

Astronomy 330



This class (Lecture 7):

Why does the Sun Shine?

Next Class:

Making C, O, and N

HW2 due Wednesday.

Music: *Sonne*– Rammstein

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.



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.

Outline



- We are elements
- Why does the Sun shine?

Drake Equation HW #1 Result

= 50

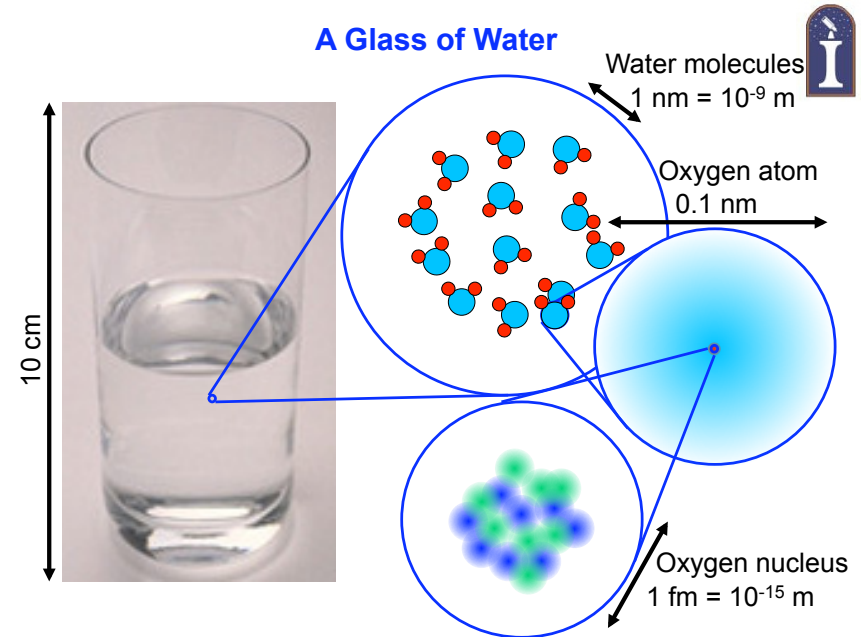


N =

of
advanced
civilizations
we can
contact in
our Galaxy
today



A Glass of Water



The Periodic Table of the Elements

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																							



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!)

Periodic Table of the Elements																					
1 H																	2 He				
3 Li	4 Be															5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg															13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr				
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe				
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn				
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110	111	112	114	116								

* Lanthanide Series	58	59	60	61	62	63	64	65	66	67	68	69	70
	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb
* Actinide Series	90	91	92	93	94	95	96	97	98	99	100	101	102
	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No

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

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



By Number...

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

Question



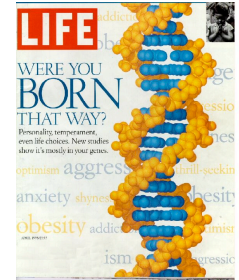
What can say about the elemental make-up of life on Earth, the Earth, and the Universe?

- 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.

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 very 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.

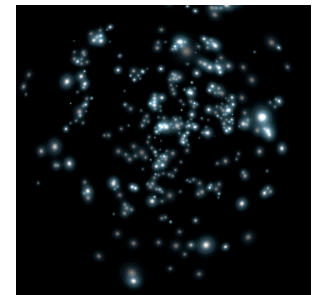


<http://www.chromosome.com/lifeDNA.html>

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.

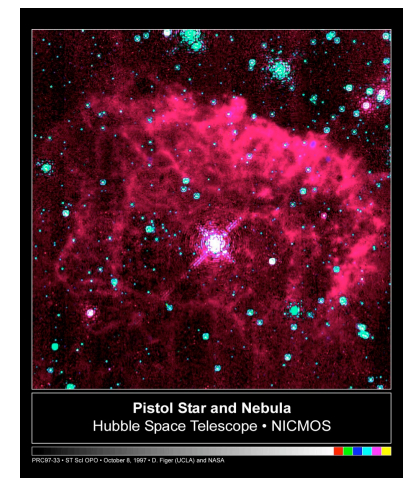


<http://lgeku.energyunderground.com/images/images-deepearth/BURNERBL.jpg>

The Most Massive Star in the Milky Way Today



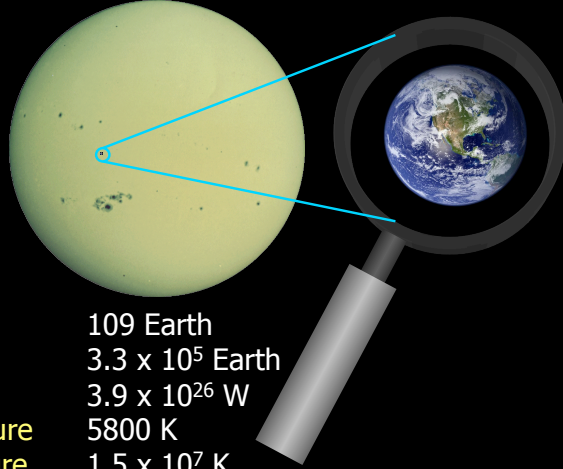
- The Pistol star near the Galactic center started as massive as 200 solar masses.
- Releases as much energy in 6 seconds as the Sun in a year.
- But it blows off a significant fraction of its outer layers.
- How did the first stars stay so massive?
- Perhaps they are slightly different than this case?



<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.

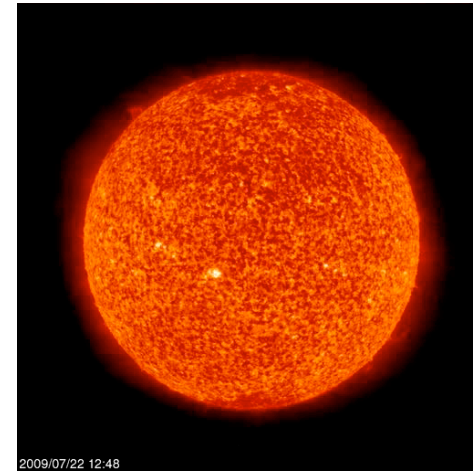


Visual radius
Mass
Luminosity
Surface temperature
Central temperature
Rotation period

109 Earth
 3.3×10^5 Earth
 3.9×10^{26} W
5800 K
 1.5×10^7 K
25 days

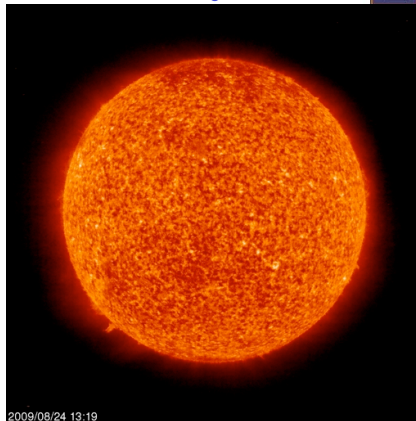
LIVE from the Sun

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



Question of Stability

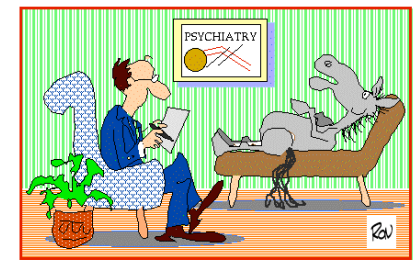
- The Sun's size is constant.
- No weatherman says it will be especially hot tomorrow as the Sun's size will be increasing.
- Not expanding or collapsing.
- The Sun is stable! Why?



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

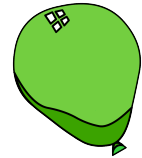


- What is pressure?

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

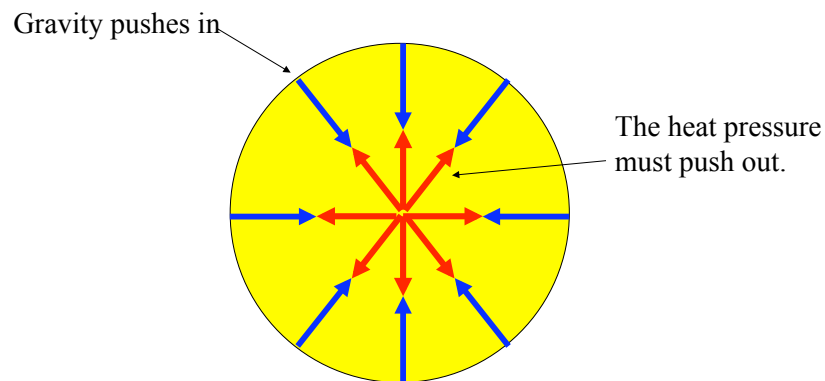
Pressure of Earth's atmosphere is 14.7 pounds per square inch

- 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?

- Keeps the Sun burning H into He.
- Keeps the Sun from turning into a big cloud in the shape of a bunny.
- Keeps the Sun a flattened disk.
- Keeps the Sun a constant size.
- Keeps the Sun unstable.

The Sun's Energy Output



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

A 100W light bulb...

...the Sun could supply 4×10^{24} light bulbs!



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



... Sun = 3×10^7 times this *every second*

World's nuclear weapons: 3×10^4 megatons...

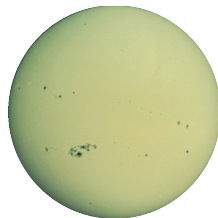
... Sun = 4 million times this *every second*



How to Test?



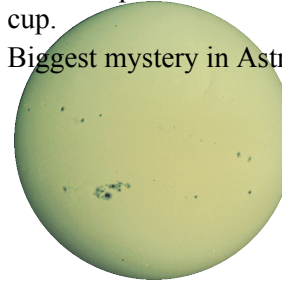
- Without an energy source, the Sun would rapidly cool & contract
 - Darwin: evolution needs Sun & Earth to be $> 10^8$ years old
 - Lyell: geological changes also need $> 10^8$ years
- Process must be able to power Sun for a long time! At least 4.5 Byrs.



So, What Powers the Sun?



- The Sun does not collapse nor even change its 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.

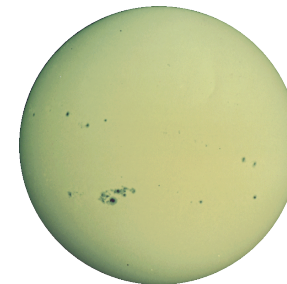


So, What Powers the Sun?



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

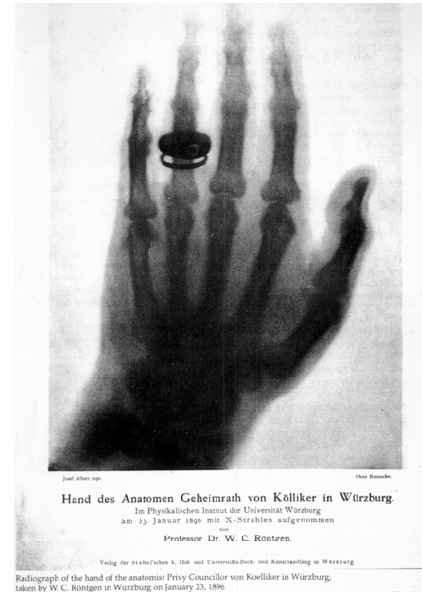
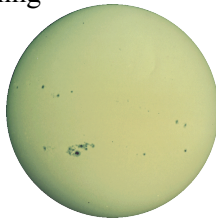
Then, click
B on your
iclicker.



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!



Eyes began to
turn to the
nuclear
processes of the
Atoms

What is Fusion?



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