Astronomy 150:
Killer Skies

This Class (Lecture 14):
The Aging Sun

Next Class:
The Dying Sun

HW4 due on Sunday!

Music: *See the Sun*– Dido

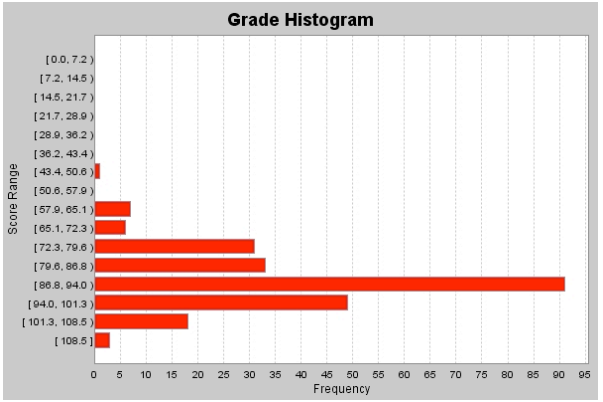
Exam 1

Good job!

Average = 88.9

Median = 90.8

If you aren't happy with your grade, remember I will take the higher of this grade and the final exam (section Exam1)



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 yet?

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 Lab: 15% of Grade!

- 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.

Question

Did you go to the Computer Lab on Monday?

a) Yes, it was very cool! I saw an NEA!
b) Yes, it was okay.
c) Yes, but it sucked.
d) No, I am going on Oct 5th.
e) No, I am going on Oct 12th.

Outline

- The HR Diagram– learning the secrets of the Stars!
- The Sun gets older and the Earth gets hotter.
- The Sun runs out of fuel
  - Red Giant!

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

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

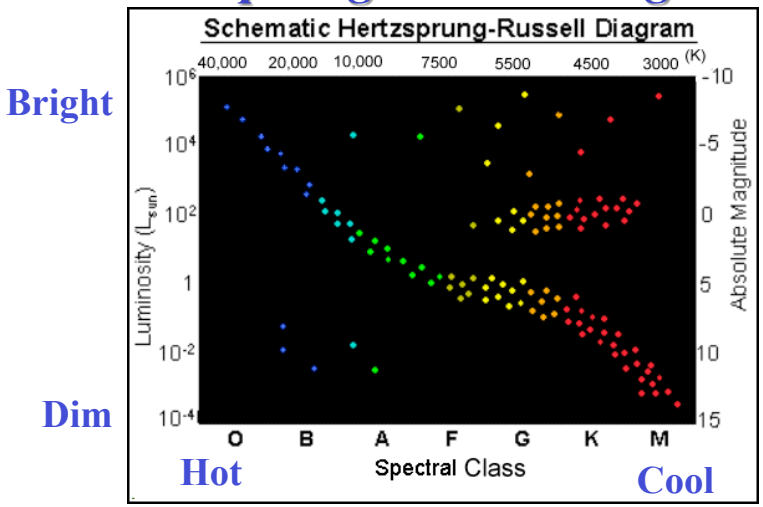
L and T

- We have the luminosity (brightness) 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?

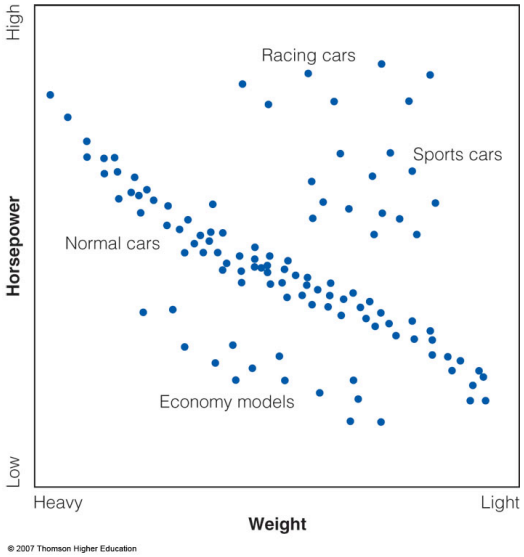
The H-R Diagram

- 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



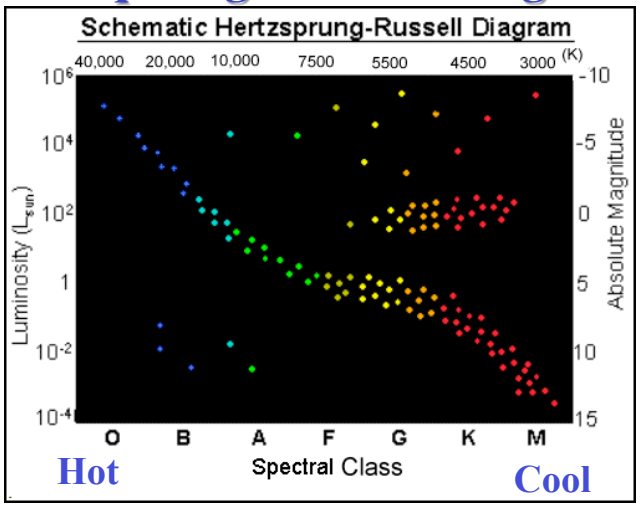
Compare to Cars



Hertzsprung-Russell Diagram

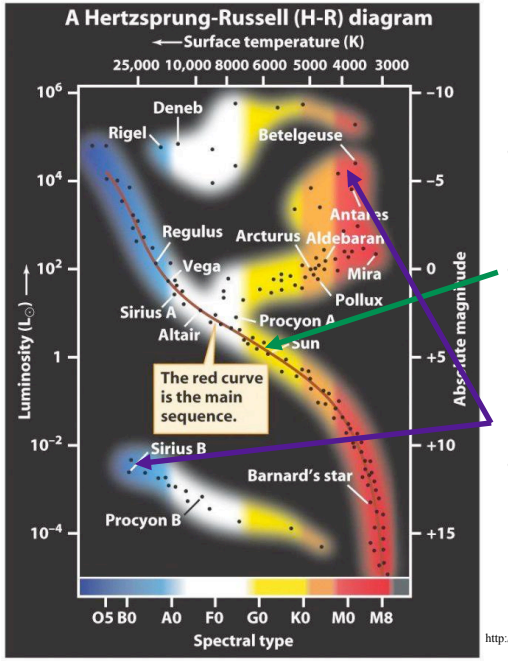
Bright

Dim



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?
  - Burning H into He
- But, there are also very bright cool stars and very dim hot stars

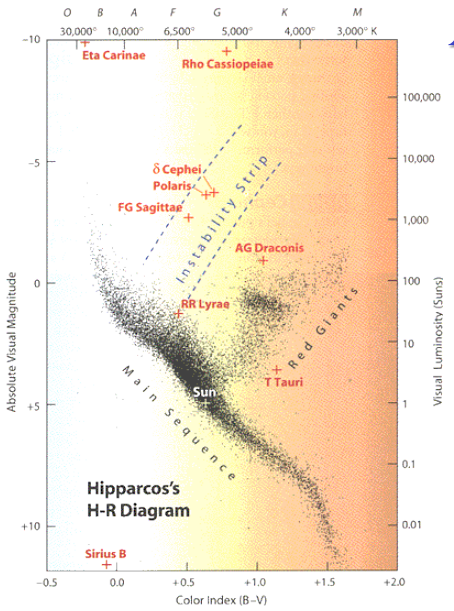
http://www.kosmologika.net/Stars/HR-fordelning_av_samplade_stjarnor.gif

Question

We can plot stars on the HR diagram. Is there correlations between luminosity and temperature?

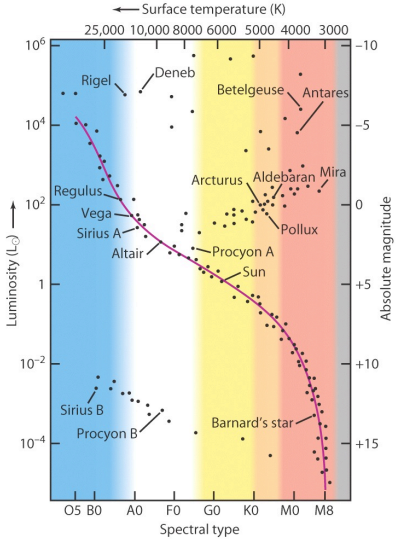
a) Yes
b) No

A Real Example



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

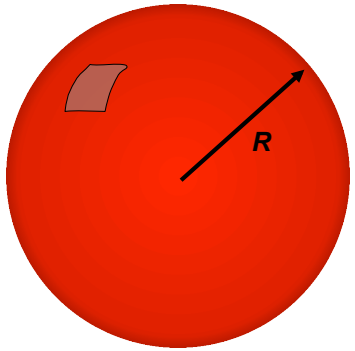
The H-R Diagram

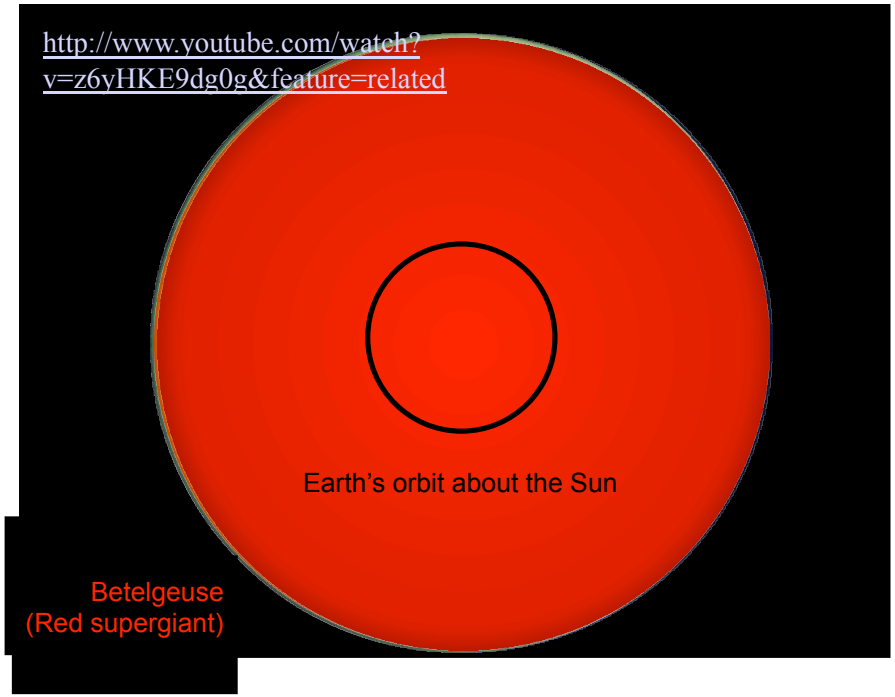


How does the size of a star near the top left of the H-R diagram compare with a star of the same brightness near the top right of the H-R diagram?

Luminosity

- Bright cool stars must be large (remember $L \sim R^2$)
  - **Giants & Supergiants**
- Dim hot stars must be small
  - **White dwarfs**





HR-ing It

http://www.youtube.com/watch?v=6hOAuyb4D7U

So the color (temperature) of a Star on the main sequence really tells us about the mass or size of the Star. Warning: only on the main sequence!

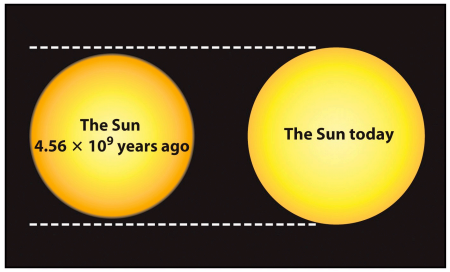
Off the main sequence, it depends…

What does the HR Diagram Tell us?

- By observing the number of stars on the main sequence and those off, we have come to understand how stars die.
- Both low-mass and high-mass, but for now, we are interested in only the Sun-like stars.
- As all stories go, it ends when the fuel runs out.
- We the Sun runs out of gas (hydrogen), it will leave the main sequence, but even now it has changed over its 4.6 billion years.

Life of a Low Mass (Sun-like) Star

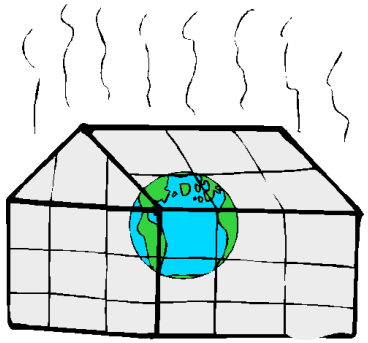
- Most of its life is spent in the happy pursuit of burning H ⇒ He
- With time, luminosity and temperature evolve gradually in response
  - Stays on the Main Sequence, but still evolves..
- The Sun is now 40% brighter and 6% bigger than zero age MS.



http://wings.avkids.com/Book/Myth/Images/ocean_sun.gif

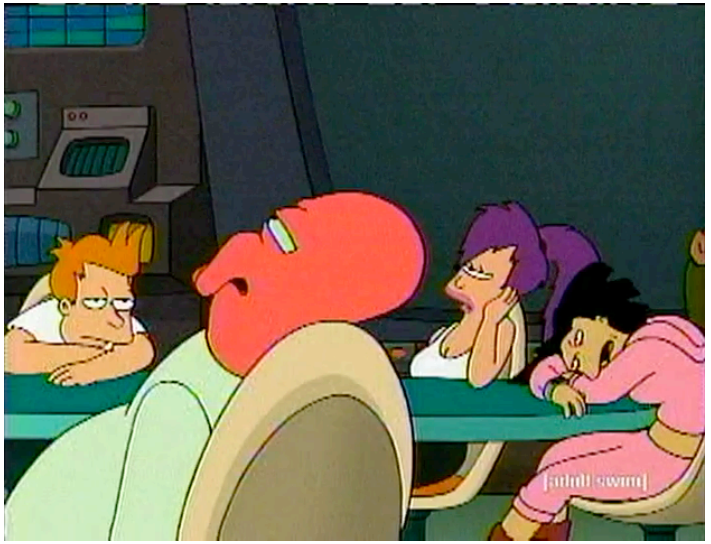
Life of Our Sun

- Over the next billions of years, our Sun will continue to increase in luminosity.
- So in 1+ billion years, our Sun will be 10% more luminous.
- This will cause a "moist" greenhouse effect adding 10 degrees F to the average temp.



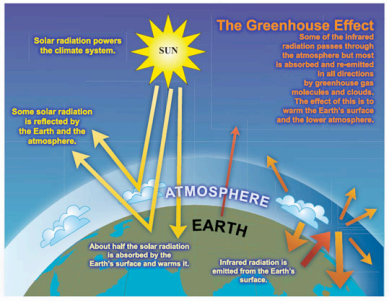
http://www.solcomhouse.com/Greenhouse_Effect.gif

Greenhouse Effect Explained



Converting Light into Heat

- Greenhouse gases (water, CO^2, etc.) trap heat
- Release heat back to Earth, so less heat lost to space
- Without greenhouse gases in our atmosphere, Earth average temperature would only be -14C (0F), instead of 14C (57F)
- But, humans are putting extra greenhouse gases into atmosphere, so Earth is getting warmer, but in this case the Sun is adding heat directly!



http://andrian09.files.wordpress.com/2008/12/greenhouseeffectdiagram.jpg

Life of Our Sun

- This increase in total energy will have a major impact on the Earth!
  - Ice caps melt
  - Costal regions flood
  - Equator becomes inhabitable
  - Antarctica becomes warm

http://changeyourways.wordpress.com/2009/06/12/what-on-earth/

Question

As the Sun evolves on the main sequence, it will

a) turn into a Red giant.
b) get brighter
c) get dimmer
d) turn into 100% helium
e) turn into a white dwarf.

Life of Our Sun

- Increased temperature means that the lighter elements, like water molecules in the air, will have enough speed to escape Earth completely.
- The water of Earth begins to pack up and leave!
- In 1.1 billion years, the continents will be deserts and the oceans are beginning to evaporate.

http://www.esquire.com/cm/esquire/images/Gd/desert-1108-lg.jpg

Life of Our Sun

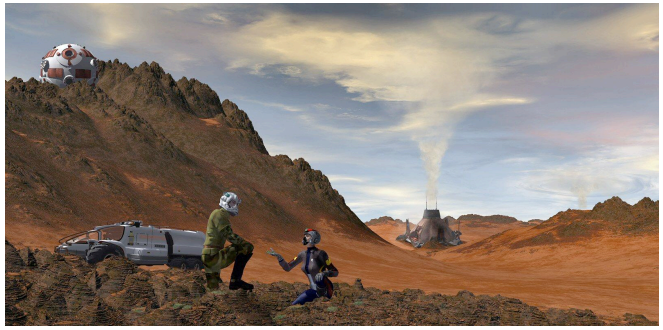
- As the Sun, uses up the hydrogen in the core, the Sun increases by 40% in brightness in 3.5 billion years.
- By that time, all of the oceans are gone!
- The baking sediments at the bottom of the oceans, release CO2
- Earth will become Venus-like!
- Then the heat makes even those heavier molecules leave the Earth.
- The Earth will be a barren rock in about 4 billion years!

http://wings.avkids.com/Book/Myth/Images/ocean_sun.gif

Mitigation

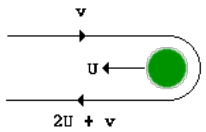
1. Move the population
   - I hear that Mars could be a nice place to live.
   - Need to terraform Mars, which could take a while.

http://www-cache.daz3d.com/sections/contests/upload_files/3195.jpg



Mitigation

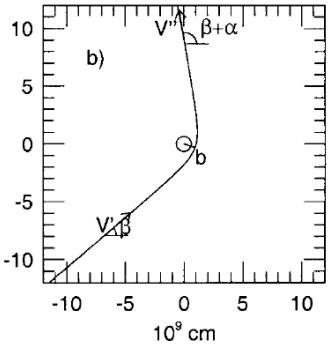
2. Move the Earth
   - There is no place like home, so move it to a nicer place, farther away from the Sun.
   - Use gravity assist or the sling shot technique.



http://upload.wikimedia.org/wikipedia/commons/8/8e/Grav_slingshot_simple_2.gif

Mitigation

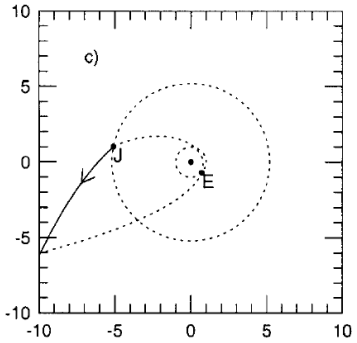
2. Move the Earth
   - Asteroids to the rescue?
   - Move many large asteroids in front of the Earth, sends them toward the Sun and the Earth outwards.
   - Need to do this every 6000 years to make Earth survive until the Sun hits the Red Giant phase.



Korycansky et al. 2001

Mitigation

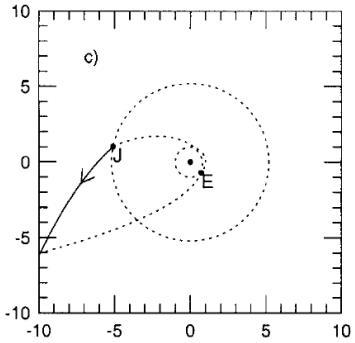
2. Move the Earth
   - For billions of years!
   - We don't have enough large asteroids.
   - We'll have to recycle.
   - The idea is to transfer energy from Jupiter's orbit to Earth's orbit.



Korycansky et al. 2001

Mitigation

2. Move the Earth
   - Could keep us safe for a good 6 billion years!



Korycansky et al. 2001