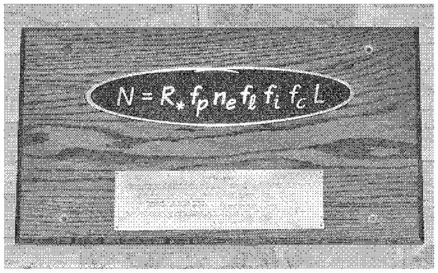
Monday, November 22

The Drake Equation



P.S. #4 will be due Monday, Nov. 29.

The Drake Equation
Key Concepts

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 measured; others are conjectural estimates.
3) Even optimistic estimates suggest that advanced, communicating life is rare.

A reason for thinking that intelligent life with advanced technology exists elsewhere is the **sheer number** of stars.

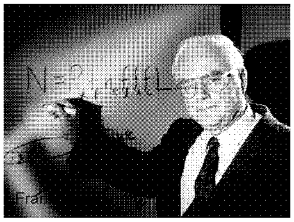
~ 100 billion (10^{11}) galaxies in the visible universe

~ 100 billion (10^{11}) stars per galaxy

~ 10,000 billion billion (10^{22}) stars

Even if each star has a **one-in-a-trillion** chance of hosting an advanced civilization, there should be **billions** of them.

The **Drake equation**, devised by the astronomer Frank Drake in 1961, estimates the number of advanced civilizations in our galaxy.



An “advanced civilization” is assumed to be 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 our galaxy, is fairly well known.

In our galaxy:

Supernovas go off at a rate of ~2 per century.

One in ~400 stars becomes a supernova.

Stars must form at a rate of ~800 per century (~8 per year) to keep the supernova rate constant.

f_p, the fraction of stars with planets, is known from exoplanet searches.

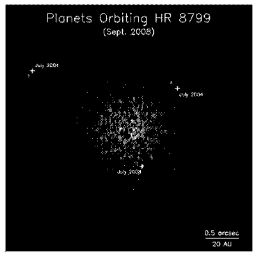
The presently observed fraction is

$f_p \approx 0.15$

However, some planetary systems may contain only small (& so far undetected) rocky planets.

Optimistic Estimate:

$f_p \approx 0.5$

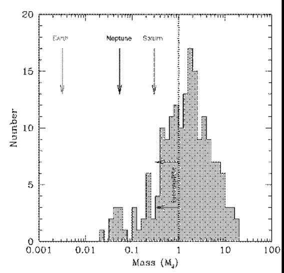


n_e, the number of exoEarths per planetary system, is not yet known.

It should become known in the next decade, but right now, we're clueless.

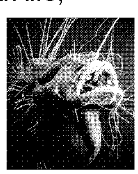
Optimistic Guess:

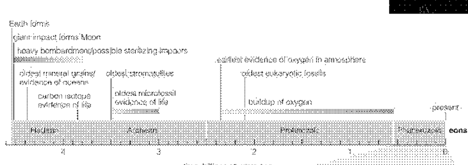
$n_e \approx 1$



f_l, the fraction of exoEarths with life, is wildly conjectural.

We get some guidance from the history of the Earth, where life arose soon after heavy bombardment stopped.

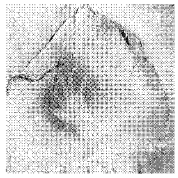




Optimistic Guess: $f_l \approx 1$

f_i, the fraction of life that is intelligent, is even more wildly conjectural.

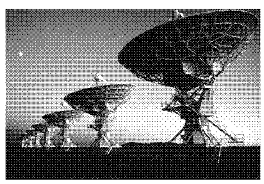
On Earth, it took hundreds of millions of years for life to arise; it took **billions** of years for human intelligence to arise.



Wild (& Optimistic) Guess: $f_i \approx 0.1$

f_c, the fraction of intelligent life that is capable of (& interested in) communication, is conjectural.

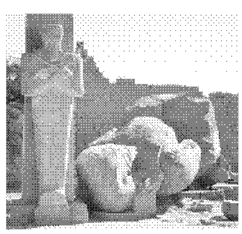
The rise of communication technology is a recent human development.



Shamelessly optimistic guess: $f_c \approx 1$

L, the average lifetime of an advanced civilization, is uncomfortable to conjecture about.

Lower Bound:
We've had radio technology for ~100 years.



Upper Bound:
Next year?
100 years from now?
When the Sun becomes a red giant (5 Gyr)?

$R_* = 8$ per year
$f_p = 0.5$
$n_e = 1$
$f_l = 1$
$f_i = 0.1$
$f_c = 1$
$L = 1000$ years (we won't destroy ourselves quite yet…)

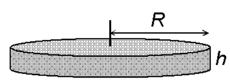
A conjectural, and optimistic, application of the Drake equation.

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

$$N = 8\,\mathrm{yr}^{-1} \times 0.5 \times 1 \times 1 \times 0.1 \times 1 \times 1000\,\mathrm{yr}$$

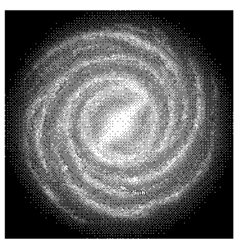
$$N = 400$$

Even an optimistic set of numbers gives a relatively low density of advanced civilizations.



Our galaxy has a volume of 8 trillion cubic light-years.

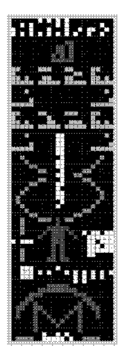
If it contains 400 civilizations, that's one civilization per 20 billion cubic light-years.



The low density of civilizations implies a large distance between them.

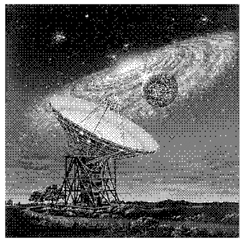
If 400 civilizations were scattered randomly throughout our galaxy, the average distance between them would be ~4000 light-years.

An exchange of messages would take about 8000 years.



The Drake Equation is open to numerous criticisms, and is not without its detractors.

It relies on many unknown quantities, and is heavy on conjecture.



It doesn't account for population dynamics if colonization is possible.

It provides a reasonable starting point for discussing what to look for and how.

Tomorrow's Lecture:

SETI: The Search for Extraterrestrial Intelligence

This Week's Reading:

Chapter 13