Astronomy 122

This Class (Lecture 12):

Stellar Evolution: The Main Sequence

Next Class:

A Star is Born

HW5 due on Sunday

Midterm in 2 weeks!

Music: *We Only Come Out at Night* – Smashing Pumpkins

Eclipsed

- Did you see it?
- If not, you will need to wait until December 20th, 2010 to see another!

HW

- Good job 30% looked at HW before discussion class.
- Important to note that after Short HW is graded, your answers and my answers are posted in Compass
- View submission…

Midterm in 2 weeks

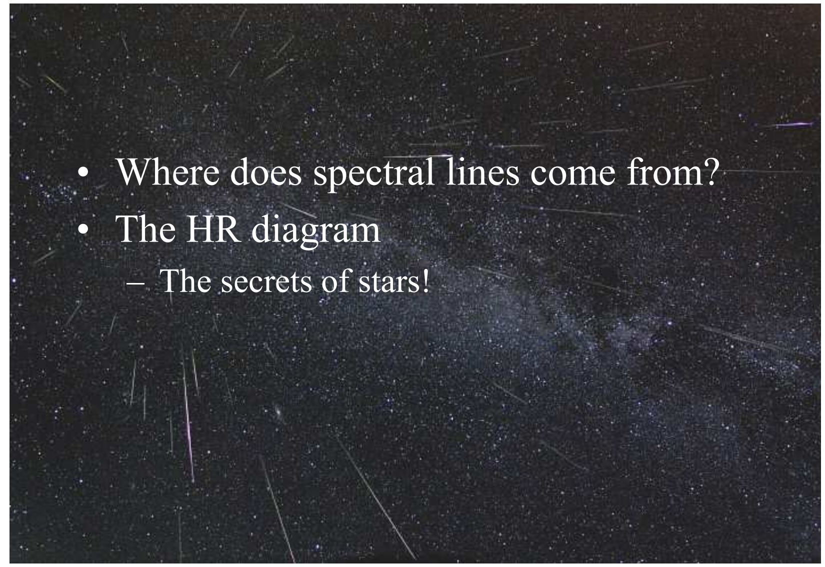
- All multiple choice questions.
- Approximately 10-25% will include math.
- Can bring a sheet of paper with notes on each side.
- Will try to create a study guide for discussion section.
- Exam will be worth 105 points, but graded out of 100 (extra credit).

Midterm in 2 weeks

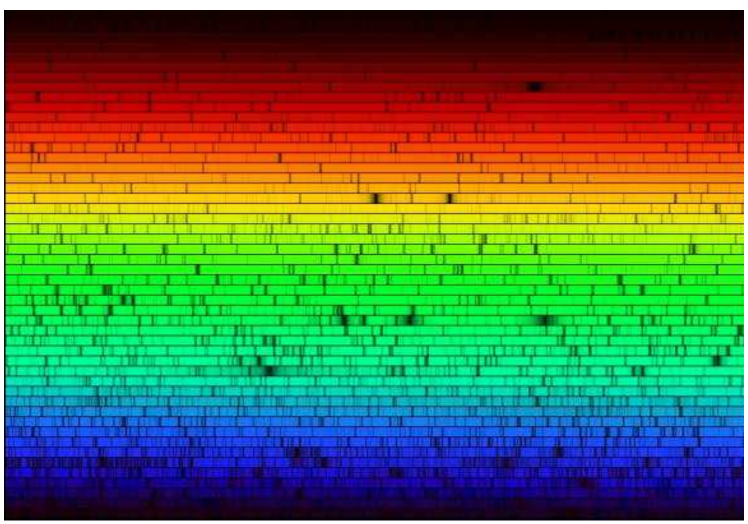
How many multiple choice questions would you prefer?

a) 25
b) 35
c) 40
d) 45
e) 50

Outline



What Color is Sunlight?



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

Question

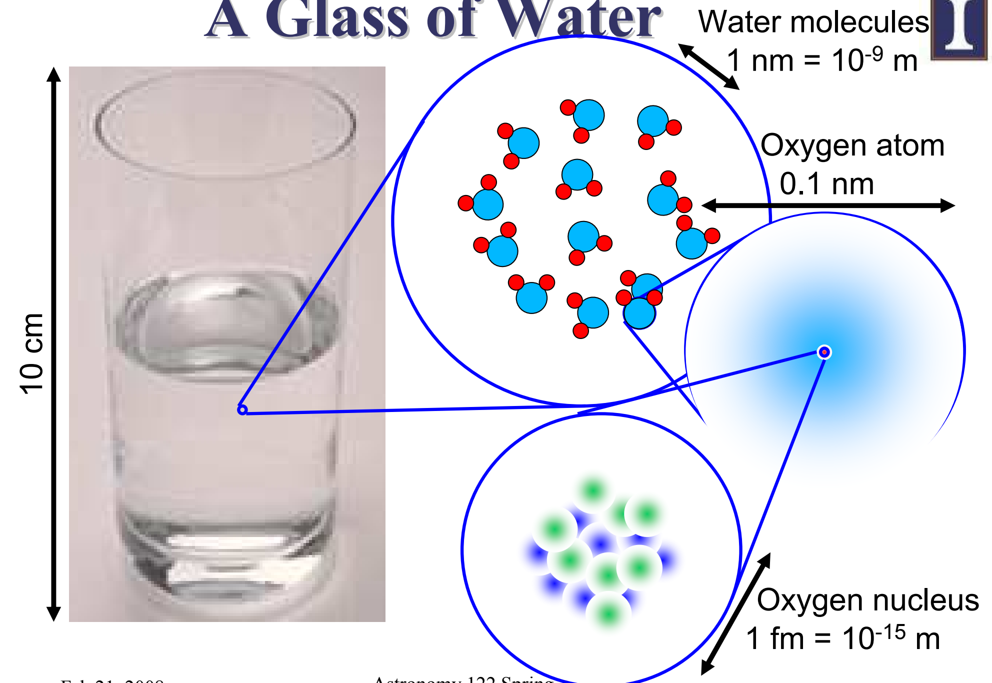
What does the spectra of the Sun look like?

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 due to the 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.

How Do the Spectra Lines Form?

To answer this question, we need to delve into the structure of matter itself…

A Glass of Water



Periodic Table

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	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	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110	111	112		114		116		
				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
				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

Atoms and Elements

- All matter is made of **elements**
  - 92 natural and 23+ "artificial"
  - Hydrogen, Carbon, Oxygen, Iron, Uranium, etc.
  - Each element is composed of a different kind of **atom**
- The number of protons (or Z) in an atom determines the type of element
  - Hydrogen has 1 proton (Z=1), oxygen has 8 protons (Z=8), etc.

Atoms and Elements

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

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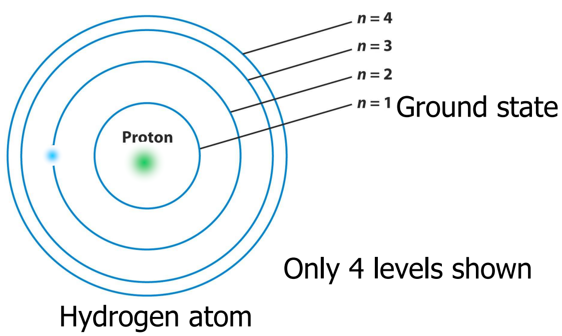
Atomic Structure

- 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*



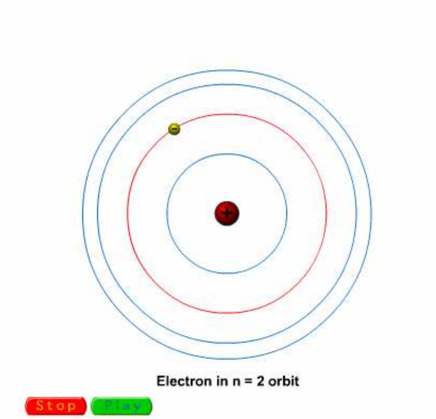
Question

What is an atom mostly made of?

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

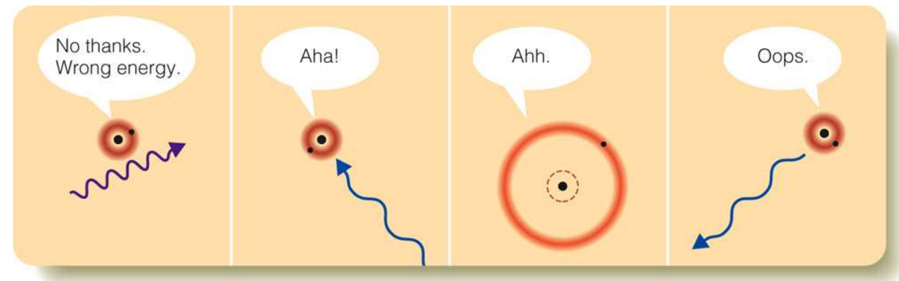
How Do Spectrum Lines Form?

- Spectrum lines correspond to electron transitions between energy levels in an atom
- **Absorption:** light energy absorbed by atom, electron jumps to a higher energy level
- **Emission:** electron drops down to lower energy level; releases energy as light



How Do Spectrum Lines Form?

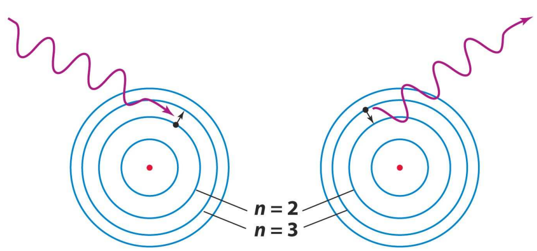
Need the right energy to excite = electron level gap



Usually, the atom will de-excite quickly.

How Do Spectrum Lines Form?

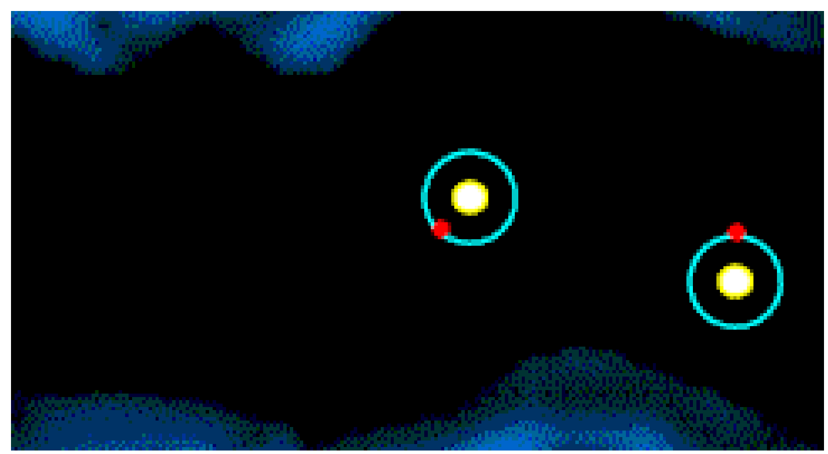
- Spectral lines correspond to electron transitions between energy levels in an atom
- **Excitation:** electron jumps to a higher energy level
  - Collision
  - Photon absorption
- **Emission:** electron drops down to lower energy level; releases energy
  - Collision
  - Spontaneous



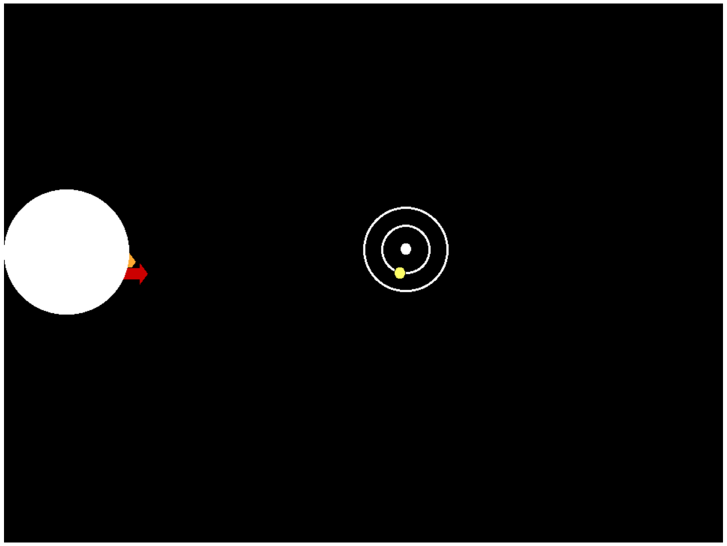
a Absorption b Emission

Atom Collisions

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



Creation of Absorption and Emission Line Spectra



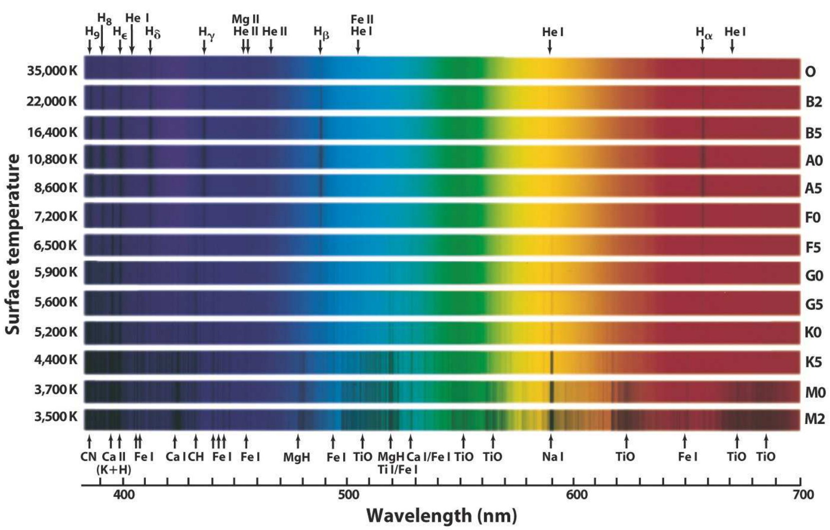
Question

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) Sponge.

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.

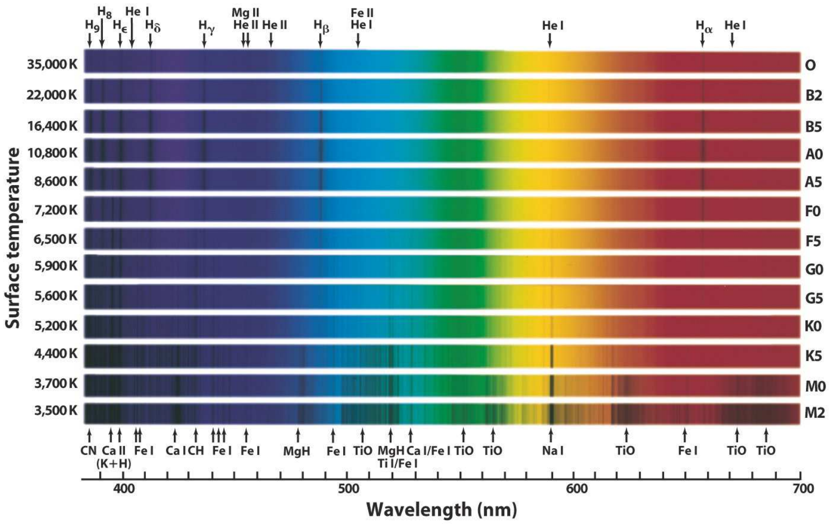


Classifying Butterfiles

- 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…
  - Wrong classification order.. but..

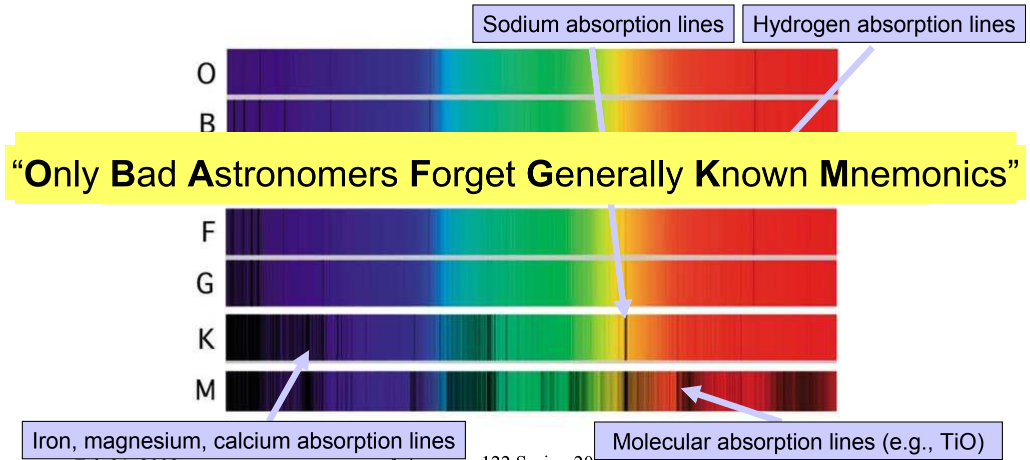
Stellar Spectra: Classification

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



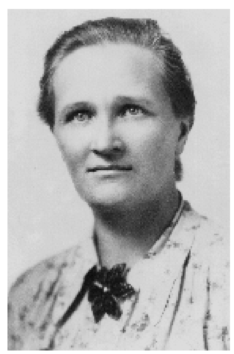
Spectral Classes

- Today, only 9 main classes (with sub-classes) based on spectrum lines
- Our Sun is a "G2" star



What do the spectra tell us?

- The spectra tell us about both the compositions and temperatures of the stellar atmospheres
- Astronomer Cecilia Payne found that most stars' compositions are very similar to the Sun's
- The spectral sequence is due to *temperature*, not composition
  - M & K stars are 92% hydrogen, but their photospheres aren't hot enough to excite it



Cecilia Payne

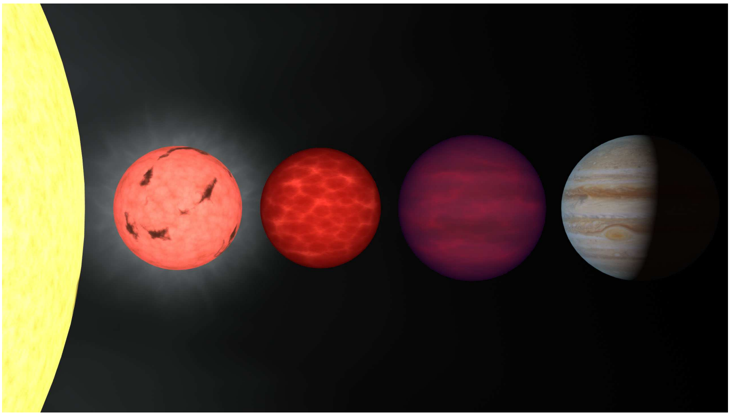
Properties of Spectral Classes

table 19-2 The Spectral Sequence

Spectral class	Color	Temperature (K)	Spectral lines	Examples
O	Blue-violet	30,000–50,000	Ionized atoms, especially helium	Naos (ζ Puppis), Mintaka (δ Orionis)
B	Blue-white	11,000–30,000	Neutral helium, some hydrogen	Spica (α Virginis), Rigel (β Orionis)
A	White	7500–11,000	Strong hydrogen, some ionized metals	Sirius (α Canis Majoris), Vega (α Lyrae)
F	Yellow-white	5900–7500	Hydrogen and ionized metals such as calcium and iron	Canopus (α Carinae), Procyon (α Canis Minoris)
G	Yellow	5200–5900	Both neutral and ionized metals, especially ionized calcium	Sun, Capella (α Aurigae)
K	Orange	3900–5200	Neutral metals	Arcturus (α Boötis), Aldebaran (α Tauri)
M	Red-orange	2500–3900	Strong titanium oxide and some neutral calcium	Antares (α Scorpii), Betelgeuse (α Orionis)
L	Red	1300–2500	Neutral potassium, rubidium, and cesium, and metal hydrides	Brown dwarf Teide 1
T	Red	below 1300	Strong neutral potassium and some water (H_2O)	Brown dwarf Gliese 229B

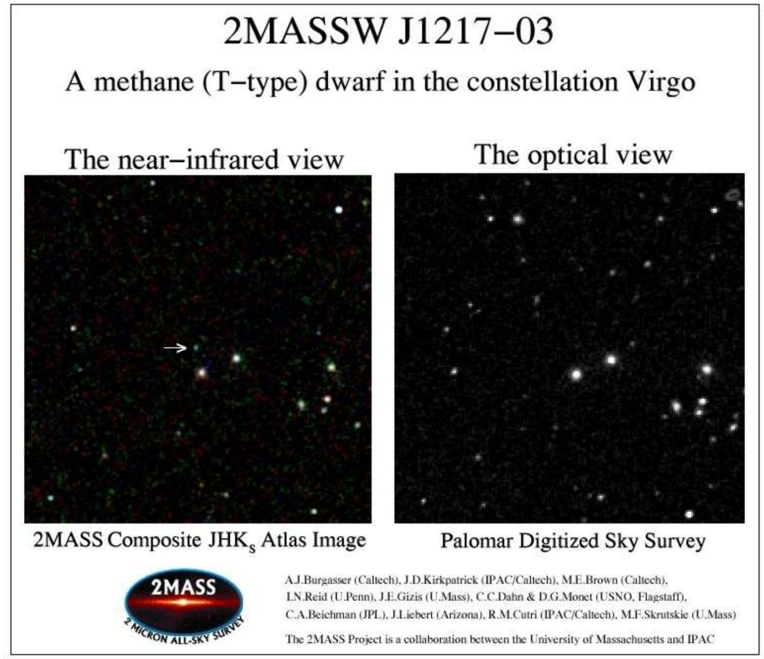
Brown dwarfs were added later. Very cool and very red – named L and T spectral classes. Brown dwarfs are too small to sustain fusion.

Dwarfs



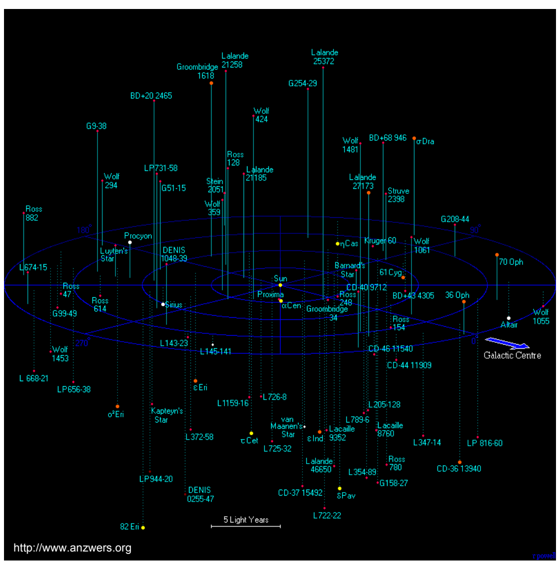
http://spider.ipac.caltech.edu/staff/davy/ARCHIVE/

T Dwarves



http://spider.ipac.caltech.edu/staff/davy/ARCHIVE/

Hot Stars Are Rare



A Census of stars within 20 lys	
2	Type A stars
1	Type F star
6	Type G stars
16	Type K Stars
75	Type M Stars
1	Type M Brown Dwarf
1	Type L Brown Dwarf
4	Type T Brown Dwarfs
6	White Dwarfs

Stellar Properties

- Apparent brightness
- Luminosity
- Distance
- Color
- Stellar spectra

The Mosquito Dilemma

- It's like a mosquito trying to understand humans.
- They don't live long enough to watch humans be born and die, so they have to extrapolate.
- How do we understand stars that live for 10 billion+ years?

http://news.uns.purdue.edu/html3month/2004/040823.Williams.fallwnv.html

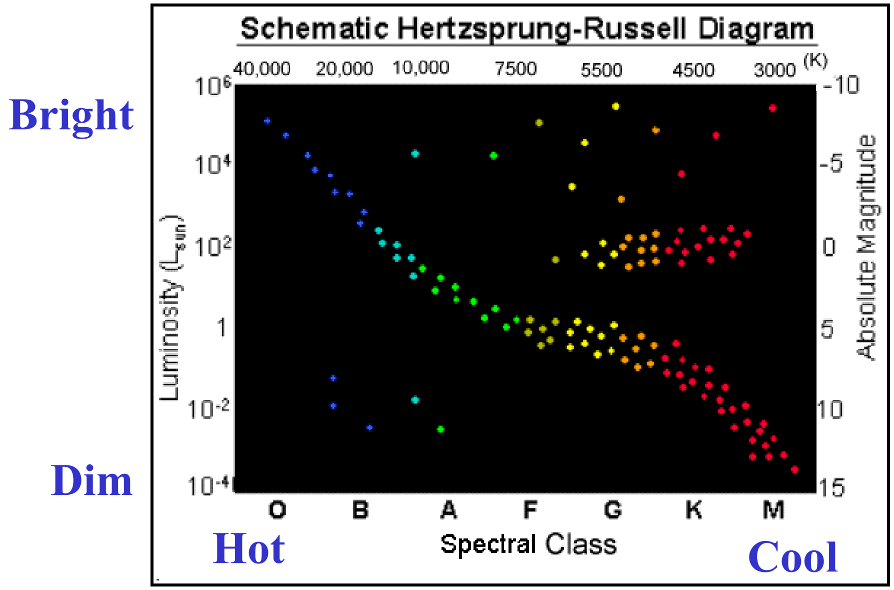
L and T

- We have the luminosity and temperature of stars.
- How do they correlate?
- Think about it.
- If we can have any L for any T, what do we expect?
- If only one L for one T, then what?

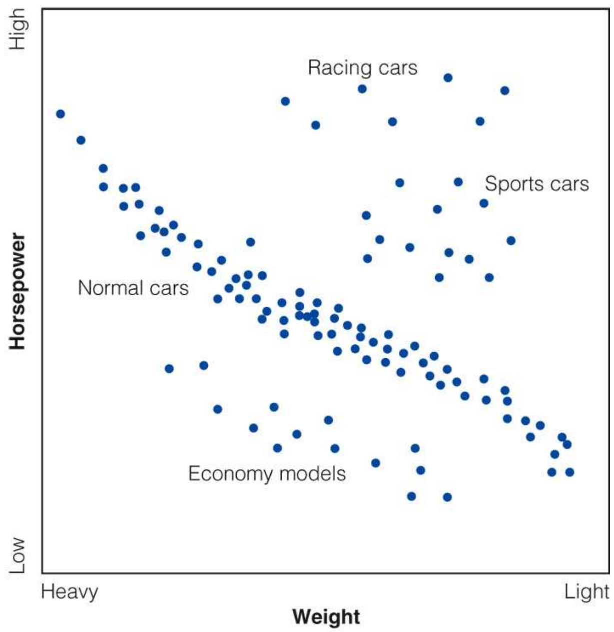
The H-R Diagram

- In the early 20th century, two astronomers plotted luminosity vs. temperature and found an interesting correlation in different regimes.
- It is not a random plot of points!
- The resulting plot is now named for them
- The **Hertzsprung-Russell Diagram**

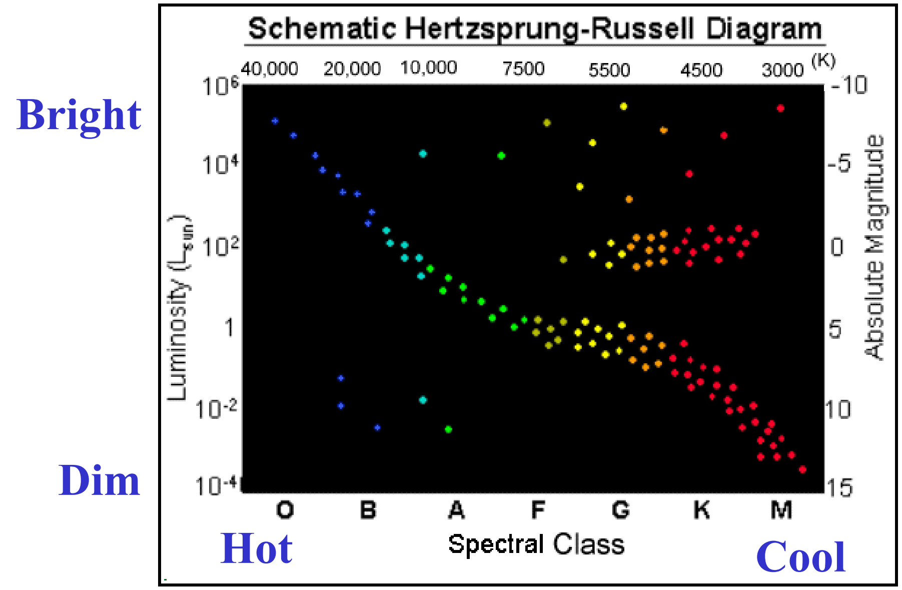
Hertzsprung-Russell Diagram



Compare to Cars

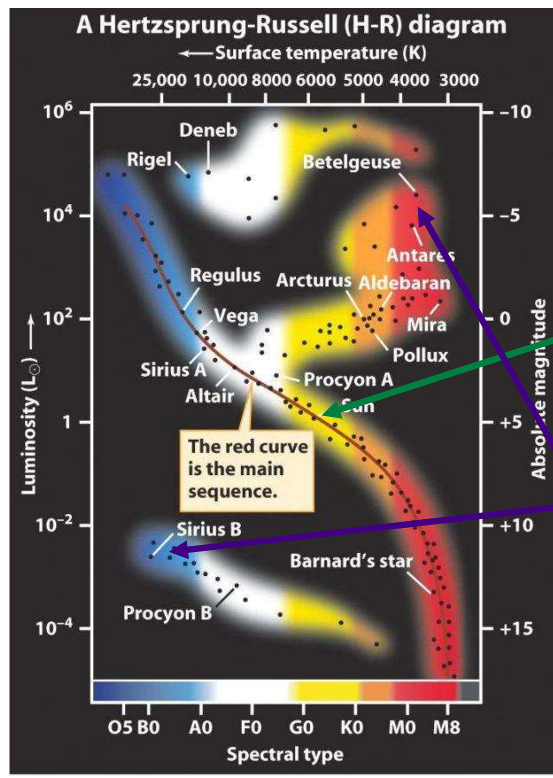


Hertzsprung-Russell Diagram



Family Jewels?

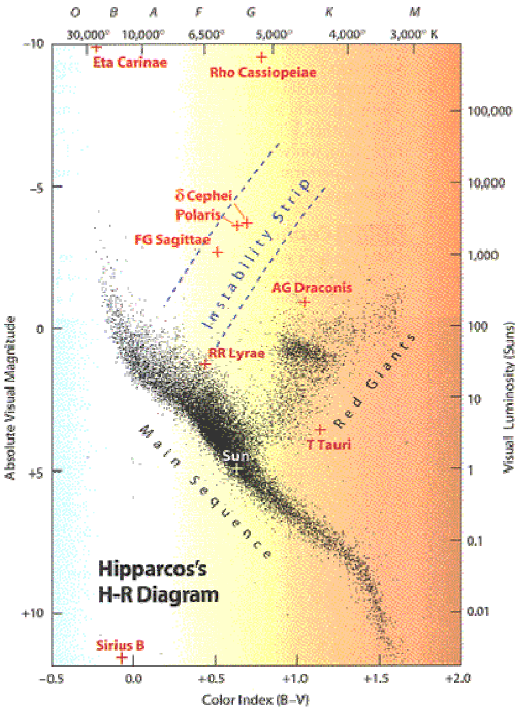
- The HR diagram can tell us a lot of information about stars, how they work, and how they die.
- It reveals the family secrets of the stars.



- Stars do not have random temperatures and brightness
- 91% of all stars are on the Main Sequence.
  - Why?
- But, there are also very bright cool stars and very dim hot stars

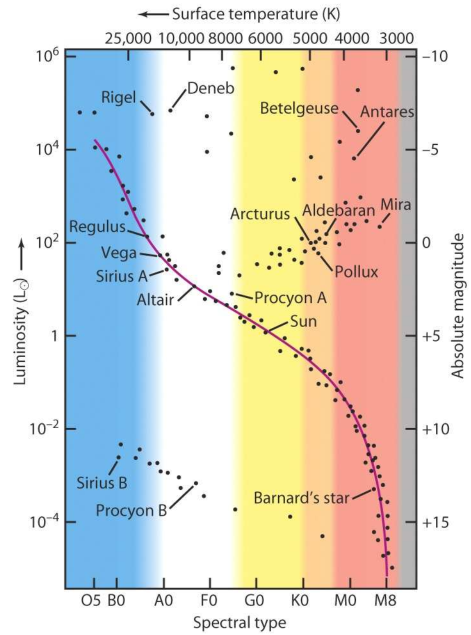
http://www.kosmologika.net/Stars/HR-fordelning_av_samplade_stjarnor.gif

A Real Example



- Notice the large number of stars on the main sequence.
- The Sun is very average.

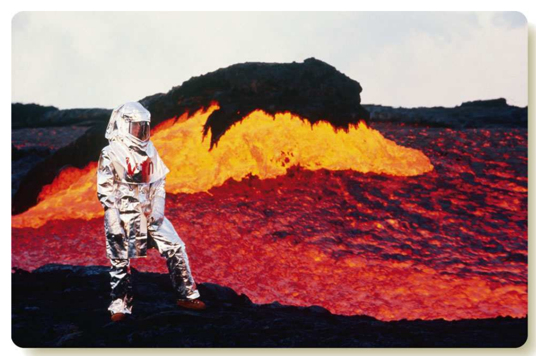
The H-R Diagram



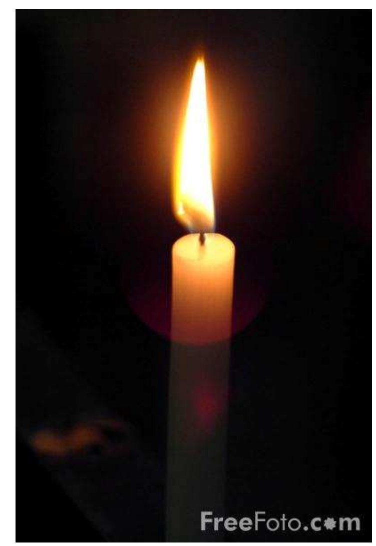
How does the size of a star near the top left of the H-R diagram compare with a star of the same brightness near the top right of the H-R diagram?

In Hawaii

Temperature and Surface Area



Which is hotter?



Luminosity and Size

$$L = 4\pi R^2 \sigma T^4$$

A star's intrinsic brightness (luminosity) depends on its temperature and its size.

A small hot star can be less bright than a huge cool star.

Luminosity

- Bright cool stars must be large
  - **Giants & Supergiants**
- Dim hot stars must be small
  - **White dwarfs**