

Light – Photons
3 Ways their ENERGY (color)
is

Useful to you as an
ASTROPHYSICIST

THE PHOTONS are the DATA

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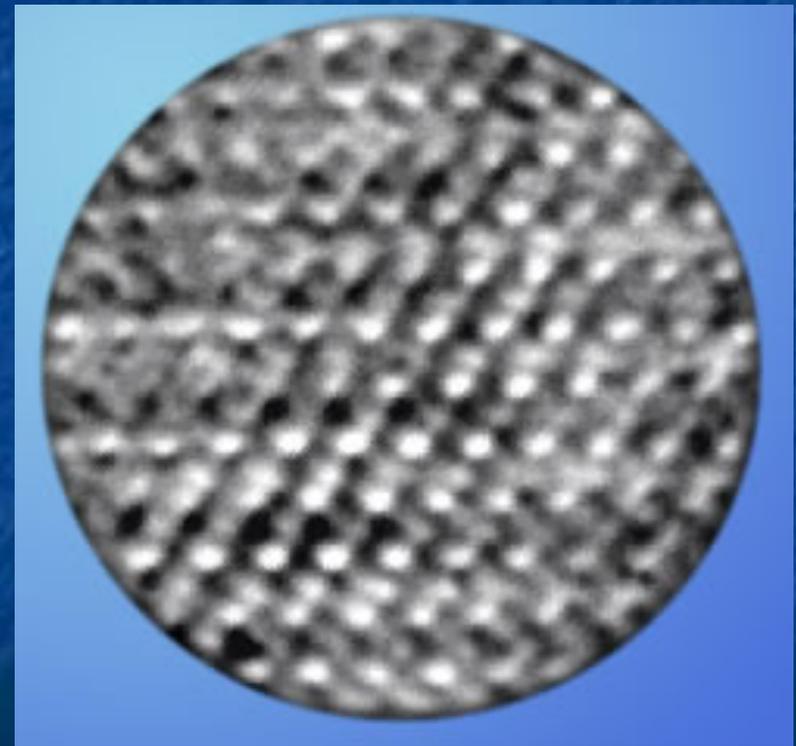
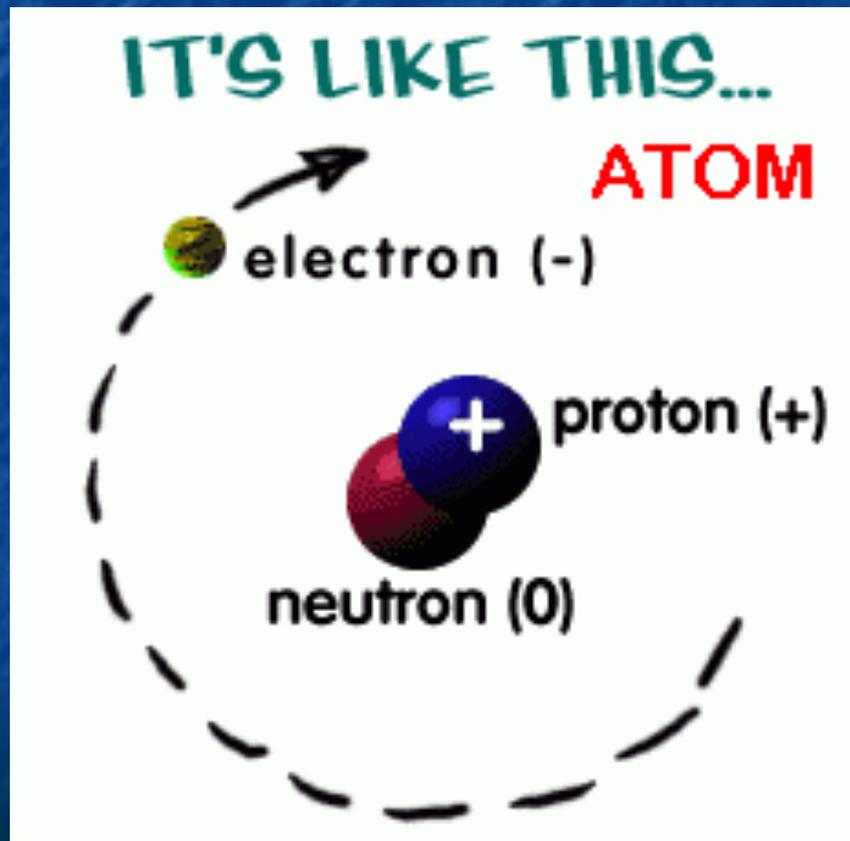
University of Oregon's Pine Mountain Observatory

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)

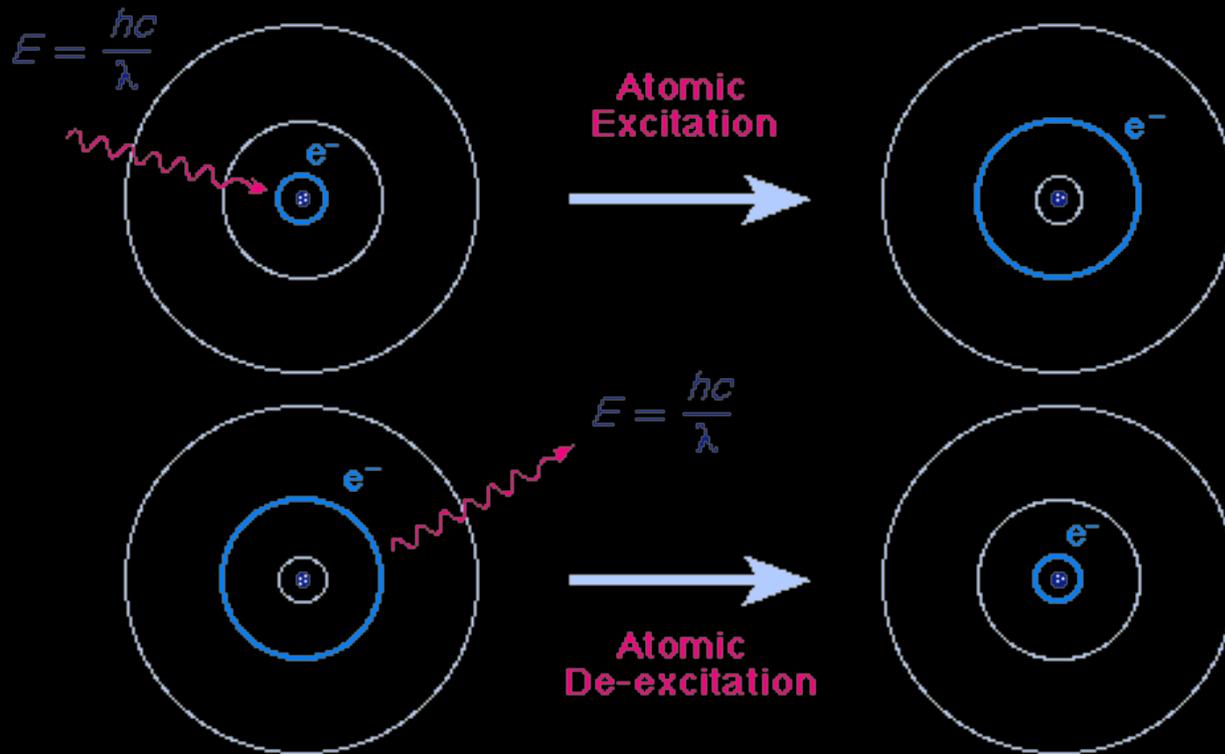
To understand PHOTONS we need to look at ATOMS (indivisible? tiny bits of matter)



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**

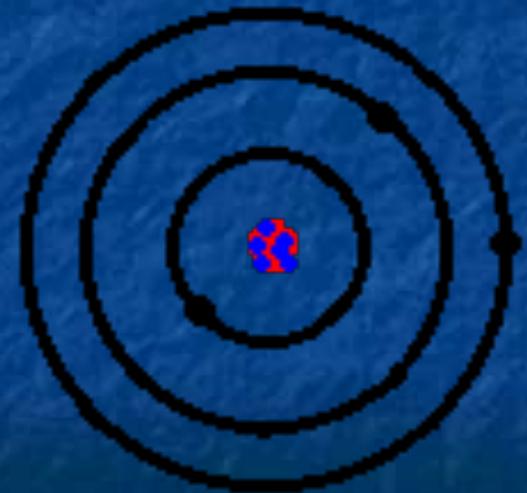
Periodic Table of the Elements

1	2											3	4	5	6	7	8	9	10																
H	He											B	C	N	O	F	Ne																		
3	4											13	14	15	16	17	18																		
Li	Be											Al	Si	P	S	Cl	Ar																		
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36										
Na	Mg	Al	Si	P	S	Cl	Ar	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr										
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
87	88	89	104	105	106	107	108	109	110	111	112	81	82	83	84	85	86	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103			
Fr	Ra	+Ac	Rf	Ha	106	107	108	109	110	111	112	Tl	Pb	Bi	Po	At	Rn																		

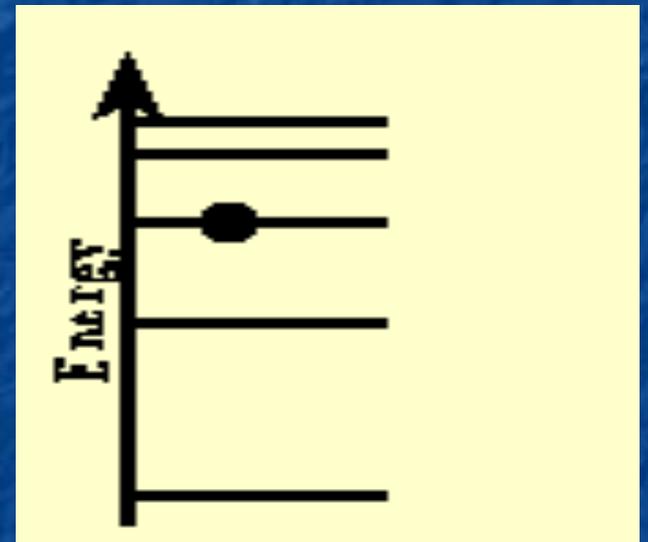
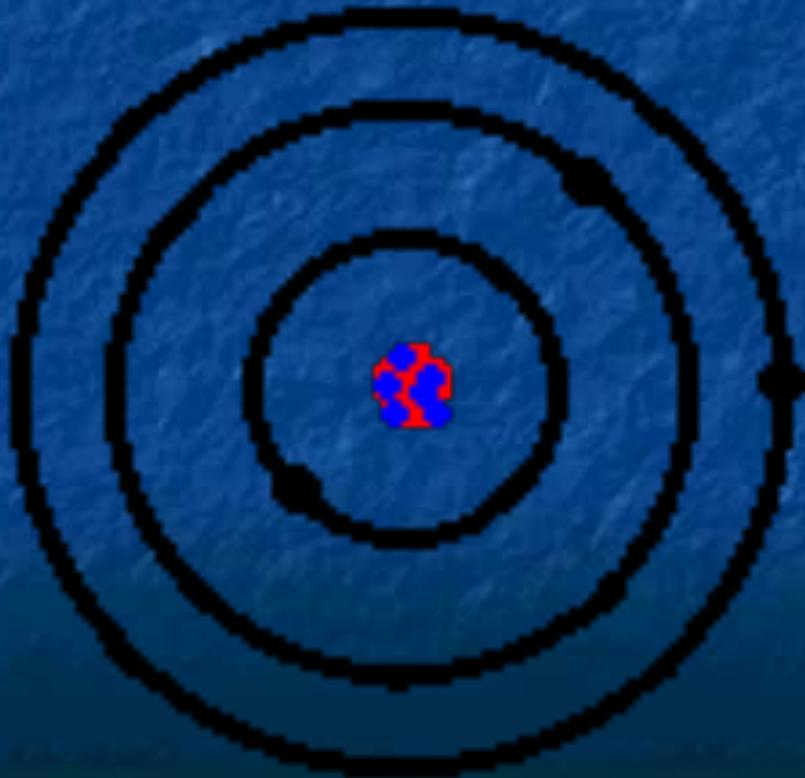
Naming conventions of new elements

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
90	91	92	93	94	95	96	97	98	99	100	101	102	103
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

* Lanthanide Series
+ Actinide Series



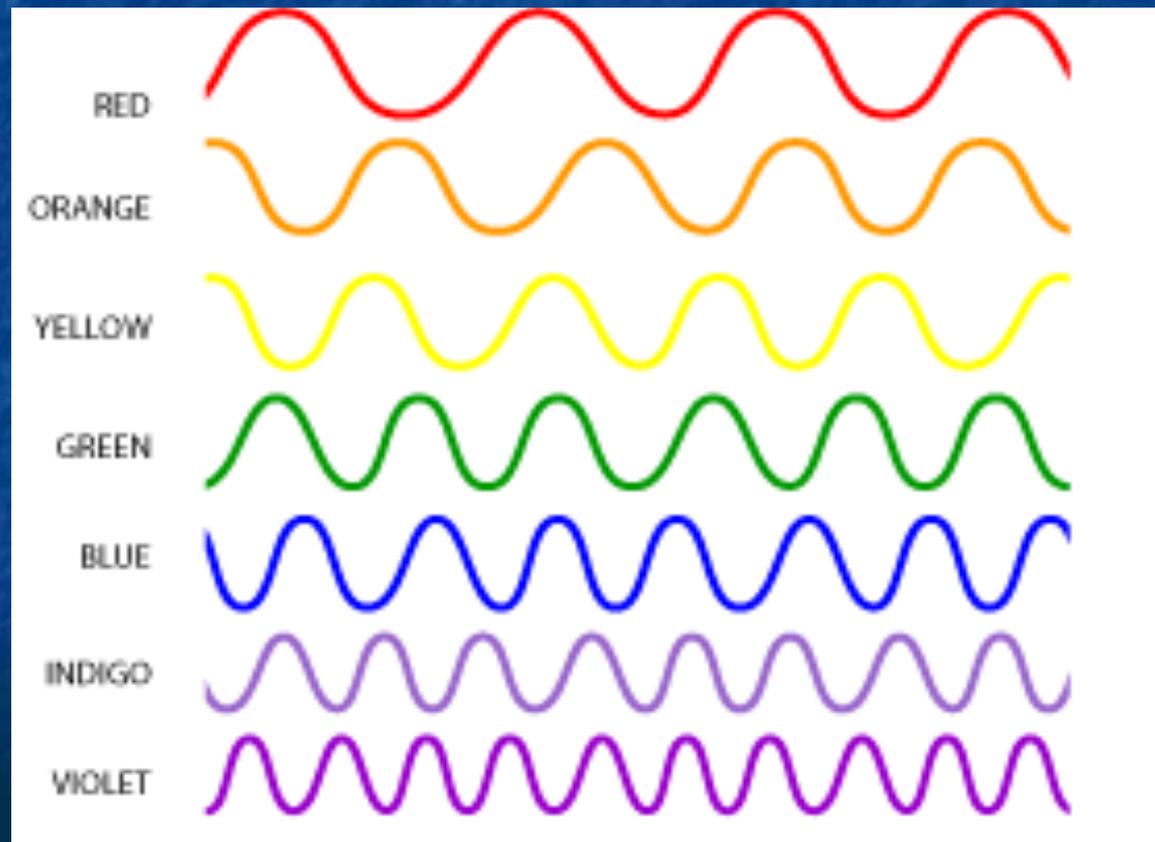
IMPORTANT INFO: Only certain specific QUANTUM JUMPS are allowed for electron structure of a specific ELEMENT!



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)

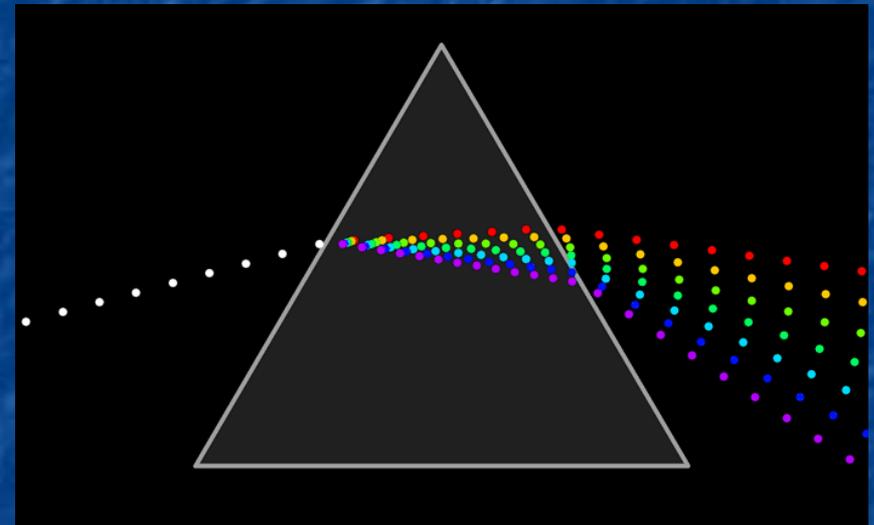
How we use SPECTRAL LINES
to “fingerprint” (identify)
chemicals/elements present:

Allowable jumps for each
ELEMENT' s electrons will only
EMIT PHOTONS of a few specific
ENERGIES (COLORS!)

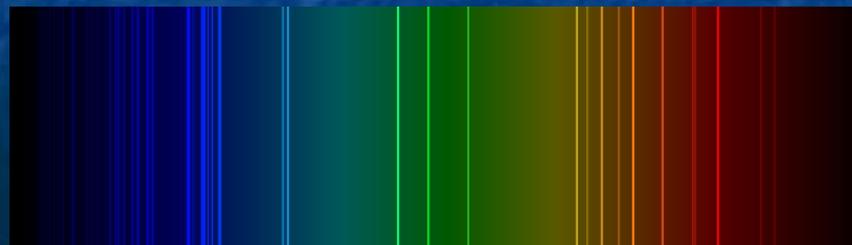
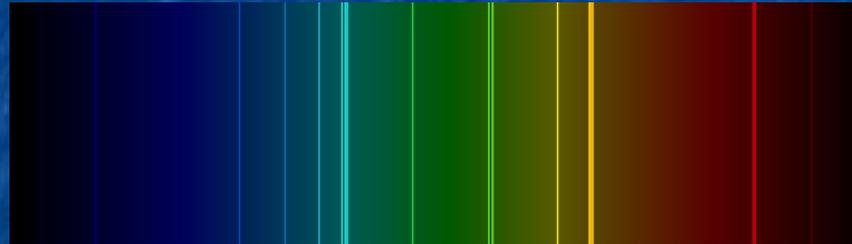
therefore, a specific
“fingerprint” or “barcode” of
light, an EMISSION or
ABSORPTION SPECTRUM =
a pattern of colored or black
lines.

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

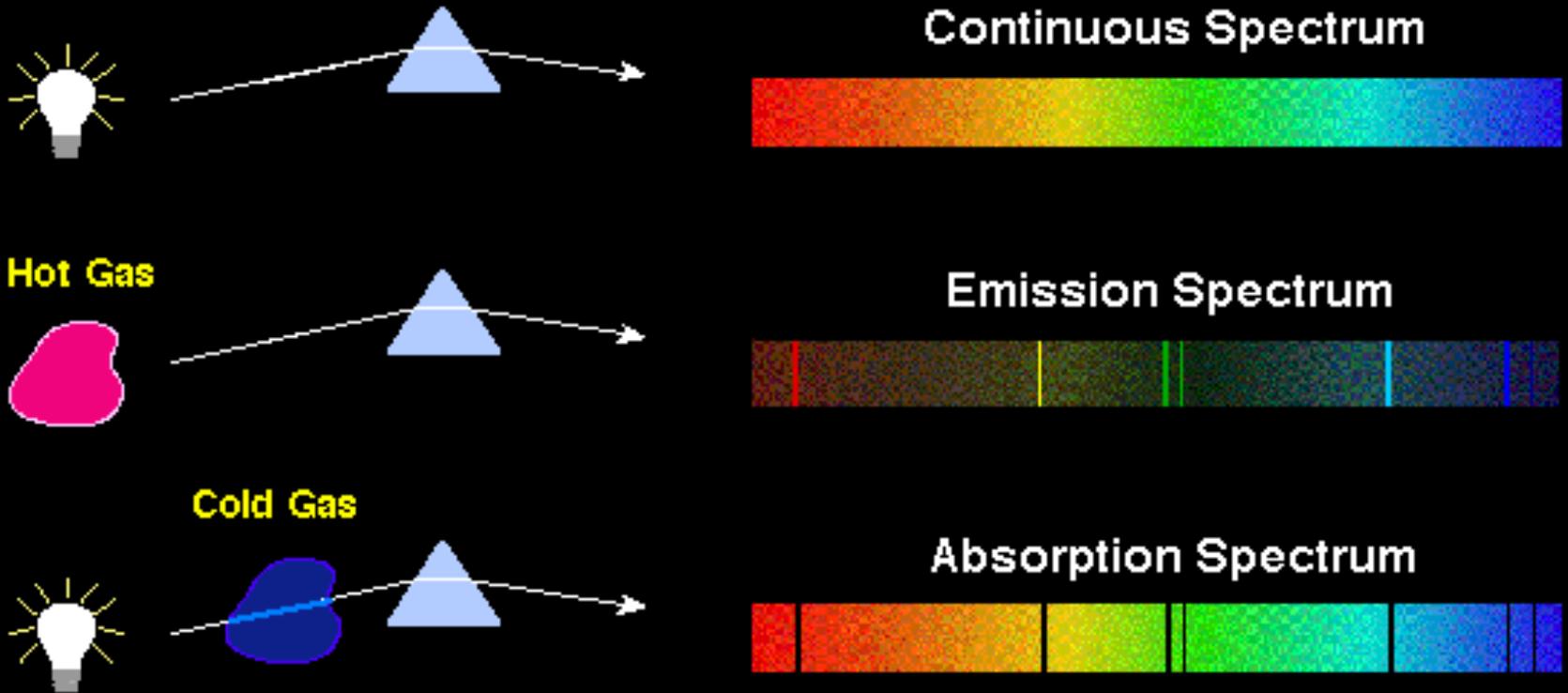


YOUR TURN!

- 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.

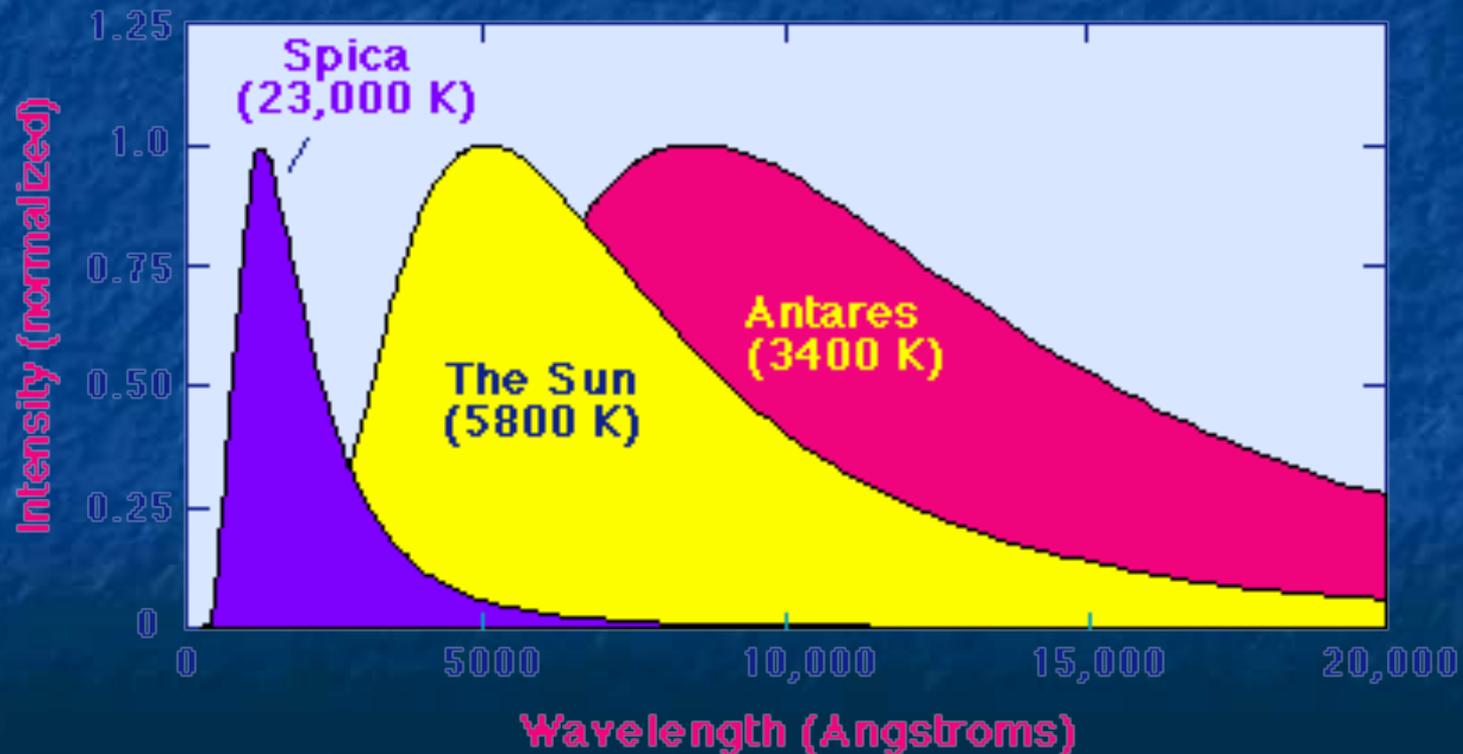
- What **PHYSICAL CHARACTERISTICS CHANGE** as we vary the amount of **ENERGY** to the lamp?

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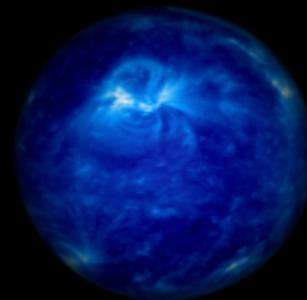
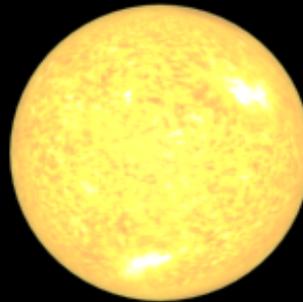
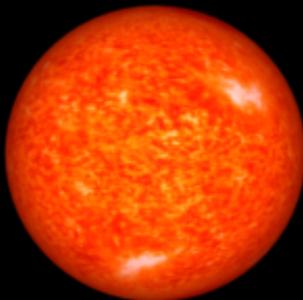
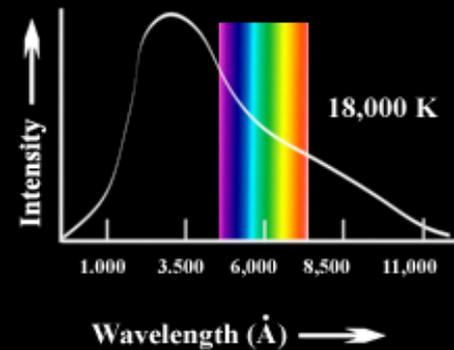
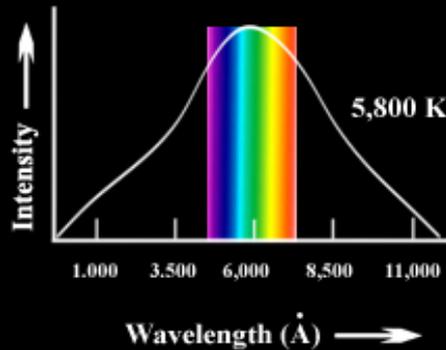
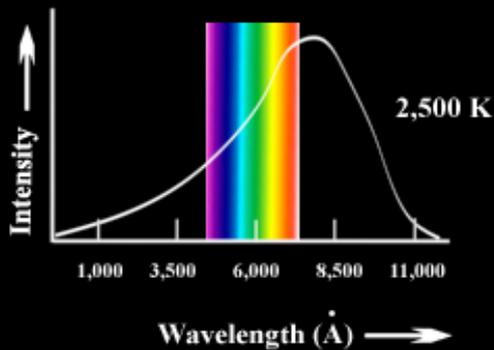
- What **PHYSICAL CHARACTERISTICS CHANGE** as we vary the amount of **ENERGY** to the lamp?

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



Colors are exaggerated

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

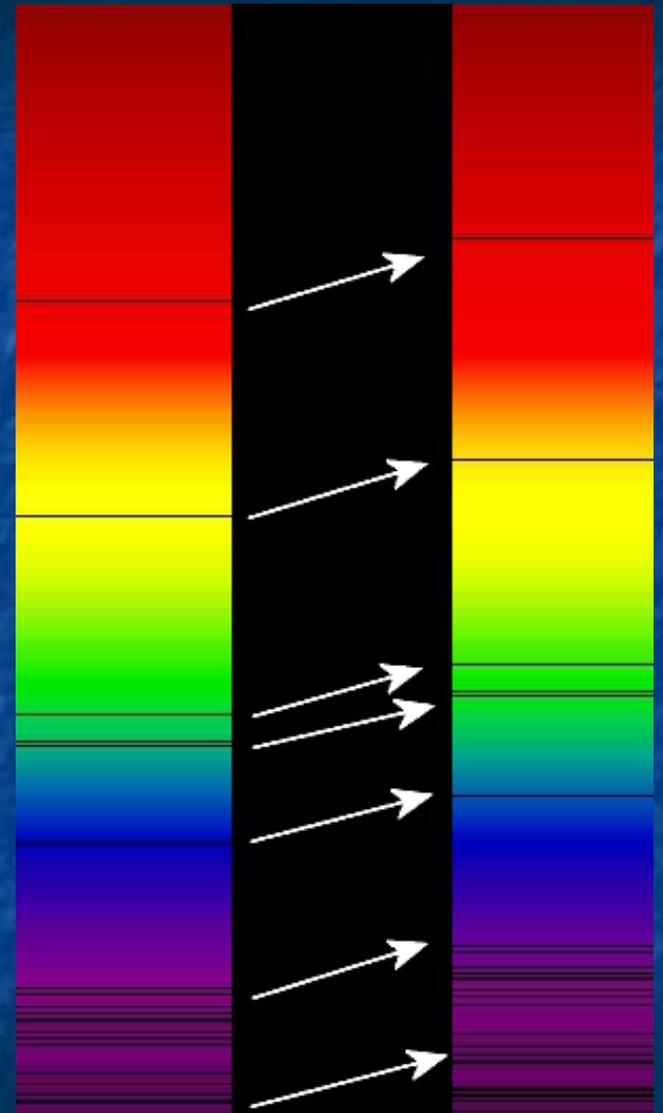
Ice Cream occurs in different colors due to different FLAVORS.

- 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**.

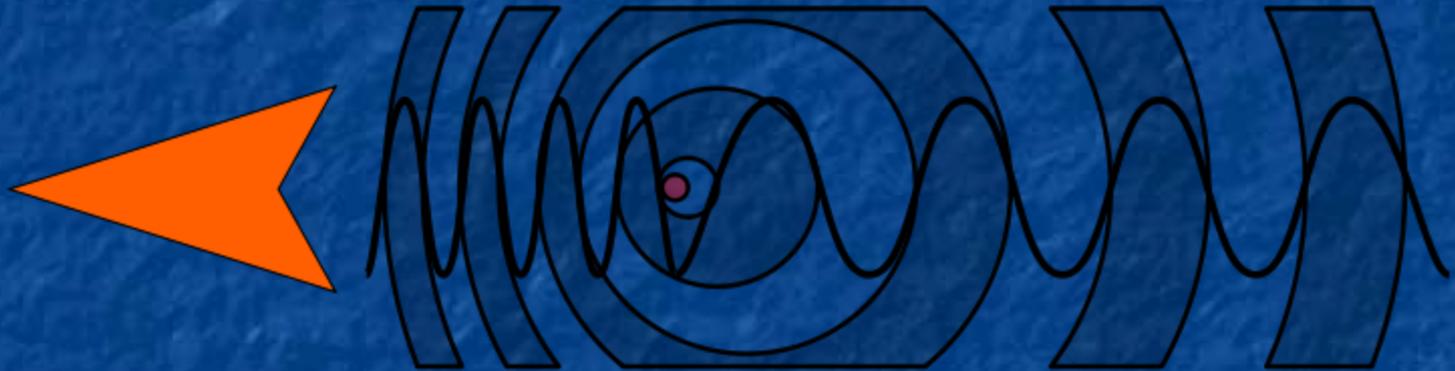
One more
observable aspect
of COLOR:
Spectral Line
SHIFT!
Sun on left, Galaxy
Cluster on right:



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!

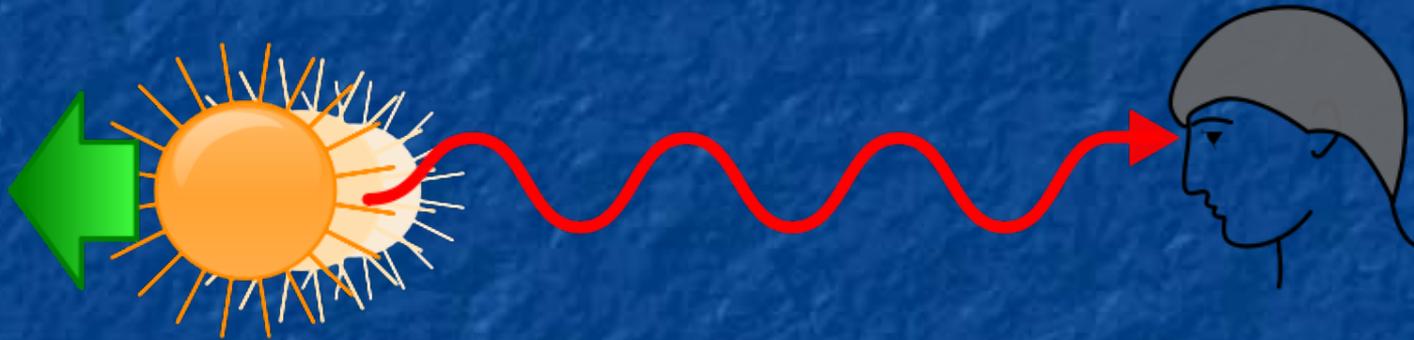




Indication of COLOR SHIFTS:

- 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.

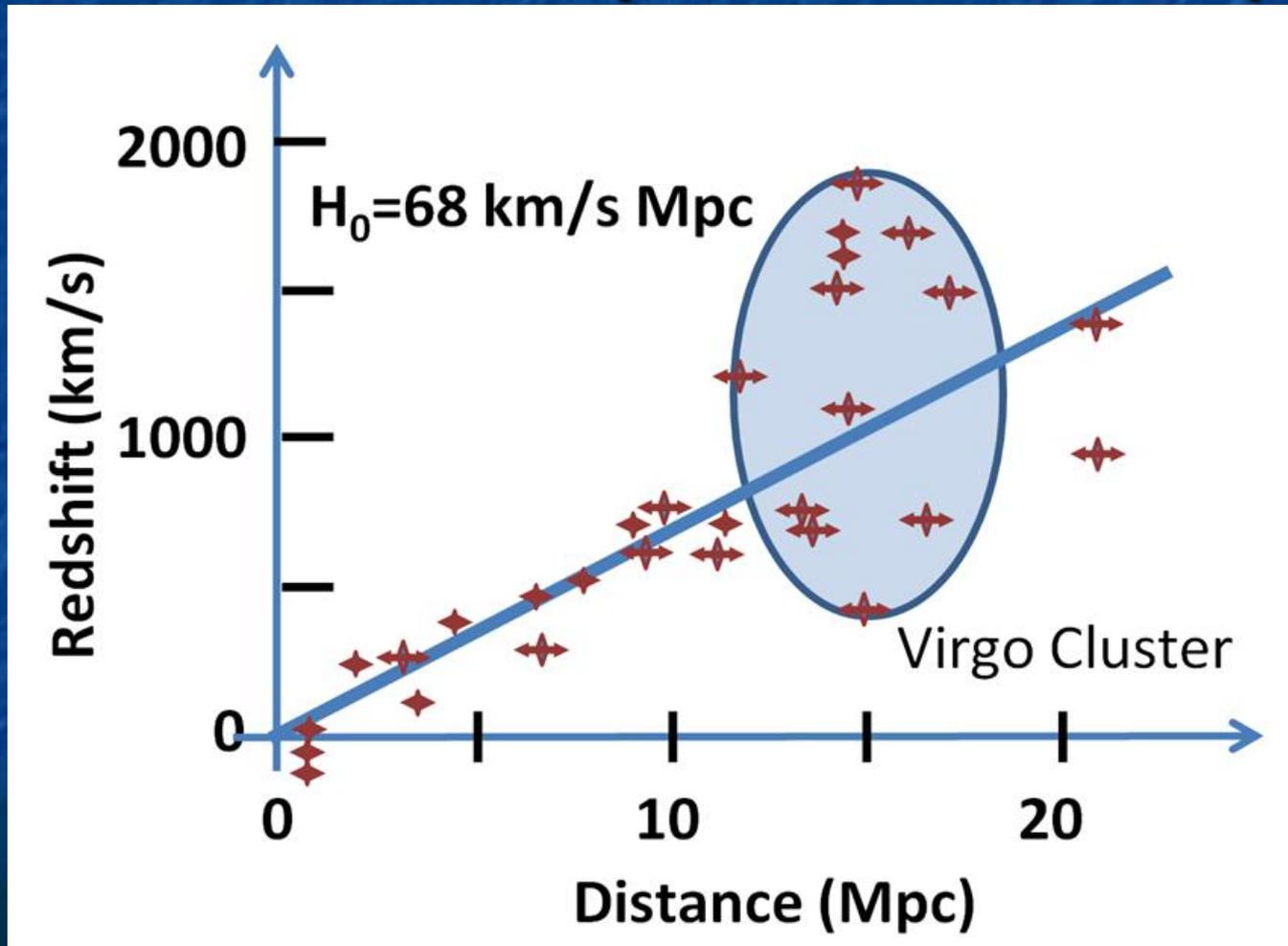
Let's demo with SLINKY



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!