Lecture 41: Science Fact or Science Fiction?
Intelligent Life in the Universe

Four Opinions:
1. It is highly likely that intelligent life has arisen elsewhere in the Universe.
2. There is no evidence of extraterrestrial visits to the Earth, now or in the past.
3. Lack of visits may be explained by the extreme difficulty of interstellar travel.
4. If we do make contact, it will be by receiving radio signals.

Basic Requirements for Life

Energy
   - Warmth to permit liquid water (liquid methane?)
   - Energy to fuel chemical reactions

Complex chemistry
   - Elements heavier than H and He
   - Carbon as building blocks for complex molecules

Protection from harmful UV light
   - Mutations inhibit emergence of complex life
   - Ozone layer, underwater, or underground

Extreme Life on Earth

Dark Life
   - Bacteria that thrive many kilometers beneath the Earth or deep in polar ice.

Hot Life
   - Microbes surviving in boiling geysers, pools and deep ocean thermal vents

On the Moon:
   - Strep bacteria survived 3 years on the lunar surface!
Life in the Solar System?
Mars
   May have liquid water and a thicker atmosphere in the past
Europa
   Liquid water ocean warmed by tides
   Protected by outer shell of ice
Titan
   Methane chemistry
   Complex molecules present

Each may satisfy the basic requirements for life to develop

What do we mean by “Intelligent”
This usually means:
   A highly advanced technological civilization
   Capable of communicating across interstellar distances
   Capable of interstellar travel by spacecraft
   Interested in finding and communicating with other intelligences.

In other words: life like us.

Do we qualify as “Intelligent”?  
Just barely:
   Only had radio communications technology for ~100 years
   Only had limited (short-duration) manned spaceflight for ~40 years.
   Only sent robotic spacecraft to the edges of our Solar System in the last decade
   May or may not yet have sufficiently sensitive radio reception technology

Sheer Weight of Numbers
The primary reason I think life must have arisen elsewhere is the sheer number of stars in the visible Universe:
   ~200 billion galaxies in the visible Universe
   ~100 billion stars per galaxy

Total of $\sim 2 \times 10^{22}$ (20 billion trillion) stars
   Even one chance in a trillion would yield more than 20 billion possible sites for life.
Planetary Requirements for Life

Long-lived, stable star
   Good: F, G, & K stars: last > 3 Gyr
   Bad: O, B & A stars: short-lived, high UV output (damaging to organic molecules)
   Bad: M stars: small & dim, powerful flaring

Stable orbital environment
   Excludes more binary star systems

Metals = chemically evolved environment
   Need metals to make rocky planets
   Need carbon for complex molecules

The Drake Equation

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

\( N \) = number of advanced civilizations in the Galaxy
\( R_* \) = rate at which Sun-like stars form
\( f_p \) = fraction of stars with planetary systems
\( n_e \) = number of Earth-like planets per system
\( f_l \) = fraction of Earth-like planets with life
\( f_i \) = fraction where intelligent life has evolved
\( f_c \) = fraction with communication technology
\( L \) = lifetime of an advanced civilization

Measurement and Conjecture

Only the first 3 terms of the Drake Equation can be measured by astronomers:
   Star formation rate:
      \( R_* \approx 1 \) per year (F, G, & K stars)
   Fraction of Stars with Planets
      \( f_p \approx 0.1-0.2 \) from recent planet searches
      \( n_e \) number of Earth-like planets per system may be measurable in the next few years
   The rest are purely conjectural
Shameless Optimism
One very optimistic view:

\[ n_e = 0.1 \text{ (1 in 10 solar systems have earths)} \]
\[ f_l = 1 \text{ (if earth-like, life is inevitable)} \]
\[ f_i = (\text{if life, intelligence is inevitable}) \]
\[ f_c = (\text{if intelligence, technology is inevitable}) \]
\[ L = 100 \text{ years (we made it this far...so far...)} \]

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

\[ N = 1 \times 0.2 \times 0.1 \times 1 \times 1 \times 1 \times 100 \]
\[ N = 2 \]

Extraterrestrial Visitations? No.

“Extraordinary claims require extraordinary proof”
No extraordinary proof has been offered:
- Fuzzy photographs
- Anecdotal accounts of visits & abductions
- Claims of government conspiracies
- These do not count

There are unexplained sightings, but failure to explain them does not justify a leap to a truly wild explanations.

Where are they?
The extreme difficulty of interstellar travel is a plausible explanation of a lack of visits.
The distances between stars are enormous:
- Need very large amounts of time or
- Extremely large amounts of energy
The fastest spacecraft: Voyager 1&2
- Outward bound at 15 km/sec (0.005% c)
- Need 80,000 years to reach the nearest stars
Relativistic Starships
Accelerate a starship to near-light speeds
Need 0.1c to reach nearest star in 50 years
Energy costs are enormous
Amount of fuel increases exponentially with the acceleration time
(use more fuel at first)
50% max efficiency for matter/anti-matter fuel
But the production efficiency is extremely low

Possible given a sufficiently advanced technology?

Talk is Cheap! (and travels at the speed of light)

If you really want to bridge interstellar distances, use light to send messages.
Messages travel at the speed of light
Very low energy cost per message
What wavelengths to use?
Microwaves 1000-10000 MHz is a region of relatively low cosmic
background “noise”
Lasers at visible to IR wavelengths: very few natural lasers in the sky
to cause confusion

Earth is already on-the-air

We have been inadvertently beaming radio signals into space for the last 80 years:
Radio broadcasts from the 1920s onward
Television broadcasts from the 1950s onward
We could detect these with current technology

Episodes of “I Love Lucy” will have already reached most solar
neighborhood stars (~40 light years)... is this a good thing?

Increasing radio silence

Earth’s radio brightness has been decreasing
Introduction & spread of cable TV
Increased use of “directed” communication (e.g., fiber optics, beamed satellite, etc.)
Sufficiently advanced civilizations may emit less “waste radio” & become radio quiet:
   If a civilization wants to be found, it may have to deliberately broadcast its presence.

The Search…

SETI:
   Search for Extra-Terrestrial Intelligence
A relatively inexpensive search strategy to look for radio signals from extraterrestrial civilizations.
   Phoenix project of the SETI Institute
   Optical & Microwave SETI at Harvard
   Various smaller projects

What are we looking for?

Signals that appear “artificial”
   Very narrow “bandwidth” (<300 Hz, the narrowest natural maser sources)
   Pulsed signals (common way to encode information)
   Highly polarized signals (another encoding scheme)
   Very little frequency “drift”
So far, no detections…

Pioneer 10 detected. Nice to know we can detect our own artificial signals from deep space.

What if we detect something?