

Astronomy 150: Killer Skies



Exam 1



- Exam 1 is in 2 weeks, Oct 1st.
- Was moved back by 1 week as we are running slightly behind.

This Class (Lecture 9):
Jupiter in Peril

Next Class: **HW4 due on Monday**
Impact Mitigation **EC due on Wed.**

Music: Until the End of the World– U2

Outline

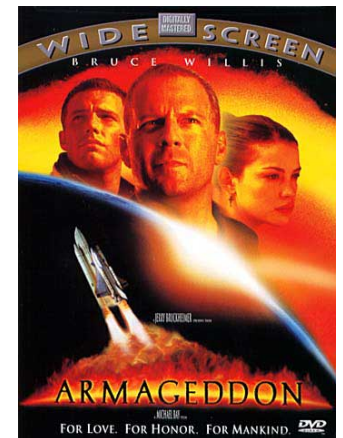


- Big rocks do fall from the Sky– the Story of Tunguska
- Big rocks do fall from the Sky– the case of Shoemaker Levy 9!
- We are looking for dangerous rocks. Don't worry.. trust us..

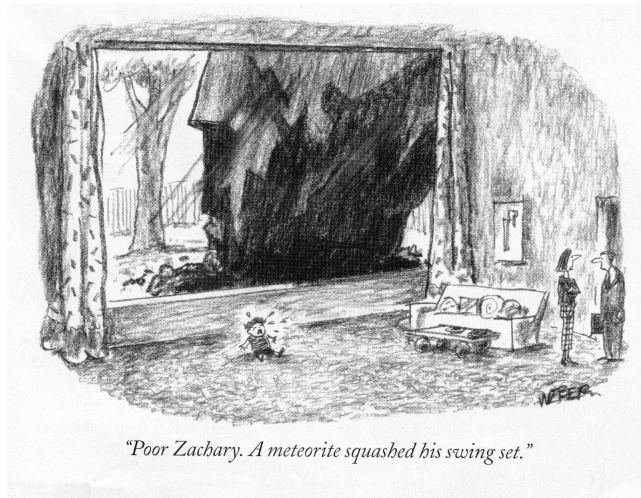
Massive Impacts = Extinctions?



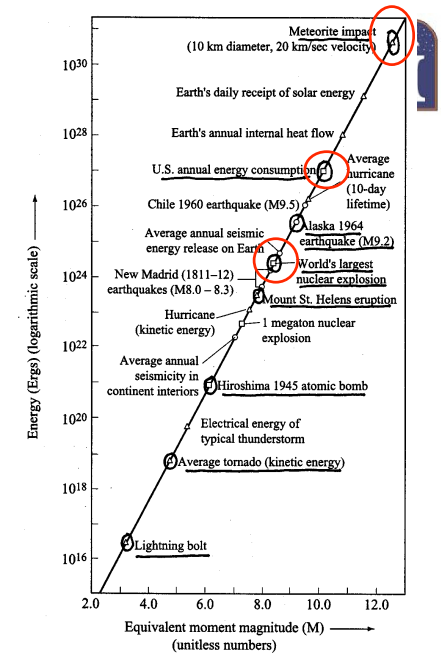
- Asteroids and comets have hit the Earth.
- A major impact is only a matter of time: not IF but WHEN.
- Major impacts are very rare: For an extinction level event, you have to wait millions of years.
- But! For an event that causes major damage to a city, you have to wait only roughly tens to hundreds of years.



Effects upon children



Comparative energies



Tunguska, Russia 30 June 1908



- Something big (20-60 meters) 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..”

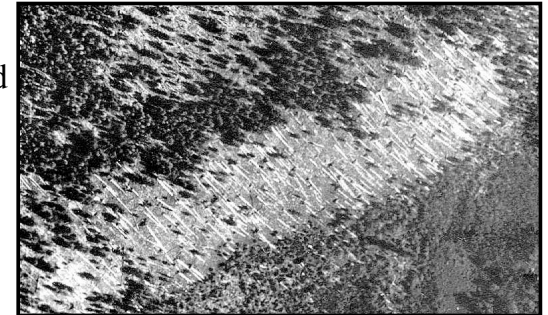
http://en.wikipedia.org/wiki/Tunguska_event

What happened?



- The object's entry was 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



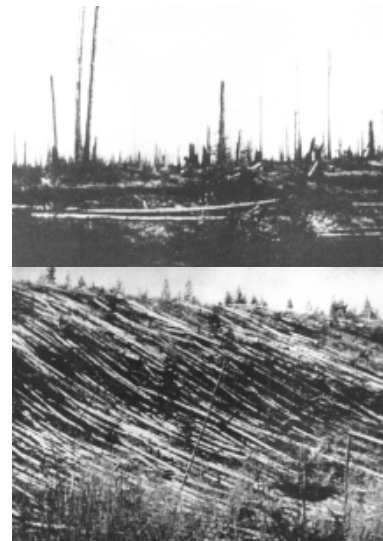
Big fires



- 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 km² 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 (ongoing investigation).



Tunguska, Siberia: June 30, 1908

A 20-60 meter object disintegrated and exploded in the atmosphere



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

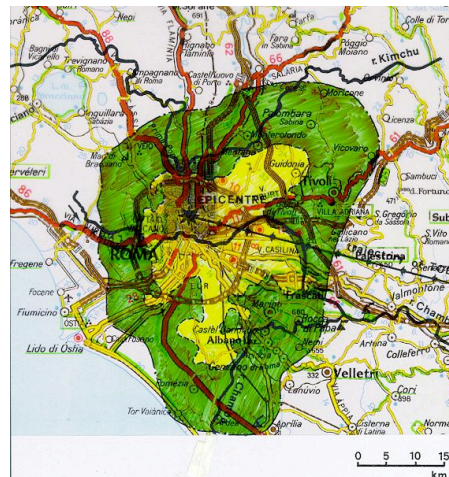


Several hundred square miles of forest were destroyed.
What if this had happened over a city?

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



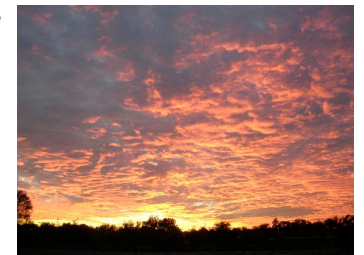
- Devastation!
- Over a city, it could kill millions.



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.

Interesting Questions



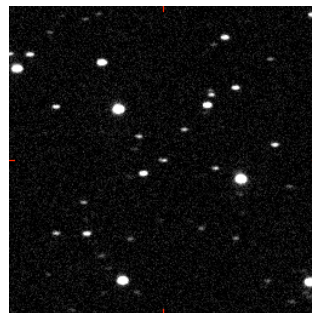
Because there is no crater at Tunguska, many “ufo-ologist” posit that a UFO exploded over Siberia. What is our explanation for the lack of a crater?

- The object was probably loosely collected pile of rock and ice (i.e. a comet).
- We can't explain the lack of crater, so UFO explosion is just as valid a theory.
- Um..UFOs don't exist.
- Although there wasn't a crater, we did find many small rocks at the site.

Killer Asteroids

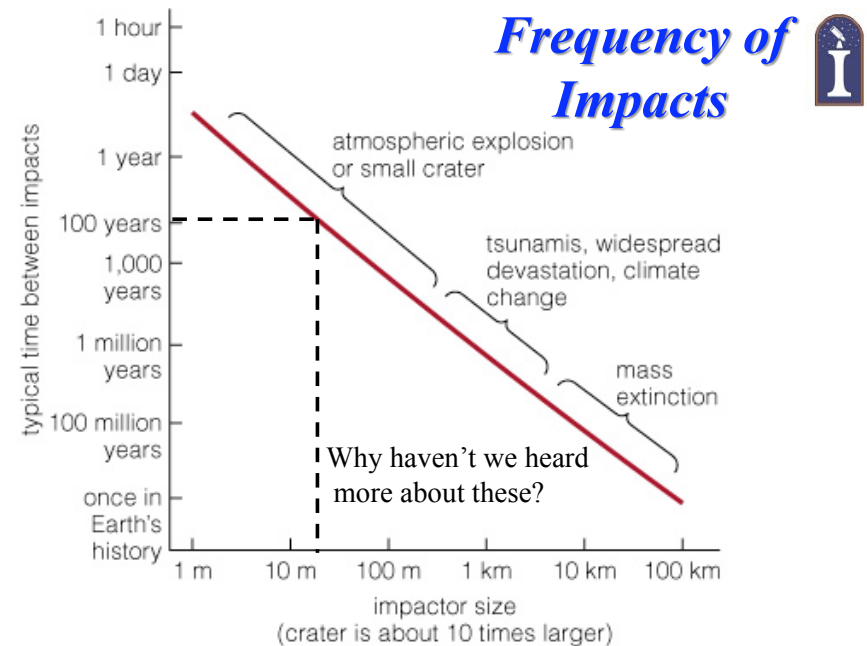


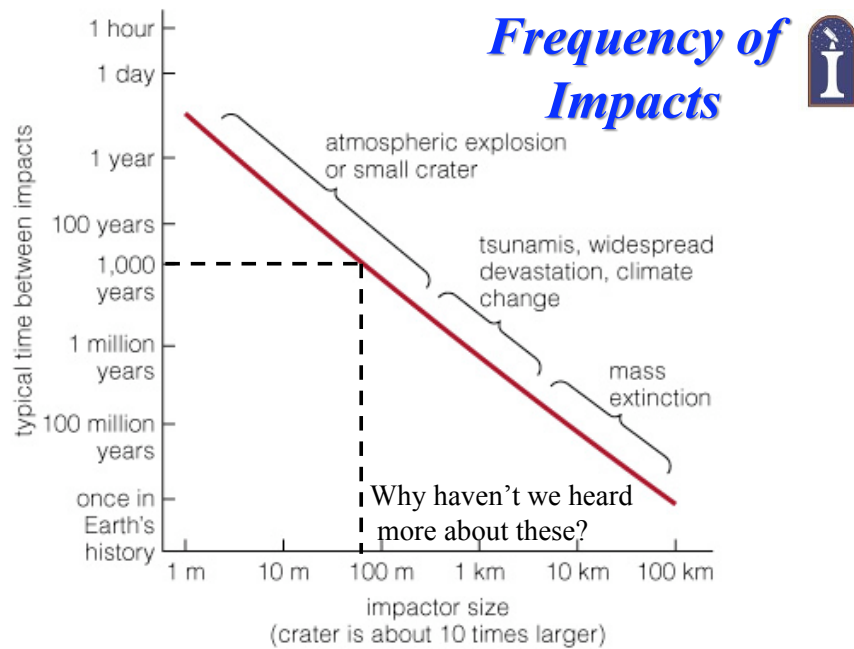
- Small asteroids are often hitting the Earth's atmosphere.
- Commonly giving off around 10 kilotons of energy.
- But how often are Killer Asteroids (~ 0.5 km in diameter) expected?



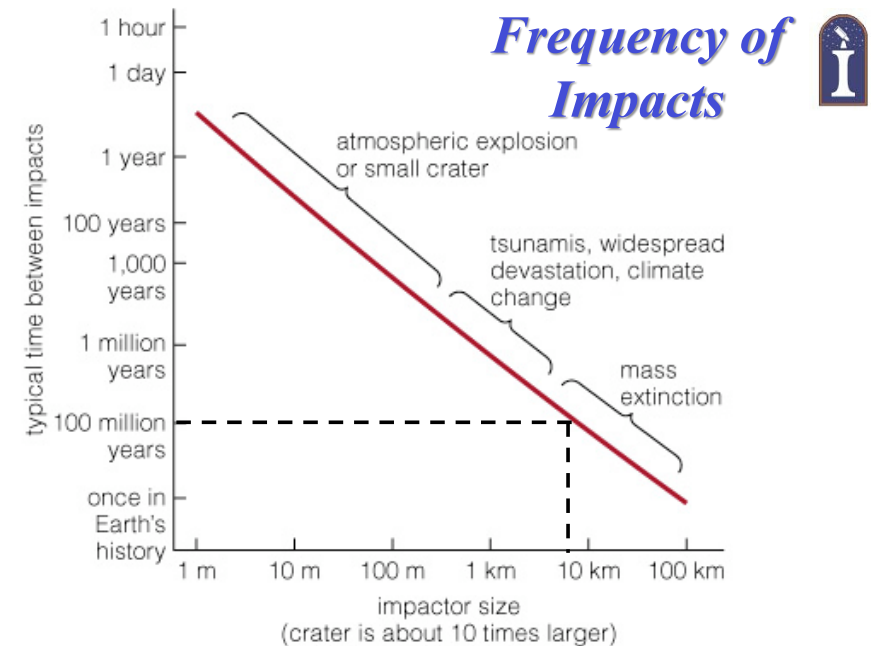
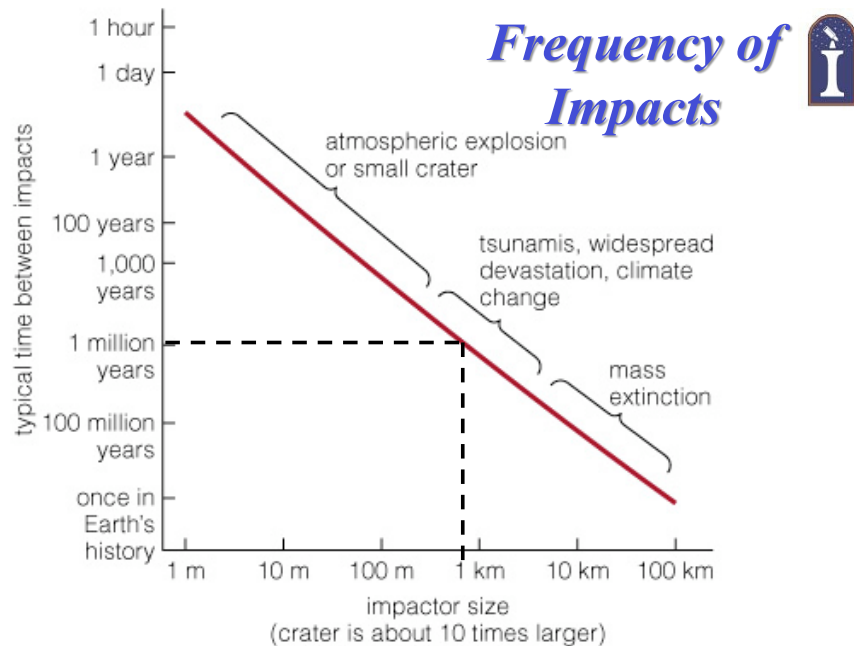
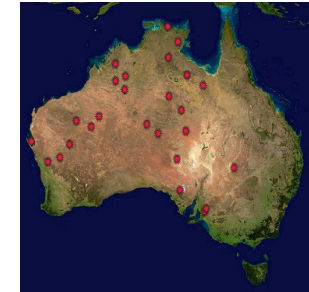
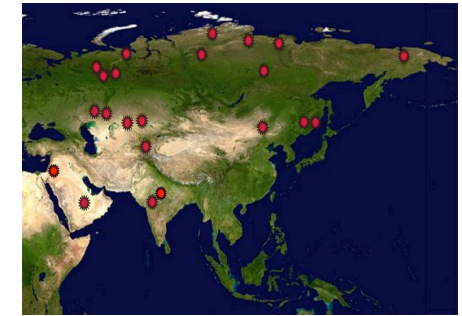
Asteroid 2004 FH. 30 meters in diameter. About 1 Megaton of TNT energy in an Earth impact! Passed within 7 Earth radii of Earth. Hiroshima was 15 kilotons.

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

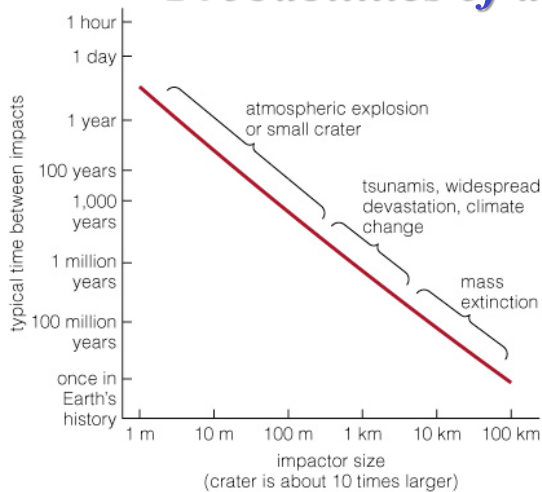




Well there are many known impact craters -- but the oceans would hide a lot more!



Probabilities of a collision



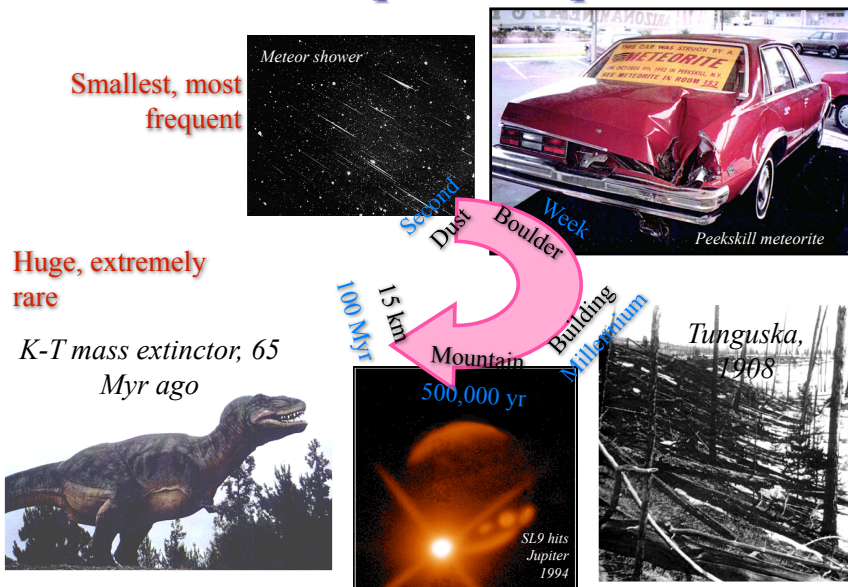
- Small impacts happen several times a year -- but our atmosphere protects us.
- Impacts large enough to cause mass extinctions are many millions of years apart.

Natural Catastrophes



- Common?
 - 5-10 m object hits Earth every ~1 years.
 - 100 m object hits Earth every ~1,000 years (Tunguska++).
 - 1km object hits Earth every ~500,000 years.
 - 5km object hits Earth every ~10 million years.
 - >10 km object hits Earth ... last one was 65 million years ago
- Not a clock, just random events

Sizes and Impact Frequencies



Interesting Questions

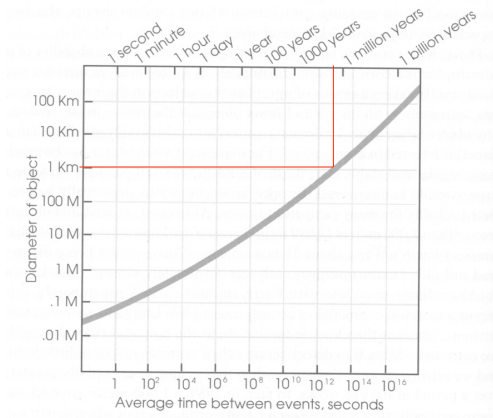


- A scientist determines that Dino-killers should hit the Earth every 65 million years. What does that mean?
- Since the last one was 65 million years ago, we can expect another killer asteroid within the next decade.
 - It is an educated guess and it means nothing.
 - The dinosaurs were just unlucky.
 - This is the average impact time, but it could be much longer or much shorter, so we worry only slightly.

Other Probabilities - Zebrowski



Some scientists suggest that, on average, collisions of 1 km-diameter objects occur every 250,000 years

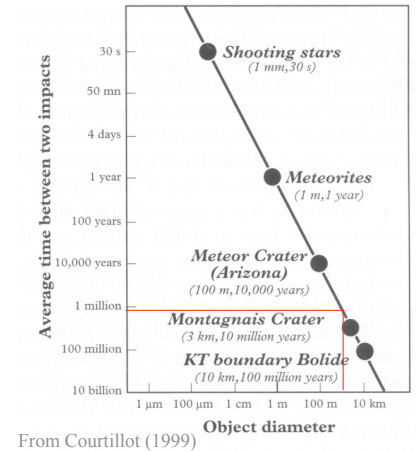


From Zebrowski (1997)

Probabilities - Courtillot



- Is the previous estimate too high?
- Other scientist suggests it is about 1 Ma between events.
- Other scientist suggest that the rate is much longer.
- Does that make you feel safer?



Zebrowski vs. Courtillot

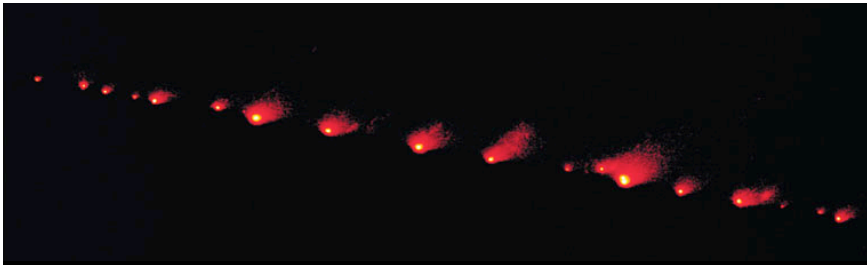


The differences we see on the two graphs give you some idea of the uncertainties involved.

Nature of the event



- Impact cratering is an important process in the history of Earth and other planets
- Have we ever seen such a large impact?

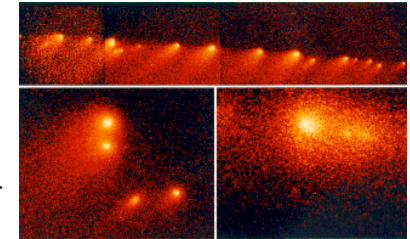


YES, we have seen a major impact....on Jupiter:
 In 1994, Comet Shoemaker-Levy 9 (5km!) -- already broken up into fragments -- collided with Jupiter.
 Each fragment impacted, reminding us that catastrophic collisions can and do happen.

The sequence of events



- The collision of the comet with Jupiter occurred over several days, 16-22 July 1994
- It was the first collision of two solar system bodies ever observed
- At least 20 fragments hit Jupiter at speeds of 60 km/second

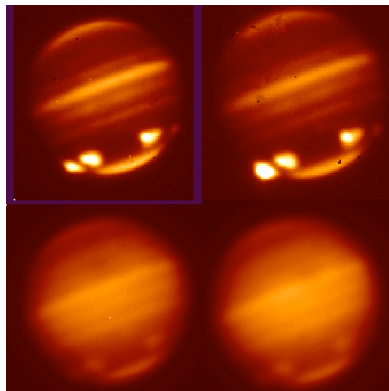


<http://www2.jpl.nasa.gov/sl9/background.html>

Sizes of fragments



- The largest fragments were about 2 km in diameter
- Huge plumes thousands of km high were generated
- Comparisons can be made with the Cretaceous-Tertiary (KT) extinction event--Dino Killer



<http://www.as.utexas.edu/mcdonald/comet/jul21.gif>

Stop Giggling?

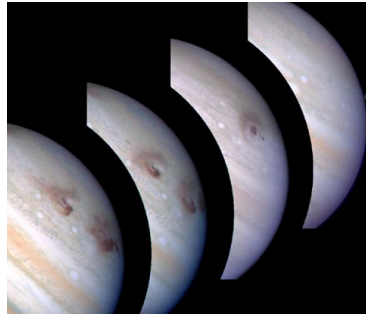


<http://www.youtube.com/watch?v=l6Alt36-whc>

Energies



- Fragment A struck with energy equivalent to 225,000 megatons of TNT, the plume rising to 1000 km
- Fragment G was the biggie, with 6,000,000 megatons TNT energy and a plume rising to 3,000 km
- Fragment G (and K, L) created dark impact sites whose diameters were at least that of Earth's radius

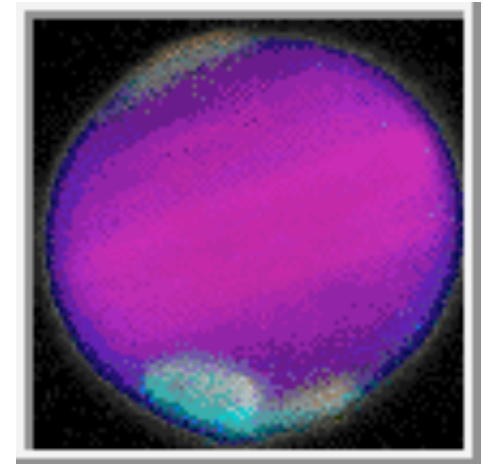


http://www.sai.msu.su/apod/image/9808/sl9gevol_hst.jpg

Fragment G



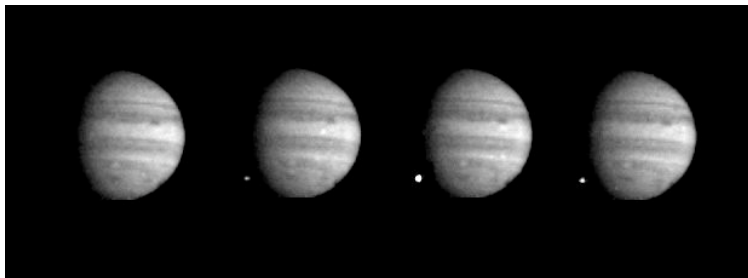
- This image shows a ring of hot gas about 33,000 km in diameter and expanding at 4 km/second from the impact of fragment G



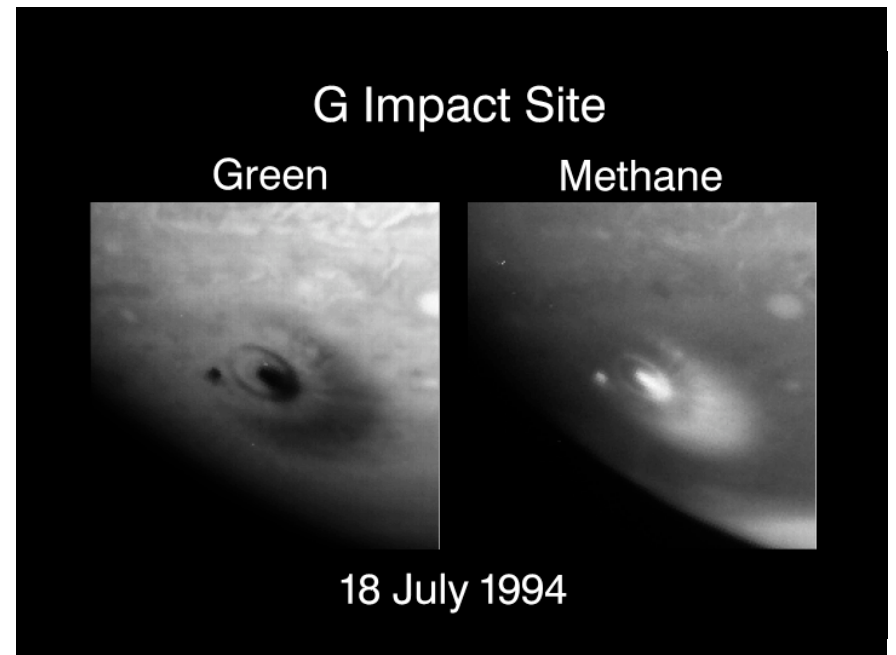
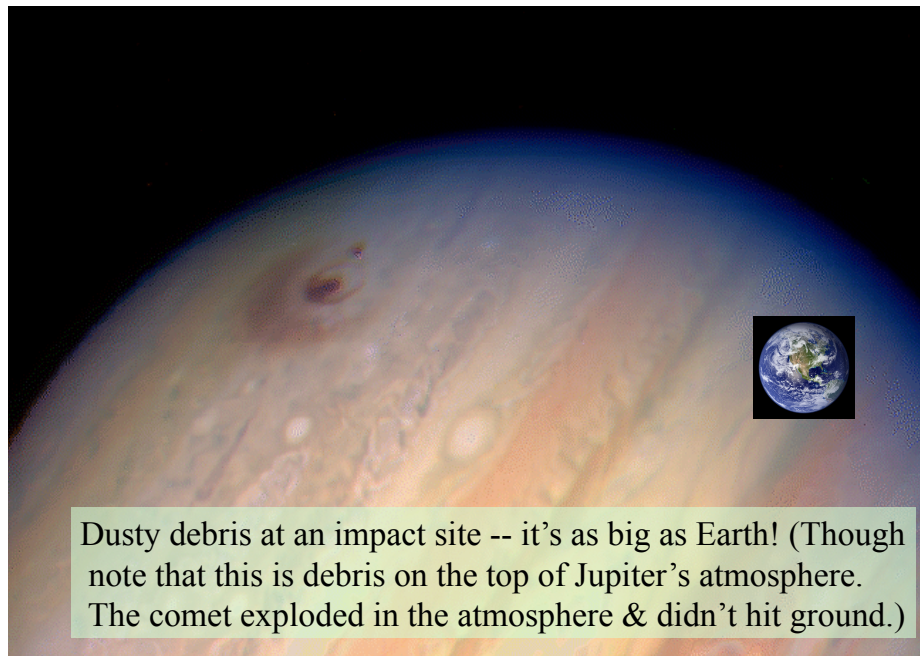
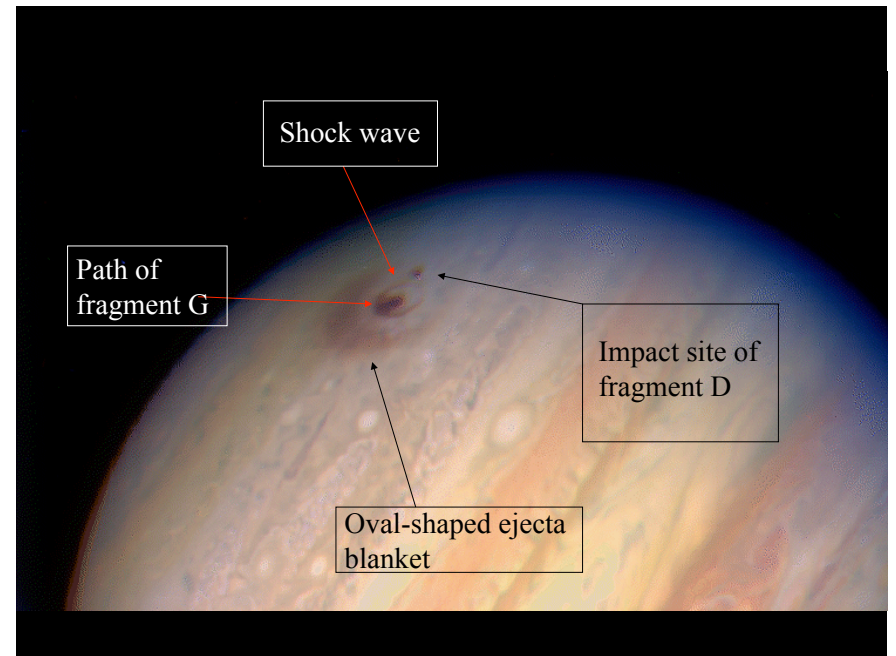
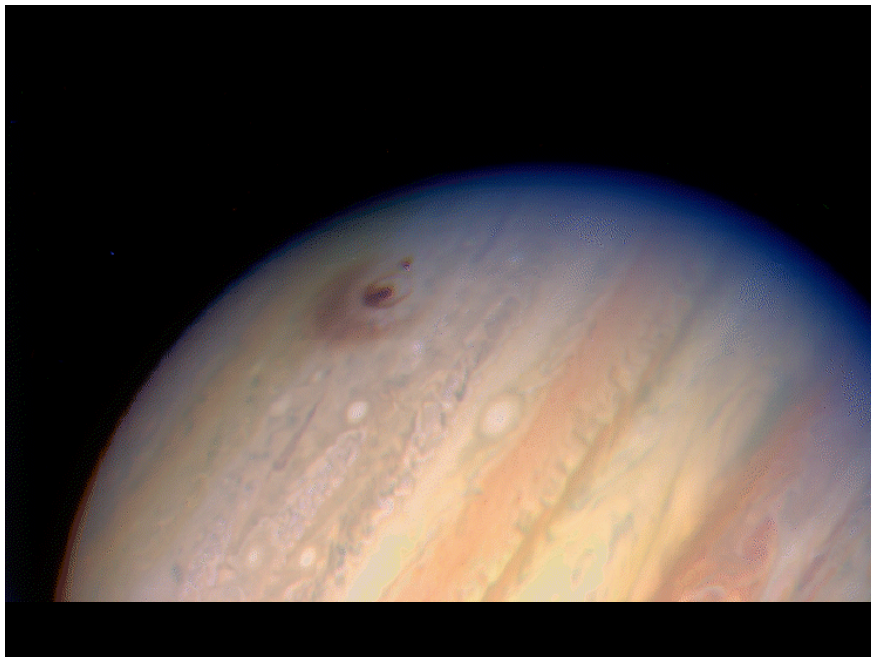
Fragment G impacting: observe four things



- 1) Thin dark ring: atmospheric shock wave from fragment explosion below cloud tops
- 2) Dark streak within ring: path of fragment
- 3) Broad oval feature: ejecta blanket
- 4) Small black dot: impact site of fragment D a day earlier



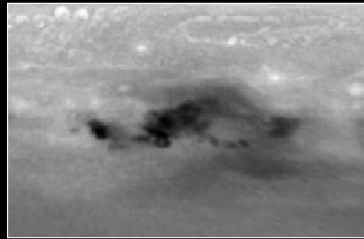
Images of Jupiter catch the fireball of fragment G. Amazing!



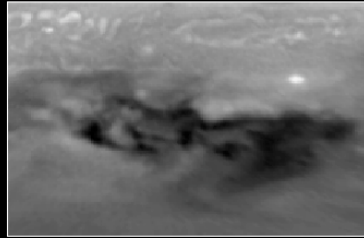
Evolution of D/G Comet Impact Sites on Jupiter



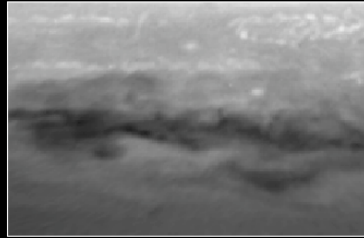
July 18, 1994



July 23, 1994

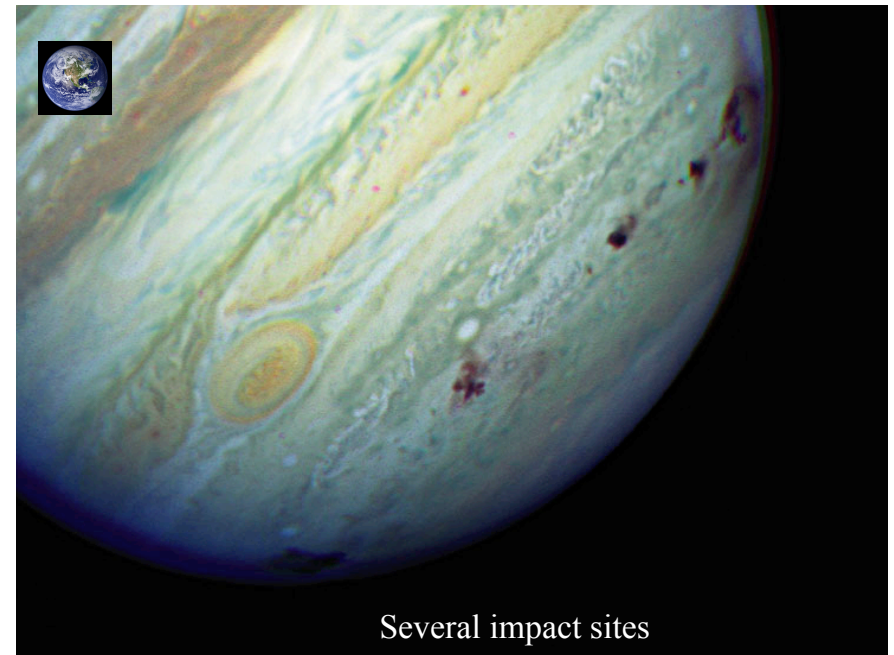


July 30, 1994



August 24, 1994

Hubble Space Telescope • Wide Field Planetary Camera 2

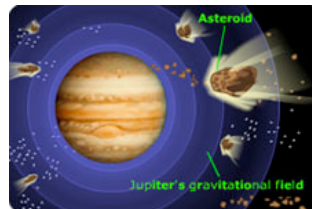


Several impact sites

Jupiter: The Vacuum Cleaner



- Strong gravitational influence, so many small comets and asteroid impacts.
- Estimate that rate of impacts is 2000 to 8000 higher than the rate on Earth!
- Without Jupiter, the probability of asteroid impacts with the Solar System's inner planets would be greater.



http://www.bnsc.gov.uk/assets/channels/education/se/jupiter_3.jpg

Interesting Questions



What is the important lesson learned from Shoemaker-Levy 9?

- A comet is more likely to hit the Earth than an asteroid.
- That large impacts can happen today.
- We are protected from all asteroids by the atmosphere.
- That Jupiter will “suck-up” all of the dangerous asteroids.

Even More Recently: July 19, 2009



- Anthony Wesley, a 44-year-old computer programmer from Australia, made the discovery using his 14.5 inch telescope.
- Probably a comet impact, but we don't know.



<http://jupiter.samba.org/>

Consequences of a large impact event



For an object of
about 1 km or
larger



<http://www.spacelightnow.com/news/n0602/22plutoimpact/>

Consequences



- A base surge is generated by the impact
- For a terrestrial impact, rock will be pulverized and/or vaporized, sending up huge amounts of dust into the stratosphere

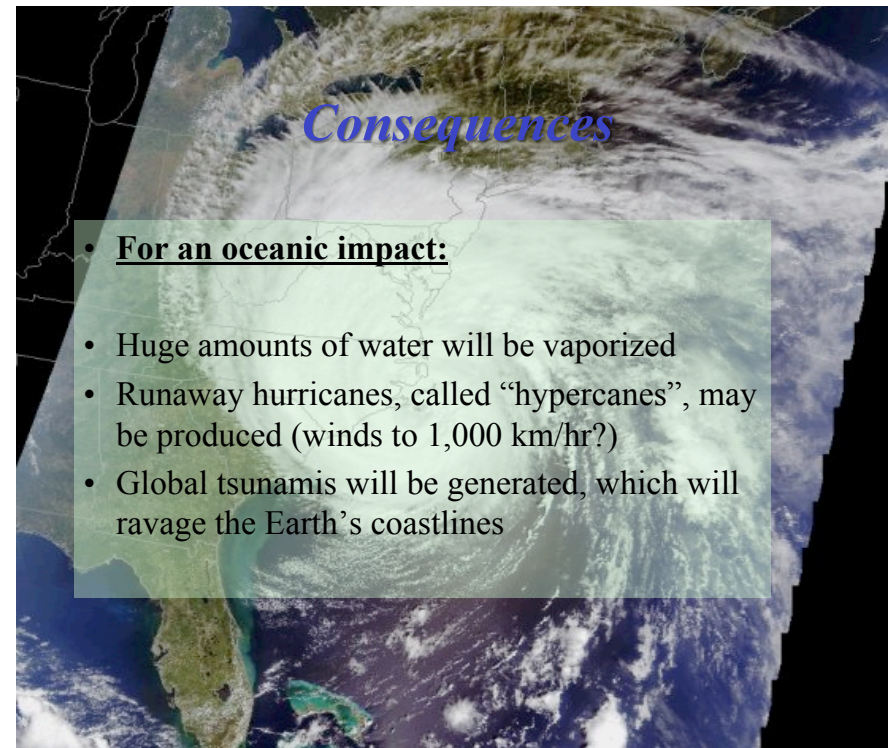


http://www.geology.sdsu.edu/how_volcanoes_work/Thumblinks/surgecap_page.html

Consequences

• For an oceanic impact:

- Huge amounts of water will be vaporized
- Runaway hurricanes, called “hypercanes”, may be produced (winds to 1,000 km/hr?)
- Global tsunamis will be generated, which will ravage the Earth's coastlines



Consequences



- In the short term, global wildfires will be generated by the impact event
- These fires will burn uncontrollably across the globe, sending more soot, dust, and gas into the stratosphere

Consequences



- All this suspended dust and soot will cause global winter and global darkness
- Acid rains will fall
- Crops will fail catastrophically
- The end result will be **MASS EXTINCTIONS**

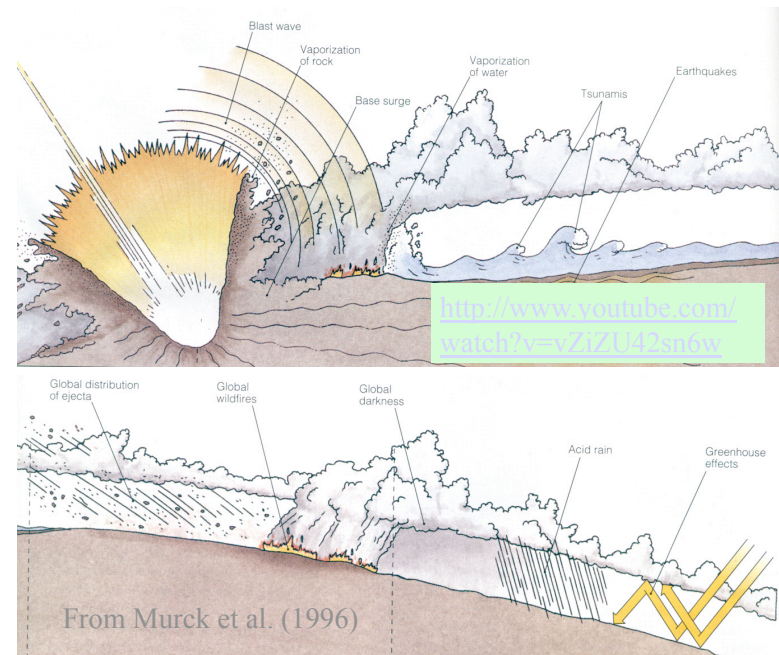
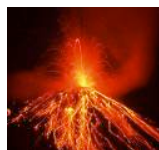


<http://www.reason.com/blog/archive/2008-07-13.html>

Consequences



- The impact likely will trigger devastating quakes around the globe, especially where tectonic stresses are high (i.e., plate margins)
- Volcanism (flood basalts) may occur on the opposite side of the globe from the impact, as a result of shock waves travelling through the center of the Earth



Interesting Questions



Which of the following is not a consequence of a large impact?

- a) For a terrestrial impact, rock will be vaporized and thrown into the stratosphere.
- b) For oceanic impacts, global tsunamis.
- c) The Moon's orbit will be dragged Earthward.
- d) Global winter and global darkness
- e) Devastating Earthquakes .

Near Earth Object Program

<http://neo.jpl.nasa.gov/>



Kitt Peak Natl. Observatory

LINEAR, New Mexico

LONEOS

LSST

- Survey: 1998 to 2009, find >90% of NEOs >1 km diameter (Near Earth Objects)
- Congress ordered NASA to find 90% of NEOs >140 m by 2020
- http://www.youtube.com/watch?v=9_EZfxvTmNA