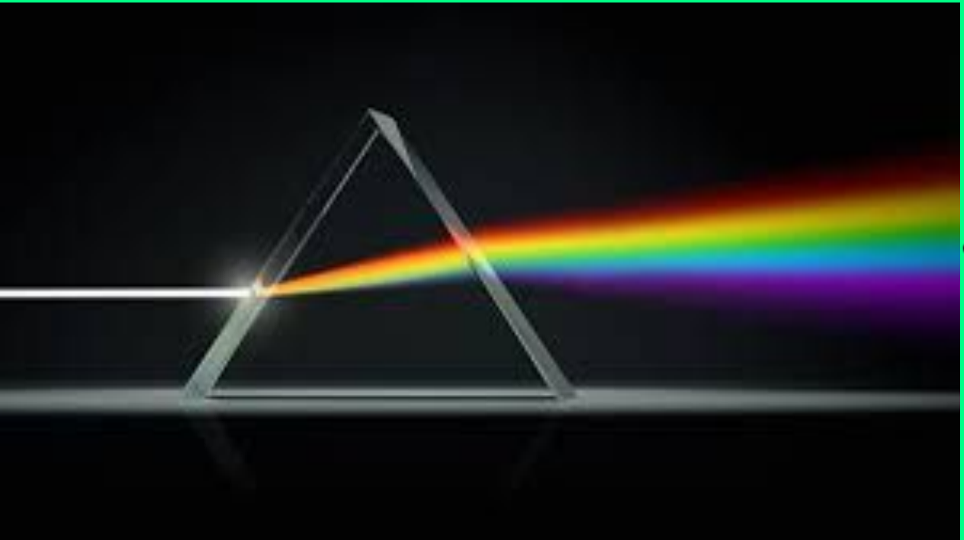
Spectroscopy

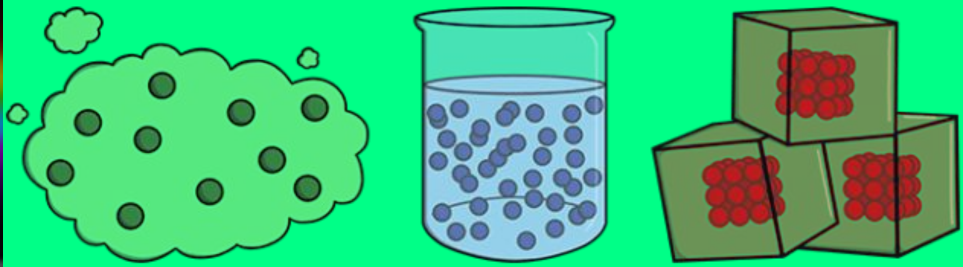
Announcements

- First lab is graded
  - Check comments directly on the submission to see where/why points were marked off
  - General comments are for if pages are missing/out of order or if there are technical issues
- Please remember to put pages in order and a ***<u>single</u>*** file
  - I gave warnings this time since it was the first lab
  - I can show you a couple ways to make sure you have the right formatting if you come to office hours
- Remember Pre-Lab (Should be done already) and Quiz
- Sign in Sheet

Spectroscopy

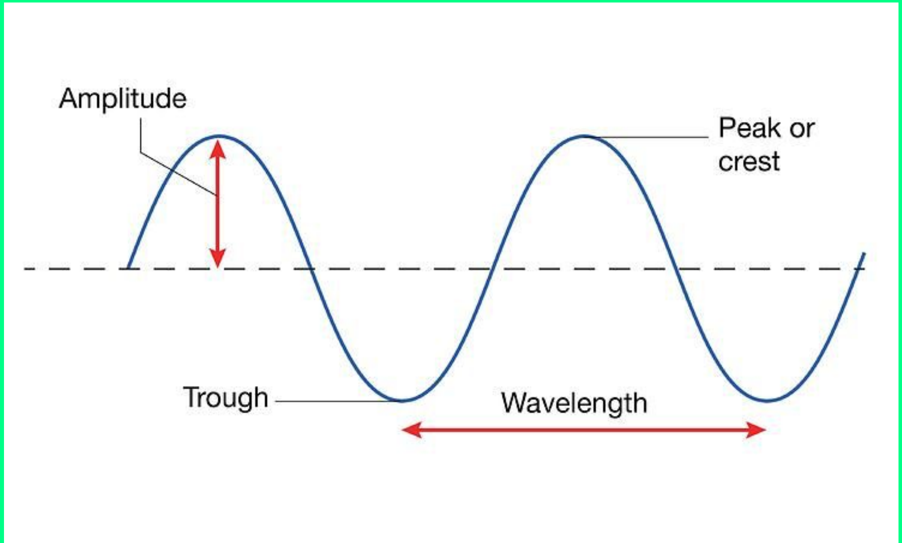
- Spectroscopy is the study of the interactions between light and matter





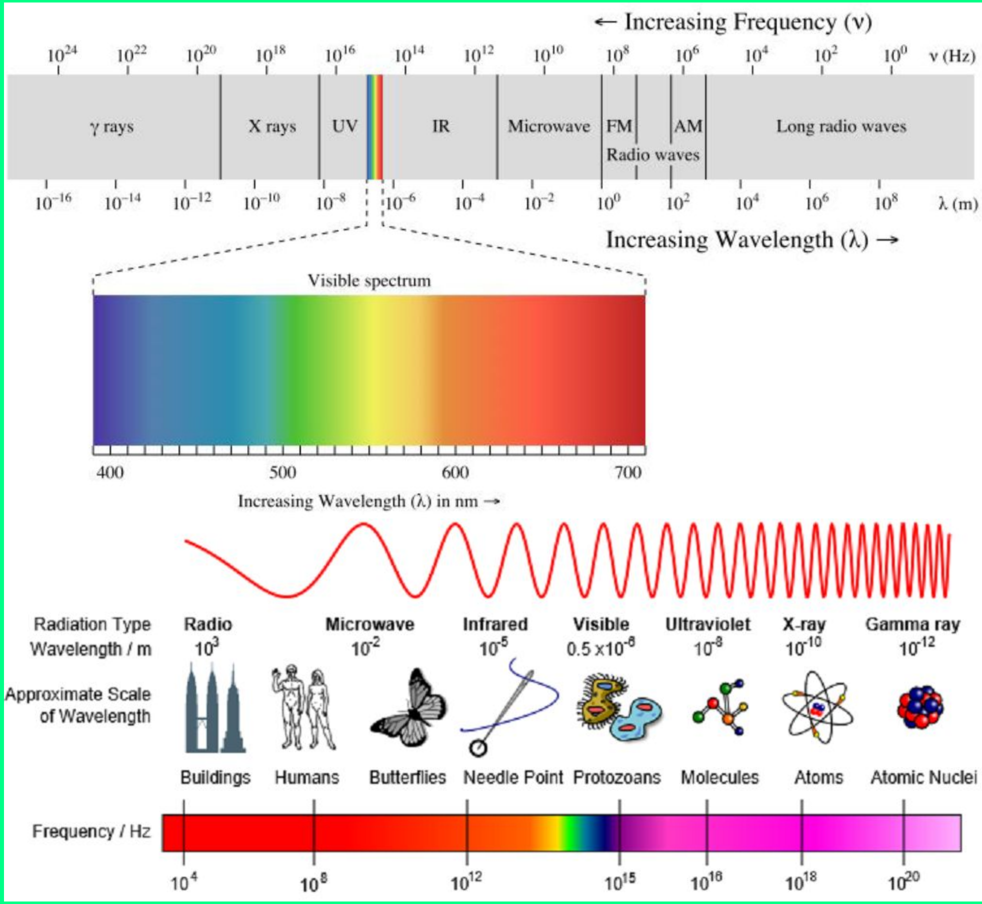
Light

- A wave (kind of)
- Wavelength (λ), with units of distance, is the most important for this lab
- Also, frequency (f), with units of Hertz (a.k.a. per second)
- c (the speed of light) = λ*f (distance per time)
- Amplitude is how “tall” the wave is



A Spectrum

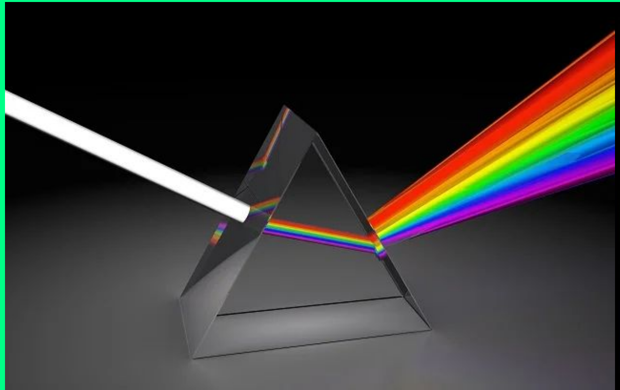
- Different wavelengths correspond to different “colors”
- Energy:
  - E = hc/λ
  - h = Planck’s Constant = 6.626 x 10^-34 m^2 kg/s
  - c = speed of light = 3 x 10^8 m/s
- Shorter wavelength (higher frequency) means more energy and is bluer
  - Lower energy is redder

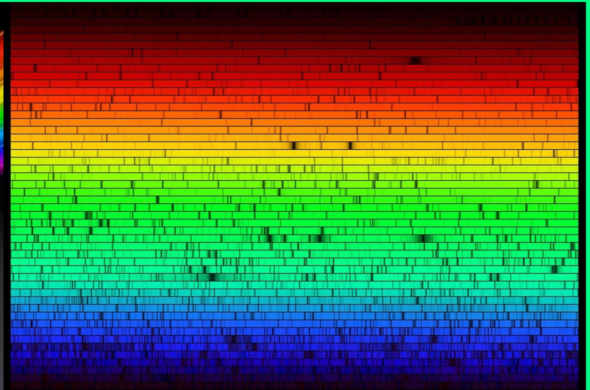


Spectra (Plural of “Spectrum”)

An element you will be looking at today

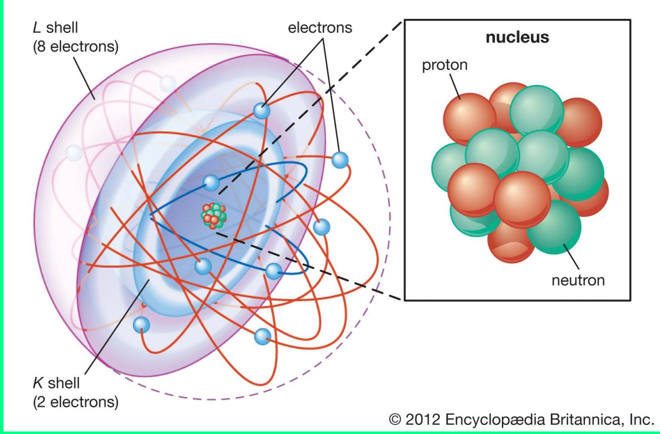
- Light can be separated with a prism - this is called a spectrum
  - See: Rainbows, where water droplets act as prisms
- This happens because different wavelengths refract (bounce or deflect) by different amounts
- We don’t always see a full spectrum when we observe things
  - Sometimes only a few wavelengths (“colors”) are there
  - Sometimes it's mostly there, but a few are missing
- We need to look at how light interacts with matter (specifically atoms)



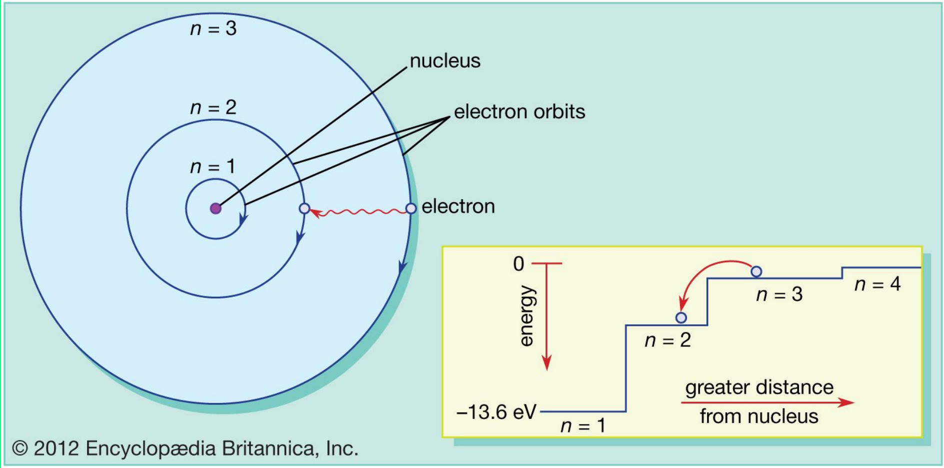


The Sun!

A Brief Aside About Atoms

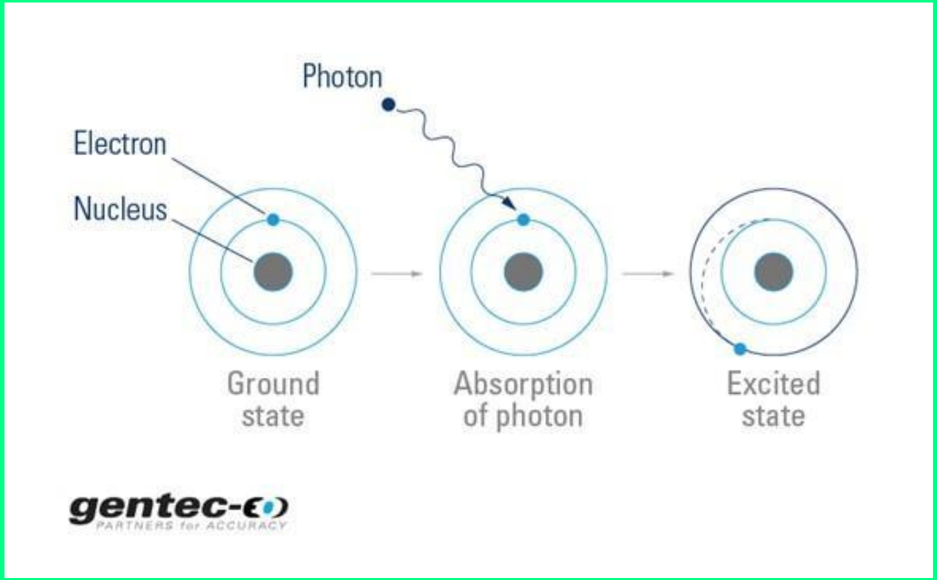


- A nucleus made of protons and neutrons
  - Not too important for today's lab
- Surrounded by electrons
- The electrons can be separated into different "shells" or "orbits"
- Each shell represents a single quantized energy level, increasing as you get further from the nucleus
  - The word "quantized" here is important - it means a specific, discrete (not a continuum) amount
    - Also where the word "quantum" as in quantum mechanics comes from
  - Electrons orbiting an atom can ***only*** exist at these specific energy levels
  - Each shell has a maximum number of electrons



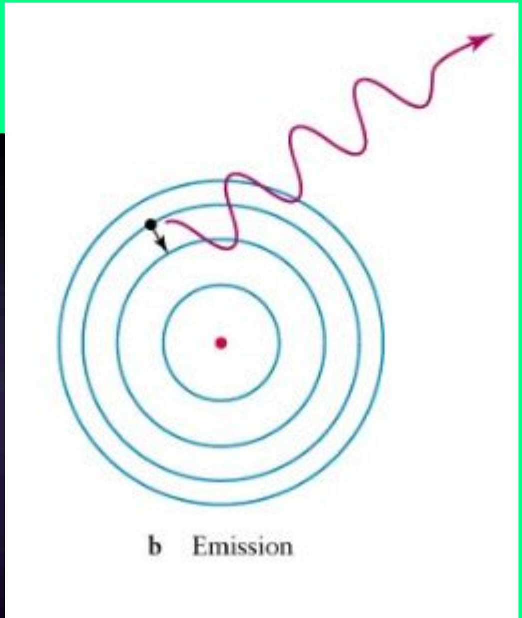
What Happens When Light Hits an Atom?

- Absorption!
- But light has energy
- Energy can never be created or destroyed*
  - *(Outside nuclear reactions)**
    - **(But matter is equivalent to energy, see E = mc^2)
- So the total energy has to be the same. Where did it go?
  - One of the electrons took that energy and went up to a higher energy level
  - Sometimes, the energy is so much that the electron leaves the atom altogether - this process is called **"ionization"** and the atom is said to be **"ionized"**



But Does it Stay There?

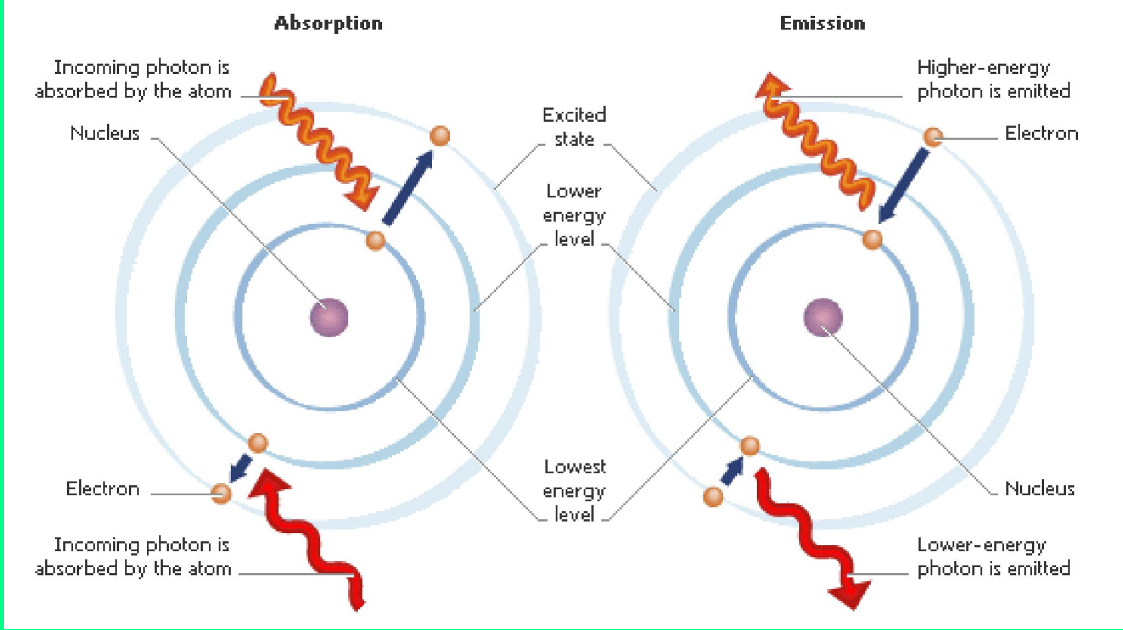
- Electrons don't like having a lot of energy, they want to be as close to the "ground state" as they can
- When an electron drops back down to a lower energy level, the energy it did have still has to go somewhere
- So, the atom emits light



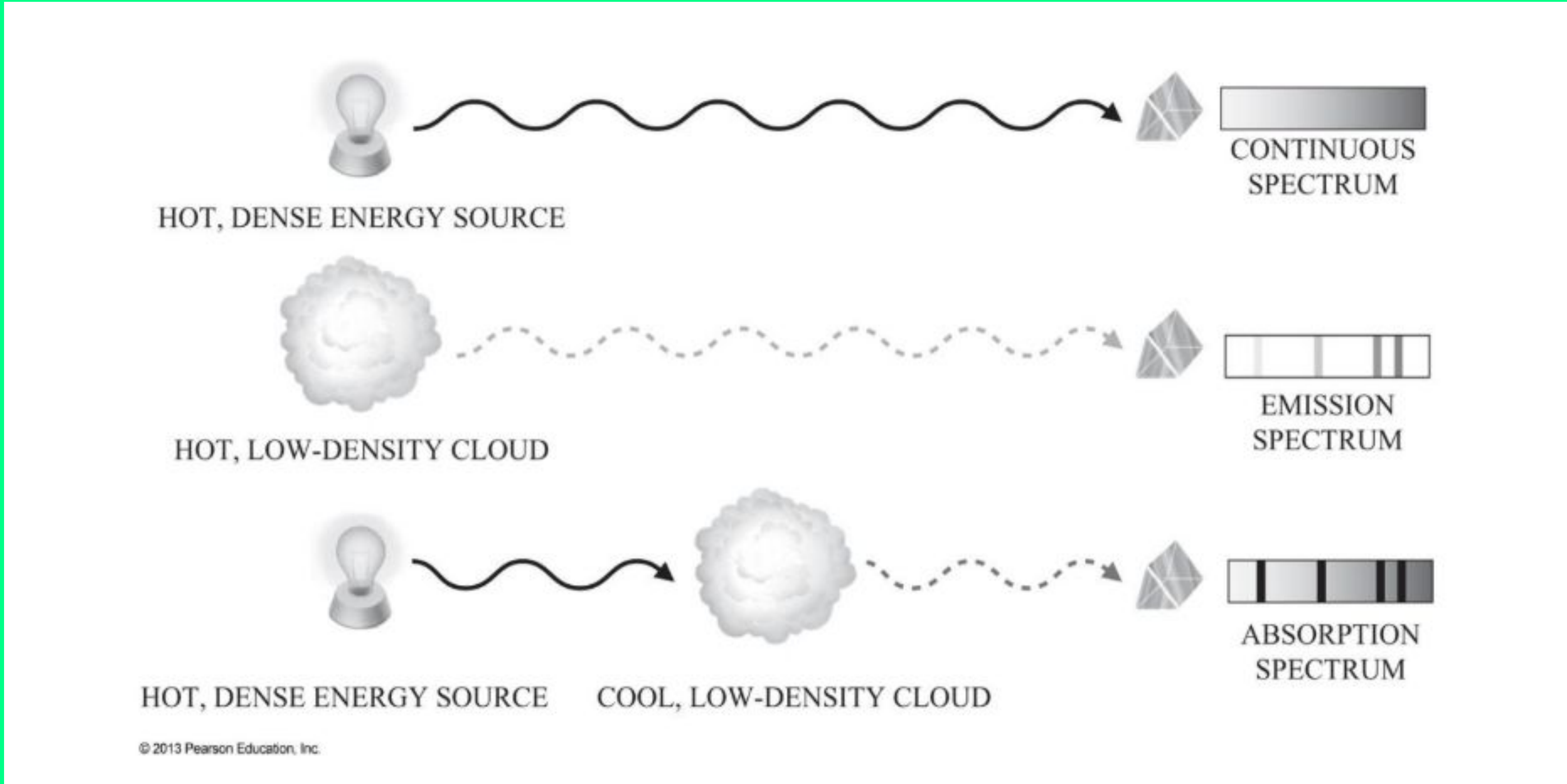
ν_0 (pronounced "v-nought)" is the speed divided by the wavelength, for us, that is c/λ

What Does This Mean For Us?

- The specific quantized amount of energy absorbed or emitted depends on the atomic structure of the atom - so different elements absorb and emit different ***specific*** wavelengths
    - The more levels up or down the electron goes - the bigger the energy change
- So, by looking at what wavelengths (colors) of light are emitted or absorbed we can determine what element something is made out of



What Does This Mean For Us?

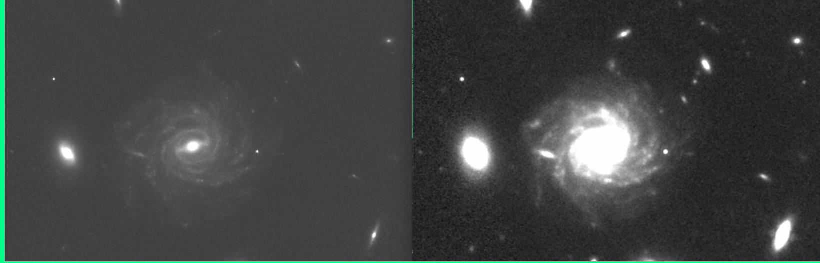


Real-World Examples (Outside Astronomy)

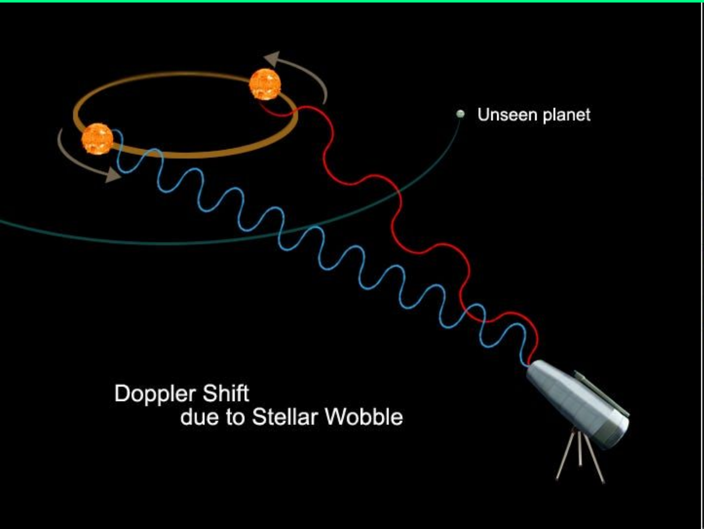
- Phosphorescence and Fluorescence are two processes where the absorbed and emitted wavelengths are different
  - Because of weird quantum mechanics stuff

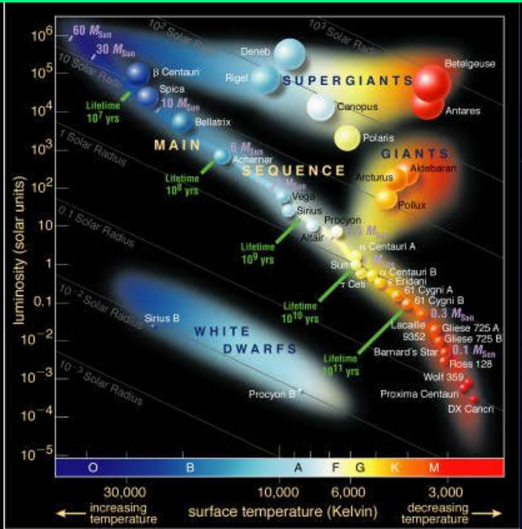
- Phosphorescence
  - Slow (minutes or hours)
  - Used on glow in the dark stuff - toys, watch faces, etc.
- Fluorescence
  - Fast (nanoseconds)
  - Used for lighting, forensics, road signs, industrial QC, and medicine
  - Some animals even glow
- Regular Spectroscopy
  - Used for finding toxins in food or blood samples, determining the amount of dissolved oxygen in water, and more
- Similar Techniques (other types of waves i.e. sound)
  - Useful in linguistics, geology, music, structural engineering, etc.

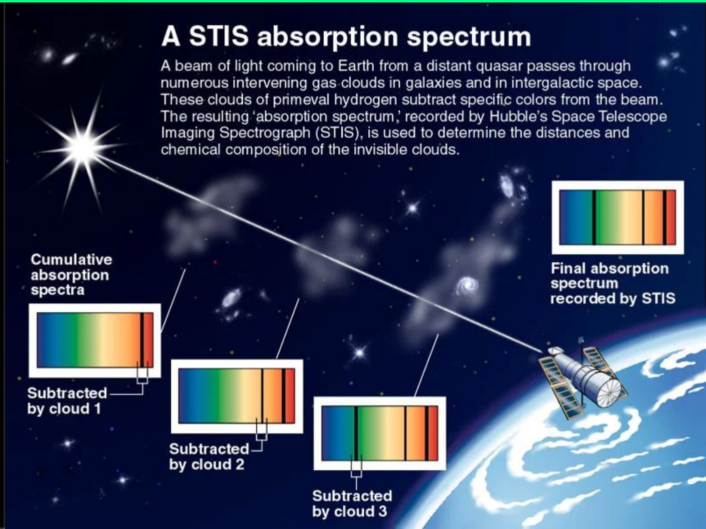
Real World Examples (In Astronomy)

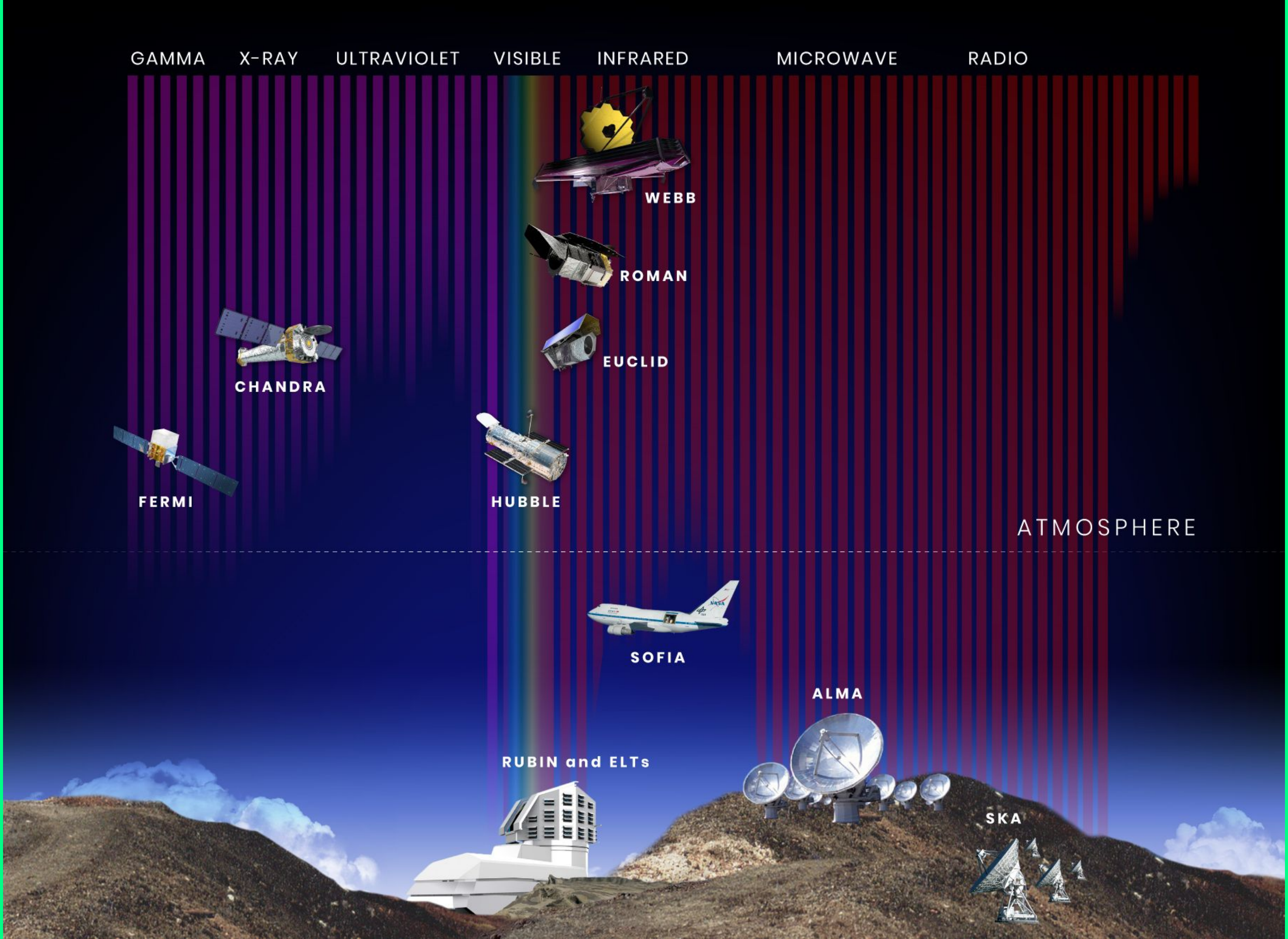


- Exoplanets (radial velocity and atmospheric spectroscopy) (learn about in AST 111)
- Star temperatures (and therefore mass and age - H-R Diagram) (learn about today and later this semester)
- Composition of gas clouds
- From the above two: Galaxy age and evolution (my research)
- Galaxy movement (later this semester)








GAMMA
X-RAY
ULTRAVIOLET
VISIBLE
INFRARED
MICROWAVE
RADIO
WEBB
ROMAN
EUCLID
CHANDRA
FERMI
HUBBLE
ATMOSPHERE
SOFIA
ALMA
RUBIN and ELTs
SKA

Today

- You will be using the spectroscopes to identify 6 elements
  - If you can’t see anything through them, let me know - it likely just needs to be recalibrated
- You will also be using them to look at a fluorescent light (the ceiling lights) and an incandescent light (in the corner)
- We don’t have enough stations for everyone at once, so take turns
  - No need to go in order

Today

- Question 9 is one that most people struggle with every semester
  - Ask for help if you need it
- Question 12 doesn't actually have much work to show since you can just plug it into a calculator…
  - But make sure to include ***<u>UNITS</u>***
- Questions 18 through 24 are extra credit
  - Worth quite a bit
- Remember to do the quiz - due at the same time as the lab
- Next week's lab is Parallax

Scattering

- Light can be deflected off an atom and be scattered into the environment
  - Sometimes this involves splitting up the light into a bunch of different wavelengths, and sometimes it involves reflecting all the light at a specific angle
- This is not important to your lab today, but it is why the sky is blue, and why you can use mirrors
  - It's also why stealth aircraft often have weird shapes