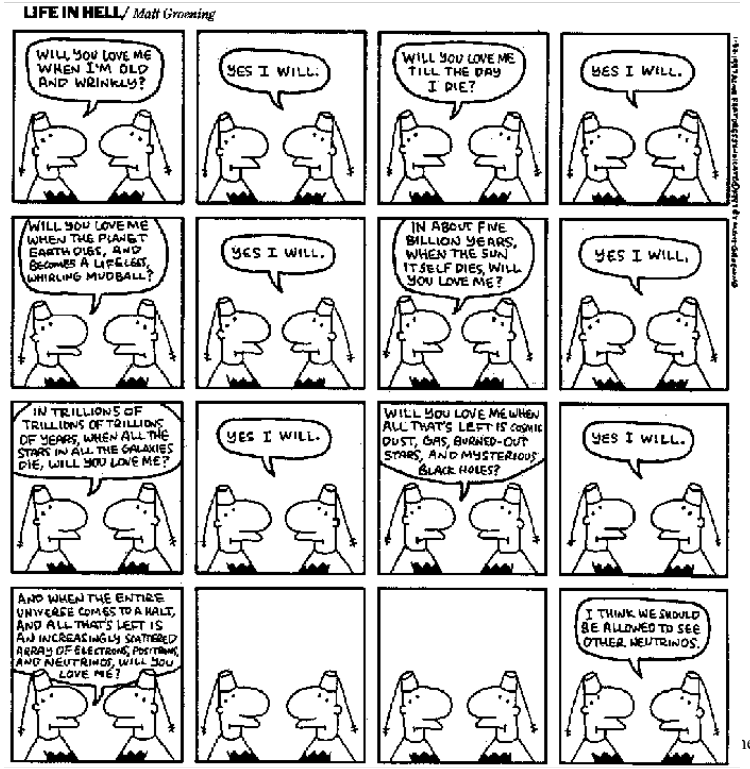


ET: Astronomy 230

EC HW due Dec 7th

Papers are due ASAP.

This Class (Lecture 40):
Travel

Next Class:
Visitations

Music: *Lucy in the Sky with Diamonds*
– The Beatles

Outline

- Alternative fuels for space travel
  - Nuclear Fission
  - Nuclear Fusion
  - Antimatter
  - Solar Sails
  - Warp Drives?
    - General Relativity
  - Weird science?

Fuel Efficiency

- To really think about interstellar travel or even going to Mars, we need the most bounce for the ounce:
  - Need to carry (probably MUCH) fuel
  - Must be very thrifty about efficiency
  - In other words, if we are going to carry fuel mass on a ship, we had better get as much energy from it as possible!

Project Daedalus

- Continuation/extension of Orion
- British Interplanetary Society project (1973-1978 planned)
- A robotic fly-by probe to Barnard's Star
  - 2nd closest star system to Earth, 6 lyr away
  - In human lifetime scale (chose 50 yrs)
  - Needs to reach 12% c.
- Idea was to also use nuclear pulsed power, but fusion.

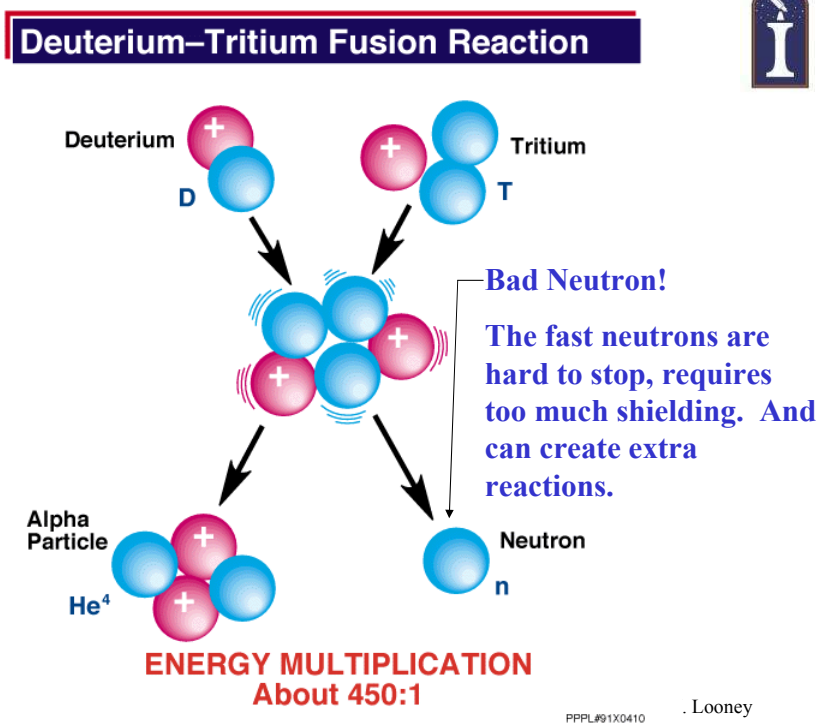
http://www.daviddarling.info/encyclopedia/D/Daedalus.html

Project Daedalus

- Good example of interstellar travel with foreseeable technology.
- Use fusion, like the stars.
- But, we have to use the more energy efficient part of hydrogen → helium.
- But there's a problem.

http://www.daviddarling.info/encyclopedia/D/Daedalus.html

Dec 5, 2005 Astronomy 230 Fall 2005 L.W. Looney

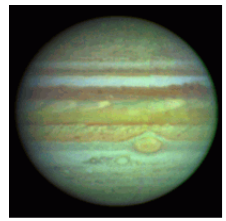


Project Daedalus

- Instead Daedalus would use:

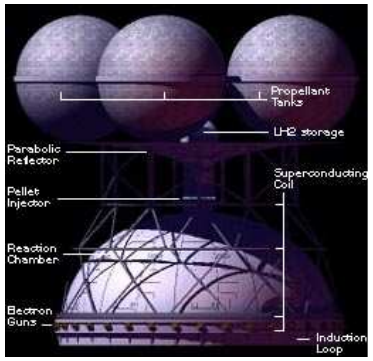
$$d + {}^3He \rightarrow {}^4He + p$$

- The by-products are normal helium and a proton.
- Both are positively charges and can be deflected with magnetic fields into an exhaust.
- Reasonably efficient, converting 4 x 10^{-3} mass into energy.
- 1 MINOR problem. ^{3}He is very rare on Earth.
- Could be collected from the moon or Jupiter's atmosphere.



Project Daedalus

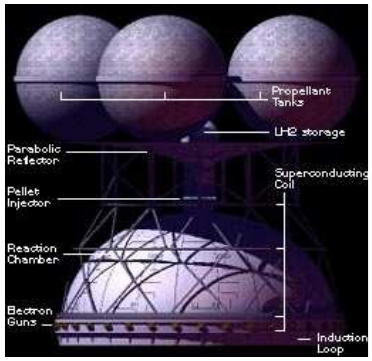
- Daedalus would accelerate for 4 years, then coast for 50 years to reach Barnard's star.
- At blastoff the mass would be 54,000 tons, of which 50,000 would be fuel.
- That's an $R_M = 12$.
- The fuel would be in pellets that enter the reaction chamber 250/sec.
- Sophisticated robots needed for repair.



http://www.daviddarling.info/encyclopedia/D/Daedalus.html

Project Daedalus

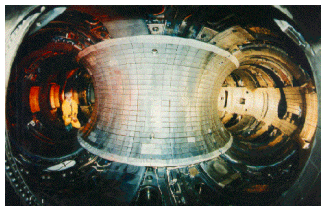
- For dust erosion at 0.12c, requires a beryllium erosion shield 7mm thick and 55 meters in diameter.
- Once it reached Barnard's star, it would disperse science payload that would study the system.
- Would transmit back to Earth for 6-9 years.
- So does not require a return trip.

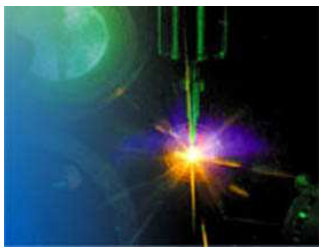


http://www.daviddarling.info/encyclopedia/D/Daedalus.html

Project Daedalus

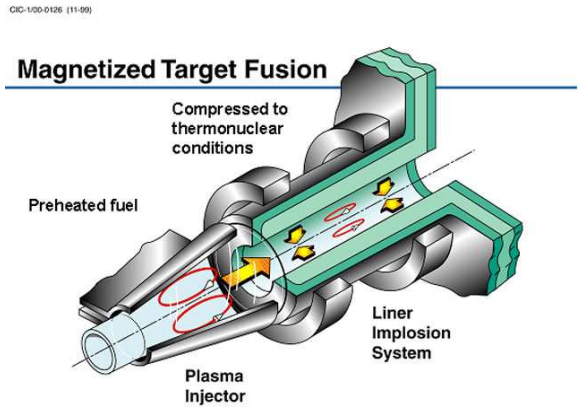
- Still requires more technology.
- How to get the deuterium and ^{3}He close enough to fuse in the first place.
- This requires a hot, compressed collection of nuclei that must be confined for long enough to get energy out
  - It's like "herding cats"
- As we have discussed, nuclear fusion reactors on the ground are trying to use magnetic (heavy containers) confinement [MCF] or inertial (high powered lasers) confinement [ICF].
- Daedalus would have to use a hybrid of the two.





MTF: Magnetic Target Fusion

- You make a small, magnetically confined plasma (like MCF) then compress it to thermonuclear conditions with a magnetically driven imploding liner (sort of like ICF).
- Being studied at numerous research centers for possible ground use too.



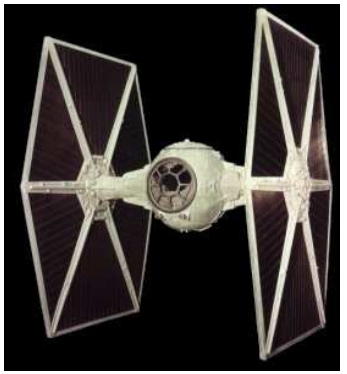
http://wsx.lanl.gov/mtf.html

Fusion Rockets

- We are still not there.
- Fusion is not viable on the ground or in rockets at this time.
- MTF and other methods are being worked on, but it can easily take decades before the technology is feasible.

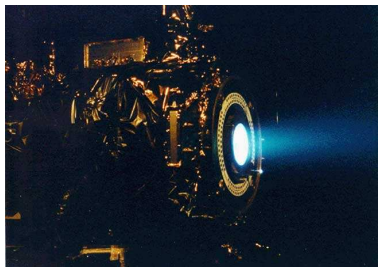
Ion Drives

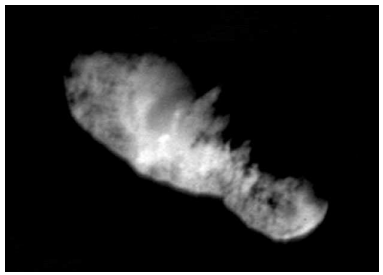
- These are not science fiction.
- A propellant system: "stuff" is thrown backwards propelling the ship forwards.
- They eject a beam of charged atoms out the back, pushing the rocket forward
  - Kind of like sitting on a bike and propelling yourself by pointing a hairdryer backwards



Ion Drive

- First successful used in Deep Space 1, which took the closest images of a comet nucleus (Comet Borrelly).
- The engine worked by ionizing xenon atoms, then expelling them out the back with strong electric fields.
- The only waste is the propellant itself, which can be a harmless gas like xenon.
- But, requires energy input to power electric field which pushes the ions out the back
  - Solar cells usually provide power.

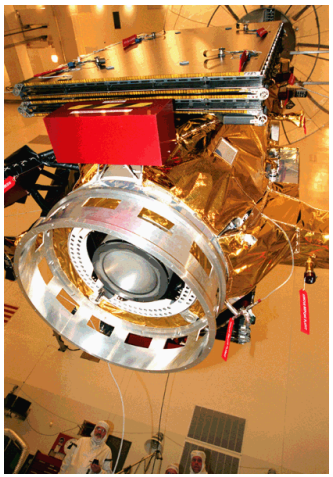




http://antwrp.gsfc.nasa.gov/apod/ap030720.html

DS1

- DS1 only used 81.5 kg of xenon.
- Thrust of engine is only about as strong as the weight of a piece of paper in your hand!
  - If you keep pushing lightly, you will keep accelerating, so after time you can build up speed
  - DS1 eventually reached velocity of 4.5 km/s (10,000 mph!)
  - Remember fastest space vehicle is Pioneer which is still going about 12km/s
- Not useful for missions that need quick acceleration
- But, more efficient than chemical
  - Can achieve 10 times greater velocity than chemical!



http://nmp.jpl.nasa.gov/ds1/img/98pc1191.gif

Our Problem

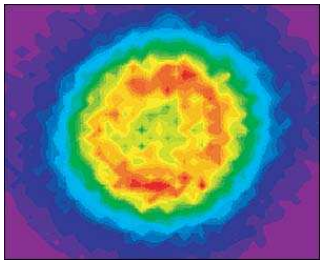
- For interstellar travel with any propellant, you must carry with you the stuff that you eventually shoot out the back
  - Fine for Saturn V rocket and "short" lunar missions
  - Bad for interstellar travel
    - Maybe even prohibitive
- But, it is unlikely that the methods discussed up to now will enable us to reach the stars in any significant manner.
- It is unlikely, therefore, that ET civilizations would use these methods
- We may do better, though…with the biggest bang for the buck.

Antimatter

- The most energy you can get from a hunk of mass is extracted not by
  - Chemical Burning
  - Nuclear fission or fusion
  - Pushing it in an ion drive
- The most efficient way to get energy from mass is to annihilate it!
- When they annihilate all of their mass is turned into energy ($E=mc^2$), eventually photons.
- $V_{ex} = c$

Anti-(Anti-matter)

- But, antimatter does not normally exist.
- We have to make it.
- We can make small quantities in giant particle accelerators, but total amount ever made is on order of a few nanograms.
- Would take 200 million years at current facilities to make 1kg!



Anti-Hydrogen from CERN.

http://news.bbc.co.uk/2/hi/science/nature/2266503.stm

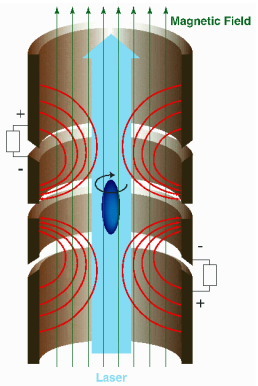
Anti-(Anti-matter)

- The amount of antimatter made in Illinois at Fermi-Lab in 1 day can provide energy to light a 100 W light bulb for ~3 seconds. If 100% efficient.
- And right now it takes about 10 billion times more energy to make antiprotons than you get from their annihilations.

http://news.bbc.co.uk/2/hi/science/nature/2266503.stm

Storage Issues

- Antimatter can be like a battery– storing energy.
- But antimatter ***must*** not touch matter!
- So, you have to store it without touching it
- Can be done by making electromagnetic "bottle" that confines particles with electric and magnetic force fields
  - "Penning trap"



http://www.engr.psu.edu/antimatter/

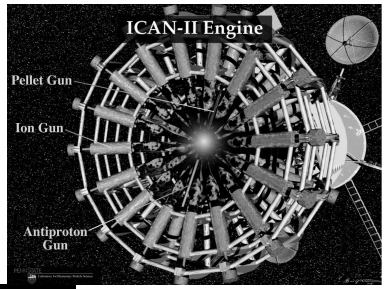
Nonetheless

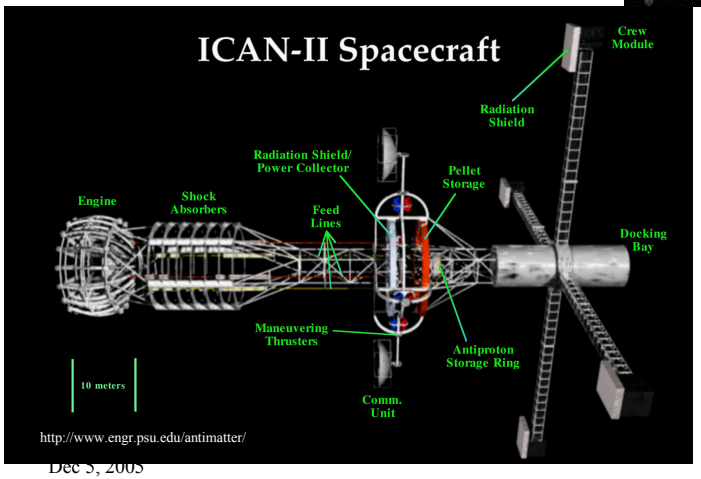
Propulsion	**Specific Impulse** [sec]
Chemical	200 - 450
Electromagnetic	600 - 3000
Nuclear Fission	500 - 3000
Nuclear Fusion	5000 - 10000
Antimatter	1000 - 100000

- Antimatter has potential to be about 1000 times more powerful than chemical combustion propulsion
- Antimatter propulsion has potential to be about 10 times more powerful than fusion

ICAN

- Ion Compressed Antimatter Nuclear
  - Designed at Penn State for Mars Mission
- Mixture of antimatter and fusion pellets.





http://www.engr.psu.edu/antimatter/

Interstellar Problem

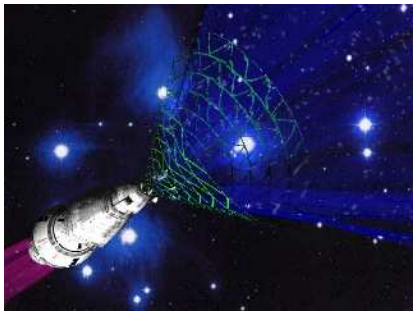
- Still for interstellar trips, we got a problem with carrying around the fuel.
- Edward Purcell thought about antimatter interstellar travel and found even that to be lacking!
- The lightest mass U.S. manned spacecraft was the Mercury capsule– the "Liberty Bell". It weighed only 2836 pounds (about 1300kg) and launched on July 21, 1961.
- It would still take over ***50 million kg*** of antimatter fuel to get this tin can to the nearest star <u>and back</u>.

http://lsda.jsc.nasa.gov/images/libertybell.jpg

http://www.craftygal.com/archives/september/table0900.htm

Lose the Fuel, Fool

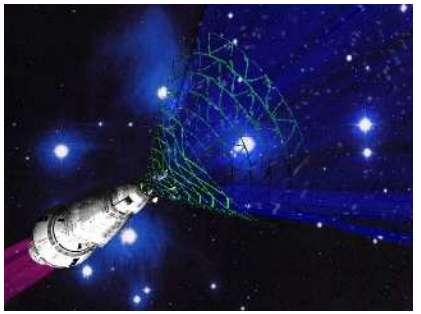
- What if we didn't have to carry all the fuel?
- One option is the Bussard ramjet.
- The spacecraft collects its own fuel as it moves forward.
- But, in interstellar space there is only 1 atom/cm3.



http://www.sternenreise.de/weltraum/antrieb/bussard.htm

Lose the Fuel, Fool

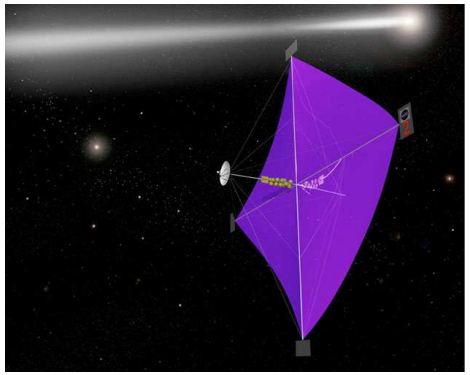
- The scoop would have to be 4000 km in diameter (size of US).
- Or magnetic fields to collect the material.
- But would mostly be low-grade hydrogen fuel, so it is a technological step ahead of what we already discussed.
- Could reach speeds close to 0.99c.



http://www.sternenreise.de/weltraum/antrieb/bussard.htm

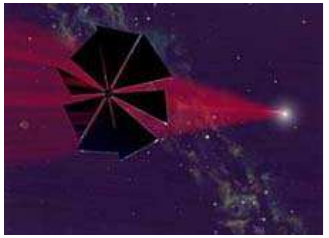
Light Sails

- Imagine a space sailboat but with photons of light hitting the sails and pushing it forward.
- No need to carry propellant, distant laser could be used to illuminate sails.
- Photons have energy but no rest mass.
- But, they do carry momentum!
  - It is related to the energy such that p= E / c
- So, such a craft is not propelled by solar winds!
- But by light bouncing off, like a mirror.



COSMOS 1

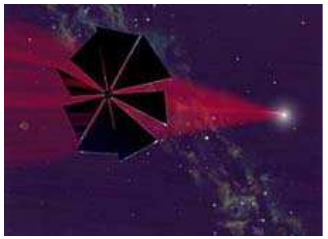
- First solar sail spacecraft (and private!) launched from a Russian nuclear submarine on June 21, 2005!
- Unfortunately, the first stage of the Volna never completed its scheduled burn, and the spacecraft did not enter orbit.
- Built in Russia at Babakin Space Center
- Had 8, 15m sails
  - 100kg payload (small, but first step!)
- The planetary society is going to try again, if they can raise the money.



- http://www.planetary.org/solarsail/animation.html

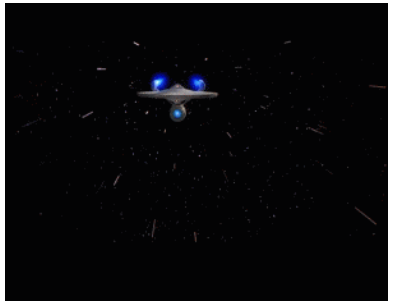
COSMOS 1

- It would take about 1,000 years for a solar sail to reach one-tenth the speed of light, even with light shining on it continuously.
- It will take advanced sails plus a laser power source in space that can operate over interstellar distances to reach one-tenth the speed of light in less than 100 years.
- So probably not useful for interstellar travel.



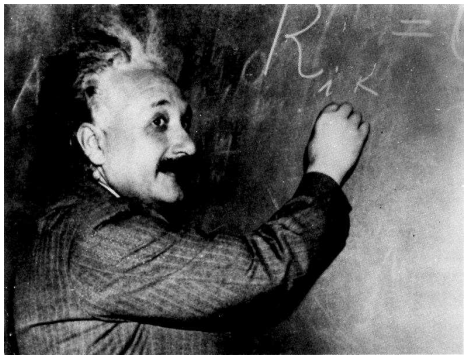
Warp Drives

- Again, science fiction is influencing science.
- Due to great distance between the stars and the speed limit of c, sci-fi had to resort to "Warp Drive" that allows faster-than-light speeds.
- Currently, this is impossible.
- It is speculation that requires a revolution in physics
  - It is science fiction!
- But, we have been surprised before…
- Unfortunately new physics usually adds constraints not removes them.



http://www.filmjerk.com/images/warp.gif

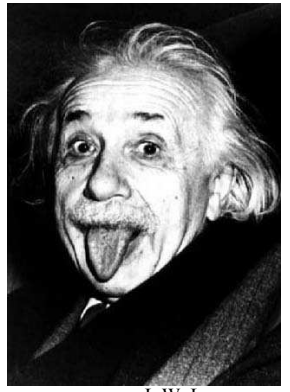
Einstein Is Warping My Mind!



- Einstein's General Relativity around 1918
- Space and time were re-interpreted
- No longer were they seen as immutable, constant properties
- Space itself can be "warped" by mass.

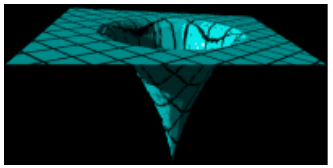
Special Relativity Summary

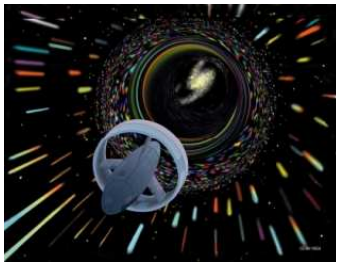
- **Length of space depends on observer's speed.**
- **Length of time depends on observer's speed.**
- **Mass depends on observer's speed.**



General relativity

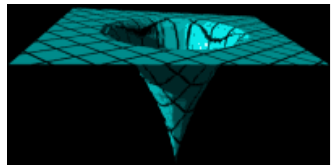
- Gravitational fields can also change space and time
  - A clock runs more slowly on Earth than it does in outer space away from any mass, e.g. planets.
- Einstein revealed that gravity is really 'warped' space-time.
- A black hole is an extreme example.

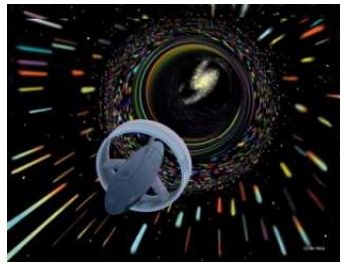




General relativity

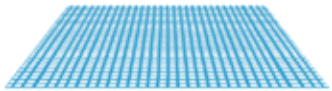
- Rotating black holes may form wormholes to "elsewhen" but they are thought to be short-lived.
- Researchers are considering stabilizing them with exotic matter.
- What if it were possible to create a localized region in which space-time was severely warped?
  - A car has a speed limit on a road, but what if you compress the road itself?





Quantum field theory

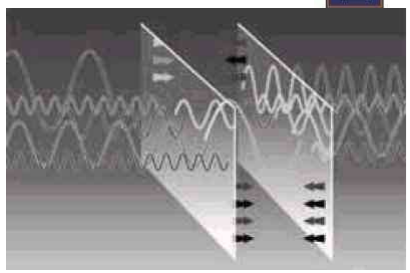
- The subatomic world is not a world of billiard ball-like particles
- "Empty space" is full of waves/particles popping in and out of existence
  - Like a choppy sea, "virtual particles" are born and interact for an allowed window of time
- This sea of "virtual particles" that inhabits space-time can be a source of energy
  - This is real physics, not Sci-fi

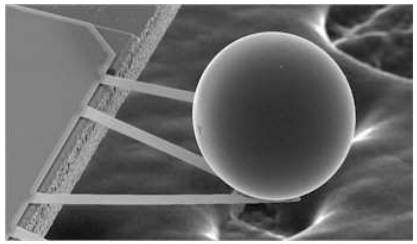


http://zebu.uoregon.edu/~js/glossary/virtual_particles.html

Quantum field theory

- In 1948, Hendrik Casimir predicted a weak attraction between two flat plates due to the effect of the sea of virtual particles.
- Two 1 meter plates placed a micron apart, would have 1.3mN of force. This is like a weight of 130 mg.
- But it is force from nothing!
- Maybe this effect can create a subtle propulsion system?





Dark Energy

- Imagine harnessing the power of dark energy (which seems to occupy all space) to form an anti-gravity generator?
- It is crucial to investigate new ideas with open minds and freedom.
- Right now, we really don't have a firm idea for any new propulsion system (space warp-driven propulsion, etc.).
- But, be patient – a long wait may be ahead
  - Hundreds of years?
  - Thousands of years?
  - Remember that the civilization lifetime can be millions of years!

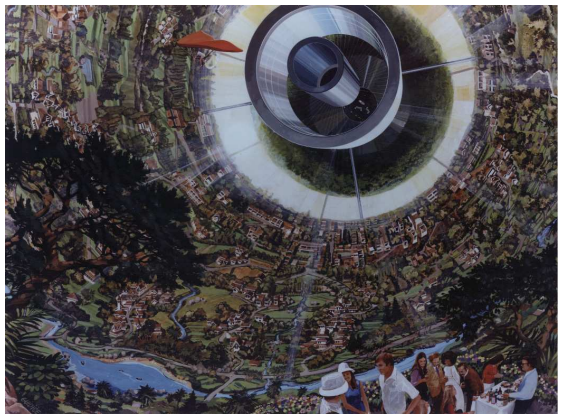
ET's Spacecraft?

- We really don't know yet how to get to the stars realistically, so we don't know what advanced civilizations might use.
- But it is
  - Smarter
  - Cheaper
  - Still very informative and
  - Realistic

  to send an unmanned probe into stars first
  - Lighter payload!
- Self-replicating probes?

Long Haul Space Travel

- Spacecraft that we can envision easily would take a lifetime to get to the nearest star.
- Colonizing missions would be multi-generation missions.
- Space colonies with propulsion systems would slow down things, so maybe it would take 1000 yrs.
- How many of you would sign up today?



Nikolai Kardashev: Civilization Types

Type 0: Not in complete control of planet's energy
Understand the basic laws of physics
Chemical and nuclear propulsion, solar sails

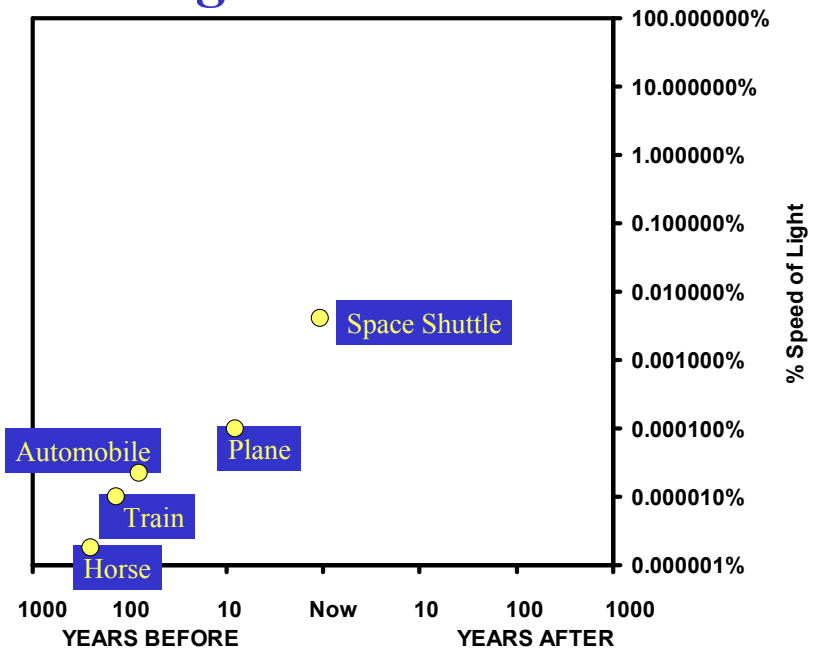
Type I: Harnesses energy output of an entire planet.
Laser sails.

Type II: Harnesses entire output of their host star.
Dyson Sphere–can provide a trillion times more energy than we use on the Earth now. Antimatter drives?

Type III: Colonizes and harnesses output of an entire galaxy
Use a trillion times the energy of Type II civilizations
Use a trillion trillion times the energy of Type I civilizations

http://www.unm.edu/~astro1/ET109/types/types.html

Going Interstellar!

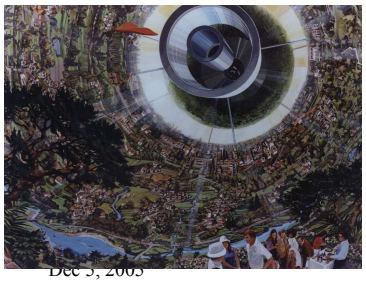


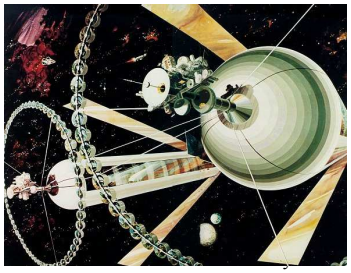
Problems to Overcome?

1. Space is Big.
   - Nothing we can probably do about this one.
2. Time.
   - Because of #1, interstellar travel would take a lot of time.
   - But arguably do-able.
     - Maybe lifetime is expanded, generation ships, suspended animation, or intelligent robots.
3. Cost
   - Right now, colossal budget of a few trillion dollars. Impossible now, but in the future?
   - Medieval blacksmiths could have made an oil tanker, but too costly. 500 years later, piece of cake.
   - In future, cost of interstellar travel may also go down.

1000 Years?

- So in 1000 years from now, we should be able to travel to other stars. But will we?
- It would be nuts to speculate on what will motivate our descendents (if any) 1000 years from now. But if interstellar travel really is easy and cheap, surely someone will give it a go?





Getting Out of Here

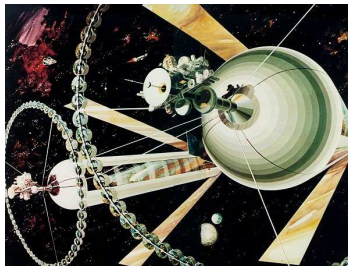
- Distances between stars are much greater than we can imagine– freaky big distances, plus difficult environment and time consuming makes interstellar travel hard to conceive.
- SciFi books and movies have dramatized space travel to make it seem possible
  - But, interstellar travel may never happen
- Even the Voyager spacecraft (one of the fastest ever flown) travels at only 20 km/s through space - not even 1% of the speed of light. They would take 60,000 years to reach even the nearest star.
- In our discussions, we argue that with foreseeable technology 10% the speed of light is possible.
- Is that enough to expect to see aliens on Earth?

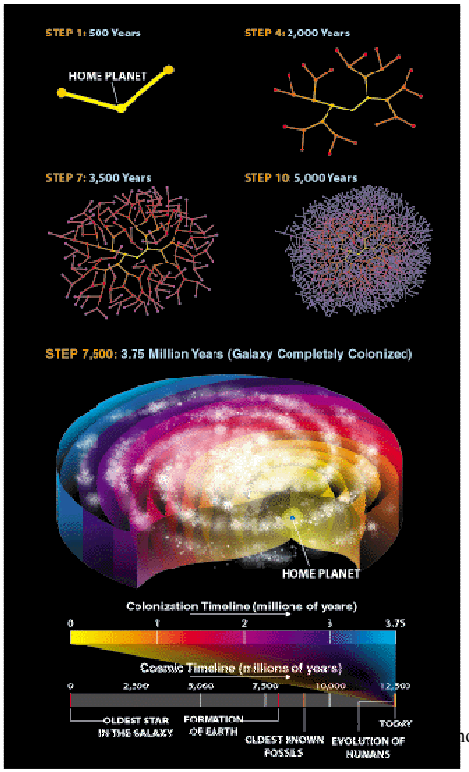
Galaxy Colonization

- If our Drake equation estimate is roughly right, there should be civilizations that are 1 billion years old!
- Think of the accomplishments.
- Even if interstellar travel is limited to 0.1c, civilizations with advanced telescopes could send colonizing craft to new planets.
- That group regenerates for 500 yrs and sends out another craft.
- An advanced civilization could colonize the entire galaxy in maybe only 5 million yrs!

How long to colonize the Galaxy?

- With 0.1c, we can travel 10 light years in 100 years
- We can reach the nearest star in 43 years
- Allow each new colony 50 years to duplicate the technology
- Colonies could spread out about 50 light years every 3,000 years





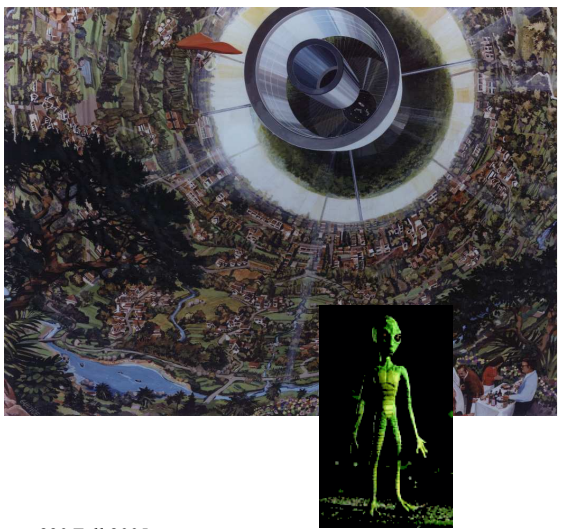
Optimistic

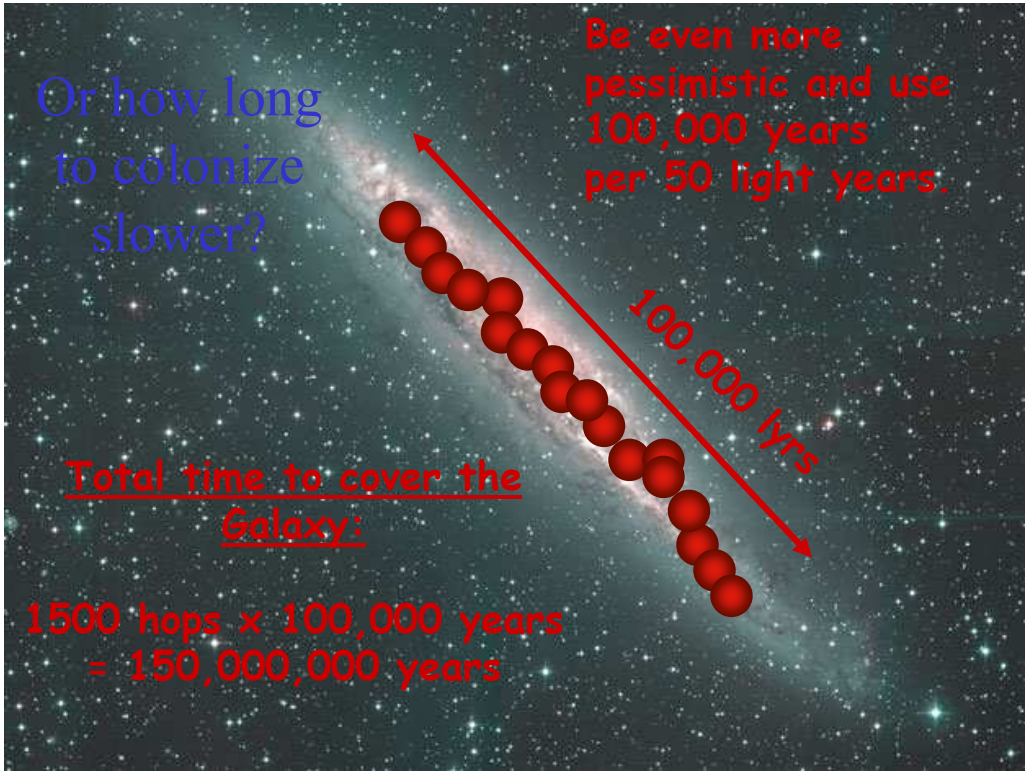
Every 500 years, the colonization craft makes it to the next suitable solar system– small delay.

Then, it only takes about 4 million years!

Slow Long Haul Space Travel

- Spacecraft that we can envision easily would take a lifetime to get to the nearest star.
- Colonizing missions would have to be multi-generation missions.
- Space colonies with propulsion systems would slow down things, so maybe it would take 1000 yrs for each trip.
- How many of you would sign up today?





The Fermi Paradox

The Drake Equation – Even for a few hundred technical civilizations.

Only 150 million years to colonize the Galaxy.

WHERE IS EVERYBODY?????

The Fermi Paradox

- Our estimate for communicable civilizations was around 12,000.
- Given such a large number, one of them must have developed earlier than we did.
- So "Where are they?"
- Even if interstellar travel is very slow and difficult, there has been a lot of time to do it.
- Furthermore, many of the objections to interstellar travel do not apply to artificial intelligence (intelligent robots.)

Life on Earth is of One Type?

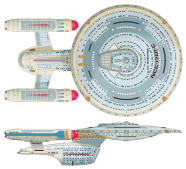
- Life got started on Earth pretty quickly. To some, this suggests that life forms easily, whenever conditions are right.
- So why are all creatures on Earth descended from the same microbe?
- You can tell from the similarities in our DNA and cells that all living things come from the same ancestors. Why?
- The average time needed to spread over the Earth was much less than the average time to evolve. Not true for the Galaxy.

Timescales

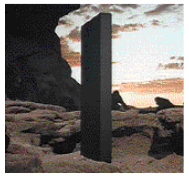
- For pessimist: 150 million years to colonize the Galaxy.
- For optimist: 4 million years to colonize the Galaxy.
- This may seem like forever, but it is actually pretty tiny compared to the time it takes evolution (about 0.1%).
- So, if we believe our condition, there should only be one intelligent family of species in our galaxy - whoever reached intelligence first should have spread everywhere before anyone else reaches intelligence.
- This is the main point of the Fermi Paradox.
- Where are they?

Limits

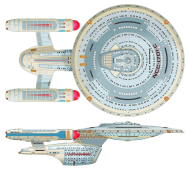
- So, if we go back to two alternatives - a galaxy packed with billions of intelligent life-forms, and a cold and lonely empty one, Fermi is suggesting that the truth lies closer to the second alternative.
- Does this seem reasonable?
- There may be a few (or a few hundred) intelligent species out there.
- But if there really were billions, we would have surely have been visited?



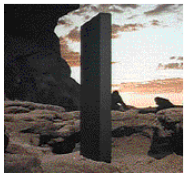
Where is Everyone?



- **They are around, but we can't tell yet**
  - They are too advanced or alien to recognize or detect
  - They don't bother with us (or traveling or broadcasting)
  - Do civilizations hide to avoid a "galactic scourge?"
  - They are keeping us "quarantined" (the "zoo" or prime directive hypothesis)
  - They've been here (or are here), and we don't know it
  - They are not "technical" in a way we can understand.



Where is Everyone?



- **They are not around**
  - Some factors in Drake equation may be much smaller than we believe – life, or intelligent life, is very rare
  - They wipe themselves out too quickly
  - Other factors wipe them out too quickly
  - Life hardly ever develops technical civilizations
  - There is very little life out there
  - We are among the first to develop