ET: Astronomy 230

Section 1– MWF 1400-1450

134 Astronomy Building

HW #3 is due today.

This Class (Lecture 13):

Nature of Life

Next Class:

Andrew Coughlin
Nicolas Jaramillo
Chris Fischetti

Presentations Monday
Andrew Coughlin
Nicolas Jaramillo
Chris Fischetti

Presentations Wednesday
Jeremey Grimaldi
Michael Yurgil
Tianxiao Ma

Music: *Blackhole Sun* – Soundgarden

Outline

- What is n_e?
  - Broken into 2 terms.
- Life on Earth.
- Protein and Nucleic acids are the two main polymers of life.

Drake Equation

= 3.8

Planetary systems /year

Earth Chauvinism?

Frank Drake

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

# of advanced civilizations we can contact in our Galaxy today	Rate of star formation	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	10 stars/ yr	0.38 systems/ star	planets/ system	life/ planet	intel./ life	comm./ intel.	yrs/ comm.

$$n_e = n_p \times f_s$$

n_p: number of planets suitable for life per planetary system

The class value (median) was $n_p = 1$!

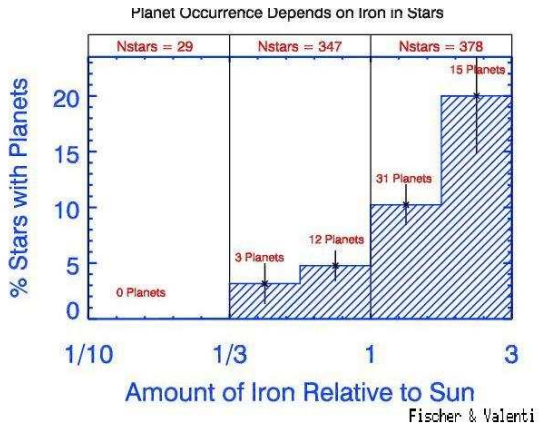
f_s: fraction of stars whose properties are suitable for life to develop on one of its planets

- We can list 5 situations that will have an effect on f_s.

http://nike.cecs.csulb.edu/~kjl/vic/Wallpapers/Planets%2001.jpg

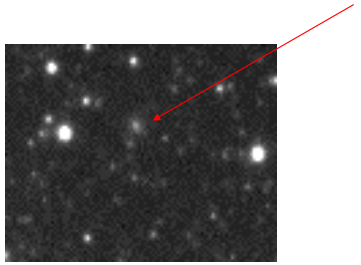
Differences of Stars to Life

1. **Metal rich stars**. Stars with heavy elements, probably more likely to have planets. Suggested in the current planet searches. About 90% of all stars have metals.



Differences of Stars to Life

2. **Main sequence stars**. Need the brightness to stay as constant as possible. Otherwise the temperature changes dramatically on the planets. This is 99% of all stars.

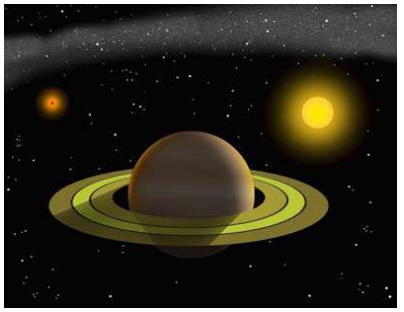


Differences of Stars to Life

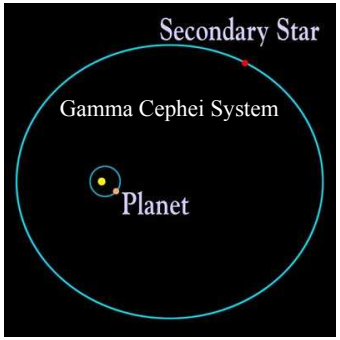
3. **Length of time on the main sequence**. We need temperature stability for 5 billion years to get intelligence on Earth. This rules out stars more massive than 1.25 solar masses! 90% of all stars are less massive than that.
4. **Minimum mass of star**. If ice exists close to the star, that would imply the formation of Jupiter-like planets not Earth-like planets. And, any life bearing planet would have to be closer to the star– and closer to stellar effects (e.g. tidal locking and more flares from low mass stars). That limits us to a minimum of 0.5 solar masses, about 25% of all stars.

Differences of Stars to Life

5. **Binarity**. Planets may form. But they may have odd orbits unless the 2 stars are far enough apart or the planet orbits the pair. Only 30% of all stars are single stars. 50% of all stars are single stars or wide binary stars.



http://spaceflightnow.com/news/n0210/11planet/



Adding it all up

	Stellar Requirement	*Mass Limit*	*Fraction OK*	*Cumulative Fraction*
✓	Heavy Elements	…	0.9	0.9
✓	Main Sequence	…	0.99	0.891
	Main Sequence Lifetime	$M < 1.25\ M_{sun}$	0.90	
	Synchronous Rotation/ Flares	$M > 0.5\ M_{Sun}$	0.25	
✓	Not a Binary	…	0.30	0.267
	Wide Binary Separation	…	0.50	

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f_s

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So Far, We have Studied

- The Universe
  - Big Bang
    - Creation of hydrogen, helium…
  - Galaxy formation
    - Swirls of elements embedded in self-gravitating cloud of dark matter
  - Star birth
    - Energy generation and element production in self-gravitating mass of gas
  - Planets
    - Ice, rock, gas surrounding star form planetesimals, then planets

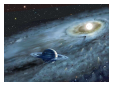
Drake Equation

= ?

Earthlike planets /year

Frank Drake








$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

N	R_*	f_p	n_e	f_l	f_i	f_c	L
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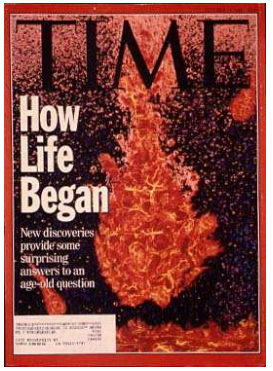
Life on Earth

- Time to examine terrestrial evolution.
- Need to understand what is needed for life to arise.
- Again, some Earth chauvinism.
- Relies on chemical evolution
- Eventually life began?



http://www.accessexcellence.org/bioforum/bf02/awramik/bf02a1.html

Life on Earth

- In our scientific approach, we look at life as a result of chemical evolution of complexity.
- We will view the formation of "life" on planets as we did star formation
  - A natural consequence of natural laws
  - More specifically, as a consequence of the complex chemistry that is sometimes achieved.

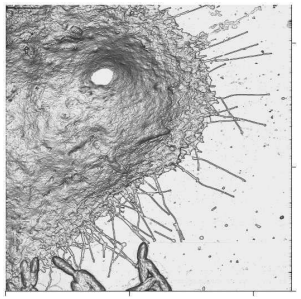
http://www.toothpastefordinner.com/052802/science-only-happens.gif

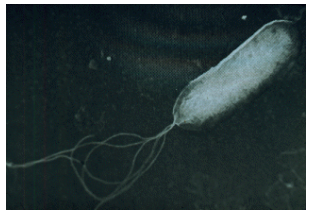
Cosmic Imperative?

- But is life a cosmic imperative?
- Just like gas forms galaxies, and in galaxies stars and planets form, do chemicals on some planets form molecules that lead to life?

All Made from the Same Stuff





Element Basis of Life

- About 95% of the mass of all terrestrial organisms is composed of only 4 out of 90 elements
  - **H**ydrogen (61% in humans)
  - **O**xygen (26% in humans)
  - **N**itrogen (2.4% in humans)
  - **C**arbon (10.5% in humans)
- **HONC** is essential to life, and it's common in space.

Trace Elements

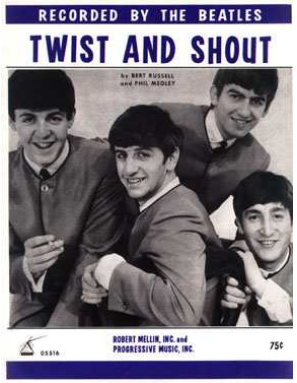
In addition to HONC, there are some other elements that are essential for life but in *smaller* amounts:

- Sulfur, magnesium, chlorine, potassium, sodium
  - These other elements make up about 1% of mass of living organisms
  - Exist in roughly the same concentration in organisms as in ocean water
  - Highly suggestive that life began in oceans
  - Furthermore suggests that the evolutionary processes occurred on Earth. Panspermia problems?

http://www.maxxiweb.com/pics/wallpapers/paysages/oceans-006.jpg

Good News

- H,O,N,C is very common in universe everywhere as far as we can tell
  - If life were based totally on rare elements, we might expect its occurrence to be extremely rare…
- So, we expect ET life to be based primarily on HONC.
  - The four primary chemical elements of life with some other simple components can produce staggering complexity.
- But, each planet will feature its own environment of trace elements giving each planet's life a unique twist to the standard HONC chemistry



http://www.rarebeatles.com/sheetmu/smtwist.jpg

Nature's Complexity

- The workings of biological molecules are an absolute marvel
  - How did this complexity develop?
  - How did it evolve?
- As complex and mysterious as life on Earth may be, we can begin understand it
- Start with the basics:
  - Why are H,O,N,C the basis for living organisms?
  - How do the molecules formed by these (and other elements) work to make DNA, proteins, life?

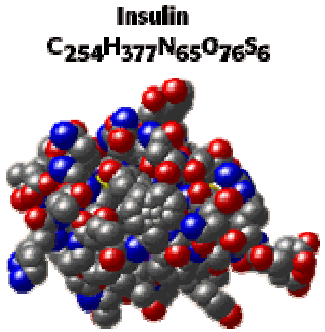
http://europa.eu.int/comm/environment/life/toolbox/logo_life_high_resolution_2.jpg

We Are Special Stuff?

- Why is Earth life based on H,O,N,C instead of the more abundant elements found on Earth?
  - Suggests that the formation of life is not able to be formed just out of anything lying around.
  - The selection of H,O,N,C seems to be a necessity of the chemistry of life.
  - In general, Earth life is a carbon based life. Carbon is the main backbone of the chemistry.
- Is this good news?

Why Carbon Based Life?

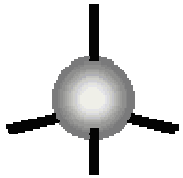
- Carbon's electronic structure allows it to form long chains
  - Chains of atoms and chains of molecules– complexity
  - Life needs bonds to be stable but breakable
- Good for us, at temperatures at which water is liquid, carbon bonds are stable but breakable
- Organic chemistry is the special branch devoted to carbon chemistry.



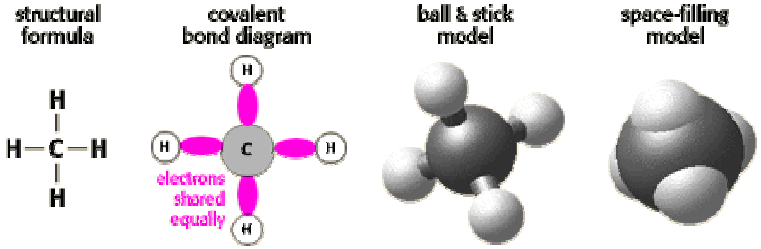
http://www.biology.arizona.edu/biochemistry/tutorials/chemistry/page2.html

Bond, Carbon Bond

- Carbon has 6 protons, 6 neutrons, and 6 electrons
  - Electrons distribute themselves in "shells"
    - Pauli exclusion principle
    - 1st (inner-most) shell wants to be filled by 2 electrons
    - 2nd shell wants to be filled with 8 electrons
    - BUT, Carbon only has 6 electrons!
      - So, Carbon has 2 electrons in inner shell and 4 in 2nd shell
      - It likes to bond: to "fill" second shell by sharing with four other electrons



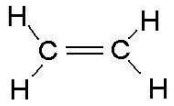
The Simplest C Bond– Methane

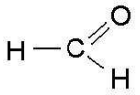


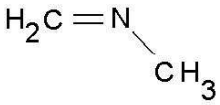
Not many other elements can share 4 bonds.
Silicon, which is much more abundant, can.
Silicon based life?

http://www.biology.arizona.edu/biochemistry/tutorials/chemistry/page2.html

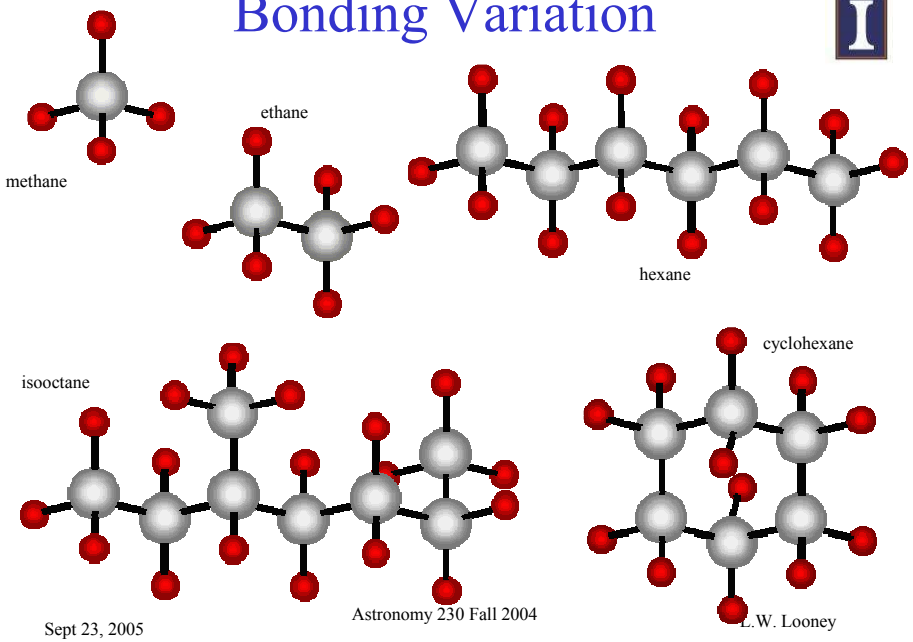
More Bonds







Bonding Variation



Unique?

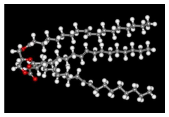
- As far as we know, the complexity of terrestrial biochemistry can only be achieved with carbon-based molecules.
  - Especially considering the need for liquid water
    - Which puts restrictions on the temperature in which the chemical reactions occur

Nitrogen

- Actually plays a central role in organic chemistry.
- It is prominent in biological compounds due to its reactivity with carbon and its propensity to form chains in organic compounds

Molecular Basis of All Life

- Great diversity of Life on Earth, but still it is 70% water and 24% four large molecules:
  - Proteins
  - Nucleic Acids
  - Lipids
  - Carbohydrates
- Not completely true. The simplest life, viruses, can have a single molecule of nucleic acid surrounded by a protein coating.



Lipids and Carbohydrates

- Lipids are almost entirely composed of carbon and hydrogen with some oxygen.
- The group of fats, oils, waxes, etc.— hydrophobic
- Lipids are essential for cell membranes.
- Carbohydrates are comprised of sugar molecule chains.
- Carbohydrates are used for energy storage in cells.
- In this class, we will concentrate on **proteins** and **nucleic acids** as the crucial bits for life.
- That's enough for viruses, and probably protolife was similar?

Monomers and Polymers

- All of the fundamental chemicals of life are organic polymers
  - A monomer is a small molecule (like carbon bonds we have seen).
  - A polymer is a number of monomers joined together to form larger, more complex molecules.
  - Polymers are nice for life, as they can form complex and repetitive sequences

Proteins vs Nucleic Acids

- Proteins are either structural elements or provide catalytic reactions (enzymes).
- Nucleic acids carry the genetic information– Replication of nucleic acid is crucial to reproduction of organism.
- They are the polymers of life!
- Can form complex, repetitive sequences.
- The order of the monomers determines the function of the polymers.
- Monomers are the letters and words in the molecular basis of life, and polymers are the messages.

How is Life Put Together?

- Living things are not just bags of large molecules and polymers mixed in a big soup
  - Living things have structure
  - Plants, animals have different parts
    - Skin, Hair, Leaves, Hearts, etc.

How do these structures relate to the complex organic polymers and DNA?

DNA Based Life

- All life is based on DNA. What does this mean?
  - The basic reproducible unit of all living organisms is centered around the complex DNA molecule.
  - DNA lives in cells
    - Except in viruses, which are basically pure DNA
  - Cells of different types form different parts of each organism
    - Heart cells different from blood cells.
    - Leaf cells different from root cells.