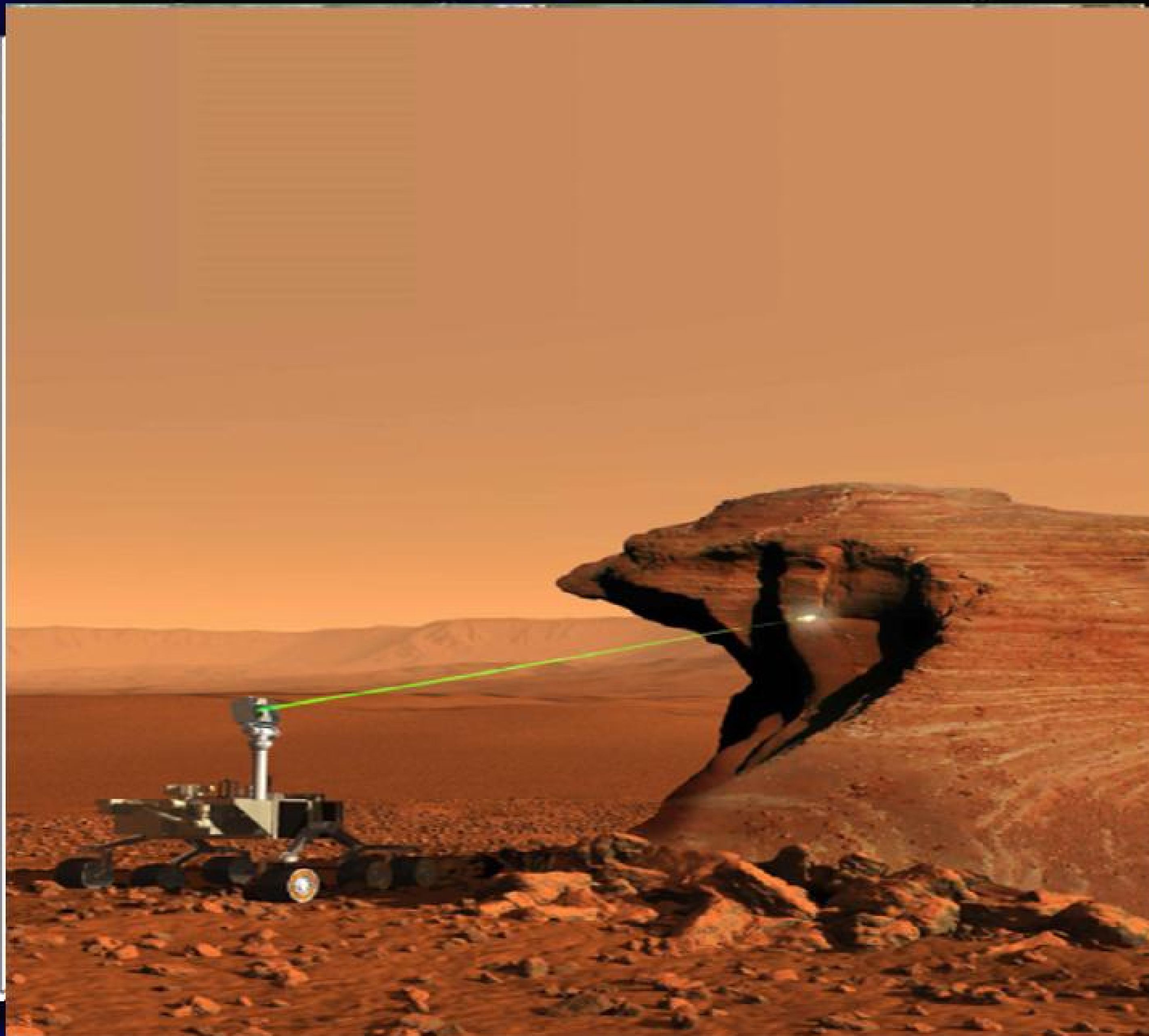
# Curiosity on the way to Mars



# How Many Are Out There?

# What do we REALLY hope to find?

Alien microbes on a rather inhospitable world…

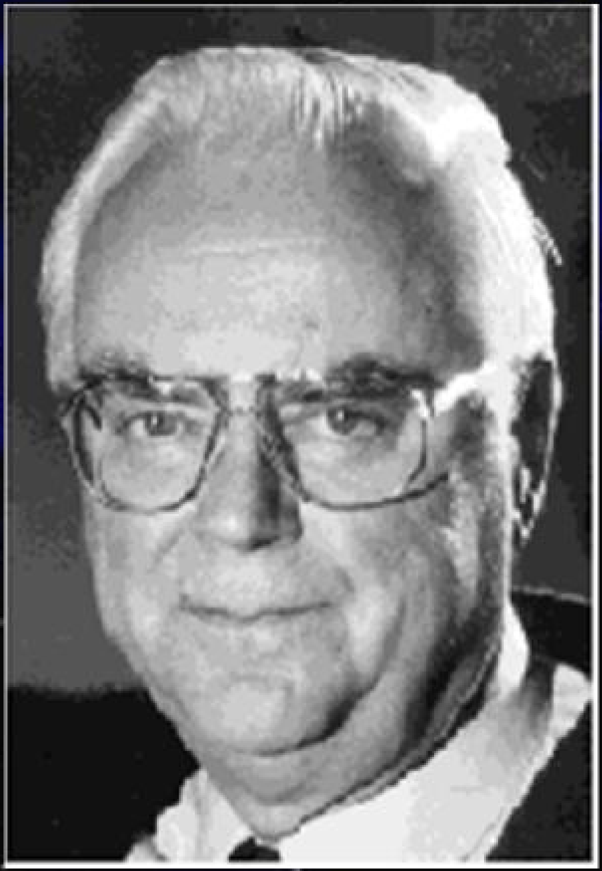
Intelligent extraterrestrials that we can communicate with to share ideas about culture, technology, and science.

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

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

# Frank Drake

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



# The Drake Equation - 1961

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

- The number of civilizations in the Milky Way whose emissions are detectable
- 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:**

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

# R*

- 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

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

# R*

- If we use our previous spectral type range of F5 – K8
- If we assume 300 billion stars in MW
- Approximately 70 billion stars
- ~ 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

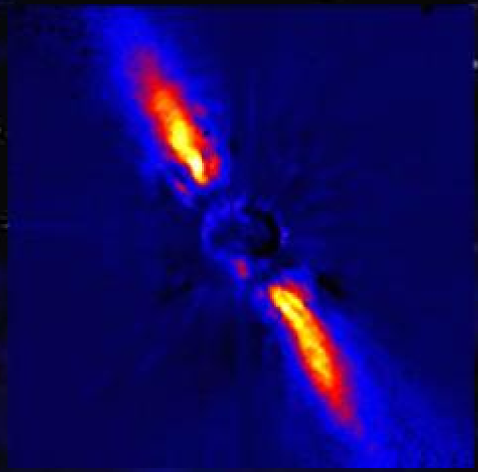
- Astronomers generally suspect that planetary formation is very common.
- Discovery of extrasolar planets by Marcy & Butler seems to confirm this.

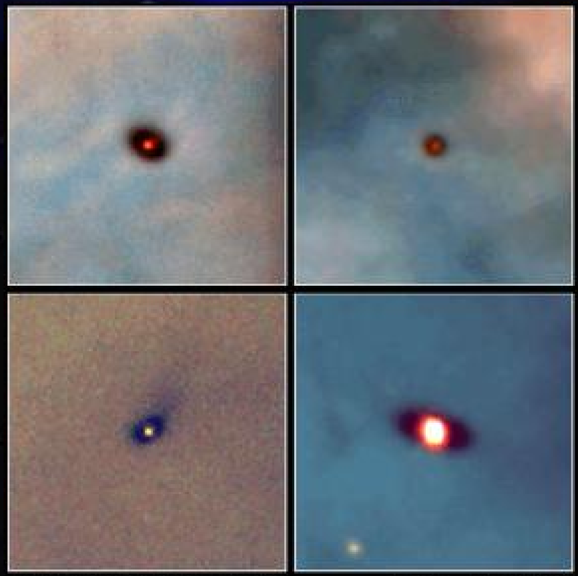
# $f_p$

- Beta Pictoris
- Orion protoplanetary disks

**$f_p$ = 20% – 50%**

- Could be higher (perhaps 100%)
- 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

# $n_e$

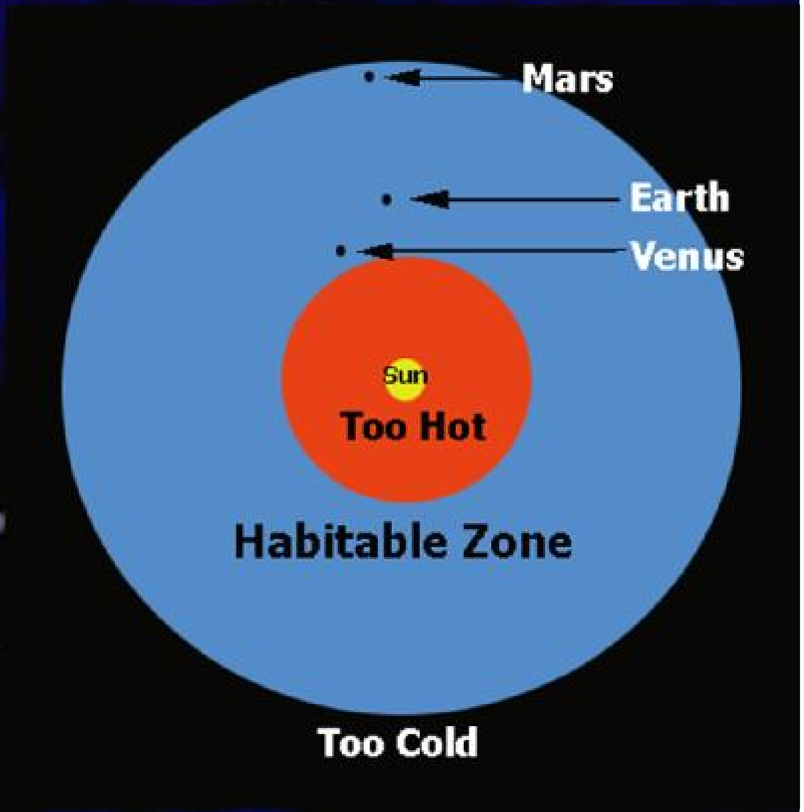
$$N = R^{*} \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

$n_e$ = the number of "earths" per planetary system

- Planets that are located within the habitable zone
- Planets that have similar conditions to the Earth

# $n_e$

- Consider the number of planets per stellar system
- Our solar system has 1 and nearly 3 “earths”
- 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

- Marks the point in the equation where observational science gives way to pure speculation
- We have only one example - Earth

# $f_l$ - speculation

**The optimist would say:**

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

**The pessimist would say:**

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

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

# What is Intelligence?

EQ = Encephalization Quotient =

$$(\text{brain weight})/(0.12(\text{body weight})^{0.67})$$

EQ < 1: animals less brainy than expected for their body size

EQ > 1: animals more brainy than expected for their body size

# What is Intelligence?

Among primates this correlates with innovatory behavior, social learning and tool use

Among birds behavioral flexability

Humans = 7.1

Homo erectus = 5.3
Homo habilis = 4.3

Dolphins = 4.6 (5.0 highest)

Dog = 1.2

Great apes = 1.9-2

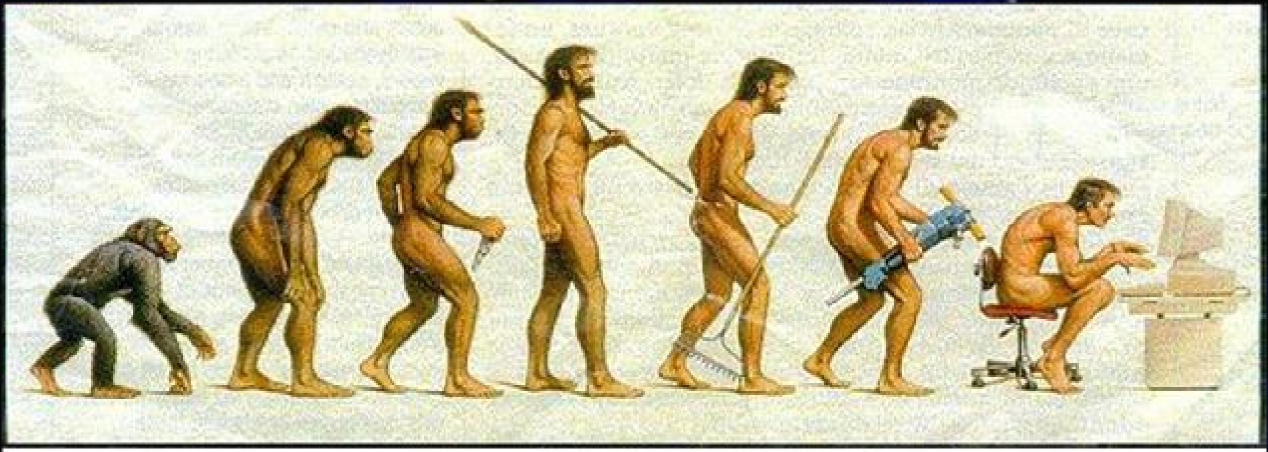
Cat = 1.0

## Is intelligence *inevitable*?

## Does natural selection ***guarantee*** intelligence?

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

# $f_i$



Somewhere, something went terribly wrong

- The speed with which intelligence has developed is encouraging
- 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

- Development of intelligence does not necessarily lead to technology
- A species might be intelligent but not have the need or the means for tool making
- Remote possibility that a species works very hard to NOT broadcast their presence.

# $f_c$

ON THE OTHER HAND...

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

$$f_c = 0.75 - 1$$

# L

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

L = The lifetime of a communicating civilization

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

- Nuclear war
- Biological war or benevolent biological research

There are non-man made potential catastrophes

- Cosmic catastrophes

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

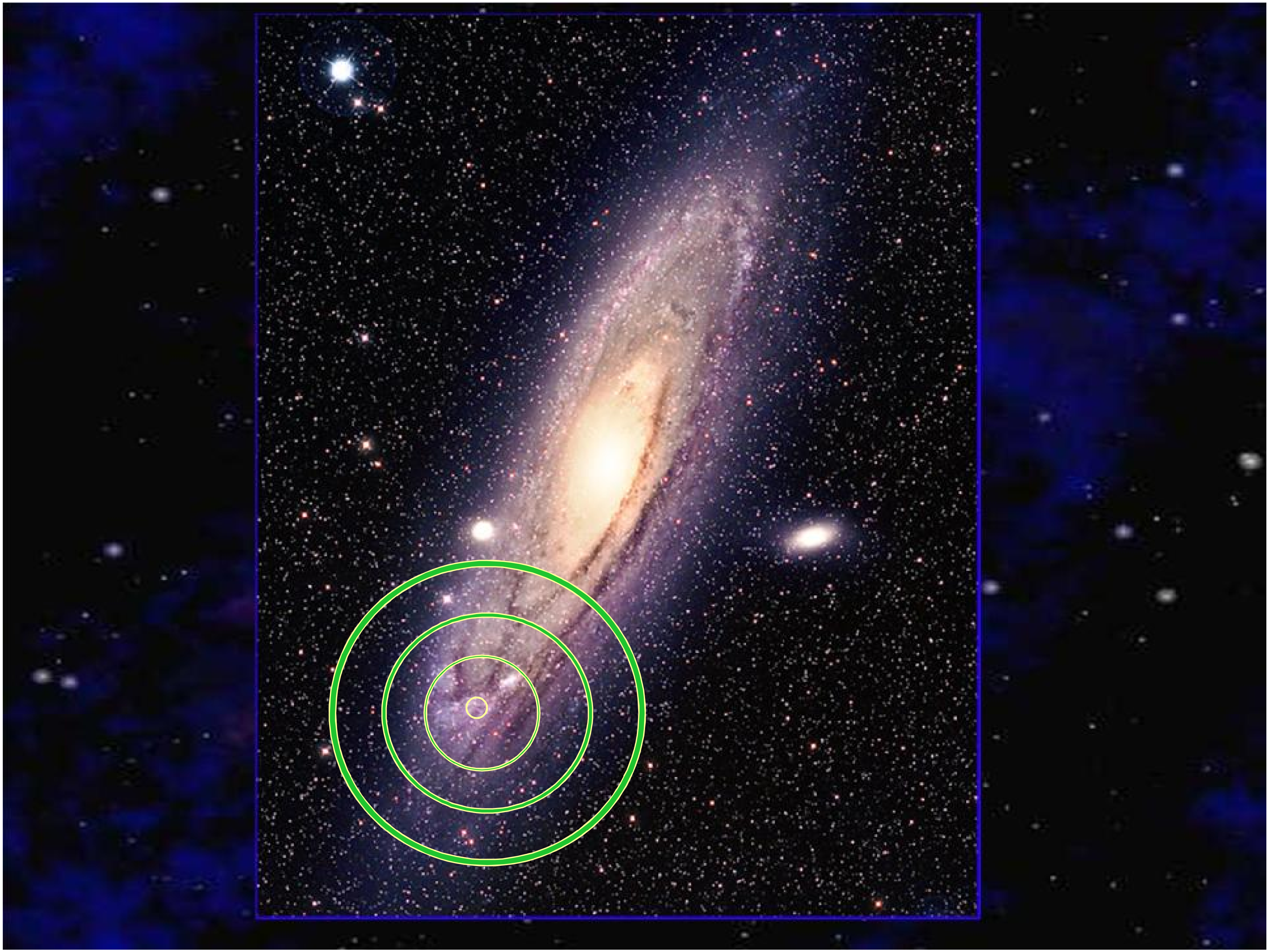
# RESULTS OF DRAKE EQUATION

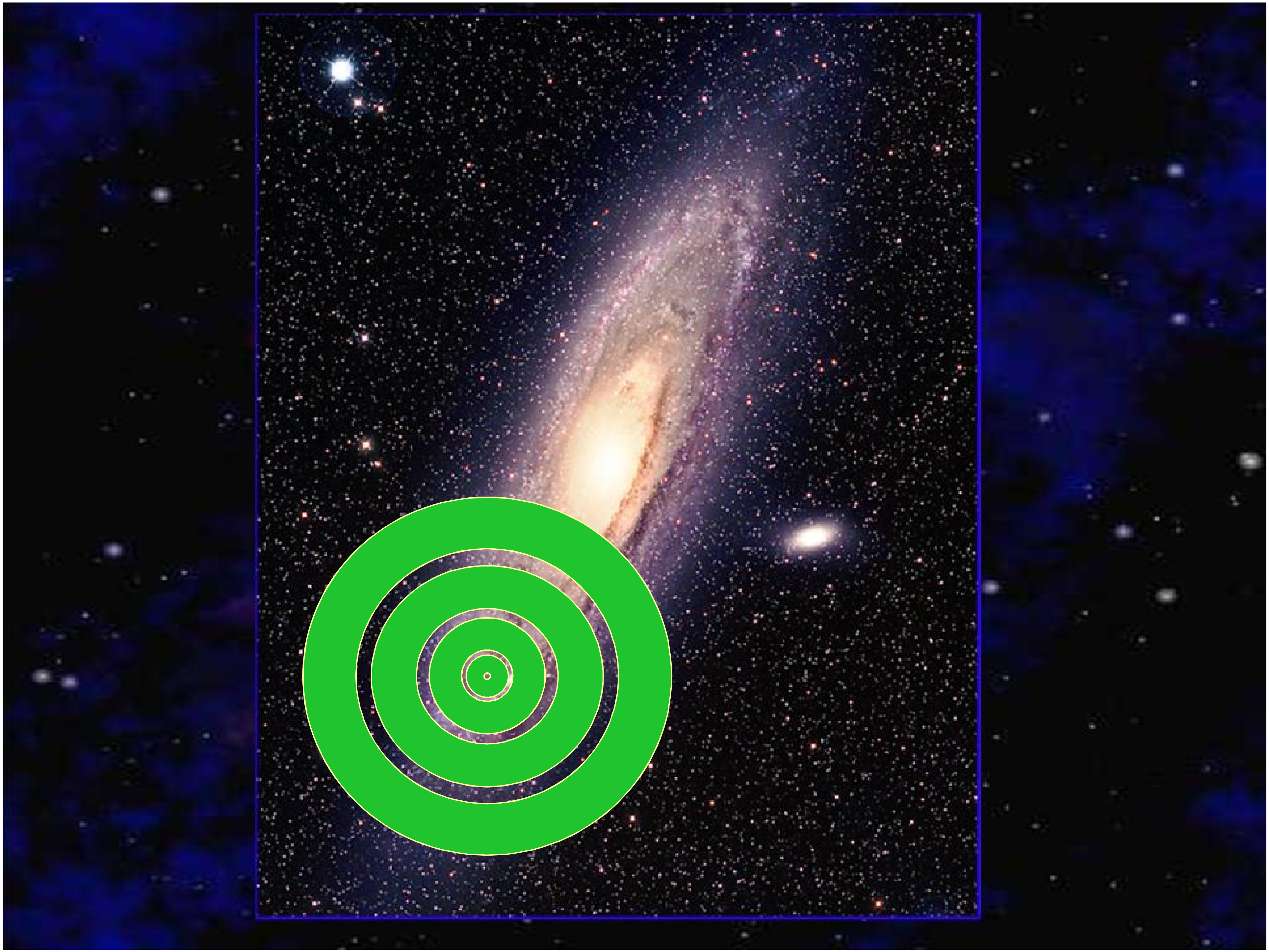
Unknown quantities dramatically affect outcome

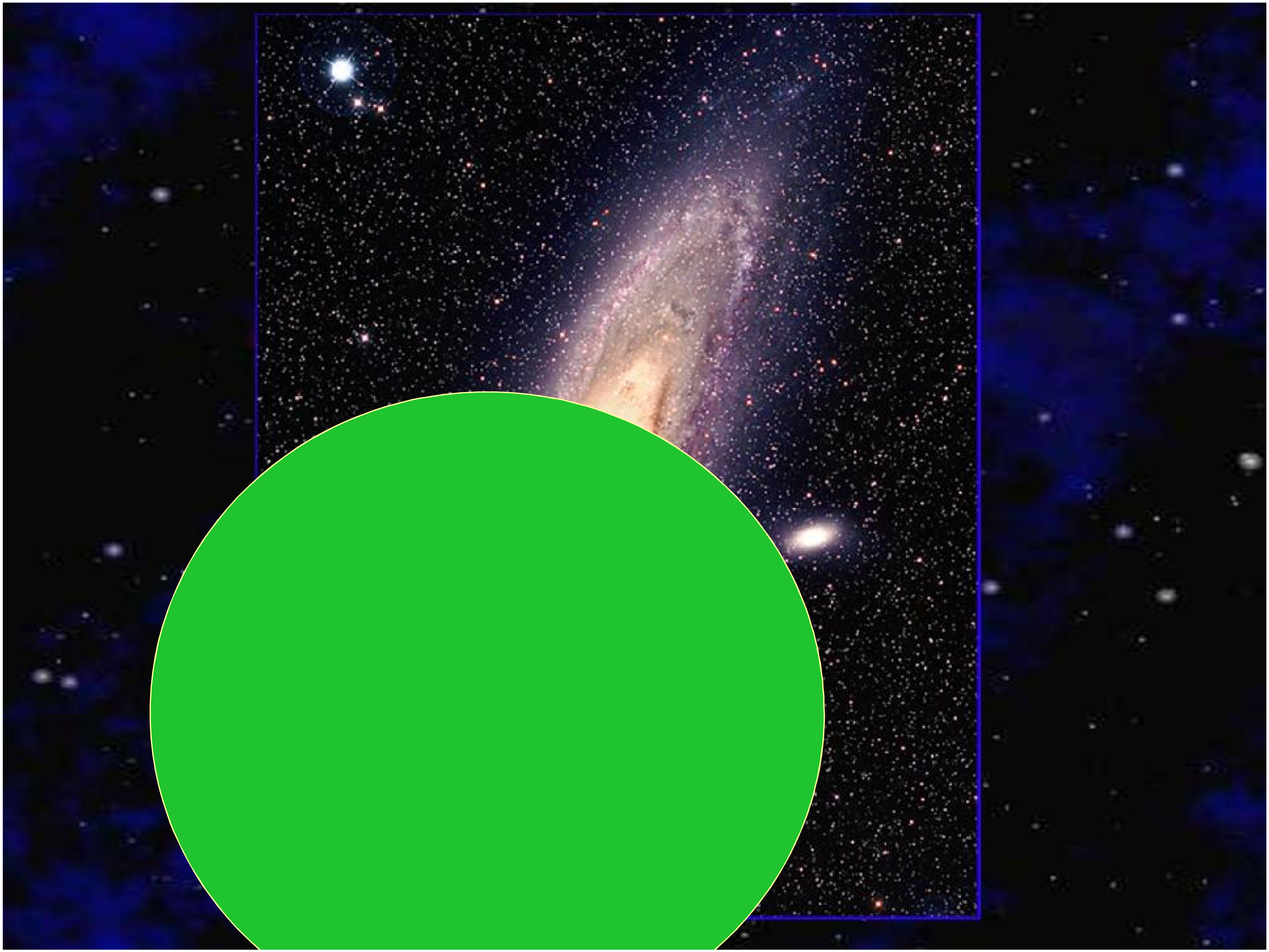
- N = 1 (we are alone)
- N = few (we are rare)
- N = billions (we are in good company)

**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 <<1 to 240,000

Range from 2400 to 240,000

# RESULTS OF DRAKE EQUATION

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

**Which ultimately begs the question....**

# Where is everybody?