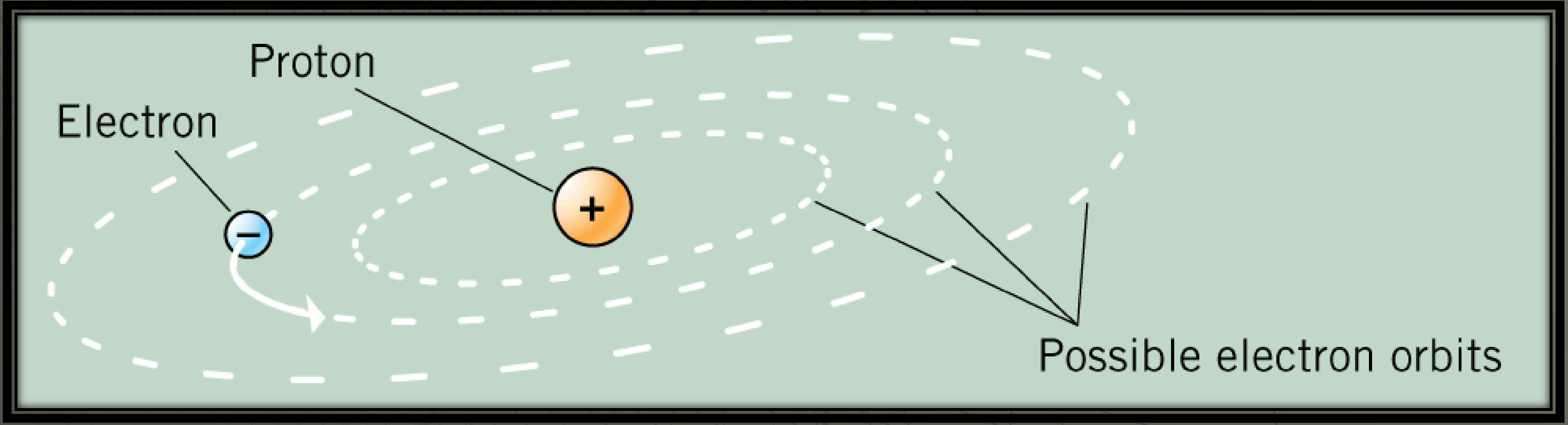
Atoms & Spectra

- Objectives
  - How does light interact with elements
  - Different types of spectra

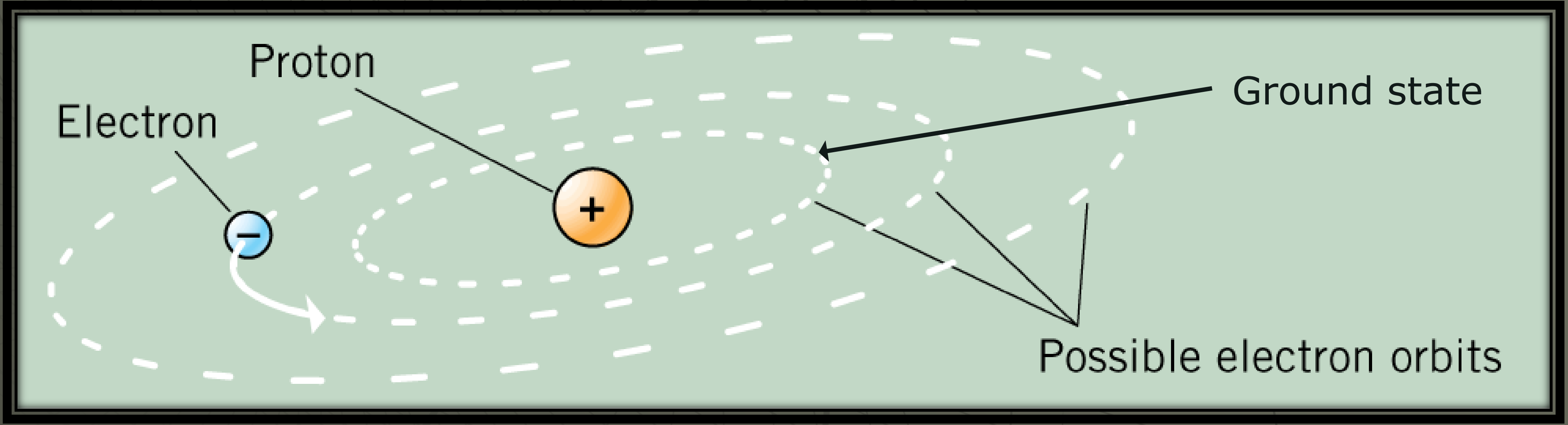
Bohr Model of Atom

- Hydrogen atom
  - 1 proton (nucleus), and 1 electron (orbit)
- Proton mass/electron mass ~ 2000!
- Will light interact with the electron or the proton?



Bohr Model of Atom

- Electron “orbits” the proton
- Has very specific stable “orbits”
- Smallest orbit is called the ground state
  - Lowest energy

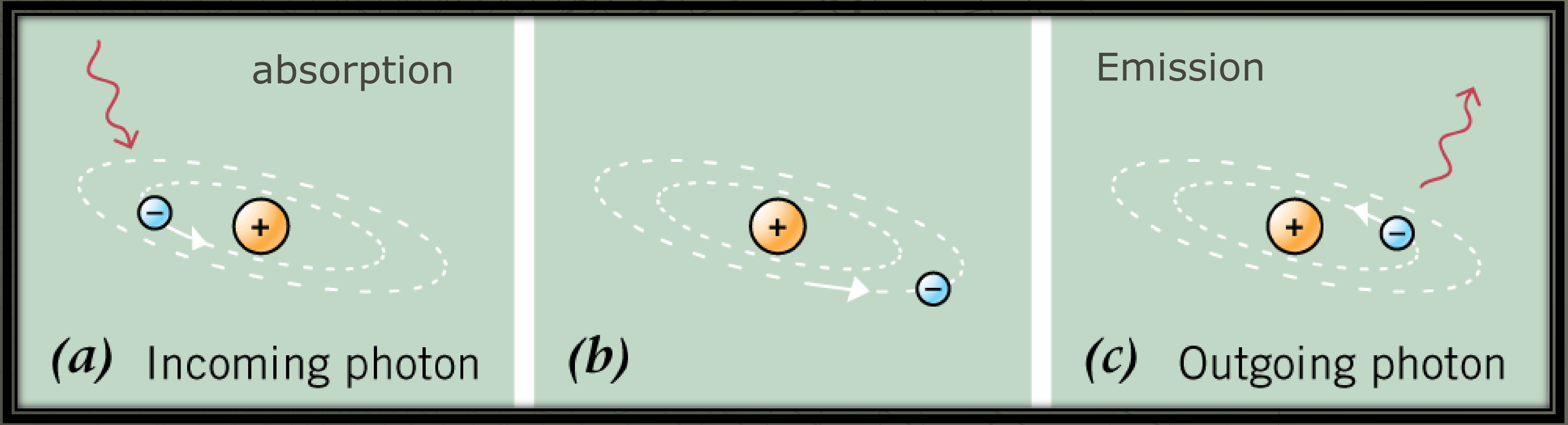


Absorption & Emission of Light

(a) Photon strikes electron in ground state

(b) Absorption: Photon *absorbed* as electron gains energy, moves to excited state

(c) Emission: Electron falls from excited state to ground state, emits a photon of the same λ and energy



Orbit Energies

- Each orbit change requires an EXACT amount of energy
- These EXACT energies correspond to specific colors of light

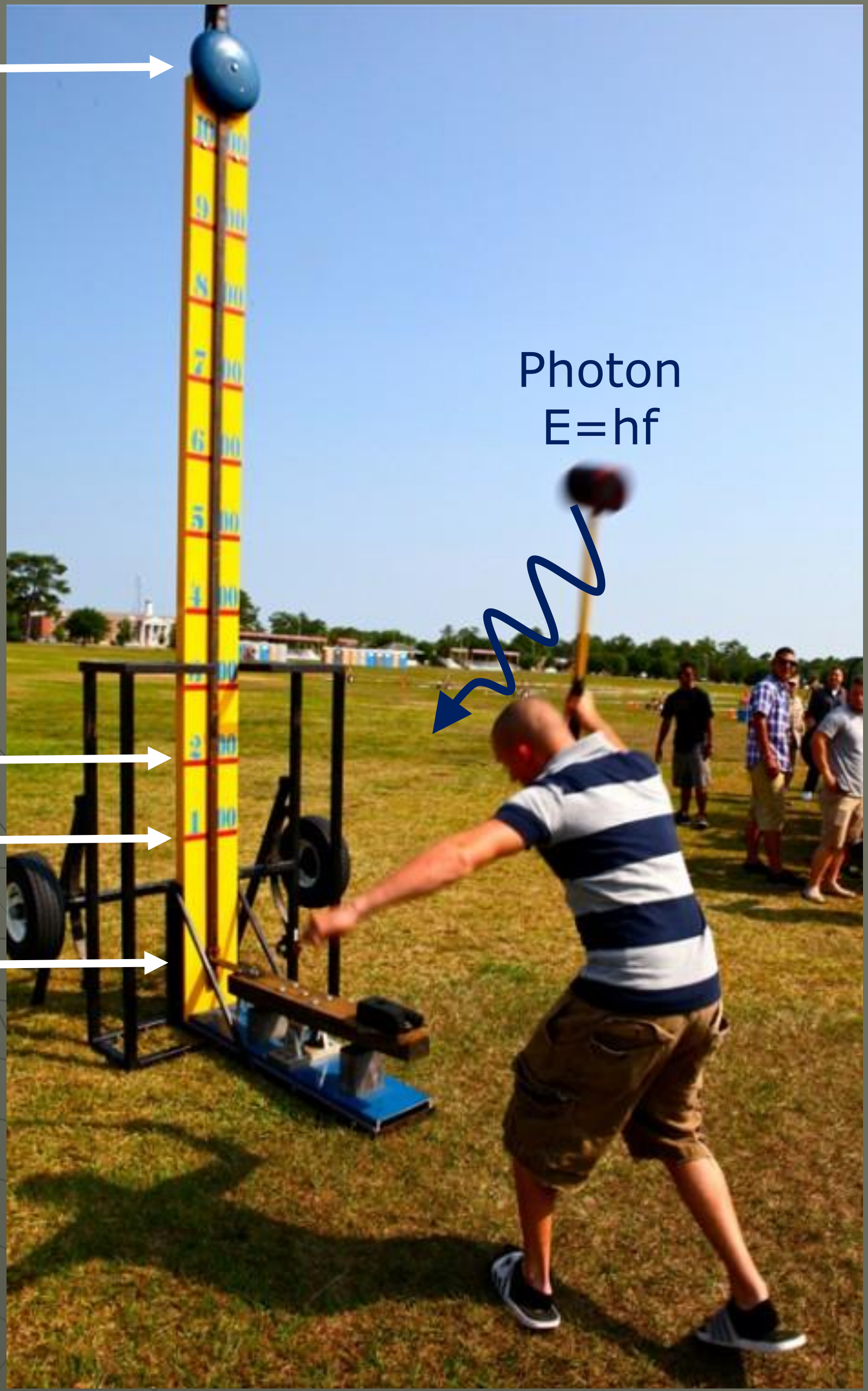
Higher energy

"Ionized" (electron escapes) $n=\infty$

2nd excited state $n=3$

1st excited state $n=2$

Ground State $n=1$



Energies

- Gravity analog: a ball bearing held at a greater height has more energy ($PE = mgh$)
- Higher orbits (n is greater) = higher energy
- Conservation of Energy: same amount of energy absorbed must be released.
  - Photon released has the same wavelength as the photon absorbed

Energies

- Proton and electron *attracted* to one another with electrostatic force
  - Think magnets – really strong force
- Electrostatic force: $F \sim \frac{1}{r^2}$ (similar to gravity)
- Stable orbit: balancing forces
- What would happen to a stable orbit if the Mass of Earth increased.
  - A: move further away

Different Atoms

- H has 1 proton (plus charge)
  - Needs 1 electron (negative charge)
- He has 2 protons
  - Needs 2 electrons

n=2 → n=1
H: 660 nm

He: 580 nm
n=2 → n=1

TPS

1. You see a yellow-orange streetlight in Laramie, which is a “sodium vapor” light. What are the electrons in the sodium doing as they emit the yellow light you see?

A. Moving toward the sodium nucleus
B. Moving away from the sodium nucleus
C. Moving to higher energy states
D. Electron magic

TPS

2. Which transition corresponds to the highest energy light being emitted?

A. 4 to 1
B. 2 to 1
C. 3 to 1
D. 4 to 3

3. Imagine the transition from n = 4 to n = 1 gives us violet light. Now let’s say we witness the light emitted when an electron jumps down from n = 6 to n = 1. Hypothesize what kind of light this would be…

A. Radio waves
B. Microwaves
C. Infrared
D. Ultraviolet

4. A photon strikes an electron in the ground state. This photon's energy exceeds the maximum energy of any transitions (jumps) the electron can make. What happens?

A. The photon is reflected

B. The electron stays in the ground state and just moves faster

C. The atom absorbs heat

D. The electron is ejected from the atom

E. "Hulk SMASH!"

LT

- Light & Atoms

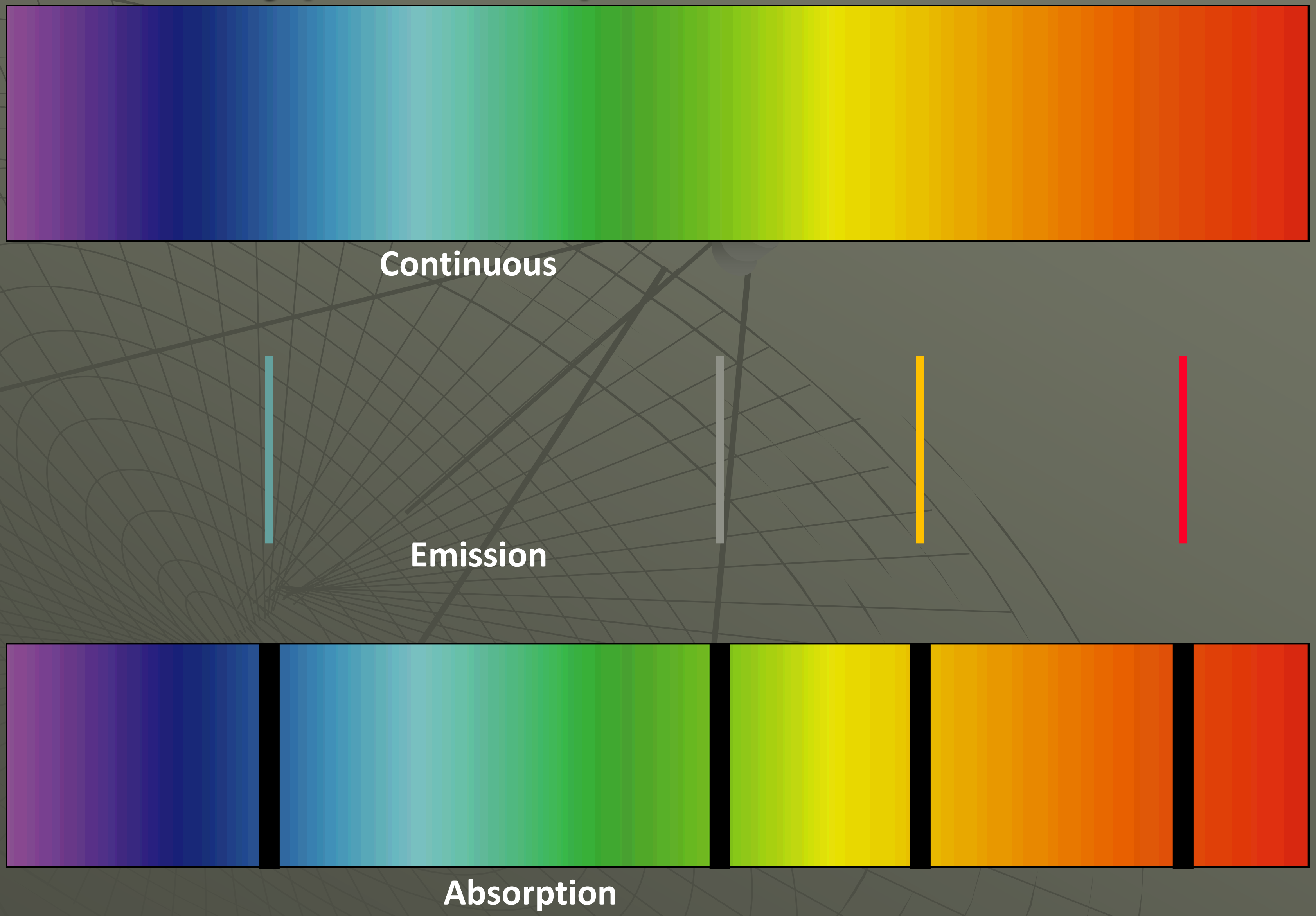
Spectroscopy

- Light we see from astronomical objects is filled with info that our eyes can't pick apart.
- **Spectroscopy:** The process of breaking light apart into its components, analyzing the colors present, their relative intensities, positions, etc.

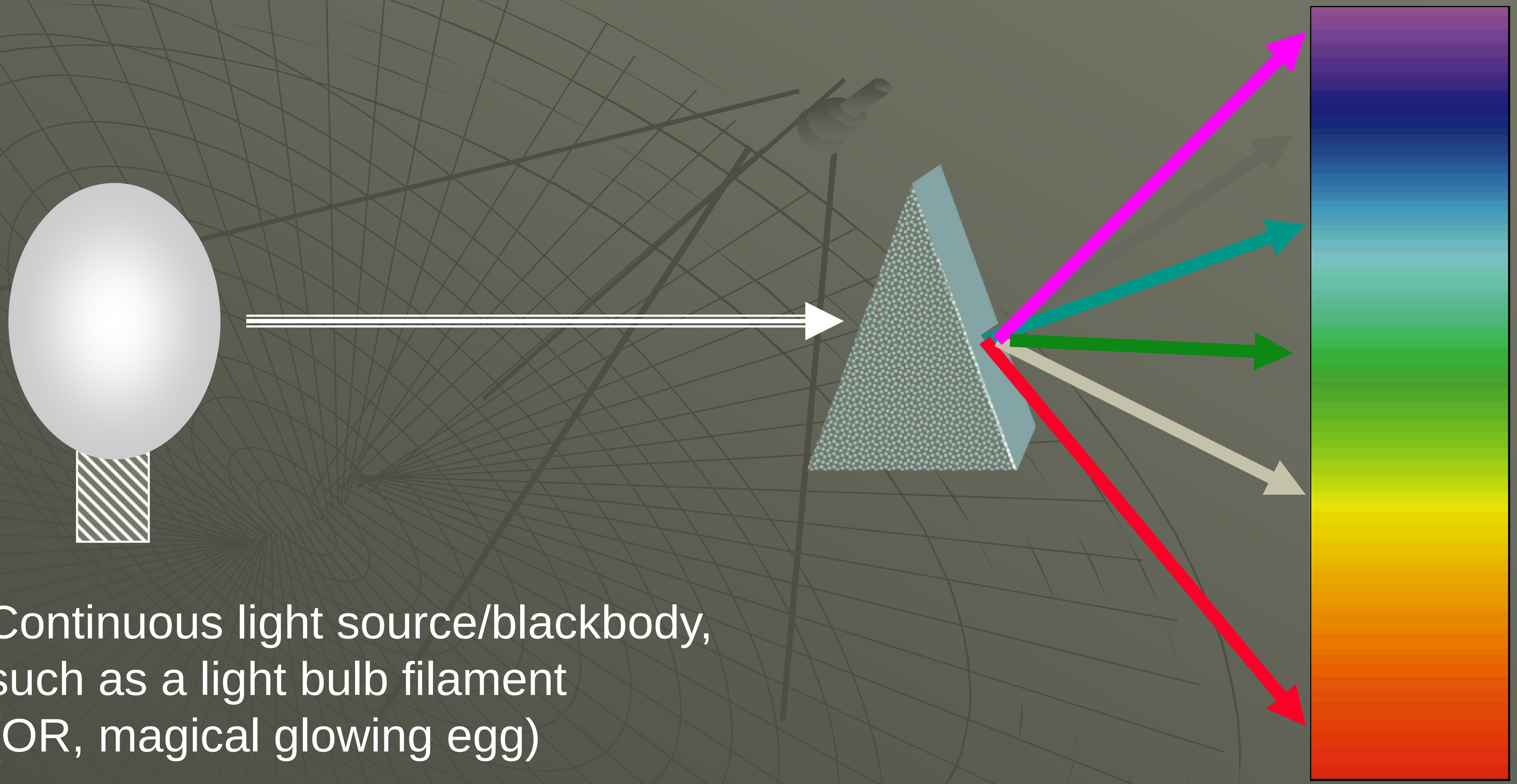
Kirchoff’s Laws – Types of Spectra

- 3 types of spectra we observe from objects
- Conditions of material(s) generating the light determine which of the 3 types we see
- The 3 types are…

3 types of spectra observed

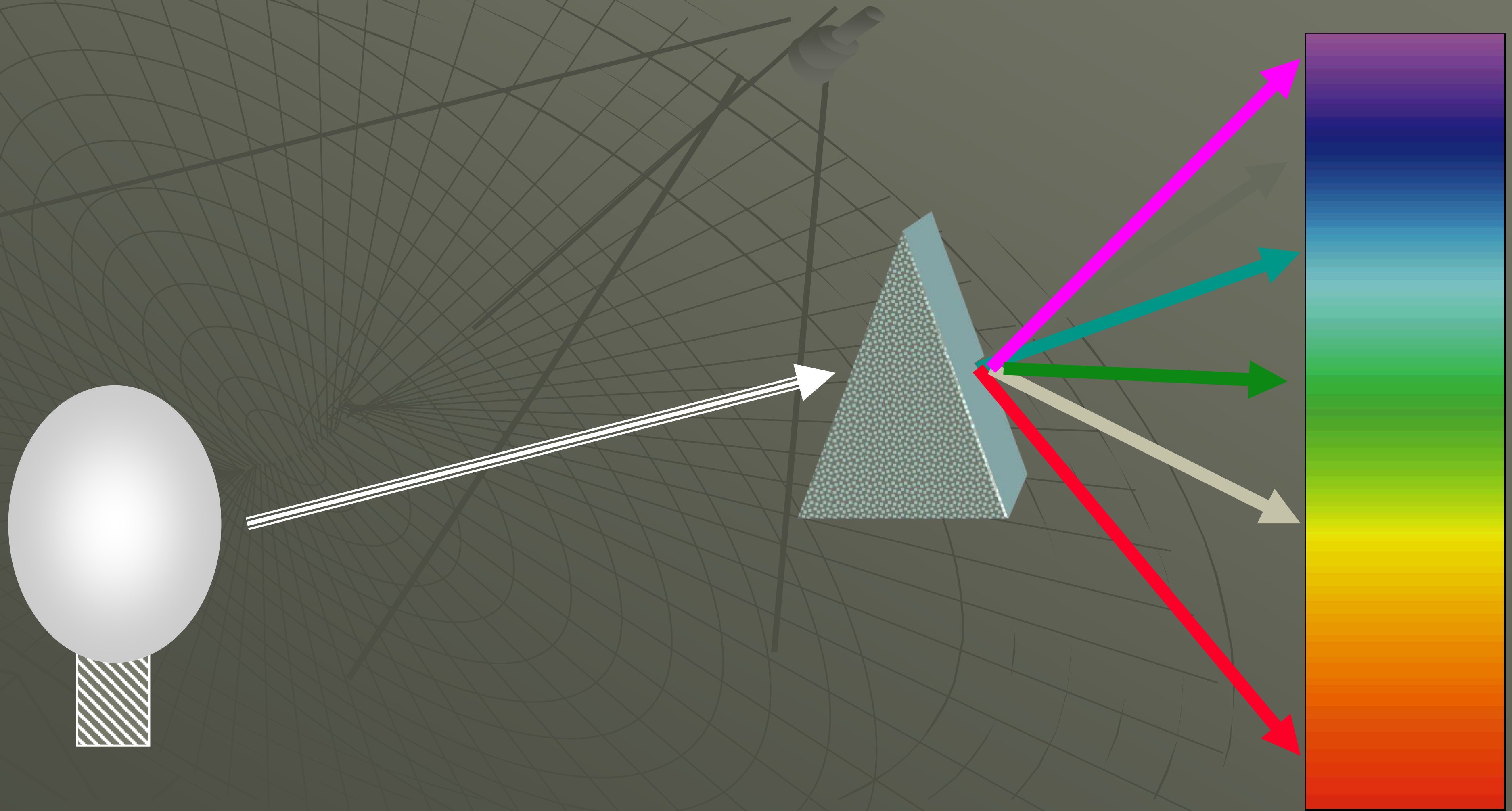


Kirchhoff's Laws: # 1



Continuous light source/blackbody,
such as a light bulb filament
(OR, magical glowing egg)

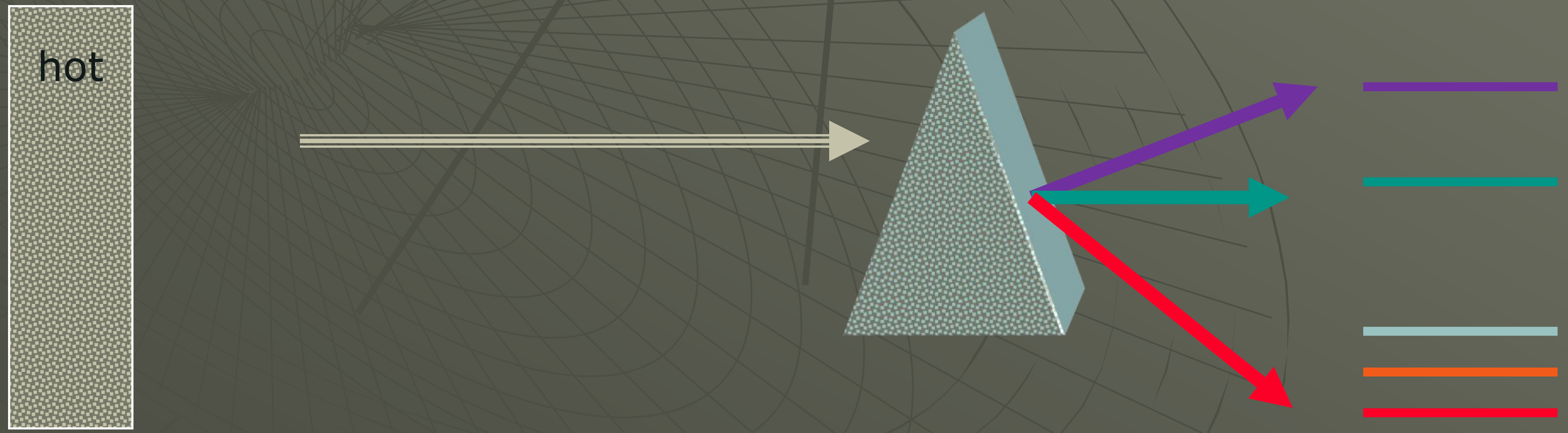
- A solid or a liquid, or a gas at a *high pressure*, emits a continuous spectrum. (a full "rainbow" of colors)



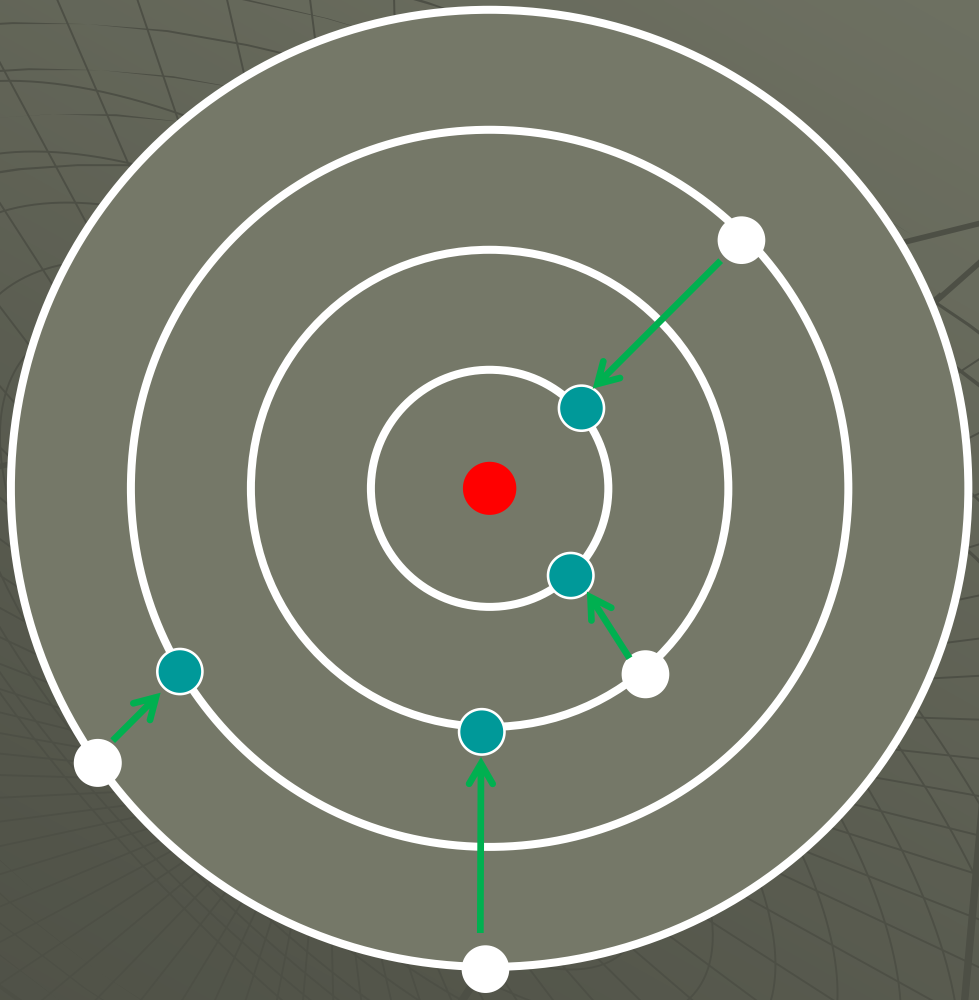
Kirchhoff's Laws: # 2

2. A hot, rarefied (low density) gas shows an emission spectrum (very specific colors)

- Gas must be warm/hot – electrons in high energy states, and can emit light



Specific Energies…



Remember our Bohr Model. Only certain energy levels exist for the electron(s)

Each transition for an electron corresponds to a specific color of light

Now the cool part… (why spectra are a big deal for astronomers)

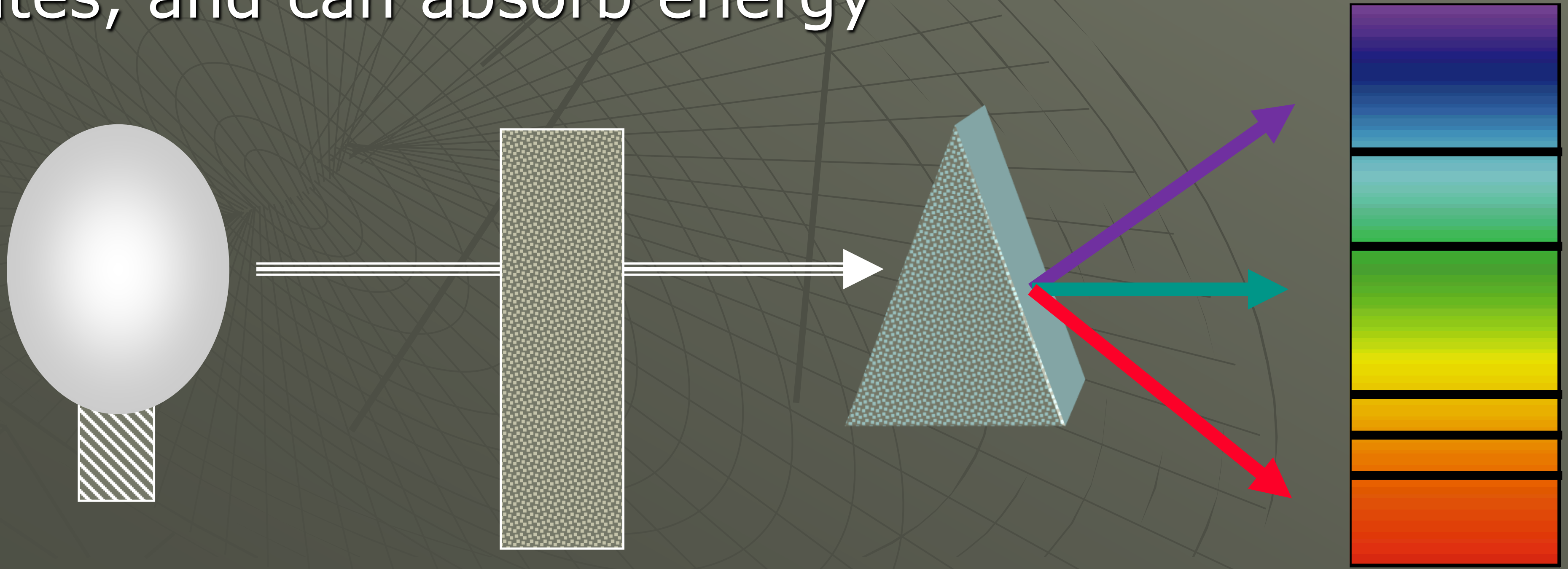
- These energy gaps are unique in each and every element in the universe.
- They are very specific, and can be measured with *extreme precision*.
- These spectra serve as chemical "fingerprint" for elements

- See poster in lab…

Kirchhoff's Laws: # 3

3. Light from continuous source, when passed through a cooler gas, may be absorbed at certain wavelengths, giving an absorption spectrum

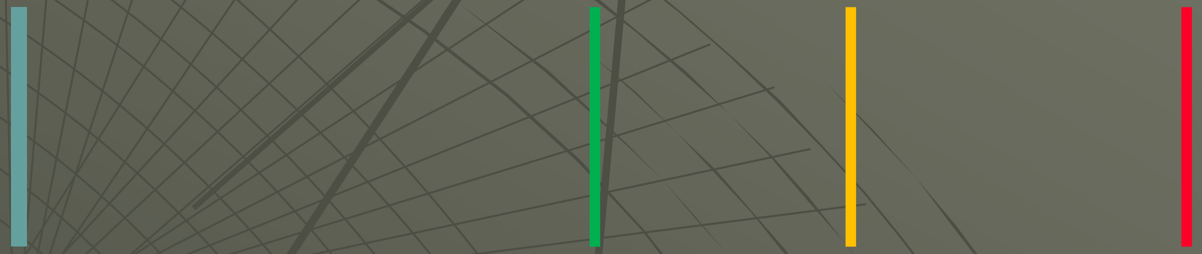
- Gas must be relatively cool -- electrons in low energy states, and can absorb energy



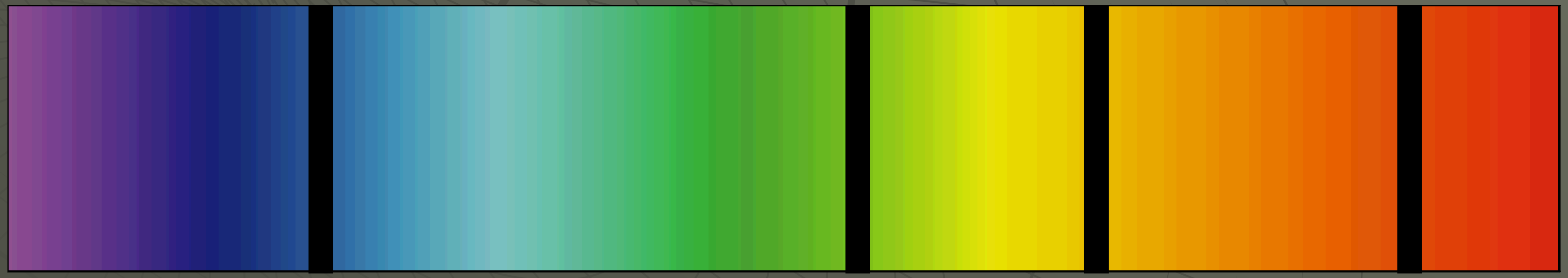
Not surprisingly…

A certain type of gas will ***emit*** light at very specific colors. It will ***absorb*** light at these exact same colors! Emission vs. absorption simply depends on if electrons are

1. jumping down (emission)
2. jumping up (absorption)

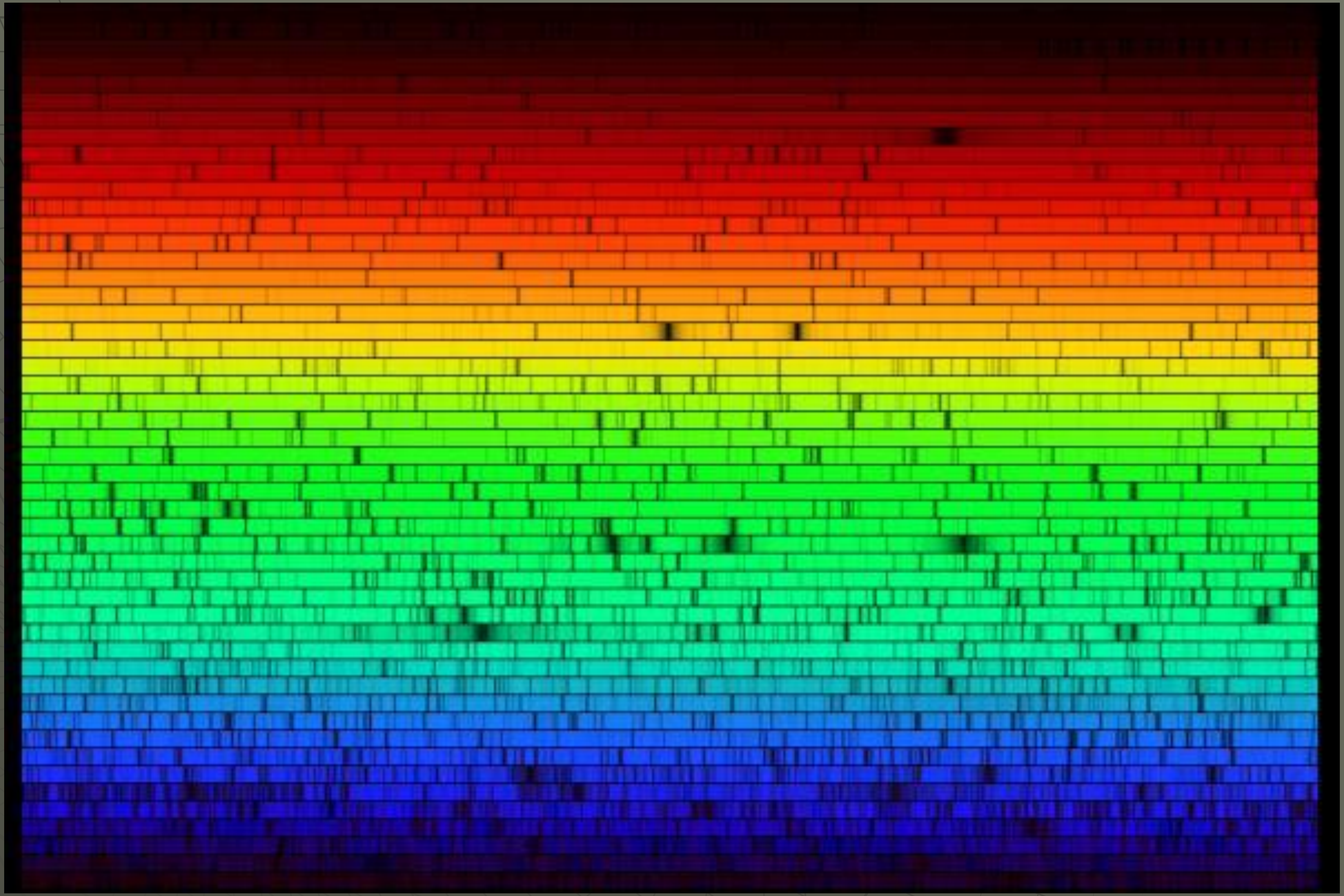


Emission Spectrum



Absorption Spectrum

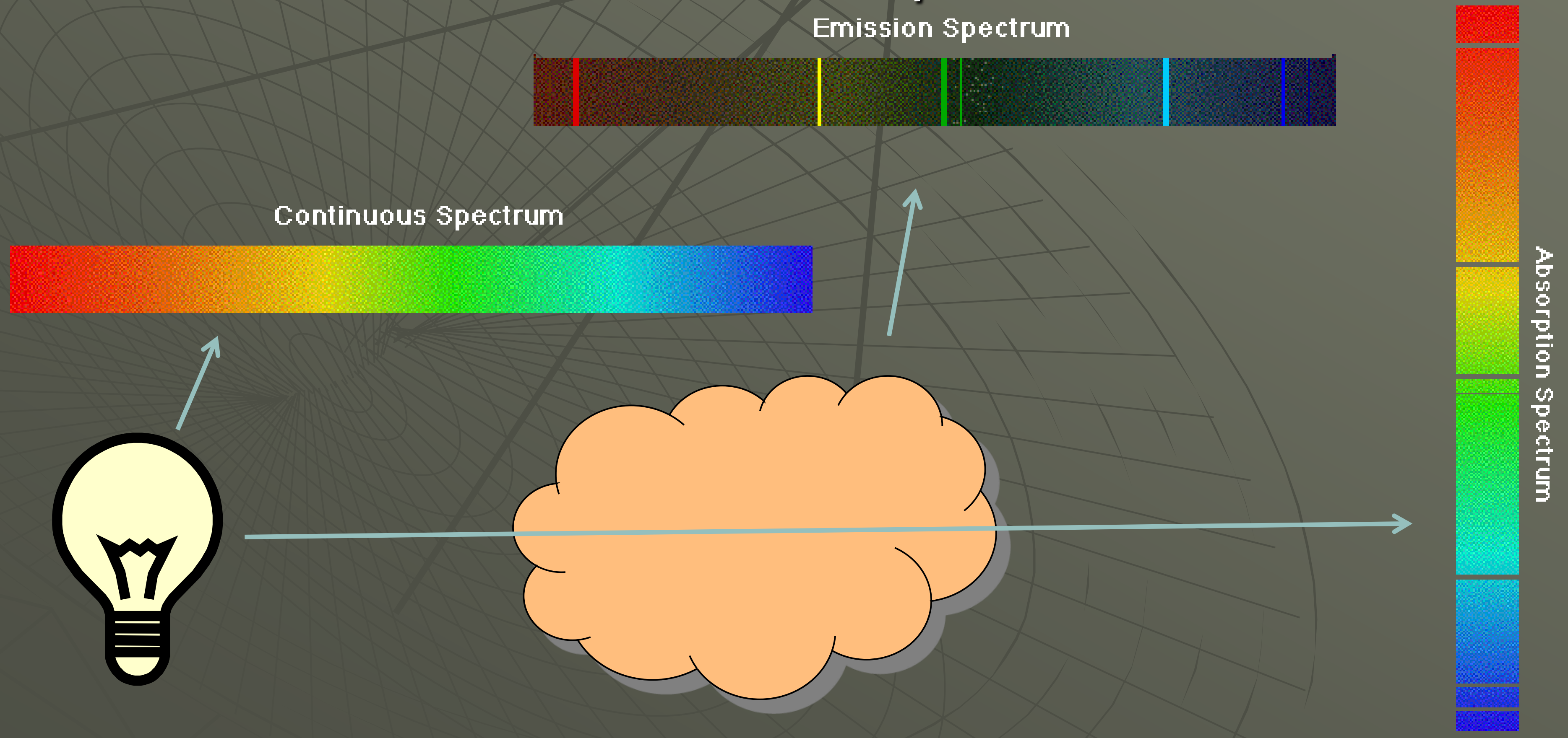
The Solar Spectrum (an absorption spectrum)



Using a spectrograph, we can resolve the sun's spectrum in great detail.
Every single one of these dark lines is absorption from a specific element.

Kirchoff's Laws: Summary

- When do we see *emission lines*, and when do we see *absorption lines*?



LT

- Types of Spectra