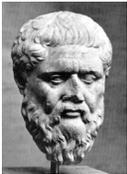


Habitable Planets

The Search for Life in the Galaxy

Is There Life Elsewhere?



- **Plato:** Earth is the only habitable world

Epicurus: There is an infinity of worlds

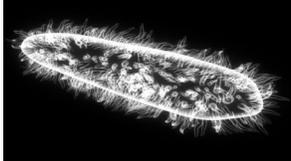


What is Life?

- **Energy:** life extracts energy from the environment
- **Structure:** organized units
- **Replication:** organisms reproduce
- **Adaptability:** organisms adapt to changing conditions

Life As We Know It

- Made up of **cells**
- The cells are filled with **water**.
- Chemistry is based on **carbon**.



Requirements for life

- Water
- Source of energy
- Reducing atmosphere (no oxygen)



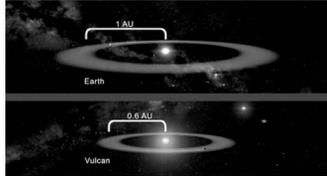
Life on the Solar System

- Mars
 - Had water in the past
- Europa
 - Sub-surface ocean
- Titan
 - Nitrogen atmosphere
 - Methane lakes
 - But cold temperature
- Uranus & Neptune
 - Warm, watery interiors



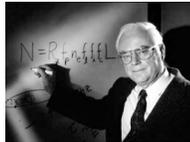
The Habitable Zone

- *The region around a star where liquid oceans can exist.*



The Drake Equation *the search for N*

- N = the number of radio loud planets in the Galaxy
- "radio loud" = sending radio signals that can be detected from other stars



Frank Drake

The Drake Equation *the factors*



- 3 astronomical factors

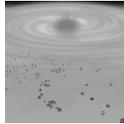
- 2 biological factors



- 2 sociological factors

The Drake Equation *the astronomical factors*

- R : the rate of star formation
- f_p : the % of stars that have planets
- n_p : the number of habitable planets per solar system



The Drake Equation *the biological factors*

- f_l : % of planets on which life develops
- f_i : % of life-bearing planets on which intelligent life develops



The Drake Equation *the sociological factors*

- f_c : % of intelligent species that can send radio signals over interstellar distances
- L_c : average lifetime of technological civilizations



What is N?

- Drake (1960): $N = 4$ to 200,000,000 depending on L_c
- Sullivan (1964) *We Are Not Alone*:
 $N =$ a lot
- Bracewell (1975): *The Galactic Club*:
 $N =$ millions
- Rood & Trefil (1981): *Are We Alone?*:
 $N = 5000$ to one

The Bottleneck Scenarios

- Only G stars?
- Only single stars?
- Only in *continuously* habitable zone
- Only on planets with a large moon
- Ice ages needed to trigger technology
- Why broadcast?

The Fermi Paradox

- The Galaxy is 10 billion years old, but only 150,000 LY across
- Even at 1% of c , spacecraft could cross the Galaxy in 15 million years.
- Why aren't they here yet?



Enrico Fermi

The Fermi Paradox

What does it mean?

- 1) They have been here already, but didn't leave any traces.
- 2) They are really here, but are hiding.
- 3) They are avoiding us.
- 4) There is only one other civilization in the Galaxy and it hasn't got here yet.
- 5) Civilization lasts less than 15 million years.



SETI

the Search for Extraterrestrial Intelligence

- 1) There are many other civilizations.
- 2) They have probably been around much longer and are much more advanced.
- 3) They will have learned to send radio messages to us.
- 4) They want to send messages to us.

SETI

- Project Ozma (1960)
 - 2 stars
 - 1 channel
- The SETI program (1984-)
 - 1000 stars
 - Millions of channels



Dr. Jill Tarter



Allen Telescope Array
