Why to do Astronomical Spectroscopy ?

Olivier THIZY

BAA Spectroscopy Workshop

Norman Lockyer Observatory, 10 june 2015

Agenda

- because it's FUN to learn Optics !
- Because it's FUN to learn (Astro)Physics
- because it's FUN to share & teach !
- because it's FUN to contribute !

Inside the Alpy 600 spectroscope

...or how it is FUN to learn Optics

Importance of the slit

3mm slit (hole)

300μm slit

25μm slit

Cat's eye nebula / no slit Vs slit

Slit:

- *helps for resolution*
- *isolates target*
- *allows light pollution removal*

© Torsten Hansen, Robin Leadbeater, O. Thizy

Mirror slit

- Centering
- (auto)Guiding

© C. Buil, O. Thizy

The Alpy 600 system on a scope

Guiding camera

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

Alpy 600 spectrograph

Acquisition camera

Astronomical Spectroscopy

...or how it is FUN to learn from the stars

beta Cygni (Albireo)

Stars won't look the same!

Photos: Jim Edlin (Cygne), Eric Coustal (Albireo)

Albireo A vs B

(1) Overshape profile

(2) Absorption lines

(3) Emission line

?

Perfect exemple of Kirchhoff's laws...

Photos: Eric Coustal (Albireo) & Wikipedia

1: overall profile --> Temp.

Analyse: VisualSpec; photo Aliréo: Eric Coustal

2: stellar atmosphere

Spectral classification

Oh, **B**e **A** **F**ine **G**irl/Guy... **K**iss **M**e !

Absorption lines physics

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

Exemple for the hydrogen atom

Sources: http://culturesciencesphysique.ens-lyon.fr/ressource/Quantique.xml
&: http://e.m.c.2.free.fr/niveaux-energie-hydrogene-emission-absorption.htm

Temperature Vs line strength

Luminosity class

Hertzspring-Russell diagram

© J. Kaler / N. Walker

3: emission lines

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

Photos: Eric Coustal (Albireo) & Wikipedia

Cf: http://www.shelyak.com/dossier.php?id_dossier=24

Emission lines physics

excitation by radiation

excitation by shocks

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

Exemple for the hydrogen atom

Sources: http://culturesciencesphysique.ens-lyon.fr/ressource/Quantique.xml
&: http://e.m.c.2.free.fr/niveaux-energie-hydrogene-emission-absorption.htm

Summary

(1) Overall profile = effective Planck temperature

(2) Energy absorption = stellar atmosphere

(3) Energy emission = circumstellar disk

...thanks Mr Kirchhoff !

Photos: Eric Coustal (Albireo) & Wikipedia

Doppler-Fizeau effect:

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

Galaxies redshift
=
Expansion of our Universe !

Galaxies redshift

3C273 quasar

Hbeta red-shifted from 4861A to 5629A :

z =(5629.27/4861.32)-1

z = 0.158

P Cygni Luminous Blue Variable

P Cygni profile / Doppler effect

Lhires III high-resolution spectrogr.

Interchangeable gratings

Micrometer to set wavelength

Telescope entrance

Neon lamp for calibration (inside)

Guiding port

Access to mirror slit

Spectrum image output

Grating (inside)

Access door to focus doublet

		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

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

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

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

Share your passion

...or how it is FUN to share & teach

Visual solar spectrum

Crédit: O. Garde, O. Thizy

Charlie Bates Solar Project (Steve Ramsden)

High School level projects

Cf: http://www.shelyak.com/dossier.php?id_dossier=77

...and all the „learning“ observation shown before !

Nova Del 2013

...or how it is FUN to contribute with a professionnal astronomer

Photo: F. Cochard, OHP

Nova Del 2013

Nova Del 2013

„P Cygni“ profile

Nova Del 2013: Pro-Am campaign

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

Source: Google Map / O. Thizy

Nova Del 2013: Pro-Am campaign

#	Date	Start Time (UT)	Mid J.D.	Observer	Site							
1	14/08/2013	19:45:16	2456519.344	OlivierGarde	Observatoi							
2	14/08/2013	20:45	2456519.385	OlivierGarde	Observatoi							
3	14/08/2013	21:12:32	2456519.396	TdeFrance	MEZI							
4	14/08/2013	21:12:32	2456519.396	ThibaultdeFrance	Meze							
5	14/08/2013	21:38:09	2456519.405	J.Guarro	STAMARIAD							
6	14/08/2013	21:48:03	2456519.419	TdeFrance	MEZI							
7	14/08/2013	21:48:35	2456519.412	J.Guarro	STAMARIAD							
8	14/08/2013	21:58:59	2456519.42	J.Guarro	STAMARIAD							
9	14/08/2013	22:07	2456519.443	OlivierGarde	Observatoi							
10	14/08/2013	22:09:26	2456519.427	J.Guarro	STAMARIAD							
11	14/08/2013	22:15	2456519.449	OlivierThizy	Revel38							
12	14/08/2013	22:19:50	2456519.434	J.Guarro	STAMARIAD							
13	14/08/2013	22:40:24		P.J.H.Gerlach	Houten,The							
14	14/08/2013	22:54:54	2456519.458	J.Guarro	STAMARIAD							
15	14/08/2013	22:59:49	2456519.474	TdeFrance	MEZI							
16	14/08/2013	23:06:27	2456519.466	J.Guarro	STAMARIAD							
17	14/08/2013	23:07	2456519.485	OlivierGarde	Observatoiredela	C14-Eshel-ATIK460EX	10000	4185 - 7318	3683	novadel2013_20130814_964_full.fit	zip4	v
18	14/08/2013	23:15:12	2456519.472	J.Guarro	STAMARIADEMONTM	A16REMOTATIK460EX	755	3715 - 7431	528	novadel2013_20130814_969_J.Guarro.fit		v
19	14/08/2013	23:24:02	2456519.479	J.GUARRO	STAMARIADEMONTM	A16REMOTATIK460EX	755	3715 - 7431	688	novadel2013_20130814_975_J.Guarro.fit		v
20	14/08/2013	23:40:22	2456519.489	J.GUARRO	STAMARIADEMONTM	A16REMOTATIK460EX	772	3715 - 7431	421	novadel2013_20130814_986_J.GUARRO.fit		v
21	14/08/2013	23:45:07	2456519.507	TdeFrance	MEZE	C9.25LISAATIKTITA	614	4868 - 6798	2959.001	novadel2013_20130814_4897_TdeFrance.fit		v
22	14/08/2013	23:49	2456519.514	OlivierThizy	Revel38420	TV85Alpy600Atik460E	607	3676 - 7350	3695	novadel2013_20130814_993.fit		v
23	15/08/2013	00:02:34	2456519.504	J.GUARRO	STAMARIADEMONTM	A16REMOTATIK460EX	741	3715 - 7431	423	novadel2013_20130815_002_J.GUARRO.fit		v
24	15/08/2013	0:09	2456519.527	OlivierGarde	Observatoiredela	C14-Eshel-ATIK460EX	10000	4266 - 7318	3624	novadel2013_20130815_006_full.fit	zip5	v
25	15/08/2013	00:09:40	2456519.509	J.GUARRO	STAMARIADEMONTM	A16REMOTATIK460EX	772	3715 - 7431	422	novadel2013_20130815_007_J.GUARRO.fit		v
26	15/08/2013	00:16:45	2456519.514	J.GUARRO	STAMARIADEMONTM	A16REMOTATIK460EX	769	3715 - 7431	426	novadel2013_20130815_012_J.GUARRO.fit		v
27	15/08/2013	00:23:54	2456519.519	J.GUARRO	STAMARIADEMONTM	A16REMOTATIK460EX	734	3715 - 7431	421	novadel2013_20130815_017_J.GUARRO.fit		v

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

Photometry or Spectroscopy?

⇒ **BOTH ARE IMPORTANT AND COMPLEMENTARY !!!**

Source:ARAS

Photometry or Spectroscopy?

Source:ARAS

Spectro-Photometry: special slit

HD180163

Source:C. Buil

Absolute spectrophotometry #1

Source:C. Buil

Absolute spectrophotometry #2

Source: F. Teyssier

Absolute spectrophotometry #2

Source: F. Teyssier

Absolute spectrophotometry #2

Source: F. Teyssier

Absolute spectrophotometry #2

Source: F. Teyssier

The Sky is our Playground

...or how it is FUN to contribute
with more professionnal astronomers !

Pulsating stars: RR Lyrae

BVR photometry

RR Lyr

Spectres: C. Buil

Pulsating stars: RR Lyrae

Halpha and Ca K lines equivalent width in Angstroms

Photospheric temperature (K)

Halpha equivalent width vs Temperature diagram

Spectres: C. Buil

Pulsating stars: RR Lyrae

Spectres: O. Thizy (LISA) / Olivier Garde (eShel)

Pulsating stars: quest for higher resolution

Christian Buil
Valérie Desnoux
Michel Pujol
Olivier Thizy

R Cyg: S type, near maximum

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

Symbiotic star: CH Cyg

- Red Giant + white dwarf
- Mass transfer

another Symbiotic star: BF Cyg

VV Cep – a zeta Aur type star

Source: Ernst Pollmann / Phil Bennett

20.3 years period !
Next eclipse: 2016-2018
(eclipse lasts for 1000 days)
(totality ~300-500 days)

VV Cep – a zeta Aur type star

Source: Ernst Pollmann

Microquasars

Spectre: Christian Buil / Dessin: wikipedia

The future: robotic observations!

Spectre: T. Lemoult

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The future: robotic observations!

Spectre: T. Lemoult

Conclusions

Spectroscopy is FUN to learn from the stars:

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

Spectroscopy is also FUN
***for variable stars** study*

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

Schéma : Bengt Gustafsson

Shelyak
INSTRUMENTS
Merci ...
http://www.shelyak.com/