

ET: Astronomy 230



HW 8 due today!

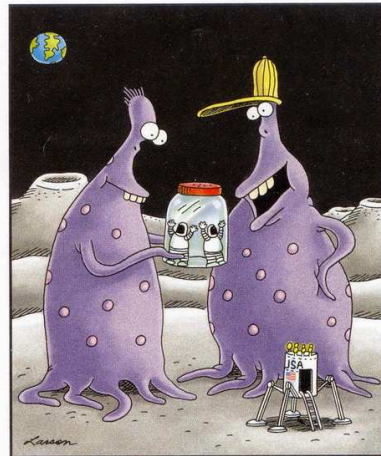
This Class (Lecture 33):

Lifetime

Next Class:

Communication

Music: *It's the End of the World* – R.E.M.



"Pretty cool, Dewey. Hey! Shake the jar and see if they'll fight!"

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Outline



- We need to estimate the average lifetime of all civilizations in our galaxy.
- What factors determine the lifetime of a civilization?
 - Resource Exhaustion
 - Population growth
 - Nuclear war
 - Natural catastrophe
- Arguably, the most uncertain factor in the Drake Equation.

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= 1.28

Comm. Life
/decade

Drake Equation

Frank Drake



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

# of advanced civilizations we can contact in our Galaxy today	Rate of star formation	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that communicate	Lifetime of advanced civilizations
	10	0.38	0.11	0.5	0.75	0.801	yrs/
	stars/	systems/	planets	life/	intel.	comm./	comm.
	yr	star	/syste	planet	/life	intel.	

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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.

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Issues



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

Hiroshima



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

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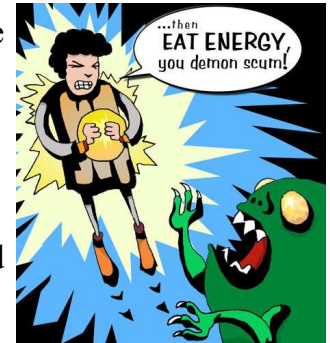
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1. Depletion of Resources



- 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>

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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>

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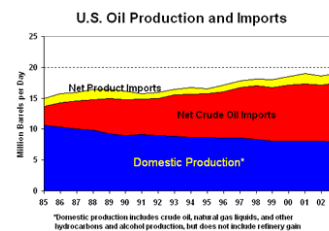
Energy



- 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/sa/s/graphics/oilwells.jpg>



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

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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
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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.capefare.com/seasonone.php>

Nuclear Fission Chain Reaction

- — ^{235}U
- — Neutron
- — Fission Product

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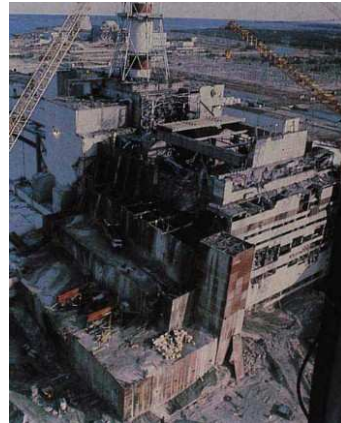
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Nuclear Fission



- 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>

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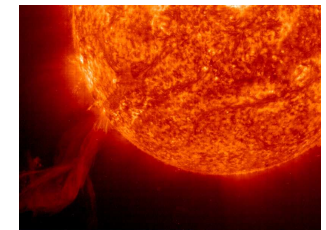
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Nuclear Fusion



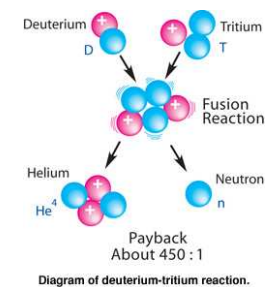
- What the Sun does for energy— $\text{H} \Rightarrow \text{He}$.
- Requires high density and temperature.
- How to contain it on Earth— Sun uses gravity.



<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

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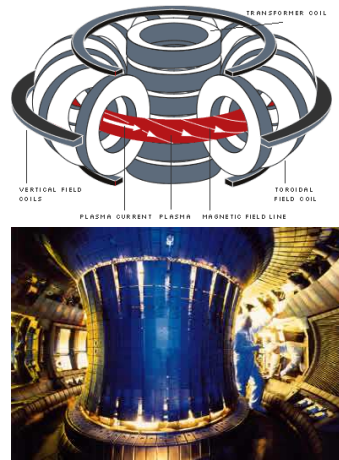


Nuclear Fusion



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>

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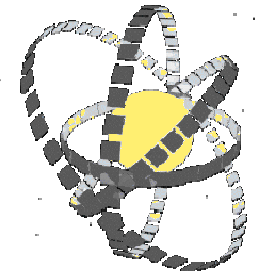
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Long-Lived Civilizations



- 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.homoeconomics.com/omega.db/data/megascale_engineering/dyson_sphere/237

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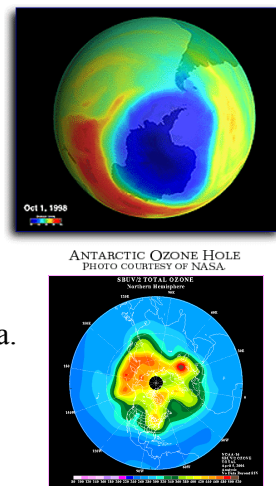
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Pollution from Civilization



- 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.
- 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.



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>

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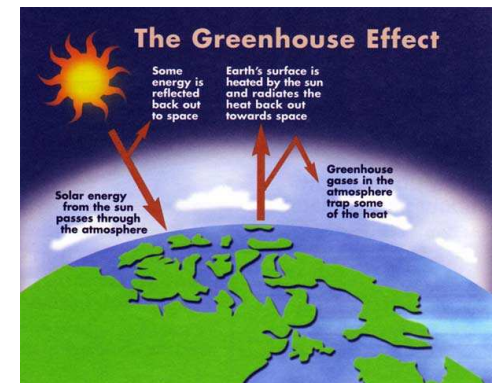
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Global Warming



- 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_1g_e.jpg

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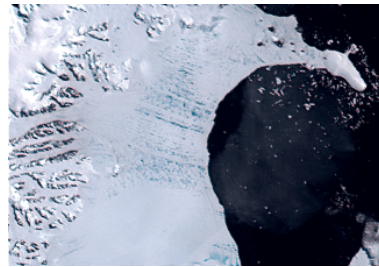
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Global Warming



- 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 CO₂ 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 km² over 35 days. That's bigger than Rhode Island! Existed for at least 400yrs maybe 12,000yrs.

<http://www-nsidc.colorado.edu/iceshelves/larsen2002/animation.html>

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2. Population Growth



- Currently world population is around 5 billion (5 x 10⁹).
- Population roughly doubles every 50 years—
 - 2050: 10 billion
 - 2100: 20 billion
 - 2150: 40 billion
 - 3000: 2.6 x 10⁵ times present population = 1.3 x 10¹⁵
- 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/about/searo/88-97-7.htm>

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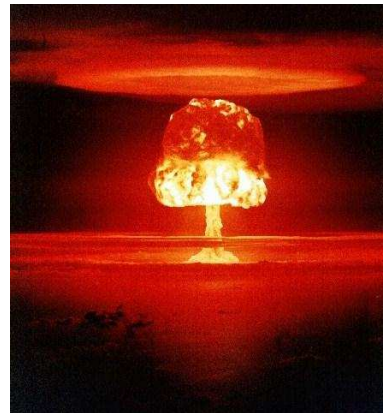
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3. Nuclear War



- 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-lives.
- Most destructive global nuclear war could cause a nuclear winter.



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

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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>

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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”



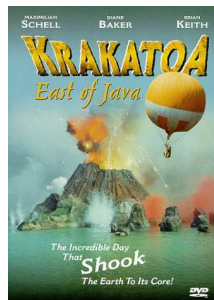
From Simkin and Fiske, 1983

Nov 11, 2005 <http://www.vulkaner.no/v/volcan/indo/krakatau.html>



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<http://charm.hendrix.edu/astro/krakatau.jpg>

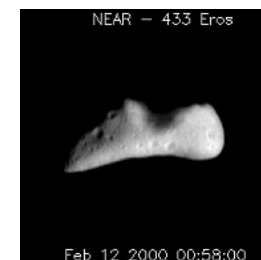


4. Natural Catastrophes



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.



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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?
- In 1992 congress asked NASA to find near Earth objects.
- So far over 400,000 objects.
- The most dangerous known 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.

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

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<http://antwrp.gsfc.nasa.gov/apod/ap040322.html>
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Be Aware



DOCTOR FUN

11 April 96



"Today's asteroid encounter was a near miss, but some scientists warn that an actual impact could have serious long-term effects on life on Earth as we now know it."

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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/](http://www.ll.mit.edu/LINEAR/AR/)

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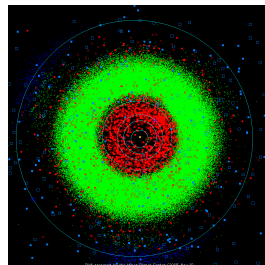
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Killer Asteroids



- 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/>

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4. Natural Catastrophes



3. Stellar Evolution

- The Sun is halfway through its lifetime on the main sequence.
- Its luminosity will increase 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>

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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

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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.
- As Brian Fields will discuss, it is posited that a supernova event 2 Myrs ago may account for a mass extinction event.



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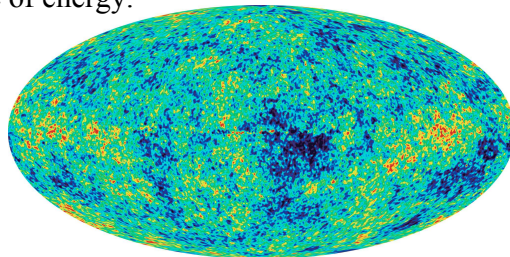
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4. Natural Catastrophes



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.
- Then it is an issue of energy.



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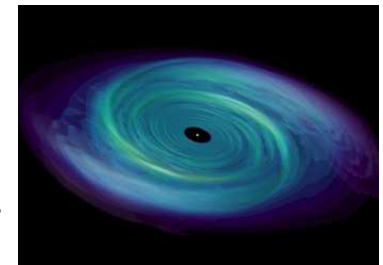
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4. Natural Catastrophes



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.
- 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

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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!

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Drake Equation For Optimist



$$= 2.5 \times 10^{11}$$

Communicating Civilizations

62.5% of all stars in our Galaxy.



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

# 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 commu- nicate	Lifetime of advanced civilizations
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50	1	1	1	1	1	1	5×10^9
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Birthrate of 50/year!

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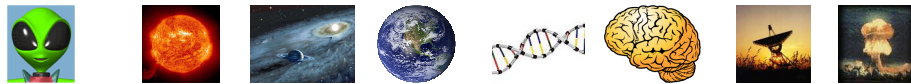
$$= 7.5 \times 10^{-6}$$

Communicating Civilizations

Drake Equation For Pessimist



Must wait 10^7 years for one!



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

# 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 commu- nicate	Lifetime of advanced civilizations
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5	0.1	0.15	0.01	0.01	0.01	0.01	100
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Birthrate of 7.5×10^{-8}
/year!

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$$= 9.3 \times 10^5$$

Communicating Civilizations

Drake Equation For Average



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

# 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 commu- nicate	Lifetime of advanced civilizations
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10	0.5	0.89	0.5	0.7	0.6	1	1×10^6
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Birthrate of 0.93 /year!

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