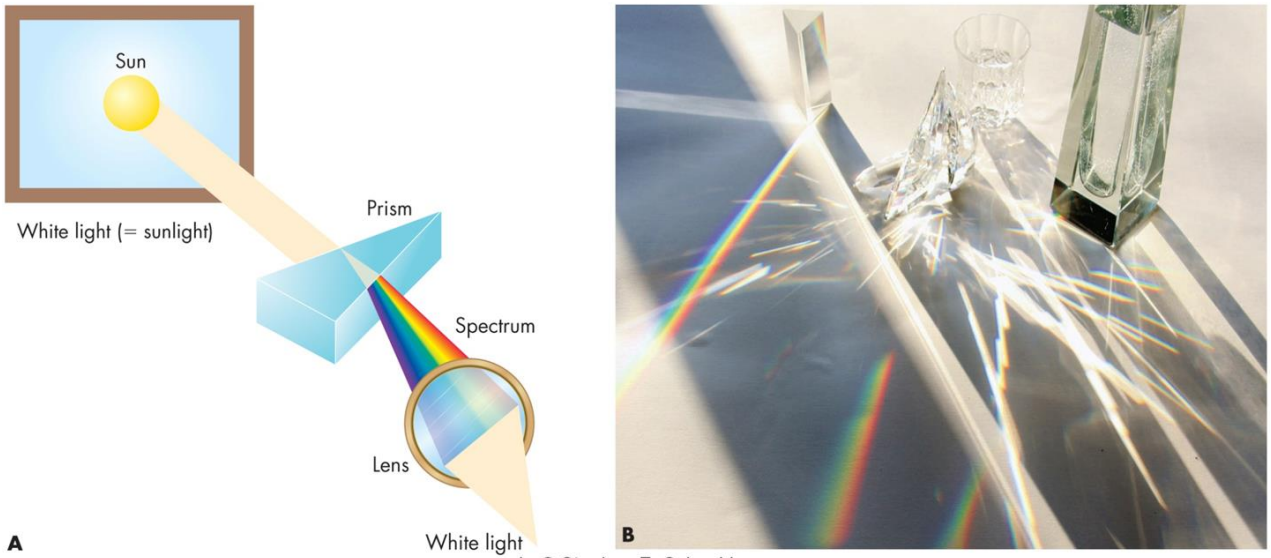
STARS AND LIGHT

Astronomy

Light

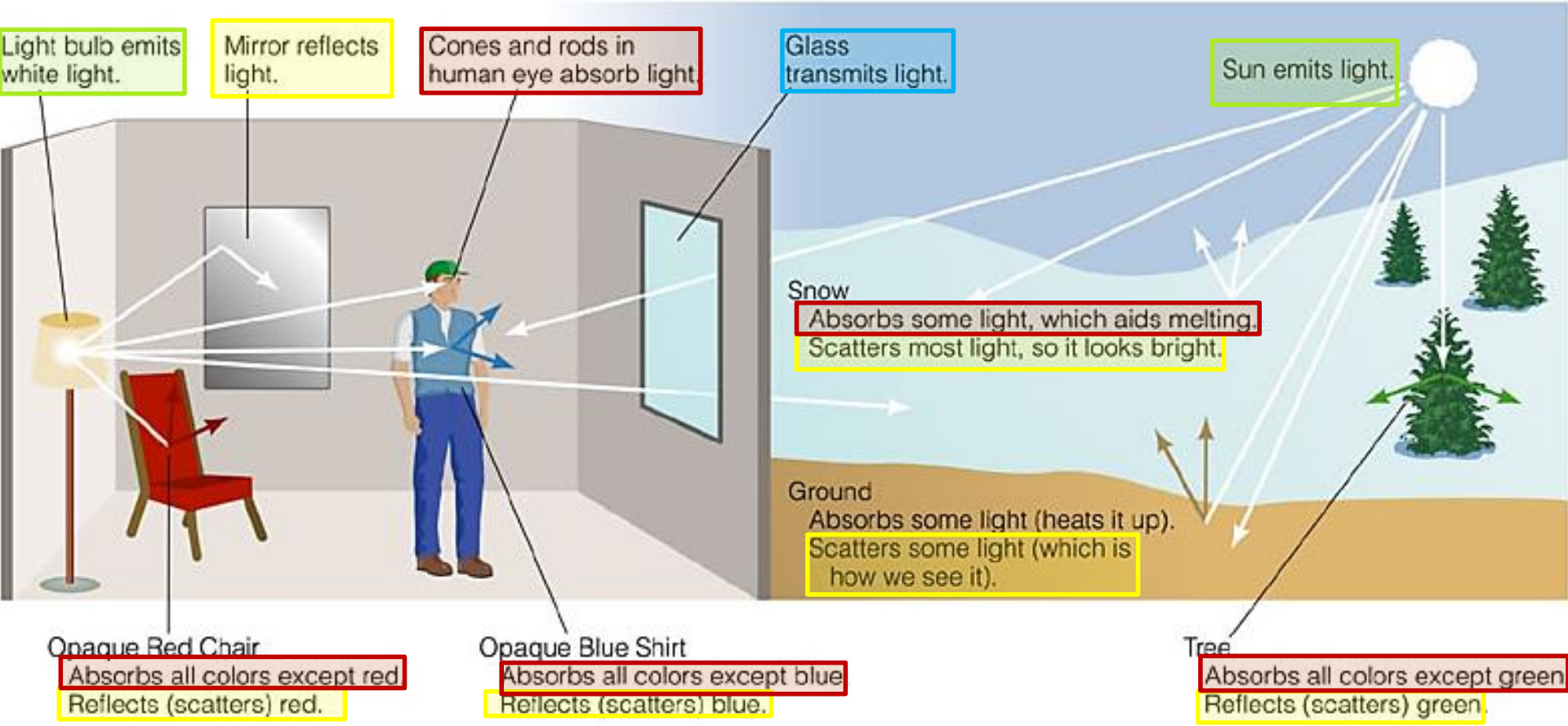
- Light interacts with _____ in 4 ways: _____ , *absorption*, _____ , *and reflection*

- The light we see is referred to as "_____ light"
  - We see a "_____ of colors", that when perceived together produce *white light*.



b: © Stephen E. Schneider

4 Interactions between Light and Matter

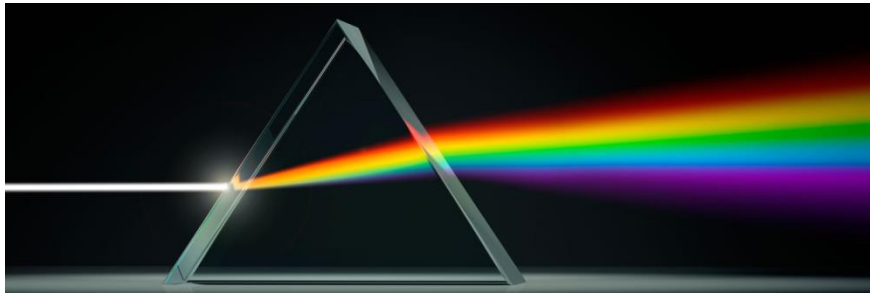


4 Interactions between Light and Matter

1. **Emission**: a light bulb _____ visible light.
2. **Absorption**: when you place your hand near an _____ light bulb, your hand _____ some of the light. *"Opaque" objects absorb light*.
3. **Transmission**: Some forms of _____ , such as glass or air, _____ light, or allow light to pass through.
4. **Reflection/scattering**: light can _____ off matter, leading to _____ (bouncing is in same general direction) or _____ (bouncing of light is more random)

Light

- **Spectrum-** a _____ showing light in its _____ forms(colors).
  - *"ROY G BIV"*



- ***White Light*** is what we call light from the _____ or from a light bulb.
  - Seen when we view equal _____ of all colors
  - *Black* is what we perceive when there is no _____ and hence no _____ .
  - We see the color that is being _____ from objects to our eyes (that object is absorbing all other colors)

What is Light?

Light , AKA "_____ **Radiation**" is a form of energy

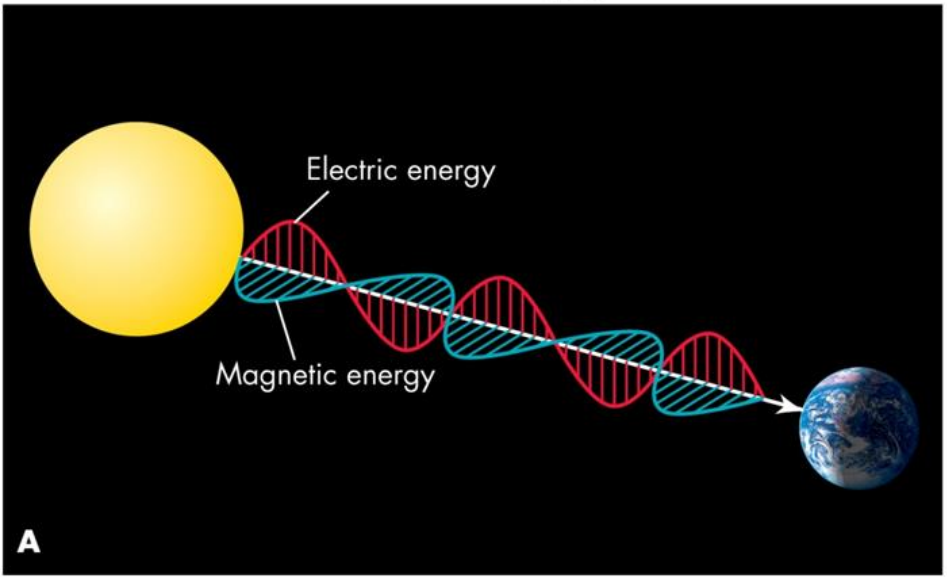
Light is both a _____ and a particle.

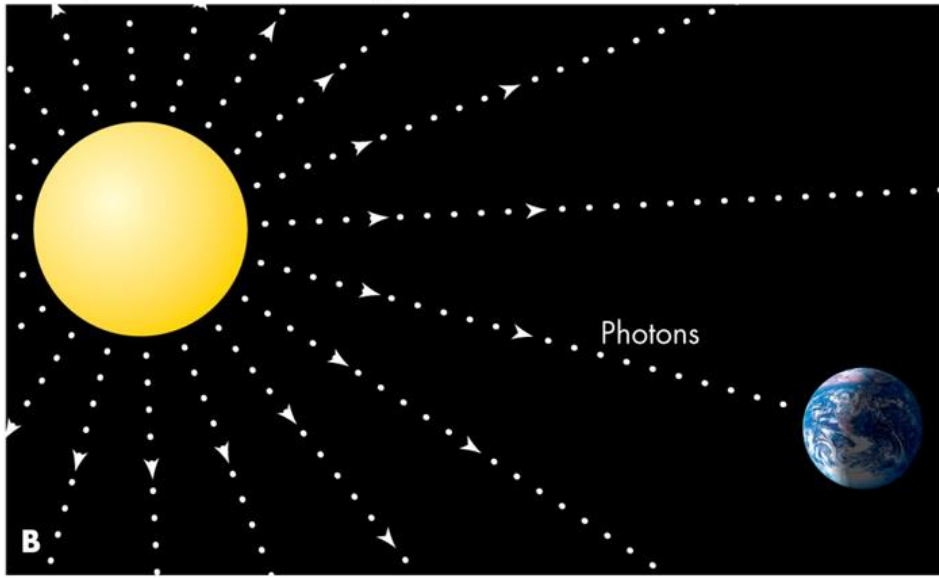
- **Electromagnetic Wave-** vibrates electric and _____ fields (not particles).
  - *Can be observed by lining up _____ that wriggle like a snake when they interact with electromagnetic waves.*
- **Photon**- a "_____ " or particle of light.
  - _____ can be counted because they strike objects one at a time.
  - Every photon carries a specific amount of energy.

What is Light?

Light , AKA "**Electromagnetic Radiation**" is a form of energy

Light is both a wave and a particle.

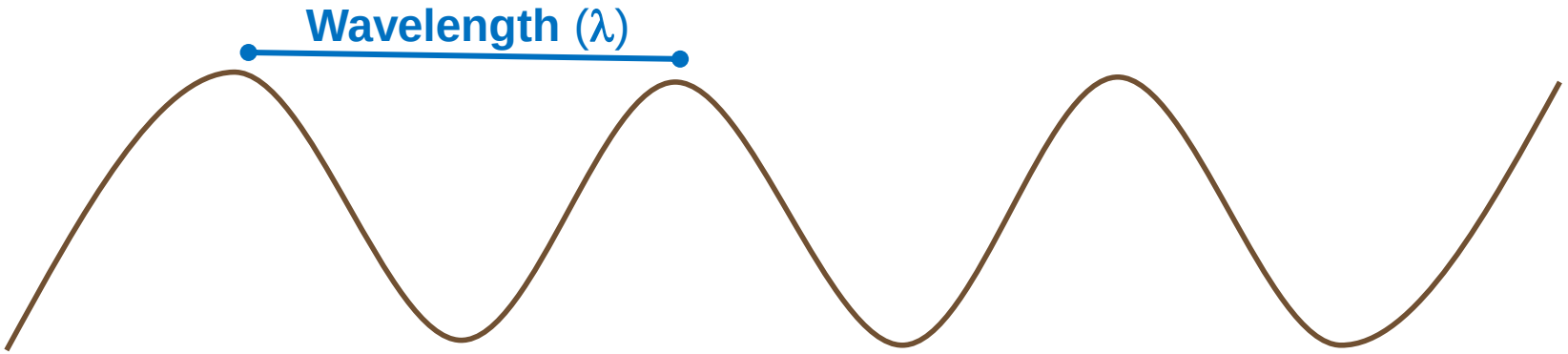




What is Light? (cont'd)

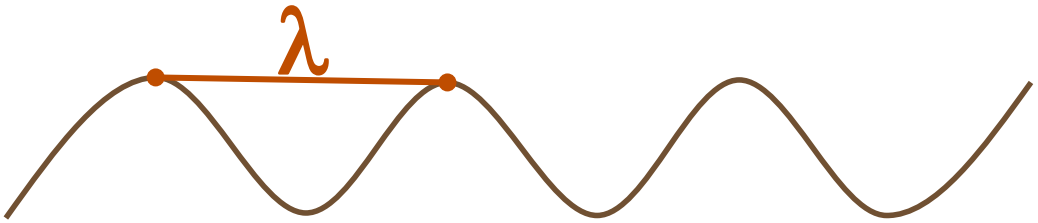
Electromagnetic Waves have 3 basic properties:

1. _____(λ) - distance from one peak to the next
2. _____(f) – number of peaks that pass by any point in one second.
3. _____(c) – how fast the peaks travel.
   - ***Speed of Light (c) = _____ km/s***
   - The "speed of light" is always the same for any time of electromagnetic radiation.

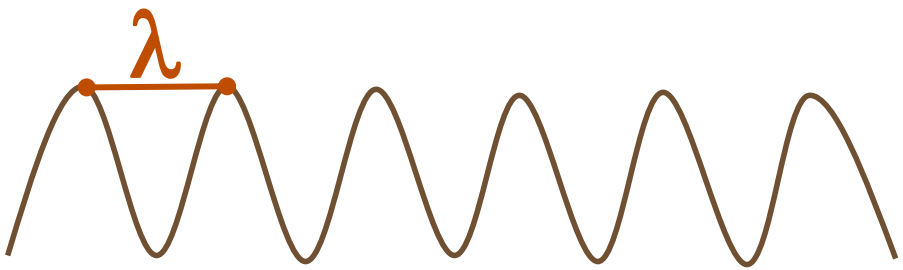


What is Light? (cont'd)

Wavelength and frequency of a light wave are related to energy.



_____ *Wavelength*
_____ *Frequency*
_____ *Energy*



_____ *Wavelength*
_____ *Frequency*
_____ *Energy*

What is Light? (cont'd)

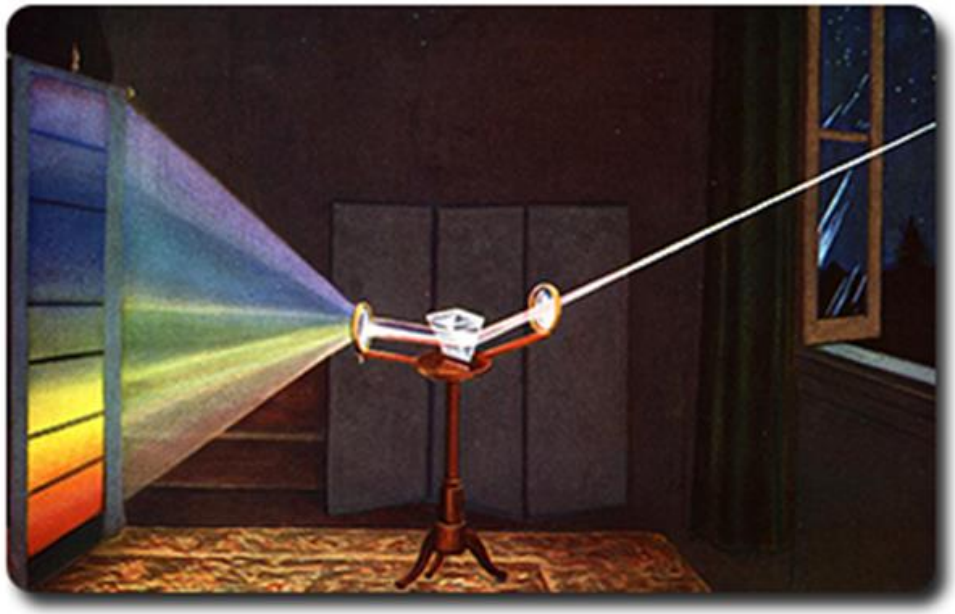
Humans can _____ electromagnetic waves within a short range of _____ . Each color of the rainbow has a different wavelength and frequency.

Visible Light wavelengths range from

_____ nm (blue/violet) → _____ nm (red)

Violet (short wavelength)

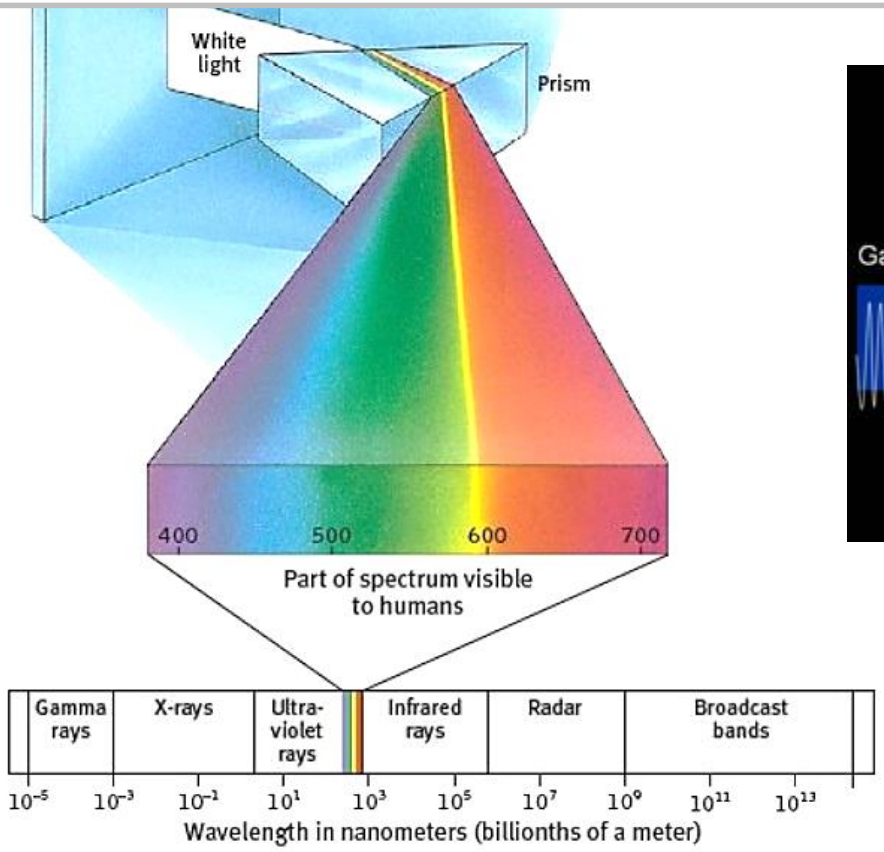
Red (longer wavelength)

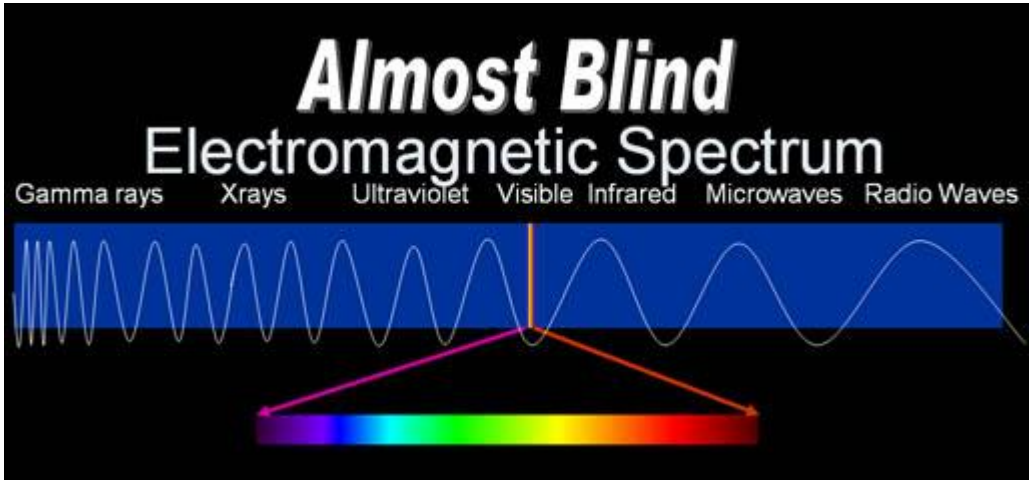


Each color on the electromagnetic spectrum has a different wavelength.

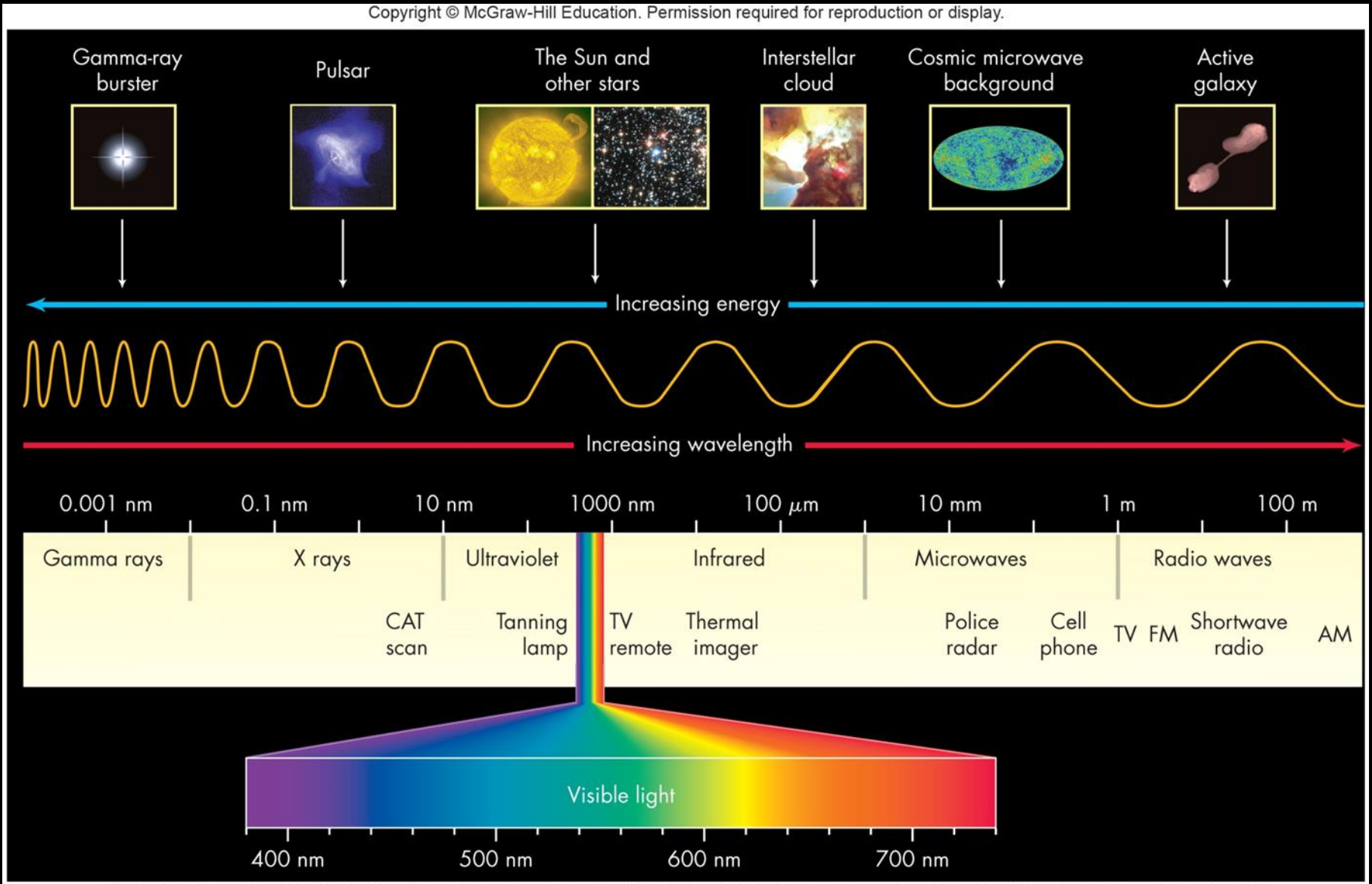
Electromagnetic Spectrum

- There is light "beyond the rainbow".
- Visible Light differs from other forms of _____ only in the _____ and _____ of photons.





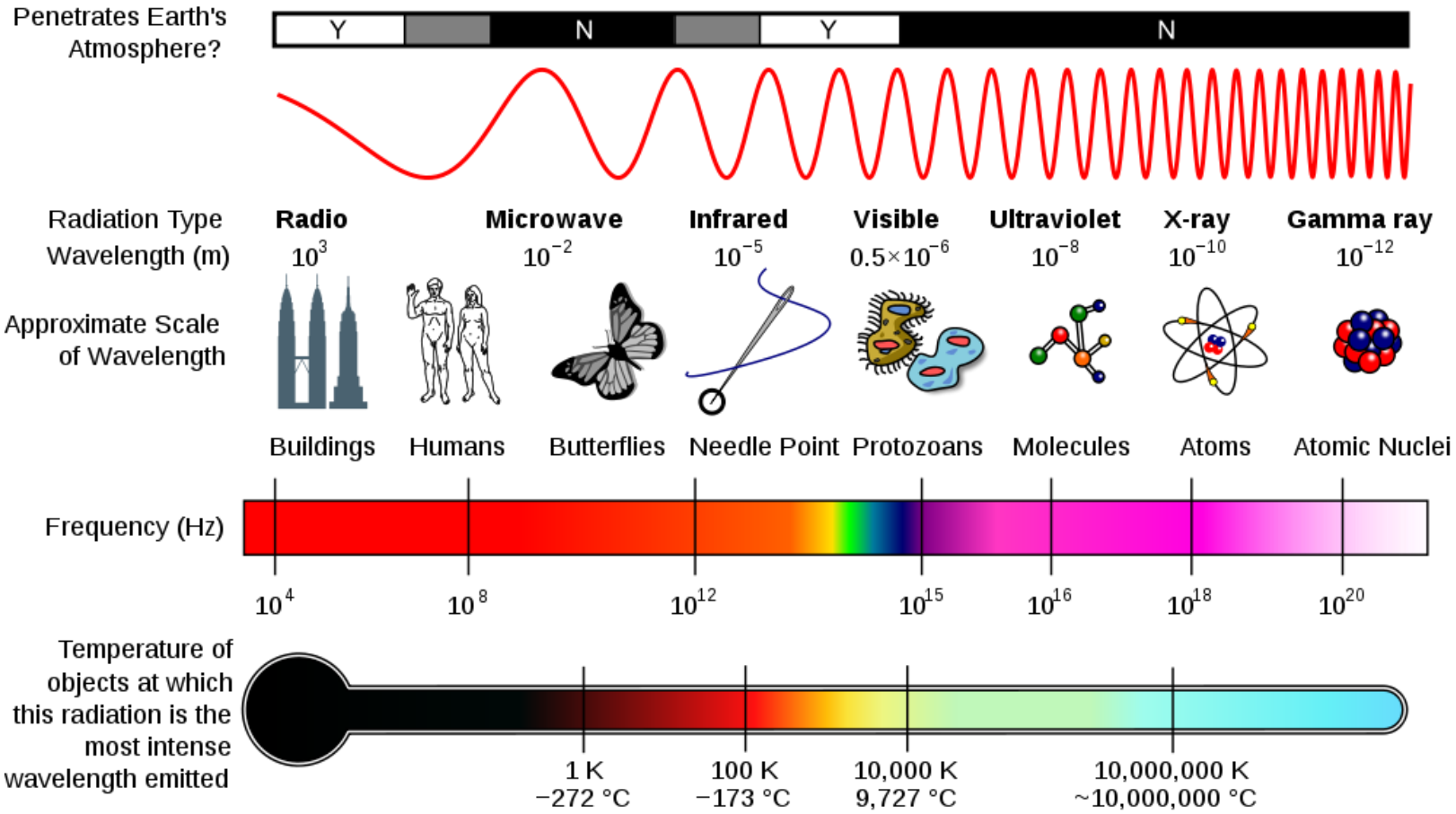
The Electromagnetic Spectrum is the entire range of wavelengths from short gamma rays to long radio waves.



(Pulsar): © Courtesy of NASA/CXC/ISAO; (the Sun): Courtesy of SOHO, NASA/ESA; (other stars): NASA and The Hubble Heritage Team (STScI/AURA); (Interstellar cloud): A. Caulet (ST-ECF, ESA) and NASA; (Cosmic microwave background): Courtesy of NASA/WMAP Science Team; (Active galaxy): © NRAO/AUI/NSF; © Science Source

Electromagnetic Spectrum

- *Note: This graphic shows higher energy radiation on the _____ and lower on the _____ (opposite from previous slide)*



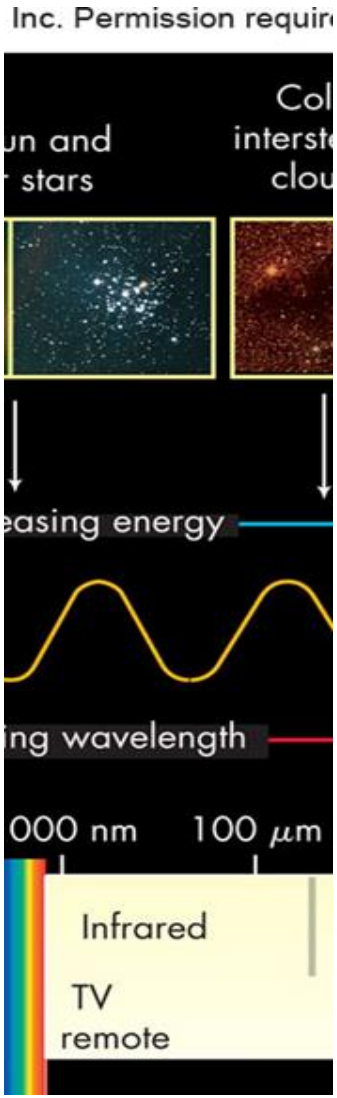
The Electromagnetic Spectrum

- The ***electromagnetic spectrum*** is composed of _____ waves, _____ , infrared, visible light, _____ , x rays, and _____ rays

- _____ wavelengths are more than 10^{3} km
- _____ wavelengths are less than 10^{-18} m
- Various instruments used to explore the various regions of the spectrum

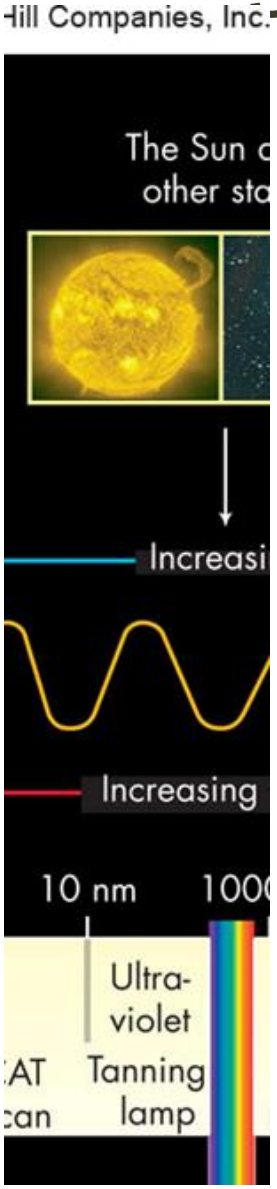
Infrared Radiation

- Sir William Herschel (around 1800) showed heat radiation related to visible light
- He measured an elevated temperature just off the red end of a solar spectrum – ***infrared*** energy



- Our skin feels _____ as heat

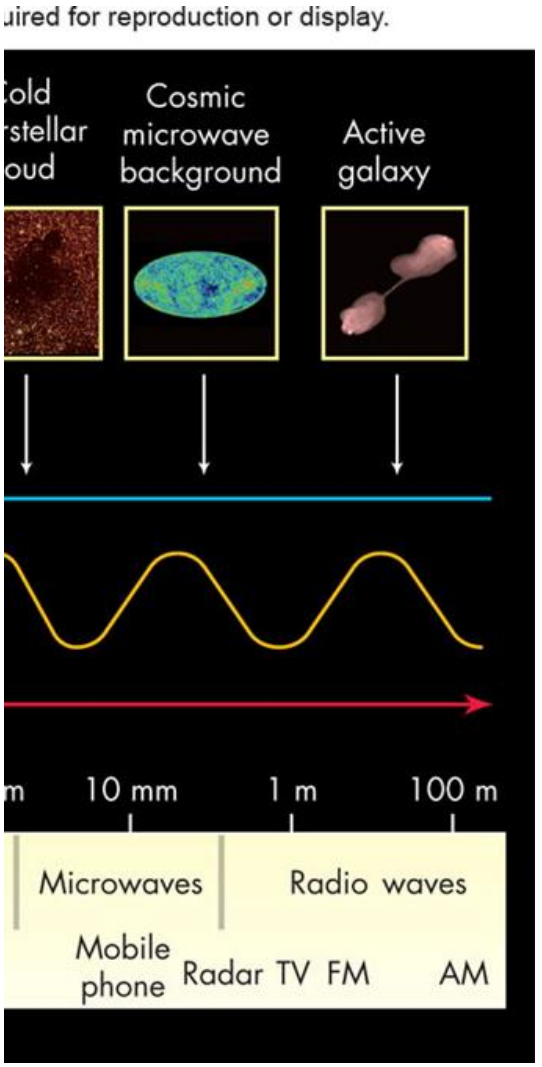
Ultraviolet Light



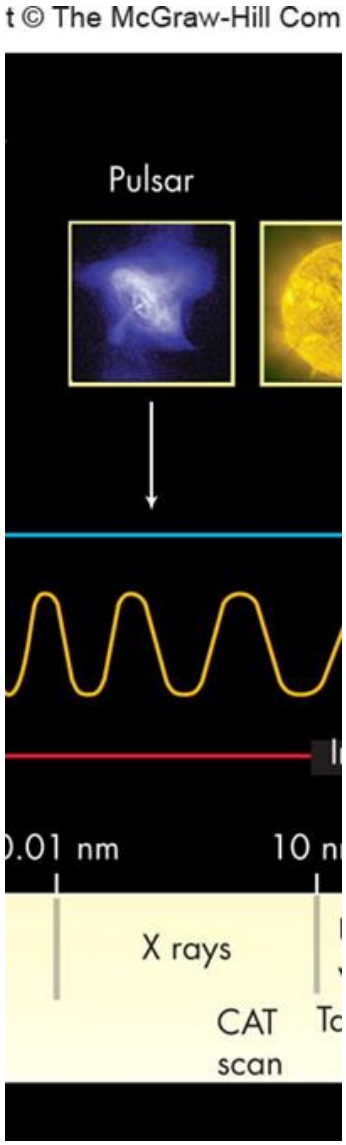
- J. Ritter in 1801 noticed silver _____ blackened when exposed to “light” just beyond the violet end of the visible spectrum
- Mostly absorbed by the _____
- Responsible for suntans (and burns!)

Radio Waves

- Predicted by Maxwell in mid-1800s, _____ produced ***radio waves*** in 1888
- Jansky discovered radio waves from cosmic sources in the 1930s, the birth of radio astronomy
- Radio waves used to study a wide range of astronomical processes
- Radio waves also used for _____ , microwave ovens, and search for extraterrestrials

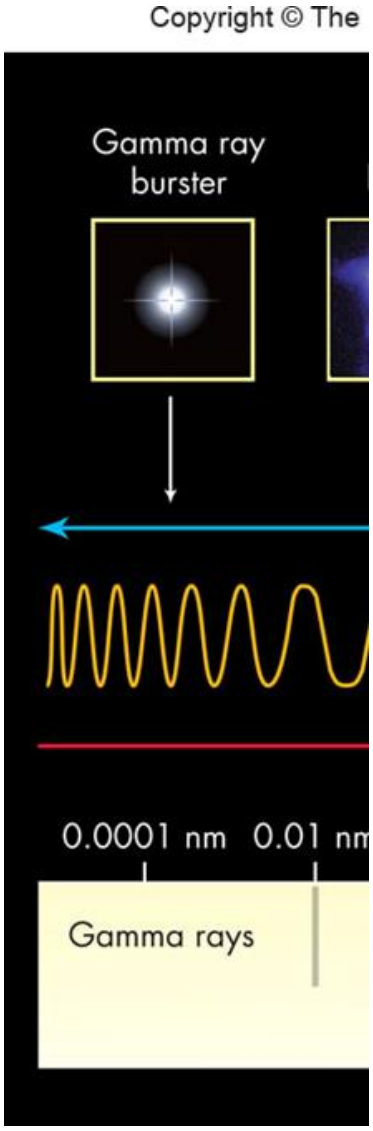


X-Rays



- Roentgen discovered X rays in 1895
- First detected beyond the _____ in the Sun in late 1940s
- Used by _____ to scan bones and organs
- Used by astronomers to detect black holes and tenuous gas in distant galaxies

Gamma Rays



- Gamma Ray region of the spectrum still relatively _____
- _____ absorbs this region, so all observations must be done from orbit!
- We sometimes see bursts of gamma ray radiation from deep _____

We can see MORE using long and short-wave detecting telescopes

Antennae: Merging Galaxies

Composite image
NASA

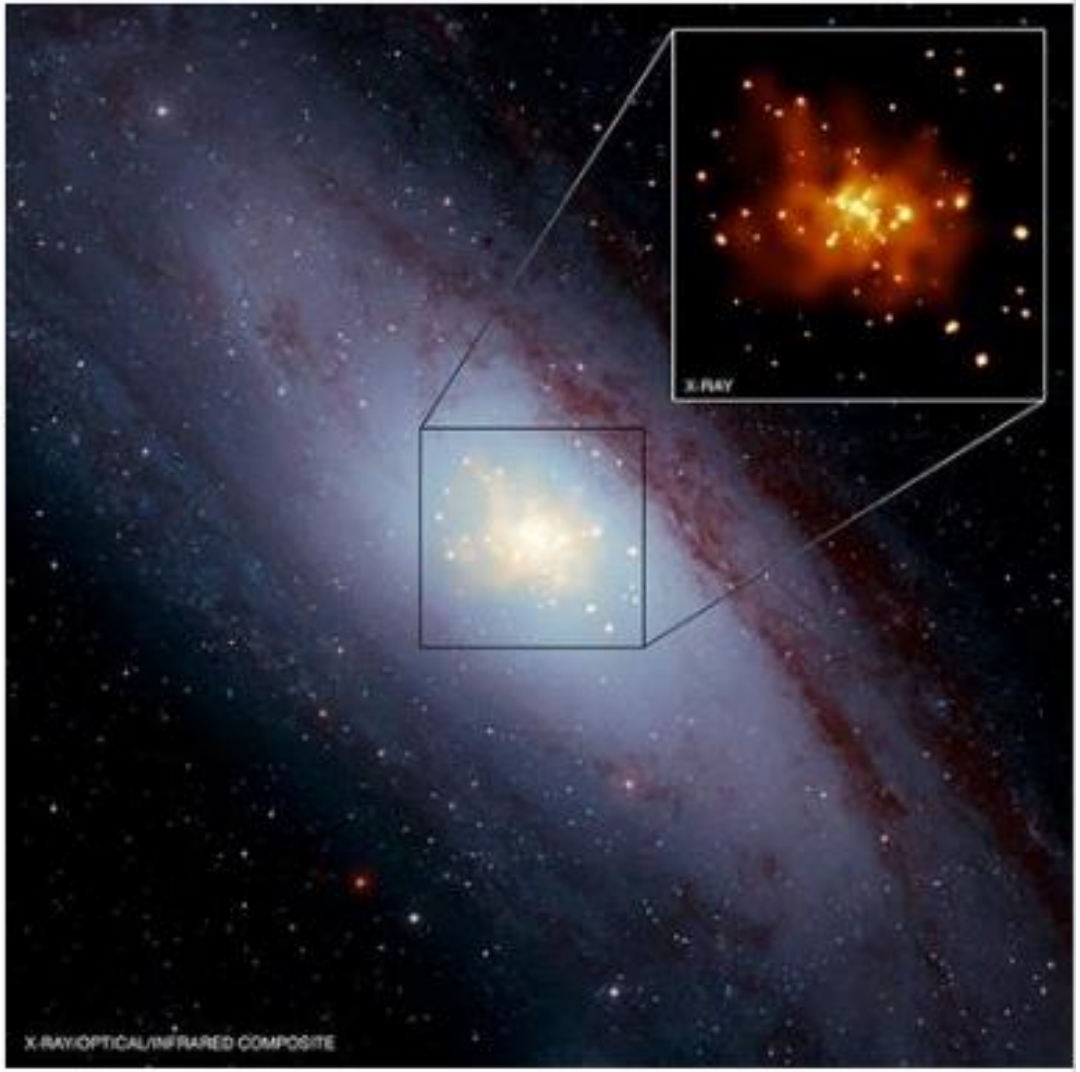
Visible 1, Infrared B, X-ray III

We can see MORE using long and short-wave detecting telescopes

M31 Andromeda Galaxy

Composite Image
NASA

Visible 6, Infrared D, X- Ray II



NASA/JPL Caltech/CXC/SAO/STScI

Energy Carried by Electromagnetic Radiation (as mentioned previously)

- Each photon of _____ λ carries an _____ E given by the formula:

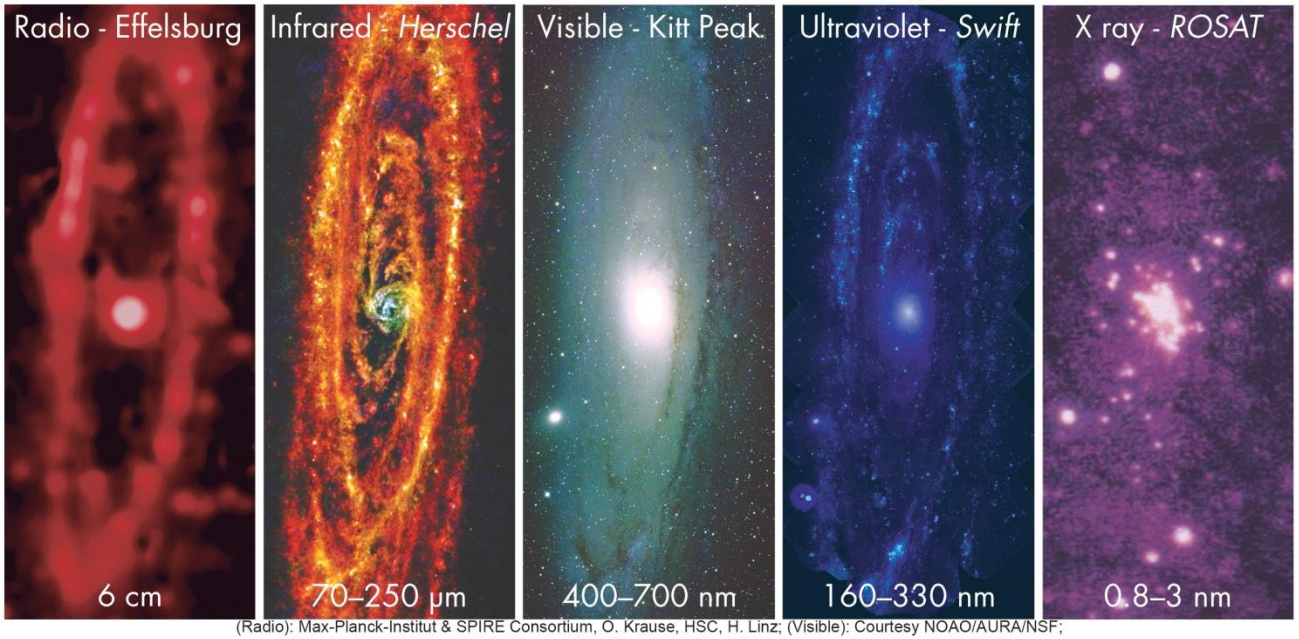
$$E = hc/\lambda$$

where h is Planck's constant, c is speed of light

- **Notice that a _____ of short wavelength radiation carries more energy than a long wavelength _____**

- _____ wavelength = high frequency = _____ energy
- _____ wavelength = low frequency = _____ energy

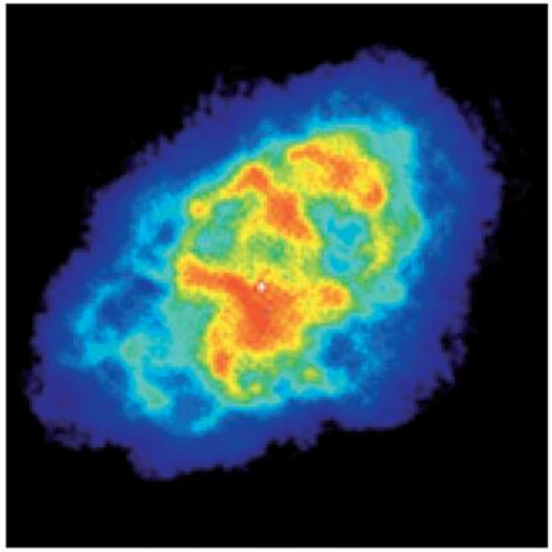
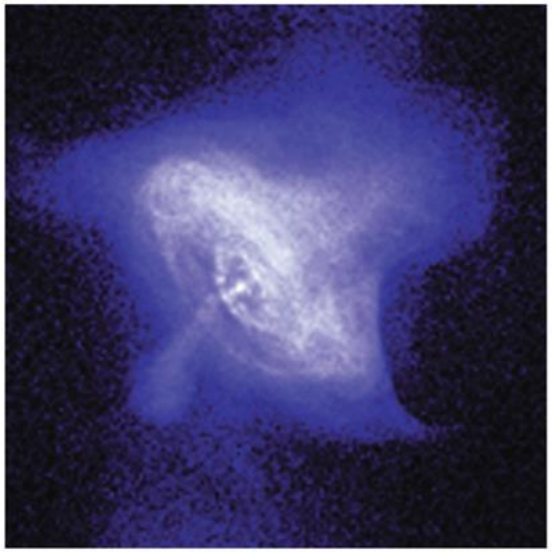
Different Wavelengths, Different Science



(Radio): Max-Planck-Institut & SPIRE Consortium, O. Krause, HSC, H. Linz; (Visible): Courtesy NOAO/AURA/NSF;
(Ultraviolet): NASA/Swift/Stefan Immler (GSFC) and Erin Grant (UMCP); (X-ray): ROSAT, MPE, NASA

- We “see” different phenomena in different wavelengths.
- _____ light shows the distribution of stars.
- Infrared reveals dust in the galaxy.
- _____ reveal supernovae, etc.

Crab Nebula

A  B  C 

a: © Courtesy of Richard Wainscoat; b: © NRAO/AUI/NSF; c: Courtesy of NASA/CXC/SAO

Visible Light Photograph

Radio Image

X-Ray Image in false color

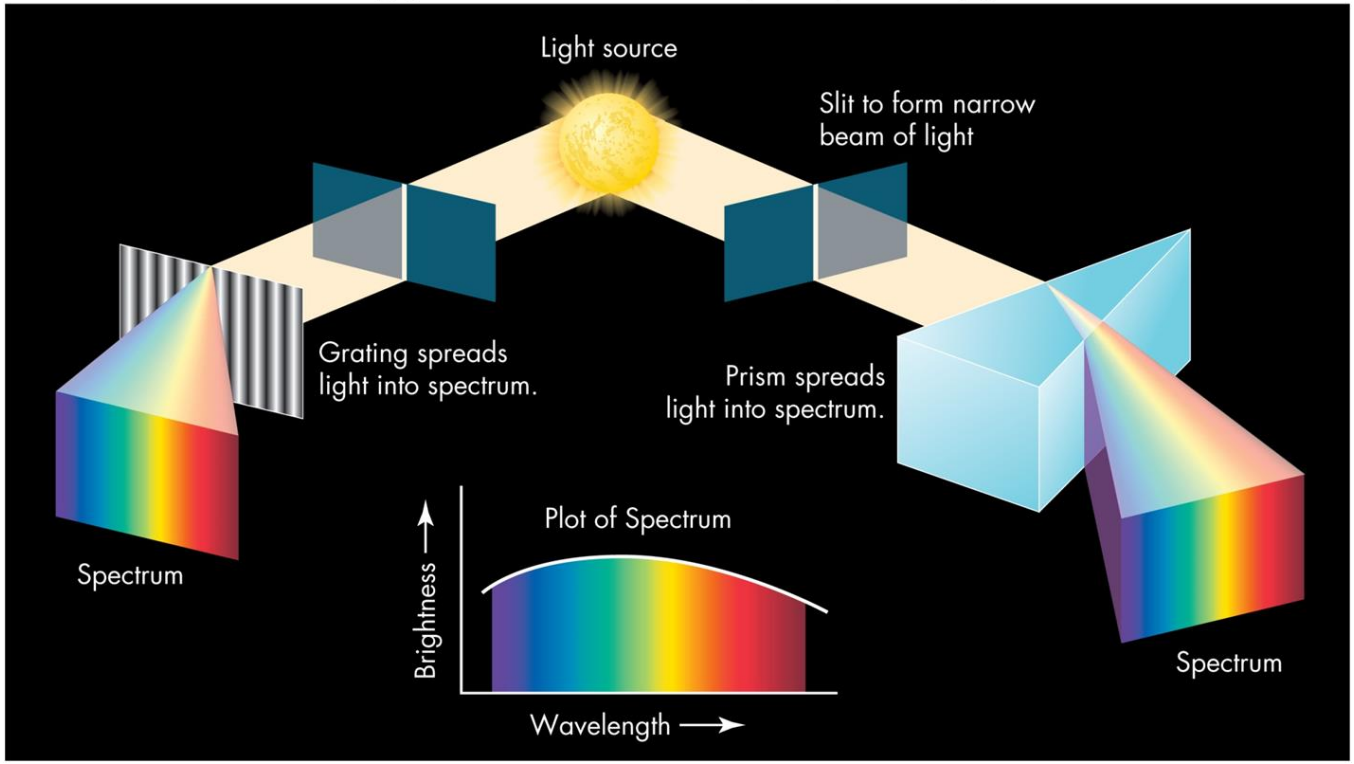
Check for Understanding!

- What is wavelength? What's the symbol for wavelength? Draw a diagram to show what wavelength is.
- Which has a longer wavelength, blue or red light?
- How is wavelength related to frequency and energy?
- What form of electromagnetic energy has the highest energy? Lowest energy?

Electromagnetic Spectrum, cont'd

- The various forms of _____ Radiation each interact with matter in unique ways.
- Atoms and _____ that make up objects in the universe leave unique "fingerprints" in light that astronomers decode.
- Astronomers seek to _____ light of all wavelengths to determine the _____ of objects, their _____ , and **relative** _____ .

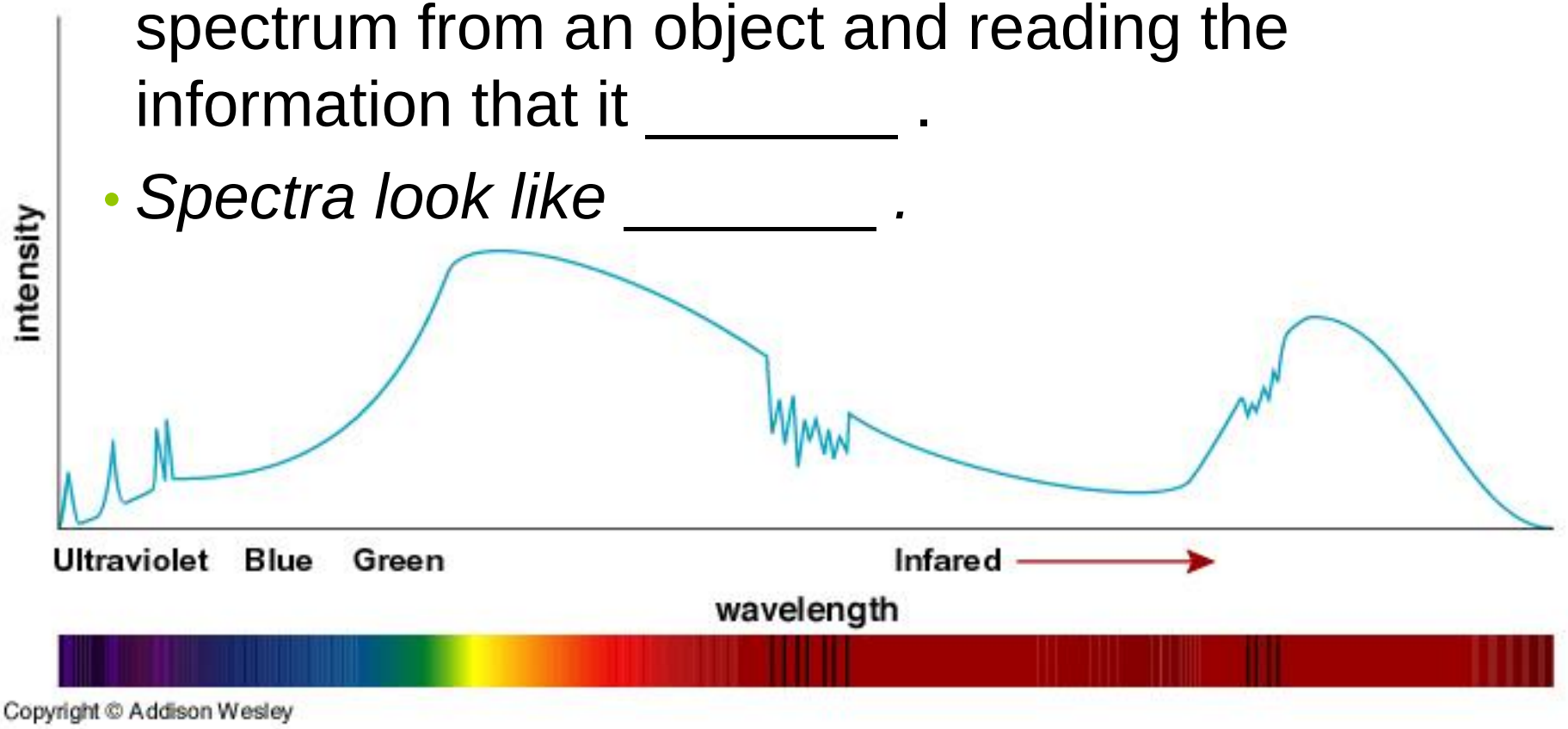
Spectroscopy



- Allows the determination of the composition and conditions of an astronomical body
- In _____ , we capture and analyze a spectrum
- Spectroscopy assumes that every _____ or molecule will have a unique spectral signature

Spectra

- **Spectroscopy-** the process of _____ a light spectrum from an object and reading the information that it _____ .
- *Spectra look like _____ .*



Types of Spectra

Continuous spectrum

- Spectra of a _____ (source that emits all wavelengths of visible light)
- Produced by an incandescent light bulb, for example.

Emission-line spectrum

- Produced by _____ , tenuous gases, as photons emit a specific wavelength of electromagnetic radiation.
- _____ tubes, aurora, and many interstellar clouds are typical examples

Absorption-line spectrum

- Light from blackbody passes through cooler _____ leaving dark absorption lines (shows which wavelengths are absorbed by the gas)
- Fraunhofer lines of Sun are an example

A

B

C

Can you identify the names of spectra A, B, & C?

Spectra, *continued*

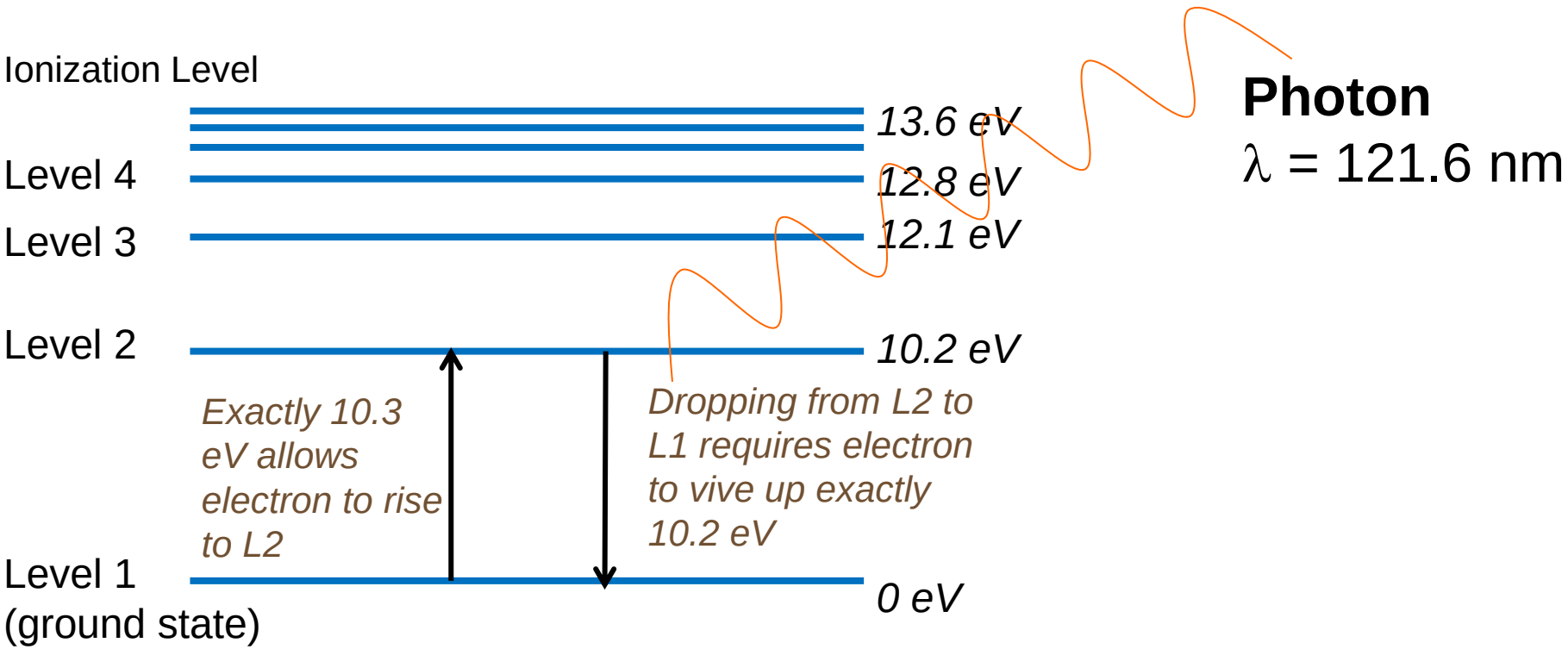
In a cloud of _____ , atoms are constantly colliding and exchanging energy, causing:

1. Atoms like to _____ in new directions, colliding with other atoms.
2. A transfer of energy to _____ , making them move to higher energy levels.

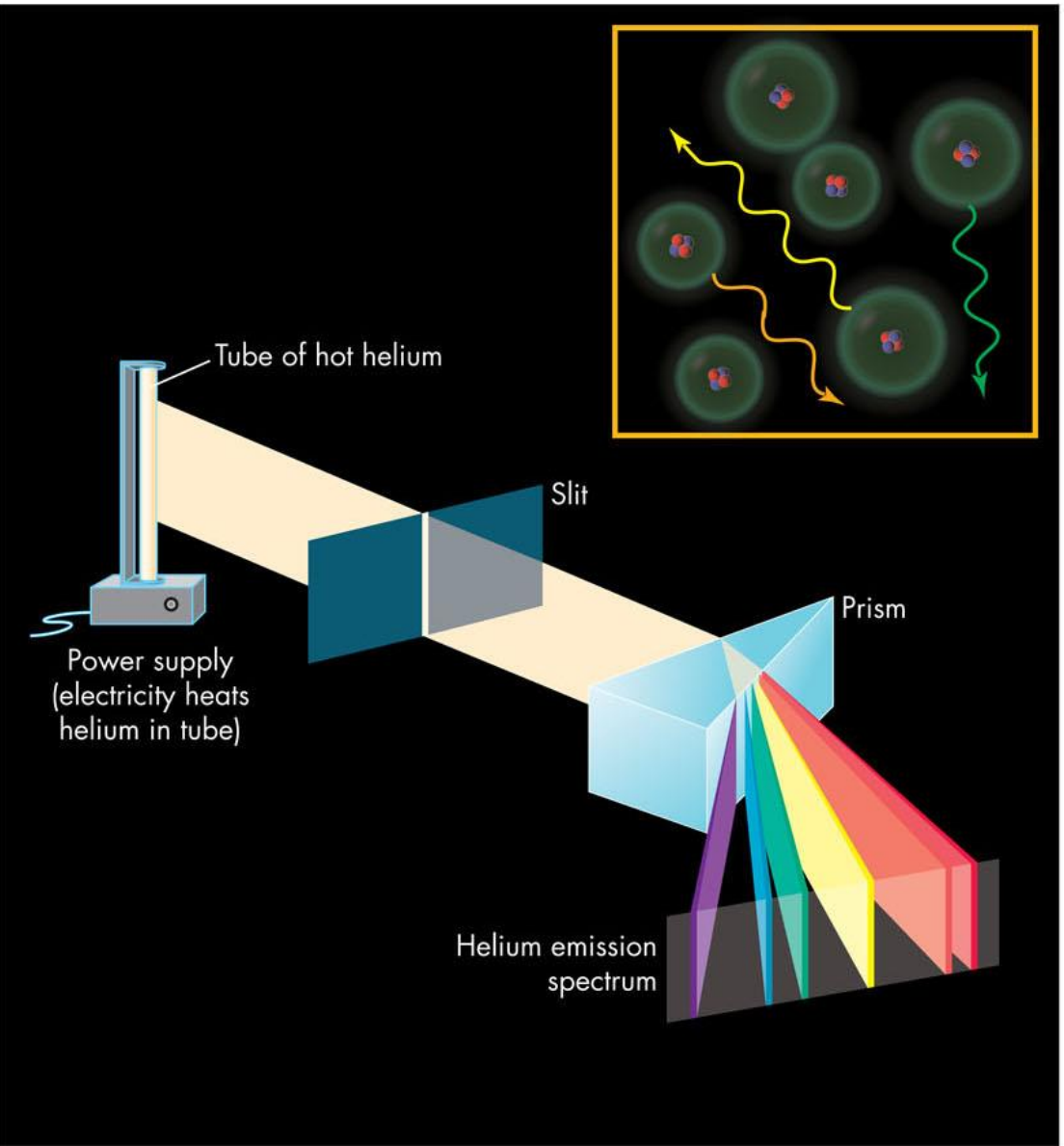
An electron can ONLY get to next higher level if given the exact amount of _____ energy. It will then drop back down to its _____ level, releasing the amount of _____ it gained in the form of photons.

Spectra, *(Emission Lines)*

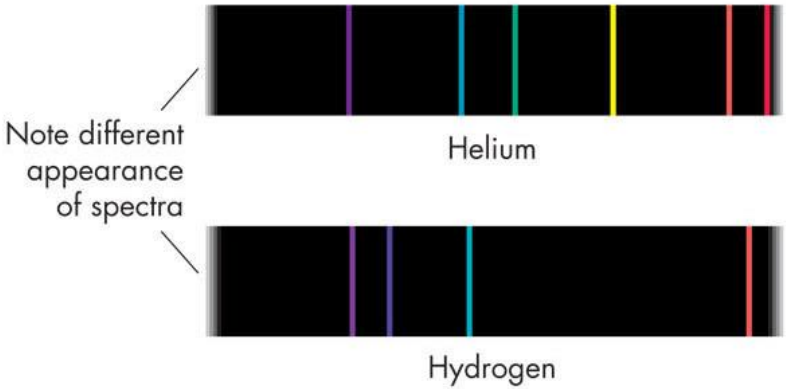
*Elements release _____ of unique wavelengths



Helium Emission Spectrum

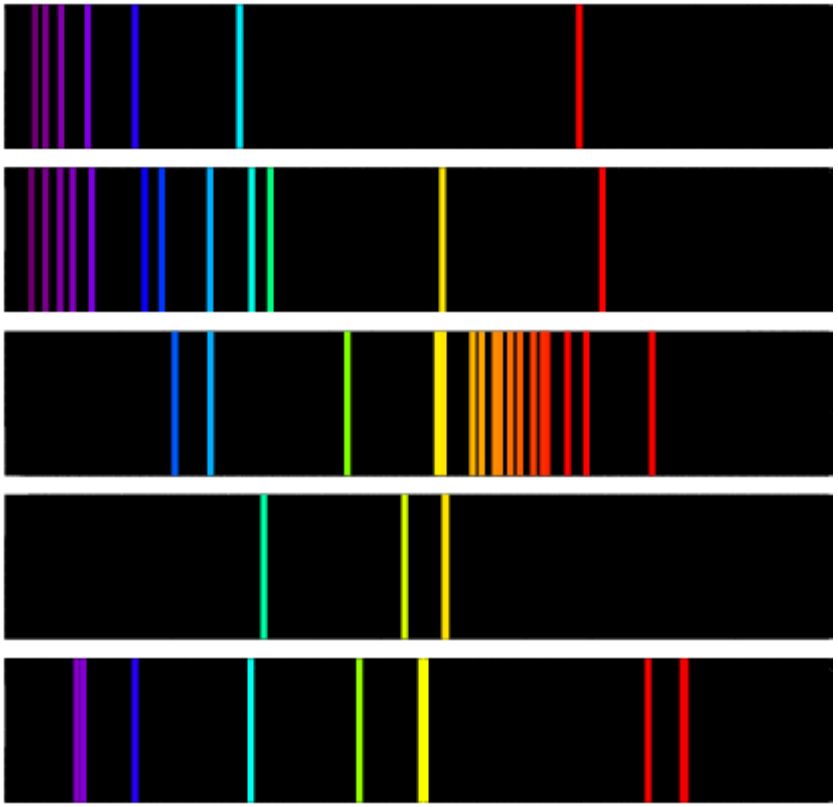


Helium atoms in tube
The electron orbits for helium atoms are different from the orbits in hydrogen. The light they emit therefore differs from that of hydrogen.



Spectra, *(Emission Lines)*

*Elements release _____ of unique wavelengths

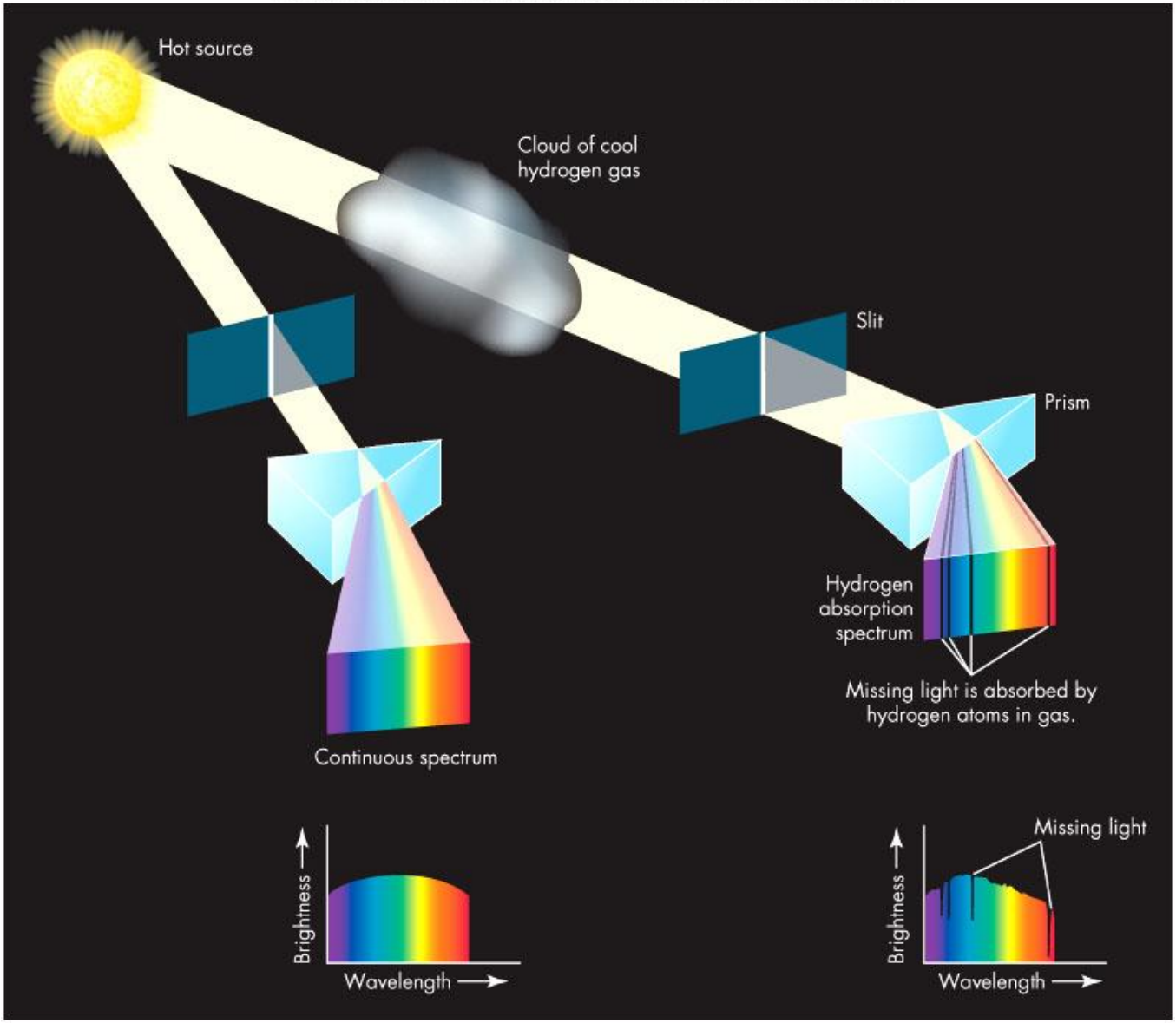


The bright _____ show the wavelength of photons that are emitted from a gas cloud.

Remember, each color has a specific _____ .

Each of the spectra above comes from a different gaseous element.

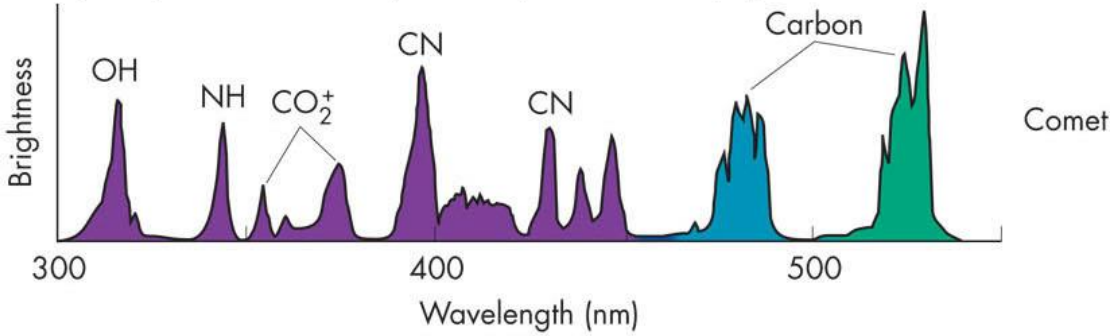
Continuous and Absorption Spectra

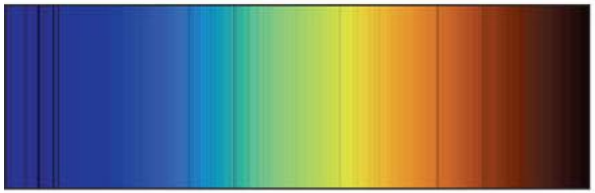


Spectra, *continued*

*__Spectroscopy__ is used to determine the _____ of bodies in space

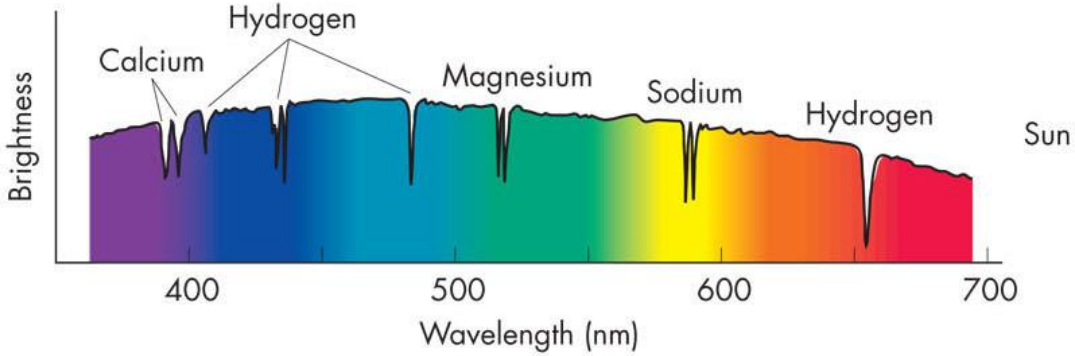
Spectrum of a comet





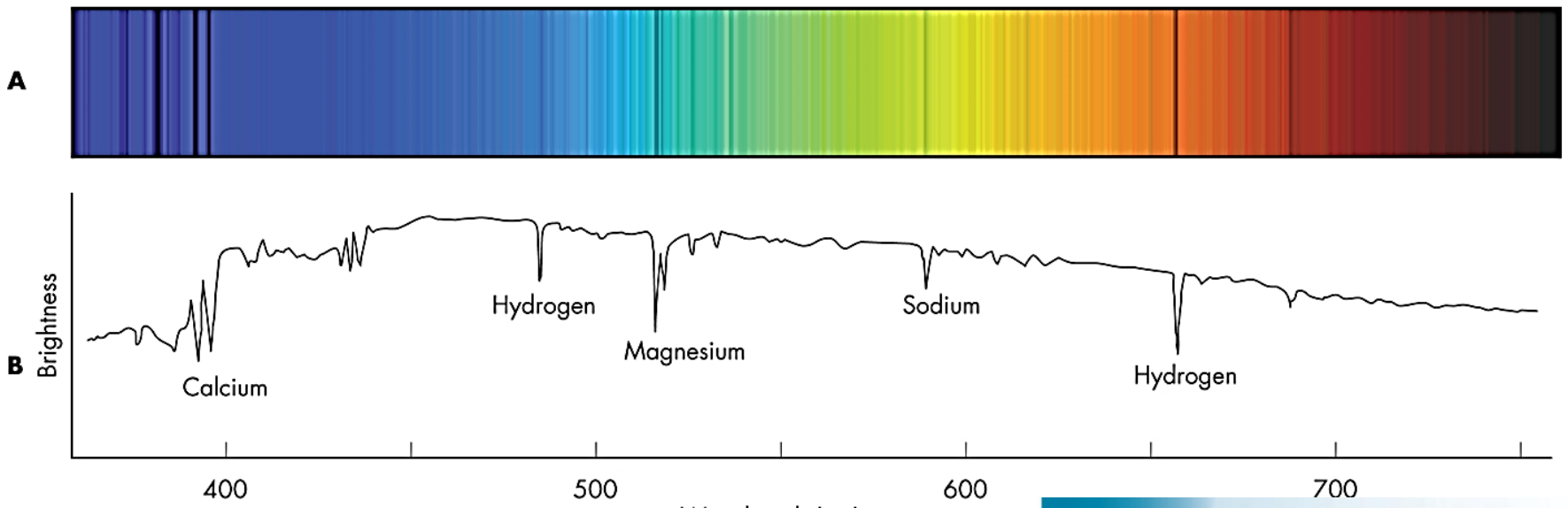
Solar spectrum

A



B

The Solar Spectra



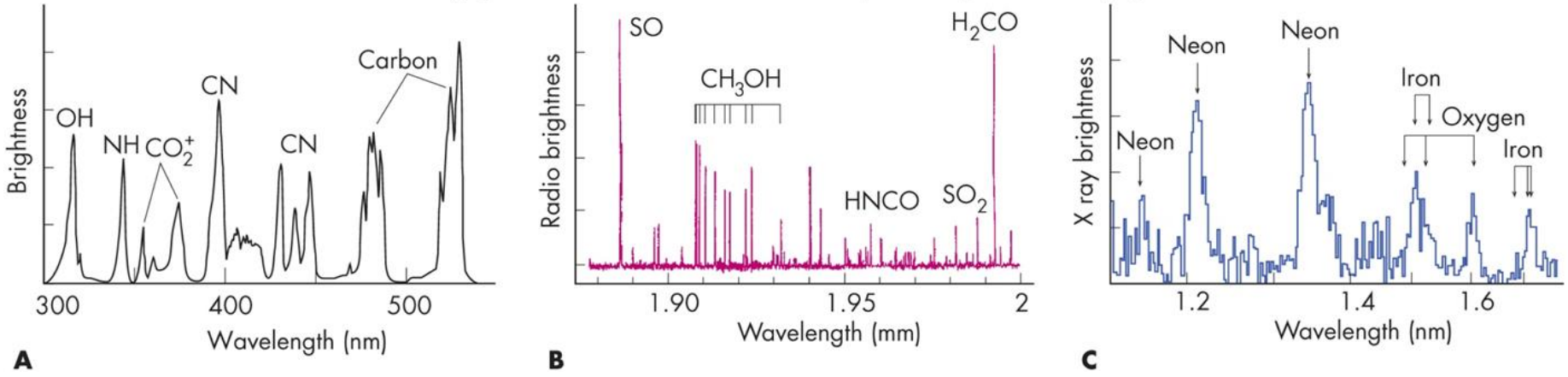
The composition of the _____ has been determined using a careful study of spectral lines.

Table 4.4 Composition of a Typical Star, Our Sun*

Element	Relative Number of Atoms	Percent by Mass
Hydrogen	10^{12}	71.1%
Helium	9.64×10^{10}	27.4%
Oxygen	5.75×10^{8}	0.65%
Carbon	2.88×10^{8}	0.25%
Neon	8.91×10^{7}	0.13%
Nitrogen	7.94×10^{7}	0.08%
Silicon	4.07×10^{7}	0.06%
Iron	3.47×10^{7}	0.14%
Gold	8	0.00000011%
Uranium	0.4	0.000000007%

Spectra *(wavelength intensity graphs)*

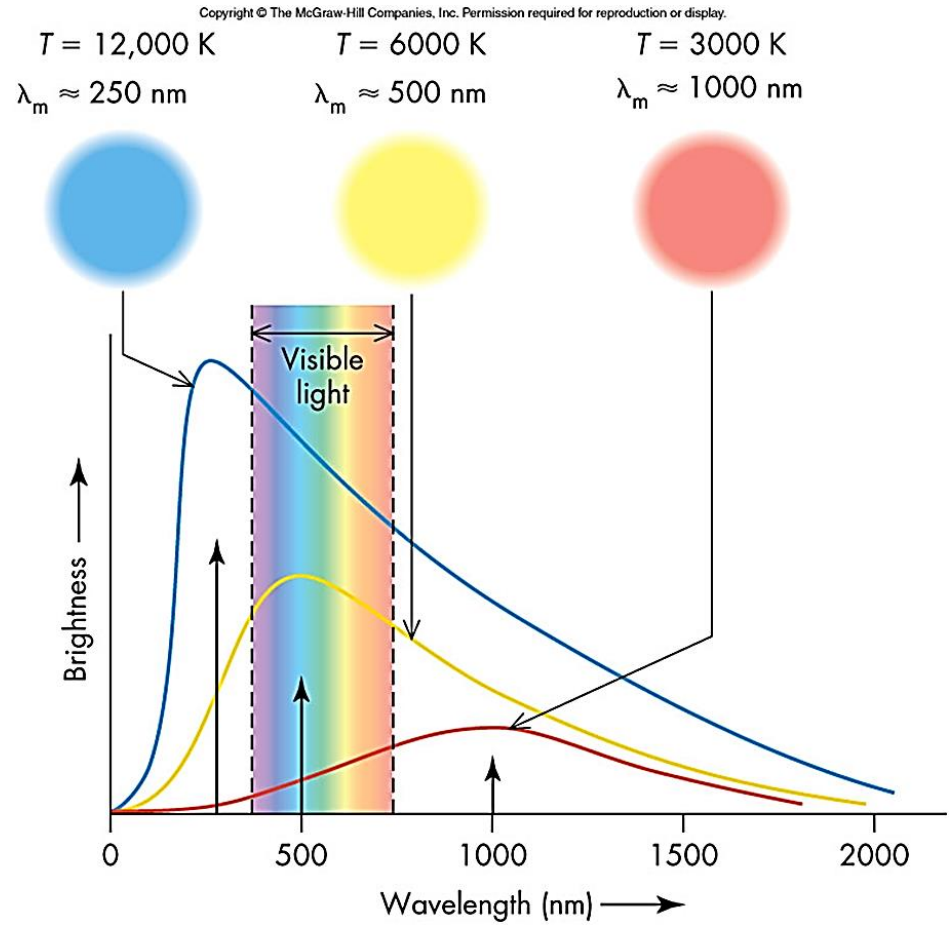
- The pattern observed in wavelength _____ graphs is sometimes more _____ than just the spectral lines.



Spectra (temperature)

Temperature of light emitting objects can be _____ using spectroscopy.

Temperature- *average* _____ *energy of an object.*



Wein's Law:
Hotter objects emit photons with a higher average energy.

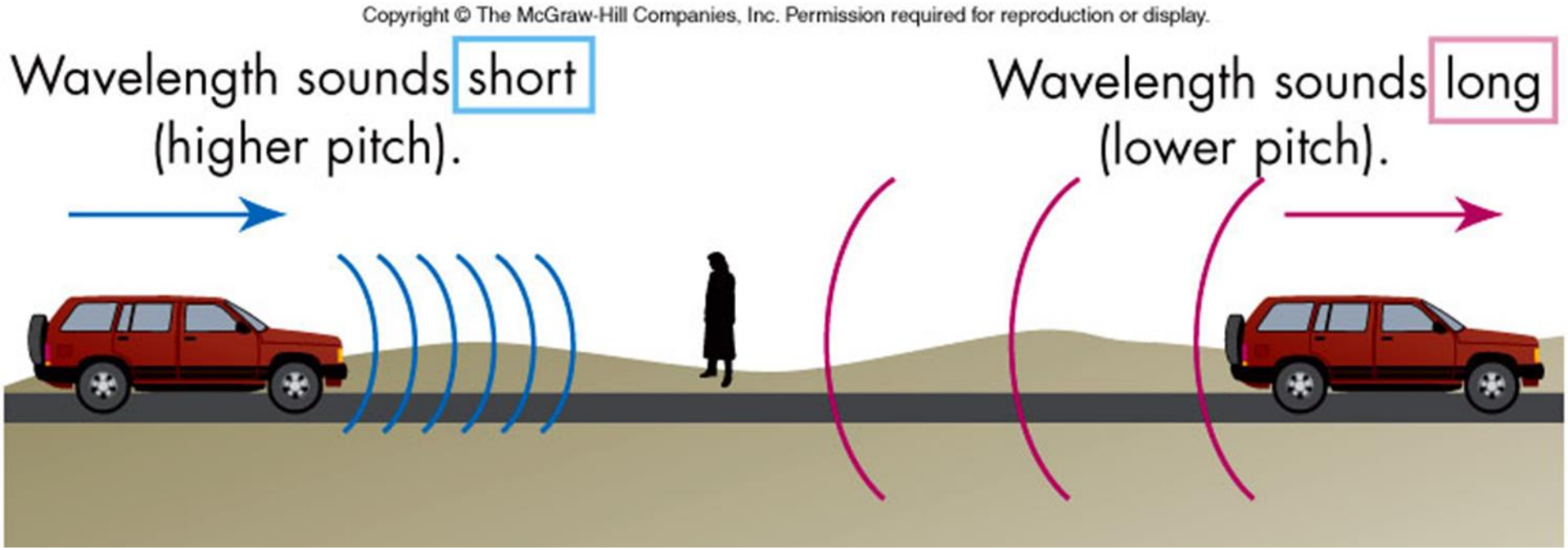
Wein's Law shows this Rule:

BLUE = HOT STAR

RED = COOL STAR

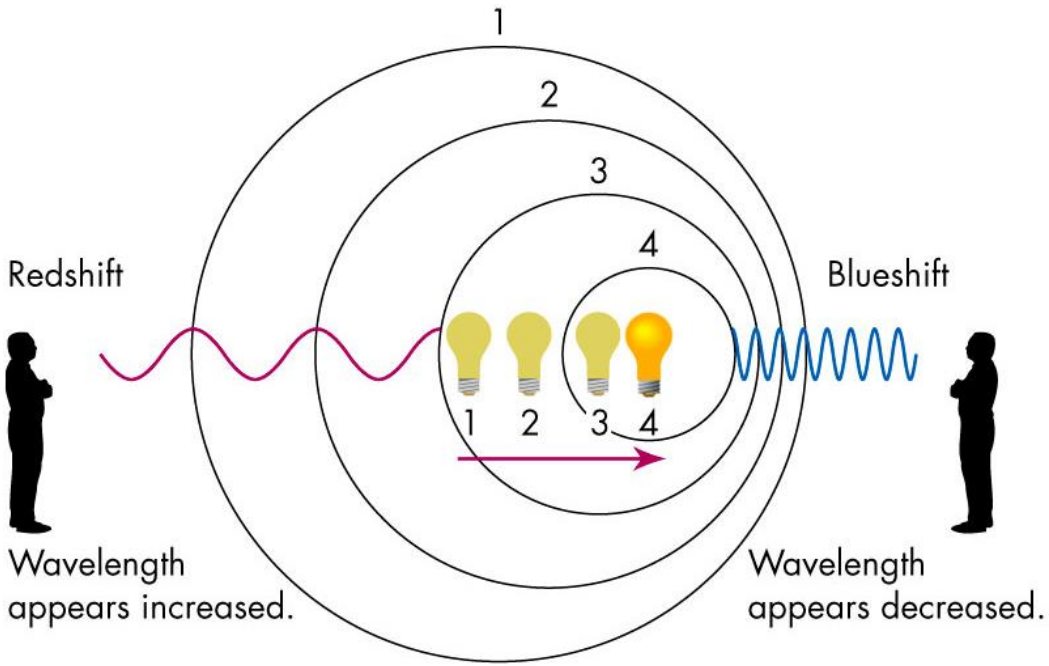
Spectra (motion)

Doppler Shift in Sound- *pitch (_____) gets higher when an object is coming toward you; pitch (_____) gets lower when an object is moving away.*



Spectra (motion)

Doppler Shift in light: *If a source of _____ is set in motion relative to an _____ , its spectral lines shift to new wavelengths in a similar way*



Redshift: the shift to longer wavelengths when an object moves away from us.

Blueshift: the shift to longer wavelengths when an object moves towards us.

TABATHA BOYAJIAN, ASTRONOMER

TED TALK: "THE MOST MYSTERIOUS STAR IN THE UNIVERSE"

https://www.youtube.com/watch?v=gypAjPp6eps

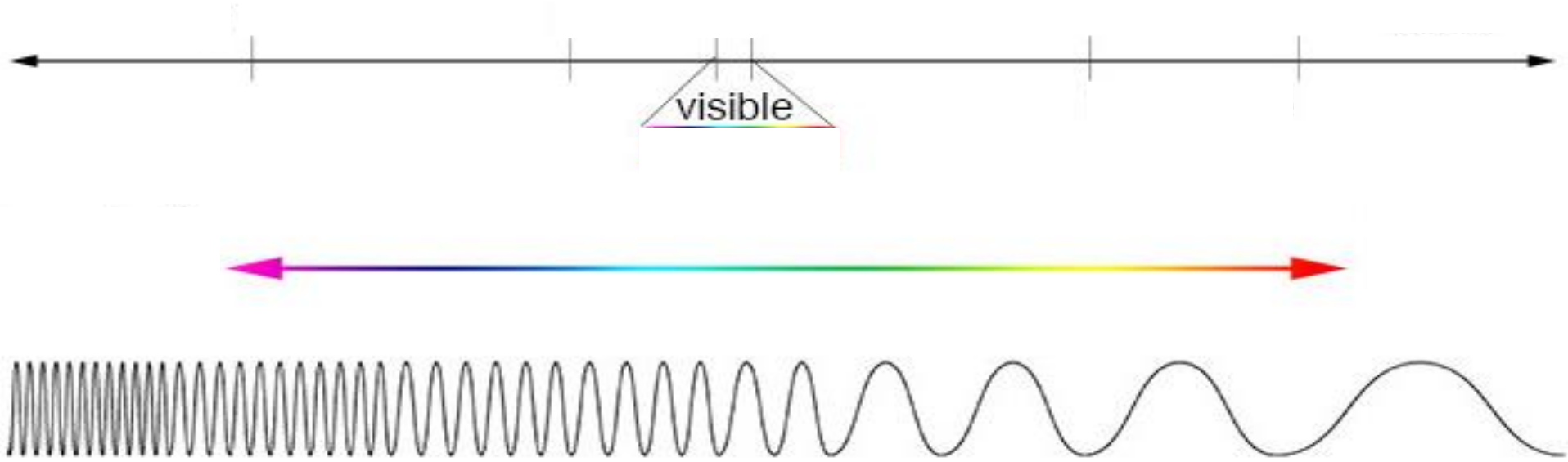
Tabetha Boyajian

Astronomer Royale, Yale University

I am a postdoctoral Fellow at Yale University. My research interests involve determining the fundamental properties of stars and characterization of exoplanet host stars. My observing experience includes long baseline optical/infrared interferometry, and optical spectroscopy. I also work on modeling data from the Kepler space telescope for the PlanetHunters project (www.planethunters.org).

How are you doing?

1. What type of spectrum is this?
2. How are these lines produced?
3. Explain how composition of an object can be determined using spectral lines.
4. You observe a blue star and a red star. Which is hotter?
5. An astronomer notices the shift of spectral lines towards higher wavelengths. What does this indicate about the motion of that object?



fill in the spectrum