Lecture 34: Where is everyone

APOD: Earth at night

Lecture Topics

- Why don’t we see them?
- Limits to growth
- Star flight
How far? (cont’d)

- If the lifetime of a technical civilization is less than 3000 years

⇒ Average distance is so large that civilizations will die, on average, before two-way communications can be established!

Search volumes of SETI

Yellow circle: Earth-level radio transmitters (out to 4000 light-years)
Red circle: Type I advanced civilizations (out to 40,000 light-years)

Earth level => Arecibo Observatory transmission
Type 1 => $10^{16}$ W (power equivalent to solar energy striking earth)
Where is everyone?

- If life is common in the Universe and we are typical, then eventual exploration and colonization seem likely.
- How long to colonize the galaxy?
- If traveling at 1/100th speed of light, about ten million years.
Where is everyone? (cont’d)

- The galaxy is ~10 billion years old, so colonization should have happened long ago.
- We should be descendants of some ancient settlers!
- We certainly are not!!

Which assumptions are wrong?

Possibilities

- Civilizations don’t live very long?
  - Overpopulation
  - Self-destruction (war, eco-disaster, ...)
- Peaceful bliss? (Sociological Changes)
- Interstellar travel is too hard.
  - Don’t have to travel but just communicate!
- We are alone.
Overpopulation?

- Currently: 7 billion people in the world.
- Every minute:
  - 255 babies are born & 106 people die
- The world gains 149 people each minute.
  - 8,960 per hour
  - 215,000 per day
- About 78.5 million people per year!

Source: US Census Bureau

History Population of growth

<table>
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<tr>
<th>Year</th>
<th>Population</th>
<th>Doubling time</th>
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<td>2011</td>
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</table>
Lec 34: Where is everyone

### Historical Population

- **Data from US Census Bureau**

#### Limits to growth

- If left unchecked, problems with:
  - Energy production
  - Food production
  - Ecological destruction
  - etc.

- The rate of increase has slowed down –
  - Current growth rate is 1.15% per year
  - Give doubling time of 61 years
Lec 34: Where is everyone?

**Population Growth Rate**

- **Food Limit**
  1. All land used for production of wheat.
  2. Production of 800 tons/square mile.
  3. Wheat yields 3.7 Calories/gram.
  4. One person needs 2500 Calories/day.
  5. Final density of 3140 people/square mile.
  6. Total earth population 180x10^9.
  7. 30 times greater than current population.
  8. If growth rate stops at:
     - 2.0 % / year ⇒ reached in 172 years
     - 1.0 % / year ⇒ reached in 342 years
     - 0.5 % / year ⇒ reached in 682 years
Energy Limit

- Limit due to temperature balance of the earth.
- If allowed maximum energy production is 1% of solar input = 2 x 10^{15} \text{ Watts}.
- Present consumption \sim 10^{13} \text{ Watts for the world}
  - 1990: US \sim 1/4 of world power consumption
  - 2011: US \sim 1/6 of world power consumption
- Project (based on US) exceeding this limit in
  - 500 years for 1% growth
  - 153 years for 2% growth

**US Power Consumption**
In-Class Question
1) What are three limits to population growth?
   a) Food production
   b) Energy production
   c) Ecological destruction
   d) all of the above
   e) none of the above
In-Class Question

2) Do you think the human race will “solve” the population growth problem?

   a) Yes
   b) No
   c) Not an issue

Space flight

- The galaxy is many light years across ~100,000 ly
- So we want to go fast, that is, as near to the speed of light as possible.
- It still takes a long time to travel between the stars (from Earth’s perspective).
The practicalities.

- Interstellar flight is not easy!
- The first starships are on their way.
- 4 spacecraft are on interstellar voyages:
  - Pioneer 10 and 11
  - Voyager 1 and 2
- Voyager 1 will approach within 1.64 ly of another star in 40,300 years!!

How do rockets work?

- Newton’s third law:
  - For every action there is an equal and opposite reaction.
  - Conservation of momentum
- Rockets are self-contained.
- They do not “push against” the outside world.
How rockets work (cont’d)

- A spring or explosive pushes the two blocks apart.
- The blocks going in opposite directions.
- The smaller block moves faster.

How rockets work (cont’d)

- In a rocket, the burning of fuel pushes material away from the rocket at high speed.
- The “payload” moves (accelerates) in the opposite direction.
- The faster the exhaust material, the greater the acceleration.
Starships and Propulsion

- Classical rockets carry their own fuel, so they must push it too (until it is “burned up”).
- Chemical rockets won’t work.
- Nuclear propulsion may be possible.
- Alternatives are “beamed” energy (lasers, pellets), interstellar ramjet, and interstellar solar sails.

How long?

- For flight to Proxima Centauri (4.3 ly) Fly-Through mission at 0.05c.
- About 86 years.
- For a standard rocket, the mass of the rocket would be 1000 to 1,000,000 times the mass of the payload, for the “best” impulse fusion vehicles.
Patience

- It is not necessary to travel at relativistic speeds, but long range planning is necessary.
- The first star travelers will be unmanned probes/robots.
- Interstellar arks?
  - Many generations go by during travel to stars -- need to know the destination!

von Neuman probe

- Build a smart probe which travels between stars and replicates itself.
- It will fill the galaxy in a short time (millions of years) with such probes.
- Where are they?
  - too hard to build? (unlikely)
  - no interest (by all civilizations?)
  - we are alone?
Galactic “Club”

- Wild speculation ----
- Maybe we’re part of a protected region set aside by the advanced civilizations
  - Are we in the zoo or nature preserve?
  - How would we “join”?
- We have a problem defining the criteria.
  - Space travel? Interstellar travel?
  - Survival past a certain technological state?

Further readings

- “Astrobiology: The Study of the Living Universe”
  - by Christopher Chyba and Kevin Hand

- “Origins of Life”
  - by Freeman Dyson

- “Where Are They?”
  - by Ian Crawford
  - in Scientific American, June 2000
  - www.sciam.com