# Astronomy 330

This class (Lecture 7):

Why does the Sun Shine?

Next Class:

Making C, O, and N

**HW2 due Wednesday.**

Music: *Sonne*– Rammstein

# Presentations

- The presentation schedule has been decided by random selection.
- It is posted in the schedule section of the webpage.
- Make sure to check those dates ASAP.

# *Iclicker Grades!*

- Iclicker grades are posted.
- Check them now!
- If you don't have a grade, then assume that something is wrong and contact me ASAP.
- If you don't you may not be able to get those grades back!
- Go to link on syllabus to register your clicker.


# Outline

- We are elements
- Why does the Sun shine?

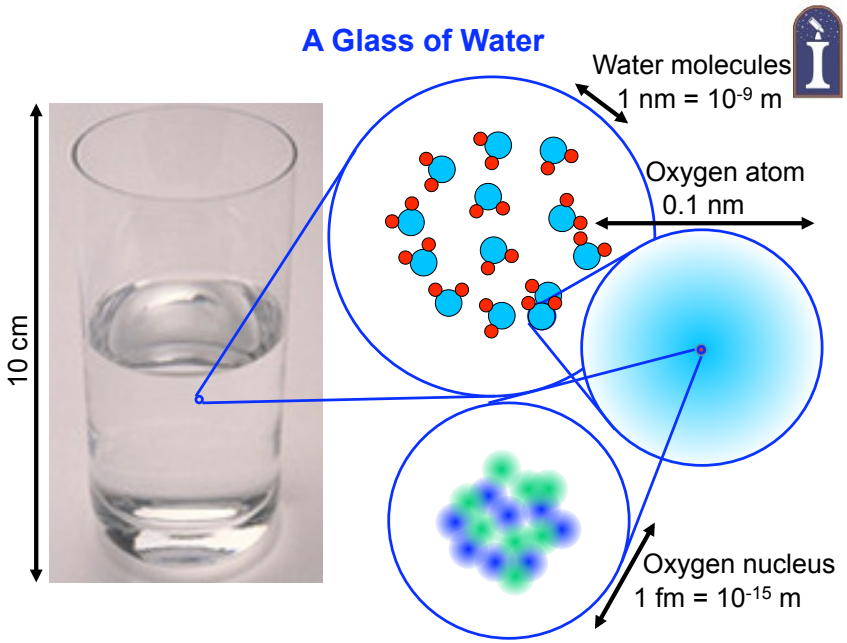
# Drake Equation HW #1 Result

= 50

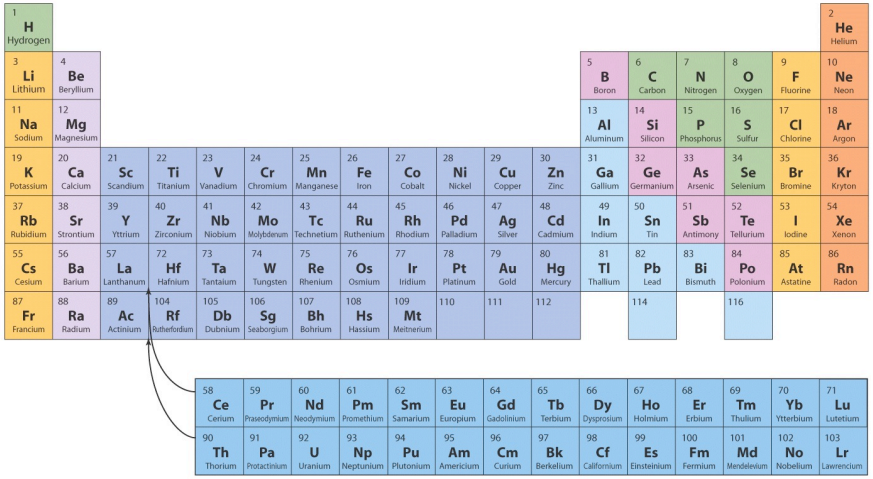
N =

# of advanced civilizations we can contact in our Galaxy today

## A Glass of Water



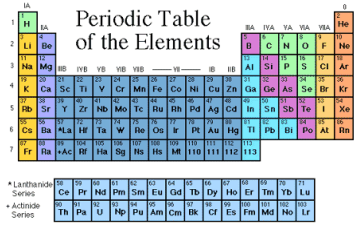

## The Periodic Table of the Elements




The number of protons in an atom determines the type of element, and the number of protons and neutrons determine the atomic weight.

# Chemical Basis for Life

- The average human has:
  - 6 x $10^{27}$ atoms (some stable some radioactive)
  - During our life, $10^{12}$ atoms of Carbon 14 ($^{14}C$) in our bodies decay.
  - Of the 90 stable elements, about 27 are essential for life. (The elements from the Big Bang are not enough!)




http://www.genesismission.org/science/mod2_aei/

# Chemical Basis for Life

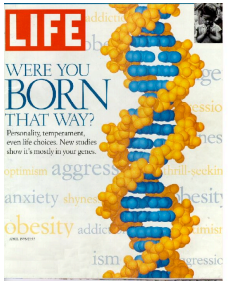
- Life on Earth is mostly:
  - 60% hydrogen
  - 25% oxygen
  - 10% carbon
  - 2% nitrogen
  - With some trace amounts of calcium, phosphorous, and sulfur.
- The Earth's crust is mostly:
  - 47% oxygen
  - 28% silicon

By Number…

- The Universe and Solar System are mostly:
  - 93% hydrogen
  - 6% helium
  - 0.06% oxygen
  - 0.03% carbon
  - 0.01% nitrogen

# Little Pink Galaxies for you and me

- Life as we know it, needs more elements than the Big Bang could provide.
  - Composition of life is unique.
- Does the environment of the Galaxy nourish life?
- At the vary least we need galaxies to process the material from the Big Bang into materials that life can use.
- The Universe does this through star formation.




http://www.chromosome.com/lifeDNA.html

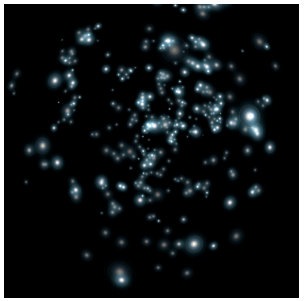
# Question

What can say about the elemental make-up of life on Earth, the Earth, and the Universe?

a) All three are made up of the same elements in the same amounts.
b) The Universe is mostly hydrogen, but the Earth and life on Earth are mostly carbon.
c) The Earth and the Universe are mostly hydrogen.
d) Life on Earth and the Universe are mostly carbon.
e) They are made up of the same elements but very different concentrations.

# The First Stars

- From the initial seeds of the Big Bang, our local group of galaxies probably broke into clumps of hydrogen and helium.
- First Stars may have formed as early as 200 million years after the Big Bang.
- Probably more massive than stars today, so lived quickly and died quickly.
- What happened? Why did this "raw" gas form anything?



http://www.blackshoals.net/ImageBank/gallery/gallery/huge/The-first-stars-clustering.jpg

# Water Power?

- Does a bottle of water have any stored energy? Can it do work?

The water has potential energy. It wants to flow downhill. If I pour it out, the conservation of energy tell us that it must turn that potential energy into kinetic energy (velocity). The water wants to reach the center of the Earth. This is how we get hydro energy from dams.

# Gas powered

- Similar to my bottle of water, these initial gas clumps want to reach the center of their clump-ness.
- The center gets hotter and hotter. The gravitational energy potential turns into heat (same as velocity actually).
- It is a run-away feature (or snowballing), the more mass at the center, the more mass that wants to be at the center.
- The center of these clumps gets hotter and denser.

http://www.rob-clarkson.com/duff-brewery/snowball/04.jpg

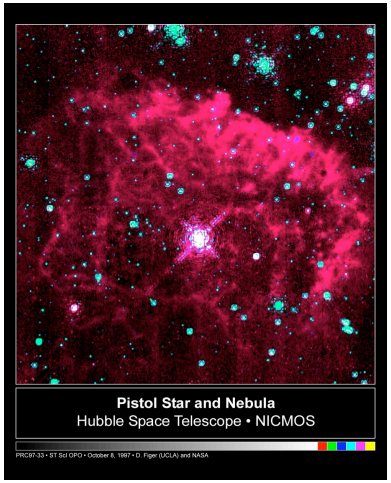
# Cooking with Gas

- For the first time, since 1-month after the Big Bang, the centers of the clumps get above $10^7$ K.
- Now hot enough for nuclear fusion to occur. If that had not happened, life would never have existed.
- But are things different than what we learned in Astro 100? These are the First Stars after all.

http://lgeku.energyunderground.com/images/images-deepearth/BURNERBL.jpg

# The Most Massive Star in the Milky Way Today

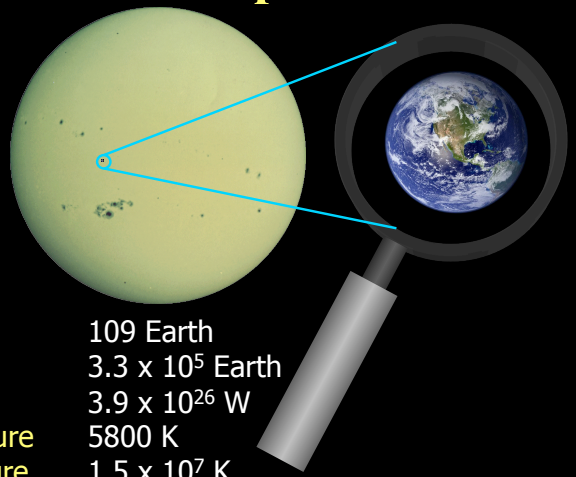
- The Pistol star near the Galactic center started as massive as 200 solar masses.
- Releases as much energy in 6 seconds as the Sun in a year.
- But it blows off a significant fraction of its outer layers.
- How did the first stars stay so massive?
- Perhaps they are slightly different than this case?




http://www.u.arizona.edu/~justin/images/hubblepics/full/PistolStarandNebula.jpg

# Earth-Sun Comparison

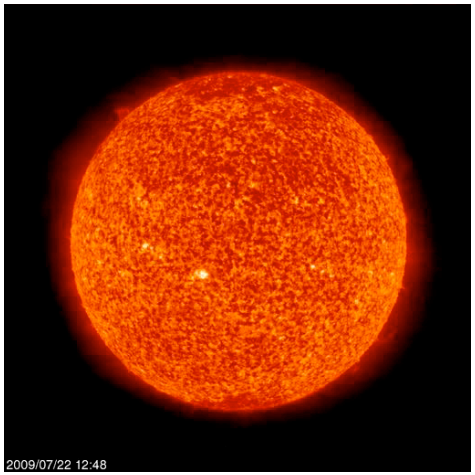
In general, a very typical star. Keep in mind that it is really a ball of gas.



| | |
|---|---|
| Visual radius | 109 Earth |
| Mass | $3.3 \times 10^5$ Earth |
| Luminosity | $3.9 \times 10^{26}$ W |
| Surface temperature | 5800 K |
| Central temperature | $1.5 \times 10^7$ K |
| Rotation period | 25 days |

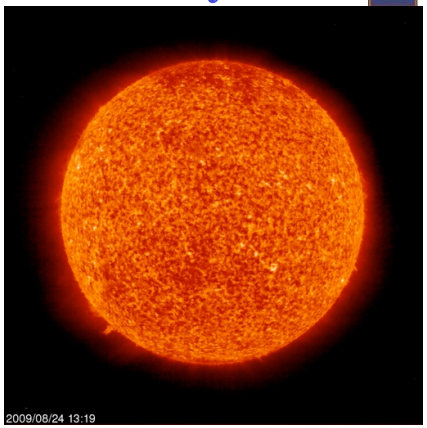
# *LIVE from the Sun*

http://sohowww.nascom.nasa.gov/data/realtime/mpeg/




# Question of Stability

- The Sun's size is constant.
- No weatherman says it will be especially hot tomorrow as the Sun's size will be increasing.
- Not expanding or collapsing.
- The Sun is stable! Why?

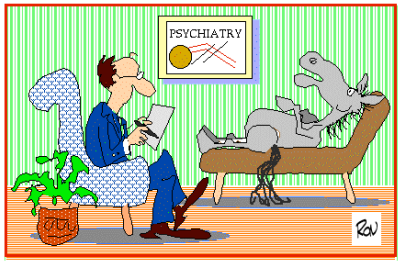



http://sohowww.nascom.nasa.gov/data/realtime/eit_304/512/

http://www.londonstimes.us/toons/index_medical.html

# Question of Stability

- Not trivial, could have gone the other way
- Think: Sun is made of gas, yet not like a cloud, for example, which is made of gas but size, shape changes all of the time
- Not a coincidence: really good reason




"I just don't feel stable."

http://www.londonstimes.us/toons/index_medical.html

# Why is the Sun Stable?

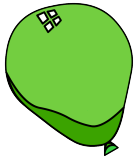
- What keeps gravity from collapsing the Sun?
- What keeps the Sun from exploding?

# Pressure

- What is pressure?
  - Pressure $= \frac{Force}{Area}$

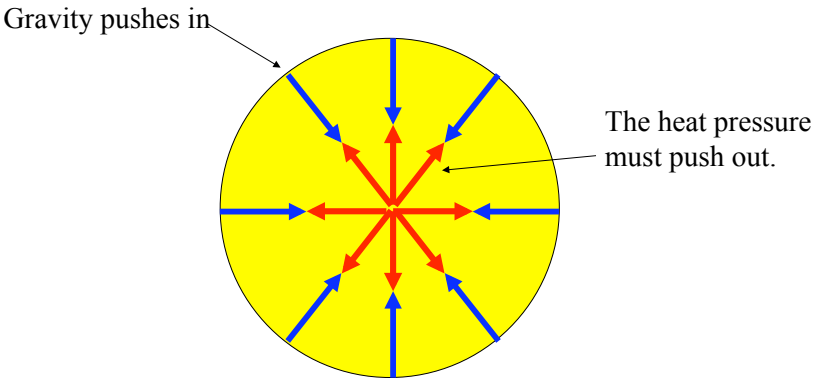
Pressure of Earth's atmosphere is 14.7 pounds per square inch

- Explain blowing up a balloon?



- http://www.phy.ntnu.edu.tw/java/idealGas/idealGas.html

## The Battle between Gravity and Pressure




Hydrostatic equilibrium: Balanced forces

# Question

A star is in hydrostatic equilibrium. What does that mean?

a) Keeps the Sun burning H into He.
b) Keeps the Sun from turning into a big cloud in the shape of a bunny.
c) Keeps the Sun a flattened disk.
d) Keeps the Sun a constant size.
e) Keeps the Sun unstable.

# The Sun's Energy Output

3.85 x $10^{26}$ Watts, but how much is that?

A 100W light bulb…

…the Sun could supply 4 x $10^{24}$ light bulbs!

U.S. electricity production in 2006: 4.1 trillion kWh…

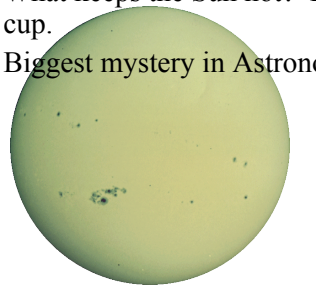
… Sun = 3 x $10^{7}$ times this *every second*

World's nuclear weapons: 3 x $10^{4}$ megatons…

… Sun = 4 million times this *every second*

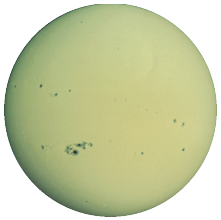
# So, What Powers the Sun?

- The Sun does not collapse nor even change it's radius.
- Gravity pushes in, but what pushes out?
  - Okay, heat, but what makes the heat?
- What is its power source?
- What keeps the Sun hot? It doesn't cool like a hot coffee cup.
- Biggest mystery in Astronomy up until 20th century.




# How to Test?

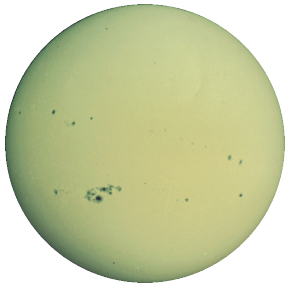
- Without an energy source, the Sun would rapidly cool & contract
  - Darwin: evolution needs Sun & Earth to be > $10^{8}$ years old
  - Lyell: geological changes also need > $10^{8}$ years
- Process must be able to power Sun for a long time! At least 4.5 Byrs.



# So, What Powers the Sun?

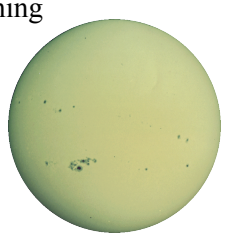
Discuss with neighbors possible heating possibilities. List at least 2 possibilities, even if you know the correct one. List all feasible ideas.

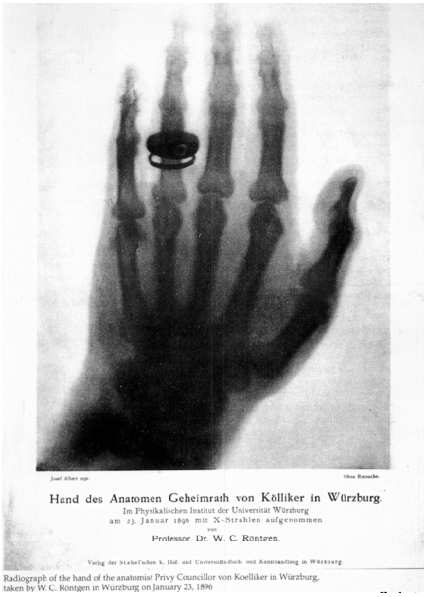
Then, click B on your iclicker.



# How to Test?

- Gravity:
  - Seems like a good idea. Remember Jupiter gives off heat.
  - A contracting Sun releases gravitational energy.
  - But only enough for 20 million years
- Chemical:
  - If the Sun was made from TNT, something that burns very well, then it would last for only 20,000 years
- Need something more powerful!





Radiograph of the hand of the anatomist Privy Councillor von Koelliker in Würzburg, taken by W. C. Röntgen in Würzburg on January 23, 1896

**Eyes began to turn to the nuclear processes of the Atoms**

# What is Fusion?

$$4\,p \rightarrow {}^{4}\mathrm{He}\ (2p,2n)$$

Basic idea is to take 4 protons (ionized hydrogen atoms) and slam them together to make an ionized helium atom.