Slit spectroscopy of variable stars
through the eyes of an Alpy 600 spectrograph

Olivier THIZY
BAV meeting
Hartha, 9 May 2015
Agenda

- How does a slit spectroscope work?
- Kirchhoff's law through Albireo example
- P Cygni: Doppler Fizeau effect
- Nova Del 2013: Spectro-photometry, pro/am
- Pulsating stars: quest for higher resolution
- Some other variable stars
- Conclusions
Inside the Alpy 600 spectroscope

- Source
- Slit
- Collimator lens
- Disperser (prism or grating)
- Objective lens
- Sensor
Importance of the slit

3mm slit (hole)

300µm slit

25µm slit
Cat's eye nebula / no slit Vs slit

R=100, without slit

R=1000, 23µm slit

R=17000, slit

© Torsten Hansen, Robin Leadbeater, O. Thizy
Mirror slit: critical in astronomy

- Centering
- (auto)Guiding

© C. Buil, O. Thizy
The Alpy 600 system on a scope

A spectrum is an image that can be also displayed as a spectral profile.
Kirchhoff's law's through Albireo
Perfect exemple of Kirchhoff's law...
1: overall profile --> Temp.

- 4000K
- Wikipedia: 4080K

- 13000K
- Wikipedia: 13200K

Analyse: VisualSpec; photo Aliréo: Eric Coustal
2: stellar atmosphere

Hydrogen lines
Spectral classification

68 Cyg
O5V

lam Cyg
B5V

40 Cyg
A3V

the Cyg
F4V

zet Cyg
G8II

61 Cyg
K5V

19 Cyg
M2IIIa

Oh, Be A Fine Girl/Guy... Kiss Me!
Absorption lines physics

Exemple for the hydrogen atom

\[ \Delta E = |E_n - E_m| = h\nu = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{\Delta E} \]
Temperature Vs line strength

40 Cyg
A3V
toward cooler effective temperature

the Cyg
F4V

19 Cyg
M2IIIa

ex: calcium 'Ca II'
hydrogène

O B A F G K M type spectral
toward cooler effective temperature
Luminosity class

Alp Cyg (A2I)

40 Cyg (A3V)
Hertzsprung-Russell diagram
3: emission lines

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

Emission lines physics

Exemple for the hydrogen atom

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

Sources: [http://culturesciencesphysique.ens-lyon.fr/ressource/Quantique.xml](http://culturesciencesphysique.ens-lyon.fr/ressource/Quantique.xml) & [http://e.m.c.2.free.fr/niveaux-energie-hydrogene-emission-absorption.htm](http://e.m.c.2.free.fr/niveaux-energie-hydrogene-emission-absorption.htm)
(1) Overall profile = effective Planck temperature
(2) Energy absorption (photons) = stellar atmosphere
(3) Energy emitted = circumstellar disk

...thanks Mr Kirchhoff!
Where is Charly?
...or how the Doppler-Fizeau effect is important...
...and why photometry & spectroscopy are complementary...
...and why high resolution is fun...
P Cygni Luminous Blue Variable

Hα
He I
Hγ
Hβ

1 mag!
Doppler – Fizeau effect

Universe expansion = red shift

\[
\frac{\Delta \lambda}{\lambda} = \frac{v}{c}
\]
P Cygni profile / Doppler effect

- Étoile
- A: gas emission
- B: gas absorption
- \( v \sim c \frac{\lambda_A - \lambda_B}{\lambda_B} \)
Wolf Rayet stars

WR 136

WR 140

WC7p+O5

WN6h
Wolf Rayet – massive stars evolution
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

Source: Google Map / O. Thizy
Photometry or Spectroscopy?

1. The fire ball and optically thick phase
   from 14-08 to 22-08-2013

2. The first decline – part I
   from 28-09 to 10-09 2013

⇒ BOTH ARE IMPORTANT AND COMPLEMENTARY !!!
Photometry or Spectroscopy?

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

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

Source: ARAS
Spectro-Photometry: special slit

HD180163

Source: C. Buil
Absolute spectrophotometry #1

Spectra required: target + reference / narrow + large slit

Source: C. Buil
Absolute spectrophotometry #2

Source: F. Teyssier
Absolute spectrophotometry #2

Nova Del 2013

Weighted intensity vs. wavelength (Å)

~V mag
Absolute spectrophotometry #2

Nova Del 2013

Source: F. Teyssier
Pulsating stars: RR Lyrae

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

RR Lyr

RR Lyr - 7-8 July 2013 - C9 + Alpy 600 spectrograph (photometric mode)
Pulsating stars: RR Lyrae

Graphs showing:
- Equivalent width (Å) of Hα and Ca K lines in Angstroms
- Photospheric temperature (K) over time
- Hα equivalent width vs temperature diagram
Pulsating stars: RR Lyrae

RR Lyr

Spectres: O. Thizy (LISA) / Olivier Garde (eShel)
Pulsating stars: quest for higher resolution

BW Vul

He I 5678

Christian Buil
Valérie Desnoux
Michel Pujol
Olivier Thizy
Where is Charly?

...or how the Universe can be very diverse...
R Cyg: S type, near maximum

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

![Graph showing R Cyg spectrum](image.png)

ZrO (zirconium monoxide)
V460 Cyg: type C6.3

- C6.3 spectral type: Carbon stars
- Teff ~3200K
- Measure the C2 bands variations
Symbiotic star: CH Cyg

- Red Giant + white dwarf
- Mass transfer
another Symbiotic star: BF Cyg
Microquasars

SS 433

V ~ 25% c

SS 433

Spectre: Christian Buil / Dessin: wikipedia
The future: robotic observations!

Spectre: T. Lemoult
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Conclusions

Spectroscopy teaches lot of information about stars

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

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

- complementary to photometry
- main tool for professional astronomers
- off-the-shelf equipment & software now available
- more and more amateur are doing spectroscopy

- active Pro/Am community – **Join Us**
Next events?

OHP workshop
13-18 august 2015

Wuppertal seminar
11-13 september 2015
Merci ...

http://www.shelyak.com/