

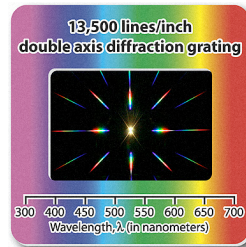


Astronomy 150: Killer Skies



Make sure to pick up a grating!

You must give them back after class.



This Class (Lecture 14):
Classifying Stars

Next Class:
Exam 1!

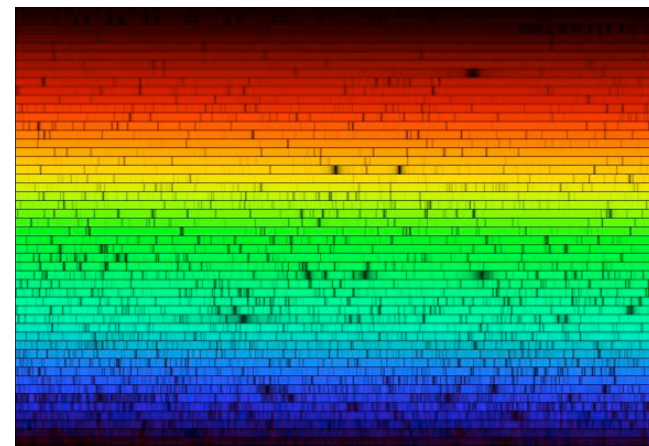
Music: *See the Sun*– Dido

Outline



- Using Spectra to understand the Universe
- The HR Diagram– learning the secrets of the Stars!
- The Sun gets older and the Earth gets hotter.

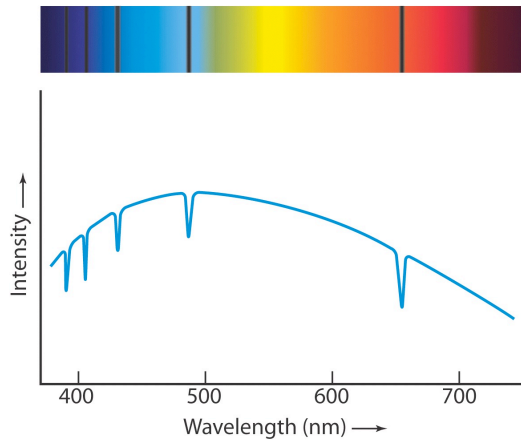
What Color is Sunlight?



Spectrum Lines



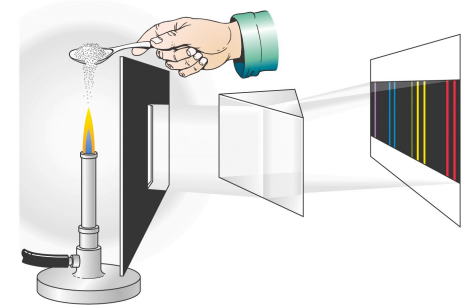
- When astronomers looked at the spectra of the Sun and stars, they saw **gaps**
- Not a perfect blackbody spectrum!
- Called *dark spectrum lines*



In the Laboratory



- Bright spectrum lines were produced and studied in the laboratory in the mid-1800s
- Discovered that burning different chemical elements produced different patterns of lines



Spectrum Lines = Fingerprints



The pattern of spectrum lines produced by a gas depends on its chemical composition



Or a barcode!

Argon	
Helium	
Mercury	
Sodium	
Neon	

<http://www.astro.washington.edu/astro101v>

Question



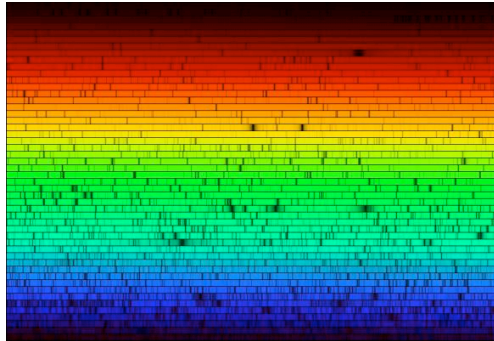
What is the mystery element?

- Hydrogen
- Neon
- Helium
- Mercury
- Blackbody

Solar Spectrum Lines



- The Sun shows dark spectrum lines
- These are also lines, but in reverse.
- Tells us about elements too.



Question



What does the spectra of the Sun look like?

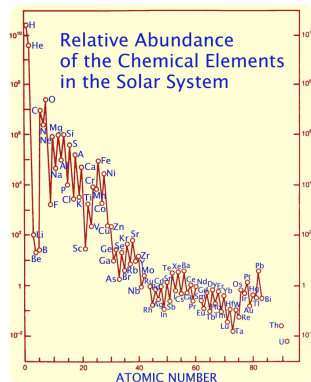
- A continuous rainbow of color.
- A few discrete colors, which depend upon the gas.
- A continuous rainbow of color with some colors reduced in brightness (look dark) due to the specific elements in the gas.
- A continuous rainbow of color with a few discrete colors brighter than the rest.
- We don't know. We can't observe the Sun; its too bright.

Solar Composition



Cecilia Payne

- From the spectra lines, we can determine the Sun's composition
 - 92% Hydrogen
 - 8% Helium
 - Less than 0.1% other stuff



How Do the Spectra Lines Form?



1 H Hydrogen																	2 He Helium														
3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon														
11 Na Sodium	12 Mg Magnesium											13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon														
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton														
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon														
55 Cs Cesium	56 Ba Barium	57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110	111	112	114	116				

Atoms and Elements

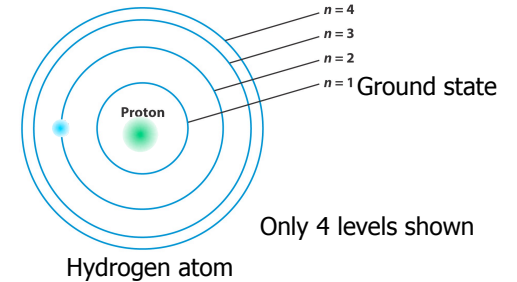


- Atoms are mostly empty space.
- Atoms interact via electrons
 - Shared among atoms to make **molecules**
 - Atoms missing or with extra electrons are called **ions**

Atomic Structure



- Electrons orbit the *nucleus* of each atom
- The nucleus consists of protons and neutrons
- Number of protons = number of electrons (total charge=0)
- The electrons can only have special orbits called *energy levels*
- The lowest energy level is the *ground state*



Question



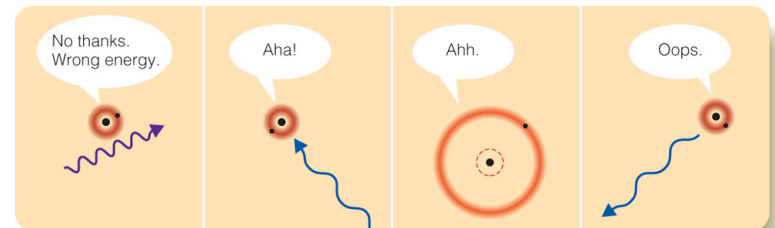
What is an atom mostly made of?

- Empty space
- Neutrons
- Protons
- Electrons
- Elves

How Do Spectrum Lines Form?



Electrons need the right energy to excite
= electron level gap



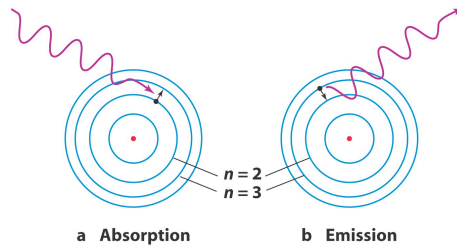
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Usually, the atom will de-excite quickly.

How Do Spectrum Lines Form?



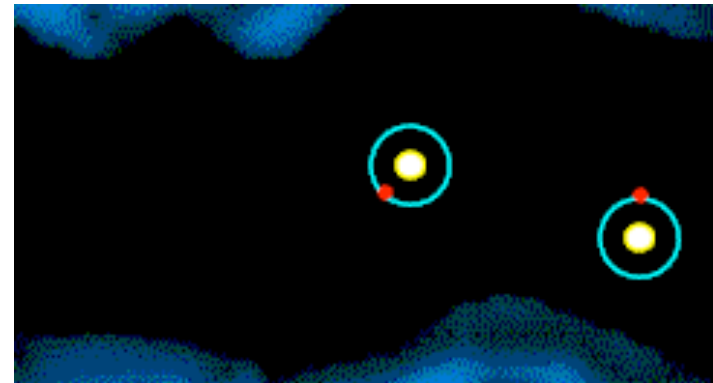
- Spectral lines correspond to electron transitions between energy levels in an atom
- **Excitation:** electron jumps to a higher energy level
 - Collision
 - Photon absorption
- **Emission:** electron drops down to lower energy level; releases energy
 - Collision
 - Spontaneous



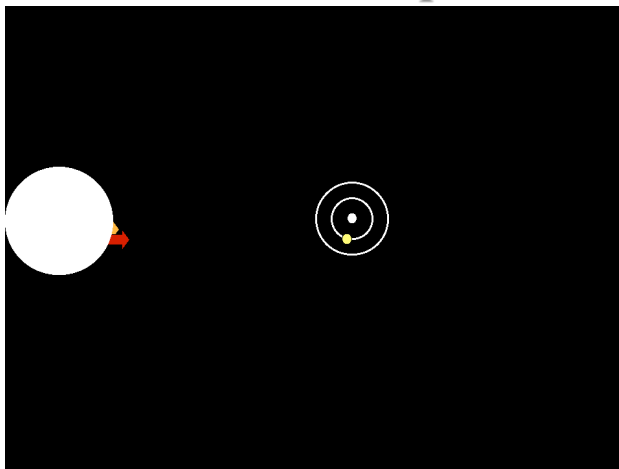
Atom Collisions



- Electrons get knocked-up to higher energy levels by collisions



Creation of Absorption and Emission Line Spectra



Question



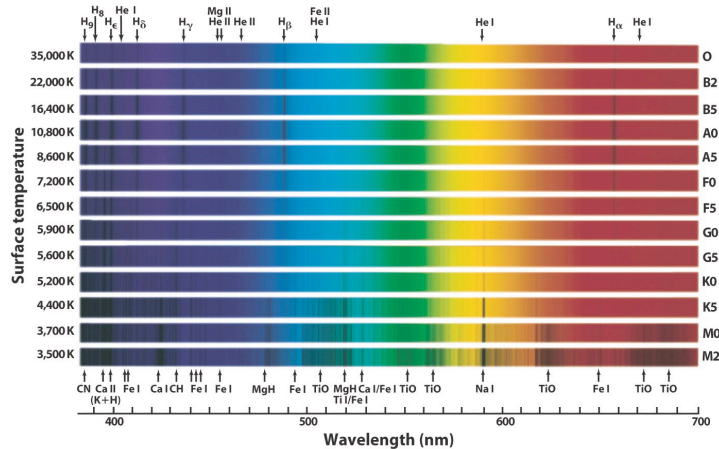
So why does the spectra of each element have a unique fingerprint?

- It doesn't.
- As the nucleus of each element is different, each has different electron levels, which correspond to different colors of light.
- As the nucleus of each element is different, when the nucleus decays, which correspond to different colors of light.
- Due to its temperature only.
- Ah... dude, no fingers

Stellar Spectra: Classification



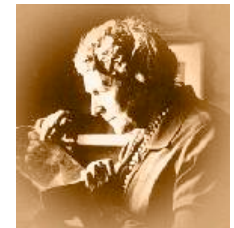
You should guess that the spectral features seen in stars are related to the temperature of the star— which elements are excited.



Classifying Butterfiles



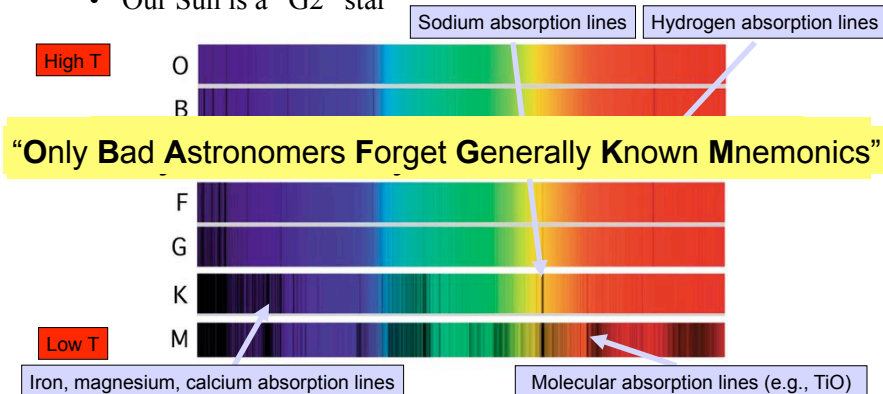
- Early astronomers (1890-1910) did not have your knowledge of stars.
- They tried to classify stars based on the spectra at Harvard.
 - Called the Harvard “computers”
- Most well known was Annie Cannon
 - Classified 250,000 stars by hand!
 - Did groups of A,B,C, etc...
 - Not Temperature....
 - Wrong classification order.. but still an amazing job



Spectral Classes



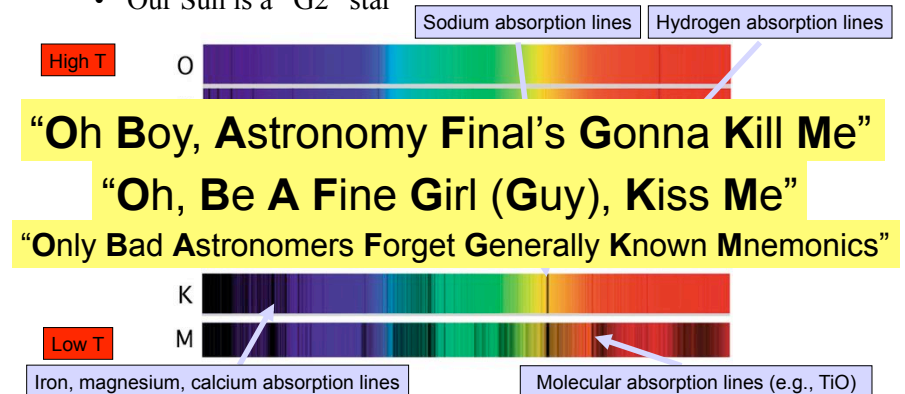
- So we had to reorder the classes, based on temperature!
- Today, only 9 main classes (with sub-classes) based on spectrum lines
- Our Sun is a “G2” star



Spectral Classes



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Stellar Properties



Okay, we have everything we need to look at stars and compare..

- Apparent brightness
- Distance
- Luminosity or absolute brightness
- Color
- Stellar spectra
- Temperature
- Spectral Class