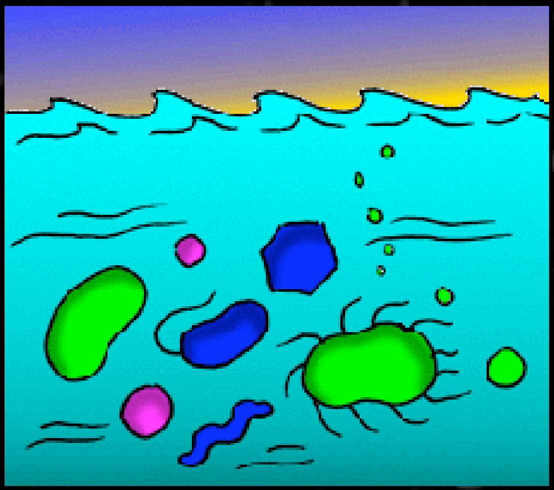
Extraterrestrial Life



the Drake Equation

$$N = R_* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

- R* = Star Formation Rate

  = Number of Stars / Age of the Galaxy

  = 400 billion stars / 10 billion years

  = 40 stars per year (10, 20, 25, 45)

Number of Stars = Mass of stars in the galaxy / Mass of the average star

= 160 billion solar masses / 0.4 solar masses/star

= 400 billion stars

Formation of Stars

- **Gravity causes a mass of gas to collapse, increasing the density and temperature until nuclear reactions begin.**
- **First generation stars formed from a gas containing hydrogen and helium, while current star formation occurs in molecular clouds (colder than the first ones – therefore less massive stars), with molecules and dust particles. (infrared observations)**
- **Stars form in large clusters, but low-mass stars can form in isolation ("inside-out collapse")**
- **Massive stars have smaller lifetimes**
- **More Low-mass stars than Massive stars.**
- **Rotation of stars while collapsing is amplified due to a principle: conservation of angular momentum.**
- **Disks common around low-mass stars and others. Possible planet formation.**
- **Brown Dwarfs are more massive than planets but don't burn H, therefore are not Stars. (between 13 Mj and 0.07 Ms)**

Fp

fraction of stars that have planetary systems

- Detection of Extrasolar Planets (1995)
  - Direct Detection (see them or infrared)
    - Not possible nowadays
  - Indirect Detection (wobbling stars)
    - Astrometric Technique ↔ stars change position in the sky to more distant (background) stars
    - Spectroscopic ↕ Doppler effect (Blue/Red)
    - Transit in front of the star
    - Gravitational lensing
- First two techniques showed that 2/3 of stars are binary stars.
- Detection techniques find Large planets Close to the star.
- Better technology will detect small planets closer to the star; plus, small stars are surrounded by disks → Fp = 1
- Stars must have heavy elements to form disk with planets → Fp >= 0.02

Properties of our Solar System

- Our Sun has a lifetime of 10 billion years
- Around 10 planets
- Regularities (predicted by theory of SS formation)
  - orbits close to the same plane
  - orbits in same direction as Sun's rotation
  - rotation in the same direction (except Venus and Uranus)
  - planets evenly spaced, increased by a factor of 1.5 to 2
  - planets sizes and compositions change with distance: terrestrial planets are rocky (iron and silicates) and gas giants are Gas (Hydrogen and Helium) and Icy
- Formation of Planetary Systems: rotating disk, Sun in the middle and planets forming in the disk. Planetesimals collide and stick together to form inner planets.

Earth formation

- Earth formed about 4.5 billion years ago
- Earth has a large Moon, which has effects on tides, axis and rotation of the Earth.
- Earth has a core of iron and other heavy elements and a mantle of silicates.
- Early Earth had a high temperature and an atmosphere produced by outgassing with N_2 and CO_2 dissolved in oceans.
- O_2 (in our current athmosphere) was produced by living organisms.

Ne

- Number of planets, per planetary system, that are suitable for life

- Ne = Np x Fs

  Np – number of planets around stars like Sun

  Fs – fraction of stars with properties for life to develop
- Water is probably essential as a solvent. So, planet must have exact temperature (distance from the star) to have water (liquid state). Between 273 K and 373 K.
- Pressure must be right too (atmosphere weights the equivalent to 3 elephants).
- Albedo (reflection of light) is important too.
- Rotation, Greenhouse effect and CO_2 cycle (negative feedback) important too. Life also stabilizes this.
- CHZ depends on all this.... And it's smaller than HZ (which moves with time). At present HZ is 0.95 to 1.5 AU.
- → Np = 0.1 or 1 or 3 (optimistic view)

Fs

- First Generation stars have no heavy elements, therefore no ingredients for life
- Only Main-sequence stars have long constant luminosity. 99% of stars.
- Temperature suitable at least for 5 billion years (rule out stars more massive than 1.25 Ms). 90% of stars.
- Problems with very low-mass stars: Jupiter too close not allowing rocky planets to form, tidal effects from close terrestrial planet (slows it down), flares...
- Binary stars (2/3 of all stars) may have stable planets?
- F2 = 0.2 to 0.9

- Ne = 3 x 0.9 = 3 planets (optimistic view)

  = 0.1 x 0.07 = 0.007 = 0.01 (1 in 100) (pessimistic view)

Venus

- Very hot (750 K). Greenhouse effect. 96% of CO_2. Pressure 90 times higher than on Earth (270 elephants).
- No O_2 because no living organisms
- Too hot for liquid water.
- Ultraviolet light decomposed H_2O, and H went away
- Volcanic activity and sulfuric acid clouds.

Mars

- Thin atmosphere with 95% of CO_2.
- Low pressure (0.6 of Earth) does not allow liquid water.
- In the past maybe had water. It lasted around 1 billion years. Evidence on dry riverbeds and large canyons. Maybe life during that time.
- Viking Mission had some tests:
  - Cameras: didn't show any Martians!
  - GCMS: found no organic molecules (no presence of dead things)
  - GEX: O_2 released by chemical reaction.
  - LR: radioactive C release, probably due to peroxide reaction
  - PR: it thoght about life adapted to Martian conditions. Maybe found chemical reactions.
- ALH84001: nanobacterias in a rock from Mars? Maybe not.

Jupiter, Europa and Titan

- Jupiter with Sinkers, Floaters and Hunters in high atmosphere?

- Europa (moon of Jupiter):
  - Ice very reflective → high albedo
  - Liquid Ocean below ice. → life near hydrotermal vents?
  - Source of energy in the interior from tidal forces from Jupiter.

- Titan (moon of Saturn):
  - Thick atmosphere with 85% Nitrogen. Pressure 1.5 times than on Earth.
  - Oceans of Methane and Ethane?