Astronomy 330

<u>This class (Lecture 23):</u>
Lifetime

<u>Next Class:</u>
Communication

Papers are due today.
HW9 is due on Tuesday
HW 10 is due on Thursday!!

Music: We got the Neutron Bomb – The Weirdos

Outline

- How long can a civilization last?
  - Give up or wiped out.
- So where are we?

Drake Equation

That's 1.33 communicating life/decade

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
	19 stars/ yr	0.4 systems/ star	1.25 x 0.07 = 0.0875 planets/ system	0.44 life/ planet	0.48 intel./ life	0.95 comm./ intel.	yrs/ comm.

Lifetime of Civilization

- If a civilization can communicate with other life forms, and wants to, how long can it last?
- This factor pulls a lot of weight in the Drake equation. Are we alone or are there aliens everywhere?
- Easy to envision 4 cases:
  1. Communication efforts stop. Bored with lack of success or funding issues.
  2. Civilization evolves away from interest or capability. But empires rise and fall.
  3. Technological civilization collapses: exhaustion of resources and population growth,
  4. Catastrophe! Nuclear war or various natural problems.

Issues

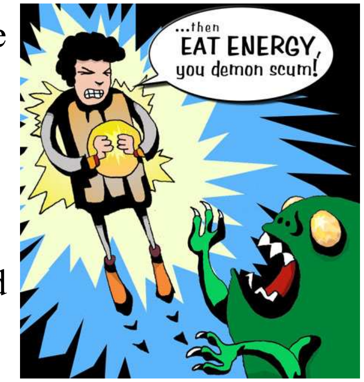
- The last 2 items:
  - Technological civilization collapses
  - Catastrophe
- Could be caused by:
  - Resource Exhaustion
  - Population growth
  - Nuclear war
  - Natural catastrophe

Hiroshima

http://gawain.membrane.com/hew/Japan/Hirosh.html

1. Depletion of Resources

- Modern life depends on metals and rare elements.
- Recycling can delay the depletion.
- Pollution of our water or air supply is still a problem.
- But, many of these issues can be solved with sufficient ***energy***.



http://www.timboucher.com/portfolio/eat-energy.jpg

1. Depletion of Resources

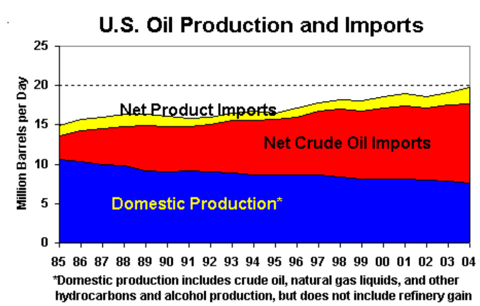
- Energy allows us to recycle, remove salt from the oceans, grow more crops, and generally convert material into the form we need.
- So, energy is our **greatest** concern.
- Remember that energy is not depleted, rather converted from useable form to less useable form (2nd law of Thermodynamics).

http://europa.eu.int/comm/mediatheque/photo/select/energy/p-009892-00-8h.jpg

Energy

- Majority from chemical means– fossil fuels– electricity and gasoline (92% in the U.S.).
- Really are from fossils, representing millions of years of life.
- And how are we spending it?
- The average US citizen uses twice that of a European, and 5 times the world average.

http://www.orps.state.ny.us/sas/graphics/oilwells.jpg



http://www.eia.doe.gov/emeu/cabs/usa.html

Energy

- Easy to obtain fossil fuels should last 50-100 yrs, coal 300-600 yrs.
- We will have to change! But US spending on renewable energy sources dropped by factor of 10 in the 1980s.
- SUVs do not help.

http://www.orps.state.ny.us/sas/graphics/oilwells.jpg

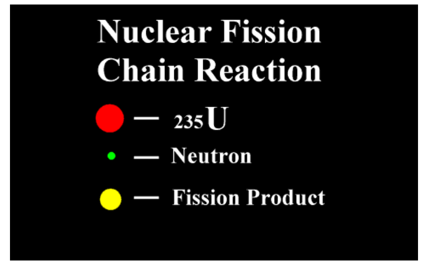
http://www.astrosurf.org/lombry/Documents/windfarm.jpg

http://www.dealerimpact.com/downloads/desktop_imgs/800x600-hummer.jpg

Nuclear Fission

- Breaking apart heavy (heavier than iron) unstable elements into lighter ones. Like an Un-Sun.
- Most widely used is ^{235}U– formed from supernovae– so limited amount on Earth.
- Supplies are limited and length of use controversial.

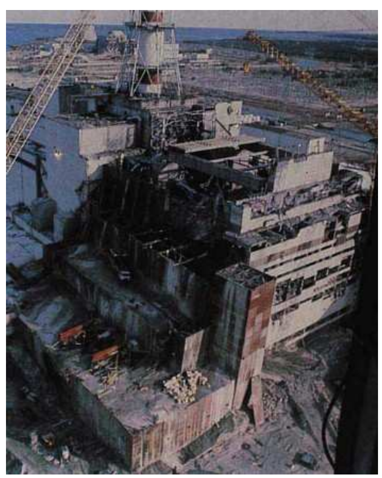
http://www.ne.doe.gov/uranium/history.html



http://library.thinkquest.org/17940/texts/images/chainreactionanim.gif
http://www.capefeare.com/seasonone.php

Nuclear Fission

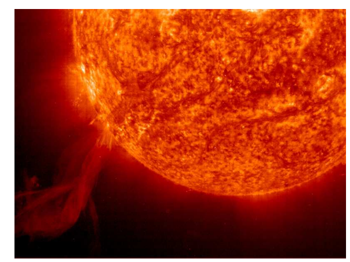
- A large reactor power plant uses 26 tons of fuel and 25 tons of waste per year.
- What do we do with the waste?
- How to prevent accidents: Three Mile Island or Chernobyl?



http://www.ourtimelines.com/hist/chernobyl.jpg

Nuclear Fusion

- What the Sun does for energy– H $\Rightarrow$ He.
- Requires high density and temperature.
- How to contain it on Earth– Sun uses gravity.



http://antwrp.gsfc.nasa.gov/apod/ap051109.html
http://www.cnn.com/SHOWBIZ/9712/24/teletubbies/
http://www.pppl.gov/fusion_basics/pics/fusion_dt_reaction.jpg

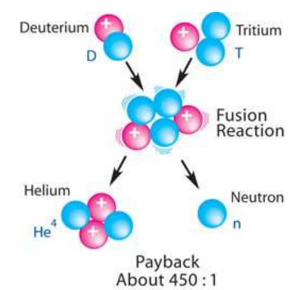
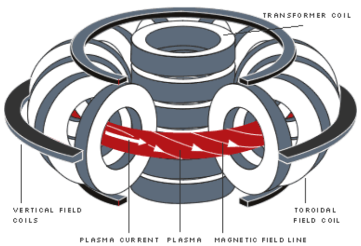


Diagram of deuterium-tritium reaction.

Nuclear Fusion

Tokamak Fusion Reactor

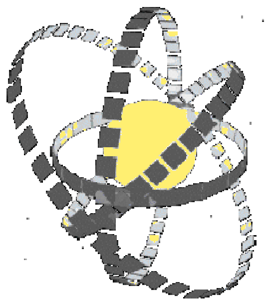
- Magnetic confinement, but not easy.
- Research continues, but unlikely to play a large role in the next 50 yrs.
- And on Earth requires deuterium (heavy hydrogen) not as abundant as hydrogen, nonetheless very promising!



http://www.ipp.mpg.de/ippcms/eng/pr/exptypen/tokamak/magnetspulen/index.html

Long-Lived Civilizations

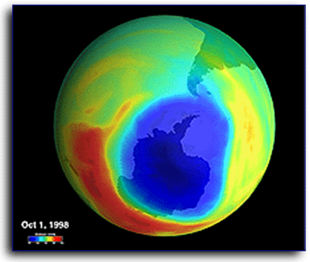
- Require renewable energy supplies, all Sun related.
- Hydroelectric (requires rain), windmills (winds), and solar power.
- Solar power is used today, but currently expensive because of manufacturing and tax subsidies for fossil fuels.
- Future example, could imagine a power plant that completely surrounds the Sun– e.g. Dyson sphere.



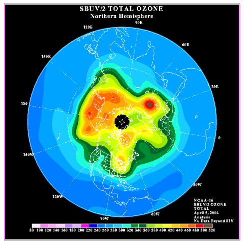
http://www.homoexcelsior.com/omega.db/datum/megascale_engineering/dyson_sphere/237

Pollution from Civilization

- Ozone layer (O_3) is formed from O_2
  O_2 broken up by ultraviolet light
- Ozone protects life against harmful Sun rays.
- Chlorofluorocarbons (CFCs) destroy the ozone.



Antarctic Ozone Hole
Photo courtesy of NASA

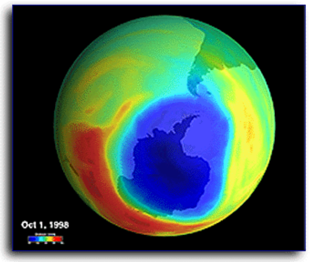


http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/gif_files/sbuv16_nh_latest.gif

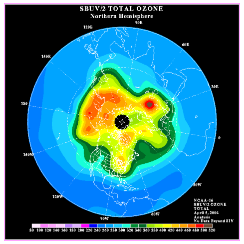
http://www.ngdc.noaa.gov/paleo/globalwarming/images/ozone.gif

Pollution from Civilization

- CFCs were used in A/C and refrigeration.
- Governments did not do much until a large hole appeared over Antarctica and N. America.
- Finally, being phased out, but the CFCs take about 20 yrs to reach stratosphere.
- The problem was predicted 25 years ago.



Antarctic Ozone Hole
Photo courtesy of NASA

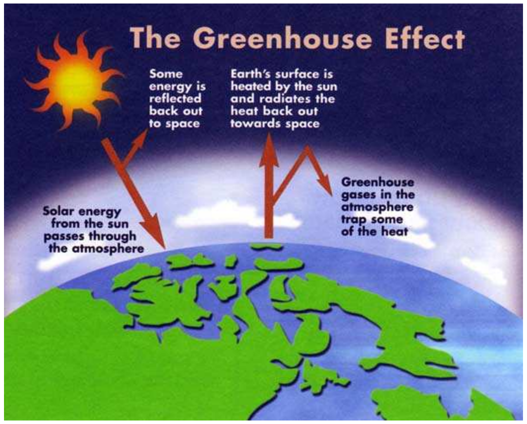


http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/gif_files/sbuv16_nh_latest.gif

http://www.ngdc.noaa.gov/paleo/globalwarming/images/ozone.gif

Global Warming

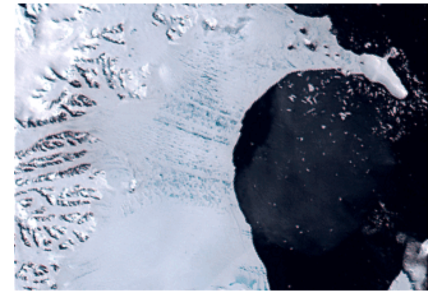
- Burning of fossil fuels releases CO_2.
- This is a greenhouse gas.
- Humans add more CO_2 to the atmosphere (50-100x) than natural sources– 25 billion tons each year!



http://www.climatechange.gc.ca/english/climate_change/images/ghg_effect_lg_e.jpg

Global Warming

- Why hasn't the temperature rise been more dramatic?
- The burning of coal releases sulfates form a haze that increases the albedo of Earth.
- So the effect is less than expected, but predictions suggest that CO_2 content will begin to dominate in this century.
- Already, large slabs of the Antarctica ice shelf have melted.



Destruction of Larsen ice shelf 2002. 3250 km^2 over 35 days. That's bigger than Rhode Island! Existed for at least 400yrs maybe 12,000yrs.

http://www-nsidc.colorado.edu/iceshelves/larsenb2002/animation.html

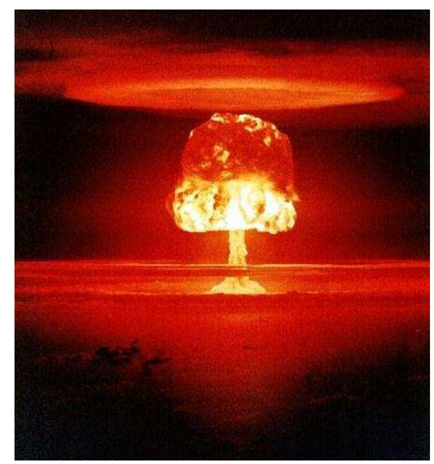
2. Population Growth

- Currently world population is around 6.6 billion (6.6 x 10^9).
- Population roughly doubles every 50 years–
  - 2050: 10 billion
  - 2100: 20 billion
  - 2150: 40 billion
  - 3000: 2.6 x 10^5 times present population = ***1.3 x*** $\boldsymbol{10^{15}}$
- In the year 3000, each person will have 4 square feet (2' by 2') of space (including the oceans!).
- A final absurdity, in 2550 years (the year 4554), the weight of humans would outweigh the Earth.
- Obviously something will have to be done!

http://w3.whosea.org/aboutsearo/88-97-7.htm

3. Nuclear War

- May be the only human activity that can catastrophically end our technological civilization.
- Effect may be seen days or years afterwards.
- Makes lots of radioactive elements with various half-lifes.
- Most destructive global nuclear war could cause a nuclear winter.



http://www.dalitstan.org/journal/recthist/nuclear/nuclear.html
http://cosmo.pasadena.ca.us/adventures/atomic/cold-war.html

3. Nuclear War

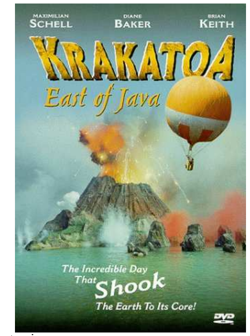
- Dust and debris thrown into atmosphere around the globe would block light and lower temperatures.
- Out of control fires would add soot to the dust layer.
- Major collapse of the world's food chain.
- Possibly extinguish our species.

http://www.randomfate.net/MT/images/N_Korea_nuke.gif
http://cosmo.pasadena.ca.us/adventures/atomic/cold-war.html

4. Natural Catastrophes

1. Volcanoes
   - Worldwide distribution of dust. Same idea as nuclear winter, but without radioactive fallout.
   - Krakatoa eruption in 1883 near Java, blew away 75% of the island of Rakata. (Heard in Austria.)
   - Prolonged low temperatures "Year with no summer"

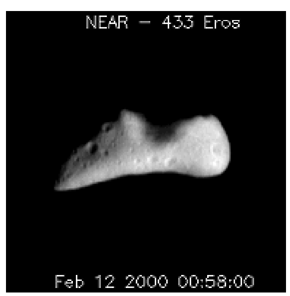
From Simkin and Fiske, 1983



http://www.vulkaner.no/v/volcan/indo/krakatau.html
http://charon.hendrix.edu/astro/krakatoa.jpg

4. Natural Catastrophes

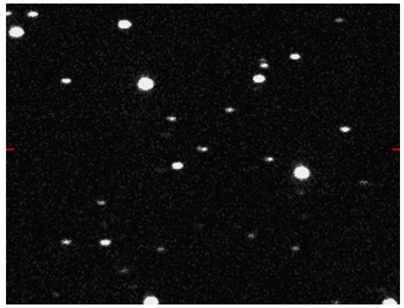
2. Comets and Asteroids
   - Many in Earth-Crossing orbits– NEOs.
   - Again, creates large amounts of dust in the atmosphere leading to global cooling.
   - Small objects can cause a lot of damage because the Earth's orbital velocity is 30 km/s $\Rightarrow KE = \frac{1}{2} M V^2$
   - That means that a 0.25 km radius rock releases as much energy as 7200 megatons of TNT, as much as a all-out nuclear war!
   - Would make a 10 km crater a few km deep ejecting 10^{12} tons of debris.



Cause of Death	Chances
Motor vehicle accident	1 in 100
Murder	1 in 300
Fire	1 in 800
Firearms accident	1 in 2,500
Asteroid/comet impact (lower limit)	1 in 3,000
Electrocution	1 in 5,000
Asteroid/comet impact	1 in 20,000
Passenger aircraft crash	1 in 20,000
Flood	1 in 30,000
Tornado	1 in 60,000
Venomous bite or sting	1 in 100,000
Asteroid/comet impact (upper limit)	1 in 250,000
Fireworks accident	1 in 1 million
Food poisoning by botulism	1 in 3 million
Drinking water with EPA limit of TCE*	1 in 10 million

Killer Asteroids

- Small asteroids are often hitting the Earth's atmosphere.
- Commonly giving off around 10 kilotons of energy.
- But how often are Killer Asteroids (~ 0.5 km in diameter) expected?

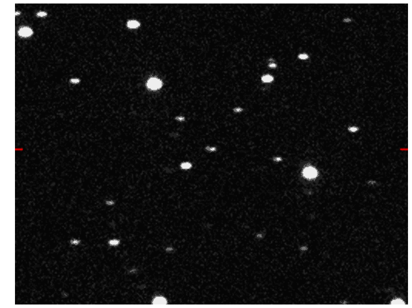


Asteroid 2004 FH. 30 meters in diameter. About 1 Megaton of TNT energy in an Earth impact! Passed within 7 Earth radii of Earth. Hiroshima was 15 kilotons.

http://antwrp.gsfc.nasa.gov/apod/ap040322.html

Killer Asteroids

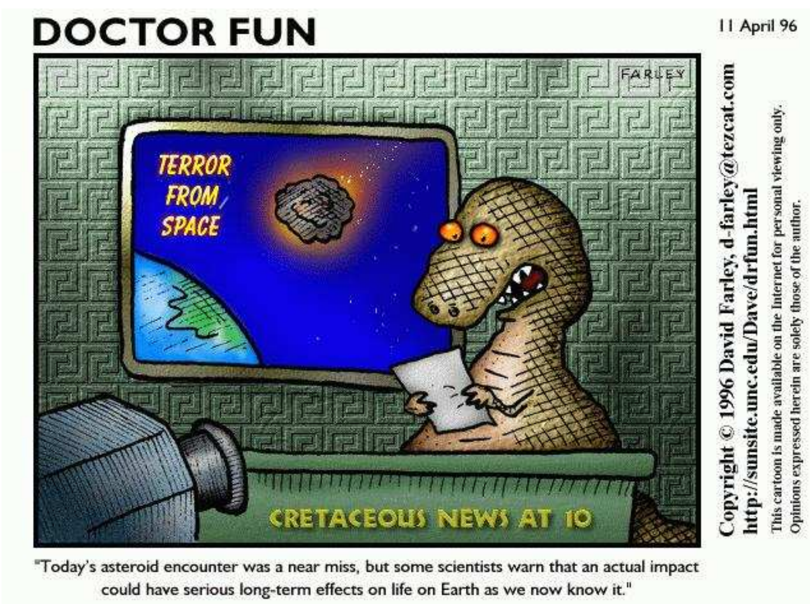
- In 1992 congress asked NASA to find near Earth objects.
- So far over 400,000 objects.
- The most dangerous <u>known</u> is 1950 DA (~1km), will get close in March 2880 (0.33% chance of collision).
- We can not predict orbits more than 20 years in advance, but 1950 DA would have 100,000 Megatons of energy.



Asteroid 2004 FH. 30 meters in diameter. About 1 Megaton of TNT energy in an Earth impact! Passed within 7 Earth radii of Earth. Hiroshima was 15 kilotons.

http://antwrp.gsfc.nasa.gov/apod/ap040322.html

Be Aware



Killer Asteroids

- The Dino Killer was about 10 km in diameter.
- And, there are many asteroids out there that we still do not know about.
- Estimation of killer asteroids impact is about every million years or so.
- What can we do if there is an immediate threat? There may be little time.

http://www2.ifa.hawaii.edu/newsletters/article.cfm?a=88&n=10

http://neat.jpl.nasa.gov/

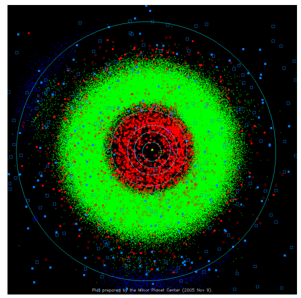
http://www.ll.mit.edu/LINEAR/

Killer Asteroids

- Diversion or destruction of object.
- With sufficient warning it doesn't take too much to miss the Earth.
- One example is to change reflectivity of surface.
- Nuclear explosions may result in many small asteroids.
- Expensive and difficult, but advanced civilizations should be able to do it.

http://neat.jpl.nasa.gov/

http://www.ll.mit.edu/LINEAR/



4. Natural Catastrophes

3. Stellar Evolution
   - The Sun is halfway through its lifetime on the main sequence.
   - Its luminosity will increases as it becomes a red giant.
   - Either Earth gets pulled in, pushed out, or nothing.
   - In about 5 billion years, the Earth's atmosphere will probably evaporate.
   - Even earlier though, the Earth will lose its oceans in about 1-2 billion years.

http://www.astroimages.net/Media/SolarSys/AR03.html

Natural Catastrophes

3. Stellar Evolution
   - But an advanced civilization can decrease greenhouse gases or increase dust in the atmosphere.
   - Eventually, we would have to leave the Earth, move the Earth, or move to Mars.
   - Even shorter variations in the Sun's luminosity can result in ice ages. Again, advanced civilizations can add greenhouse gas.

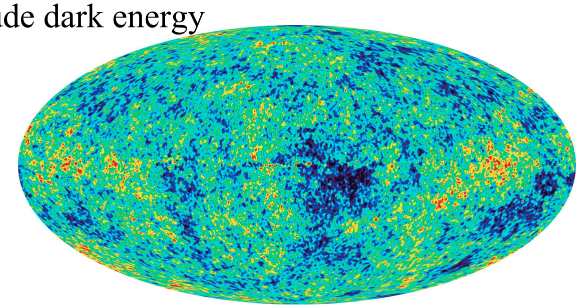
http://www.boulder.swri.edu/~terrell/dtart_old.htm

4. Natural Catastrophes

4. Killer Supernovae!
   - Death of a nearby massive star would be bad news.
   - Explosion within 30 ly would destroy ozone layer.
   - Right now, no candidates.
   - Unlikely to happen in time scales of less than 2 billion years.
   - A supernova event ~2 Myrs ago may account for a mass extinction event.

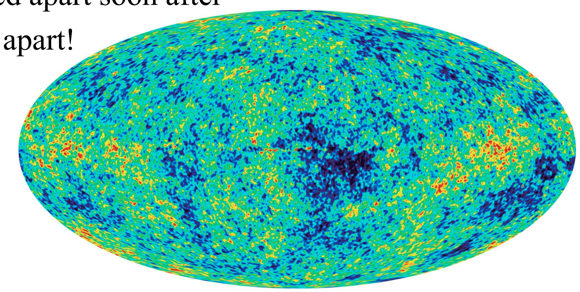
4. Natural Catastrophes

5. Ultimate limit to L!
   - Fate of the Universe.
   - A Big Crunch: 10^{12} years (a trillion years)
   - But, WMAP results from the cosmic microwave background suggest that we are in a flat universe.
   - Which does include dark energy



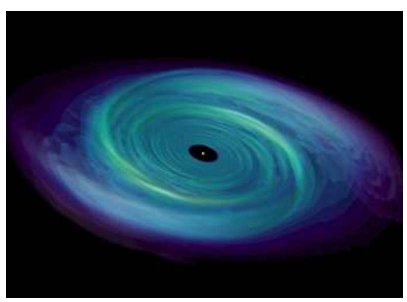
4. Natural Catastrophes

5. Ultimate limit to L!
   - The Big Rip?
     - If repulsive force increases– Brooklyn may expand too.
     - Gravity/E&M forces can not hold Galaxies rip apart
     - Could rip the MilkyWay apart in ~1 billion years
     - Earth gets ripped apart soon after
     - You get ripped apart!



4. Natural Catastrophes

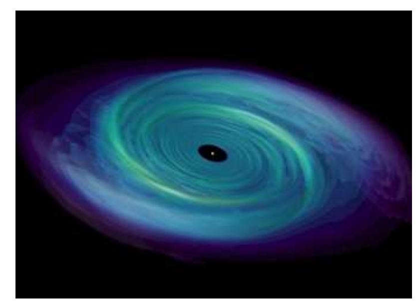
5. Ultimate limit to L!
   - Big Rip seems unlikely
   - We'll know soon.
   - If we are just in a flat Universe, then it is a matter of energy.



http://homepages.wmich.edu/~korista/web-images/accretion_ncstate.jpg

4. Natural Catastrophes

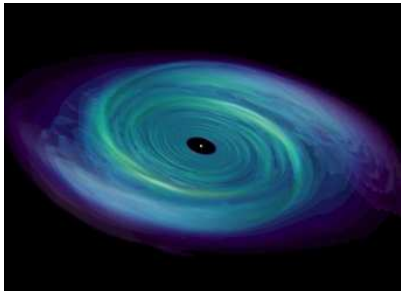
5. Ultimate limit to L!
   - Eventually all of the stars will burn out (10^{12} years).
   - Only energy source left is orbital energy.
     - Possibly extracting energy from rotating Black Holes.



http://homepages.wmich.edu/~korista/web-images/accretion_ncstate.jpg

4. Natural Catastrophes

5. Ultimate limit to L!
   - Eventually, black holes evaporate (10^{100} yrs). Remember the Universe is 13.7×10^9 or around 10^{10} years!
   - But half of all protons might decay by 10^{33} yrs.
   - Bottom line is that the maximum age is speculative.



http://homepages.wmich.edu/~korista/web-images/accretion_ncstate.jpg

What is L?

- How long on **average** can an advanced civilization exist?
- Again, we only have a sample of 1 from which to discuss. What is our civilization's lifetime?
  - Short Term (100-1000 yrs)
    - Give up on communication due to budgets.
    - Depletion of resources.
    - Population.
    - War.
  - Long Term (10^5 to 5×10^9 yrs– age of galaxy is 10^{10} yrs and we took half of that to evolve)
    - Stellar Evolution.
  - Don't forget the random volcano, asteroid, or supernova.
  - Still in many cases an advanced civilization may be prepared for many of the issues!

L-ing it

- We are talking about the amount of time that an advanced civilization (averaged over time) can communicate.
  - They may not want to for long periods of time
  - They may give up
  - They may be killed off
  - They may run out of resources
- Solving our energy problem (cheap energy) will give the largest lifetimes.

Drake Equation

That's 1.33x? 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
	19 stars/ yr	0.4 systems/ star	1.25 x 0.07 = 0.0875 planets/ system	0.44 life/ planet	0.48 intel./ life	0.95 comm./ intel.	? yrs/ comm.

Drake Equation For Optimist

$= 2.5 \times 10^{11}$

Communicating Civilizations

62.5% of all stars in our Galaxy.

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

N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact	Rate of formation of Sun-like stars	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
	50	**1**	**1**	**1**	**1**	**1**	**5×10^9**

Birthrate of 50/year!

Drake Equation For Pessimist

$= 7.5 \times 10^{-6}$

Communicating Civilizations

Must wait 10^7 years for one!

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

N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact	Rate of formation of Sun-like stars	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
	5	**0.1**	**0.15**	**0.01**	**0.01**	**0.01**	**100**

Birthrate of 7.5×10^{-8} /year!

Drake Equation For Average

$= 9.3 \times 10^5$

Communicating Civilizations

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

N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact	Rate of formation of Sun-like stars	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
	10	**0.5**	**0.89**	**0.5**	**0.7**	**0.6**	**1×10^6**

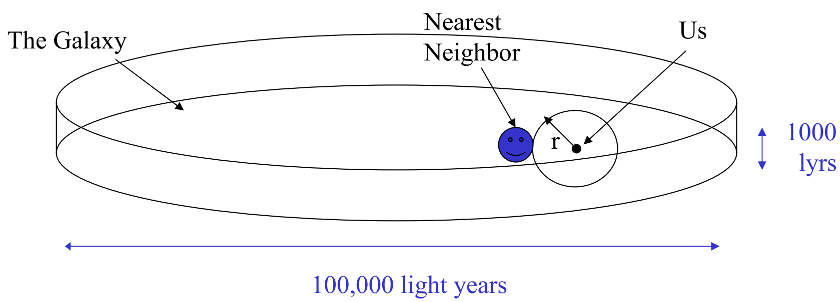
Birthrate of 0.93 /year!

Hmm..

- None of these results are wrong.
- The average results of around 1/year would suggest that any life that is contacted is presumable older and therefore more advanced.
- It is interesting to note that for our values, lifetimes greater than around 80 years give more than 10 civilizations with which to talk.
- Our number was **?** years.

Distance to Nearest Neighbor

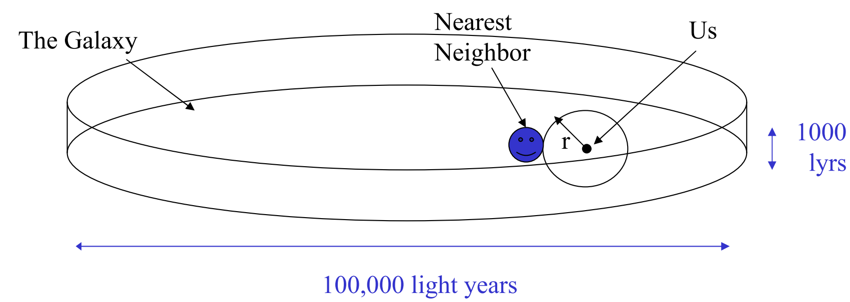
- Assume that the alien civilizations are uniformly scattered in our galaxy and N > 8000.
- We can then assume spherical volume to find ET, i.e. flatness of Galaxy not an issue.



Distance to Nearest Neighbor

- Assume N > 8000

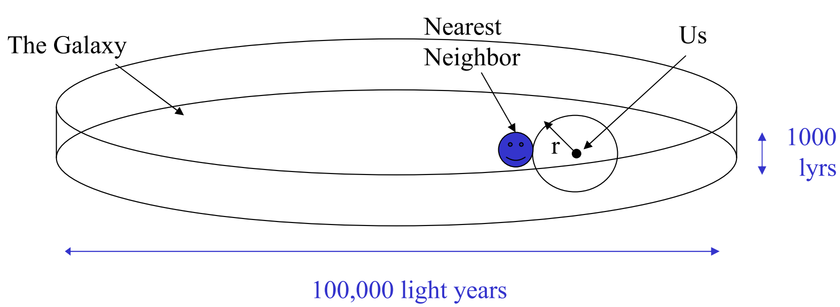
$$\frac{Average\ \ Galactic\ Volume}{Number\ of\ Civilizations} = \frac{\pi\, r_{galaxy}^2 h_{galaxy}}{N} = \text{alien density}$$



Distance to Nearest Neighbor

- Assume N > 8000

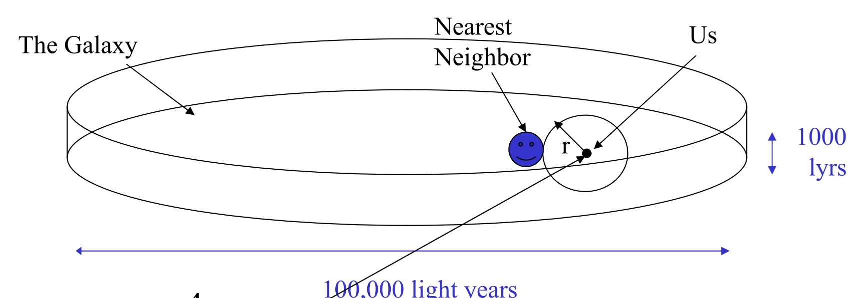
$$alien\ density = \frac{\pi\, r_{galaxy}^2 h_{galaxy}}{N} = \frac{7.85 \times 10^{12}\ \text{lyrs}^3}{\text{N}}$$



Distance to Nearest Neighbor

- Assume N > 8000

$$alien\ density = \frac{\pi\, r_{galaxy}^2 h_{galaxy}}{N} = \frac{7.85 \times 10^{12}\ \text{lyrs}^3}{\text{N}}$$

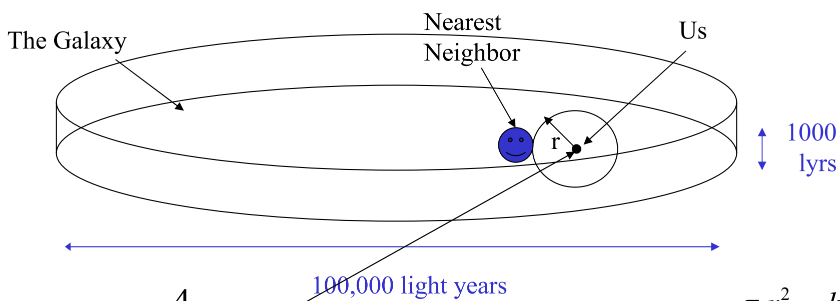


$$search\ volume = \frac{4}{3}\pi\, r^3$$

Distance to Nearest Neighbor

- Assume N > 8000

$$\frac{4}{3}\pi r^3 = \frac{7.85 \times 10^{12} \text{ lyrs}^3}{N}$$



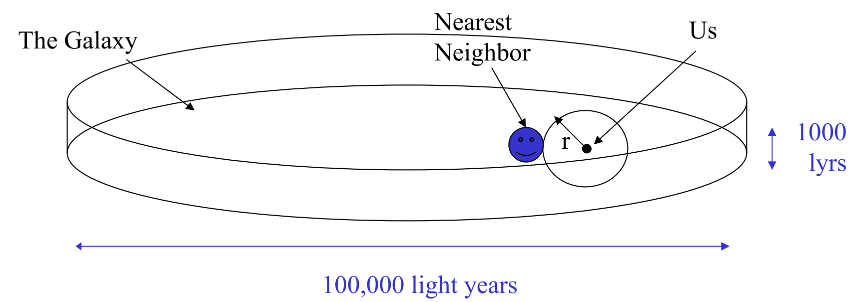
$$search\ volume = \frac{4}{3}\pi\, r^3$$

$$\text{alien density} = \frac{\pi\, r_{galaxy}^2 h_{galaxy}}{N}$$

Distance to Nearest Neighbor

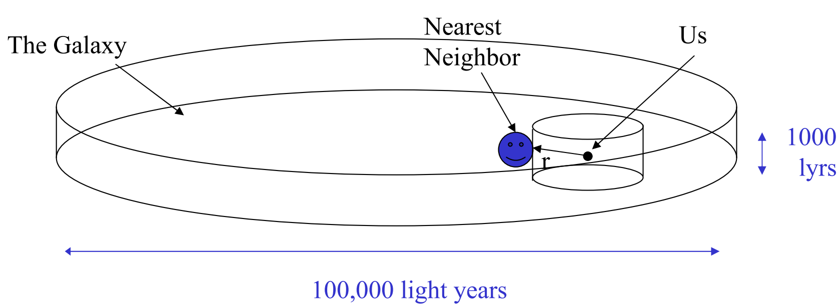
- Assume N > 8000

Then $$r \approx \frac{12000\ ly}{N^{\frac{1}{3}}}$$



Distance to Nearest Neighbor

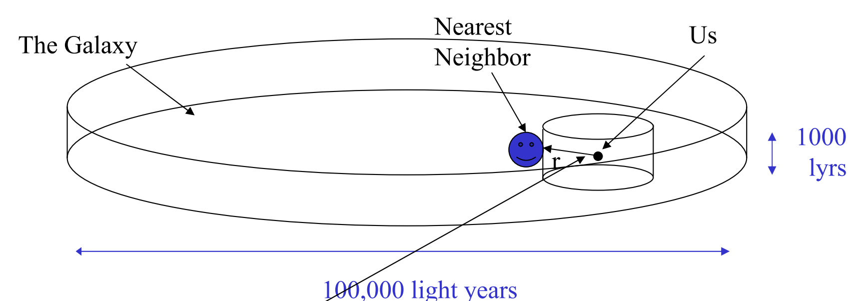
- Assume that the alien civilizations are uniformly scattered in our galaxy and N < 8000.
- Then, the flatness of Galaxy is an issue.



Distance to Nearest Neighbor

- Assume N < 8000

$$\frac{Average\ \ Galactic\ Volume}{Number\ of\ Civilizations} = \frac{\pi\, r_{galaxy}^2 h_{galaxy}}{N} = \text{alien density}$$

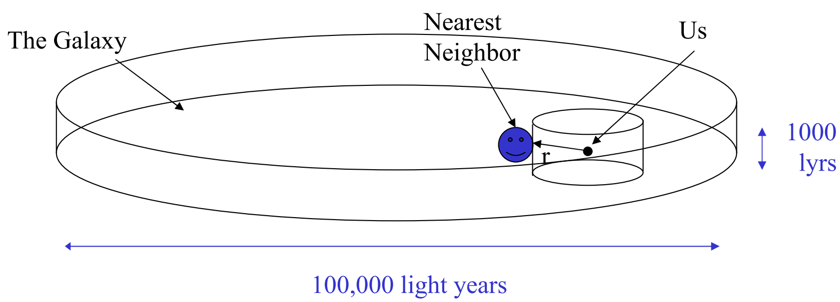


$$search\ volume = \pi\, r^2 h_{galaxy}$$

Distance to Nearest Neighbor

- Assume N < 8000

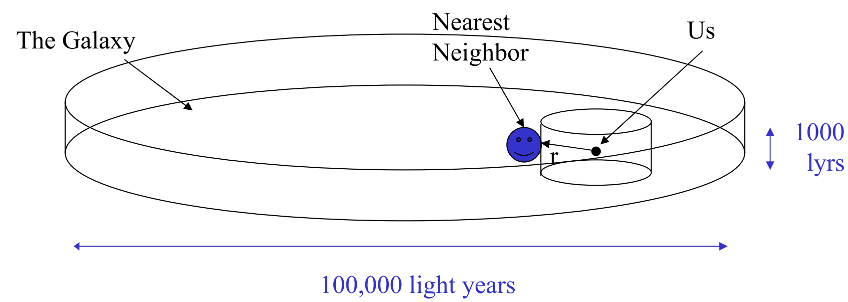
$$\pi r^2 h_{galaxy} = \frac{7.85\times10^{12}\ \text{lyrs}^3}{N}$$



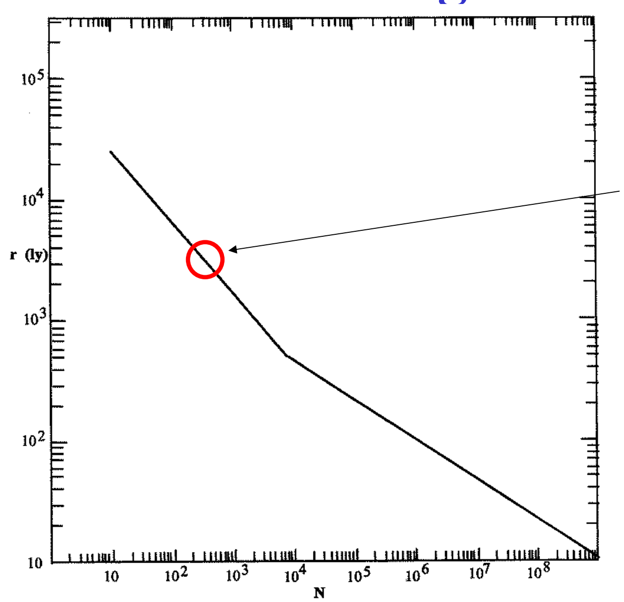
Distance to Nearest Neighbor

- Assume N < 8000

Then $$r \approx \frac{50000\,ly}{N^{\frac{1}{2}}}$$



The Neighbors



We need to look at every star within ~3000 lyrs for one detection!

Using N=333

Interesting Points

1. We assumed uniform density of civilizations.
   - Underweights the galactic center, but maybe that's okay– supernovae.
2. Distance away is the average.
   - Could be closer, but unlikely to be much closer.
3. Note that r is better defined than N.
   - R depends on $N^{1/2}$ or $N^{1/3}$.
   - If we are wrong in N by a factor of 100, then only off in r by factors of 10 or 4, respectively.
4. For communication, it may be that the distance there and back is longer than L.

How to Communicate?

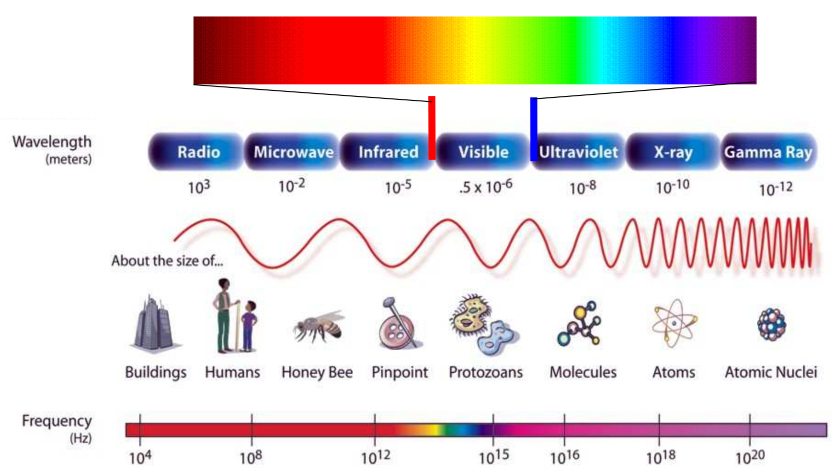
- Okay, our estimate is optimistic.
- So, how do we go about detecting our neighbors?
- Are we seriously sending out messages now?
- No.

How to Communicate?

- We are relatively a young civilization, with radio technology for only a hundred years.
- Right now, we are mostly a passive “lurker” civilization.
- Okay, so what will an advanced civilization use?
- Hard to figure out.. They are aliens!

Light me up

- Visible light is only a tiny portion of the full electromagnetic spectrum
- Red light has longer wavelength and lower frequency than blue light.
- Divisions between regions are from biology or technologies.



Frequency

- The frequency of light depends on its color.
- The unit is Hertz, equivalent to 1 cycle a second.
- For radio waves, we normally use larger units
  - 1 kHz = 1000 Hz
  - 1 MHz = 10^6 Hz
  - 1 GHz = 10^9 Hz