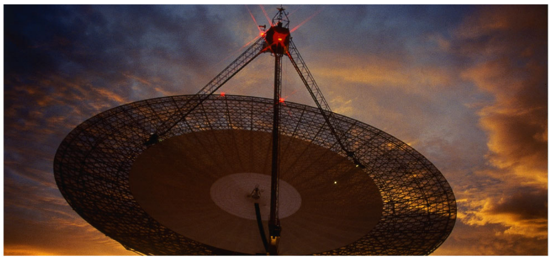
Chapter 24
Life in the Universe



Agenda

- Announce:
  - On line assignments & Solar Lab
  - **Thursday:** Review for Final; Crab Lab
  - **Tuesday:** Project Presentations
  - **May 8 1:50-4:30pm**: FINAL EXAM
- Observation tonight 8pm Great Lawn…what will we be able to see?
- Review/finish Ch. 24
- Extra Credit Presentations

Lessons from Life on Earth

- Appeared very soon (w/in hundreds of millions of years) after heavy bombardment
- Has common ancestry (evolution)
- Occurs in most extreme areas—black smokers, hot springs, artic rocks
- Its building blocks assemble naturally (amino acids, pre-cells)

Necessities for Life

- Nutrient source
- Energy (sunlight, chemical reactions, internal heat)
- Liquid water (or possibly some other liquid)

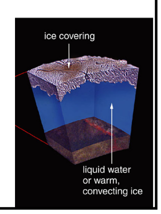
Hardest to find on other planets

Life in the Solar System

- Mercury & Moon—barren and dry
- Venus—too hot for liquid water
- Mars—
  - Liquid water in past (present?)
  - Possible volcanic activity
- Jovian Planets—strong vertical winds
- Pluto & Outer bodies—too cold

Jovian Moons

- Jupiter's Europa (and Ganymede & Callisto):
  - tidal heating begets ocean under icy crust
  - Volcanic vents
  - Presumably has lots of chemicals for life
- Saturn's Titan
  - Surface too cold for liquid water, but may have liquid methane
  - Lots of organic molecules



Life outside the solar system

- Look for stars with planets
  - Can only really look at surfaces
  - Can barely find large planets, no hope for moons
- Try to identify habitable planets:
  - Contains necessities for life
  - Not necessarily ***has*** life

Constraints on star systems:

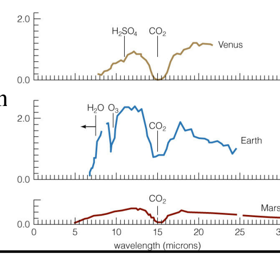
1) Old enough to allow time for evolution (rules out high-mass stars - 1%)
2) Need to have stable orbits (*might* rule out binary/multiple star systems - 50%)
3) Size of "habitable zone": region in which a planet of the *right size* could have liquid water on its surface.

Even so… billions of stars in the Milky Way seem at least to offer the possibility of habitable worlds.

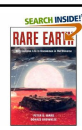
Could We detect Life in other Solar Systems?

Could We detect Life in other Solar Systems?

- Radio…assumes they want to and they're advanced
- Abundant oxygen in atmosphere…photosynesis
- Needs work…



Rare Earth?



- Multiple Earth-sized planets in our system…expect many in other systems?
- Terrestrial planets require heavy elements..galactic habitable zone?
- Can't have too many impacts…need a big Jupiter-like planet to "kick out" comets?
- Stable climate:
  - not like Venus (overheated) or Mars (froze over)
  - Large Moon stabilize tilt

SETI:
Search for Extraterrestrial **Intelligence**

- More specific than search for ET life:
  - Chances for intelligent life?
  - Intelligent life that wants to communicate?
  - Intelligent life that wants to communicate which has ceased to exist…Universe vast in space & time!
- Many factors to consider…

The Drake Equation

Number of civilizations with whom we could potentially communicate

$$= N_{HP} \times f_{life} \times f_{civ} \times f_{now}$$

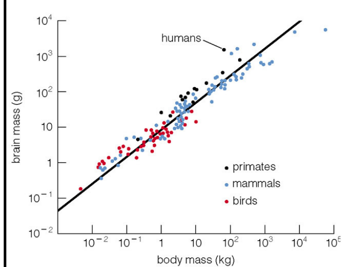
N_{HP} = total # of habitable planets in galaxy
f_{life} = fraction of habitable planets with life
f_{civ} = fraction of life-bearing planets w/ civilization at some time
f_{now} = fraction of civilizations around *now*.

We do not know the values for the Drake Equation

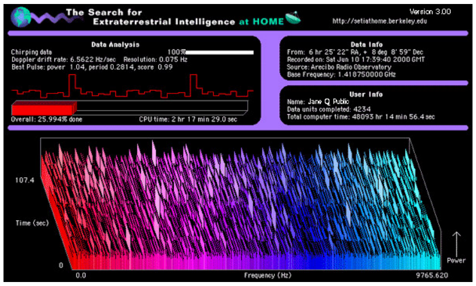
N_{HP} : probably billions.
f_{life} : ??? Hard to say (near 0 or near 1)
f_{civ} : ??? It took 4 billion years on Earth
f_{now} : ??? Can civilizations survive long-term?

...(we've only been producing radio waves for about 60 years!)

Are we "off the chart" smart?



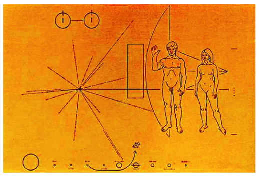
- Humans have comparatively large brains
- Does that mean our level of intelligence is improbably high?
- Does evolution reward ability to build spacecraft?



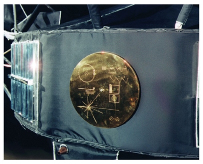
Your computer can help! SETI @ Home: a screensaver with a purpose.

Current Spacecraft

- Current spacecraft travel at <1/10,000 c; 100,000 years to the nearest stars.

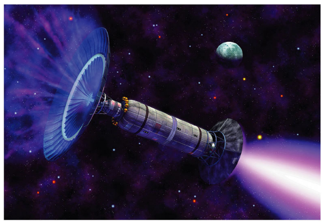


Pioneer plaque



Voyager record

Difficulties of Interstellar Travel



- Far more efficient engines are needed
- Energy requirements are enormous
- Ordinary interstellar particles become like cosmic rays
- Social complications of time dilation

Fermi's Paradox

- Plausible arguments suggest that civilizations should be common, for example:
- Even if only 1 in 1 million stars gets a civilization at some time ⇒ 100,000 civilizations
- So why we haven't we detected them?

Possible solutions to the paradox

1) We are alone: life/civilizations much rarer than we might have guessed.
   - Our own planet/civilization looks all the more precious…

Possible solutions to the paradox

2) Civilizations are common but interstellar travel is not. Perhaps because:
   - Interstellar travel more difficult than we think.
   - Desire to explore is rare.
   - Civilizations destroy themselves before achieving interstellar travel

These are all possibilities, but not very appealing…

Possible solutions to the paradox

3) There IS a galactic civilization…
   … and some day we'll meet them…