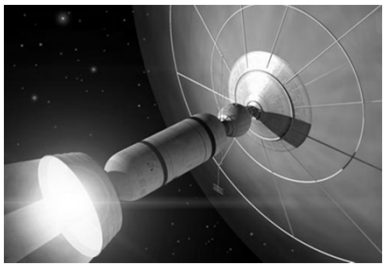
Lecture 41

Interstellar Travel and Colonization



Astronomy 141 – Winter 2012

This lecture is about the challenges of interstellar travel and colonization.

Interstellar travel is extremely challenging due to both vast distances and basic physics.

The current state of the art in spacecraft is too slow for interstellar travel by many orders of magnitude

Practical interstellar travel requires near light speeds, which entails enormous energy requirements.

Colonization of other star systems can lead to exponential growth in the number of inhabited systems.

Even with modest assumptions, the time to colonize the entire Galaxy is smaller than the lifetime of the Galaxy.

What if we find life elsewhere in the Galaxy?

An Earth-like planet in its star's habitable zone with confirmed spectral biomarkers?

A localizable radio signal from an extra-terrestrial intelligence?

The desire to go there would be overwhelming…

Getting there may be half the fun, but it is all of the problem of interstellar travel.

A problem of basic physics …

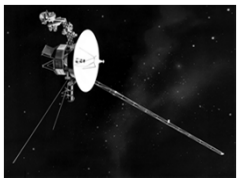
- All objects have mass
- Accelerating masses requires energy
- The more the acceleration, the greater the energy required.

…coupled with the vast scale of interstellar distances.

Locally, stars are ~6 light years apart on average.

The current state-of-the-art is orders of magnitude too slow to be practical for interstellar travel.

New Horizons:
- Launched: 2006 Jan 19
- Jupiter Encounter: 2007 Feb 28
- Pluto Flyby: 2015 July 14
- Leaves the Solar System: 2029



Voyager 1:
- Speed: 61,400 km/h (38,200 mph).
- Proxima Centauri is 4.24 ly away
- Would take 74,000 years to reach Proxima Centauri.

A big problem is the need to carry your own fuel.

Acceleration requires fuel, which has mass…

The more total mass, the more energy required to accelerate it…

The more energy required, the more fuel you need…

The "Rocket Equation":

$$\frac{\text{Initial Mass}}{\text{Final Mass}} = e^{\text{Velocity/Exhaust Velocity}}$$

Faster velocities require exponentially more mass.

To bridge interstellar distances, you need to accelerate your starship to near light-speed.

A speed of 0.1c to reach nearest star in 50 years.

Energy costs are enormous:
Amount of fuel increases exponentially with the velocity

Fuel Sources:

Chemical 

Fission or Fusion 

Max efficiency for matter/antimatter fuel

Various concepts for nuclear starships have been seriously studied (but not built).

Project Orion (US: 1960s)

Nuclear Pusher-Plate
α Cen A,B in about 100 yrs

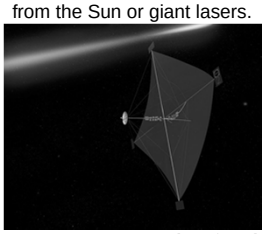
Project Daedalus (UK: 1970s)

Nuclear Fusion Pulse
Barnard's Star (6 ly) in 50 yrs

Another solution is to use means of propulsion that don't require you to carry all of your fuel

Scoop up interstellar Hydrogen gas to power fusion.
(Bussard ramjet)

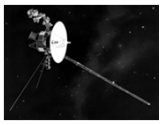
Sails that catch photons from the Sun or giant lasers.



[NASA/MSFC]

The gap between current and proposed starship technologies is enormous

Speed of Light: c = 299,792.458 km/sec



Voyager 1
Mass: 721.9 kg
Speed: 17 km/sec = 0.00006 c
Interstellar Travel Time: ~100,000 years

Project Daedalus
Mass: 54 Million kg
Speed: 0.12 c
Interstellar Travel Time: ~50 years

Requires a very advanced technological civilization

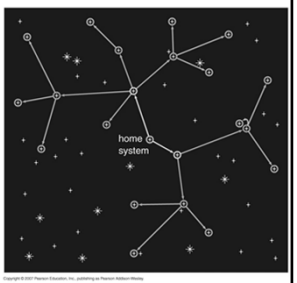
If a civilization solves the problem of building relativistic starships, then what?

Pattern of human exploration:

First: Send single ships on reconnaissance.

Second: Send colonists to start new outposts.

These become new centers of exploration & colonization.



Colonization is a rapid, exponential process.

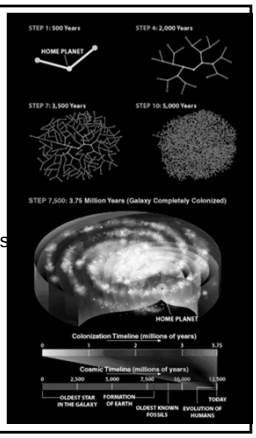
First send out two probes (N=2)

After 1 generation, each sends out 2 probes
$N=2(\times 2) = 2^2 = 4$

Next generation sends out 2 probes
$N=2(\times 2(\times 2)) = 2^3 = 8$

After 10 generations
$N= 2^{10} = 1024$

After 38 generations
$N= 2^{38} = 3 \times 10^{11}$



Colonization of the Galaxy can occur very rapidly once you achieve relativistic star flight.

Fusion Starships that can travel at 0.1c

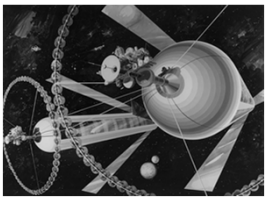
50 years to nearest star system

Wait 150 years between dispatching new colony expeditions

Inhabited region would grow outward from the home system at 1% speed of light

Unchecked, they could colonize the entire Milky Way Galaxy in 10 million years!!!

Colonization can even happen rapidly with only relatively modest interstellar travel capability.



Generation ships (aka “Arks”) that travel at 0.01c

Take 500 years to reach the nearest star system

5,000 year wait time

Inhabited region grows at 0.1% speed of light

Even this relatively relaxed star-faring civilization could colonize the entire Milky Way in 100 million years

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

The exponential population dynamics of colonization is 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?”