Life in Universe

ASTRON 1141 – Chapter 12 Seeking Other Earths, What is Intelligence? The Drake Equation, Search for Extraterrestrial Intelligence

Seeking ExoEarths

1. Detection of exoEarths (Earth-sized planets in Habitable Zones) is difficult
2. A few superEarths have already been detected in the Habitable Zone of their host stars
3. Spectral biomarkers could indicate the presence of life on an exoEarth

- Most known exoplanets are ice giants or gas giants: large planets are easier to detect
- exoEarth = a terrestrial planet on a nearly circular orbit in the Habitable Zone of a Sun-like star

- Earth Similarity Index (ESI): a number from 0 to 1, measuring a planet's similarity to the Earth in radius, density, escape speed, and equilibrium temperature

- **Beyond the hype:**
  - Kepler -62 **e** (0.83): 4x mass of Earth
  - Gliese 6672 **c** (0.82): 4.5x mass of Earth, orbits an M star
  - Gliese 581 **g*** (0.82): might not exists, orbits an M star
  - Tau Ceti **e*** (0.77): might not exist, >4x mass of Earth
  - Gliese 667C **f** (0.76): existence disputed, orbits an M star
  - Kepler 022 **b** (0.75): 6x mass of Earth, eccentric orbit?
- Some stars, like Gliese 581, have multiple planets in their Habitable Zone

- **So far, we haven't found exoEarths around other stars, but the search is on…**
  - 1st goal: find Earth-like planets in the Habitable Zones of their host stars
  - 2nd goal: find whether life exists on these exoEarths
- We can't yet study exoEarths, but we can prepare by studying ***our*** Earth from the outside

- The challenge: exoEarths reflect only a tiny fraction of their host star's light, and thus are extremely faint
  - The Earth is about 2 billion times fainter than the Sun

- **The spectrum of the Earth has two components**
  1. Reflected sunlight
  2. Thermal infrared emission
- The shape of a planet's thermal infrared spectrum tells you its temperature
- Earth's spectrum can be measured by spacecraft or by looking at Earthshine reflected by the Moon
  - Absorption lines are due to different molecules in Earth's atmosphere

- **Spectral biomarkers are spectrum features indicative of life chemistry**
  - O_2: easily confused with other features (false positives)
  - O_3: results from sunlight shining on O2
  - H_2O: necessary, but not sufficient for life
  - CH_4: byproduct of anaerobic life

- **We can learn much about an exoEarth from its spectrum**
  - Got oxygen?
  - Got water?
  - Got an atmosphere?
  - Got life?
- **As the exoEarth turns:**
  - Oceans and continents rotate in and out of view
  - We could infer climate: deserts, snowballs, or jungle worlds

Seeking Intelligence

1. Discovering intelligent life would be more interesting than discovering simple life
2. On Earth, intelligent life took billions of years to develop
3. If intelligent beings develop advanced technology, they can make their existence known

- **It would be interesting to find spectral biomarkers in the spectrum of an exoEarth**
  - However, finding intelligent extraterrestrial life would be even more interesting
- Historically, much of the speculation about extraterrestrial life has focused on intelligent life

- **What does it mean to be "intelligent"?**
  - It asks the question, "What's it all about?"
  - It uses tools to manipulate its surroundings
  - It uses language to communicate with other intelligent beings

- **On Earth, different animals are intelligent to different extents and in different ways**
  - Dolphins communicate with contact calls and "signature whistles"
  - Chimpanzees & bonobos modify sticks and use them to fish for termites
- **Intelligent beings develop a "culture" of behavior handed down from one generation to the next**
  - Dolphins teach their children how to use sponges to protect their snout
  - Chimpanzees teach their children how to use stones to crack nuts

- Language is helpful for transmitting culture (Parents can give more than DNA to their offspring)
- Written language allows storage of more information

- **On Earth, the encephalization quotient (EQ) can be used a proxy for intelligence**
  - EQ = an animal's brain mass divided by the average brain mass for other species with the same body mass
- **EQ is correlated with complex behavior, of the sort we describe as "clever"**
  - EQ of humans: 7
  - EQ of dolphins: 4.5
  - EQ of chimpanzees: 2.5
  - EQ of cats & dogs: 1
- **Some classes of animal show EQs that increase over many generations**
  - EQ is partially a heritable trait
  - Intelligence is correlated with EQ
  - Intelligence is sometimes used in survival

- **Intelligence as great as a human's took a long time to develop on Earth**
  - Life arose within a few hundred million years of the end of heavy bombardment
  - Human life took nearly four billion years to arise

- **So far, the human species has been spectacularly successful, as far as growth in numbers is concerned**
  - Intelligence can be an advantageous trait
- **Human intelligence has made it possible for us to destroy our own species**
  - Intelligence can be a disadvantageous trait

- An intelligent species with advanced technology can make itself known to intelligent species elsewhere
- Advanced technology**: ability to send radio signals and build interstellar spacecraft**
  - By this criterion, human technology *barely* qualifies as advanced
- **Will high intelligence inevitably lead to advanced technology?**
  - Appendages that can manipulate tools are useful if you want to develop technology
- **Will high intelligence plus opposable thumbs inevitably lead to advanced technology?**
  - 30,000 years ago, people had brains identical to ours; they didn't immediately build radios & spaceships
- A planet of Zen monks would not be interested in broadcasting reality TV to the universe

The Drake Equation

1. The Drake Equation is a way of estimating the number of advanced civilizations in our galaxy
2. Some inputs into the Drake Equation are well known; others are highly conjectural
3. Even optimistic estimates suggest that advanced civilizations are not common

- **A reason for thinking that intelligent life with advanced technology exists elsewhere is the sheer number of stars**
  - 100 billion galaxies in the visible universe
  - 100 billion stars per galaxy
  - 10,000 billion billion stars
- If each star has just a one-in-a-trillion chance of hosting an advanced civilization, there should be billions of them

- Downside: if each star has a one-in-a-trillion chance of hosting an advanced civilization, we're probably the only one in our galaxy

- The Drake equation**, devised by the astronomer Frank Drake, estimates the number of advanced civilizations in our galaxy**
  - An "advanced civilization" is defined as one that can communicate across space
- The uncensored Drake equation:

$$N = R_* \times f_p \times n_e \times f_L \times f_i \times f_c \times L$$

  - N = number of advanced civilizations
  - R_* = rate of star formation
  - f_p = fraction of stars with planets
  - n_e = number of exoEarths per planetary system
  - f_L = fraction of exoEarths with life
  - f_i = fraction of life-bearing planets with intelligent life
  - f_c = fraction of intelligent life with communication technology
  - L = lifetime of an advanced civilization

- R_***, the rate at which stars form in out galaxy, is fairly well known**