Effect of Source on Wave

I. Blackbody Radiation & Wein's Law
(effect of temperature)

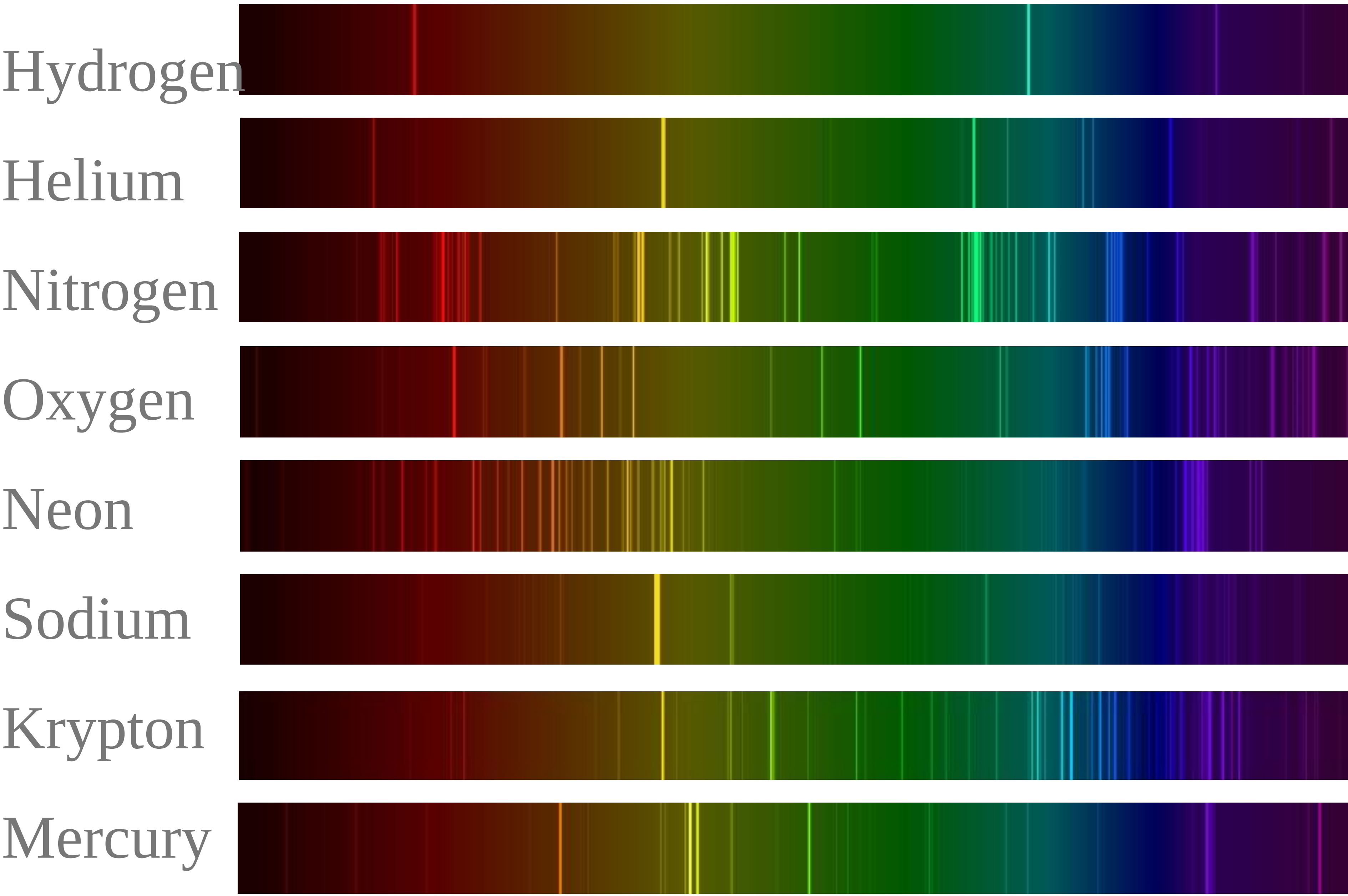
II. Doppler Effect
(effect of motion)

III. Spectroscopy
(effect of atomic properties)

	The student will be able to:	HW:
1	Define, illustrate, and apply the basic wave concepts of frequency, wavelength, and speed and relate these to source and medium.	1
2	Solve mathematical problems involving speed, frequency, and wavelength.	2 – 4
3	Describe and illustrate the nature of electromagnetic radiation.	5
4	State the six major regions of the electromagnetic spectrum in order of frequency and/or wavelength.	6 – 8
5	State the colors of the visible spectrum in order of frequency and/or wavelength.	
6	Define, illustrate, and apply the concepts of diffraction, interference, opacity and transparency.	9 – 10
7	Explain, illustrate, and apply the basic concepts of blackbody radiation.	11 – 12
8	Solve mathematical problems using Wein's law.	13 – 15
9	Explain, illustrate, and apply the concept of the Doppler effect and the astronomical terms of redshift and blueshift.	16 – 17
10	Describe the characteristics of continuous, emission, and absorption spectra and the conditions under which each is produced.	18 – 21
11	Explain how spectral lines and the width and intensity of those lines are related to properties of atoms and or molecules.	22 – 25
12	Describe and illustrate the two main types of optical telescopes – refracting and reflecting and contrast in terms of resolution, light gathering, and aberrations.	26 – 32
13	Describe how the Earth's atmosphere affects astronomical observations and current efforts to improve ground-based astronomy.	
14	Compare and contrast telescopes that create images using nonvisible radiation.	
15	Solve mathematical problems relating magnification to focal lengths of objective and ocular.	33 – 34
16	Solve mathematical problems relating angular resolution to wavelength and diameter.	35 – 38
17	Solve mathematical problems involving light gathering capacities.	39 – 42

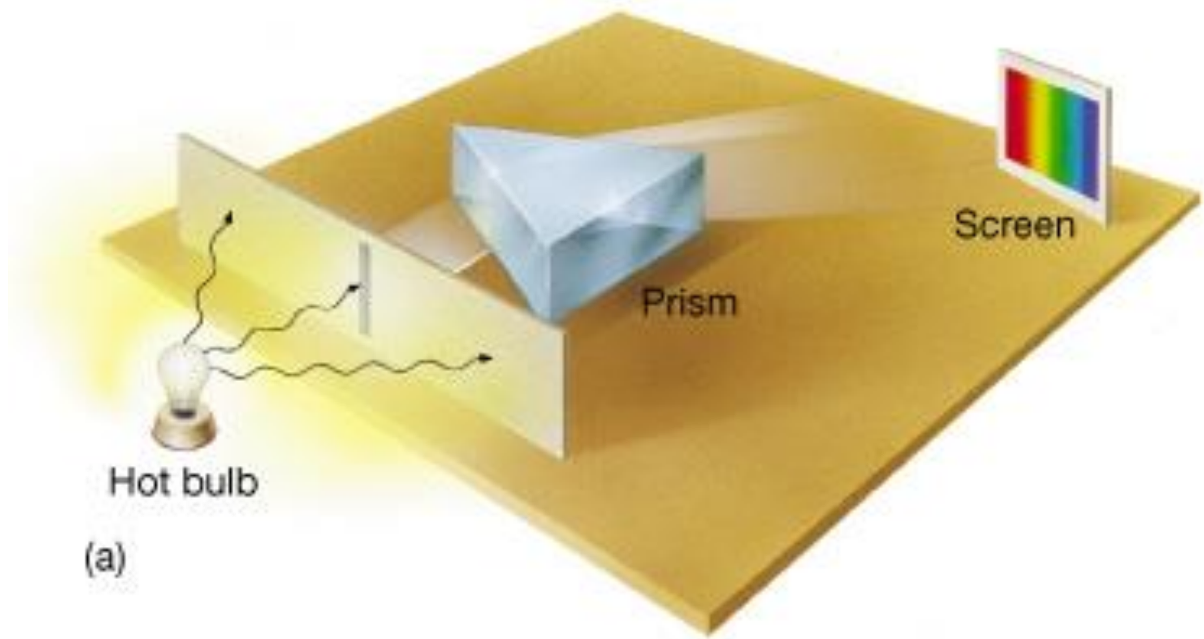
Spectroscopy

- Spectroscopy refers to the measurement and study of spectra.
- A spectrum is an arrangement of EMR in order of increasing frequency (Roy G Biv).
- There are three types of spectra: continuous, emission, and absorption.

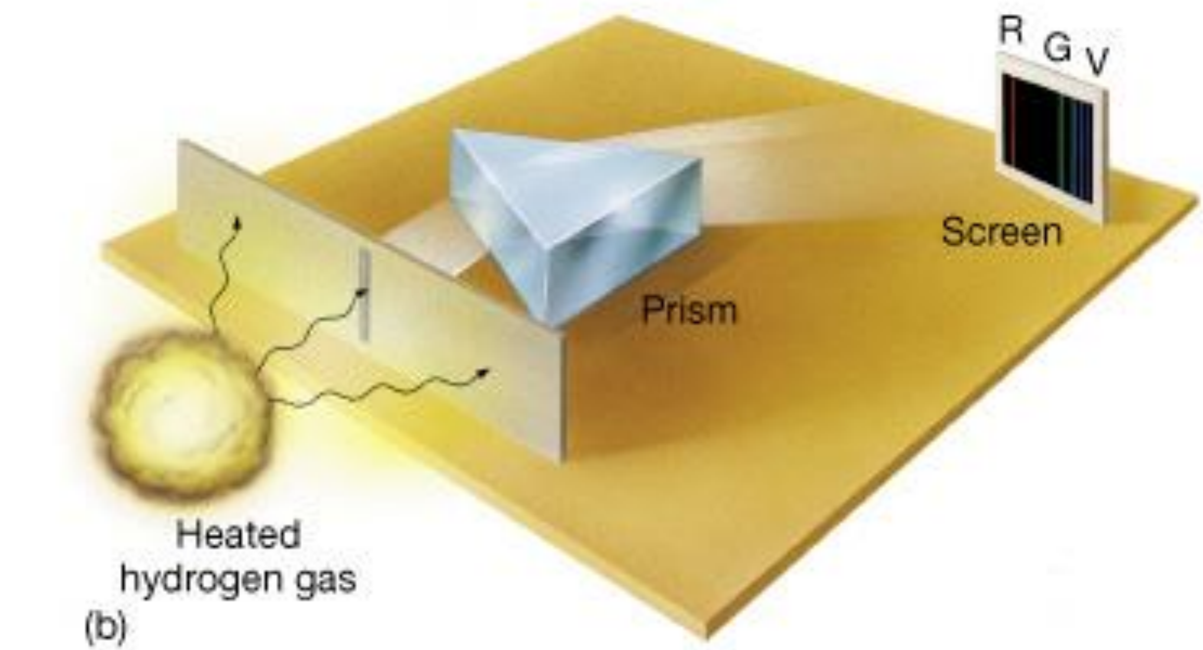

Hydrogen
Helium
Nitrogen
Oxygen
Neon
Sodium
Krypton
Mercury

Kirchoff's Laws

- A solid, liquid, or sufficiently dense gas emits light (EMR) of all frequencies and wavelengths – a continuous spectrum.
- At "high" temperatures a thin, low density gas emits unique and discrete frequencies and wavelengths – a bright line spectrum.
- At "low" temperatures a thin, low density gas absorbs unique and discrete frequencies and wavelengths – a dark line spectrum.
- For a given gas the bright lines and dark lines occur at exactly the same frequencies and wavelengths.

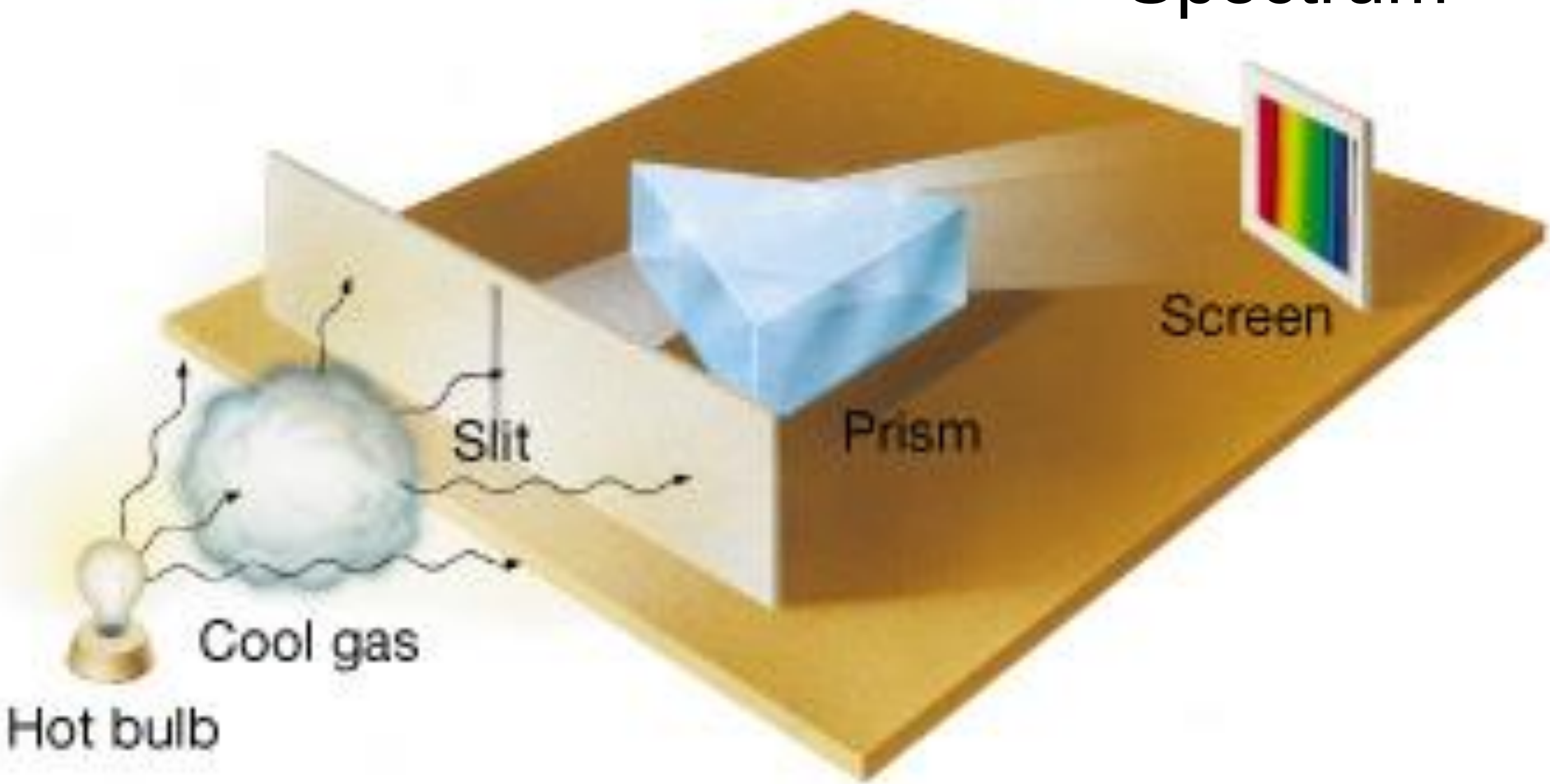


Continuous Spectrum

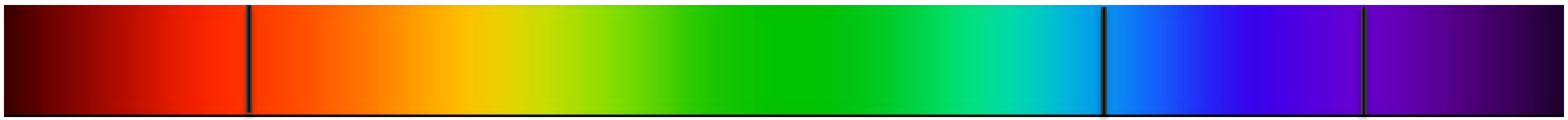


Emission Spectrum

Absorption Spectrum



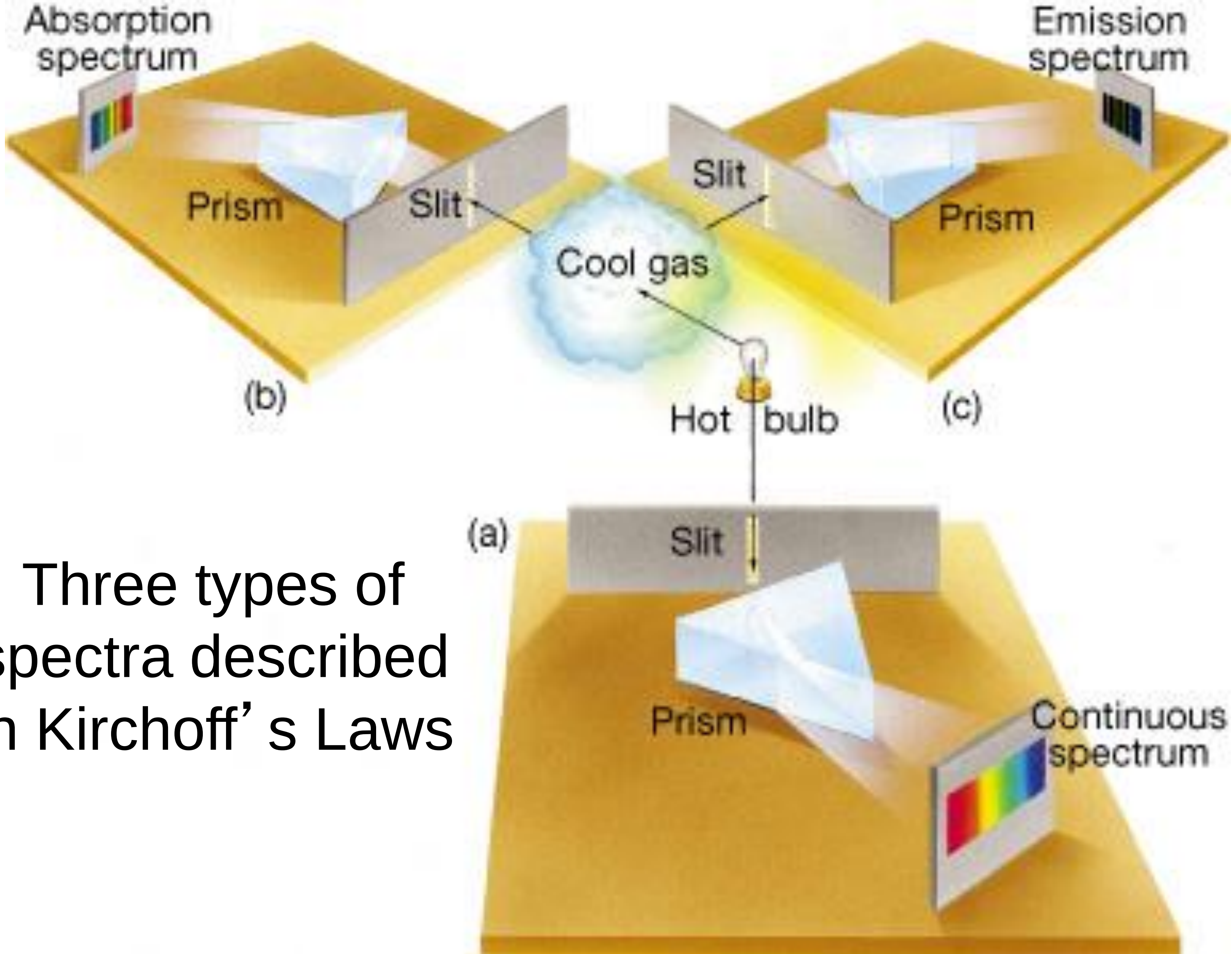
Hydrogen Emission Spectrum



Hydrogen Absorption Spectrum

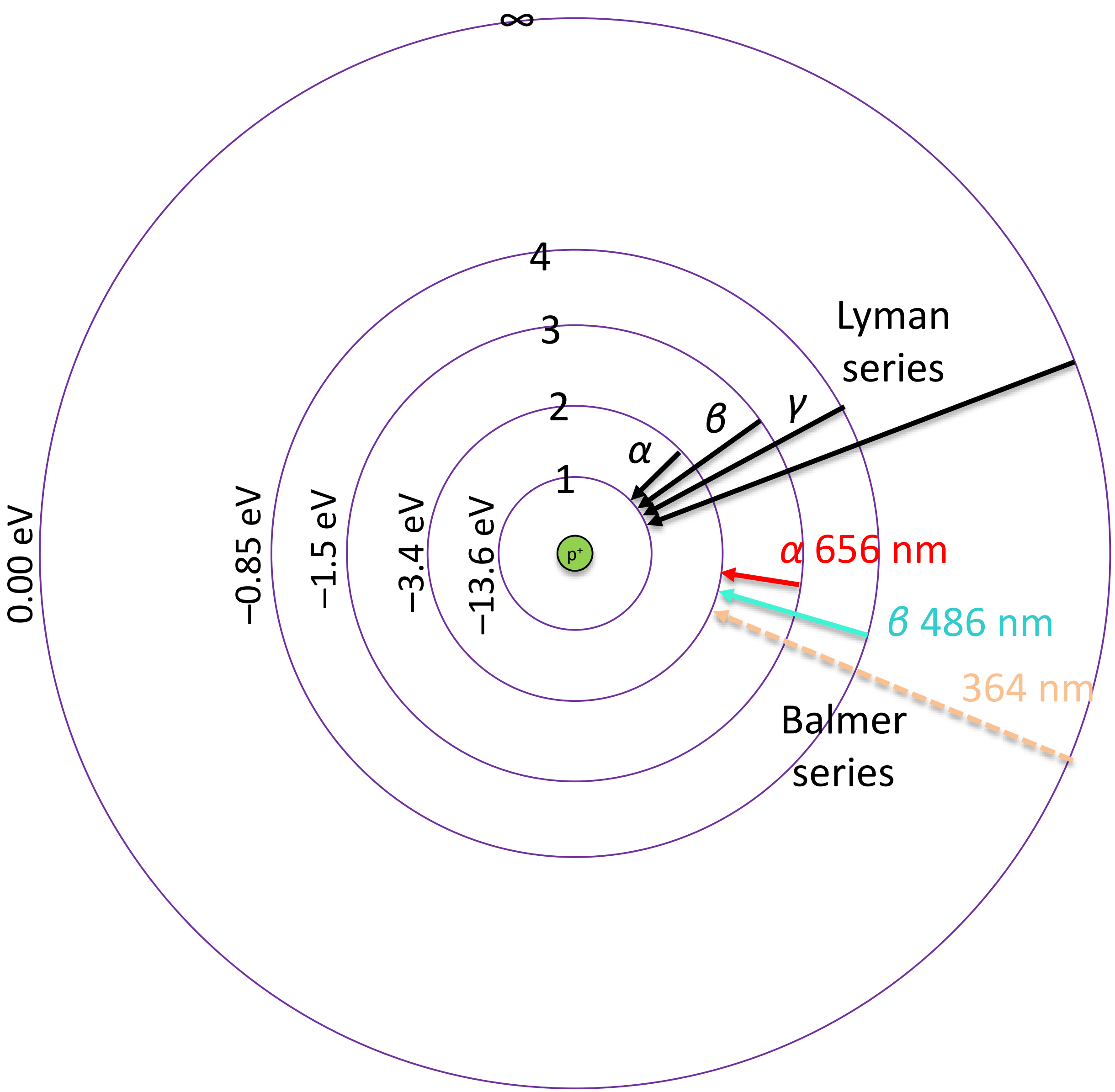
Helium Emission Spectrum

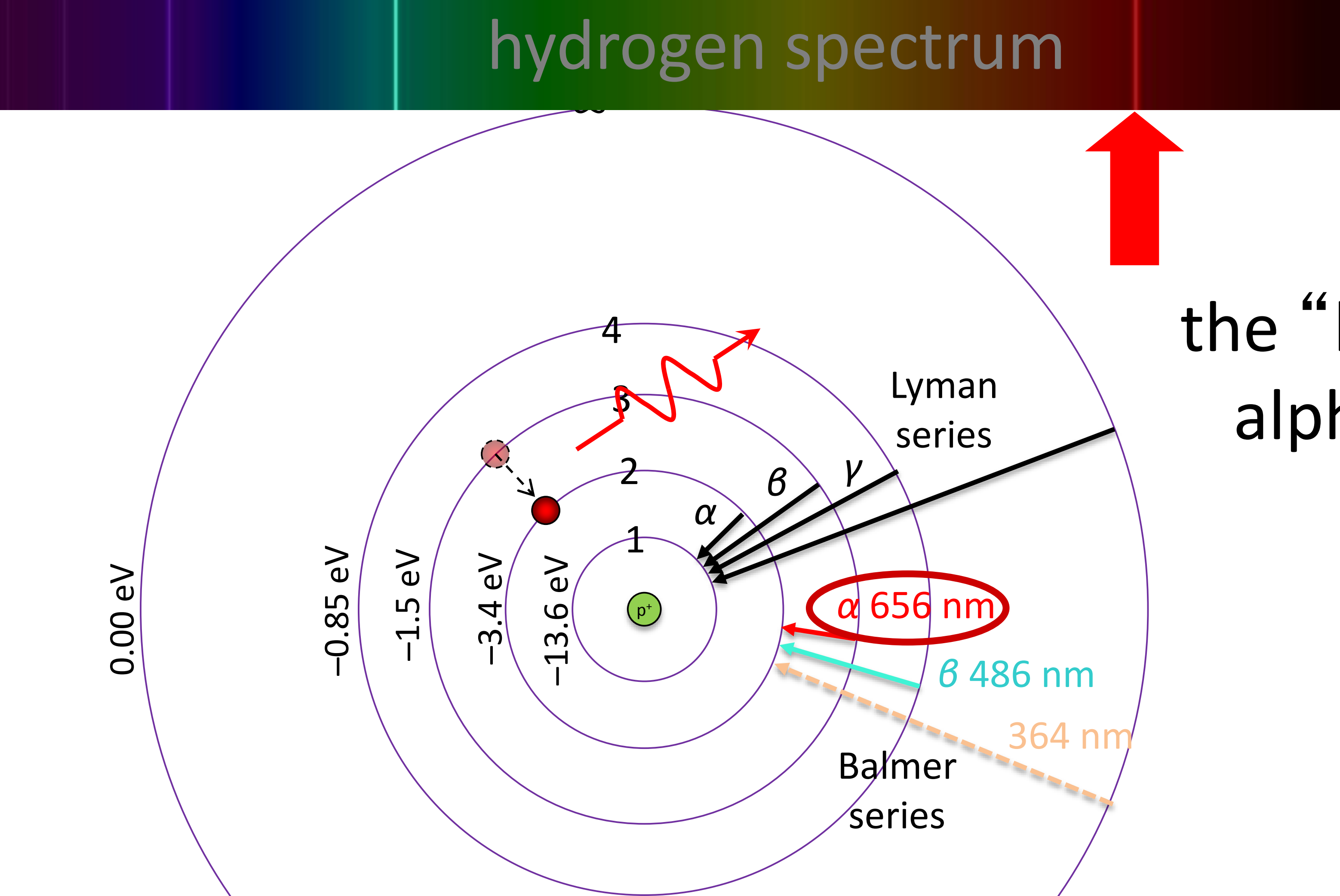
Helium Absorption Spectrum



Three types of spectra described in Kirchoff's Laws

Bohr Model of Hydrogen

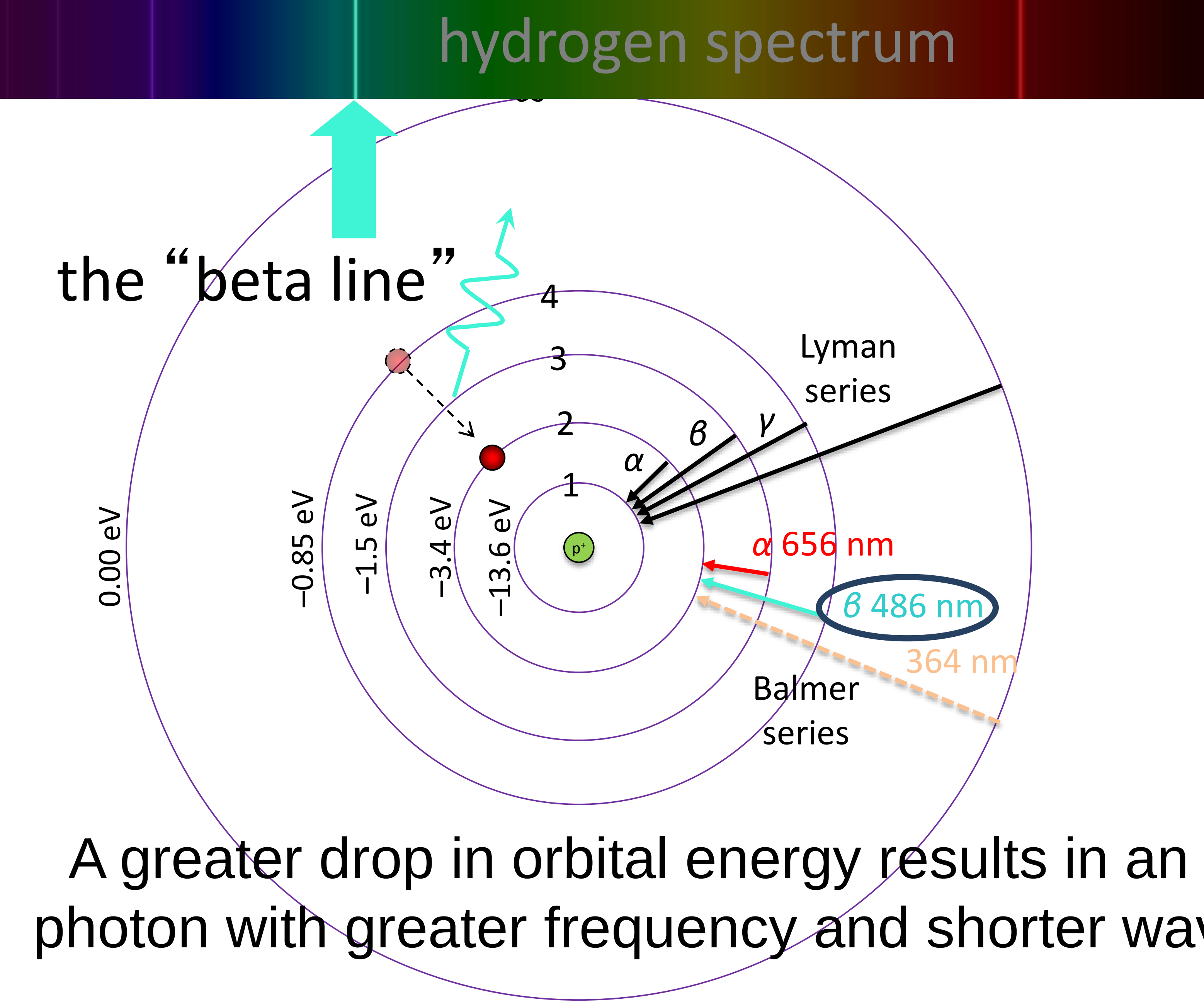




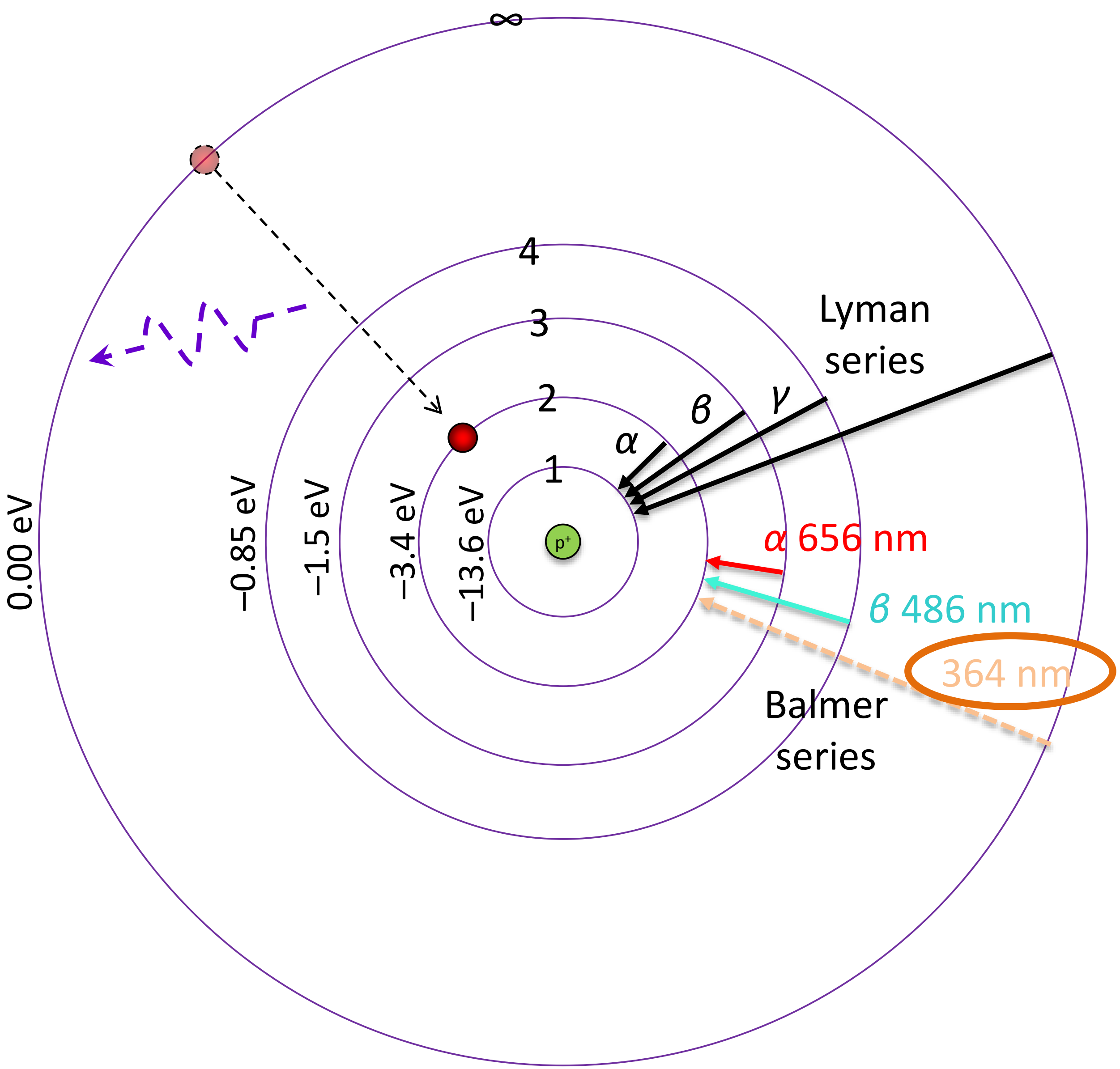
the “hydrogen alpha line”

An electron dropping to a lower orbital loses energy that becomes an emitted photon of a particular frequency and wavelength.

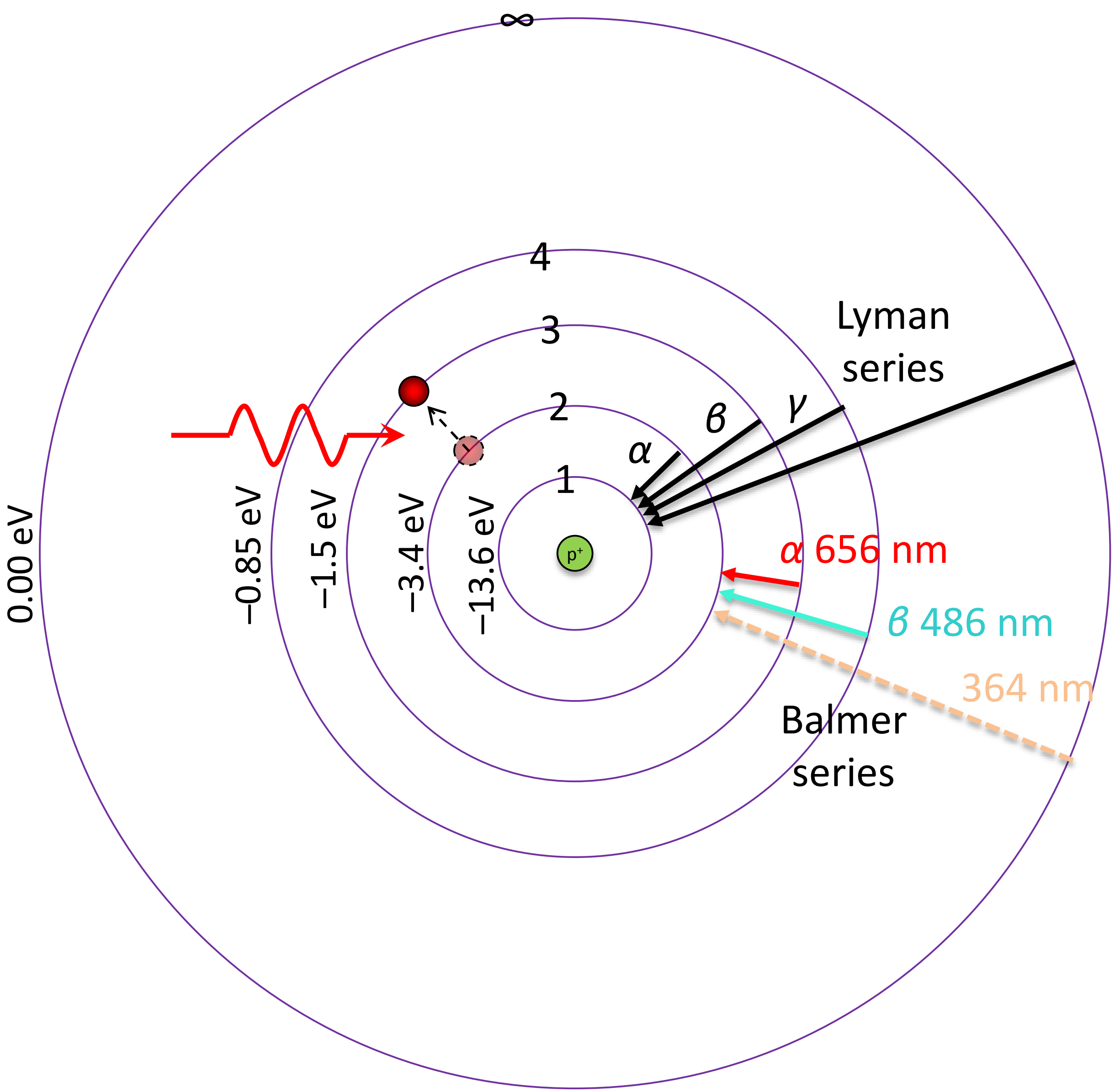
hydrogen spectrum



A greater drop in orbital energy results in an emitted photon with greater frequency and shorter wavelength.

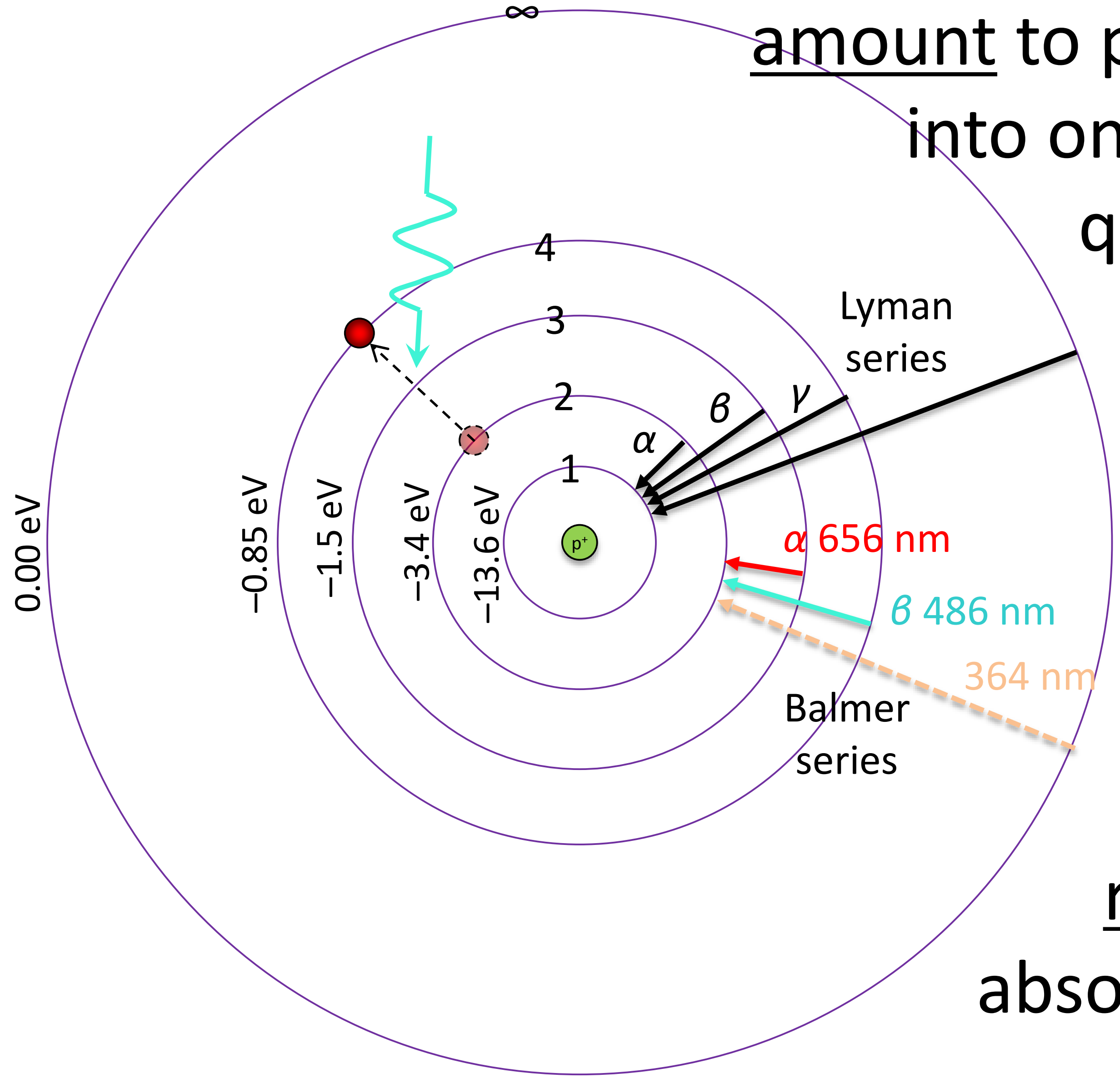


This line is ultraviolet.



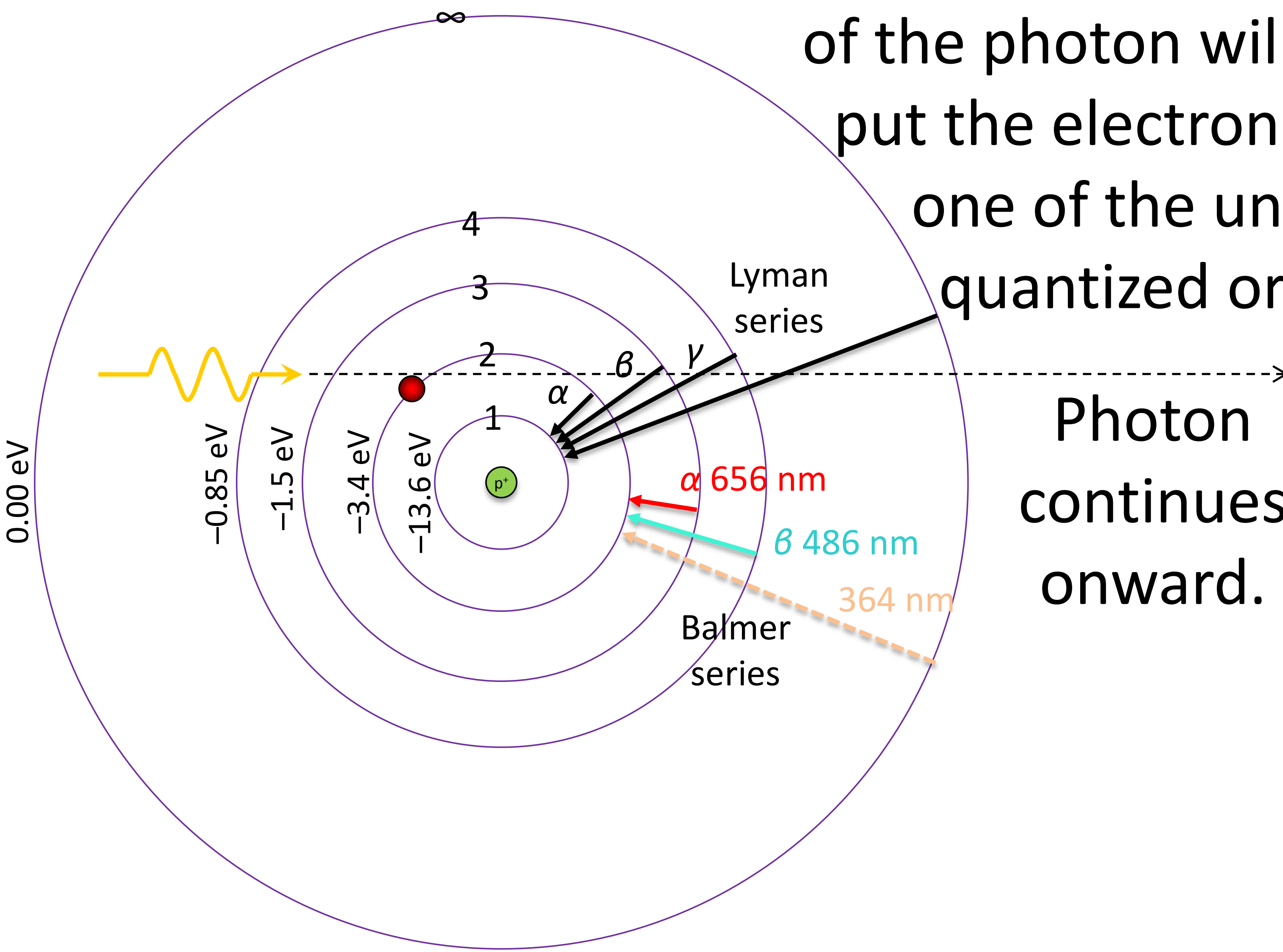
The reverse of photon emission is photon absorption. Energy of the photon goes to the electron and boosts its orbit.

Energy of the photon is the <u>precise amount</u> to put the electron into one of the unique quantized orbits.



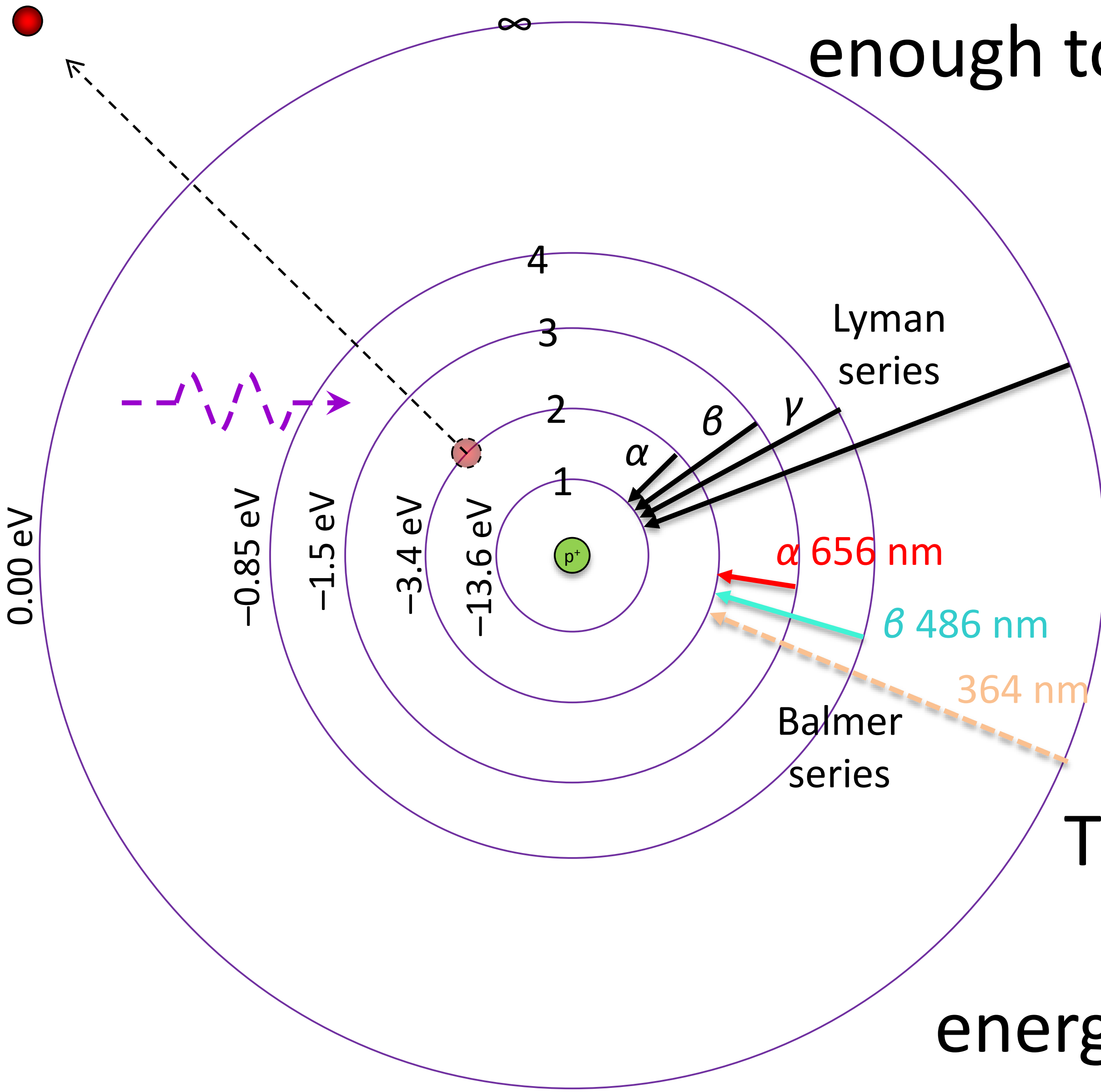
This is a <u>requirement</u> for absorption to occur.

No absorption occurs if energy of the photon will not put the electron into one of the unique quantized orbits.

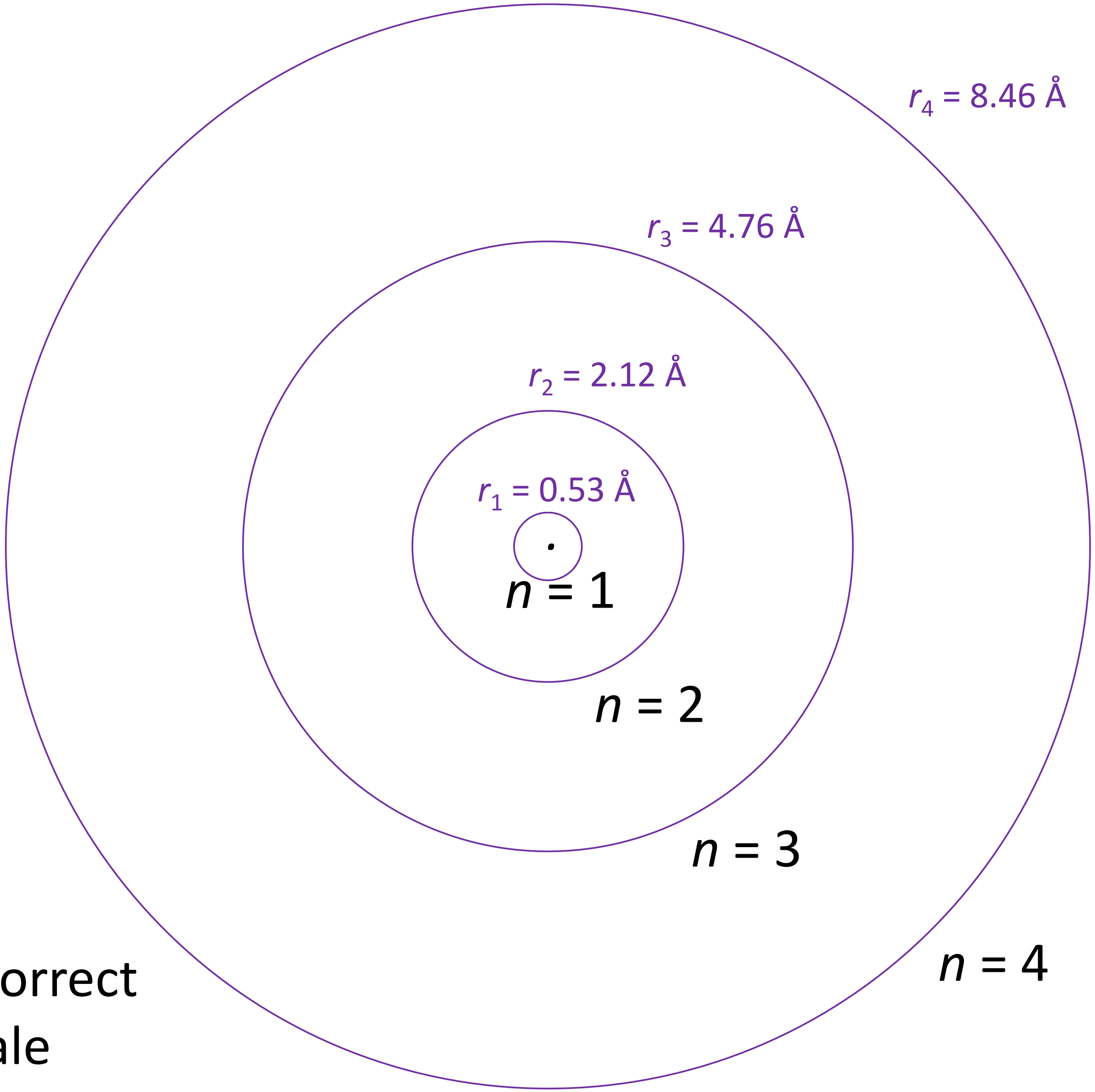


Photon continues onward.

Energy of the photon is the great enough to move electron past the highest possible orbit.

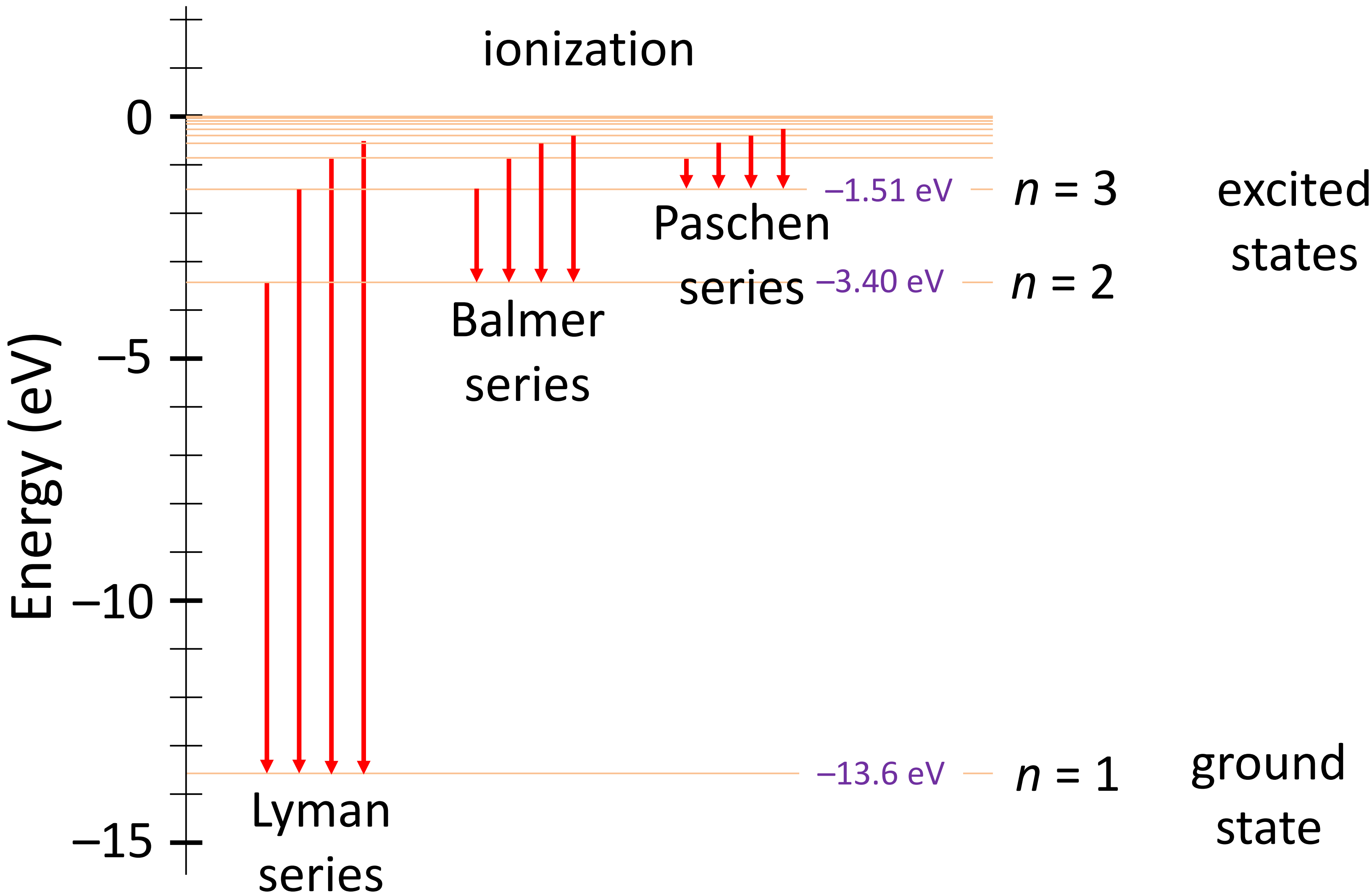


This is ionization. Any “leftover” energy of the photon becomes kinetic energy of the electron.



orbitals correct
to scale

Hydrogen Energy Levels



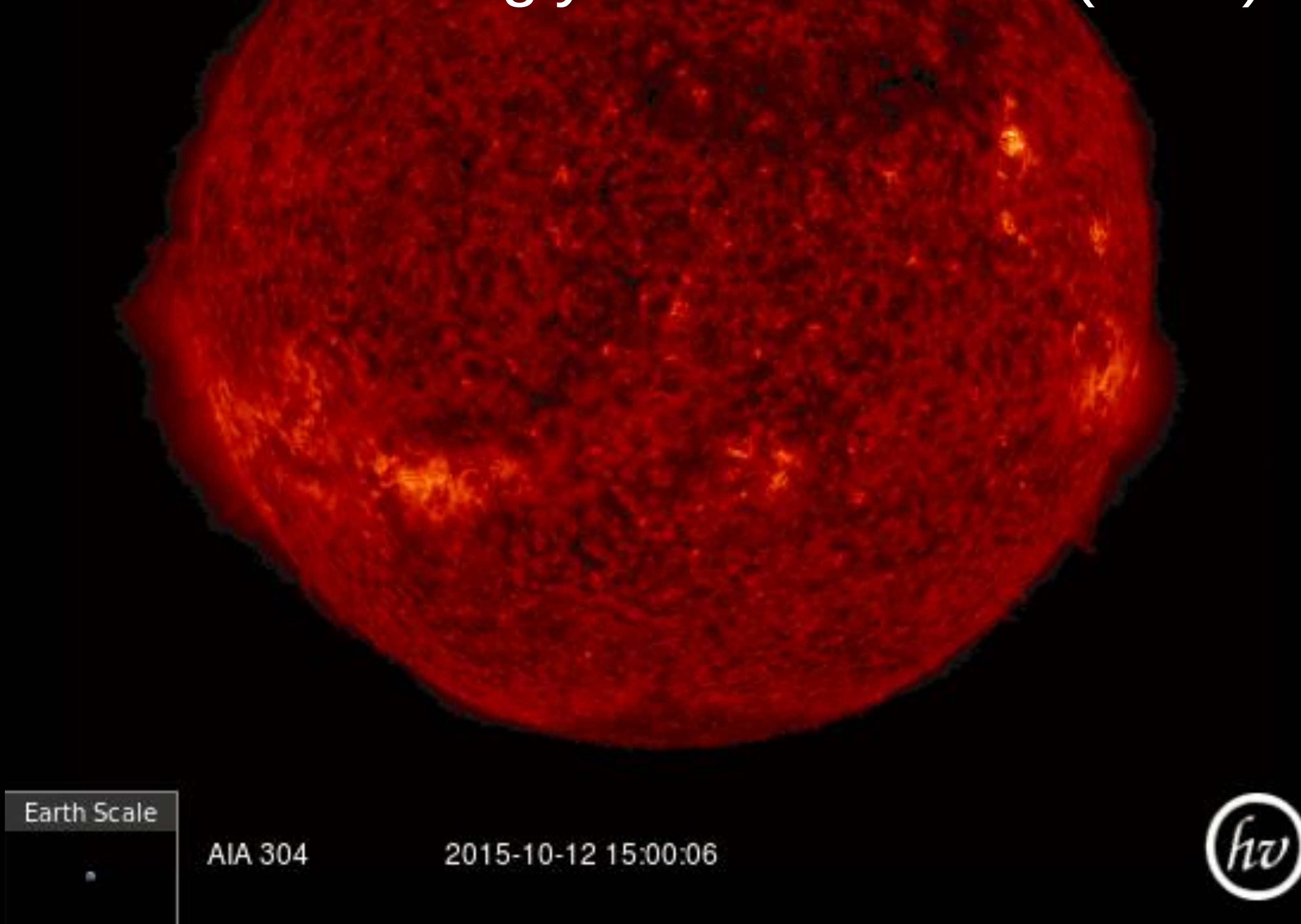
Discuss with a partner:

How was helium discovered – what tools did scientists need?

What actual specific observations of the Sun's spectrum led to the conclusion that a previously unknown element existed there?

Do you think the observed helium spectrum from the Sun was a bright line (emission) spectrum or a dark line (absorption) spectrum? Explain your reasoning.

This view of the Sun from helioviewer.org shows only EMR at wavelength 304 Å (or 30.4 nm) – an emission line of singly ionized helium (He II).



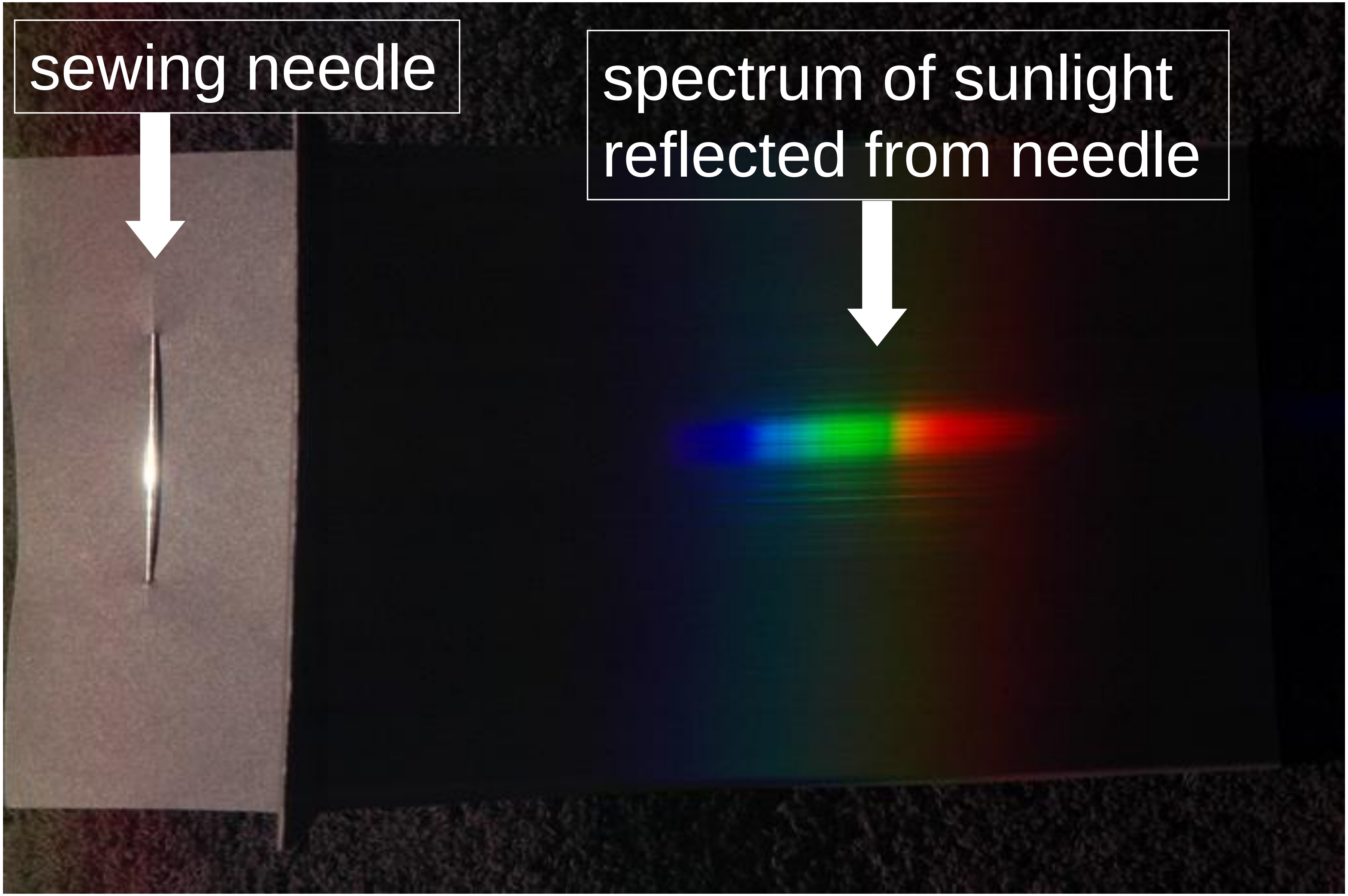


Image credit: RSpec-Astro.com

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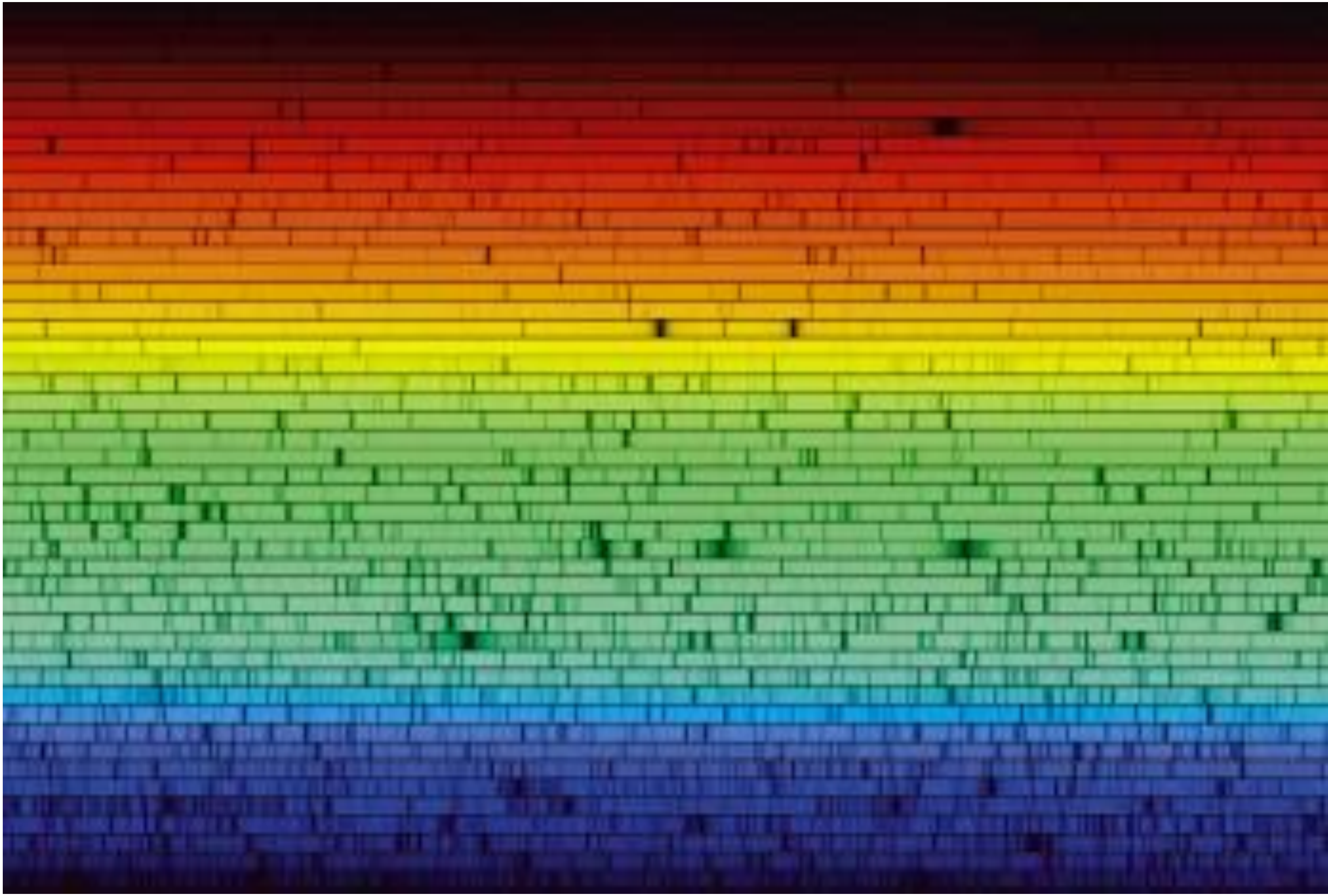


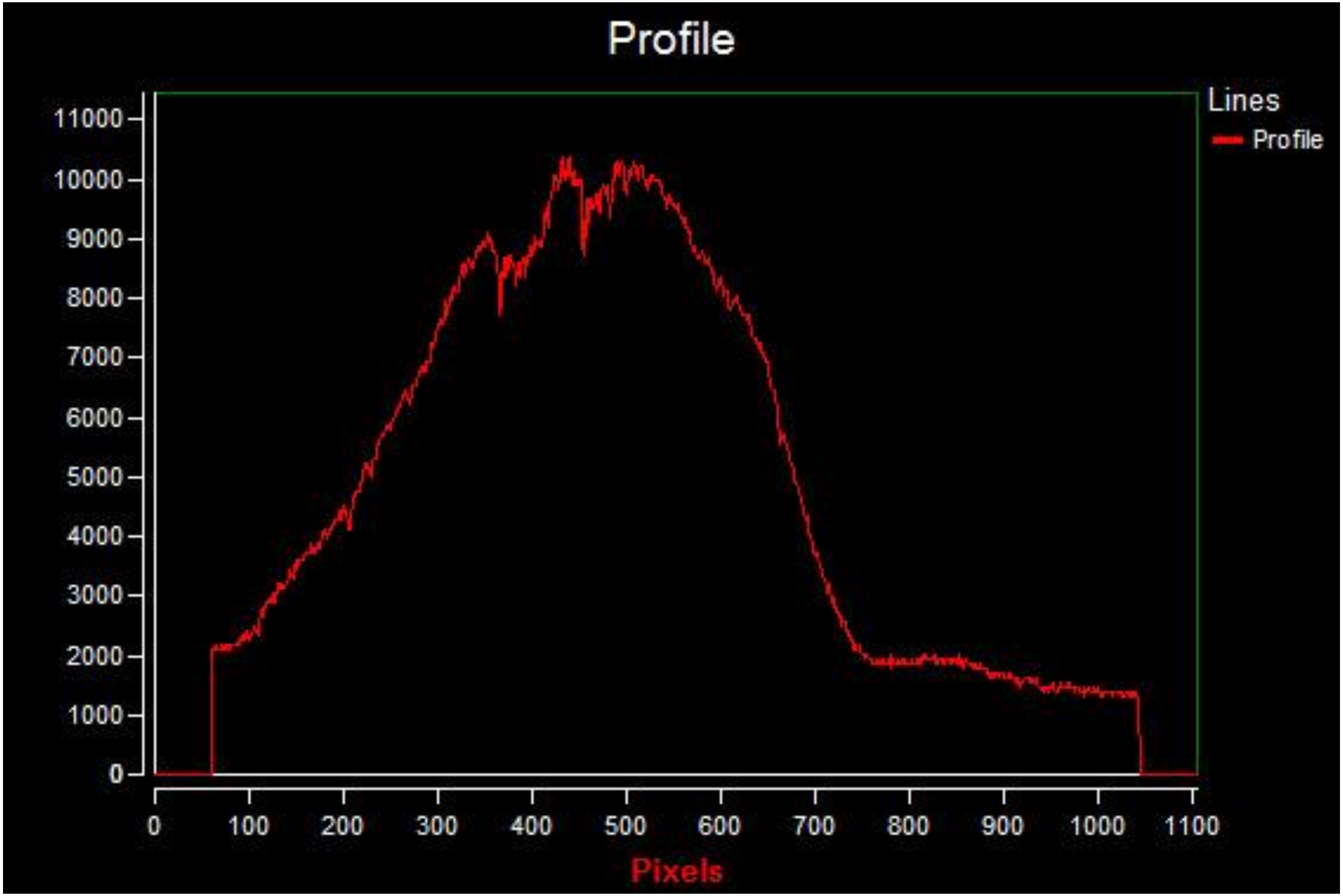


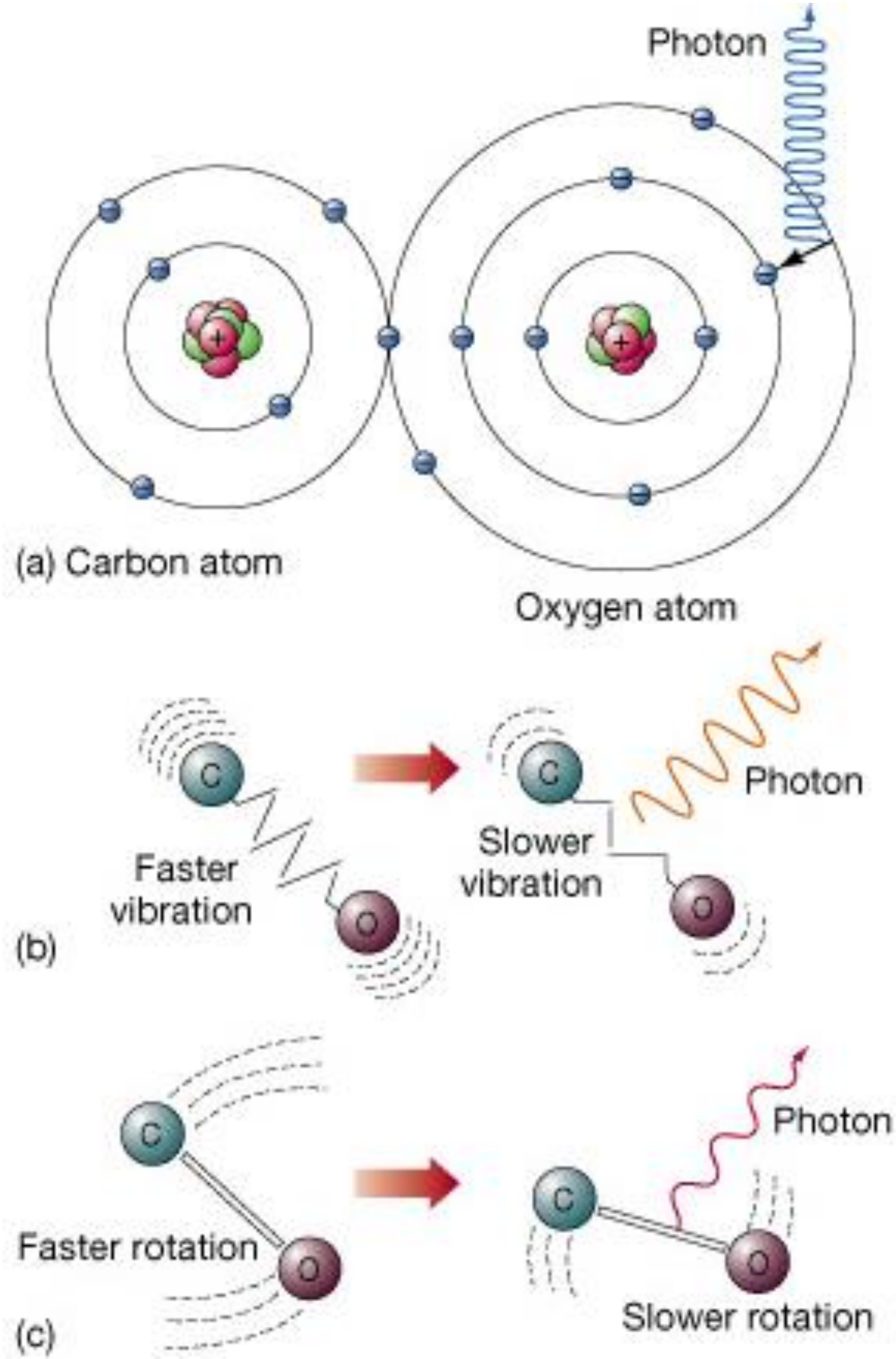
Image credit: RSpec-Astro.com

Both of these spectra are for Hydrogen.

Why the difference?

Molecular Hydrogen

Atomic Hydrogen



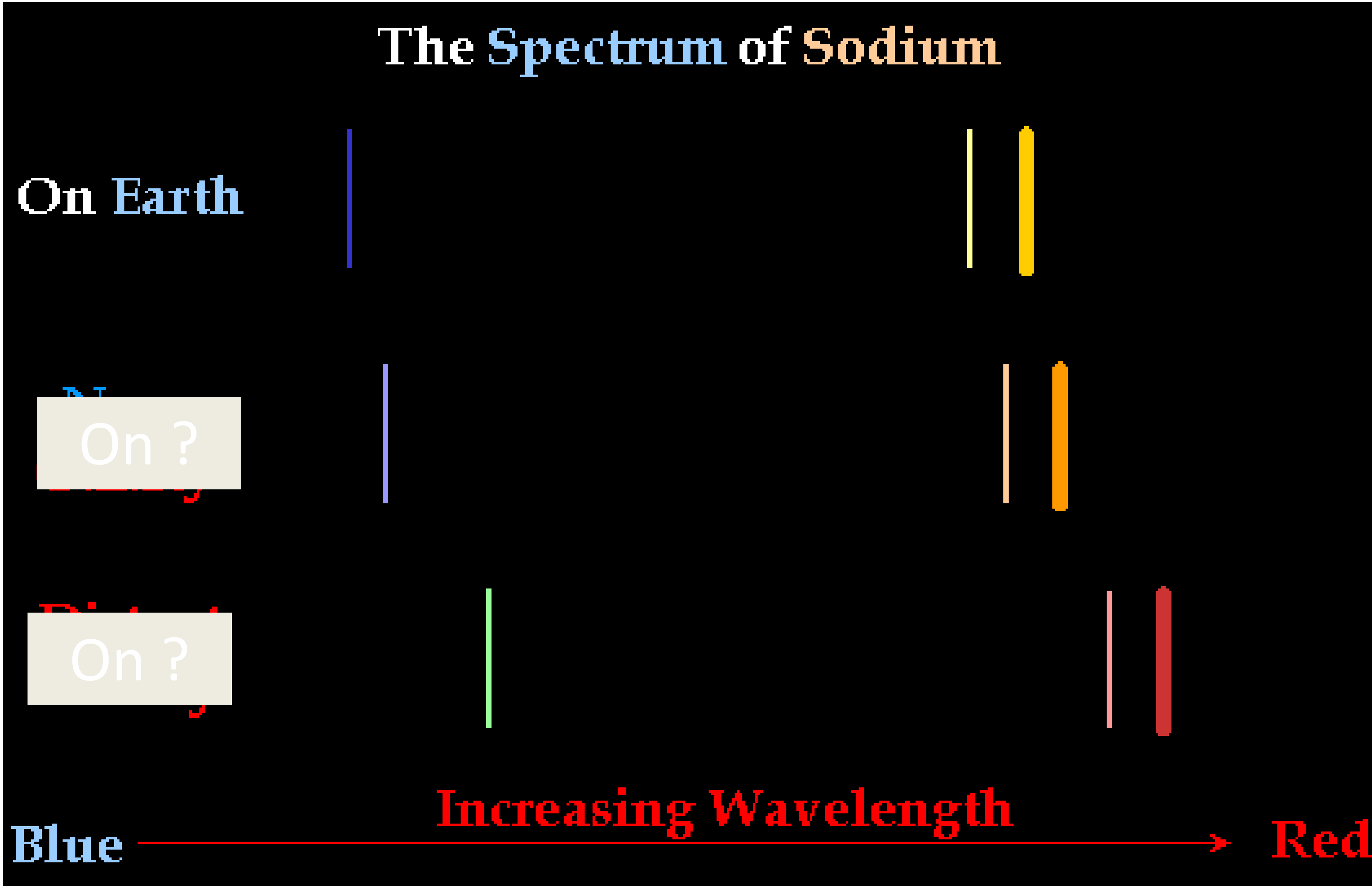
Various energy changes result in unique spectral lines for molecules.

What is different about the three stars?

Redshift

Blueshift

Without spectral lines it would be difficult, if not impossible, to judge the doppler effect!


The Spectrum of Sodium
On Earth
On ?
On ?
Increasing Wavelength
Blue
Red

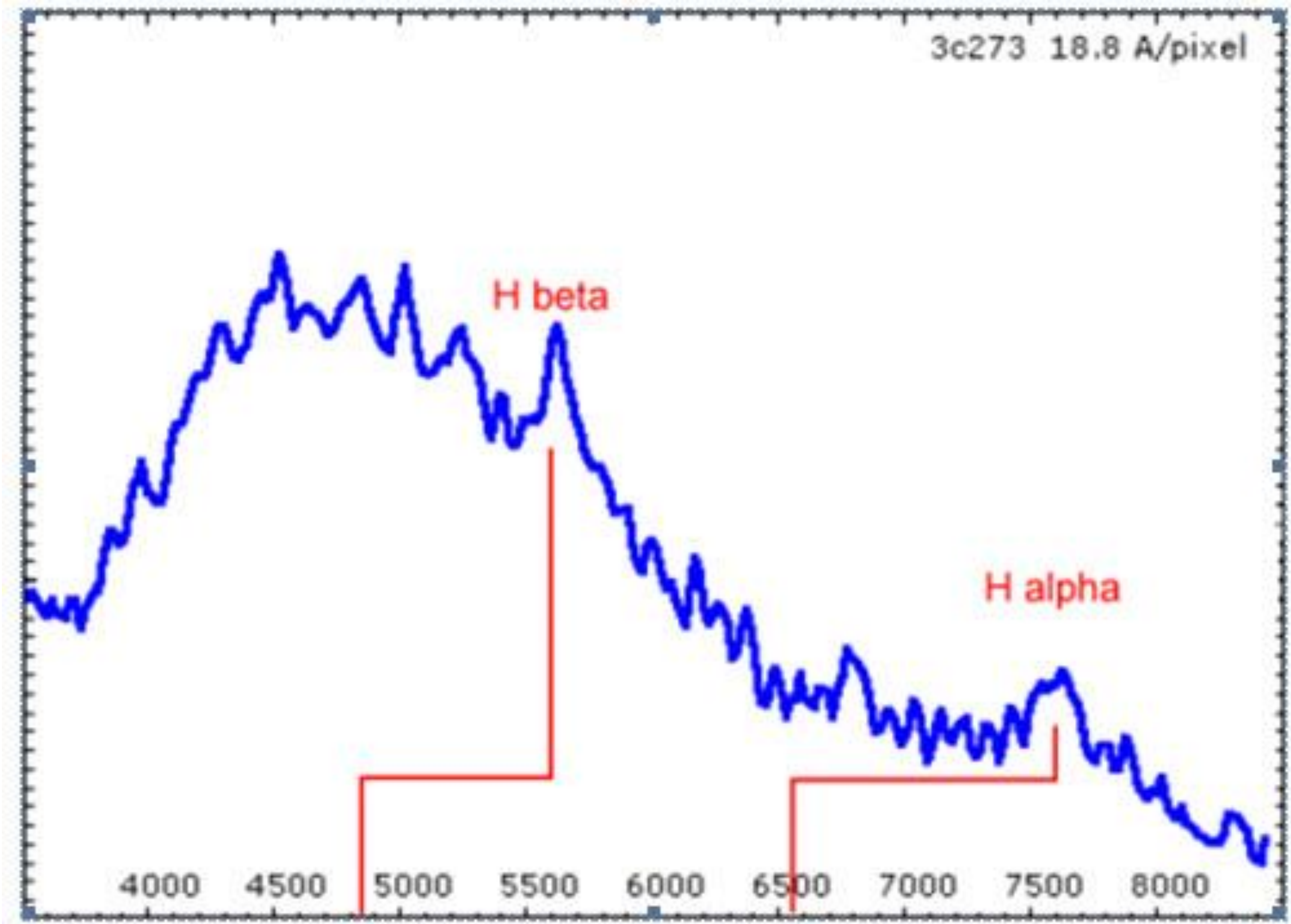
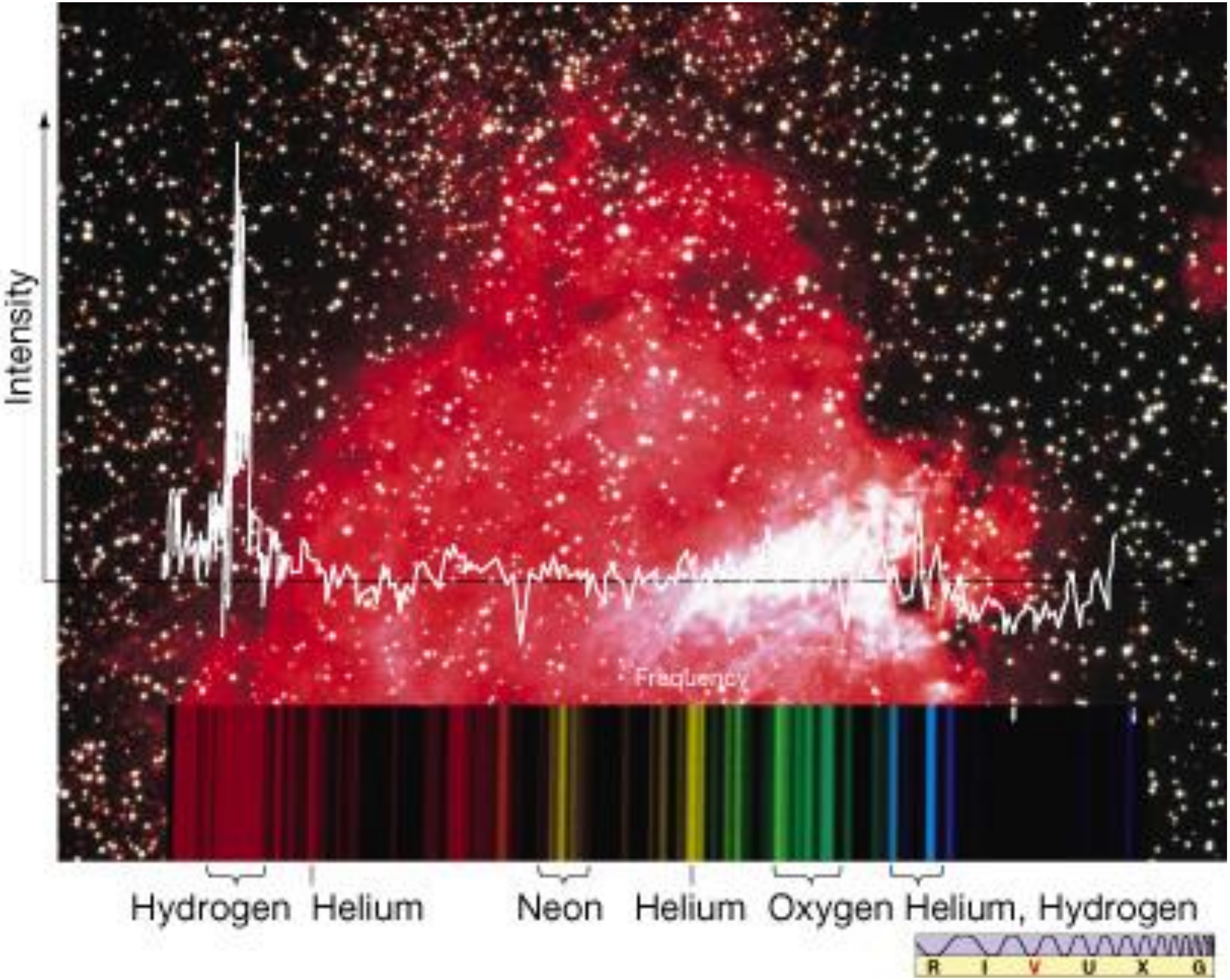


Image credit: RSpec-Astro.com

Usefulness of Lines

- Spectral lines allow astronomers to identify elements and molecules present in distant objects.
- *Which* lines are present can yield information about temperature.
- Shift of the entire pattern of lines reveals the Doppler effect and thus the velocity of the source.



Intensity
Frequency
Hydrogen
Helium
Neon
Helium
Oxygen
Helium, Hydrogen
R I V U X G

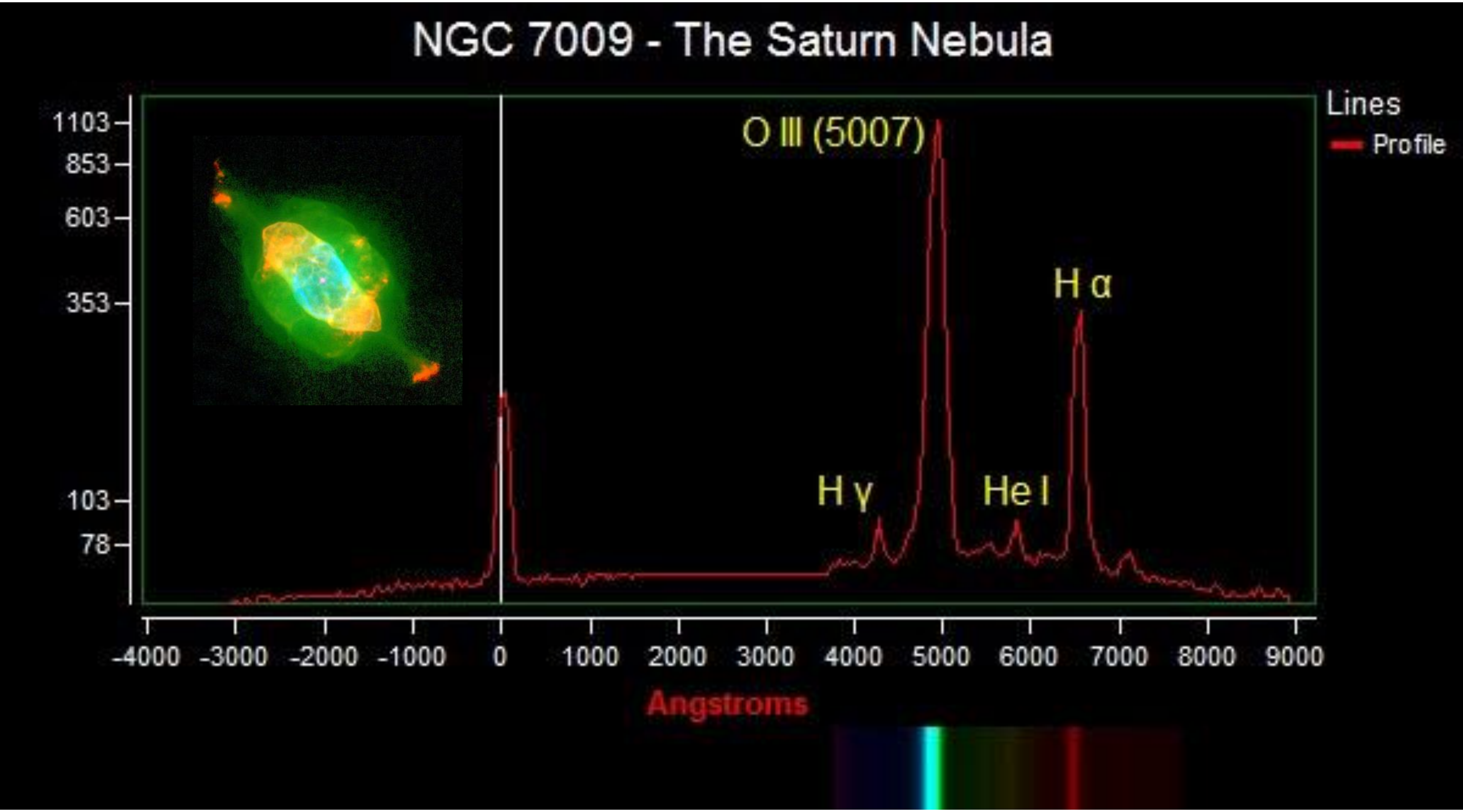


Image credits: Hubble Space Telescope and RSpec-Astro.com

Spectrum of a Super-Giant Star

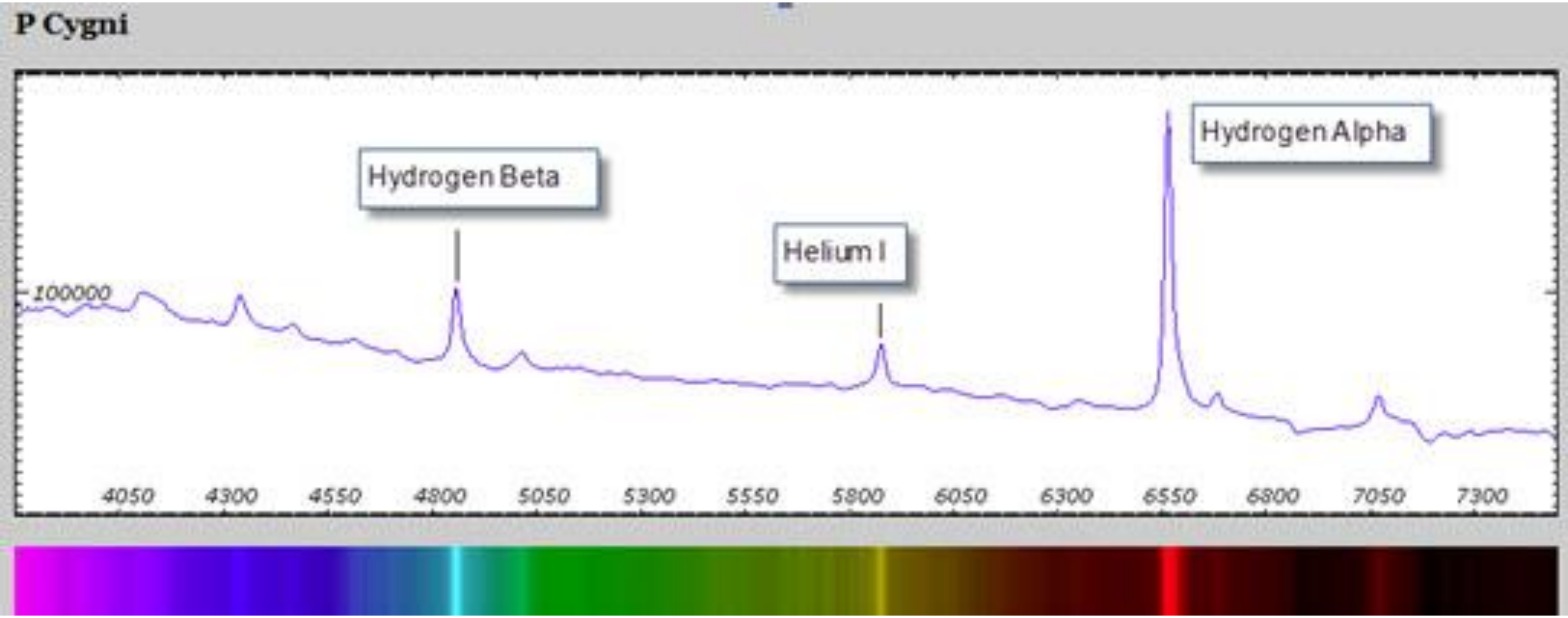


Image credit: RSpec-Astro.com

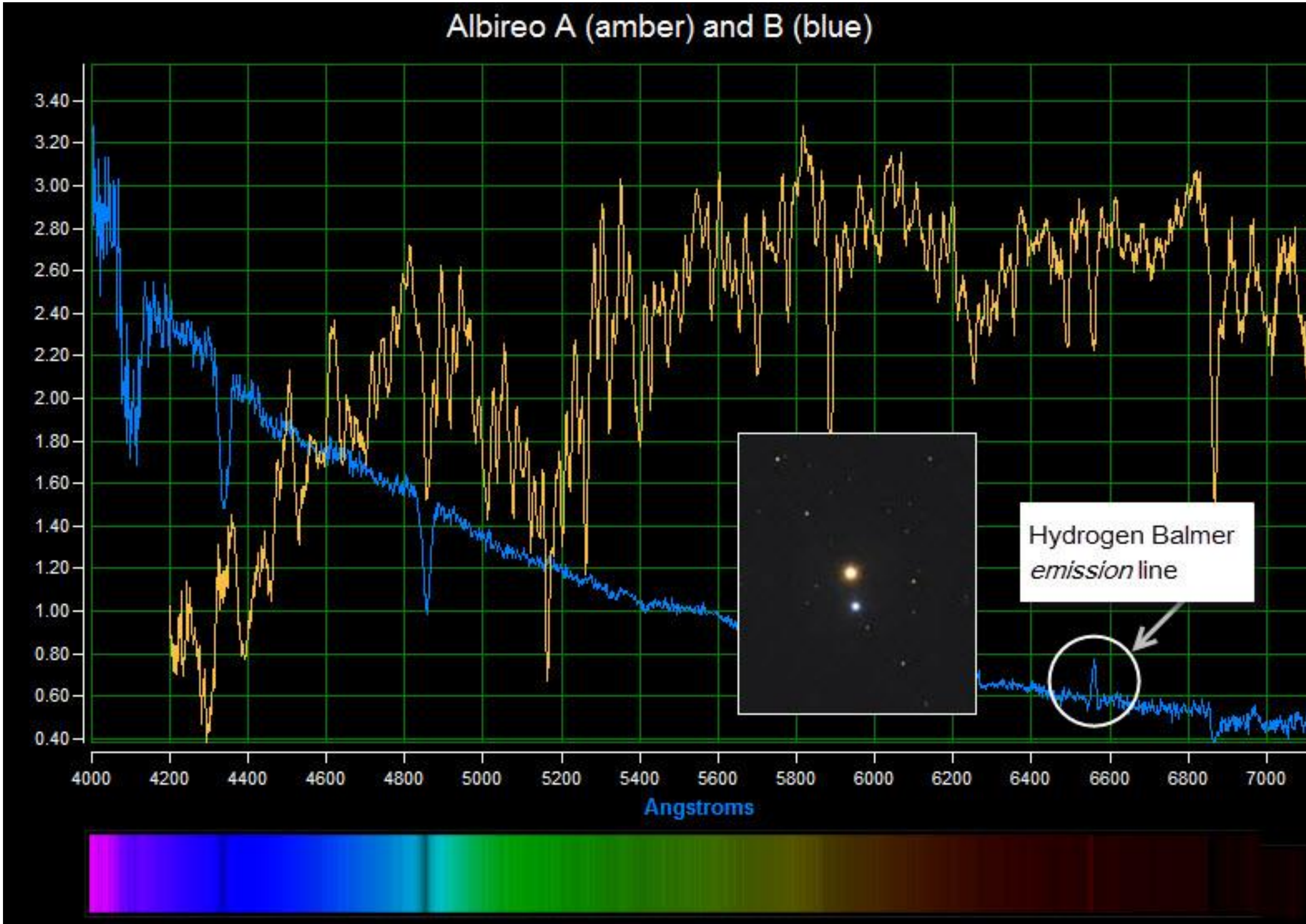
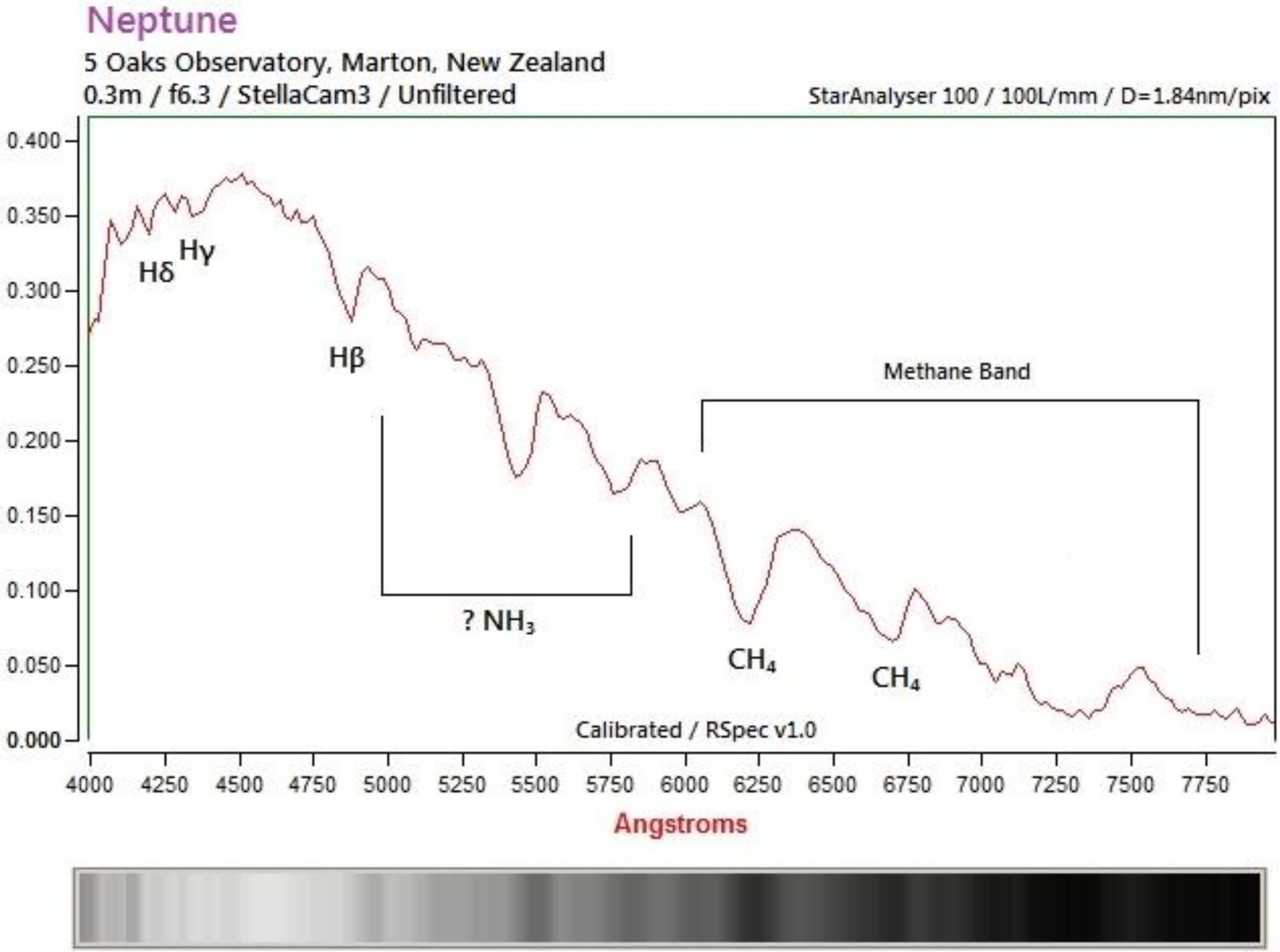


Image credit: RSpec-Astro.com



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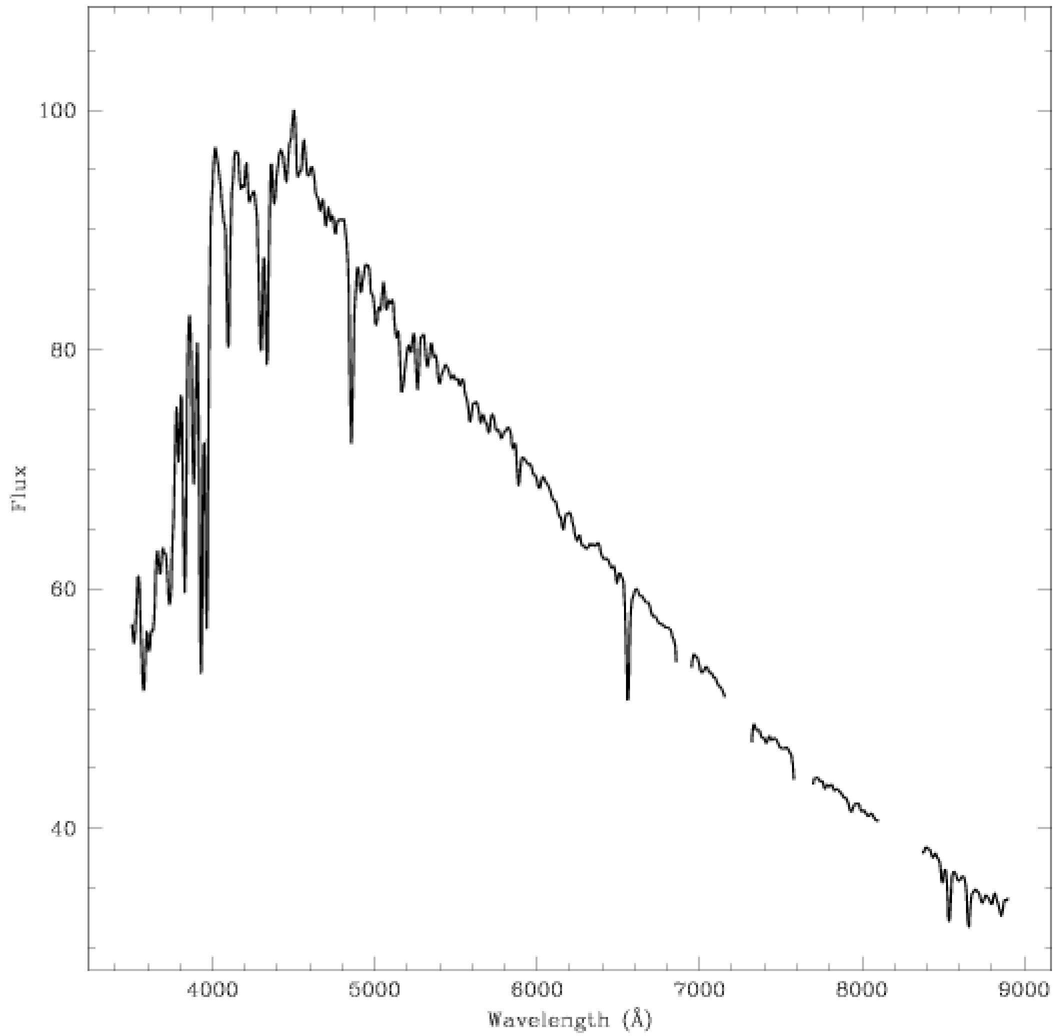
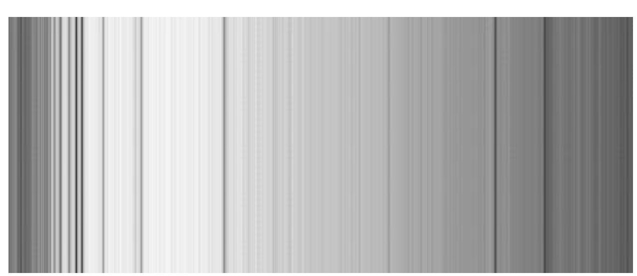
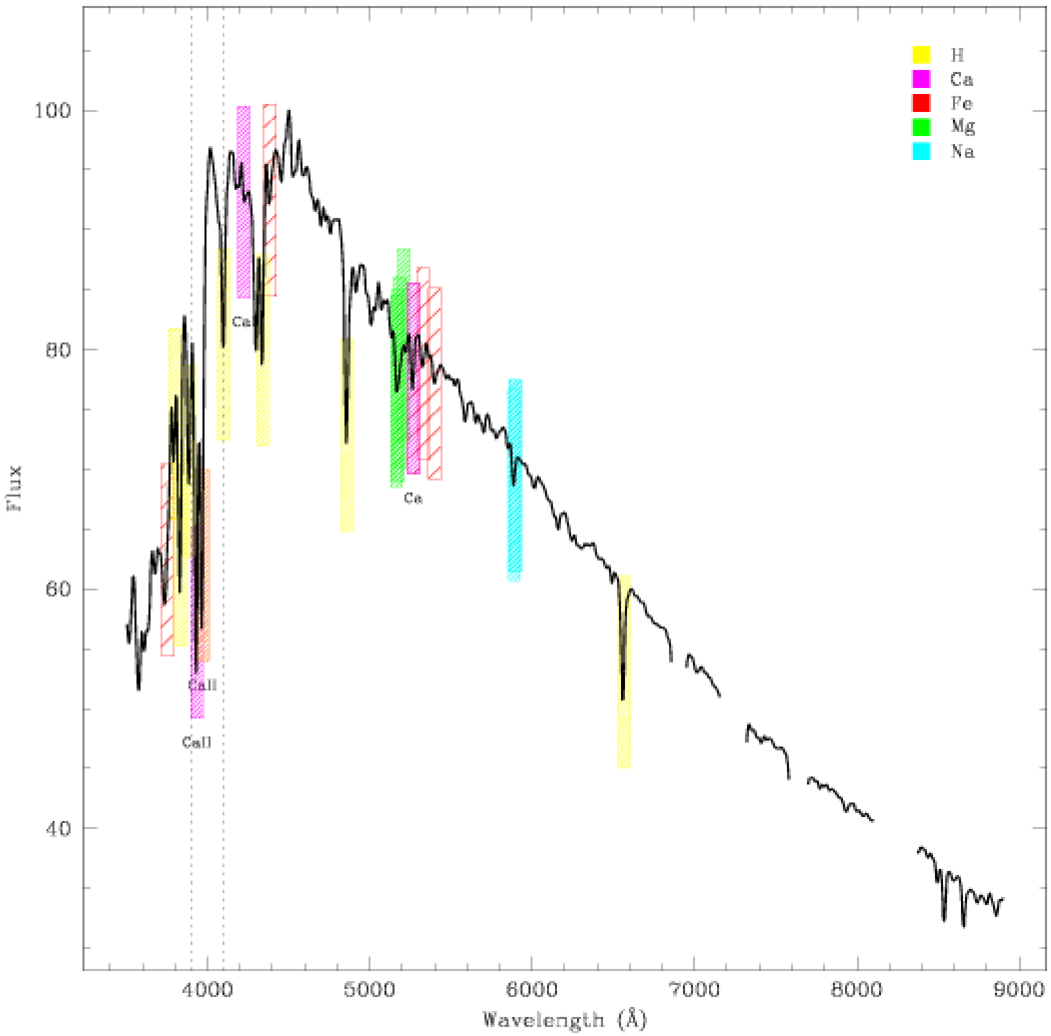
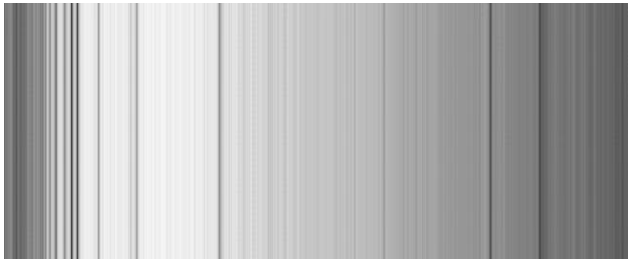


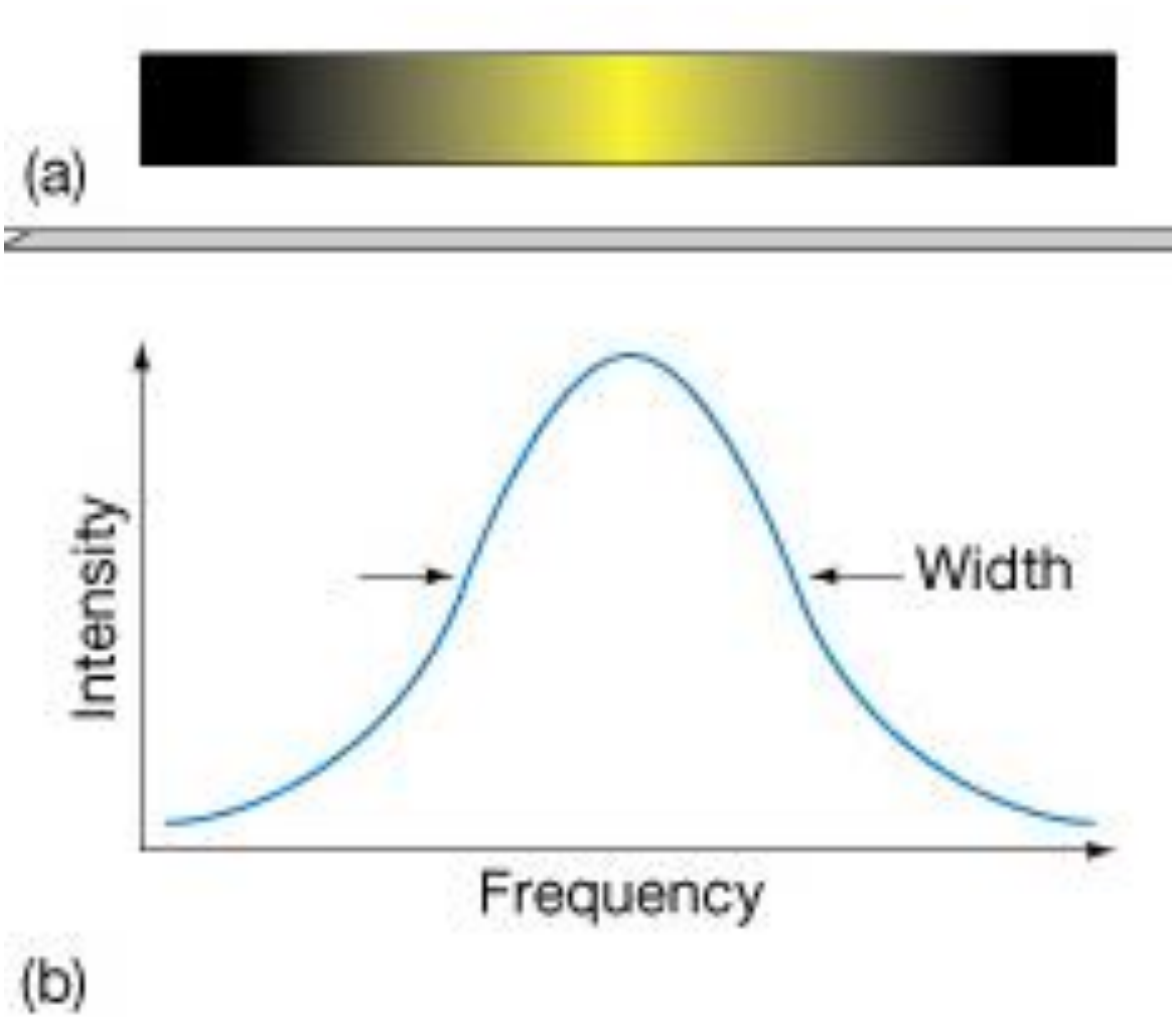
100
80
60
40
Flux
4000
5000
6000
7000
8000
9000
Wavelength (Å)

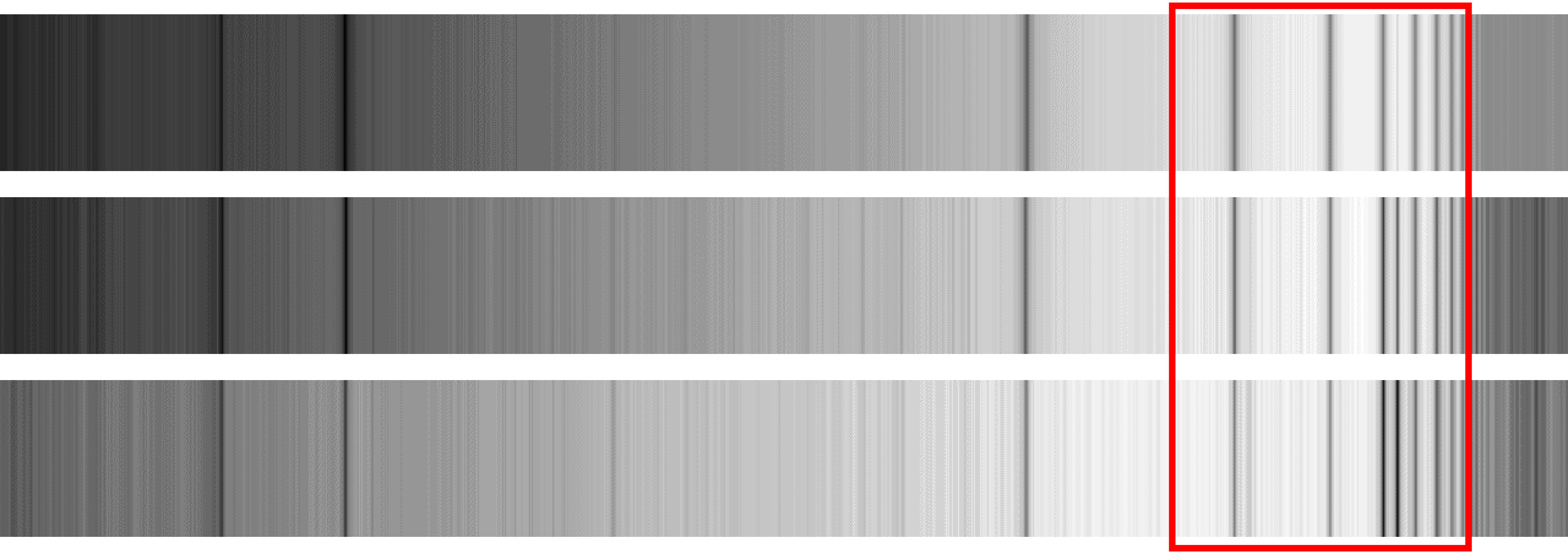


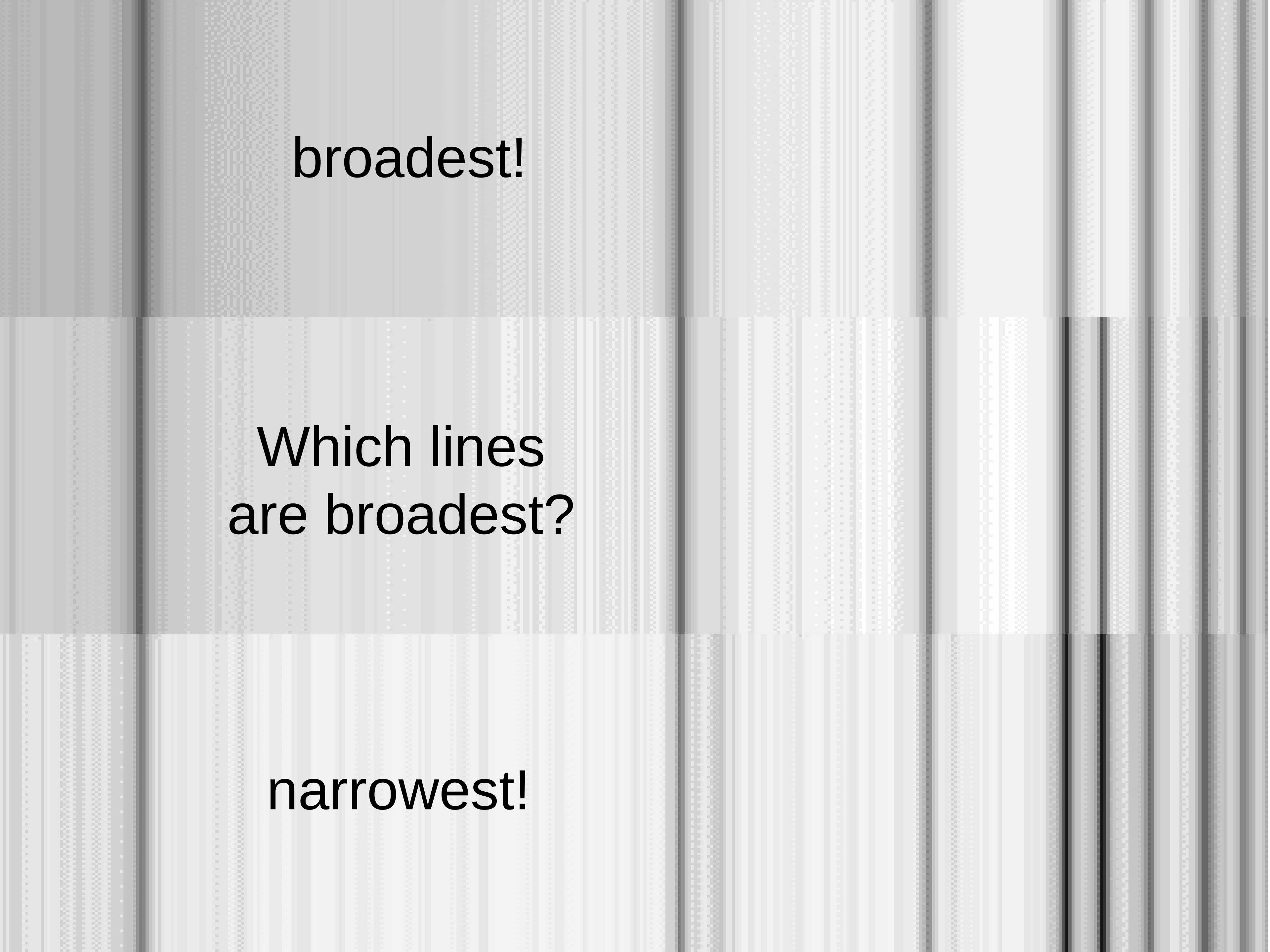

H
Ca
Fe
Mg
Na
CaII
CaII
Ca
Ca
Flux
100
80
60
40
4000
5000
6000
7000
8000
9000
Wavelength (Å)

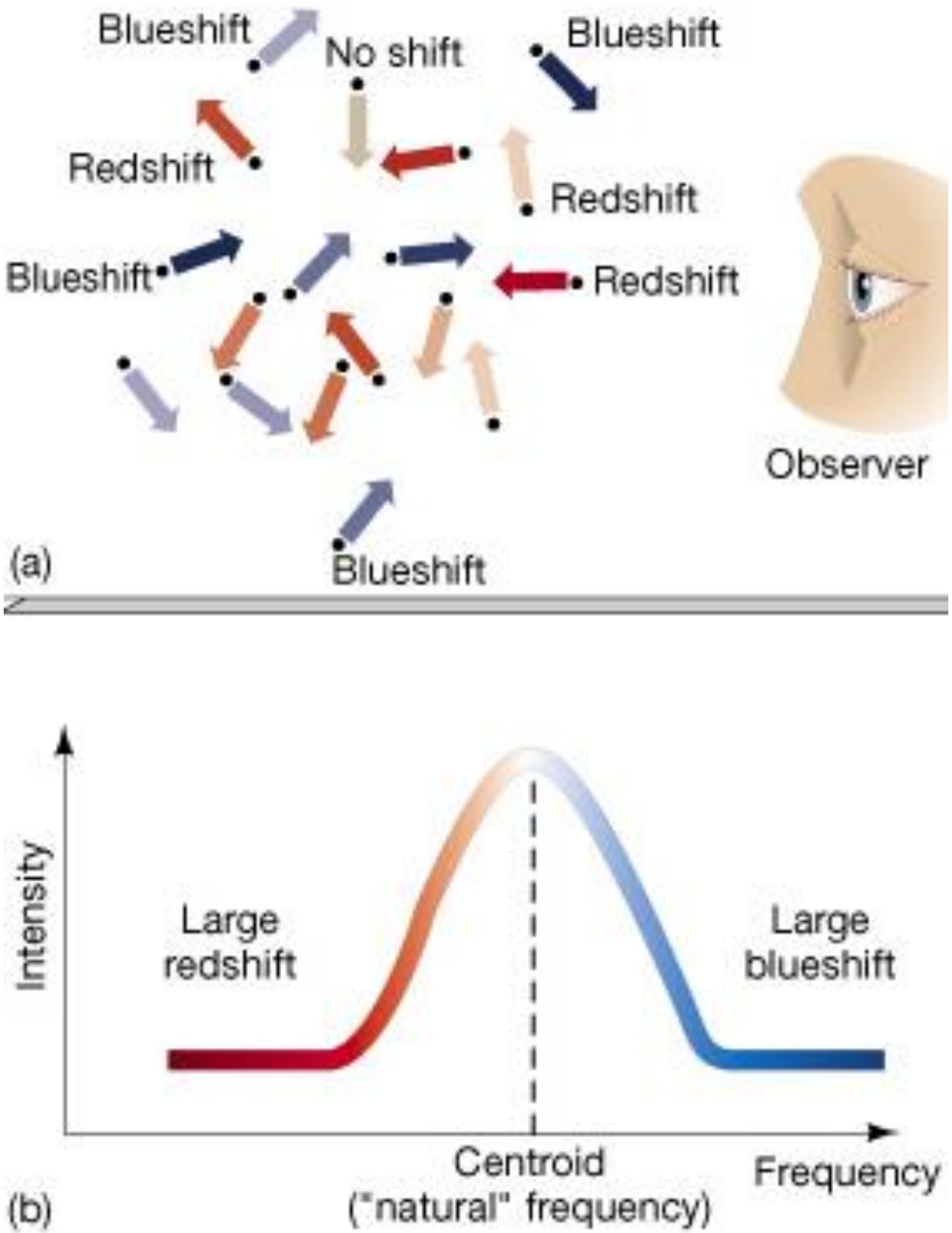


Line Broadening



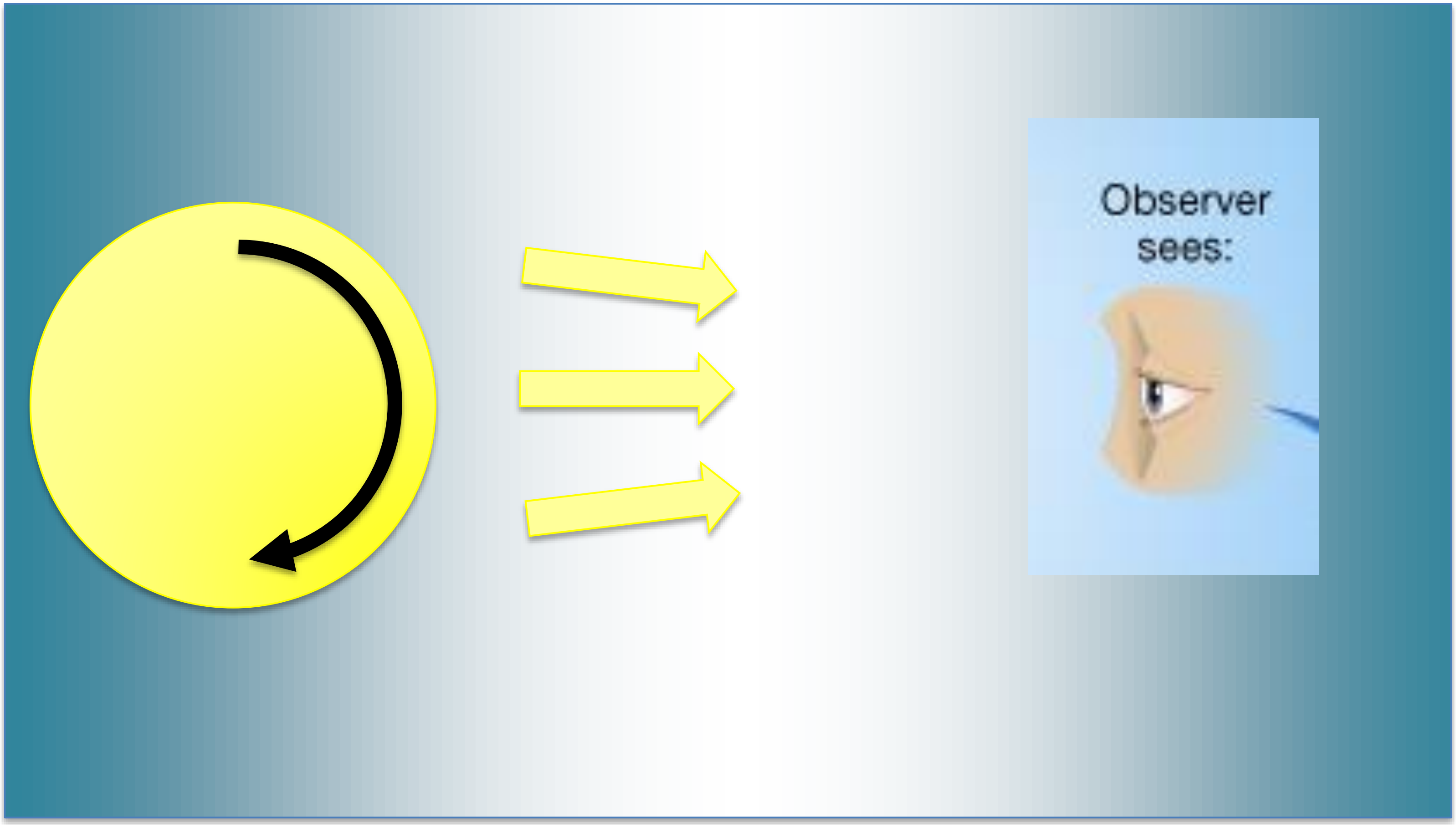



broadest!
Which lines
are broadest?
narrowest!

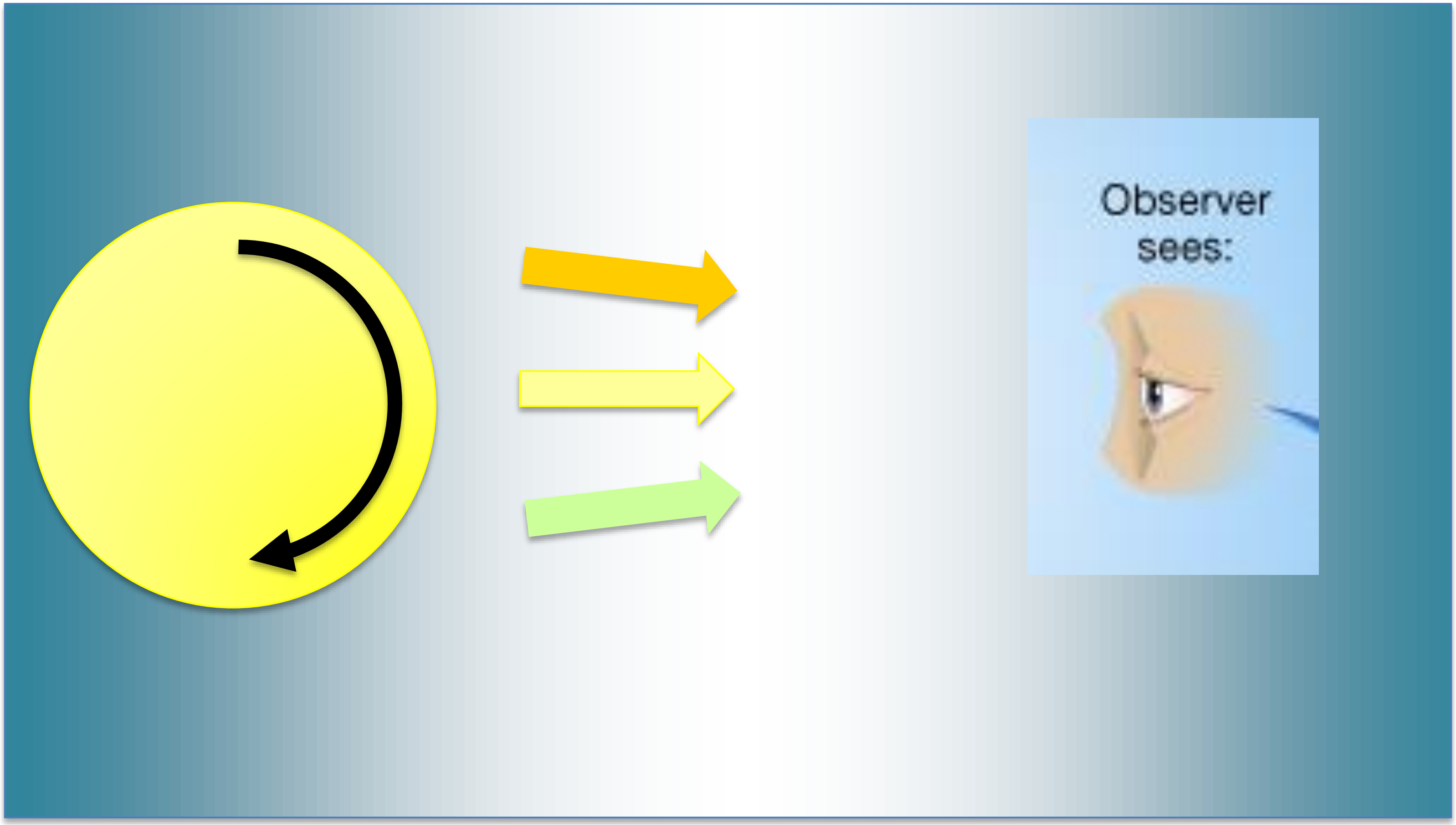


Thermal Broadening

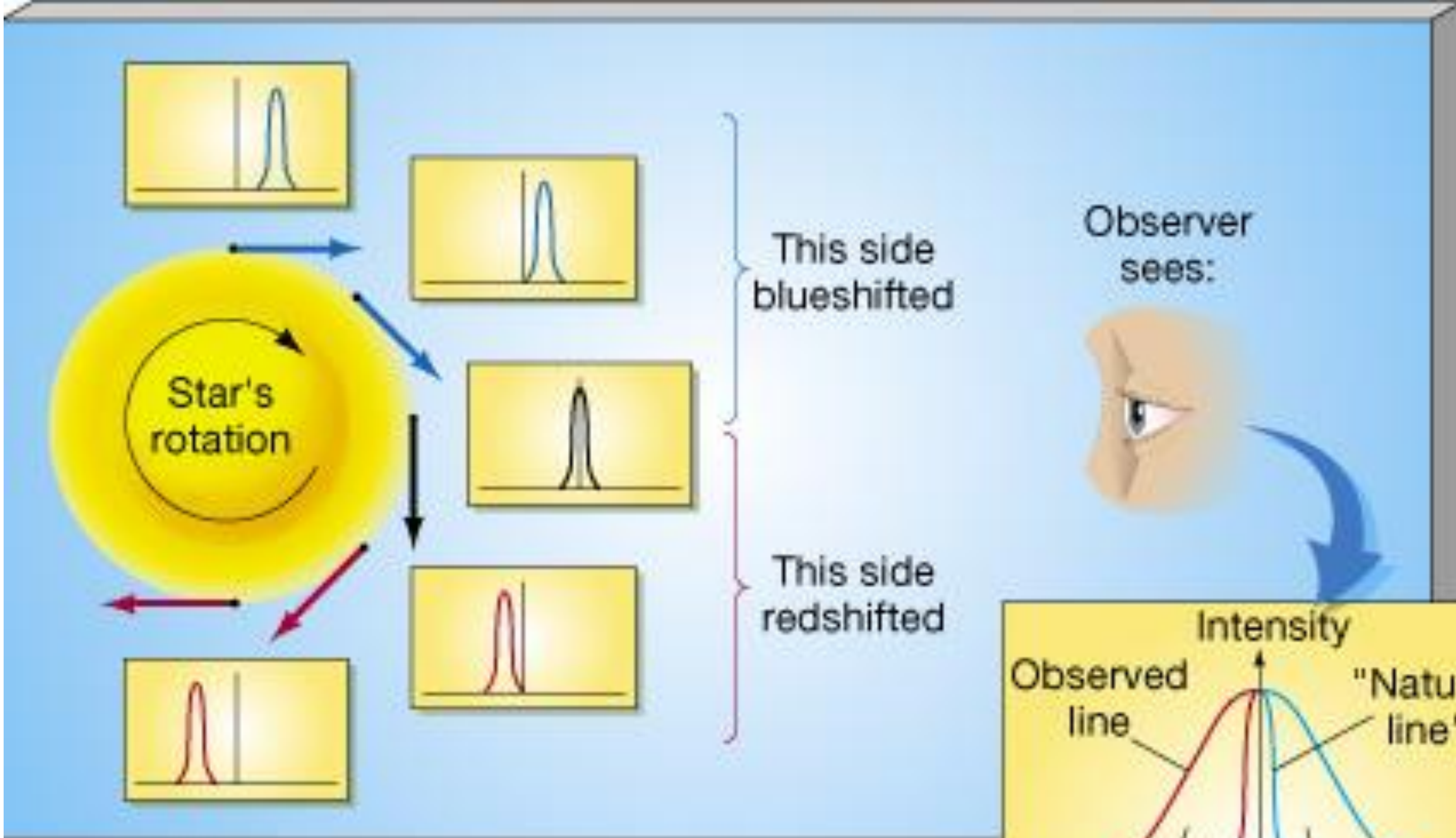
Greater temperature results in wider spectral lines.

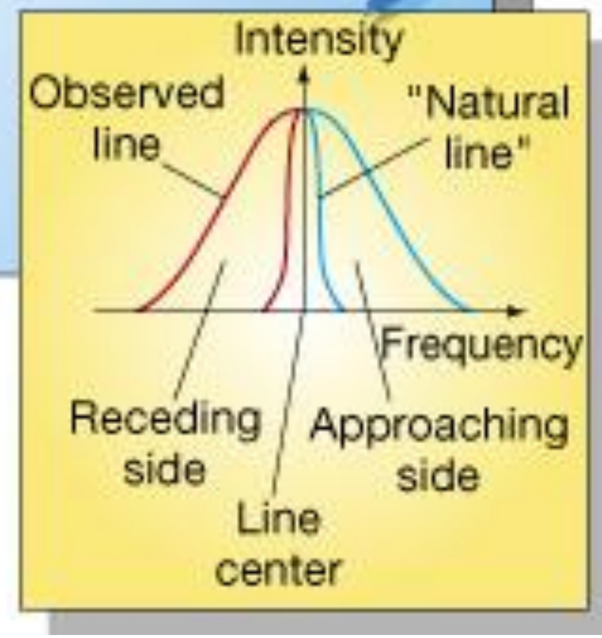


How does the light from the top, middle, and bottom of the rotating star differ?



How does the light from the top, middle, and bottom of the rotating star differ?





Rotational Broadening

More rapid rotation results in wider spectral lines.

Line Broadening

- Broadening of spectral lines help astronomers determine temperature, rotation, density, presence of magnetic field.
- Broadening can be quantified by graphing intensity vs. frequency or wavelength.

Line Intensity

- Within a spectrum some lines may appear more intense than others.
- Relative line intensity is related to relative quantities of different types of atoms and/or molecules.
- Varying intensity of lines within a spectrum is related to temperature.