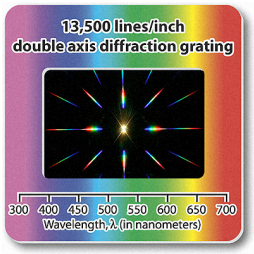
Make sure to pick up a grating from Brett! You will likely have to share with a neighbor.

You must give them back after class.



Astronomy 150:
Killer Skies

This Class (Lecture 13):
Stellar Temperatures

Next Class:
Exam 1!

Music: *Here Comes the Sun*– The Beatles

Exam 1

- Exam 1 in this classroom on Sept 25th
- 35 Multiple choice questions
- Will cover material up to and including last Friday.
- May bring 1 sheet of paper with notes
  - Both sides
  - Printed/handwritten/whatever.. I don't really care
- Major resources are lecture notes, in-class questions, and homeworks
- Try to understand major points more than anything.
- Have created and posted a study guide

Night Obs

- Dates:
  - Monday, Sept. 21st ✔
  - Tuesday, Sept. 22nd ✗
  - Wednesday, Sept. 23rd
  - Thursday, Sept. 24th
  - Monday, Sept. 28th
  - Tuesday, Sept. 29th
  - Wednesday, Sept. 30th
  - Thursday, Oct. 1st

Go to assignment page on class website for more info.

You **MUST** download worksheet before you go.

Can be cloudy, so check webpage before you go.

Question

Did you go to the Observatory Monday night?

a) Yes, it was okay.
b) Yes, it was cool!
c) Yes, it was the highlight of my life so far!
d) Yes, but it was boring.
e) No, but I will do so as soon as I can, I promise. I had other things I had to do, but I really, really want to go and I will make it a **top** priority in my life!

Computer Labs

- Computer labs to look for real killer asteroids.
- Dates:
  - Monday Sept 28th
  - Monday, Oct 5th
  - Monday, Oct 12th
- Places:
  - Nevada Labs
  - Oregon Labs
- Limited space each day, so you ***MUST*** have a reservation for that day and that lab!
- See Assignments webpage for more info and to sign up!
- Lectures are cancelled for those dates.

Outline

- Taking the Star's physical so we can compare them to our Sun
- Distance
- Better temperature through science
  - Spectral lines on the Sun
  - What is it made of?

Star's Physical

- Please step on scale. Turn head. Cough.
- No, really. How to measure the properties of objects that are very, very far away?
- What properties would we like to know about the stars.

HR Diagram

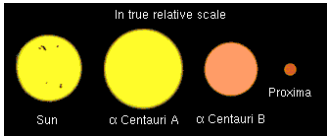
- To really explain the Sun's evolution, I need to talk about the HR diagram.
- So, excuse me for a few (okay many) slides.
  - We need to know stellar luminosity (which means that we need to know their distances)
  - We need to know stellar temperature (can do better than blackbody color though).

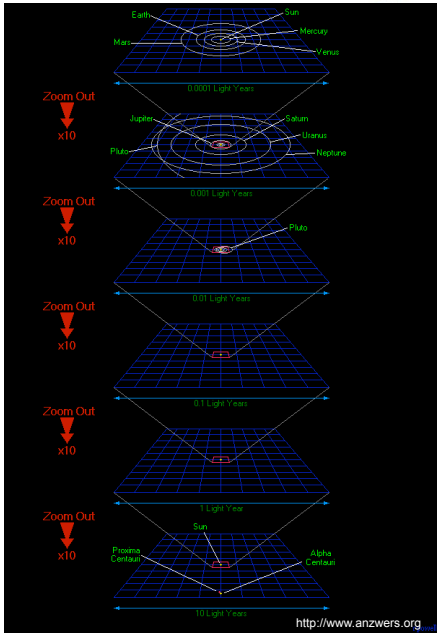
Distance

- We know that the stars must be very far away.
  - They don't move much as we orbit the Sun.
- But measuring the distance is a **hard** problem.
- We've only had the technology to do it for the last 200 yrs.

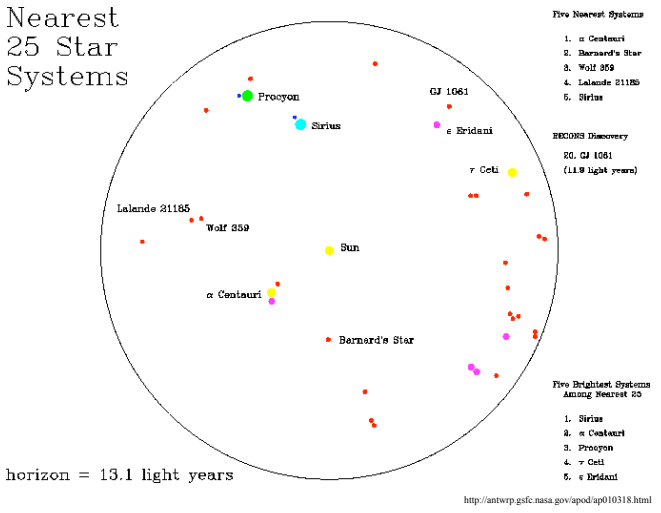
Leaving Home

- Nearest star is 4 x 10^{13} km away
  - Called Proxima Centauri
- Around 4 light years
- More than 5000 times the distance to Pluto
- Walking time: 1 billion years
- Fastest space probes: Voyagers 1 & 2, Pioneers 10 & 11) – 60,000 years at about 3.6 AU/year (38000 mi/hr)

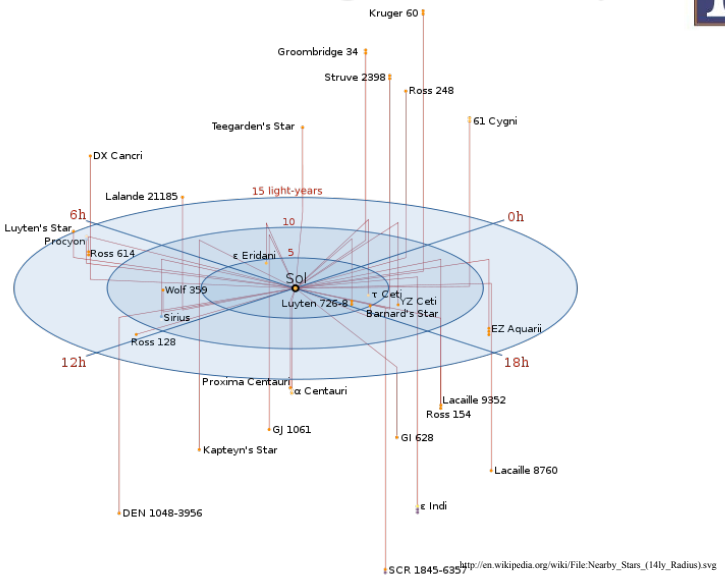




Our Nearest Neighbors



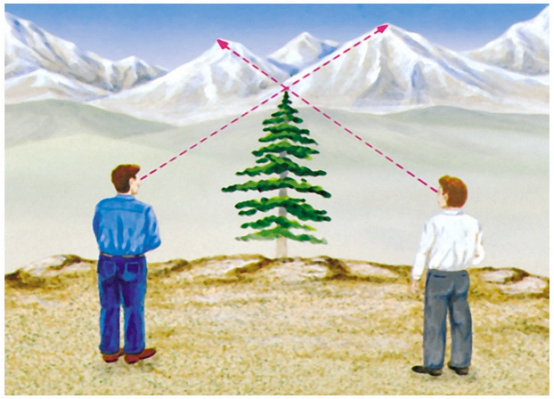
Our Nearest Neighbors: 15 lyrs



http://en.wikipedia.org/wiki/File:Nearby_Stars_(14ly_Radius).svg

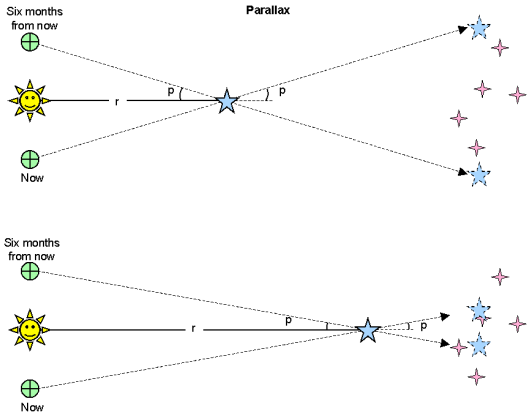
Parallax

How do astronomers measures distances to nearby stars?



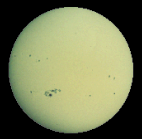
How to Measure Parallax

- Look at a star compared to background stars– and wait 6 months.
- How much, if any, have the stars moved?



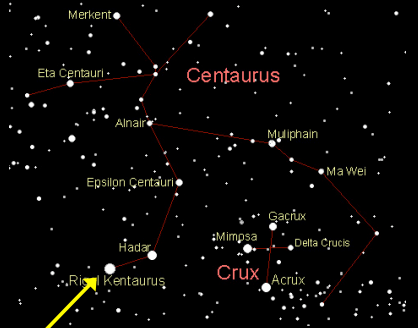
Distances to the Stars

Sun's disk seen from Earth



1/2 degree = 1800 arcsec

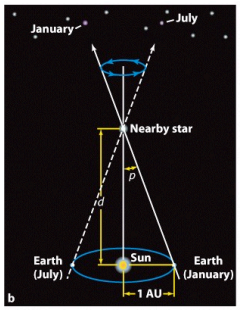
Dime at arm's length



Closest star to Earth:
Proxima Centauri
(part of α Centauri system)
Parallax: 0.77 arcseconds
Distance: 1.3 pc = 4.2 ly
like a dime 2 km away

Parallax Peril

- Drawback: measurable only for nearest stars
- Angular shift becomes tiny when star very far away
- Immeasurable when star is beyond few 100's of lyrs
- And Galaxy is 100,000 lyr across, Universe is 14 billion lyr
- What to do? ... stay tuned...

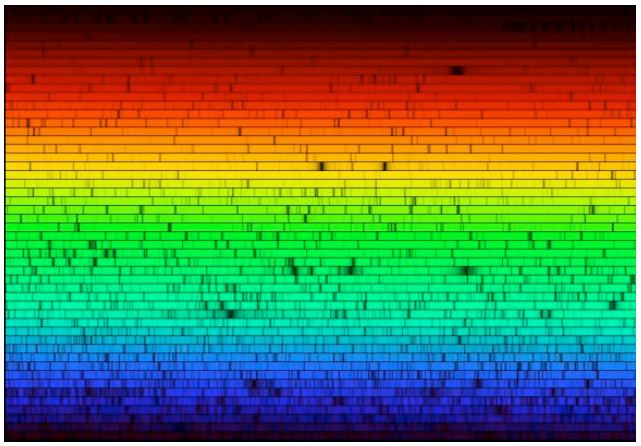


Question

Parallax can be used to measure the distance to

a) galaxies.
b) any star in the Universe.
c) only very nearby stars.
d) only far away stars.
e) the Big Bang.

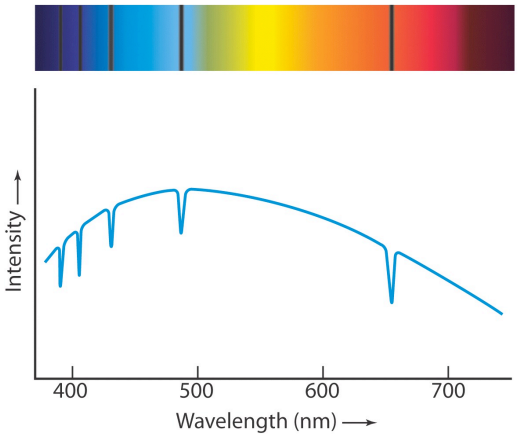
What Color is Sunlight?



http://antwrp.gsfc.nasa.gov/apod/ap000815.html

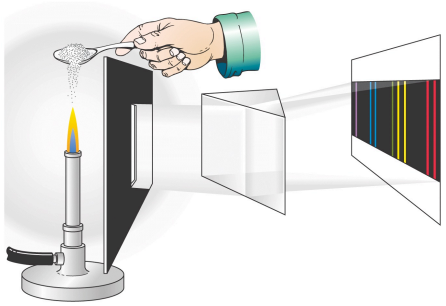
Spectrum Lines

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



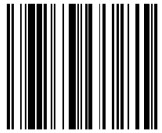
In the Laboratory

- 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

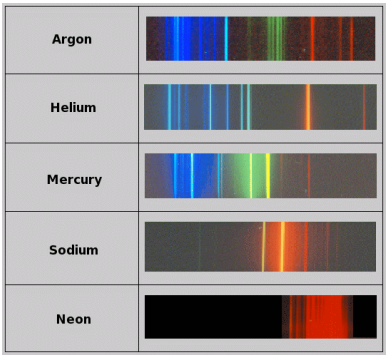


Spectrum Lines = Fingerprints

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



Or a barcode!



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

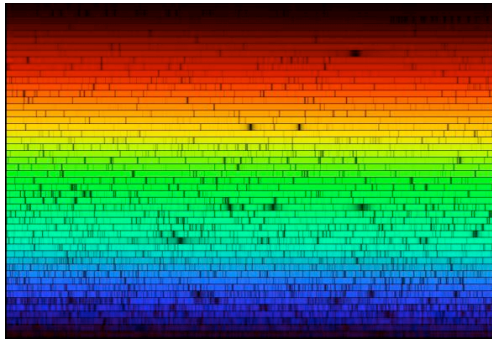
Question

What is the mystery element?

a) Hydrogen
b) Neon
c) Helium
d) Mercury
e) Blackbody

Solar Spectrum Lines

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



Question

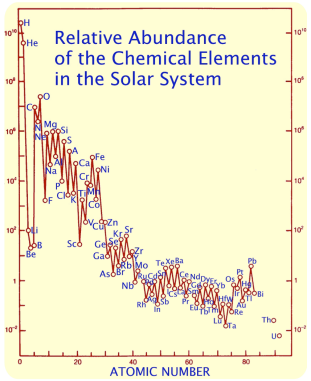
What does the spectra of the Sun look like?

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

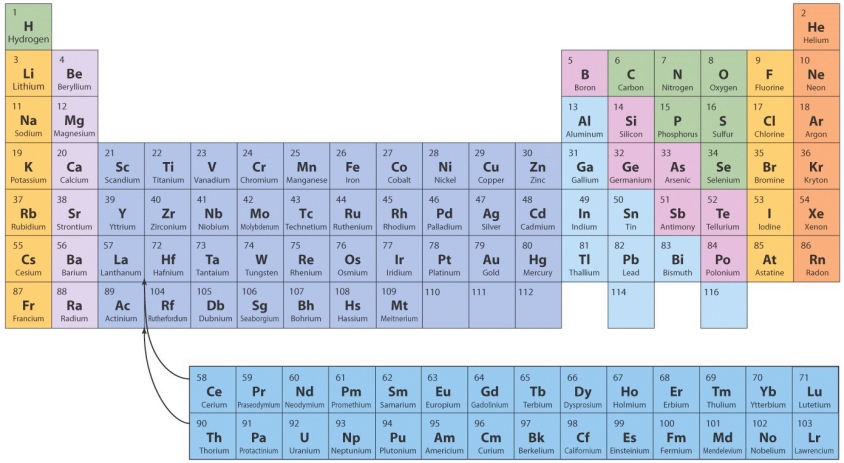
Solar Composition

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?

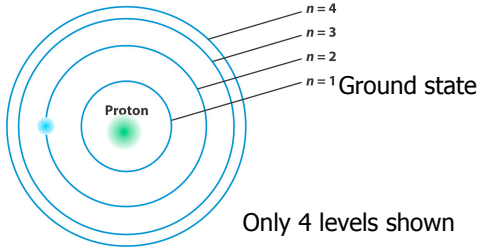


Atoms and Elements

- 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*



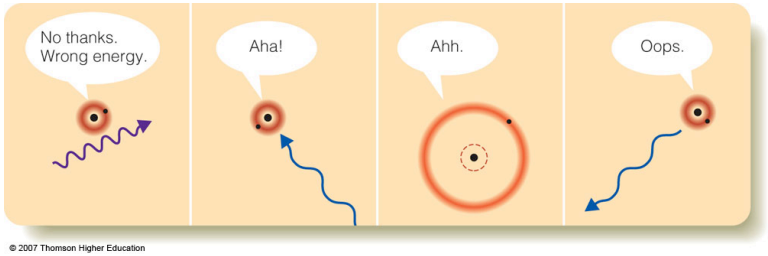
Question

What is an atom mostly made of?

a) Empty space
b) Neutrons
c) Protons
d) Electrons
e) Elves

How Do Spectrum Lines Form?

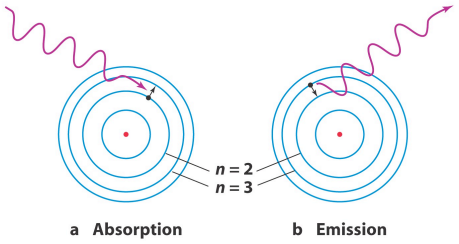
Need the right energy to excite = electron level gap



Usually, the atom will de-excite quickly.

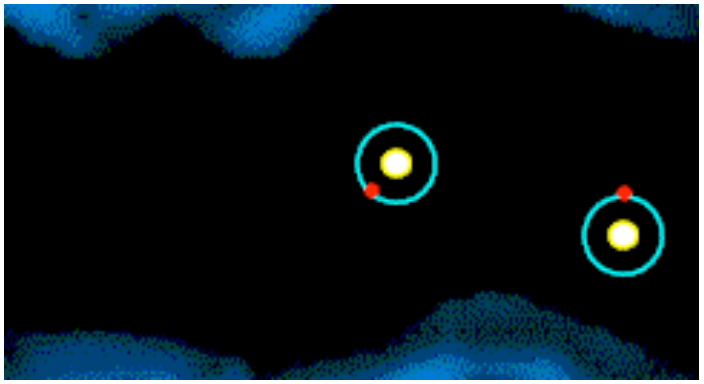
How Do Spectrum Lines Form?

- 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

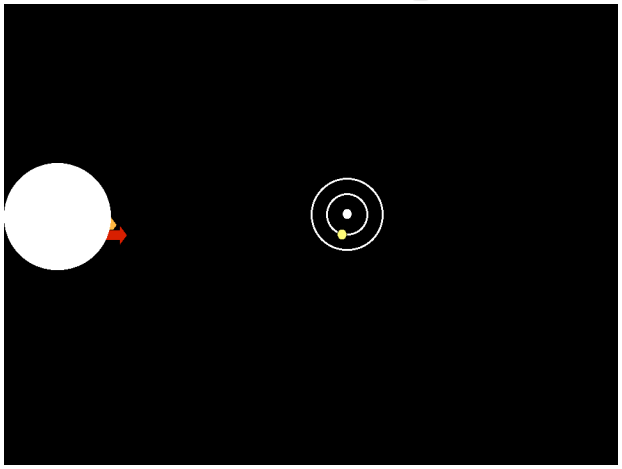


Atom Collisions

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



Creation of Absorption and Emission Line Spectra



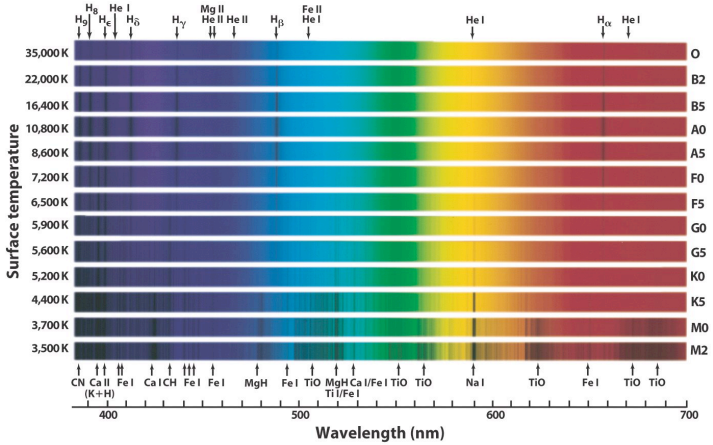
Question

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

a) It doesn't.
b) As the nucleus of each element is different, each has different electron levels, which correspond to different colors of light.
c) As the nucleus of each element is different, when the nucleus decays, which correspond to different colors of light.
d) Due to its temperature only.
e) 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