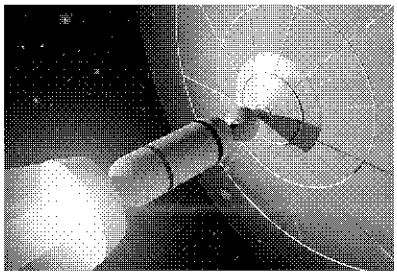
Wednesday, November 24

Colonizing the Galaxy



P.S. #4 will be due Monday, Nov. 29.

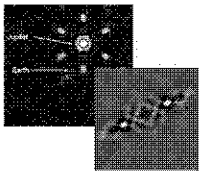
Colonizing the Galaxy
Key Concepts

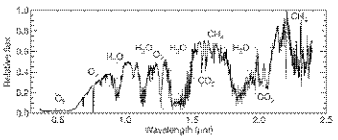
1) Practical interstellar travel involves traveling near the speed of light; this is difficult.

2) Colonizing neighboring planetary systems can lead to exponential growth.

3) The time to colonize our entire galaxy is shorter than the lifetime of our galaxy.

What if… we find an exoEarth with strong spectral biomarkers?



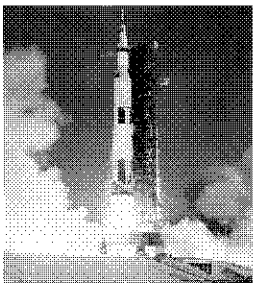


The desire to go there and check things out would be very strong.

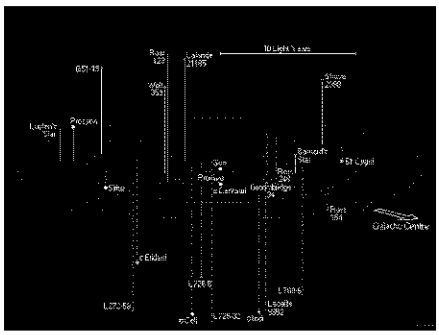
Traveling between stars is intrinsically difficult.

Spaceships have mass. Accelerating mass requires energy.

High speeds require lots of acceleration, which requires lots of energy.

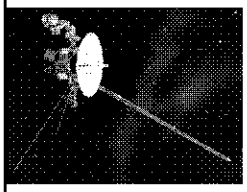


Stars within 10 light-years of us.



Current technology has produced painfully slow spacecraft.

Voyager 1:



speed = 17 kilometers/second
= 38,000 mph
= 0.00006 c
(.006% of the speed of light)

Over 70,000 years to reach Proxima Centauri...

Having to carry your own fuel is a big problem.

You need fuel to accelerate your rocket;
you need fuel to accelerate that fuel;
you need fuel to accelerate the fuel that accelerates the fuel…

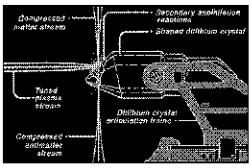
Bottom line: Faster speeds require **exponentially** more fuel mass.

To be useful, interstellar spacecraft need to travel at close to the speed of light.

A speed of 0.1c will let you reach Proxima Centauri in 42 years.

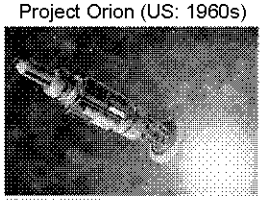
The energy costs will be enormous; chemical fuels just don't release enough energy.

Matter / antimatter fuel would be the most efficient, but antimatter is tricky to handle.



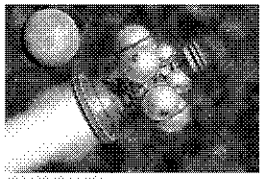
N**uclear-powered** spacecraft have been designed (but not built).

Project Orion (US: 1960s)



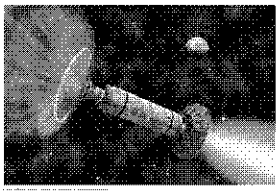
Nuclear pusher-plate
Alpha Centauri in 100 yrs

Project Daedalus (UK: 1970s)

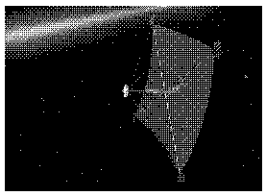


Nuclear Fusion Pulse
Barnard's Star (6 l.y.) in 50 yrs

Another solution to the fuel problem: don't carry any fuel with you.

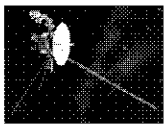


Bussard ramjet: scoop up interstellar hydrogen as you go to act as fuel.



Solar sails: use photons from the Sun or a giant laser to push your craft.

The gap between current and required starship technology is huge.

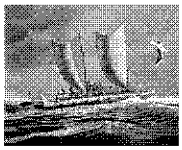


Voyager 1
Mass: 700 kg
Speed: 0.00006 c
Interstellar travel time: ~70,000 years

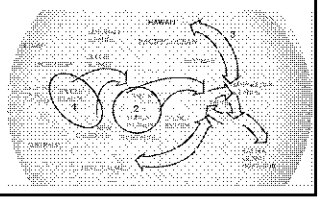
Project Daedalus
Mass: 54 million kg
Speed: 0.12 c
Interstellar travel time: ~50 years

If an advanced civilization develops starships, what comes next?

Judging from human history:
1st, single ships explore.
2nd, colonists start new outposts.



Outposts in turn become centers for exploration and colonization.



Colonization is an exponential process.

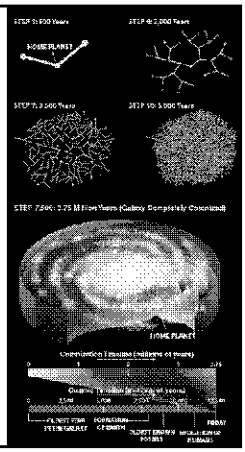
A civilization colonizes 2 neighboring stars.

Each of the 2 new colonies colonizes 2 additional stars (2×2 = 4)

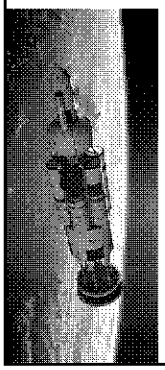
Each of the 4 new colonies colonizes 2 additional stars (2×2×2 = 8)

On the 10^{th} step, 2^{10} = 1024 colonies.

On the 38^{th} step, 2^{38} = 275 **billion** colonies!



Colonization of our galaxy can occur rapidly once starships attain speeds close to that of light.

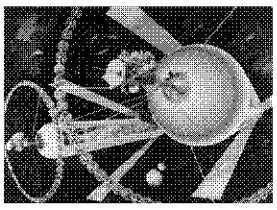


Ships that travel at 0.1c will take 50 years to reach the nearest star system.

Wait 500 years to dispatch the next batch of ships – inhabited region grows at 1% the speed of light.

Unchecked, they could colonize the entire galaxy in 10 million years!

Colonization can even occur with slower starships.



Ships that travel at 0.01c will take 500 years (many generations) to reach the nearest star system.

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

Given plausible assumptions, colonization times are small compared to the age of our galaxy (~10 Gyr).

The exponential growth of the colonized region is in contrast to the static assumptions of the Drake equation.

If advanced civilizations have the drive to colonize, the Drake equation dramatically **underestimates** the number of inhabited systems.

"So? Where is everybody?"

Monday's Lecture:

Have Aliens Visited the Earth?

Enjoy your Thanksgiving!