Astronomy 230
Section 1– MWF 1400-1450
106 B1 Eng Hall

This Class (Lecture 10):

Nature of Life

Next Class:

Nucleic Acids

Oral Presentations on Sept 22 and 24!

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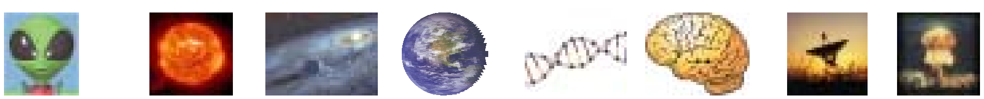
Music: *Blister In the Sun* – The Violent Femmes

Outline

- What is n_e?
- Time to turn to life on Earth.
- What are the main properties of life?
- H, O, N, and C are the main elements of life. Why?
- Carbon has 4 bonding sites.

Drake Equation

Frank Drake



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

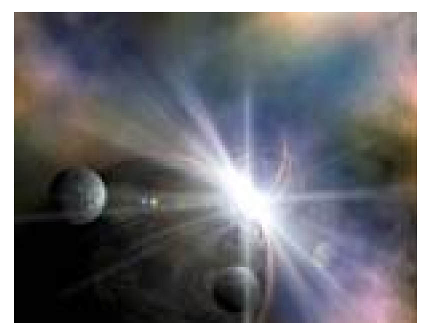
N	R*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact	Rate of star formation	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	25 stars/yr	0.34 systems/star					

= 8.5 Planetary systems/year

n_e

- Complex term, so let's break it into two terms:
  - n_p: number of planets suitable for life per planetary system
  - f_s: fraction of stars whose properties are suitable for life to develop on one of its planets

$$n_e = n_p \times f_s$$



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

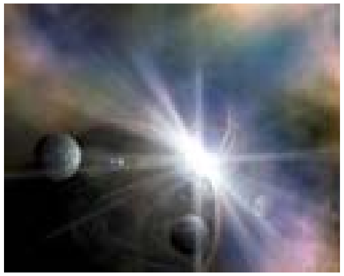
n_p

- Can range from 0.01 to >3.
  - Is seismic activity necessary to recycle bioelements?
  - How important is the first atmosphere? Ozone?
  - Is a moon needed? A large Jupiter-like planet?
  - Is liquid water a requirement? Other solvents okay?
    - Not too hot, not too cold; not too much pressure, not too little.
  - Habitable Zone around the star.
  - Galactic Habitable Zone
  - Does atmosphere need feedback mechanism?
  - But in our solar system, maybe 5 nearly possible life planets.

n_e

- Next term: We can list 5 situations that will have an effect on f_s.
  - n_p: number of planets suitable for life per planetary system
  - f_s: fraction of stars whose properties are suitable for life to develop on one of its planets

$$n_e = n_p \times f_s$$



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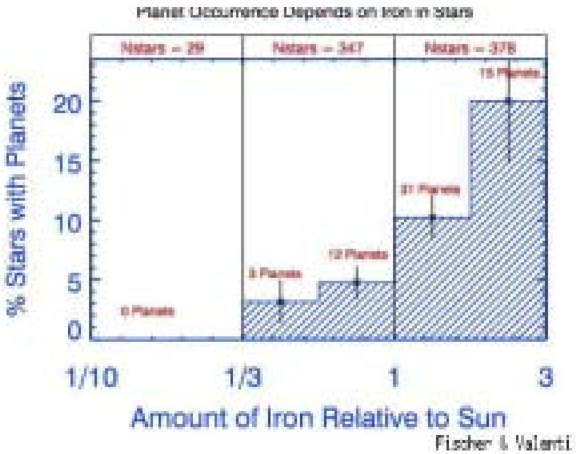
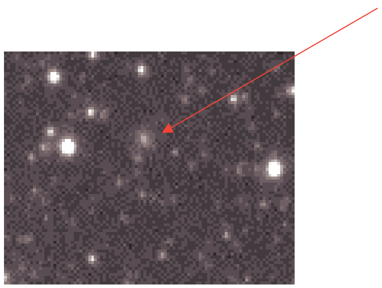
Differences of Stars to Life

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



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.



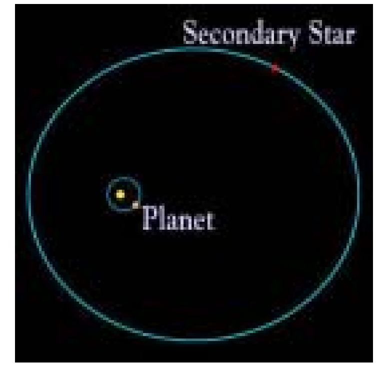
Differences of Stars to Life

3. Length of time on the main sequence. We need temperature stability for 5 x 10^9 years to get intelligence on Earth. This rules out stars more massive than 1.25 solar masses! Good news is that still leaves 90% of all stars.
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 binary. Only 30% of all stars are not binaries. 50% of stars are single stars or wide binary stars.

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



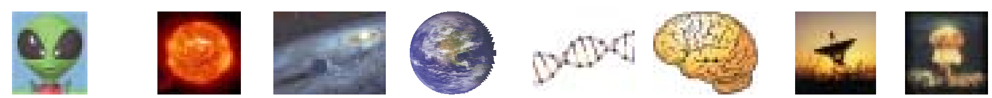
Gamma Cephei System

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	0.890
Synchronous Rotation/ Flares	$M > 0.5\ M_{Sun}$	0.25	0.200
Not a Binary	…	0.30	0.060
Wide Binary Separation	…	0.50	0.1

Drake Equation

Frank Drake



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	25 stars/yr	0.34 systems/star	? life planets/system				

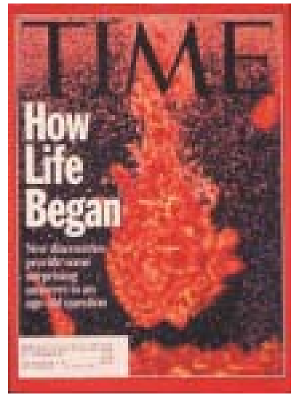
= ? Life Planets/year

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

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.

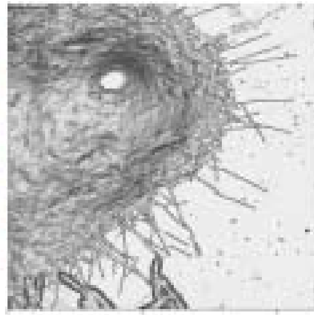
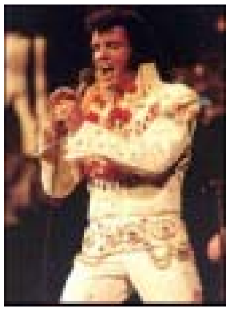
http://www.toothpastefordinner.com/052802/science-only-happens.gif

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
  - Hydrogen (61% in humans)
  - Oxygen (26% in humans)
  - Nitrogen (2.4% in humans)
  - Carbon (10.5% in humans)
- HONC is essential to life, and it is <u>common</u> in space.

Trace Elements

In addition to HONC, there are some other elements that are <u>essential</u> 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?

Good News

- H,O,N,C 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

Nature's Complexity

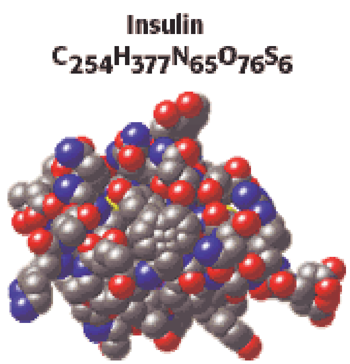
- The workings of biological molecules are an absolute marvel
  - How did this complexity develop?
  - How did it evolve?
- As complex and mysterious as life on Earth may be, we can begin understand it
- Start with the basics:
  - Why are H,O,N,C the basis for living organisms?
  - How do the molecules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

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?

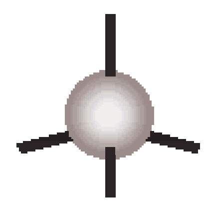
- Carbon's electronic structure allows it to form long chains
  - Chains of atoms and chains of molecules– complexity
  - Life needs bonds to be stable but breakable
- Good for us, at temperatures at which water is liquid, carbon bonds are stable but breakable
- Organic chemistry is the special branch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



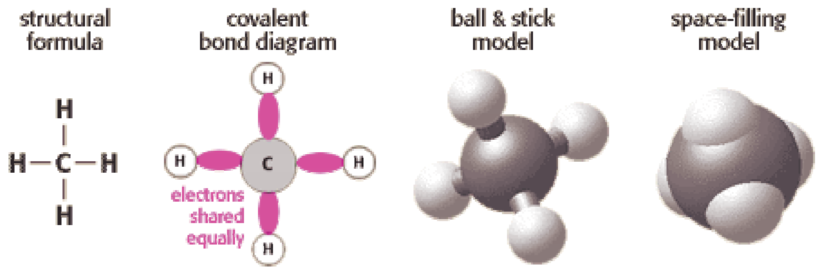
http://www.biology.arizona.edu/biochemistry/tutorials/chemistry/page2.html

Bond, Carbon Bond

- Carbon has 6 protons, 6 neutrons, and 6 electrons
  - Electrons distribute themselves in "shells"
    - Pauli exclusion principle
    - 1^{st} (inner-most) shell is filled by 2 electrons
    - The 2^{nd} shell would be 'filled' by 8 electrons, but its only got 4
      - So, Carbon has 2 electrons in inner shell and 4 in 2nd shell
      - It likes to bonds to "fill" second shell by sharing with four other electrons



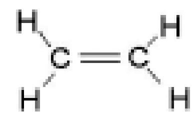
The Bond– Methane

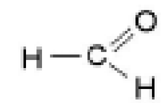


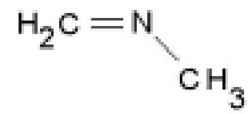
Not many other elements can share 4 bonds.
Silicon, which is much more abundant, can.

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

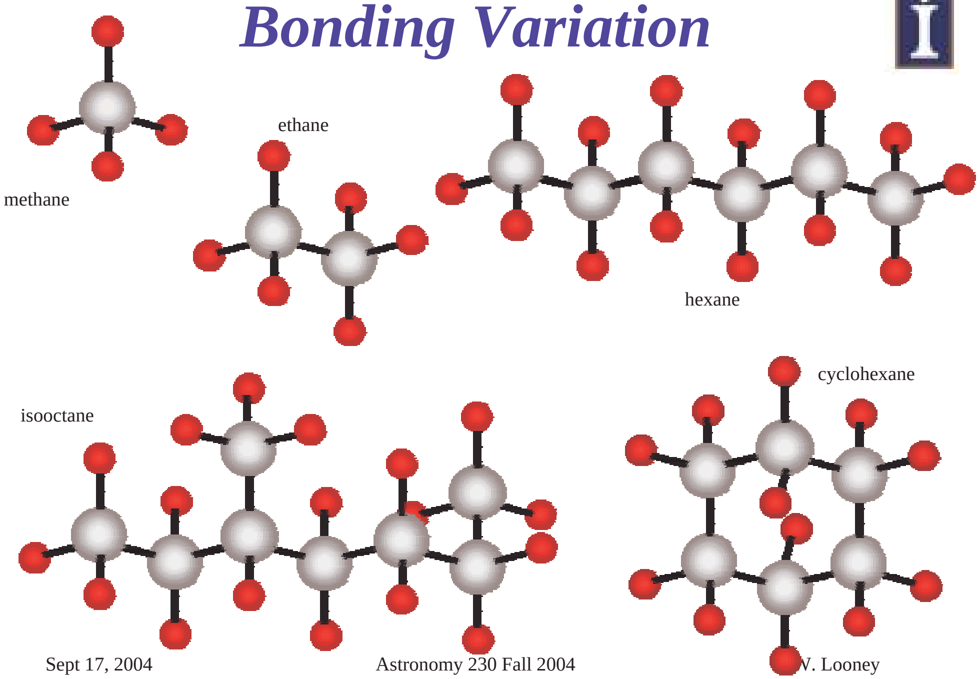
More Bonds







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 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.