# ASTR 1120
# :: Stars & Galaxies ::

# **Let there be Light!**

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# Today's Goals

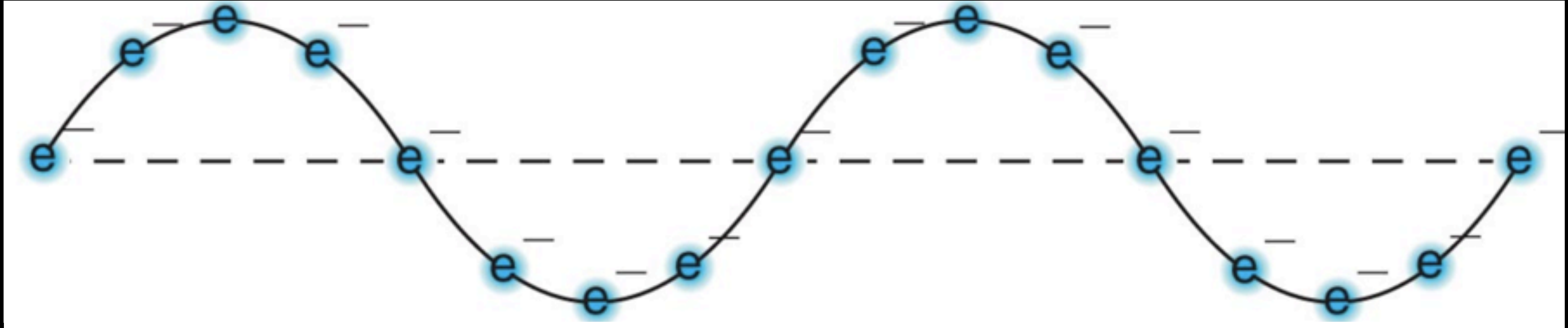
- Astro-jargon: frequency, wavelength, spectrum (continuous, emission, and absorption), spectral lines, and photon
- Understand:
  - the properties of light and how it interacts with matter
  - the conditions necessary to produce different types of spectra and what they tell us about astronomical objects
  - the nature of "black-body" radiation and what information it provides

# What is Light?

- Thoughts?
- Merriam-Webster Definition:
  - electromagnetic radiation of any wavelength that travels in a vacuum with a speed of about 186,281 miles (300,000 kilometers) per second; specifically : such radiation that is visible to the human eye
    - electromagnetic radiation: energy in the form of electromagnetic waves; also : a series of electromagnetic waves
      - electromagnetic wave: one of the waves that are propagated by simultaneous periodic variations of electric and magnetic field intensity and that include radio waves, infrared, visible light, ultraviolet, X-rays, and gamma rays

# What is Light?

- Electromagnetic means that light comes from moving charged particles and can cause other charged particles to move.
- Whenever a charged particle (such as an electron or proton) speeds up, slows down, and/or changes direction it gives off light.  The light carries energy away from the particle.
- When this light encounters another charged particle, it can cause the particle to speed up, slow down, and/or change direction.




Electrons move under the presence of light's vibrating electric field

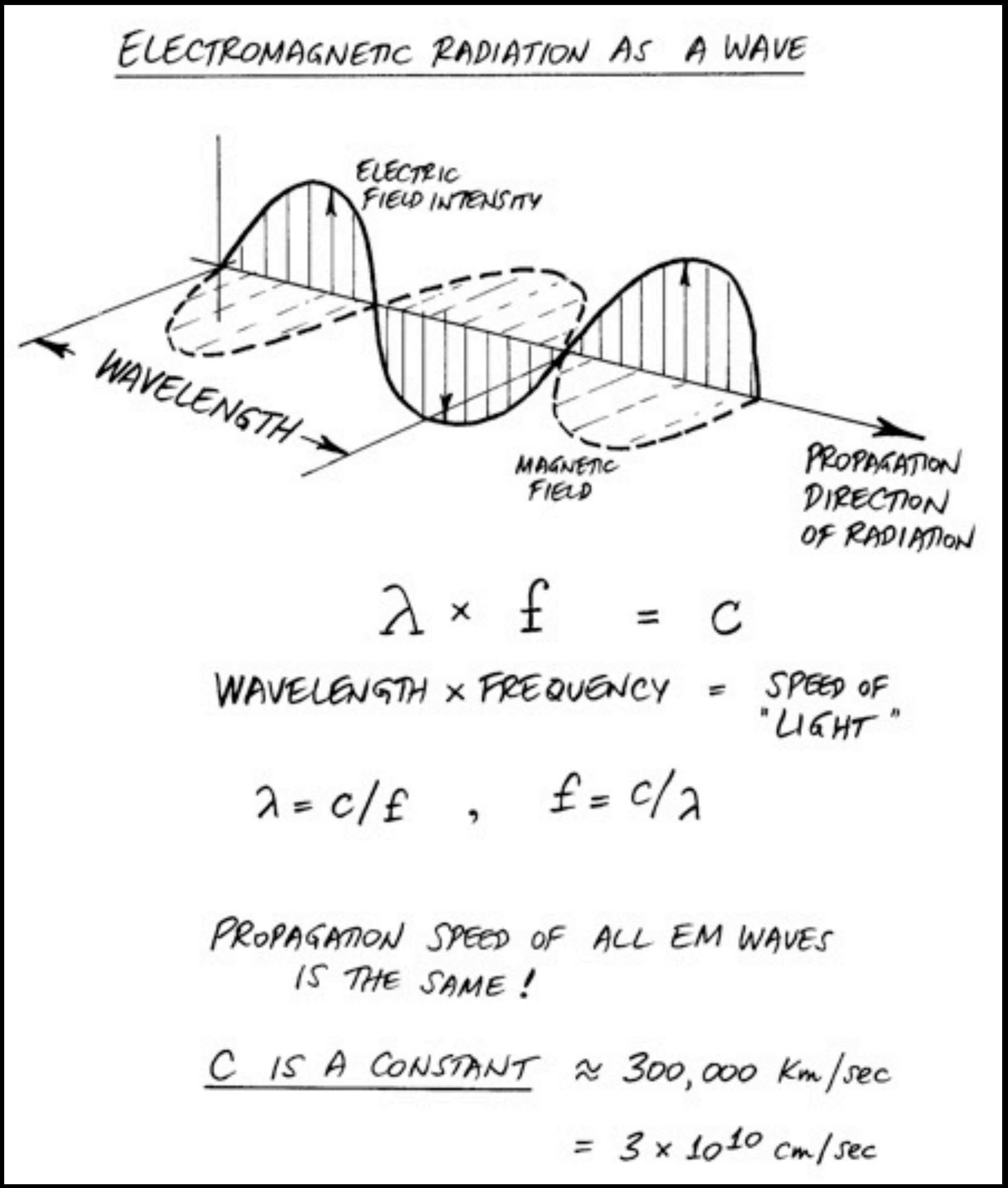
# What is Light?

## Light as a WAVE

Wavelength: Distance between peaks (or troughs) of electric (or magnetic) field
[measured in any length units, common units are Angstroms and nanometers (nm)]

Frequency: Number of wave peaks that pass a given spot per second
[measured in Hertz (Hz), which are "cycles per second"]

The speed of light is **constant**



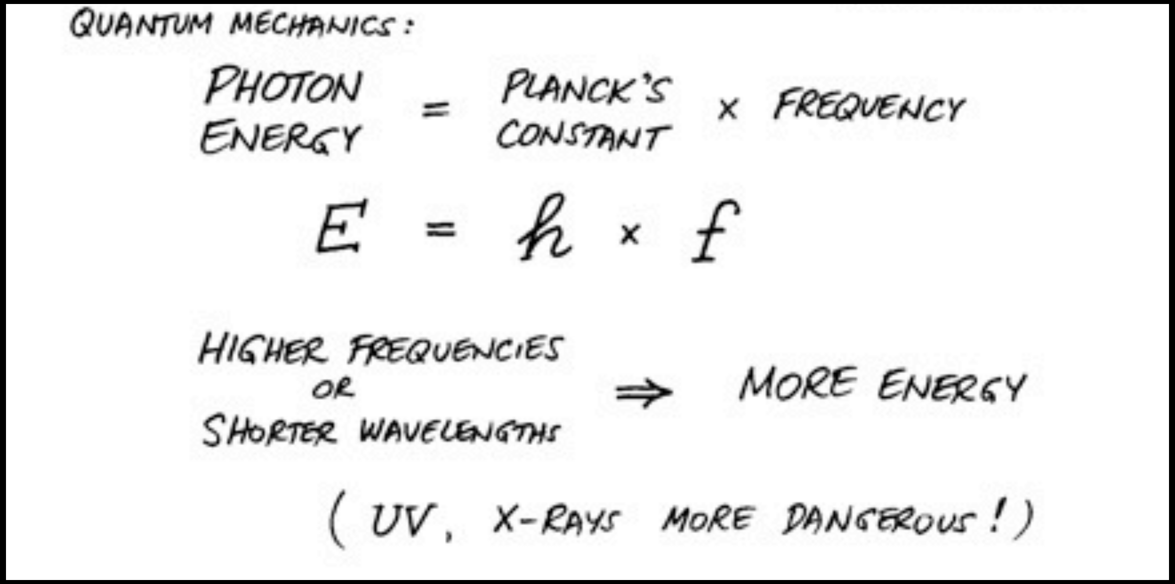
# What is Light?

Light as a PARTICLE

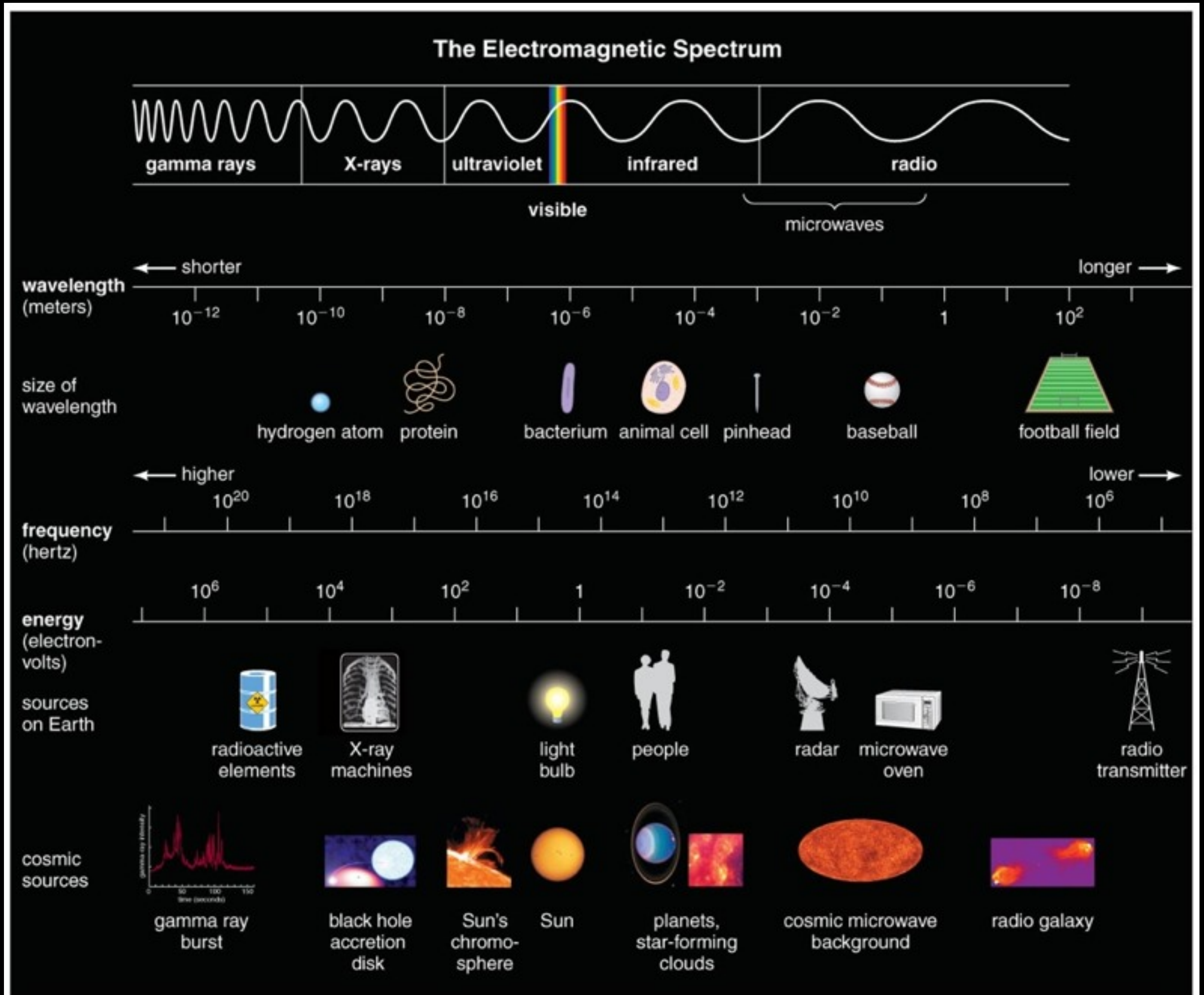
"Photon": a massless particle of electromagnetic radiation

Little "bundles/bullets" of energy

The speed of these "bundles" is **constant**



# The Electromagnetic Spectrum



## How are the wavelength and frequency of a light wave related?

A) If wavelength increases, so does frequency (direct relationship)

B) If wavelength increases, frequency decreases (inverse relationship)

C) It depends on the speed of the light wave

D) It depends on what type of light we are using (e.g. X-ray vs Ultra-violet vs Radio...)

When compared to RED light, BLUE light is:

A) Longer wavelength

B) Lower Frequency

C) Higher energy photons

D) Faster photons

E) None of the above

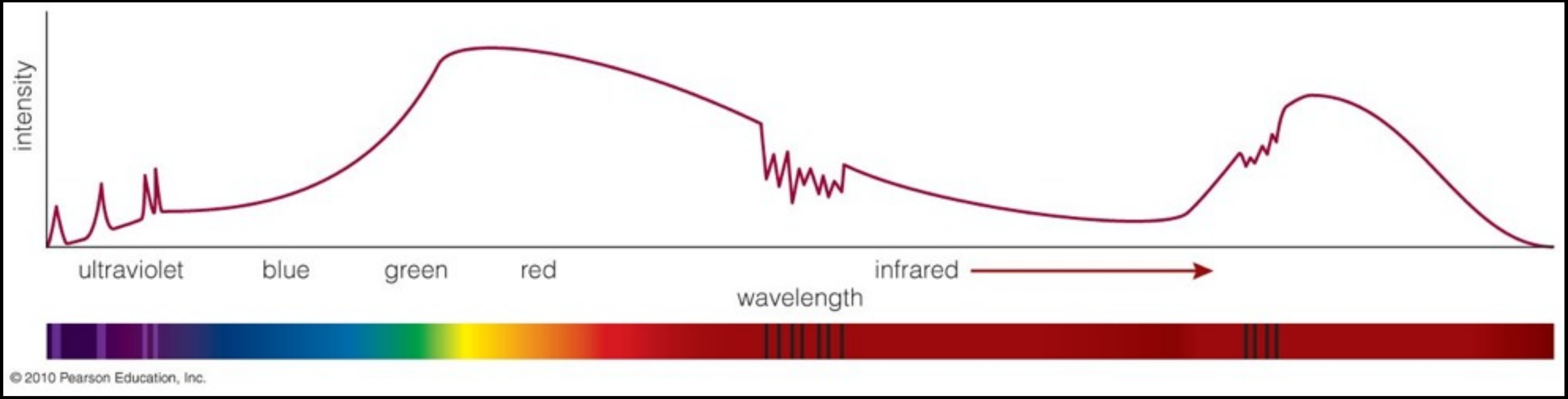
# How does light interact with matter?

- Emission – When matter emits light, it gives off light and releases energy (it shines).
- Transmission – When matter transmits light, the light passes through the matter.
- Reflection – When matter reflects light, the light bounces off the matter and changes direction.
- Absorption - When matter absorbs light, it removes that light from the environment and takes its energy.

# The nature of “white” light

- Let’s take a moment to look at a “white” light bulb and discuss what we see.
    - Do we see colors?
    - Which ones?
    - What order are they in?
    - What exactly is the grating doing?

# How do astronomers get information from light?



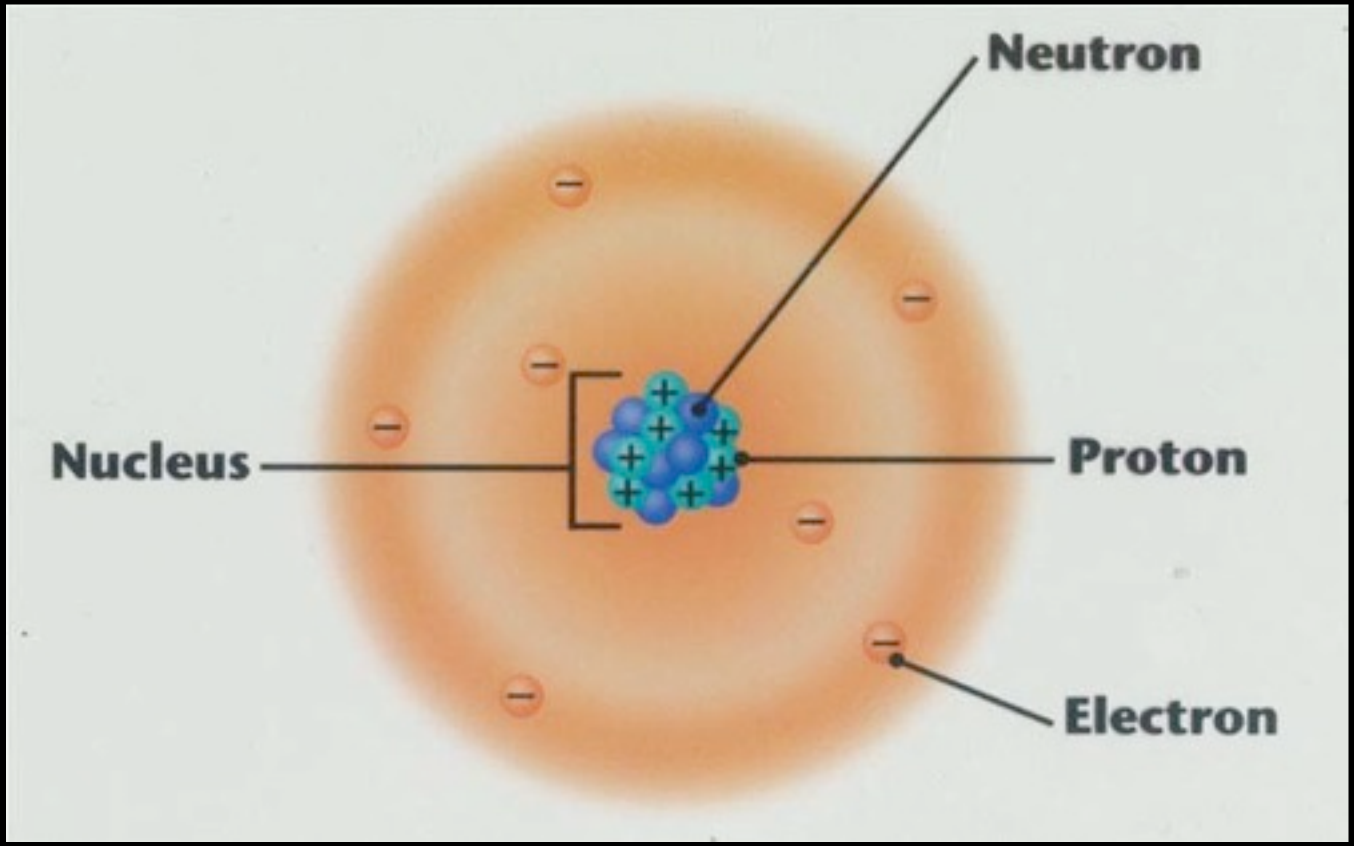

Separate light into its different wavelengths (create a "spectrum")

Different types of spectra tell us different pieces of information (i.e. composition and temperature)

But first... how does matter interact with light on the atomic scale?

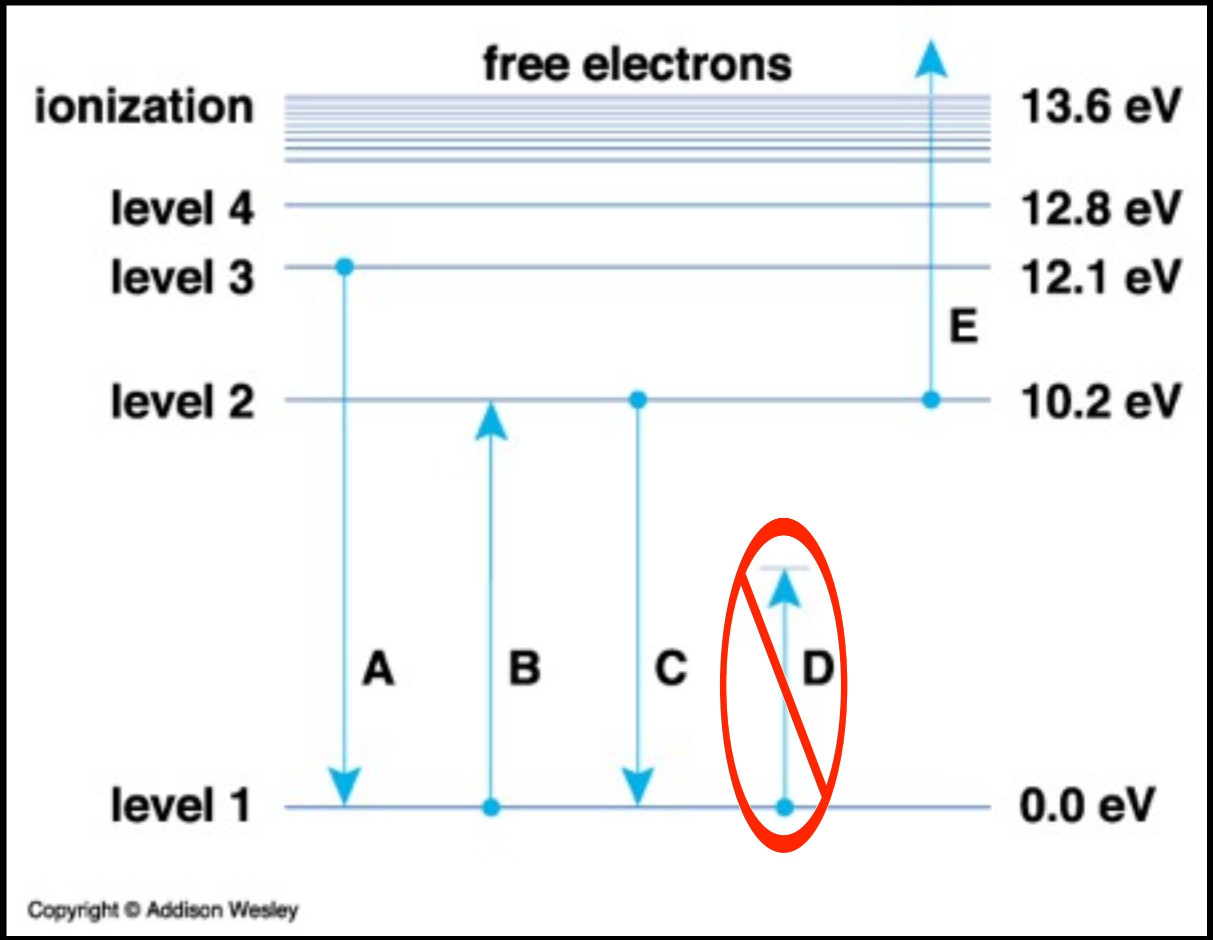
# Atomic Structure

- Two main components:
    - Nucleus: central core of the atom, made up of protons (positively charged) and neutrons (no charge). Largest particles in the atom.
    - Electron cloud: much smaller particles that float around the nucleus. Electrons are negatively charged.



# Atomic Energy Levels

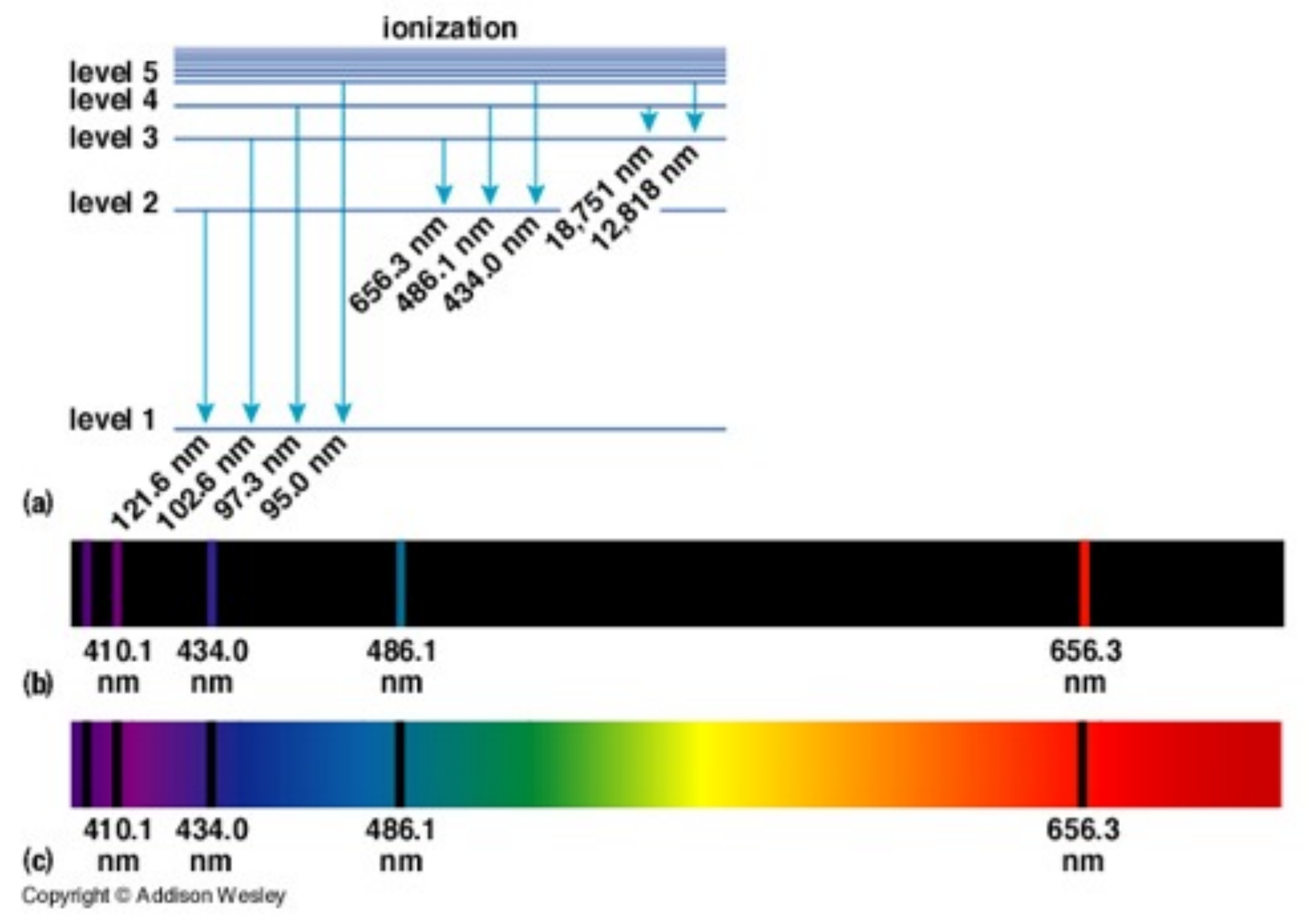
- The electrons that surround the nucleus inhabit very specific "energy states" (think of them as their "happy places").
- They can move between these energy states, but cannot exist in energy "limbo"



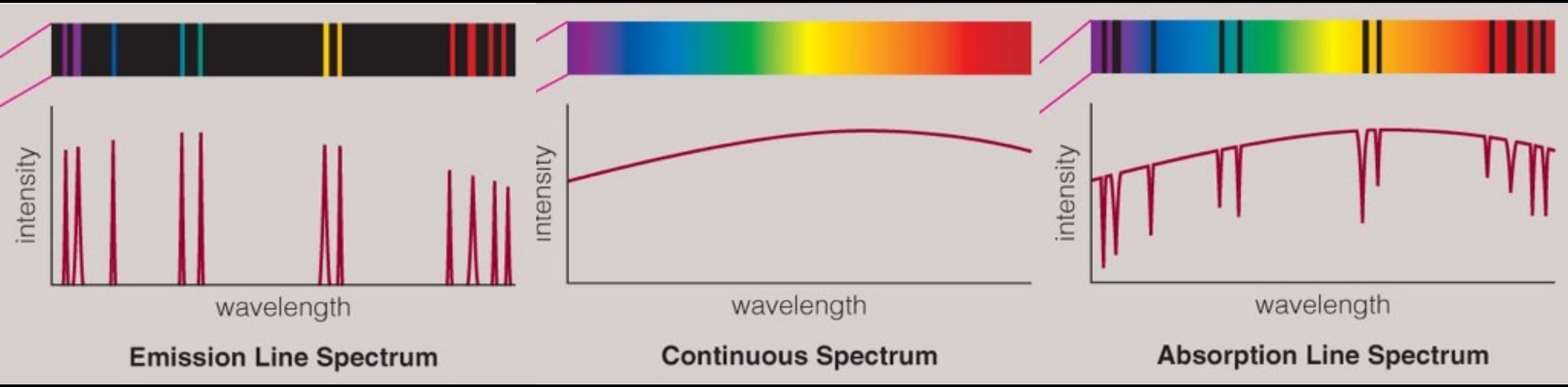
# Atomic Absorption and Emission

- When an electron "jumps down" an energy level, it emits a photon corresponding to the energy jump

- When a photon comes along and "bumps up" an electron to a higher energy level, it absorbs the photon's energy. Only certain photons with the right energy can be absorbed.



# Three types of spectra



# Spectra Recap

An emission spectrum is observed when one looks at a:

A) Hot solid, liquid, or dense gas

B) Hot, thin gas

C) Hot, thin gas viewed through a hot solid, liquid, or dense gas

D) Hot solid, liquid or dense gas viewed through a cooler, less dense gas

# Spectra Recap

An absorption spectrum is observed when one looks at a:

A) Hot solid, liquid, or dense gas

B) Hot, thin gas

C) Hot, thin gas viewed through a hot solid, liquid, or dense gas

D) Hot solid, liquid or dense gas viewed through a cooler, less dense gas

# Spectra Recap

A continuous spectrum is observed when one looks at a:

A) Hot solid, liquid, or dense gas

B) Hot, thin gas

C) Hot, thin gas viewed through a hot solid, liquid, or dense gas

D) Hot solid, liquid or dense gas viewed through a cooler, less dense gas

# Spectra Recap

Why does it need to be a HOT gas to give off and emission spectrum?

A) Hot gases glow brighter than cold gases

B) The electrons need to be in high energy levels

C) Hot gases give off higher energy photons

D) Cold photons don’t have enough energy to make it here to Earth

E) Hot things glow, cool things don’t

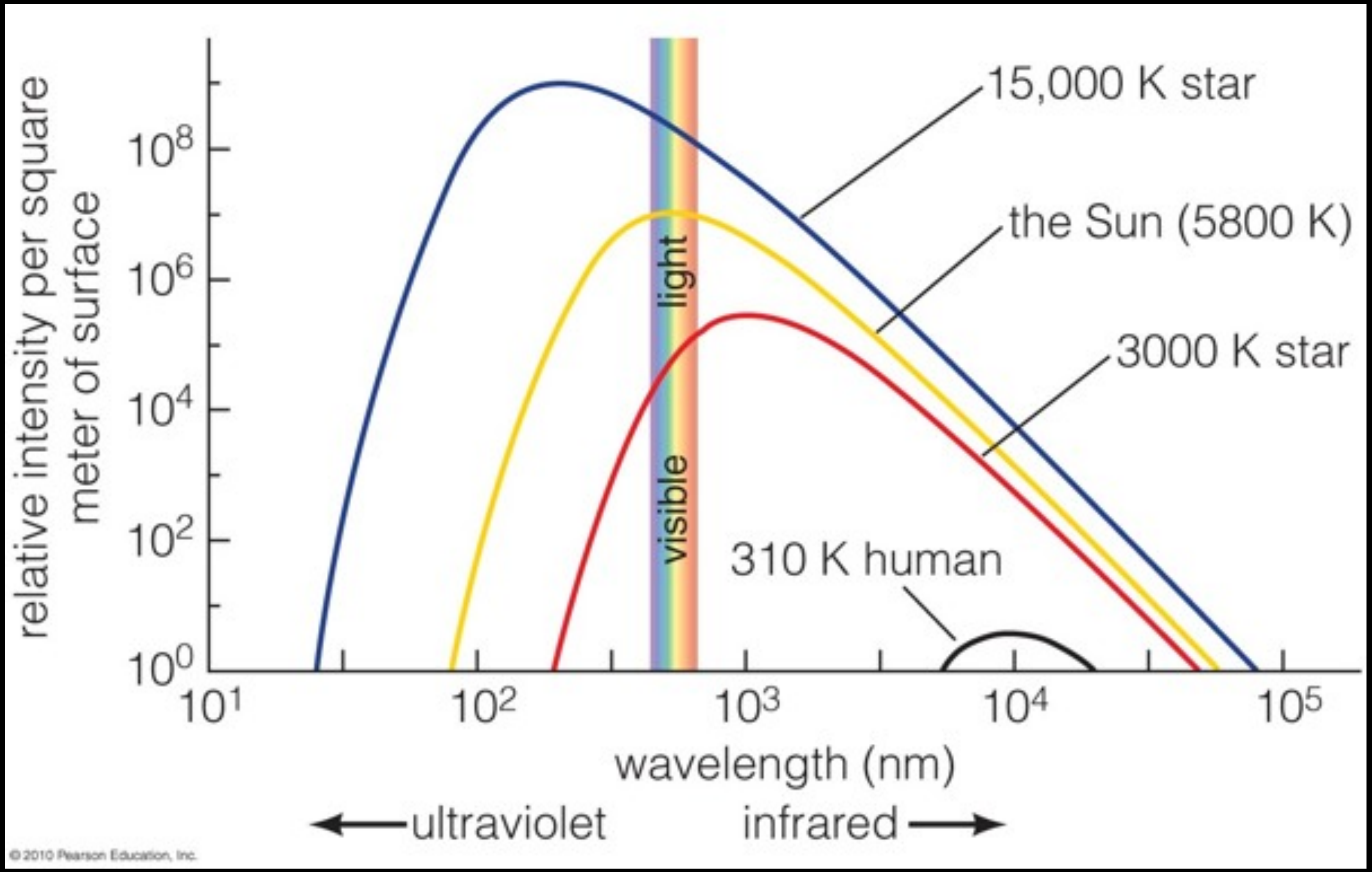
# Thermal Radiation

- Also called “black-body radiation”
- Produces a continuous spectrum

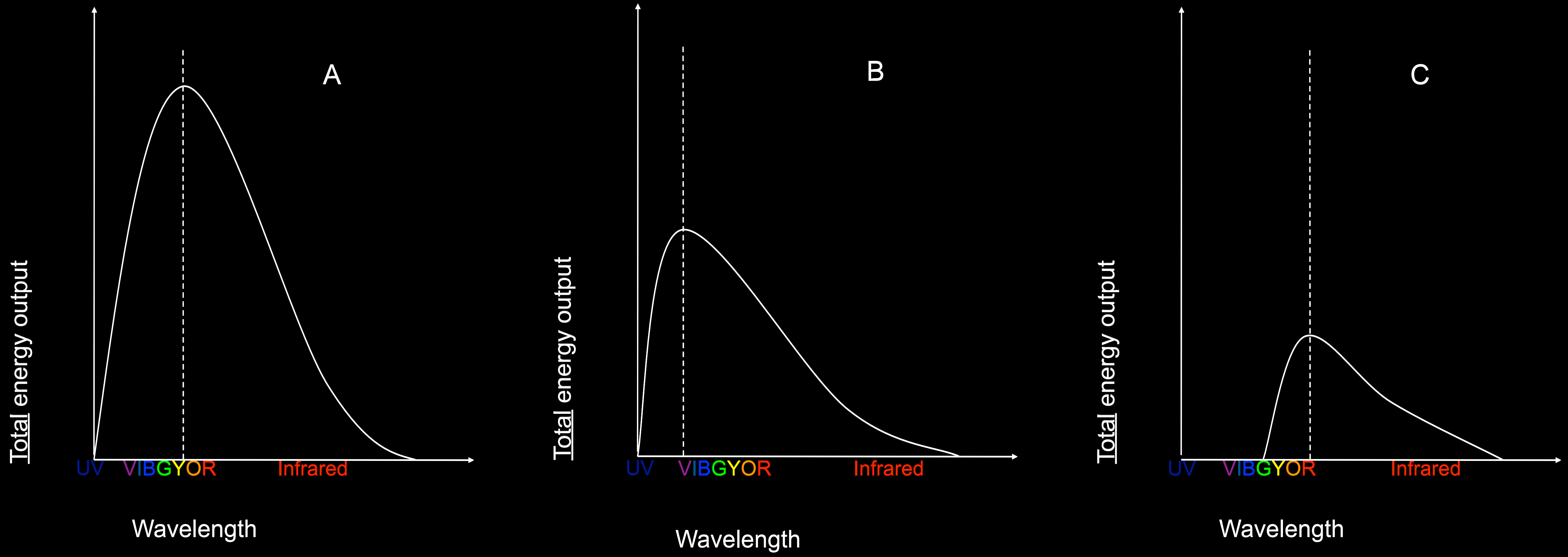
Hotter objects peak at bluer wavelengths

Hotter objects emit more light at all wavelengths per square meter of surface area

**Intensity goes as $T^4$**



The three spectral curves shown in the graphs below illustrate the total energy output (over the whole surface) versus wavelength for three unknown objects. Which of the objects has the highest temperature?



Our Sun's temperature is about 6000K, how much more light (per square meter) does a 12,000K star give off?

A) 2 times more light

B) 4 times more light

C) 8 times more light

D) 12 times more light

E) 16 times more light

# What's Next?

## Gravity, Motion, and Doppler Shift!

- Define some terms: mass, momentum, angular momentum, conservation, orbit
- Understand orbits and gravity
- Understand how Doppler Shift can be used to measure motions