Astronomy 330

This class (Lecture 26):
Interstellar Travel

Last Class:
Visitations

HW 11 is due Thursday!

Music: Space Race is Over – Billy Bragg

Classes

- CHP allows $100 for informal get togethers.
- We are meeting Thursday to watch a movie and order some pizza.
- Still want Armageddon?

Final Papers

- Final papers due on May 3rd.
  - At the beginning of class...
- You **must** turn final paper in with the graded rough draft.
- If you are happy with your rough draft grade as you final paper grade, then don't worry about it.

Final

- Take-home final
- Will email it out on the last class.
- Will consist of:
  - 2 large essays
  - 2 short essays
  - 5-8 short answers
- Due May 11th, hardcopy, by 5pm in my mailbox or office.

Online ICES

- ICES forms are available online.
- I appreciate you filling them out!
  - In addition to campus honors thingy
- Please make sure to leave written comments. I find these comments the most useful, and typically that's where I make the most changes to the course.

Outline

- What is the future for interstellar travel?
- Fermi's Paradox– Where are they?

Drake Equation

That's 22,181 advanced civs!!!

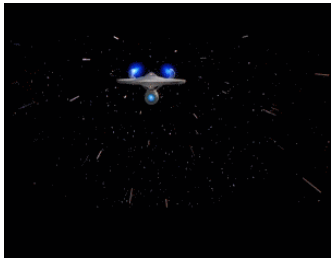
Frank Drake

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact in our Galaxy today	Star formation rate	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	15 stars/ yr	0.65 systems/ star	1.3 x 0.1 = 0.13 planets/ system	0.125 life/ planet	0.175 intel./ life	.8 comm./ intel.	$1x10^6$ yrs/ comm.

Warp Drives

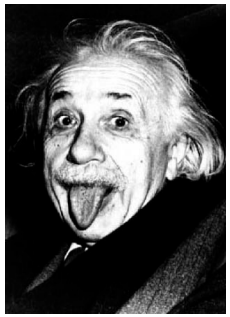
- Again, science fiction is influencing science.
- Due to great distance between the stars and the speed limit of c, sci-fi had to resort to "Warp Drive" that allows faster-than-light speeds.
- Currently, this is **impossible**.
- It is speculation that requires a revolution in physics
  - **It is science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



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

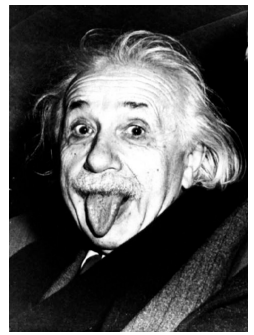
The Theory of General Relativity

- Recall Galileo/Newton: free body motion is a straight line, constant speed
- Important to note that ALL free bodies move this way. straight line, constant speed, INDEP of size, mass
- Q: Why?
- A: That's the way it is!
- Q: Be more specific: that's the way WHAT is?
- A: Einstein: that's the way space and time are if nothing else going on (no forces) space and time constructed so that free bodies move in straight lines at constant speed independent of nature of the object
- **That's the way space and time are**



The Theory of Relativity

- Einstein's Theory of Relativity tells us how gravity works
  - Space and time are not distinct
  - They are bound together in 4-dimensional **spacetime**
  - Gravity is not a force, but a curvature
  - Matter tells spacetime how to curve
  - Curved spacetime tells matter how to move



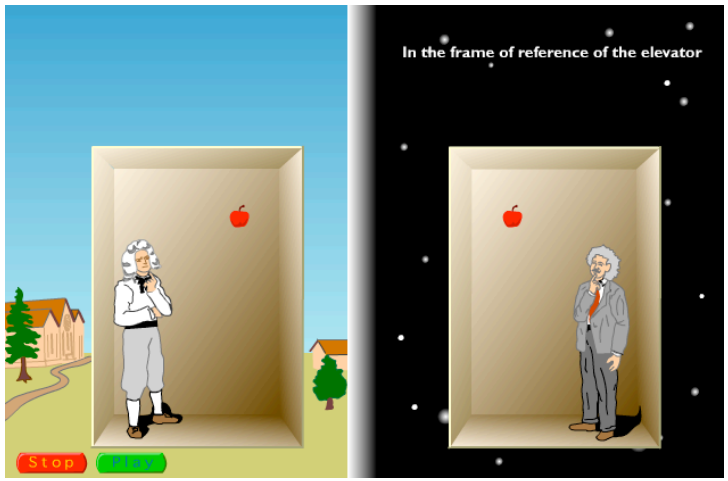
Free Fall

- Recall Galileo's experiment.
- The objects in the gravity field, move independent of mass or even object.
- For Newton, the object mass cancels out of the gravity equation.

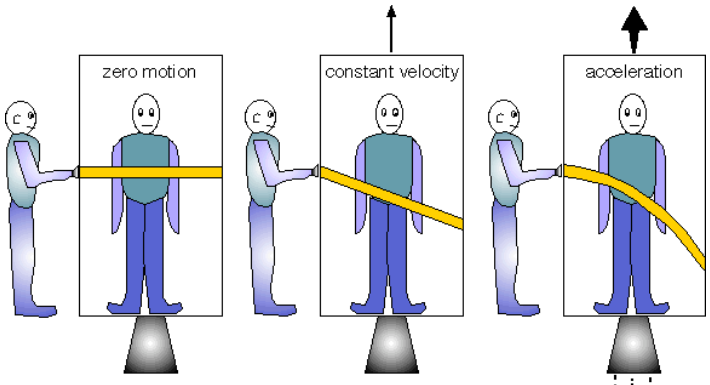
The Theory of General Relativity

- Since objects move the same in a gravity field, INDEPENDENT of object, then gravity is not a force, but also a feature of space-time!
- Objects do their best to move in a straight line.
- **Newton:** Matter causes force (gravity) ⇒ particles follow curved lines in "flat" (Euclidean geometry) space
- **Einstein:** Matter causes spacetime to be "curved" ⇒ particles follow straight lines ("geodesics") in curved space

The Theory of General Relativity



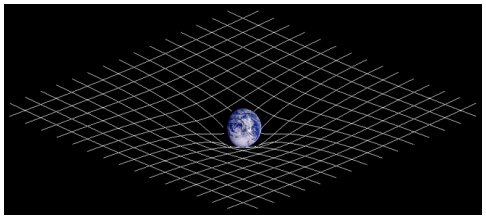
The Theory of General Relativity



The path of a light beam in three different types of reference frames moving with respect to the person *outside* the elevator. The light path shown is what the person ***inside*** the elevator sees. Under large acceleration, the beam of light will curve downward. It should also do that in a region of strong gravity.

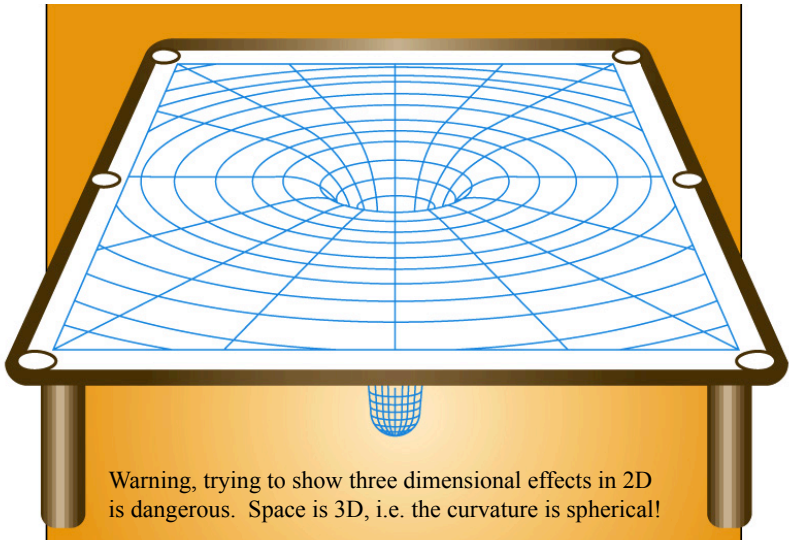
Curved Spacetime

- No matter = Flat Spacetime
- Massive object = Dent in Spacetime
  - Everything follows curvature of spacetime including light (photons)



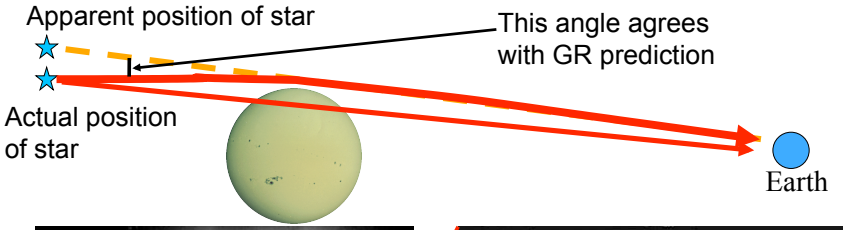
http://www.youtube.com/watch?v=0rocNtnD-yI
3:18+

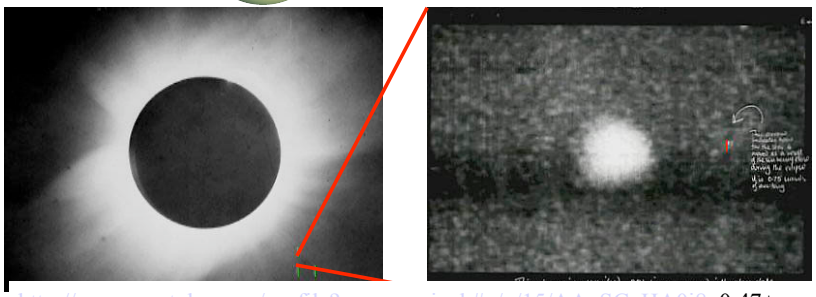
Curved Space



Warning, trying to show three dimensional effects in 2D is dangerous. Space is 3D, i.e. the curvature is spherical!

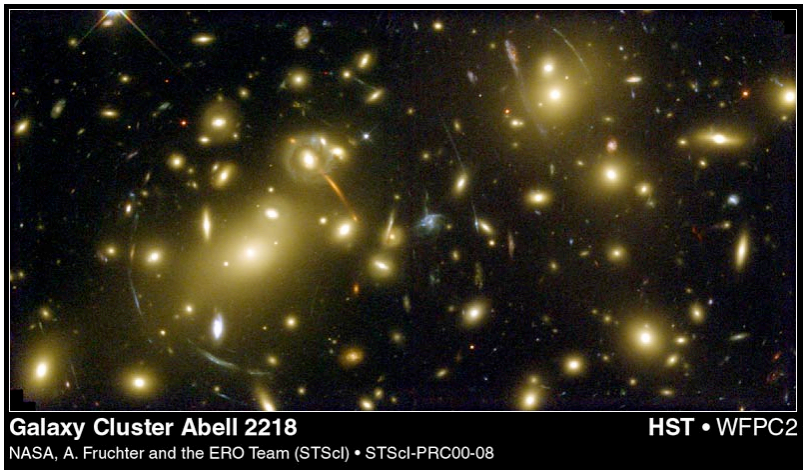
Eddington and the 1919 Eclipse





http://www.youtube.com/profile?user=ogniank#p/u/15/AAqSCuHA0j8 0:47+

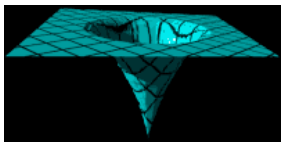
Einstein Lens

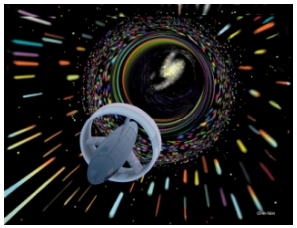


http://antwrp.gsfc.nasa.gov/apod/ap000201.html

General relativity

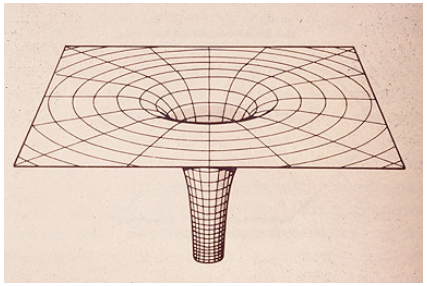
- Gravitational fields change space and time
  - A clock runs more slowly on Earth than it does in outer space away from any mass, i.e. planets.
- Einstein revealed that gravity is really 'warped' space-time.
- A black hole is an extreme example.

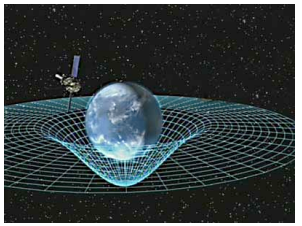




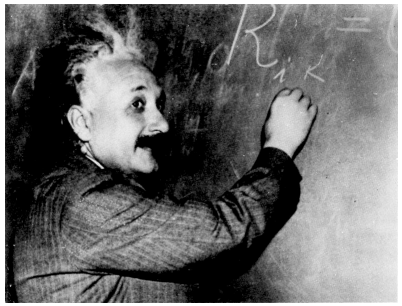
Gravity: Is relative?

- Gravity you feel is really the distance away you are from the mass of the object.





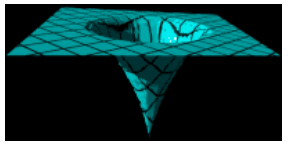
Einstein Is Warping My Mind!



- Space and time are re-interpreted
- No longer immutable, constant properties
- Space itself can be "warped" by mass.

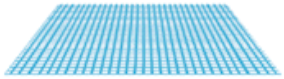
General relativity

- 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

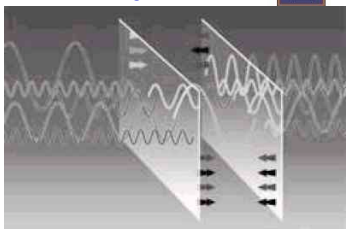
- The subatomic world is not a world of billiard ball-like particles
- "Empty space" is full of waves/ particles popping in and out of existence
  - Like a choppy sea, "virtual particles" are born and interact for an allowed window of time
- This sea of "virtual particles" that inhabits space-time can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

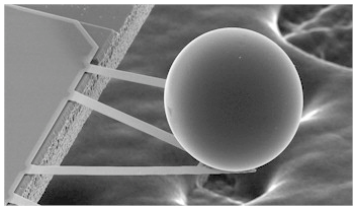


http://zebu.uoregon.edu/~js/glossary/virtual_particles.html

Quantum field theory

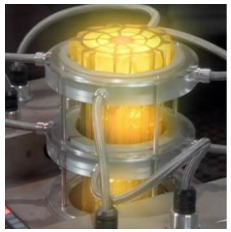
- In 1948, Hendrik Casimir predicted a weak attraction between two flat plates due to the effect of the sea of virtual particles.
- Two 1 meter plates placed a micron apart, would have 1.3mN of force. This is like a weight of 130 mg.
- It is force from nothing!





Zero Point Energy

- Harnessing this power for propulsion has been an idea since at least the 90's.
- Science fiction has even caught on.. idea of harnessing this "free" energy.
- For example, the zero point module (ZPM) from Stargate.
- Or Syndrome from The Incredibles



http://www.todayscacher.com/2005/feb/img/zero_point_module.jpg

Making Propulsion?

- Need to create repulsive effects in the quantum vacuum, which should be possible.
- This work is underway, sponsored by NASA and others.

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!

The future:

May bring us closer to the speed of light

- Right now we can travel through space at about c/25,000
- Maybe fusion-powered crafts could in the near future reach 0.01c or maybe even 0.10c

http://www.jedisaber.com/SW/wallpaper/light%20speed.jpg

Issues and Incentives

- Assume there is intelligent life out there.
- Will they try to travel to us?
  - Is it worth it?
  - Exploration?
- If a civilization has been around for 1 million more years than ours…
- But interstellar travel is HARD!!!!
- Back to thinking about autonomous probes..

ET's Spacecraft?

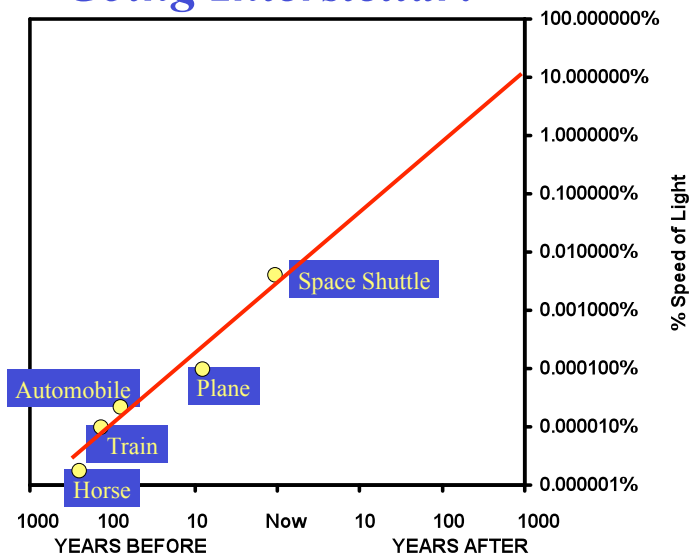
- We really don't know yet how to get to the stars realistically, so we don't know what advanced civilizations might use.
- But it is
  - Smarter
  - Cheaper
  - Still very informative and
  - Realistic

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

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.

Going Interstellar!



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.

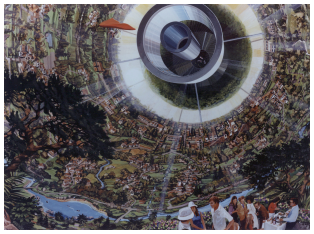
Type II: Harnesses entire output of their host star.
Dyson Sphere–can provide a trillion times more energy than we use on the Earth now. Antimatter drives?

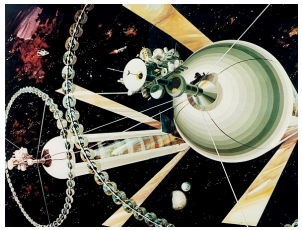
Type III: Colonizes and harnesses output of an entire galaxy
Use a trillion times the energy of Type II civilizations
Use a trillion trillion times the energy of Type I civilizations

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

1000 Years?

- So in 1000 years from now, we might 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

Getting Out of Here

- 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 could 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 "Earth-like" planets.
- That group regenerates for 500 yrs and sends out another craft.
- An advanced civilization could colonize the entire galaxy much quicker than you think.

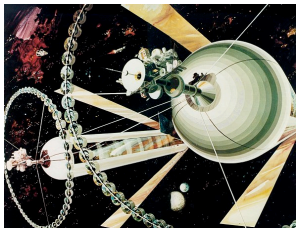
Slow Long Haul Space Travel

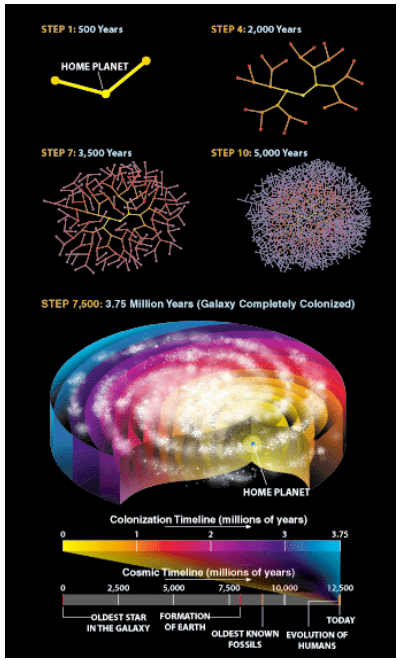
- Spacecraft that we can envision easily would take a lifetime to get to the nearest star.
- Colonizing missions would have to be multi-generation missions.
- Space colonies with propulsion systems would slow down things, so maybe it would take 1000 yrs or 100,000 for each trip.
- How many of you would sign up today?

A) Yes B) No

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 500 years to duplicate the technology
- Colonies could spread out about 50 light years every 3,000 years

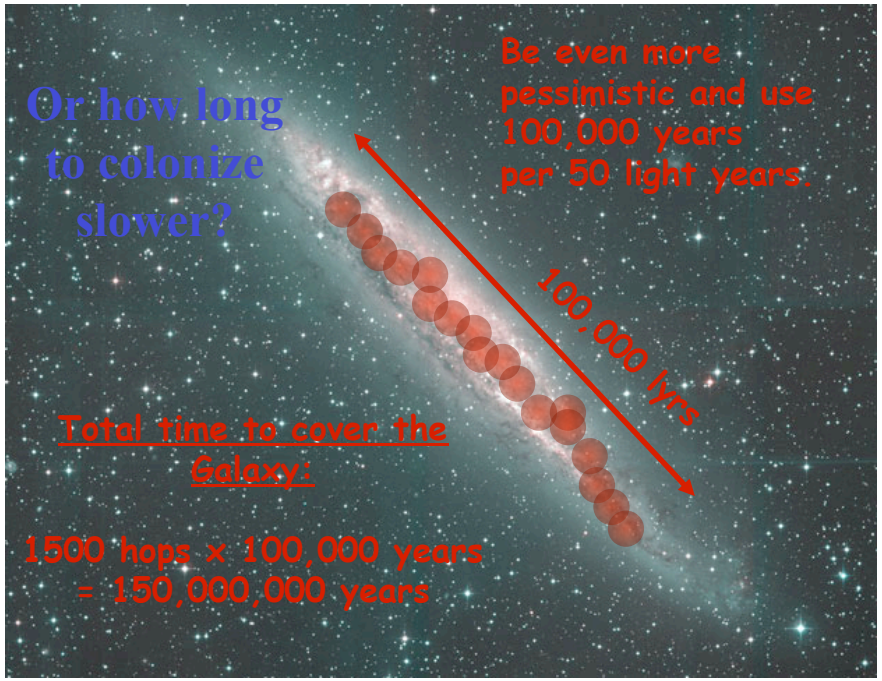




Optimistic

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

Then, it only takes about 4 million years!



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

- Given some ET civs, 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.

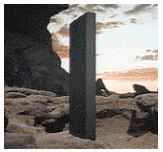
Timescales

- 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

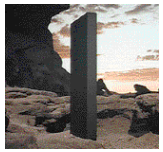
- So, if we go back to two alternatives - a galaxy packed with billions of intelligent life-forms, and a cold and lonely empty one, Fermi is suggesting that the truth lies closer to the second alternative.
- Does this seem reasonable?
- There may be a few (or a few hundred) intelligent species out there.
- 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
  - Interstellar travel is even harder than we thought