Lecture 42

Life in the Universe

“Drake equation”

Suitable Planets

Solar system searches

SETI

Speculation on Extraterrestrial Life

What is Life?

• Who knows? Most conservative: Earth-like life:
  – Carbon chemistry based
  – Self-Replicating
  – Earthlike planet (presence of liquid water)
  – Development time - $10^9$ years

• How many planets are there out there with life?
Possibilities outlined by "Drake Equation". General form

Number of Examples Now
= Rate of formation/year of suitable planets
$\times$ Fraction of planets which develop life
$\times$ Lifetime of life (years)
Suitable Stars

• How many planets have some form of (Earthlike) life? Can be estimated with astronomical data:
  \[ N_L = R_* f_p n_e f_L T_L \]
  
  \( R_* \): Rate of "suitable" star formation
  - \( M_* < 1.5 \, M_{\text{sun}} \). Otherwise main sequence lifetime < 10^9 years and life would not have a chance to develop
  - \( M_* > 0.5 \, M_{\text{sun}} \). Otherwise "Earthlike" planet would have to be so close that it would be orbiting synchronously (too conservative??)

• Leaves main sequence spectral types F5 - K5.
• \( \Rightarrow R_* = 1/\text{year} \) in our galaxy.

Suitable Planets

\( f_p \): Fraction of star systems that form stable planetary systems. 99 nearby planetary systems have been found. Seems to be common.

• Star and planet formation theories seem to inevitably form planets or binary stars (no place else to shed angular momentum during collapse).
• Likely get stable planets around single stars
• \( \Rightarrow f_p = 0.5 \)

\( n_e \): Number of Earthlike planets/planetary system. To have liquid water for > 10^9 years have narrow range of orbital sizes \( A_L \) with the right temperature.
• \( A_L = 0.9 - 1.1 \, \text{A.U.} \) for solar system? Certainly Venus and Mars are no good.
• \( \Rightarrow \text{guess} \, n_e = 0.1 \)
Suitable Life

$f_L$: Fraction of Earth-like planets which develop life at some time. Who knows?

- Evidence is that it is easy to form "organic" carbon compounds (e.g. amino acids seen in carbonaceous chondrite meteorites)
- Earth as example: evidence for self-replicating forms $10^9$ years after planet formation.
- $\Rightarrow$ guess $f_L = 1$

$T_L$: Duration of detectable life. Use our own case as example.
Life mainly detectable by alteration of atmosphere: production of O$_2$.
- $\Rightarrow T_L = 10^9$ years

Life, the Universe, and Everything

- $N_L = 1/yr \times 0.5 \times 0.1 \times 1 \times 10^9$ yrs
  $= 50,000,000$ currently life-bearing planets in our Galaxy!!

- Job for astronomers: Detect terrestrial planets in new planetary systems.
  - Doppler effect of acceleration of star by planets (almost there)
  - Detect planets directly by Optical/IR interferometry
  - Detect O$_2$ in planetary atmospheres.
  - NASA Terrestrial Planet Finder ("TPF") 2010?
Life in our Solar System

• Most promising: Mars
  – evidence for running water in past
  – no poisonous gasses

• Martian searches
  – Viking 1 and 2 (1976). 4 chemical experiments. Negative for life, though did find some surprising soil chemistry
  – A meteorite originating at Mars may have (defunct) critters
  – Mars Science Lab (“MSL”) (2010): rover with on-board lab

• Another suggested spot: Europa, Enceladus
  – Evidence for liquid water beneath ice surface, kept warm by tides (Europa: Jupiter, Enceladus: Saturn)
  – NASA Jupiter Icy Moons Orbiter (“JIMO”) 2015?
  – Next: Dropping a probe to drill into ice?

SETI, Search for Extraterrestrial Intelligence

Look for radio communications from technological civilizations

• \( N_c = R_* f_p n_e f_i f_c T_c \)
  – \( f_i \): Fraction of life-bearing planets developing "intelligent" species. < 1
  – \( f_c \): Fraction of intelligent species which choose to communicate. < 1
  – \( T_c \): Duration of communication phase. 100 < \( T_c < 10^6 \) ??

• Best case: \( N_c = 1 \times 0.5 \times 0.1 \times 1 \times 1 \times 1 \times 10^6 = 50,000!! \)
• Worst case: \( N_c = 1 \) (Us)
• Since \( T_c << T_L \) the fraction of solar-type stars now communicating is very low. Must listen to a lot of stars
• Mean separation > 1000 pc. Won’t be having any conversations!
• So far, SETI search (now Phoenix, after cancellation of SETI by Congress) is negative. (http://www.seti.org/science/ph-bg.html)
Mars Early Water

2004 Mars Rover Data

strata – flowing water

Viking Trenching Tool
Martian Meteorite: Life?

Europa
Enceladus

Detection of $\text{H}_2\text{O}$ vapor volcano

SETI/ Phoenix (local) signal

Arecibo 1000'