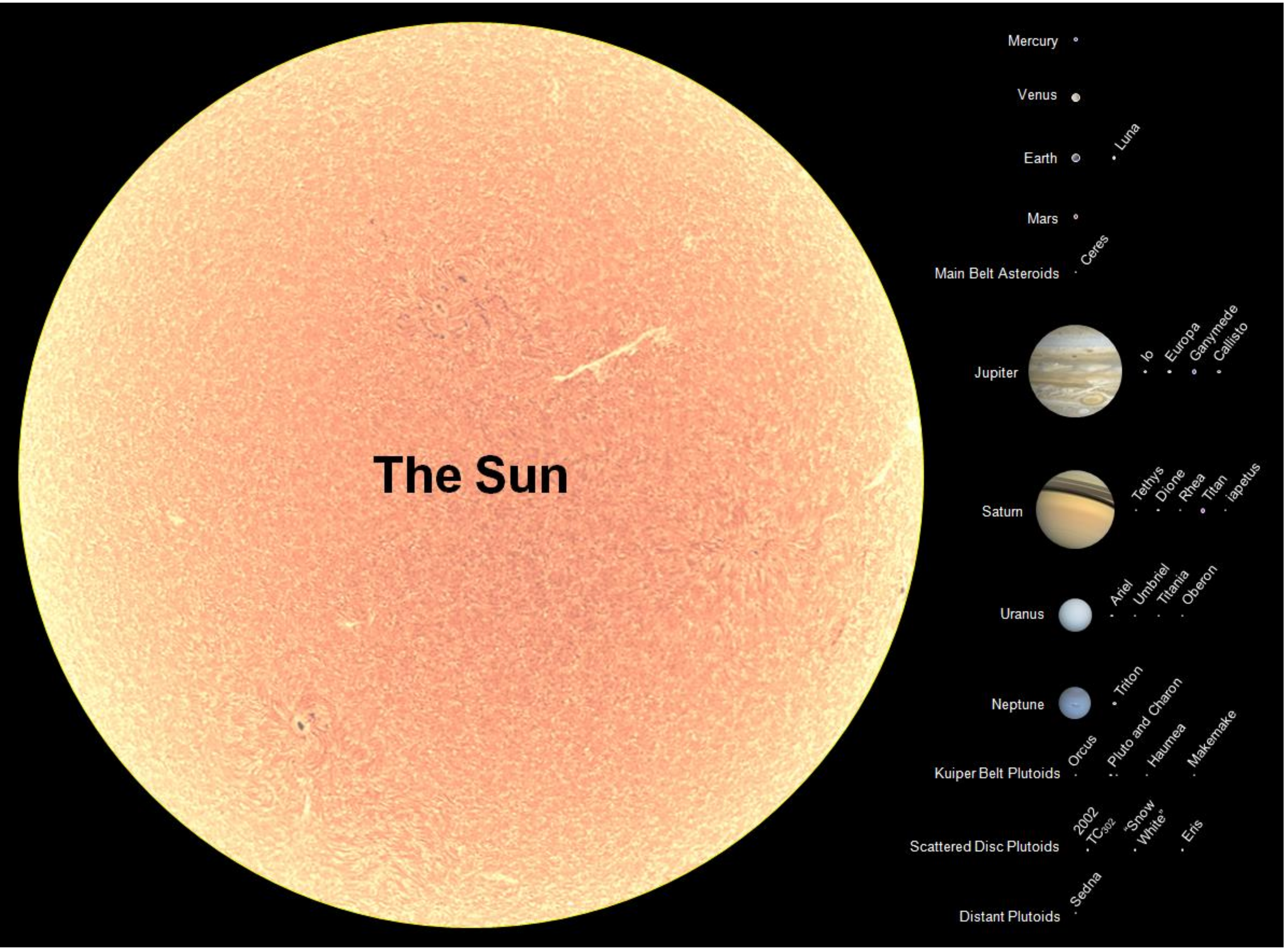
Sun light, blackbodies & spectra

Week 5

Remember:



- Sun is 99.9% of the **mass** of Solar System

- Sun's **composition** is mostly H, with lots of He and a little bit of other elements

TABLE 8-1 The Most Abundant Elements in the Sun

Element	Percentage by Number of Atoms	Percentage by Mass
Hydrogen	91.0	70.6
Helium	8.9	27.5
Carbon	0.03	0.3
Nitrogen	0.01	0.1
Oxygen	0.05	0.6
Neon	0.01	0.2
Magnesium	0.003	0.07
Silicon	0.003	0.07
Sulfur	0.002	0.04
Iron	0.003	0.1

Sun's surface Temperature is 5500 °C

TODAY

- How do we know the properties of the Sun?

    Mass?

    Temperature of the Sun?

    Composition of the Sun?

How do we know the mass of the Sun?

A. We measure the pull of gravity on the Earth and Moon.
B. We observe the orbital periods and distances of planets.
C. We track the rise and fall of tides in Earth’s oceans.
D. We estimate mass based on what the Sun is made of.

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Recall, combining Kepler and Newton:

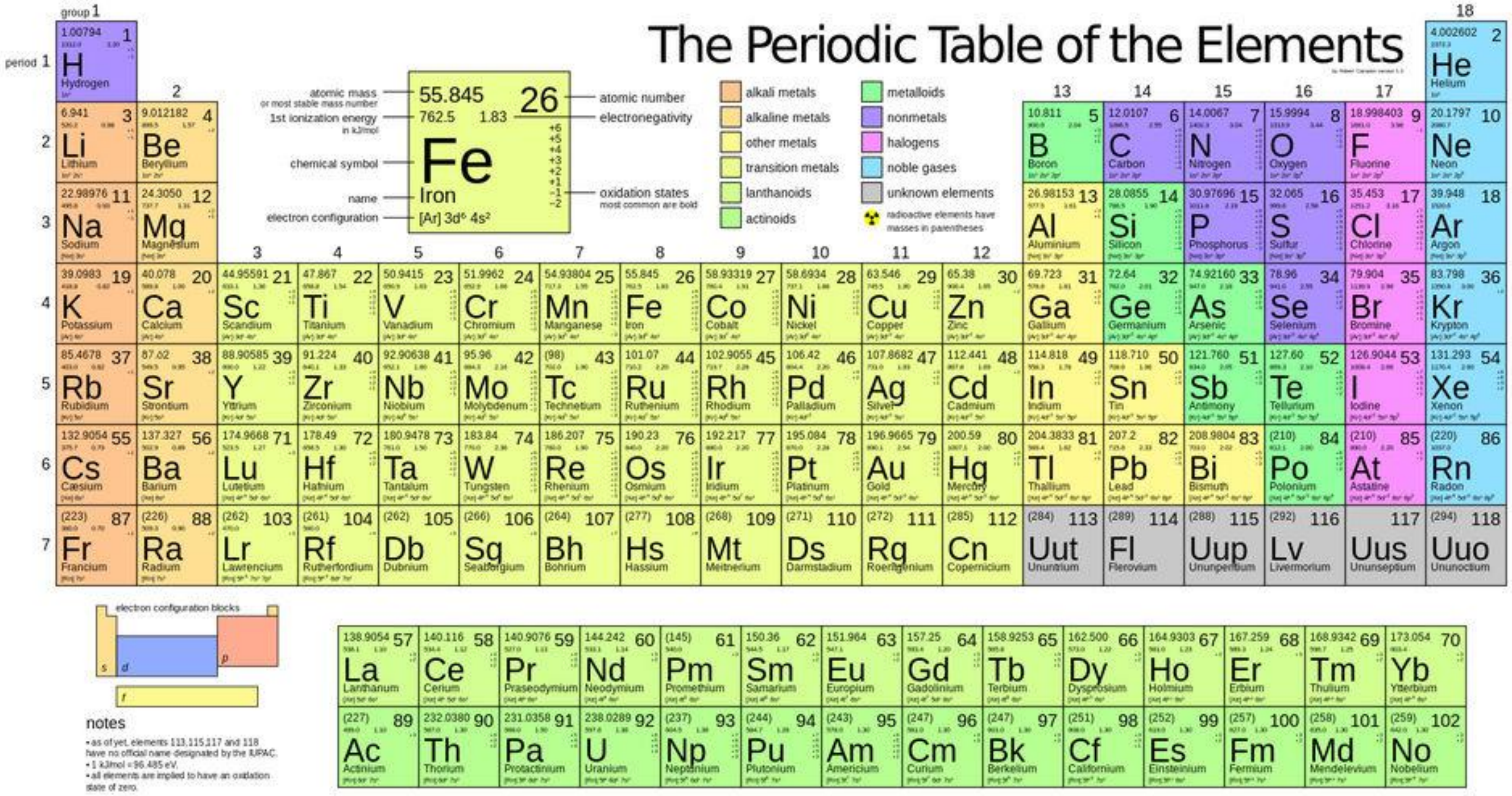
$$P^2 = \left(\frac{4\pi^2}{G\boldsymbol{M}}\right) a^3 \quad \Rightarrow \quad \boldsymbol{M} = \left(\frac{4\pi^2}{G}\right) \frac{a^3}{P^2}$$

What is Mass?

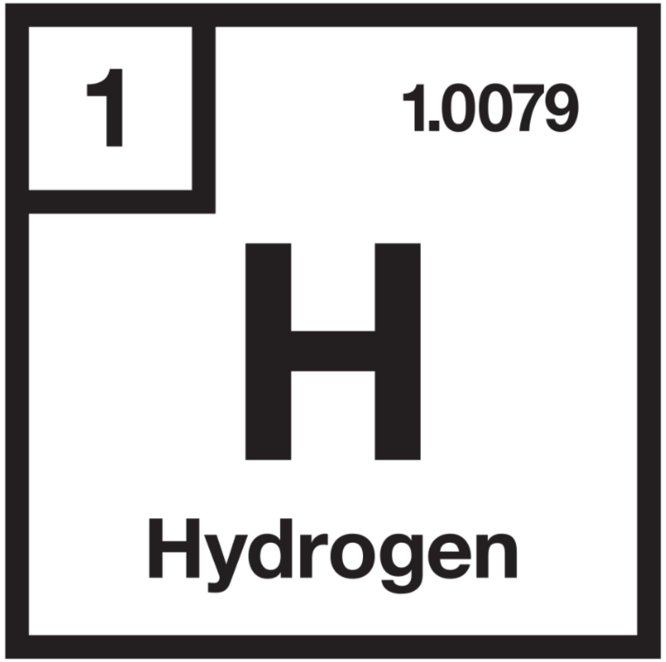
- Physical body that accelerates when a force is applied to it

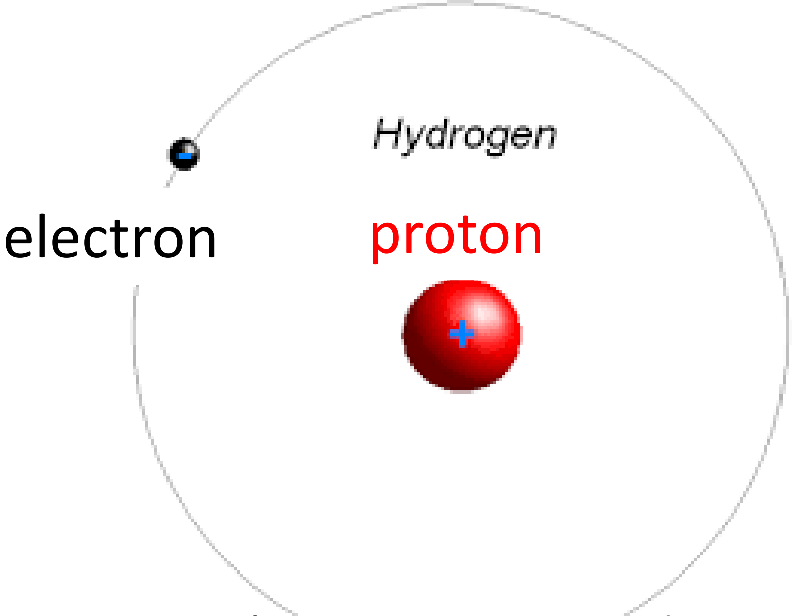
- Material

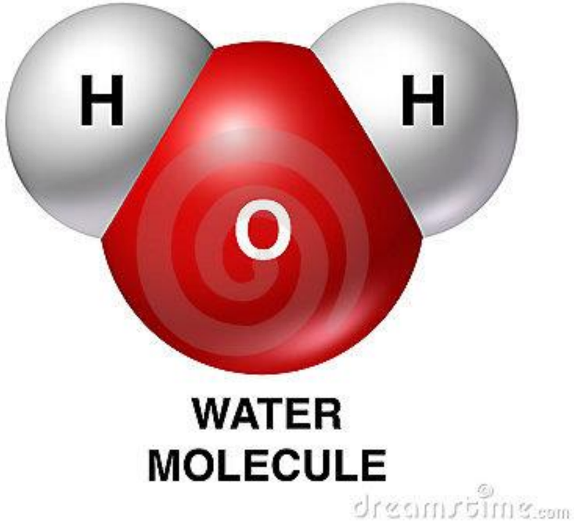
- Generally, material is made of ***elements***



Elements, atoms & compounds







H_2O

Elements have unique physical & chemical properties

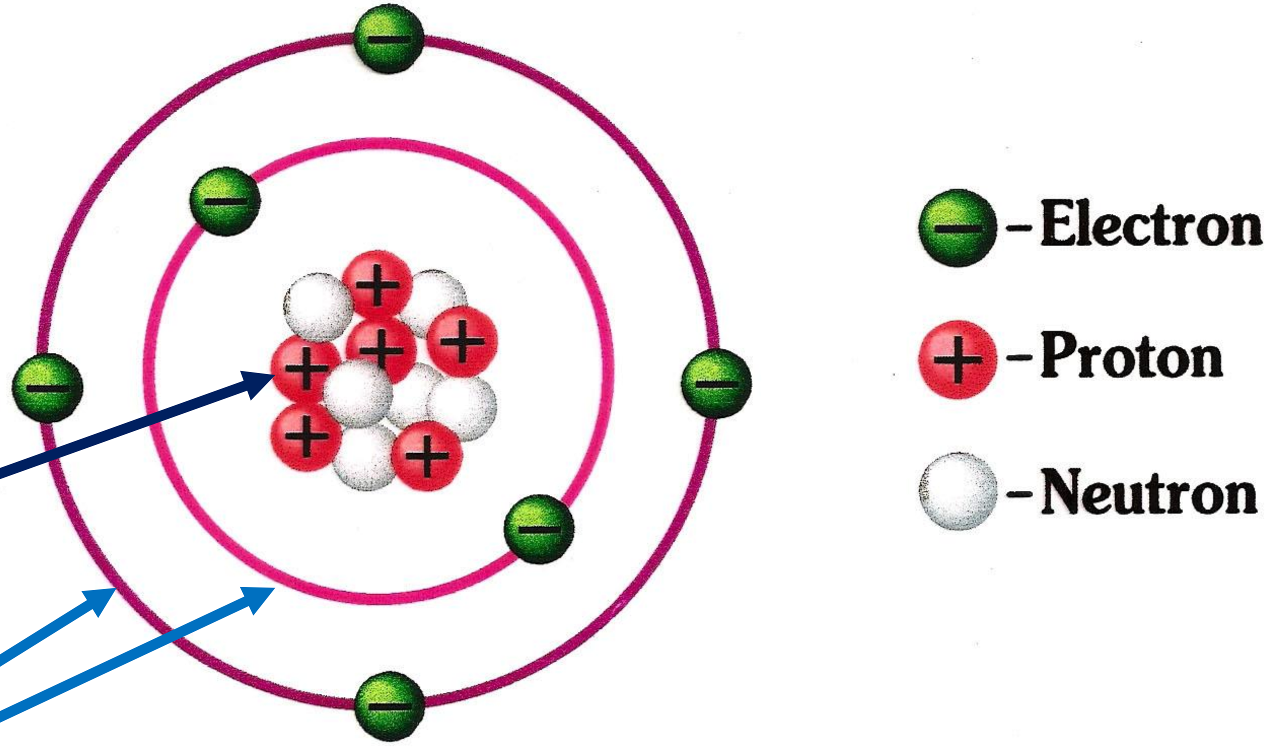
Elements are made up of ***atoms***;

Each ***atom*** carries properties of the *element*

Atoms combine with each other to form ***compounds*** via chemical bonding

Atoms

- Nucleus
  - Protons (+ charge) [p^+]
  - Neutrons (no charge) [n^0]
- Orbitals
  - Electrons (- charge) [e^-]
- Type of element = # of p^+
- Atomic mass = $p^+ + n^0$
- Electrons
  - important for bonding
  - interact with electromagnetic radiation

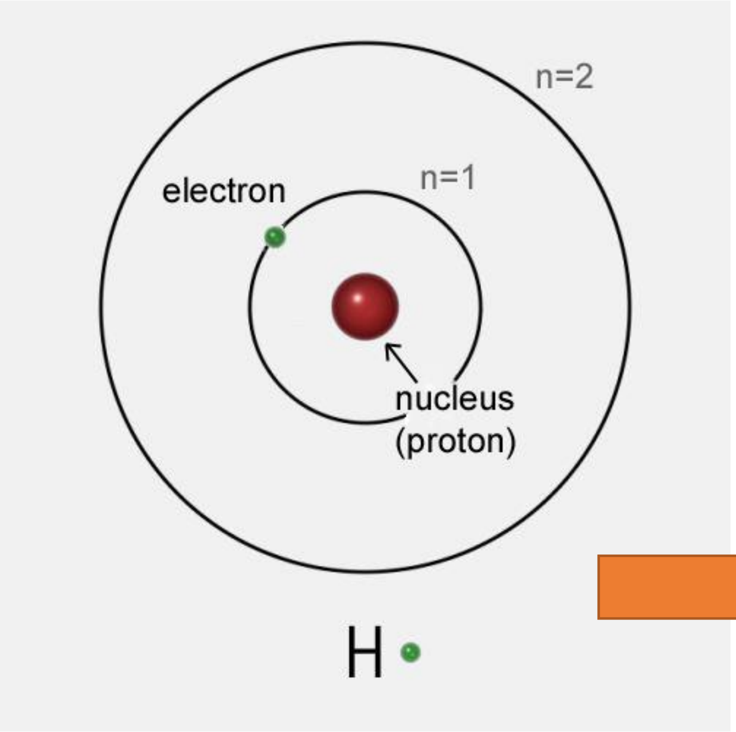


Atoms and EM radiation

- Electrons move and atoms vibrate, which releases energy

Blackbody radiation ('continuous spectra')

- Electrons in specific/discrete orbitals that have specific energy associated with them
  - Electrons move between orbitals
  - Specific orbitals depend on the number of protons (i.e., the element of the atom)



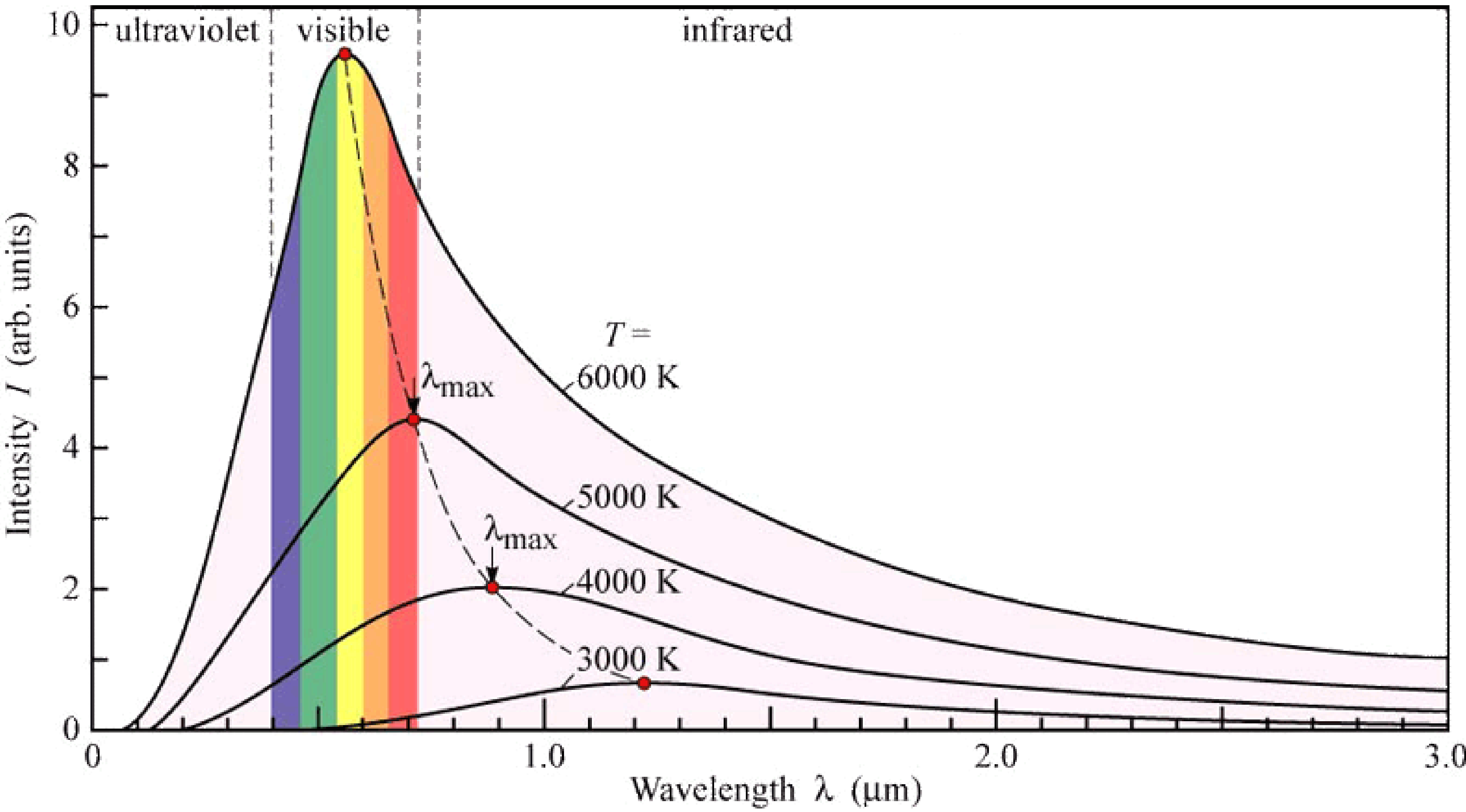
Absorption and Emission Spectra

What is a Blackbody?

Definition:

Sometimes astronomers use the term ``blackbody'' spectrum for a thermal spectrum. A ``blackbody'' is an object that absorbs all the light falling on it, reflecting none of it, hence, it appears black. ***When the ``blackbody'' object is heated, it emits light very efficiently without any gaps or breaks in the brightness****. Though no object is a perfect ``blackbody'', most stars, planets, moons and asteroids are near enough to being ``blackbodies'', that they will produce spectra very similar to a perfect thermal spectrum.*

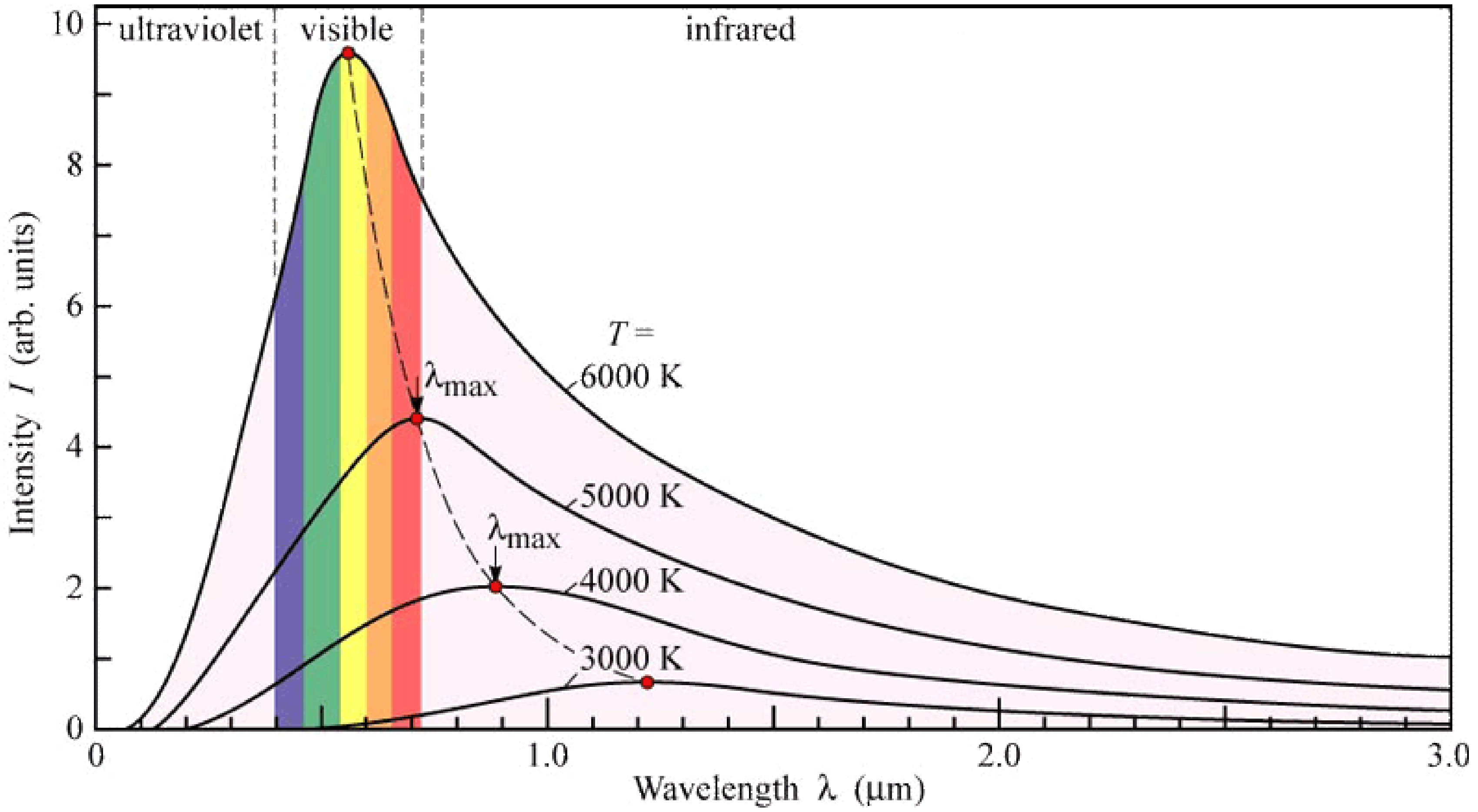
Blackbody curves



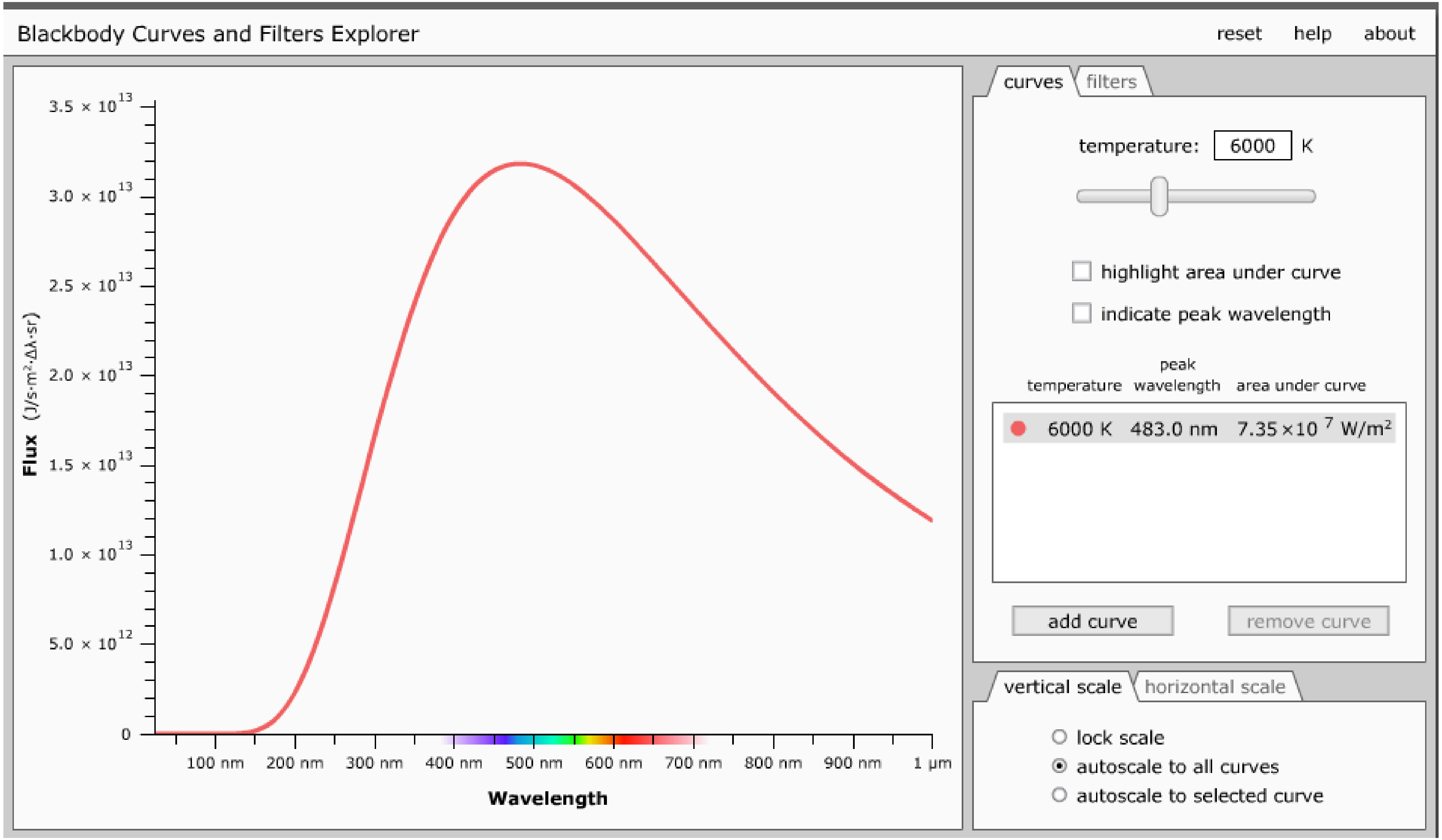
Blackbody curves

Flux (or intensity, radiance)

Amount of radiation ≈ number of photons



Wavelength (in units of m, μm, or nm)

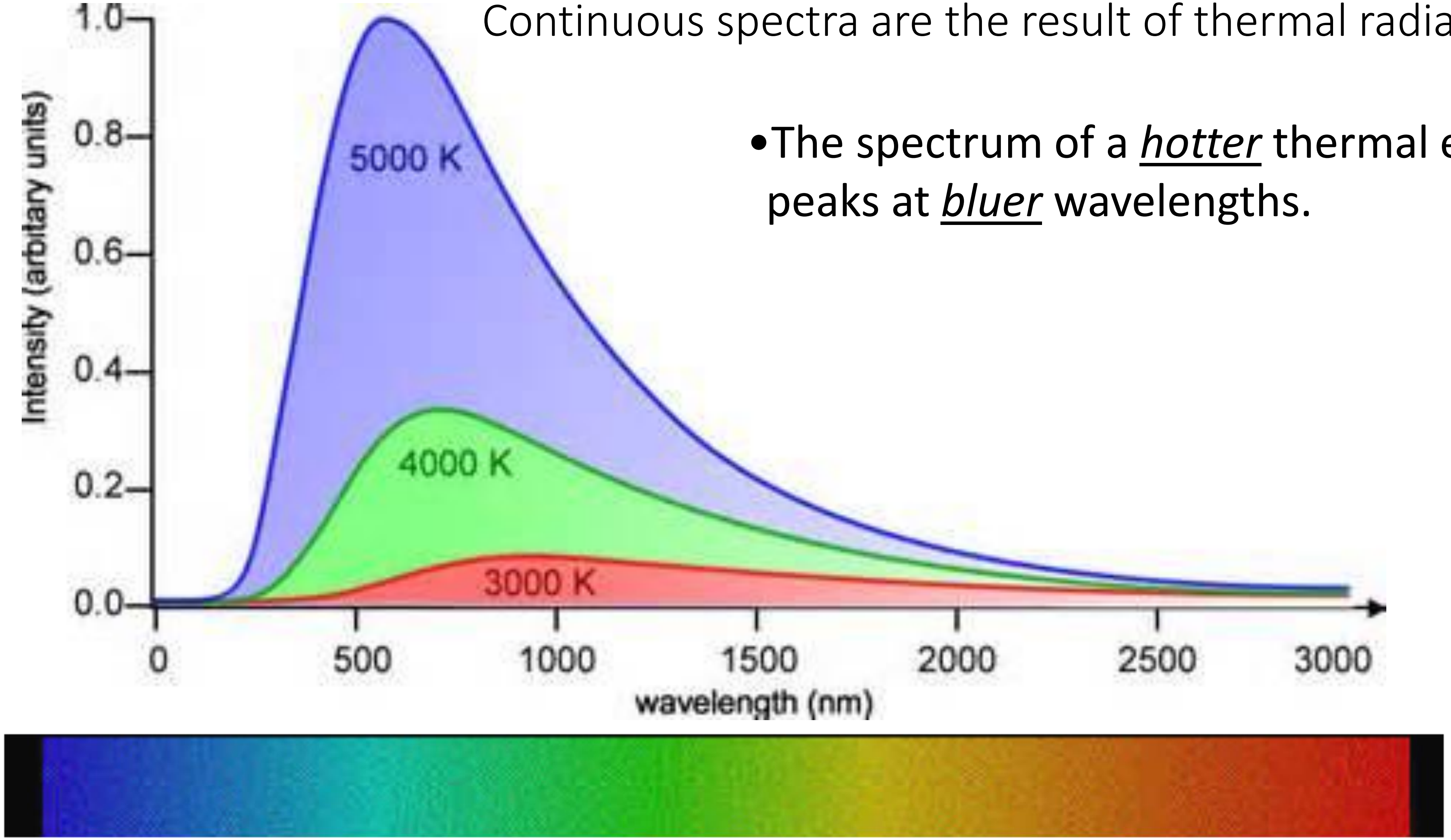


http://astro.unl.edu/classaction/animations/light/bbexplorer.html

Thermal emission produces continuous spectra.

Continuous spectra are the result of thermal radiation.

- The spectrum of a ***hotter*** thermal emitter peaks at ***bluer*** wavelengths.



Note that temperatures are given in Kelvin

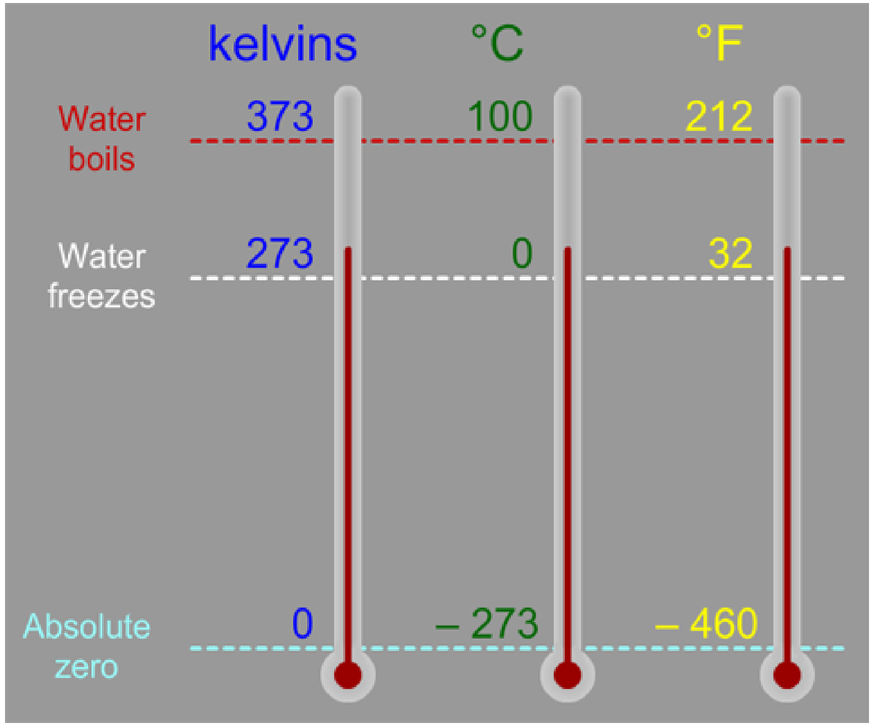
Degrees Fahrenheit (°F) → Degrees Celsius (°C)

$$°C = (°F - 32) * \frac{5}{9}$$

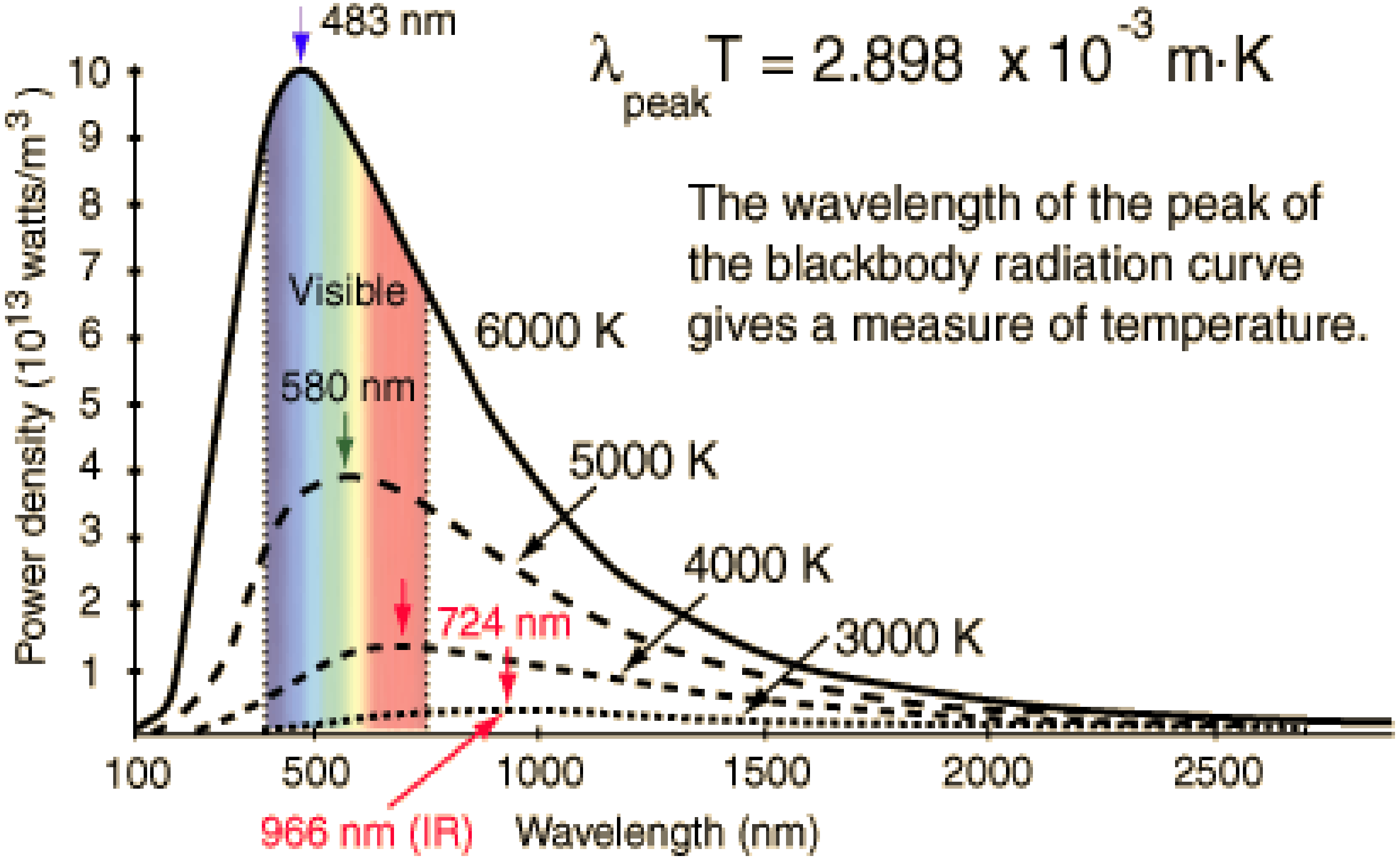
Degrees Celsius (°C) → Kelvin

$$K = °C + 273.15$$

0 K = “absolute zero” (atoms stop vibrating)



Wien's Law



For more info http://hyperphysics.phy-astr.gsu.edu/hbase/wien.html

The peak of the blackbody curve can tell you the surface temperature of the star using Wien's law but it can also tell you what color the star will appear.

Will the star that has a surface temperature of 6000K appear…

A. Red
B. Blue
C. White

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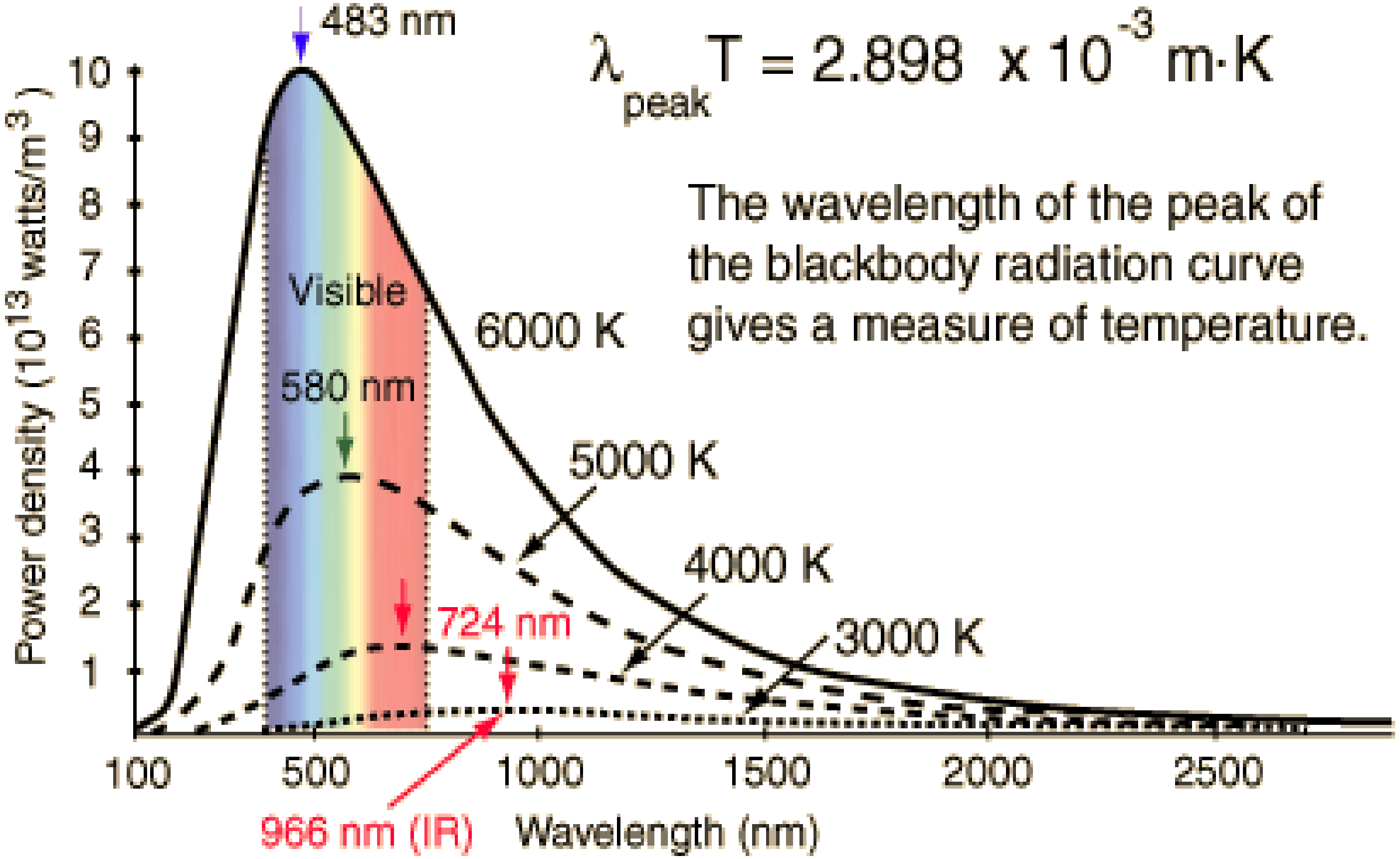

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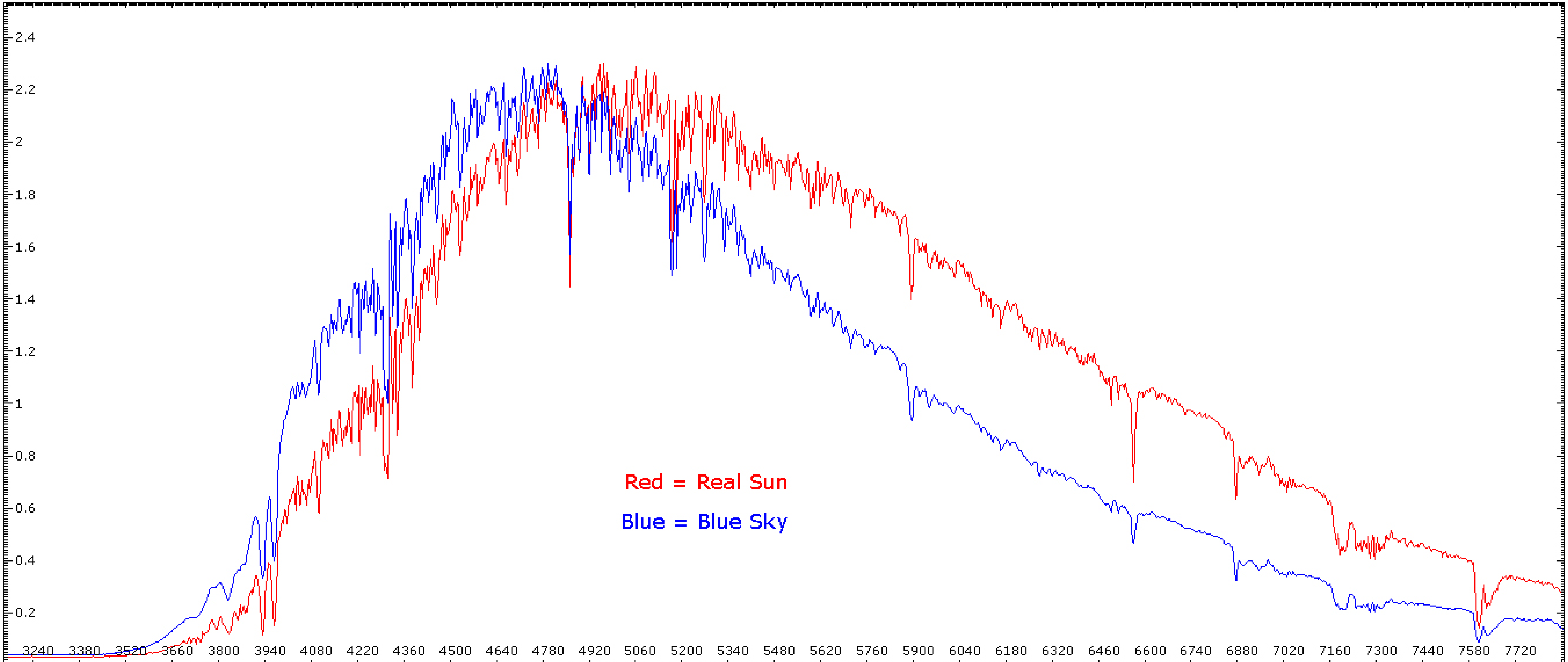
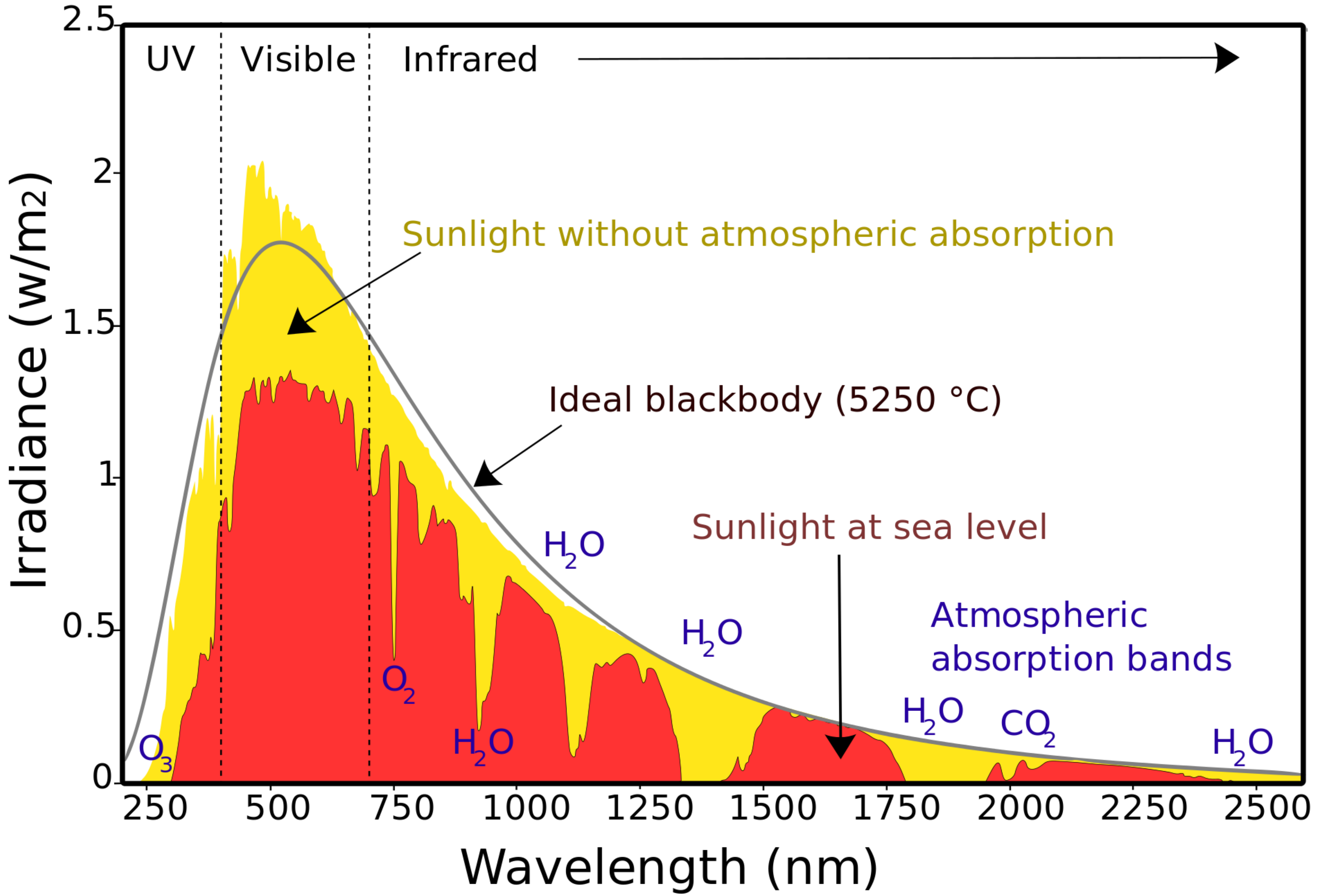
Actual spectral measurements of the Sun and Earth's Sky

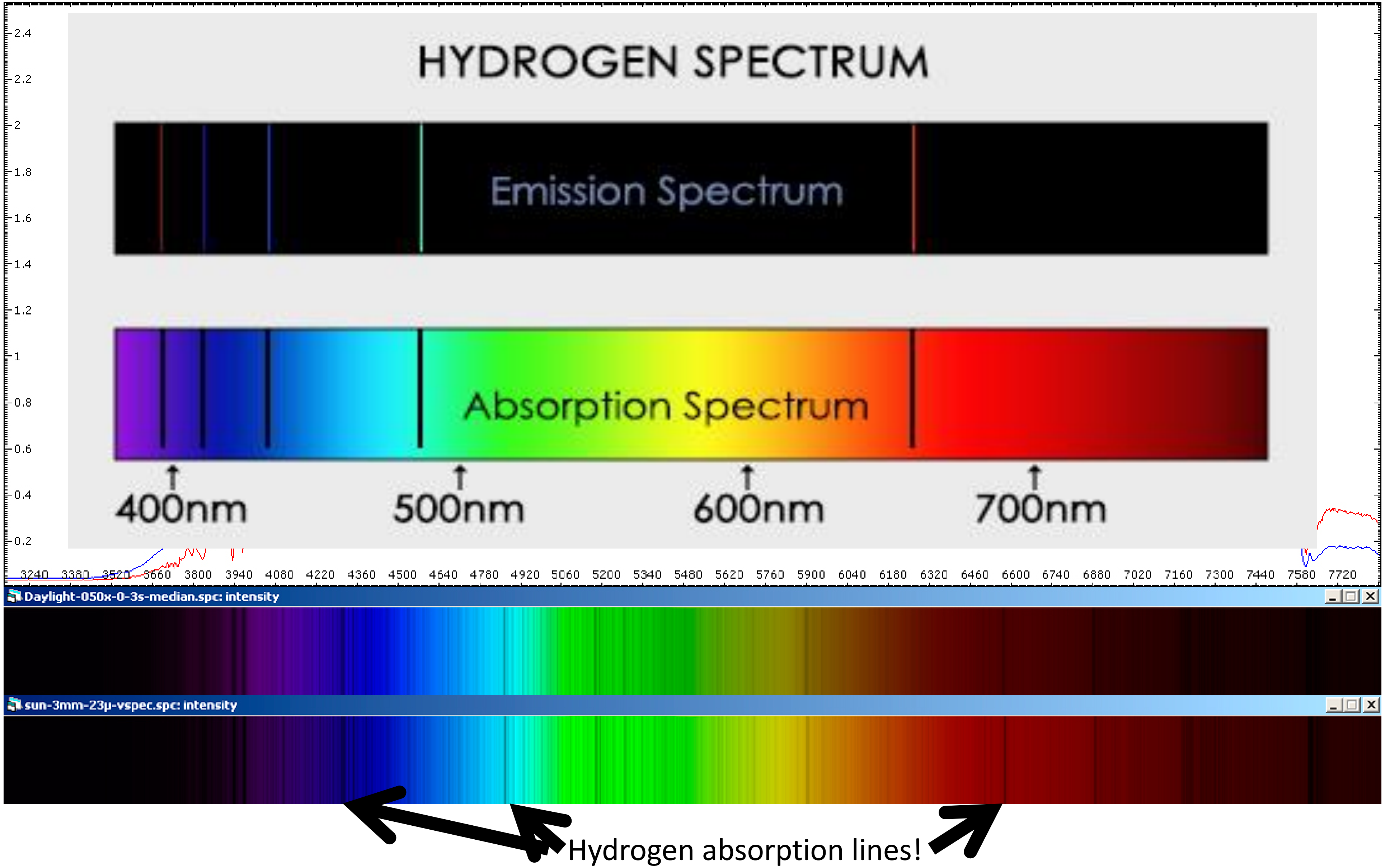
Blackbody curves, but more complex



Spectrum of Solar Radiation (Earth)

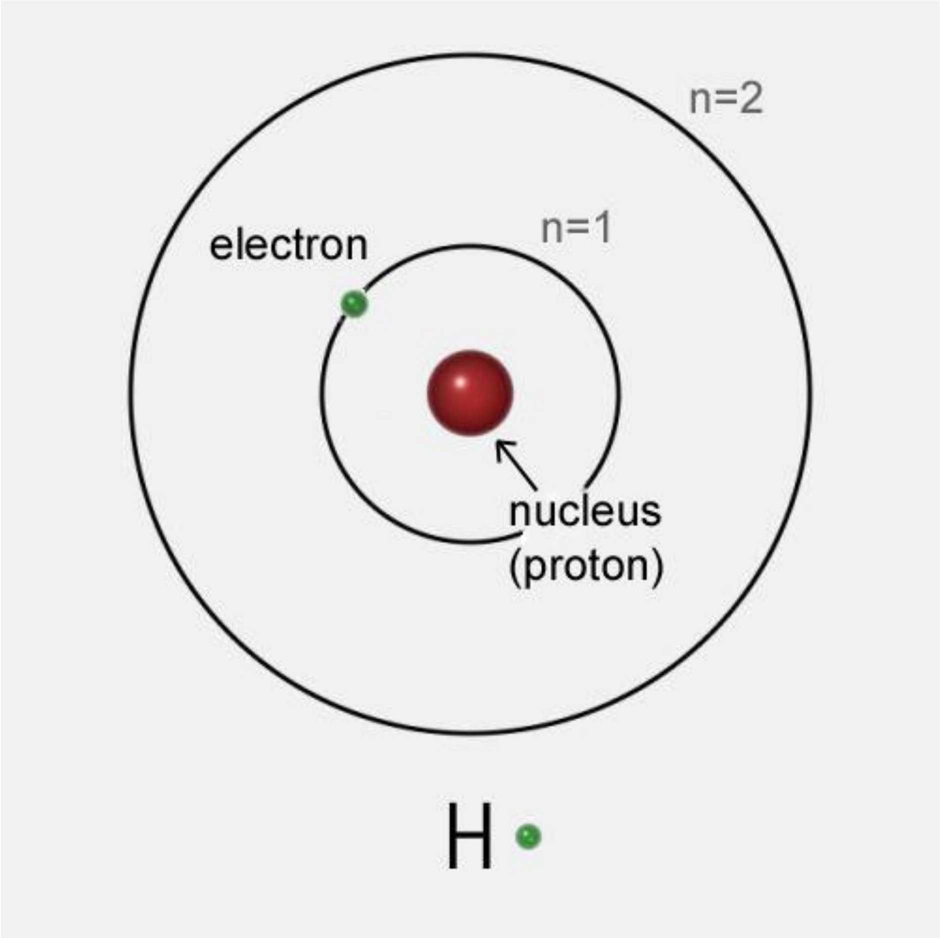


The mean solar spectrum also contains absorption lines that precisely match the colors+wavelengths of **Hydrogen lines**.

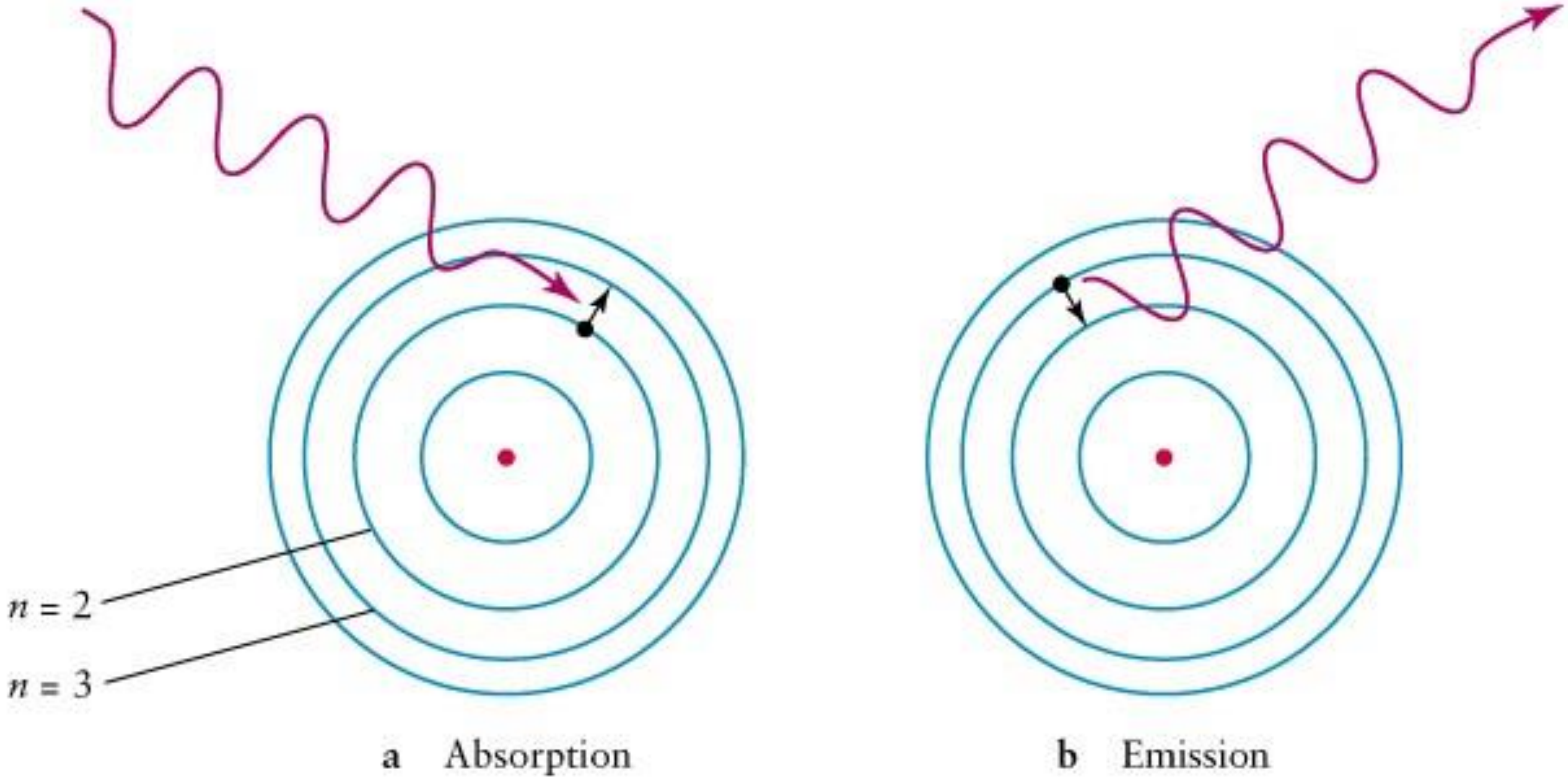


Atomic structure: electrons orbit atomic nuclei in specific orbits/energy levels.

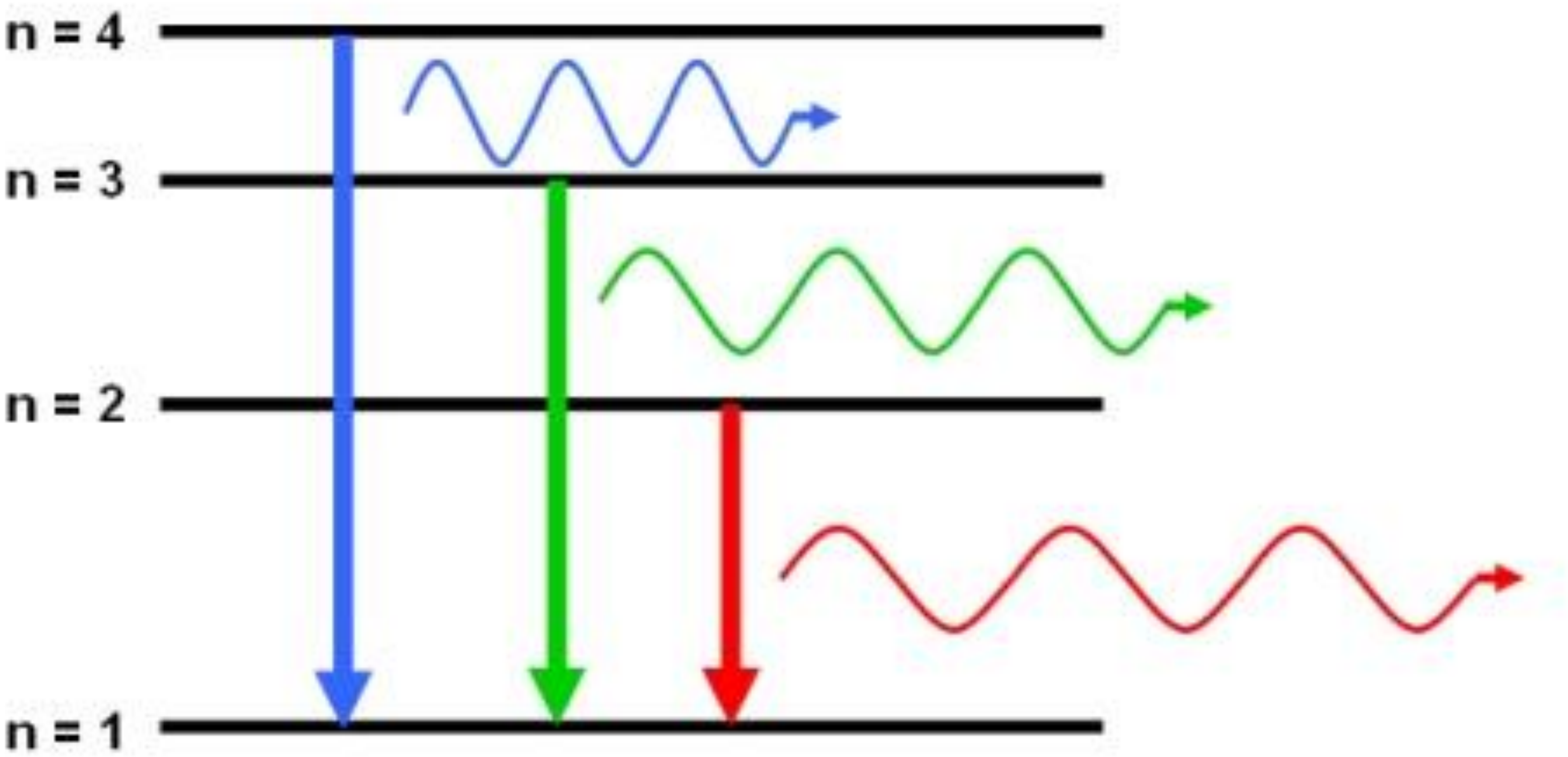
- Each orbit has a particular energy associated with it.
- To move from one orbit to another, an electron must absorb or emit energy.



Atomic emission: electrons can move to a higher energy level by absorbing a photon, or can move to a lower energy level by emitting a photon.

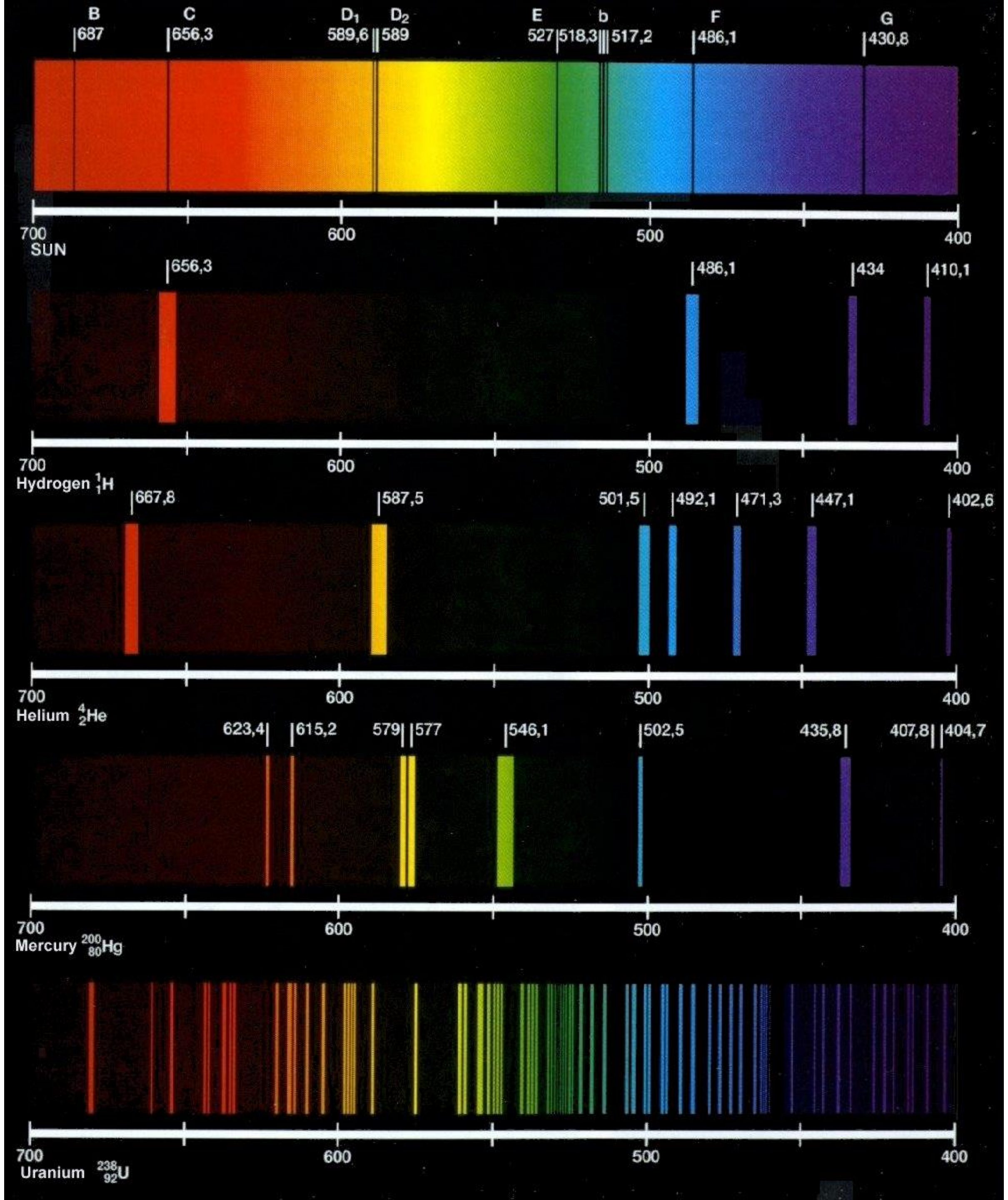


Atomic spectra: changes between different electron energy levels are associated with particular types of light.

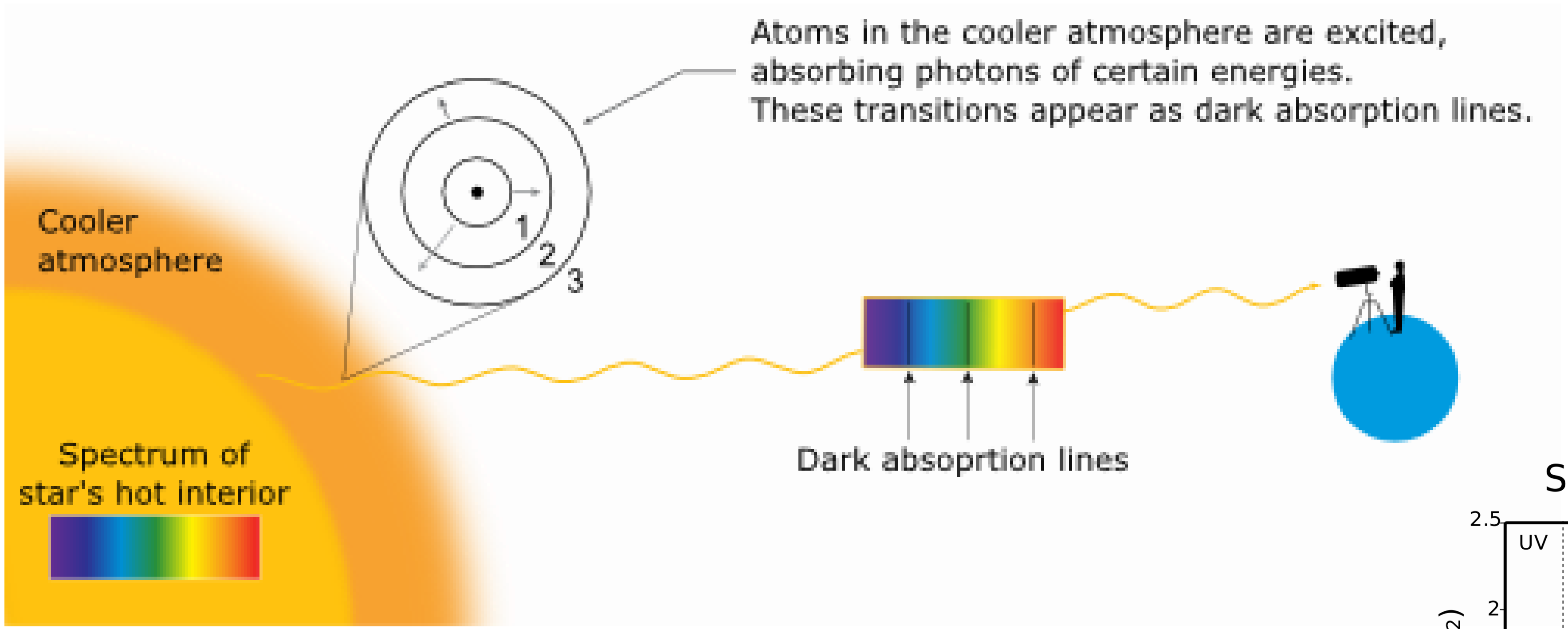


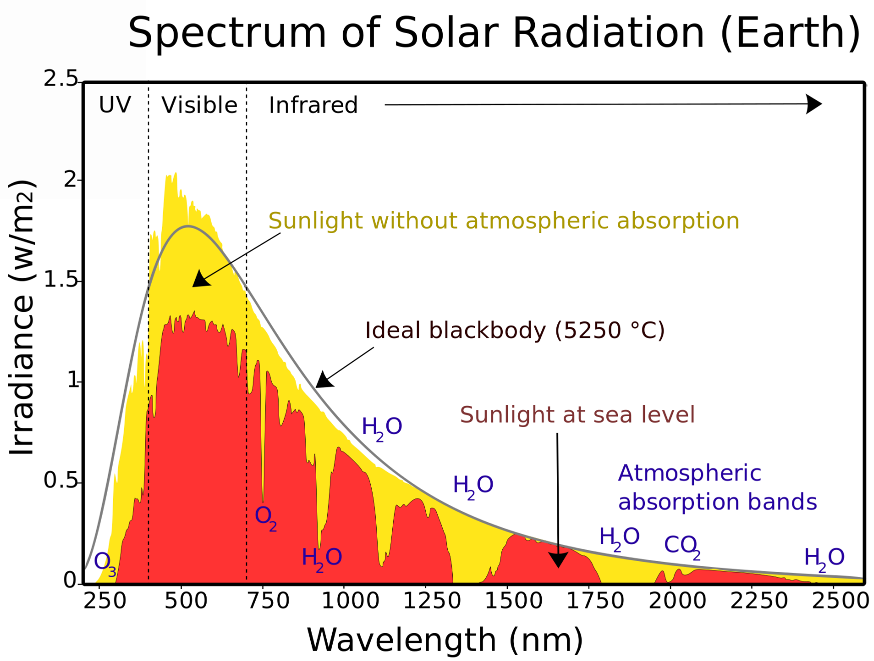
Atomic spectra: each element has a unique pattern of energy levels, and thus produces a unique spectral pattern when atoms emit light.

Spectroscopy: The study of absorption and emission spectra. These spectra can tell you what elements are in the atmosphere of Stars like our Sun or can tell you what elements are in a gas being heated up.



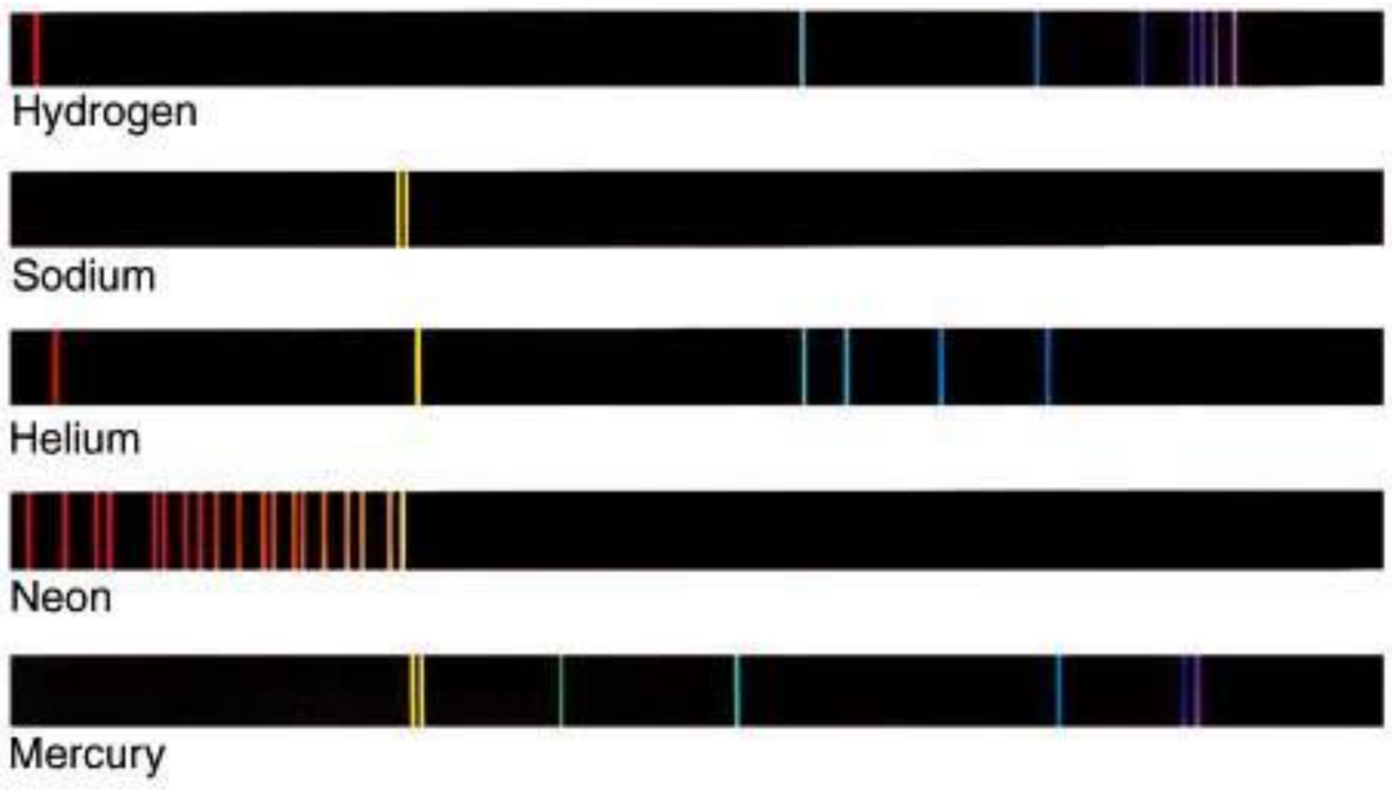
The presence of Hydrogen absorption lines in the Solar spectrum proves that the Sun has a cooler 'atmosphere' containing Hydrogen.

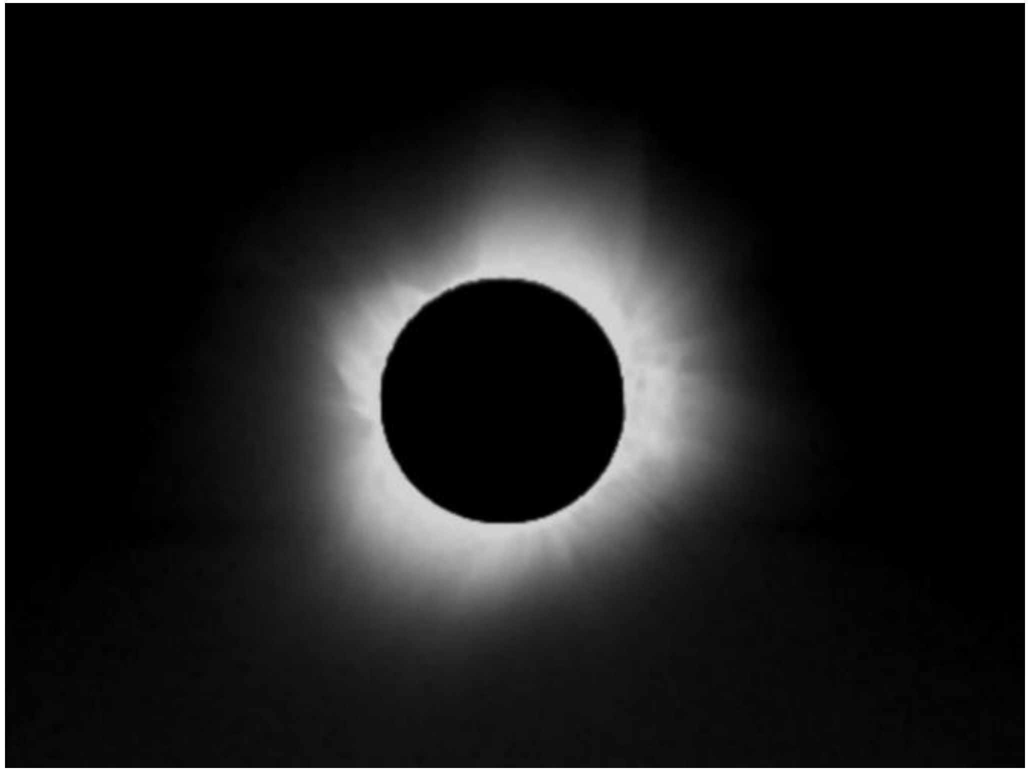




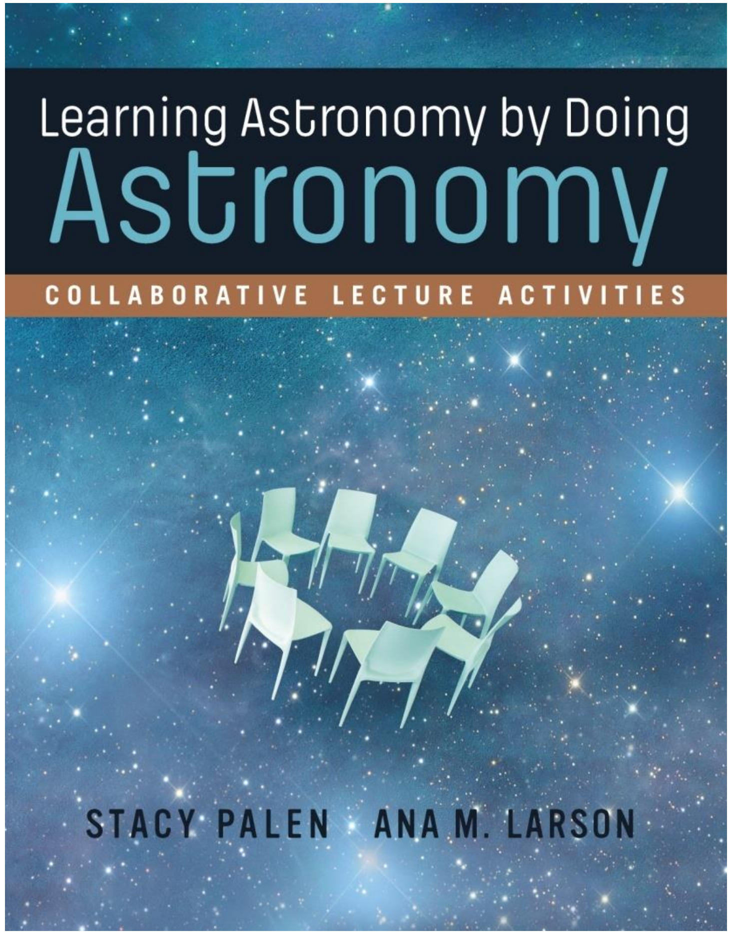
Aug. 18, 1868: Helium Discovered During Total Solar Eclipse

http://www.wired.com/2009/08/dayintech_0818/





Activity 8: Light and Spectra



Pre-8.1: If you used a spectrometer to view a 500-W incandescent light bulb at full power, what colors would dominate the spectrum?

a. only the blue-green part of the spectrum
b. primarily the orange-red part of the spectrum
c. the full continuous rainbow of colors
d. bright lines at specific wavelengths

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b. primarily the orange-red part of the spectrum
c. **the full continuous rainbow of colors**
d. bright lines at specific wavelengths

Pre-8.2: If you used a spectrometer to view a 500-W incandescent light bulb dimmed to its lowest power, what color(s) would dominate the spectrum?

a. only the blue-green part of the spectrum
b. primarily the orange-red part of the spectrum
c. the full continuous rainbow of colors
d. bright lines at specific wavelengths

Pre-8.2: If you used a spectrometer to view a 500-W incandescent light bulb dimmed to its lowest power, what color(s) would dominate the spectrum?

a. only the blue-green part of the spectrum
b. primarily the orange-red part of the spectrum
c. the full continuous rainbow of colors
d. bright lines at specific wavelengths

Pre-8.3: If you used a spectrometer to view a 500-W incandescent light bulb at its brightest and then at its lowest power, what would happen to the overall intensity of the light?

a. The overall intensity will not change very much.
b. The overall intensity will be less because less power is being produced.
c. The overall intensity will be more because more power is being produced.
d. The overall intensity will depend on what kind of incandescent light bulb is being used.

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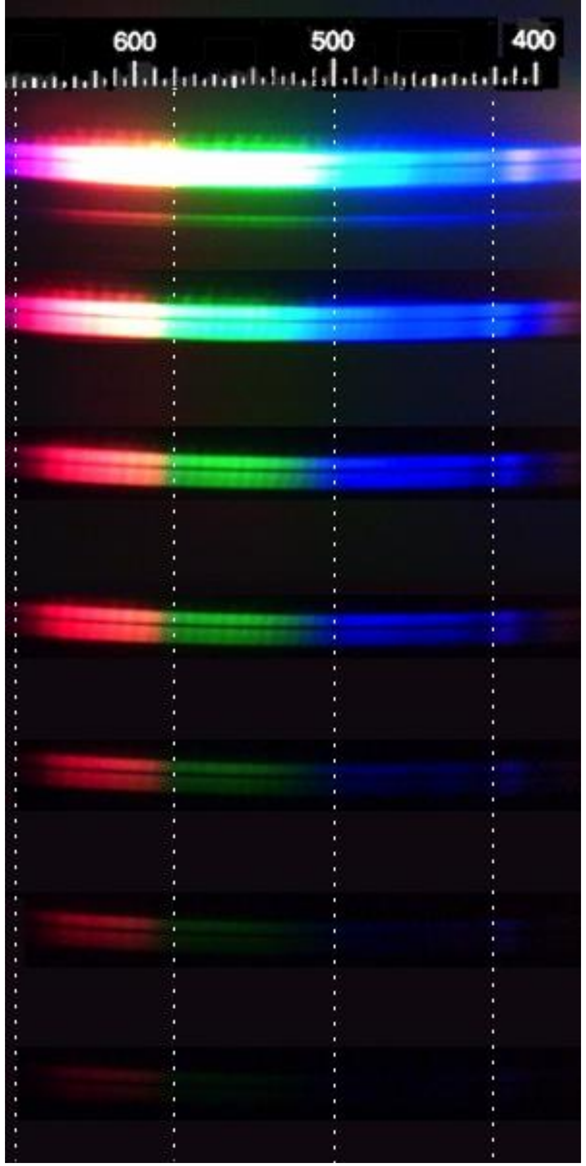
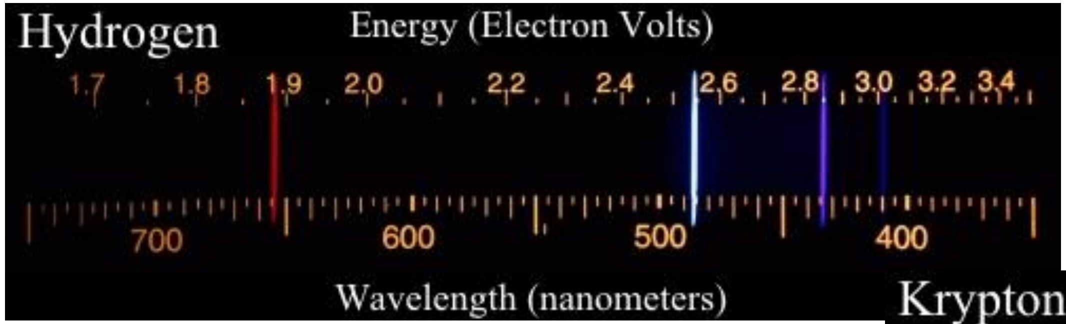
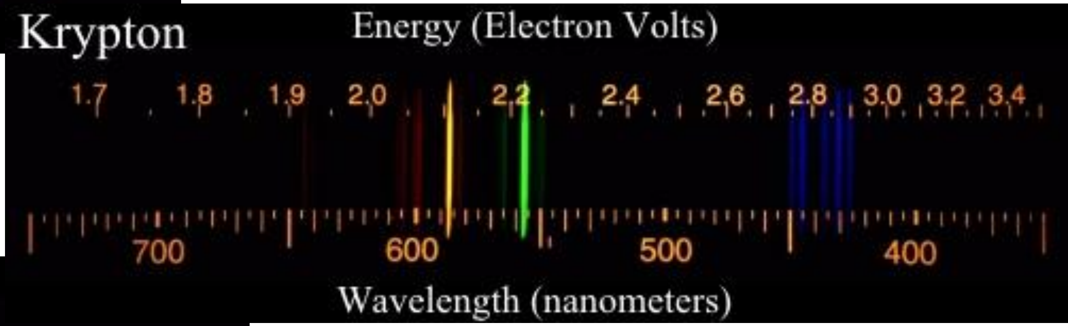
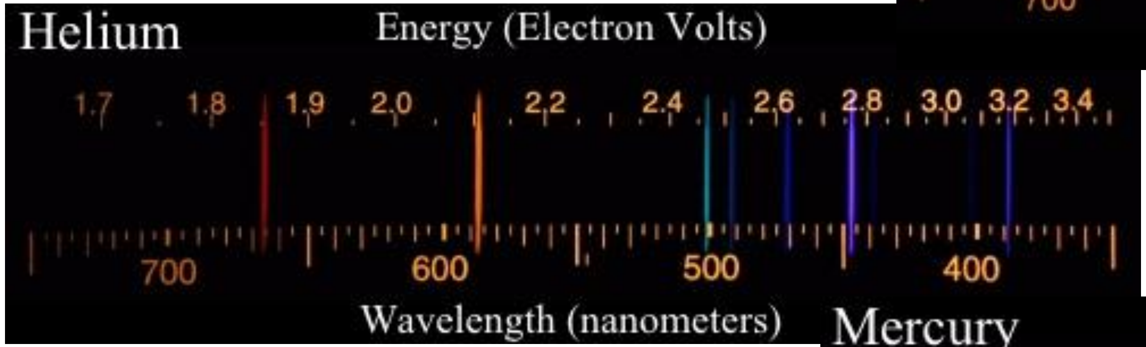
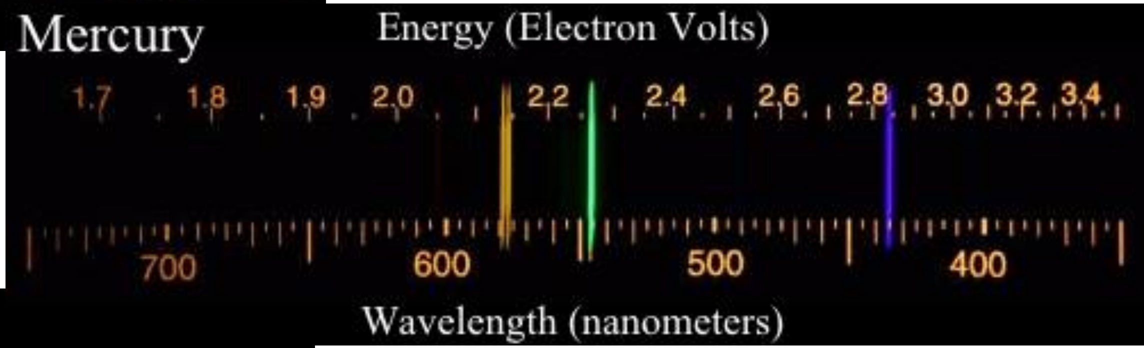










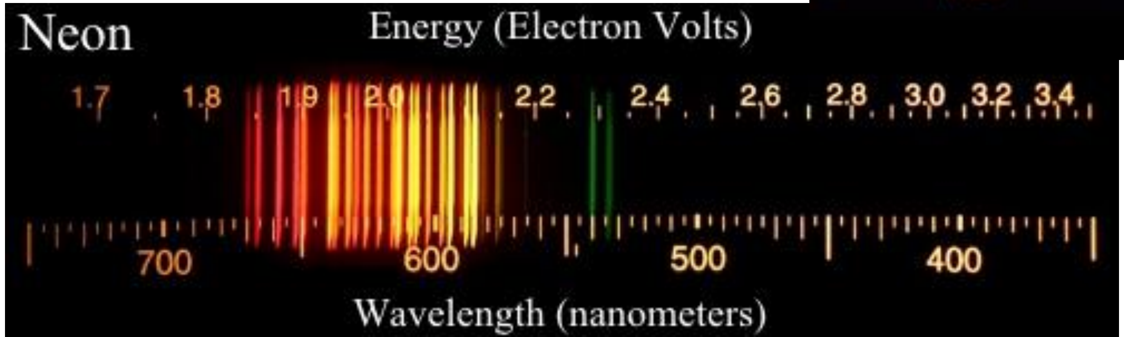
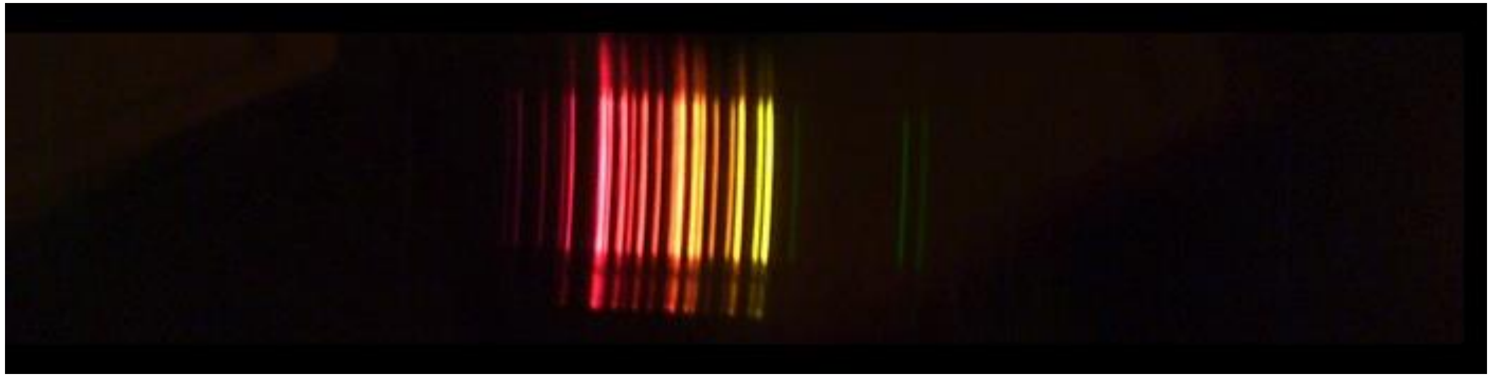


Image contains spectra of an incandescent bulb ranging from very bright to very dim.

Unknown Elements

A = ?

B = ?



C = ?

Post-8.1: If we assume the incandescent light bulb is a good representation of how stars "work," we would conclude that

a. the hotter the star is, the more luminous it is, and the brighter the colors will be overall.
b. the cooler the star, the less luminous it is; the brighter part of the spectrum will be toward longer wavelengths.
c. the luminosity of a star, its temperature, and the overall color pattern are all related.
d. All of these answers are correct.

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Post-8.3: True or False: Because the heaviest elements in the periodic chart—tungsten, gold, mercury, lead—have so many electrons their emission spectra are identical.

a. true
b. false

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a. true
b. false

This concludes Activity 8: Light and Spectra