The Fermi Paradox

So is there life in space? In addition to the issues we’ve already discussed, there is a rather amusing argument.
A Wacko Argument?

• Bear in mind that this argument is supported by a lot of very intelligent people, so do not dismiss it out of hand.
• But also bear in mind that a lot of equally intelligent people think that this argument is nonsense.
• You may think that it is nonsense, but you may begin to see its strengths.
Fermi’s Paradox

• This paradox was proposed by Enrico Fermi, he was the man who helped build the first nuclear reactor.

• Consider the question - why did life only start once on Earth?
Analogous Story

- Life got started on Earth relatively quickly
  - Perhaps life forms easily
    - whenever conditions are right.
- DNA evidence suggests all living creatures on Earth are descended from the same microbial ancestors
  - Why?
Origins from Behind the Fridge

- Let’s say the first self-reproducing chemical (whatever it was) appeared in a pool of slime in Africa. Why couldn’t a second self-reproducing chemical have appeared in say North America, and a third in the pool of slime behind your fridge, for example.
- Then there might be three completely unrelated families of life-forms on Earth.
Is this typical?

- Will most inhabited planets have only a single family of life-forms? What do you think?
  - A Yes
  - B No
- Consider this
  - life forms take hundreds of millions of years to evolve
  - But how long would it take one to spread?
Timescales

• Even the most primitive organism can be carried around the world in only a few thousand years
  – by the wind
  – by ocean currents

• Thus, the time needed to spread throughout the world is far less than the time needed to evolve.
First come, first served

- So any new life that forms, unless it is first, probably has to compete with previously existing life.
- The new life will probably lose, the old life has had time to evolve and is probably far more capable than something newly created by chance.
- Thus it makes sense that we are all descended from the first life form to evolve. Other subsequent life will have been wiped out by our competing ancestors.
The Premise

• So - here is the premise for there to be more than one family of life in some region:

  The average time needed to spread throughout the region is much greater than the average time to evolve.

• This premise is not met on Earth. If a planet were much bigger than Earth, it might be met, and you would get different families of life in different regions.
Does our Galaxy Meet the Basic Premise?

• Does our galaxy meet this premise, specifically for intelligence?
  – A Yes B No

• Once intelligence evolves on some planet, how long would it take to spread throughout the Milky Way?

• Is this greater or less than the time it takes to evolve intelligence?
Are we first in the galaxy?

- If an intelligent species can spread through the galaxy fast enough, then you would expect whichever species evolved first to completely colonize the galaxy before the second species even gets started.
- So what are the two timescales?
- Evolution (if Earth is typical) seems to take billions of years.
**Interstellar Colonization**

- How does the time needed for evolution compare with the time needed for a typical alien species to colonize the galaxy?
  - A Evolution >> Colonization
  - B Colonization >> Evolution
  - C Roughly the same timescales for both

- The galaxy is BIG! – Consider this:
  - If we scaled the Earth down to the size of a pea, the Sun would be 300 meters away, while Pluto would be orbiting 12 kilometers away.
The Galaxy is Humungous

- On this scale, the nearest other star (Proxima Centauri) would be twice around the world.
- Consider that humanity’s fastest spacecraft, Voyager, has taken 30 years to get where it is now.
- The gaps between the stars seem very intimidating. Could we ever cross them?
Take it Slowly

• We do have lots of time.
  – Distances that seem impossible to humans, used to dealing with weeks and months, seem pretty easy when you have thousands of years at your disposal.

• Consider what we could do even with current technology.
1% Solution

• With nothing much more than current technology, we could accelerate a spacecraft up to 1% of the speed of light.
• At this speed, we would take about 1000 years to reach the nearest likely locations of habitable planets.
• The only drawback - it would cost trillions of dollars and maybe bankruptcy.
How would it work?

• A thousand years sounds like forever. But this may not be a barrier.
• Consider a trip in something like suspended animation.
  – Frozen fertilized eggs could be sent out, implanted in artificial wombs and raised by robots.
• The spacecraft could be really big and inhabited for generations.
Robots or Humans

• Consider just sending robots, and downloading something of our own personalities into them.

• 100 years from now, medical technology may slow aging. Do you believe this?
  – A Yes  B No

• A 1000 year trip may not sound so bad if you live to be 10,000 years old.
Budget

• Thus, length of time for travel may not be an issue
  – we may well figure out faster methods of travel
• How about that colossal budget?
• A few trillion dollars may sound like a lot today. But if the world’s economy continues to grow, does this become affordable.
  – A Yes  B No
$10 approach

- If we assume 3% per year economic growth, then by the year 3000, the world economy will be $6,000,000,000,000,000,000$ times bigger than it is now.
- A few trillion dollars may be “small change.”
Realistic?

• Is this realistic? It’s not as silly as it seems. Imagine that the medieval world had wanted to build a modern oil tanker. In principle they could - they knew how to smelt iron and shape it.

• But doing something like an oil tanker using medieval blacksmiths would have bankrupted the world back then. 500 years later it is easy.

• Even 100 years from now, building an interstellar spacecraft may seem routine.
Motivation

• So - 1000 years from now, we may be able to travel to other stars quite easily.
• It would be rash to speculate on what will motivate our descendents (if any) 1000 years from now.
• If interstellar travel really is easy and cheap, will someone give it a go? What do you think?
  – A  Yes  B  No
Convicts or Pilgrims

• On Earth, people overcame enormous hurdles to migrate.
• Some did it for their religion, some to avoid religious persecution.
  – Some did it involuntarily (convicts).
• Population pressure or the quest for a better life motivates humans.
• Who knows which of these processes will apply in 3000 AD?
The New World

• Let’s assume that most intelligent life-forms will eventually decide to spread to other stars.
  – Assume 1000 years to develop the economy
  – Assume 1000 years to travel to their first colony

• Once they arrive at their colony, how long will it take them to establish an advanced civilization there?
  – A 1000  B 10000  C 100000  D 1000000
The Australian Example

- It took 200 years for Australia to go from the first few convicts (Botany Bay) to the populous industrialized country it is now.
- So perhaps it would take 1000 years or thereabouts to go from the first few aliens landing on a planet to a civilization capable of building new interstellar spacecraft.
Continuing the analogy

• Consider that we start off with one planet inhabited by this alien race. It sends out ten spacecraft to new planets.
• After 2000 years or so, each of these ten new planets has been reached and is industrialized, and sends out ten new spacecraft in turn.
• How long will it take them to colonize the galaxy?
Exponential Growth

- After 2000 years: 11 industrialized planets
- After 4000 years: 121 industrialized planets
- After 6000 years: 1,331 planets
- After 10,000 years: 161,051 planets
- After 20,000 years: 25 billion planets – perhaps every habitable planet in the galaxy!
Speed of Light

• It couldn’t actually be this fast - there aren’t that many planets within 200 light years of Earth (the distance you could travel in 20,000 years at ~1% of the speed of light).

• It would actually take a bit longer - 3 million years to reach every corner of our galaxy at this speed.

• A long time - or is it?
Blink of an Eye?

- This may seem like forever, but it is actually pretty tiny compared to the time it takes evolution (about 0.1%).
- So, if we believe our premise, there should only be one intelligent family of species in our galaxy - whoever reached intelligence first should have spread everywhere before anyone else reaches intelligence.
This may be pretty pessimistic. Odds are our technology will advance quite a lot in the next million years or so. We may well be able to travel at close to the speed of light, but never faster. Settling our galaxy would then only require 30,000 years or so.

That’s less than the time since humans were painting caves and hunting wooly mammoths.
So - why haven’t aliens visited Earth?

• Fermi’s original paradox was this
  – If interstellar travel is so easy and quick (compared to the time it takes species to evolve), why haven’t aliens reached us long ago?

• Perhaps an individual alien species will decide not to colonize?

• But if there really are 400 billion out there, surely one will decide to spread around.
Mavericks

- You could imagine a civilization spreading over a million worlds. Most aliens may be quite happy where they are.
- It only takes a handful to keep on colonizing, and eventually the galaxy will be theirs.
- You can argue with the numbers used - it doesn’t really make much difference.
Different Numbers

• If only 1% of planets send out new ships, they only send out one ship, and it takes 100,000 years to develop an industrial society, the species would still spread over enough planets to colonize the galaxy in about 250 million years.

• And that is still tiny compared to the evolution timescale.
Prime Directive

• Perhaps aliens have been here, but have decided not to disturb our primitive slumbers? (Star Trek calls this the “Prime Directive”)

• But can you really believe that every single one of the possible 50 billion civilizations out there would obey this rule?

• You only need one cheat.
Self Destruction

- Perhaps all alien civilizations blow themselves up before colonizing the galaxy?
- Perhaps civilizations turn into philosophers and don’t bother?
- But once again, all it takes is one expansionist, long-lasting race.
- So, the Fermi paradox isn’t really arguing that there is no life in our galaxy - just that there cannot be billions of intelligent species out there.
Two Alternatives?

• So, look at these two alternatives
  – a galaxy packed with billions of intelligent life-forms
  – a cold and lonely empty one
• Fermi is suggesting that the truth lies closer to the second alternative.
• Does this seem reasonable?
  – A Yes B No
Conclusion

• There may be a few (or a few hundred) intelligent species out there.
• But if there really were billions, wouldn’t we have been visited?
  – This is the Fermi Paradox