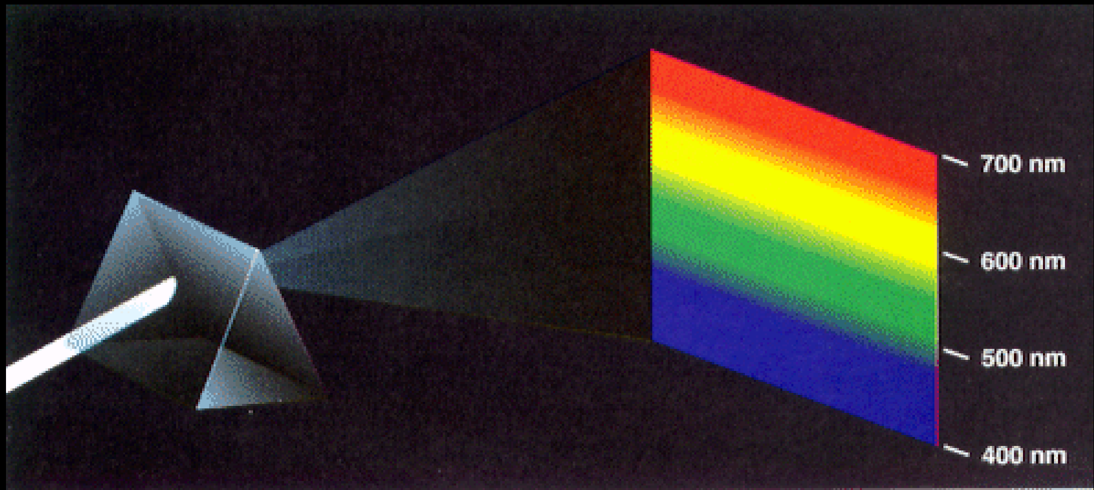
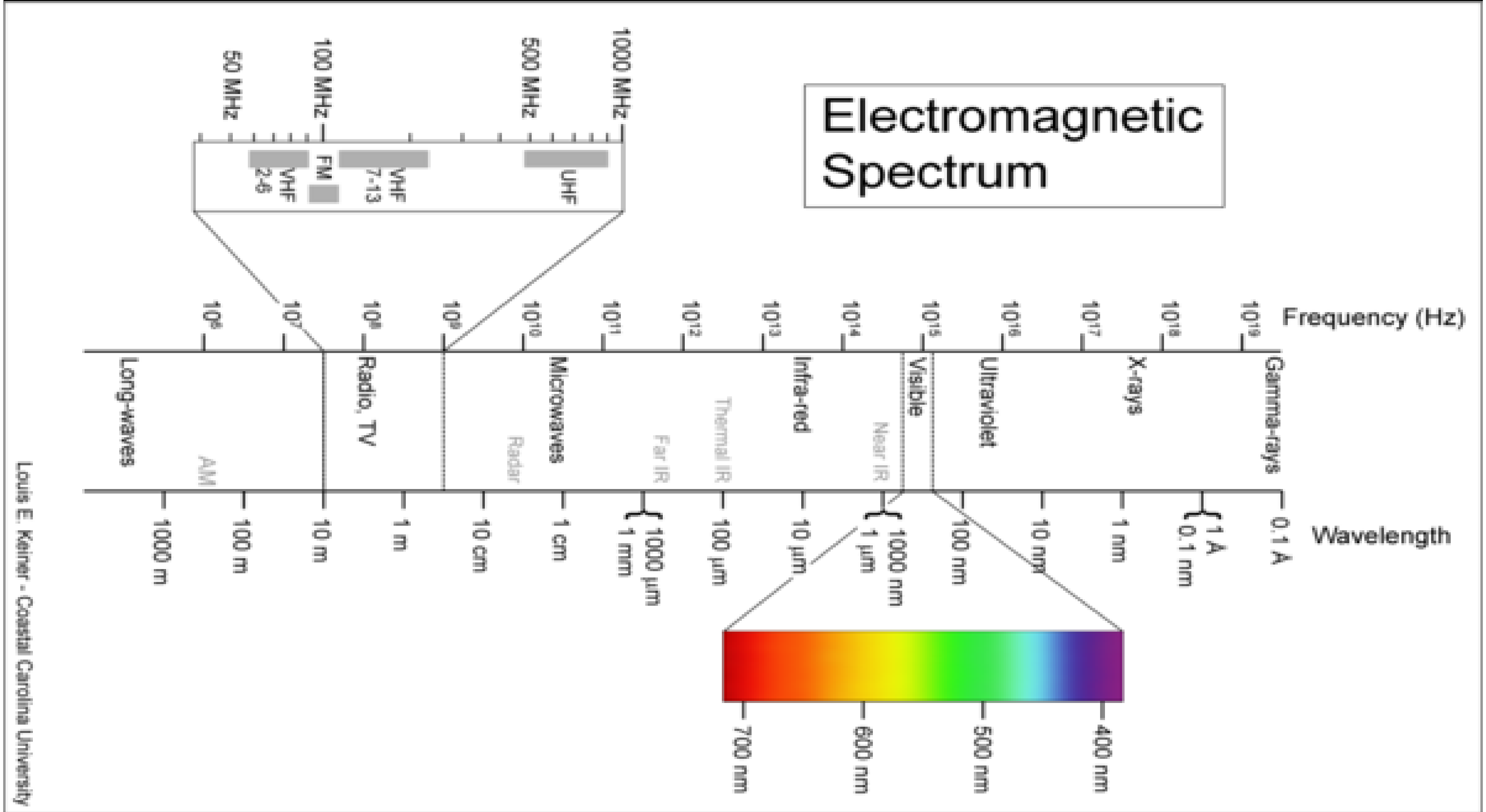
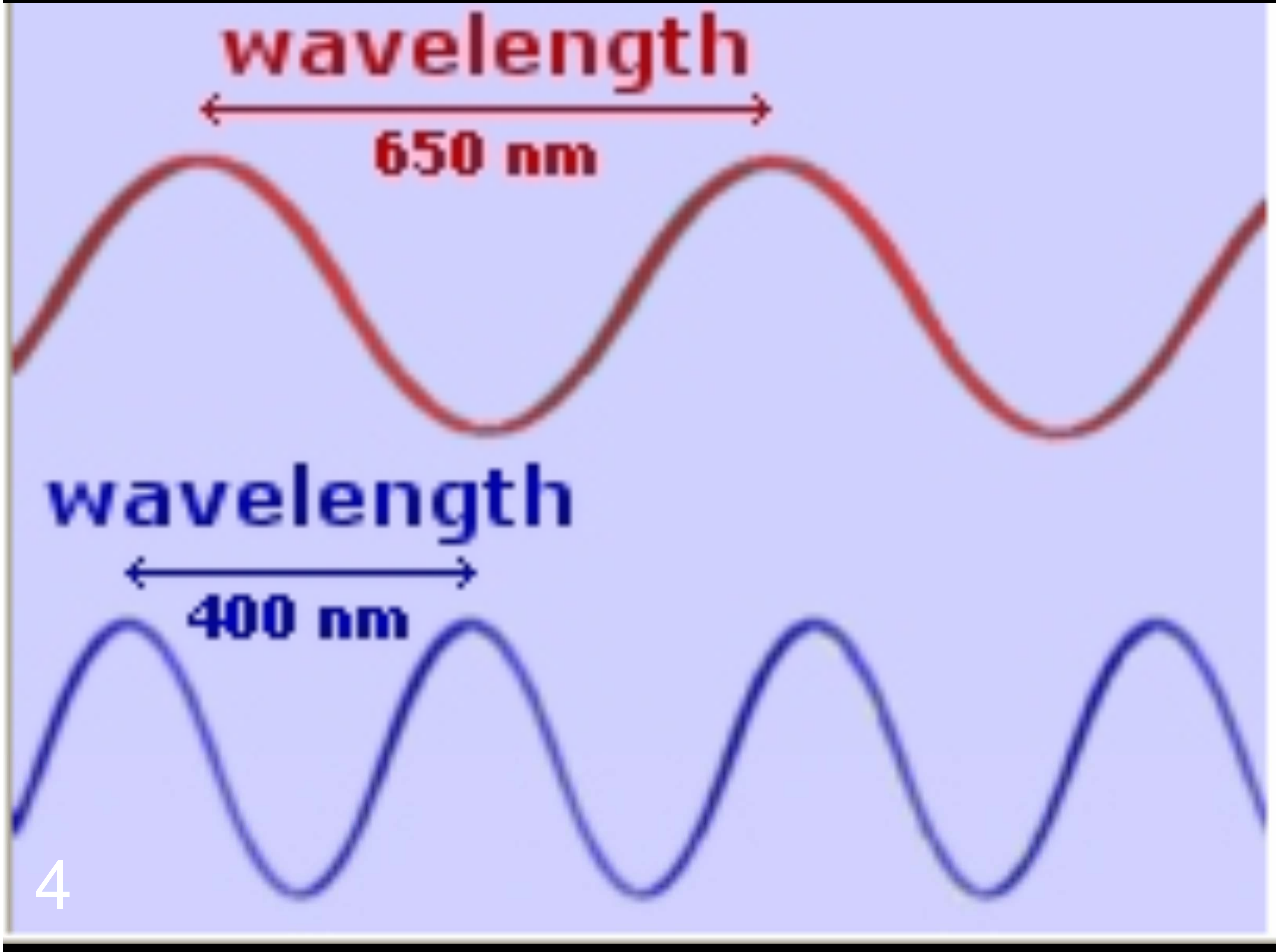
AMATEUR SPECTROSCOPY

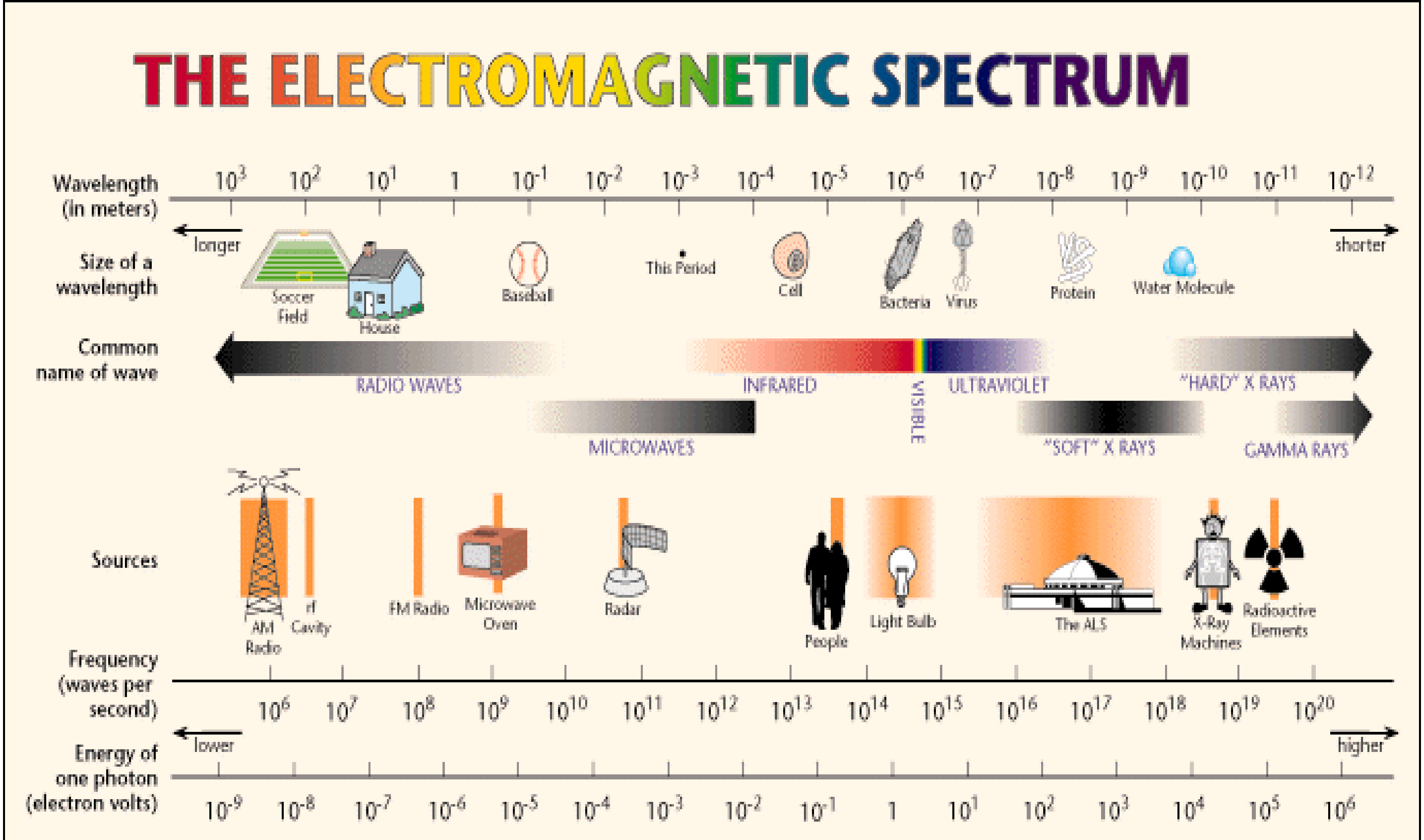


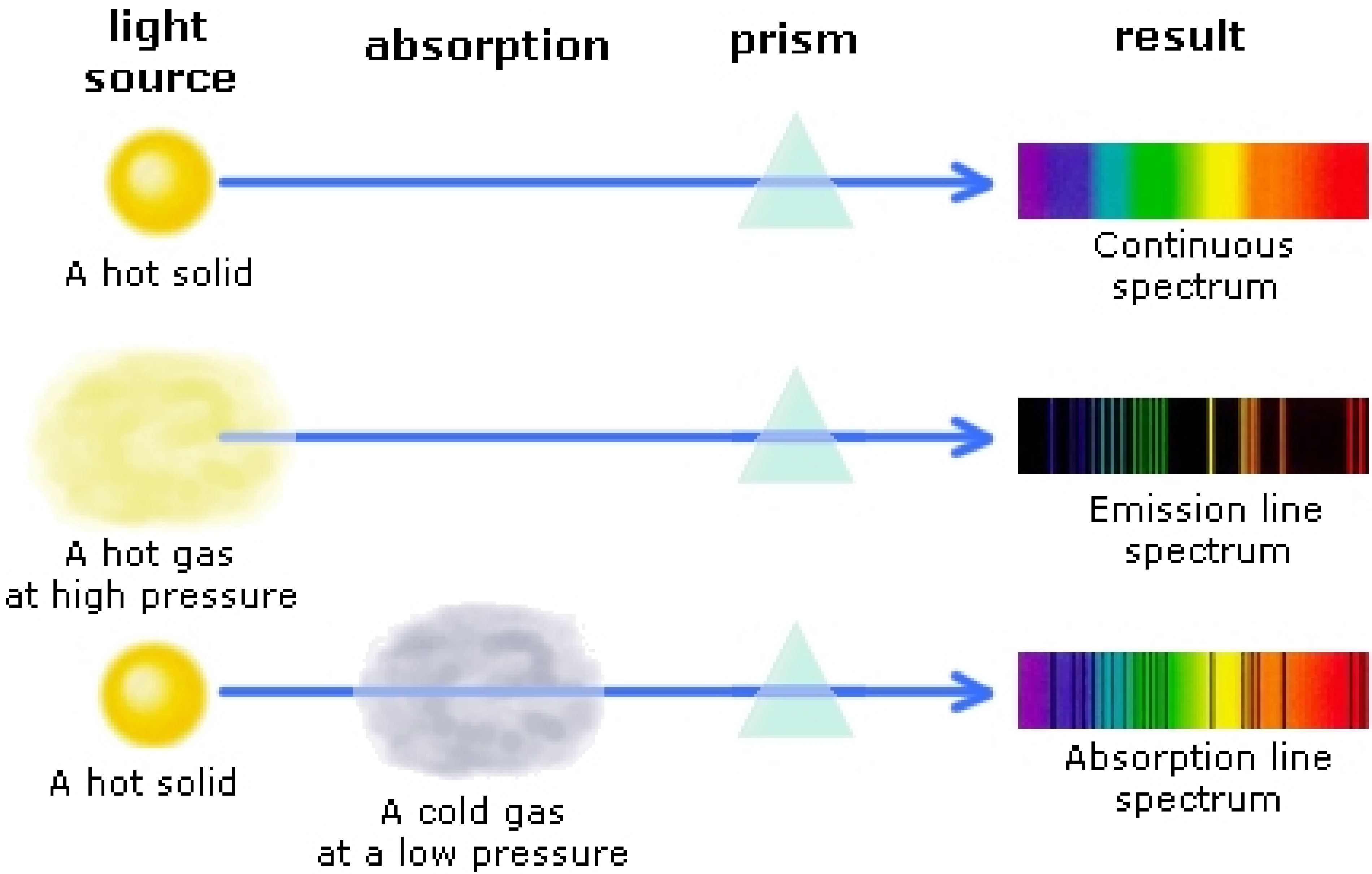
Percy Jacobs
Pretoria ASSA Center
2016

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 the temperature, velocity and composition of an object as well as be used to infer mass, distance and many other pieces of information. Spectroscopy is done at all wavelengths of the electromagnetic spectrum, from radio waves to gamma rays; but here we will focus on optical light.


Electromagnetic Spectrum
50 MHz
100 MHz
500 MHz
1000 MHz
VHF 2-6
FM
VHF 7-13
UHF
Frequency (Hz)
10^{6}
10^{7}
10^{8}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}
10^{15}
10^{16}
10^{17}
10^{18}
10^{19}
Long-waves
AM
Radio, TV
Radar
Microwaves
Far IR
Thermal IR
Infra-red
Near IR
Visible
Ultraviolet
X-rays
Gamma-rays
Wavelength
1000 m
100 m
10 m
1 m
10 cm
1 cm
1000 µm
1 mm
100 µm
10 µm
1000 nm
1 µm
100 nm
10 nm
1 nm
1 Å
0.1 nm
0.1 Å
700 nm
600 nm
500 nm
400 nm
Louis E. Keiner - Coastal Carolina University

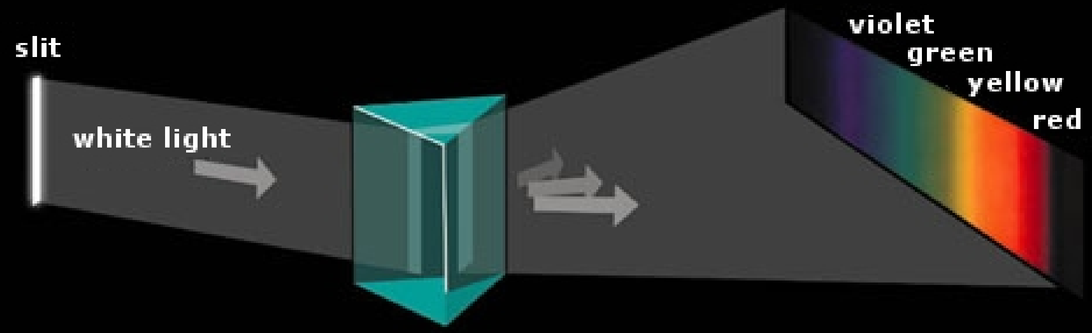

wavelength
650 nm
wavelength
400 nm


THE ELECTROMAGNETIC SPECTRUM
Wavelength (in meters)
10^3 10^2 10^1 1 10^-1 10^-2 10^-3 10^-4 10^-5 10^-6 10^-7 10^-8 10^-9 10^-10 10^-11 10^-12
longer
shorter
Size of a wavelength
Soccer Field
House
Baseball
This Period
Cell
Bacteria
Virus
Protein
Water Molecule
Common name of wave
RADIO WAVES
INFRARED
VISIBLE
ULTRAVIOLET
"HARD" X RAYS
MICROWAVES
"SOFT" X RAYS
GAMMA RAYS
Sources
AM Radio
rf Cavity
FM Radio
Microwave Oven
Radar
People
Light Bulb
The ALS
X-Ray Machines
Radioactive Elements
Frequency (waves per second)
10^6 10^7 10^8 10^9 10^10 10^11 10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19 10^20
lower
higher
Energy of one photon (electron volts)
10^-9 10^-8 10^-7 10^-6 10^-5 10^-4 10^-3 10^-2 10^-1 1 10^1 10^2 10^3 10^4 10^5 10^6


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

Equipment – Visual Spectroscopy

- Prism



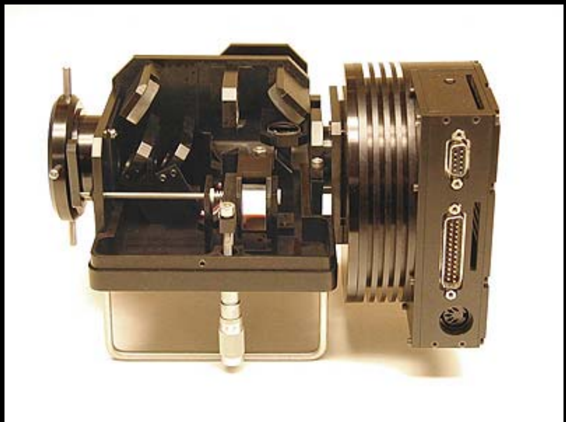
- CD or DVD

- Naked Eye

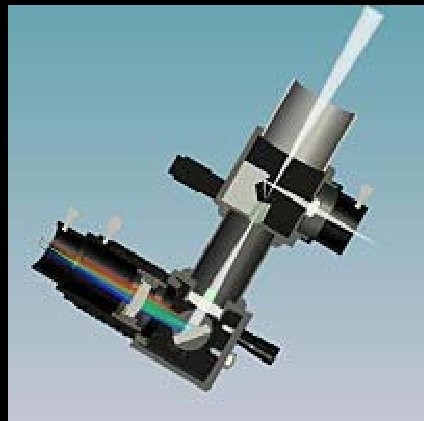
Equipment – Telescopic Spectrographs

More Expensive – R15,000 to R85,000

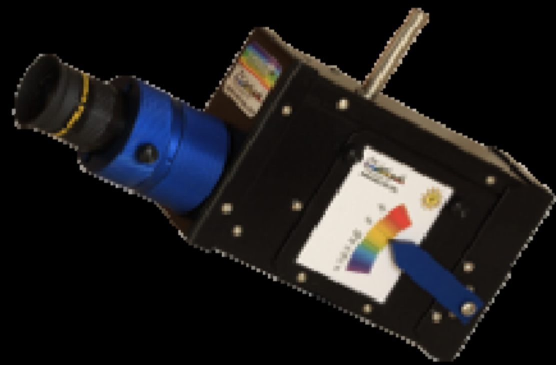
SBIG



Baader DADOS

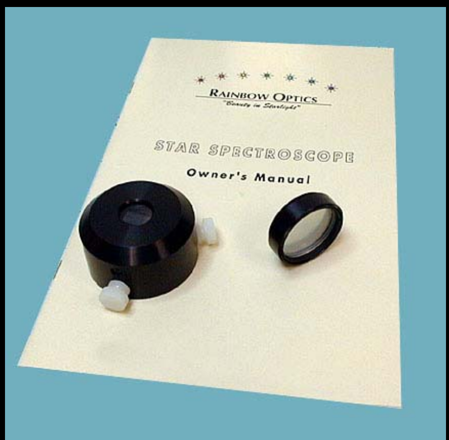


Lhires Lite

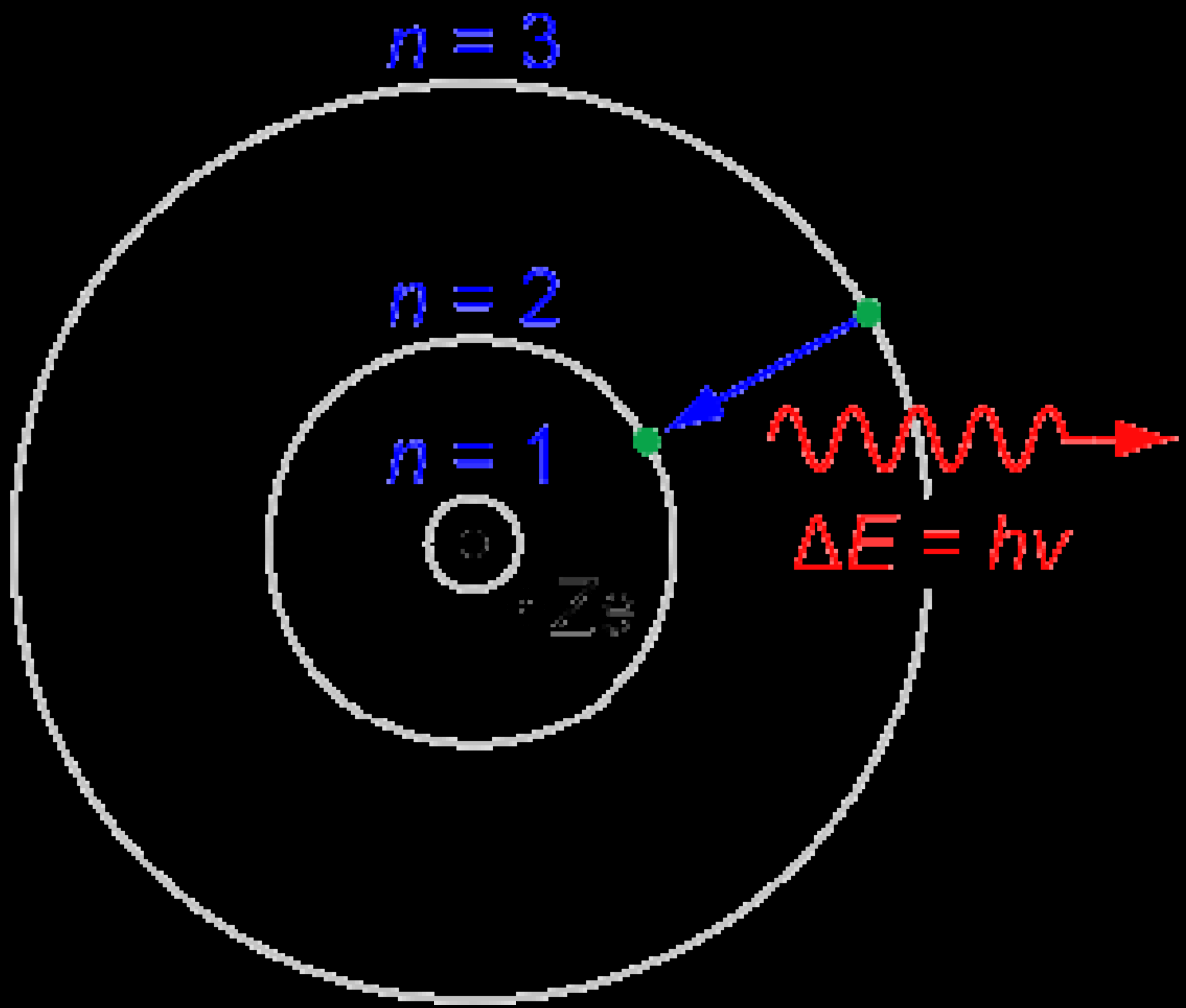


Less Expensive – R2,000 to R3,000

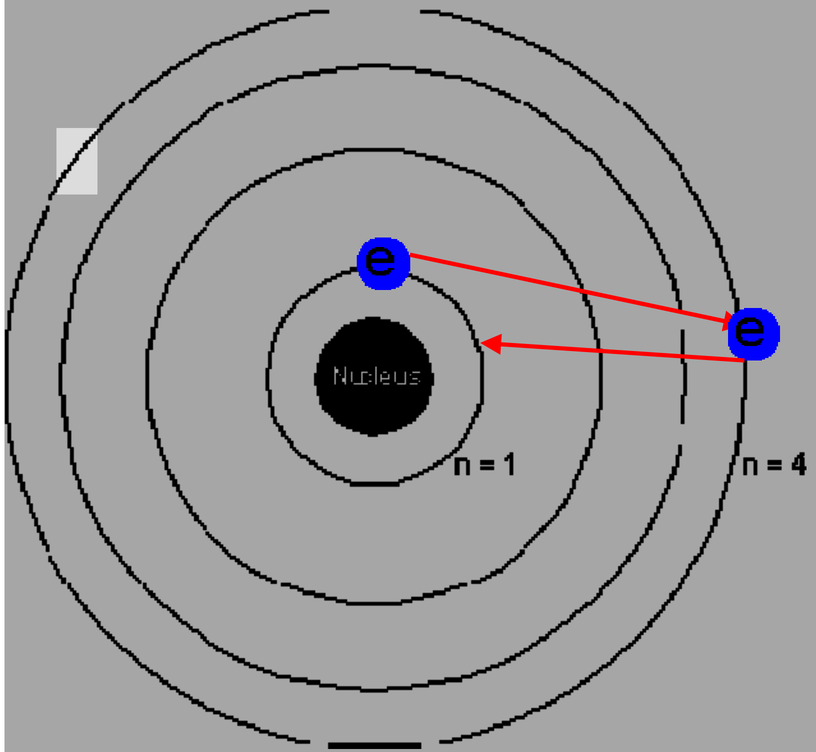
Rainbow Optics Star Spectroscopes



The Star Analyser 100 (SA-100 or 200)

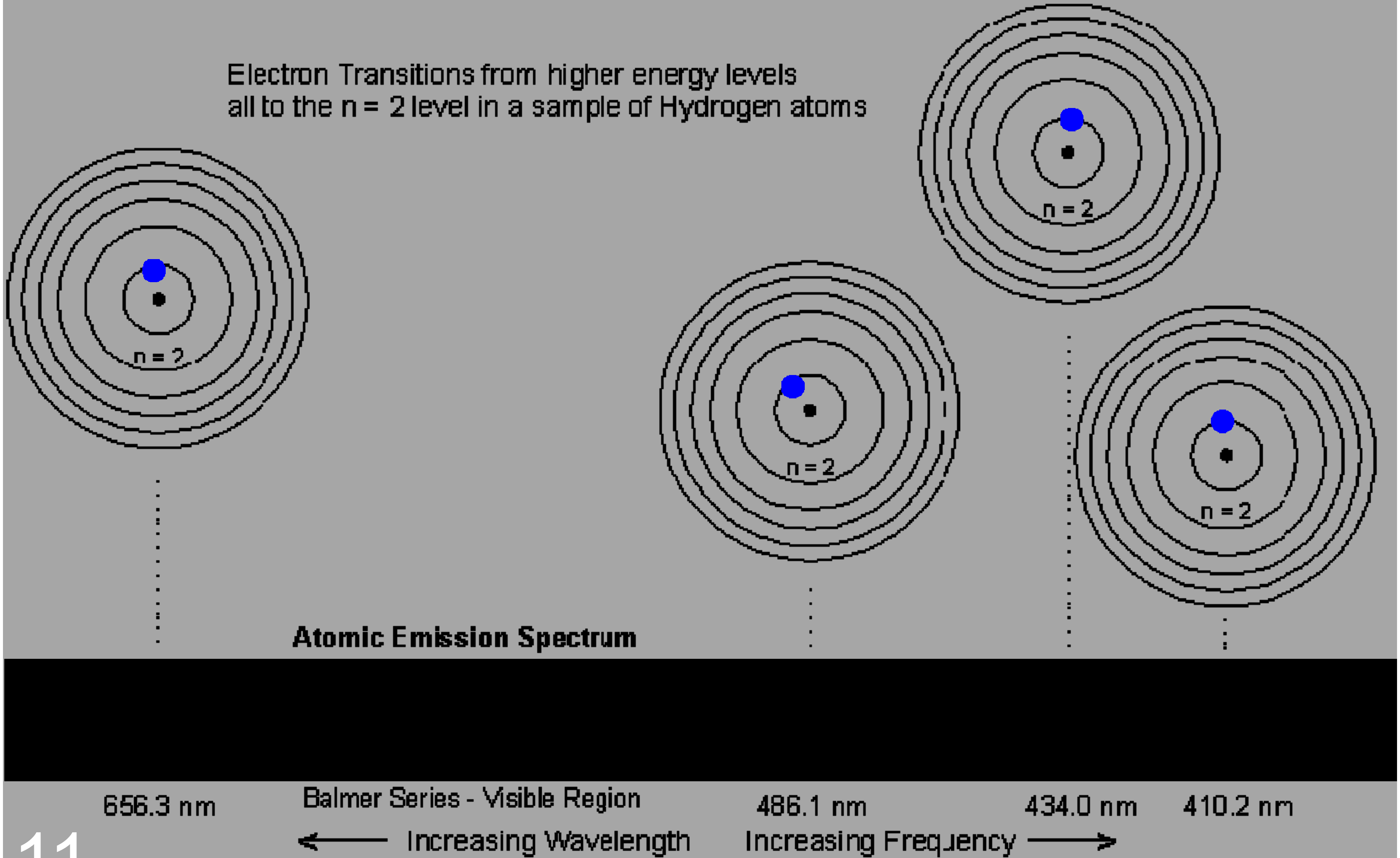

n = 3
n = 2
n = 1
ΔE = hv

GROUND STATE
A hydrogen atom in its Ground State.
The electron occupies the lowest possible energy level which in the case of hydrogen is the Principal Quantum Level n = 1.



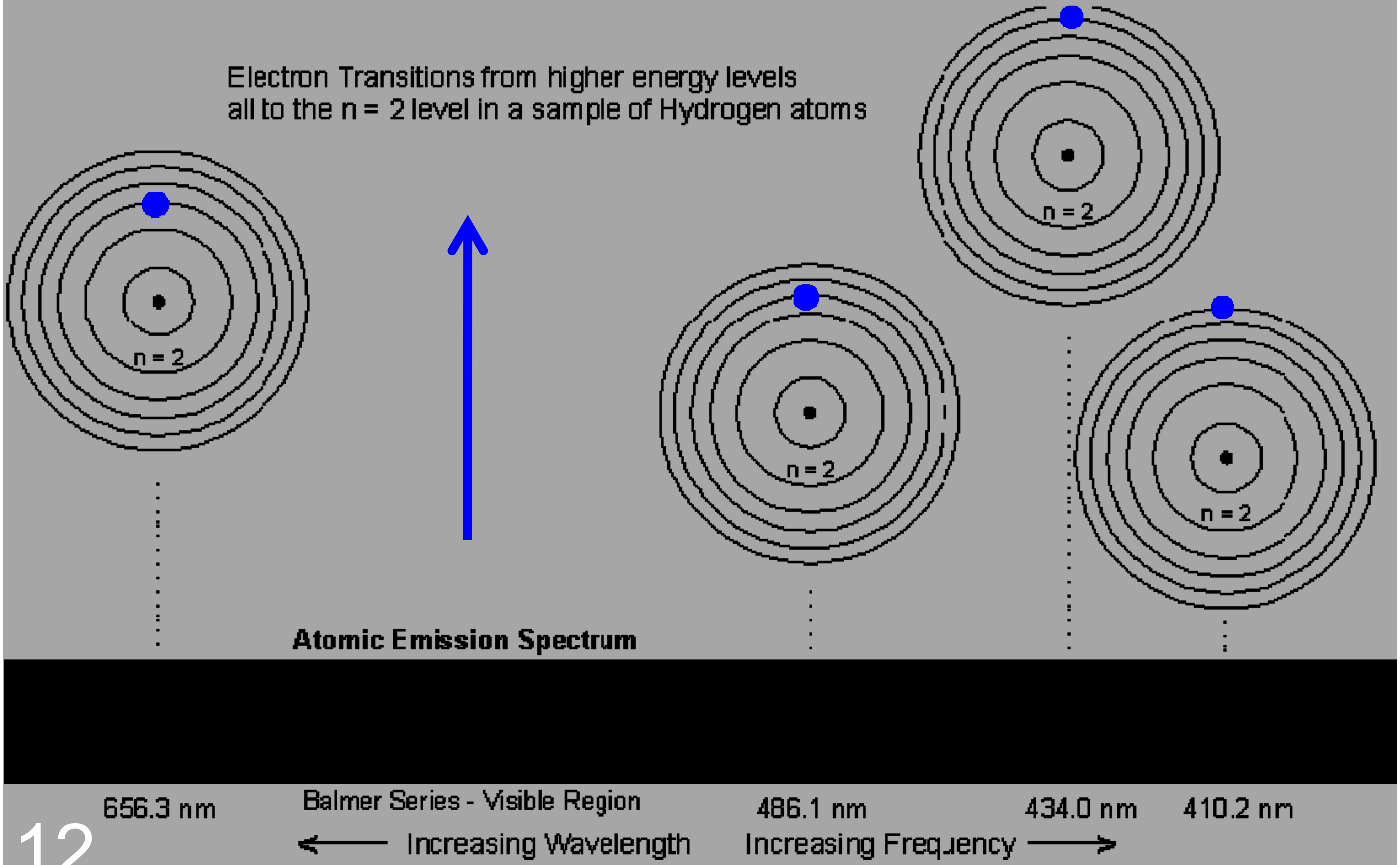
EXITED STATE – absorbs energy – a specific amount of photon energy
A hydrogen atom in an Excited State.
The electron occupies one of the higher energy levels further from the nucleus of the atom.

Ground State



Exited State (absorb energy)

Hα 6563 – n2 / n3
Hβ 4861 – n2 / n4
Hγ 4340 - n2 / n5
Hδ 4101 – n2 / n6



Blamer Series (emits energy)

Hα 6563 – n3 / n2
Hβ 4861 – n4 / n2
Hγ 4340 - n5 / n2
Hδ 4101 – n6 / n2

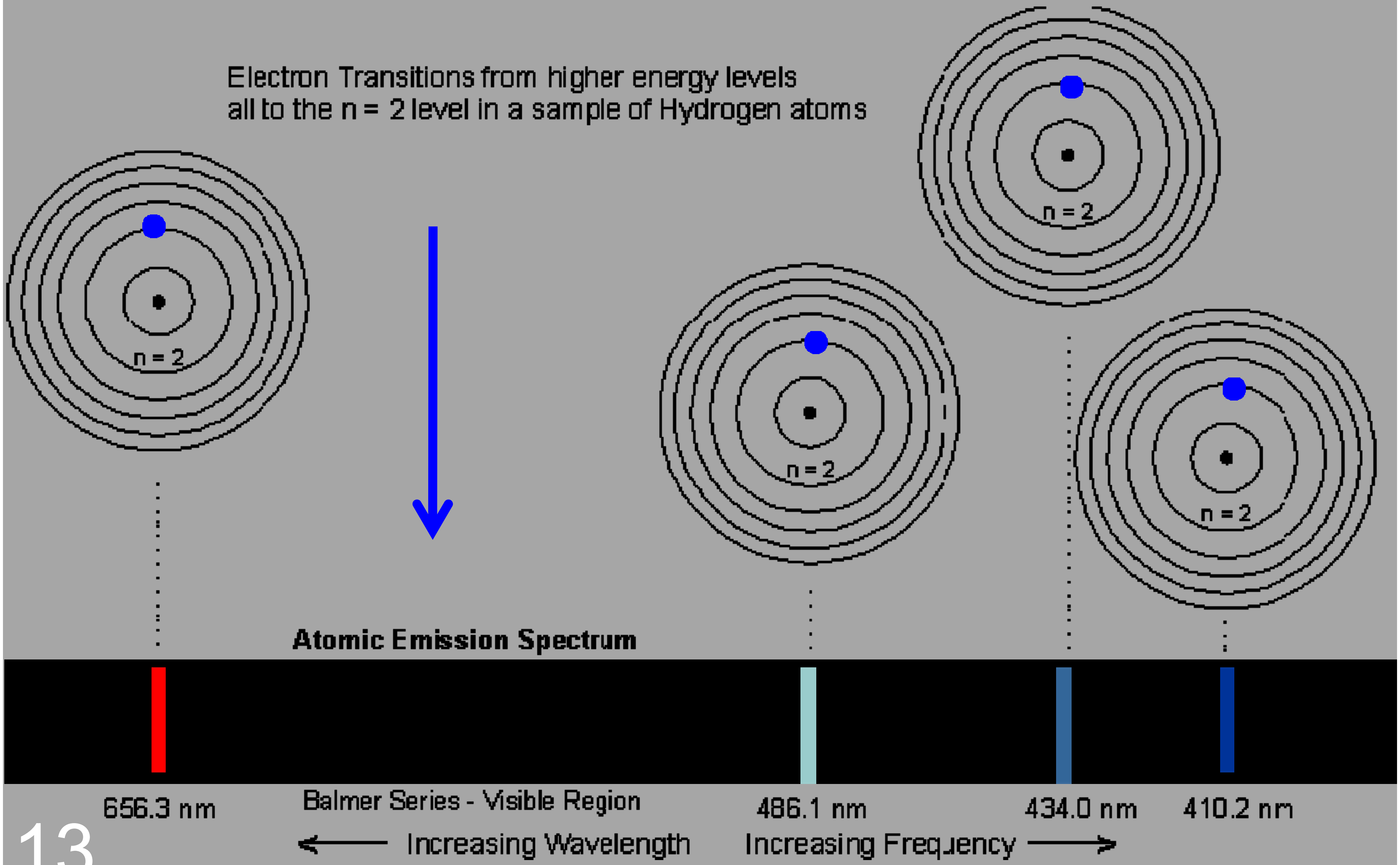
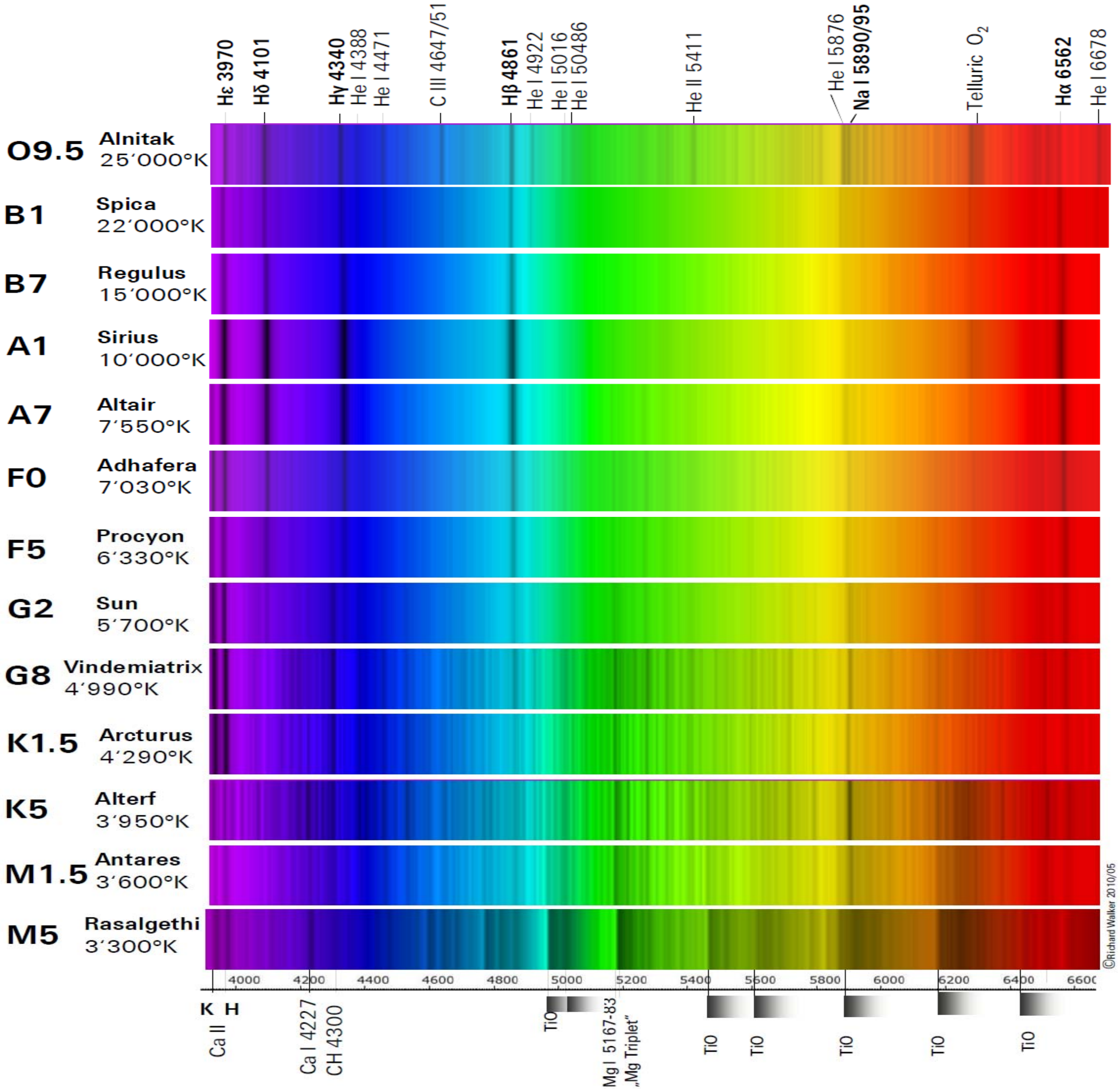
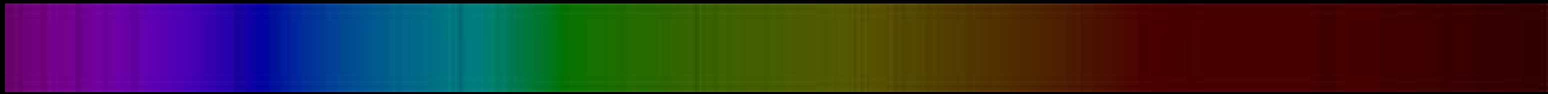


TABLE 01

Overview on the spectral classes



Class O - Lamda Orionis - Blue > 30,000K



- Class O stars are very hot and very luminous, being bluish in color. These are the rarest of all main sequence stars.
- Helium is very difficult to ionize, so spectral lines by ionized Helium (He II) only appear in these hot stars, prominent ionized Si IV, OIII, NIII, CIII,

Class B - Rigel, Spica - Blue-White 9500K - 30,000K

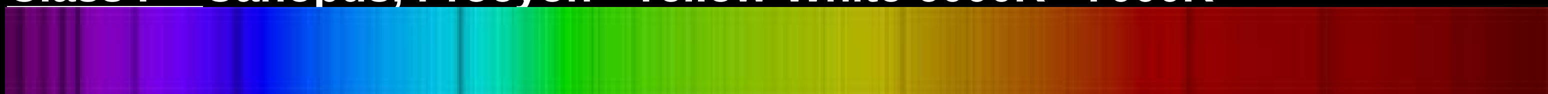
- Class B stars are extremely luminous and blue
- They are hot enough to energize their Helium, but are not hot enough to ionize it. Thus *B* stars have HeI lines (neutral He) but do not have HeII lines
- Ionized metal lines include MgII, SiII

- ***"B & O* stars"** – stars with temp's > 10,000 K, most of the Hydrogen gas in the star's atmosphere will be ionized. Since an ionized Hydrogen atom has no electron it cannot produce any spectral lines, thus the Hydrogen lines are weak

Class A - Sirius, Vega, Altair - White 7000K - 9500K

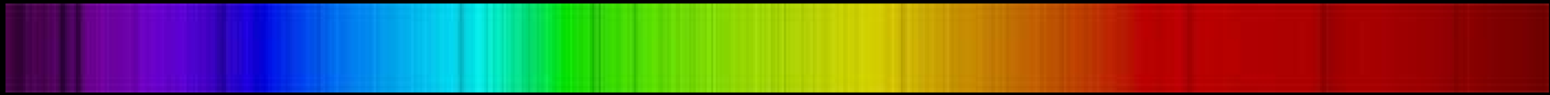
- Class A stars are amongst the more common naked eye stars, and are white or bluish-white.
- They have strong hydrogen lines and also lines of ionized metals FeII, MgII, SiII, CaII
- They do not have any Helium lines at all

Class F - Canopus, Procyon - Yellow-White 6000K - 7000K



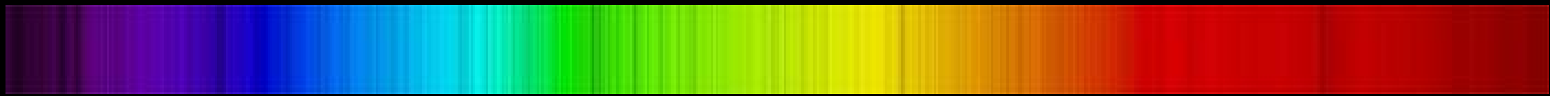
- Class F stars have strengthening CaII lines + neutral metals FeI, CrI
- These stars are within the right range of temperatures to energize their Hydrogen gas without ionizing it. Thus the Hydrogen "Balmer" lines are very strong in these stars.

Class G - The Sun, Capella - Yellow 5200K – 6000K



• Most notable are the lines of CaII.
• They have even weaker hydrogen lines than **Class F**, but along with the ionized metals, they have neutral metals.

Class K - Arcturus, Aldebaron - Orange 3900K – 5200K



•Class K are orangish stars which are slightly cooler than our Sun.
•Some K stars are giants & superdiants.
•They have extremely weak hydrogen lines, if they are present at all, and mostly neutral metals MnI, FeI, SiI.
•By late K, molecular bands of TiO become present.

Class M - Antares, Betelguese - Red < 3900K

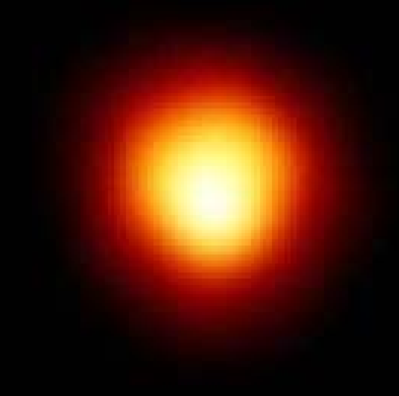
• Class M are most common.
• The spectrum of an **M star shows lines belonging to molecules** and all neutral metals but hydrogen lines are usually absent. Titanium oxide can be strong in M stars. Vanadium oxide bands are also seen in late M stars.

Class W or WR - Wolf-Rayet stars – Gamma Velorum

• Unusual since they have mostly helium in their atmospheres instead of hydrogen. They are thought to be dying supergiants with their hydrogen layer blown away by hot steller winds caused by their high temperatures, thereby directly exposing their hot helium shell. They show spectral lines of carbon, nitrogen, or oxygen emission in their spectra (and outer layers).
• These lower temp stars, the Hydrogen gas isn't as easily excitied, thus the Balmer lines aren't as strong

Class W: Wolf-Rayet

Class G & M



Class B

Common Spectral Lines (given in Å):

Hydrogen (the “Balmer Series”):

Hα 6563
Hβ 4861
Hγ 4340
Hδ 4101
Hε 3970
H8 3889
H9 3835
H10 3798
H11 3771
H12 3750

Molecular Bands:

CH “G band” 4300
CN 3880, 4217, 7699
C2 “Swan” 4380, 4738, 5165, 5635, 6122
C3 4065
MgH 4780
TiO 4584, 4625, 4670, 4760

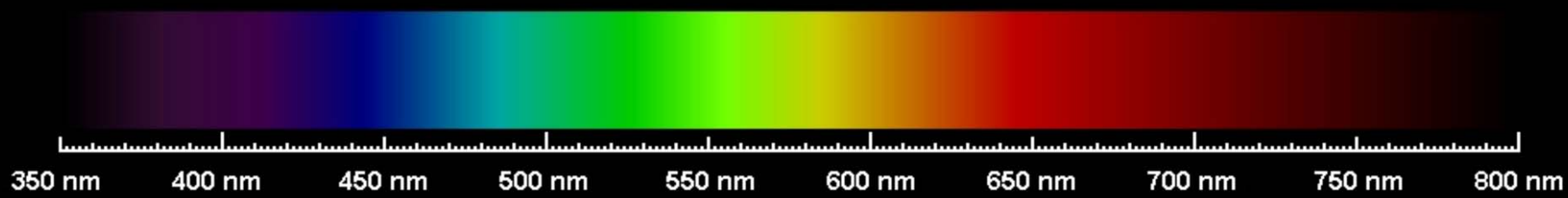
Helium:

He I 4026, 4388, 4471, 4713, 5015, 5048, 5875, 6678,
He II 4339, 4542, 4686, 5412

Metals:

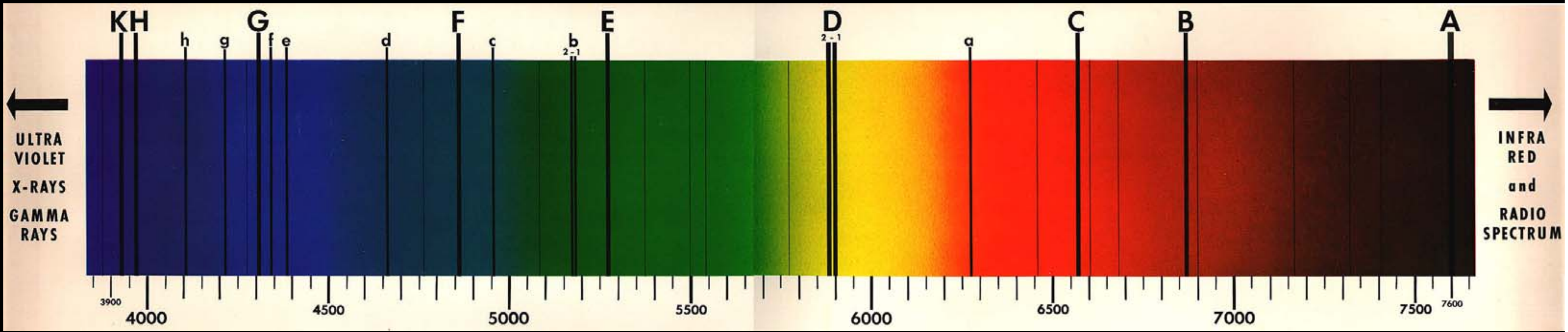
C II 4267
C III 4649, 5696
C IV 4658, 5805
N III 4097, 4634
N IV 4058, 7100
N V 4605
O V 5592
Na I 5890, 5896
Mg I 5167, 5173, 5183
Mg II 4481
Hg 4358, 5461, 5770,5791

Si III 4552
Si IV 4089
Ca I 4226
Ca II 3933, 3968
Sc II 4246
Ti II 4300, 4444
Mn I 4032
Fe I 4045, 4325
Fe II 4175, 4233
Sr II 4077, 4215



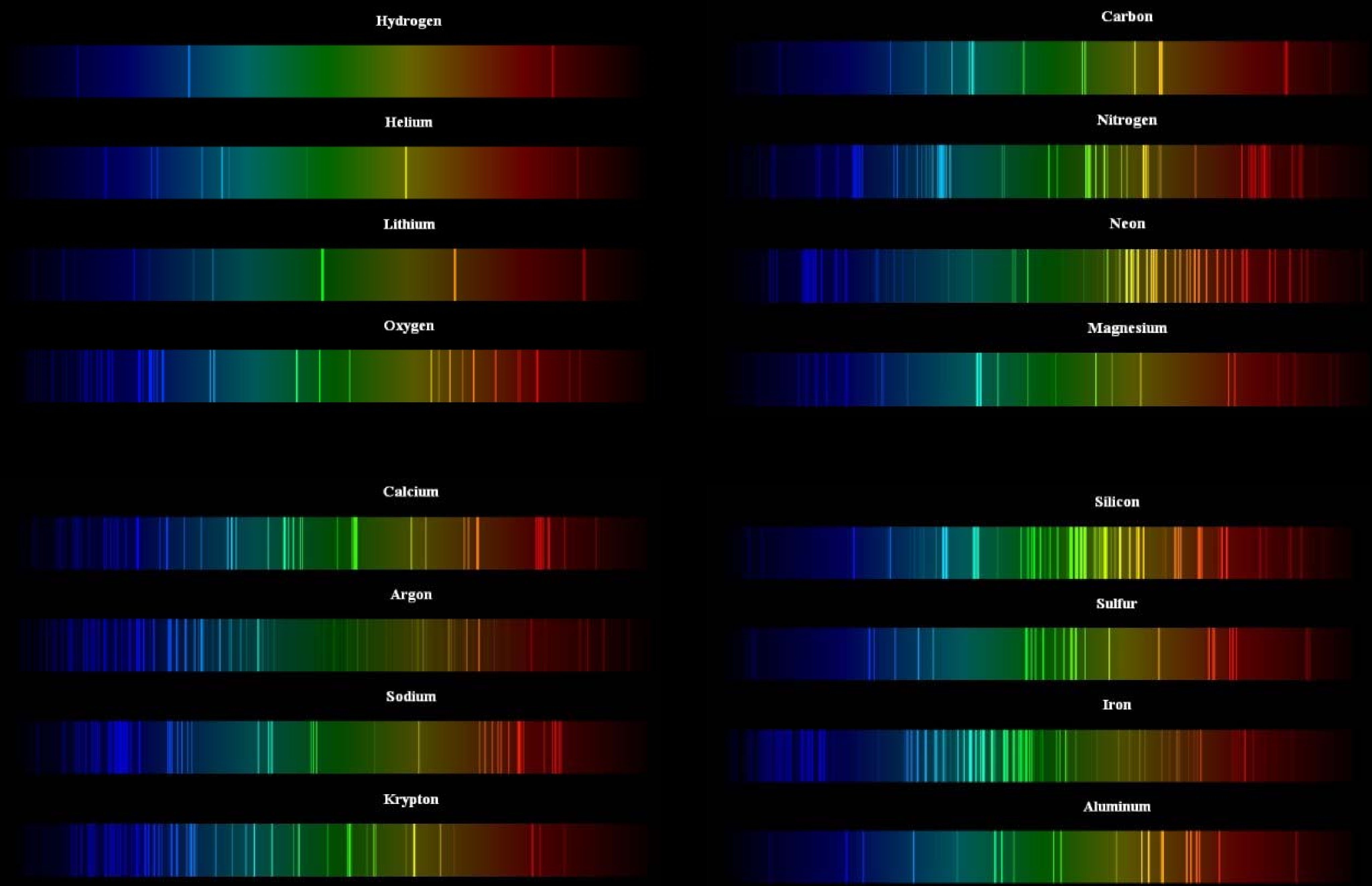
Visible Continuous Spectrum 2
(Perceived Brightness Partially to Scale)

Fraunhofer lines – Sun Spectrum

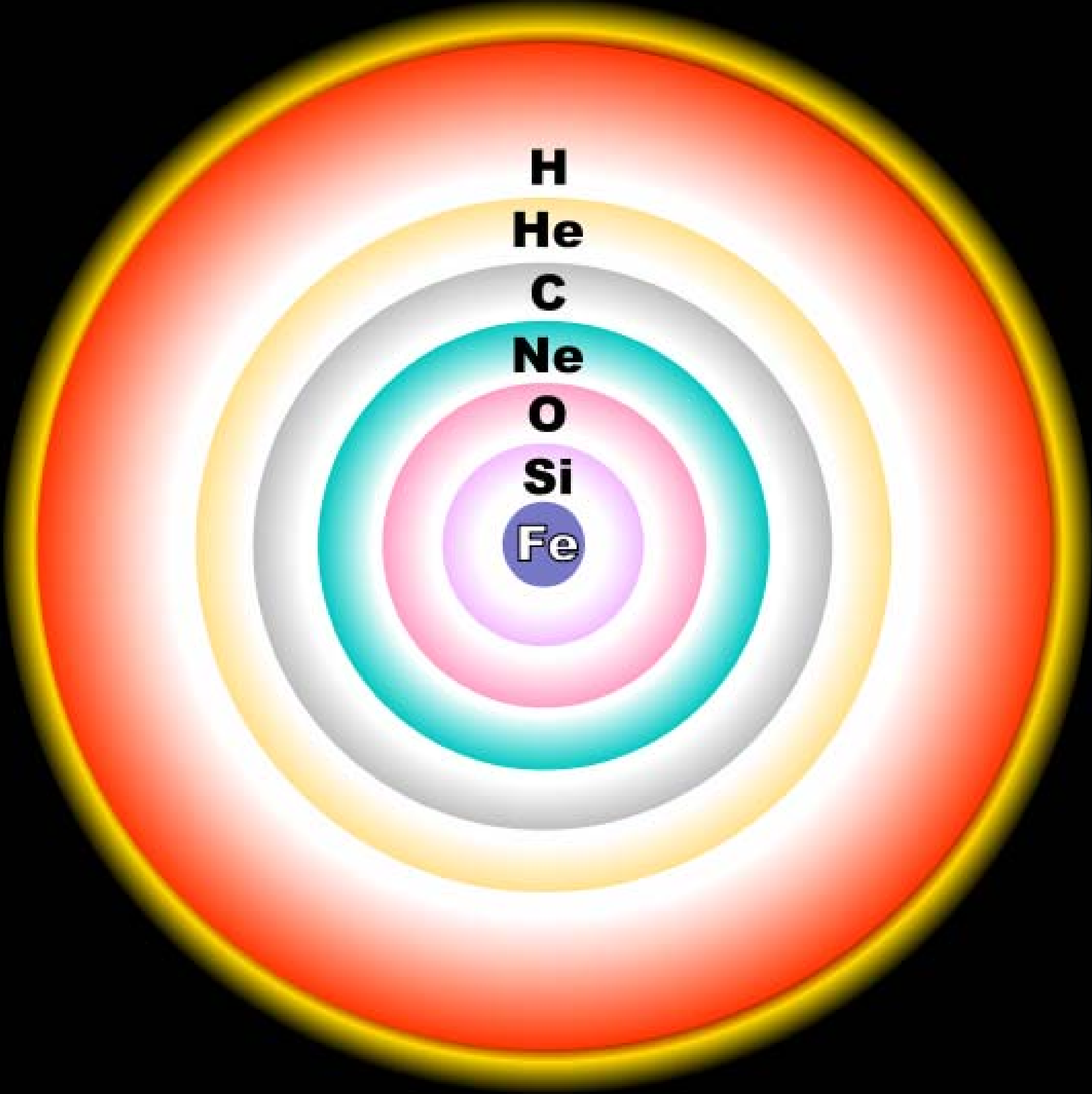


Lines	**Due To**	**Wavelengths**
A - (band)	O_2	7594 - 7621
B - (band)	O_2	6867 - 6884
C	H	6563
a - (band)	O_2	6276 - 6287
D - 1, 2	Na	5896 & 5890
E	Fe	5270
b - 1, 2	Mg	5184 & 5173
c	Fe	4958

Lines	**Due To**	**Wavelengths**
F	H	4861
d	Fe	4668
e	Fe	4384
f	H	4340
G	Fe & Ca	4308
g	Ca	4227
h	H	4102
H	Ca	3968
K	Ca	3934

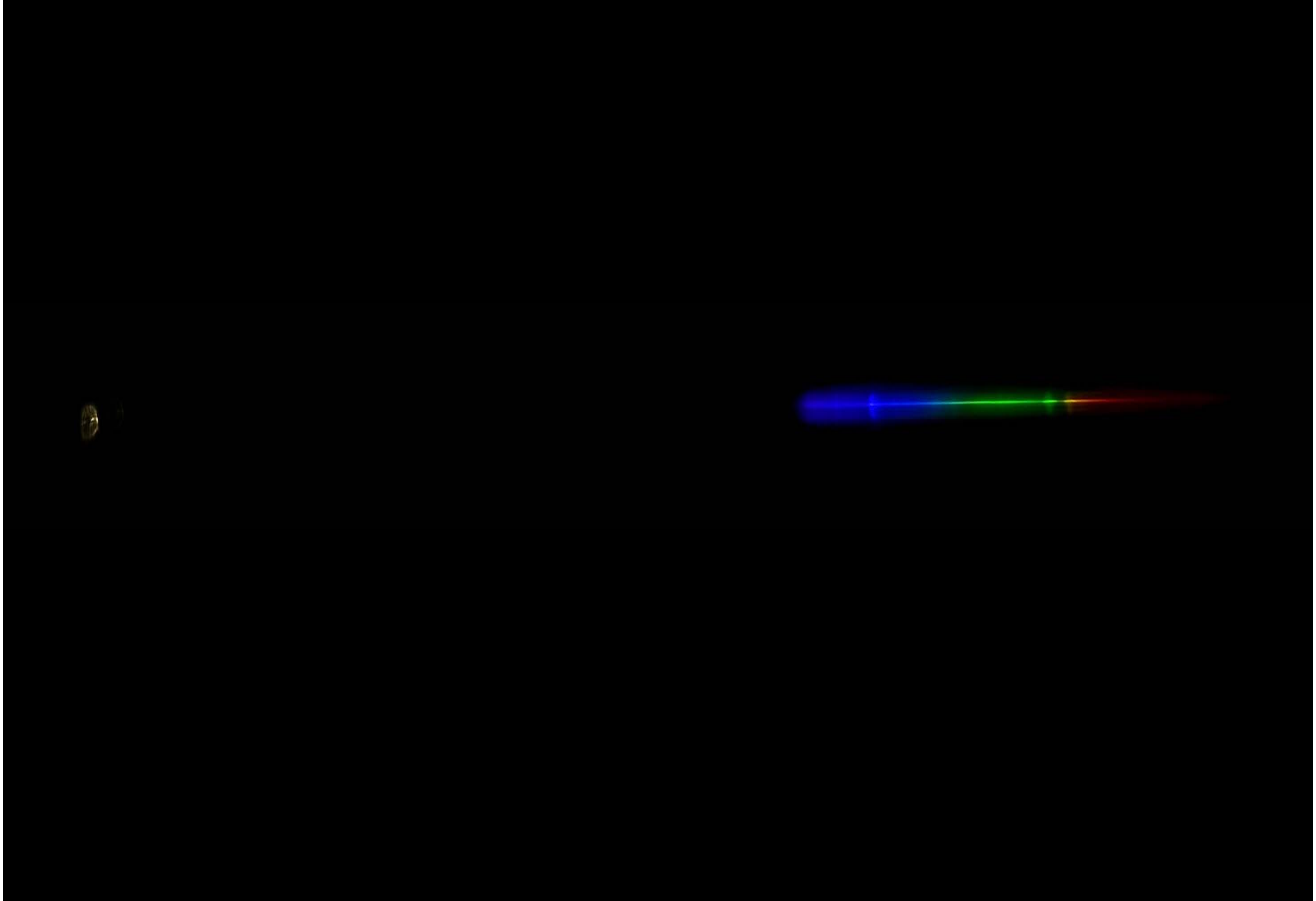

Hydrogen
Helium
Lithium
Oxygen
Calcium
Argon
Sodium
Krypton
Carbon
Nitrogen
Neon
Magnesium
Silicon
Sulfur
Iron
Aluminum

”Onion” Layers of the Sun



Author's equipment:
80 mm refractor,
Rainbow Optics Transmission Grating (200l/mm),
Nikon DSLR,
An equatorial mounting fitted with a tracking unit.

This shows the various instruments on the equatorial mounting. Left is the 80 mm refractor with the DSLR camera and grating fitted into the refractor tube where the eyepiece is currently (on the left), with the finder scope on the top. To the right is a 400 mm telephoto lens fitted with a ZWO130 CCD camera, used as a guide telescope.



4 Processing the Image to get a spectrum

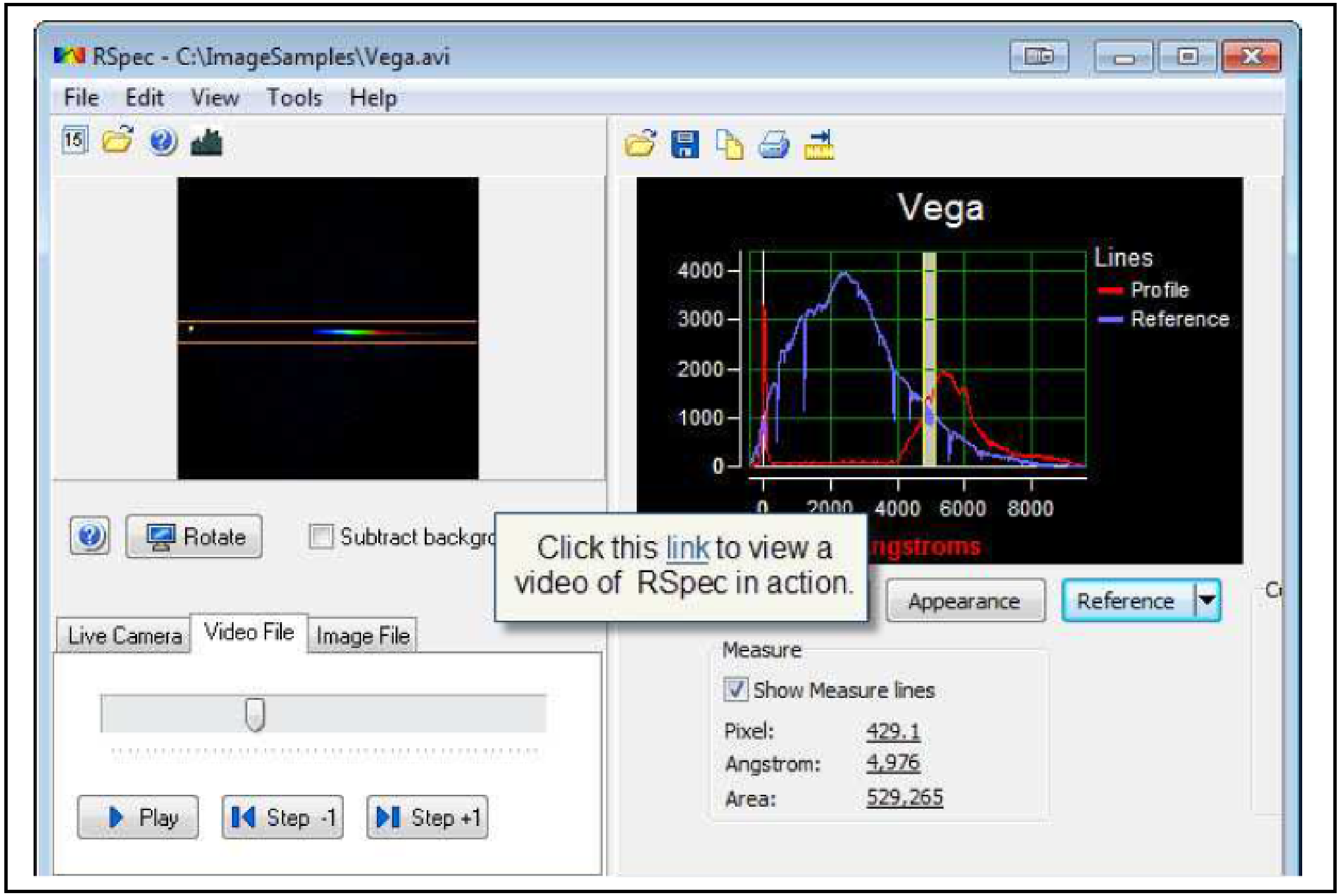
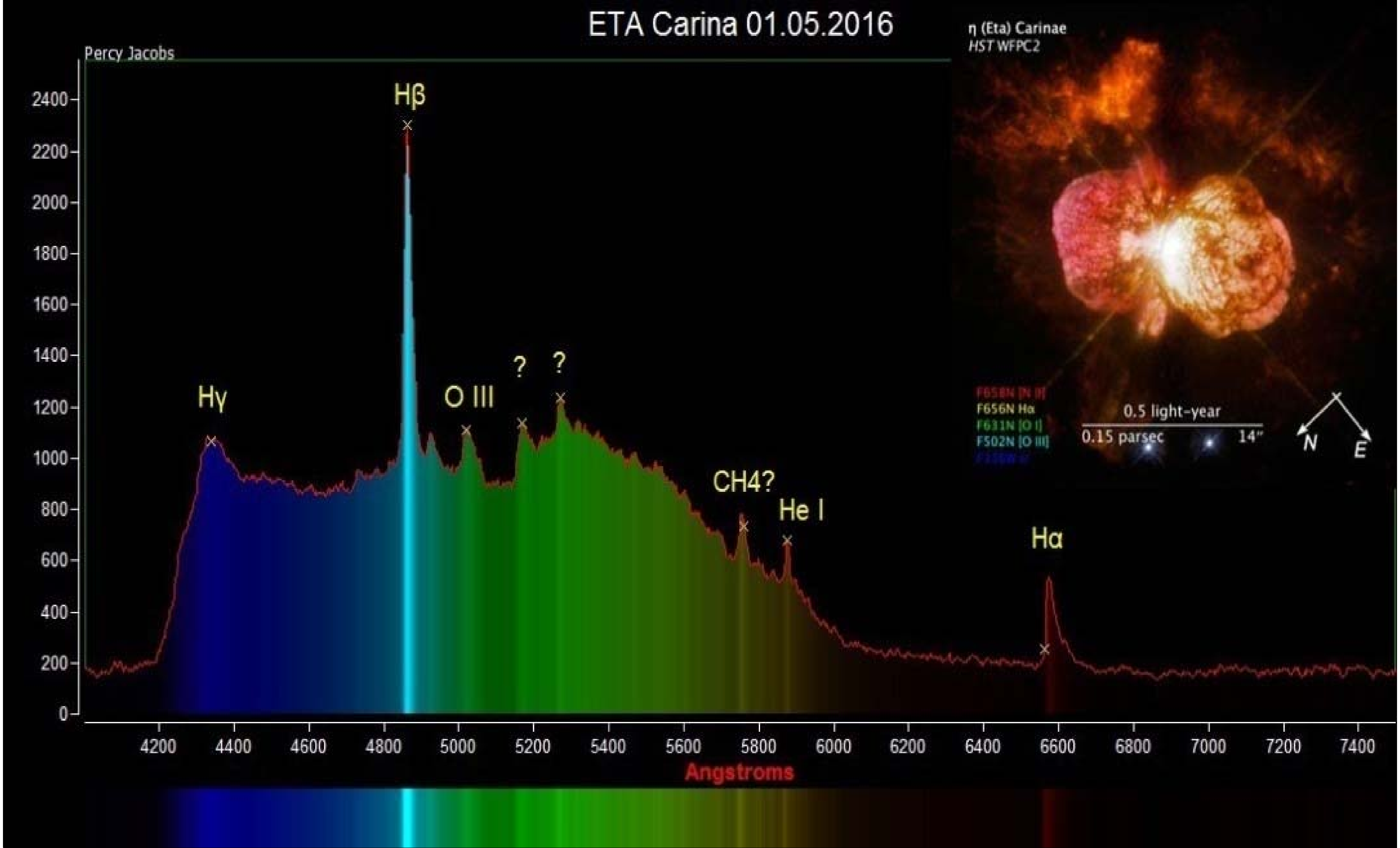
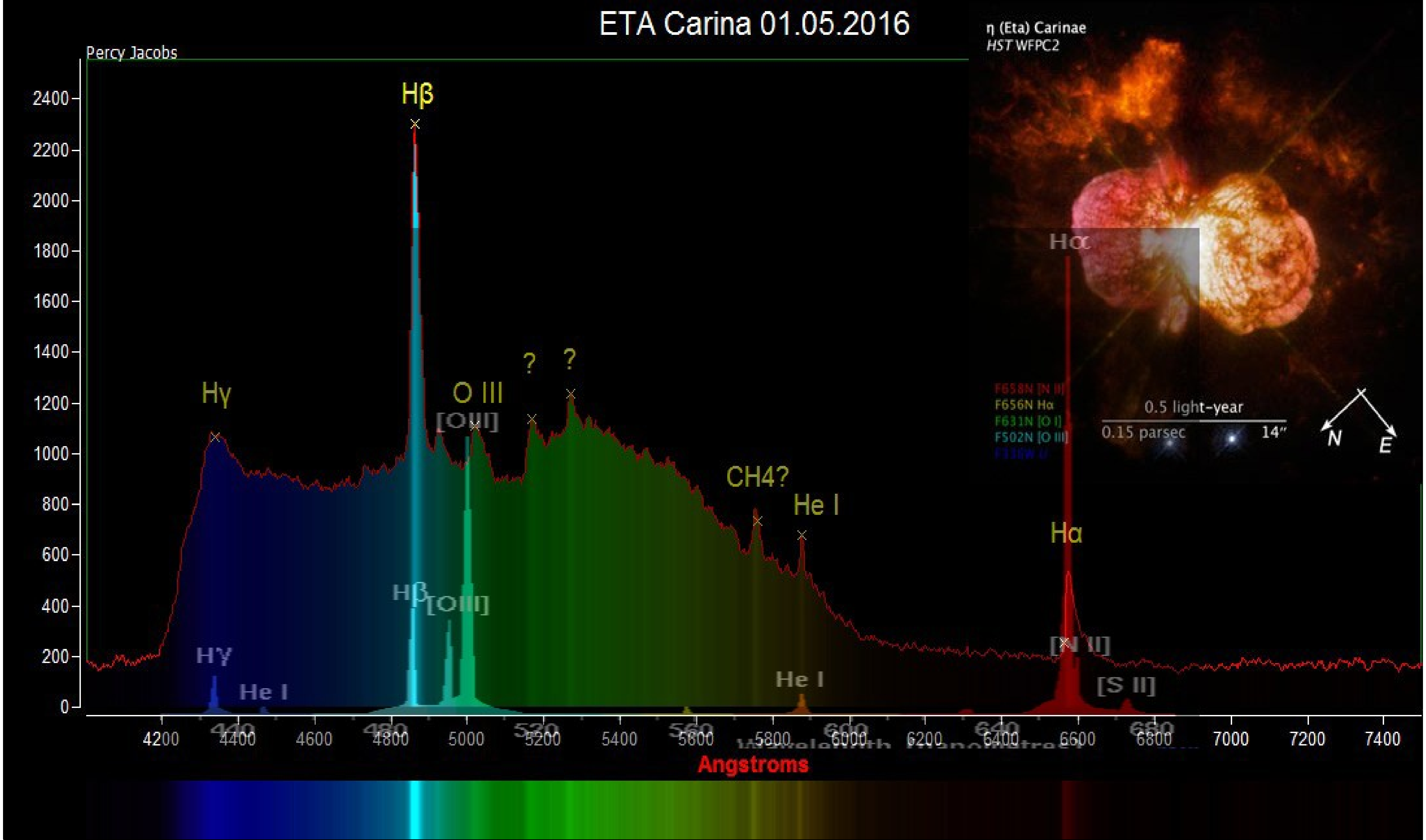


Fig. 6 Screenshot of the software used, RSPEC.

The RSPEC programme is comparing pixels to angstroms [2]. The star itself, the 1st calibration point, is taken as zero angstroms vs the pixel reading number shown by the star. The 2nd calibration point would be the



Showing the final processed image, is the spectrum of ETA Carina, with the inserted picture of the actual star. The inserted picture is only there to show what the target actually looks like.



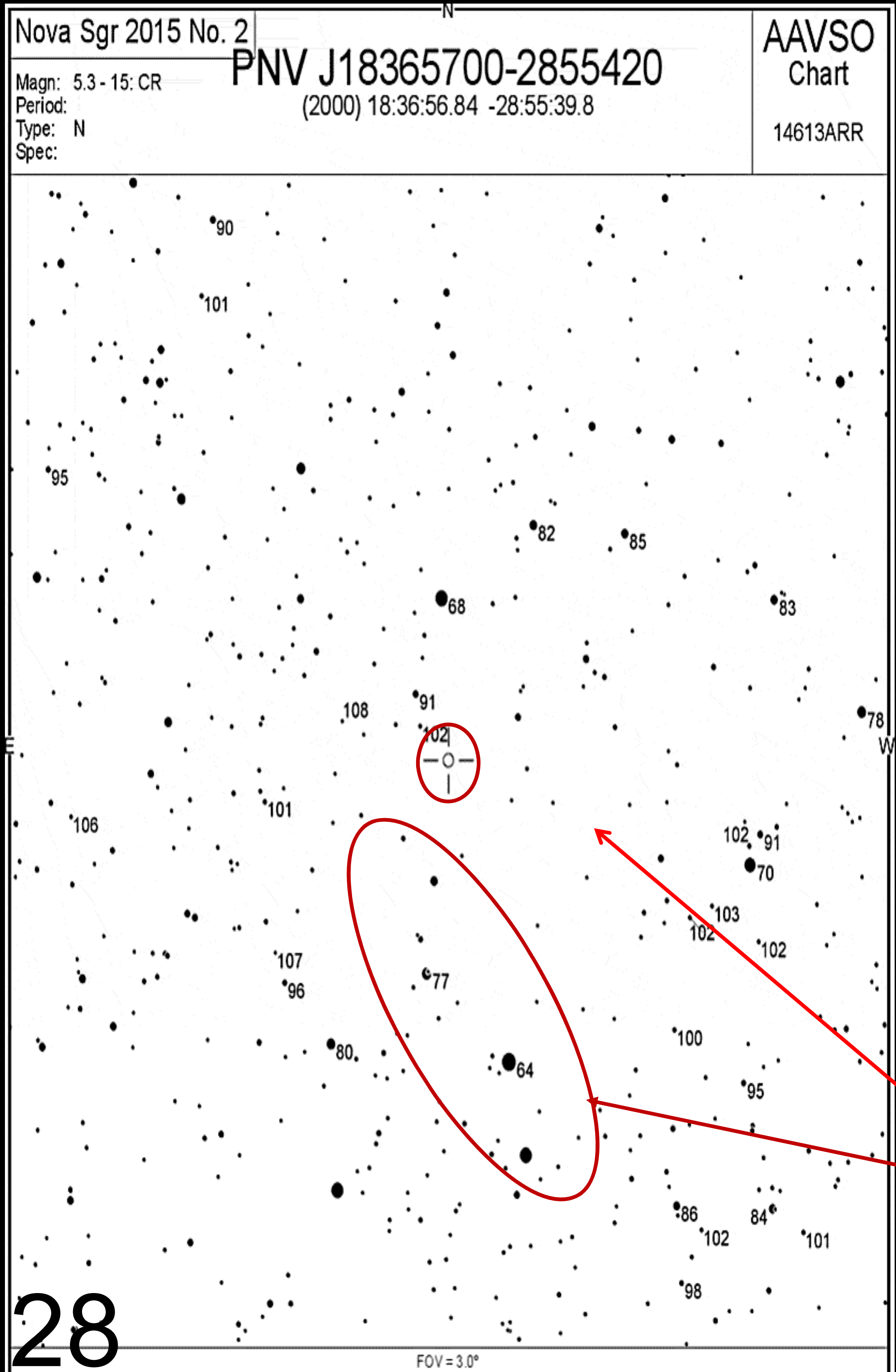
Doug Sharpe, located in the UK, superimposed a professional spectrograph on top of the one shown above and it matches pretty well.

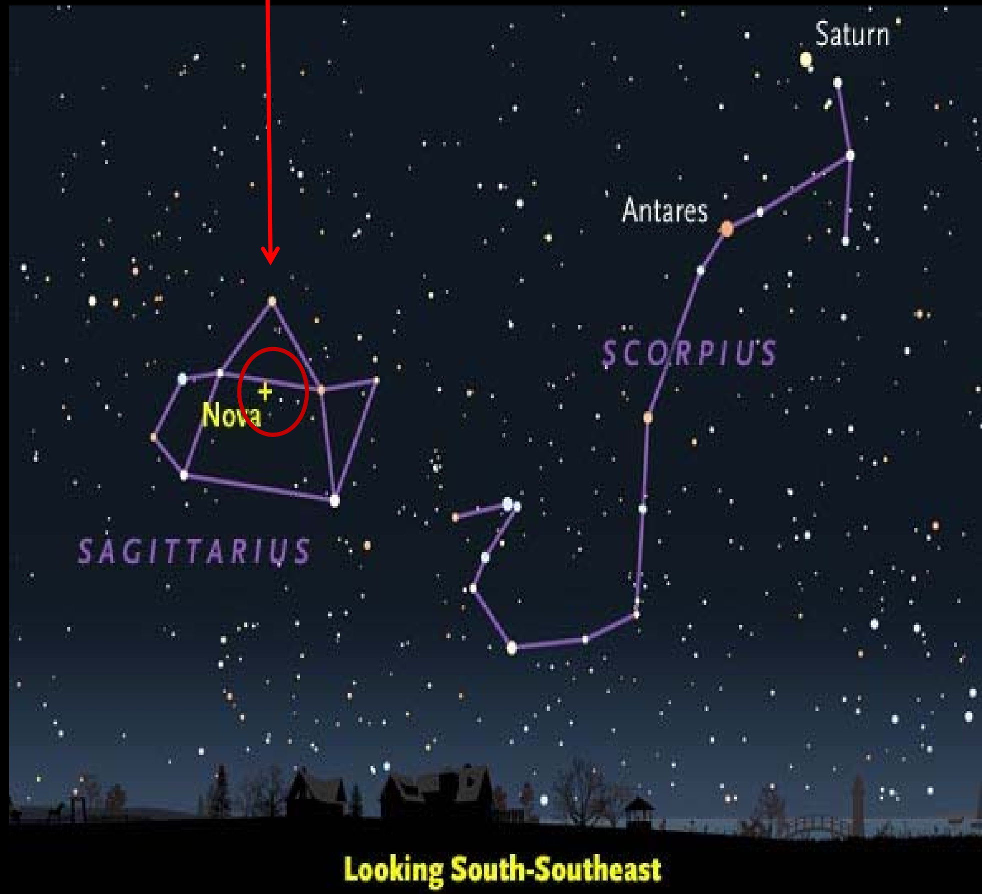
NOVA SGR 2015 No.2

Spectra Analyses by Amateurs

using both, commercial & homemade equipment

Locating Nova Sgr 2015 No.2



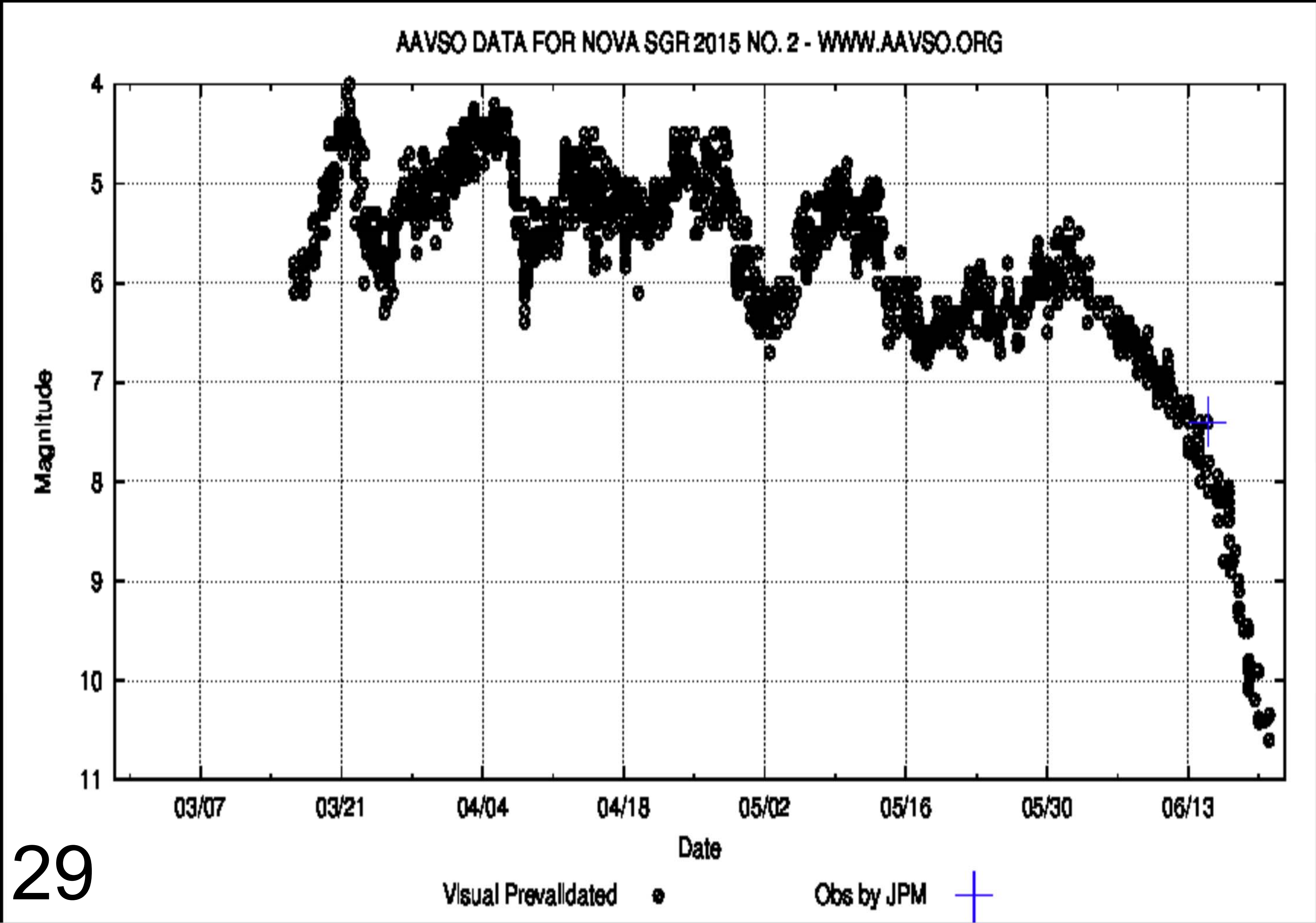


2nd step – hop to location using detailed AAVSO map

Star hop to location

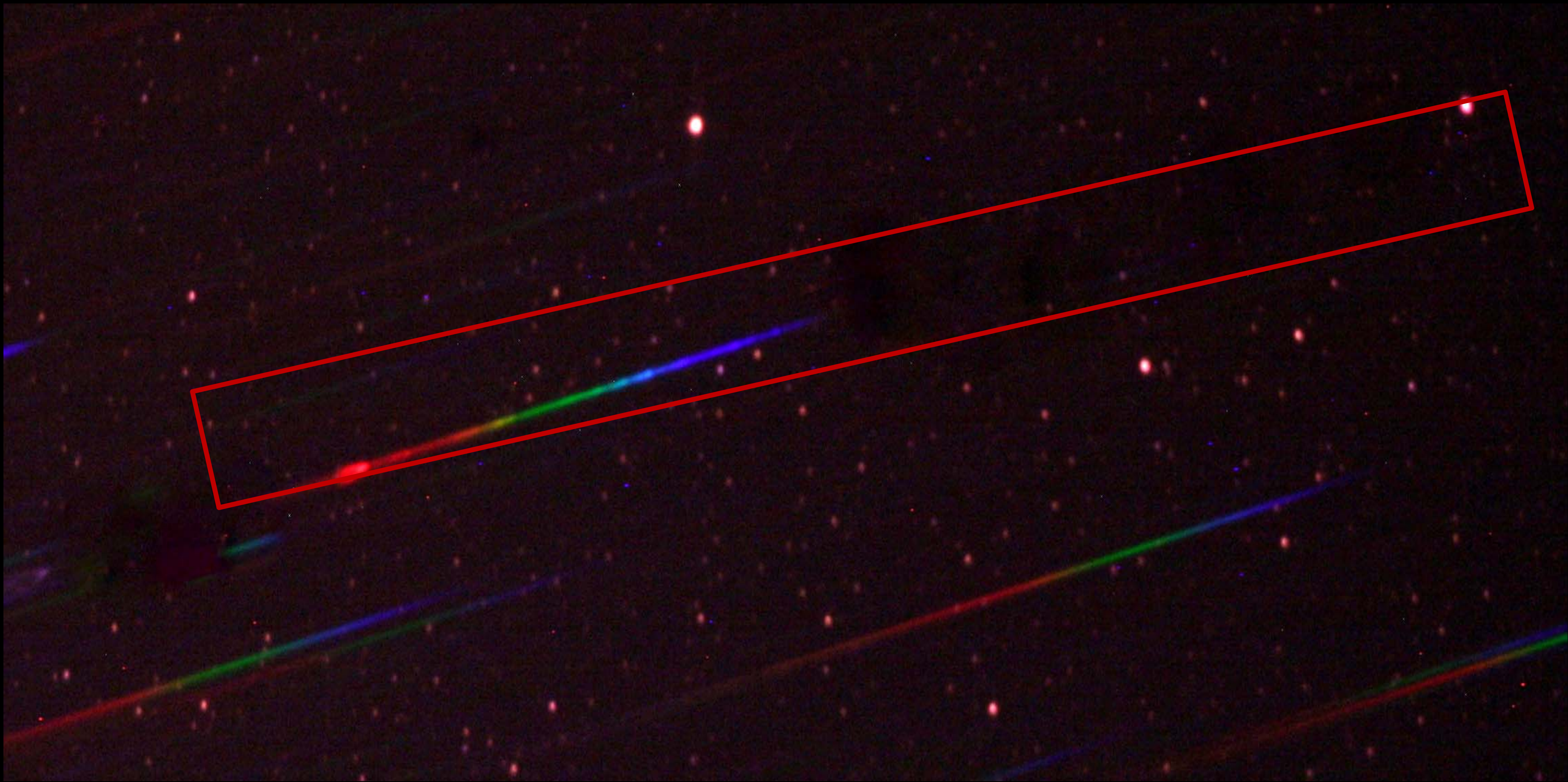
Light Curve

visual magnitude - brightness

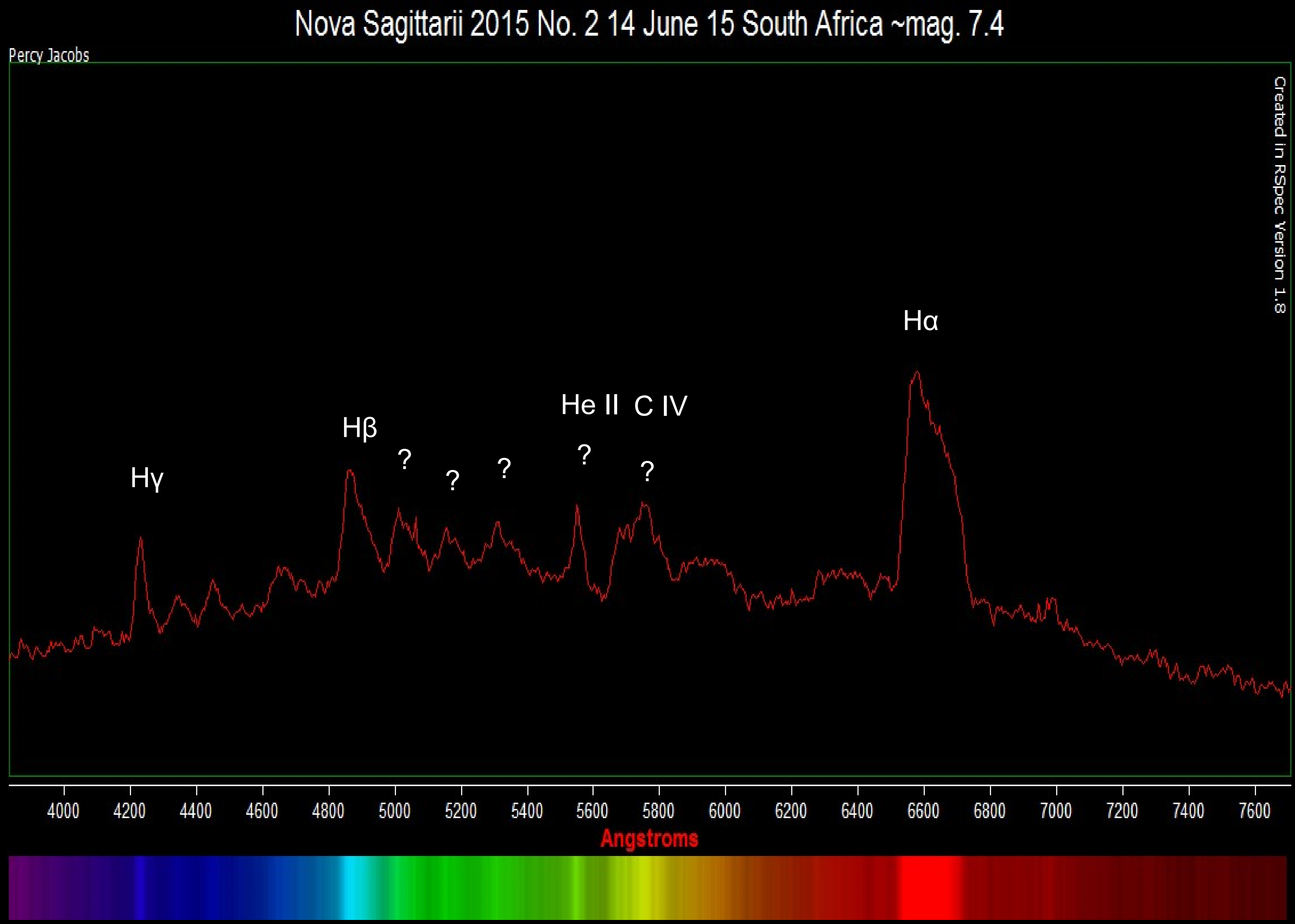


Spectra photo by Percy Jacobs of Pretoria ASSA

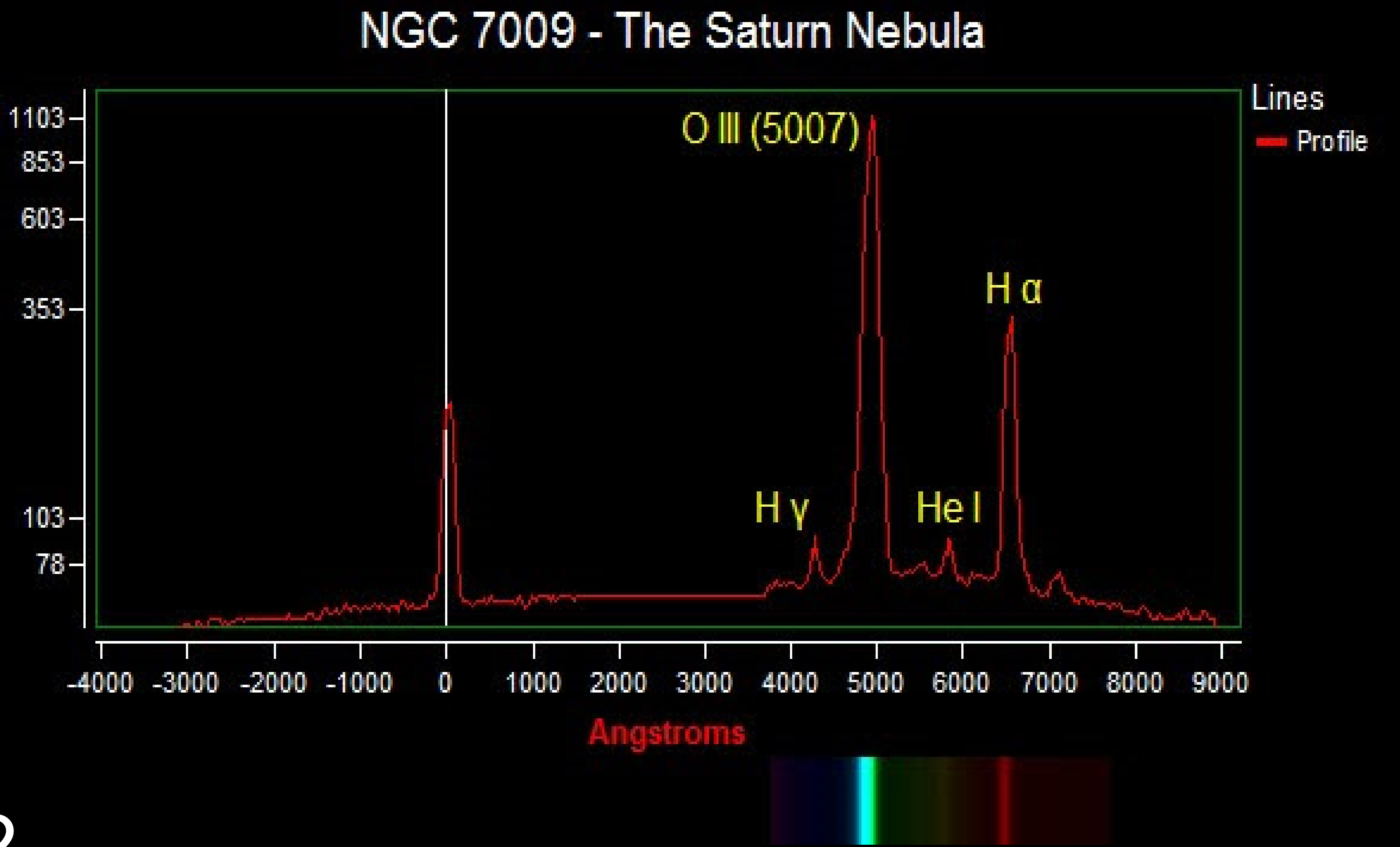
~7.5 magnitude - 14.06.2015



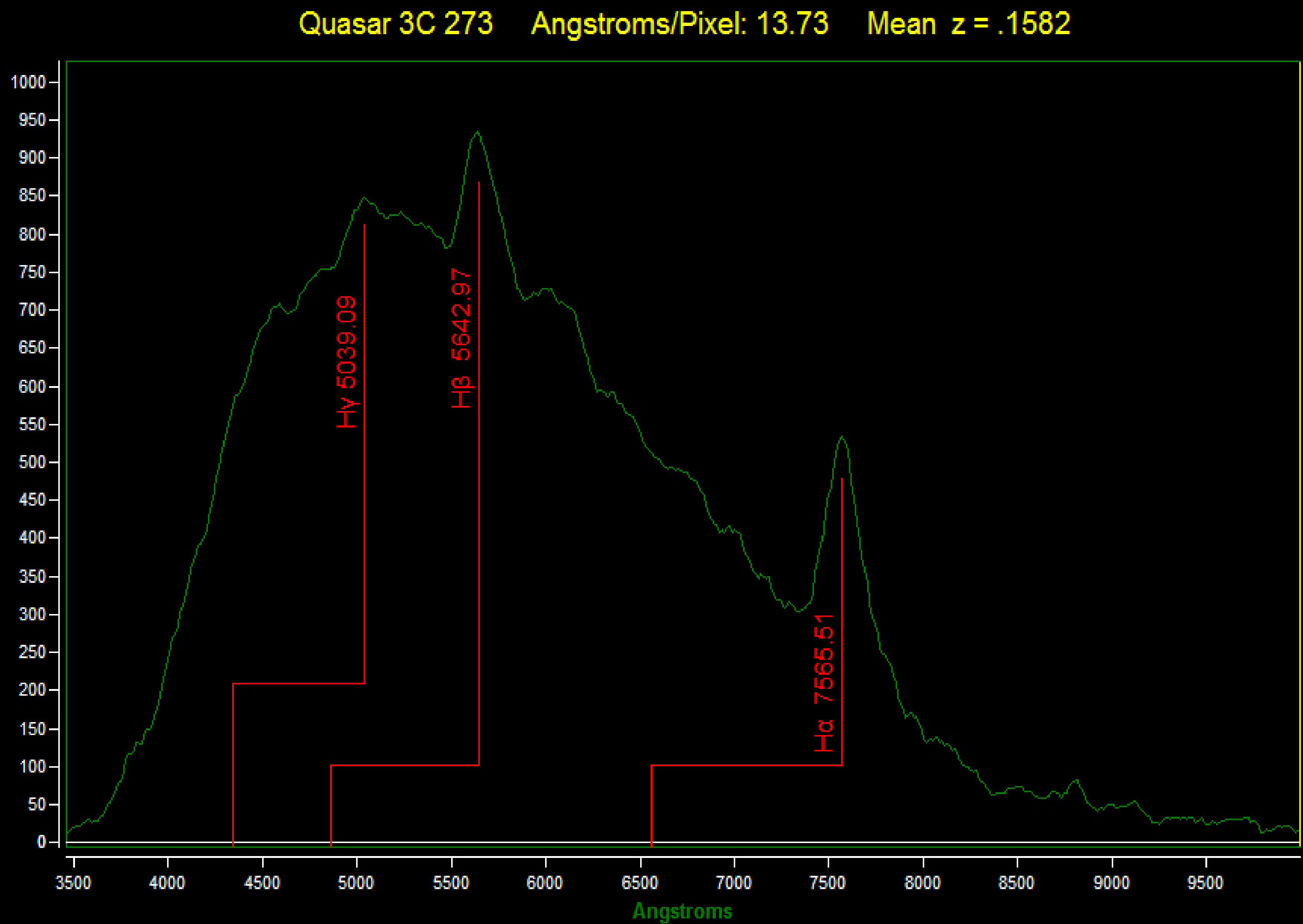
Spectra photo analysed using RSPEC software Percy Jacobs of Pretoria ASSA - ~7.5 magnitude 14.06.2015



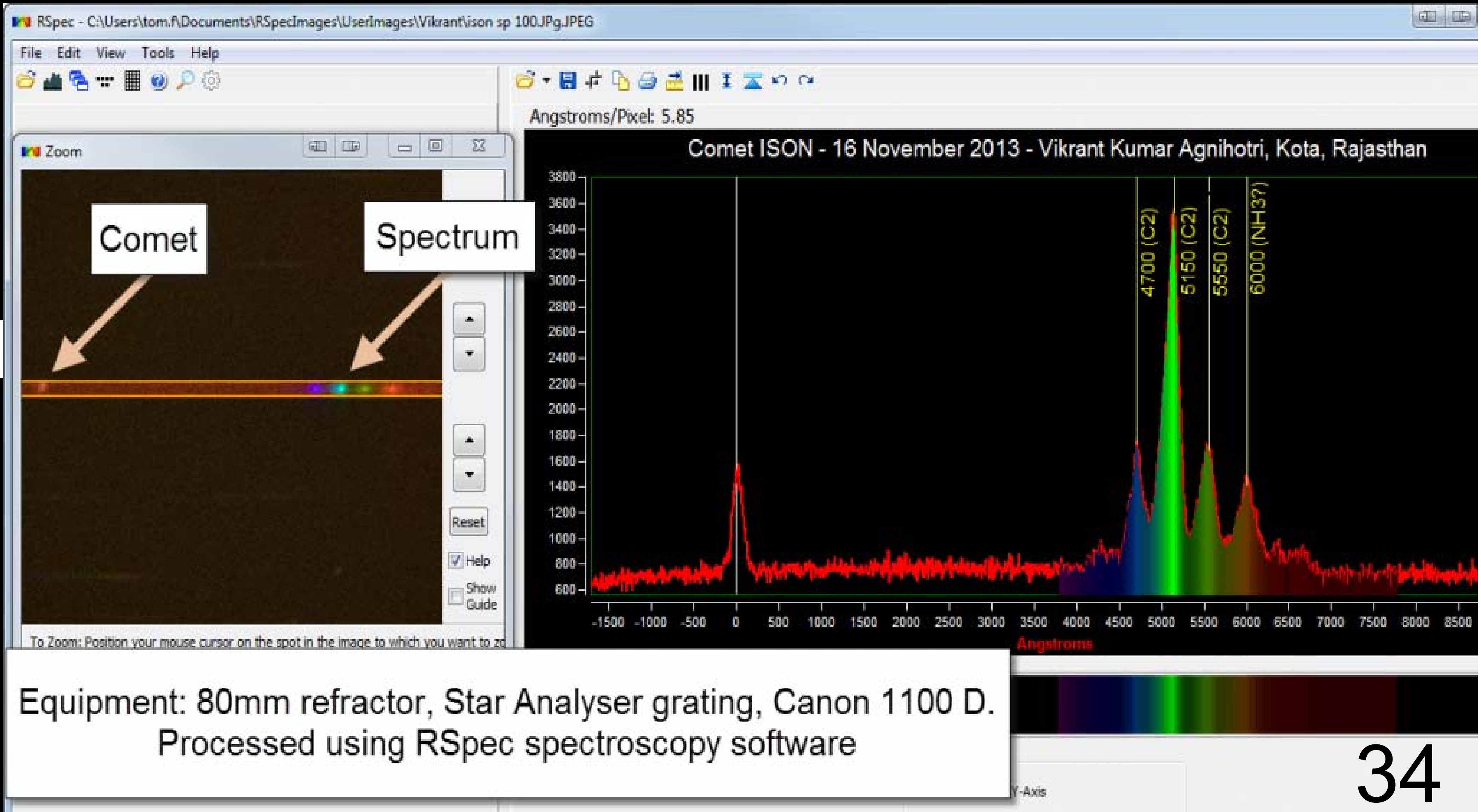
Detect the Emission lines on an Emission Nebula: An emission nebula is surrounded by a gas shell that is excited (like a florescent light). Below is a spectrum of the Saturn Nebula clearing showing its emission lines. The Orion Nebula (M42) would have a similar appearance.



Detect the Red Shift of a Quasar that is 2 billion light years away. William Wiethoff's spectra (below) of QSO 3C 273 shows the red shift due to cosmological expansion. Many amateurs capture this spectrum on 8″ telescopes with less than 15 minutes integration time.



Comet spectra: This spectrum of ISON is shows how easy it is for amateurs to study astronomical spectra. Vikrant Kumar Agnihotri in India captured this wonderful spectrum of ISON using a just an 80 mm refractor, simple Star Analyser grating, and a DSLR. It clearly shows the green glow from glowing Carbon (the so-called "Swan bands" – Wikipedia link) This image was captured from a rooftop in Rajasthan, and then processed in the RSpec software:



Books

Spectroscopy: The Key to the Stars – Keith Robinson
Astronomical Spectroscopy for Amateurs – Ken M. Harrison
Astronomical Spectrography for Amateurs – EAS Publication Series – J.P. Rozelot, C. Neiner
Spectroscopic Atlas for Amateur Astronomers (no longer a free pdf download – now buy on-line through Cambridge University Press) - Version 5.0 04/2014 (if you send me an email, I can send you a pdf copy of Version 4)

Software

Tom Field - RSpec – http://www.rspec-astro.com (most preferred – software comes with video tutorials that can be down loaded)
BASS Project (Basic Astronomical Spectroscopy Software by John Paraskeva – 2nd choice -
http://www.aesesas.com/mediapool/142/1423849/data/DOCUMENTOS/BASS_Project_1_.pdf
Visual Spec – http://www.astrosurf.com/vdesnoux
Christian Buil - http://www.astrosurf.com/~buil

Gratings

Rainbow Optics: manufacturer of the Star Spectroscope 200 l/mm grating - http://www.starspectroscope.com/
Paton Hawksley Star Analyser 100 (SA-100) - http://www.rspec-astro.com/star-analyser/

Groups

Astronomical Spectroscopy for Amateurs
https://groups.yahoo.com/neo/groups/RSpec_Real_Time_Spectroscopy/info

Basic Astronomical Spectroscopy Software
https://uk.groups.yahoo.com/neo/groups/astrobodger/info

Ken M. Harrison – very specialised in amateur spectroscopy and willing to help – ex member of the Durban ASSA group – you can contact him via the above "yahoo" group or direct on kenm.Harrison@gmail.com

Robin Leadbeater - THREE HILLS OBSERVATORY - (Formerly "ROBIN'S ASTRONOMY PAGE")
http://www.threehillsobservatory.co.uk/astro/astro.htm

A Good List of Links
http://www.stargazing.net/david/spectroscopy/links.html

Astronomical Society of Southern Africa
http://assa.saao.ac.za/sections/photometry-spectroscopy/spectroscopy/

Thank You