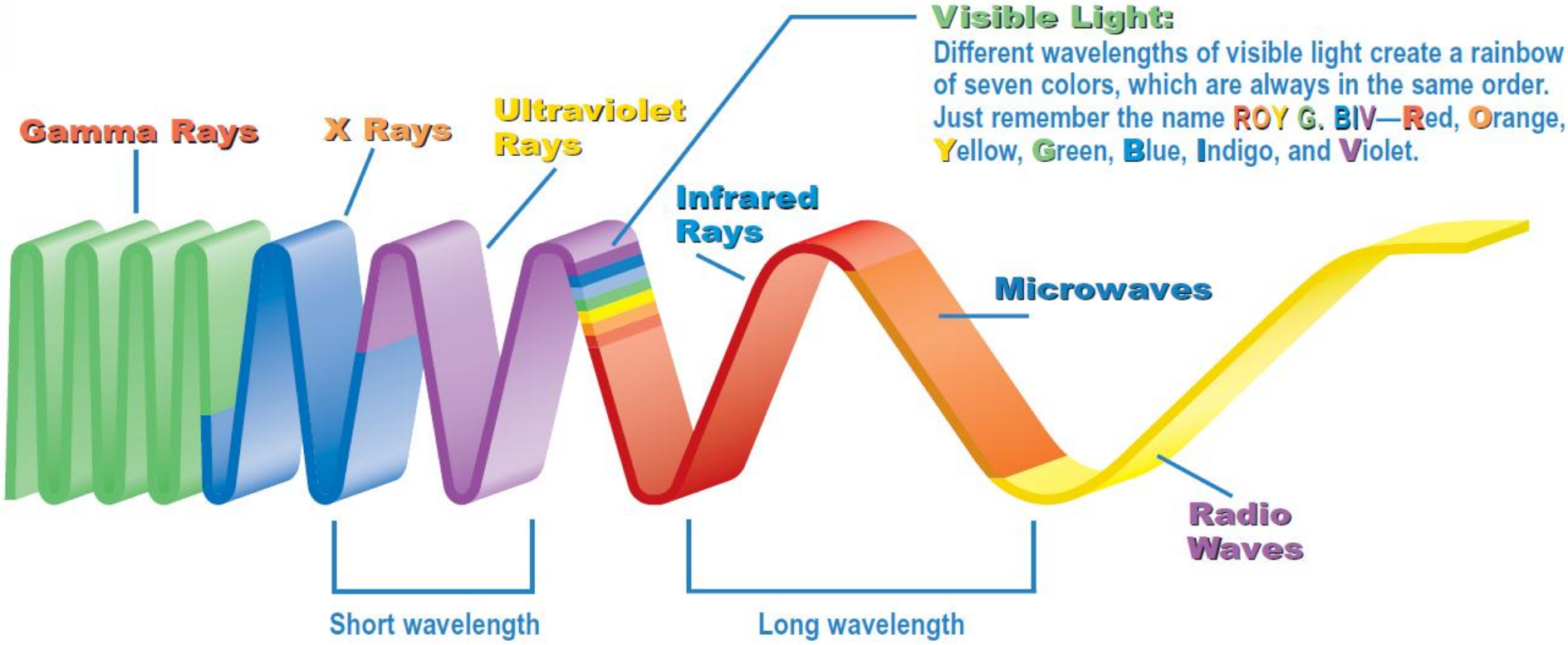
Observing the Small White Dots

The Analysis of Starlight

David Haworth - www.stargazing.net/david

Light

Electromagnetic Spectrum

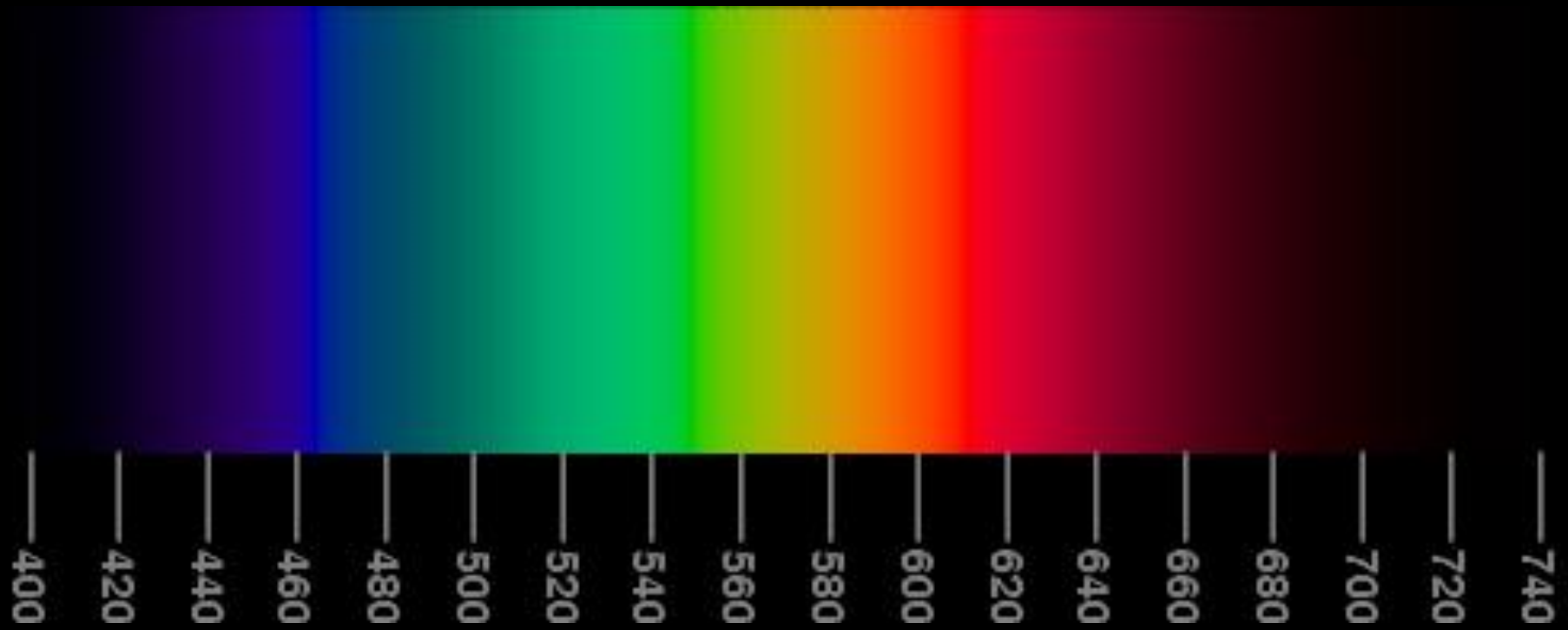


Wavelength measured in nanometers = 10^{-9} meter (nm) = 10 Å or angstroms = 10^{-10} meter (Å) = 0.1 nm

Credit: GE The Light You See www.gelighting.com/na/home_lighting/products/education/

Light Dispersion

Spectrum



Wavelength in nanometers

Credit: Rendering Spectra mintaka.sdsu.edu/GF/explain/optics/rendering.html

Solar Screwdriver CD Spectroscope

www.stargazing.net/david/spectroscopy/ScrewdriverCDROMSpectroscope.html

Do NOT look directly at the Sun

Solar Screwdriver CD Spectroscope

3 inch mailing tube

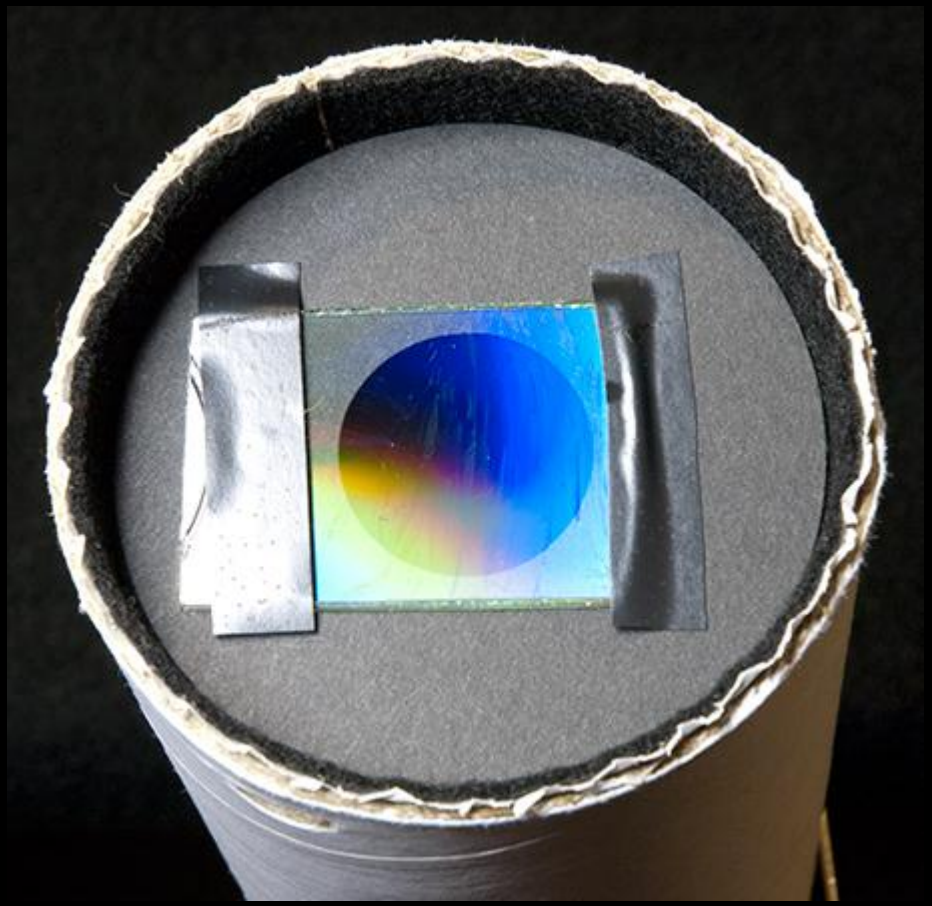
- Cut up CD with label removed
- Round screwdriver for reflecting the Sun

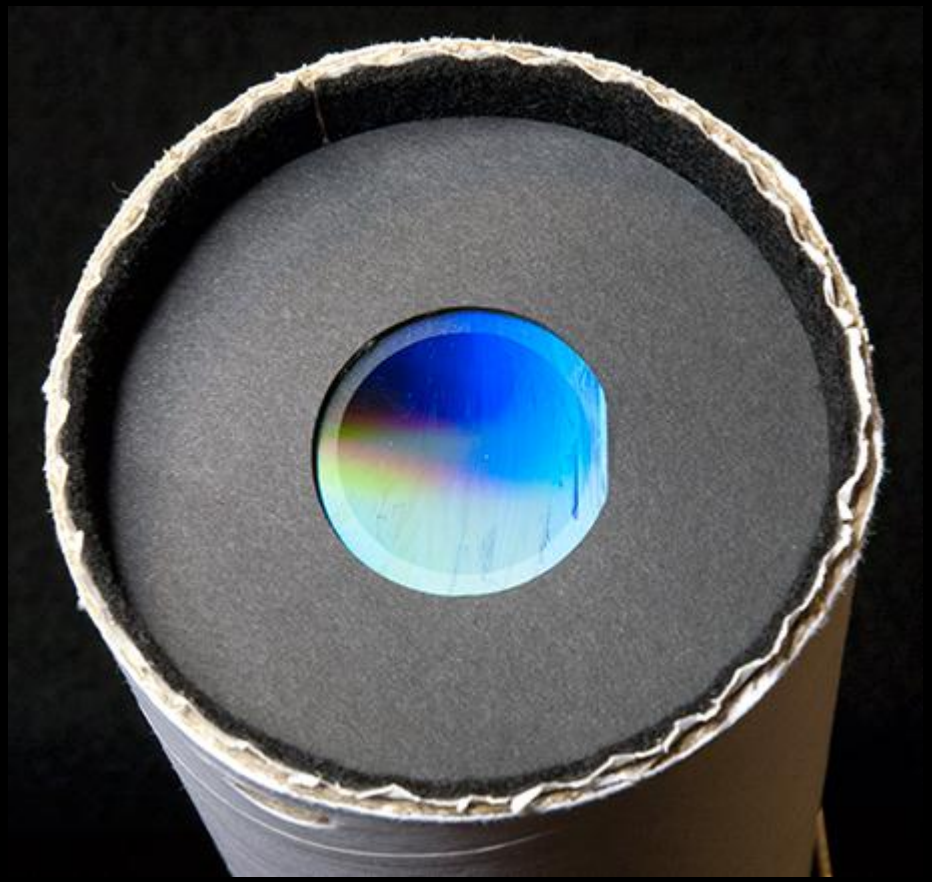
Do NOT look directly at the Sun

Solar Screwdriver CD Spectroscope

Black felt in side the tube

- CD is a >600 line/mm transmission grating



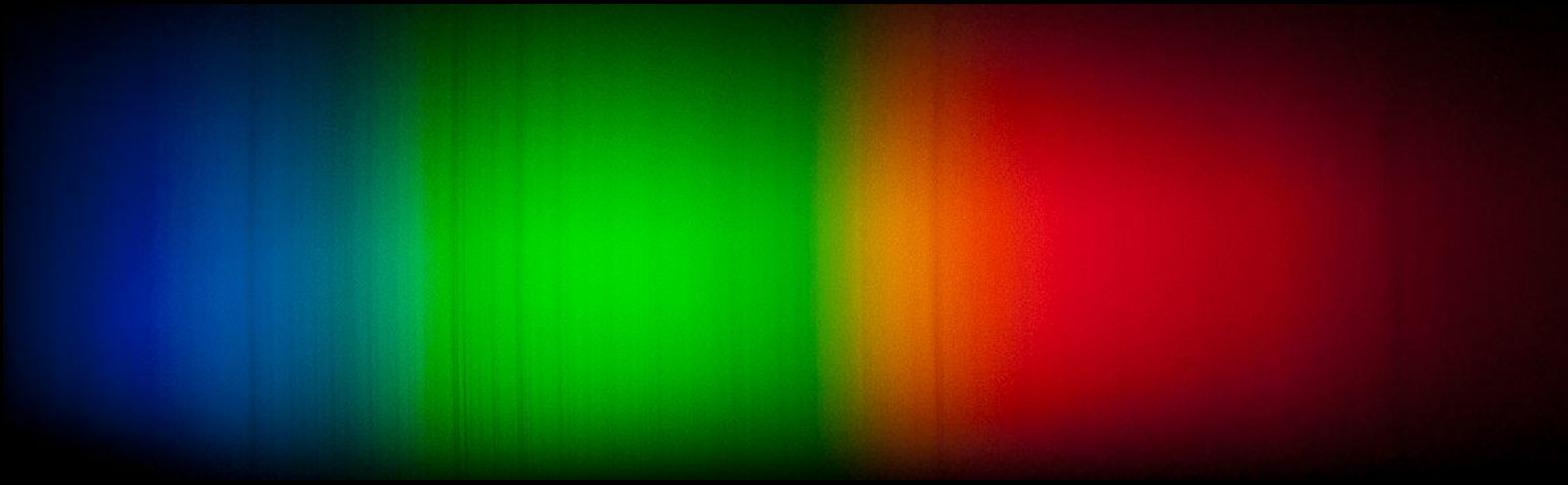


Do NOT look directly at the Sun

Solar Spectrum

Screwdriver CD Spectroscope

- Dark absorption lines
- Camera focus on green part of the spectrum



3 Types of Spectra

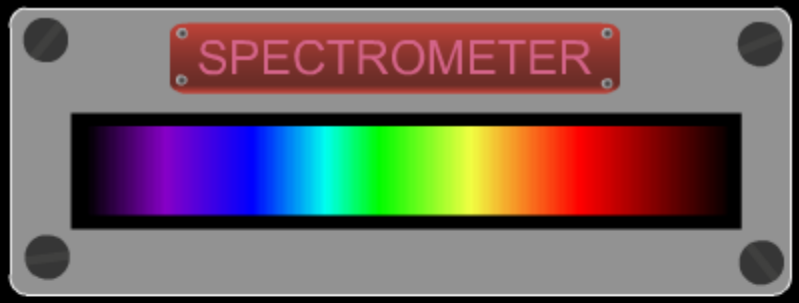
Kirchoff radiation continuous law

Type of Spectrum	Photographic example
Continuous (or continuum)	
Absorption (dark line)	
Emission (bright line)	

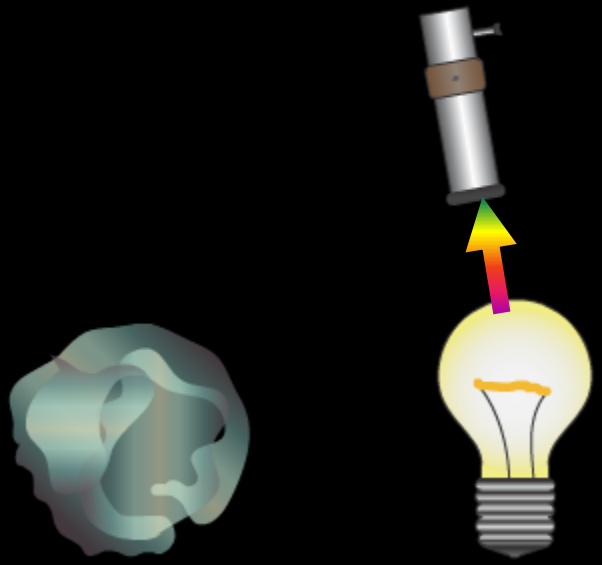
Credit: outreach.atnf.csiro.au/education/senior/astrophysics/spectroscopyhow.html

Continuous Spectrum

Kirchoff radiation continuous law



Drag the telescope around to see how the three main types of spectra (continuous, absorption, and emission) are obtained from a cold, thin gas cloud and an incandescent lightbulb in space.



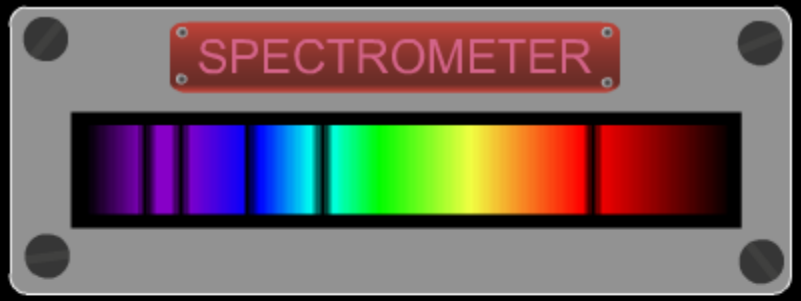
Star atmosphere, Nebula, etc.

Star

Credit Nebraska Astronomy Applet Project astro.unl.edu

Absorption Spectrum

Kirchoff radiation absorption law



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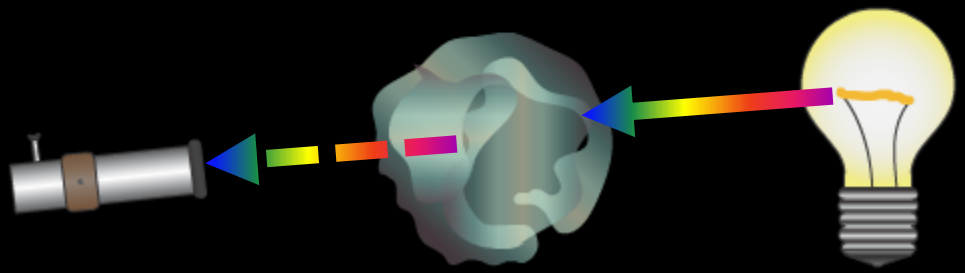
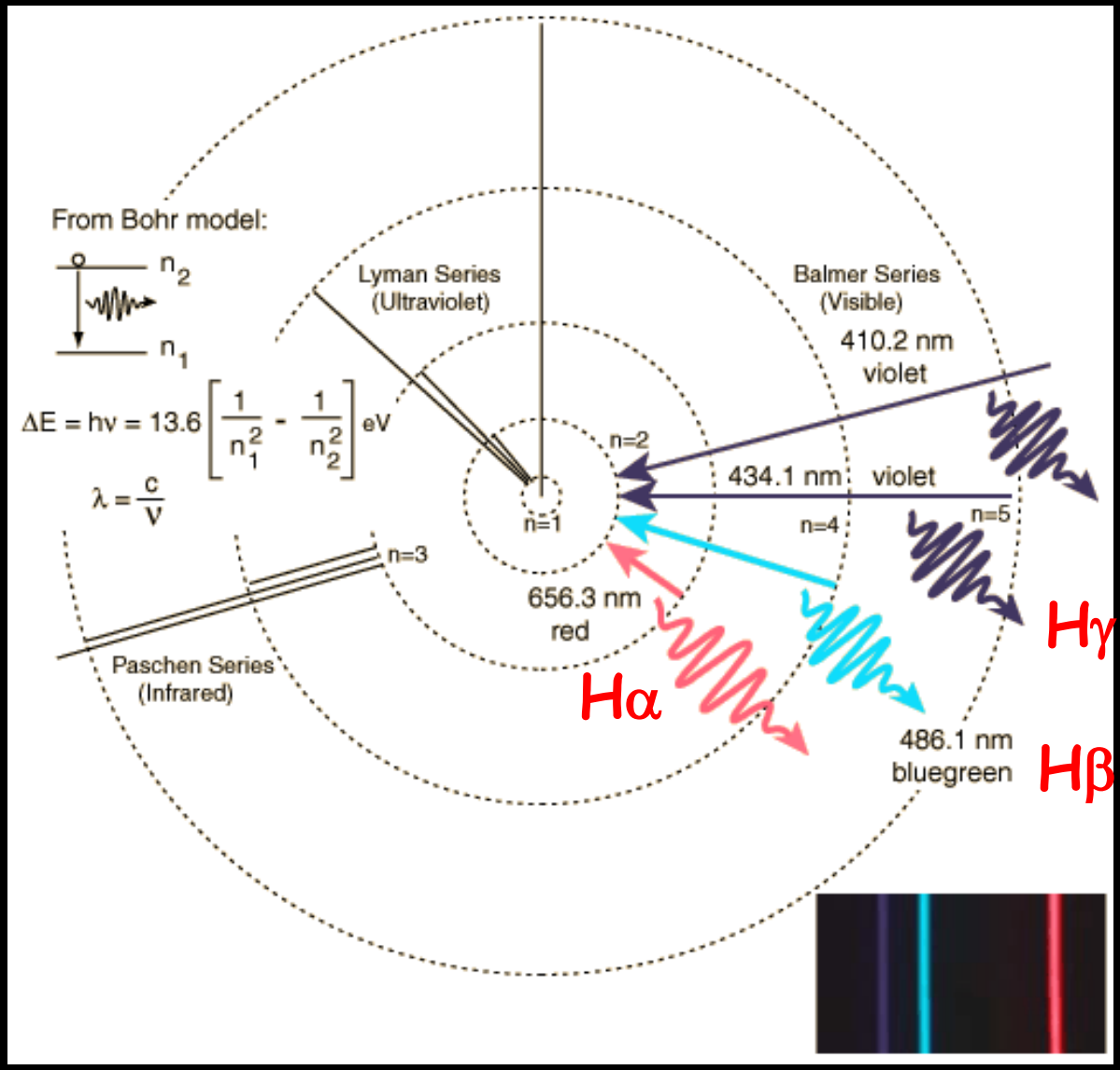


Star atmosphere, Nebula, etc.

Star

Credit Nebraska Astronomy Applet Project astro.unl.edu

Hydrogen Atom Energy Levels



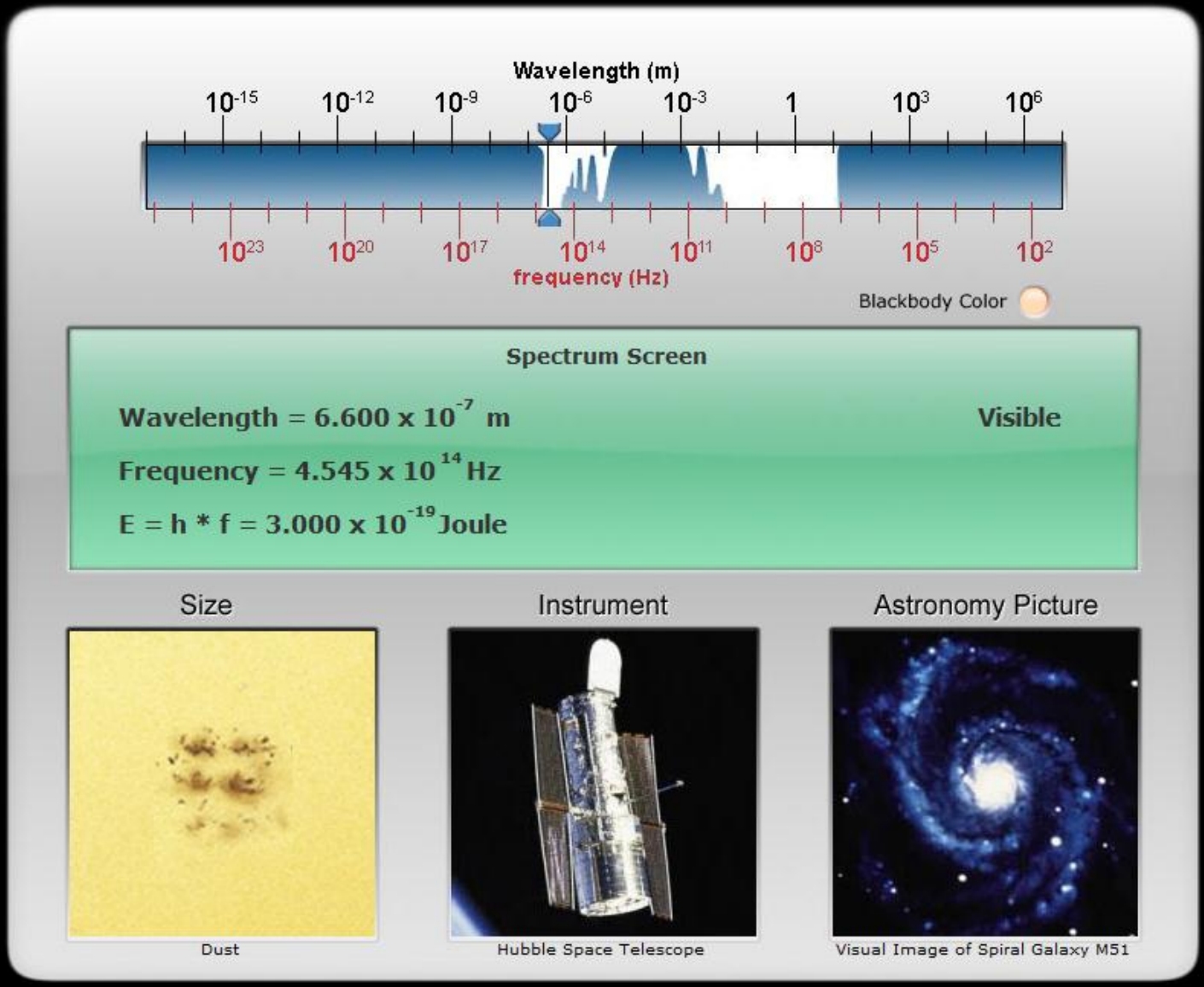
Credit: HyperPhysics hyperphysics.phy-astr.gsu.edu/hbase/hframe.html

Element Spectral Patterns

Each element has unique spectral absorption/emission lines

- Each element has unique number of
  - Electrons
  - Protons
  - Neutrons
- Each element has unique set of energy levels
- Energy levels maps into unique set of spectral absorption/emission lines

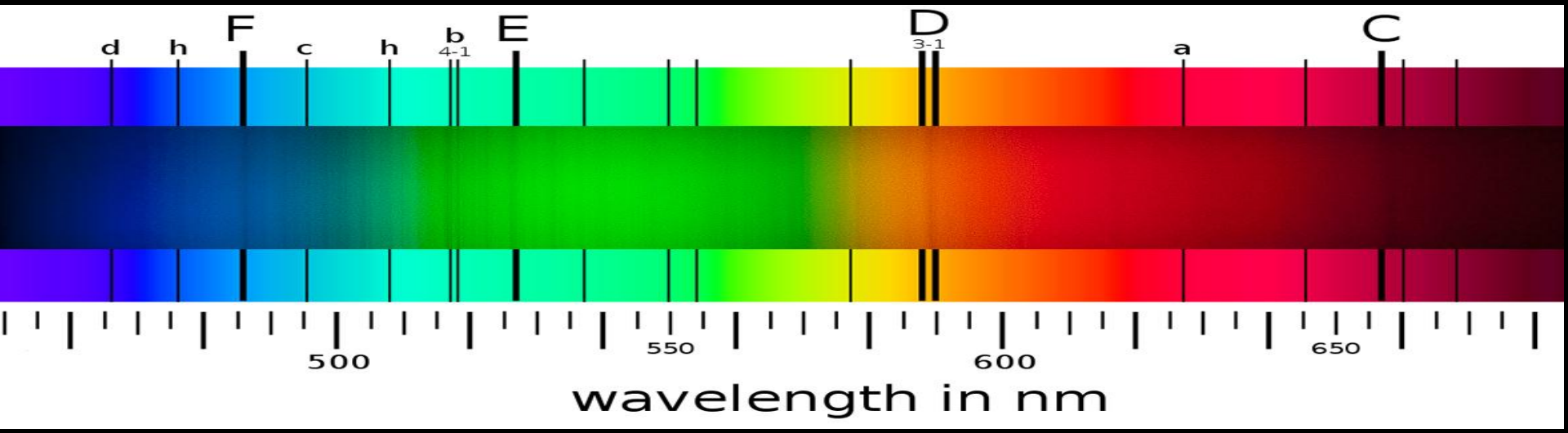
Electromagnetic Spectrum



Credit: astro.unl.edu

Screwdriver CD Sun Spectrum

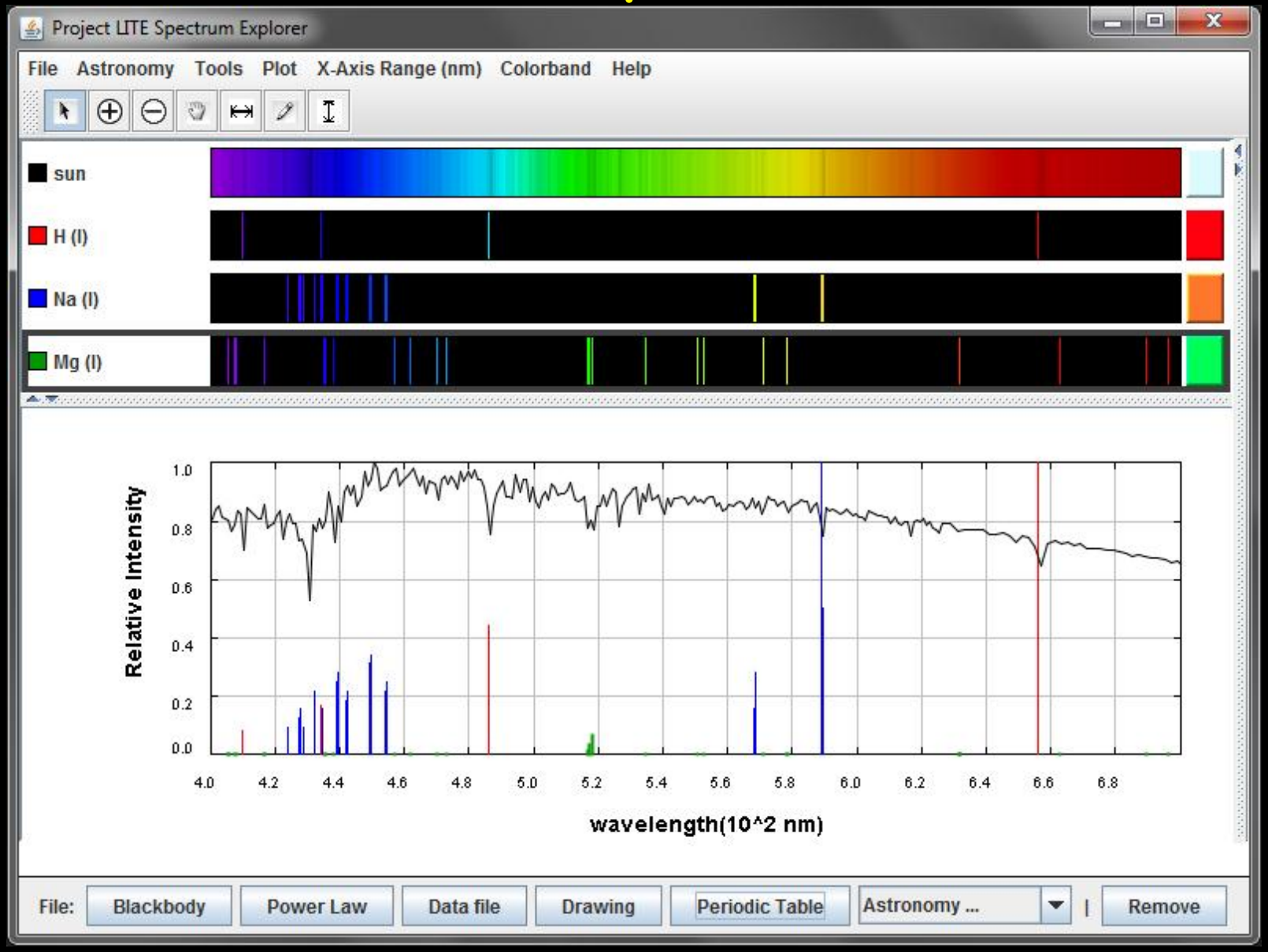
Fraunhofer absorption lines



- C line is hydrogen alpha (Hα)
- $D_{1,2}$ lines are sodium doublet (Na)
- E line is iron (Fe)
- $B_{1,2,4}$ lines are Magnesium triple (Mg)
- F line is hydrogen beta (Hβ)

Credit: Fraunhofer Lines en.wikipedia.org/wiki/Fraunhofer_line

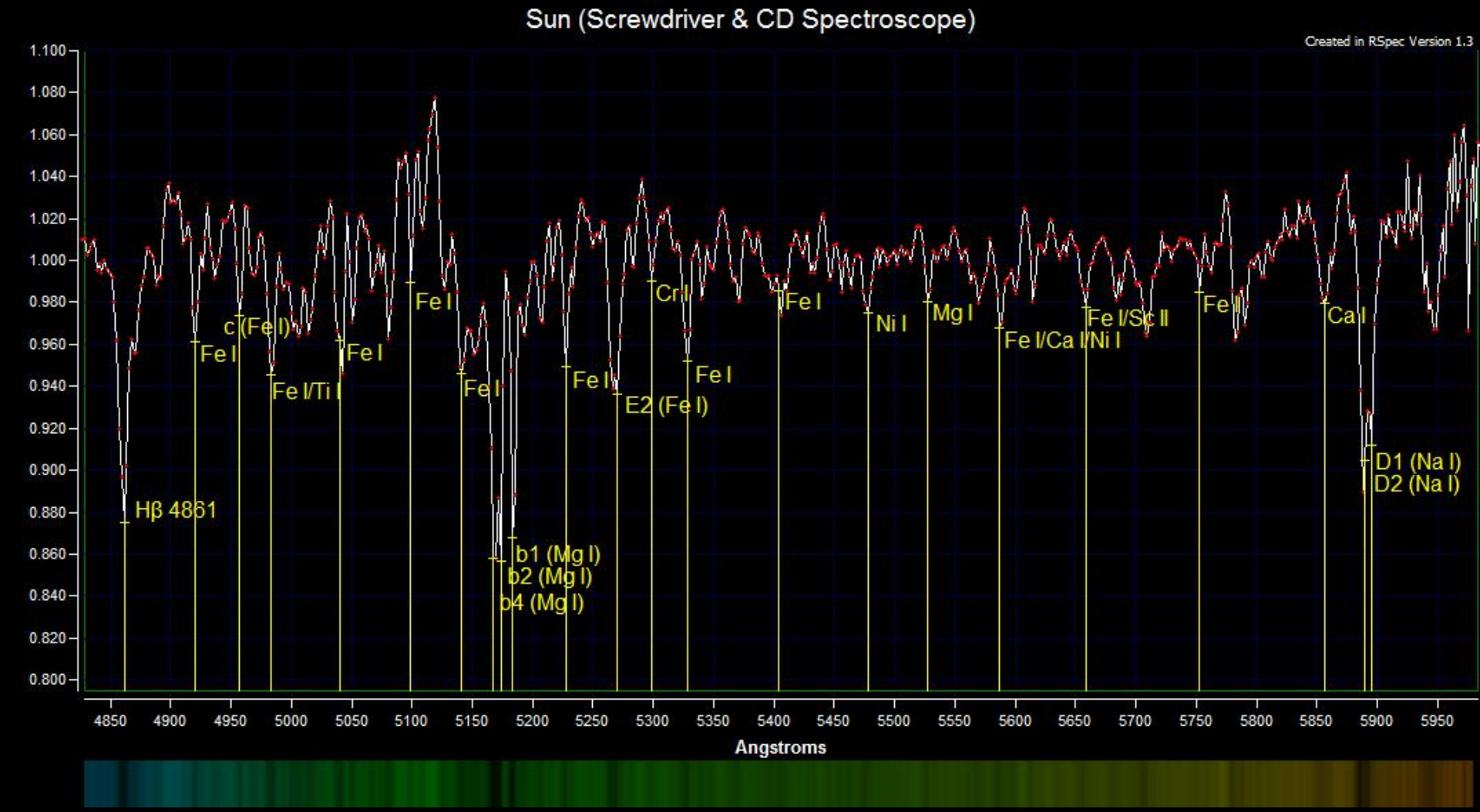
Solar Spectrum



Credit: Spectrum Explorer lite.bu.edu/spex/v3/

Screwdriver CD Sun Spectrum

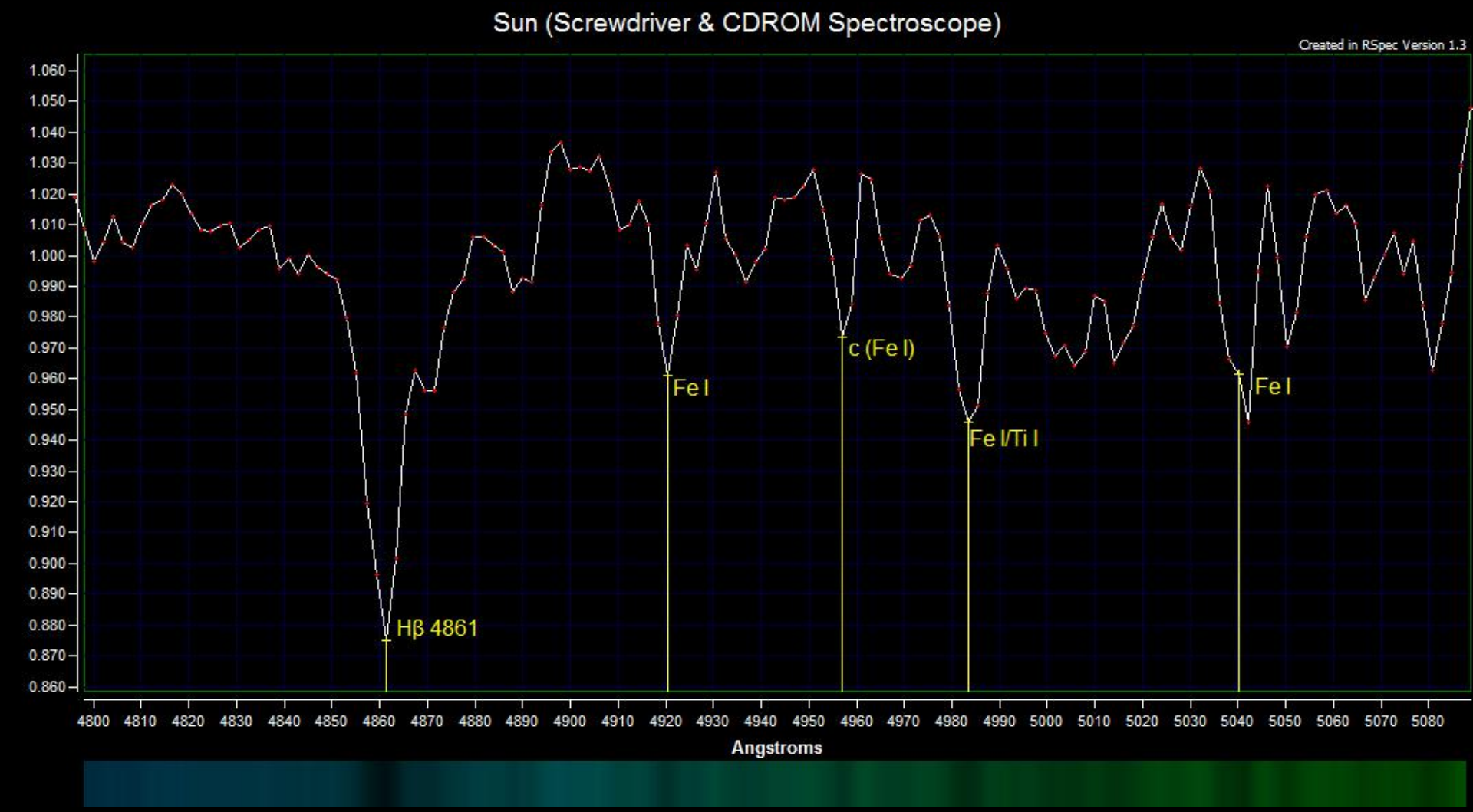
Absorption lines from Hβ to Na doublet



Rspec Software www.rspec-astro.com/

Screwdriver CD Sun Spectrum

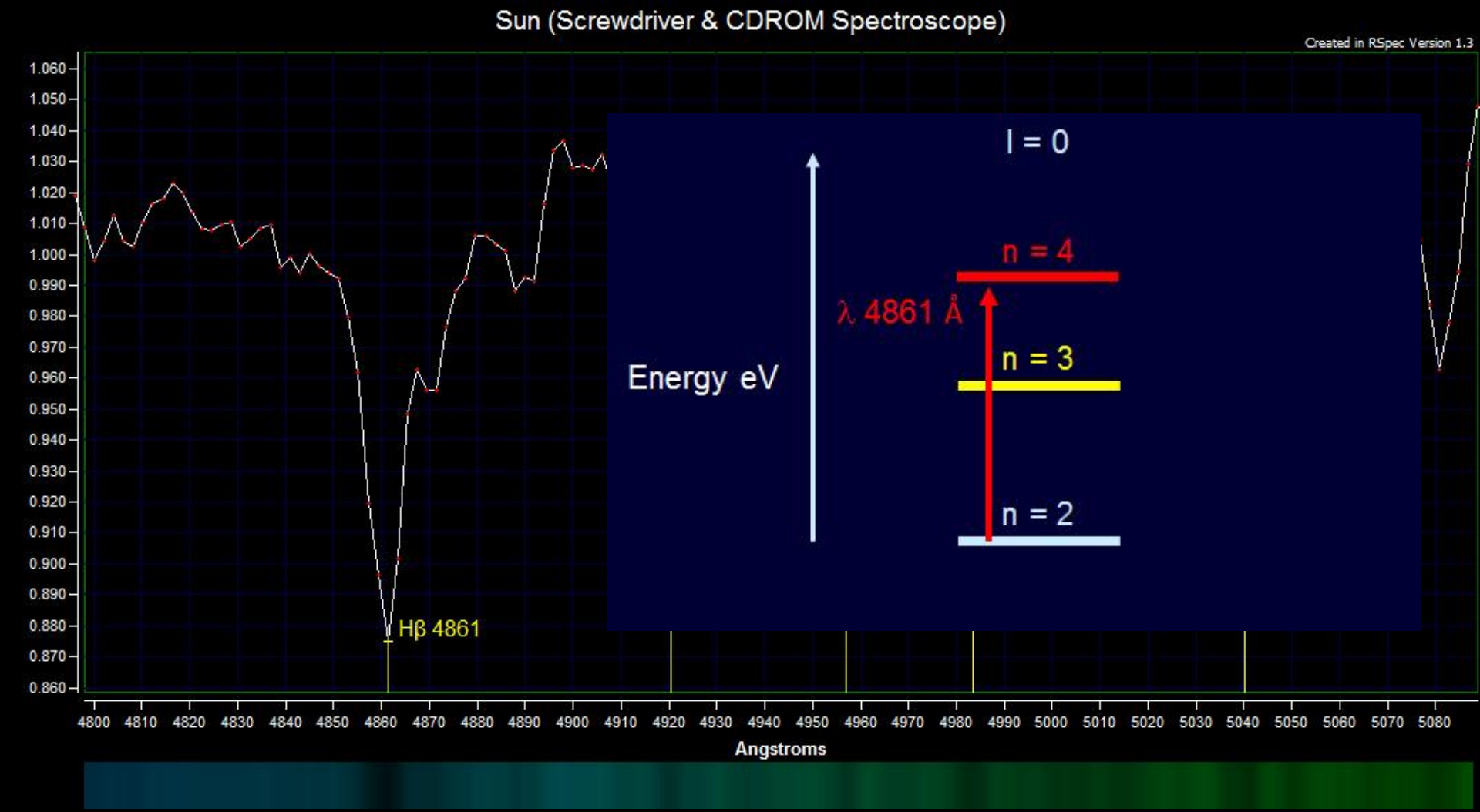
Hβ absorption line



Rspec Software www.rspec-astro.com/

Screwdriver CD Sun Spectrum

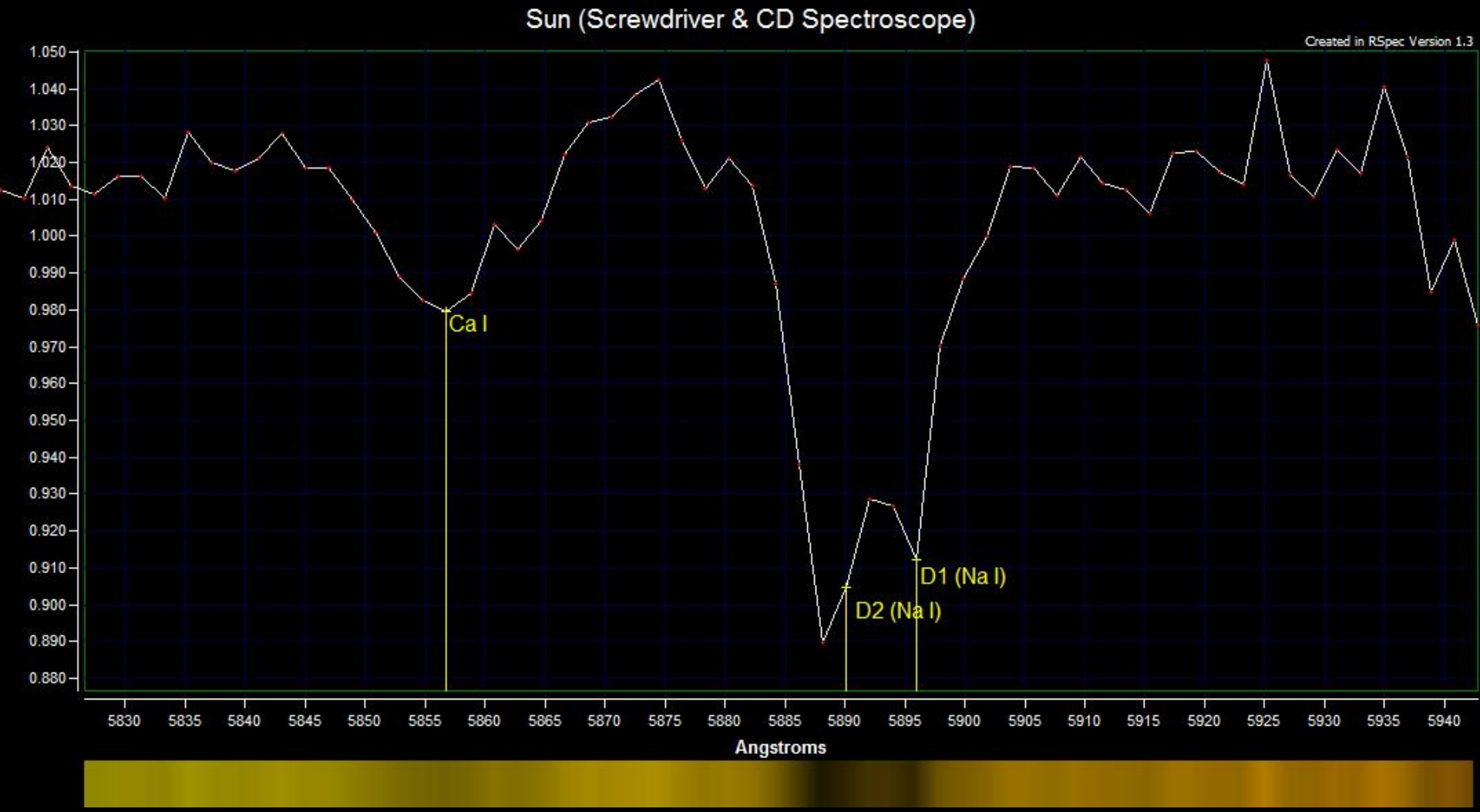
Hβ absorption line is a transition from n = 2 to n = 4



Rspec Software www.rspec-astro.com/

Screwdriver CD Sun Spectrum

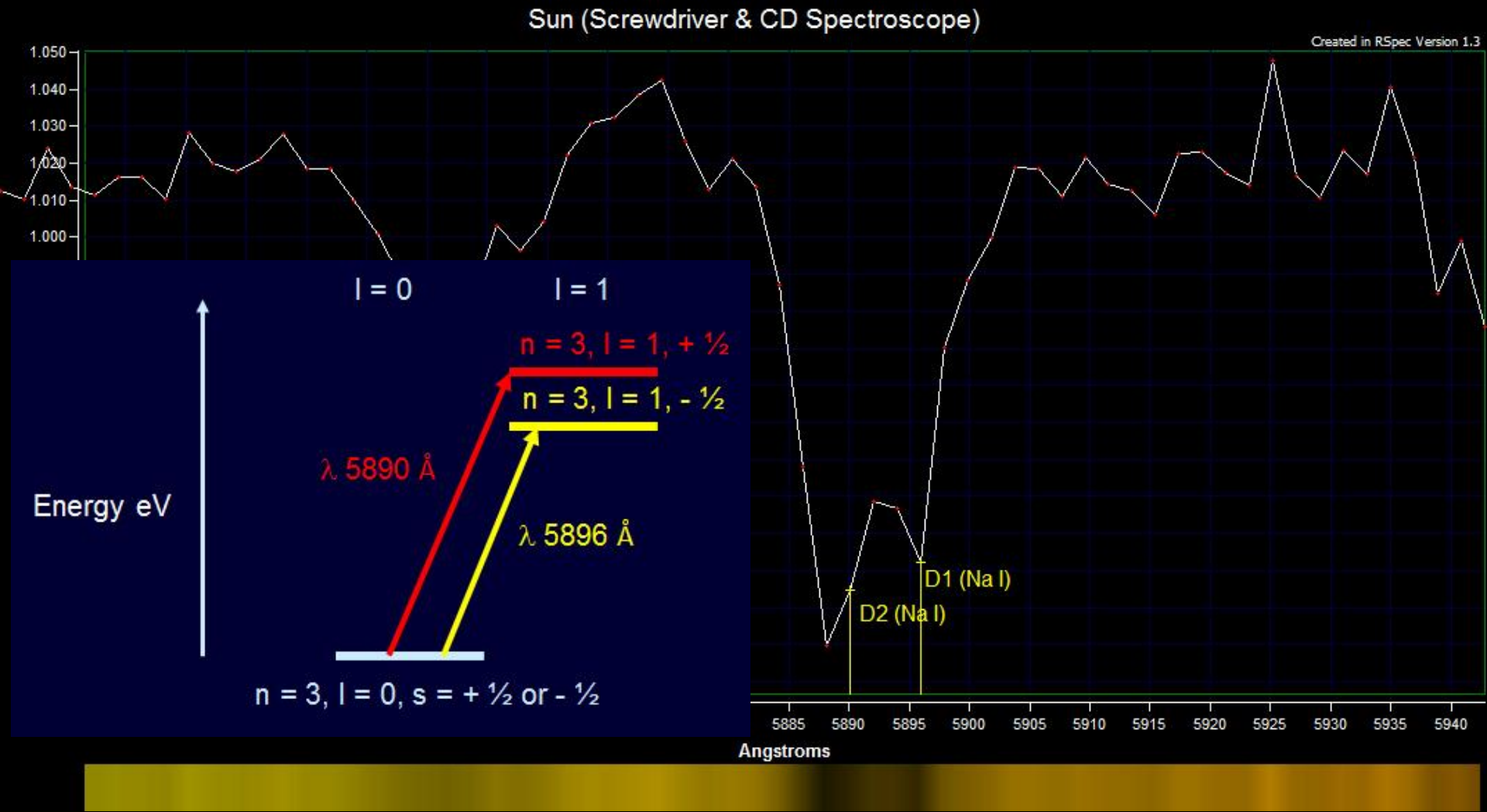
Na doublet absorption lines



Rspec Software www.rspec-astro.com/

Screwdriver CD Sun Spectrum

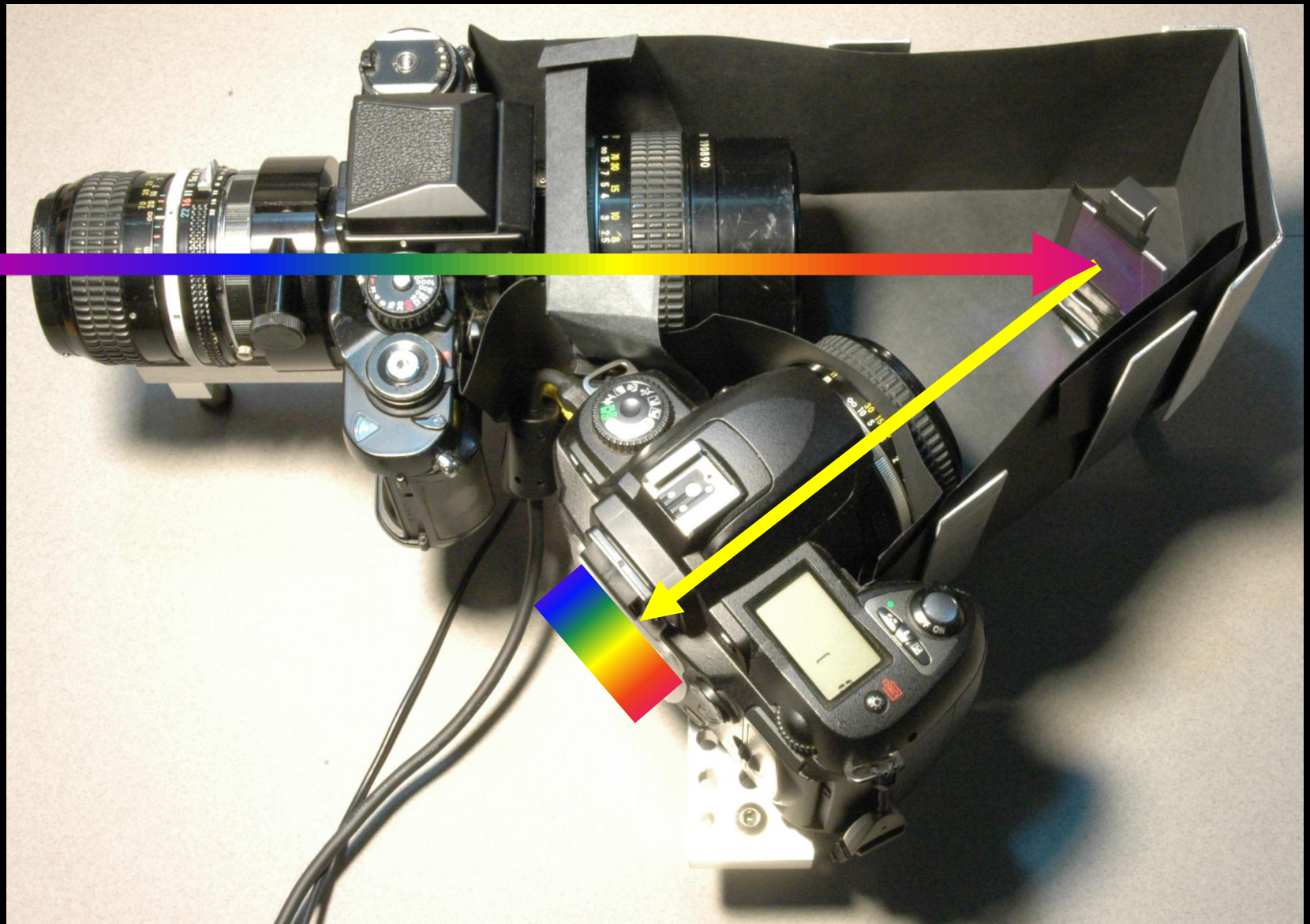
Na doublet absorption lines



Rspec Software www.rspec-astro.com/

38° Classical Spectrograph

Nikon Camera Parts DVD Spectrograph



Fraunhofer Solar Lines

DVD Spectrograph

G: Ca, Fe, H_γ

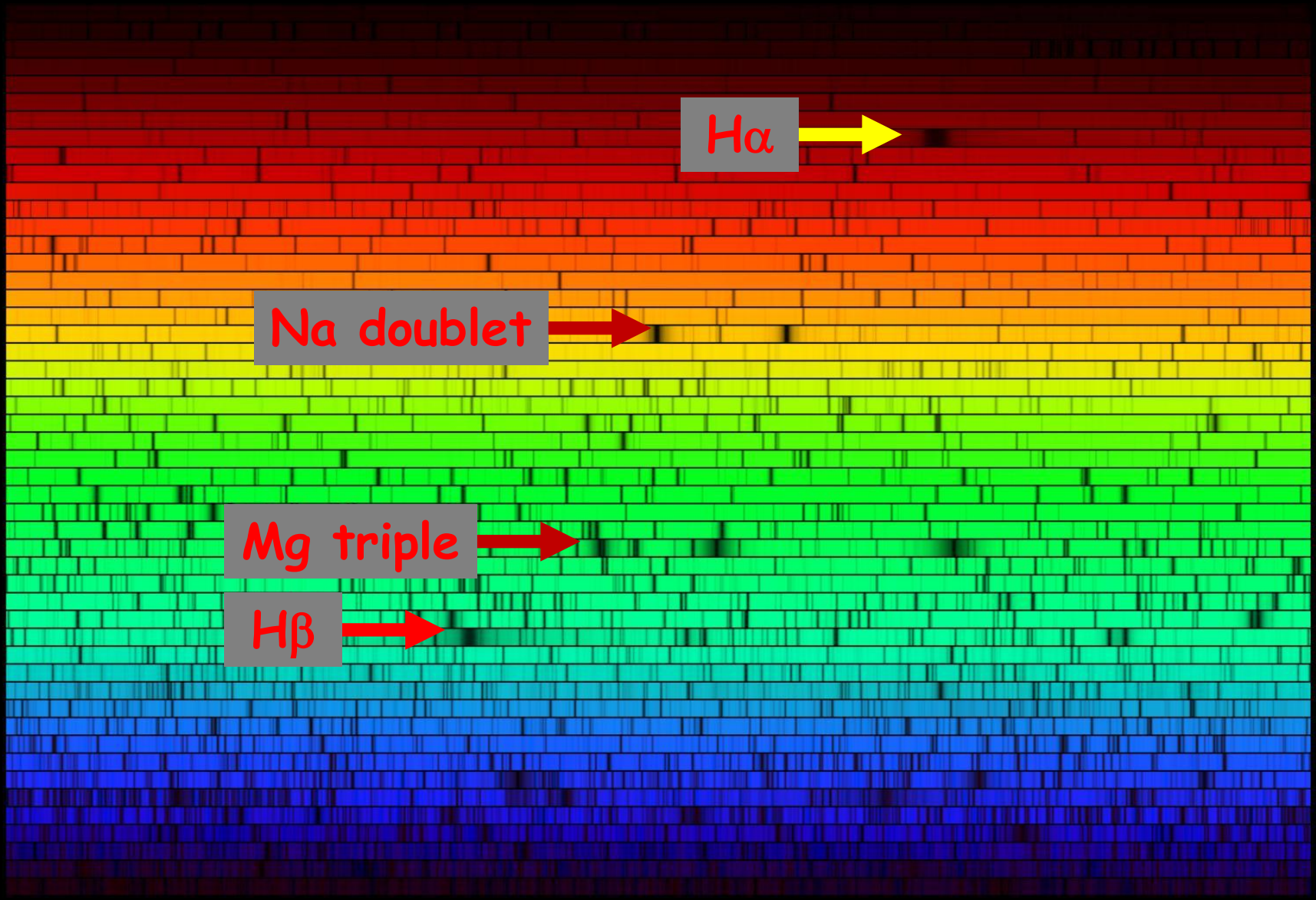
F: H_β

b: Mg

E: Fe

D: Na

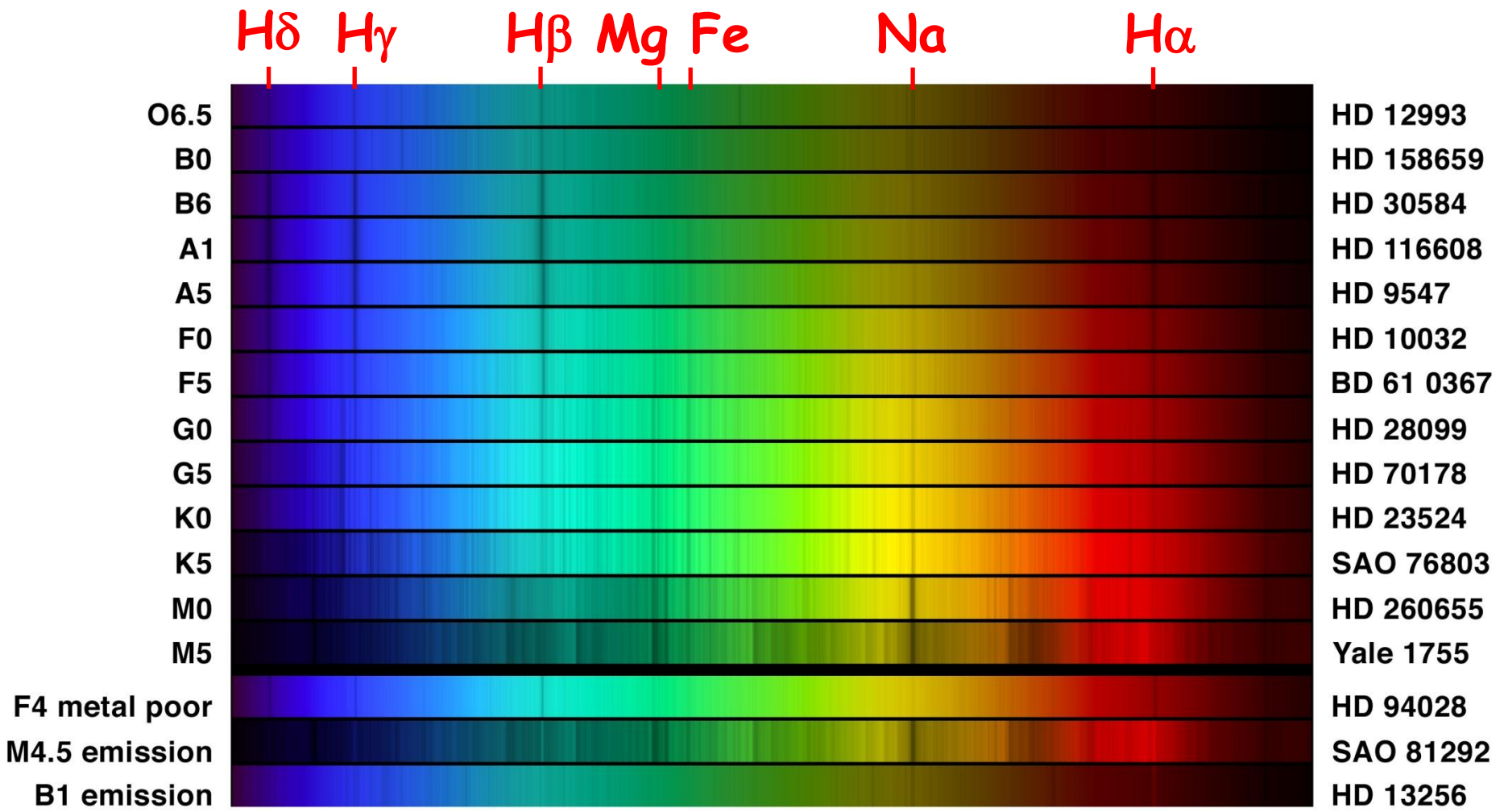
High Resolution Solar Spectrum



Credit: N.A.Sharp, NOAO/NSO/Kitt Peak FTS/AURA/NSF www.noao.edu/image_gallery/html/im0600.html

Spectral Classification

OBAFGKM



Credit: NOAO/AURA/NSF http://www.noao.edu/image_gallery/html/im0649.html

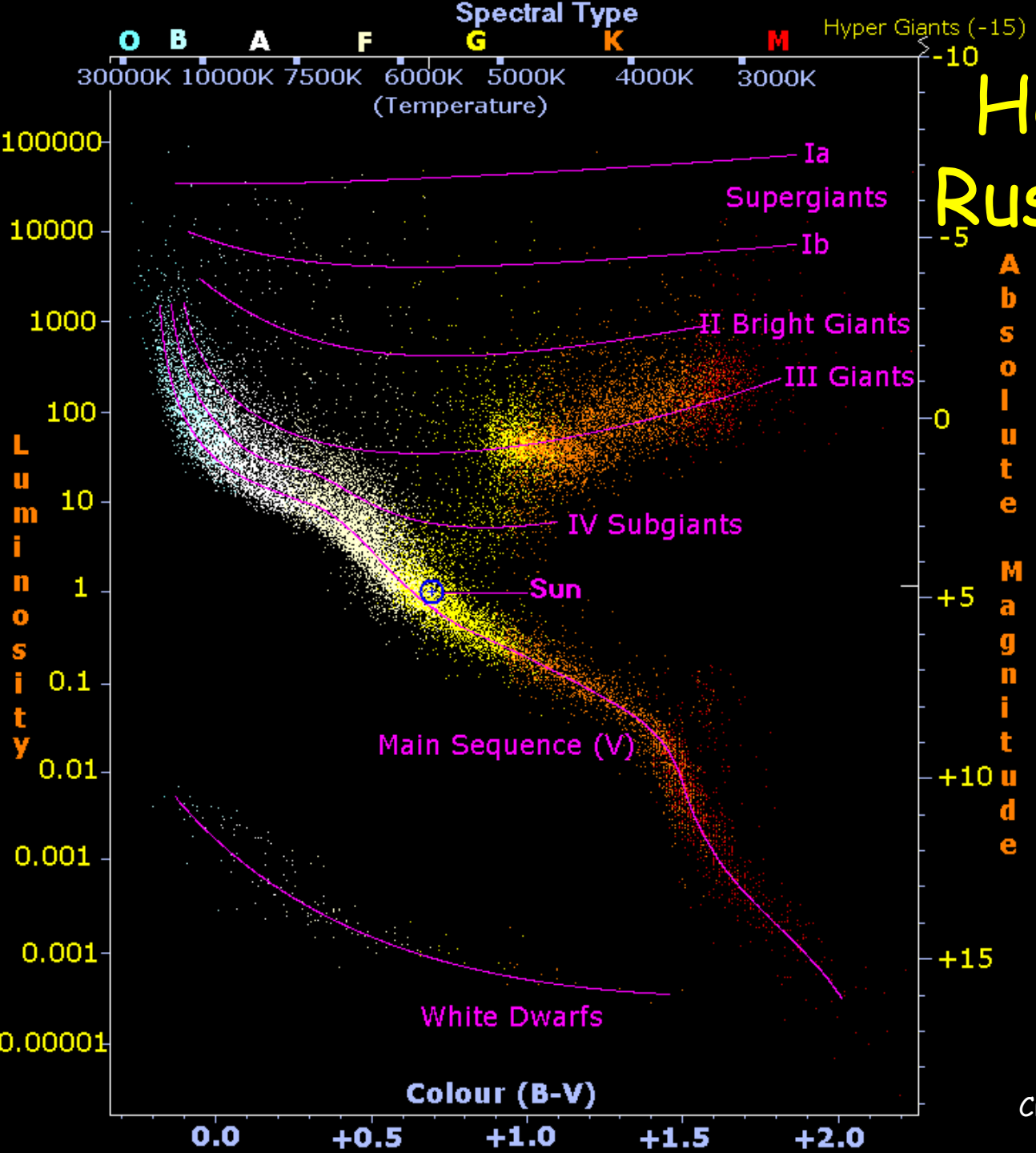
Star Spectral Classification

OBAFGKM

Spectral Class	Effective Temperature (K)	Colour	H Balmer Features	Other Features	M/M_{Sun}	R/R_{Sun}	L/L_{Sun}	Main Sequence Lifespan
O	28,000 - 50,000	Blue	weak	ionised He^+ lines, strong UV continuum	20 - 60	9 - 15	90,000 - 800,000	1 - 10 Myr
B	10,000 - 28,000	Blue-white	medium	neutral He lines	3 - 18	3.0 - 8.4	95 - 52,000	11 - 400 Myr
A	7,500 - 10,000	White	strong	strong H lines, ionised metal lines	2.0 - 3.0	1.7 - 2.7	8 -55	400 Myr - 3 Gyr
F	6,000 - 7,500	White-yellow	medium	weak ionised Ca^+	1.1 - 1.6	1.2 - 1.6	2.0 - 6.5	3 - 7 Gyr
G	4,900 - 6,000	Yellow	weak	ionised Ca^+, metal lines	0.85 - 1.1	0.85 - 1.1	0.66 - 1.5	7 - 15 Gyr
K	3,500 - 4,900	Orange	very weak	Ca^+, Fe, strong molecules, CH, CN	0.65 - 0.85	0.65 - 0.85	0.10 - 0.42	17 Gyr
M	2,000 - 3,500	Red	very weak	molecular lines, eg TiO, neutral metals	0.08 - 0.05	0.17 - 0.63	0.001 - 0.08	56 Gyr
L?	<2,000	Tentative new (2000) classification for very low mass stars.			<0.08	May or may not be fusing H in cores?		

Credit: outreach.atnf.csiro.au/education/senior/astrophysics/spectral_class.html

Hertzsprung-Russell Diagram

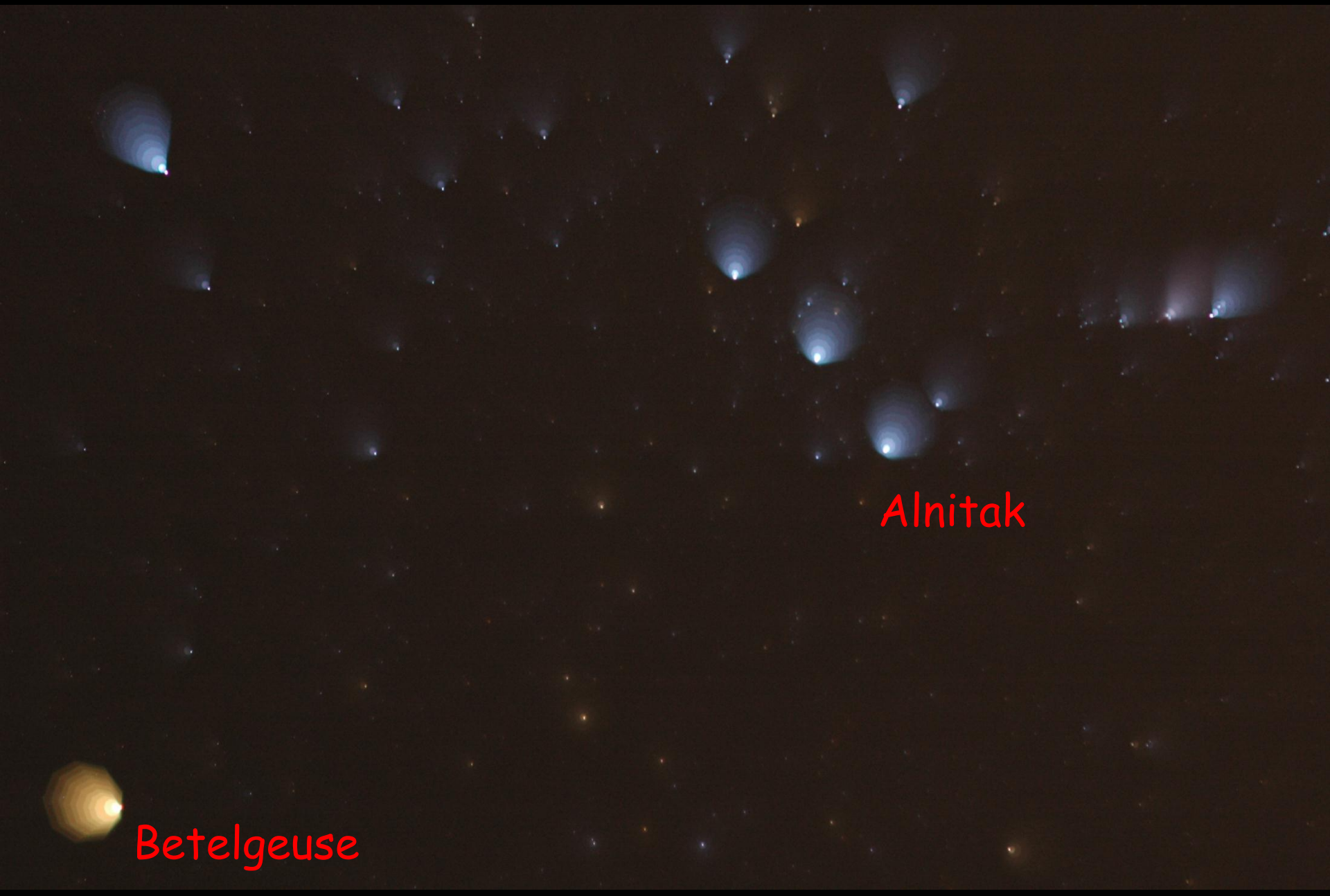


22,000 stars from the Hipparcos Catalogue + 1,000 Low-lum.

Credit: en.wikipedia.org/wiki/HR_diagram

Orion

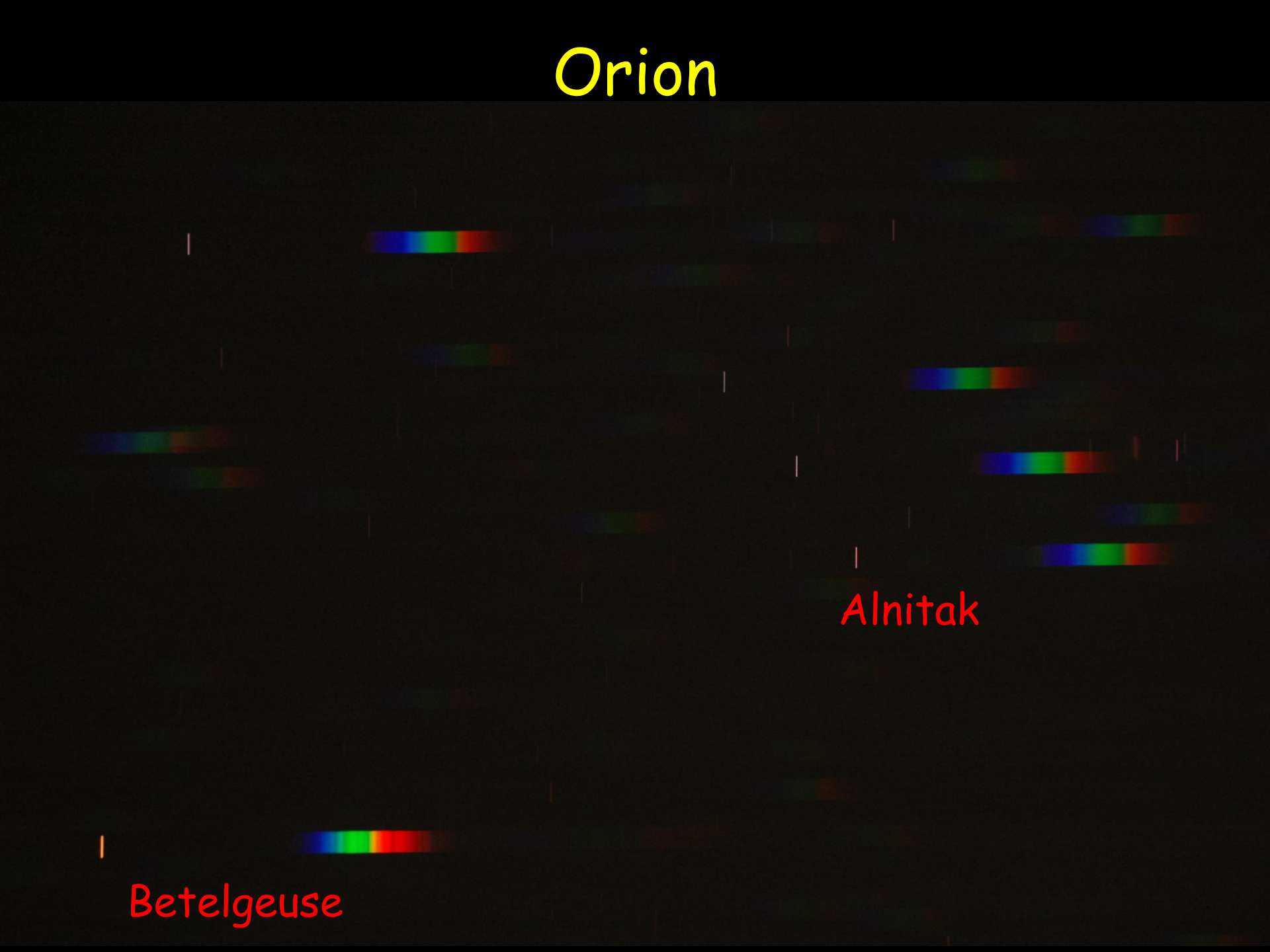
Orion



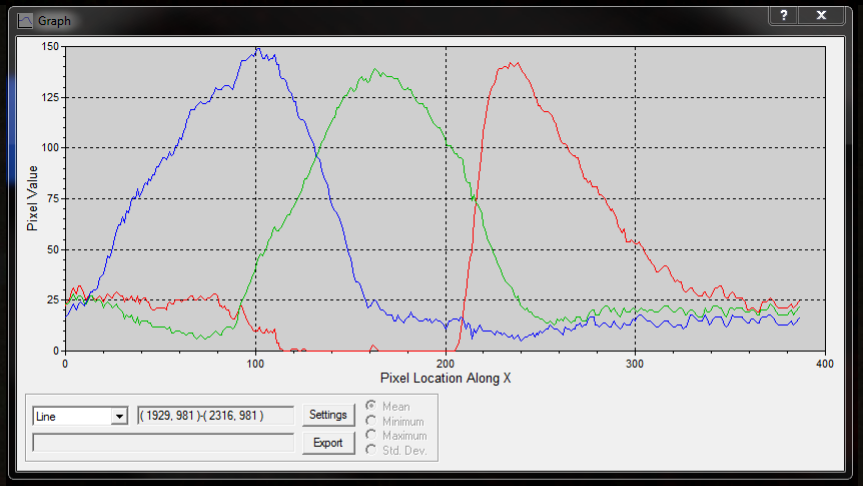
Star Analyzer 100 on DSLR

100 lines/mm blaze grating

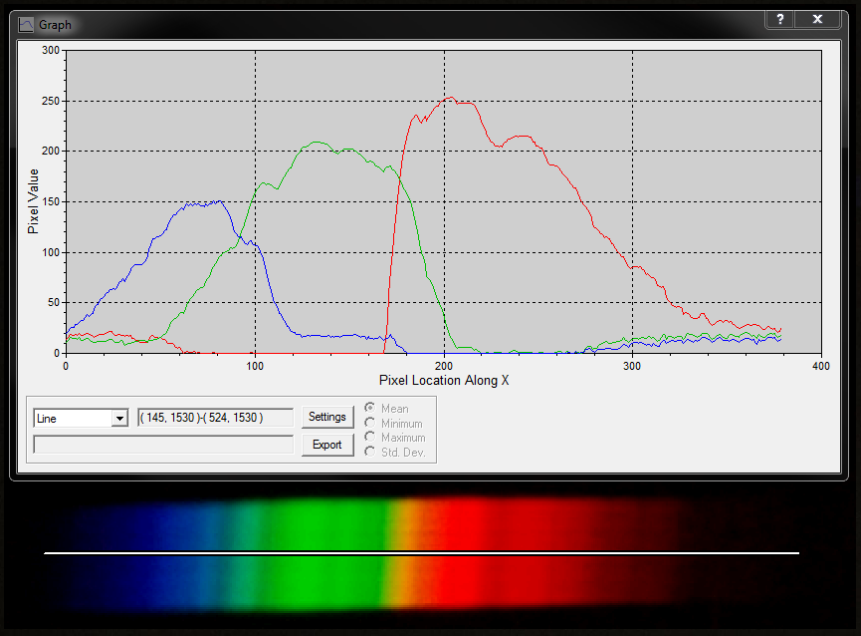
Orion



Orion



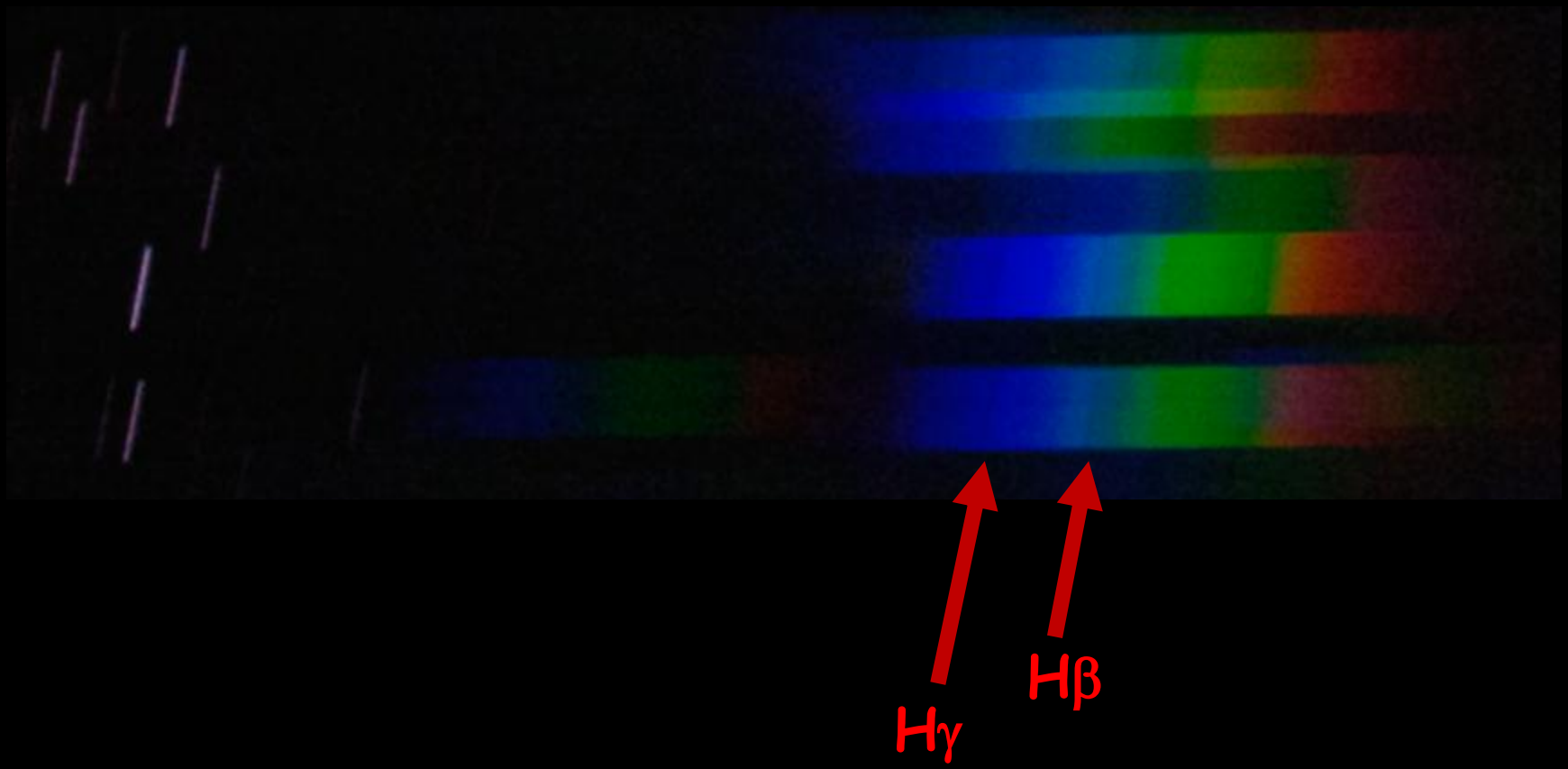
Alnitak O9.7Ib



Betelgeuse M2Iab

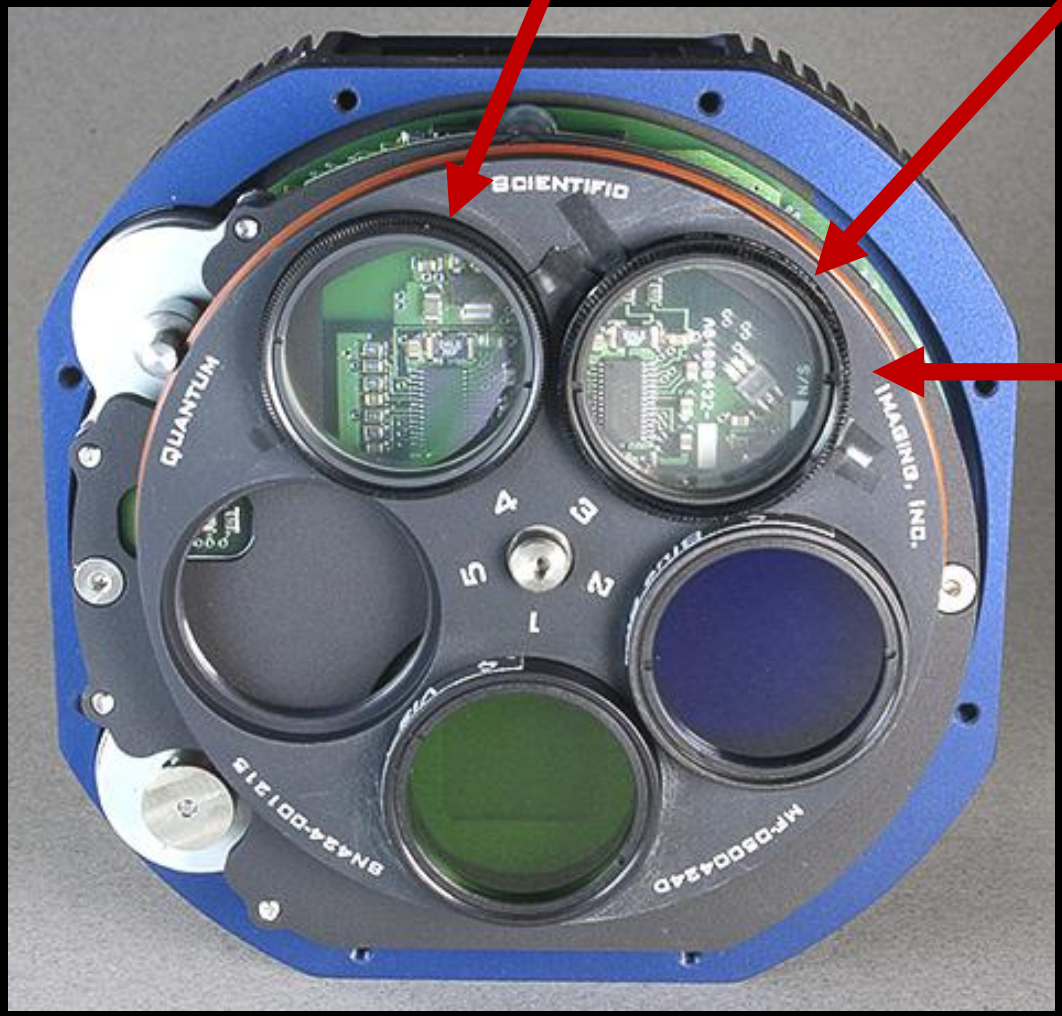
Pleiades M45 Stars Spectrum

SA100 on Nikkor 85mm lens, 1 minute image



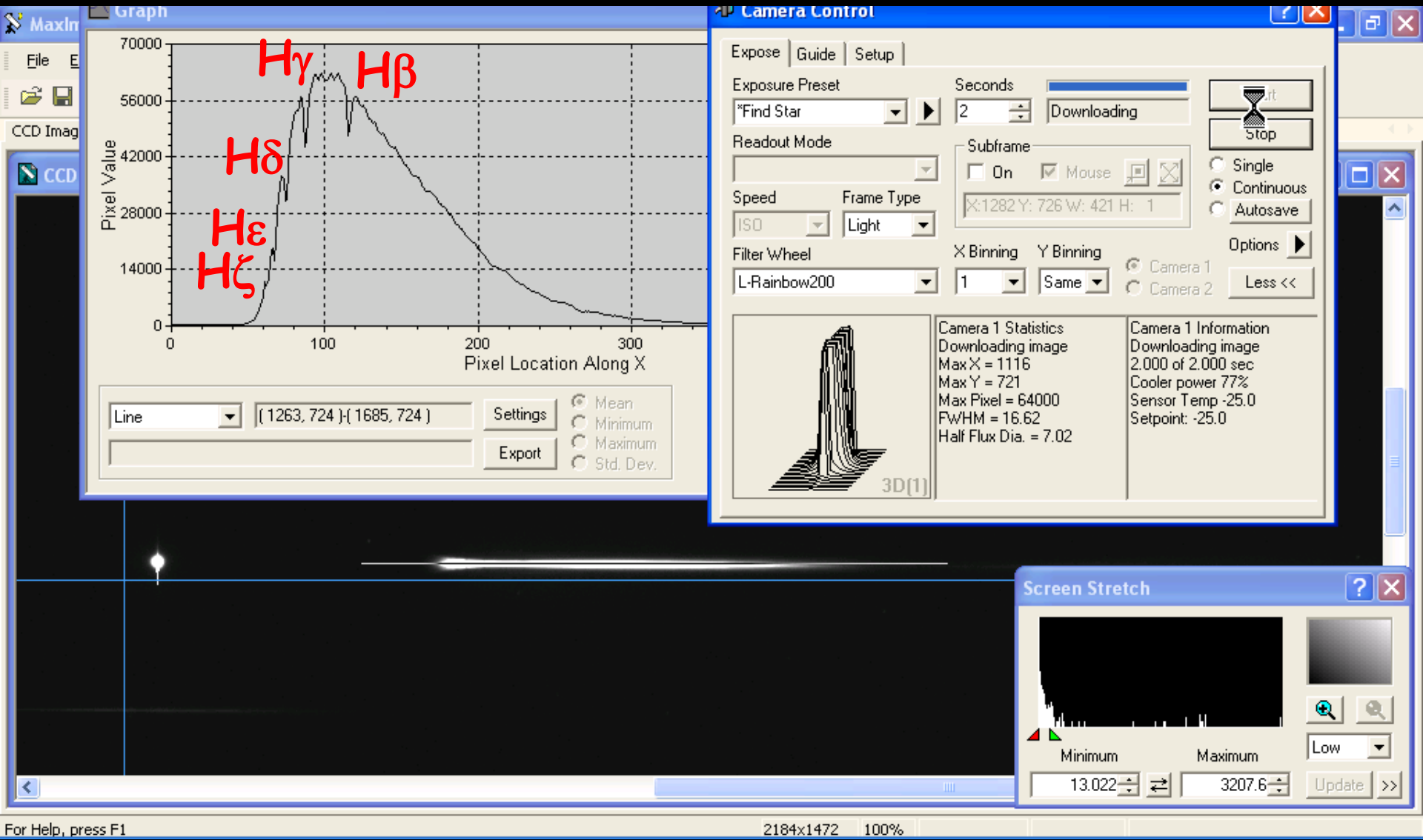
2 Gratings in QSI 532 Camera

Star Spectroscope 200 l/mm & Star Analyzer 100 (100 l/mm)



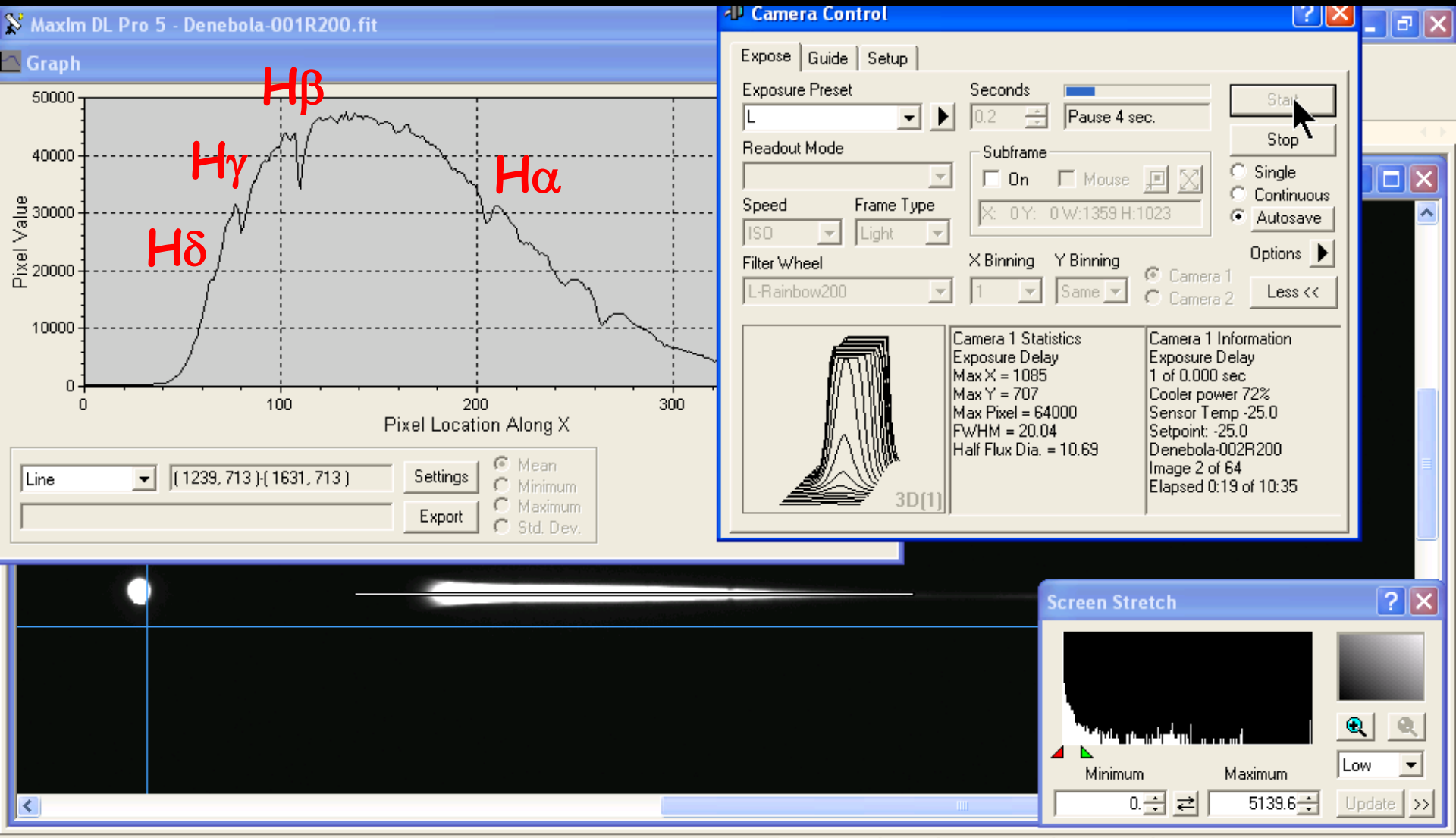
Denebola A3Va Spectrum

Star Spectroscope in QSI532 & NP127is



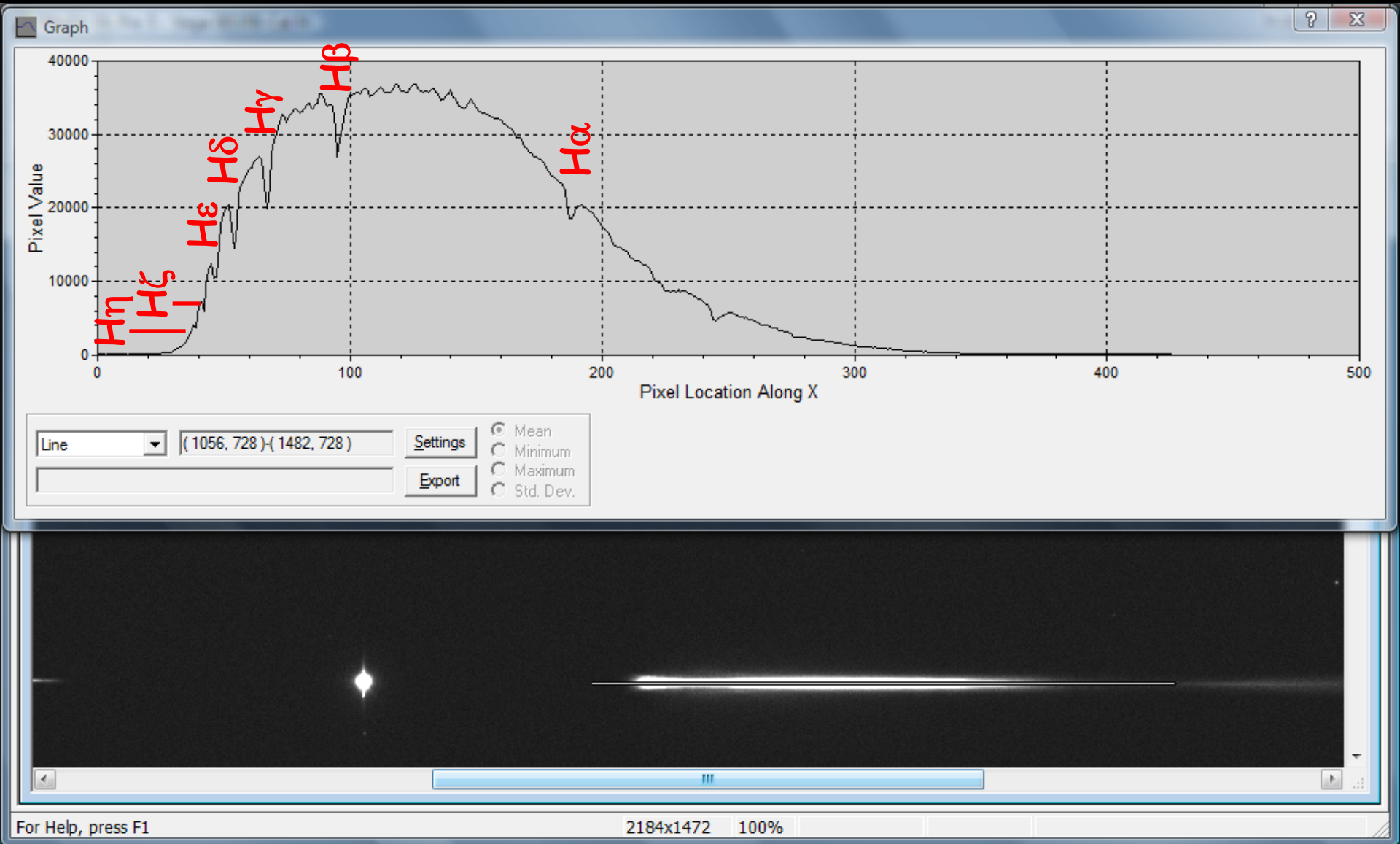
Denebola A3Va Spectrum

Star Spectroscope in QSI532 & NP127is



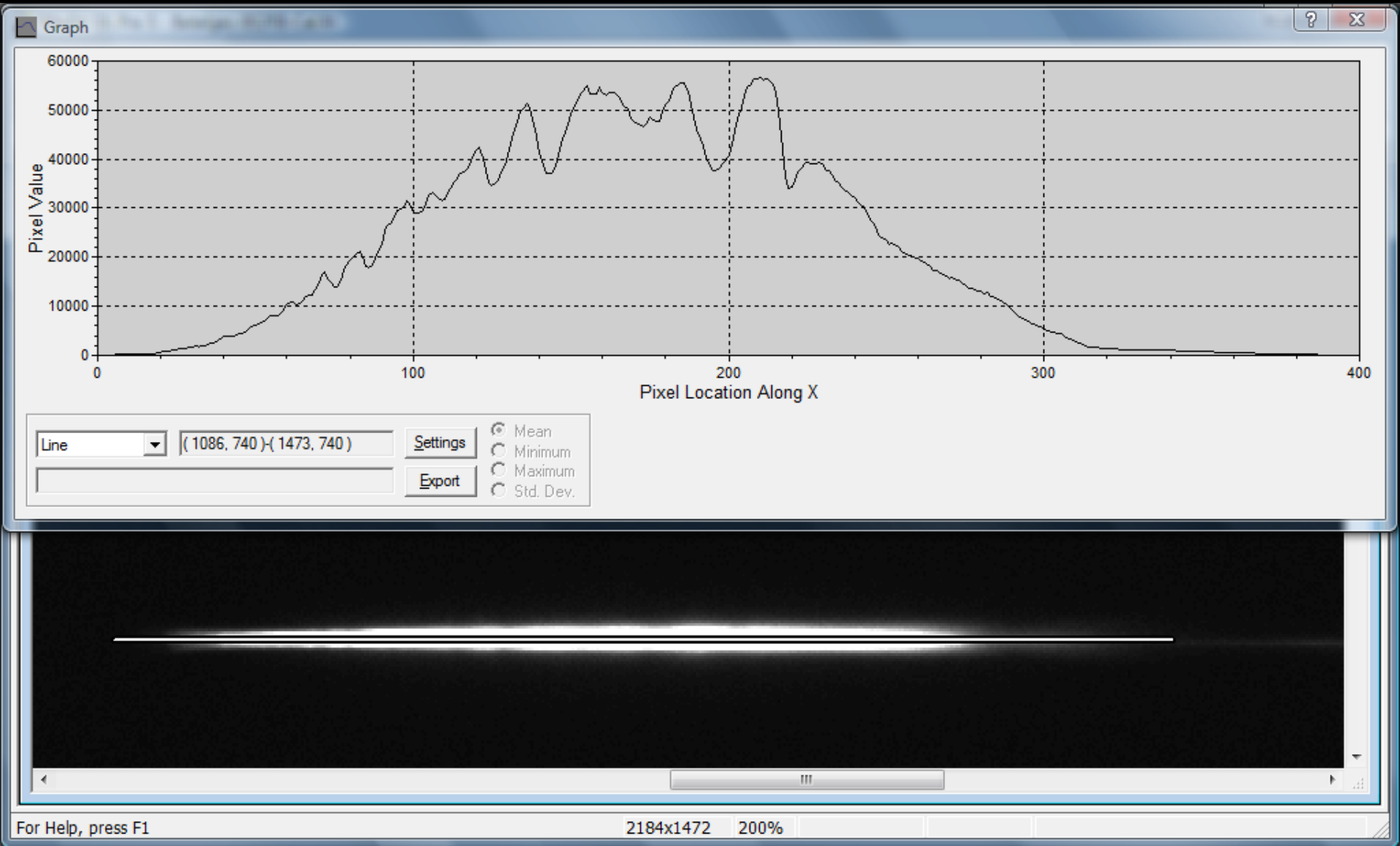
Vega Spectrum A0V

Star Spectroscope in QSI532 & NP127is



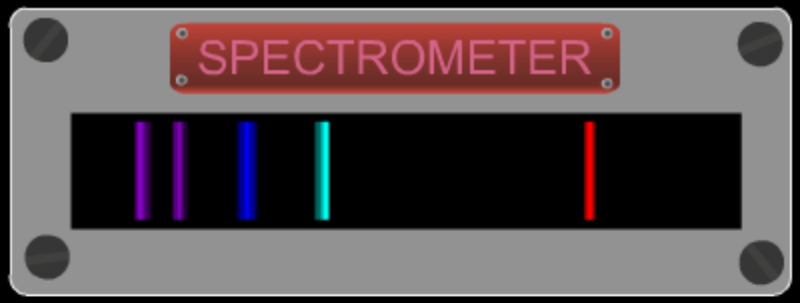
Betelgeuse M2Iab Spectrum

Star Spectroscope in QSI532 & NP127is



Emission Spectrum

Kirchoff radiation emission law



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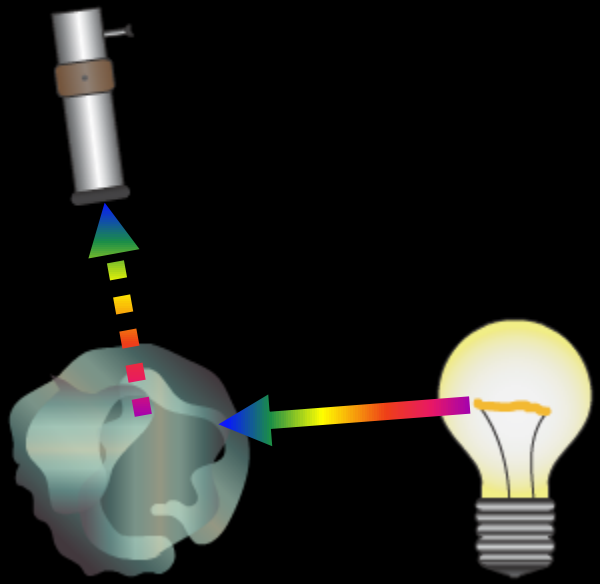


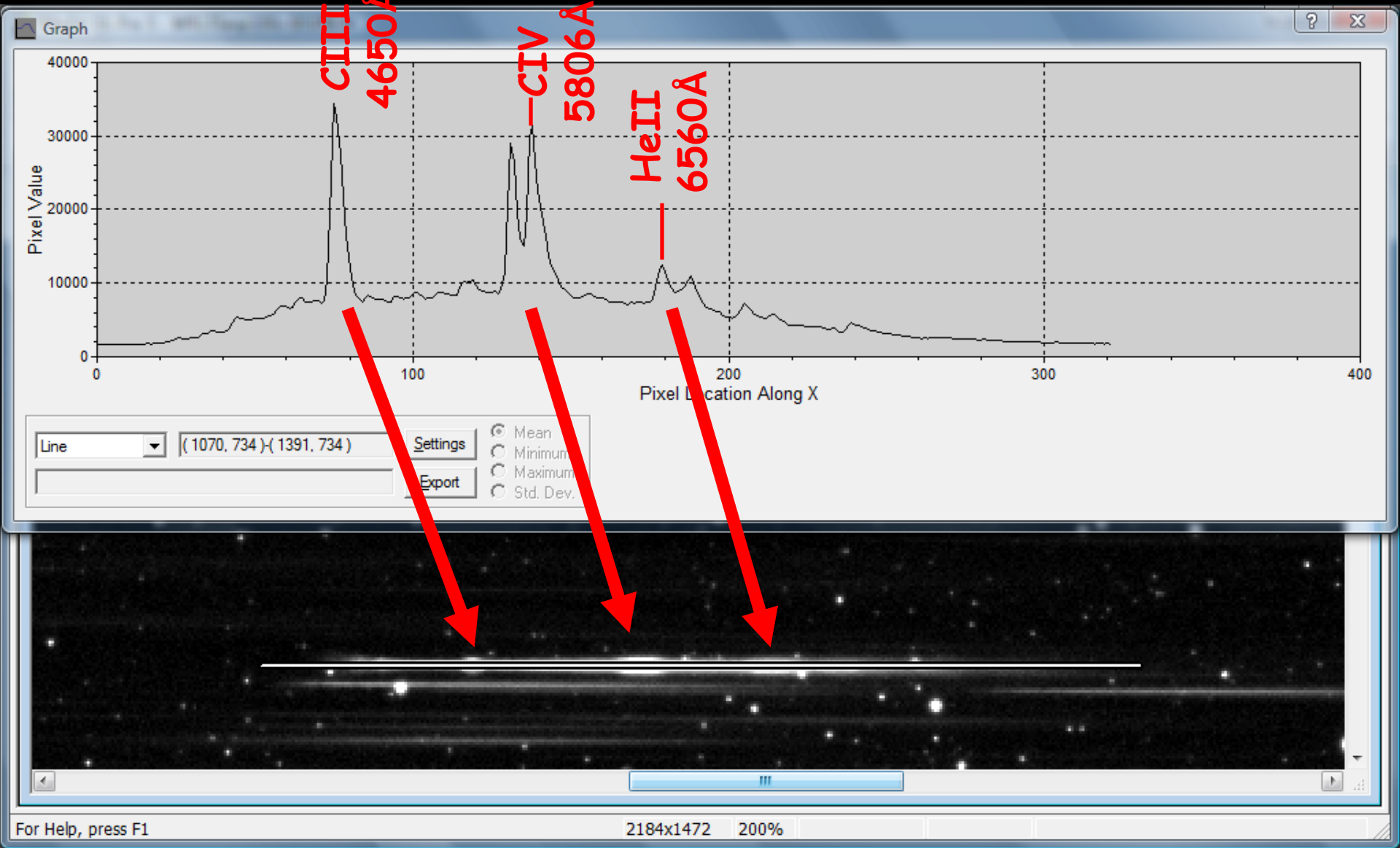
Star atmosphere, Nebula, etc.

Star

Credit Nebraska Astronomy Applet Project astro.unl.edu

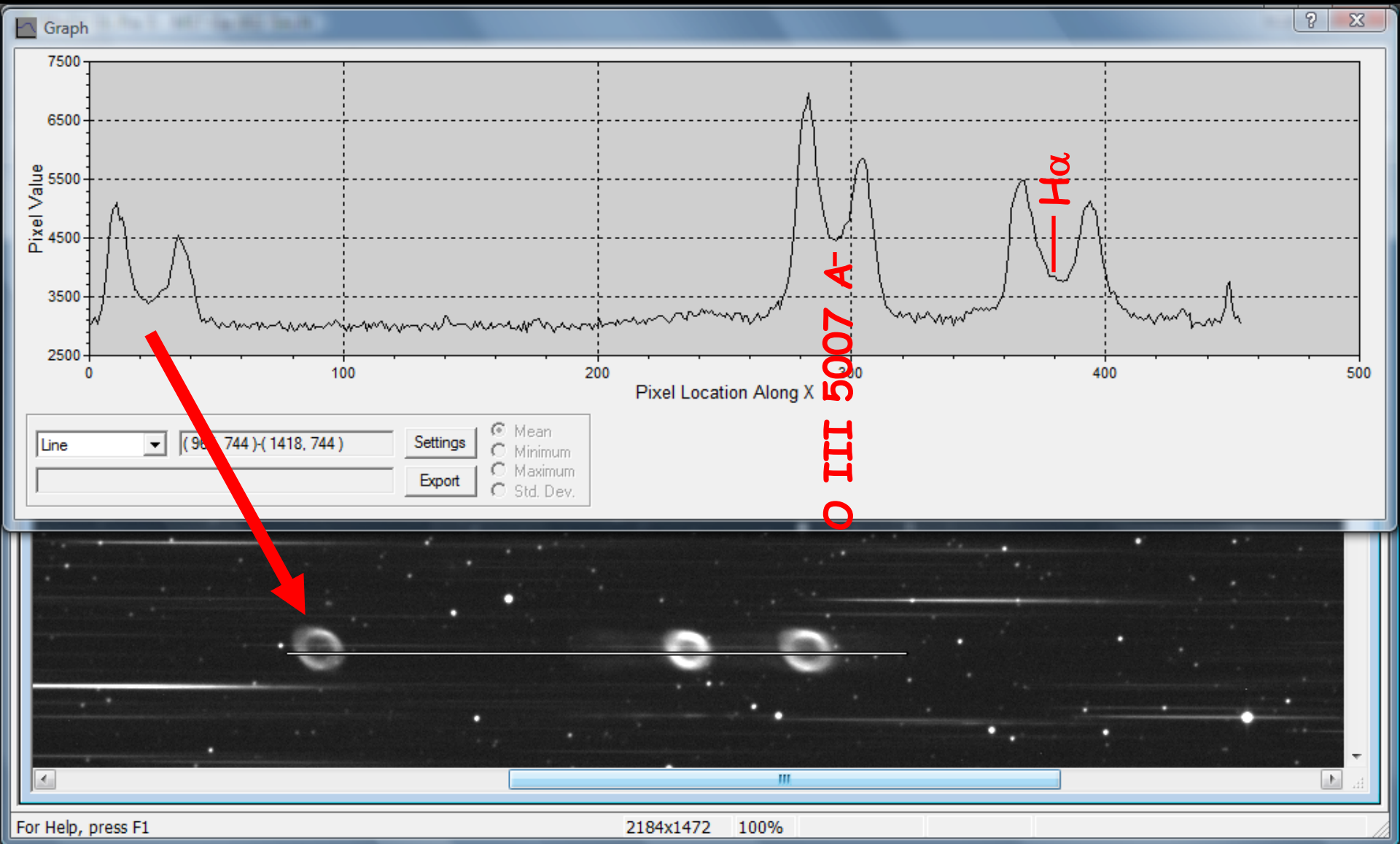
Wolf-Rayet Star WR135 WC8 Spectrum

Star Spectroscope in QSI532 & NP127is



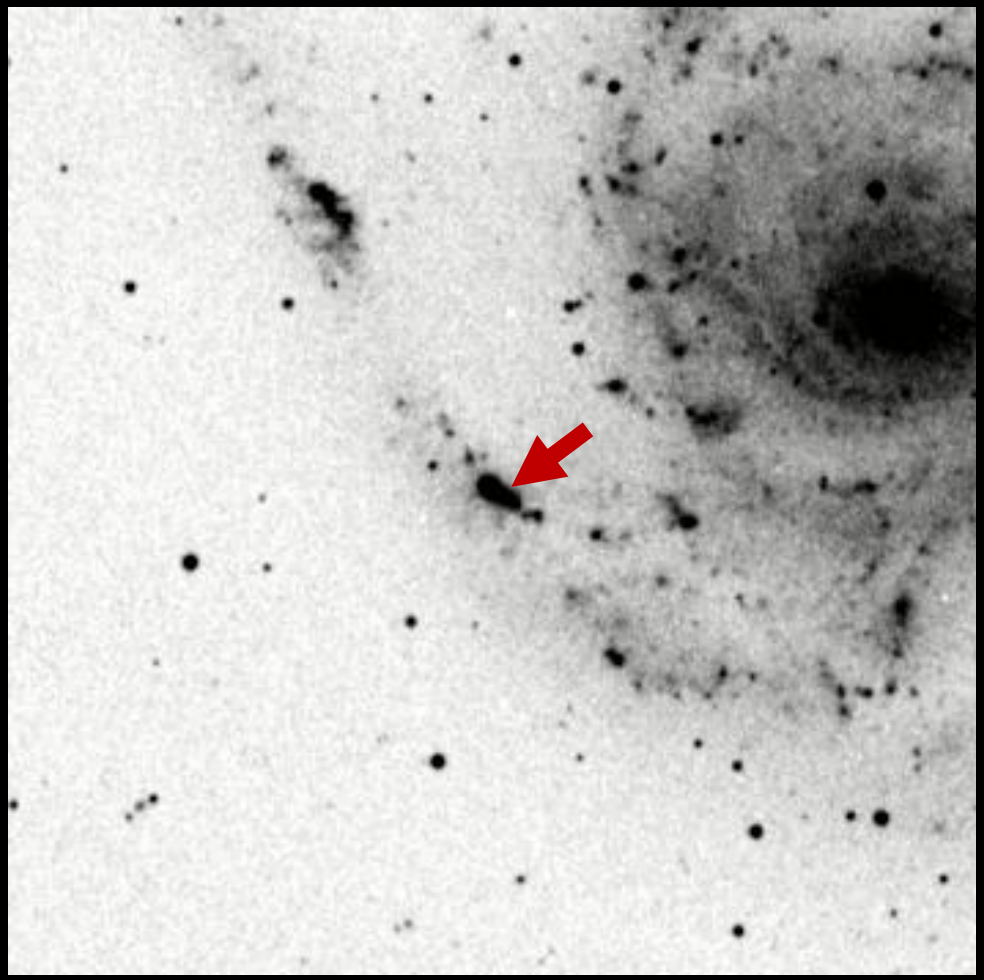
M57 Spectrum

Star Spectroscope in QSI532 & NP127is



M101 HII Region Spectrum

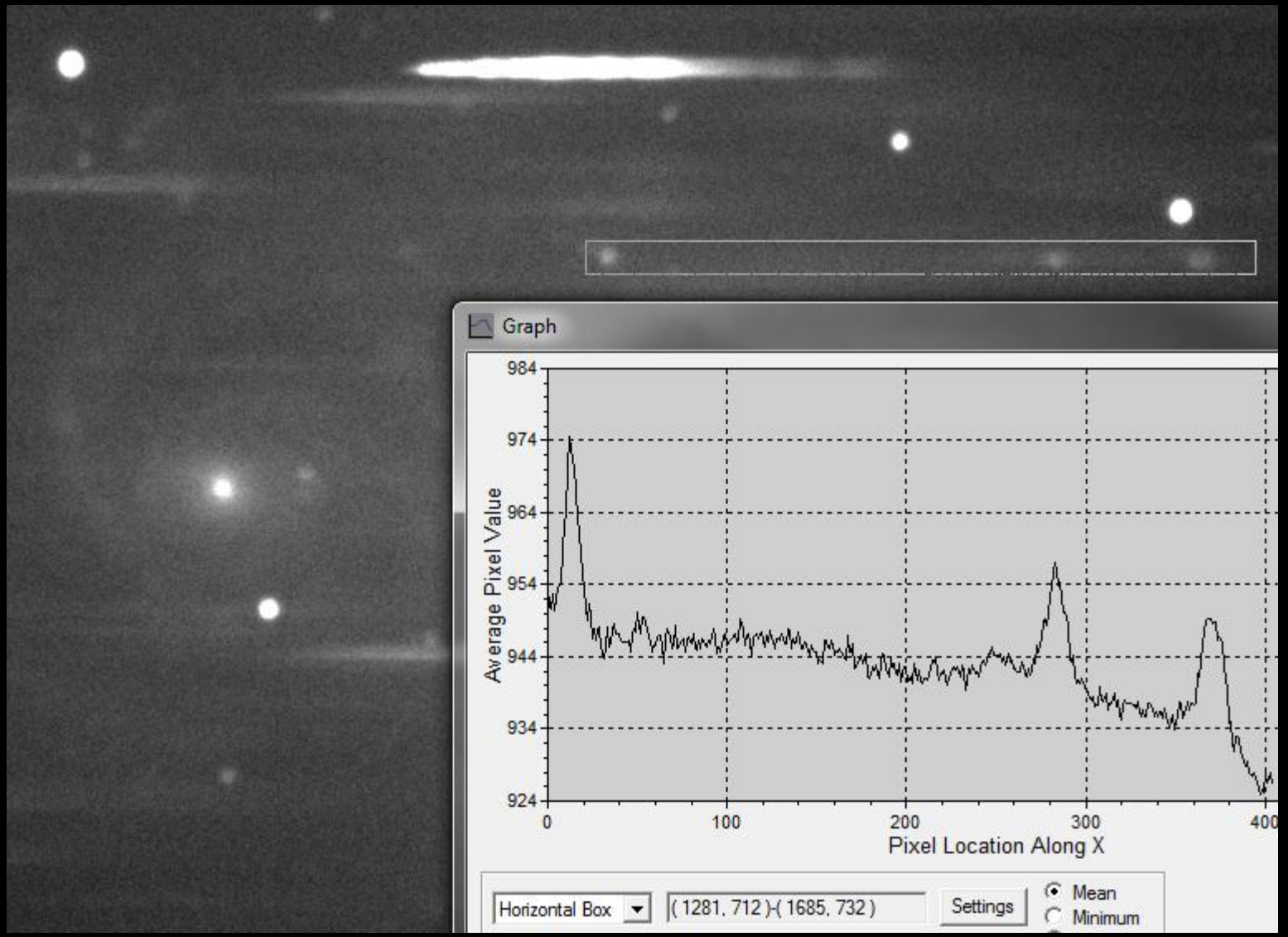
NGC 5461



Credit NED DSS Image

NGC 5461 M101 HII Region Spectrum

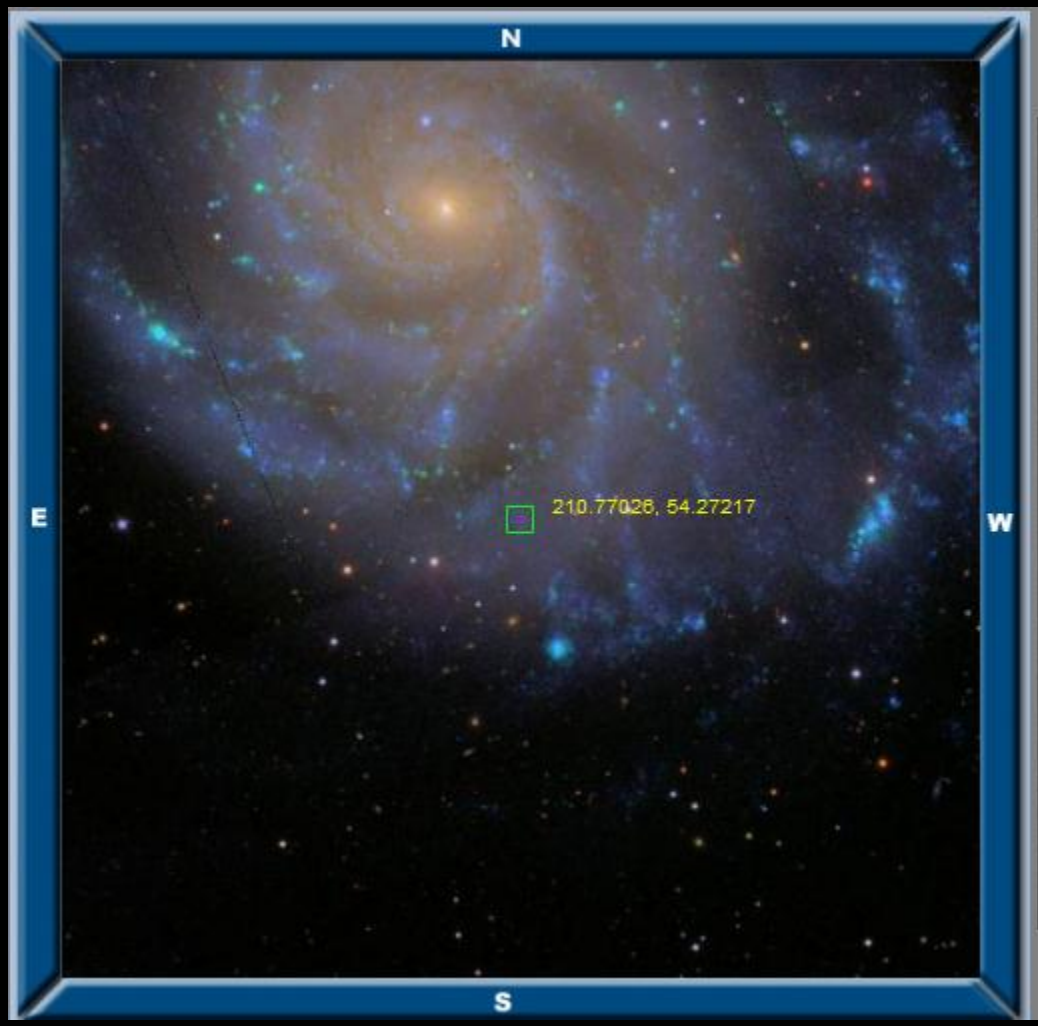
Star Spectroscope in QSI532 & 150mm Maksutov-Cassegrain



M101 HII Region Spectrum

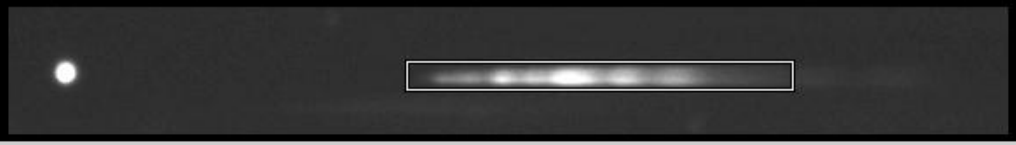
Supernovae SN 2011fe Spectrum

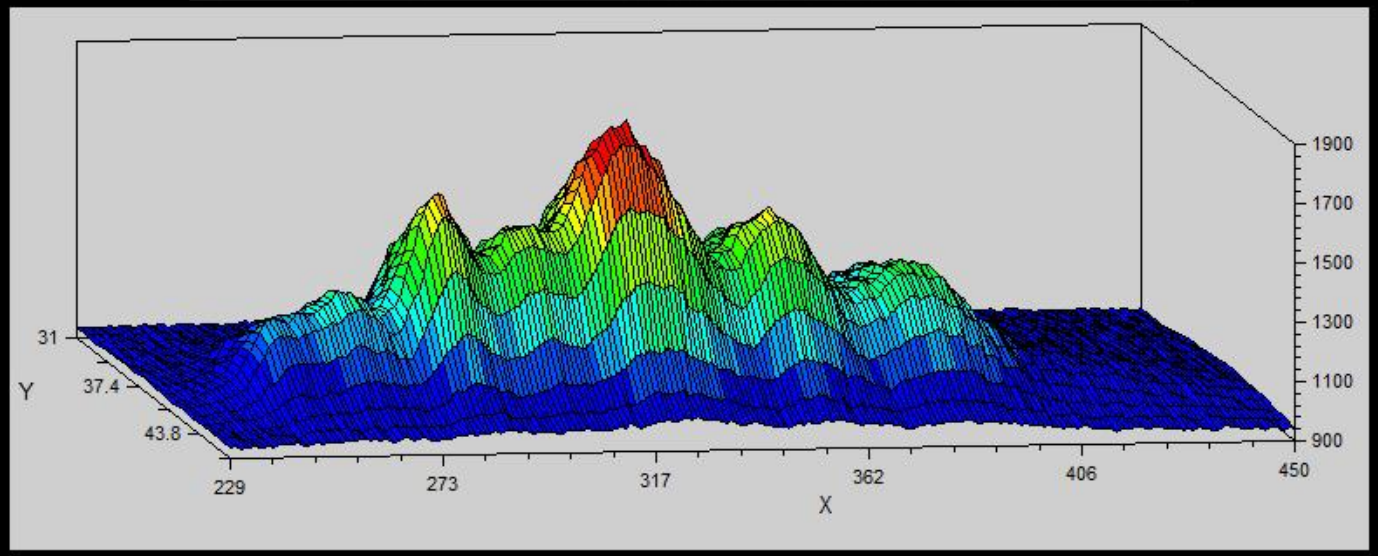
M101 light travel-time = 16 Myr

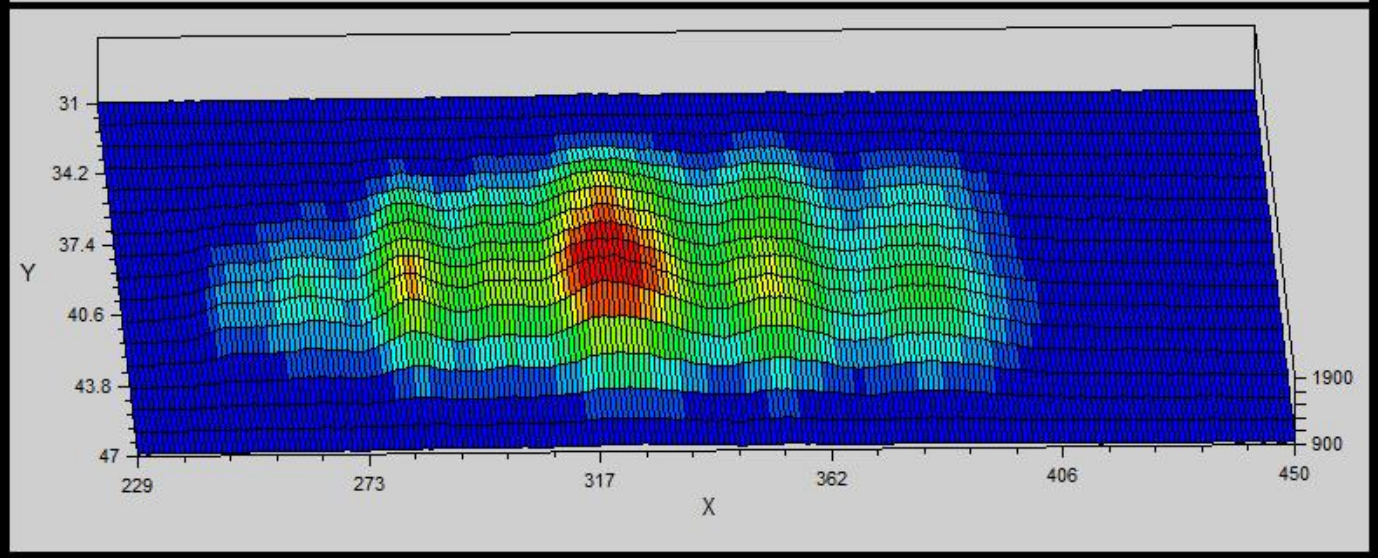


SDSS Image

Supernovae SN 2011fe Spectrum



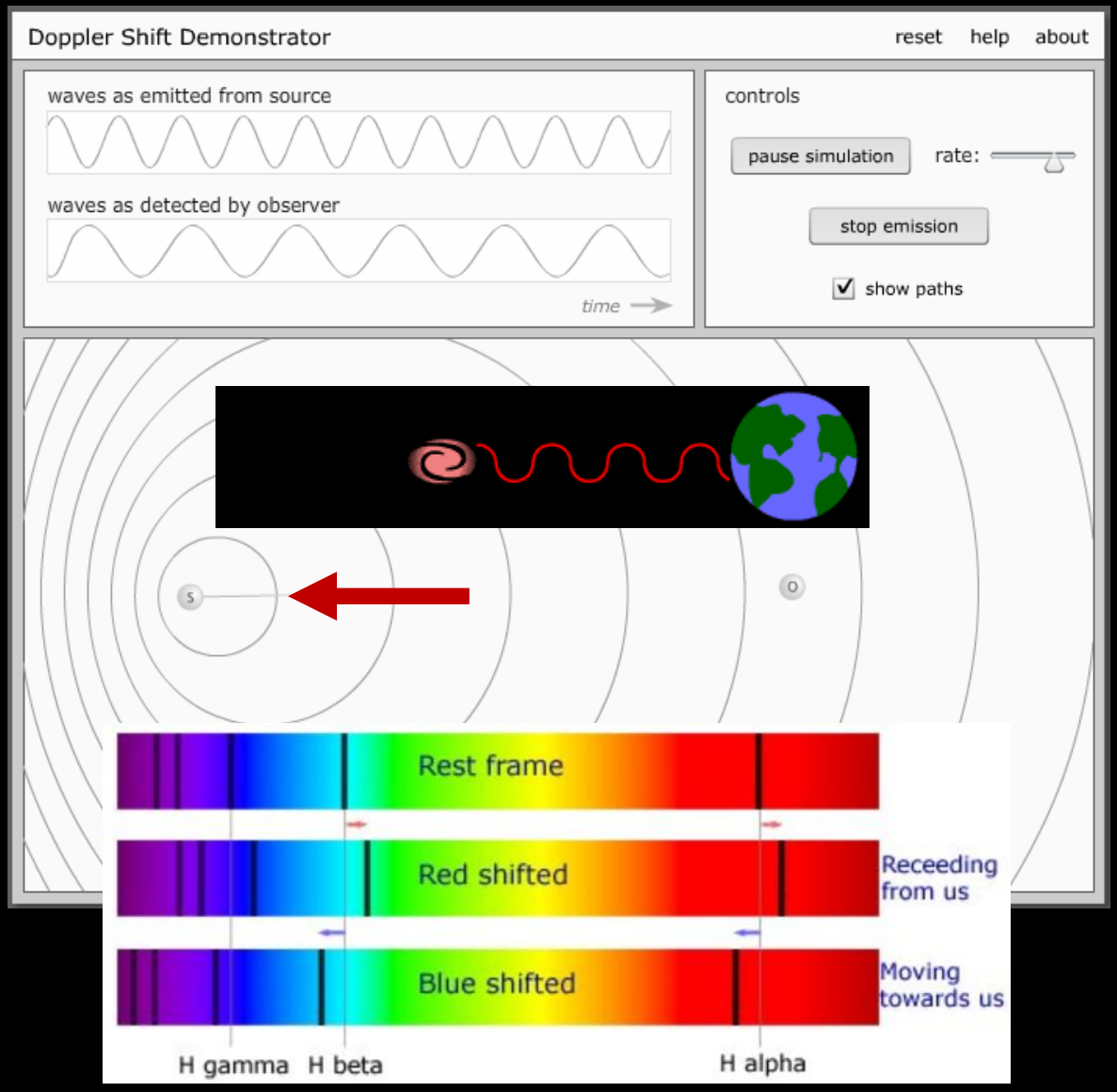




Supernovae SN 2011fe Spectrum

Supernovae type Ia = absence of hydrogen lines & presence of a SiII absorption near 6150 Å.

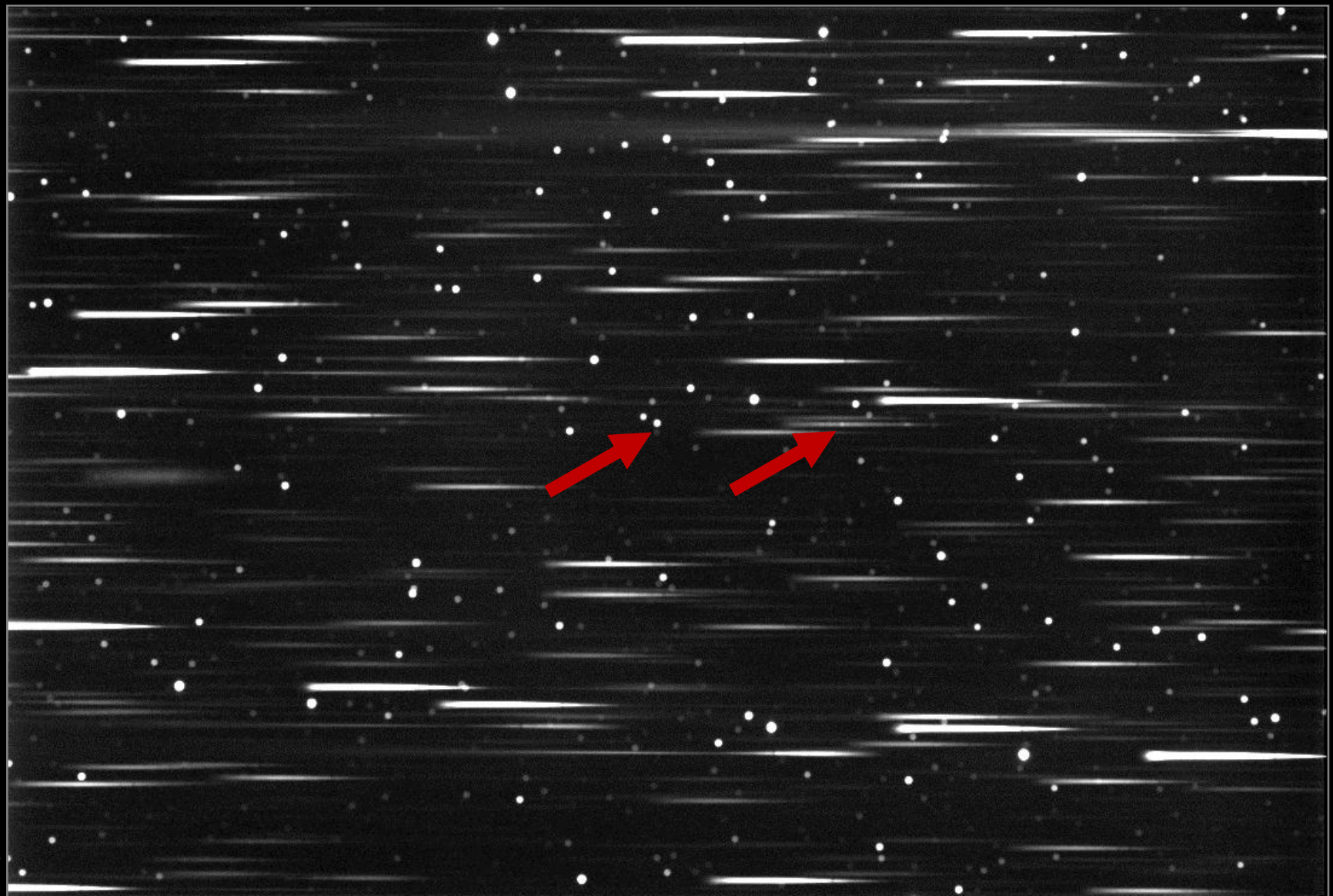
Radial Velocity Red & Blue Shift



Credit: Nebraska Astronomy Applet Project astro.unl.edu
http://outreach.atnf.csiro.au/education/senior/astrophysics/spectra_info.html

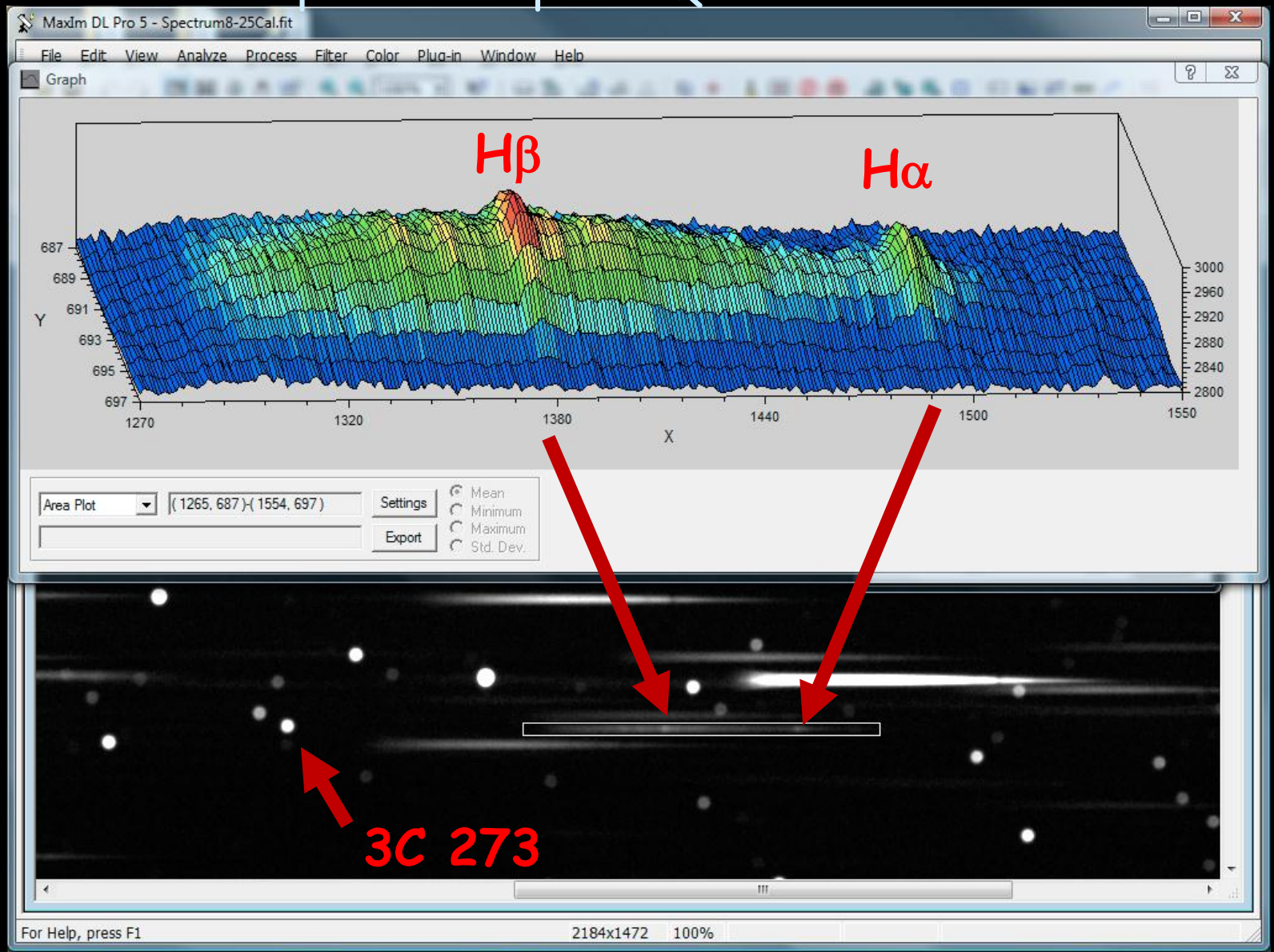
Quasar 3C 273 Spectrum

Redshift Measurement



Quasar 3C 273 Redshift

Star Spectroscope in QSI532 & NP127is



Quasar 3C 273 0.158 Redshift

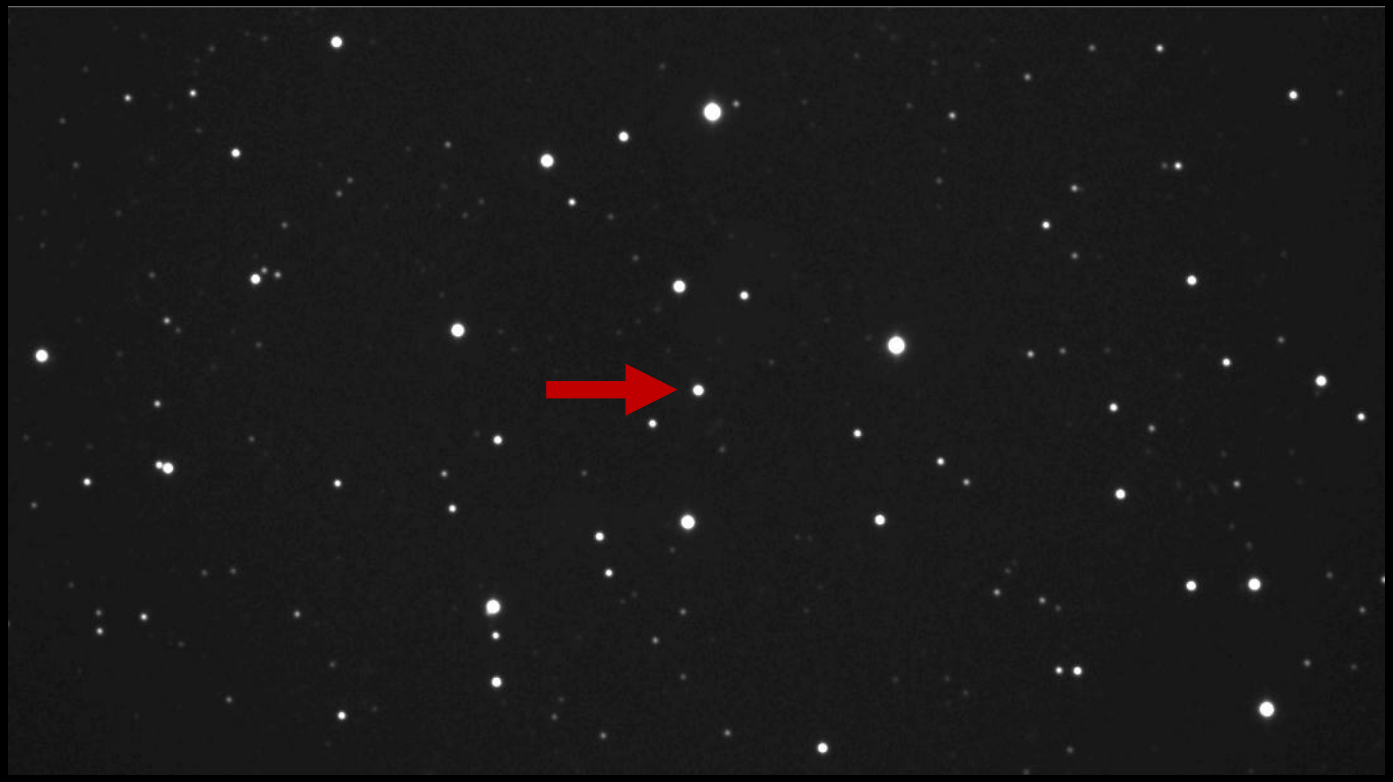
3C 273 Redshift
z=0.158339

$$z = \frac{\lambda_{obsv} - \lambda_{emit}}{\lambda_{emit}}$$

Elements	Emit Wavelength	Redshift Change in Wavelength	Observed Wavelength
H-alpha	6563 Å	1039 Å	7602 Å
[O III]	5007 Å	793 Å	5800 Å
H-beta	4861 Å	770 Å	5631 Å
H-gamma	4340 Å	687 Å	5027 Å
H-delta	4102 Å	650 Å	4752 Å

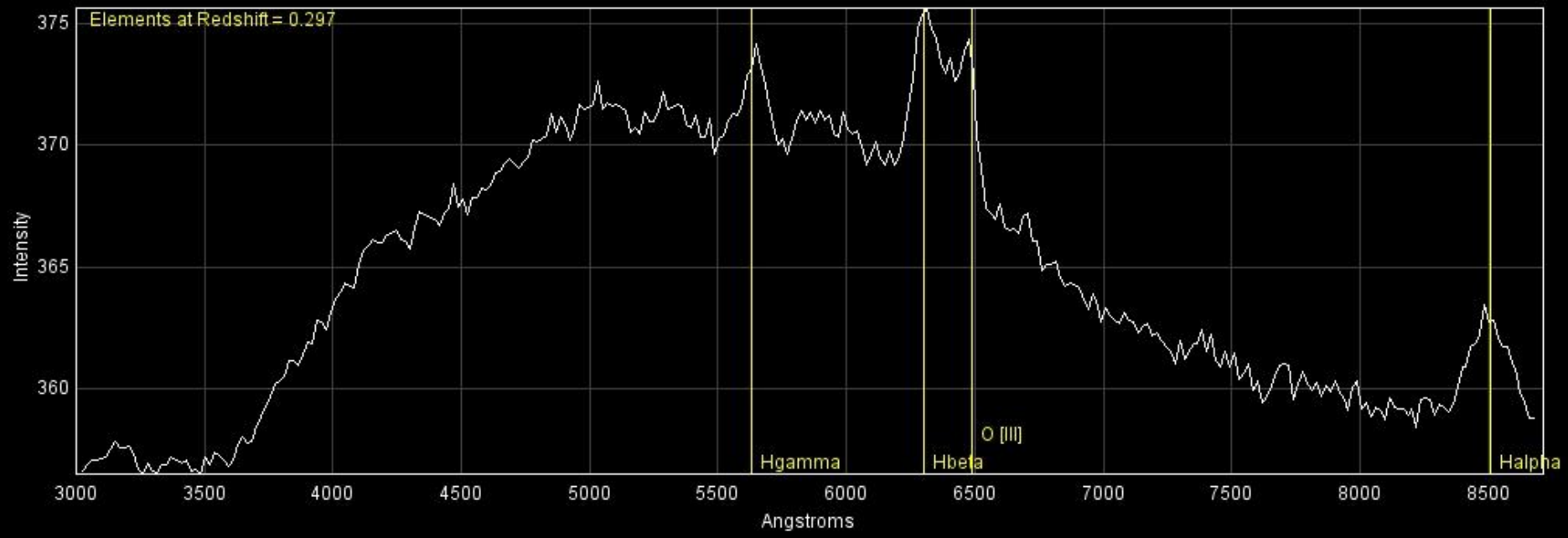
Quasar KUV18217+6419 Spectrum

Redshift Measurement



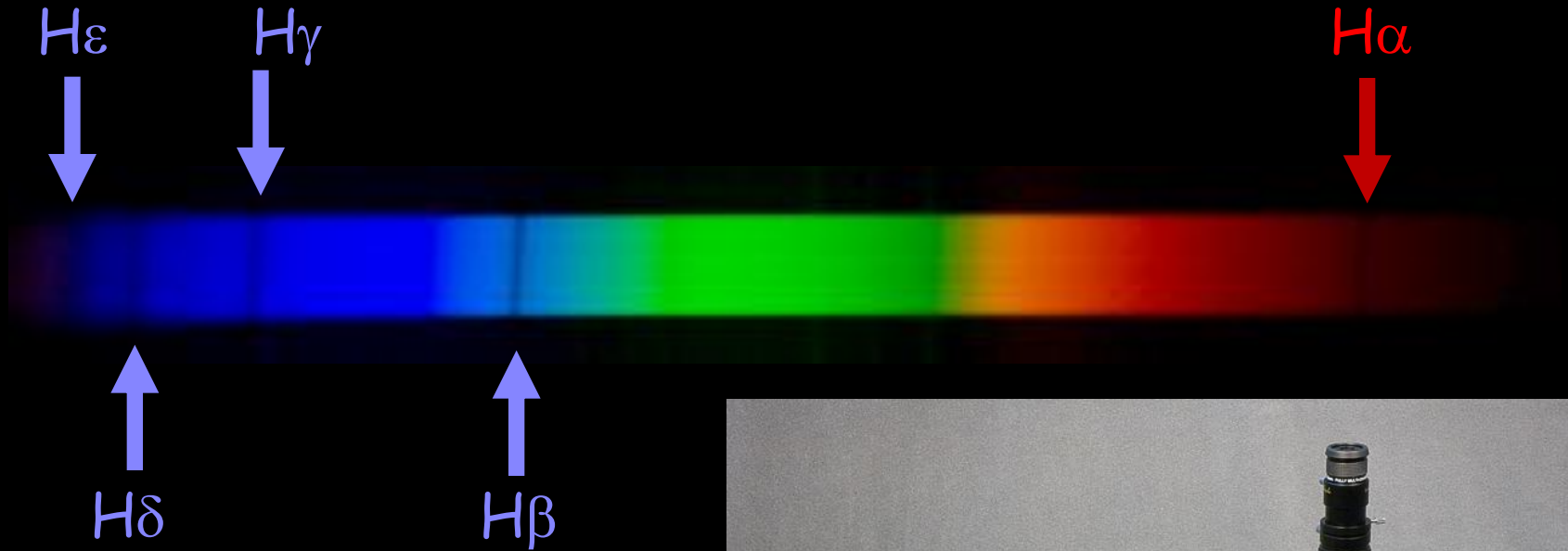
Quasar KUV18217+6419 Redshift 0.296

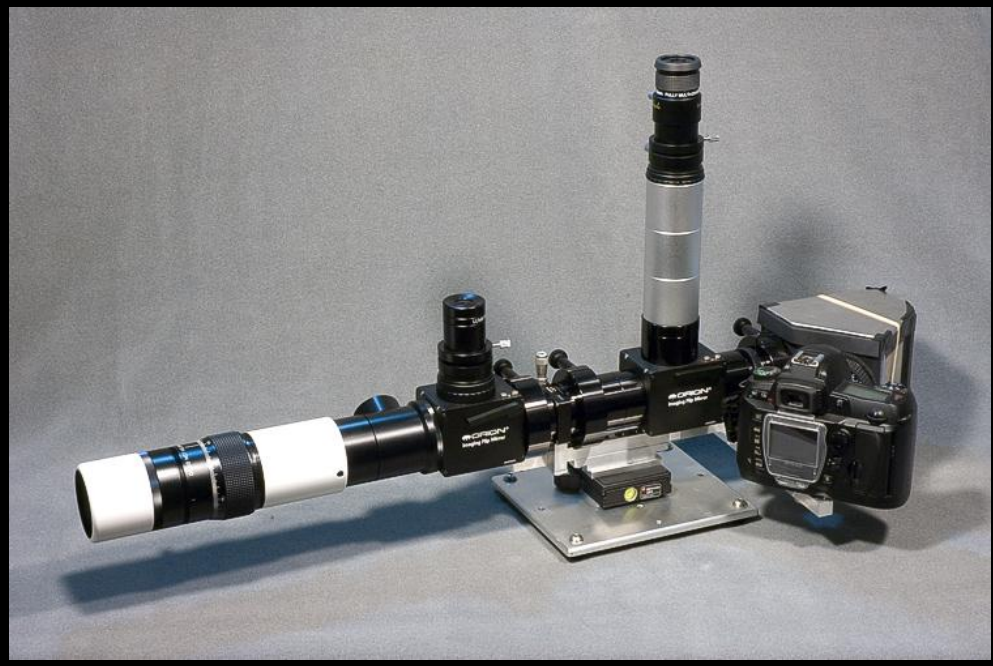
Light travel time = 3.264 Gyr



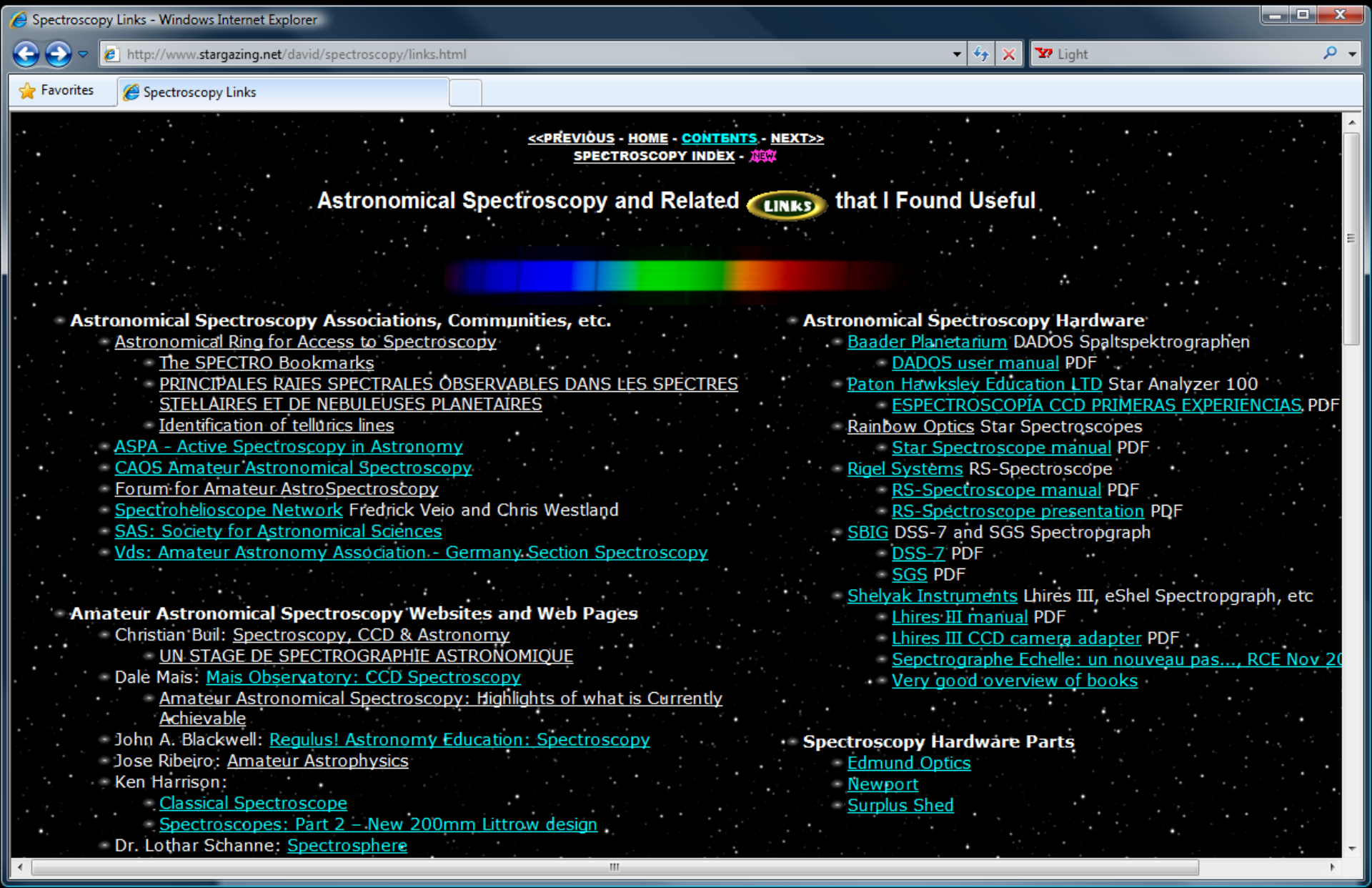
Vega Hydrogen Absorption Spectrum

600 lines/mm grating





http://www.stargazing.net/david/spectroscopy/links.html



www.stargazing.net/david