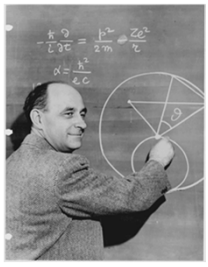
Lecture 42

Where is everybody?

The Fermi Paradox



Astronomy 141 – Winter 2012

This lecture is about the Fermi Paradox.

Apparent contradiction between estimates of the speed of colonization and the lack of evidence of extraterrestrials.

Proposed solutions:

We *have* come in contact with them (UFOs are real Hypothesis)

Civilizations choose not to be noticed (the Zoo Hypothesis or an ethical decision like the “Prime Directive”)

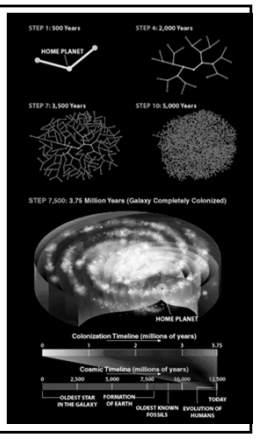
Civilizations by nature are self-destructive (Doomsday Hypothesis)

Complex life never develops (the Rare Earth Hypothesis)

Interstellar Colonization is a rapid, exponential process.

The time to colonize the entire Galaxy is 10-100 Myr even with very modest assumptions

- Ships that travel at 0.01c and take 500 years between stars.
- 5,000 year wait time before dispatching the next ships.
- Inhabited region grows at 0.1% speed of light.
- Fills the Galaxy in ~100 Myr



Colonization times are small compared to the age of the Galaxy for reasonable assumptions.

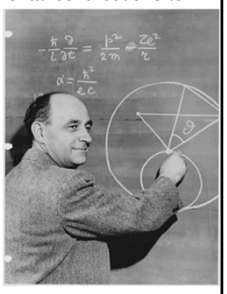
The exponential population dynamics of colonization stands in stark contrast to the static assumptions of the Drake Equation.

Even a pessimistic computation with the Drake Equation could be a dramatic *underestimate* of the number of intelligent civilizations…

"So? Where is everybody?"

Enrico Fermi (1901-1954)

Italian physicist best known for fundamental contributions to quantum theory, particle physics, and statistical mechanics.



Won Nobel Physics Prize in 1938

Built the first nuclear reactor at Chicago in 1942.

Worked on the Manhattan Project and at Los Alamos after WWII

The Fermi Paradox came out of a 1950 lunchtime conversation with colleagues at Los Alamos

If any civilizations have been around in our Galaxy for at least ~10–100 Myr they should have colonized the entire Galaxy by now.

We should have been visited many times over.

But, we have no evidence of extraterrestrial visitation,

nor have we found any alien artifacts on Earth.

1950 New Yorker Cartoon by Alan Dunn

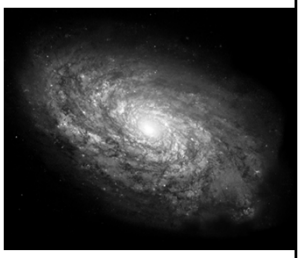
The Fermi Paradox is a statement about the rapidity of colonization, not the frequency of civilizations

Only need one civilization around for at least 10 to 100 Myr to colonize an entire Galaxy.

Galaxy is at least 10 Gyr old.

Could colonize it 100 to 1000x over at that rate.

But, it only has to happen once or twice.



If life and intelligence are very rare, but civilizations are long-lived, get at least a few…

$$N = N_* \times f_p \times n_e \times f_l \times f_i \times f_c \times \frac{L}{Age}$$
$$= 100 \text{ Billion} \times 0.2 \times 1 \times 10^{-5} \times 10^{-5} \times 1 \times \frac{5 \text{ Gyr}}{10 \text{ Gyr}}$$
$$= 1$$

Number over the age of the Galaxy:

10 Gyr / 5 Gyr = 2 civilizations.

If life and intelligence are common, but civilizations are short-lived, get many over the age of the Galaxy

$$N = N_* \times f_p \times n_e \times f_l \times f_i \times f_c \times \frac{L}{Age}$$
$$= 100 \text{ Billion} \times 0.5 \times 1 \times 1 \times 0.1 \times 1 \times \frac{100 \text{ yr}}{10 \text{ Gyr}}$$
$$= 50$$

Number over the age of the Galaxy:

10 Gyr/100 years × 50 = 5 Billion civilizations!

A number of solutions have been proposed to explain the Fermi Paradox.

We are alone…
- and always have been (Rare Earth Hypothesis)
- because civilizations blow themselves up (Doomsday Hypothesis)
- because Nature eradicates us (Inhospitable Universe Hypothesis)

Civilizations have not colonized the Galaxy…
- because it's hard
- because they don't want to

Civilizations *have* colonized the Galaxy but we don't know it
- because they aren't telling us (Zoo Hypothesis)
- because we can't tell

We do have evidence of their existence…
- but the government won't tell us (UFOs Are Real Hypothesis)

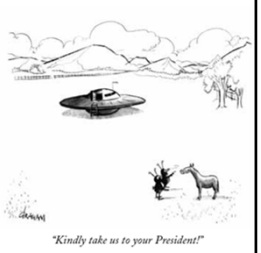
UFOs Are Real?

Extraterrestrial Visitations? No.

Fuzzy photographs and anecdotal accounts of visits and abductions aren't proof.

Claims of secret government conspiracies?

Most can't balance a budget let alone keep secrets for years…



A.S. Graham, *New Yorker*, 1953

There *are* unexplained sightings, but failure to explain them does not justify wild leaps of the imagination.

Civilizations *have* colonized the Galaxy, but…

They aren't telling us…
- "Zoo Hypothesis"
- "Sentinel Hypothesis"
- A "Prime Directive" (ethics)

We are too "primitive" to tell
- They are too advanced or too different from us.

Many examples of "fatal impacts" between peoples in human history, even when well-intentioned.

Civilizations *have* colonized the galaxy but...
we haven't noticed (yet).

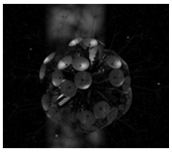
Perhaps aliens live among us, covertly monitoring our culture.

Perhaps aliens use a form of communication that we haven't developed yet...

Makes our radio and microwave "eavesdropping" useless.

Civilizations have not colonized the Galaxy…

…because it is too expensive



Use slow autonomous robotic probes instead of expensive starships

Self-replicating Von Neumann machines

Bracewell "Messenger Probes"

…because they don't want to

No precedent in human history

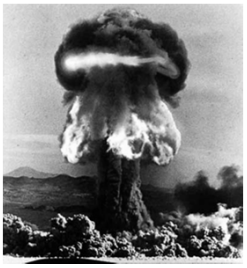
…because civilizations self-destruct before they can colonize the Galaxy

Human populations tend to grow faster than sustainability

Tendency toward aggression
Poor long-range planning
Irresponsibility with technology

"Doomsday Hypothesis"

Nuclear war
Biological warfare
Accidental contamination
Nanotechnology catastrophe
Environmental catastrophe
Zombie apocalypse



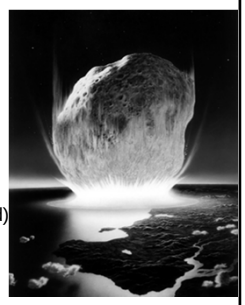
…because Nature can be cruel, which limits the lifetimes of even peaceful civilizations.

Possible exterminating events:

Asteroid or Comet Impact

Supernova or Gamma-Ray Burst sterilizes planet.

Geological Catastrophy
Massive volcanism (Deccan Flood)
Deep ice age (Snowball Earth).



Ample precedent for this in Earth's geological history.

The Rare Earth Hypothesis posits that complex intelligent life and habitable Earths are very rare

We are a product of an extremely unlikely combination of geological & astronomical circumstances.

We're in the right part of our Galaxy.

We're around the right kind of star.

We're on the right kind of planet.

Earth has a large moon that stabilizes its rotation

Complex life arose late, and intelligence even later

Concludes that we are the only intelligent species.