Extraterrestrial Life
Extraterrestrial Life

Extraterrestrial implies the Universe
But we only KNOW about life on Earth (will use as “model”)
Danger of “Earth Chauvinism”

Objectives:
Scientific Perspective
Understand connection between Universe and Life
Give you tools to make your own judgments

Controversial Issues:
Evolution
Visits by Aliens (UFO’s)

Themes:
Cosmic Evolution
The Drake Equation
Contact
Signature Course Features

• Introduction to college expectations
• Develop your skills (study, writing, oral)
• Use University “gems”
  – Museums, lectures, star parties
• Attendance at University Lecture and report
• Much of interaction will be in Friday sections
  – Discussion, writing, oral, prep for tests
• Discussion, questions also encouraged in lectures
2009 is a special year

• 400 years since Galileo first used the telescope to study the sky
  – International Year of Astronomy

• 150 years since Darwin published the “Origin of Species”
  – Special editions, e.g., Scientific American
Temperature Scales

We will use the Kelvin temperature scale. Absolute zero is 0 K.
Kelvin is Celsius + 273
Celsius = \(\frac{5}{9}(F - 32)\)

Water freezes 273 K
Water boils 373 K
“Room temp” 300 K
The Cosmic Context

<table>
<thead>
<tr>
<th>Star</th>
<th>Color</th>
<th>Distance</th>
<th>Closest Approach</th>
<th>Minimum Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>Yellow</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alpha Centauri A</td>
<td>Yellow</td>
<td>4.3</td>
<td>29,000 A.D.</td>
<td>3.2</td>
</tr>
<tr>
<td>Alpha Centauri B</td>
<td>Orange</td>
<td>4.3</td>
<td>29,000 A.D.</td>
<td>3.2</td>
</tr>
<tr>
<td>Proxima Centauri</td>
<td>Red</td>
<td>4.2</td>
<td>28,000 A.D.</td>
<td>3.2</td>
</tr>
<tr>
<td>Barnard’s Star</td>
<td>Red</td>
<td>5.9</td>
<td>12,000 A.D.</td>
<td>3.8</td>
</tr>
<tr>
<td>Wolf 359</td>
<td>Red</td>
<td>7.8</td>
<td>13,000 B.C.</td>
<td>7.3</td>
</tr>
<tr>
<td>Lalande 21185</td>
<td>Red</td>
<td>8.2</td>
<td>22,000 A.D.</td>
<td>4.6</td>
</tr>
<tr>
<td>Sirius A</td>
<td>White</td>
<td>8.6</td>
<td>64,000 A.D.</td>
<td>7.7</td>
</tr>
<tr>
<td>Sirius B</td>
<td>White</td>
<td>8.6</td>
<td>64,000 A.D.</td>
<td>7.7</td>
</tr>
</tbody>
</table>

*Note: Distances are in light-years with reference to the sun.*
The Nearest Stars

Wolf 359

Sirius
A + B

Alpha Centauri
Proxima Centauri
B

Sun

Lalande 21185

Light Year

Galaxy Rotation

Barnard’s Star

To Center of Galaxy
25 Nearest Star Systems

Nearest 25 Star Systems

Five Nearest Systems
1. α Centauri
2. Bernard's Star
3. Wolf 359
4. Lalande 21185
5. Sirius

Records Discovery
22. GJ 1061
(1.4 light years)

Five Brightest Systems Among Nearest 25
1. Sirius
2. α Centauri
3. Procyon
4. β Gieni
5. α Eridani

horizon = 13.1 light years
Larger Structures

- Milky Way Galaxy 100,000 \((10^5)\) ly across
- Local Group about 3 million \((3 \times 10^6)\) ly
- Virgo Cluster about 30 million \((3 \times 10^7)\) ly
- Most distant galaxies we can see are about 13 billion \((13 \times 10^9)\) ly away
The Milky Way
Our Location in the Milky Way

25000 light years
Beyond the Milky Way we have located galaxies in every direction. Our own is part of a loosely bound cluster of some 20 galaxies, called prosaically the Local Group. "Galaxies are to astronomy what atoms are to physics," astronomer Allan Sandage has said, and this group illustrates the variations. The Milky Way, its sister Andromeda (M31), and the smaller M33 are fast-rotating spirals. Hundreds of star clusters and dust clouds lie within the Andromeda galaxy, itself once mistakenly identified as a nebula, or cloud, in the Milky Way galaxy. NGC 205 is an elliptical galaxy, consisting mainly of old stars. The Large and Small Magellanic Clouds are irregular galaxies, described as haze in the southern sky by Magellan's crew in 1520. These member galaxies, all moving in random paths, are held together by gravity, even as the universe expands.
Central Part of Virgo Cluster
The Hubble Deep Field
Try this Link

http://www.atlasoftheuniverse.com/index.html
Questions

- How far from Earth are the astronauts in the Space Station?
- How far have humans traveled (in light-time units)?
- What fraction of the distance to the nearest star is that?
- Are we likely to travel to another star in your lifetimes?
Life

3.21. Ophiacanthus, showing the frontal nozzle with terminal claw, five eyes on the head, body sections with gills on top, and the tail piece in three segments. Drawn by Marianne Collins.
Five Attributes of Life

1. Composed of Organic Molecules (Carbon Based)

2. Engages in Metabolism

3. Reproduces

4. Mutates (Evolves)

5. Changes in Response to Environment (Sensitivity)
Questions

• Can you think of a counter-example to each of these?
• Something alive without these attributes?
• Something not alive with these attributes?
Alternative Approach to Definition of Life

Based on Ecological aspect
Clare Folsom (Onsager-Morowitz)

“Life is that property of Matter that results in the Coupled Cycling of bioelements in Aqueous Solution, ultimately driven by radiant energy to attain Maximum Complexity”

Very general - but what does it mean?

Gaia - Geochemical & Biological Cycles
Life on Earth as “Organism” (James Lovelock)
Requirements for Life

To Make a: 

You Need:

Virus < 17 Elements
Bacteria ~ 17
Human (Mammal) ~ 27
Phosphorus (P) and Potassium (K) in shortest supply

Average Human Being contains $6 \times 10^{27}$ atoms

⇒ At least one atom of every stable element and some unstable (radioactive) elements ($^{14}$C, $^3$H, $^{40}$K)

⇒ Some atoms from every species that ever existed

Facts from R. Davies U. Penn.
Leaving aside rare elements, all life has similar composition: (All % by number of atoms)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Element</th>
<th>Bacteria</th>
<th>Human Beings</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>Hydrogen</td>
<td>63%</td>
<td>61%</td>
</tr>
<tr>
<td>O</td>
<td>Oxygen</td>
<td>29%</td>
<td>26%</td>
</tr>
<tr>
<td>C</td>
<td>Carbon</td>
<td>6.4%</td>
<td>10.5%</td>
</tr>
<tr>
<td>N</td>
<td>Nitrogen</td>
<td>1.4%</td>
<td>2.4%</td>
</tr>
<tr>
<td>P</td>
<td>Phosphorus</td>
<td>0.12%</td>
<td>0.13%</td>
</tr>
<tr>
<td>Ca</td>
<td>Calcium</td>
<td></td>
<td>0.23%</td>
</tr>
<tr>
<td>S</td>
<td>Sulfur</td>
<td>0.06%</td>
<td>0.13%</td>
</tr>
</tbody>
</table>

HCON  
Essential, most common
P,S   
Also essential
Ca    
Bones

Also Fe (Iron) Hemoglobin
Mg (Magnesium) Chlorophyll
## Composition of the Earth:

<table>
<thead>
<tr>
<th>Element</th>
<th>Crust</th>
<th>Ocean</th>
<th>Atmosphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>47%</td>
<td>~33%</td>
<td>21%</td>
</tr>
<tr>
<td>Silicon</td>
<td>28%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td></td>
<td>78%</td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td>~67%</td>
<td></td>
<td>(0.011% Carbon)</td>
</tr>
</tbody>
</table>

**Question:** Which is most similar to that of life?
Composition of life **more** like Composition of Sun (Universe)

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<thead>
<tr>
<th>Symbol</th>
<th>Element</th>
<th>% in Sun</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>Hydrogen</td>
<td>93%</td>
</tr>
<tr>
<td>He</td>
<td>Helium</td>
<td>6.4%</td>
</tr>
<tr>
<td>O</td>
<td>Oxygen</td>
<td>0.06%</td>
</tr>
<tr>
<td>C</td>
<td>Carbon</td>
<td>0.03%</td>
</tr>
<tr>
<td>N</td>
<td>Nitrogen</td>
<td>0.011%</td>
</tr>
</tbody>
</table>

Aside from He, HOCN

Where did these elements come from?
Appendix 5

Drake Equation:

\[ N = R_* f_p n_e f_f f_i f_c L \]

- \( N \): number of communicable civilizations in our galaxy
- \( R_* \): rate at which stars form
- \( f_p \): fraction of stars which have planetary systems
- \( n_e \): number of planets, per planetary system, which are suitable for life
- \( f_f \): fraction of planets suitable for life on which life actually arises
- \( f_i \): fraction of life-bearing planets where intelligence develops
- \( f_c \): fraction of planets with intelligent life which develop a technological phase during which there is capability for and interest in interstellar communication
- \( L \): average lifetime of communicable civilizations
- \( r \): average distance to nearest civilization

<table>
<thead>
<tr>
<th>( R_* )</th>
<th>( f_p )</th>
<th>( n_e )</th>
<th>( f_f )</th>
<th>( f_i )</th>
<th>( f_c )</th>
<th>( L )</th>
<th>( N )</th>
<th>( r )</th>
</tr>
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<tr>
<td></td>
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</tr>
</tbody>
</table>

Estimate

Birthrate

If \( N > 8000 \)

\[ r = \frac{10^{4}}{N^{0.3}} \text{ l.y.} \]

If \( N < 8000 \)

\[ r = \frac{5 \times 10^{4}}{N^{0.75}} \text{ l.y.} \]

The Drake Equation
Drake Equation:

\[ N = R \ast f_p n_e f_l f_i f_c L \]

- \( N \) = number of communicable civilizations in our galaxy
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