ET: Astronomy 230

This Class (Lecture 22):

Alternatives

HW #6 is due today

Midterm in 1 week

Next Class:

Life in the Solar System

Presentations Monday Oct 24th
Jonathan Dellinger
Nathan Louer
Amit Behal

Music: *Galaxies* – Laura Veirs

Midterm

- 1 hour exam in this classroom.
- It will cover material up to, but not including, Life in the Solar System
- Will consist of a 20ish multiple choice, 1-2 short essay, and a larger essay + extra credit.
- Total exam is worth 105 points, graded out of 100
- You can bring a normal-sized sheet of paper with notes on both sides.

Outline

- What are the chances for random life?
- Transition to life
  - Protolife (protein only or nucleic acid only?)
- Exotic life

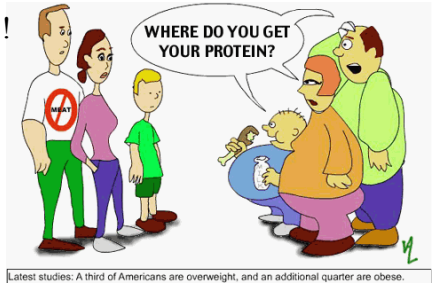
Life was Chance?

- Seems 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 (½) times 1 throw (½) times…etc. or $(½)^{10}$ or 1 time out of 1024 attempts.

http://cruel.org/kitchen/shrunken.html

Probability of Randomly Forming Life?

- 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!!!!



http://www.citypaper.net/hth/

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 $(1/20)^{200}$!

http://members.aol.com/LILAUTHOR1/hourglass.jpg

Pessimistic?

- A generous estimate of the number of trials that the early Earth had was about 10^{51}.
- But, maybe the early Earth only had a few amino acids at first. Then the odds are better for certain proteins.
- But, we require more than just 1 protein to be formed.
- And first life probably needed many proteins as well.

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.

Poly Summary

- Polymerization of amino acids on the early Earth is plausible.
- Synthesis of nucleic acids seems to be much harder.
- Perhaps proteins from amino acid polymers played a role? Chicken came first?
- It is still more difficult, because life requires useful polymers. The order of the monomers determines the properties.

Life – Gen Eds

1. Precise way to reproduce instruction set (but not perfect)
2. Ability to control chemical reactions via catalysts.
3. A protective enclosure that separates the instructions and the catalysts from the environment. Becomes an individual not just a soup of chemicals
4. Method for acquiring and using energy.
5. Interconnections of the above.

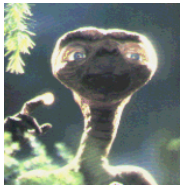
Transition to Life?

- 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

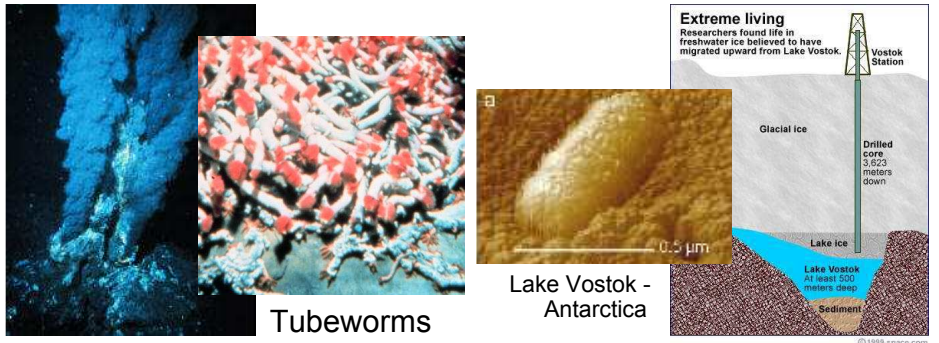
- Life is based on cells
  - Protective enclosures formed from lipids
- Cells contain nucleic acids and protein enzymes
  - Instructions and catalysts that allow replication of nucleic acids
- Methods for acquiring energy
  - **Most** organism now on Earth get energy from the Sun– either directly or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

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



Not your Parent's ET-- Extremophiles

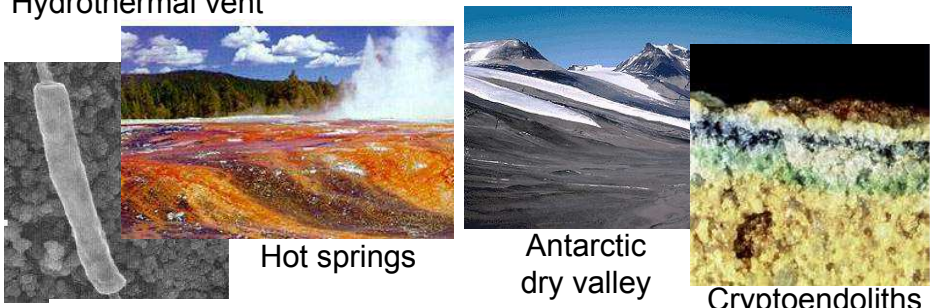
- These are microbes that live in the most extreme places on Earth.
- Temperature extremes
  - boiling or freezing, 100^0C to -1^0C (212F to 30F)
- Chemical extremes
  - vinegar or ammonia (<5 pH or >9 pH)
  - highly salty, up to ten times sea water
- They are exciting, as they are the most likely candidate for extraterrestrial life.
- Probably dominated life on early Earth until fairly recently.



Tubeworms

Hydrothermal vent

Lake Vostok - Antarctica



Hot springs

Thermophilic bacteria

Antarctic dry valley

Cryptoendoliths

Transition to Life

- Two possibilities
  - 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 can call it protolife.
- The statistical arguments would argue against primitive life and for protolife.

http://www.lbl.gov/Science-Articles/Archive/sb/July-2004/2_spinach.html

Protolife

If we assume that early life must have been protolife, then

- Two protolife concepts based on nucleic acids or proteins.

1. Protein life
2. RNA life

http://www.perantivirus.com/sovirus/graficos/bilgates.jpg

1. Protein Protolife?

- Sydney Fox heated 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

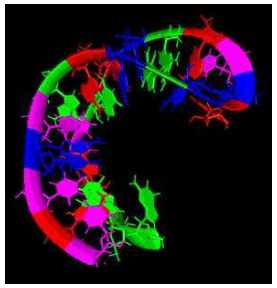
1. Protocells

- If so, how do nucleic acids come into play?
- Perhaps one proteinoid 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

2. The RNA World: Protolife

- The other camp believes that the transition to life was dominated by nucleic acids, 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

2. RNA World

- The idea is that RNA is mutating away– eventually one RNA develops an enzyme function.
- This evolves to fill many of the niches that today's enzymes perform.
- At some point, the RNA encode and produce proteins through amino acid encoding, using one of the RNA enzyme functions.
- This would make better enzymes that would replace the RNA versions.
- Is this possible?

2. 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. Still the Chicken and egg problem?
- If protein-like polymers of amino acids formed, they would have to polymerize (create) the nucleotides.
  - The resulting nucleic acid would have to direct the synthesis of more protein, leading to more of the nucleic acid. Etc.
- Or in some RNA world ribozymes began to construct the proteins– the favored view.

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 argued 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.

http://www.antivegan.de/kochkurs/chicken-wings/chicken_egg2.jpg

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 ET life would be very different? Probably very alien!
- If other options are possible, then that gives 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 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.

http://www.decipher.com/startrek/cardlists/mirrormirror/images/horta.gif

http://soundwavs.trekkieguy.com/25.html

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

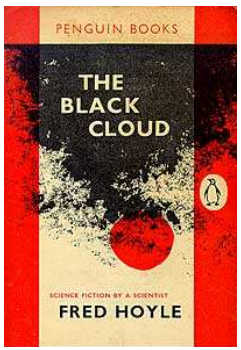
Water is about twice as good as ammonia or methyl alcohol. Water also has a high energy of vaporization, so it is very good at evaporative cooling (sweat).

http://www.talisman-activities.co.uk/winter/images/ice%20climbing.jpg

http://web.media.mit.edu/~fletcher/tags/boiling.jpg

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 Speaks

Paraphrased "badly"

- It is most unusual to find animals with technical skills inhabiting planets
- Living on a planet, greatly limits your size, thus the scope of your neurological activity.
- Living on a planet, forces you to possess muscular structures to promote movements.
- Your 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. At the moment, I myself am building basic chemicals at about 10,000,000,000 times the rate as your whole planet.

Cloud Problems

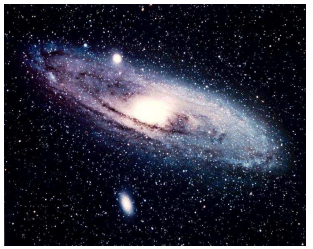
- How would such a cloud evolve?
- The most dense clouds are 10^{13} times less dense than our atmosphere, which makes molecule interactions very rare.
- In space, interstellar clouds are torn apart in about 10^7 years. It took 10^9 years for intelligent life to form on Earth.
- Still it is a cute idea.

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 instead of molecules
  - They interact quickly 10^{-21} seconds, much faster than chemical reactions.
- It has been fictionalized by Robert Forward in *Dragon's Egg*
  - Talking to these beings would be difficult.
  - Their Biology uses the strong nuclear force.
  - A time difference of a million to one.
  - In 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 life is occurring, it is only at the stage where life was when the Earth was a few years old.



Summing Up

- Existence of organic molecules in space implies that amino acid complexity is common.
- Fact: On Earth polymers arose and evolved to life.
- Life it seems evolves naturally through a number of intermediate steps if conditions are right and $\mathbf{f_l = 1}$
- But how often are the conditions right?
- Nonetheless, even with only a vague notion of how life on Earth evolved, it seems that there are possible pathways that take the mysterious polymerization to transition to life steps.
- Still a number of questions:

Summing for f_l

- 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 to produce life's monomers?
- Monomers from space?
- Will polymerization occur?
- Are tides necessary to wash polymers back into liquid water?
- Will basic life occur? Protolife or life?
- Alternative life?
- Maybe the conditions that produced life on Earth are unusual or maybe common.
- That means f_l can range from small numbers 0.0001 to 1.