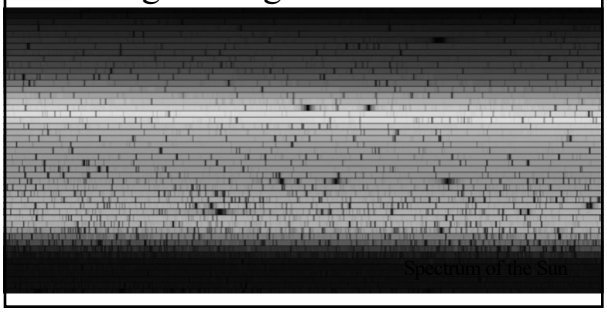
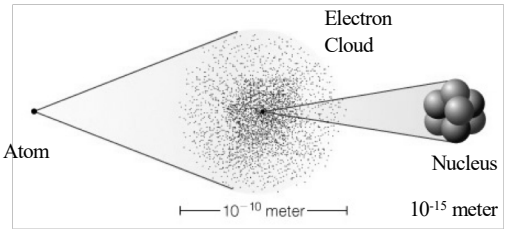
Chapter 5
Light and Matter: Reading Messages from the Cosmos



1

What is the structure of matter?

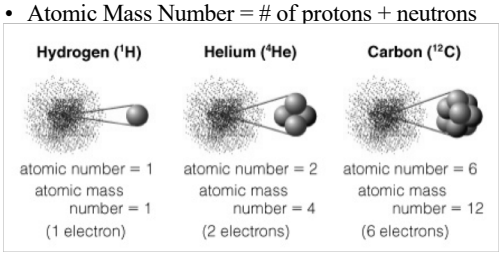


- Nucleus contains **protons** (positive charge) and **neutrons** (no charge)
- **Electrons** (negative charge) orbit nucleus at positions set by the electrical forces and energy

2

Atomic Terminology

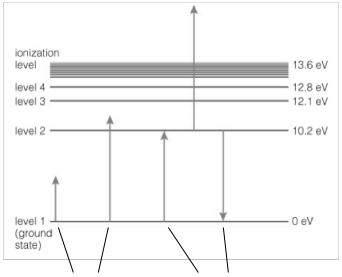
- Atomic Number = # of protons in nucleus
- Atomic Mass Number = # of protons + neutrons



- Molecules: consist of two or more atoms (H_2O, CO_2)

3

Energy Level Transitions

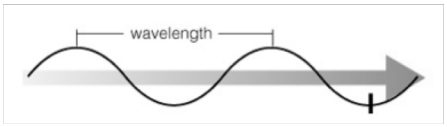


- Electrons in atoms are restricted to particular energy levels: *Quantum Theory*
- The only allowed changes in energy are those corresponding to a transition between energy levels

Jump down can lead to the emission of a photon of light; Jump up can occur by the absorption of a photon.

4

Properties of Light Waves



- **Wavelength** is the distance between two wave peaks
- **Frequency** is the number of times per second that a wave vibrates up and down
- A light wave is a vibration of electric and magnetic fields
- Light interacts with charged particles through these electric and magnetic fields

5

Energy bundles = Photons

$\lambda \times f = c$

λ = wavelength, f = frequency

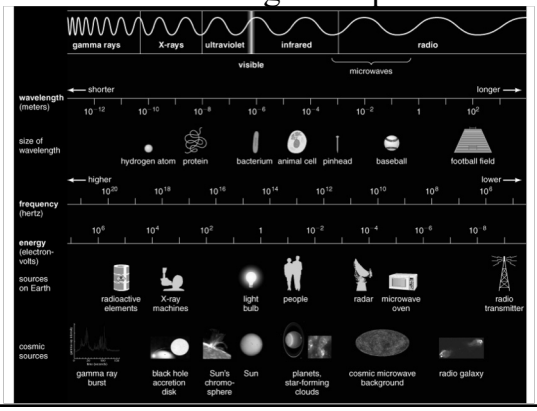
$c = 3.00 \times 10^8$ m/s = speed of light

$E = h \times f$ = photon energy

$h = 6.626 \times 10^{-34}$ joule x s = Planck constant

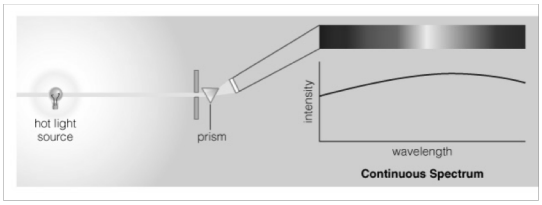
6

The Electromagnetic Spectrum



7

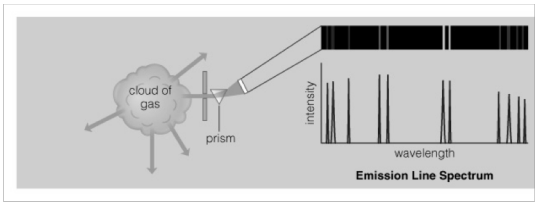
Continuous Spectrum



- The spectrum of a common (incandescent) light bulb spans all visible wavelengths

8

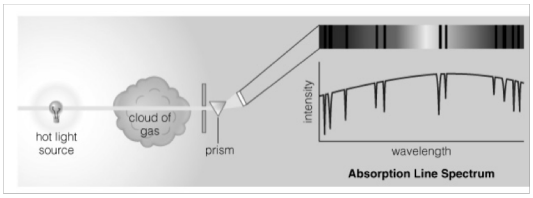
Emission Line Spectrum



- A thin or low-density cloud of gas emits light only at specific wavelengths that depend on its composition, producing a spectrum with bright emission lines

9

Absorption Line Spectrum

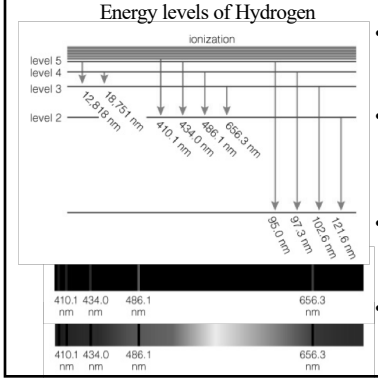


- A cloud of gas between us and a light bulb can absorb light of specific wavelengths, leaving dark absorption lines

10

Chemical Fingerprints

Energy levels of Hydrogen

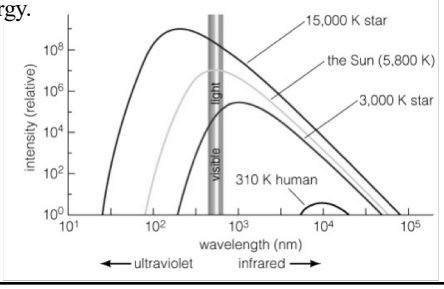


- Each type of atom has a unique set of energy levels
- Each transition corresponds to a unique photon energy
- Downward transitions produce emission lines
- Upward transitions produce absorption lines

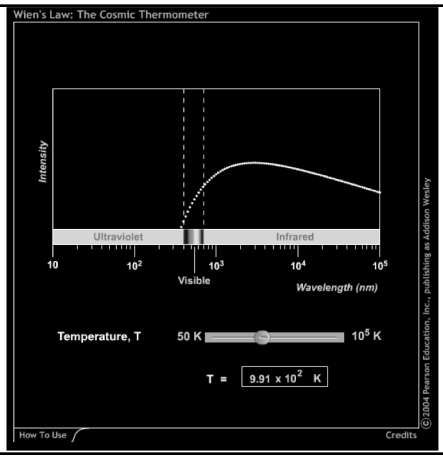
11

Properties of Thermal Radiation

1. Hotter objects emit more light at all frequencies per unit area.
2. Hotter objects emit photons with a higher average energy.



12



13

Thought Question
Which is hotter?

a) A blue star.
b) A red star.
c) A planet that emits only infrared light.

14

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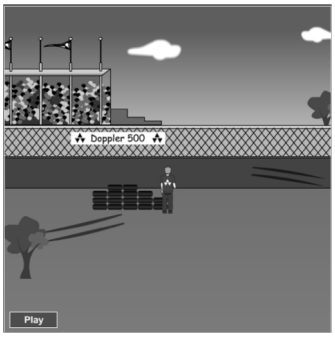
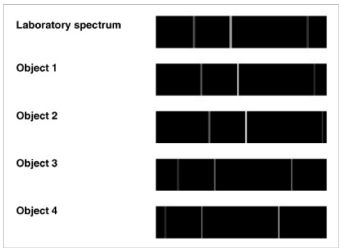
15

5.5 The Doppler Effect



16

Measuring the Shift in Light

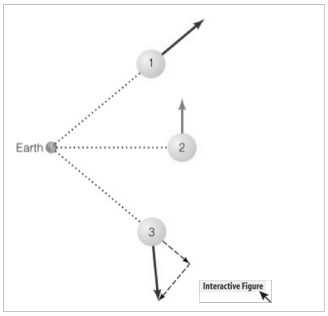


Stationary
Moving Away
Away Faster
Moving Toward
Toward Faster

- We generally measure the Doppler Effect from shifts in the wavelengths of spectral lines

17

Doppler shift tells us ONLY about the part of an object's motion toward or away from us:



18

Thought Question
I measure a line in the lab at 500.7 nm.
The same line in a star has wavelength 502.8 nm.

What can I say about this star?

a) It is moving away from me.
b) It is moving toward me.
c) It has unusually long spectral lines.

19

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v/c = (observed-lab)/lab = (502.8-500.7)/500.7=0.004

v = 0.004 c = 0.004 × 3x10^5 km/s = 1200 km/s

20