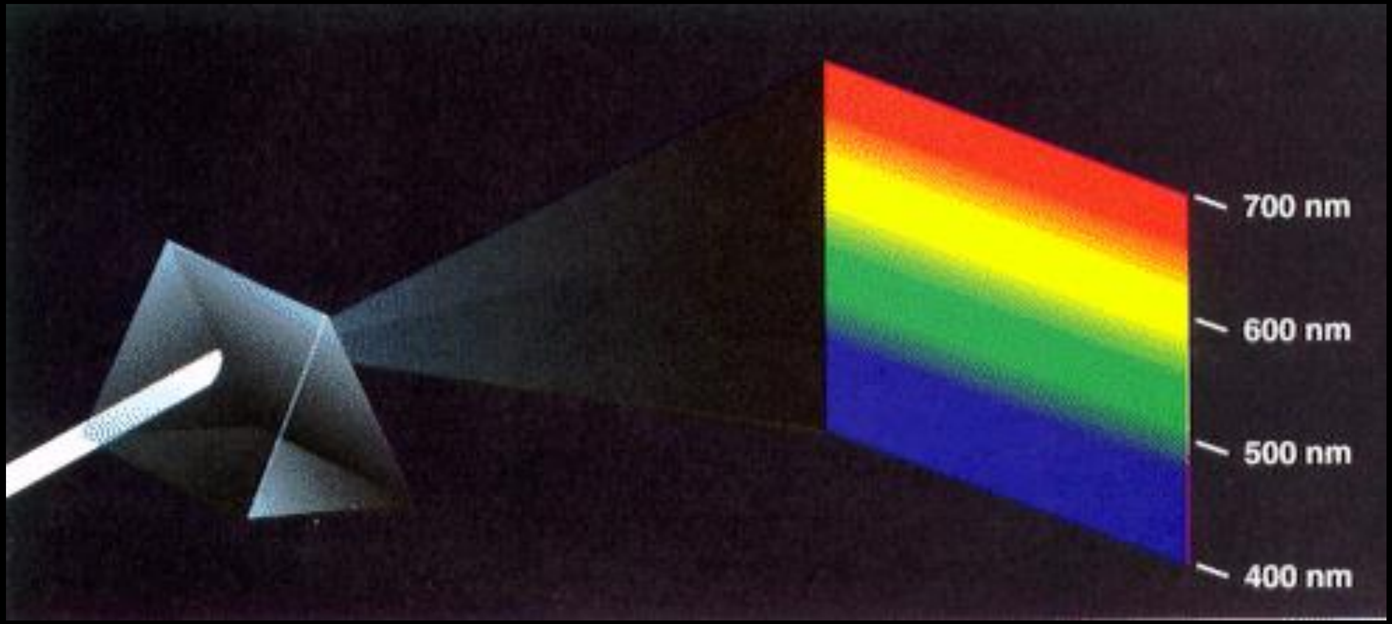
AMATEUR SPECTROSCOPY



Percy Jacobs
Pretoria ASSA Centre

2017

The Agenda

- Spectroscopy
- Equipment
- Planning
- Preparation
- Taking the spectra
- Processing the spectra
- The maths
- Some high resolution & more expensive equipment

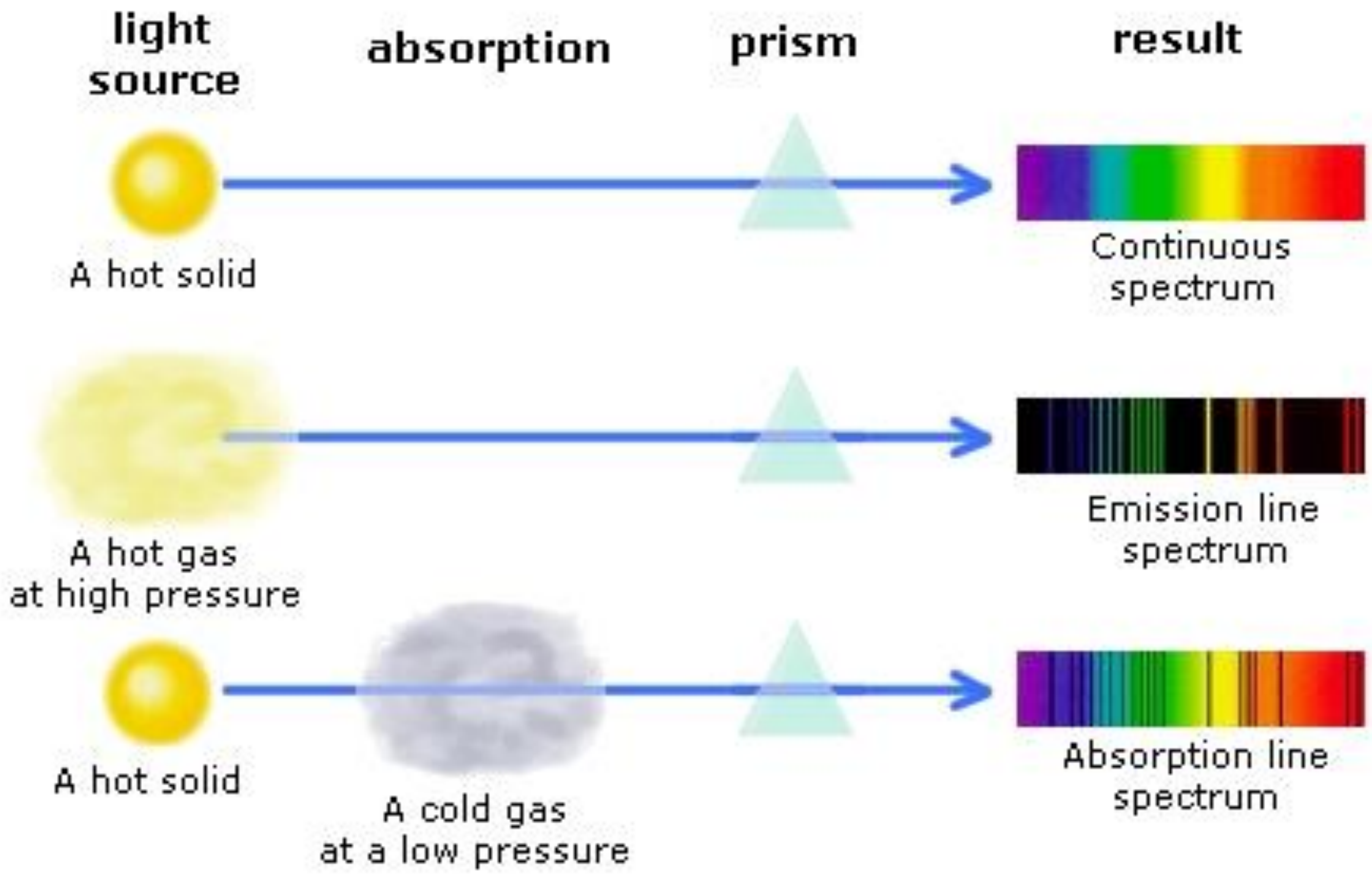
What is spectroscopy?

Spectroscopy is the study of the different wavelengths/frequencies of light we see from an object. It is a measure of the quantity of each colour of light (or more specifically, the amount of each wavelength of light). It is a powerful tool in astronomy. In fact, most of what we know in astronomy is a result of spectroscopy.

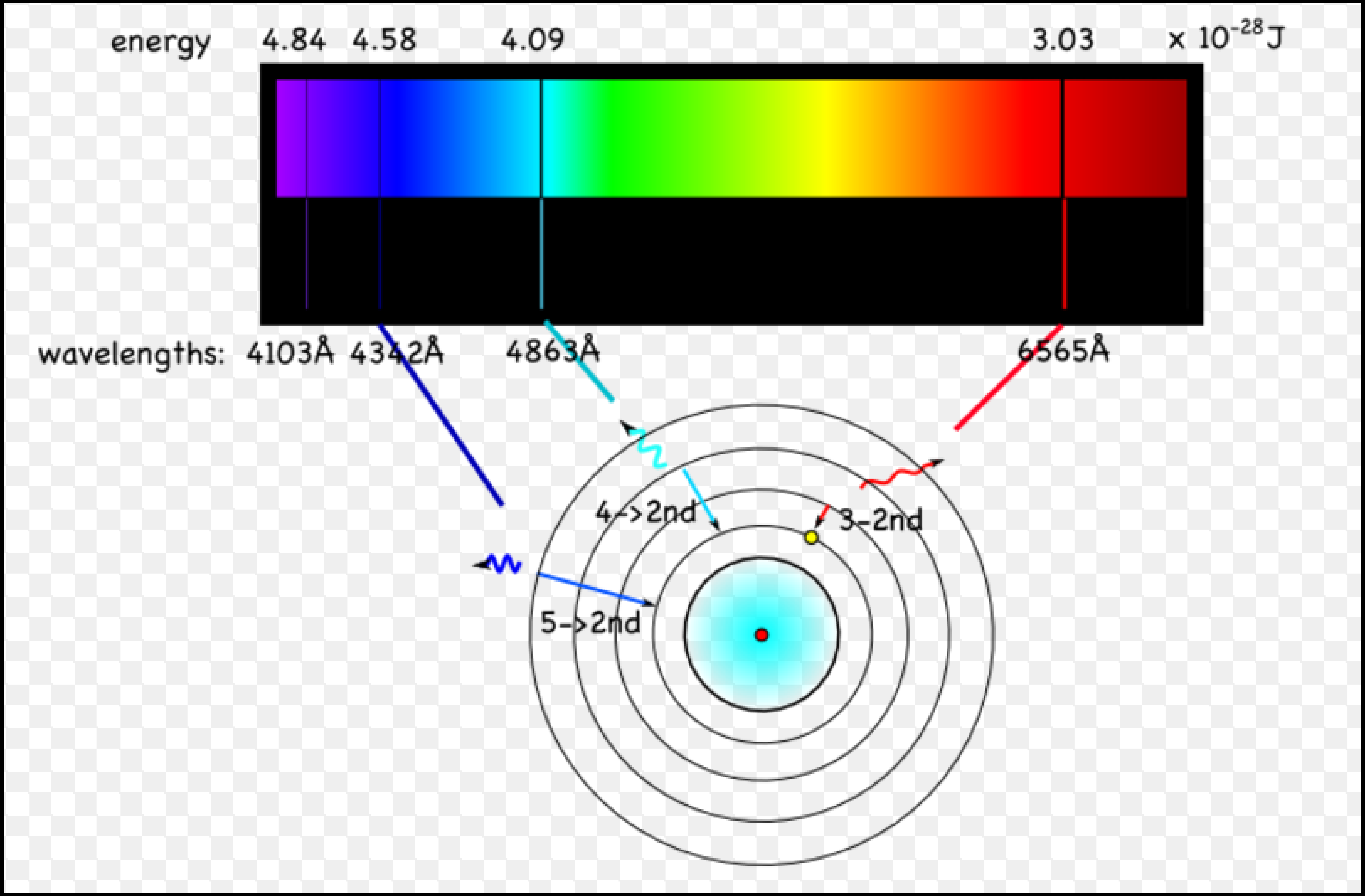
It can reveal;

- Composition of the object (surface conditions),
- Temperature,
- Red or blue shift,
- Speed of shift,
- Distance,
- and more

Spectroscopy is done at all wavelengths of the electromagnetic spectrum, from radio waves to gamma rays; but here we will focus on optical light.


light source
absorption
prism
result
A hot solid
Continuous spectrum
A hot gas at high pressure
Emission line spectrum
A hot solid
A cold gas at a low pressure
Absorption line spectrum


Hδ
410 nm
Hγ
434 nm
Hβ
486 nm
Hα
656 nm


energy 4.84 4.58 4.09 3.03 x 10^-28 J
wavelengths: 4103Å 4342Å 4863Å 6565Å
4->2nd
3-2nd
5->2nd

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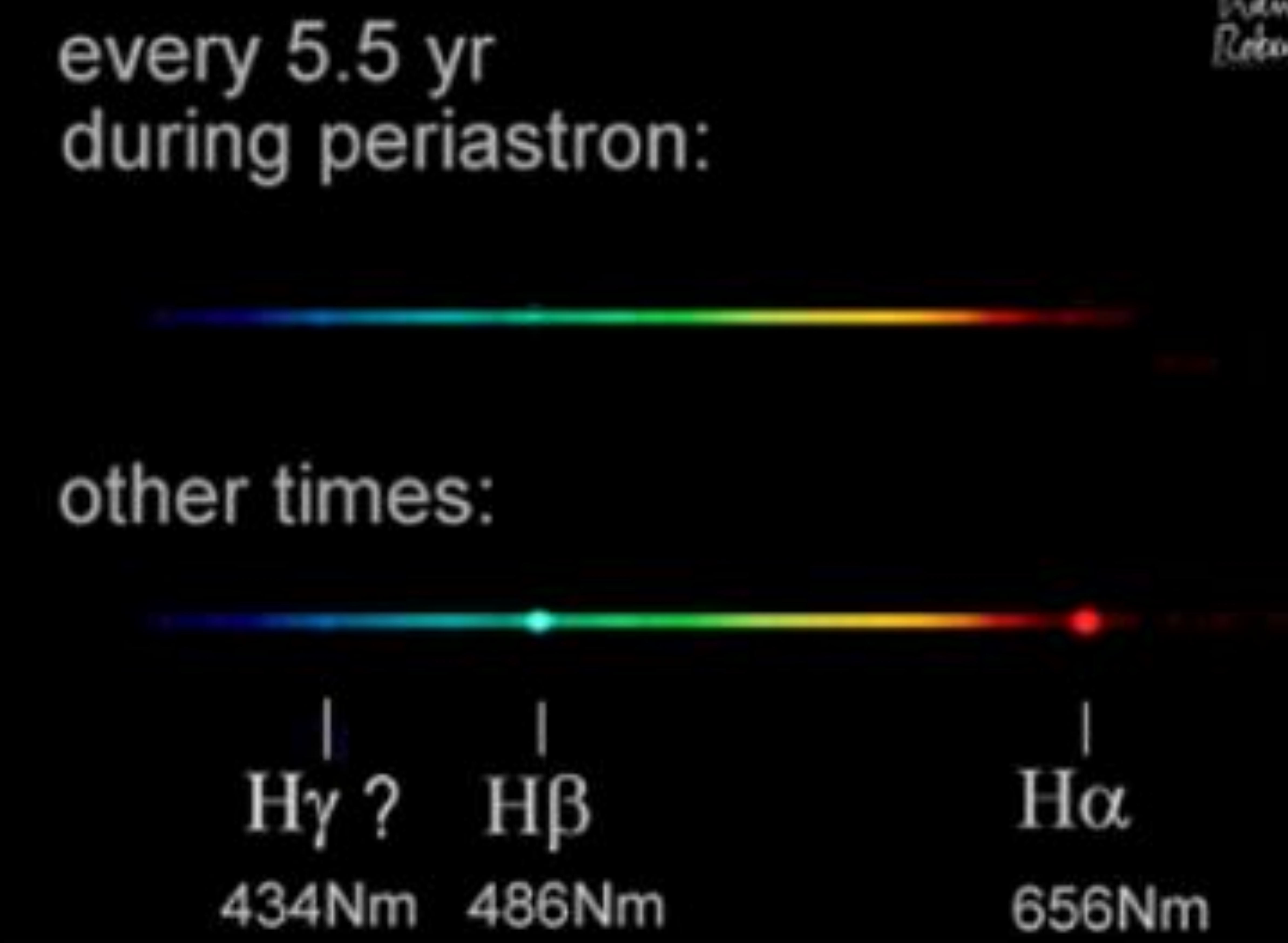
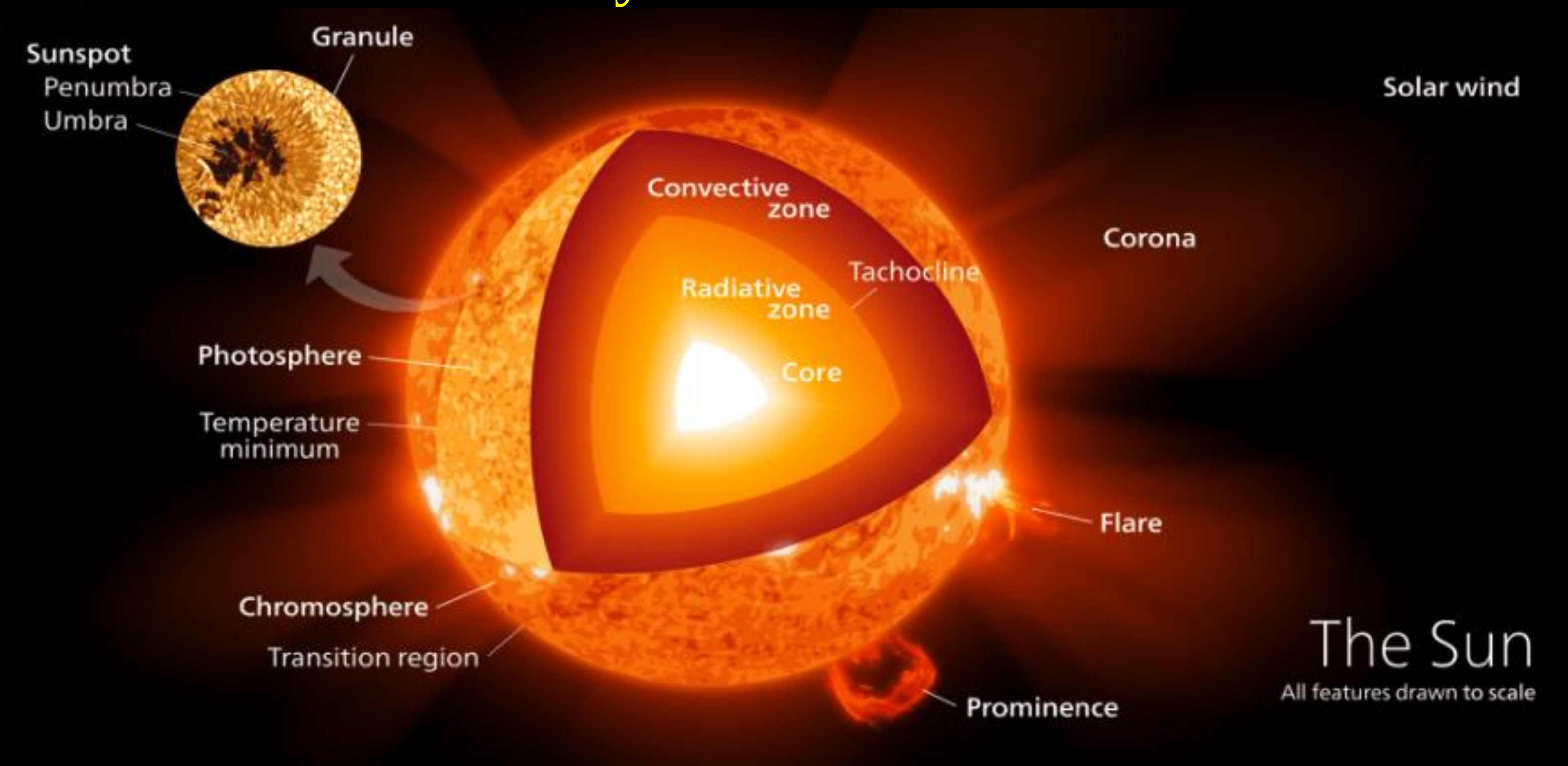

every 5.5 yr
during periastron:
other times:
Hγ ?
Hβ
Hα
434Nm
486Nm
656Nm

NASA Spectrum photo of 21ST Aug 2017 Solar Eclipse

"Flash Spectrum" of the chromosphere during a solar exclipse.

In a flash, the visible spectrum of the Sun changes from absorption to emission during the brief total phase of a solar eclipse. The absorption spectrum of the solar photosphere is hidden. What remains, is the emission spectrum the thin arc of the solar chromosphere.

Hydrogen atoms that produce the red hydrogen alpha emission at the far right and blue hydrogen beta emission to the left. In between, the bright yellow emission image is caused by atoms of Helium.



Equipment

Author's equipment:

6" reflector / Newtonian

Rainbow Optics Transmission Grating (200l/mm),

Canon 650D DSLR,

Tracking equatorial mount

Camera & Mount connected and driven from laptop

Planning

- Are you just taking spectra of the targets, or are you wanting to measure, red or blue shifts, speeds, distances, temperature, etc

- Identify your STD STAR. A star with “strong” Hβ lines. A typical “A” type star

- Make a list of your planned targets – stars, nebula, comets, etc

Preparation

- Fit your grating to the DSLR noise tube. Ensure it is a tight fit. It must not be able to turn loose, at all, through the night, with all the movement on the scope

- Attach camera into focuser

- Take test image spectra on a known std star and setup the focus

- Rotate camera so the spectrum is horizontal in the image with the star on the left hand side of the spectra

- From “pin-point” focus, turn the focuser inwards until the star is now slightly round and defocused and spectrum clearly shows the Hydrogen Beta Line (on the blue side of the spectrum)

- Make sure the spectrum is not over exposed and ensure the complete spectrum is clearly defined and seen. Set your ISO & exposure as needed

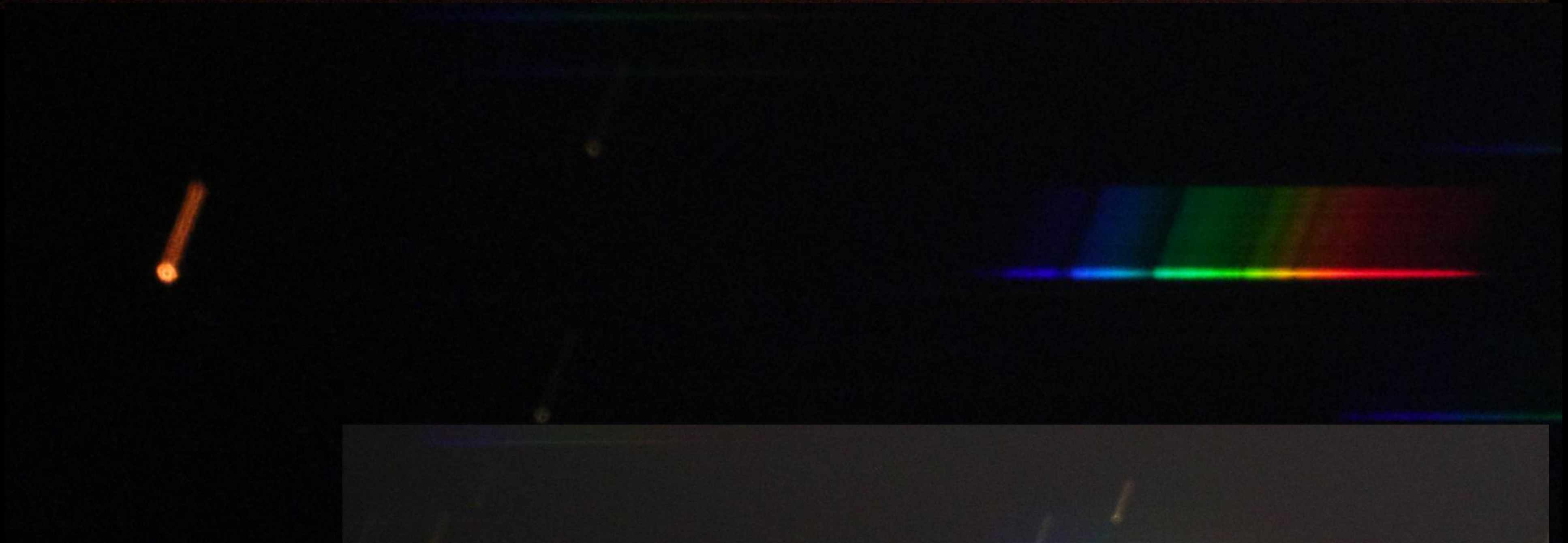
- Once a decent & clear spectrum is seen, do not then ever change the distance of the grating to the ccd chip or the focus. Tighten and lock the focuser

Taking the spectra

Std star
ALTAIR

1st Target
Saturn
Nebula
NGC 7009

2nd Target
Variable
Star T Ind



3rd Target
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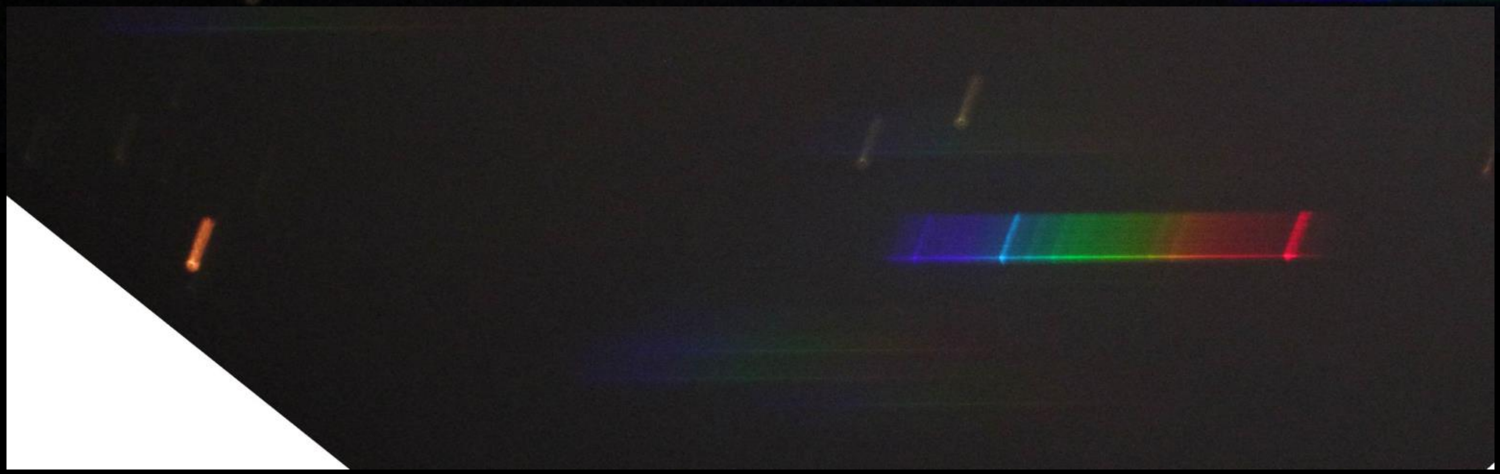
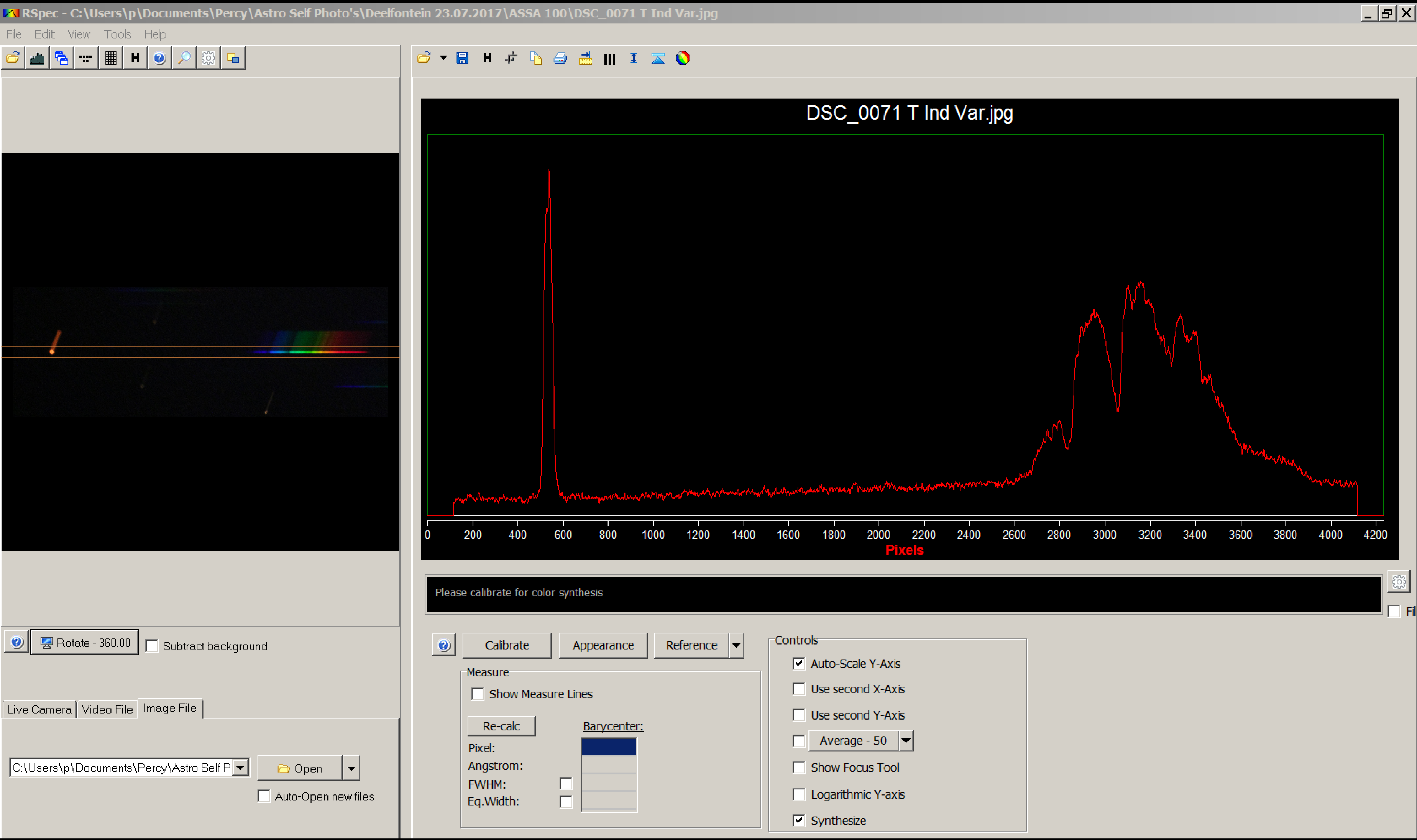


Processing the spectra

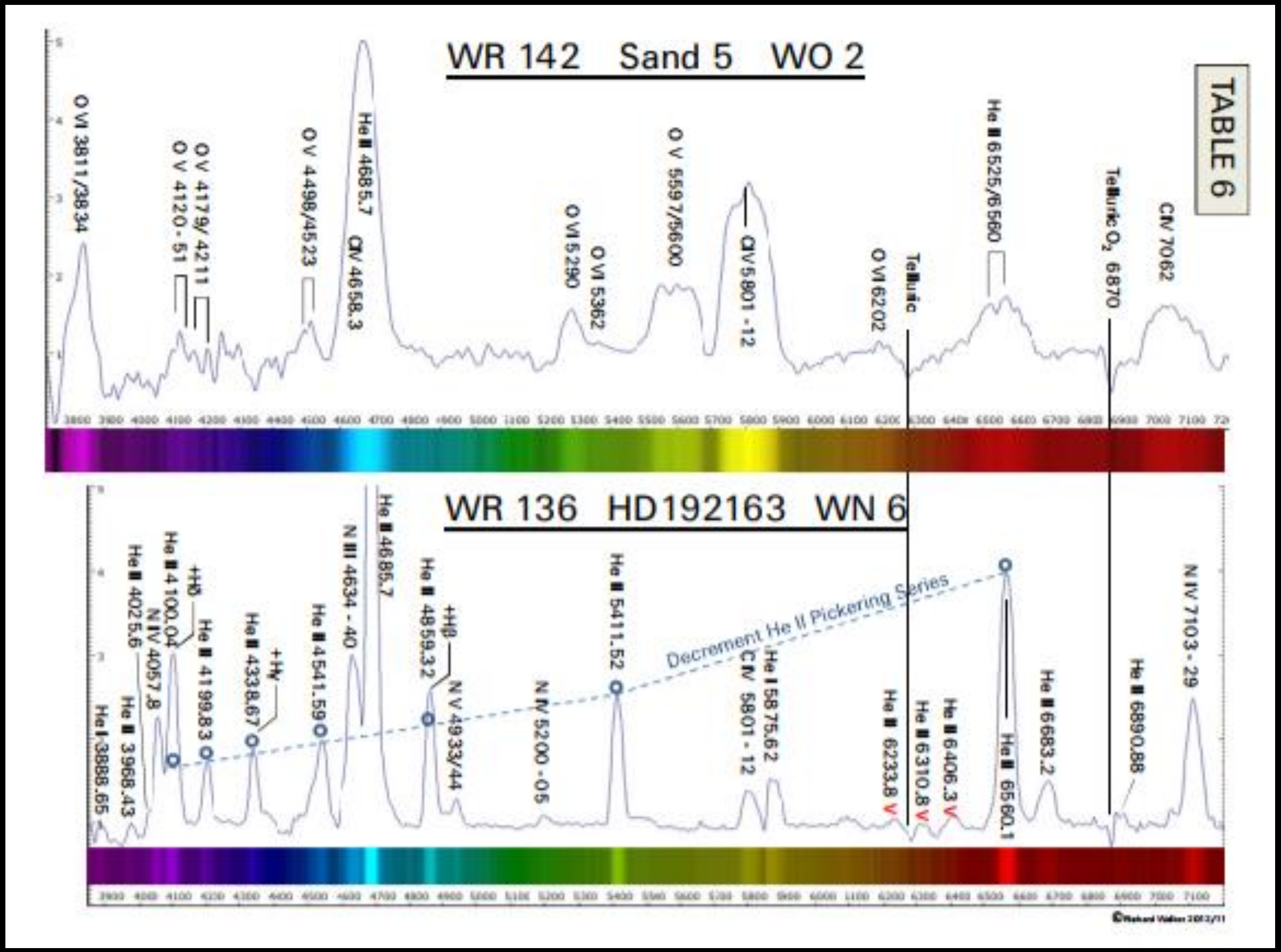

RSpec - C:\Users\p\Documents\Percy\Astro Self Photo's\Deelfontein 23.07.2017\ASSA 100\DSC_0071 T Ind Var.jpg
File
Edit
View
Tools
Help
DSC_0071 T Ind Var.jpg
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
4200
Pixels
Please calibrate for color synthesis
Rotate - 360.00
Subtract background
Calibrate
Appearance
Reference
Controls
Auto-Scale Y-Axis
Use second X-Axis
Use second Y-Axis
Average - 50
Show Focus Tool
Logarithmic Y-axis
Synthesize
Measure
Show Measure Lines
Re-calc
Barycenter:
Pixel:
Angstrom:
FWHM:
Eq.Width:
Live Camera
Video File
Image File
C:\Users\p\Documents\Percy\Astro Self P
Open
Auto-Open new files

Spectroscopic Atlas for Amateur Astronomers

A Spectroscopic Guide
to Astronomical Objects
and Terrestrial Light Sources

Richard Walker

Version 5.0 04/2014



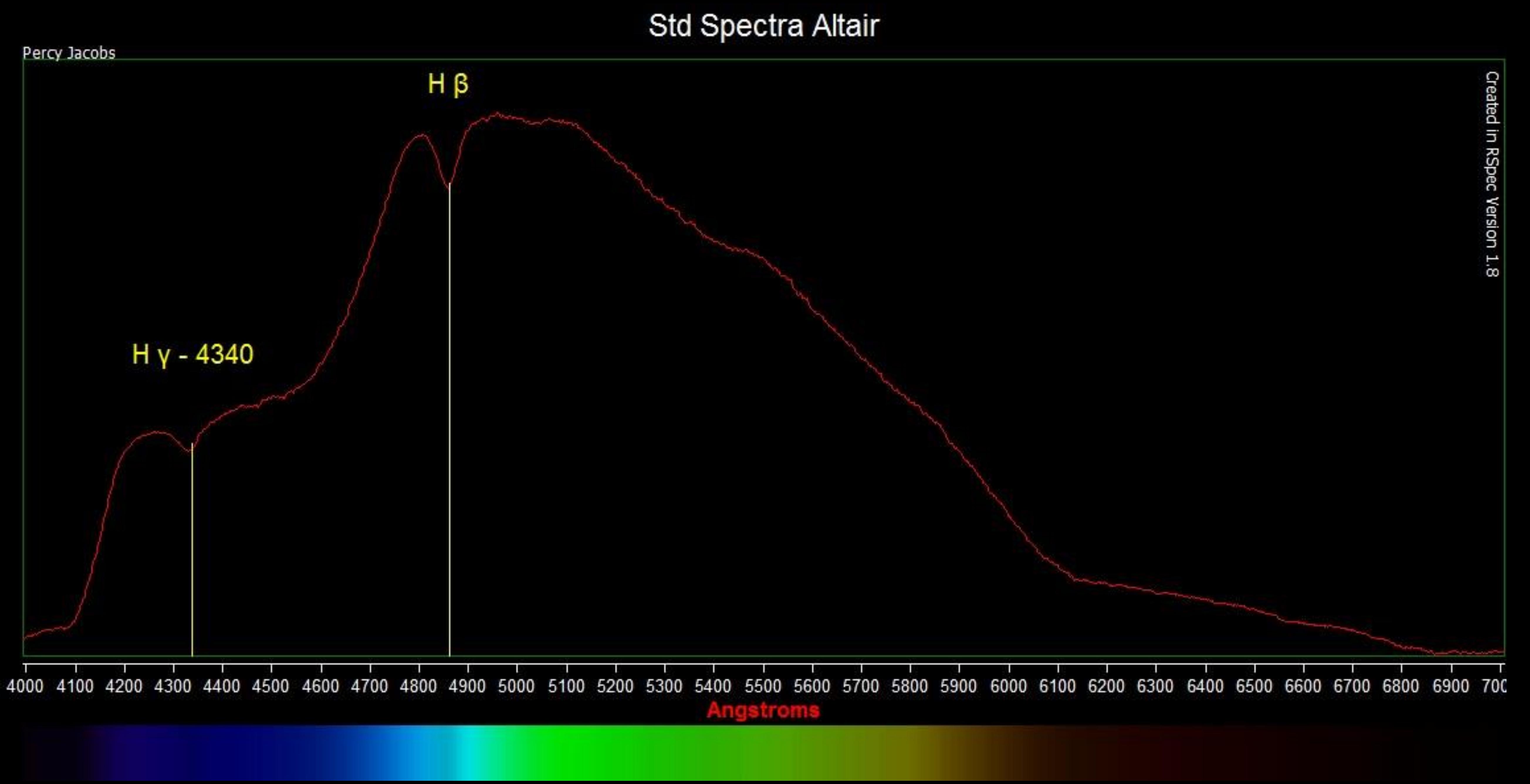
- Use “spectroscopic-atlas-5_0-English” to identify lines seen in the spectrum

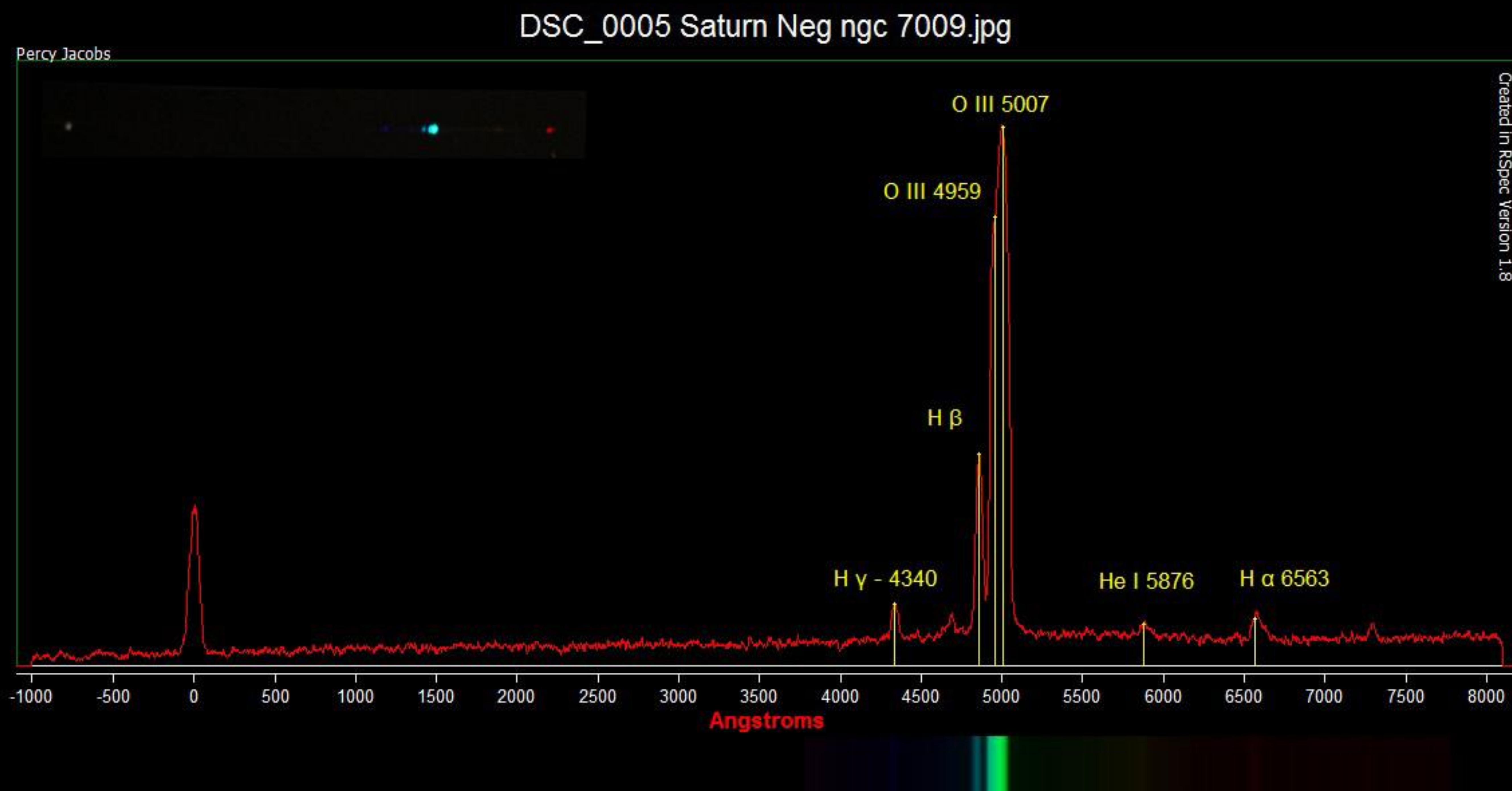
- RSPEC Software
  - Std Star - full calibration on the Hβ line
  - Establish the ratio of Pixel to Angstrom on the std star

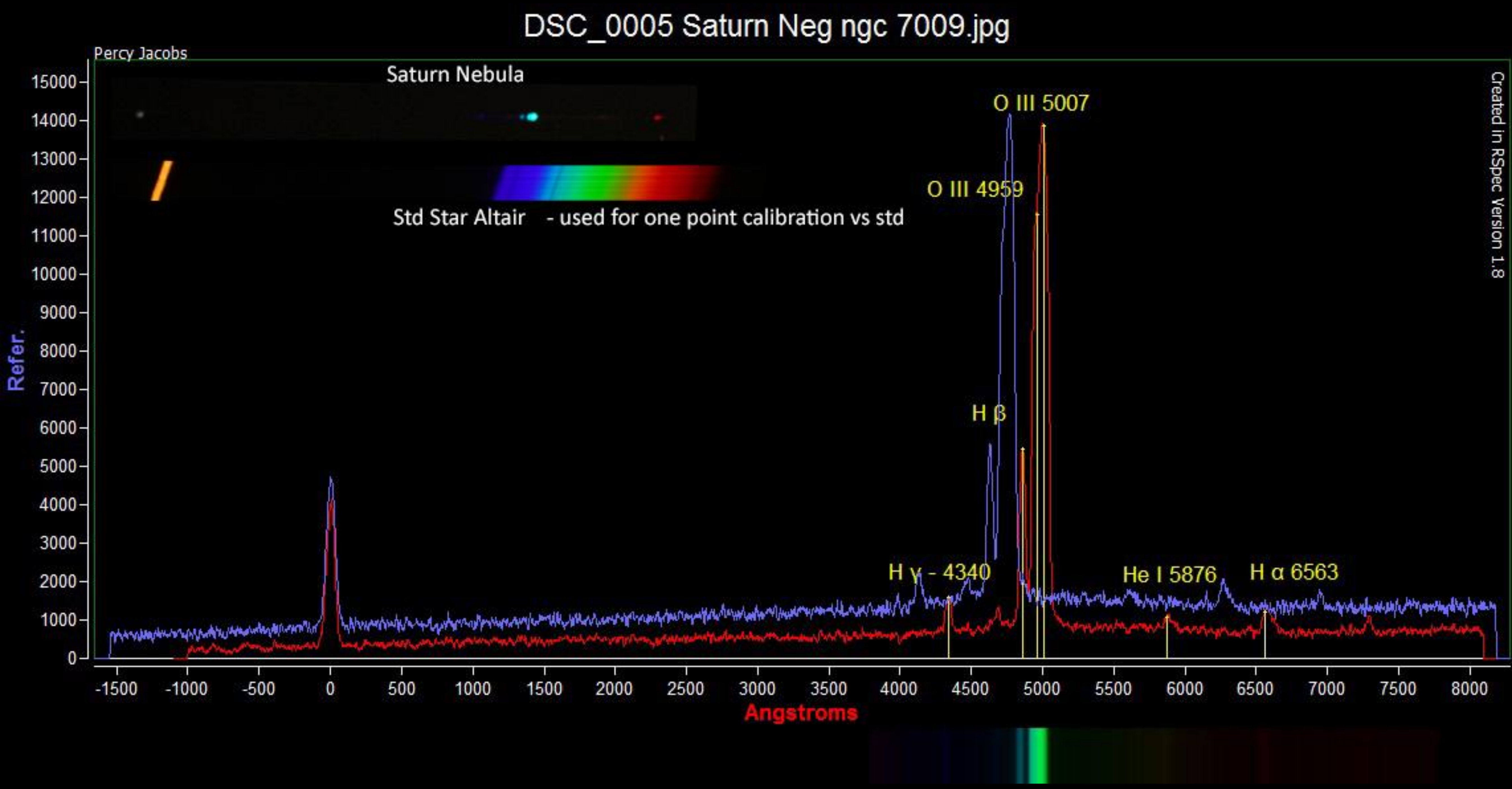
  - Using this pixel to angstrom ratio, now do what we call a “one point” calibration of the 1st target

  - Then, once you have identified one particular feature, such as say Hβ, do a full calibration. Refer to as the “rest wavelength” calibration

  - Now, take the two, and superimpose the two spectrums

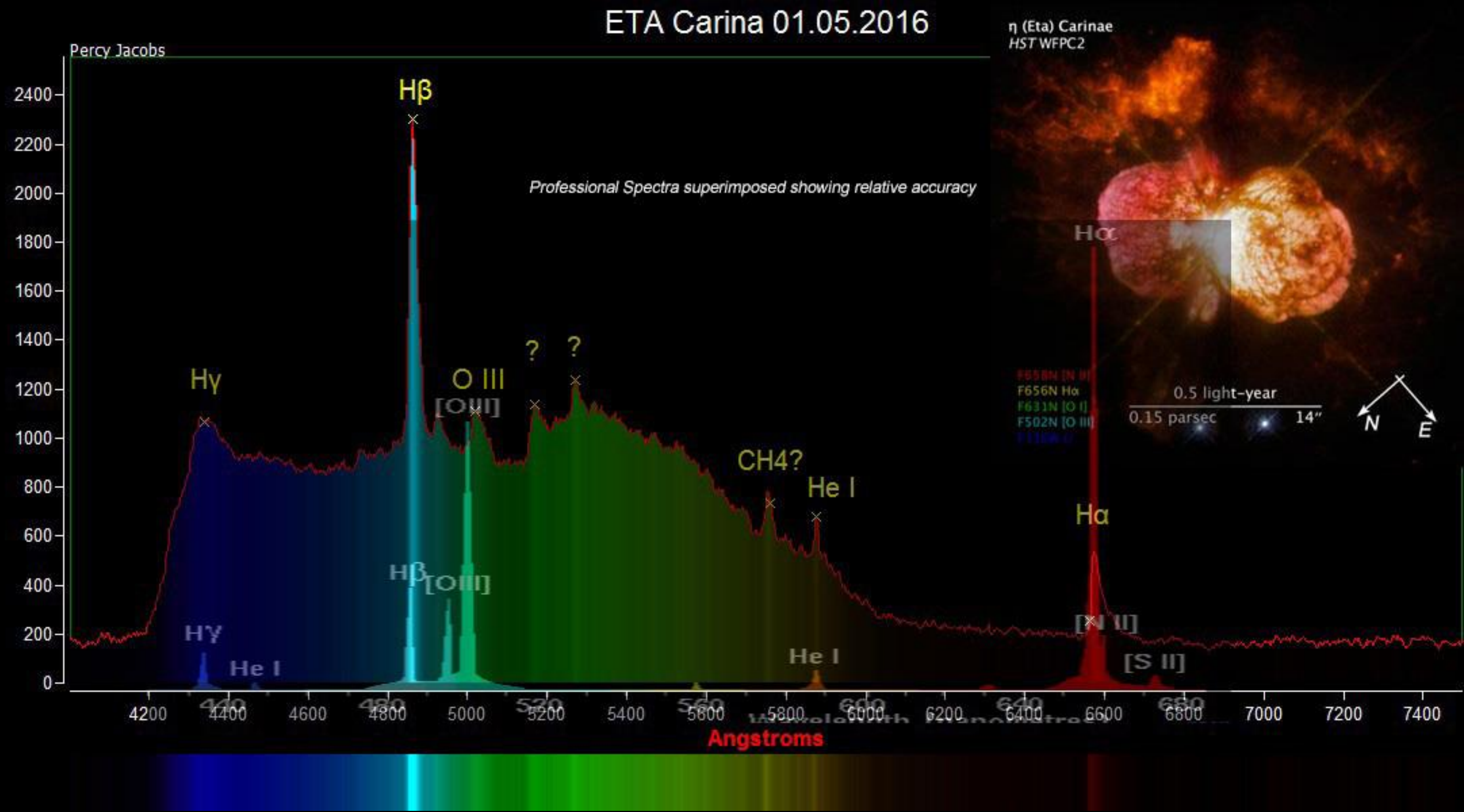

Std Spectra Altair
Percy Jacobs
H β
H γ - 4340
Created in RSpec Version 1.8
4000 4100 4200 4300 4400 4500 4600 4700 4800 4900 5000 5100 5200 5300 5400 5500 5600 5700 5800 5900 6000 6100 6200 6300 6400 6500 6600 6700 6800 6900 700
Angstroms


DSC_0005 Saturn Neg ngc 7009.jpg
Percy Jacobs
Created in RSpec Version 1.8
O III 5007
O III 4959
H β
H γ - 4340
He I 5876
H α 6563
-1000
-500
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
Angstroms



The shift shown is not real and correct for this nebulae – it is exaggerated to show the principle

ETA Carina 01.05.2016



The Maths

Distance

v = Ho d

v = velocity

Ho – Hubbles Constant

d = distance

So, lets say NGC 7009 has a radial velocity of 45km/s towards the Earth. Lets say the "hubble constant" is 70 km/s/Mpc

Therefore,

d = v / Ho

45 x 0.00007 = 0.00315 Mpc (10,200 Ly – Internet says 5,200 Ly)

Doppler Shift

$v = (c \times \Delta \lambda) / \lambda$

• v = velocity of the object, km/s - same units used by "c"

c = speed of light, either 299 792 km/s

• $\Delta \lambda$ = Shift in the wavelength of a feature in the spectra, often measured in Ångstroms, just so the units are the same

• λ = the wavelength the feature should have, often measured in Ångstroms

The $\Delta \lambda$ is the difference or change in the value of the spectral feature from its normal wavelength (λ), and the change could be positive or negative. If it is positive (red shift), the motion is away from you, if it is negative (blue shift) the motion is towards you.

Relativistic formula

$z = \Delta \lambda / \lambda$

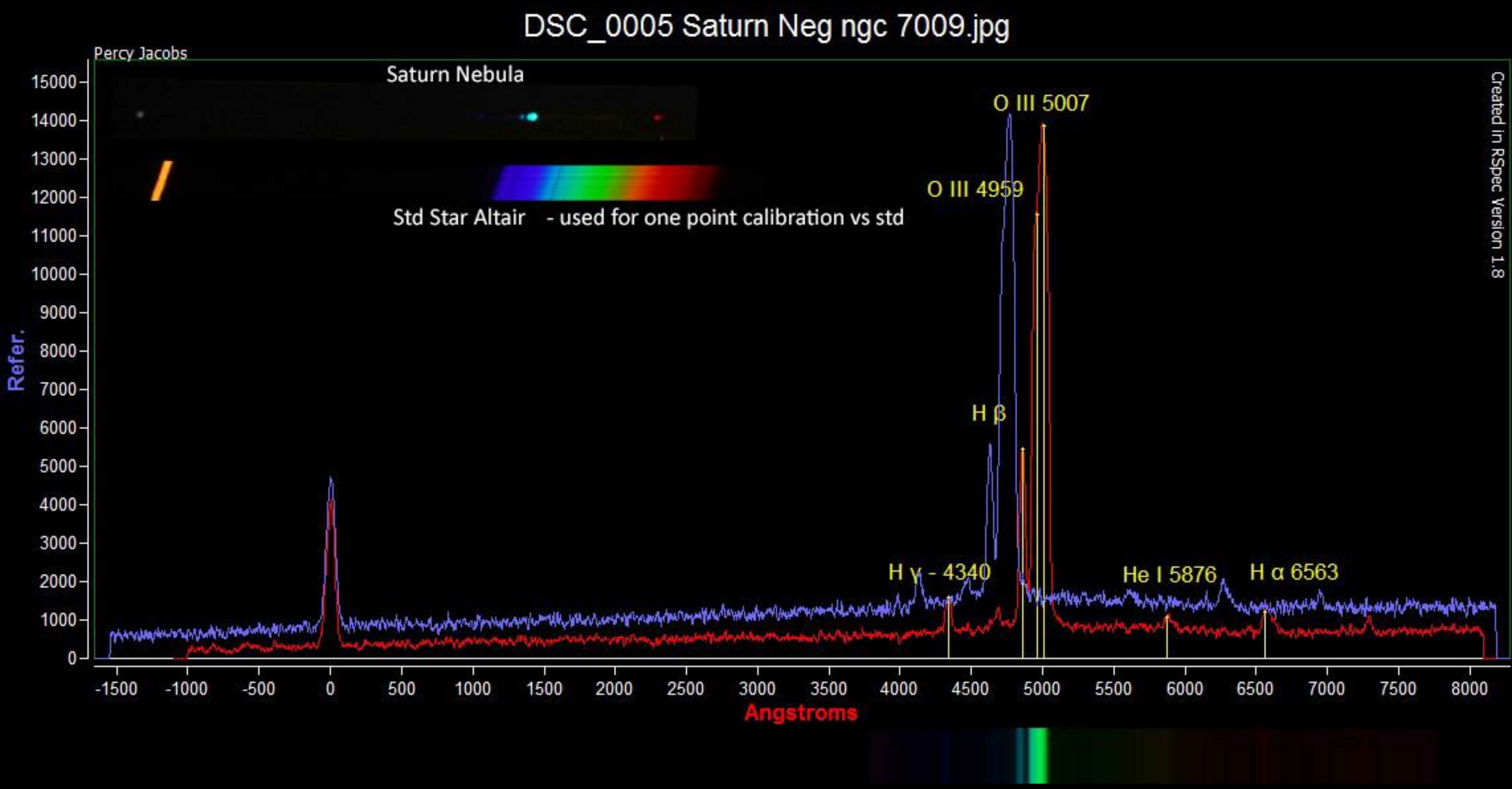
v = [(z+1)2 -1] / [(z+1)2 +1] x 300,000 km/s

Relativistic Redshift - This is used in place of the Doppler formula when the velocities become too large to be accurately represented by the regular Doppler formula, typically any velocities greater than 10% the speed of light.

z = redshift

- $\Delta \lambda$ = Shift in the wavelength of a feature in the spectra, often measured in Ångstroms, just so the units are the same as used for

- λ= the wavelength the feature should have, often measured in Ångstroms



The shift shown is not real and correct for this nebulae – it is exaggerated to show the principle

If we now take my NGC 7009, the absorption feature of Hγ is at a wavelength of 4340 Å, but it is observed at a wavelength of ~4100 Å. What is the redshift?

$\Delta \lambda$ = 4100 – 4340 = -240 Å (negative – blue shift – moving towards us)

Now you can plug the values into the **Relativistic** formula;

$z = \Delta \lambda / \lambda$

z = 240 / 4340

z = 0.055 (<1 & <10% of the speed of light)

So, we can use the Doppler Formula

$v = (c \times \Delta \lambda) / \lambda$

v = (300,000 x 240) / 4340 = 16,590 km/s

(Error? Not so, because it is ~ 45km/s)

If we now take my NGC 7009, the absorption feature of Hγ is at a wavelength of 4340.47 Å, but it is observed at a wavelength of ~4339.67 Å. What is the redshift?

$\Delta \lambda$ = 4339.67 – 4340.47 = -0.8 Å (negative – blue shift – moving towards us)

Now you can plug the values into the **Relativistic** formula;

$z = \Delta \lambda / \lambda$

z = 0.8 / 4340.47

z = 0.00018 (<1 & <10% of the speed of light)

So, we can use the Doppler Formula

$v = (c \times \Delta \lambda) / \lambda$

v = (299,792 x 0.8) / 4340.47 = ~55km/s

An absorption feature of calcium usually has a wavelength of 3934 Å, but it is observed in a distant galaxy to have a wavelength of 8209 Å. What is the redshift?

$\Delta \lambda$ = 8209 - 3934 = 4275 Å.

Since this is a positive value, the object is moving away from us. Now you can plug the values into the formula -

$z = \Delta \lambda / \lambda$

$z = 4275 / 3934$

$z = 1.09$ (close or >10% of the speed of light)

$$v = [(z+1)2 - 1] / [(z+1)2 + 1] \times 300{,}000 \text{ km/s}$$

$$v = [(1.09 + 1)2 - 1] / [(1.09 + 1)2 + 1] \times 300{,}000 \text{ km/s}$$

$$v = [(2.09)2 - 1] / [(2.09)2 + 1] \times 300{,}000 \text{ km/s}$$

$$v = [4.18 - 1] / [4.18 + 1] \times 300{,}000 \text{ km/s}$$

$$v = [3.18] / [5.18] \times 300{,}000 \text{ km/s}$$

$$v = 0.61 \times 300{,}000 \text{ km/s}$$

$$v = 183{,}000 \text{ km/s}$$

Some high resolution & more expensive equipment

So, to get a resolution of R ~600 (10 A°), we need to use a “slit” spectroscope.

Cheapest one on the market, is the Alpy 600 @ ~R24,000

Alpy 600

Spectroscope wide range

PF0035

732.00 € incl VAT

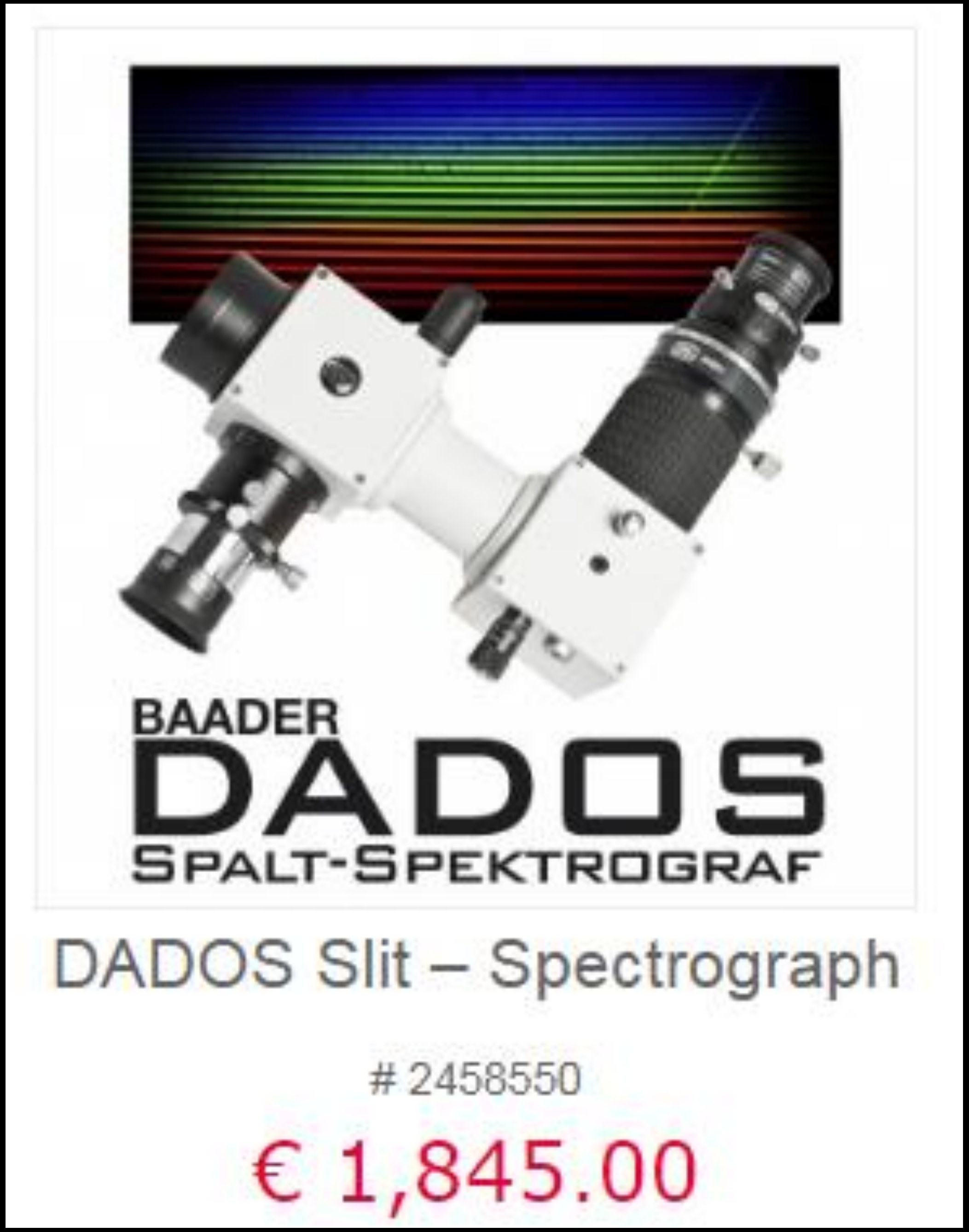
Alpy guiding module

Compulsory on the telescope

PF0036

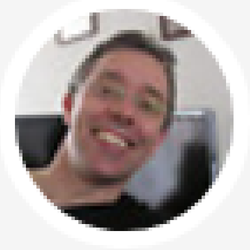
828.00 € incl VAT

Next cheapest on the market, the DADOS, @ ~R30,000



So, to get a resolution of R ~900 or 1,500 (5 to 1 A°), you can build your own "slit" spectroscope for about R10,000 or as low as R5,000. **Very similar to the DADOS design**

Compliments of



Spectrograph / Spectroscope (LOWSPEC)

by PJHGerlach, published Jul 27, 2017

https://www.thingiverse.com/thing:2455390

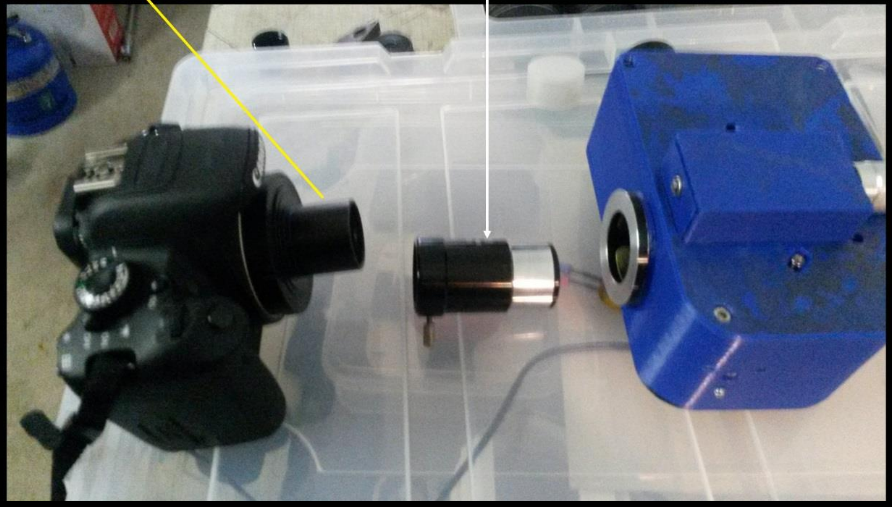
Costs

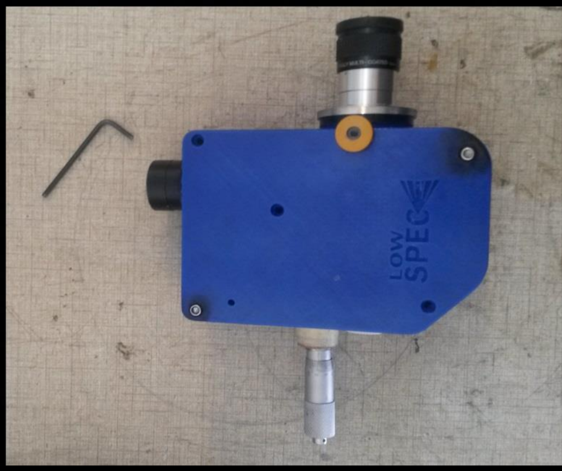
1. 3D Printing
2. Mirrors, lenses, grating
3. Slit
4. Hardware – screws, bolts, etc
5. Courier costs
6. Vat on import

Spectra of std household fluorescent light
Complete spectrum fits onto a Canon 650D ccd chip
Spectroscope has a 600l/mm grating
Adaptions to get this spectra to fit onto the chip - 2x’s barlow lens, achromat lens approx. 80mm,
Setup by Percy Jacobs

Achromat fitted inside camera noise piece - recessed 10mm inside

Barlow lens





THANK YOU