Astronomy 330

This class (Lecture 21):
Lifetime
Maggie Sharp

Next Class:
Lifetime
Alex Bara

HW #8 due Thursday
Paper Draft due next Thursday

Music: *Concerning the UFO Sighting near Highland, Illinois* – Sufjan Stevens

Presentations

- Maggie Sharp
  Ancient Astronauts

Outline

- Worldview of a civilization.
- What is fc?
- What is the lifetime of a civilization that can communicate?

Drake Equation

That's 2.8 intelligent systems/century

Frank Drake








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

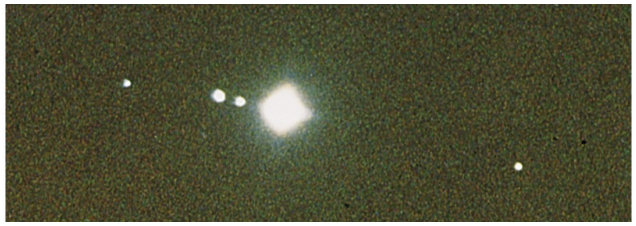
N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact in our Galaxy today	Star formation rate	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations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

Galileo (1609)
402 Years!

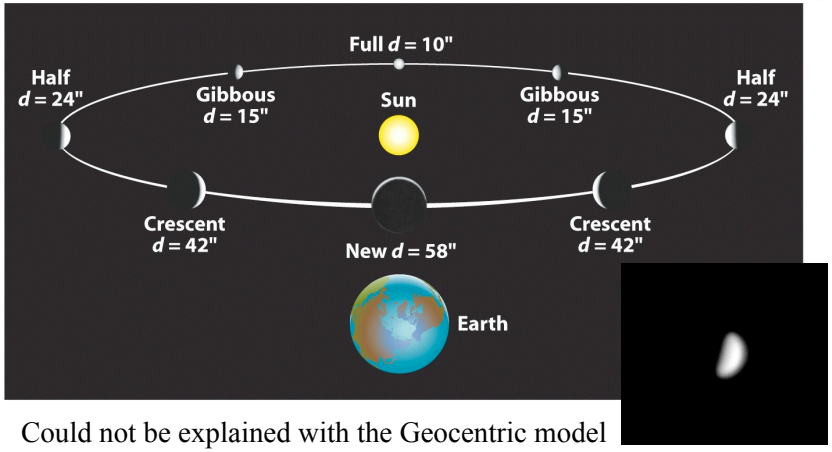
First to systematically use the telescope (but did not invent it).

- Moon has mountains and valleys
- Milky Way consists of faint stars
- Saturn is elongated
- Venus shows phases
- Jupiter has moons (now called Galilean moons)

Wow! Big stuff. The moons of Jupiter did not orbit the Earth!



The Phases of Venus



Could not be explained with the Geocentric model

http://www.astro.ubc.ca/~scharein/a310/SolSysEx/phases/Phases.html

http://www.calvin.edu/academic/phys/observatory/images/venus/venusb.html

Implications

- Kepler showed that ellipses needed to explain heliocentric model movement.
- New Twist– even the Sun isn't at the center of the solar system now. How does that change our view of the Universe and our place in it?

http://antwrp.gsfc.nasa.gov/apod/ap010101.html

Galileo (1610)

- Disproved Ptolemaic system
- Rome bullied him into recanting (cleared in 1992)
- Now we understand the motions and the fact that the solar system MUST be Heliocentric, but now we need a reason why?
- Need something with predictive power– Newton and gravity!

f_c Your Guess!

- Given that an intelligent civilization exists, what is the likelihood that it can (technologically advanced) and will want to (knows astronomy and thinks that its chances are good) communicate?
- Cultural evolution to **technology** and **worldview** are essential components of f_c
  - Extra-somatic storage of info crucial.
  - Technology and innovation– quantum mechanics
  - Copernican revolution played an important role.
  - ET has to realize that they are not the center of the Universe and that there might be other life.
  - How fast were these accomplishments? What is fast?

Big Questions for f_c

- Our capacity for interstellar communication arose at the same time as our interest in it. Coincidence?
- Can a society have a highly developed technology with an incorrect astronomy?
- What if the skies were constantly cloudy?
- What if their solar system had no other planets?
- What if they lived in a molecular cloud?
- What if they lived in a huge cluster of galaxies?

f_c Development

- Are we typical?
- Is it inevitable f_c = 100% or a fluke 1/10000?
- Remember civilizations come and go, but in general the gains (technology/worldview) aren't lost.
- Picked up by the next civilization.
- Even if one civilization goes dark for centuries, eventually another rekindles the technology/worldview.
- We are talking about the ability to communicate, not that the civilization is communicating.

Drake Equation

That's ? Communicating life/century

Frank Drake








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

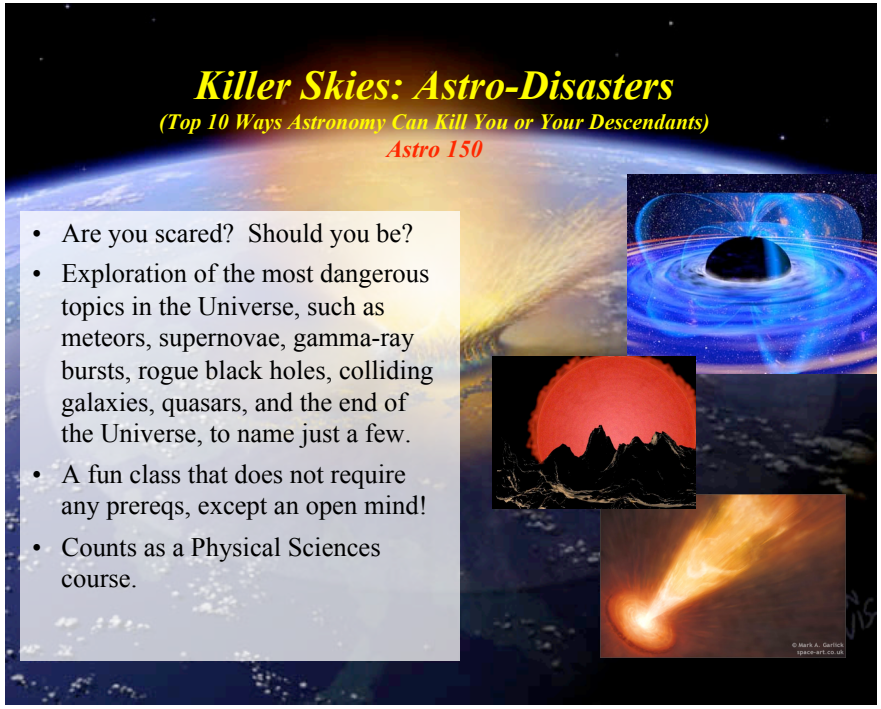
N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact in our Galaxy today	Star formation rate	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations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

Lifetime of Civilization

- If a civilization can communicate with other life forms, and wants to, how long can it last?
- We are taking about the long haul here, not necessarily short time scales.

Lifetime of Civilization

- 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/ astronomical problems.



Issues

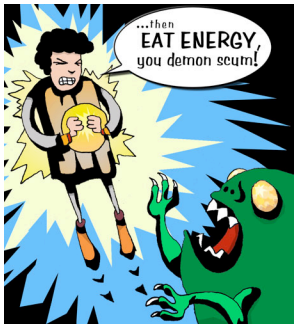
- The last 2 items:
  - Technological civilization collapses
  - Catastrophe
- Could be caused by:
  - Resource Exhaustion
  - Population growth
  - Nuclear war
  - Natural catastrophe
  - Other…

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

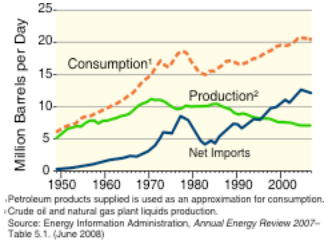
- Energy allows us to recycle, remove salt from the oceans, grow more crops, and generally convert material into the form we need.
- So, energy is our **greatest** concern.
- Remember that energy is not depleted, rather converted from useable form to less useable form (2^{nd} law of Thermodynamics).

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://tonto.eia.doe.gov/energy_in_brief/foreign_oil_dependence.cfm

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.

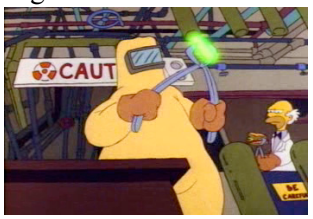
http://www.orps.state.ny.us/sas/graphics/oilwells.jpg

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.

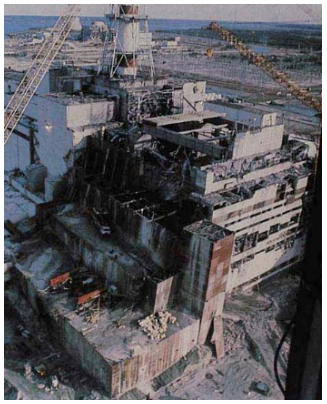


http://library.thinkquest.org/17940/texts/images/chainreactionanim.gif

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 or Japan?

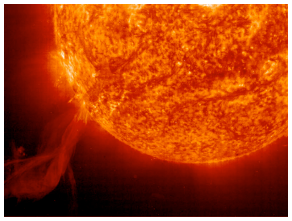


http://www.ourtimelines.com/hist/chernobyl.jpg

Nuclear Fusion

- What the Sun does for energy– H ⇒ He.
- Requires high density and temperature.
- How to contain it on Earth– Sun uses gravity.
- Put the Sun in a box, but how to build that box?

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



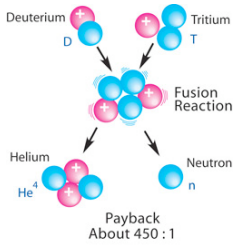
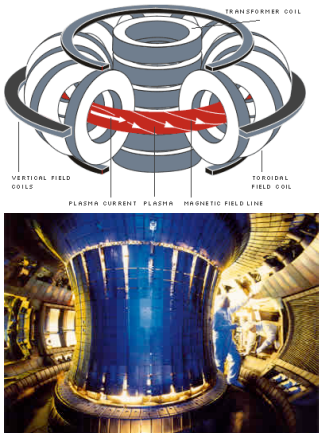


Diagram of deuterium-tritium reaction.

Nuclear Fusion

Tokamak Fusion Reactor

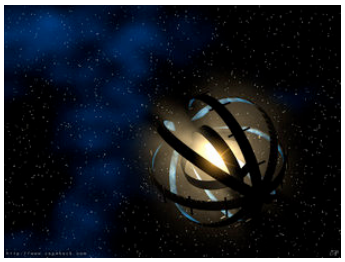
- Magnetic confinement, but not easy.
- Research continues, but unlikely to play a large role in the next 50 yrs.
- And on Earth requires deuterium (heavy hydrogen) not as abundant as hydrogen, nonetheless very promising!



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

Long-Lived Civilizations

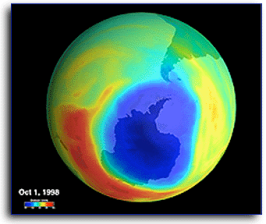
- Require renewable energy supplies, all Sun related.
- Hydroelectric (requires rain), windmills (winds), and solar power.
- Solar power is used today, but currently expensive because of manufacturing and tax subsidies for fossil fuels.
- Future example, could imagine a power plant that completely surrounds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



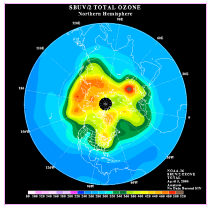
http://capnhack.deviantart.com/art/Dyson-Sphere-11008136

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

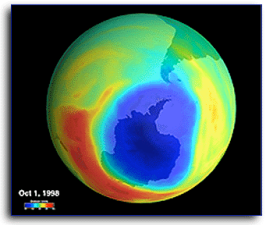


http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/gif_files/sbuv16_nh_latest.gif

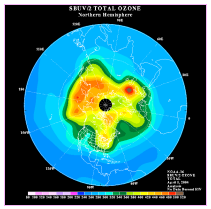
http://www.ngdc.noaa.gov/paleo/globalwarming/images/ozone.gif

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

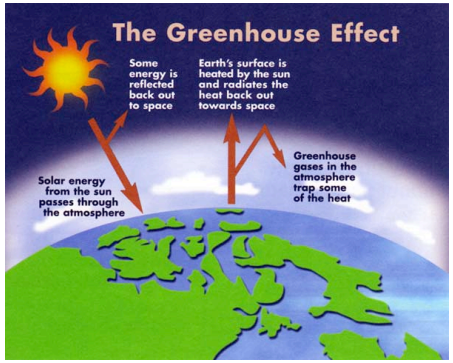


http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/gif_files/sbuv16_nh_latest.gif

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

Global Warming

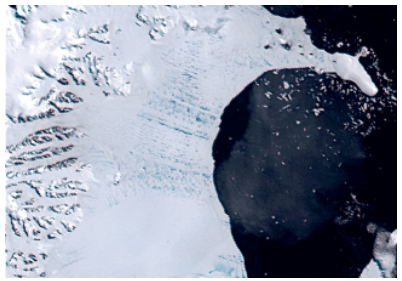
- Burning of fossil fuels releases CO_2.
- This is a greenhouse gas.
- Humans add more CO_2 to the atmosphere (50-100x) than natural sources–
  25 billion tons each year!



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

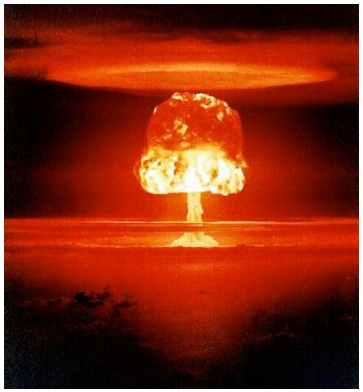
2. Population Growth

- Currently world population is around 6.9 billion (6.9×10^9).
- Population roughly doubles every 50 years–
  - 2050: 10 billion
  - 2100: 20 billion
  - 2150: 40 billion
  - 3000: ~200,000 times present population = ***1.3 x 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.

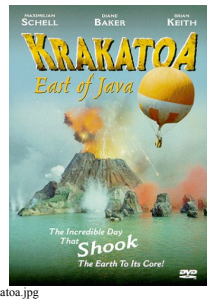
http://www.randomfate.net/MT/images/N_Korea_nuke.gif
http://cosmo.pasadena.ca.us/adventures/atomic/cold-war.html

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://charm.hendrix.edu/astro/krakatoa.jpg

Question

Although depletion of resources is a major issue for long term survivability of an advanced civilization, resource depletion really highlights a larger issue,

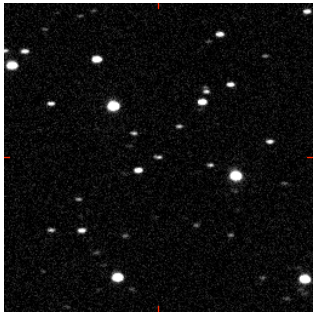
a) energy.
b) population growth.
c) global warming.
d) pollution.
e) asteroids.

4. Natural Catastrophes

2. Comets and Asteroids
   - Many in Earth-Crossing orbits– NEOs.
   - Again, collision would create large amounts of dust in the atmosphere leading to global cooling.
   - Small objects can cause significant damage because the Earth's orbital velocity is 30 km/s $\Rightarrow$ KE = ½ 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.

Killer Asteroids

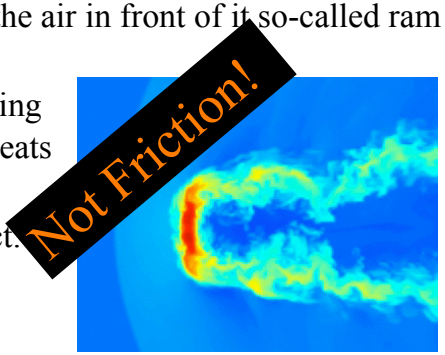
- Small asteroids are often hitting the Earth's atmosphere.
- Commonly giving off around 10 kilotons of energy.
- But how often are Killer Asteroids (~ 0.5 km in diameter) expected?


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

Ramming Speed!

- A meteor compresses the air in front of it so-called ram pressure.
- Just like quickly pumping up a bicycle tire, this heats up the air.
- This heats up the object.
- The outer layers of the object can melt or boil away, called ablation.
- The meteor light seen is a combination of ablation and ionizing of the atmosphere by the extreme heat.

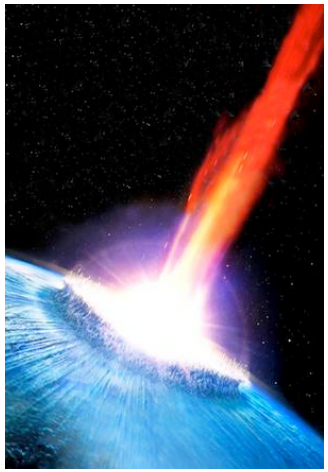


Ramming Speed!

- Objects less than a few kilograms will burn up completely in the atmosphere.
- Objects a few kilograms to 7000 kg will slow down due to the atmospheric drag.
- These reach their terminal velocity– about 90-180 m/s (200-400 mph).

The Big One

- Objects around 9,000 kg will keep some of their initial velocity– about 2-4 km/s (1.5 mps).
- Really big objects (9 x 10^5 kg) will hardly notice the atmosphere, impacting at near their initial velocities (>11 km/s!).
- http://www.youtube.com/watch?v=vZiZU42sn6w



It's a Drag

- Atmospheric flight puts a lot of stresses on the object.
- Larger objects, particularly stone varieties, may break apart into many objects at 11-27 km (7-17 miles).
- This causes an ellipse of smaller meteorites on the ground.

Cool Touch

- After the meteor reaches terminal velocity, the ram pressure is gone, and the lights go out.
- At this time, the meteorite cools off quickly.
- The inside of the meteorite has been in space for 4.5 billion years, so it is cold and the upper atmosphere is cold.

Cool Touch

- Sometimes newly fallen meteorites are actually covered in frost.
- But they are never above ambient temperature.
- You will not get burned.
- Big ones, it is a different story.

It's a myth that they can start fires!

What do they Look like?

- New rocky meteorites will still have their fusion crust– dark color.
- Iron meteorites, a welded metal look.
- But not always. It can wear away quickly, or the meteorite could have broken up after terminal velocity.
- http://www.aerolite.org/museum-quality-meteorites.htm

Tunguska, Russia 30 June 1908

- Something big seems to have exploded in the atmosphere
- The exact cause is uncertain, but we suspect a comet or a meteor

Aerial view of Tunguska Natural Reserve

Eye Witness

I suddenly saw the sky split in two and fire appeared high and wide over the forest. The split in the sky grew larger, and the entire northern side was covered with fire. At that moment, I became so hot that I couldn't bear it, as if my shirt was on fire; from the northern side, where the fire was, came strong heat. I wanted to tear off my shirt and throw it down, but then the sky shut closed, and a strong thump sounded, and I was thrown a few yards. I lost my senses for a moment, but then my wife ran out and led me to the house. After that such noise came, as if rocks were falling or cannons were firing, the earth shook, and when I was on the ground, I pressed my head down, fearing rocks would smash it. When the sky opened up, hot wind raced between the houses, like from cannons, which left traces in the ground like pathways, and it damaged some crops. Later we saw that many windows were shattered, and in the barn a part of the iron lock snapped.

http://en.wikipedia.org/wiki/Tunguska_event

Theories?

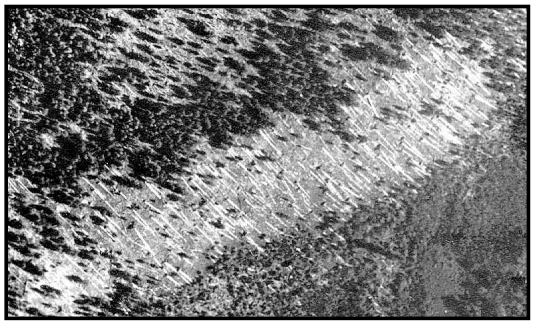
"Perhaps the earliest widely-held theory for the Tunguska explosion was that the world was about to end. As the minutes passed, this theory was dropped in favor of other, less final theories, until today one is hard-pressed to find anyone who truly believes the world ended on the morning of June 30, 1908.."

http://en.wikipedia.org/wiki/Tunguska_event

What happened?

- The object's entry appeared to be at an angle of 30-35°
- The object shattered in a series of explosions at about 8 km altitude

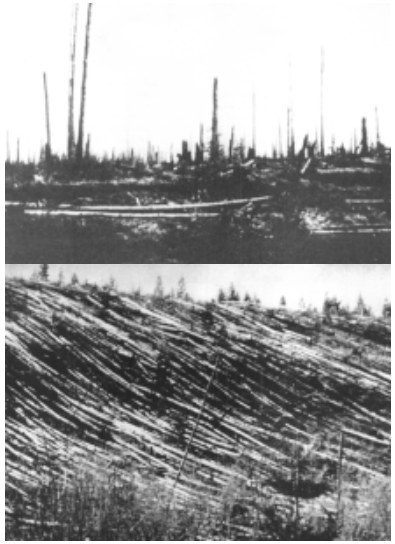
Tree blowdown from the explosions; Note parallel alignment of the trees



Big fires

- In the central region, forests flashed to fires that burned for weeks
- A herd of 600-700 reindeer was incinerated

Tunguska, Siberia, June 30, 1908



Black and white photos taken during field expedition in 1927; color photo taken in 1990

Aligned trees

- Trees were felled in a radial sense
- About 2,000 km^2 were flattened by the blasts

What happened?

- Our best scientific guess is that it was part of a comet 20-60 meters in diameter…
- …no crater was found…
- …and no meteoritic debris has been found

Felled trees aligned parallel to each other

Lake Cheko

- Recently, a team has suggested that a fragment from the event did impact 8 km away.
- They argue that it made Lake Cheko (elongated in correct direction).
- It has a strange conical shaped bottom with dense object at the bottom (investigated this year).

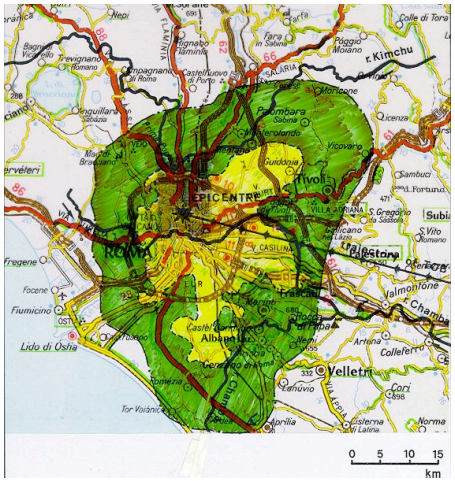
Tunguska, Siberia: June 30, 1908
A ~40 meter object disintegrated and exploded in the atmosphere

The energy of the explosion was equivalent to 1,000 Hiroshimas

Several hundred square miles of forest were destroyed.
What if this had happened over a city?

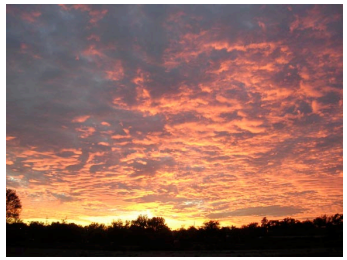
Area of devastation superimposed on a map of Rome.
Yellow=charred trees; Green=felled trees

- Devastation!
- Over a city, it could kill millions.



A Global View

- Soot from fires circled the globe, producing spectacular sunrises and sunsets for months afterward
- The Tunguska event was the largest known comet/asteroid event in the history of civilization
- http://www.youtube.com/watch?v=mQSwVMBIeKg
- We expect such events every 100 years or so!



http://visionoftheworld.com/_wsn/page4.html

If something like Tunguska happens every ~100 years, how come we haven't heard about it? Why haven't more people been killed by asteroid impacts in the past?

- Before the 20th Century, human population was much lower, so likelihood of someone being affected is lower.
- If someone did see a Tunguska, less likelihood of word getting around -- news didn't disperse as easily back then.