Life in Universe

ASTRON 1141 – Final Review

The Drake Equation

- **Star Formation Rate (R*):** it's hard to measure star formation rate directly
  - Only a small fraction of stars undergo supernovae
  - Only very massive stars explode
  - Massive stars are also extremely rare
  - Get a rate 8 stars form per year
- **Fraction of Stars with Planets (f_p):** planets are extremely difficult to direct directly
  - Need indirect methods: Transit Method and Doppler Method
  - Biases of our detection methods
  - We also only find systems, which are well aligned along our line-of-sight
  - Bias makes us sensitive to very strange "hot Jupiter" systems
  - Shows that types of solar systems we didn't even think were possible are quite common
  - We're finding smaller and smaller planets farther and farther away
    a) This implies that planets are far more widespread than we can currently find
    b) Leads to an optimistic guess that the fraction of stars with planets is 0.8
- **Number of exoEarths around each Star (n_e):** planet needs to be in the habitable zone in terms of size and temperature
  - Ideal stars are F, G and K stars
    a) Not to small or large or harsh or shot-live or dim…
  - Very few Earth-sized planets have been found
  - Can be explained by detection biases: exoEarths are small and far away
    a) This ignores moons warmed by tidal heating
  - Estimate for this is based on our solar system: 1
- **Fraction of exoEarths with Life (f_L):** life arose very soon after the Earth formed (.5 Gyr)
  - Ingredients for Life:
    a) Energy source
    b) Complex chemistry
    c) Liquid solvent
  - Once you have a liquid solvent, the others are fairly easy to get
  - We can tell if a planet has life on its through and infrared spectrum
  - Spectral biomarkers include oxygen, ozone, water and methane
  - Also look out for red edge
  - Once life arises, it's extremely resilient; extinctions have not been able to fully wipe out life
  - It's likely all habitable planets develop life
- **Fraction of exoEarths with Intelligent Life (f_i):** humans are just one branch of the tree
  - How do we determine intelligence?
  - We know it when we see it
  - Encephalization Quotient
  - Complex life, and particularly intelligent life took a lot of time to evolve
  - Out of 4.5 billion year history, intelligence was only around for a few hundred thousand years
  - Value is very uncertain; can optimistically guess 0.1

- **Fraction of Intelligent beings with High Technology (f_c)**

- We won't be able to find intelligent beings unless they have some way to communicate outside of their planet
- Spacecraft and radio waves make for good communication methods
- The road from thinking to tinkering is not very clear
- We only developed interplanetary communication in the last few decades, and we're built for building!
- We'll go ahead and assume this fraction is 1

- **Lifetime of Civilization (L)**
  - High technology is a double-edged sword
  - Enables a lot of possibilities for a civilization to grow
  - Also allows a civilization to wipe itself out
  - Determining this is not fun to think about
  - We have only been communicating by radio within the last century
  - Optimistic estimate is 1000 years
- **Number of Civilizations in our Galaxy**
  - Multiplying all of these through yields 640 civilizations
  - Galaxy is big, and 640 civilizations randomly distributed means an average distance of ~3500 light-years