

How Many Are Out There?





What do we REALLY hope to find?

Alien microbes on a rather inhospitable world...

Intelligent extraterrestrials that we can communicate with to share ideas about culture, technology, and science.

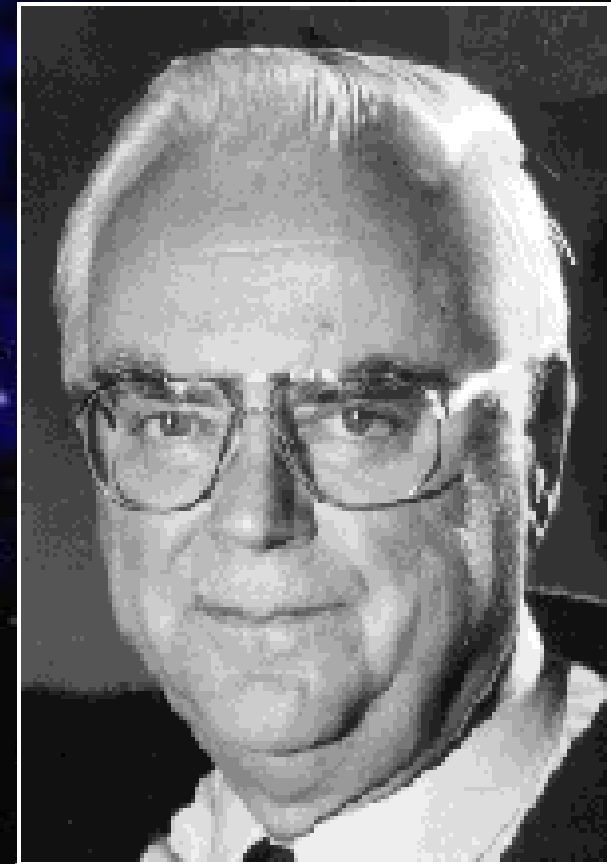


**What are our chances that we might
truly be alone?**

**If we are not alone, how many are
there like us?**

Frank Drake

- n NRAO – Green Bank W.V.
- n Director of Project OZMA (later Project SETI)
- n Currently Chairman of the Board of Trustees for SETI Institute



The Drake Equation - 1961

- n Used to estimate the number of communicative civilizations in the Milky Way
- n Variables are used to represent individual factors related to the overall concept.
- n Each variable can either be scientifically determined or an educated guess can be made.
- n Variables range from reliably estimated to controversial

The Drake Equation (cont'd)

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

N = the number of communicative civilizations

n The number of civilizations in the Milky Way whose emissions are detectable

n Equation is meant as a tool that organizes our thinking rather than restrict our efforts

R^*

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

R^* = The rate of formation of suitable stars

Recall considerations:

- n Large enough habitable zone
- n Not too energetic
- n Long enough lifespan
- n Single star preferred



R^*

- n Involves the rate of star formation AND how many of them are considered *suitable*

Star formation is generally accepted to be 10 – 25 stars per year

- n More low mass stars formed than high mass
- n Star formation has probably slowed over time



R^*



- n If we use our previous spectral type range of F5 – K8
 - n If we assume 300 billion stars in MW
 - n Approximately 70 billion stars
 - n ~ 24% of all MW stars are "suitable"
- 3 – 6 suitable stars form per year**

f_p

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

f_p = the fraction of those stars with planets

n Astronomers generally suspect that planetary formation is very common.

n Discovery of extrasolar planets by Marcy & Butler seems to confirm this.

f_p

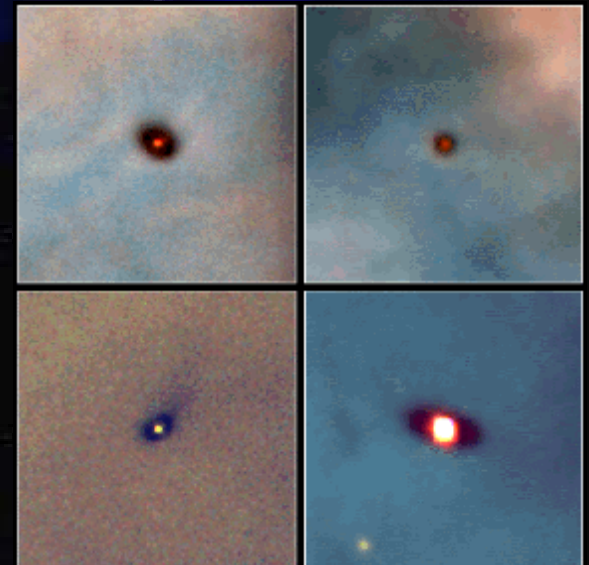
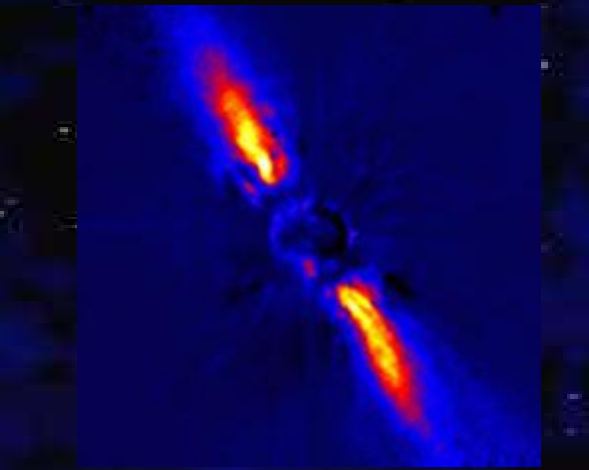
n Beta Pictoris

n Orion protoplanetary disks

$$f_p = 20\% - 50\%$$

n Could be higher (perhaps 100%)

n Future observations with higher sensitivity will help settle this variable down.



Protoplanetary Disks
Orion Nebula

HST • WFPC2

PRC95-45b • ST ScI OPO • November 20, 1995
M. J. McCaughrean (MPIA), C. R. O'Dell (Rice University), NASA

n_e

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

n_e = the number of
"earths" per planetary
system

n Planets that are located
within the habitable
zone

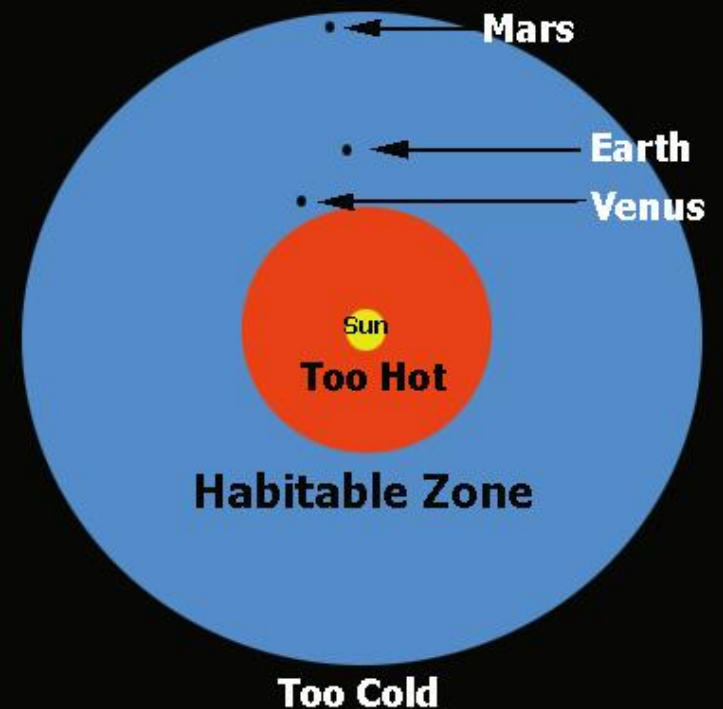
n Planets that have similar
conditions to the Earth



n_e

- n Consider the number of planets per stellar system
- n Our solar system has 1 and nearly 3 "earths"
- n Earlier in our solar system's past, the number was probably more like 3

$$n_e = 1/10 - 4$$



f_l

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

f_l = the fraction of those planets where life actually develops

n Marks the point in the equation where observational science gives way to pure speculation

n We have only one example - Earth

f_l - speculation

The optimist would say:

- n the chemistry of life is universal
- n given enough time, life is inevitable

The pessimist would say:

- n Life on Earth benefited from a series of circumstances that are perhaps unique ("Rare Earth" hypothesis)
- n Some planets that form life might fail to sustain it
- n Cosmic catastrophes will affect survival of life

$$f_l = 1$$

f_i

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

f_i = The fraction of life bearing planets where intelligence develops.

What is the definition of intelligence?



What is Intelligence?

- n **Compotential:** consists of mental mechanisms for processing information.
- n **Experiential:** involves dealing with new tasks or situations and the ability to use mental processes automatically.
- n **Contextual:** the ability to adapt to, select, and shape the environment.
- n **Technological:** the capacity for science and technology.

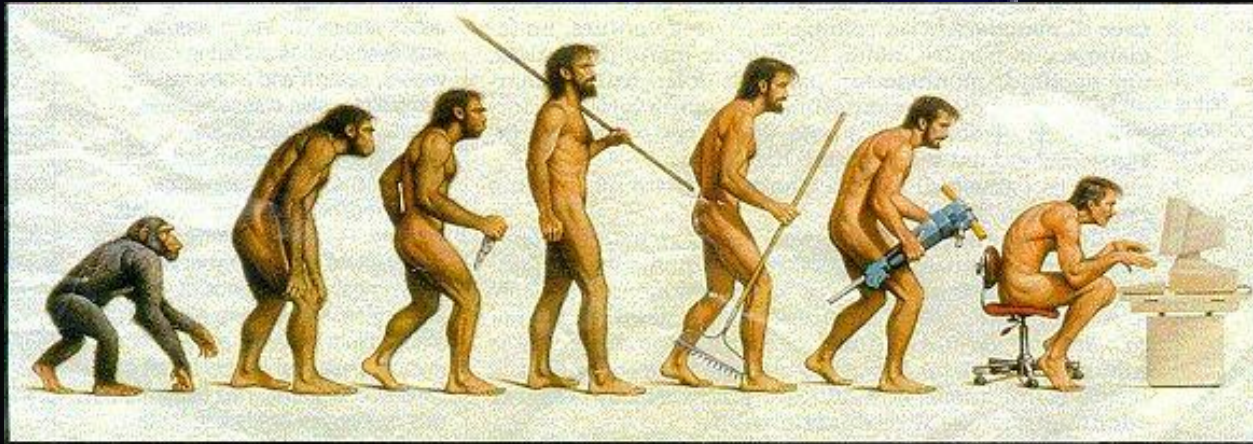
f_i

Is intelligence *inevitable*?

Does natural selection guarantee
intelligence?

- n In general, natural selection tends to lead to complexity.
- n Development of intelligence has a great survival value.
- n Caution: Intelligence does not guarantee survival!

f_i



Somewhere, something went terribly wrong

- n The speed with which intelligence has developed is encouraging
- n 700 million years for life to progress from very basic to incredible diversity and intelligence

Let's be optimistic and say $f_i = 1$

f_c

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

f_c = the fraction of planets where communicative technology develops

n Development of intelligence does not necessarily lead to technology

n A species might be intelligent but not have the need or the means for tool making

n Remote possibility that a species works very hard to NOT broadcast their presence.

f_c



ON THE OTHER HAND...

- n *IF* intelligent species develop technology, we can assume that certain milestones would be similar for all.
- n "Local" broadcasts would leak to space
- n Basic curiosity might lead to intentional broadcasts.

$$f_c = 0.75 - 1$$

$$L \quad N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

L = The lifetime of a communicating civilization

n We have been leaking signals into space for about 100 years.

n We have had the ability to intentionally broadcast signals into space for the last 50 years.

L



Does intelligence carry with it the seeds of inevitable destruction?

There are many man made potential catastrophes

- n Nuclear war

- n Biological war or benevolent biological research

There are non-man made potential catastrophes

- n Cosmic catastrophes

Ironically, we cannot know what L is until we find other alien civilizations

RESULTS OF DRAKE EQUATION

Unknown quantities dramatically affect outcome

n $N = 1$ (we are alone)

n $N = \text{few}$ (we are rare)

n $N = \text{billions}$ (we are in good company)

Most astronomers generally agree that

$$N = L$$

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

3-6

0.1-1

0.1-4

0.1-1

0.001-1

0.5-1

100-10000

Range from $\ll 1$ to 240,000

Range from 2400 to 240,000

RESULTS OF DRAKE EQUATION

- n If N is too small, then civilizations will potentially miss each other over time
- n If N is large then intelligent, communicating life in the universe is commonplace

Which ultimately begs the question....

Where is everybody?



