Light – Photons
3 Ways their ENERGY (color) is Useful to you as an ASTROPHYSICIST

THE PHOTONS are the DATA
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Open Fri/Sat June-September for visits
This program will cover

- What is a PHOTON, How are PHOTONS produced by ATOMS.

- How the ENERGY of the light relates to its COLOR, and to the type of ATOMS that EMITTED the PHOTON.

- How EMISSION and ABSORPTION SPECTRAL LINES are produced and what the lines can tell us about the ATOMS that produced them.

- What a CONTINUOUS SPECTRUM can tell us about the ATOMS that produced it.

- The significance of a Red or Blue SHIFT of spectral lines. (Doppler Shift/Cosmological Shift)
To understand PHOTONS we need to look at ATOMS (indivisible? tiny bits of matter)
The ELECTRONS can only be in specific ENERGY LEVELS (quantum jumps), never in between!
Photons are emitted (given off) by an ATOM if its ELECTRONS are energized and then fall back down to their “Ground State”, giving up the energy they’d gained.
ELEMENTS are different types of matter, each element has a specific number of PROTONS and ELECTRONS – periodic table lists all known ELEMENTS.
IMPORTANT INFO: Only certain specific QUANTUM JUMPS are allowed for electron structure of a specific ELEMENT!
The ELECTROMAGNETIC SPECTRUM has lots of varieties of PHOTONS, few energy ranges are Visible to our eyes!
Photons come in many ENERGIES, each corresponding to a COLOR if in visible portion of the SPECTRUM.
All Photons travel at the same SPEED, but can be of a variety of WAVELENGTHS/FREQUENCY as they are produced by different sources of ENERGY.

Shorter wavelength, higher frequency, bluer color photons have more ENERGY. (shake a rope more rapidly)
How we use SPECTRAL LINES to “fingerprint” (identify) chemicals/elements present:
Allowable jumps for each ELEMENT’s electrons will only
EMIT PHOTONS of a few specific
ENERGIES (COLORS!)

therefore, a specific
“fingerprint” or “barcode” of
light, an EMISSION or
ABSORPTION SPECTRUM =
a pattern of colored or black
lines.
To See the “barcode” (spectrum), we need to spread out the energies (colors).

- We use a piece of Technology called a SPECTROMETER.
- The Spectrometer can use a GRATING (rows and rows or ridges), or
- Can use a PRISM to spread the colors.
Examples of Hydrogen, Carbon, Oxygen EMISSION SPECTRA in Lab
YOUR TURN!

- You’ll be given spectral emission patterns of several ELEMENTS and spectral absorption patterns for several actual STARS.

- Your job is to DETERMINE WHICH CHEMICALS ARE PRESENT IN WHICH STARS.

- (Line up the elemental spectra with left edge of star spectral patterns.)

- Why some “line broadening”???
Next, let’s investigate COLORS of HOT OBJECTS (like stars):
Producing the 3 types of SPECTRA associated with STARS:
Now let’s observe the CONTINUOUS SPECTRUM of an incandescent light source.

- What PHYSICAL CHARACTERISTICS CHANGE as we vary the amount of ENERGY to the lamp?
Now let’s observe the CONTINUOUS SPECTRUM of an incandescent light source.

- What PHYSICAL CHARACTERISTICS CHANGE as we vary the amount of ENERGY to the lamp?
  1. BRIGHTNESS
  2. COLOR
  3. TEMPERATURE
Atoms of a given element will emit a range of photon energies (colors) depending on TEMPERATURE of the atoms.
Continuous Spectra (overall color) tells us a Star’s TEMPERATURE.
Bear in mind that COLD objects like ice cream or clothing also come in a variety of COLORS...WHY?
Ice Cream occurs in different colors due to different FLAVORS.

- There are different flavors because
Ice Cream occurs in different colors due to different FLAVORS.

- There are different flavors because the ice cream is made of DIFFERENT MATERIALS.
- The chemistry of the various compounds absorbs/reflects different energies (colors) of light, again due to quantum effects of electrons interacting/or not, with incoming photons. Another method to analyze COMPOSITION!
Photon/Spectra SUMMARY

1. PHOTONS are PACKETS of ENERGY Emitted by Electrons as they “Fall Down” to lower energy levels within their ATOM.

2. The COLOR of the PHOTON tells you its ENERGY (WAVELENGTH).

3. Because of the “Allowable” Quantum Jumps for each type of ATOM, we can “fingerprint” CHEMICAL ELEMENTS by their EMISSION/ABSORPTION SPECTRAL PATTERNS.

4. The CONTINUOUS SPECTRUM of colors coming from excited ATOMS tells us their TEMPERATURE.
One more observable aspect of COLOR: Spectral Line SHIFT!
Sun on left, Galaxy Cluster on right:
Consider SOUND WAVES of a siren coming toward you and then going away from you...

- **DOPPLER SHIFT!** An APPARENT squashing and stretching of the waves, changing their PITCH to the RECEIVER.
APPARENT effect due to relative motion of emitting object and observer...let’s listen to the zooming buzzer!
Indication of COLOR SHIFTS:

- RED SHIFT: You and emitter are moving FURTHER APART.

- BLUE SHIFT: You and emitter are moving TOWARD ONE ANOTHER.

- The MORE THE SHIFT, the FASTER THE RADIAL MOTION.
Let’s demo with SLINKY
Note that the emitter and the observer can be at any separation for this to occur...

- The Red/Blue SHIFT is NOT a direct indicator of DISTANCE, only relative motion!

- But, in the COSMOLOGICAL realm, observations by Slipher, Humason, and Hubble found a strong CORRELATION of DISTANCE (apparent diameter/brightness) of GALAXIES to their RED SHIFT!

- MORE DISTANT GALAXIES DISPLAY GREATER RED SHIFT...implications???
What is implied by this correlation (Hubble Law)?
Our UNIVERSE is EXPANDING!

- The SPACETIME IS STRETCHING carrying the Galaxies with it (Bungee cord demo).
- This is one of the three major types of data that support the “Big Bang” scenario for the growth of our Universe.
We can also measure ROTATION RATES of Galaxies and ORBITAL RATES of Clusters of Galaxies...

- This data yielded disturbing results: there has to be a lot more mass exerting gravitational pulls than we can account for visually...
- This spawned the concept of DARK MATTER, an ongoing conundrum... nobody has a clue, yet!
But it gets even better!

- Ten years ago TWO INDEPENDENT TEAMS of COSMOLOGISTS discovered that supernovas in distant galaxies appeared too far away...too dim for their redshift.

- THE UNIVERSE IS NOT ONLY EXPANDING, but IT IS ACCELERATING!

- BIG QUESTION: what ENERGY is driving this major motion???? DARK ENERGY???
Consider how something as basic as COLORS has led to major understandings and major mysteries, about our UNIVERSE!