

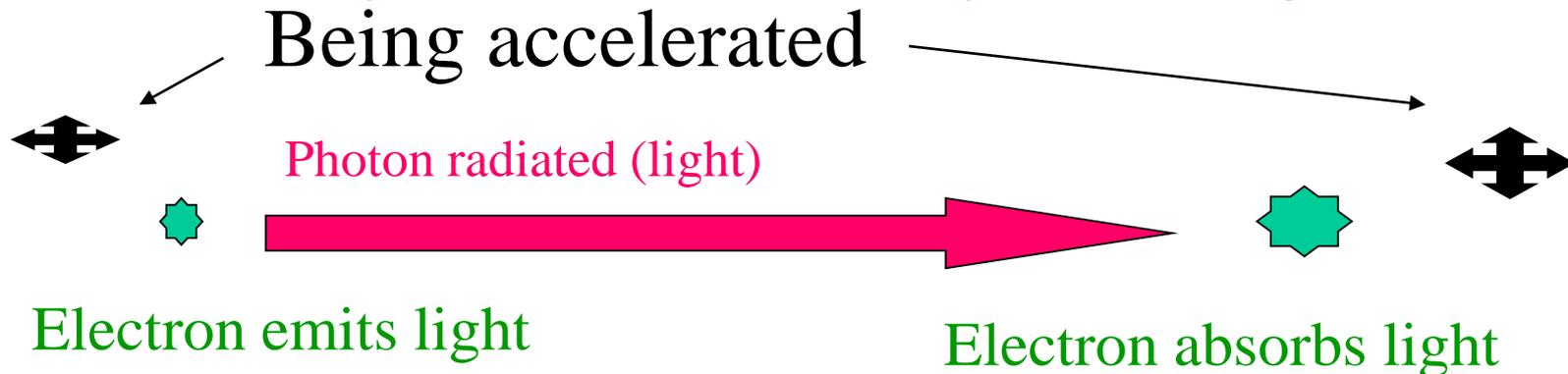
LIGHT

- We measure the property of stars by looking at the light they emit
- Visible light, infrared, UV, radio are all types of Electromagnetic Radiation. They differ by having different frequencies → different colors

- EM Radiation is caused by

accelerating electric charge

(usually electrons since they are the lightest)



Electromagnetic Force

- There is a force between any two bodies 1 and 2

$$F = Cq_1q_2/r^2$$

with q_1 and q_2 being the charges and r being the distance between 1 and 2

- Both attractive and repulsive (positive and negative charge)
- Depends on the charges of the two bodies
- Decreases as the distance increases
- Is the same force everywhere in the Universe
- Stronger than Gravity but average charge usually equal 0

Electricity and Magnetism are different aspects of the same force.

Electromagnetic Force Examples

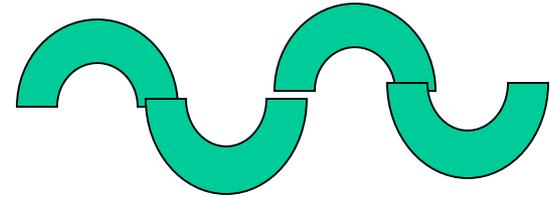
Rubbing a balloon on your hair or a cat builds up excess electrons on the balloon which can then stick to a wall, or even better, to a cat.

2 magnets pull towards each other or push away from each other depending on what “pole” faces each other. Both attractive and repulsive.



Gravity pulls me toward the center of the Earth but the repulsive electromagnetic force between like charges on my shoe's surface and on the floor's surface prevents me from going through the floor

- Light is a bunch of photons → EM radiation or EM waves
- wavelength (λ) = distance between waves



- Period = time between wave peaks
- Frequency (ν) = $1/\text{period}$ = how rapidly wave is changing

So 60 Hz = 60 Hertz = 60 beats per second is the same as a period of 0.016 seconds

- Can use either wavelength or frequency to characterize light → frequency proportional to energy
- $E = hf$ = constant*frequency
→ high frequency photons are also high energy photons

velocity = wavelength X frequency

velocity sound = 1 mile/5 seconds

velocity light = 1 mile/5 microseconds = 300,000 km/sec

Lightning occurs. You see the flash almost immediately but hear the thunder later. If you count slowly, then if thunder happens at 5 seconds the lightning strike occurred about 1 miles away

If you see and hear lightning at the same time it has struck very close to you (my homes have been hit 3 times. In 1967, lightning hit the window well of my basement bedroom 8 ft from me at 6:00 AM and set the wall on fire. I put out the fire, went upstairs to tell my Dad who said “go back to sleep”. Later, after seeing the destroyed wall he said “I guess you were right”)

high energy

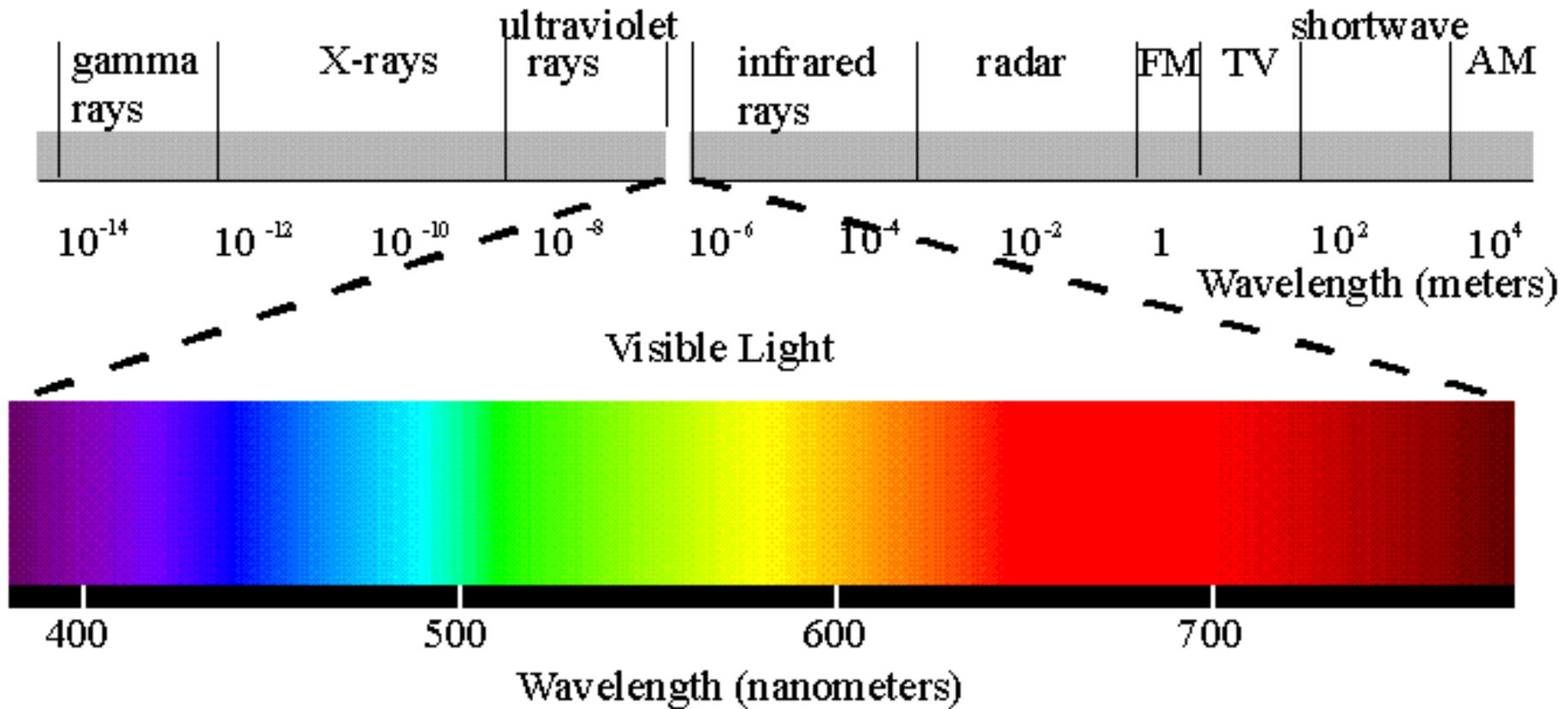
low energy

high frequency

low frequency

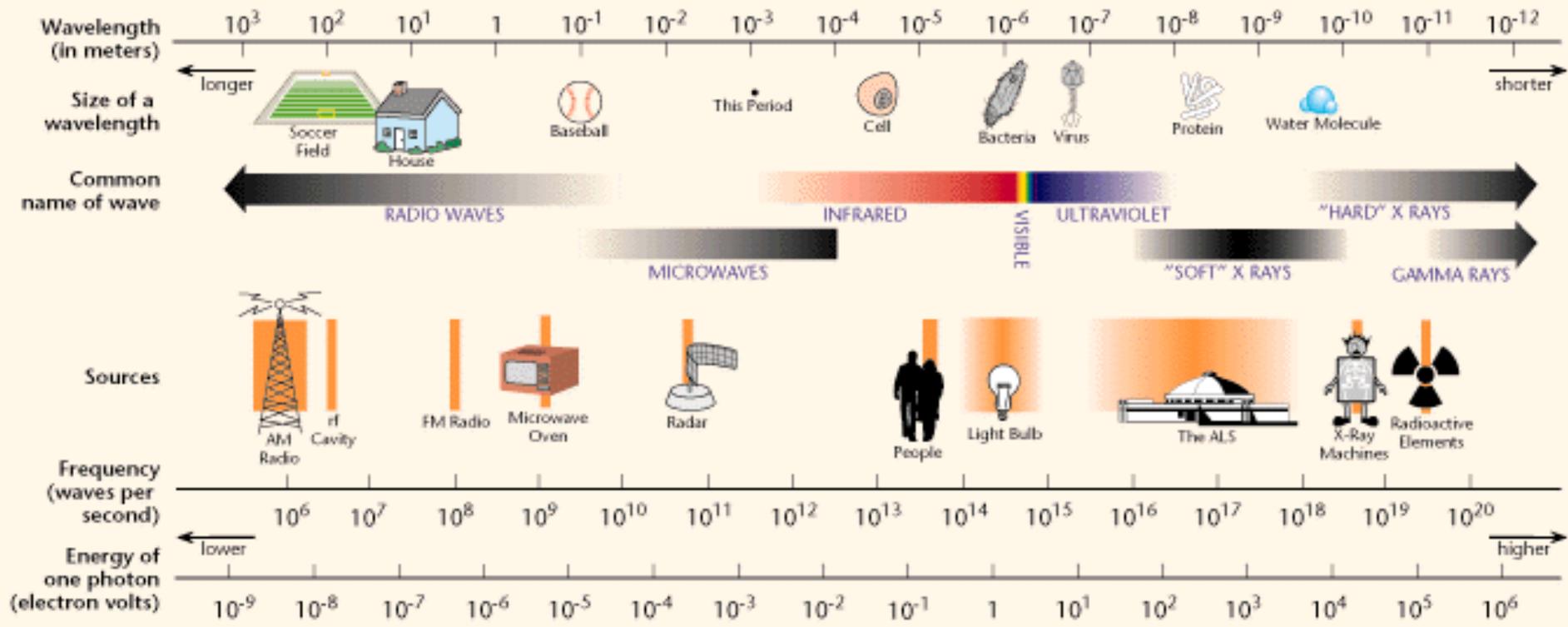
Small wavelength

Large wavelength

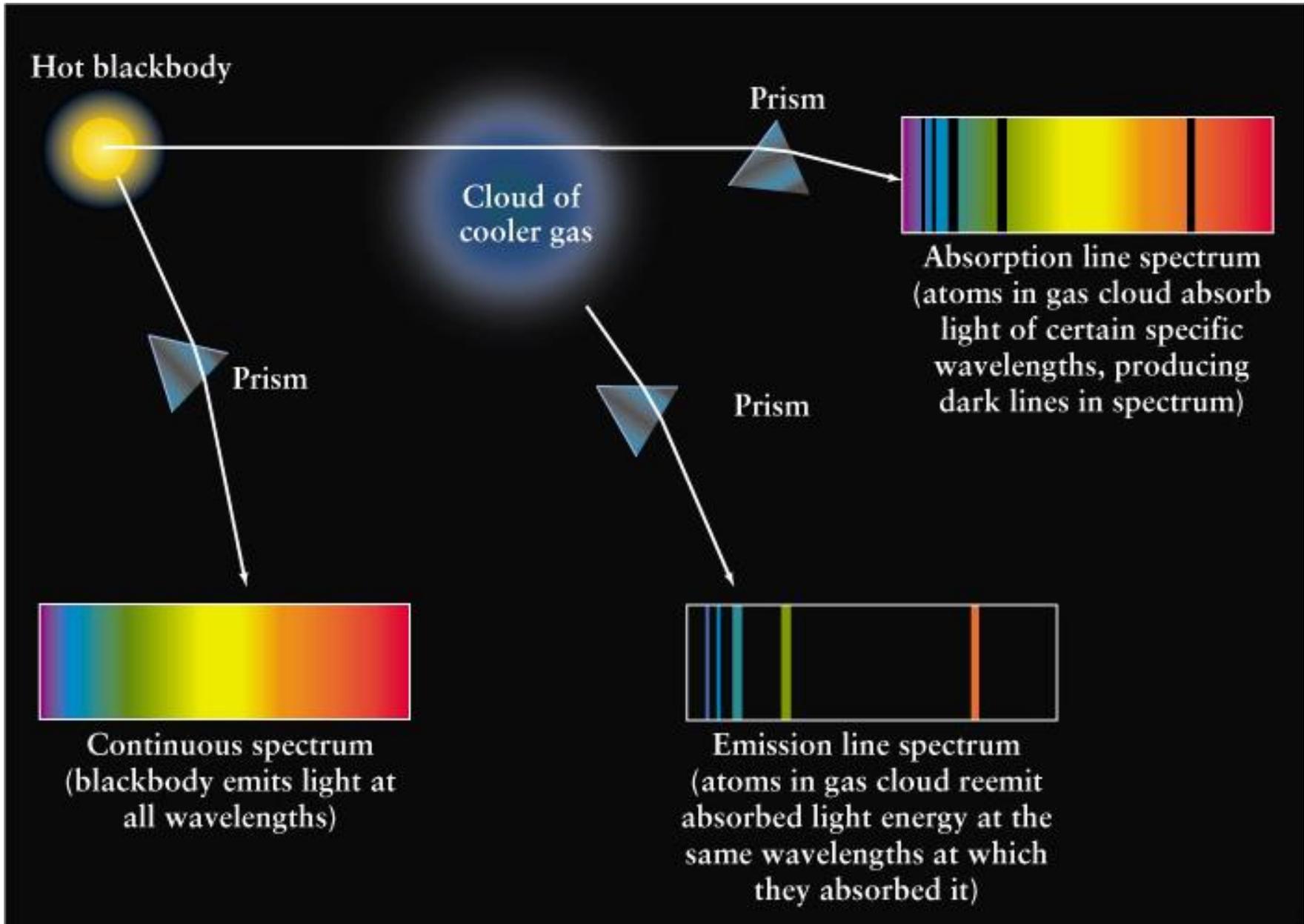


Different types of electromagnetic radiation

THE ELECTROMAGNETIC SPECTRUM



We observe light as continuous or discrete spectrum



Continuous Spectrum

- Radiation of light due only to Temperature of object

- All frequencies

- Peak of frequency spectrum depends on Temperature

$$\text{wavelength}_{\text{max}} = 3,000,000/T$$

with wavelength in nanometers and T in Kelvin

- Total energy emitted

$$E = \sigma \times T^4 \quad \sigma = \text{constant}$$

Temperature

Temperature \leftrightarrow Velocity \leftrightarrow Energy

At higher Temps

higher velocities

more acceleration of electrons

more light emitted

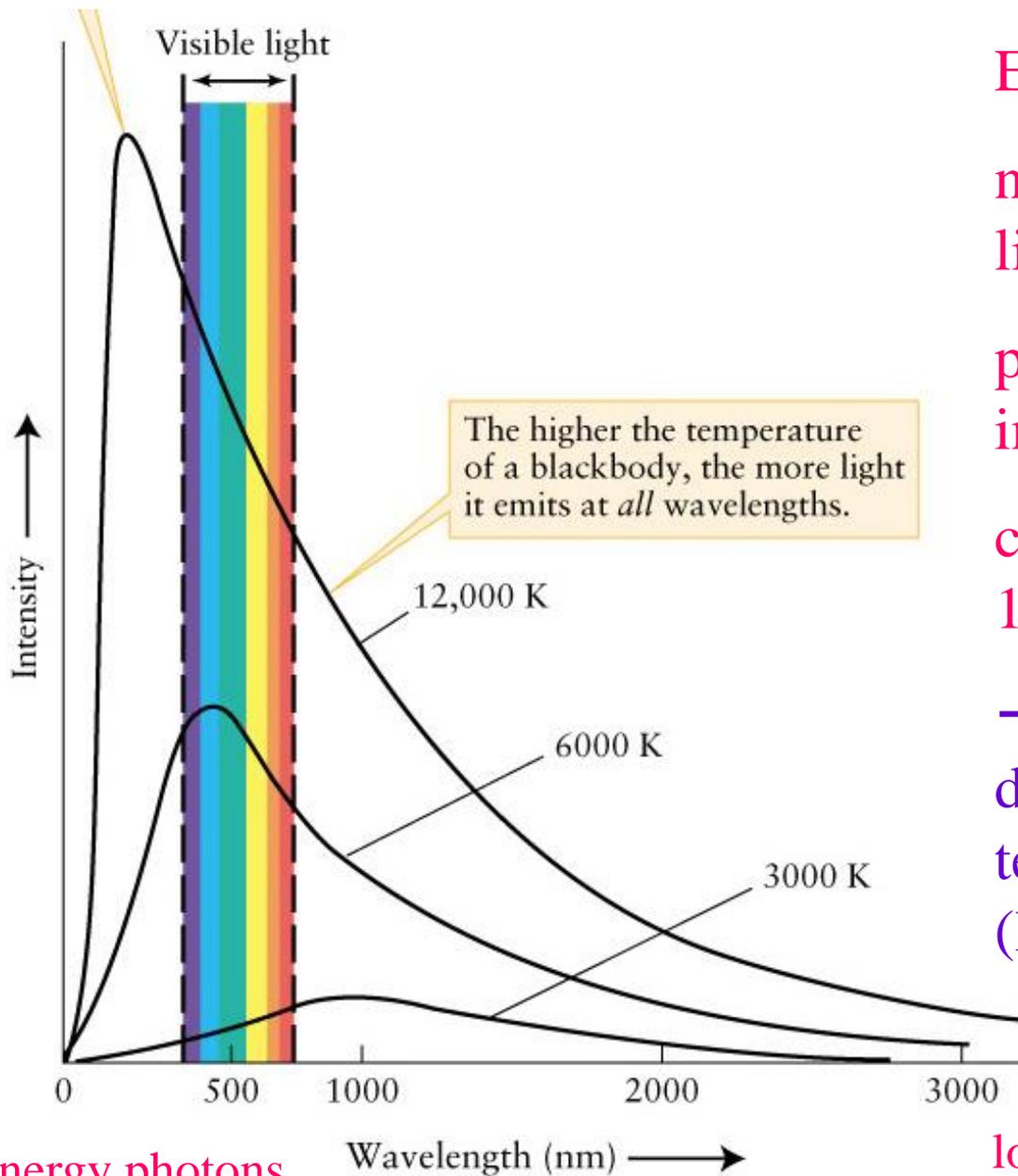
- Kelvin Scale

Absolute 0 = 0° K

= -273° C

= -459° F

at high T Kelvin and Centigrade about same



EXAMPLES

normal, incandescent light bulbs $T=5000\text{K}$

people $T=300\text{K}$ → infrared

campfires, stoves $T=600-1000\text{K}$, start to glow red

→ Measure spectrum at a distance → measures temperature of source (like a star)

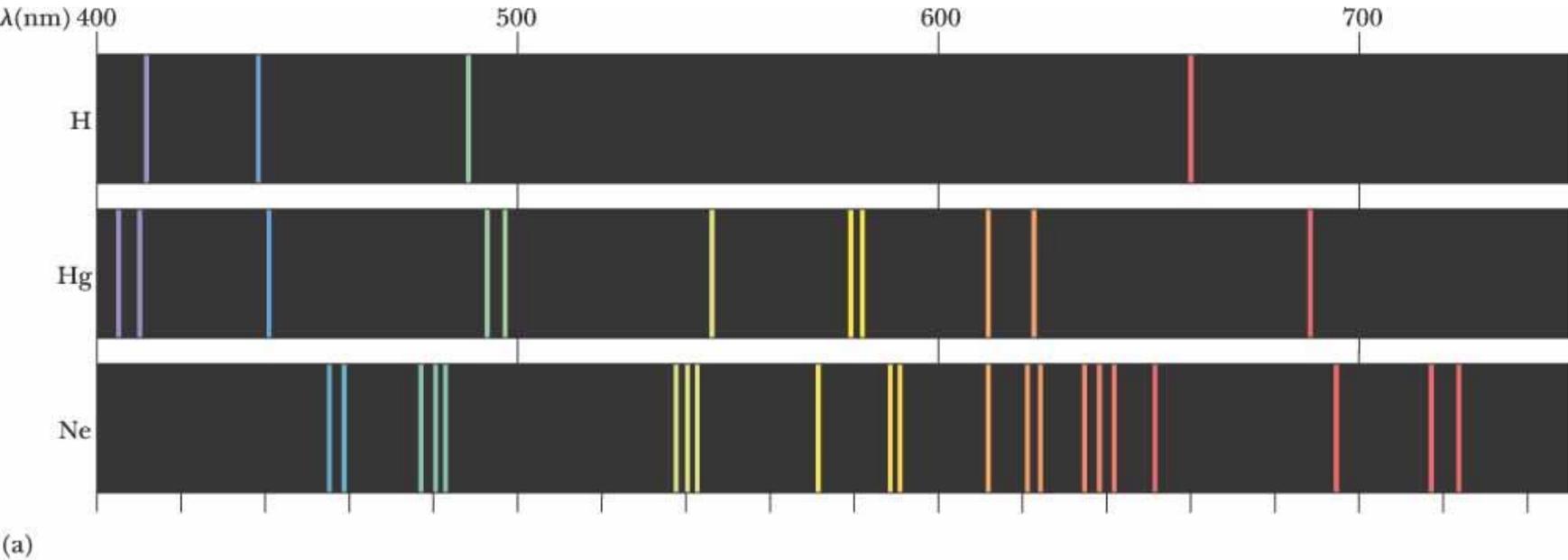
high energy photons

low energy photons

Discrete Spectrum

- “spikes” at specific frequencies
- Depends on which atoms are present
- Examples include fluorescent or Neon or Mercury lights
- Can be used to identify chemical composition of objects (spectroscopy)

Atoms and Energy Levels



emission lines can tell one atom from another – in this case Hydrogen from Mercury from Neon

Atoms and Energy Levels

- An atom is a nucleus surrounded by electrons held together by the electromagnetic force
- Electron can be in different energy states; Changes in electron energy states (Quantum Leaps) produce discrete spectrum
- Transitions between different atomic energy states either emit or absorb light; the energy of the light (the photon's frequency) is equal to the difference between the atomic energy states
- Pattern of photon frequencies tells what atom is emitting the light

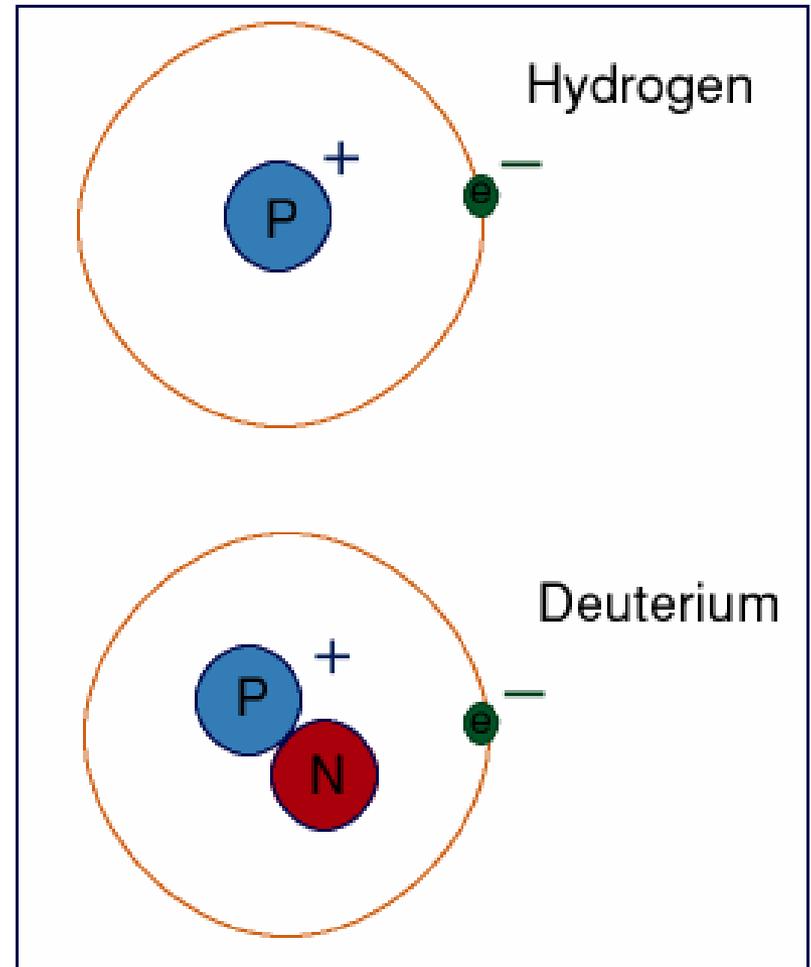
$$E(\text{photon}) = hf$$

h = Planck's constant

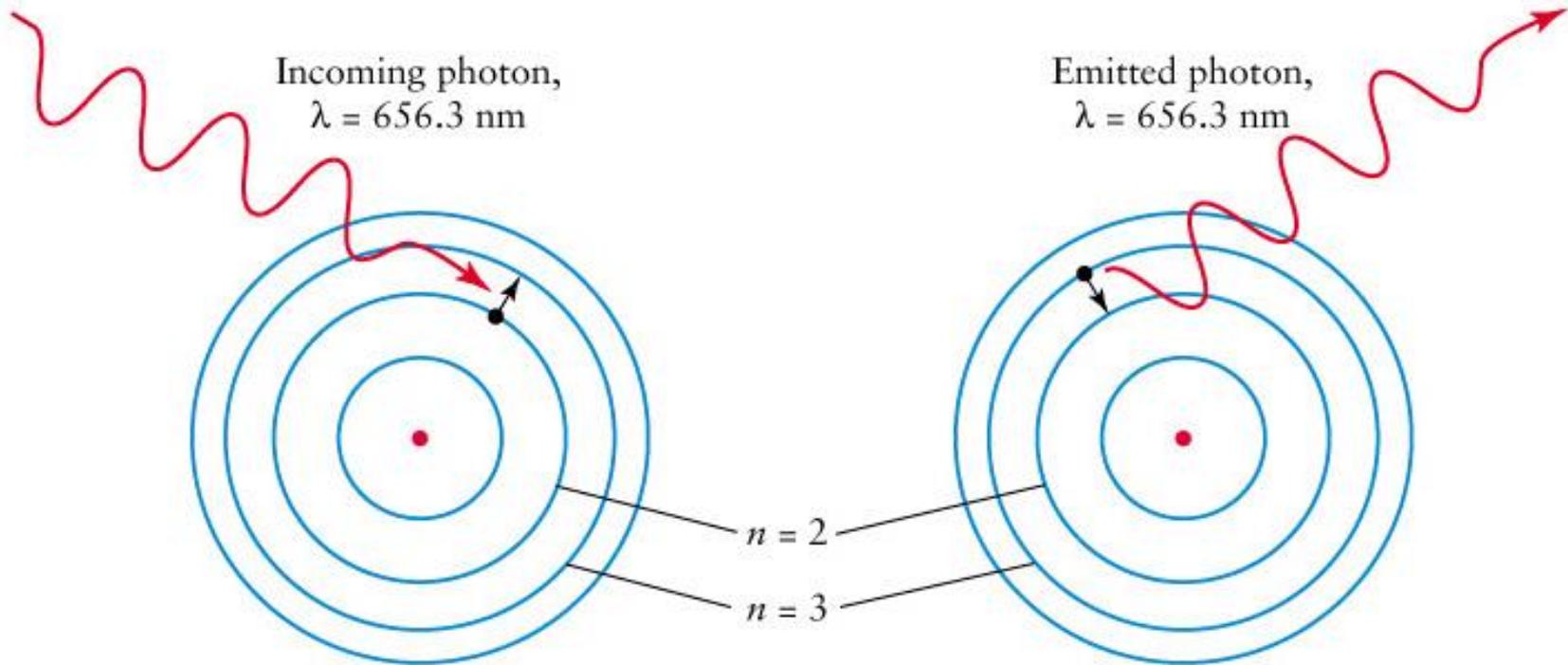
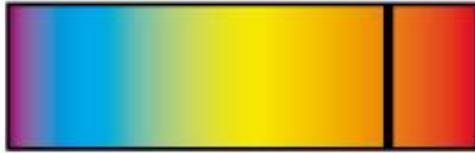
f = frequency

Hydrogen

- Simplest atom – just one electron and one proton
- “heavy” hydrogen or deuterium adds one neutron to the nucleus



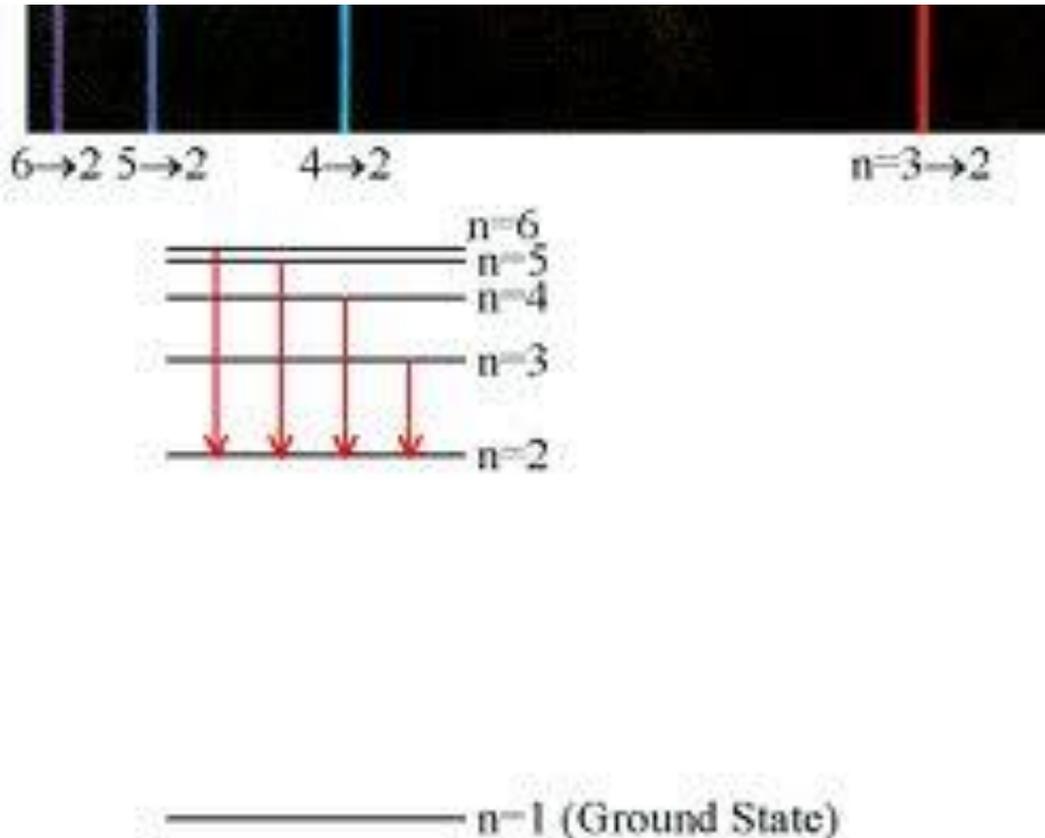
Atoms and Energy Levels - H



Absorbs light

emits light

Hydrogen lines



For Hydrogen, the lines in the visible spectrum are transitions to the $n=2$ (Balmer) Those to the $n=1$ are in the UV (Lyman series)

Brightness → Luminosity → Magnitude

Absolute:

intrinsic brightness

Ex. 25W vs 100W light bulb



30 m away

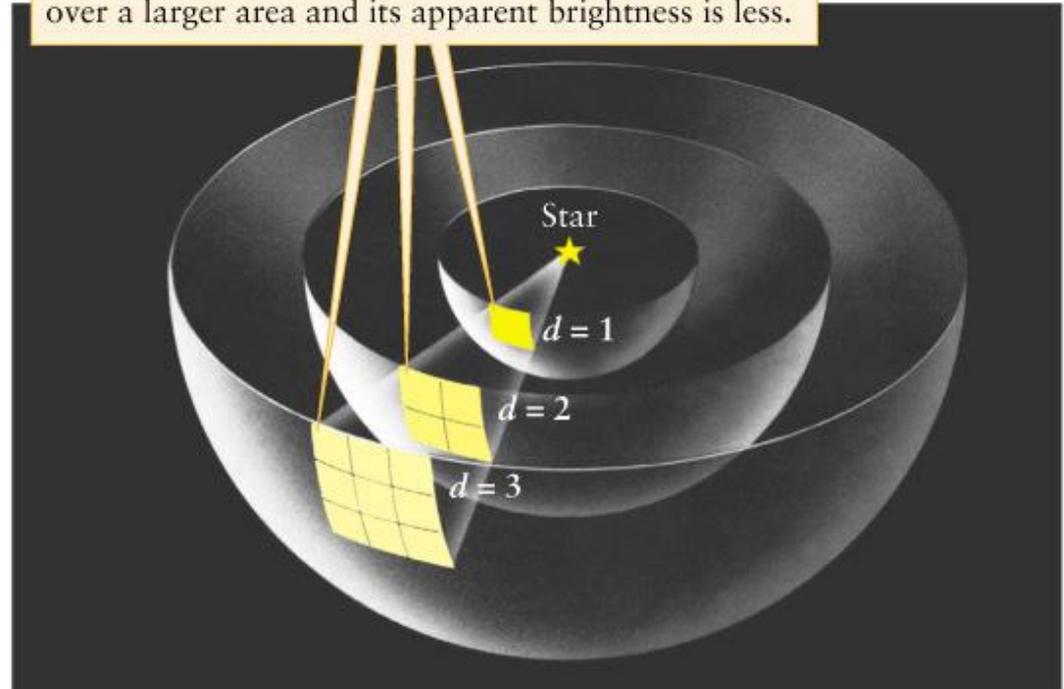


20 m away



10 m away

With greater distance from the star, its light is spread over a larger area and its apparent brightness is less.



Apparent:

observed brightness

depends on absolute brightness and how far away you are. Falls as $1/(\text{distance})^2$

Brightness → Luminosity → Magnitude Use for Stars

We will go over when discussing stars

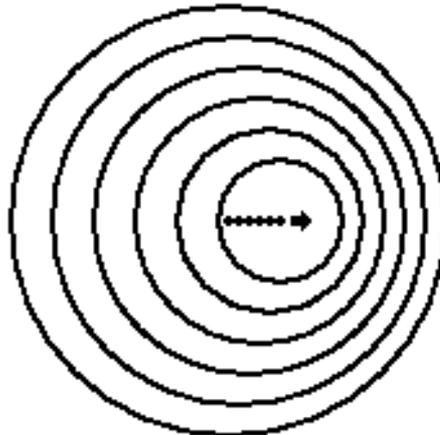
The Apparent brightness of a star is what we see by eye or in a telescopic image and it depends on the star's absolute brightness and how far away it is. One of the first things an astronomer needs to do is determine the distance to a star to then determine the absolute brightness after measuring the apparent brightness

Doppler Shift

Change in frequency of light due to relative motion of the source to the observer

- Red Shift - changes to lower frequency if source is moving away from observer
- Blue Shift - changes to higher frequency if source is moving towards observer
- Easy to measure even if object very far away. Mostly use Hydrogen spectrum for astronomy. Can measure a star's velocity to human running speed of 10 m/s

OBJECT RECEDING:
LONG RED WAVES



OBJECT APPROACHING:
SHORT BLUE WAVES



EXTRA SLIDES

How fluorescent light works

- Tube filled with Mercury and Argon gas
- Initial HV heats up gas → Argon “plasma”
- moves electrons in Mercury to higher energy levels
- electrons “fall” to lower energy levels and emit UV light
- UV light absorbed by phosphor coating on inside walls of tube and is reemitted at lower energy, with mix of colors that appears white

Gravity vs Electric Force

- electric force dominates daily life
 - all senses
 - all chemistry
- easy to observe much stronger than gravity
 - floor prevents us from falling to Earth's center
 - can stick a balloon to the wall
 - levitating magnets
- why gravity is so weak is one of the unanswered questions in physics. Extra Dimensions? more later in course

