Astronomy 230

Section 1– MWF 1400-1450

106 B6 Eng Hall

Presentations MWF:

This Class (Lecture 22):

Lifetime of Civilizations

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Next Class:

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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.

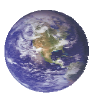
= 3.6

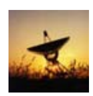
Communicating Civilizations /century

Drake Equation

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	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	**0.34**	**0.208**	**0.235**	**0.265**	**0.823**	
	Stars/year	Planetary System/star	Livable Planets /Planetary System	Evolved Life /Livable Planet	Intelligence /Evolved Life	Comm. ET /Intelligence	

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

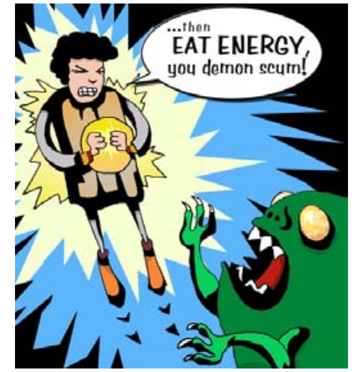
- The last 2 items:
  - Technological civilization collapses
  - Catastrophe
- Could be caused by:
  - Resource Exhaustion
  - Population growth
  - Nuclear war
  - Natural catastrophe

Hiroshima

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

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***.
- 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://www.timboucher.com/portfolio/eat-energy.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.
- 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.dealerimpact.com/downloads/desktop_imgs/800x600-hummer.jpg

Nuclear Fission

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

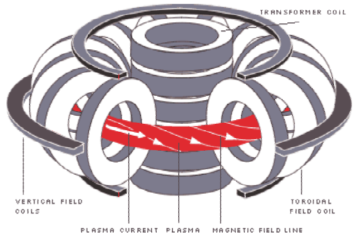
http://www.ne.doe.gov/uranium/history.html

http://www.capefeare.com/seasonone.php

Nuclear Fusion

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

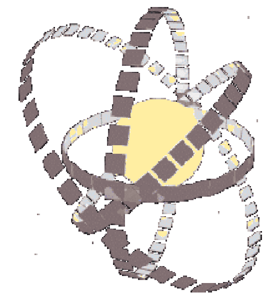
Tokamak Fusion Reactor



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

Long-Lived Civilizations

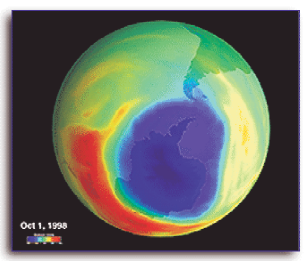
- Require renewable energy supplies, all Sun related.
- Hydroelectric (requires rain), windmills (winds), and solar power.
- Solar power is used today, but currently expensive because of manufacturing and tax subsidies for fossil fuels.
- Future example, could imagine a power plant that completely surrounds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



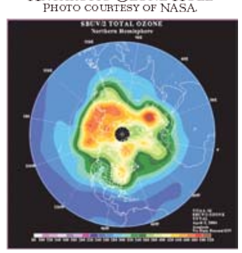
http://www.homoexcelsior.com/omega.db/datum/megascale_engineering/dyson_sphere/237

Pollution from Civilization

- Ozone layer (O_3) is formed when O_2 is hit by ultraviolet light, which breaks up O_2.
- 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.



ANTARCTIC OZONE HOLE
PHOTO COURTESY OF NASA.

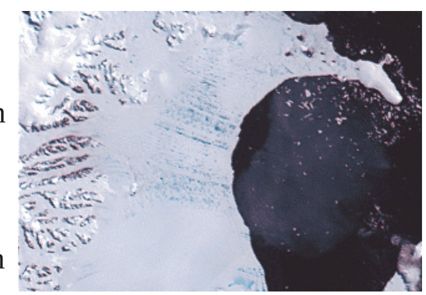


http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/gif_files/sbuv16_nh_latest.gif

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!
- Then 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

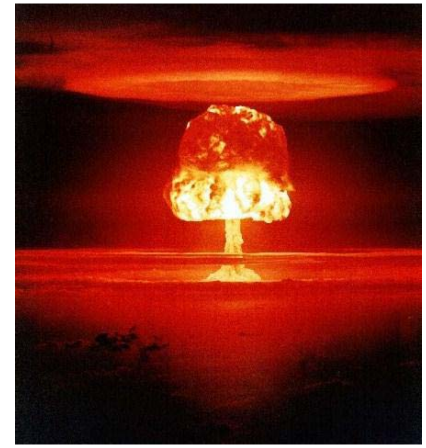
Population Growth

- Currently world population is around 5 billion (5×10^9).
- Population roughly doubles every 50 years–
  - 2050: 10 billion
  - 2100: 20 billion
  - 2150: 40 billion
  - 3000: 2.6×10^5 times present population = ***1.3×10^{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 weight of humans would outweigh the Earth.
- Obviously something will have to be done!

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

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.
- 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.

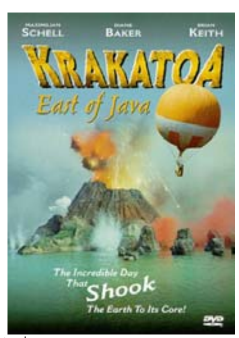


http://www.dalitstan.org/journal/recthist/nuclear/nuclear.html
http://cosmo.pasadena.ca.us/adventures/atomic/cold-war.html

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

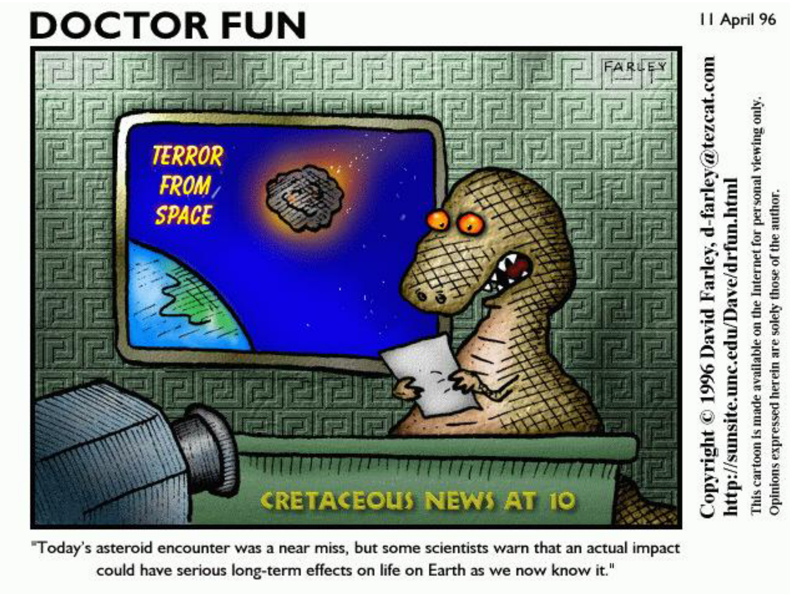


http://www.vulkaner.no/v/volcan/indo/krakatau.html
http://charm.hendrix.edu/astro/krakatoa.jpg

Natural Catastrophes

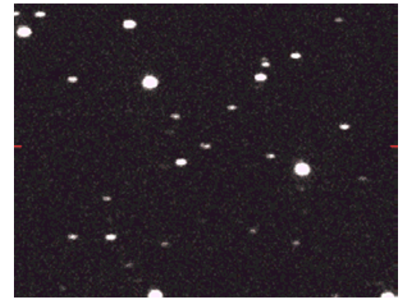
2. Comets and Asteroids
   - Many in Earth-Crossing orbits– NEOs.
   - Again, creates large amounts of dust in the atmosphere leading to global cooling.
   - Small objects can cause a lot of damage because the Earth's orbital velocity is 30 km/s $\Rightarrow KE = \frac{1}{2} M V^2$
   - That means that 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.

Be Aware



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.

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

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

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

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

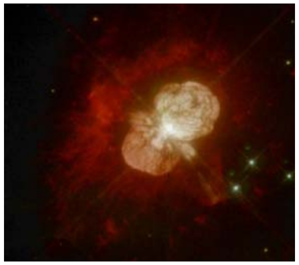
Natural Catastrophes

3. Stellar Evolution
   - The Sun is halfway through its lifetime on the main sequence.
   - Its luminosity will increases as it becomes a red giant.
   - 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.
   - But an advanced civilization can decrease greenhouse gases or increase dust in the atmosphere.
   - Eventually, we would have to leave the Earth and 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

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 discussed, it is posited that a supernova event 2 Myrs ago may account for a mass extinction event.



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.
   - 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 hole evaporate (10^{100} yrs). Remember the Universe is 13.7 x 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.

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 x 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!