Astronomy 330

This class (Lecture 11):

Origins of Life

Next Class:

Amino Acids

Music: *Jesus Came From Outta Space*– Supergrass

Exam 1

- 40 MC questions in this classroom on Thursday!
  - Plus 2 extra credit (possible score of 105)
- You can bring 1 sheet of paper with notes
- Will cover material up to and including last Thursday's lecture.
- Major resources are lecture and discussion notes, in-class questions, and homework, the book and reading are supplemental (won't be directly on exam).

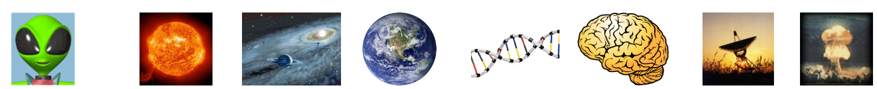
Outline

- f_s for us…
- Proteins and nucleic acids– polymers of life!

Drake Equation

That's ? Life-liking systems/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
# of advanced civilizations we can contact in our Galaxy today	Star formation rate	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
	20 stars/ yr	0.12 systems/ star	1.25 x ? = ? 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

Class number is 1.25

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

$$n_e = n_p \times f_s$$

n_p: number of planets suitable for life per planetary system

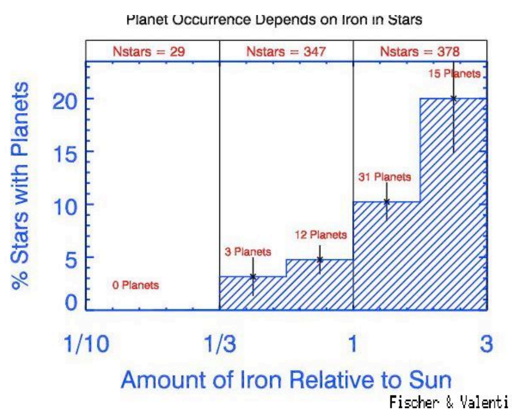
f_s: fraction of stars whose properties are suitable for life to develop on one of its planets

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

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

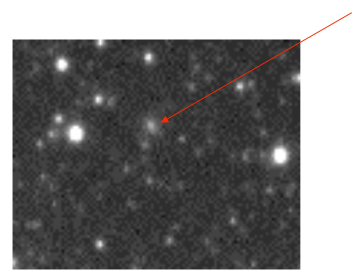
Differences of Stars to Life

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.



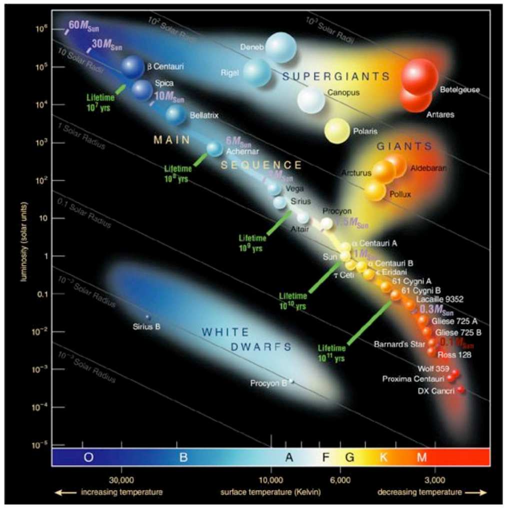
Differences of Stars to Life

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

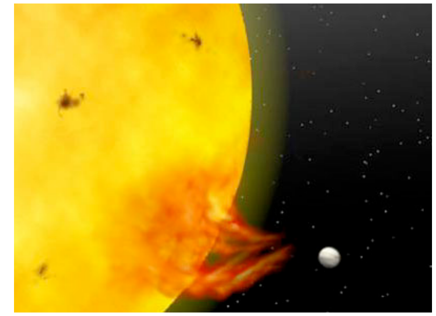
3. **Length of time on the main sequence**. We needed temperature stability for 5 billion years to get intelligence on Earth. This rules out stars more massive than 1.25 solar masses! 90% of all stars are less massive than that.



http://mjbs.org/hr.jpg

Differences of Stars to Life

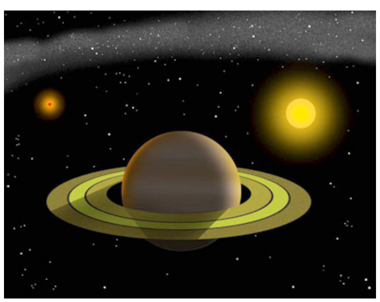
4. **Minimum mass of star**. If ice exists close to the star, that would imply the formation of Jupiter-like planets not Earth-like planets. And, any life bearing planet would have to be closer to the star– and closer to stellar effects (e.g. tidal locking and more flares from low mass stars). That limits us to a minimum of 0.5 solar masses. 25% of all stars are more massive than that.



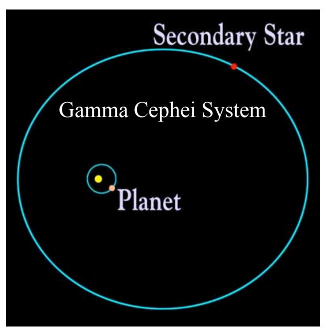
http://spaceflightnow.com/news/n0401/19planet/planet.jpg

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: fraction of stars that life can exist around

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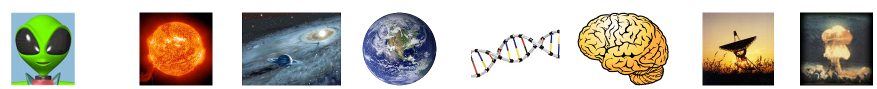
Value can range from ~ 0.06 to ?

Drake Equation

Frank Drake

That's ? Life-liking systems/year



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Question

The best type of life sustaining stars are

a) Low mass stars (less than 0.5 solar masses), as life can exist nearer the star where more terrestrial planets are probably located.

b) Binary stars, as they double the chances of life.

c) Stars off the main sequence, as they have lived the longest, they are the best chance for finding intelligent life.

d) Middle mass stars (less than 1.25 and more than 0.5 solar masses), as they live longer and don't require the planets to be too close.

e) Massive stars (more than 2 solar masses), as they have more mass from which to form planets.

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 stars 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

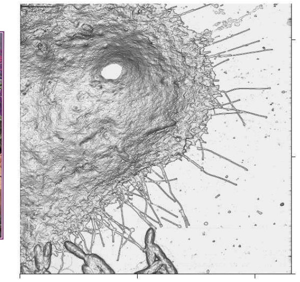
Cosmic Imperative?

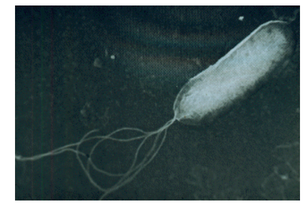
- But is life a cosmic imperative?

- 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
  - **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.

Question

Life on Earth is varied in how its made on the molecular level, i.e. elephants are made out of different stuff than bacteria.

a) True

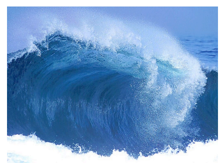
b) False

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

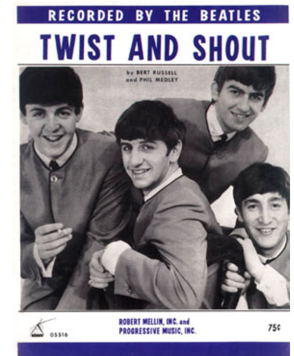
- These other elements make up about 1% of the mass of living organisms
- Exist in roughly the same concentration in organisms as in ocean water
- <u>Highly suggestive</u> that life began in oceans
- Furthermore suggests that the evolutionary processes occurred on Earth. Panspermia problems?



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 <u>absolute marvel</u>
  – How did this complexity develop?
  – How did it evolve?
- As complex and mysterious as life on Earth may be, we can begin to 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?

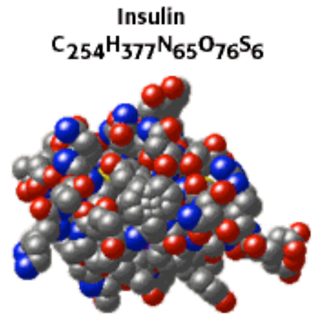
http://europa.eu.int/comm/environment/life/toolbox/logo_life_high_resolution_2.jpg

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 <u>necessity</u> 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?

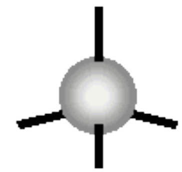
- Carbon's electronic structure allows it to form long chains
  - Chains of atoms and chains of molecules– complexity
  - Life needs bonds to be stable but breakable
- Good for us, at temperatures at which water is liquid, carbon bonds are stable but breakable
- Organic chemistry is the special branch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



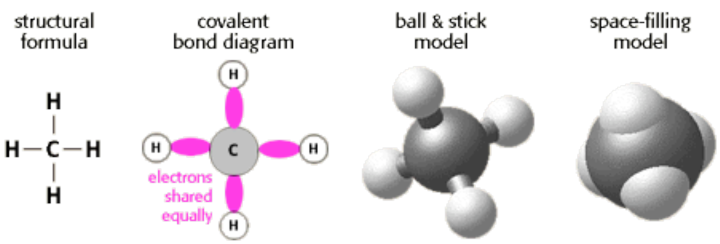
http://www.biology.arizona.edu/biochemistry/tutorials/chemistry/page2.html

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



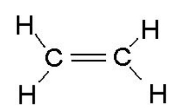
The Simplest C Bond– Methane

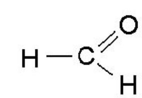


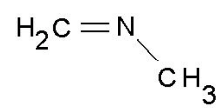
Not many other elements can share 4 bonds.
Silicon, which is much more abundant, can.
Silicon based life?

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

More Bonds

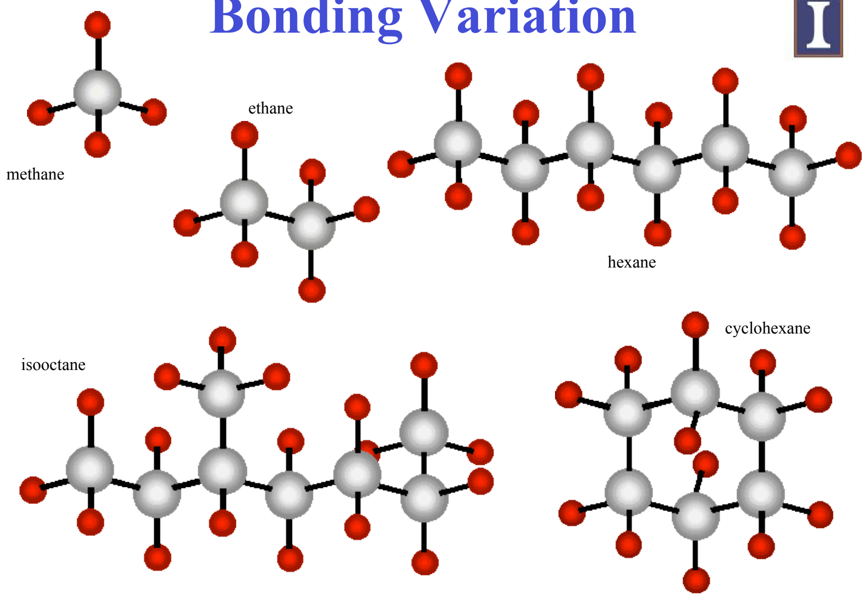






http://www.colossusblog.com/mt/archives/images/drno5.jpg

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

Question

Life uses carbon for making long molecular chains because

a) it is much more abundant than silicon.
b) it likes to share 4 electrons.
c) it is abundant in the ocean.
d) it makes chains that are not easily broken.

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

In this class, we will focus on the 2 most important molecules

Not completely true. The simplest life, viruses, can have a single molecule of nucleic acid surrounded by a protein coating.

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