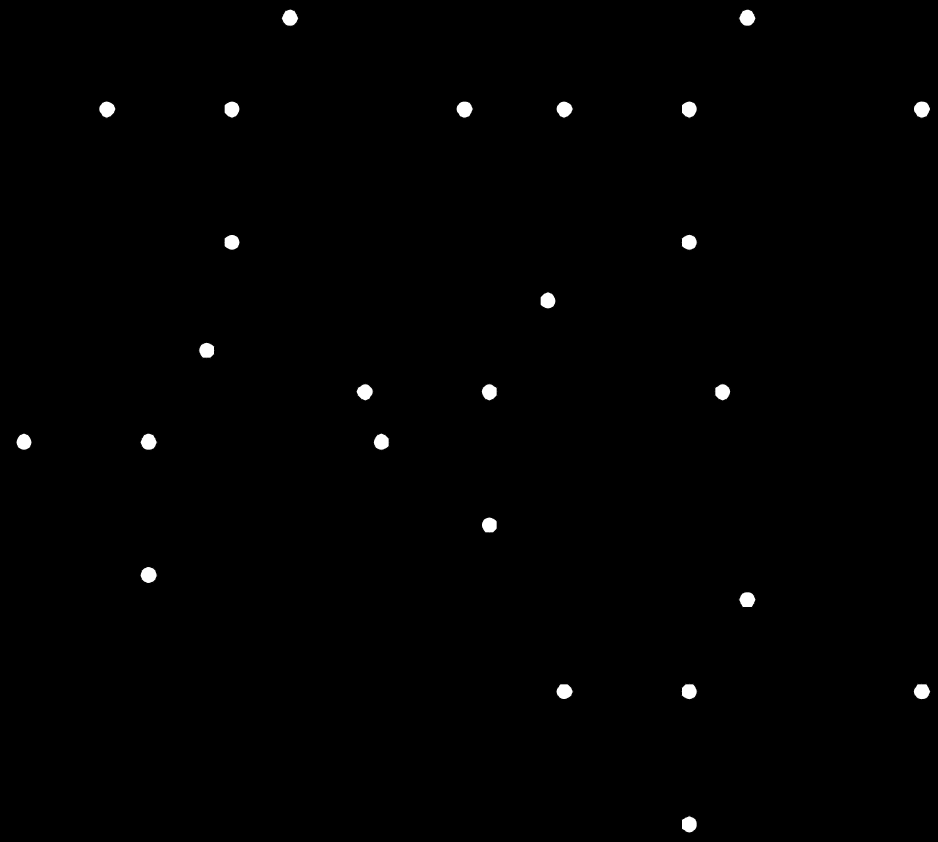
Converging beam from telescope









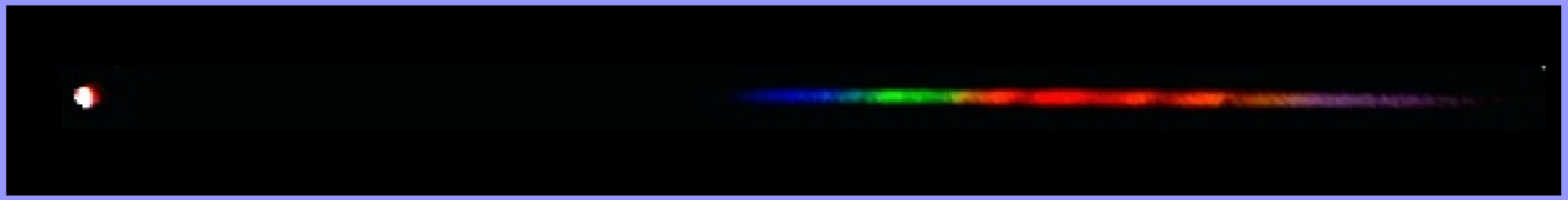


Multiple way to setup

Like a filter
(webcam)

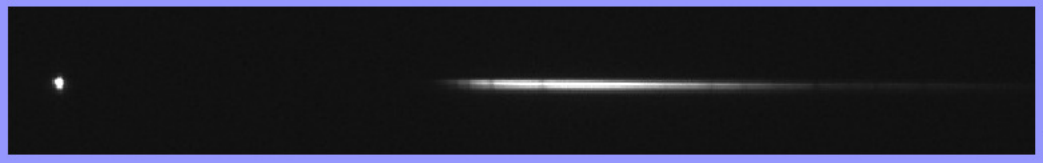
Like a filter
(CCD camera)

In front of a lens



(R.Leadbeater)

CCD vs APN ?



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

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

4-steps astronomical spectroscopy

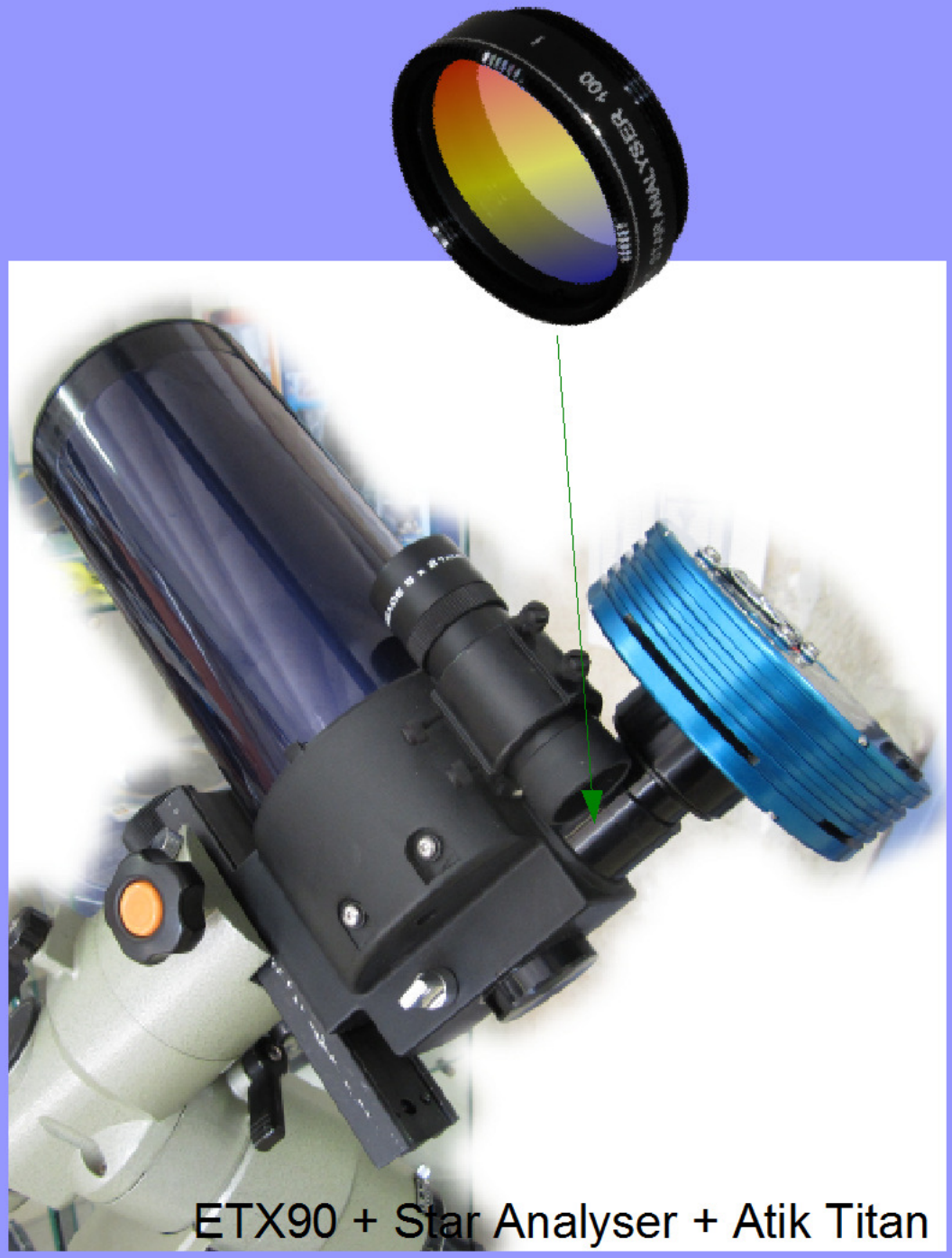
1 / Acquisition
Prepare your equipment before the night !
Acquire a reference (A-type) star, then your targets

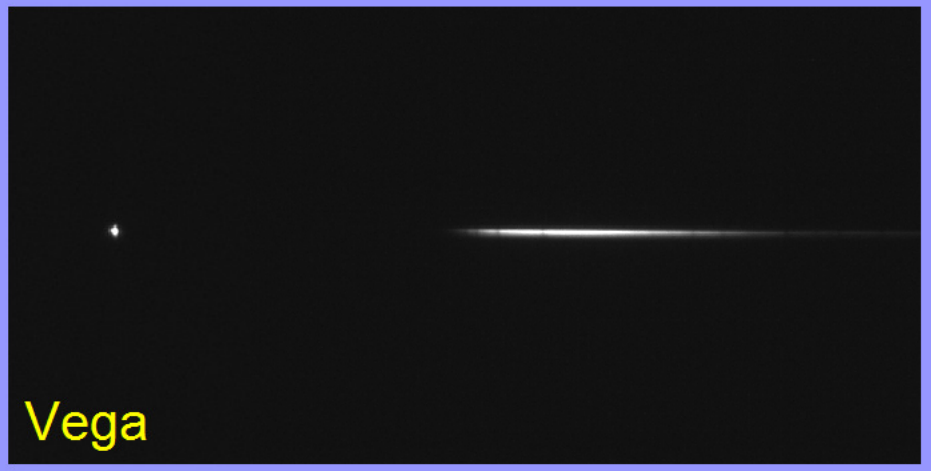
2 / Process reference star (ex: Vega)
Geometry + extract signal column by column (binning)
X axis calibration: wavelength calibration / dispersion
Y axis calibration: instrumental response

3 / Reduce all your spectra
As above using:
-wavelength calib. Law (or Zero order + dispersion)
-divide intensities by your instrumental response

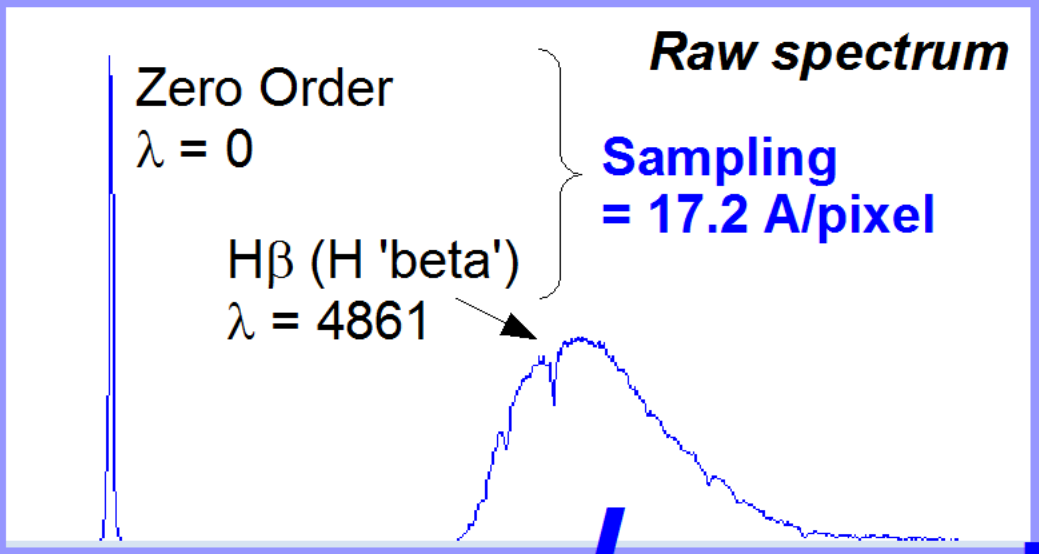
4 / Analyse & publish your spectra (ex: VisualSpec)
Measure astrophysical data from your profiles: line intensity, wavelength shift...

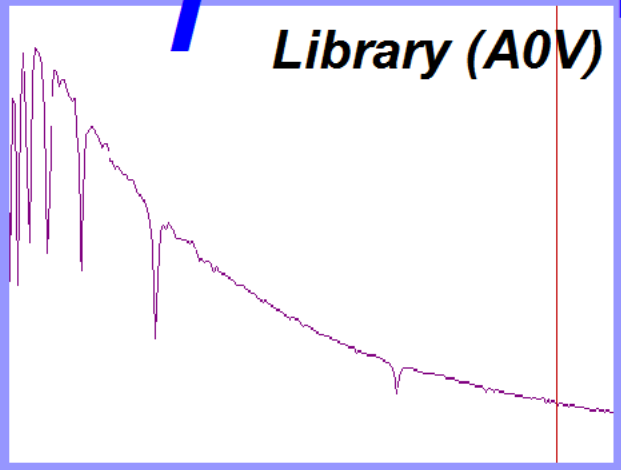
1/ Acquisition

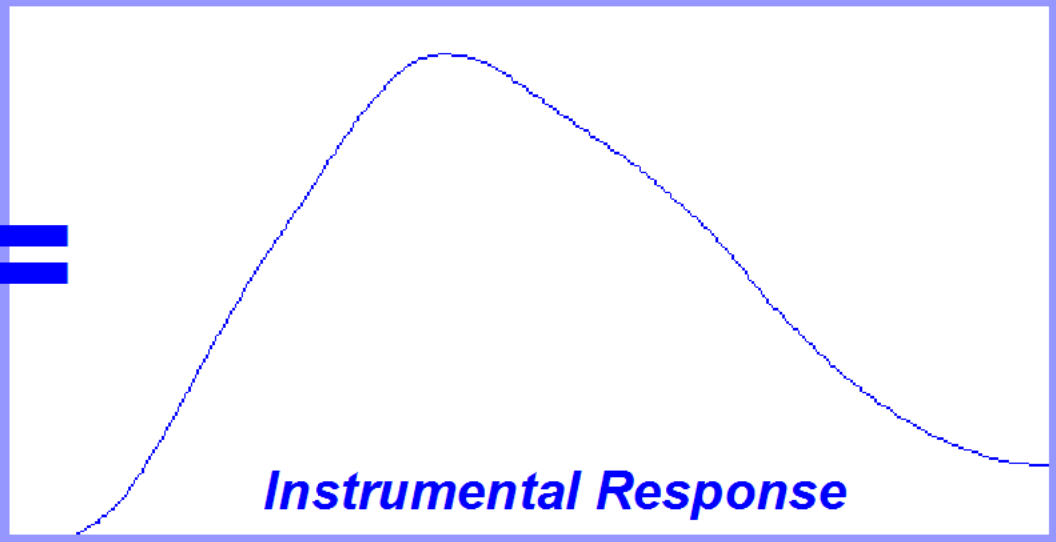




2/ Process reference star







3/ Reduce (process) your other spectra

Ordre Zéro
$\lambda = 0$

Raw spectrum

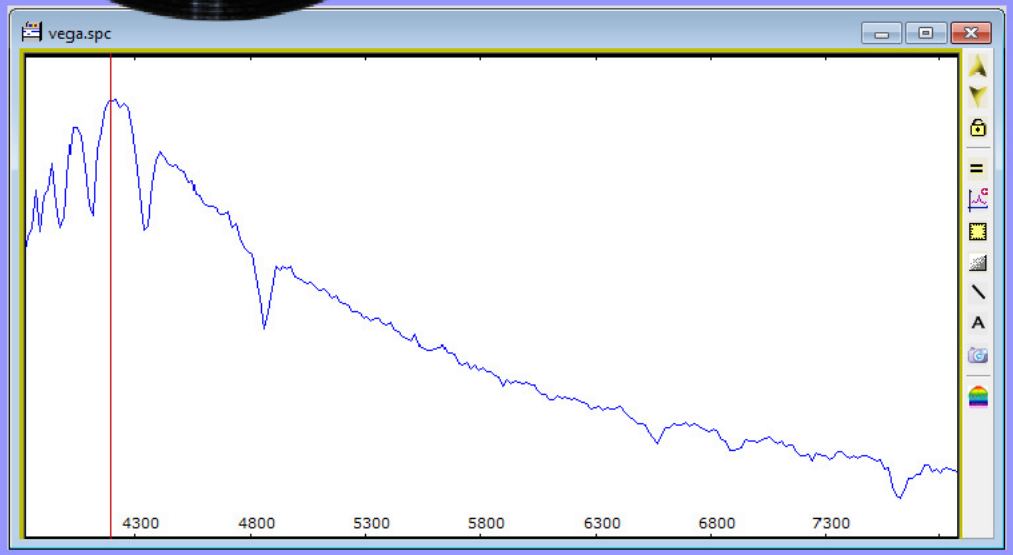
Sampling / Dispersion = 17.2 A/pix

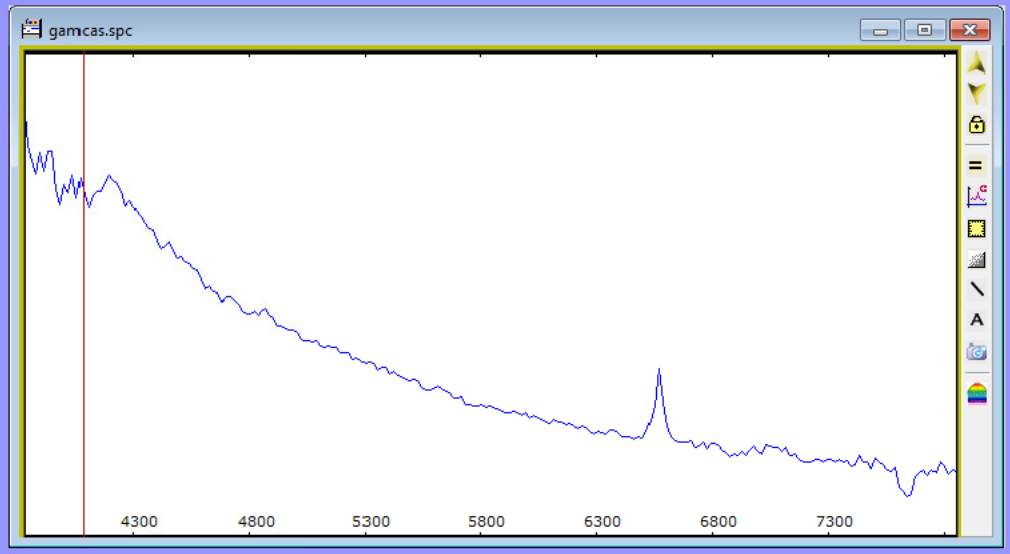
Instrumental Response

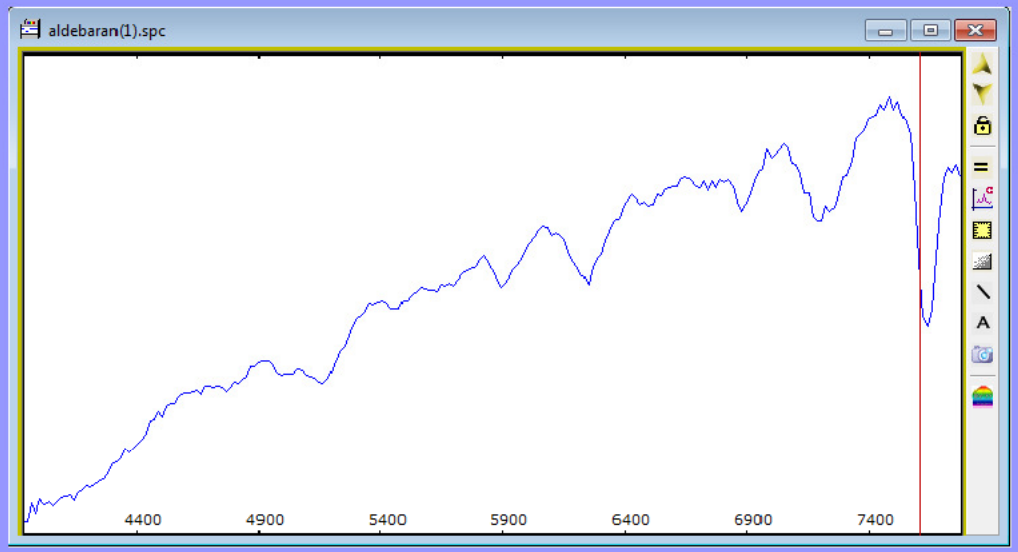
Final spectrum

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

4/ Compare your spectra







What do we see?

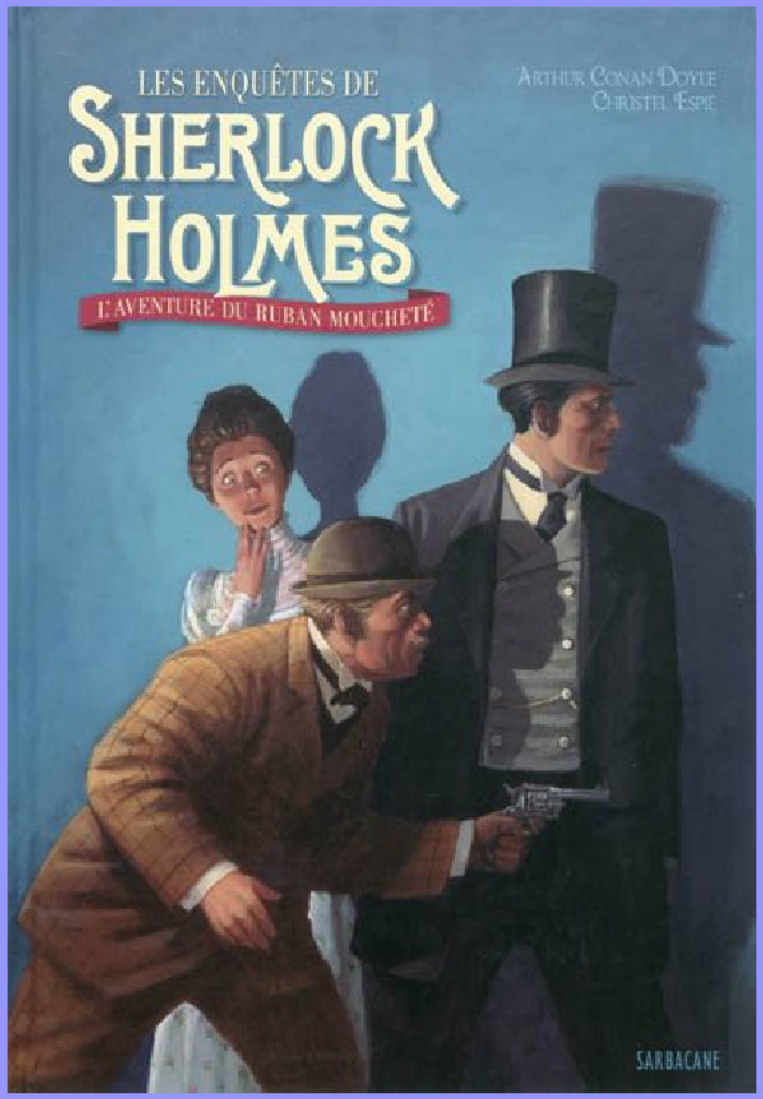
1/ overall profile varies

2/ absorption lines

3/ emission lines

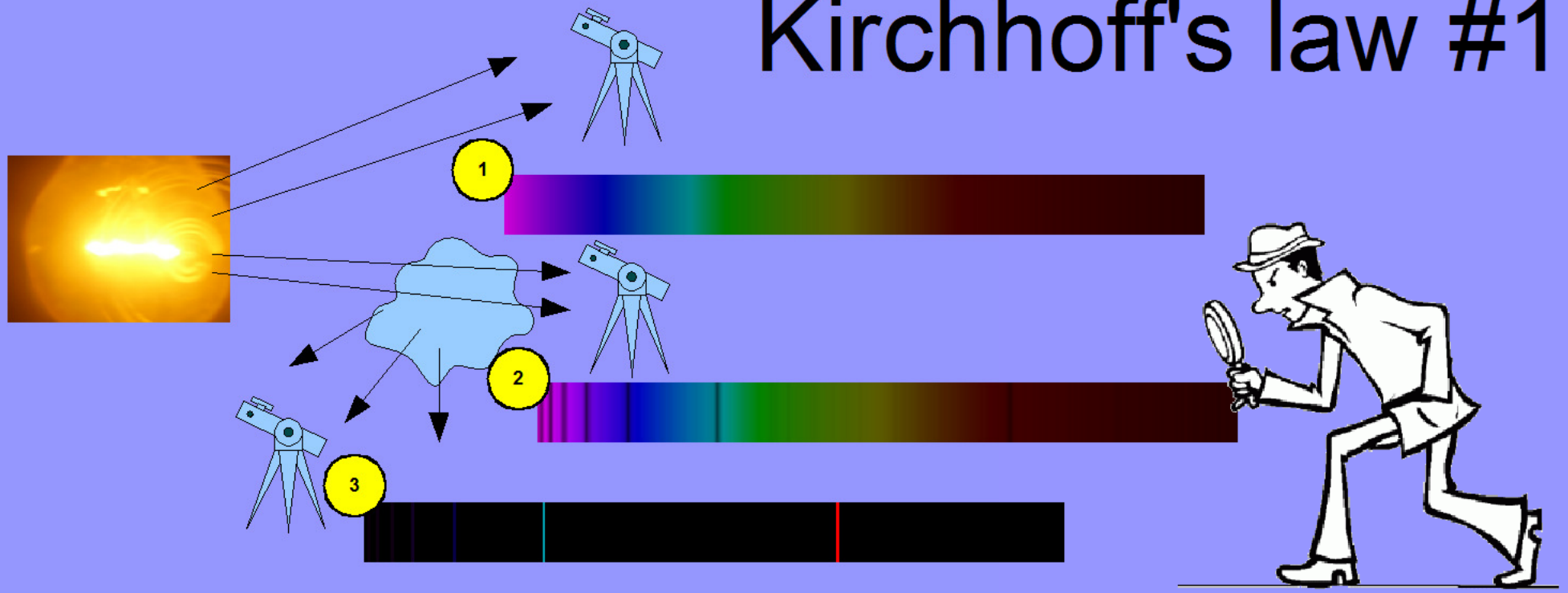
→ WHY ???

Spectroscopy is first a game !



Photos : Google Images

Kirchhoff's law #1

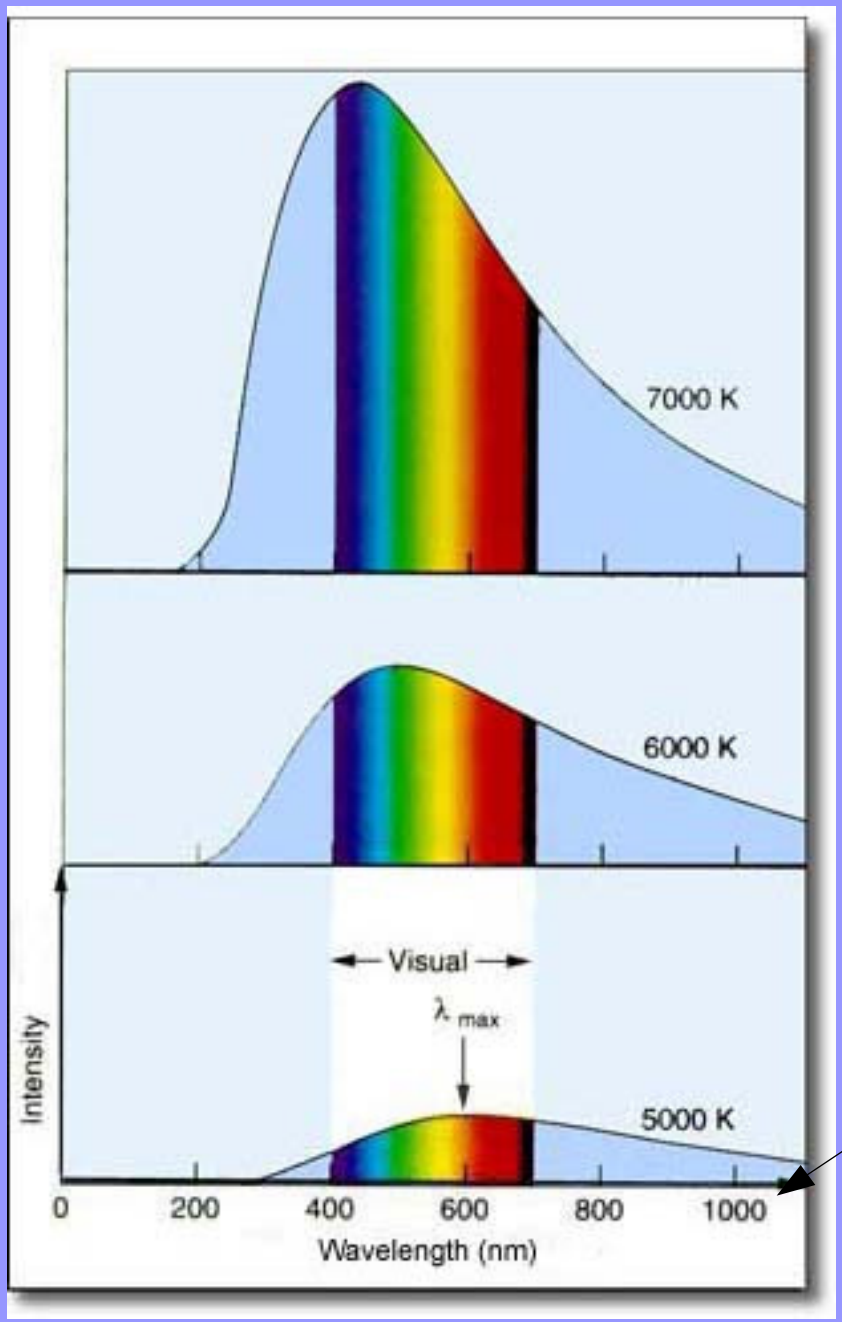


1 A **continuous spectra** is emitted by any solid of gazeous body under high presure and high temperature. Stars are, under first approximation, like black body whose continuous spectra has a shape which depends on its surface temperature;

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

Informations from Planck profile



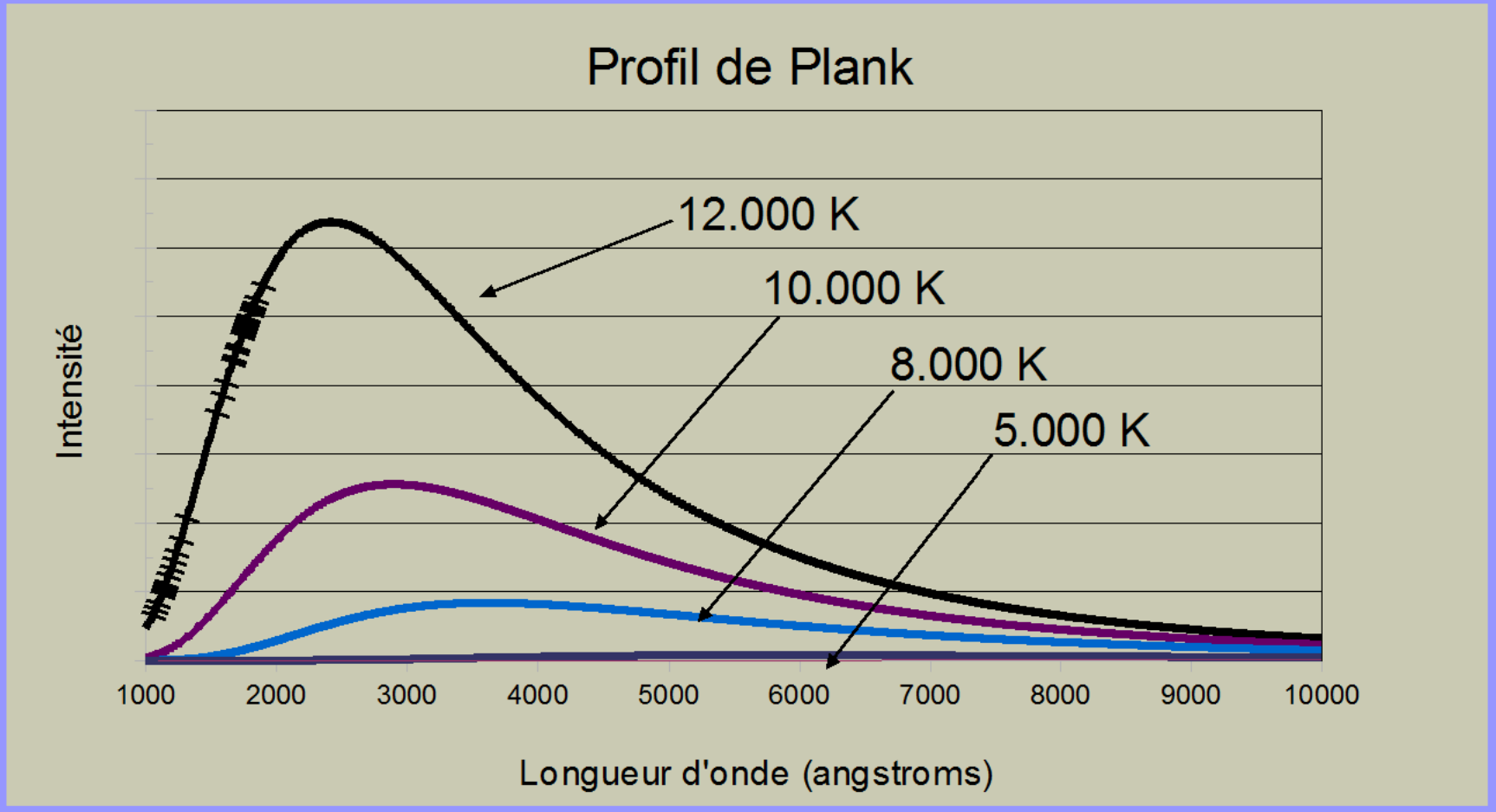
- **Stefan's law:**
  Intensity (below the curve) = Constant * T^4

- **Wien's law:**
  λ max * Temperature = Constant (2900 µm.K)

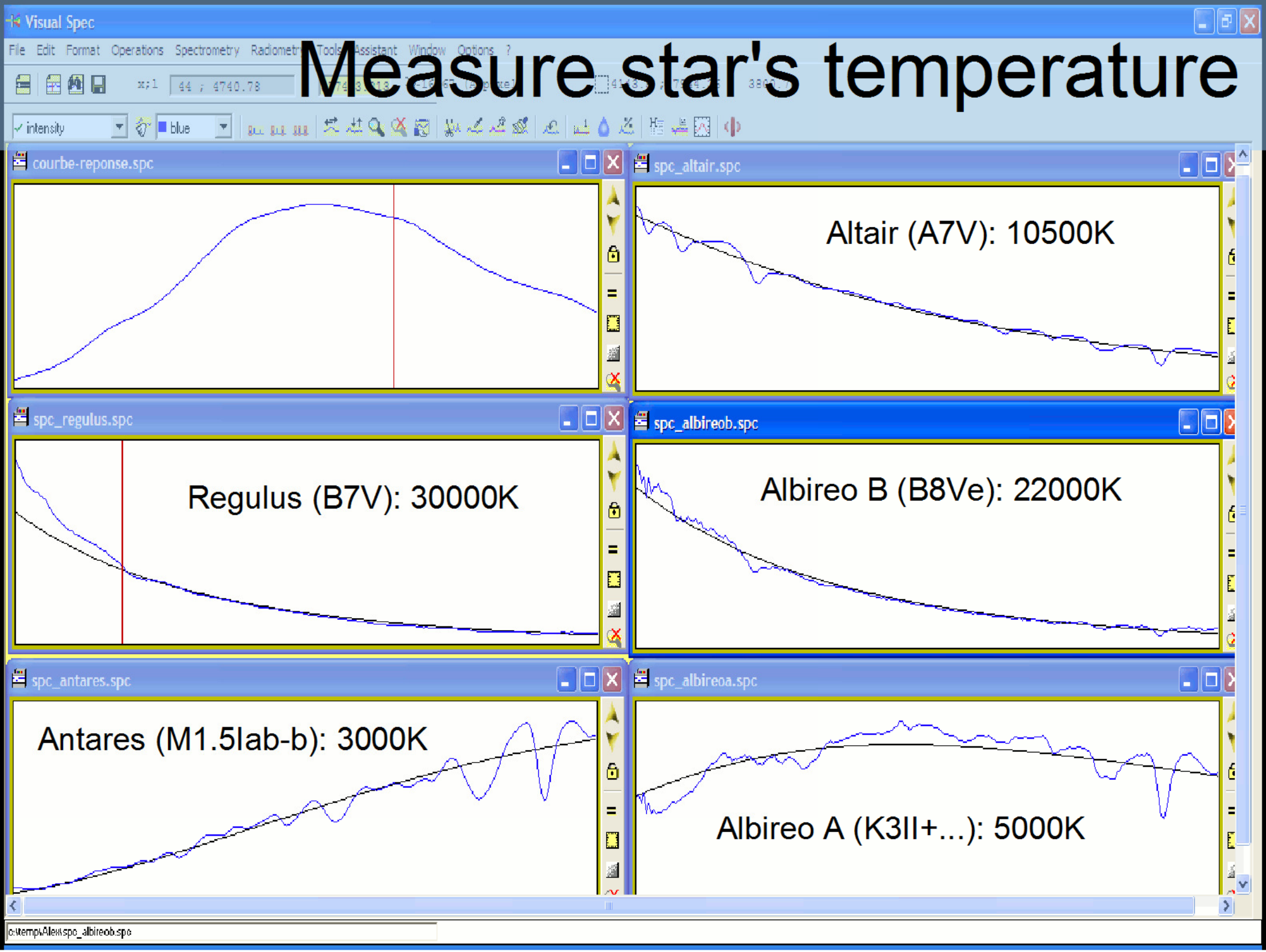
  ==>Temperature = Color !!!

Visible domain
= 400-700nm (4000A-7000A)

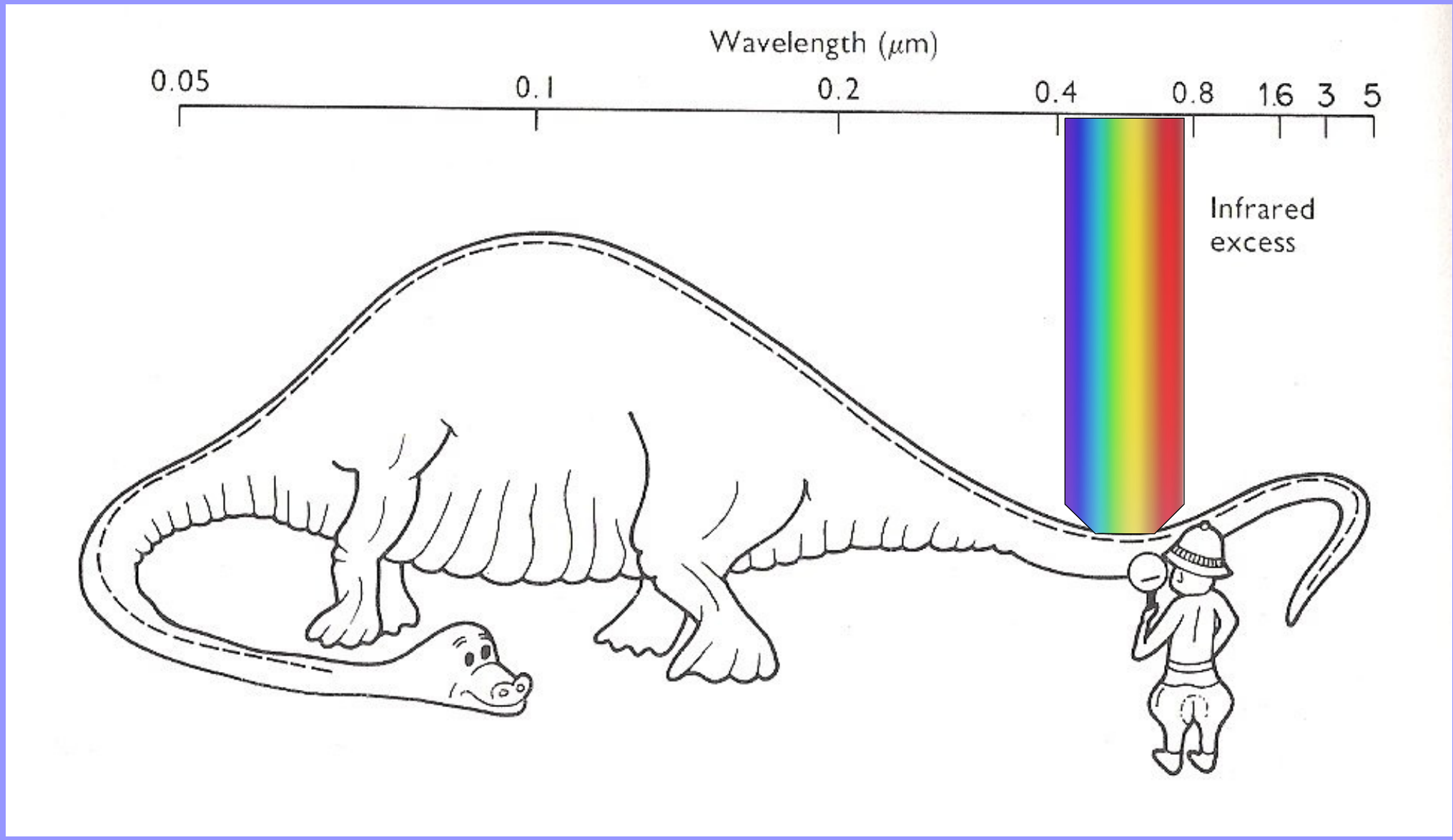
Black body profile



Measure star's temperature

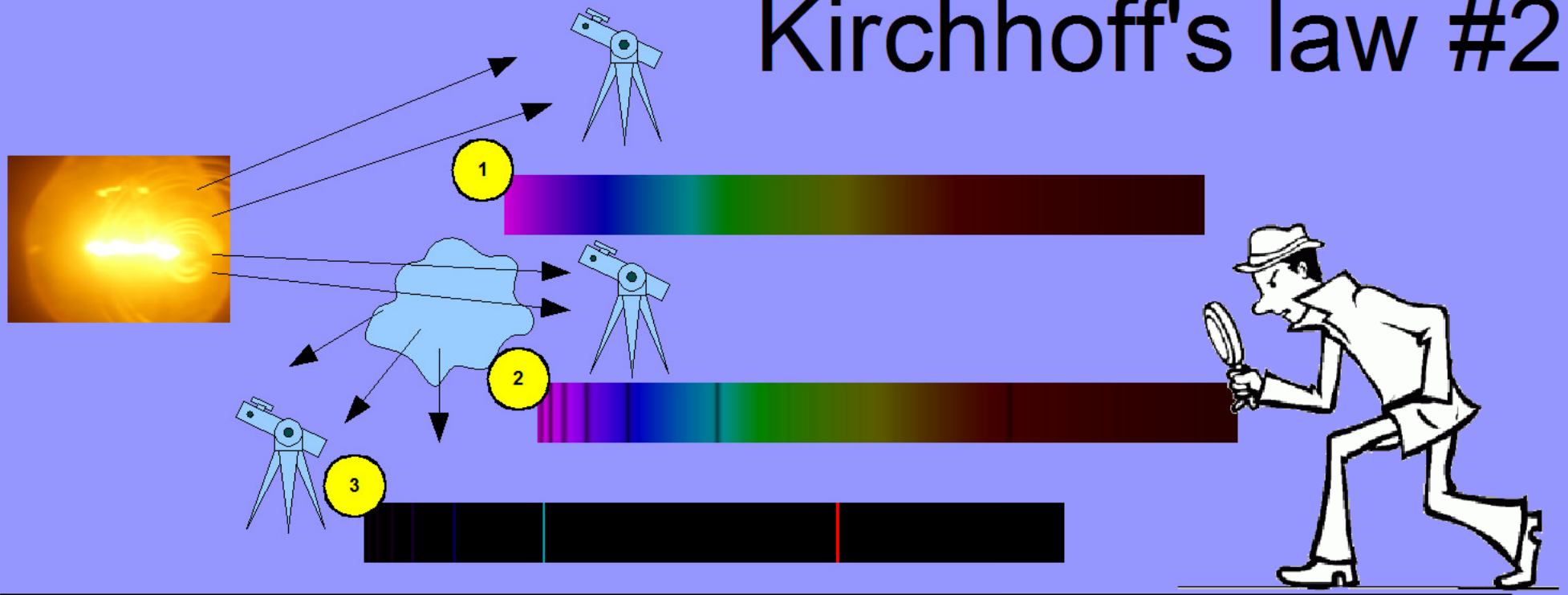


Be aware: Visible = partial view



Source: Getting the measure of the stars (WA Cooper & EN Walker)

Kirchhoff's law #2



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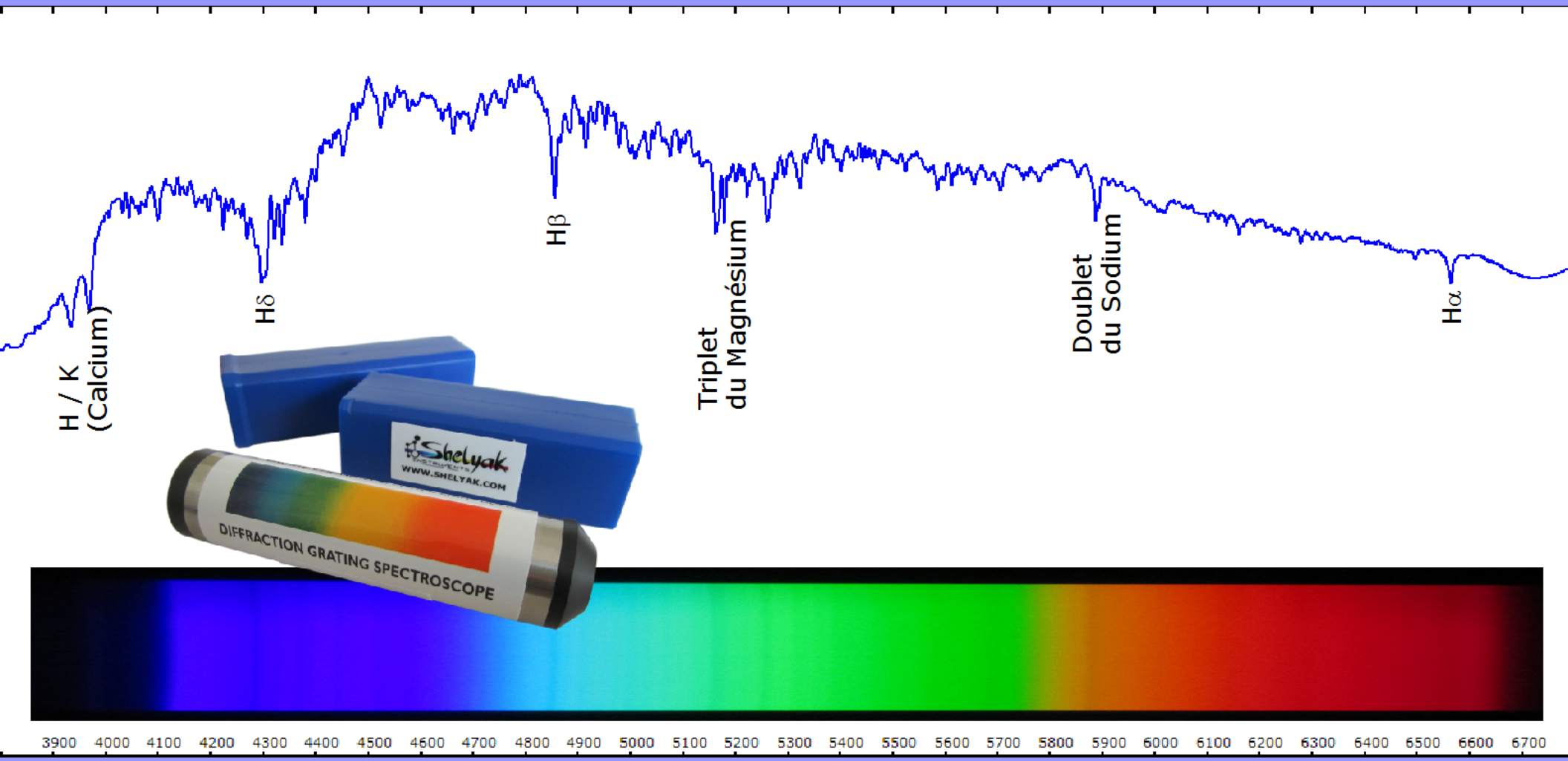
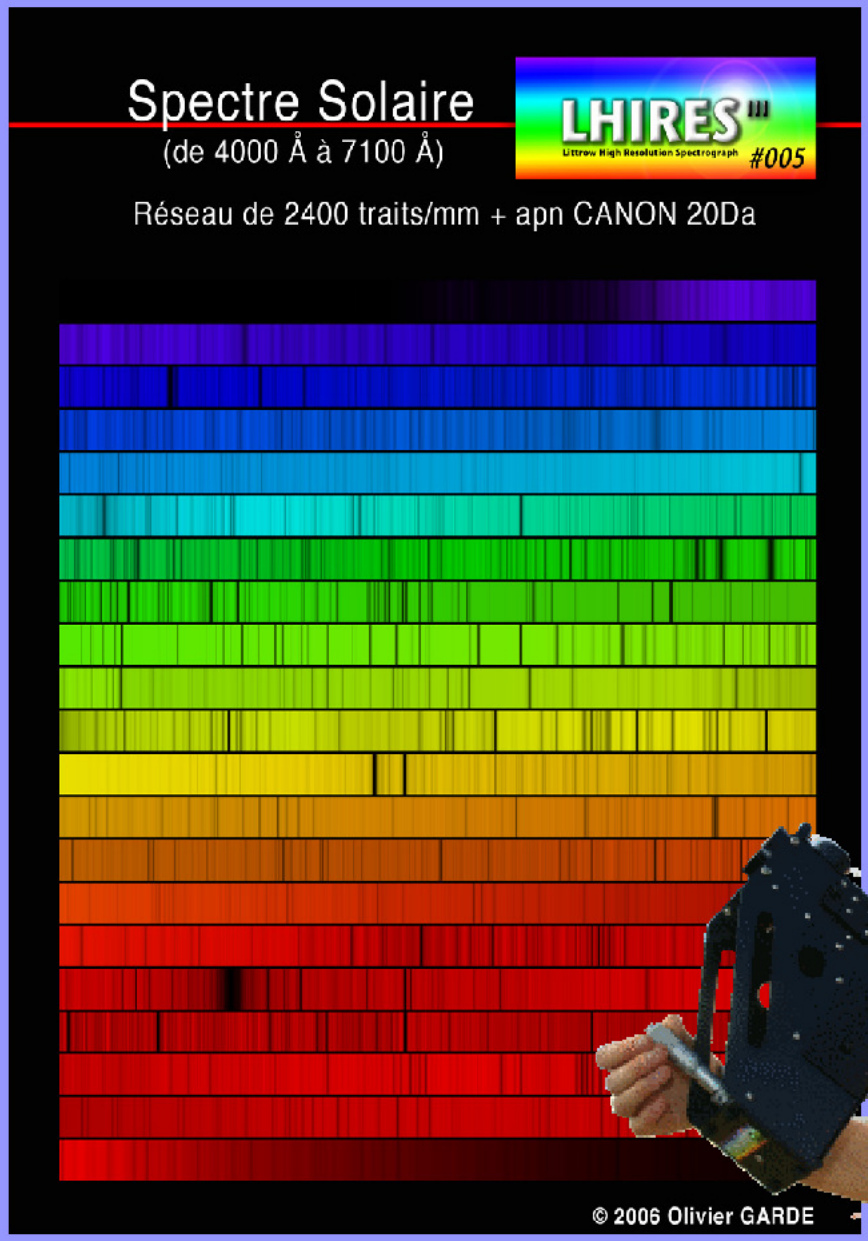
Solar spectrum absorption lines

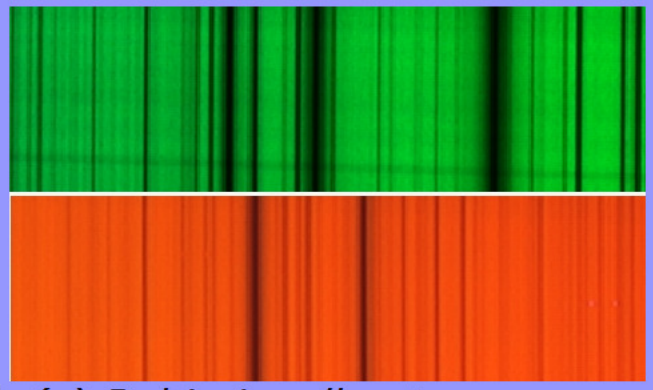


Profil : *O. Thizy, janvier 2007 ; Lhires III – 300tt/mm; Digital Rebel / EOS300D*
Pic du Midi (ie: no telluric lines)

Spectrum : recorded with the handheld spectroscope.

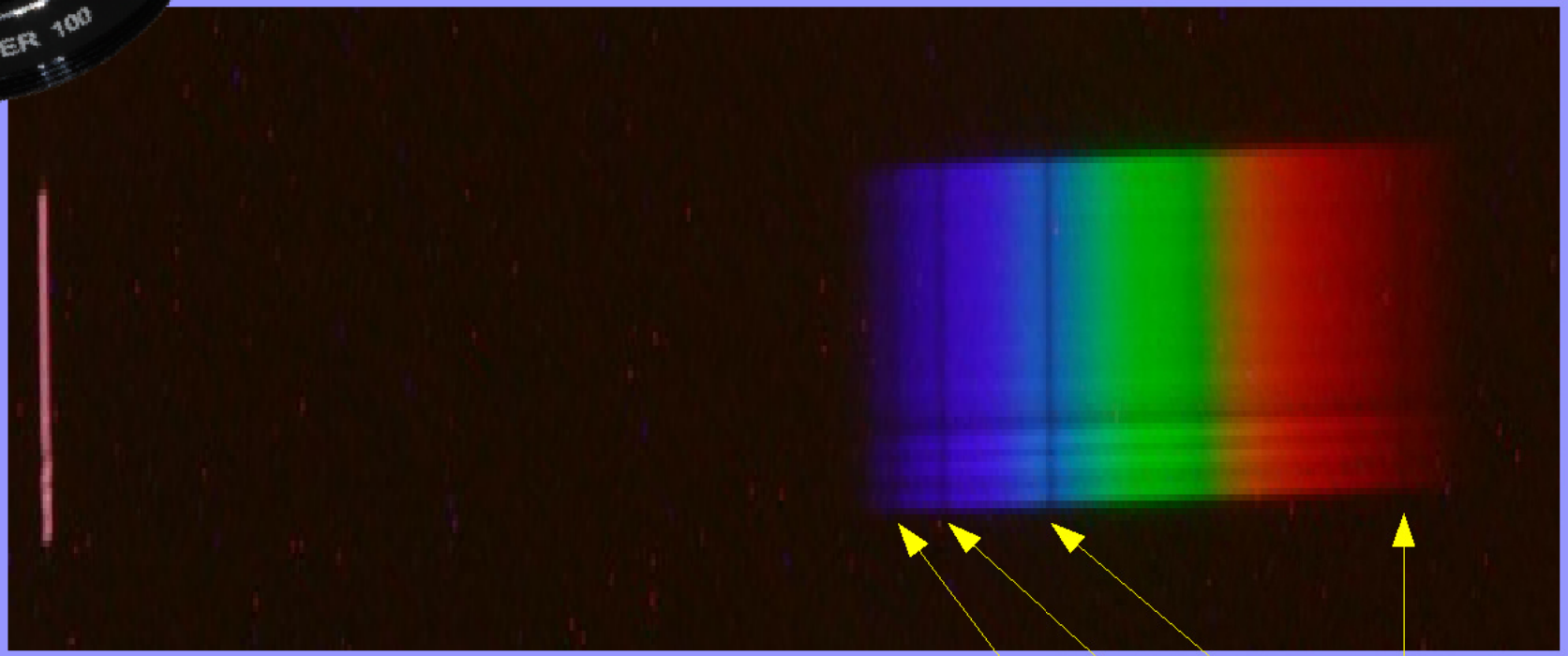
Solar spectrum (visual)





(c) Robin Leadbeater

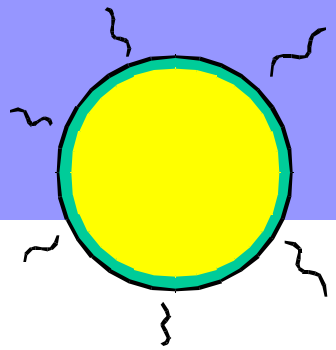
Absorption lines ?

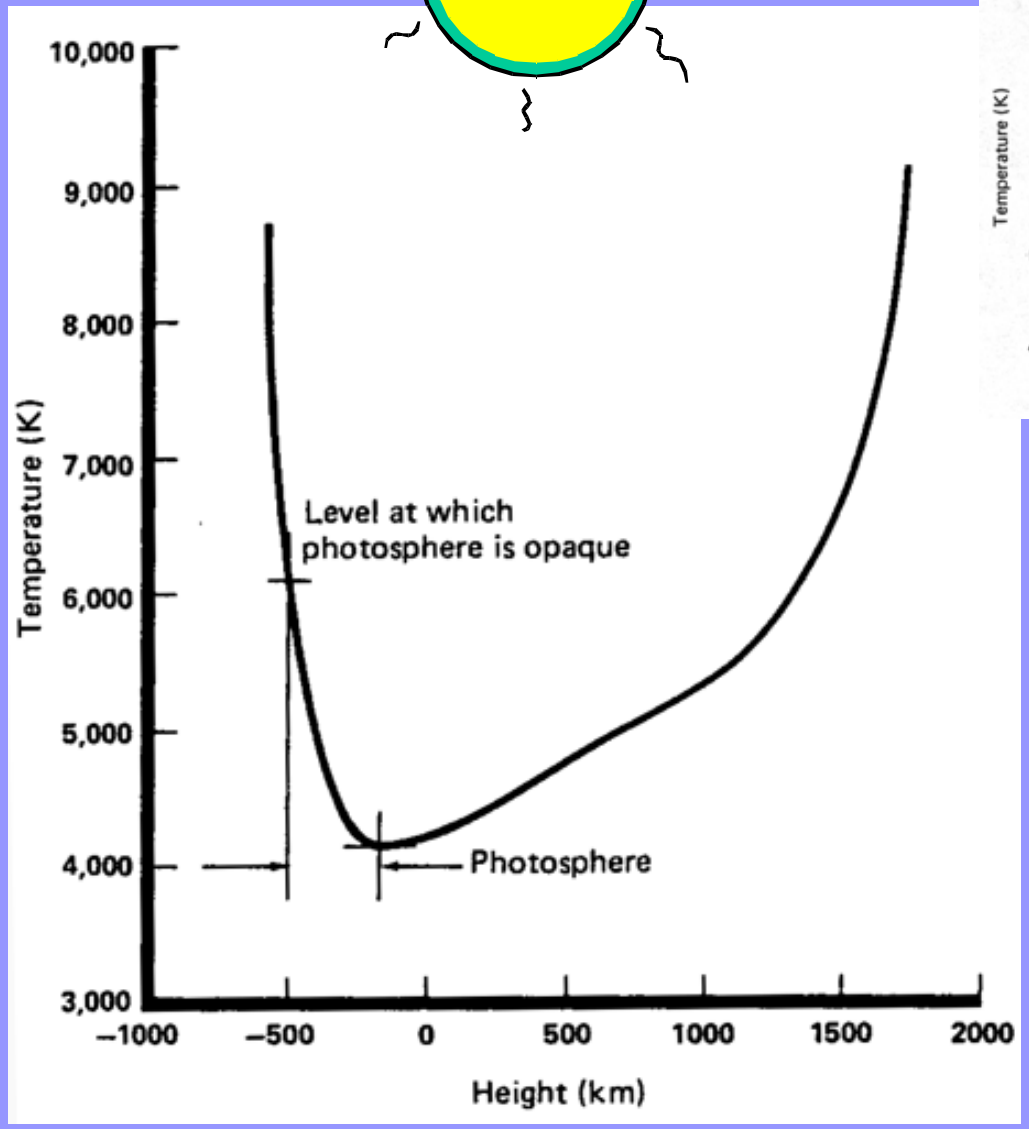


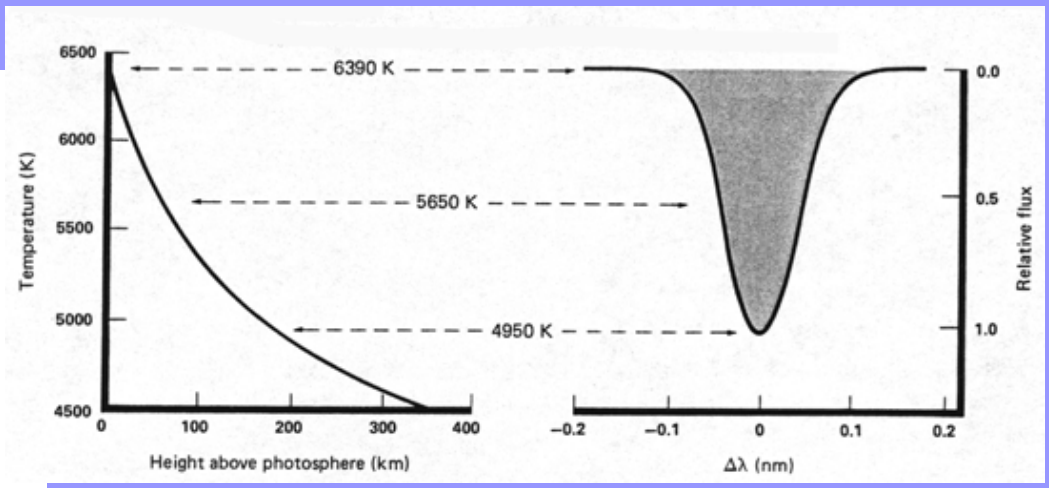
Hydrogen lines (Balmer serie : ...Hδ, Hγ, Hβ, Hα)

Spectre de Sirius – Atelier spectro Buthier / 2007

Photospheric line

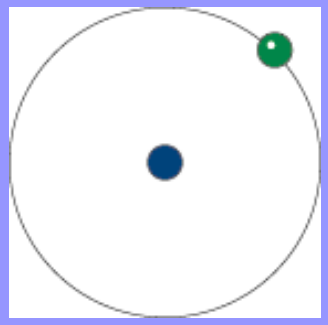




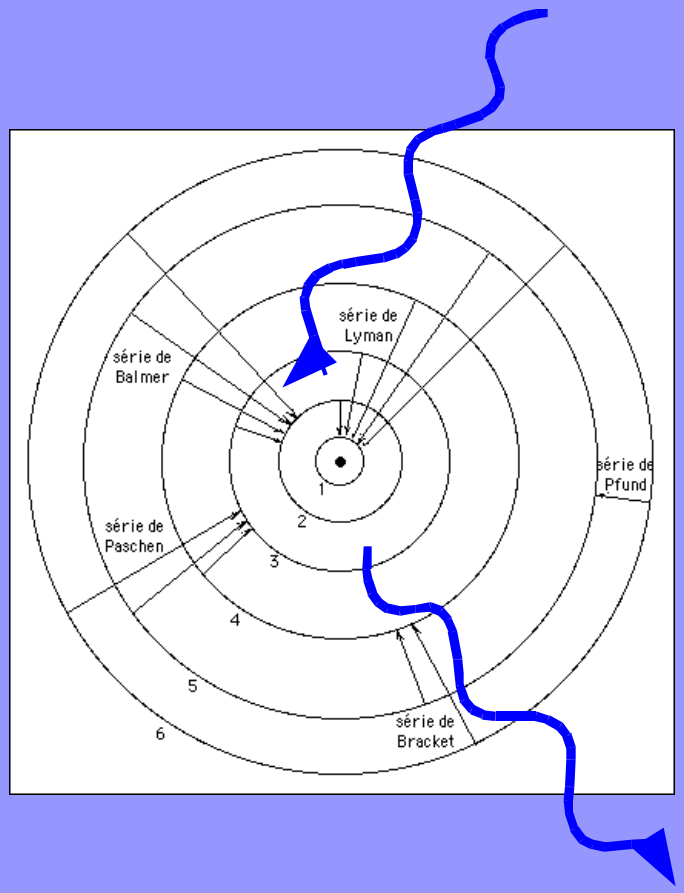


- *Photosphere is a very very thin layer*
- *'Wings' of the line come from deeper layers than the center of the line*

D'après: http://ircamera.as.arizona.edu/astr_250/Lectures/Lecture_14.htm



Absorption/Emission lines



$$\Delta Energy = h * \nu = h * c / \lambda$$

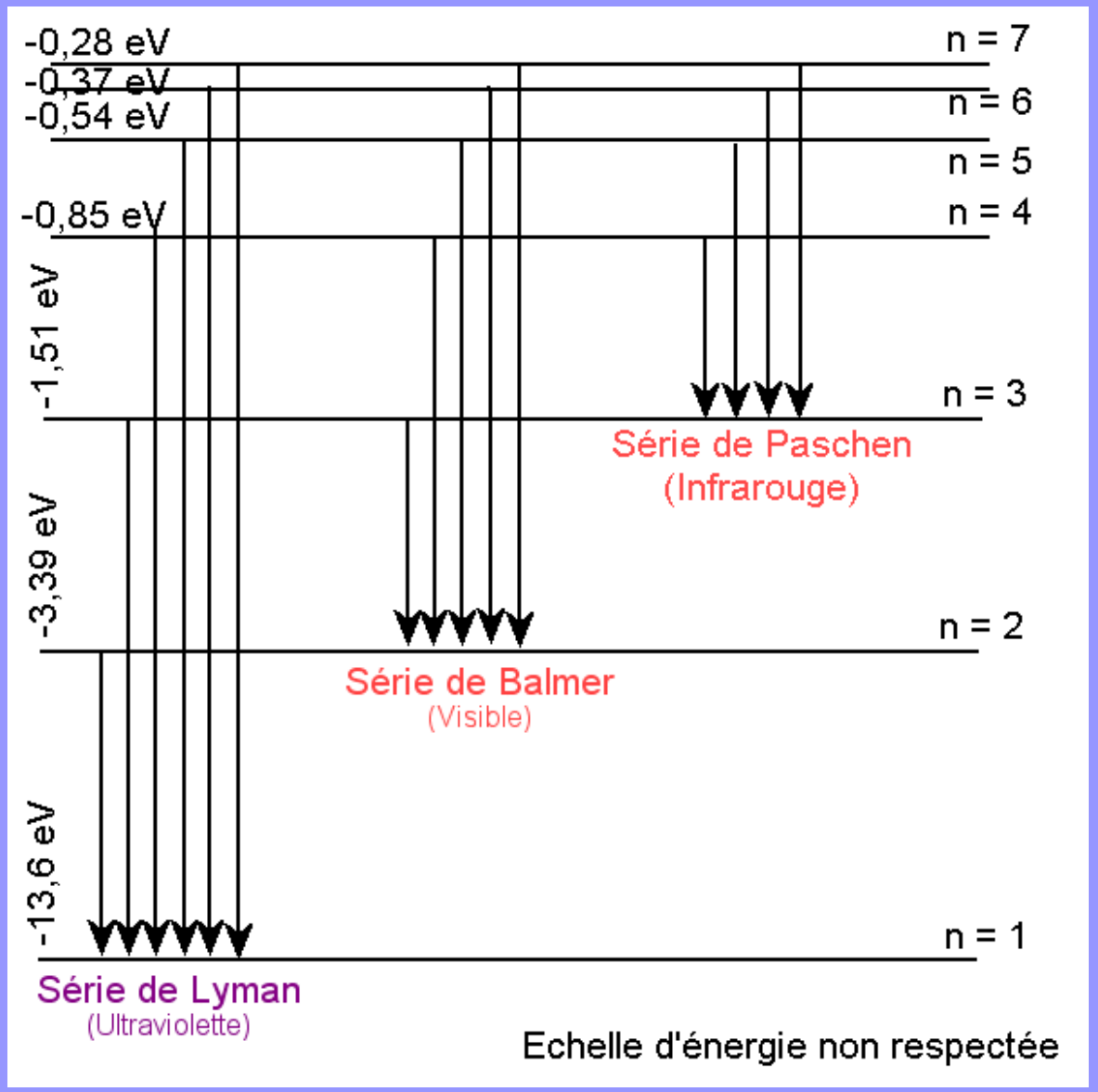
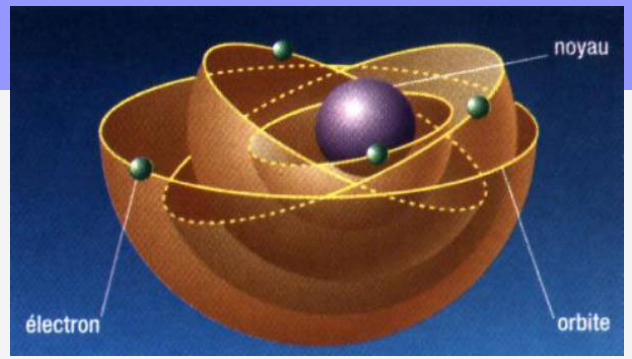


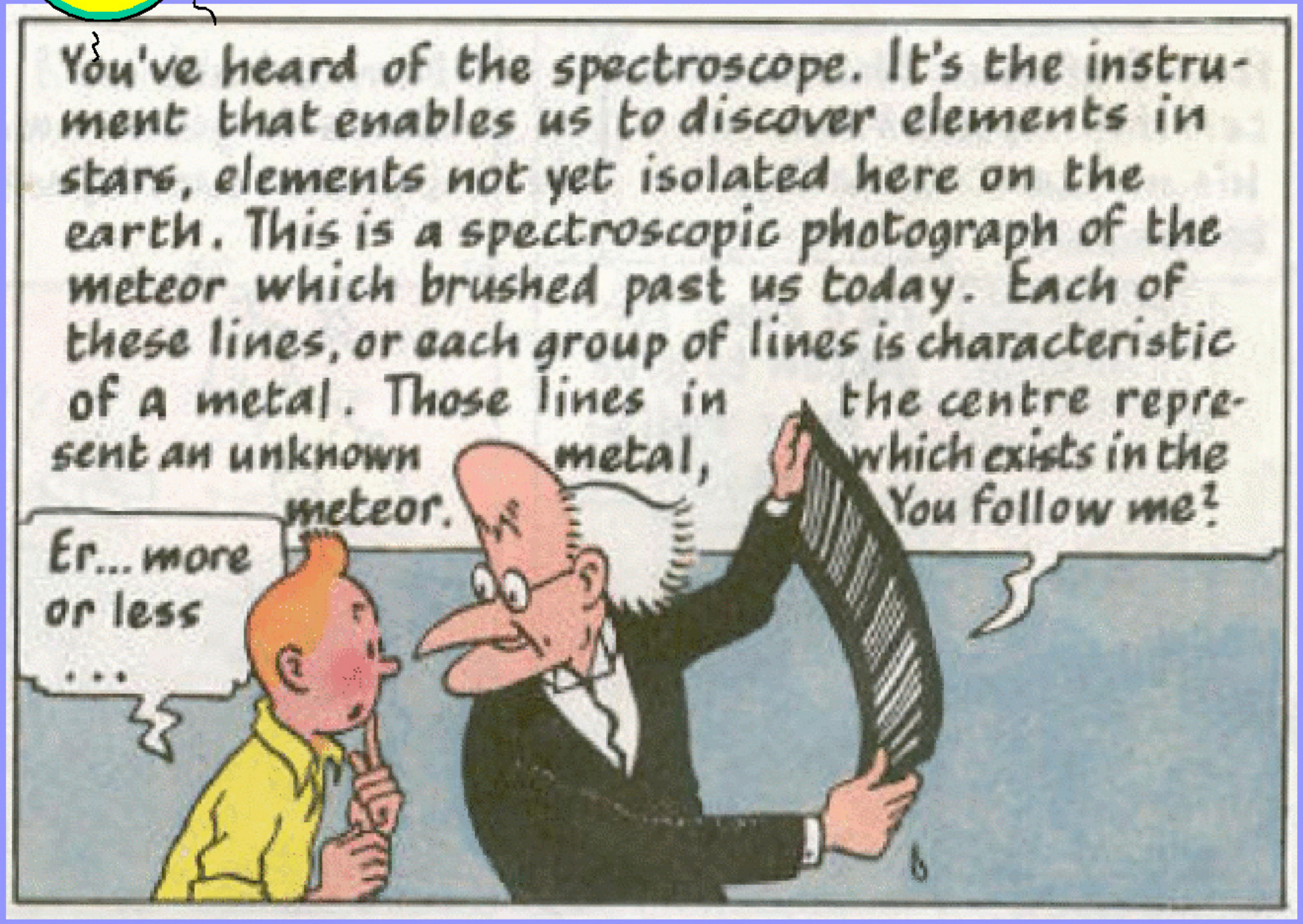
Table of elements



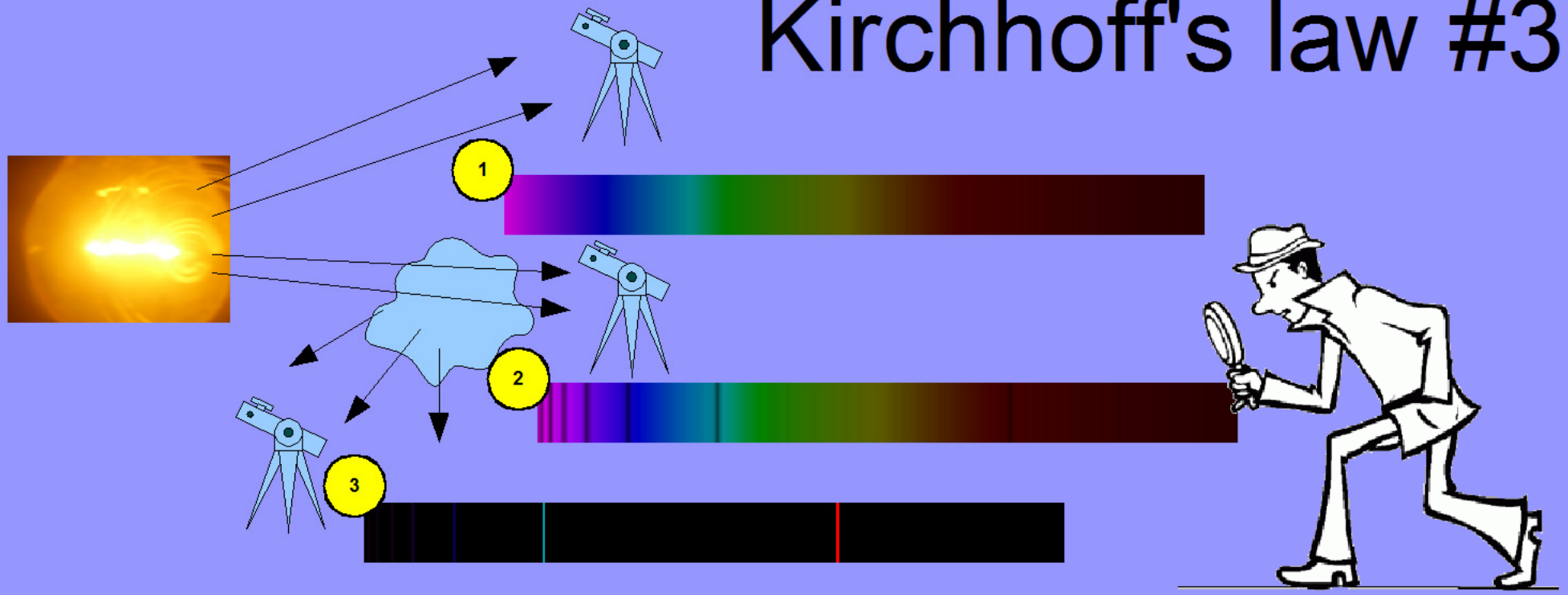
	IA											IIA	IIIA	IVA	VA	VIA	VIIA	0
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg	IIIB	IVB	VB	VIB	VIIB		VII		IB	IIB	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 *La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 +Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Uub	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo

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

Absorption lines



Kirchhoff's law #3

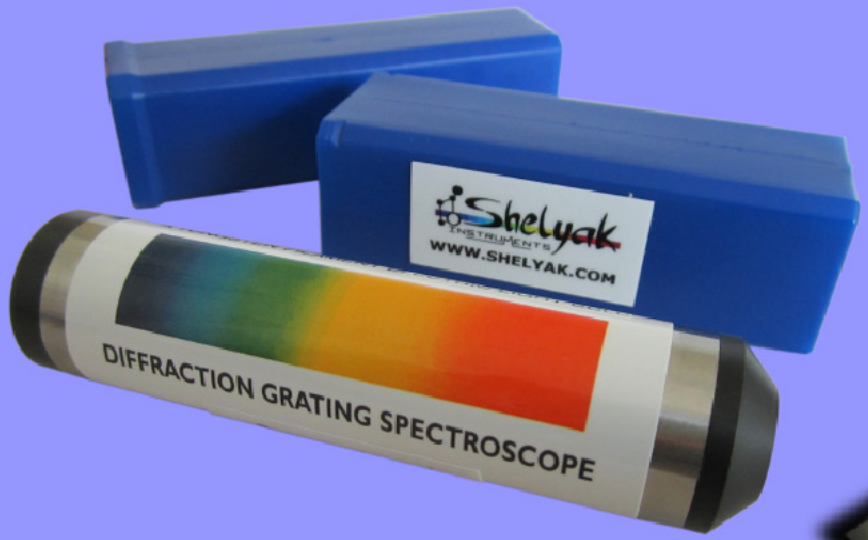


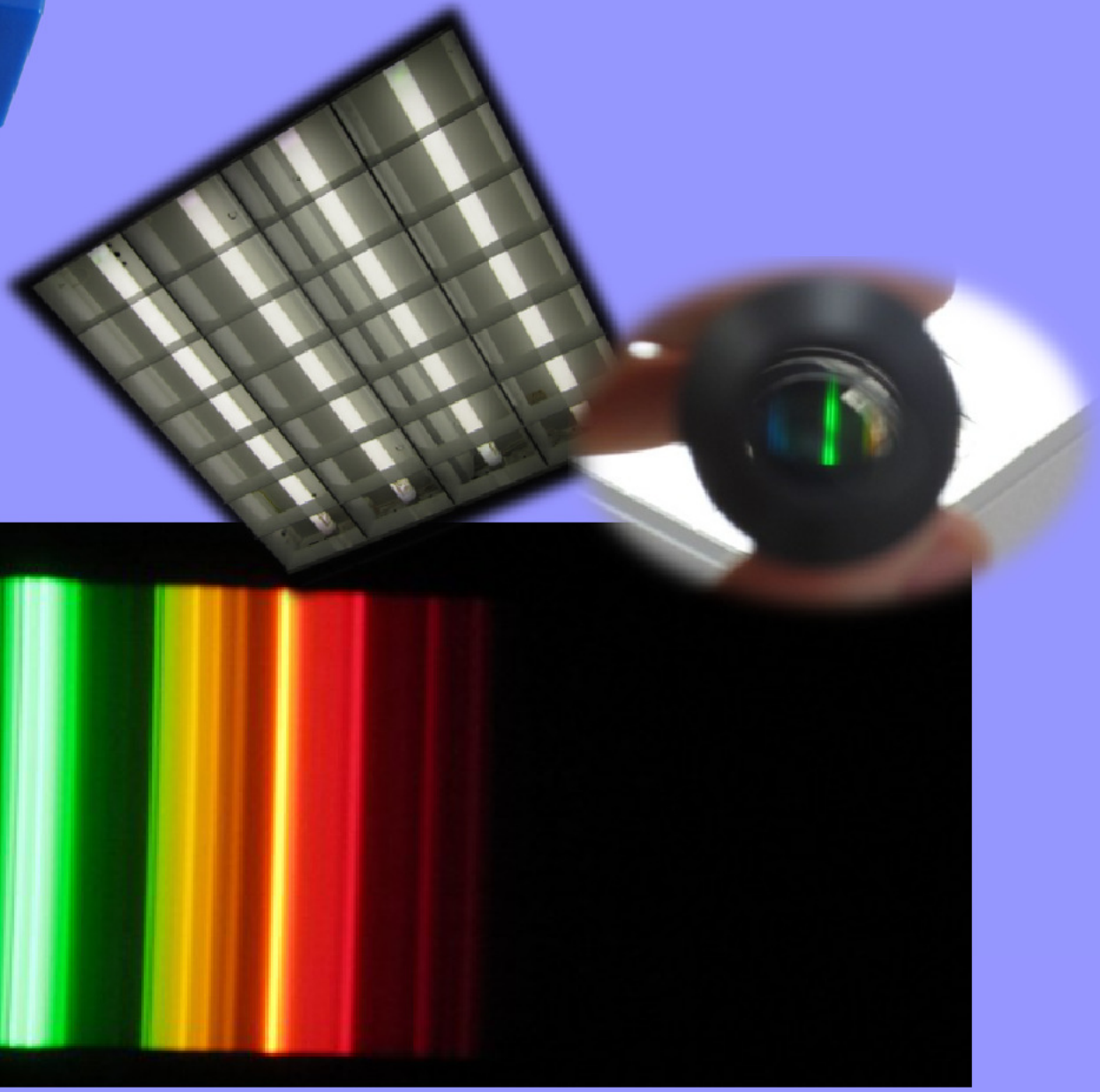
1 A **continuous spectra** is emitted by any solid of gazeous body under high presure and high temperature. Stars are, under first approximation, like black body whose continuous spectra has a shape which depends on its surface temperature;

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

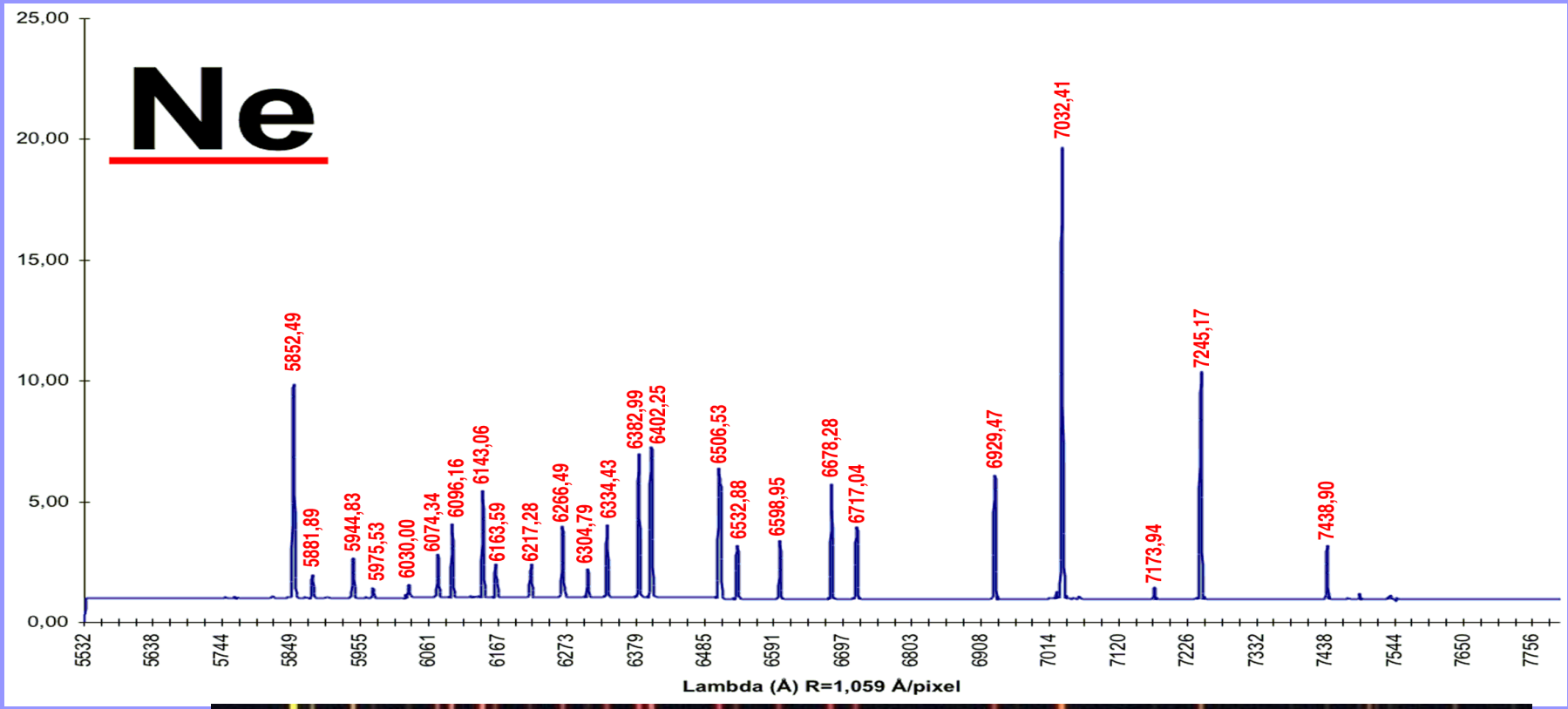
3 **Emission line spectra**: a low pressure high temperature gaz emits a light made of few radiations, characteristics of the atoms that constitutes this gaz. Each chemical element has its own line spectra, true identity card of its composition and state.

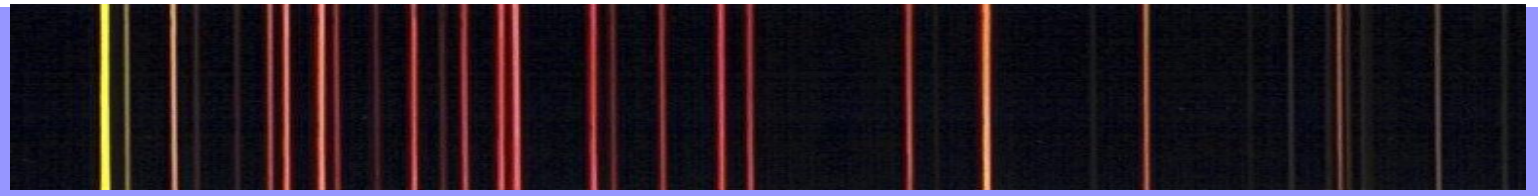
Economy saving lamp (handheld spectroscope)





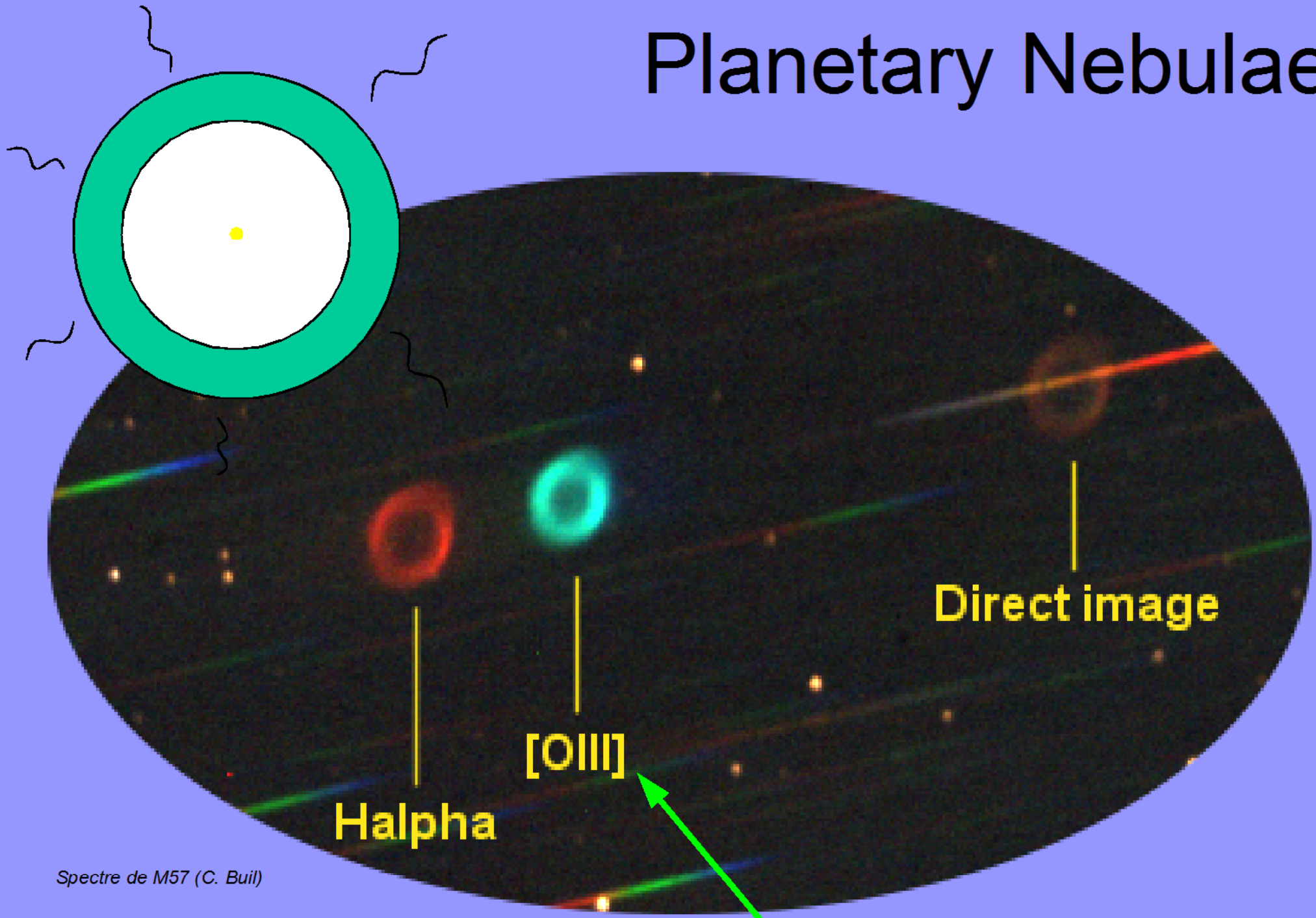
Emission lines → calibration





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

Planetary Nebulae

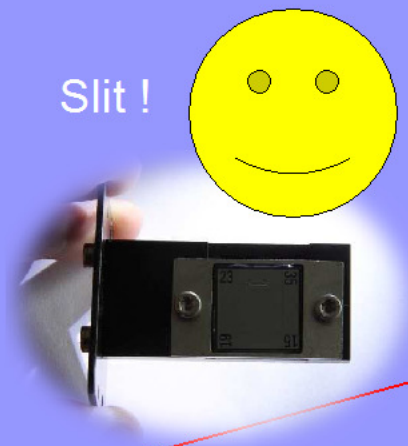


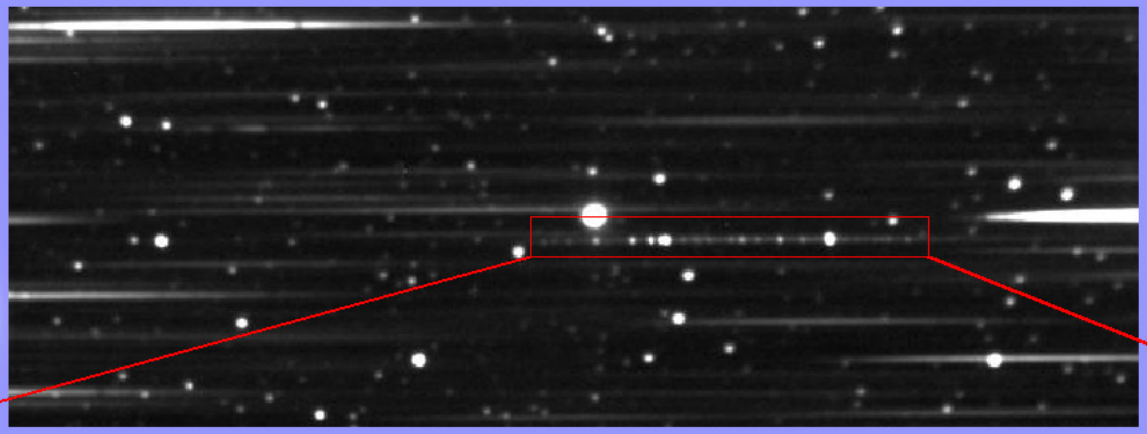
Spectre de M57 (C. Buil)

Forbidden lines
Names 'nebulium' orginally !

Slitless Vs slit spectroscopy

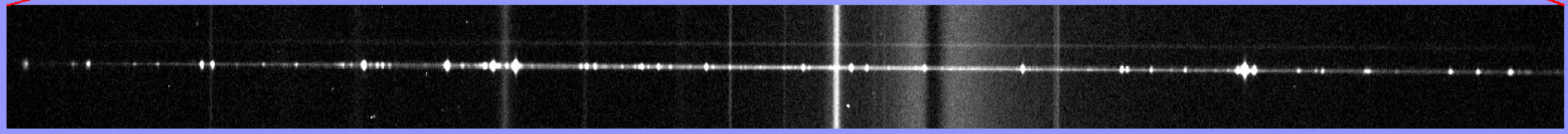
ex: symbiotic star V1016 Cyg

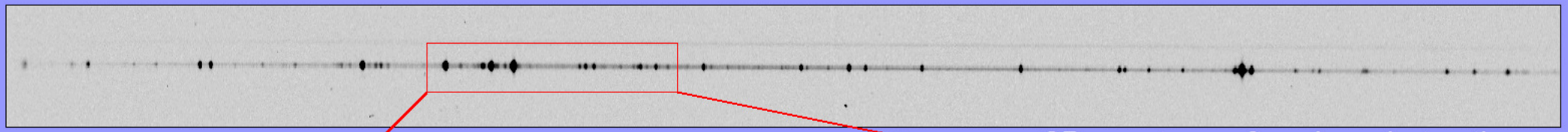




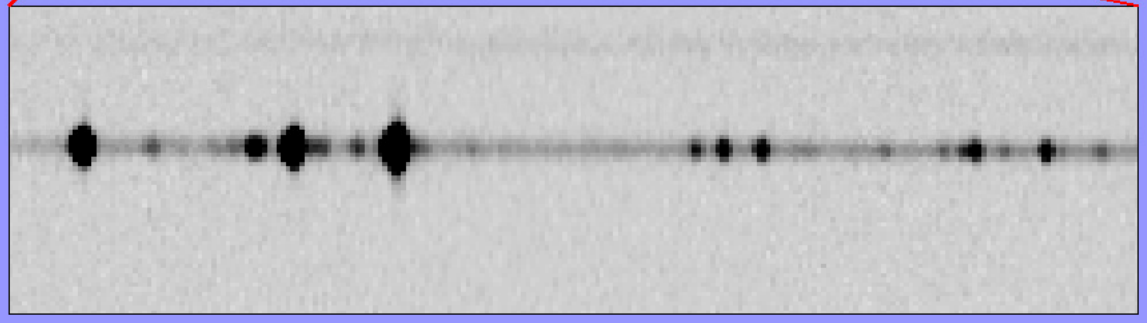
Star Analyser

2D spectrum before sky substraction (23µm slit)





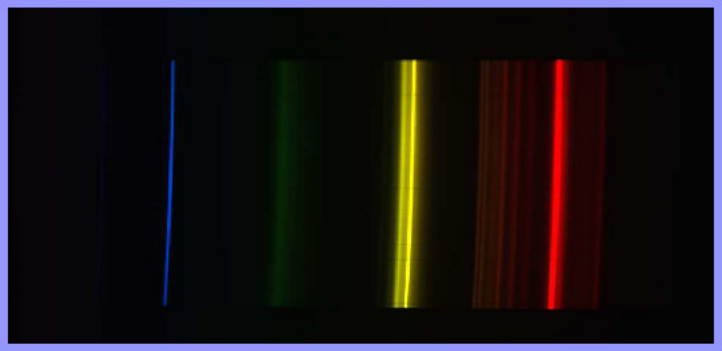
2D spectrum after sky substraction

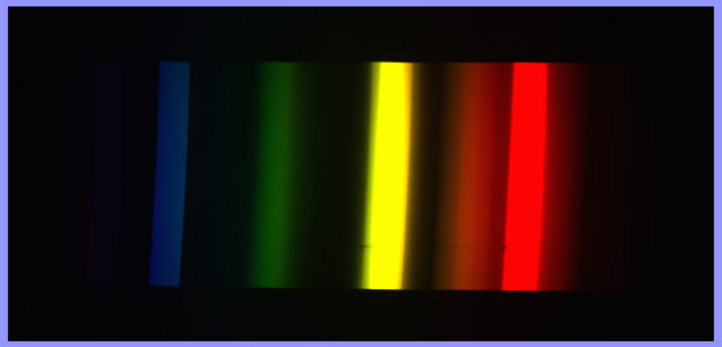


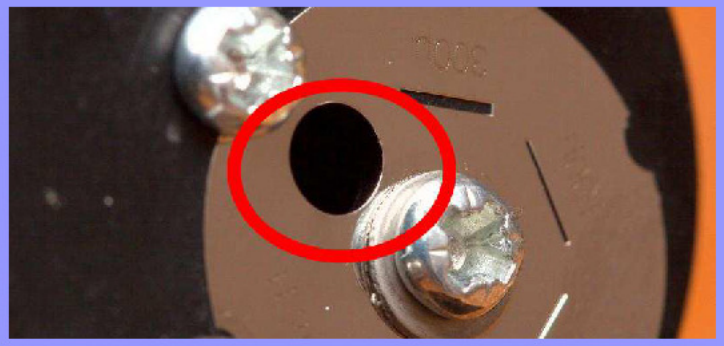
new *Alpy 600* modular spectrograph

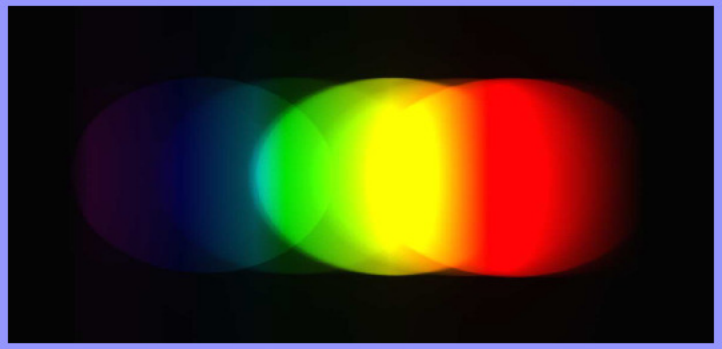
Slit

- **25µm**
- **300µm**
- **3mm**

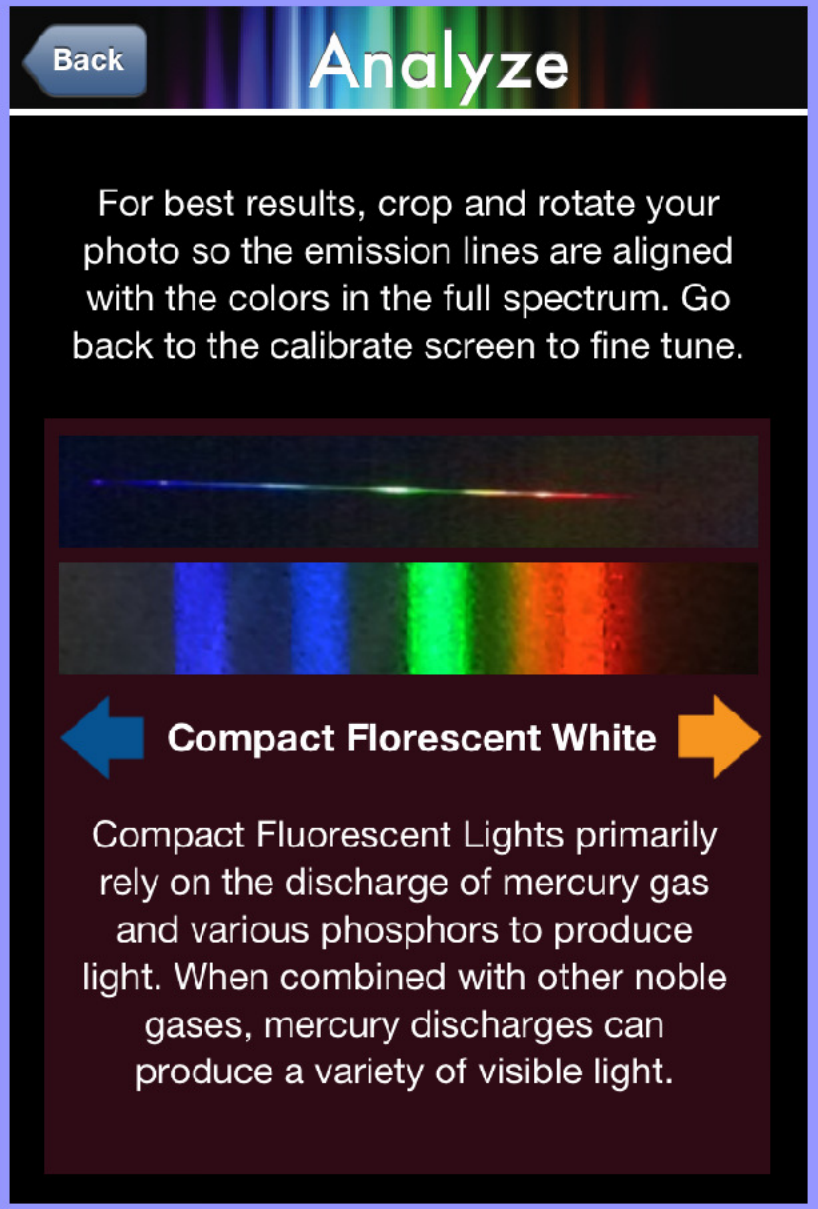






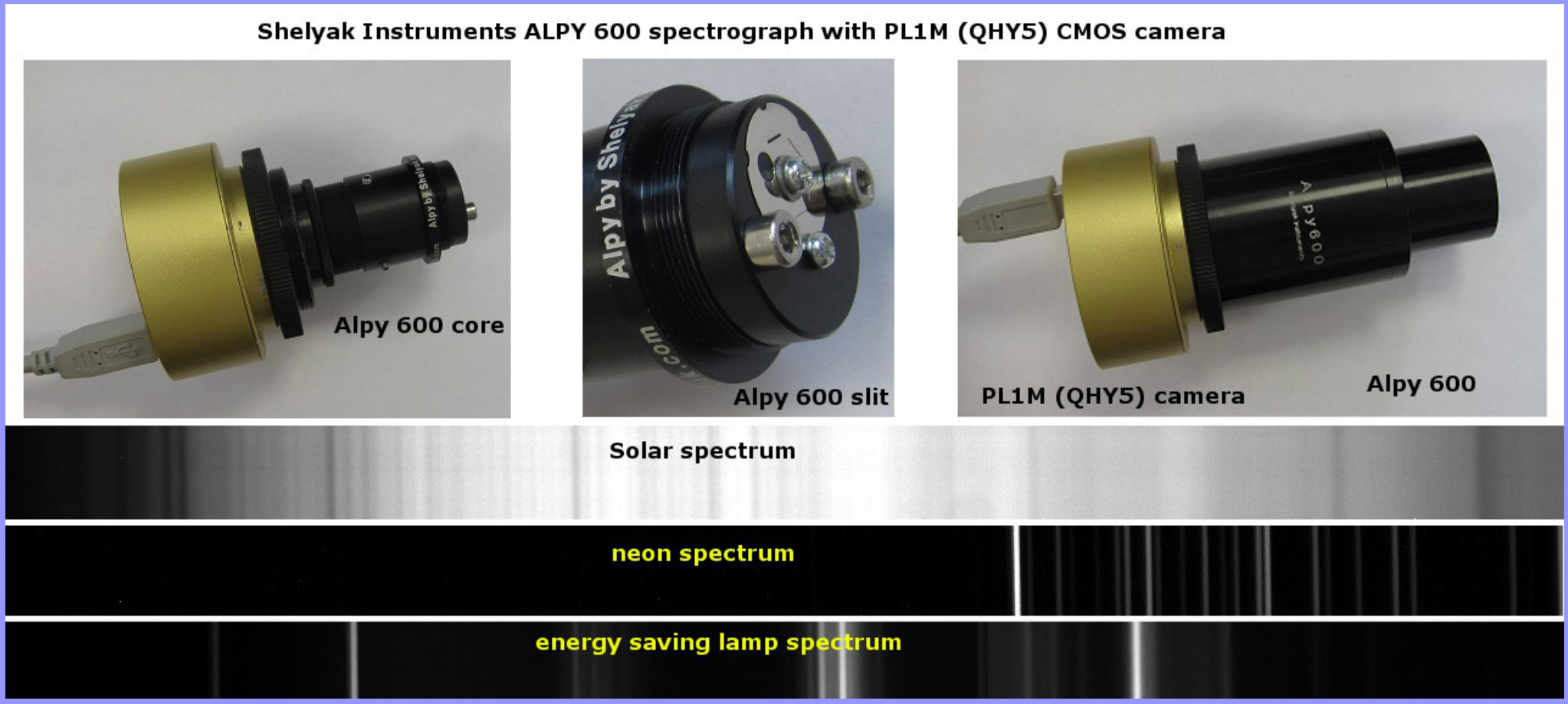


iSpectroscopy…

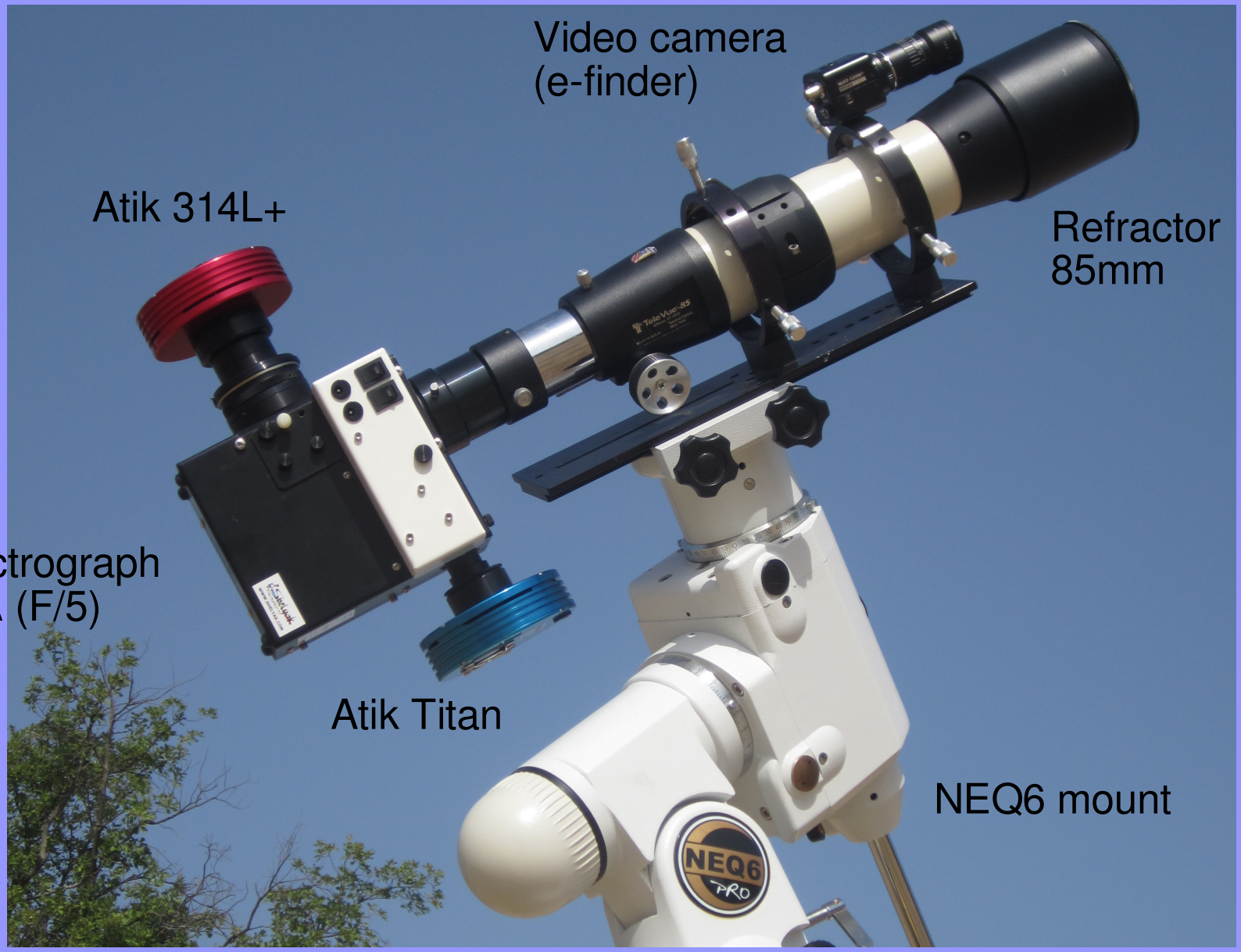


iPhone application : SpectraSnapp

Alpy 600 & CCD simple setup

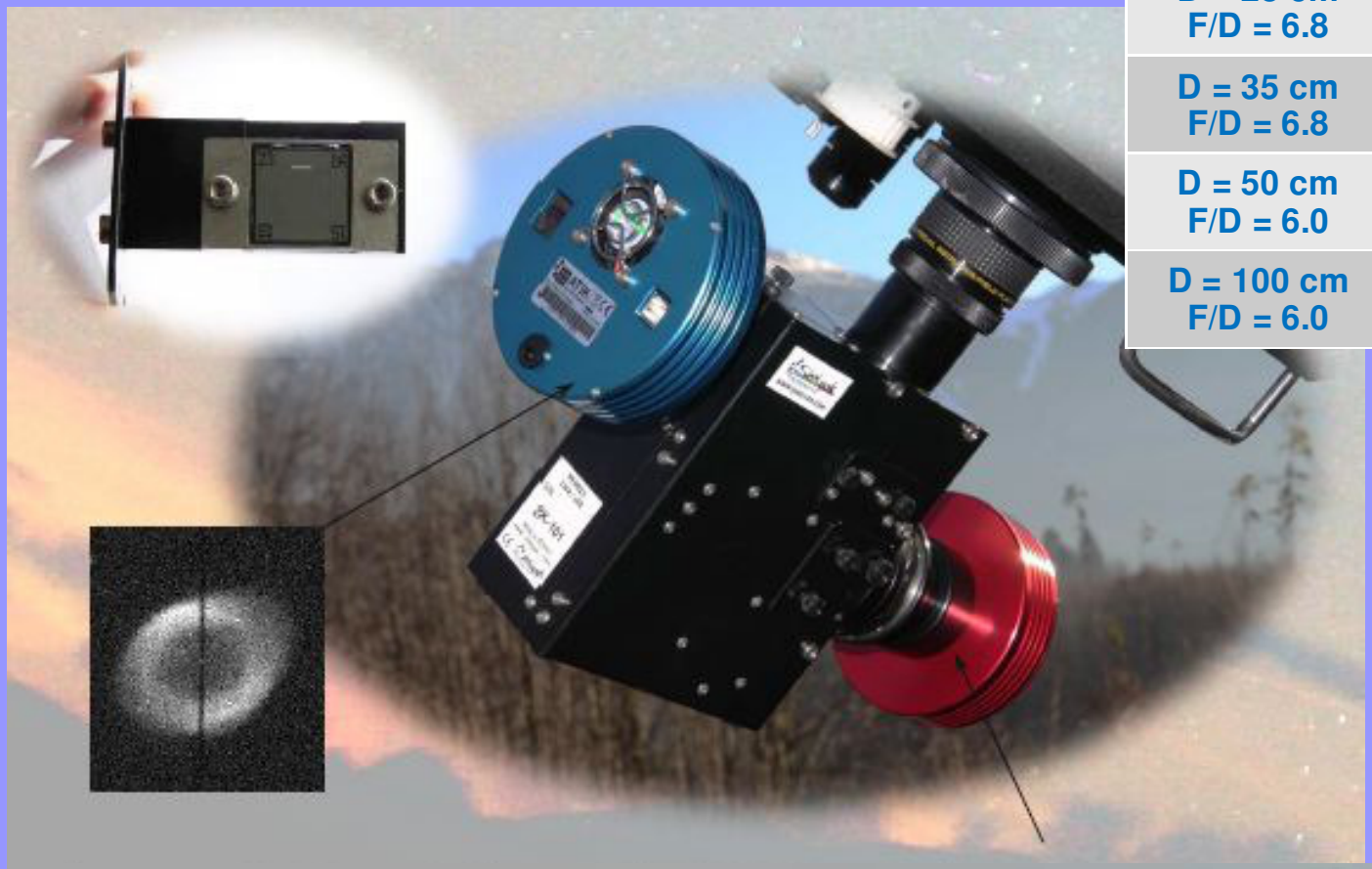


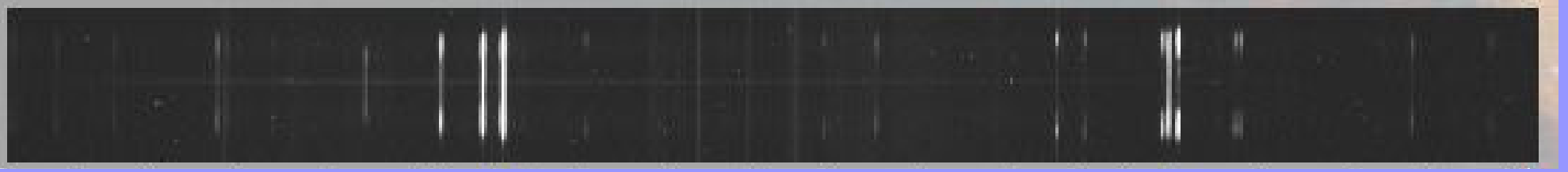
Gain resolution: LISA Pack (R ~1000)



In the field: acquisition w/ a LISA

	Slit 23 µm R = 1100	Slit 50 µm R = 600	Slit 100 µm 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

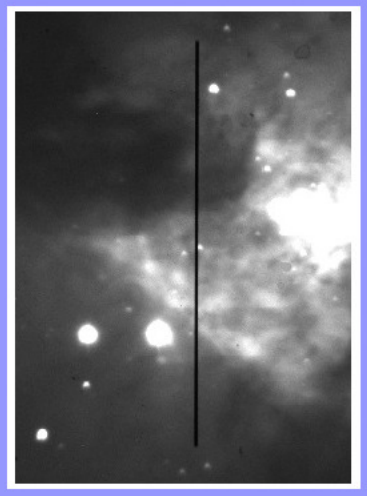


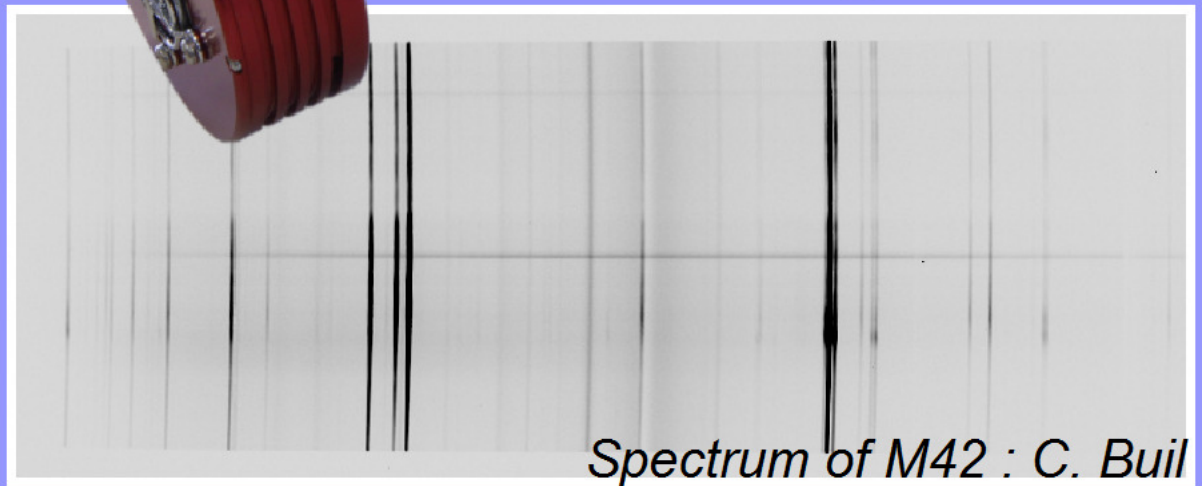


Limit magnitude :

- **A0V type star**
- **1h exposure (KAF8300)**
- **Signal/Noise = 10 (Halpha)**
- **Altitude 0, near city**

Alpy modular system





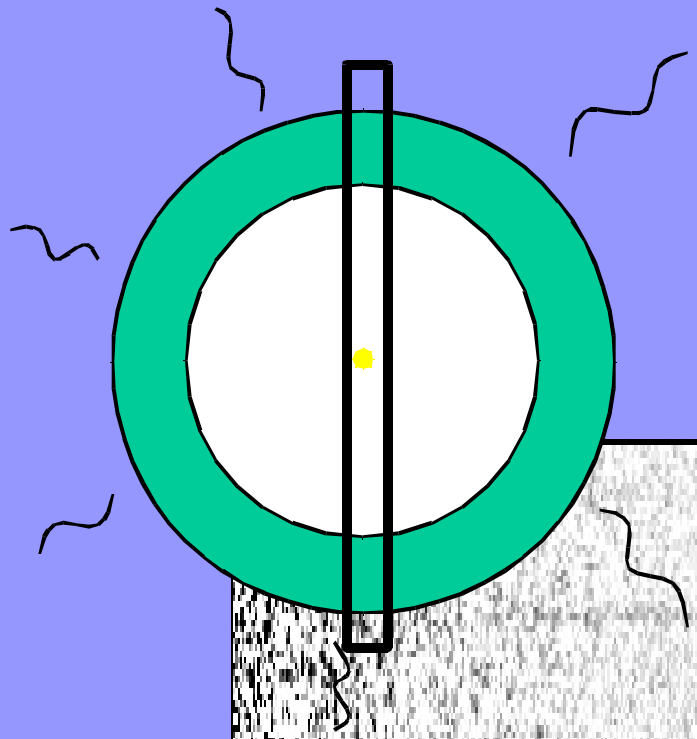
Spectrum of M42 : C. Buil

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

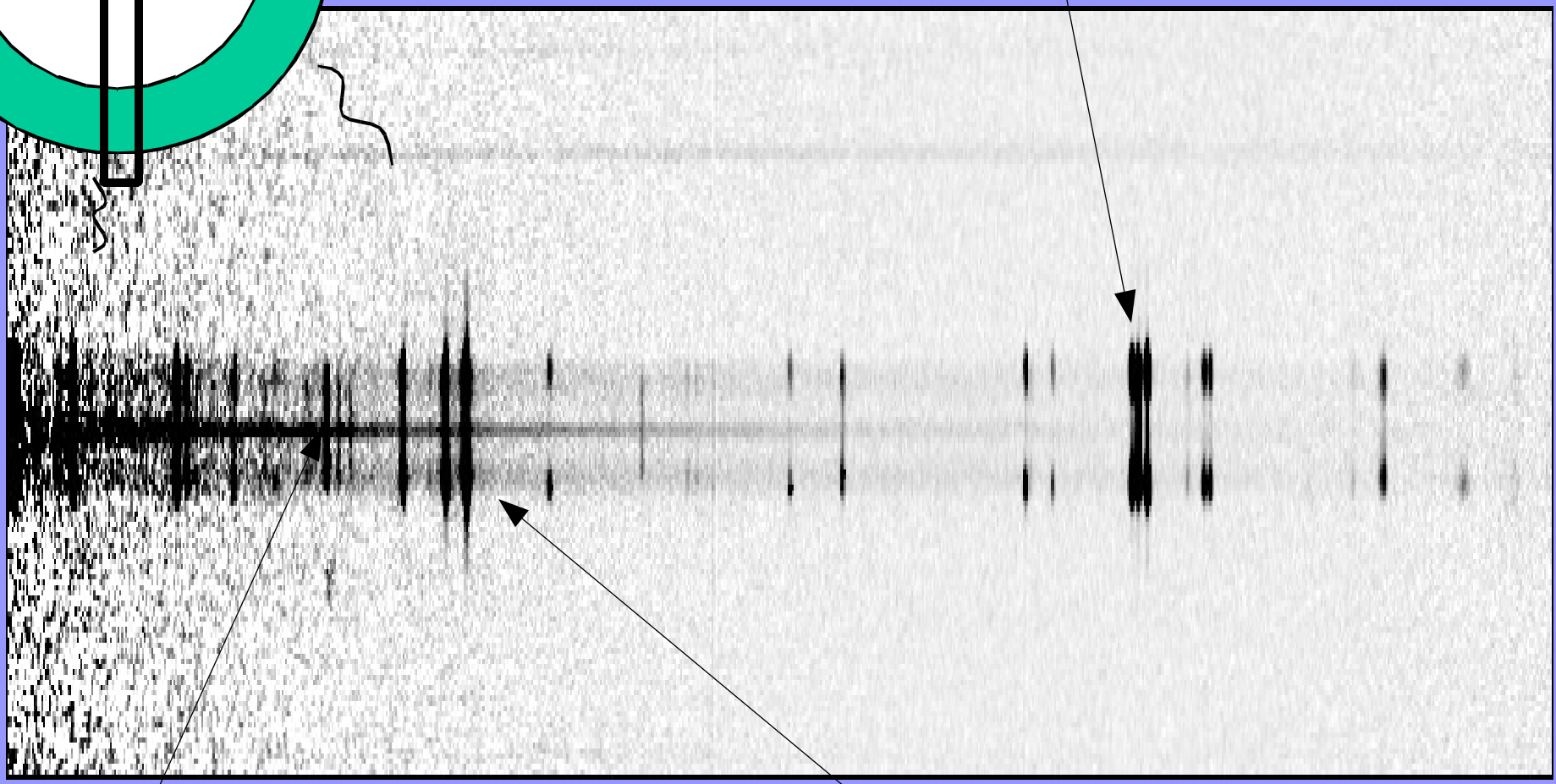
Limit magnitude :

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

Planetary Nebulae



Emission lines (nebula)

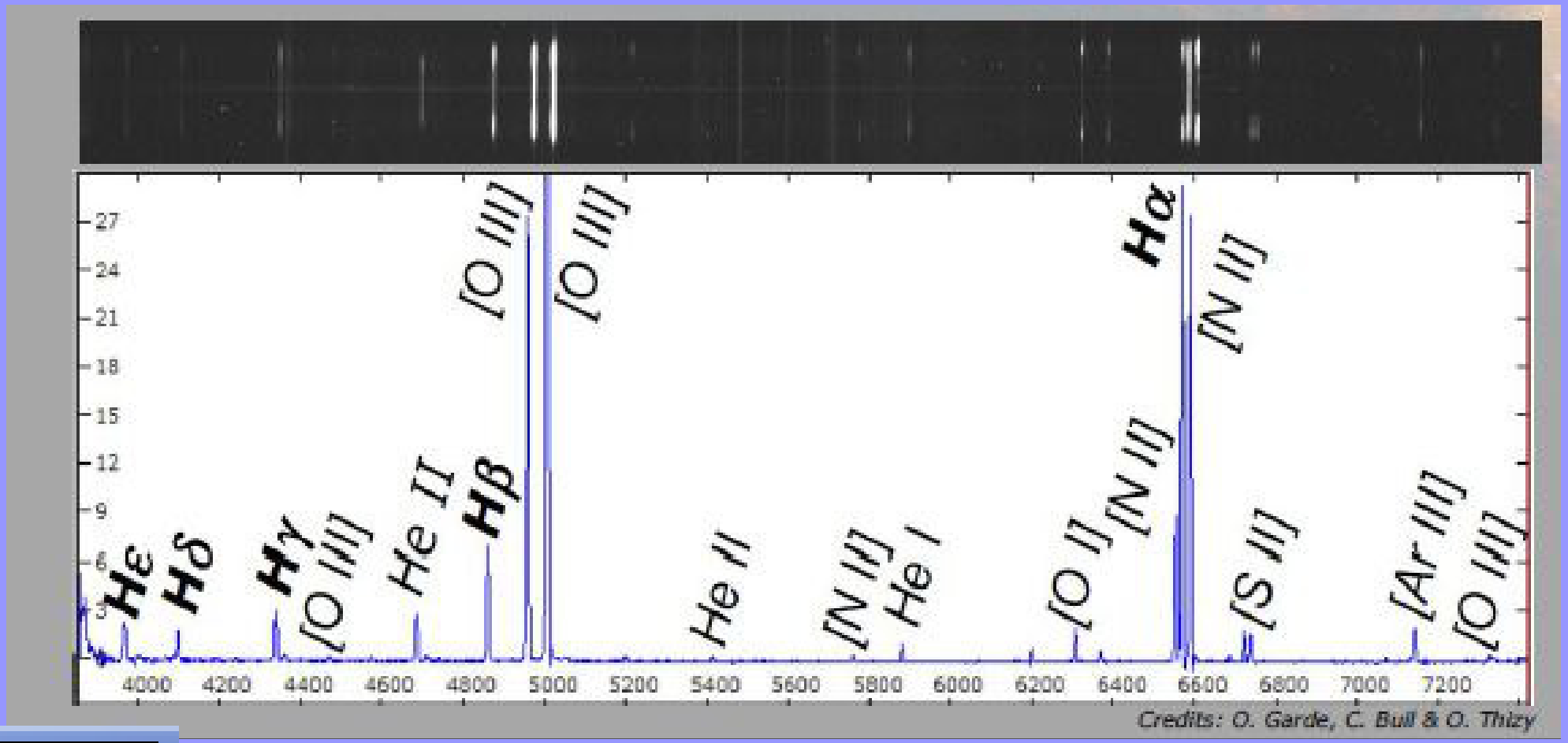


M57 spectrum (C. Buil; LISA, C9, QSI583, 70min)

Central star spectrum

Nebula continuous spectrum

In practice: data reduction



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

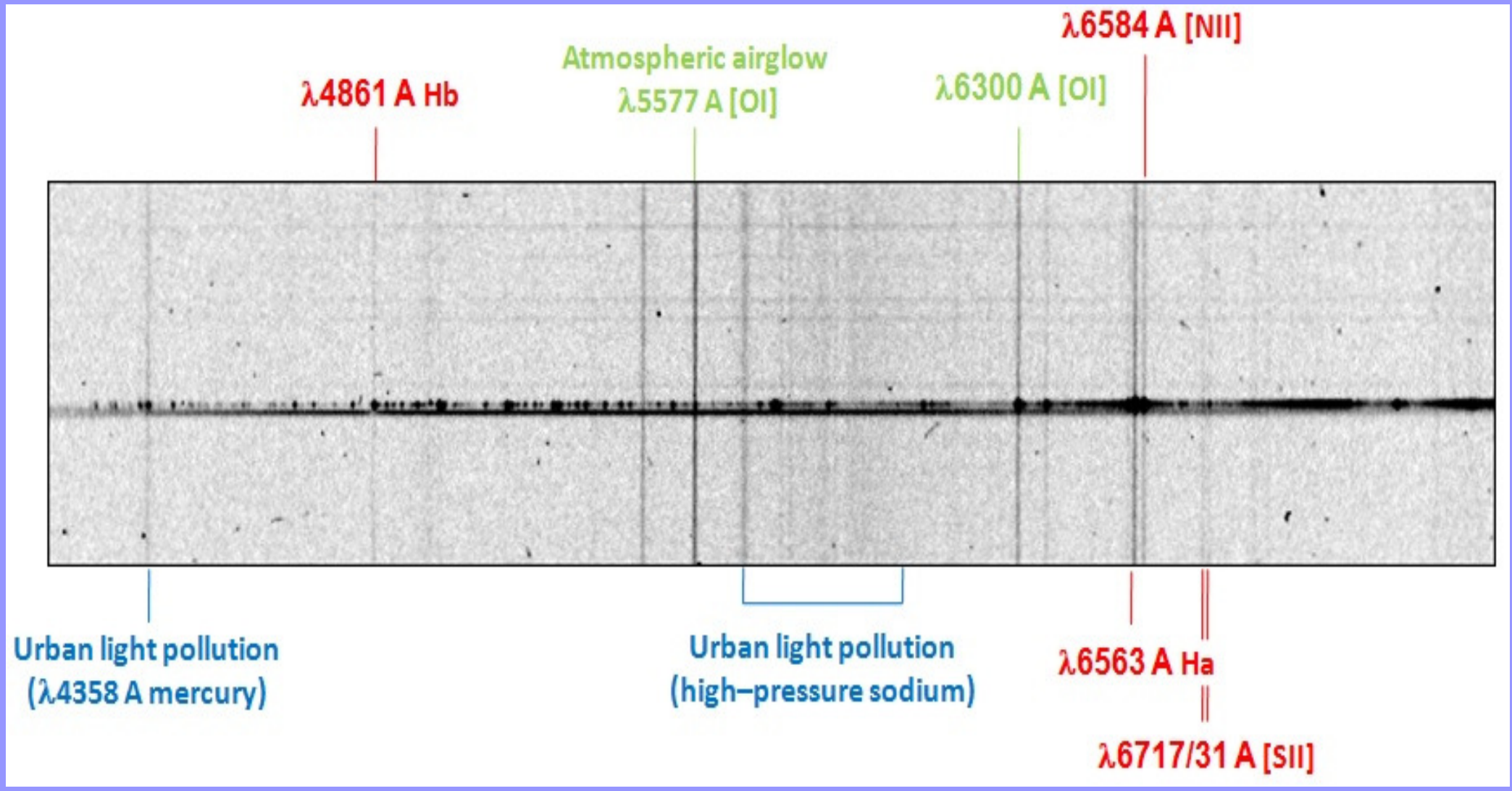
Nebulae: measure electronic temperature et density

Te=10933±174 K

Ne=2537±61 e-/cm^3

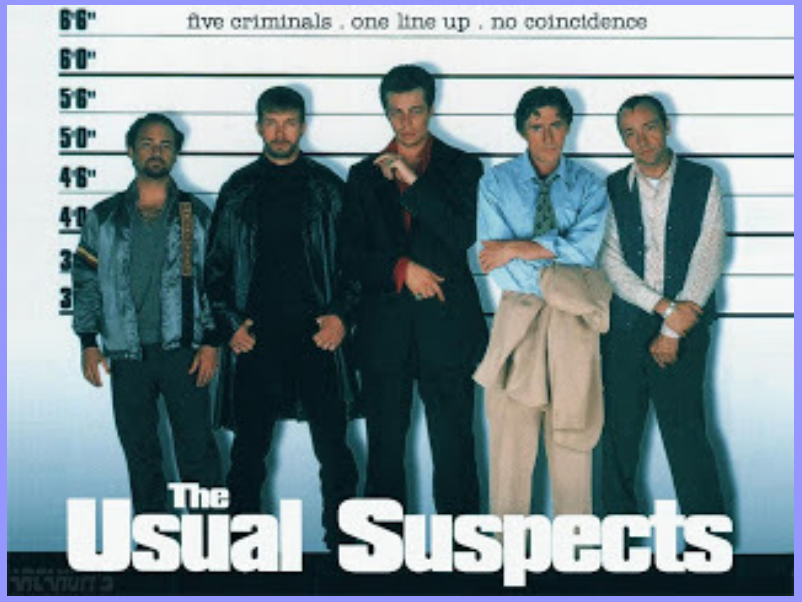
Spectre de M42 - Lhires III (150tt/mm) + KAF1600 / Acquisition: Benjamin Mauclaire / Traitement: Olivier Thizy
Cf: http://bmauclaire.free.fr/astronomie/spectro/atlas/nd/m42/
Image de M42: Olivier Garde & Adrien Viciana (CALA)

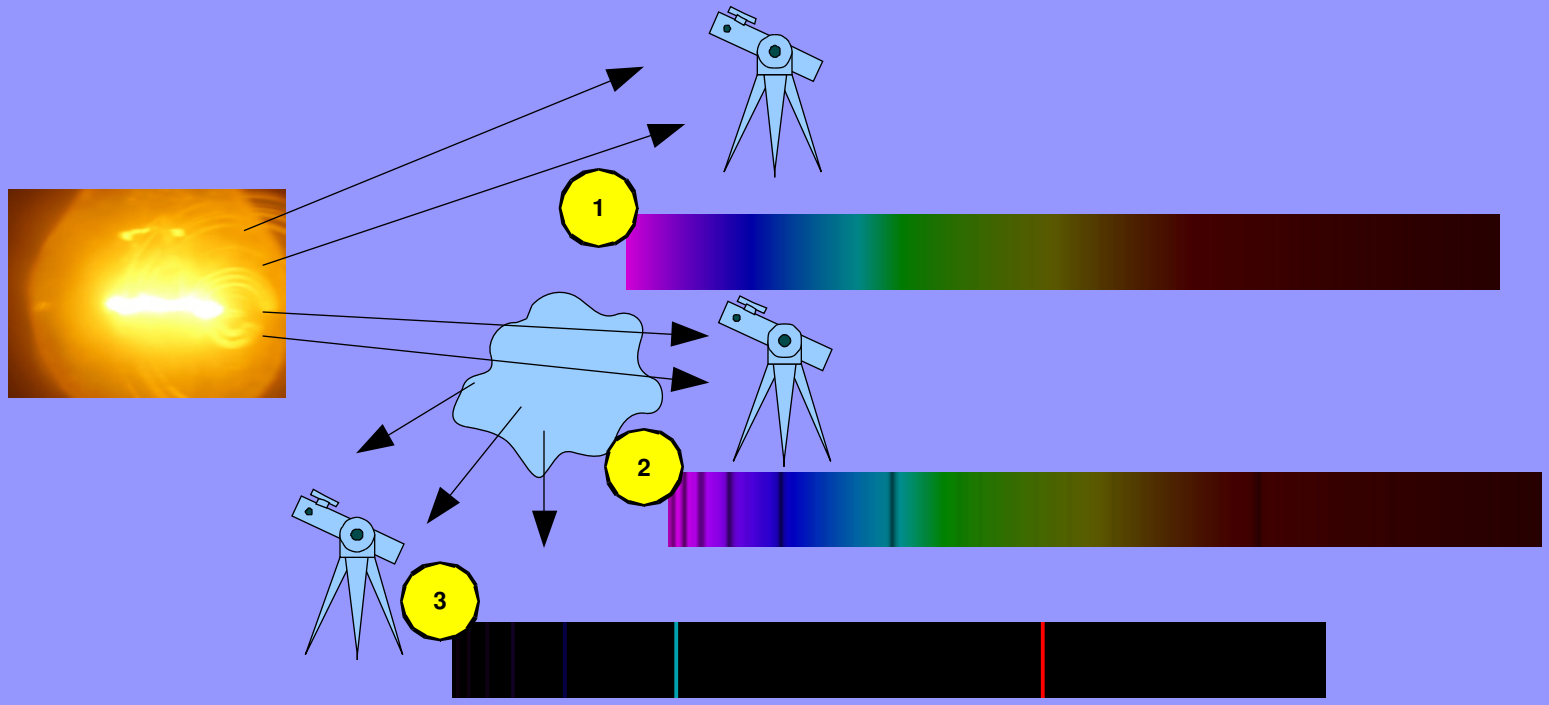
Sky “pollution” !



C9 + LISA + QSI583 (C. Buil) ; target in NGC7000 nebula

Kirchhoff's law summary



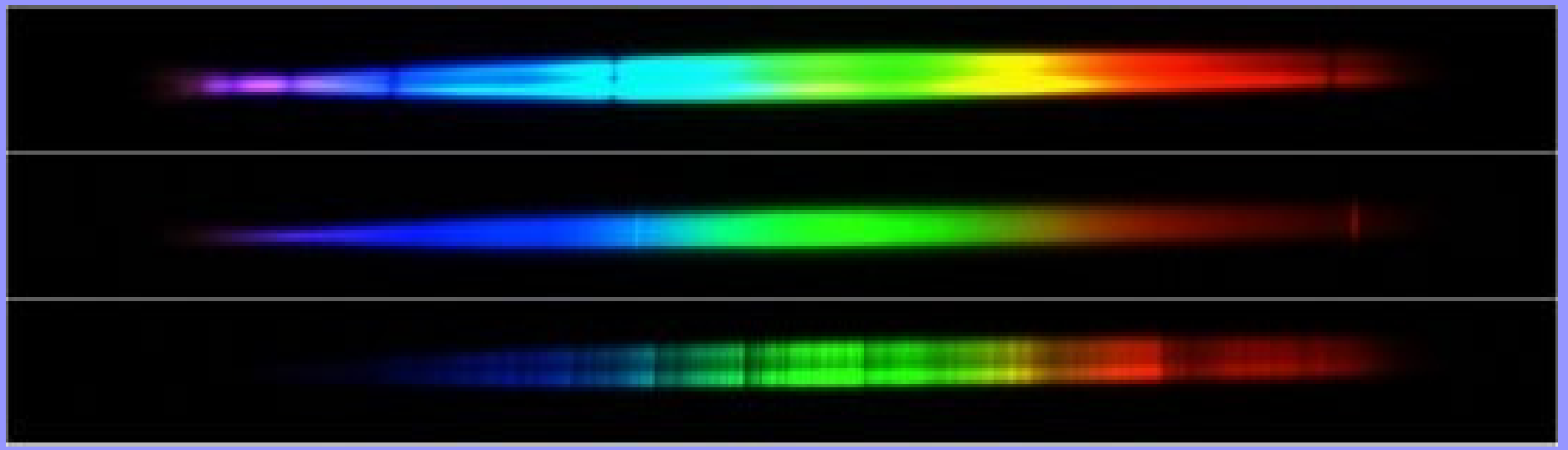


Stellar classification

- **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**
  - **Williama 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 classication**
  - **Annie Cannon (1863-1941)**
    - **"OBAFGKM" types**
    - **sub-divisions (B0..9)**
    - **~400000 spectra of her own !!!**

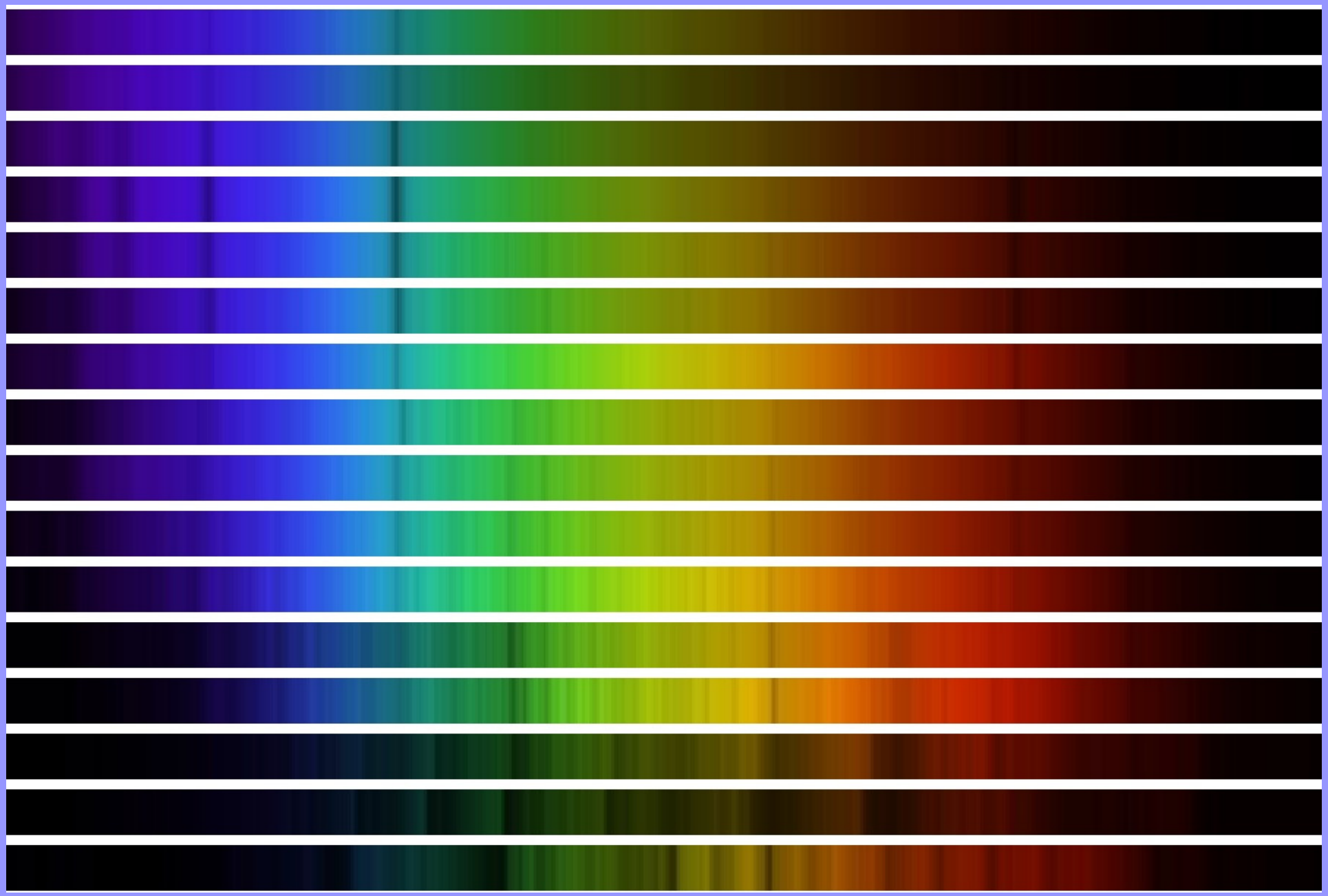
A.J. Cannon

Spectral Classification (Low Res.)



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

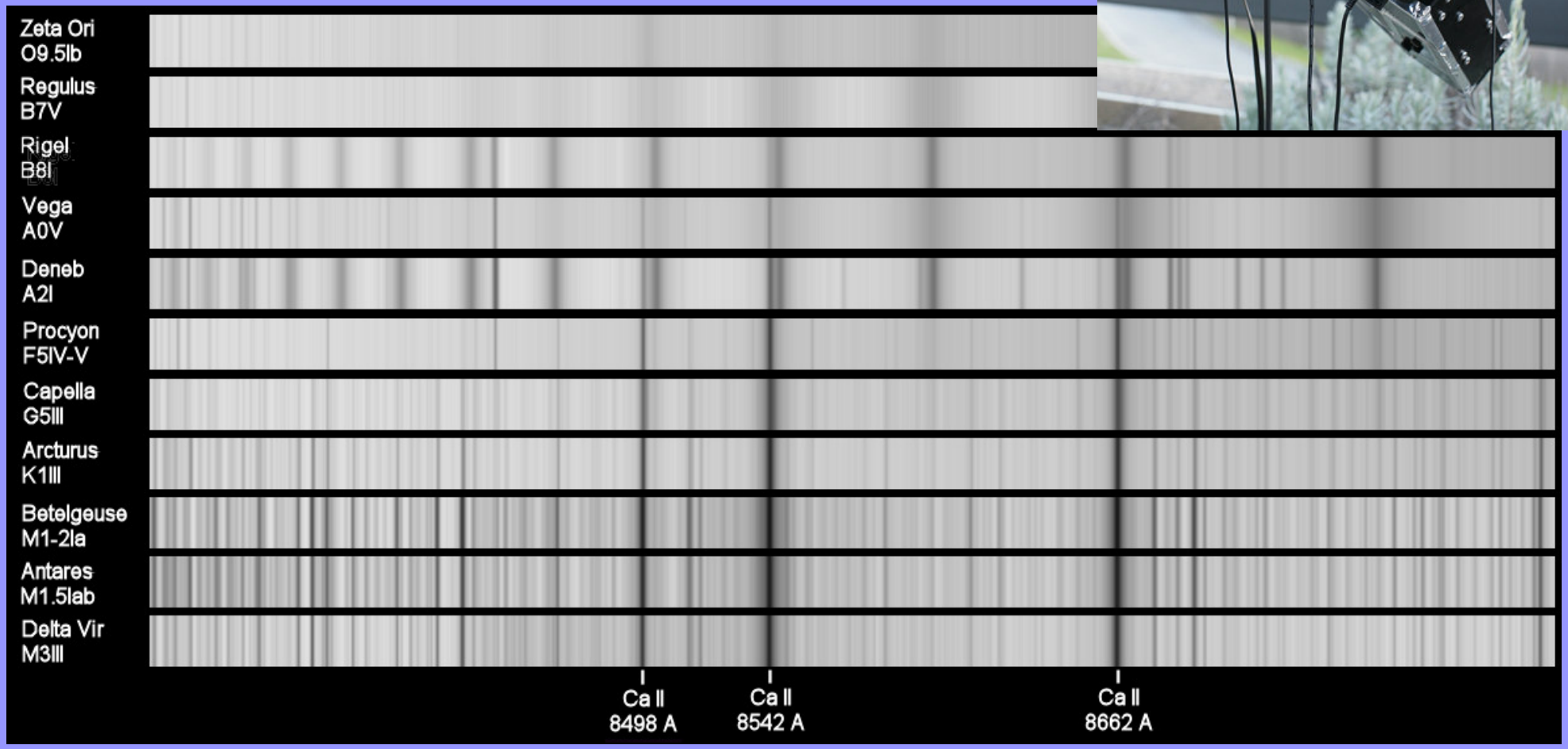
From ABC... to OBAFGKM !



Spectra by Benjamin Mauclaire; 12" telescope + Lhires III (150 gr/mm) + KAF1600 camera

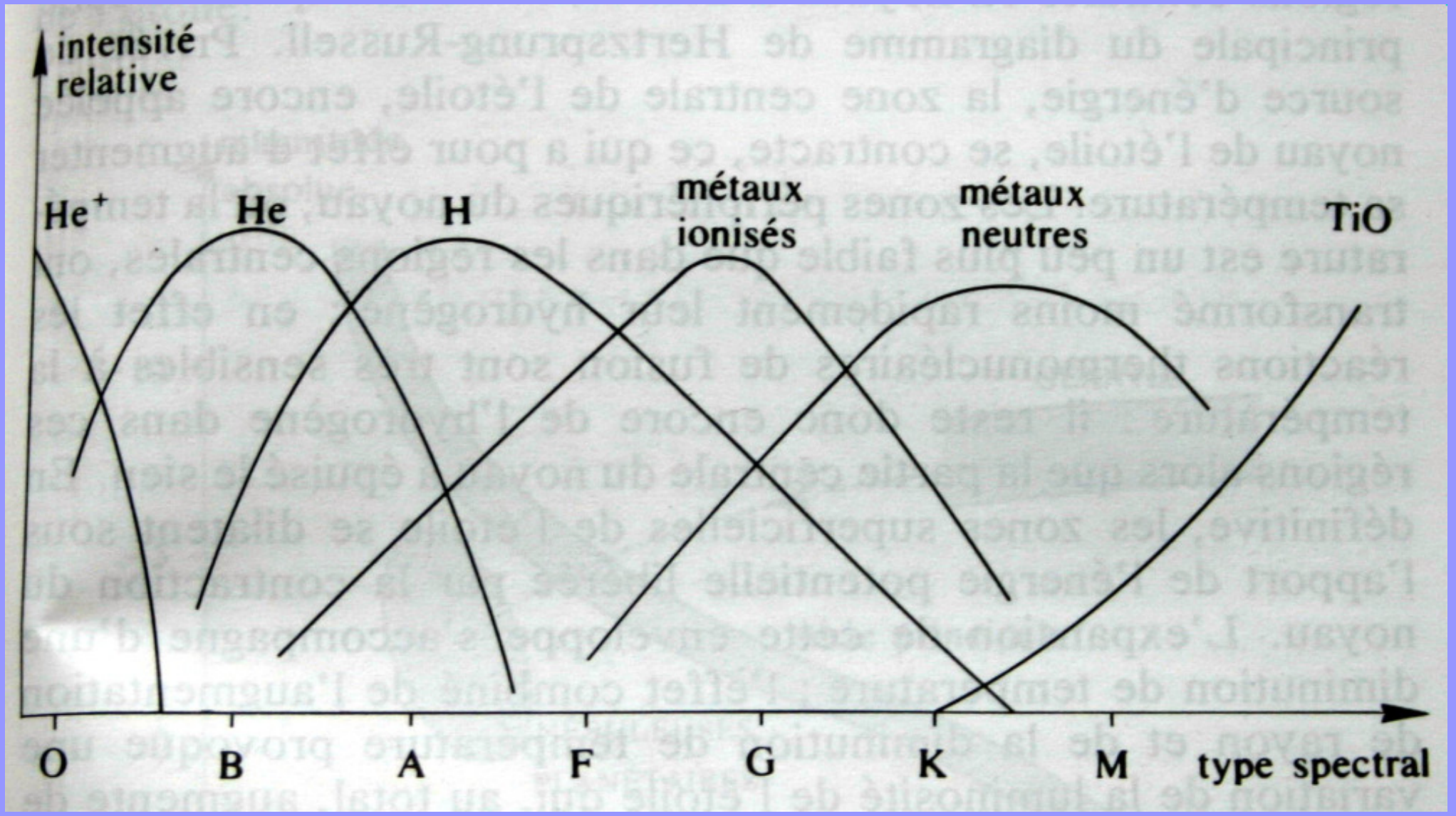
Spectral Classification (High Res.)

Oh-Be-A-Fine-Girl-Kiss-Me

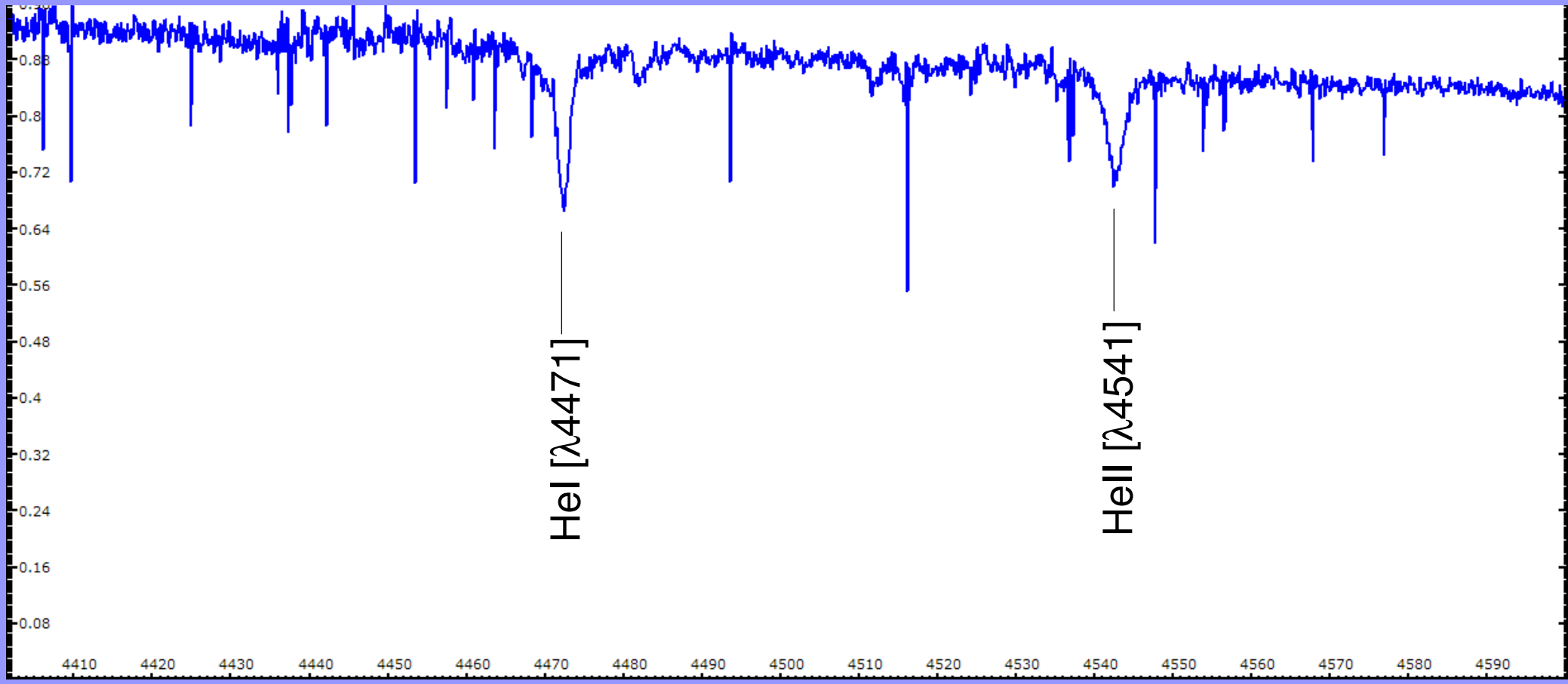


Sequence around Calcium triplet, near Infra-Red. © Christian Buil / Lhires III + Digital SLR

Relative intensity per elements



A more precise classification's method



Measuring Equivalent Width of HeI [λ4471] & HeII [λ4541] ==> precise spectral type

HD 47839: HeI [λ4471] = 0.799 et HeII [λ4541] = 0.533 ==> type = O8

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

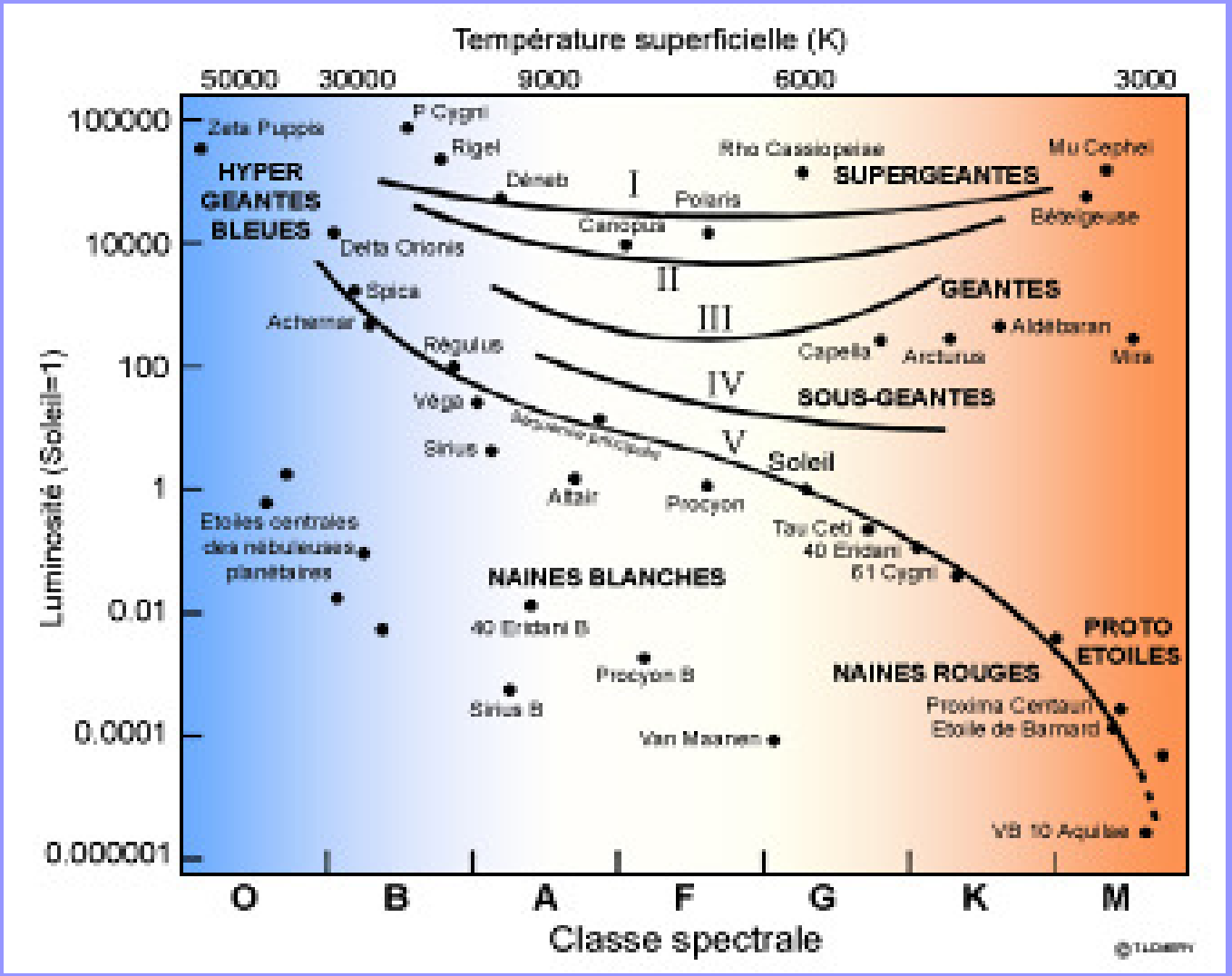
Stellar classification

- **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**

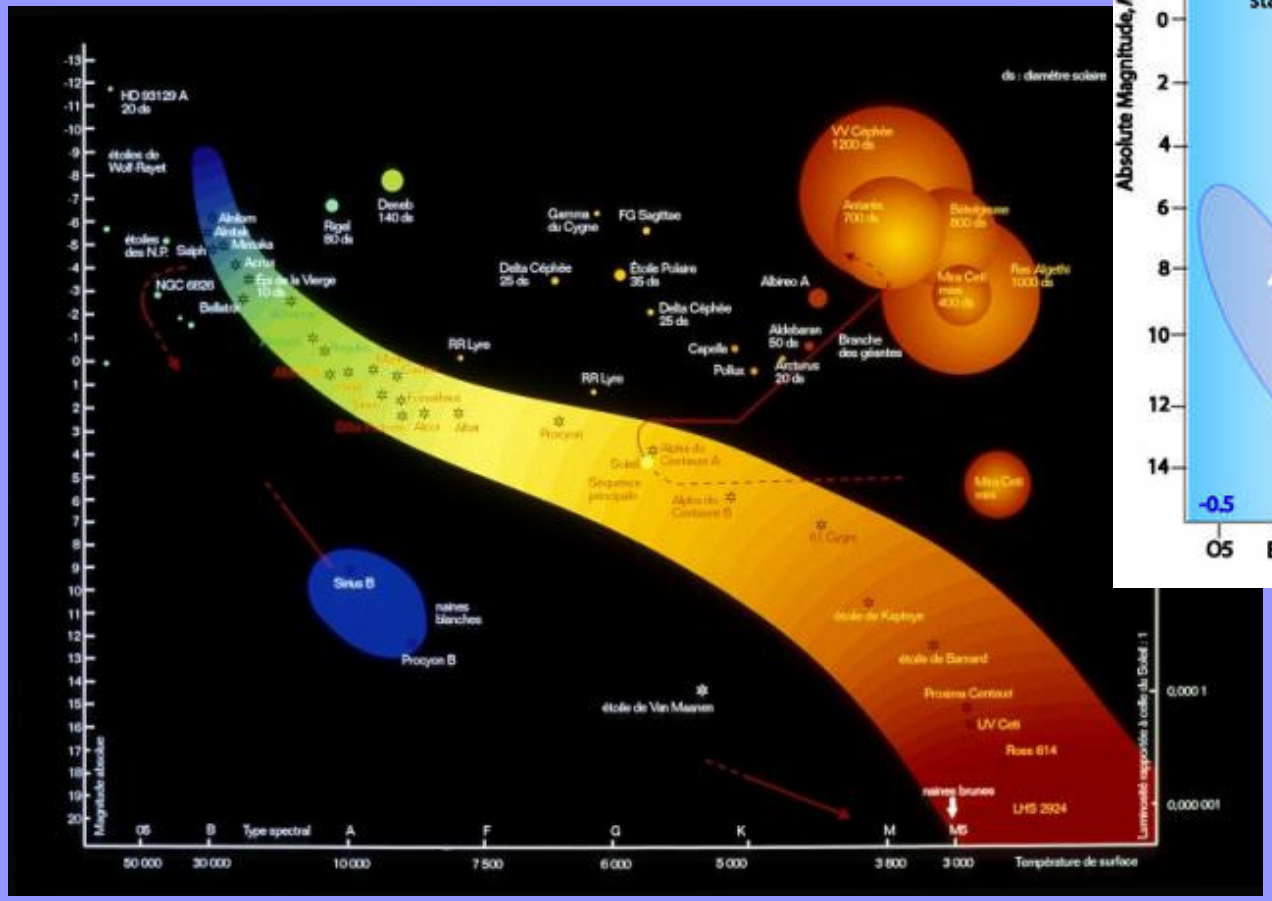
E. Pickering team (all women!) in 1913.

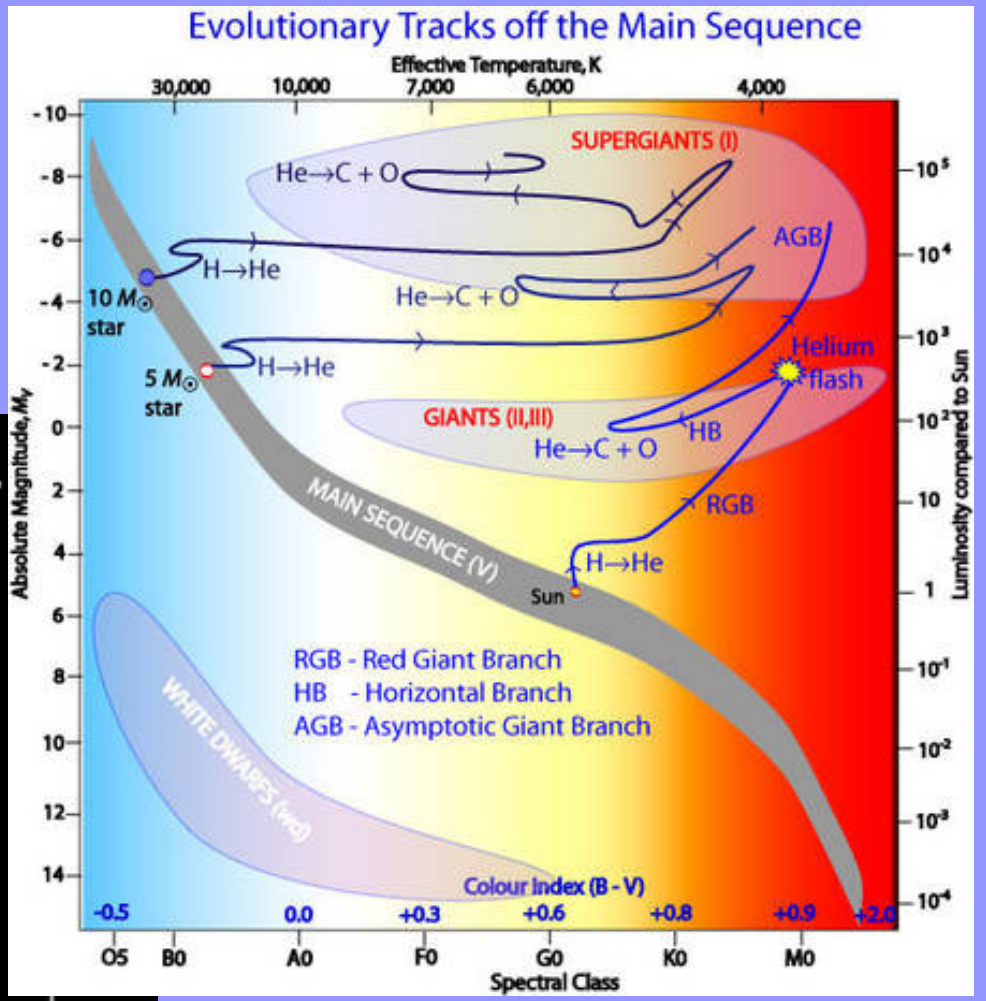
Beginning of Astrophysics

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



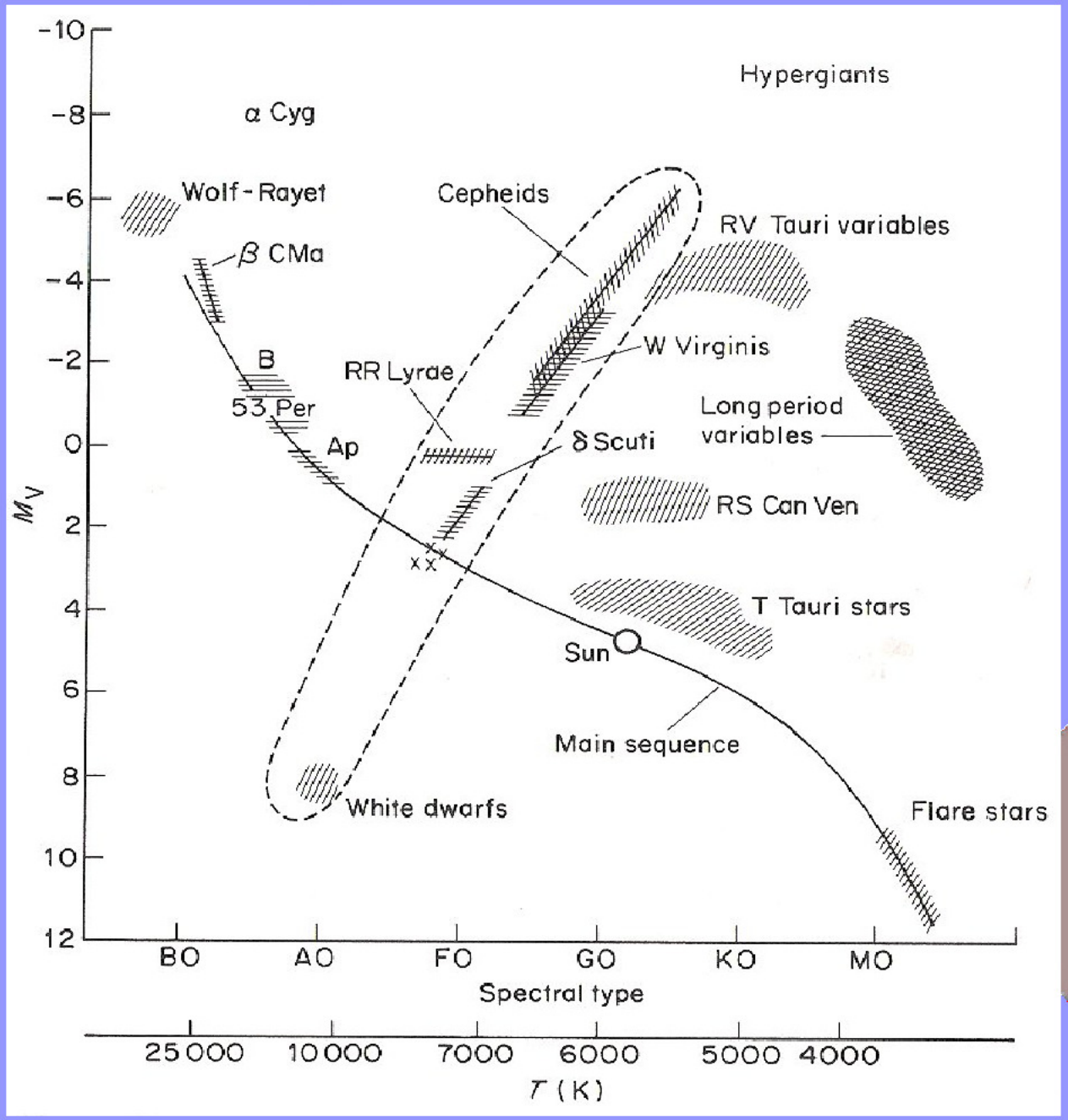
HR diagram – star life cycle



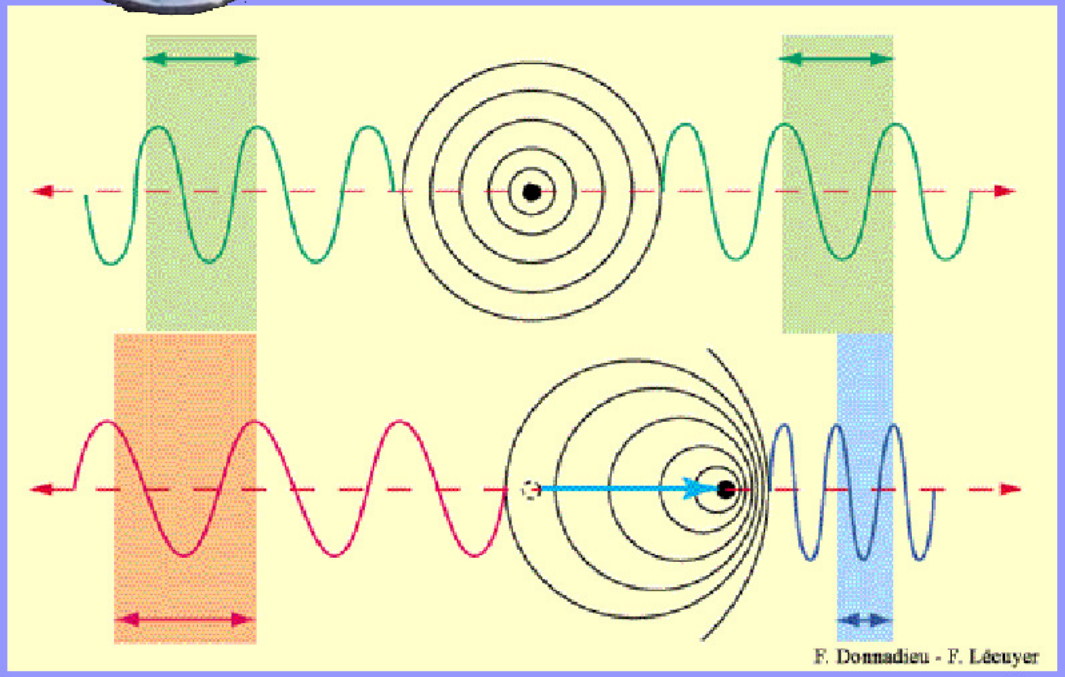


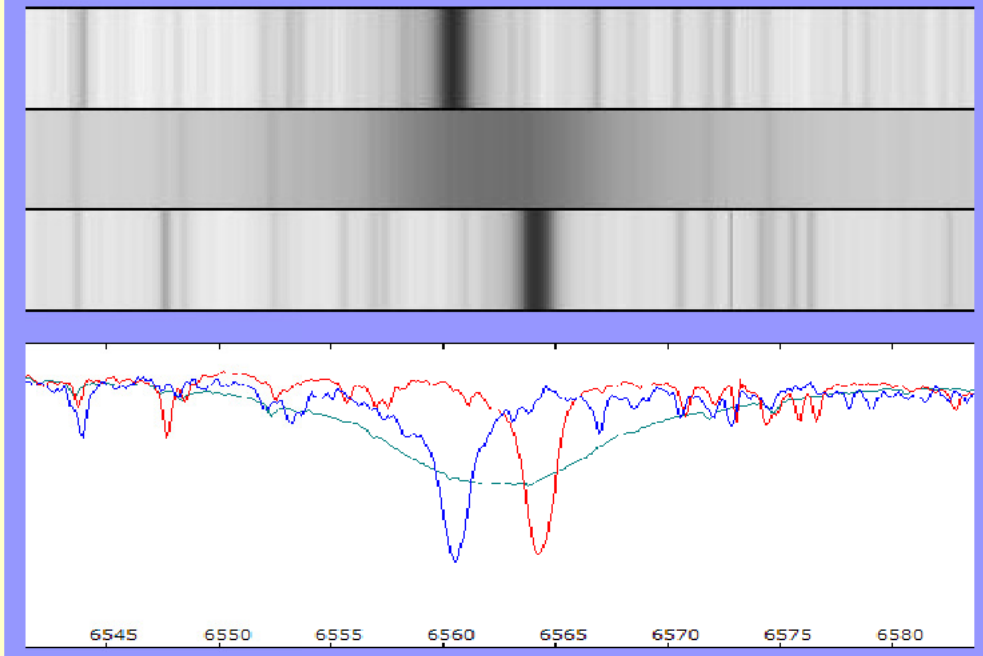
Source : Ciel et Espace

Variables stars (cf AAVSO)



Doppler-Fizeau: the ideal suspect !

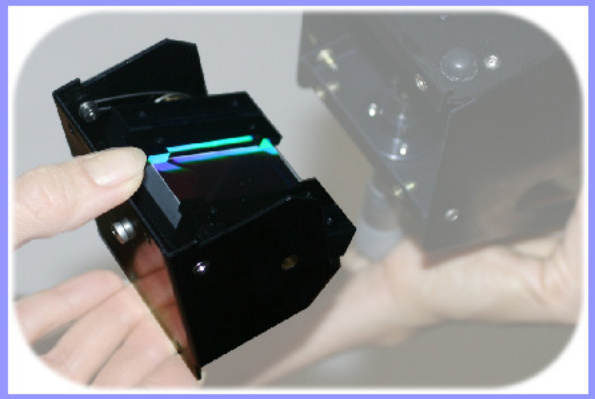




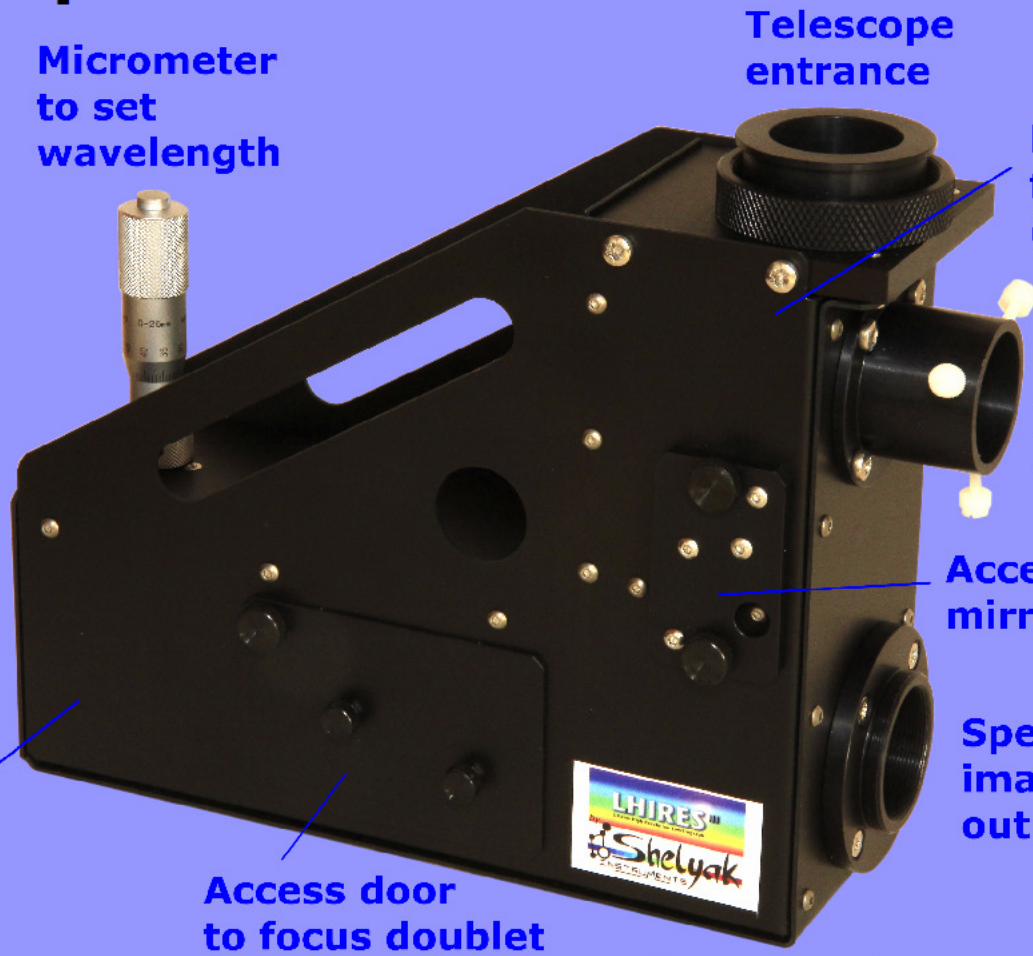
Galaxies redshift
=
Expansion of our Universe !

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

Lhires III : high-resolution spectrograph to measure Doppler

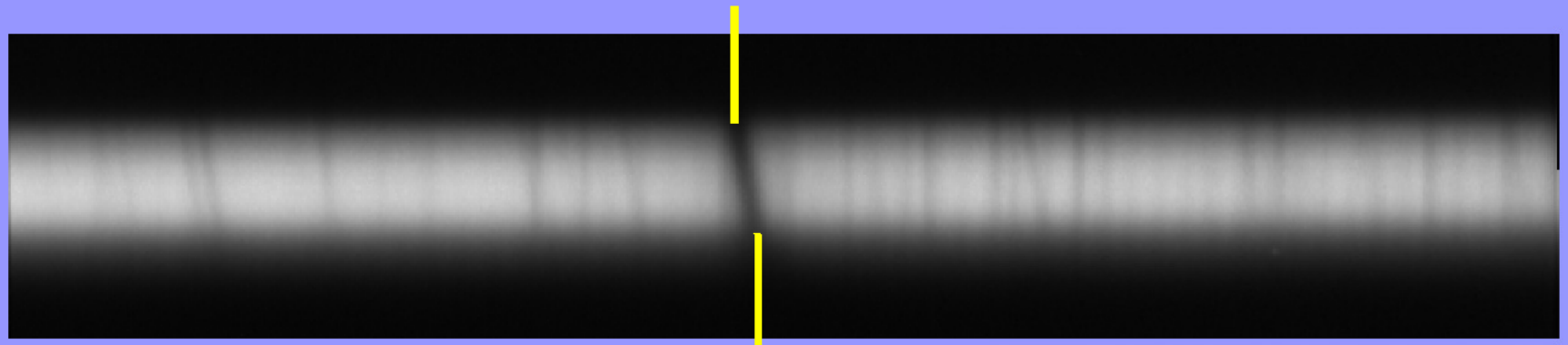


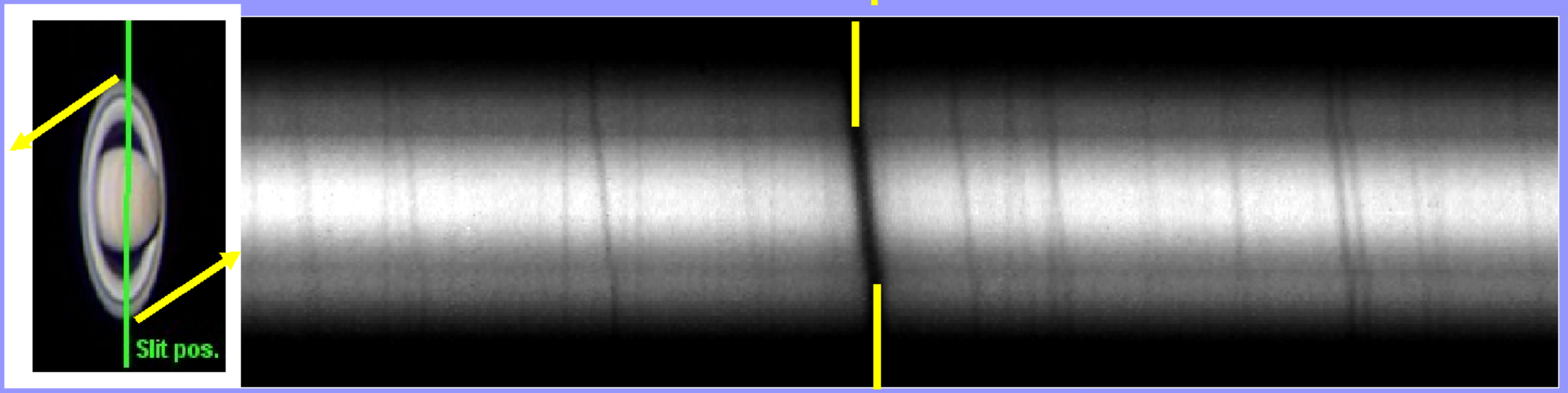
Interchangeable gratings



		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	1100	2300
Limiting magnitude		5	6	7	8	9

Planet's rotation



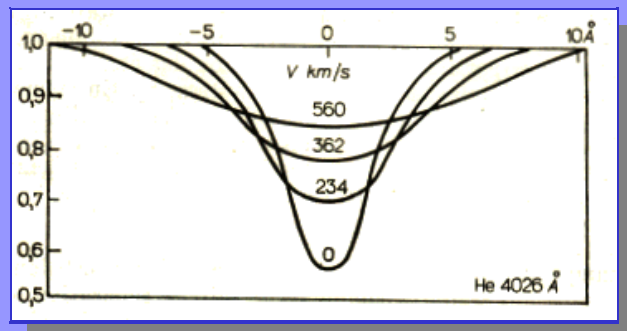


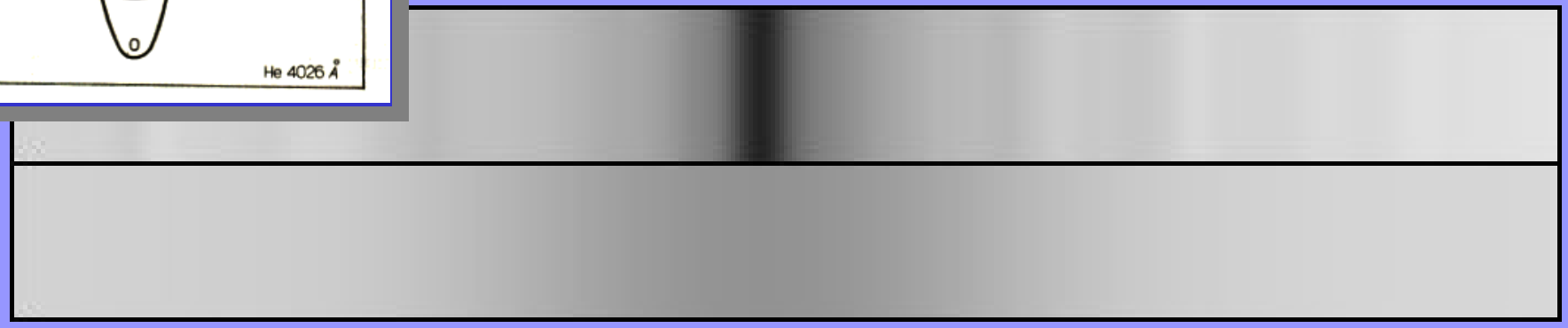
Saturn:
Shift = 7 pixels = 8,8 km/s
Period of 10,6 h >> R = 107511 km

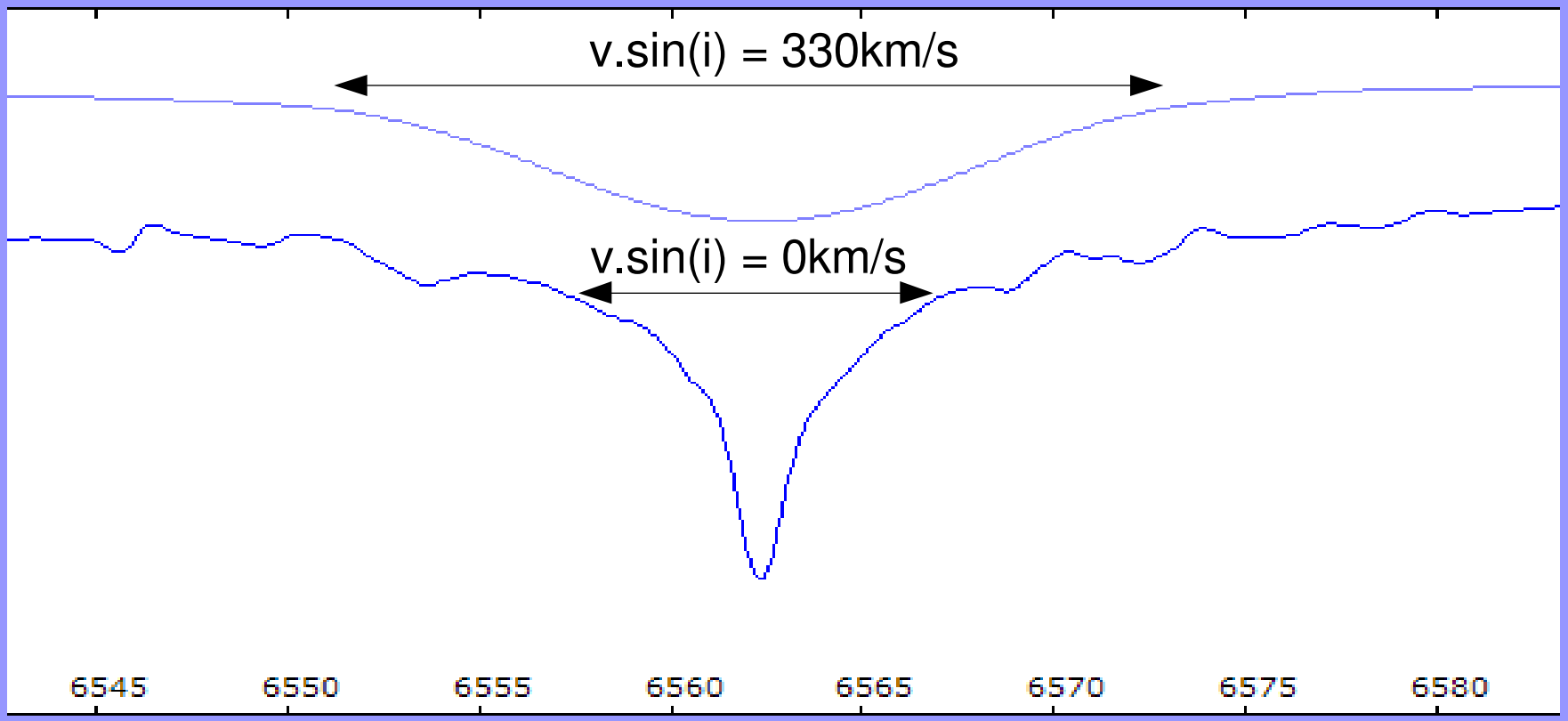
$$T^2 = \frac{(4\pi^2)}{(G(m_1+m_2))} a^3$$

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

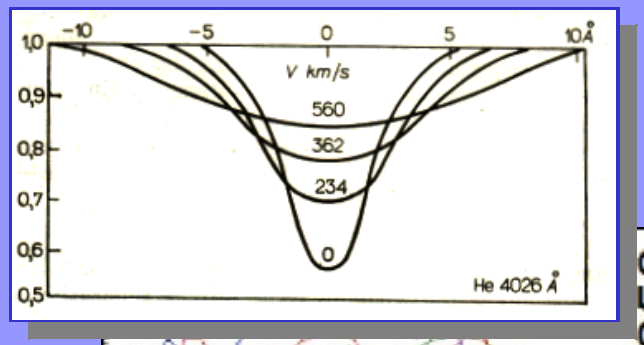
Stellar Rotation: v.sin(i)

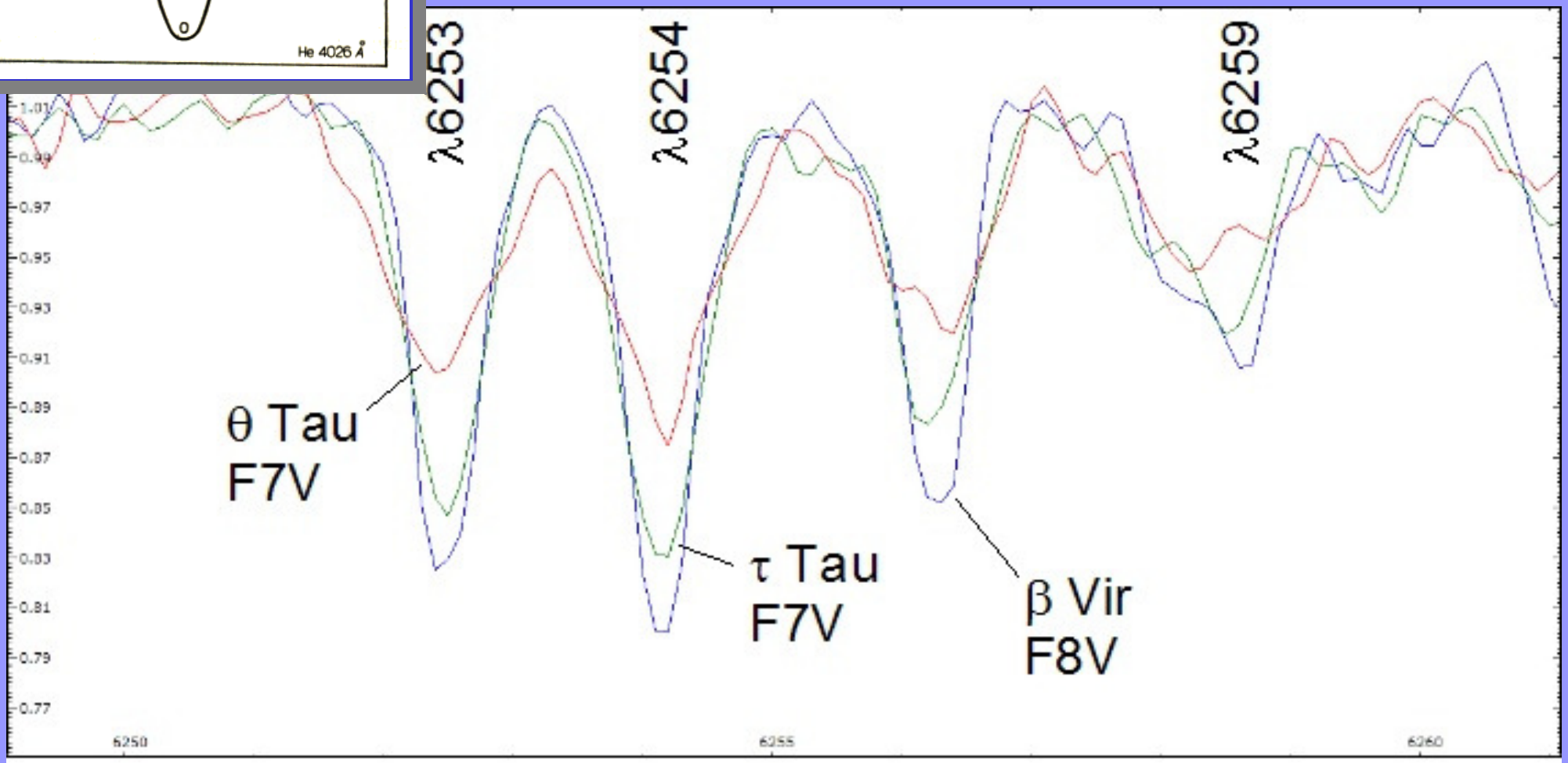






Rotation stellaire : v.sin(i)

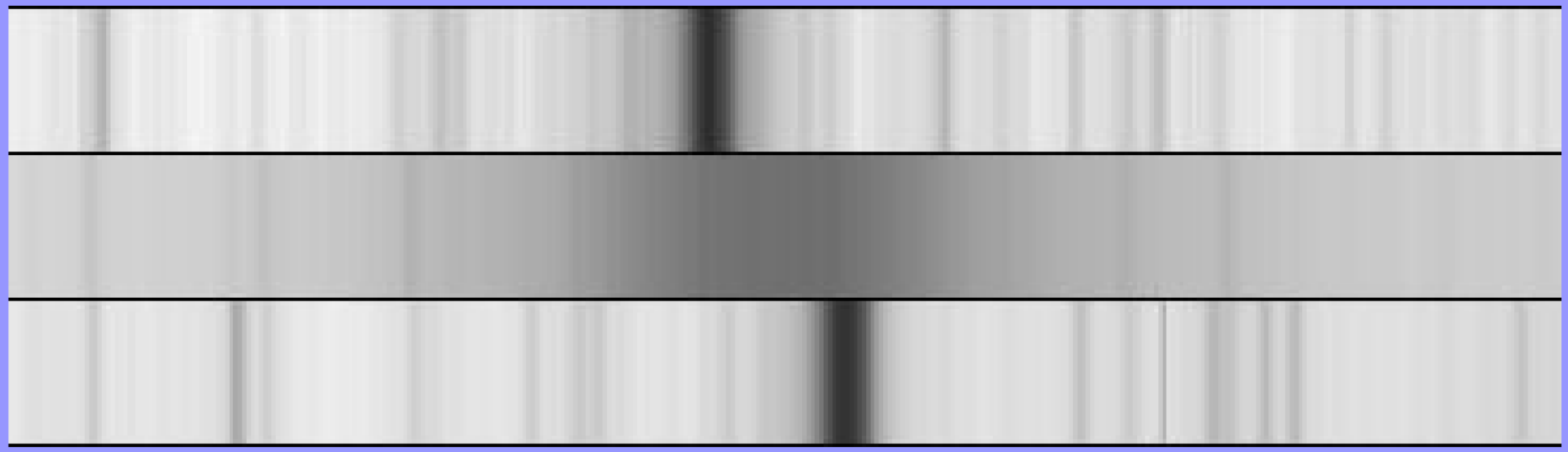




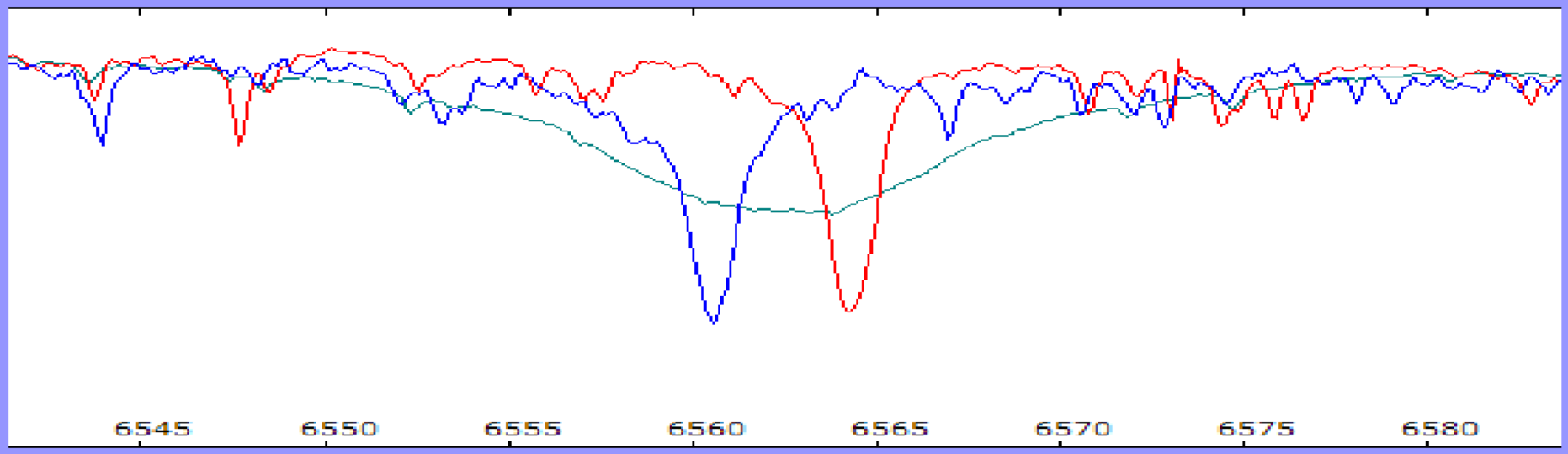
Effet de la rotation sur l'élargissement de raies spectrale.
eShel Shelyak Instruments echelle spectrograph (R~11000).
T0.28m f/6.3; Observatoire de Haute Provence – 27 février 2009.
Idée de D. Gray (observation and analysis of stellar photosphere).

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

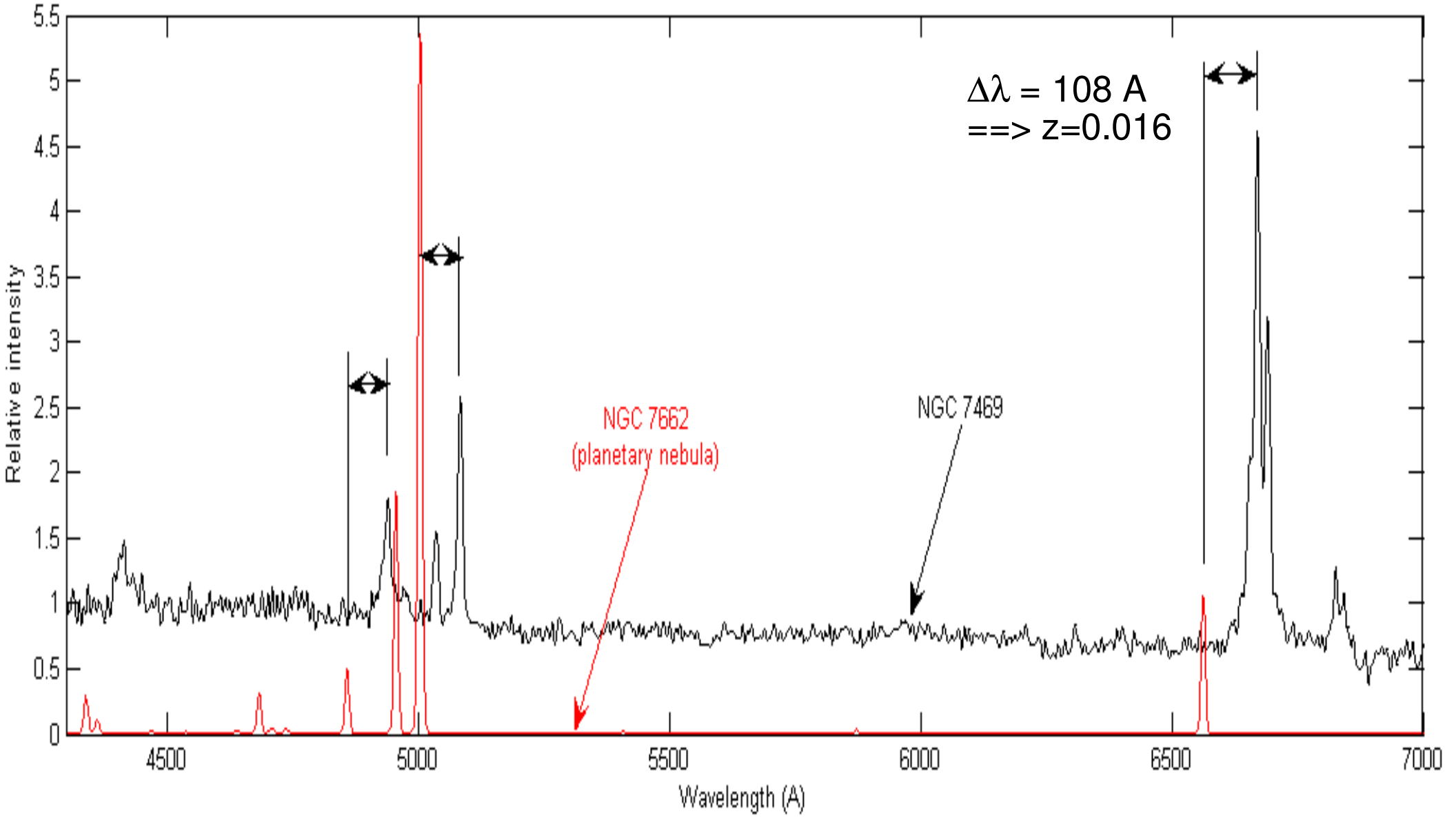
Stellar Radial Velocities



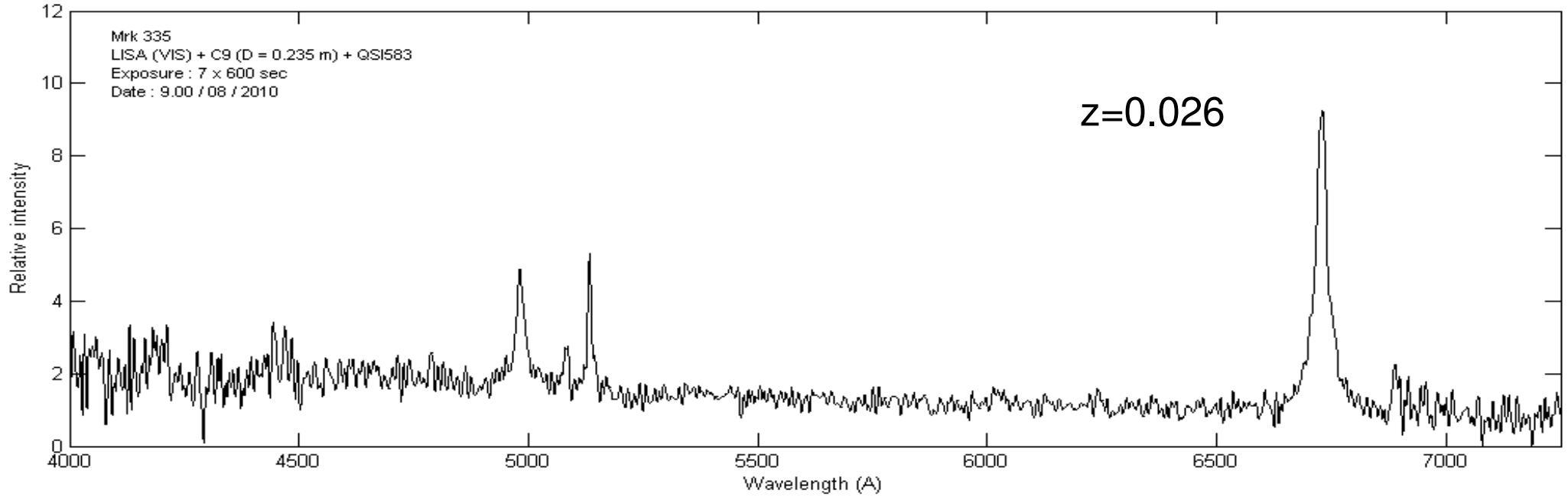
SAO104807, Altair, & SAO112958

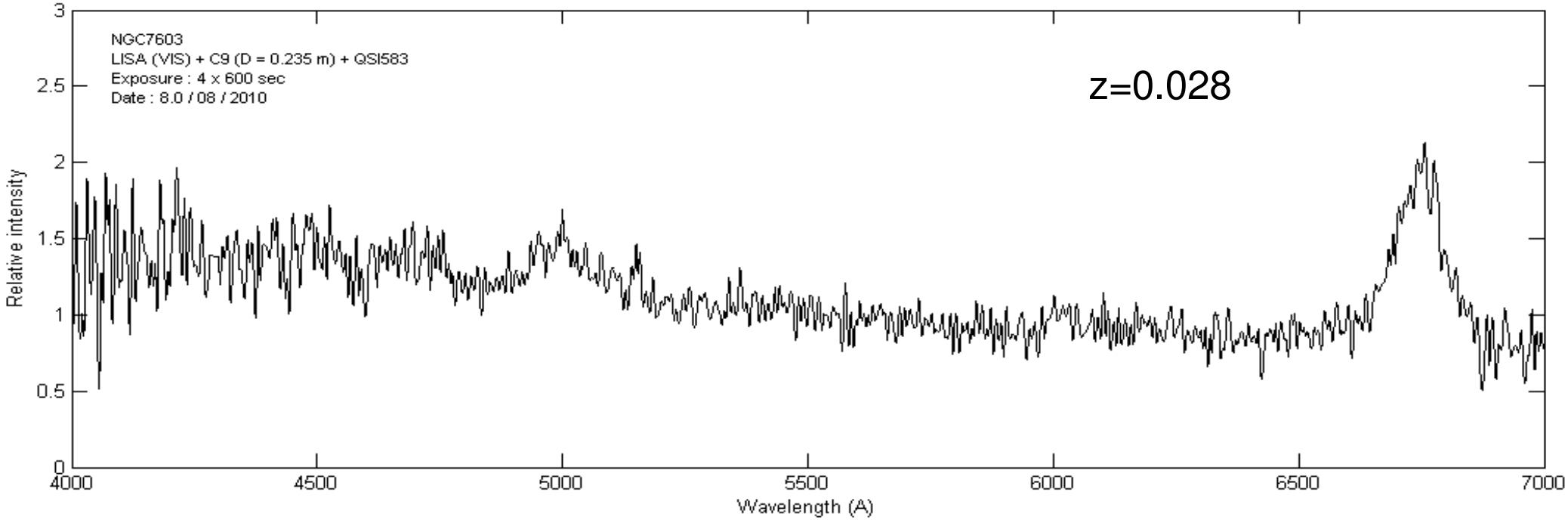


Galaxies redshift

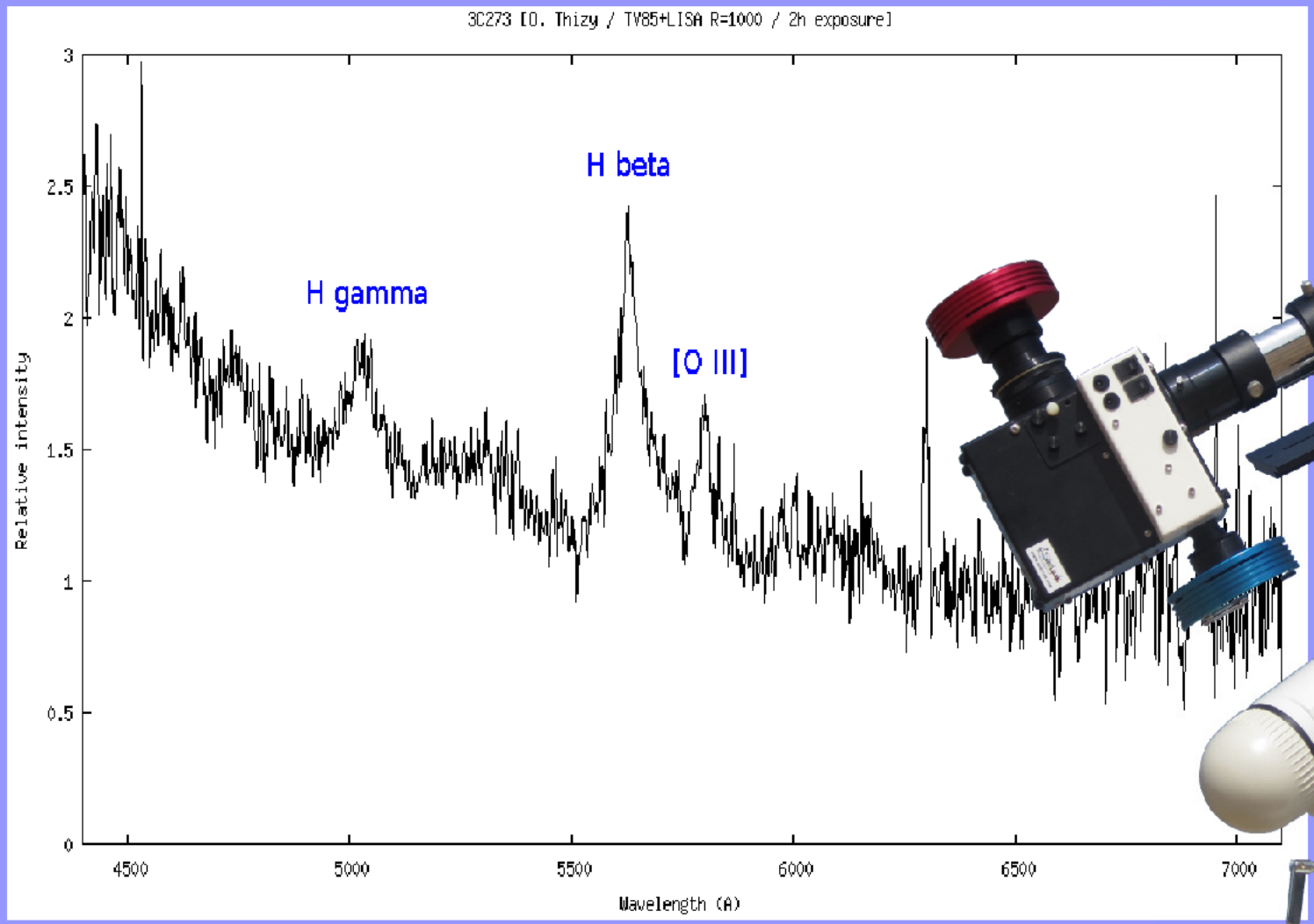


Galaxies redshifts





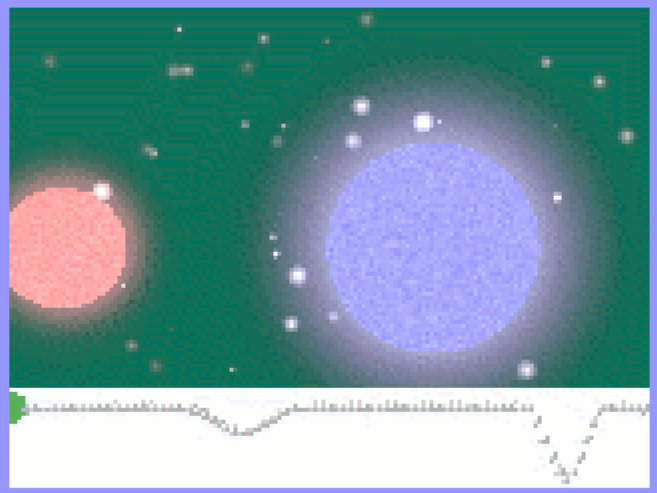
3C273 quasar



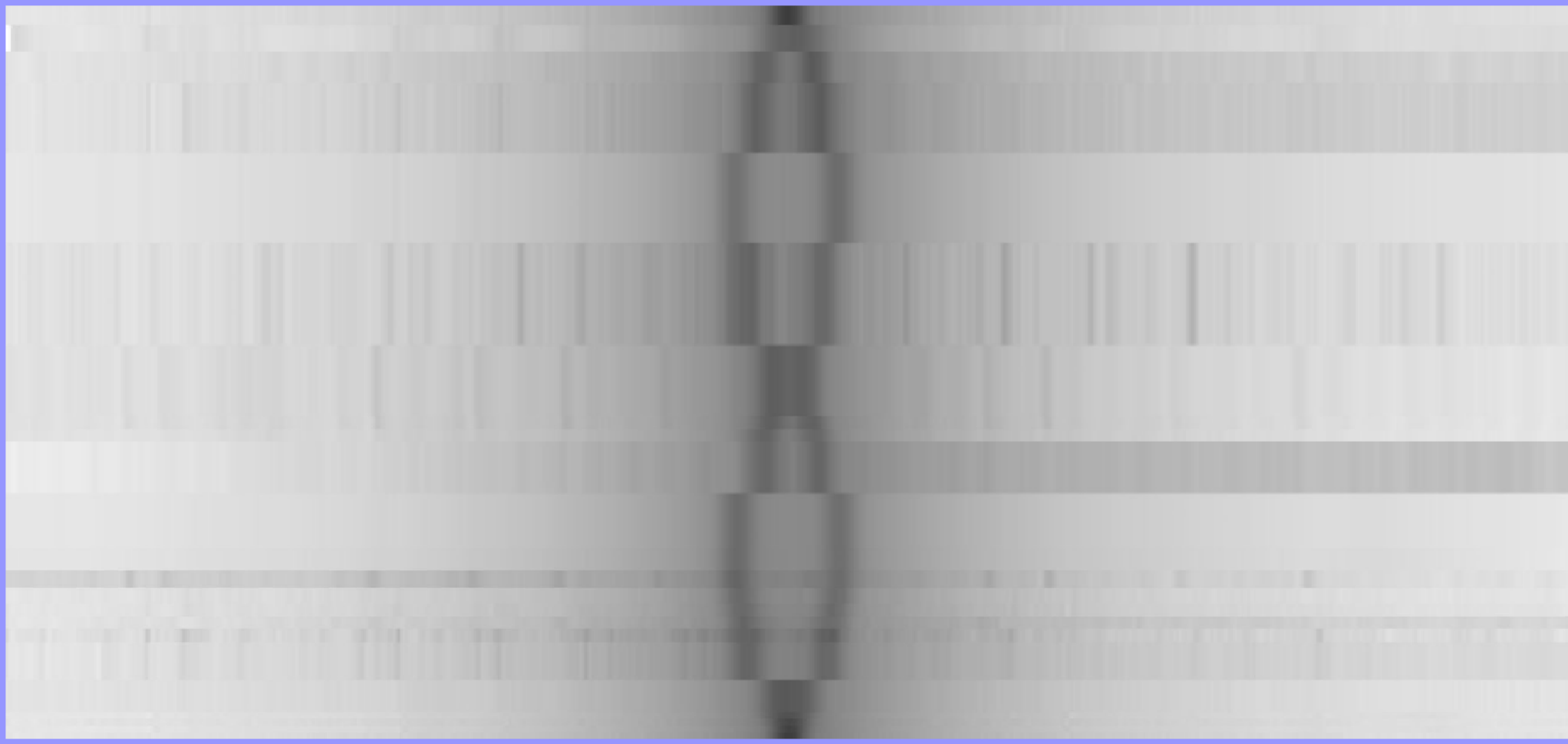
Hbeta red-shifted from 4861A to 5629A :

z =(5629.27/4861.32)-1

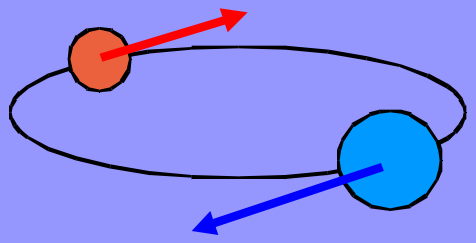
z = 0.158



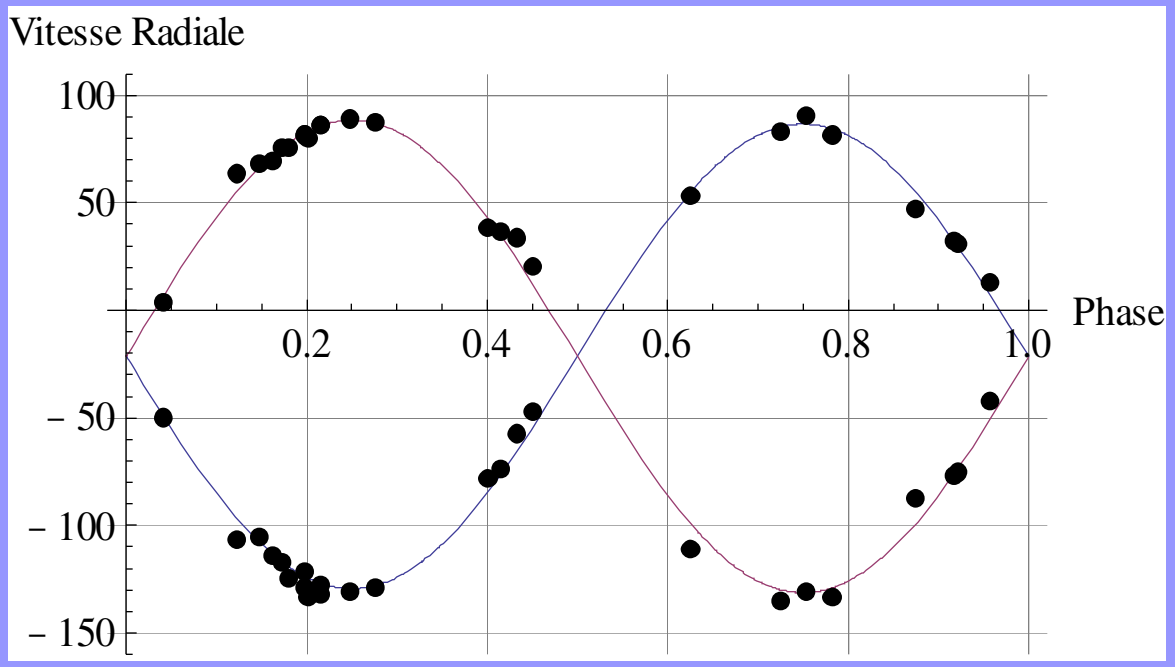
Spectroscopic binaries



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

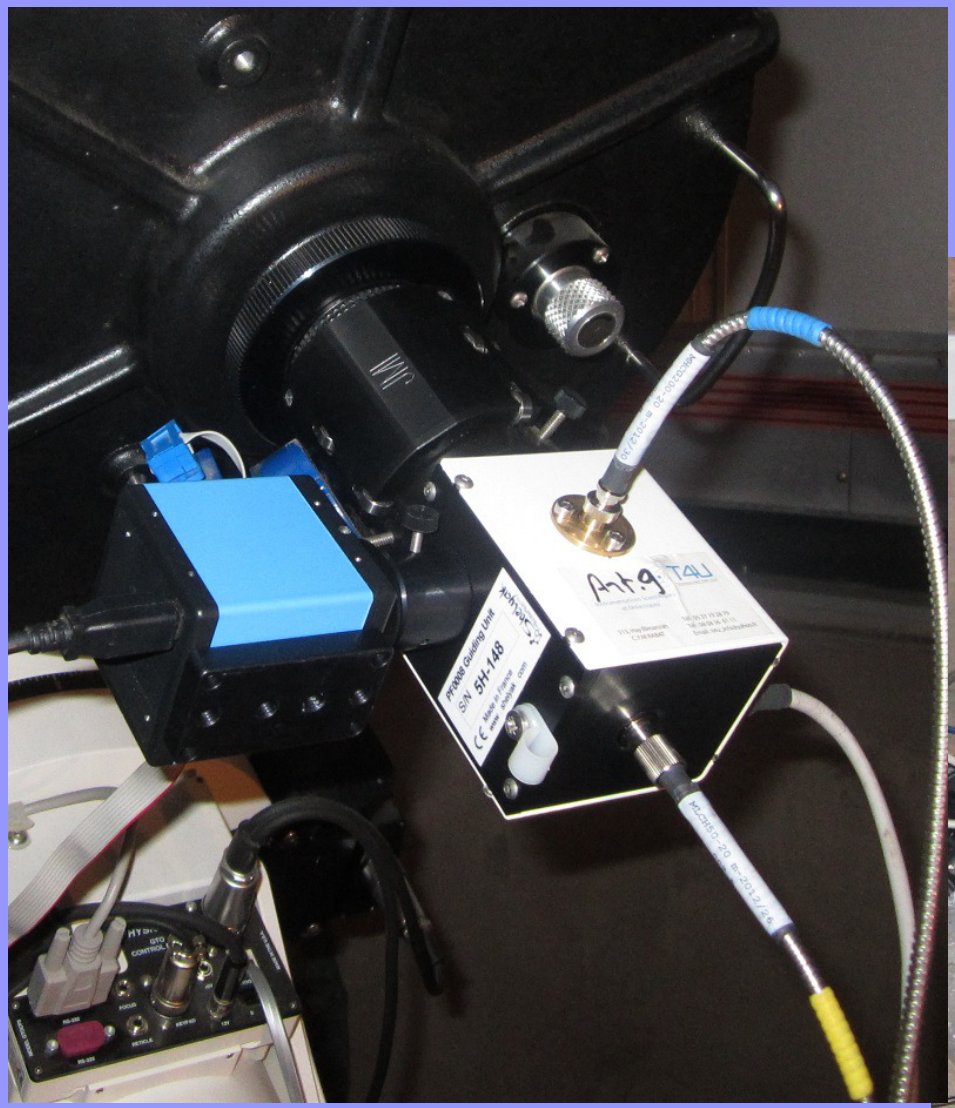


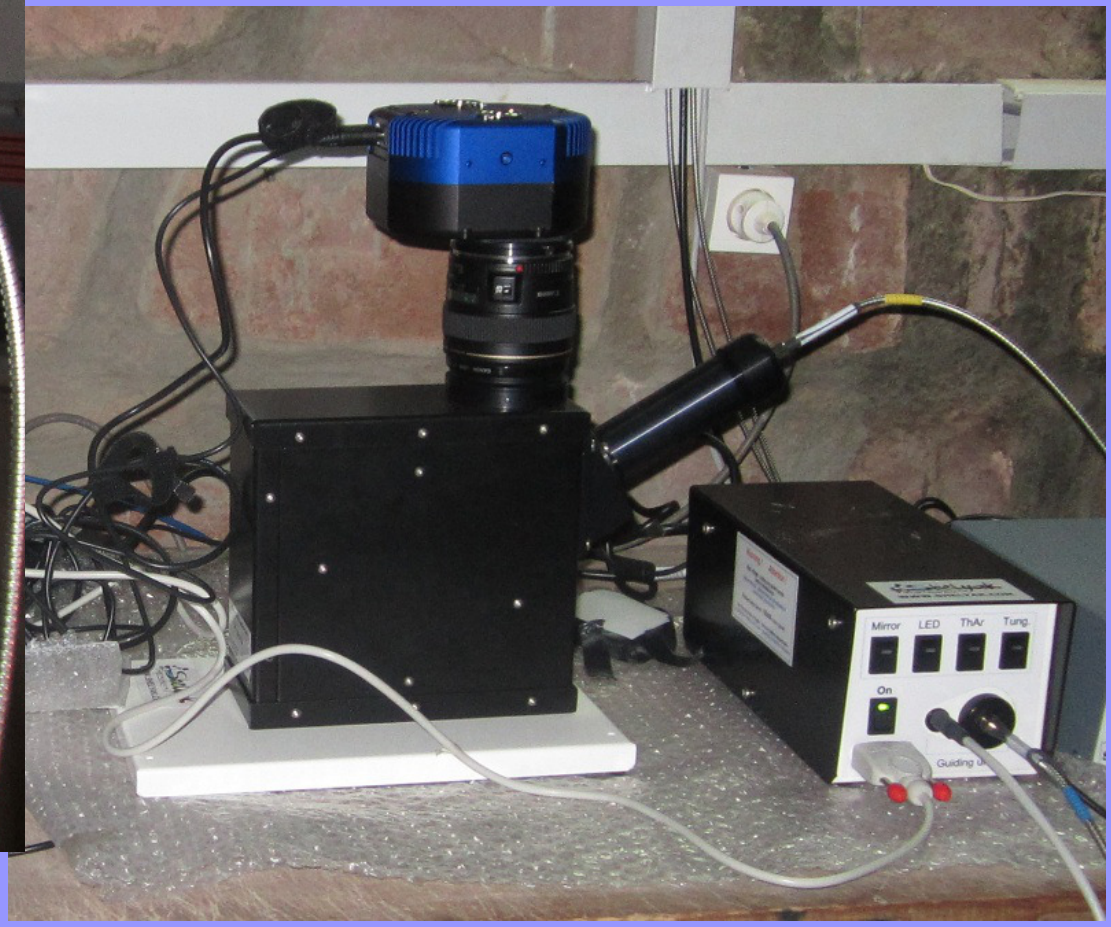
Spectroscopic binaries



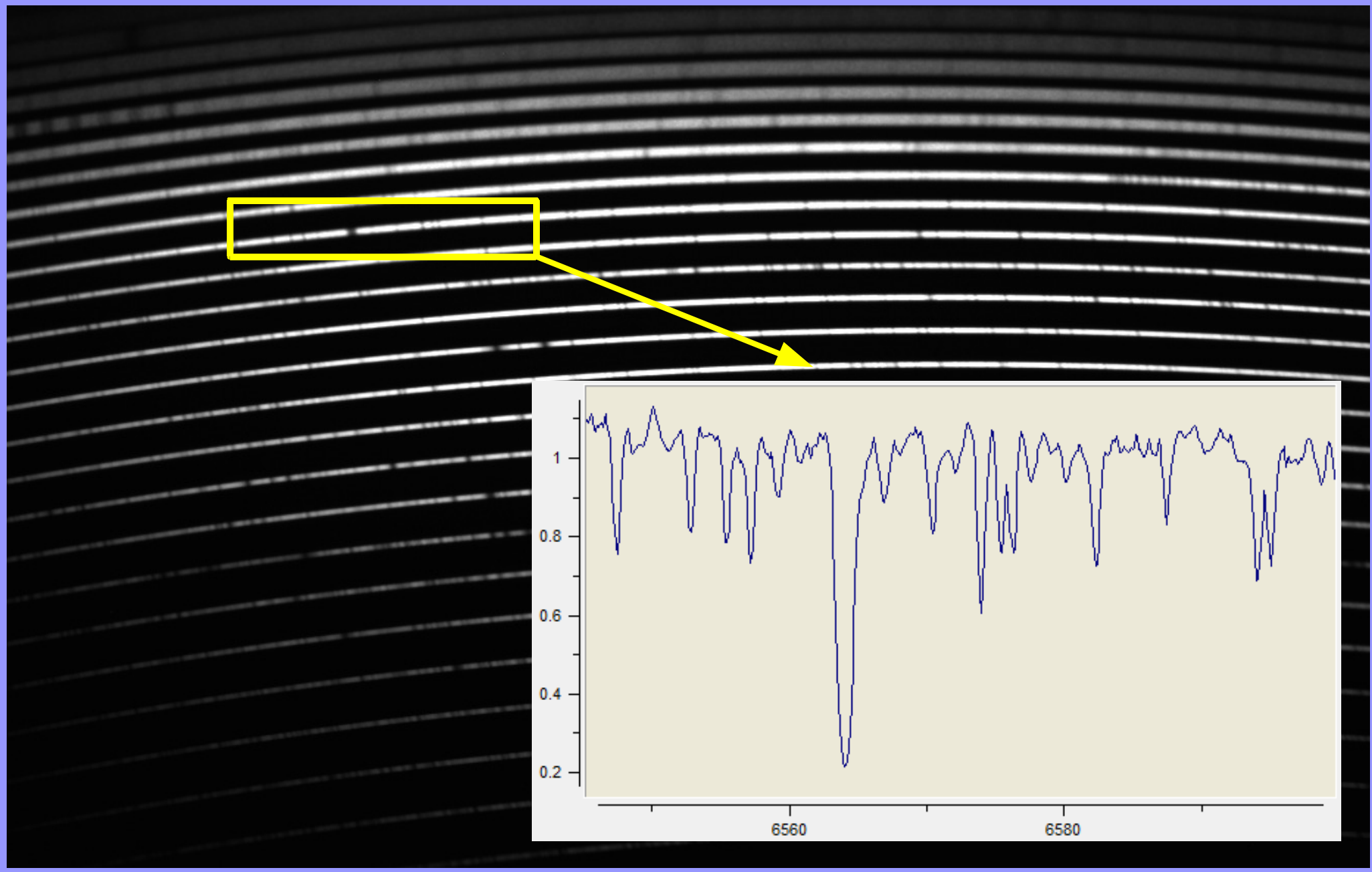
Paramètres orbitaux	Cette étude (VSpec)	Cette étude (PeakFit)	Nordström (1994)
K_1 (km.s^{-1})	106 ± 3	108 ± 3	107.75 ± 0.40
K_2 (km.s^{-1})	108 ± 3	110 ± 3	111.25 ± 0.40
M_1/M_2	0.98 ± 0.06	0.98 ± 0.06	0.97 ± 0.01
V_γ (km.s^{-1})	-20 ± 2	-21 ± 2	-17.0 ± 0.4
a.sin(i) (R_{sol})	16.7 ± 0.5	17.1 ± 0.6	17.13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

eShel optical fiber fed spectrograph : a tool for Radial Velocities



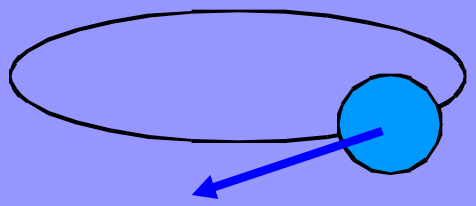


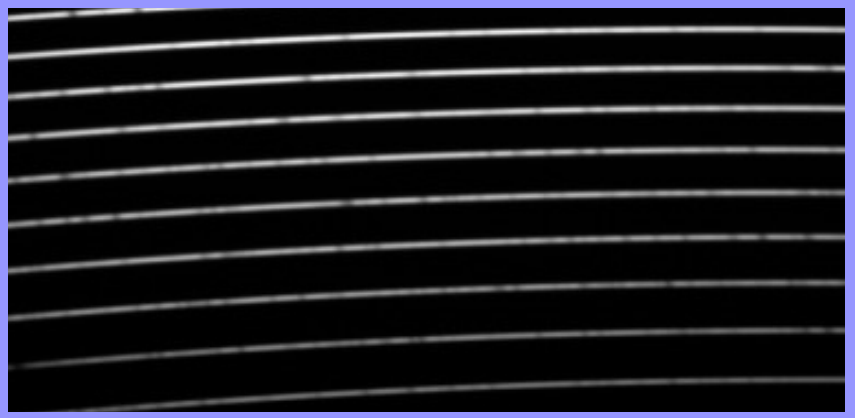
Eshel spectrum of Aldebaran

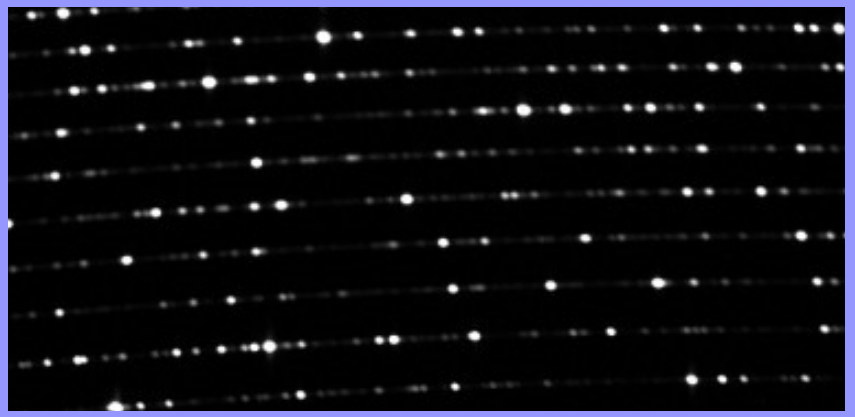


Spectre eShel / C14 Oukaimeden - Fouad Sefyani, Abdelmjid Benhida, Ahmed Daassou

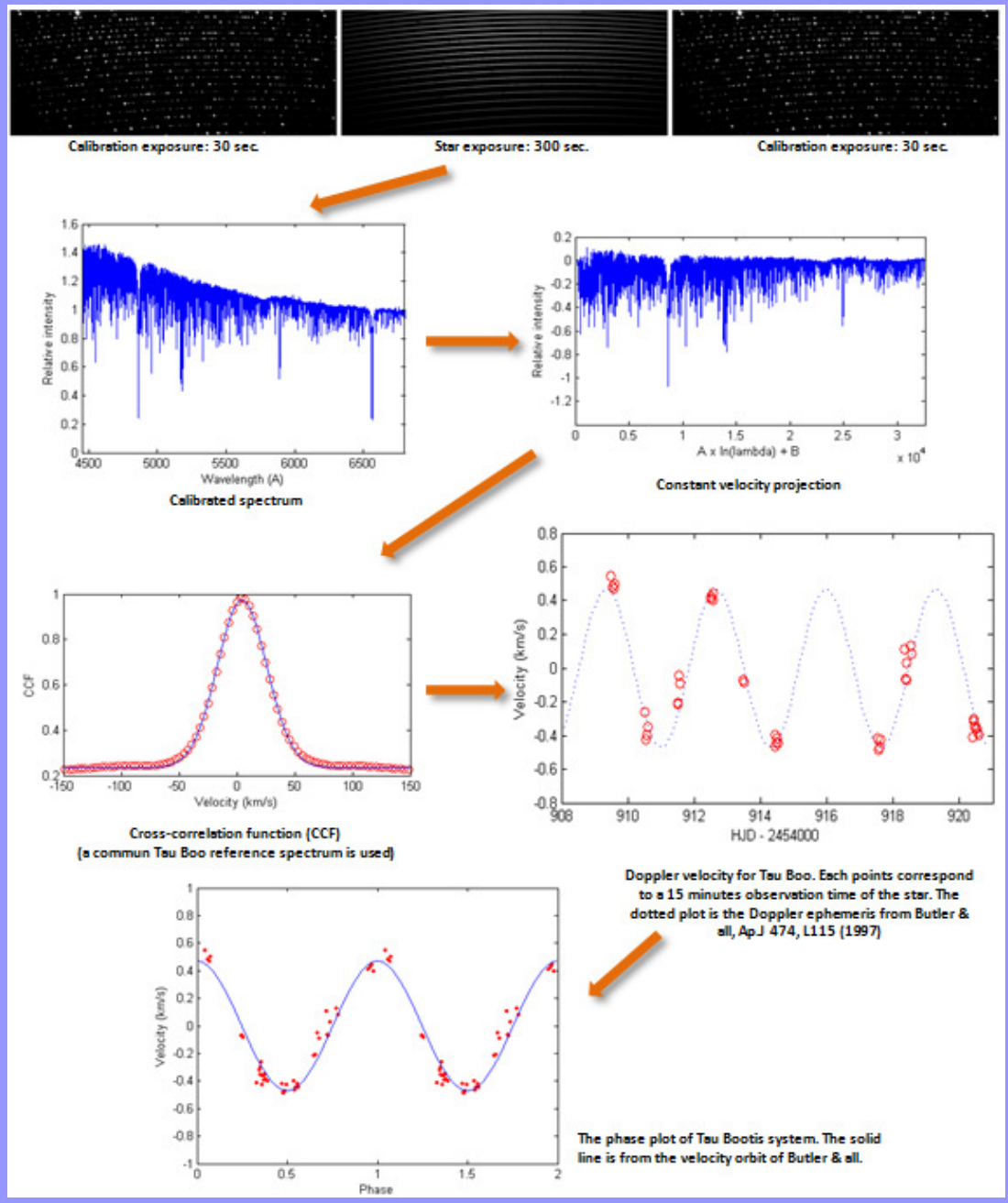
Exoplanet: tau Boo





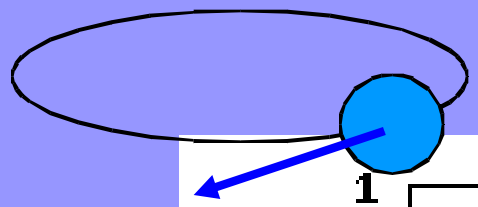


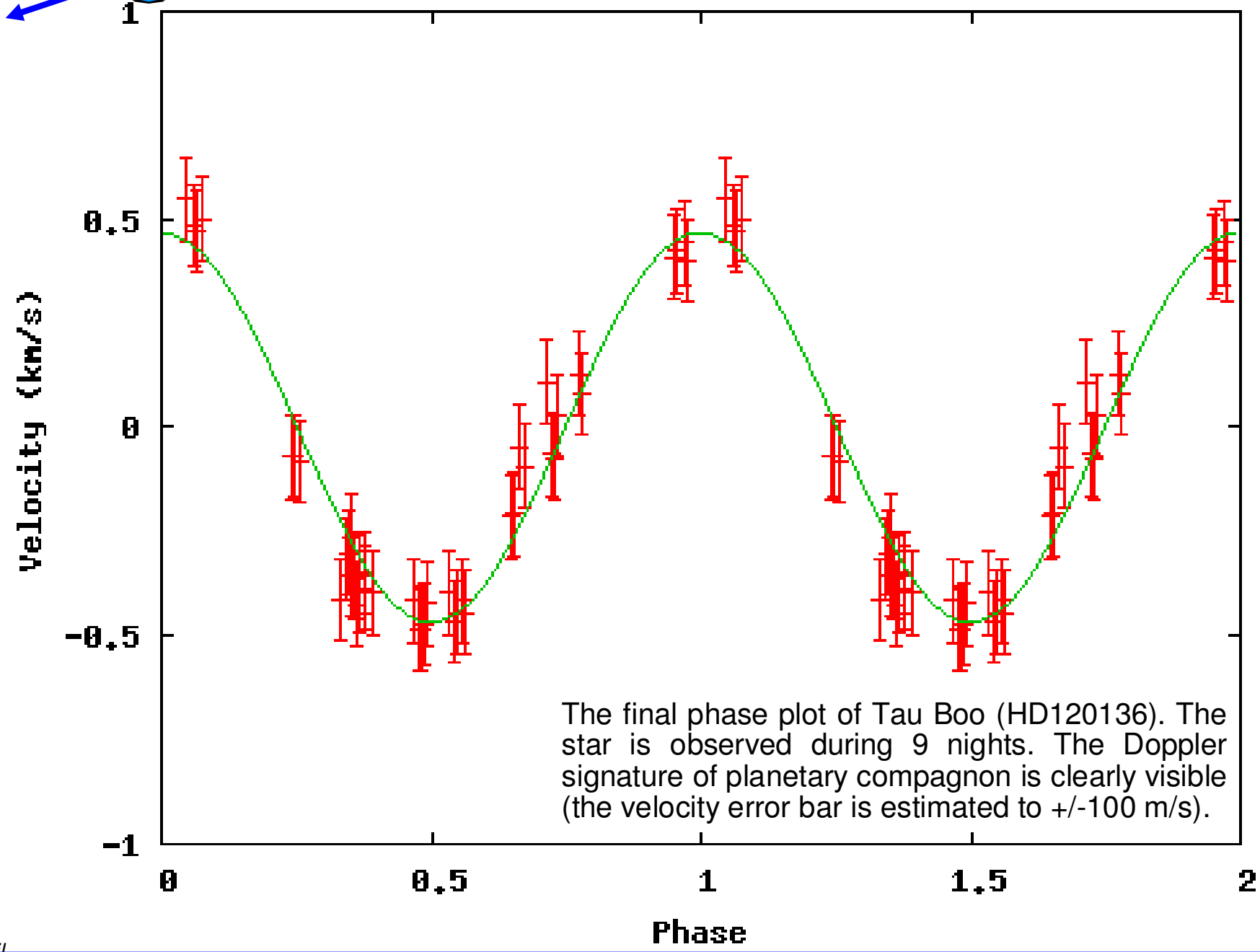
The CCF is computed by using the spectral range 4400-6445 A (the Halpha line is excluded).
The total velocity Doppler spectral amplitude shift represents only 1/25th part of the spectrograph resolution. The data
are collected between March 19-March 29, 2009.



Christian Buil

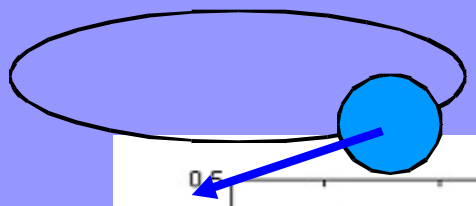
Exoplanet: tau Boo

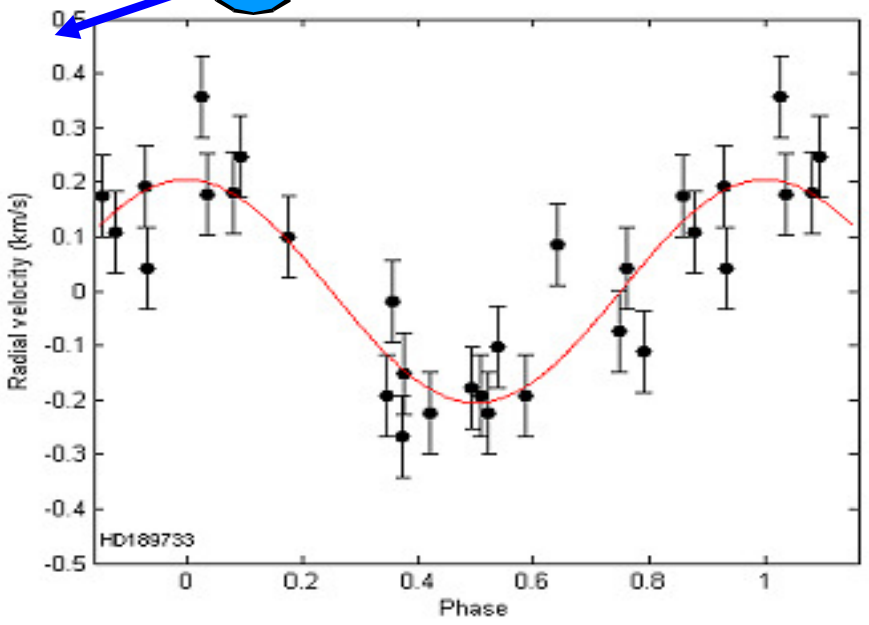


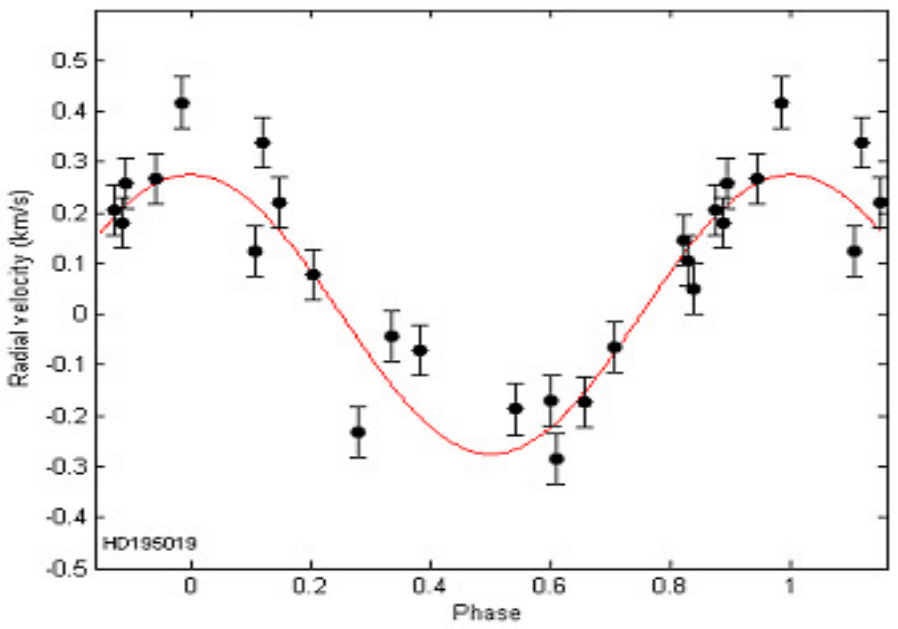


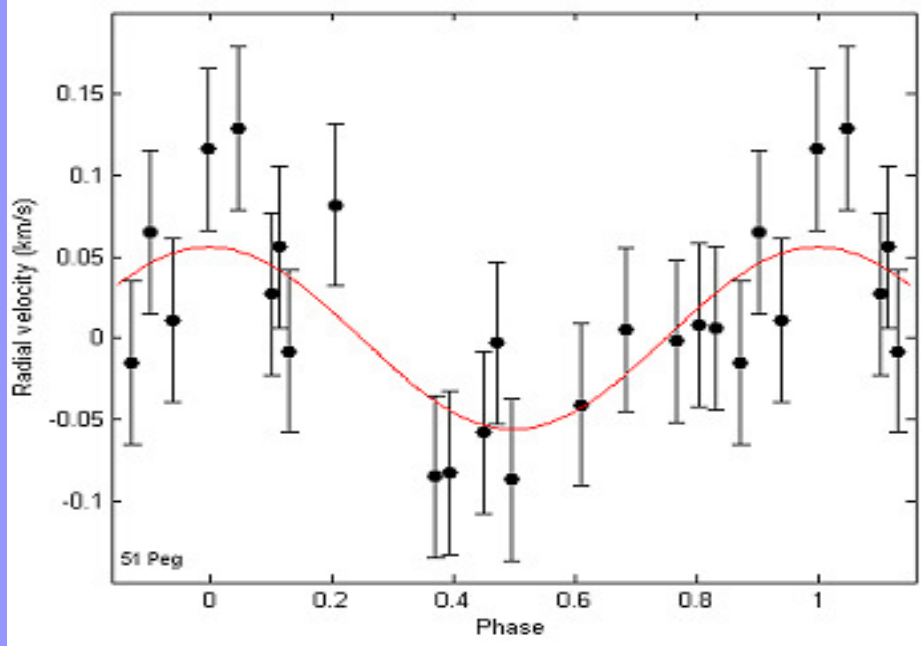
The final phase plot of Tau Boo (HD120136). The star is observed during 9 nights. The Doppler signature of planetary compagnon is clearly visible (the velocity error bar is estimated to +/-100 m/s).

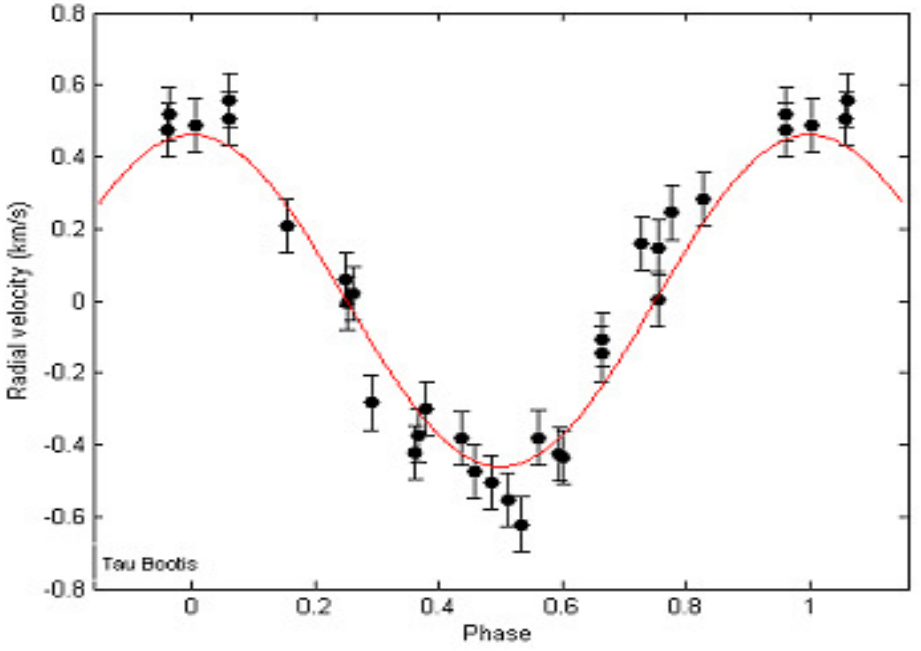
Exoplanets: 4 done so far











Christian Buil / Valérie Desnoux / Michel Pujol / Olivier Thizy

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 (**abondance**), **pressure** and **gravity** [intensity and line shape]

But also on :

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

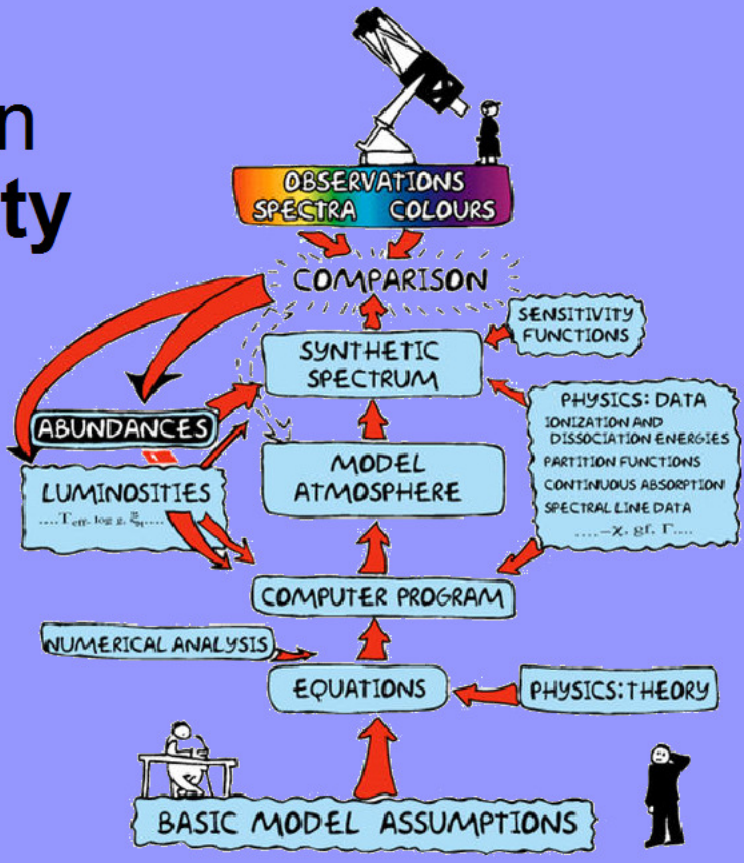


Schéma : Bengt Gustafsson

Conclusion

- Spectroscopy a «scientifical 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 !

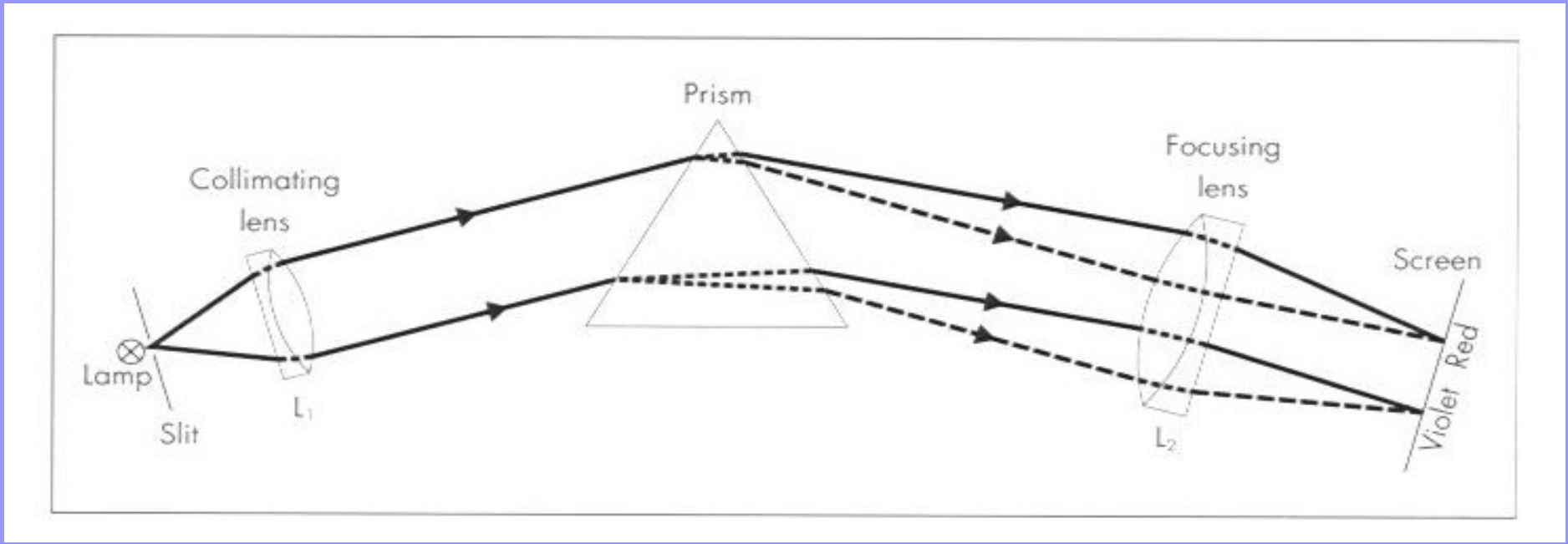
Useful links

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

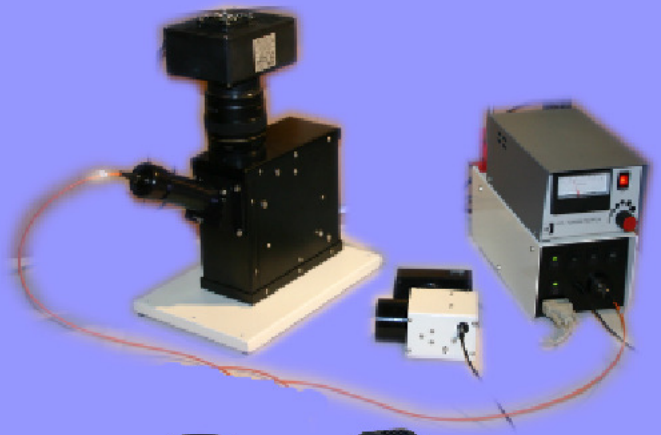
Equipment

How does a spectrograph works?

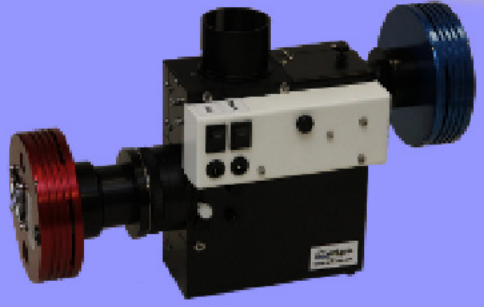


- **Dispersion can be done by a prism or a grating**
- **Slit is one key element for high resolution resolution**
- **Littrow: collimator = objective**
- **Professional astronomers also use 'echelle' spectrographs with cross dispersing**

Equipment



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



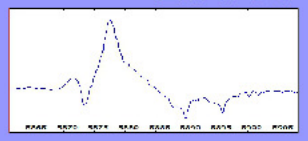
Study:
Lhires III (high resolution) and LISA Pack (high luminosity) are exploration tool allowing pro/am collcollaboration

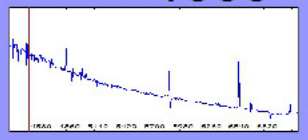
Alpy:
Our new modular instrument for educational and scientifical (astronomical) spectroscopy

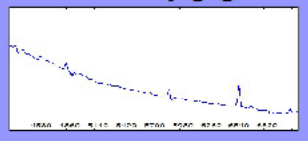
Discover spectroscopy:
The Star Analyser is the simpliest spectroscope, ideal to get started in this field with limited budget

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

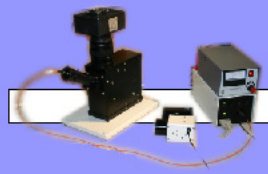
Product overview



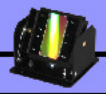




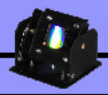
Lhires III (2400gr/mm)



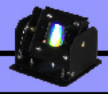
eShel



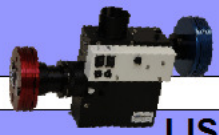
Lhires III: 1200 gr/mm module



Lhires III: 600 gr/mm module



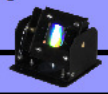
Lhires III: 300 gr/mm module



LISA Pack (visible)

LISA (near IR)

Alpy 600



Lhires III: 150 gr/mm module

Star Analyser

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

20000

10000

1000

100

4000 5000 6000 7000 8000 9000 10000

Spectral Domain (nm)

Take some good Resolutions !

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

20000

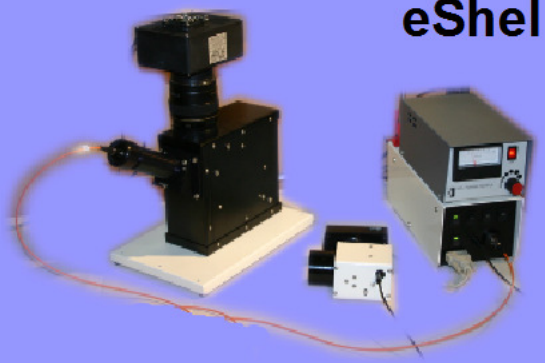
10000

1000

100

Lhires III

eShel



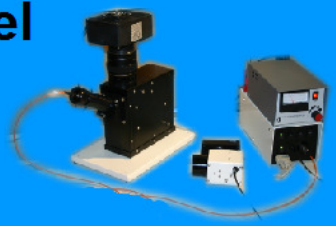
Alpy 600

LISA

Star Analyser

Spectral Domain Coverage

	Spectral Domain	Resolving Power R	Resolution (500nm)	Slit	RV	Limit mag
eShel 	430-710nm	>10000	0.5 A	50µm F/6	50 m/s	~10
Lhires III 	Visual (window of ~10nm)	~17000 with 2400 gr/mm grating	0.3 A	15-35µm F/10	~3 km/s	~10
LISA 	390nm-1µm	600-1000	5 A	15-35µm F/5	n/a	~16
Alpy 600 	370-720nm	~600	10 A	multiple slits	n/a	~15
Star Analyser 	Visual	~100	50 A	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**
  - **Preceedings 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 !**

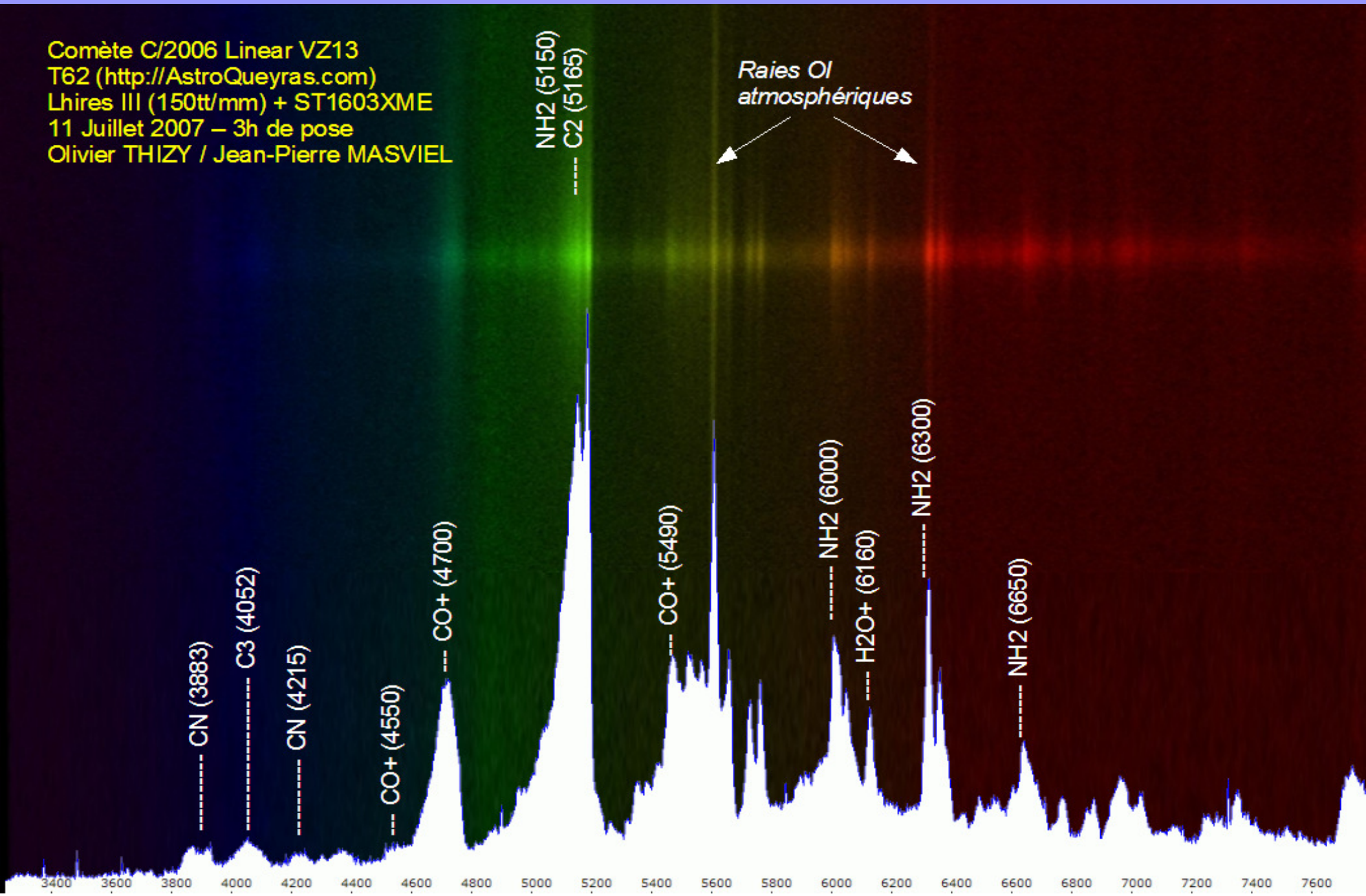
OHP practical workshops

- **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 !**

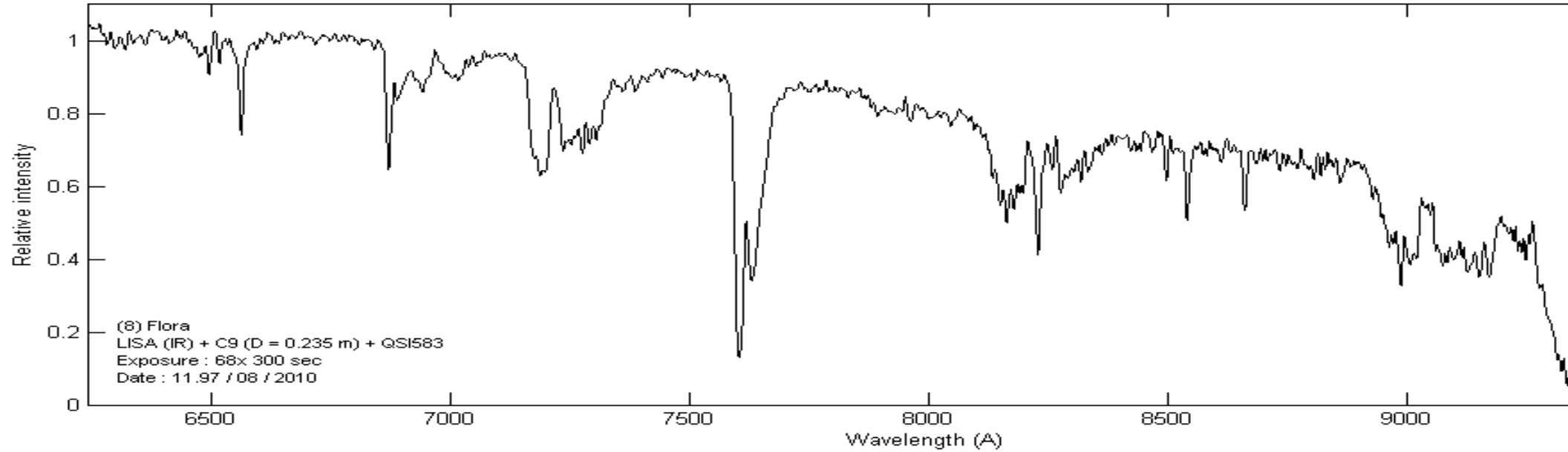
OHP ambiance...

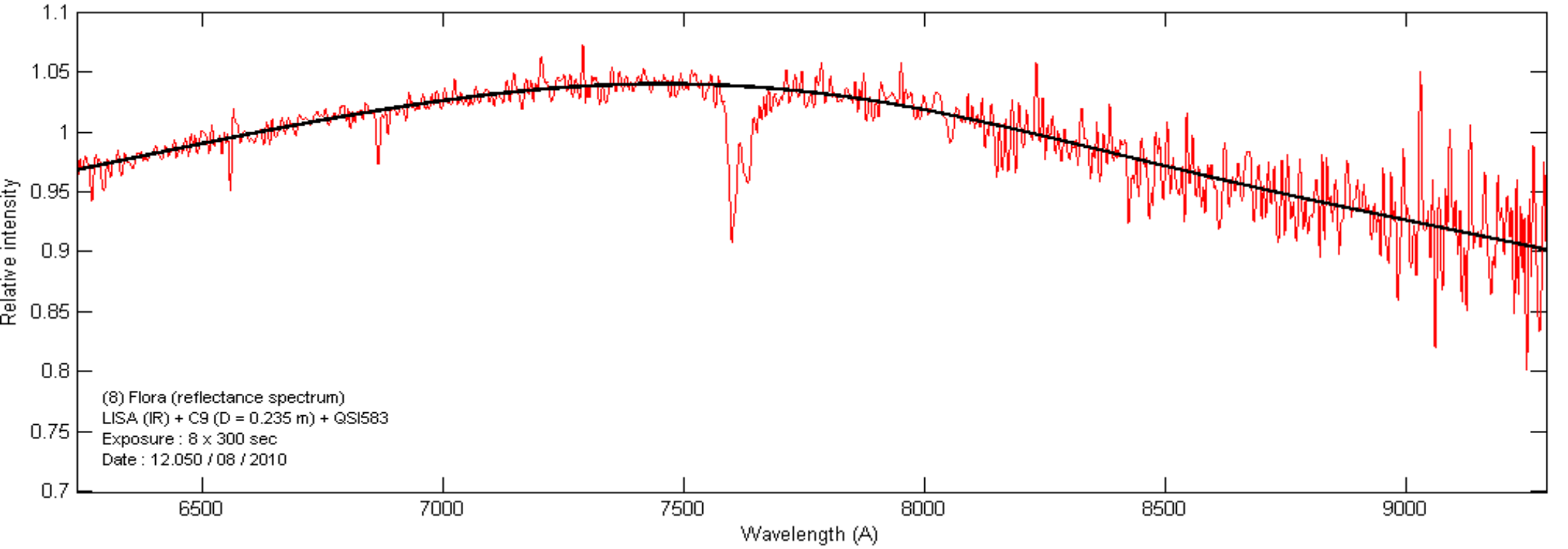
Pro/Am projects

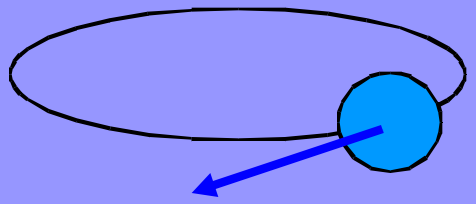
Comets


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
NH2 (5150)
C2 (5165)
Raies OI
atmosphériques
CN (3883)
C3 (4052)
CN (4215)
CO+ (4550)
CO+ (4700)
CO+ (5490)
NH2 (6000)
H2O+ (6160)
NH2 (6300)
NH2 (6650)
3400
3600
3800
4000
4200
4400
4600
4800
5000
5200
5400
5600
5800
6000
6200
6400
6600
6800
7000
7200
7400
7600

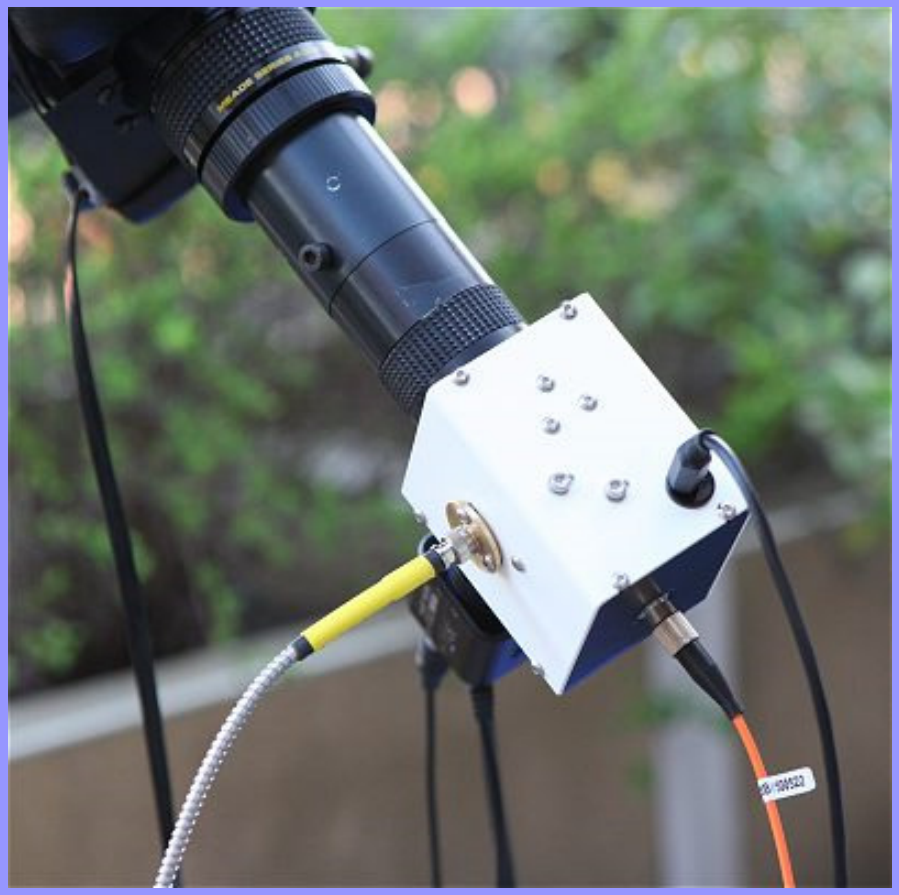
Asteroids classification

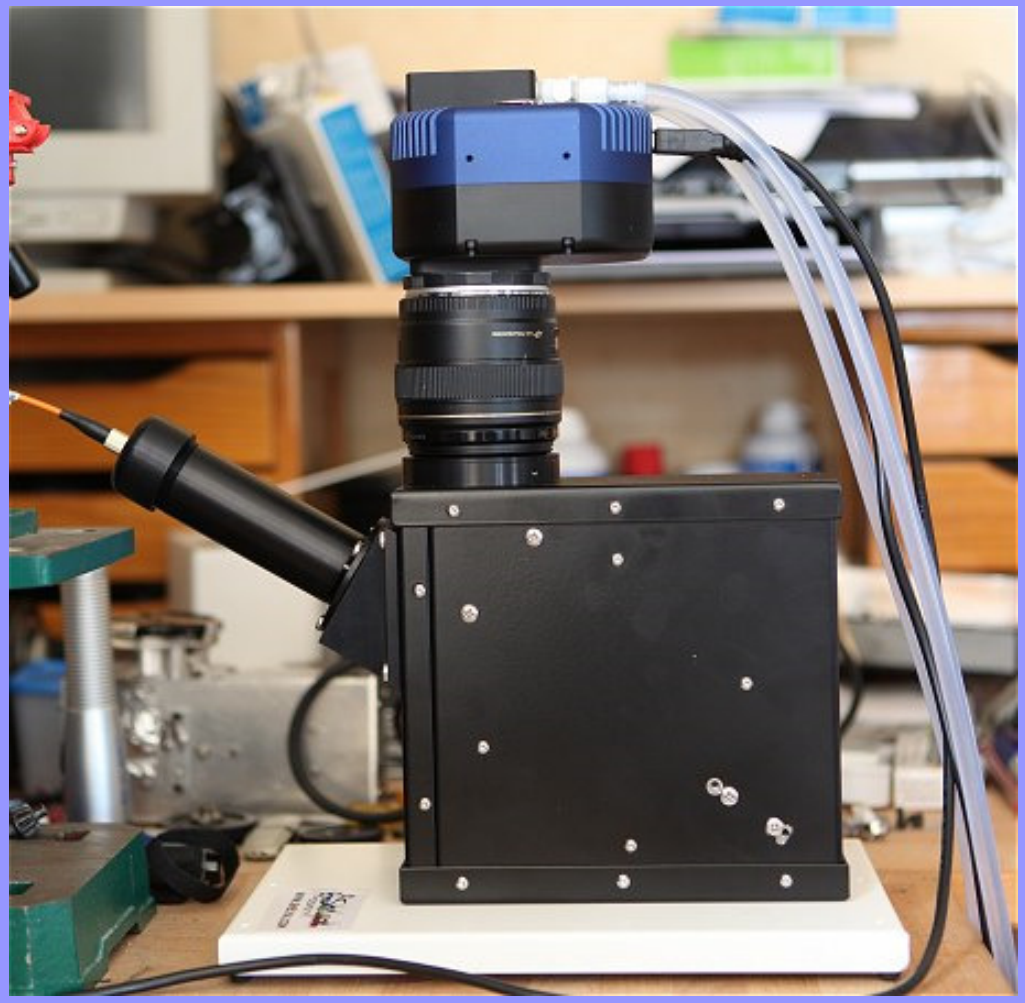




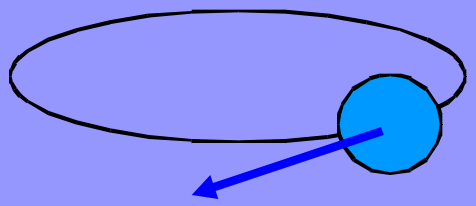


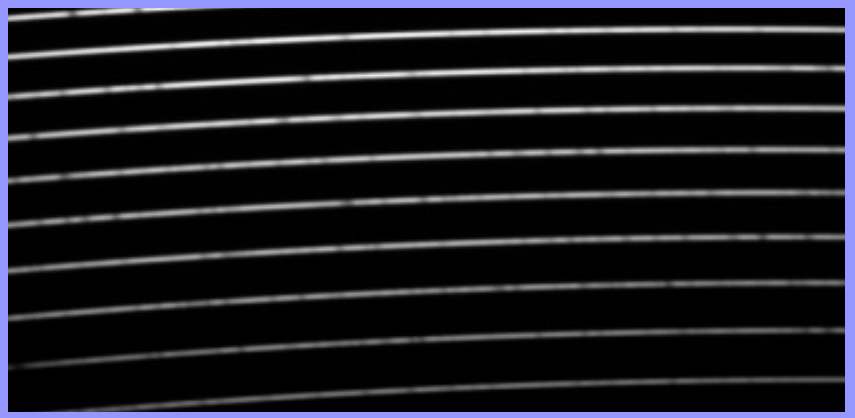
exoplanets !

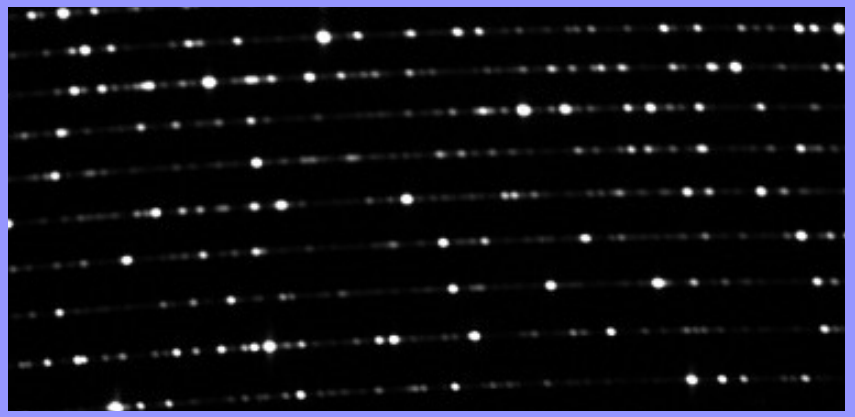




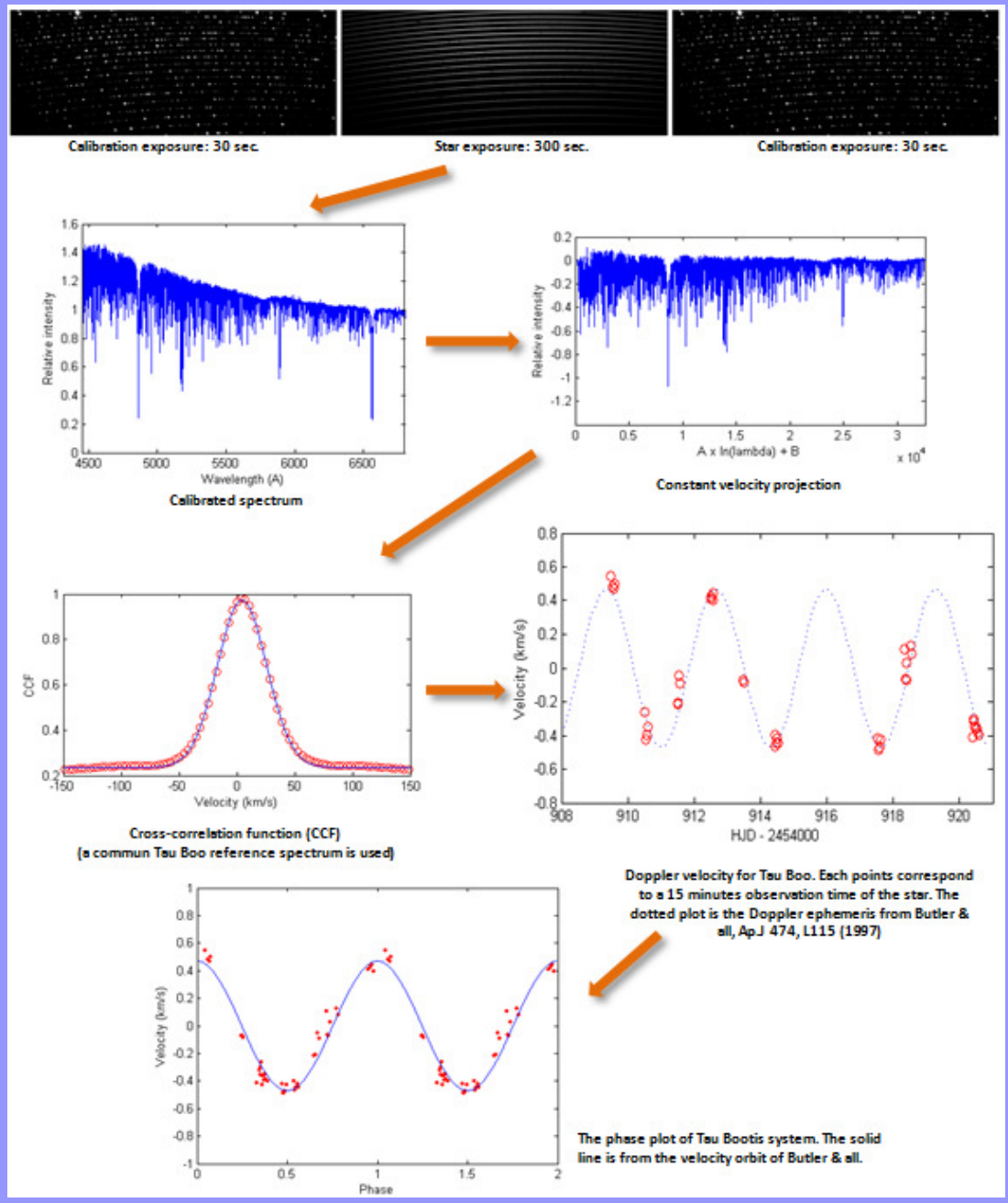
Exoplanet: tau Boo





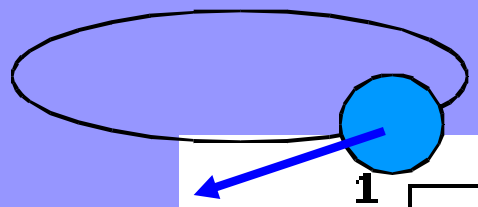


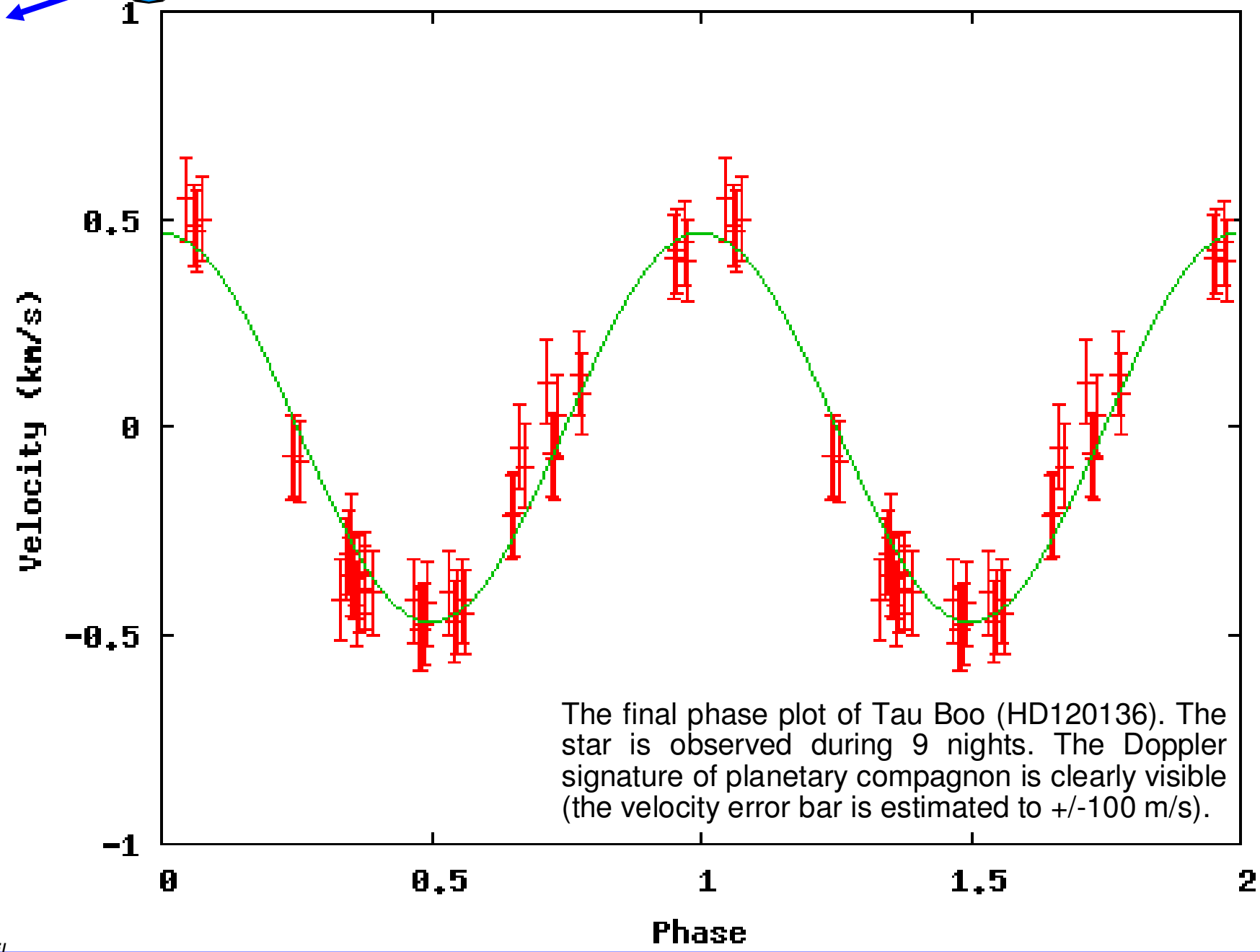
The CCF is computed by using the spectral range 4400-6445 A (the Halpha line is excluded).
The total velocity Doppler spectral amplitude shift represents only 1/25th part of the spectrograph resolution. The data
are collected between March 19-March 29, 2009.



Christian Buil

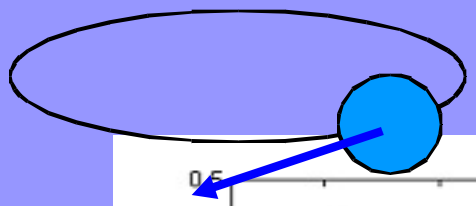
Exoplanet: tau Boo

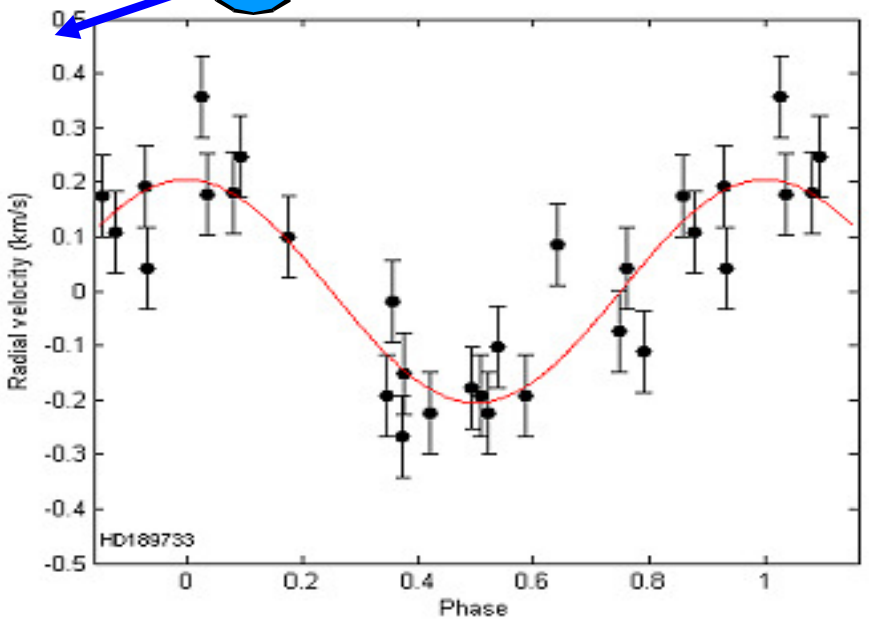


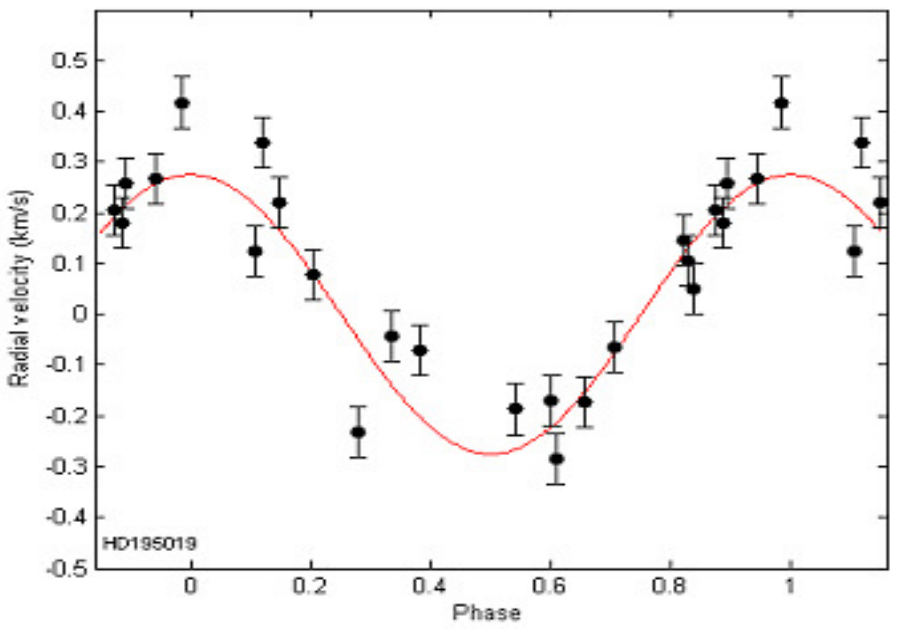


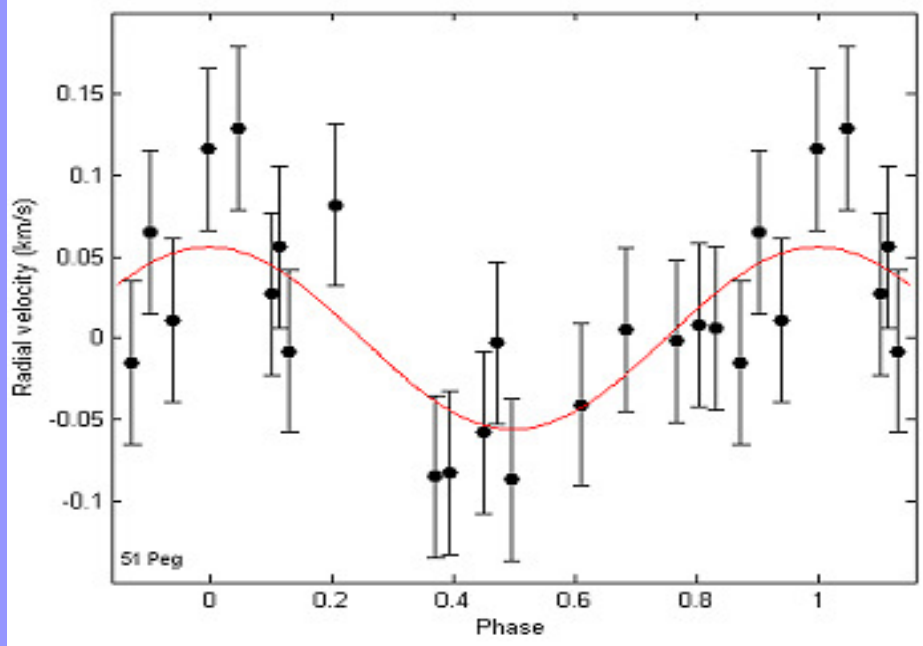
The final phase plot of Tau Boo (HD120136). The star is observed during 9 nights. The Doppler signature of planetary compagnon is clearly visible (the velocity error bar is estimated to +/-100 m/s).

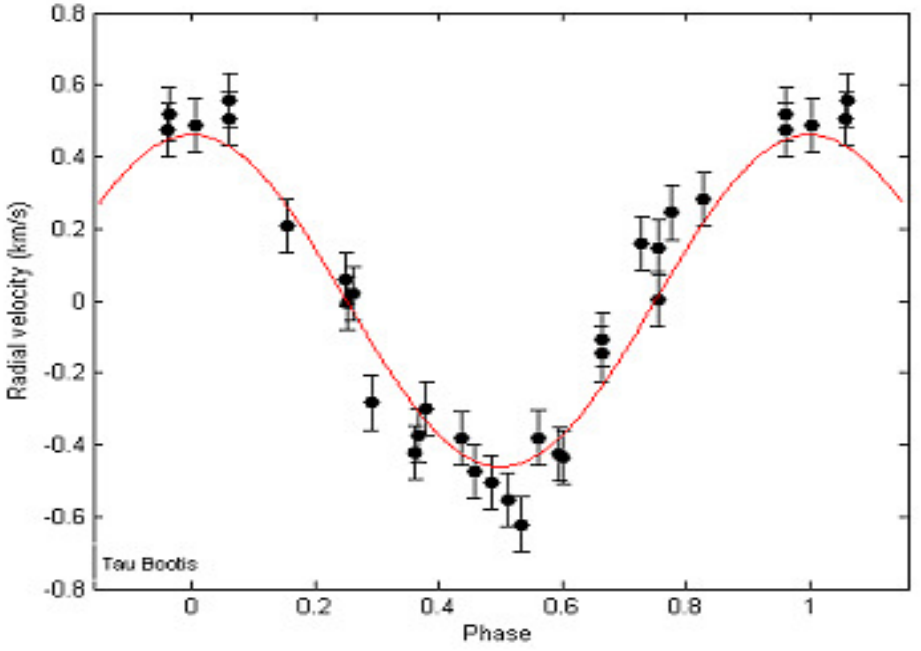
Exoplanets: 4 done so far











Christian Buil / Valérie Desnoux / Michel Pujol / Olivier Thizy

Variable stars in general !

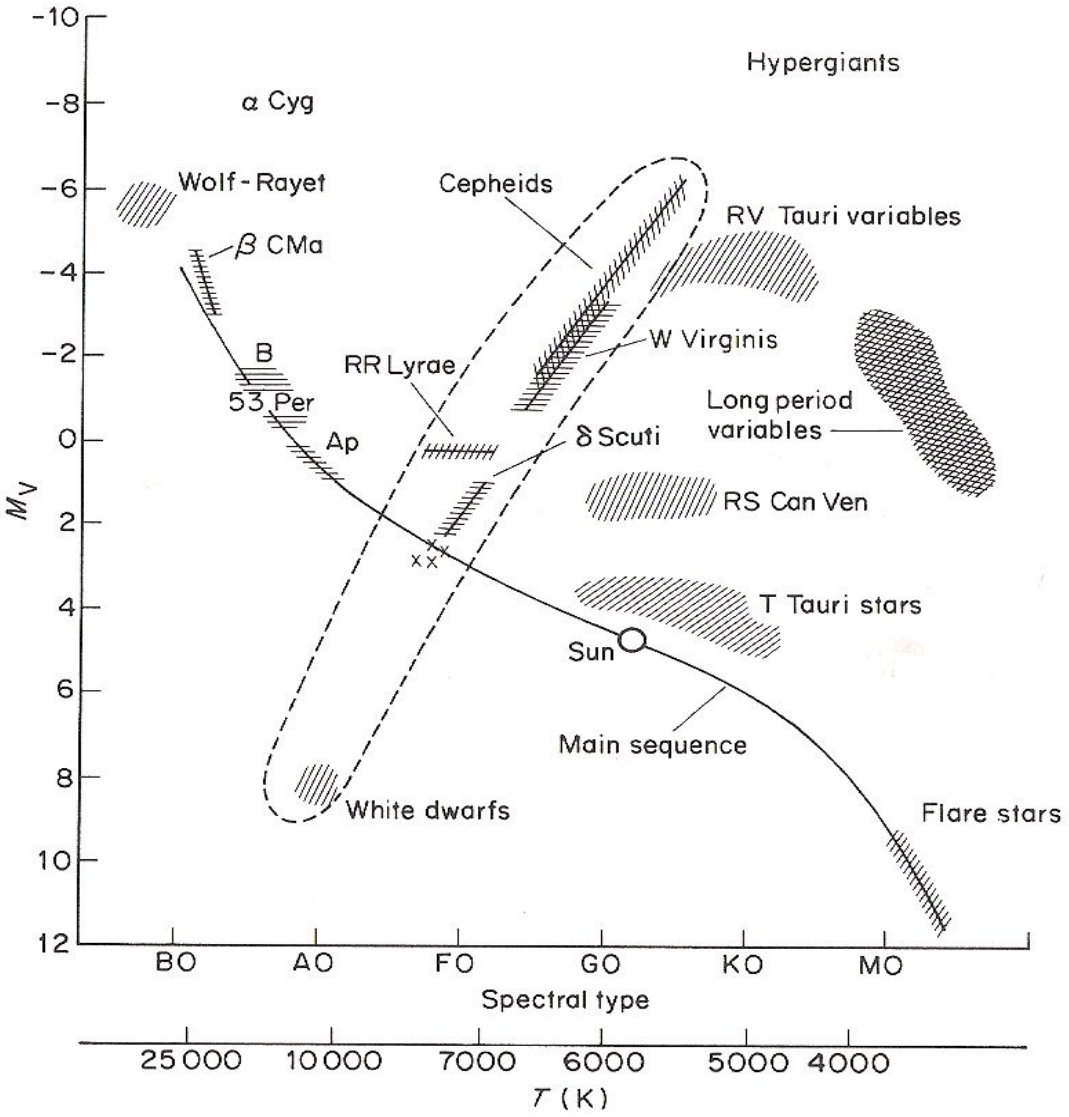
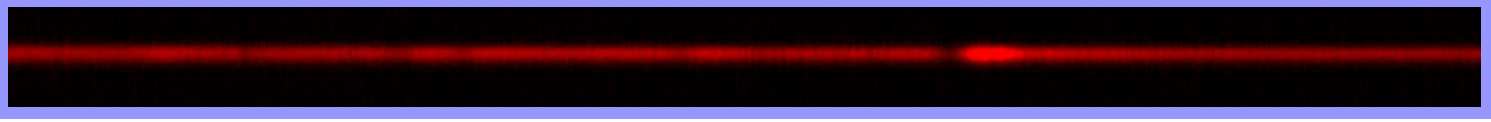
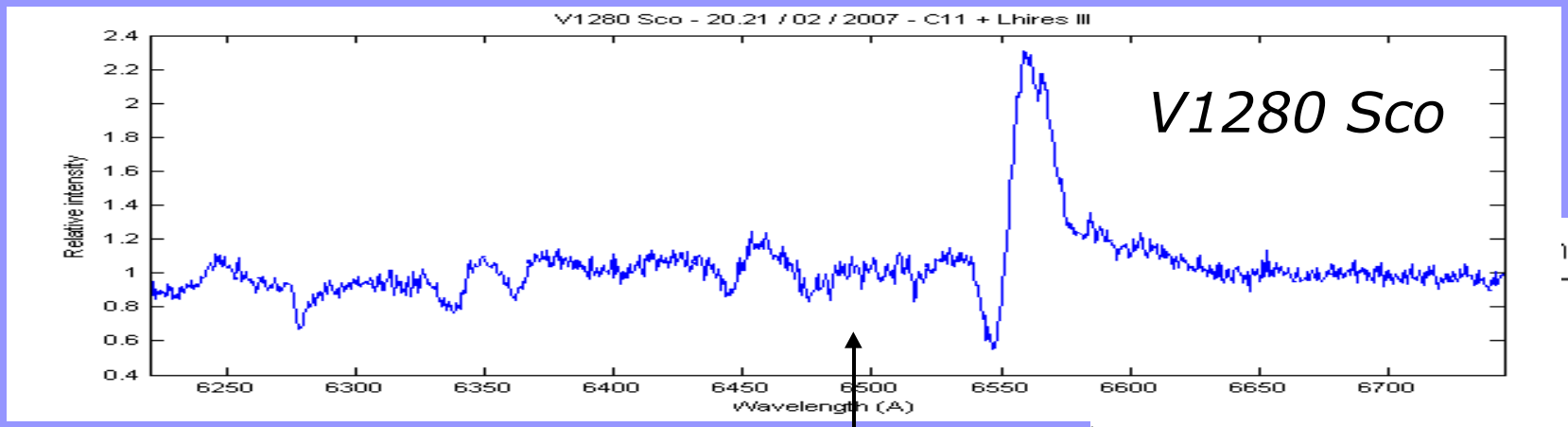


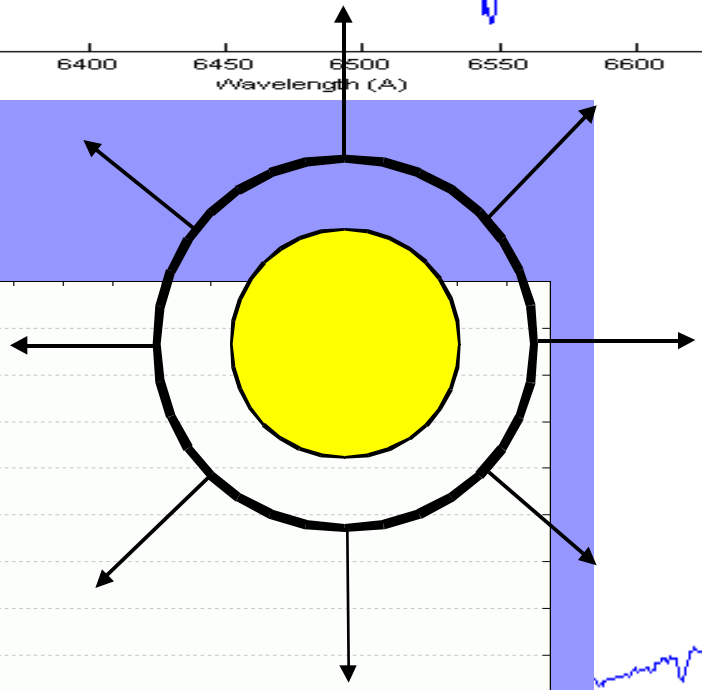
Figure 12.1 A Hertzsprung–Russell diagram showing the approximate location of various types of intrinsically variable star discussed in the text. Cataclysmic variables are binaries containing a compact star (usually a white dwarf) together with a red giant or main sequence star.

Source: Getting the measure of the stars (WA Cooper & EN Walker)

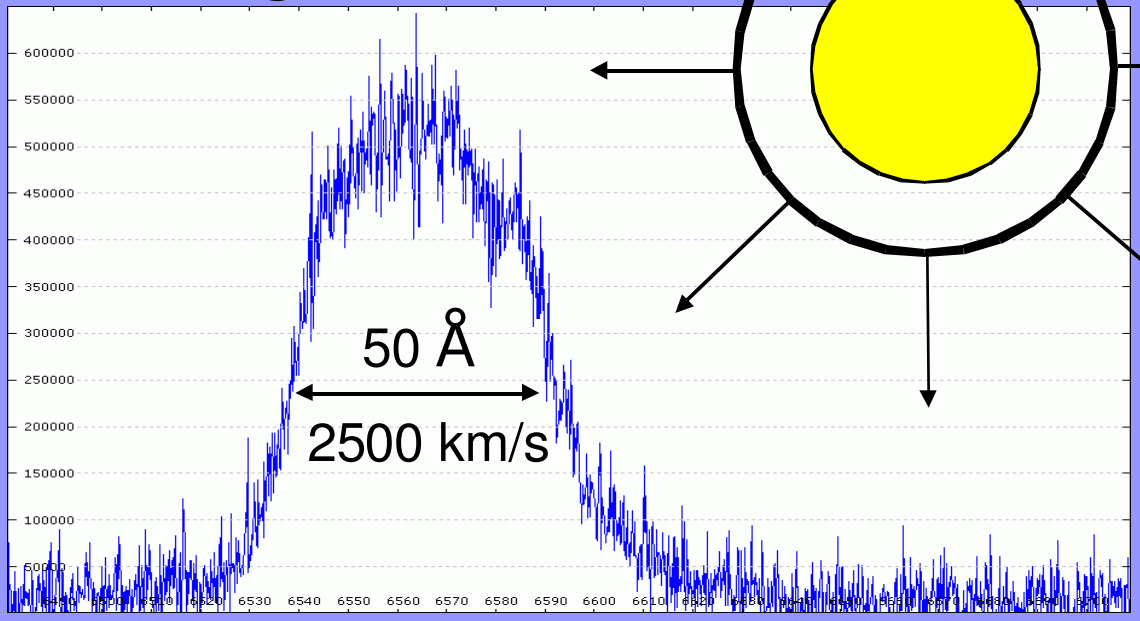
Novae

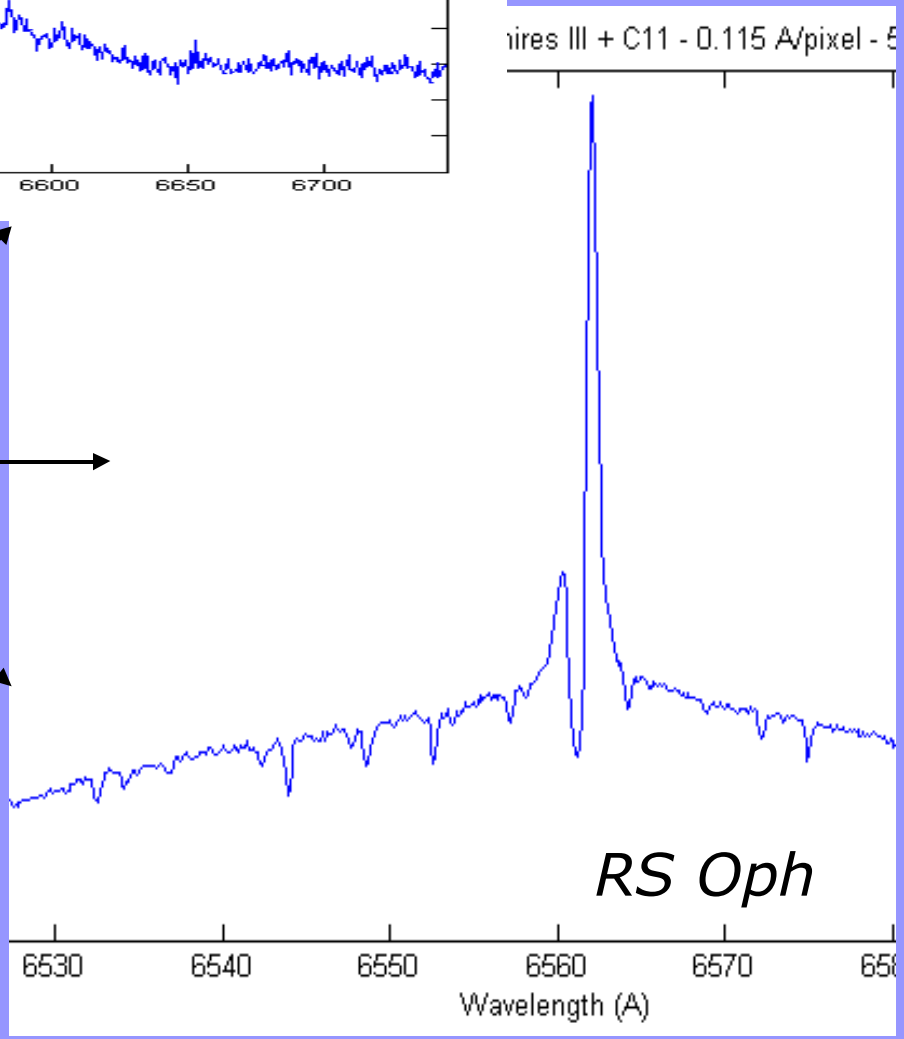




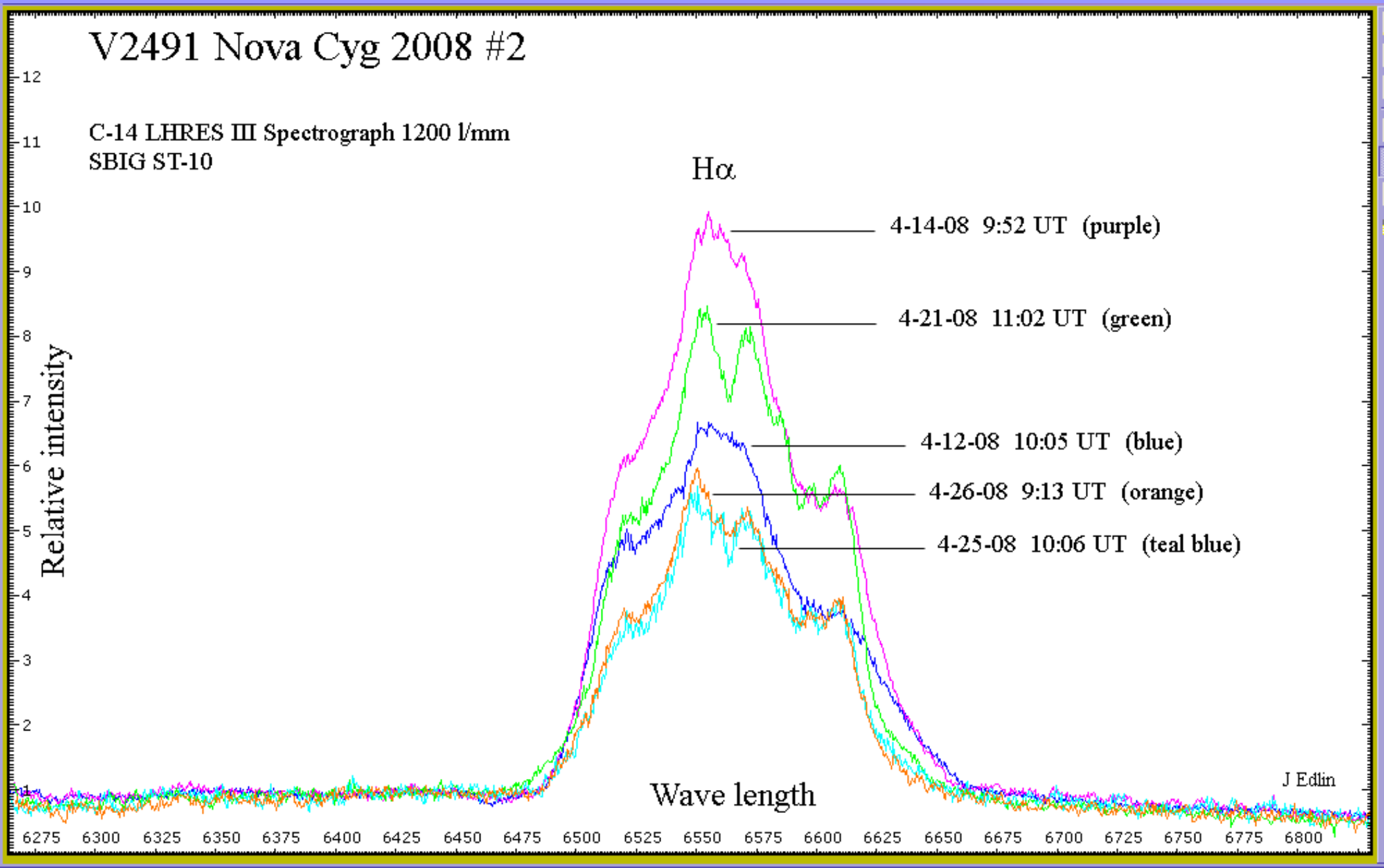


V4743 Sgr



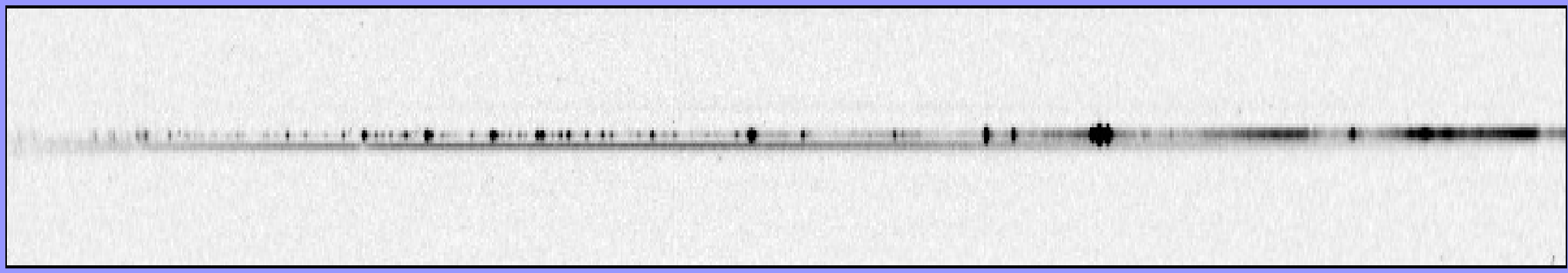


Novae

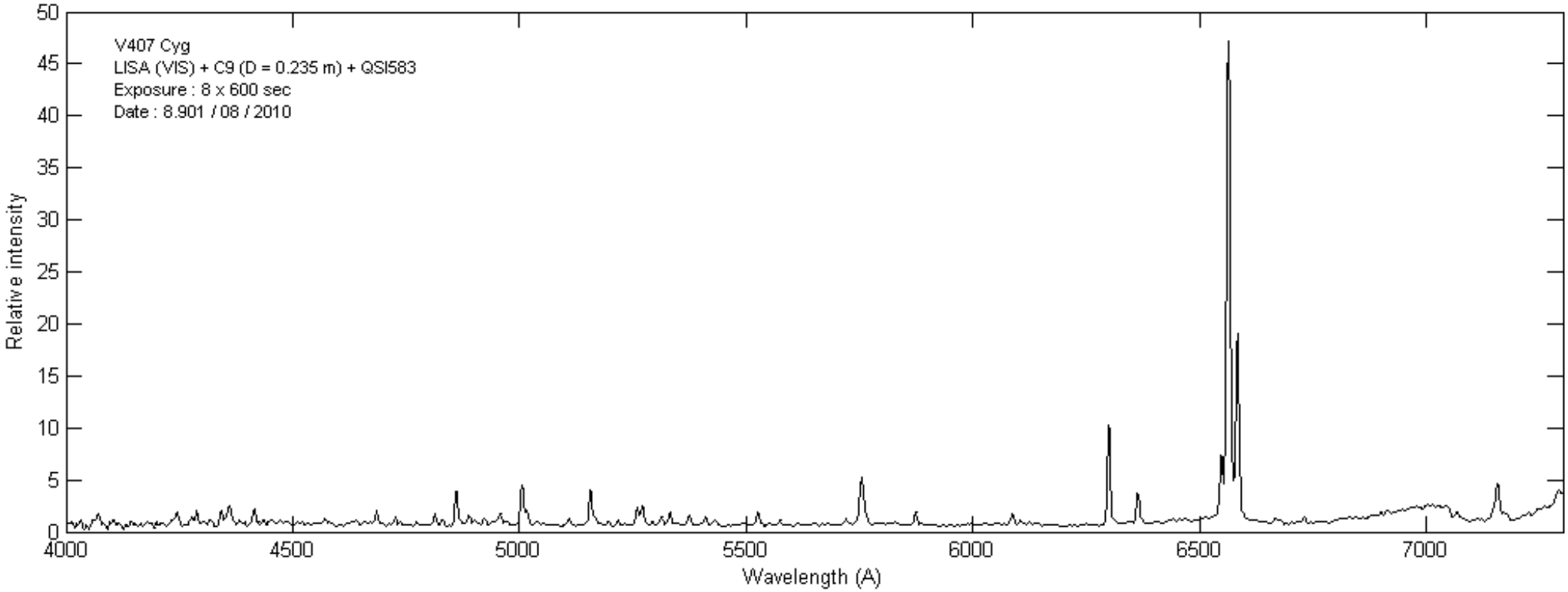


Source: Jim Edlin; Lhires III (1200 gr/mm) + ST10

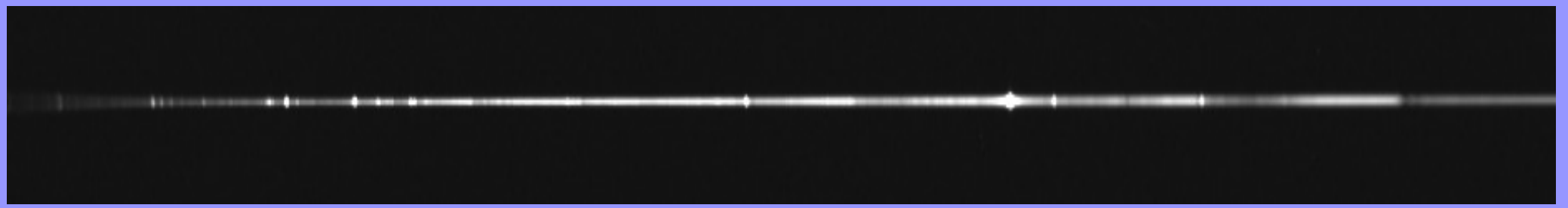
Symbiotic stars: V407 Cyg

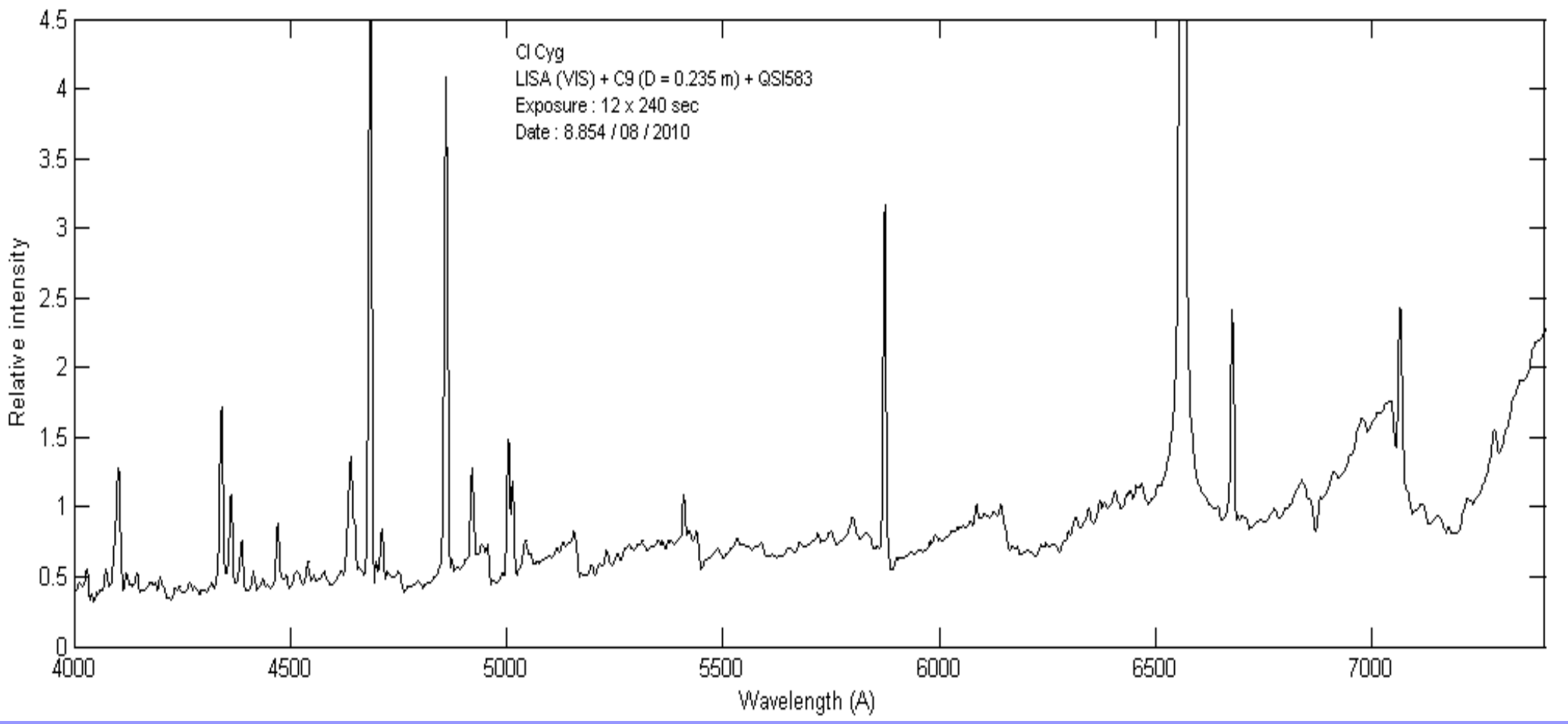


Note: another star spectrum is closed to V407 Cyg spectrum...

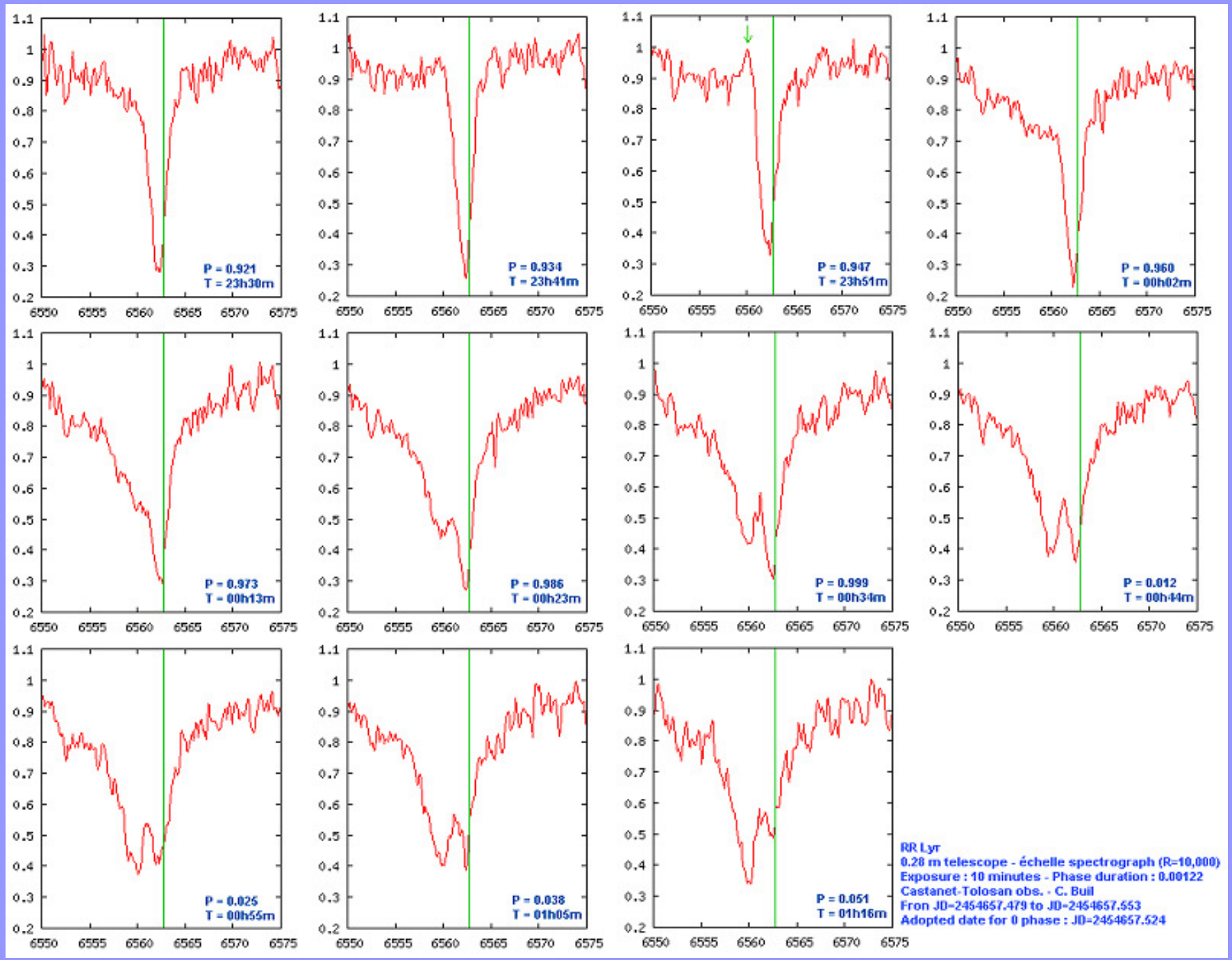


Symbiotic stars: CI Cyg



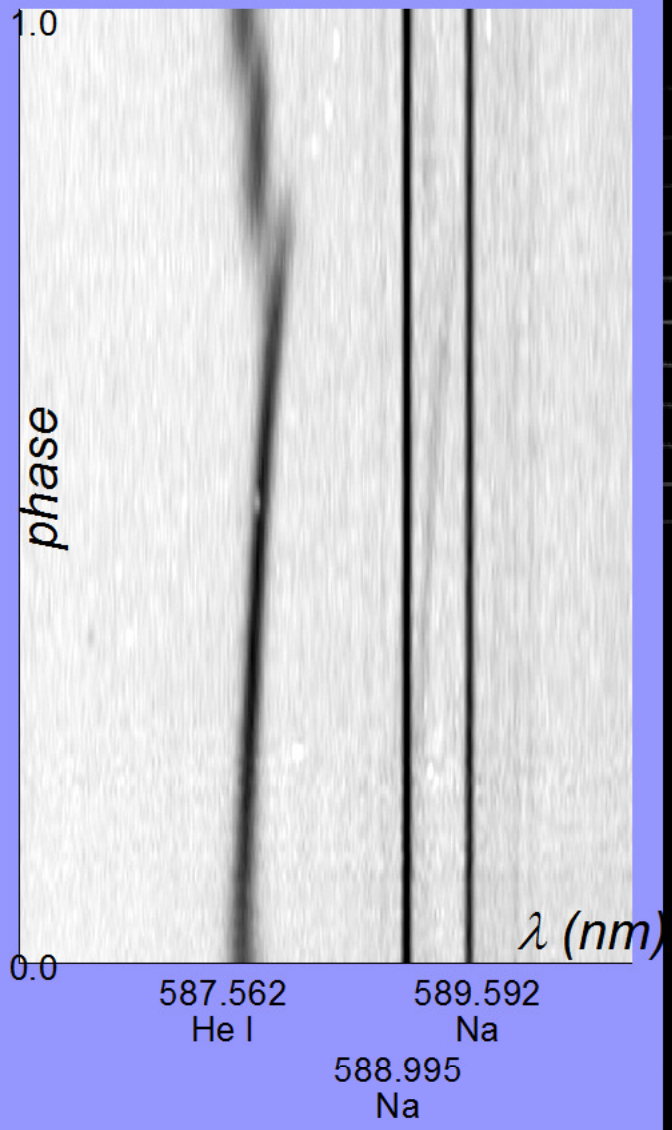


RR Lyrae: seeing stars pulsating live !

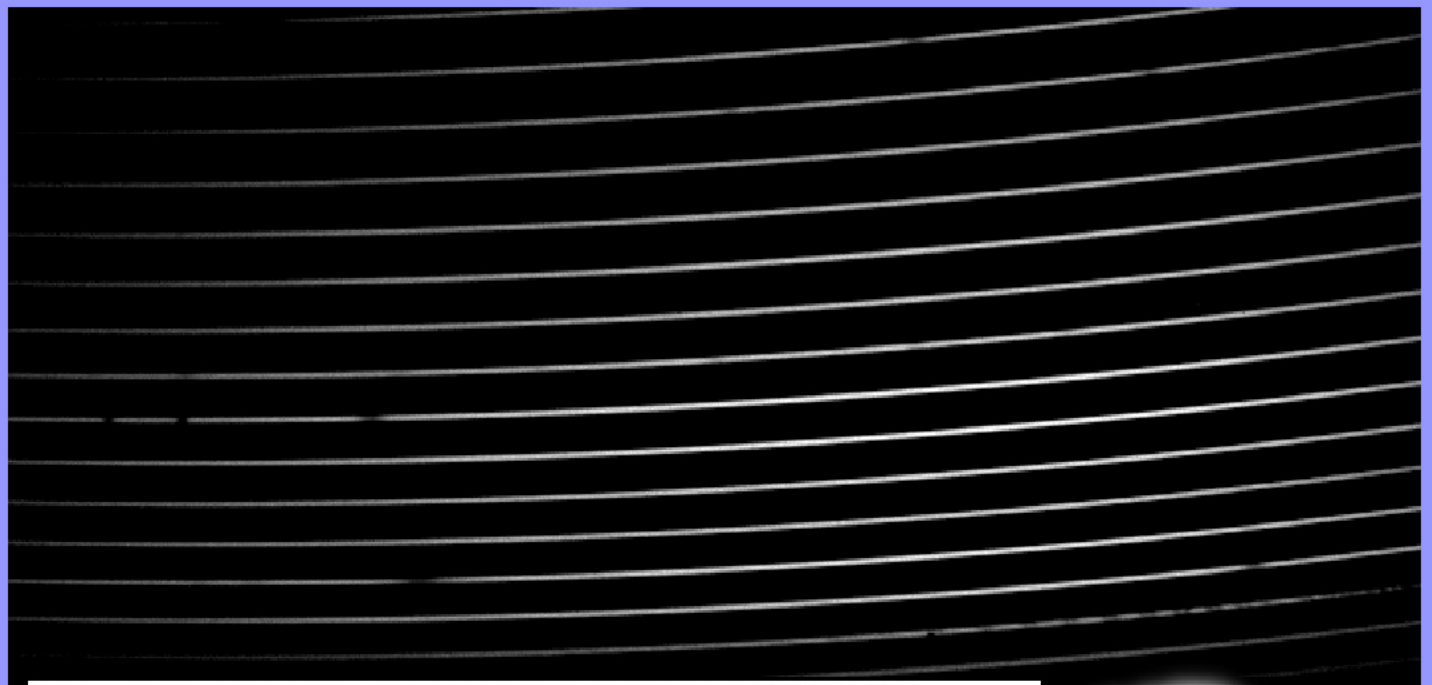


C.Buil

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

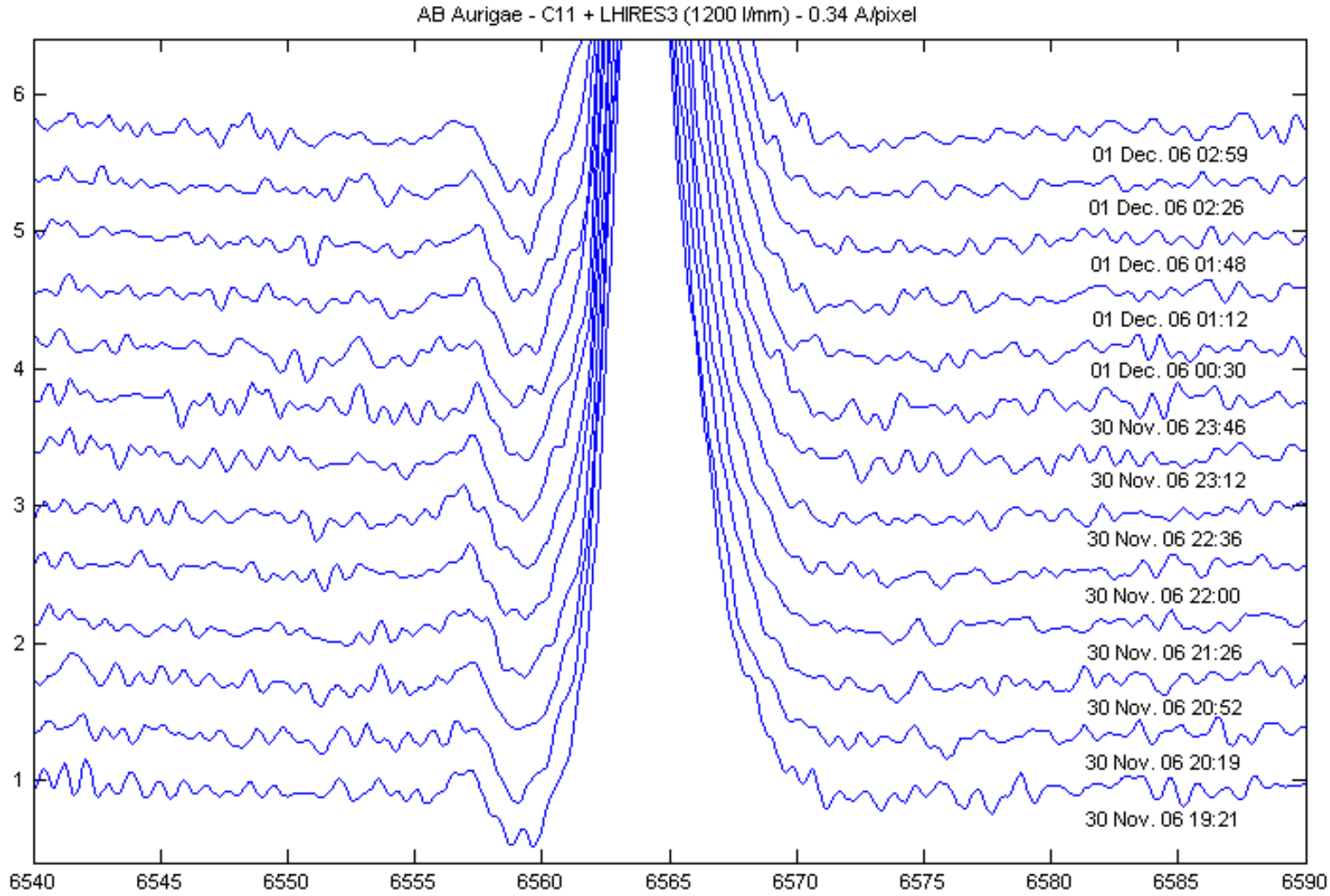


Spectrogram of HeI/Sodium doublet of BW Vul
(5min expoure, 60cm f/3.5 telescope at pic du Midi)



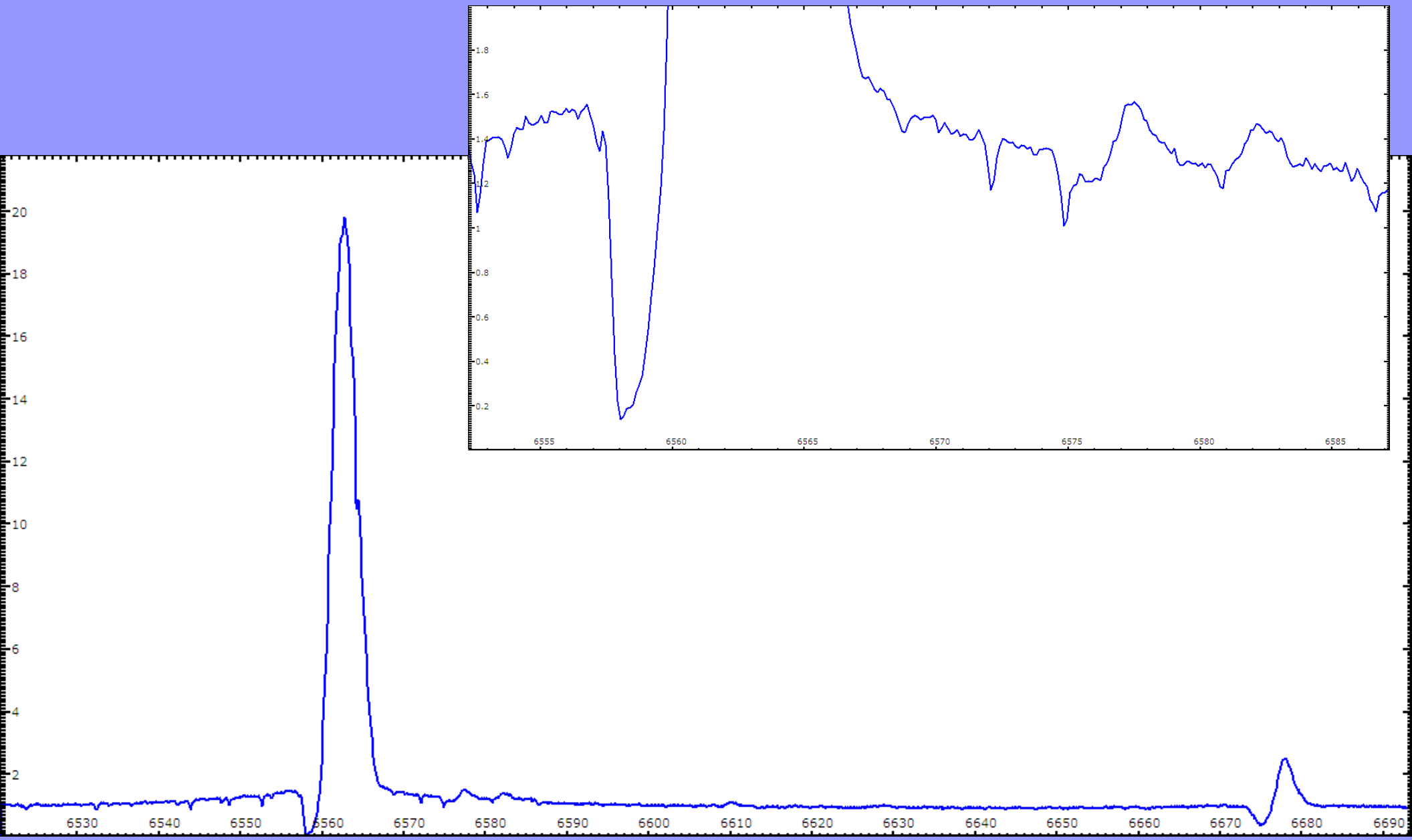
Christian Buil
Valérie Desnoux
Michel Pujol
Olivier Thizy

Herbig Ae/Be stars

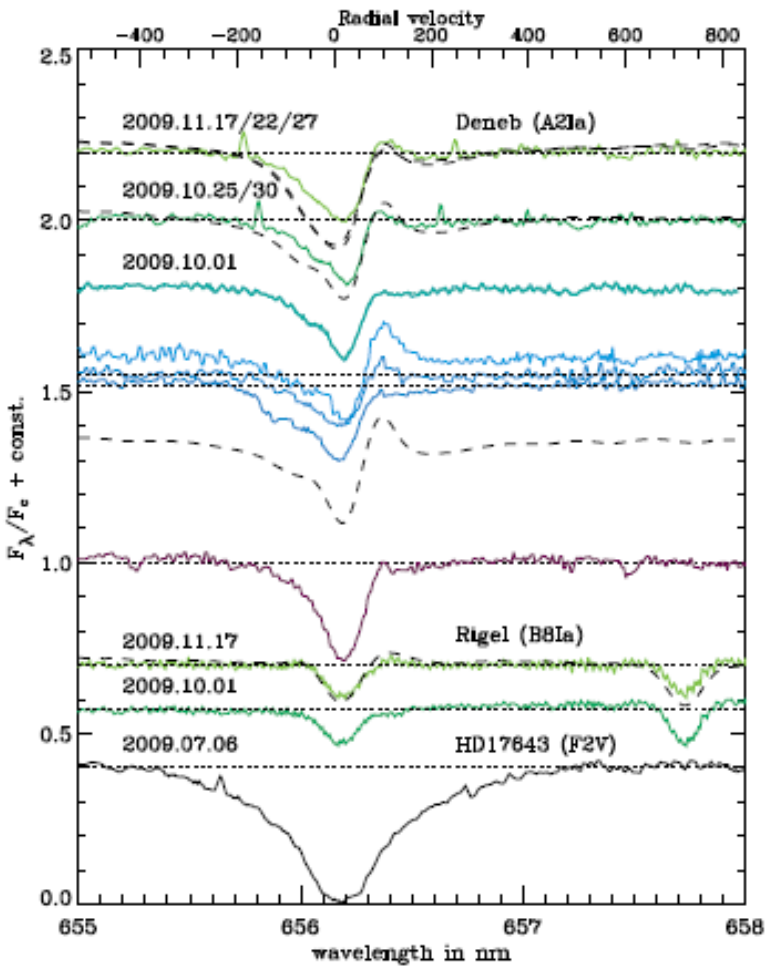


C.Buil

P Cygni


1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
6555
6560
6565
6570
6575
6580
6585
20
18
16
14
12
10
8
6
4
2
6530
6540
6550
6560
6570
6580
6590
6600
6610
6620
6630
6640
6650
6660
6670
6680
6690

other Active Hot Stars: Rigel, Deneb



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 (~3 km s^{-1}). Information from the blue camera was also used, as some important lines, e.g. SiII 6343–6371Å can be investigated (see Fig. 3 and Sect. 3.3).

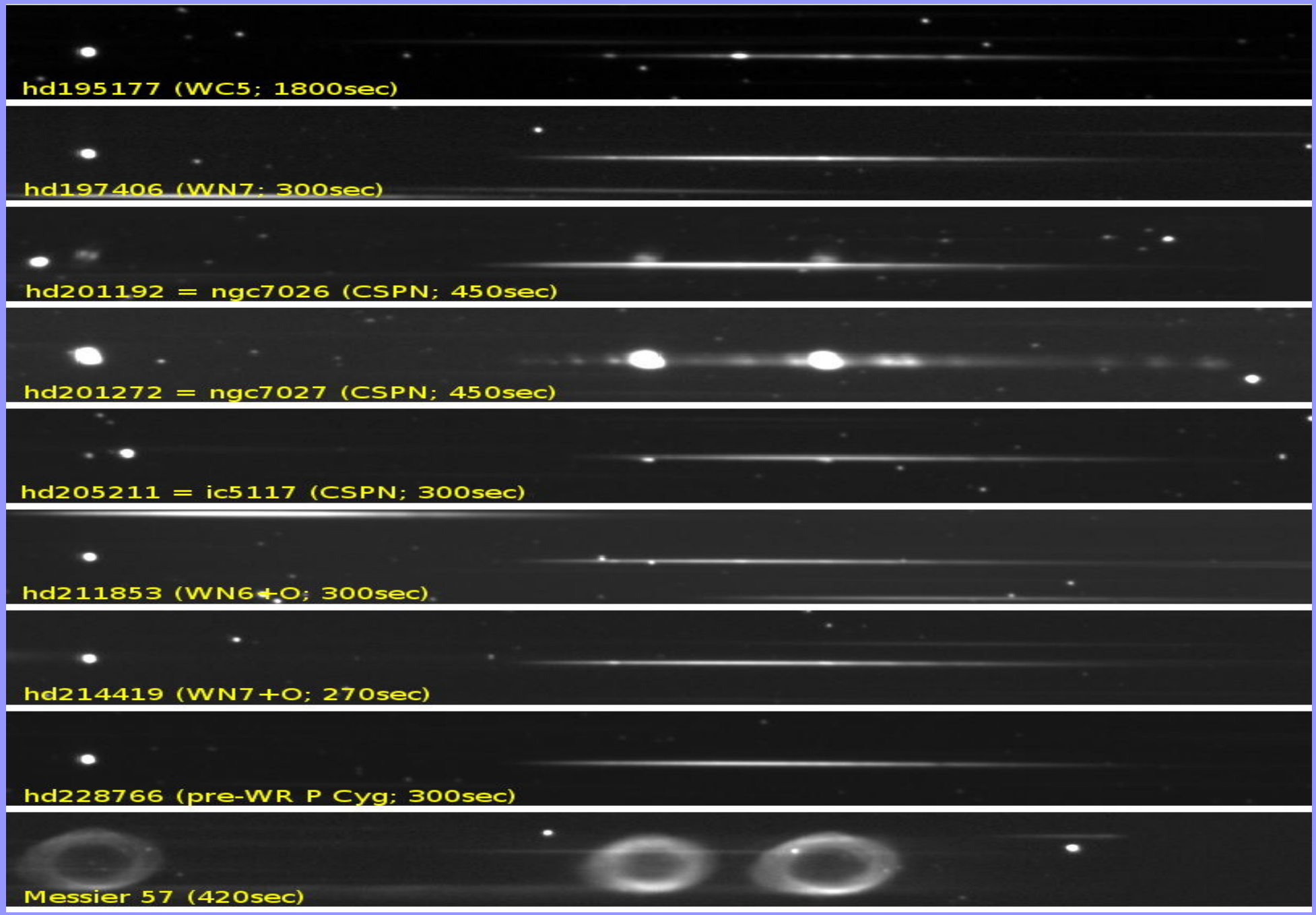
2.2. Spectroscopy from amateur astronomers

Several Hα 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 ~11 000.

The reduction of these data was performed using the standard echelle pipeline (Reshel software V1.11). H2O telluric lines are removed by means of division by a synthetic H2O 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-

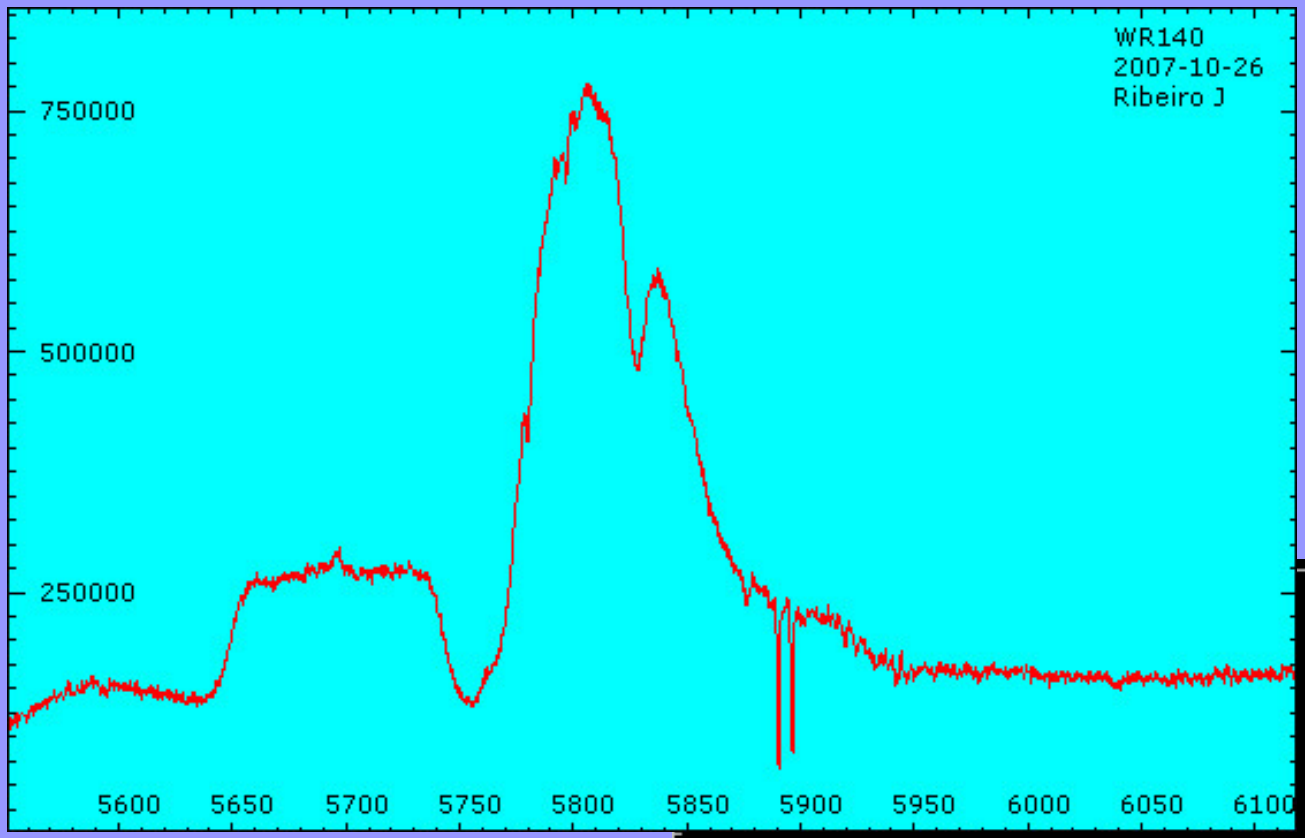
- **Ref:** arXiv:1007.2095v1 : Time, spatial, and spectral resolution of the Halpha line-formation region of Deneb and Rigel with the VEGA/CHARA interferometer

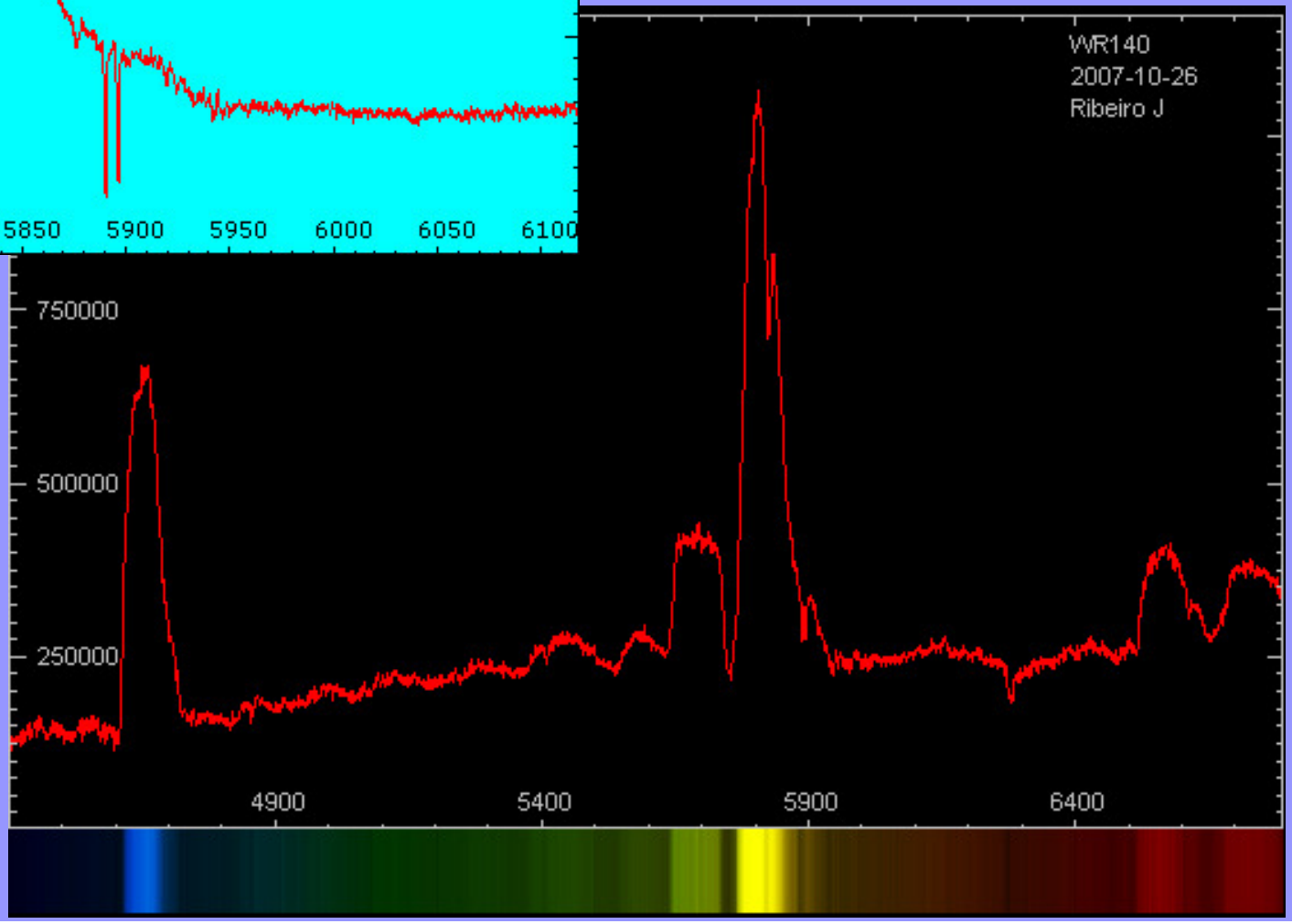
Wolf-Rayet



O.Thizy

WR140

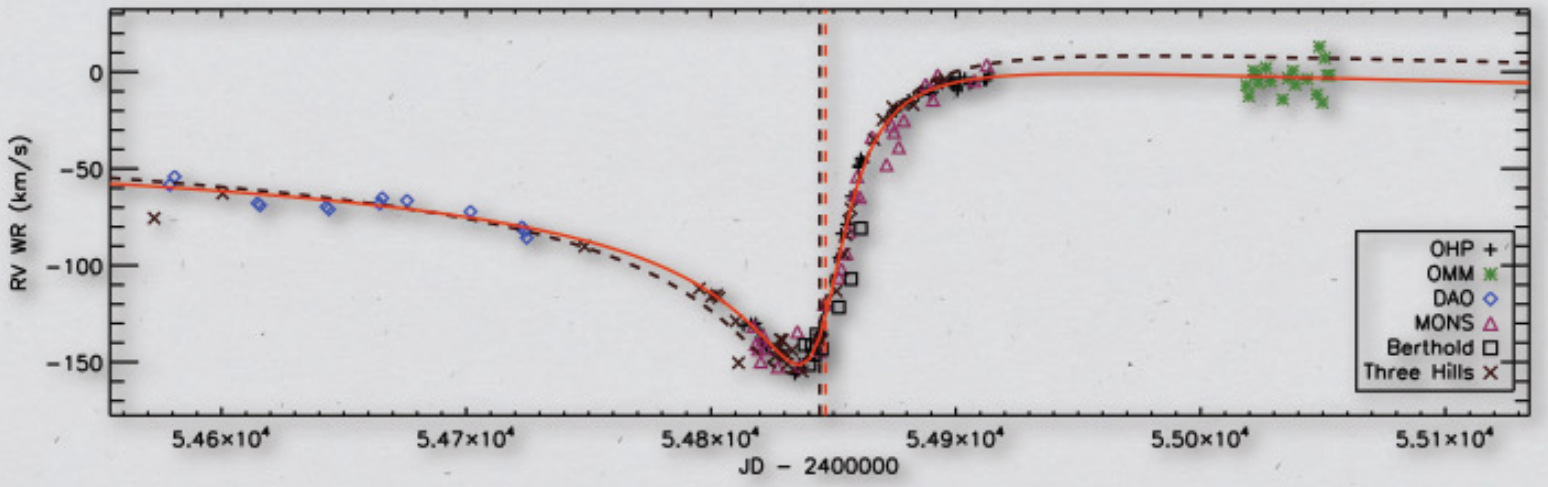


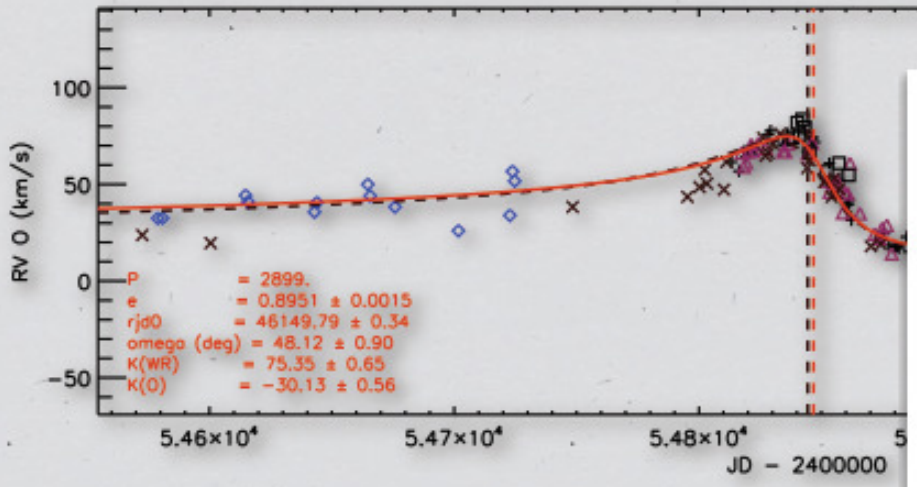


Jose Ribeiro

WR140 / 2009 periastron

Radial Velocities



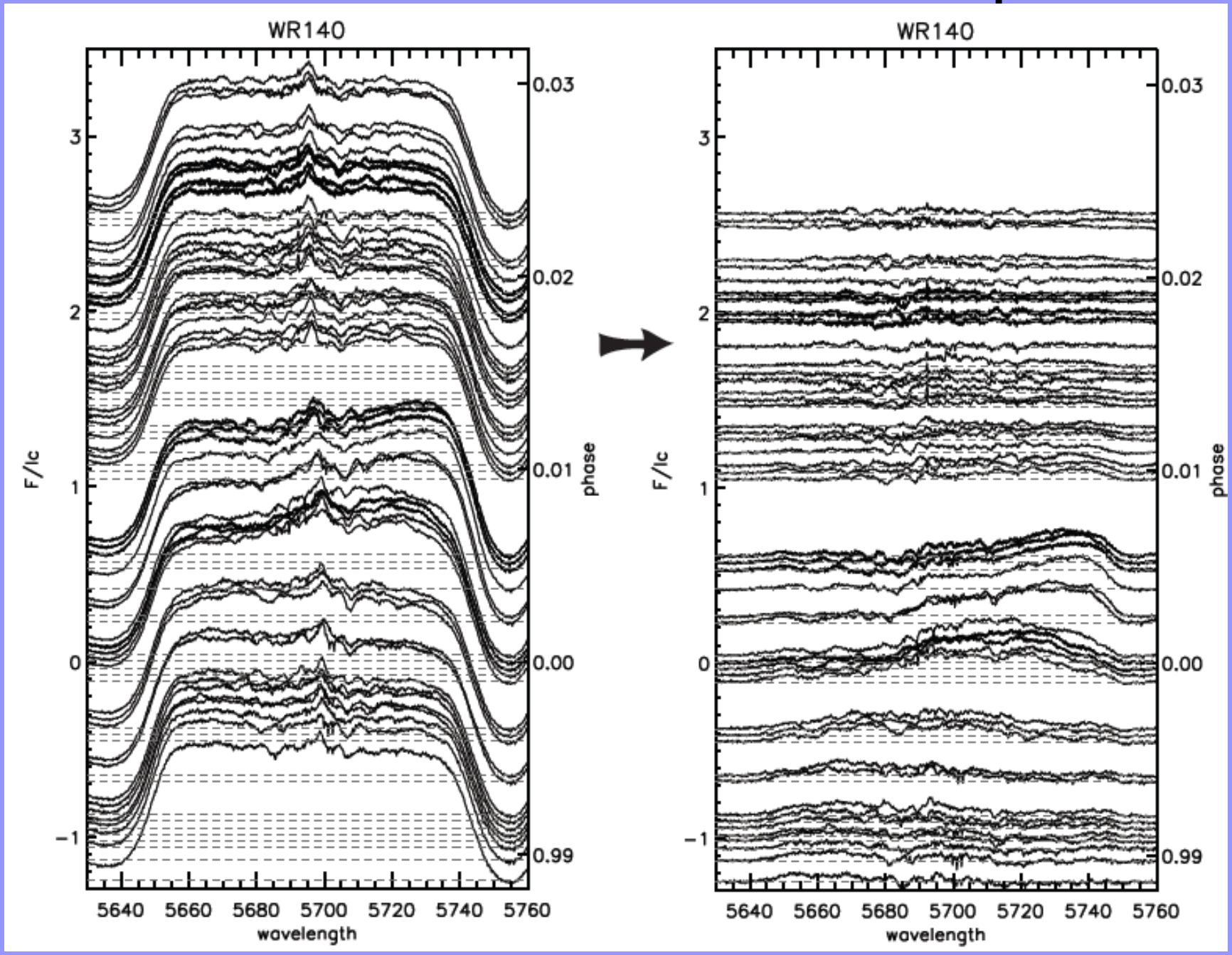


Orbital Elements of WR 140

Element	WR	O
K (km s^{-1})	82.0 ± 2.3	30.5 ± 1.9
$a \sin i$ (10^{10} km)	0.154 ± 0.007	0.057 ± 0.004
γ	assumed: 0.0	3.1 ± 1.0
P (days)	2899.0 ± 1.3	...
e	0.881 ± 0.005	...
T_0 (HJD 2,440,000+)	6147.4 ± 3.7	...
ω	46.7 ± 1.6	...

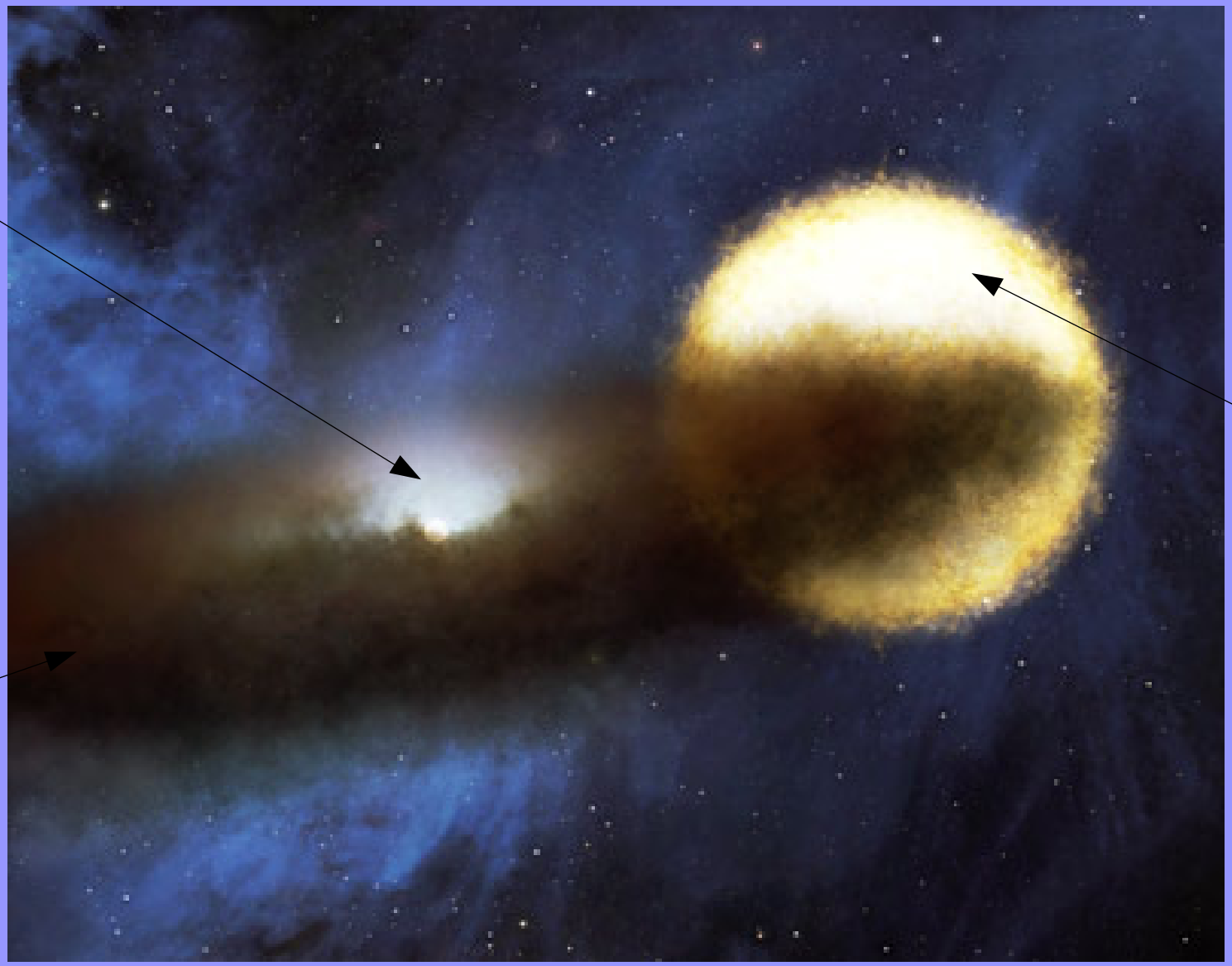
Rémy Fahed et al.

WR140 / 2009 periastron



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

Eps Aurigae eclipse



B star ?
~15000K
5.9 Msol

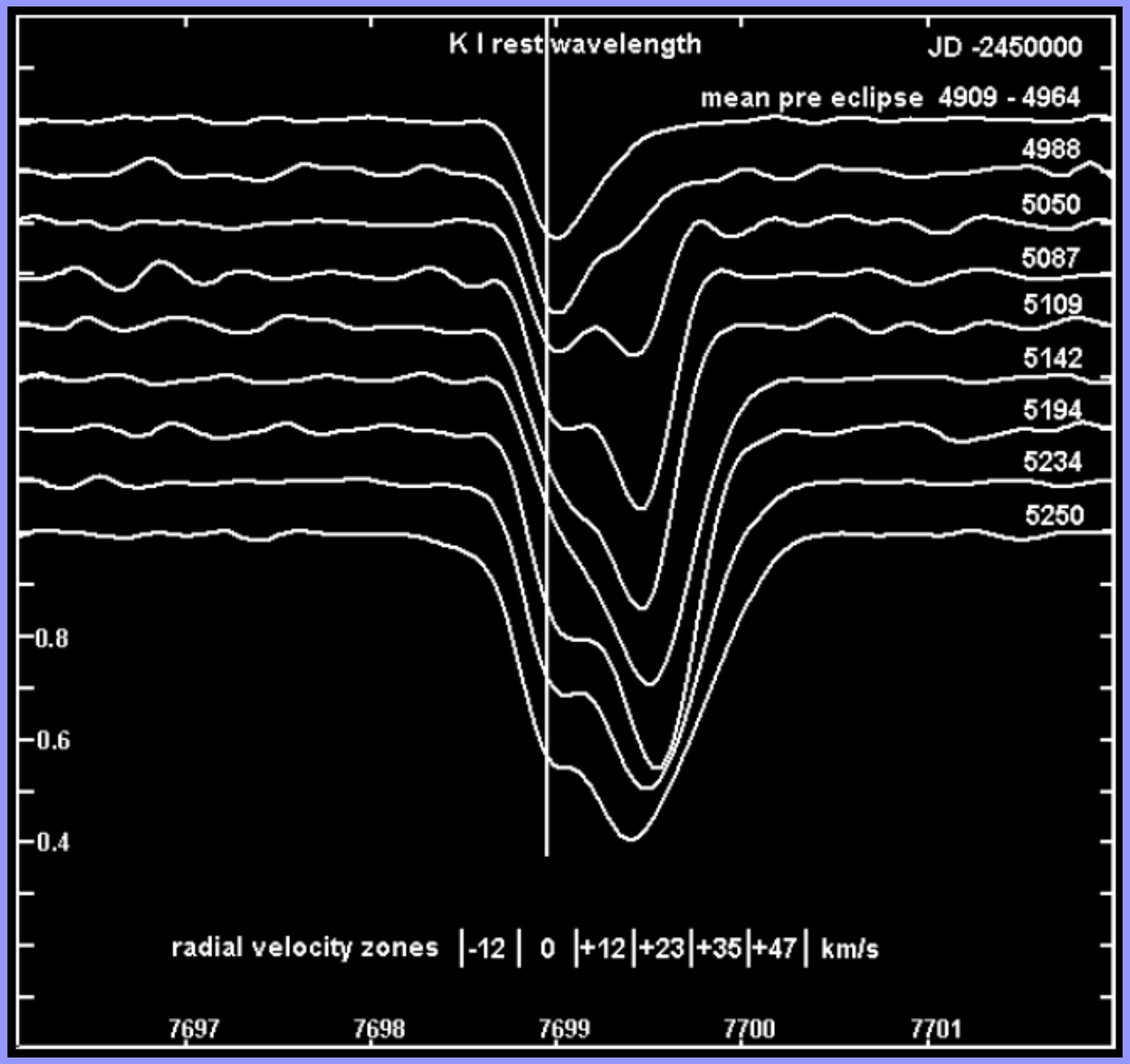
F type
star ?
~7000K
2.7 Msol ?

Disk
~500K

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

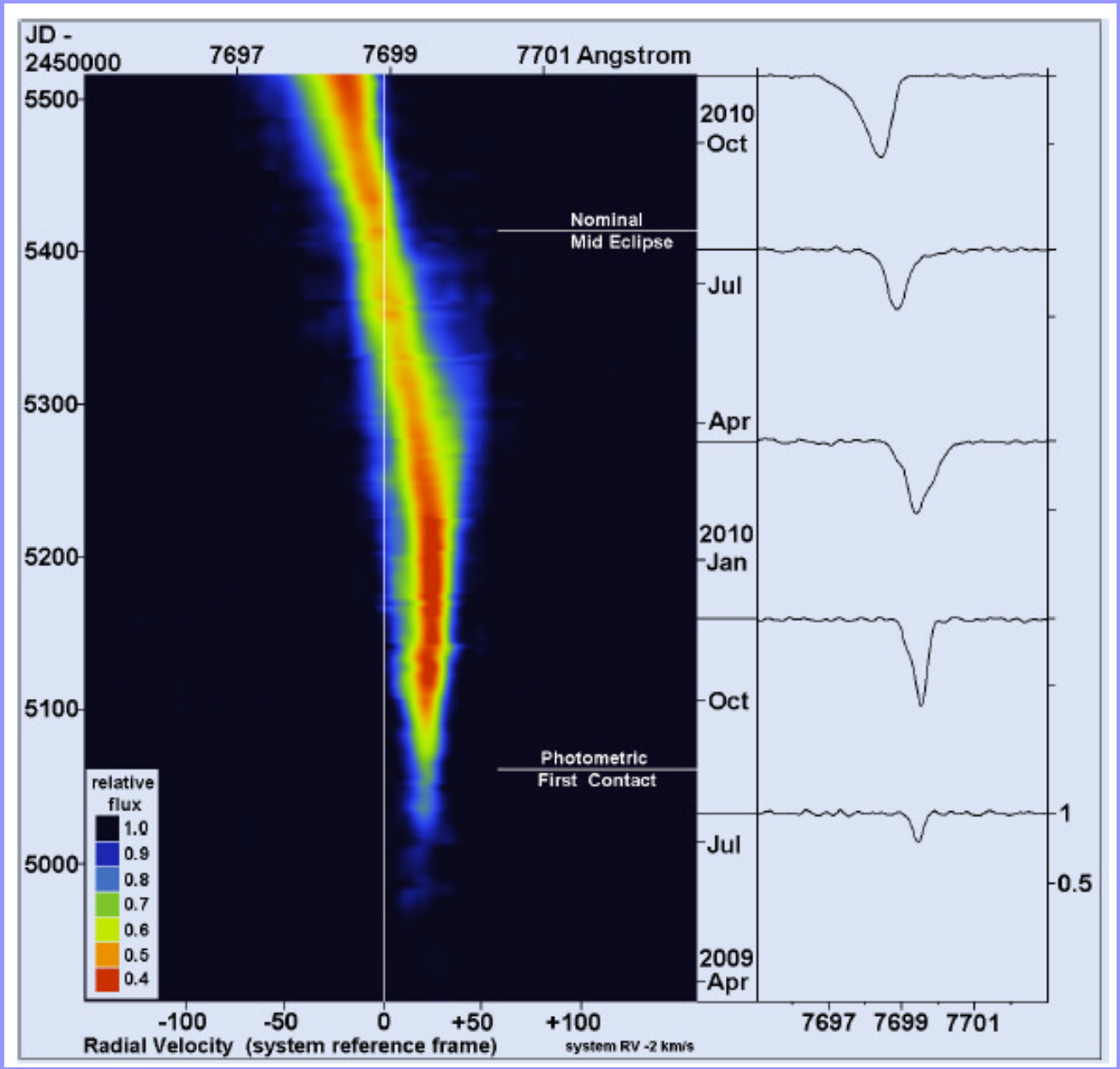
Robin Leadbeater

Eps Aurigae eclipse : KI 7699 line



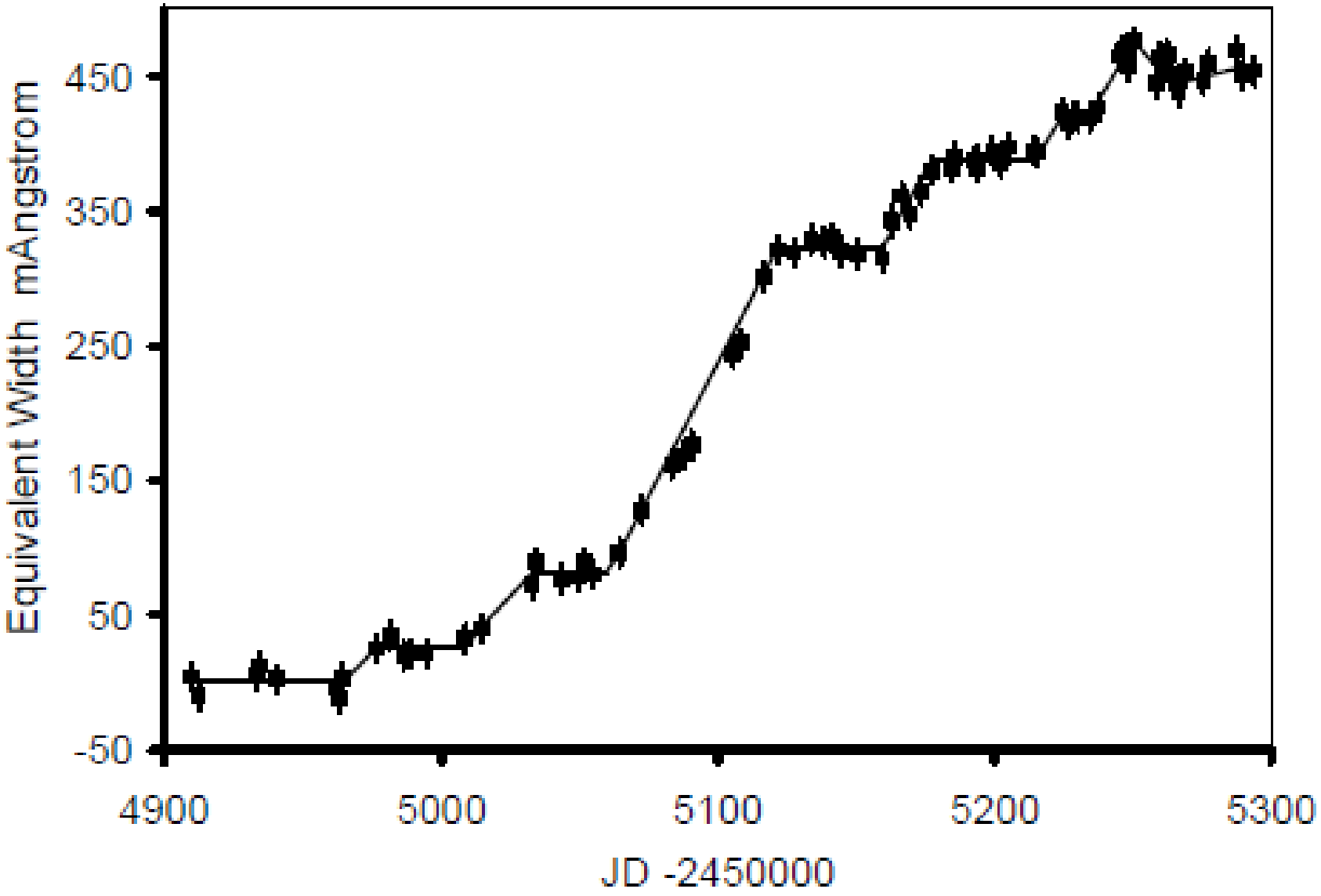
- New absorption line appearing !

Robin Leadbeater (Lhires III), Bob Stencel



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.

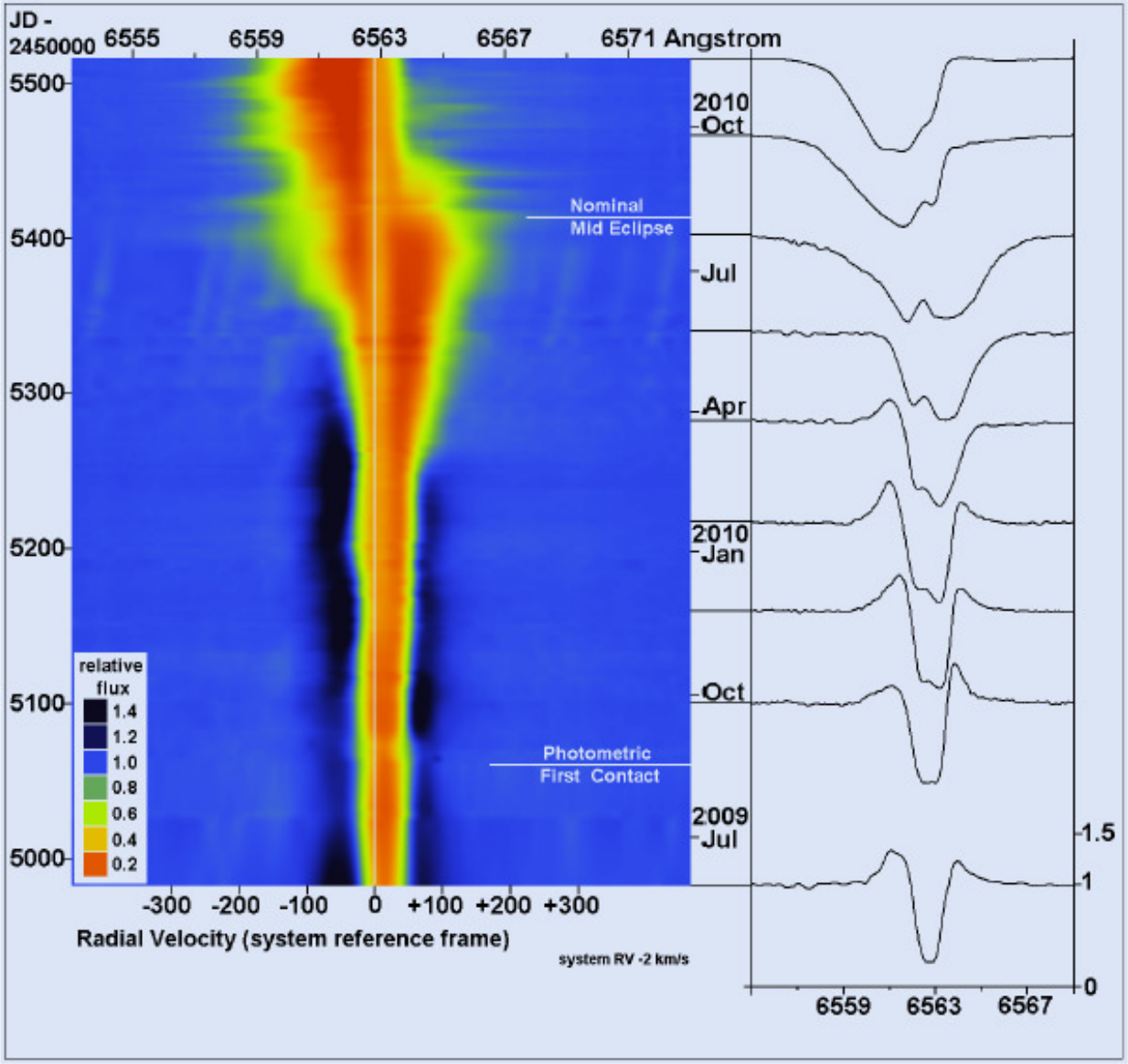
Eps Aurigae eclipse : KI 7699 line

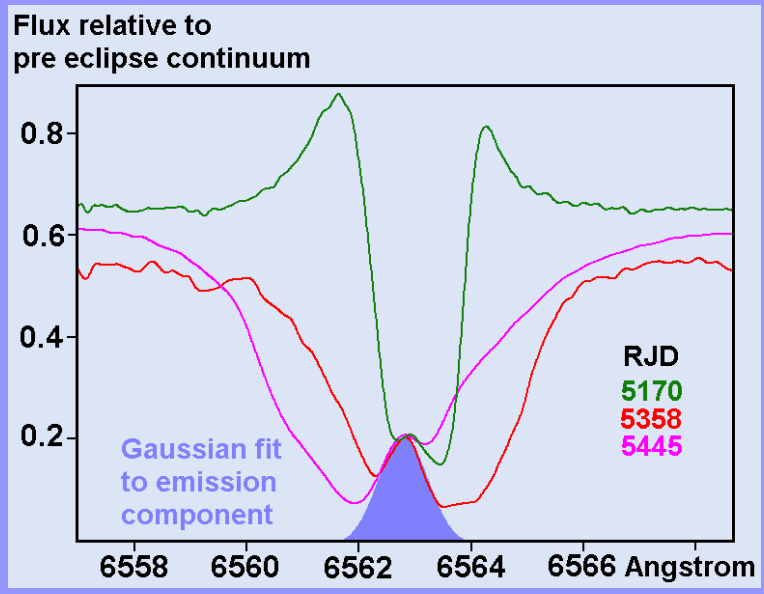


- Disk structures in « rings » ?

Robin Leadbeater, Bob Stencel

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.

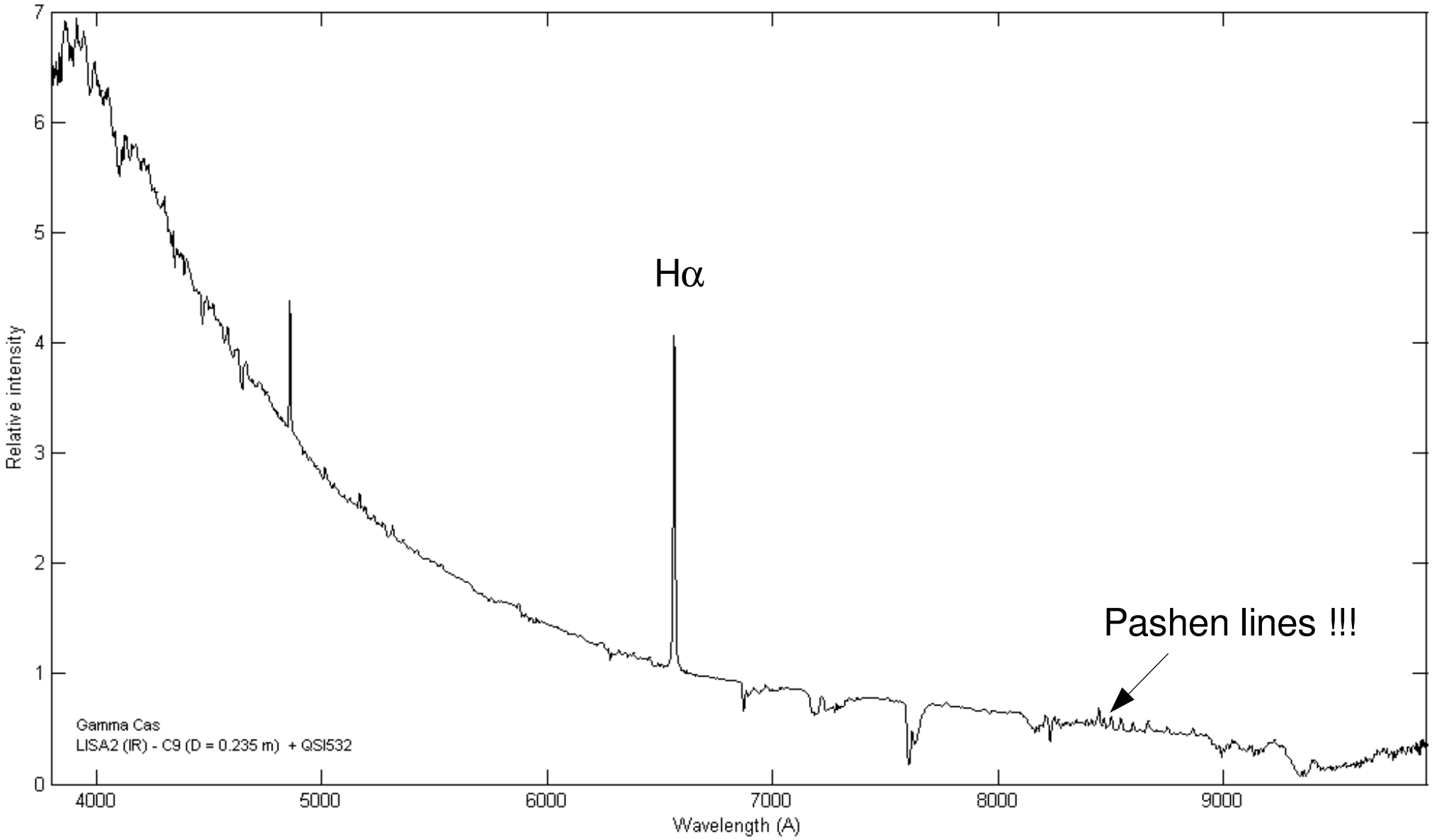
eps Aurigae pro-am campaign

- **Complementary photometry / spectroscopy campaign**
- **Over 600 spectra collected (and increasing) !**

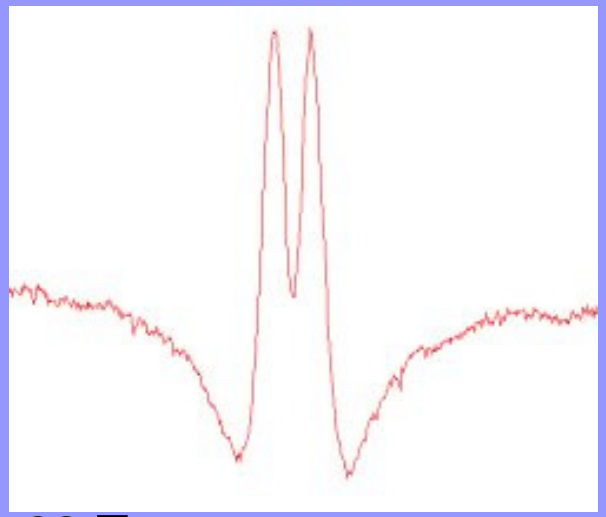
- **Contacts: Robert 'Bob' Stencel (Denver, USA)**
  Jeff Hopkins (amateur; photometry lead)
  Robin Leadbeater (amateur; spectroscopy lead)

- **Publications:**
  - http://www.threehillsobservatory.co.uk/astro/spectra_40.htm
  - 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 !

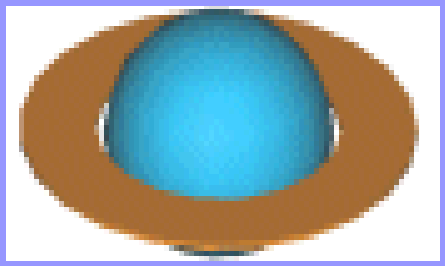
A *state-of-the-art* pro/am project: Be stars

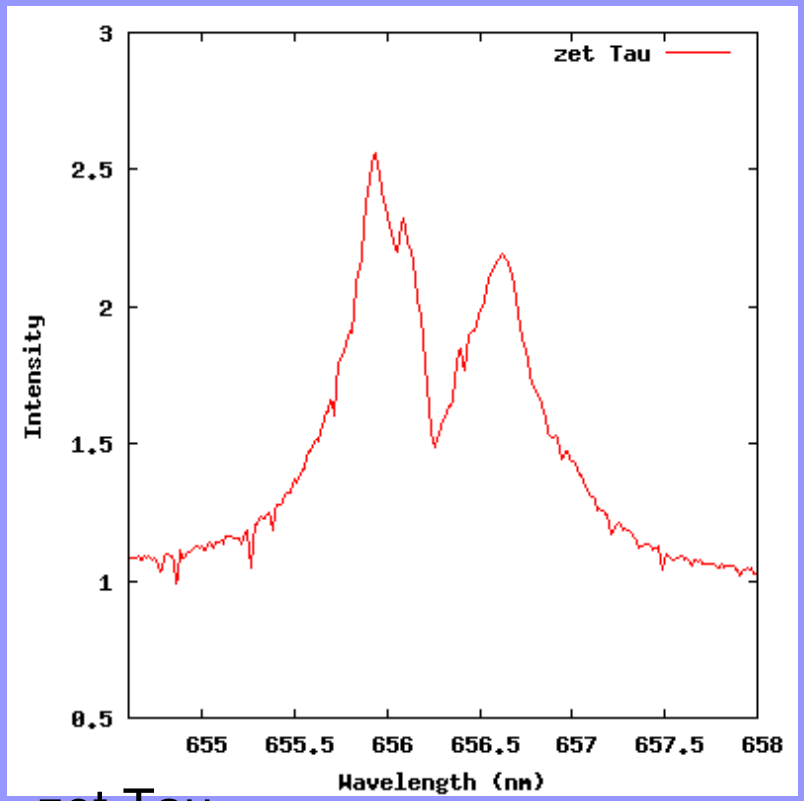


Be stars

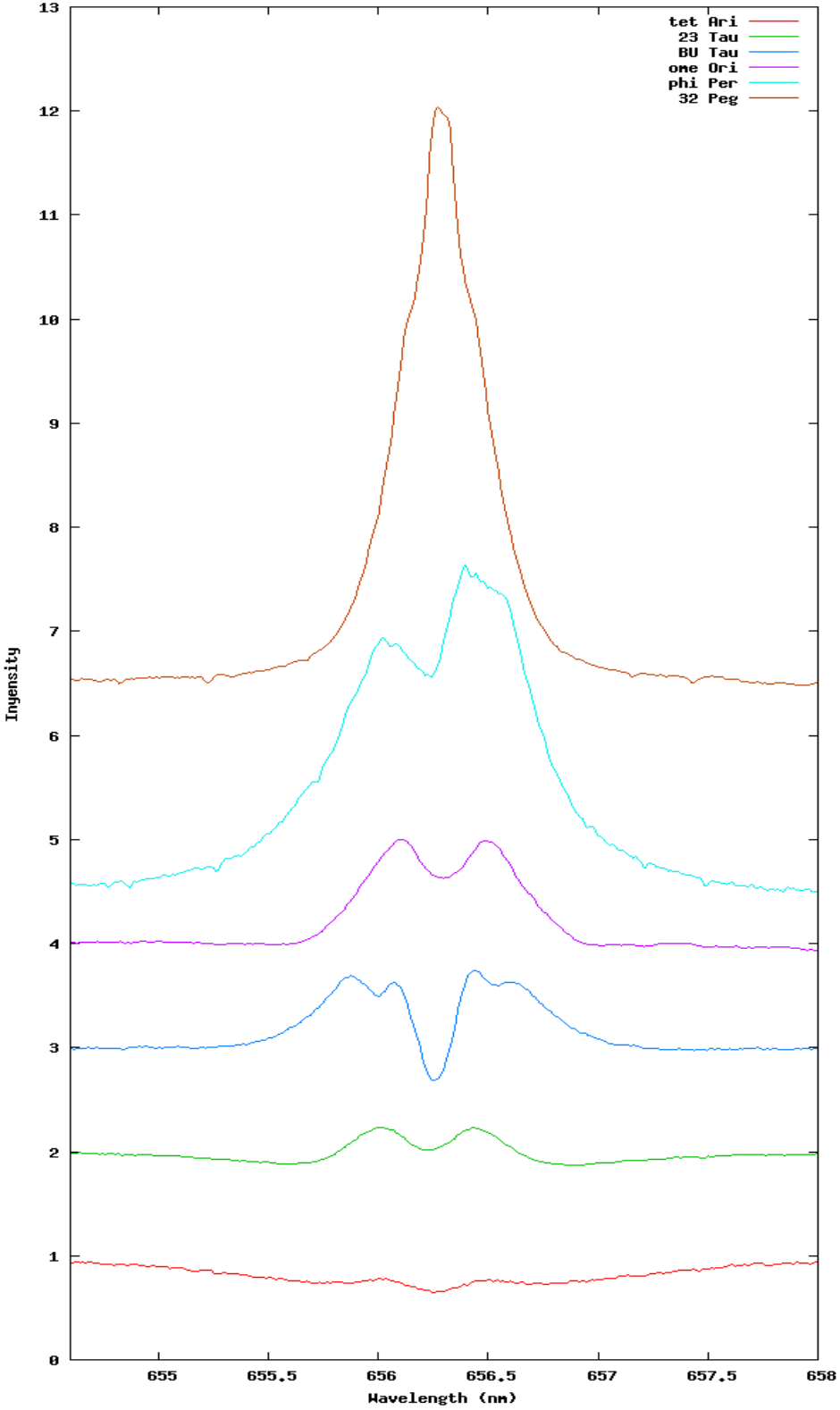


23 Tau

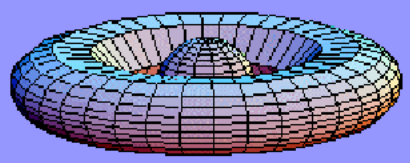


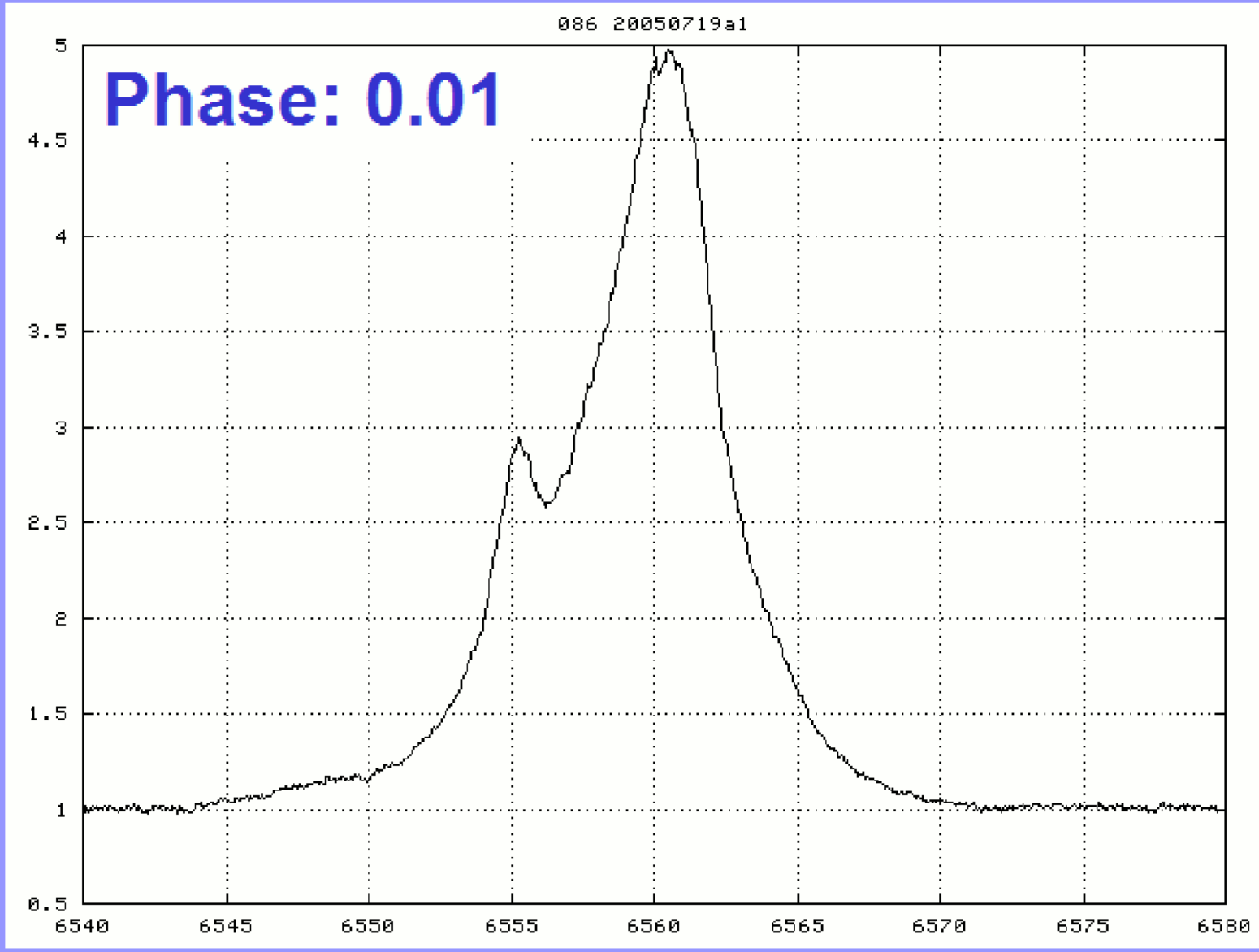


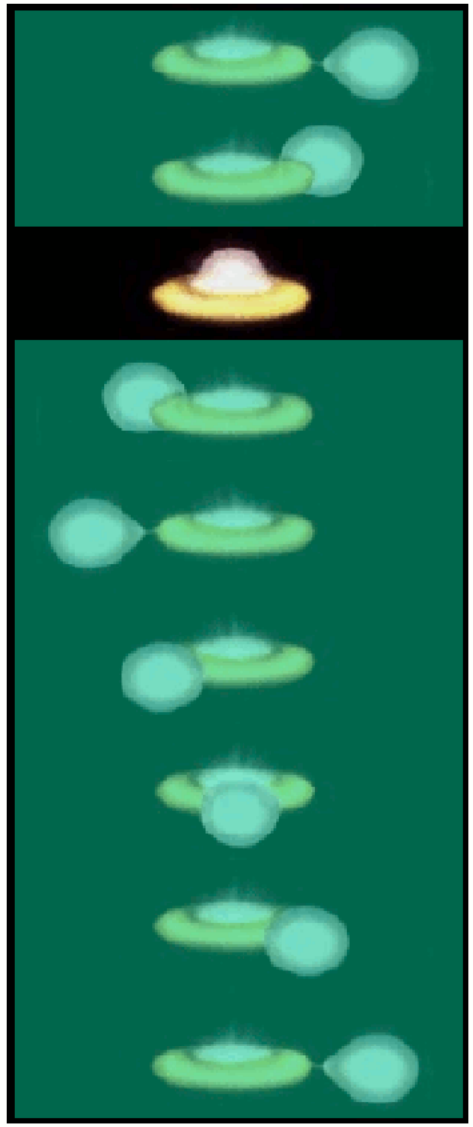
zet Tau



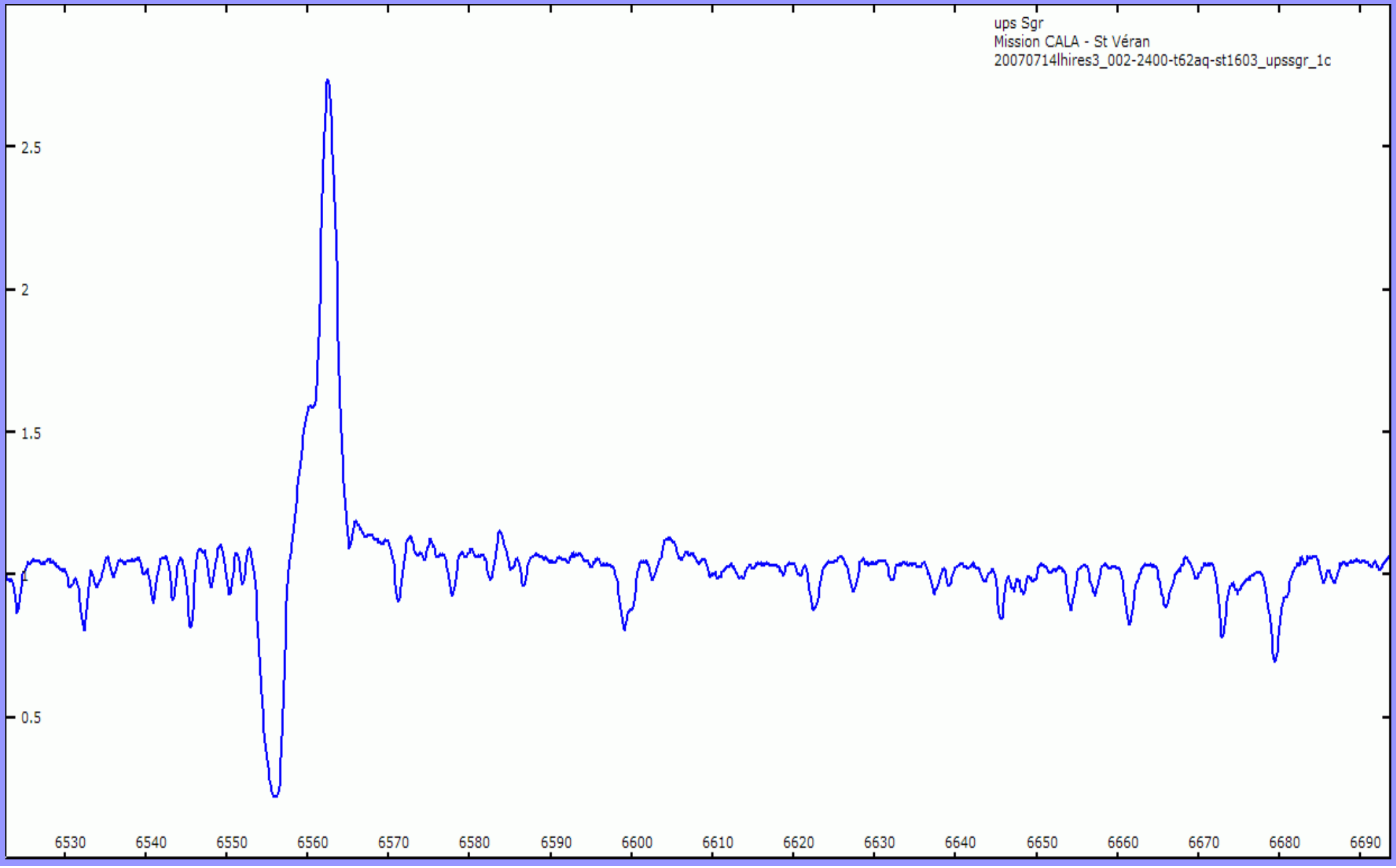
Hα - time evolution β Lyr







Exemple of Be targets: υ 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"

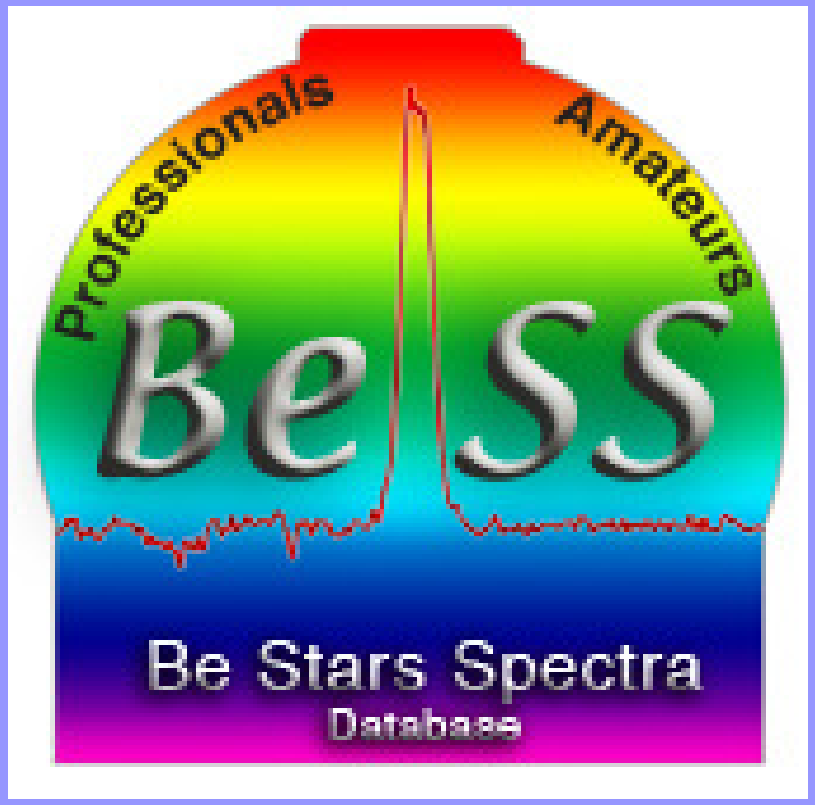
1.1

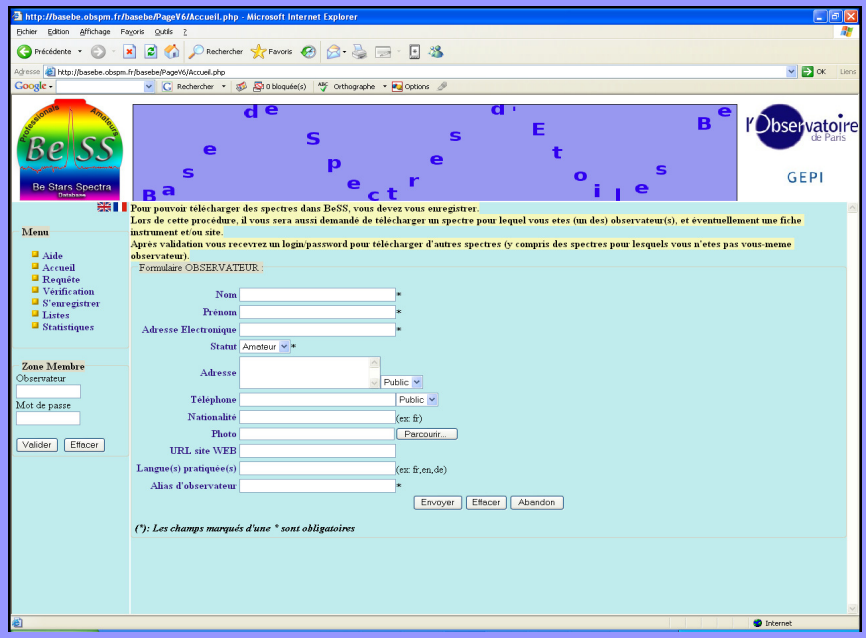
1

0.9

6420 6440 6460 6480 6500 6520 6540 6560 6580 6600 6620 6640 6660 6680 6700 6720 6740 6760 6780 6800 6820 6840

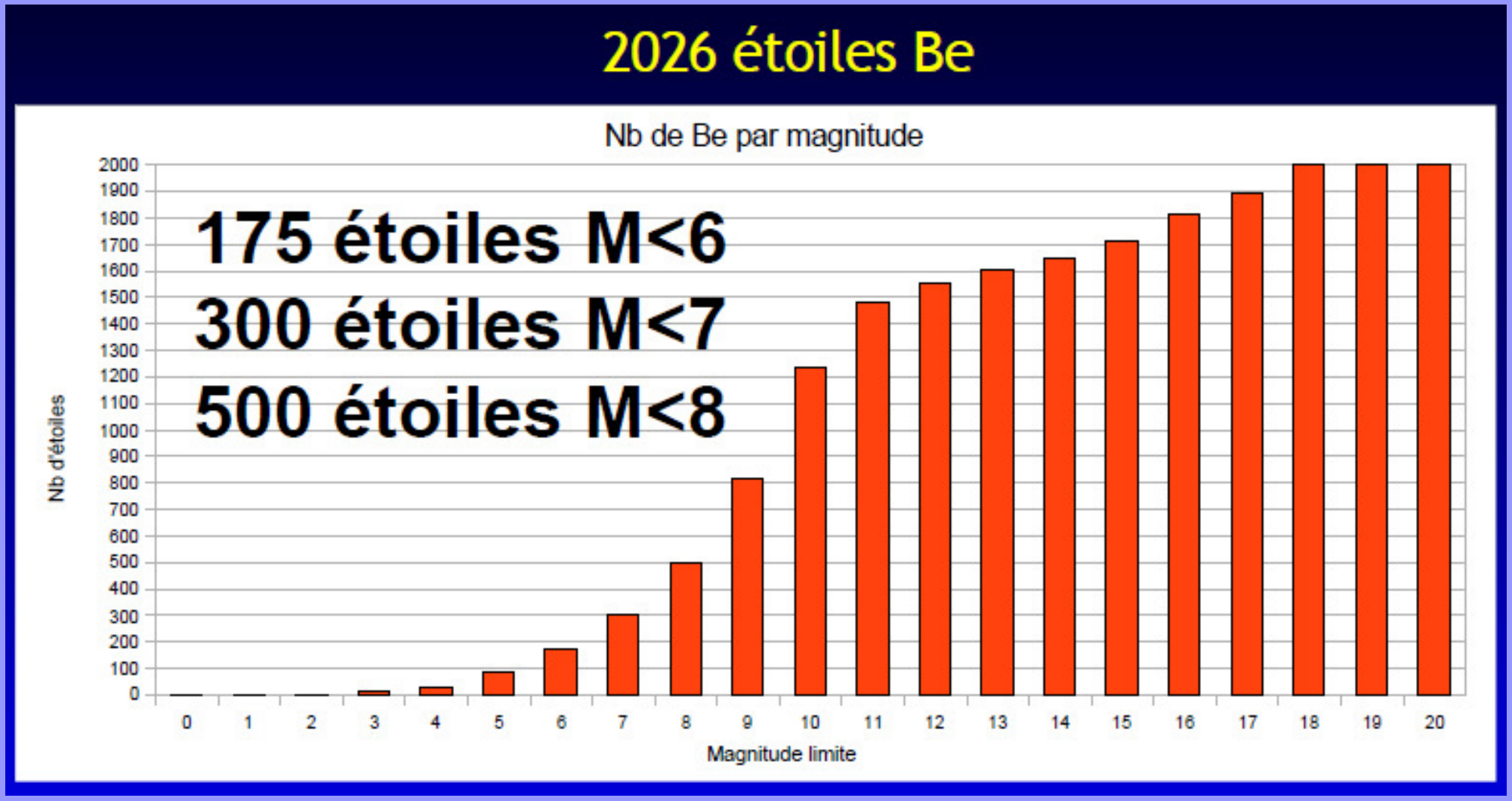
BeSS database





URL: **http://basebe.obspm.fr**

BeSS catalog



F. Cochard / V. Desnoux

- Plenty of BRIGHT stars to work on !!!

BeSS database

Top ten de tous les 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

Top ten des amateurs insomniaques

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

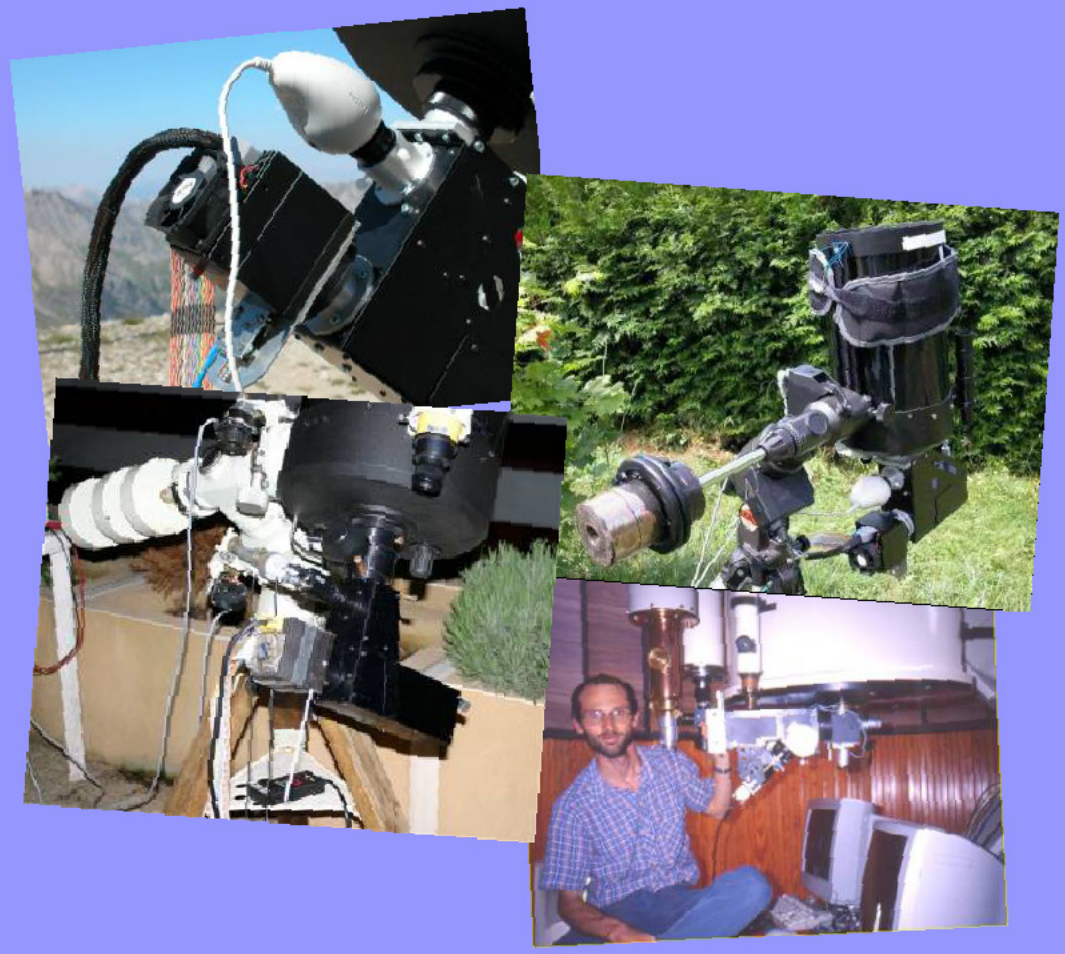
Top ten des pros insomniaques

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

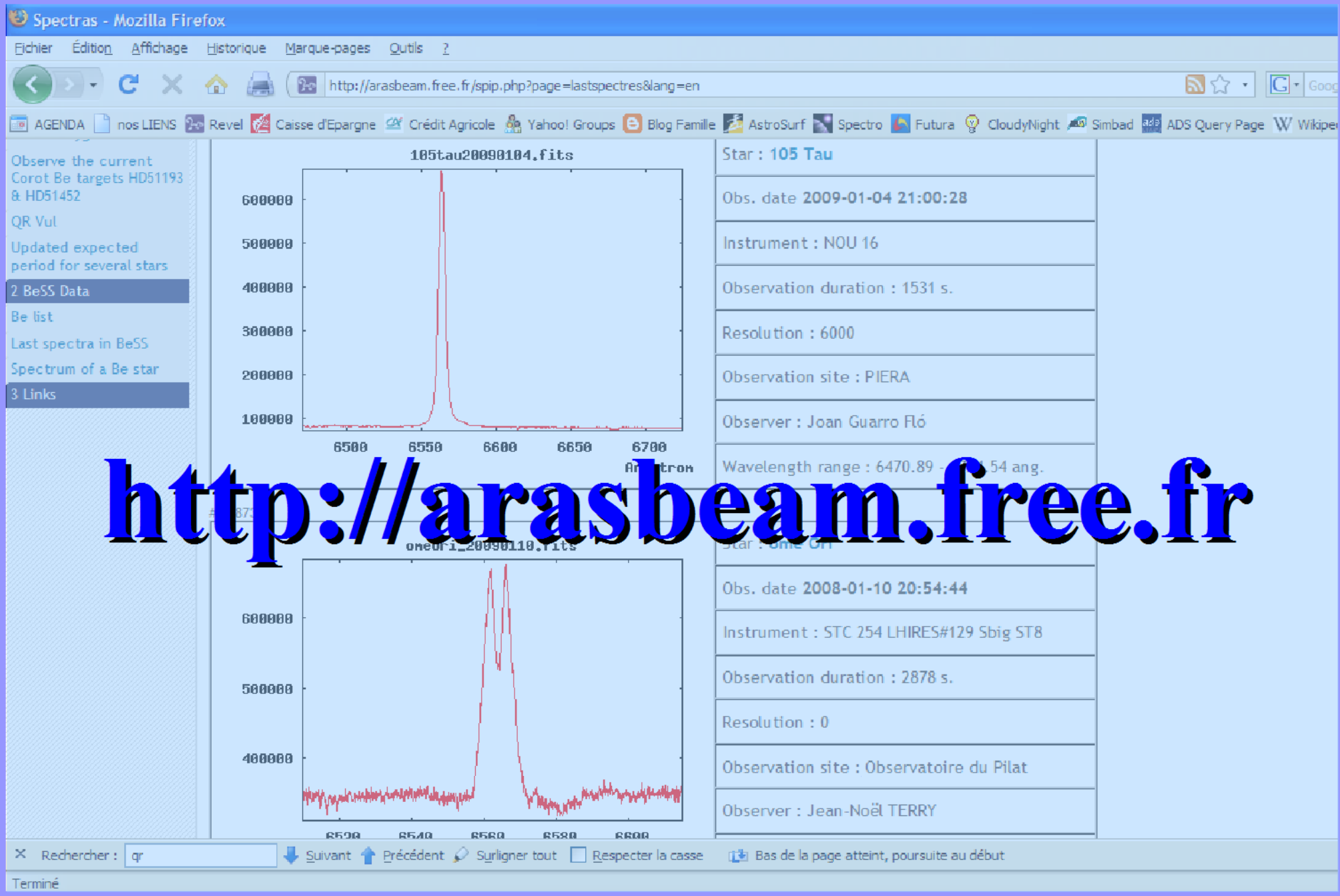
Equipment used

Type	
Lhires III	42
Pro	13
Other	6
eShel	5
Total Résultat	**66**



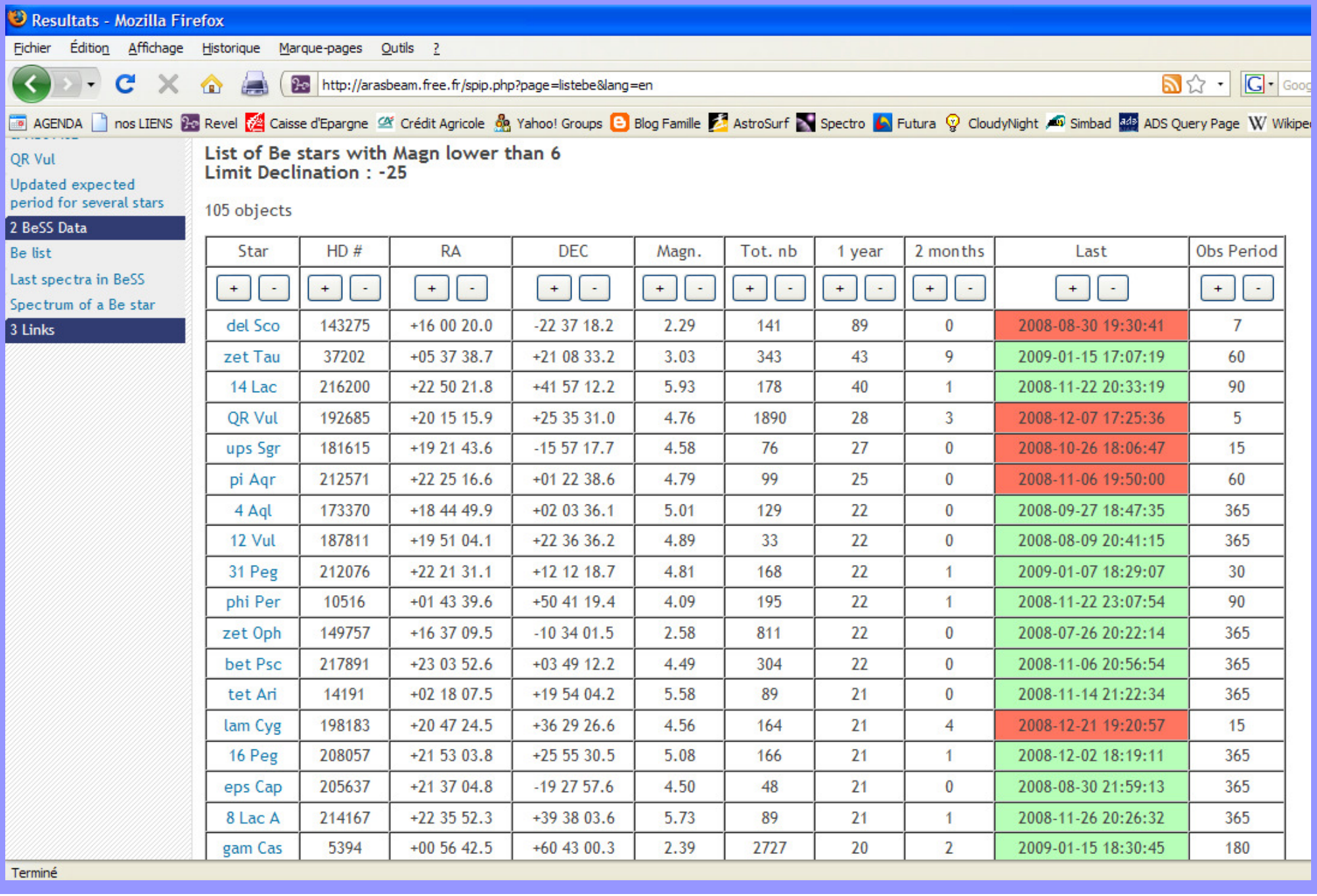
- Amateur telescope size: 12cm to 62cm
- Mainly Lhires spectrographs used by amateurs
- eShel echelle spectrograph is new
  but provides larger spectral coverage

Aras Be Am “amateur” front end



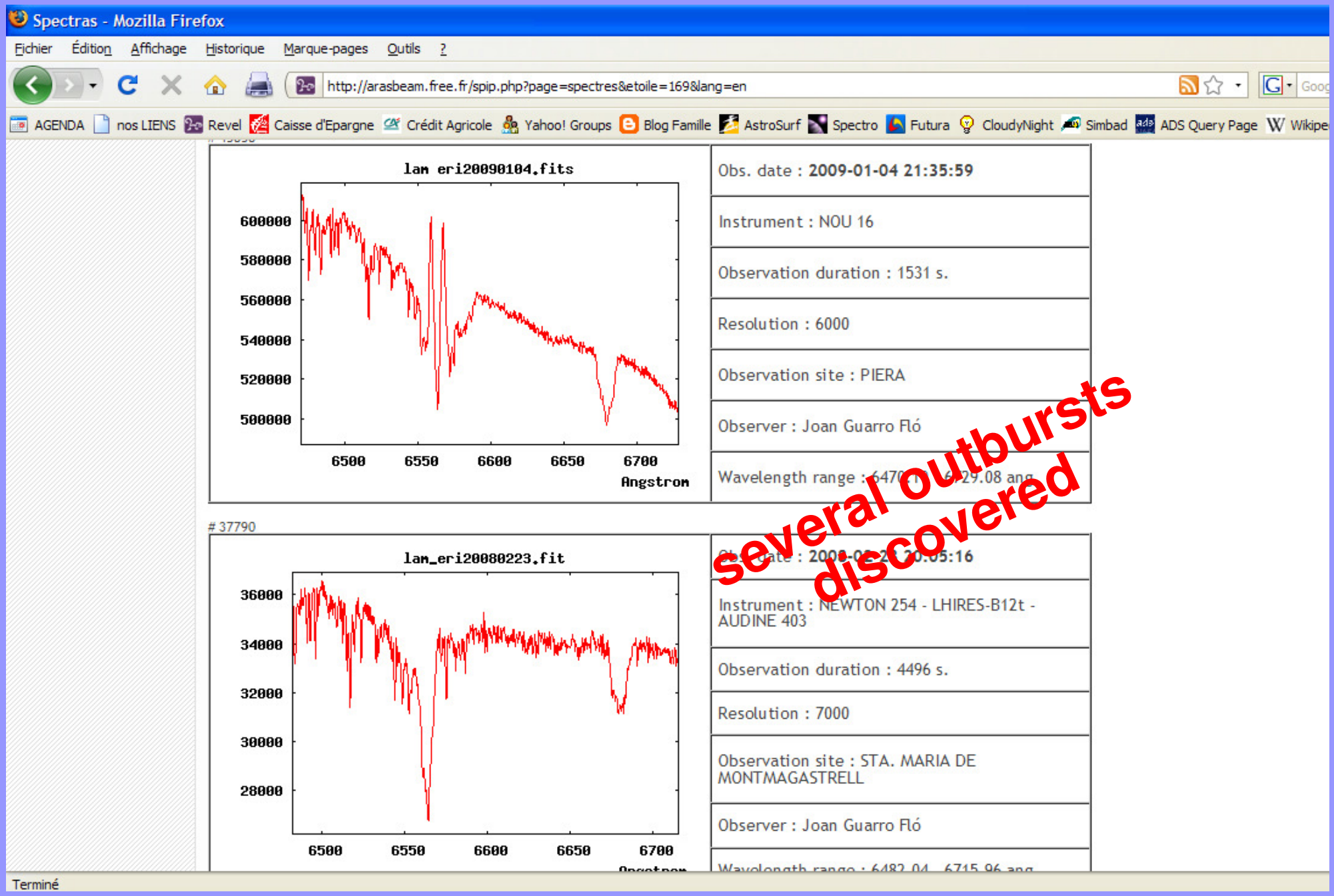
http://arasbeam.free.fr

ARAS BeAm « to do » list

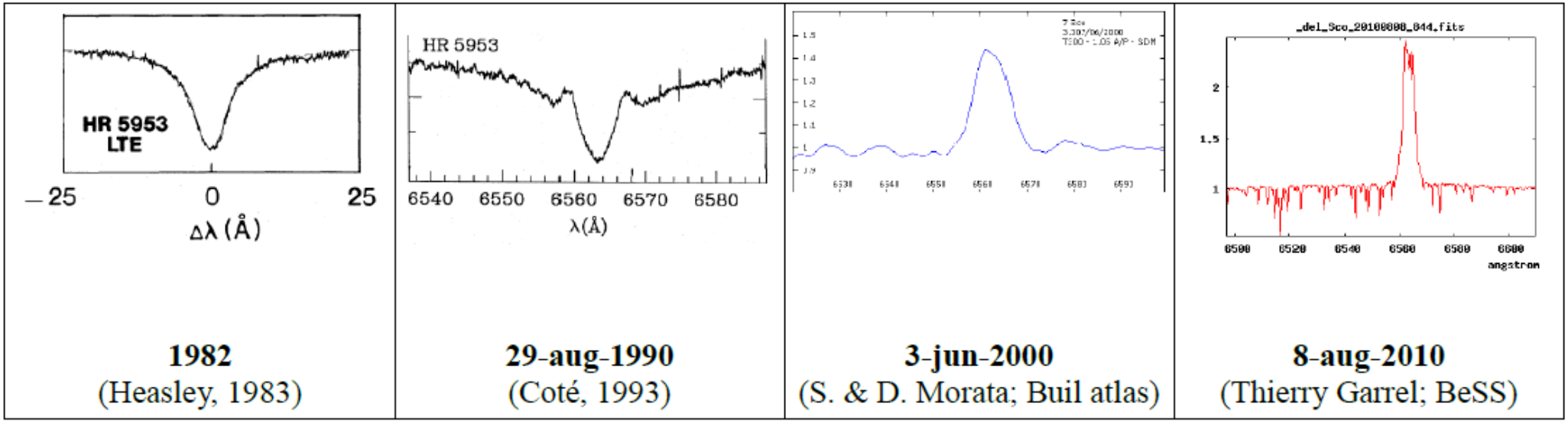


Star	HD #	RA	DEC	Magn.	Tot. nb	1 year	2 months	Last	Obs Period
del Sco	143275	+16 00 20.0	-22 37 18.2	2.29	141	89	0	2008-08-30 19:30:41	7
zet Tau	37202	+05 37 38.7	+21 08 33.2	3.03	343	43	9	2009-01-15 17:07:19	60
14 Lac	216200	+22 50 21.8	+41 57 12.2	5.93	178	40	1	2008-11-22 20:33:19	90
QR Vul	192685	+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

ArasBeAm: detecting outburst



delta Sco : 2011 periastron !!!

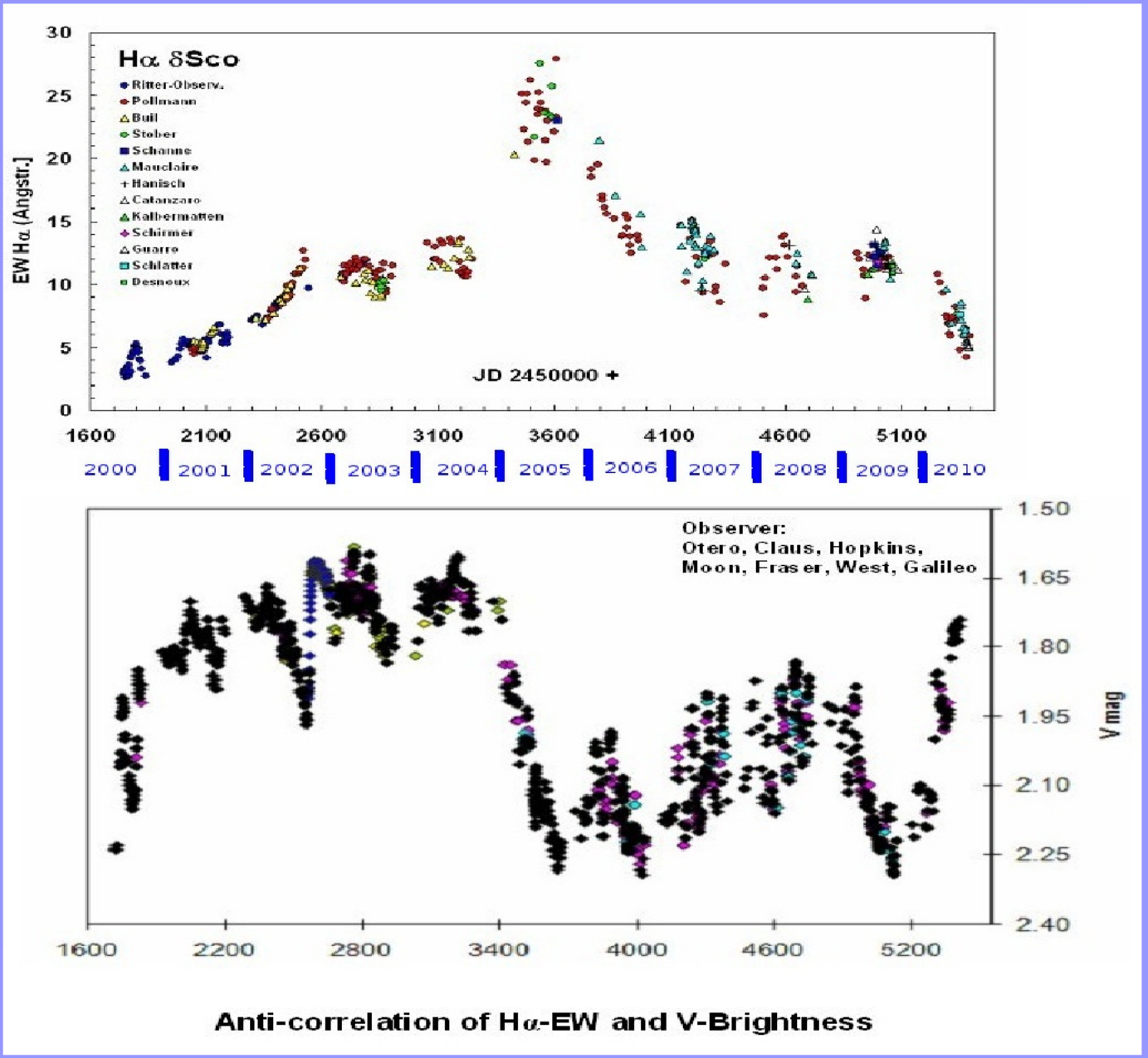


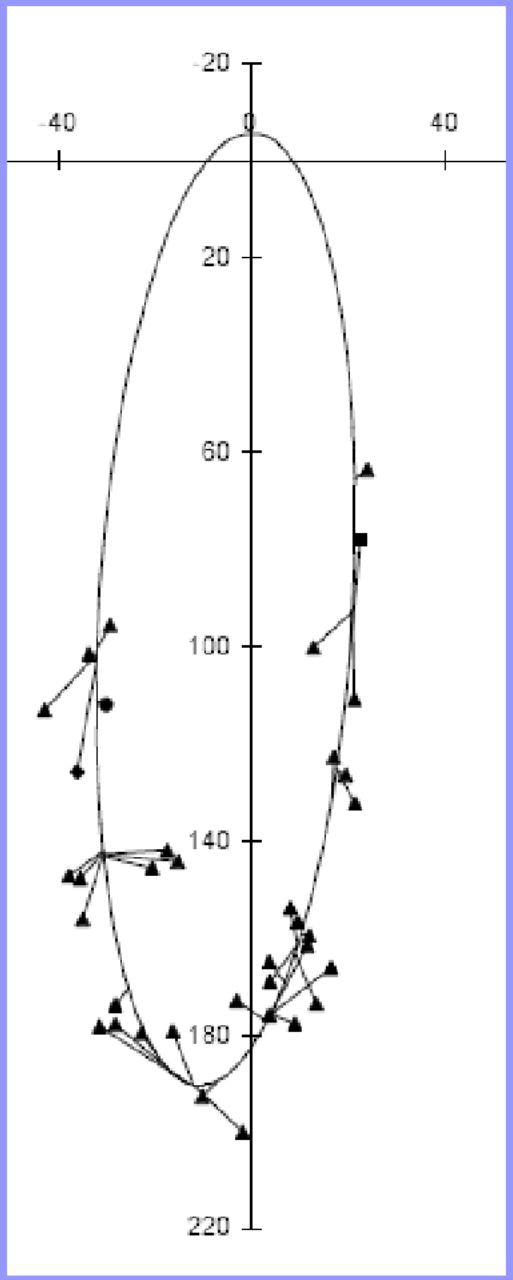
1982	29-aug-1990	3-jun-2000	8-aug-2010
(Heasley, 1983)	(Coté, 1993)	(S. & D. Morata; Buil atlas)	(Thierry Garrel; BeSS)

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

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

delta Sco : 2011 periastron !!!

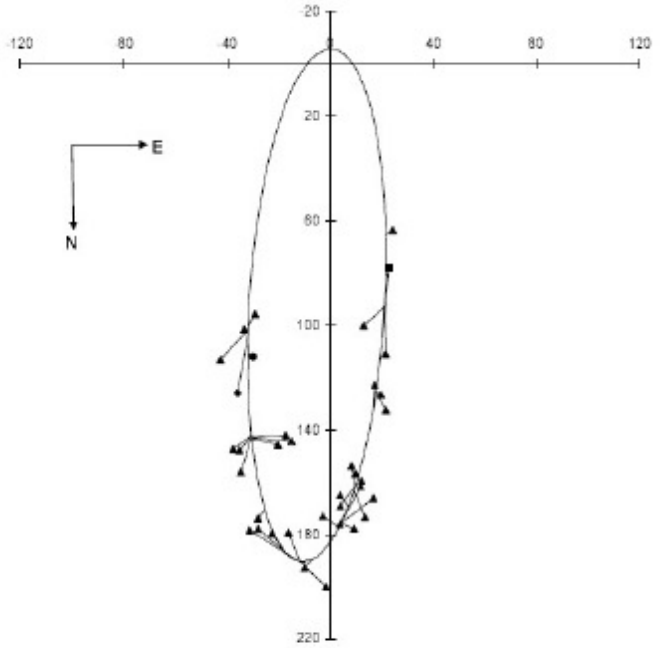




Ernst Pollmann

Tango et al. 2009

delta Sco : 2011 periastron !!!



The orbital elements for δ Sco

Element	Ref. *a*	Ref. *b*	This Work
Period P (yr)	10.58 ± 0.08	10.58[c]	10.74 ± 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 ± 0.02	0.94 ± 0.01	0.9401 ± 0.0002
Semimajor axis (mas) a''	107 ± 7	107[c]	98.3 ± 1.2
Inclination i	$48.^{\circ}5 \pm 6.^{\circ}6$	$38^{\circ} \pm 5^{\circ}$	$38^{\circ} \pm 6^{\circ}$
Long. periastron ω	$24^{\circ} \pm 13^{\circ}$	$-1^{\circ} \pm 5^{\circ}$	$1.^{\circ}9 \pm 0.^{\circ}1$
Long. of asc. node Ω	$159.^{\circ}3 \pm 7.^{\circ}6$	175°	$175.^{\circ}2 \pm 0.^{\circ}6$
Systemic RV V_γ (km·s^{-1})		-6 ± 0.5	-6.72 ± 0.05
RV amplitude K_A (km·s^{-1})			23.84 ± 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 ± 0.4

Ref. *a* Hartkopf et al. (1996)
Ref. *b* Miroshnichenko et al. (2001)
[c] Value assumed from Ref. *a*

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

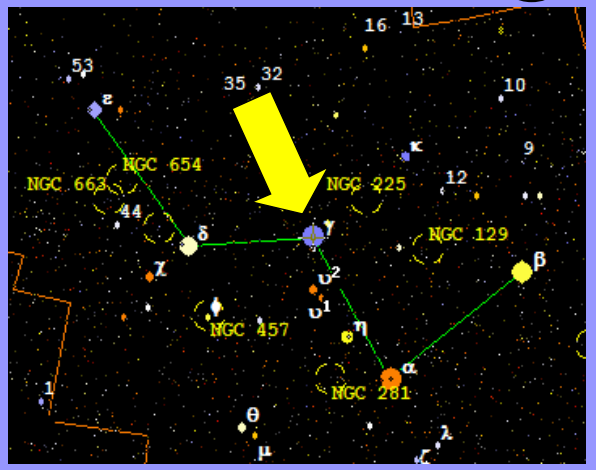
Recent interferometric observations (Tango et al., 2009) led to new orbital elements and masses estimation: M1 = 15 +/-7 M* and M2 = 8.0 +/-3.6 M*

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).

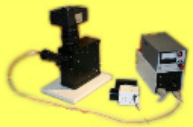
Actually, I gave him the attached compiling plots (fig. 1 & 2) of Halpha EW and visual brightness observations of my colleagues in Hungaria and Germany.

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

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


Stars won't look the same o
Thank You !!!
Shelyak
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(301) 953-2000 | www.company7.com