Astronomy 230

Section 1– MWF 1400-1450

106 B6 Eng Hall

This Class (Lecture 15):

Alternatives and f_l

Midterm is March 12!

Next Class:

Life in the Solar System

The Exam will be in the Astronomy Building Classroom, room number 134.

Outline

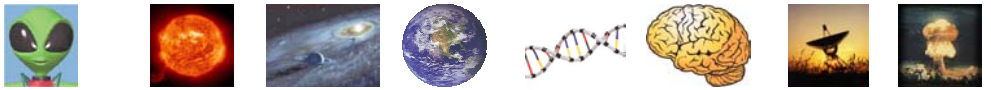
- Midterm
- How life formed?
  - Randomly
  - Proteins first
  - Nucleic acids first
  - Other?
- Exotic Life
- What is f_l?

Midterm

- 1 hour exam in Astronomy classroom.
- Will consist of 20 multiple choice/ true-false questions (worth 2 points each) and 2 essay questions (one worth 40 points and one worth 25 points) .
- A total of 105 points, so 5 extra credit points.
- You can bring a normal-sized sheet of paper with notes on both sides.

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 formation of Sun-like stars	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	**0.34**	**0.208**		**= 0.70**		
	Stars/year	Planetary System/star	Livable Planets /Planetary System		Livable Planets /year		

Probability of Randomly Forming Life?

- We think it is easiest to produce a protein, so what is the chance of getting a useful protein with the proper order of amino acids from chance?
- Toss of a coin. 50/50 (or ½) chance of heads or tails.
  - If you want 10 heads in a role you can multiple the chance of 1 throw times 1 throw times…etc… or $(½)^{10}$ or 1/1024.
- The polymer game is more complex with 20 options of amino acids. So if random, the chance of getting a single amino acid is 1/20.
- For a protein with a specific 10 amino acids in order.
  - $(1/20)^{10}$ or about $1/10^{13}$ or 1 chance in 10 trillion!!!!

Getting Lucky?

- If we throw enough coins, we will get 10 heads in a row.
- And if there were very large numbers of monomers, then even a very unlikely event can happen.
- Perhaps time is the hero of the story?
- But, don't forget a typical protein can have easily more than 200 amino acids. That is a chance of success of $(1/20)^{200}$!
- A generous estimate of the number of trials that the early Earth had was about 10^{51}.

http://www.physics.brown.edu/Studies/Demo/solids/demos/1a2020.jpg

Pessimist?

- Bottom line is that we can not expect life to arise from completely random combinations of molecules to make more complicated molecules.
- Something else must play a role.
- Some proteins might have a preferred assembly.

Transition to Life

- Really the big question.
- How difficult is it for the collection of polymers to become life?
- The last step in chemical evolution is really biological evolution.

Life

- Life is based on cells
  - Protective enclosures formed from lipids
- Cells contain nucleic acids and protein enzymes
  - Instructions and catalysts that allow replication of nucleic acids
- Methods for acquiring energy
  - Most organism now on Earth get energy from the Sun– either directly or indirectly. But that requires pigments.
  - Not sure if pigments were a primary need or if chemical sources of energy were used for early life.

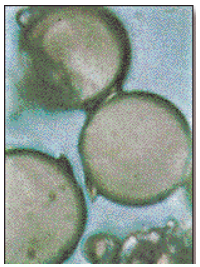
http://www.internetcash.com/en/images/baby-crying.jpg

Transition to Life

- Two general categories
  - Primitive versions of proteins, nucleic acids, and protocells arose independently and combined to form a life form.
  - One of the components was dominant and the first "life" was based on only one polymer, then developed into life as we know it. We call it protolife.
- The statistical arguments made would argue against primitive life and for the protolife option.
  - 2 protolife concepts based on nucleic acids or proteins

Protein Protocells

- Sydney Fox experiment.
- By heating amino acids, droplets of protein formed when added to water– "proteinoids"
- Could have formed on the early Earth with tides.
- Sometimes they will grow and break into daughter spheres
- It is like cell reproduction, BUT there is no replication of nucleic acids ,so not true reproduction.
- Nonetheless, they might be suitable for protocells.



http://www.biology.iupui.edu/biocourses/N100H/ch19life.html

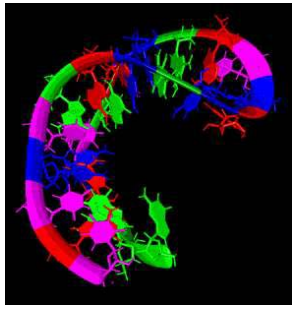
Protocells: Sydney Fox's Experiment

- Sydney argued that they formed a protolife that gradually became life as we know it.
- But how do nucleic acids come into play?
- Sydney argues that one microsphere developed the capability to make its own protein from amino acids, then passed that on to its "offspring".
- Then, nucleic acids might have been used to store the amino acid information.
- And only later took over– revolt of the bookkeepers!
- Most biologist do not like the idea, as life without nucleic acid is hard to accept.

http://vcl.ctrl-c.liu.se/vcl/Artists/Juan-Crespo/Sydney-Fox-Lz.jpg

The RNA World

- The other camp believes that the transition to life was dominated by nucleic acids.
- This has clearly the opposite problems of the Sydney Fox scenario.
- These genes are naked!
- A ecosystem of self-replicating RNA is nice, but without capability for protein synthesis, they could do little else.
- However, it's the most widely accepted concept due to numerous experiments.



http://www.bizspacebiotechnology.com/rna1.htm

RNA World Experiments

- Virus RNA is added to a test tube with replicase (an enzyme that catalyzes the synthesis of a complementary RNA molecule from an RNA template) and some activated nucleosides.
- The RNA was replicated without cell mechanisms.
- In one experiment, no RNA was added, and still RNA was produced.
- In fact, a number of variants were produced.
- The variant that replicated the fastest might win out.

Genetic Code and Origin of Translation

- One of the essential aspects of life is the synergistic interaction between proteins and nucleic acids.
- Chicken and egg problem still.
- If protein-like polymers of amino acids formed, they would have to polymerize the nucleotides.
- Then the resulting nucleic acid would have to direct the synthesis of more protein, leading to more of the nucleic acid. Etc.
- Or some RNA world ribozymes began to construct the proteins.

Neither Chicken nor Egg?

- While RNA world is favored, the difficulty is still in producing the nucleic acids on the early Earth.
- Freeman Dyson had argues that nucleic acid can not have been the first information carrying molecule.
- Transition between living and non-living requires a balance between order-preserving replication and error in replication.
- If too precise, nothing evolves.
- If too many errors, nothing consistent forms.
- He argues that RNA is not the easiest to start with, perhaps there were other polymers that preceded nucleic acids.

Pre-RNA World

- Peptide nucleic acids are similar and are more easily formed on the early Earth.
- Could act as a template for RNA later.
- Another option emphasizes the need for energy in early life– "thioester world"
- Molecules with sulfur instead of oxygen in the OH group– called thoils. Also can produce chains and large molecules.
- That would imply pre-RNA protolife started near hydrothermal sea vents where sulfur from H_2S would provide energy. Could have been the start of the RNA world.
- In fact, there are similarities to life.
  - Energy currency ATP involves thoiesters

Alternatives: Clay

- Although the RNA world idea is widely accepted, there are issues concerning the the prebiotic chemistry.
- Clay based genetic systems.
  - Layers of impurities in clay can produce patterns.
  - The layers can separate, settle elsewhere, and grow.
  - The patterns are not perfectly copied.
- Would not have been a big deal, BUT clays can capture and help polymerize amino acids.
- Maybe there was clay based life?
- Eventually the proteins make nucleic acids, which then provides a parallel genetic system that disregards the clay.
- Bottom line is that the step from molecules to life is so great that we are far from understanding it.

Exotic Life

- We have spent a long time with Earth Chauvinism, but what if ET life is very different?
- If other options are possible then that will give a more optimistic value of f_l.
- As we just discussed, there are options for life based on other molecules than amino acids, some have been shown to sort of work in the lab.

Silicon Based Life?

- Silicon makes 4 bonds like Carbon
- It is 135 times more abundant than carbon on the Earth.
- But there are 4 arguments against it:
  - C-C bonds are twice as strong as Si-Si
  - Si-O or Si-H is stronger than Si-Si, so harder to make long stands
  - Si does not usually make multiple Si bonds
  - C with O makes CO_2, but Si with O makes silicates (SiO_2), which are large solid crystals.
- Still it is a possibility that can not be ruled out.

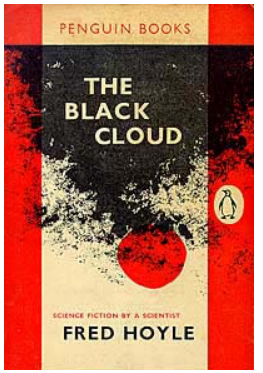
Other Solvents

Molecule	Freezes (K)	Boils (K)
Water (H_2O)	273	373
Ammonia (NH_3)	195	240
Methyl alcohol (CH_3OH)	179	338
Methane (CH_4)	91	109
Ethane (C_2H_6)	90	184

Water is about twice as good as ammonia or methyl alcohol. Water also has a high energy of vaporization, so it is very good at evaporative cooling (sweat).

Non-Chemical Life

Life is based on chemical energy. Thinking is an electrochemical activity. What about a life form that uses electromagnetic energy instead, perhaps without a body.



The Black Cloud (1957) by Fred Hoyle

The story describes a small interstellar molecule cloud that is alive. The organism is half a billion years old, as big as the orbit of Venus, and as massive as Jupiter. The brain is a complex network of molecules. Once it discovers the Earth it communicates with us:

The Black Cloud– Paraphrased

. . . it is most unusual to find animals with technical skills inhabiting planets, which are extreme outposts of life. . . . Living on the surface of a solid body, you are exposed to a strong gravitational force. This greatly limits the size to which your animals can grow and hence limits the scope of your neurological activity. It forces you to possess muscular structures to promote movements, and . . . to carry protective armor . . . [Y]our very largest animals have been mostly bone and muscle with very little brain. . . . One only expects intelligent life to exist in a diffuse gaseous medium . . . . The second unfavorable factor is your extreme lack of basic chemical foods. For the building of chemical foods on a large scale starlight is necessary. Your planet, however, absorbs only a very minute fraction of the light from the Sun. At the moment, I myself am building basic chemicals at about 10,000,000,000 times the rate at which building is occurring on the whole . . . surface of your planet.

Cloud Problems

- How would such a cloud evolve?
- The most dense clouds are 10^{13} times less dense than our atmosphere, which makes molecule interactions very rare.
- In space, interstellar clouds are torn apart in about 10^7 years. It took 10^9 years for intelligent life to form on Earth.
- Still it is a cute idea.

Other Voices, Other Energies

- Life based on nuclear energy (put forward by Drake)
  - Life on the surface of a neutron star?
  - Gravity and temperature too high for normal life.
  - Life made of closely packed nuclear matter
  - They interact quickly 10^{-21} seconds
- It has been fictionalized by Robert Forward in *Dragon's Egg*

  Talking to these beings would be difficult. Their biology depends upon the strong nuclear force instead of the electromagnetic force. Nuclear reactions happen much faster than chemical reactions, because the nuclear force is much stronger. . . . With a time difference of a million to one, a second to a human - the time it takes to say "Hello" - would be the equivalent of a week to a star creature. It would hear "He . . . " on Sunday and ". . . lo" on the following Saturday.

Or Too Big

- Life based on gravitational energy?
- In this creature, the gravity force would dominate– very large!
- The monomer of life would have to be a star.
- Perhaps individual stars play the role of individual atoms or molecules in Earth life.
- Could galaxies be alive?
- Stars interact with one another on a time scale of many millions of years, so if life is to originate from such interactions it would take longer than the age of the Universe.
- If it's occurring, it is only at the stage the Earth was a few years after it formed

Summing

- Existence of organic molecules in space implies that amino acid complexity is common.
- On Earth polymers arose and evolved to life.
- Life it seems evolves naturally through a number of intermediate steps if conditions are right.
- That means that $f_l = 1$
- But how often are the conditions right.

Summing

- Is life a natural occurring consequence of the laws of nature?
- Will each planet from n_e outgas and produce water?
- Will it have a reducing atmosphere?
- Will it have the right energy sources?
- Will it have some dry land to help in polymerization?
- Are tides necessary to wash polymers back to liquid water?

- Maybe the conditions that produced life on Earth are unusual or maybe common.
- That means f_l can range from small numbers 10^{-4}% to 100%.