Astronomy 150:

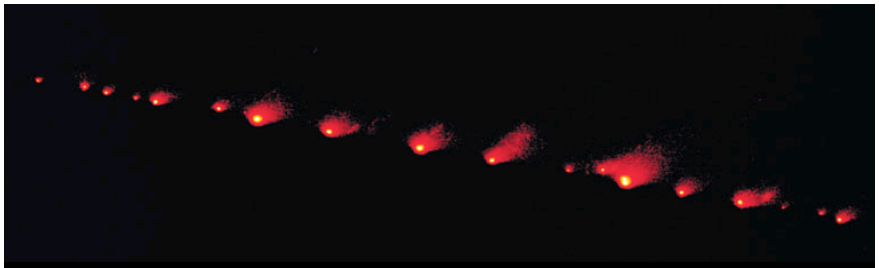
Killer Skies

This Class (Lecture 9):
Jupiter in Peril

Next Class:
Impact Mitigation

HW3 due on Sunday

Music: ***Until the End of the World*– U2**



YES, we have seen a major impact….on Jupiter:

In 1994, Comet Shoemaker-Levy 9 (5km!) -- already broken up into fragments -- collided with Jupiter.

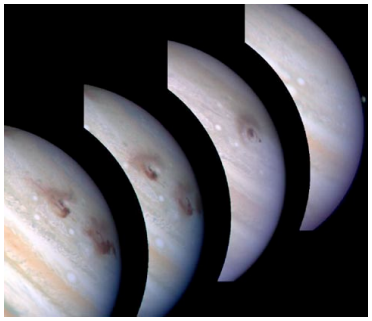
Each fragment impacted, reminding us that catastrophic collisions can and do happen.

Outline

- Big rocks do fall from the Sky– the case of Shoemaker Levy 9!
- We are looking for dangerous rocks
- Apophis was/is dangerous
- Most dangerous to date is NEA: 1950 DA

Energies

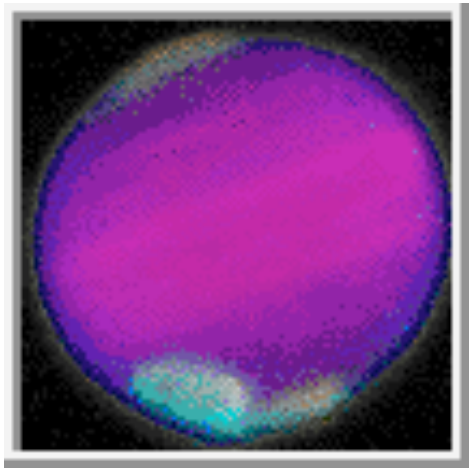
- Fragment A struck with energy equivalent to 225,000 megatons of TNT, the plume rising to 1000 km
- Fragment G was the biggie, with 6,000,000 megatons TNT energy and a plume rising to 3,000 km
- Fragment G (and K, L) created dark impact sites whose diameters were at least that of Earth's radius

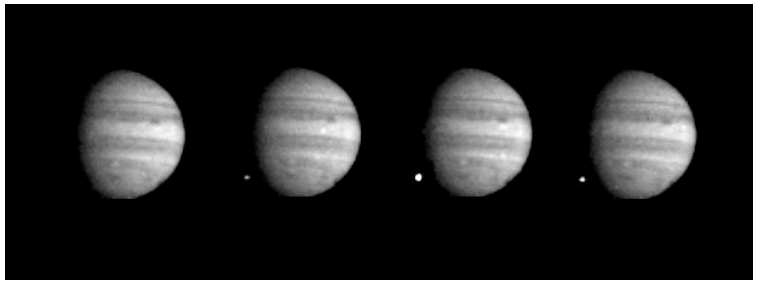


http://www.sai.msu.su/apod/image/9808/sl9gevol_hst.jpg

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





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

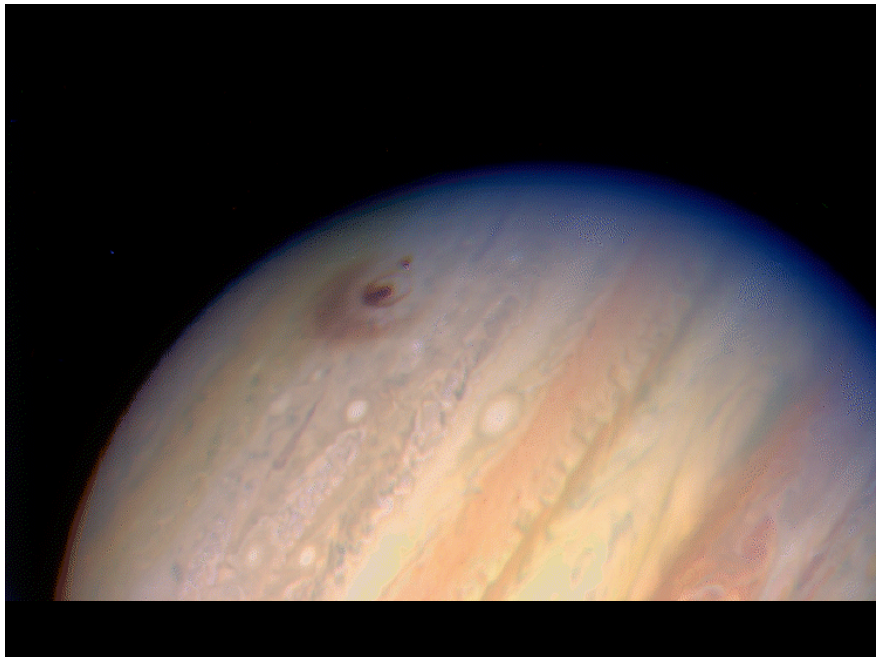
Fragment G impacting; observe four things:

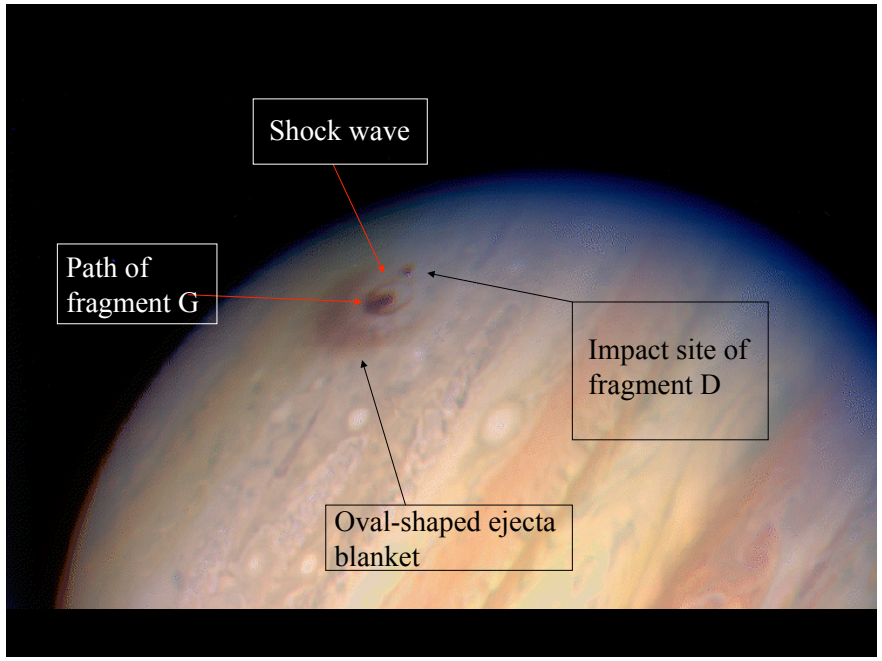
1) Thin dark ring: atmospheric shock wave from fragment explosion below cloud tops

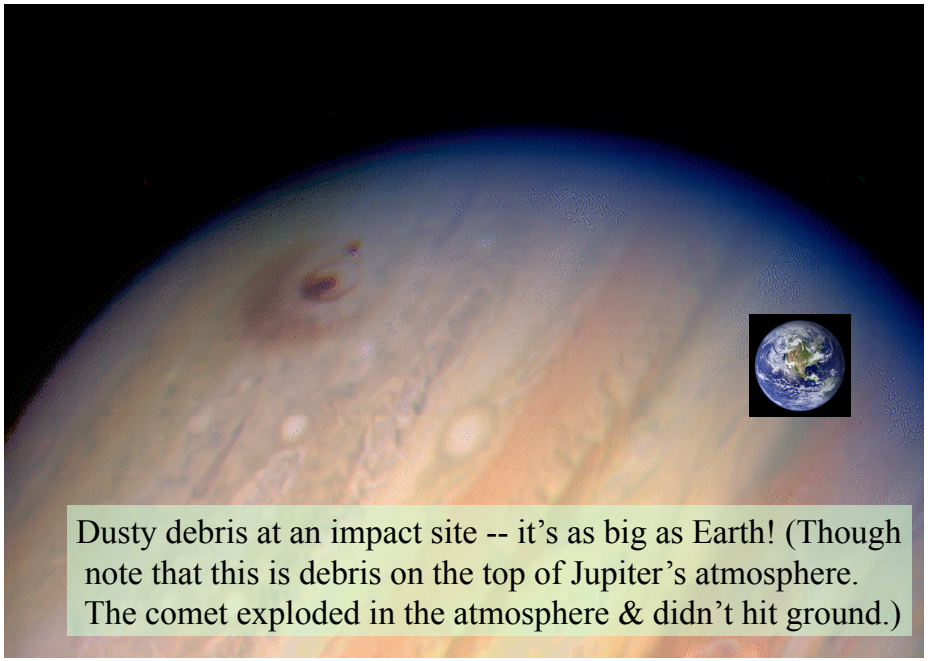
2) Dark streak within ring: path of fragment

3) Broad oval feature: ejecta blanket

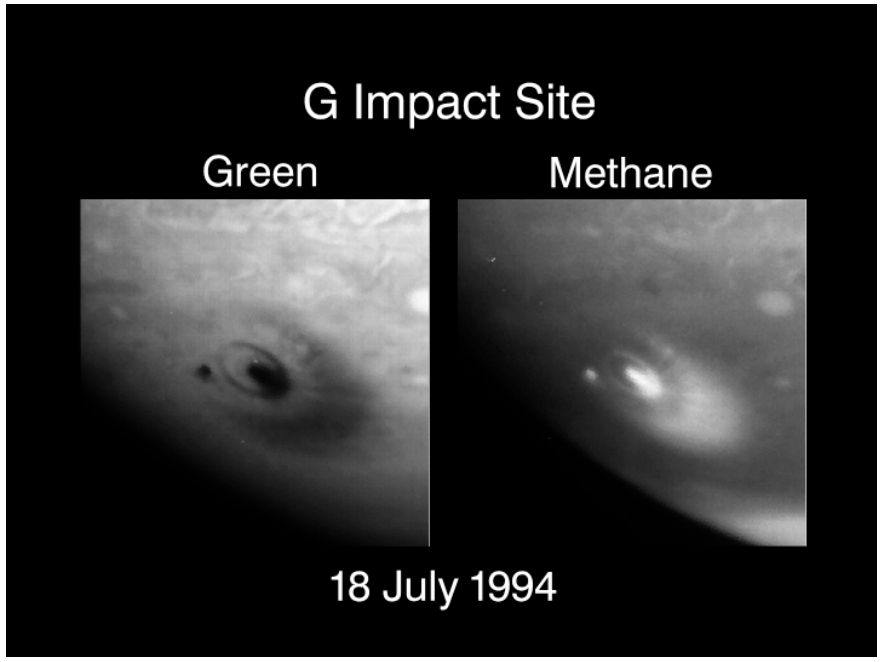
4) Small black dot: impact site of fragment D a day earlier

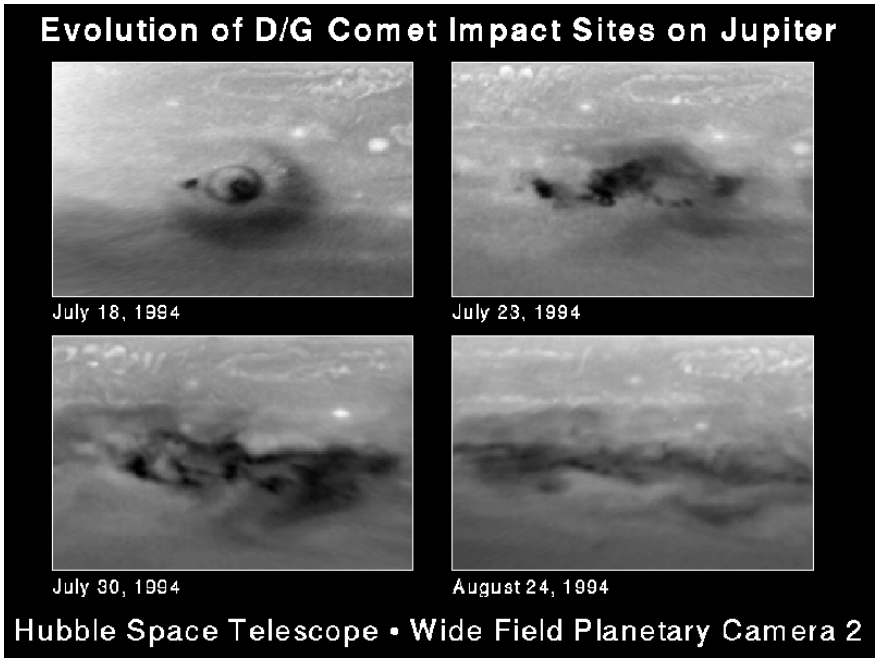


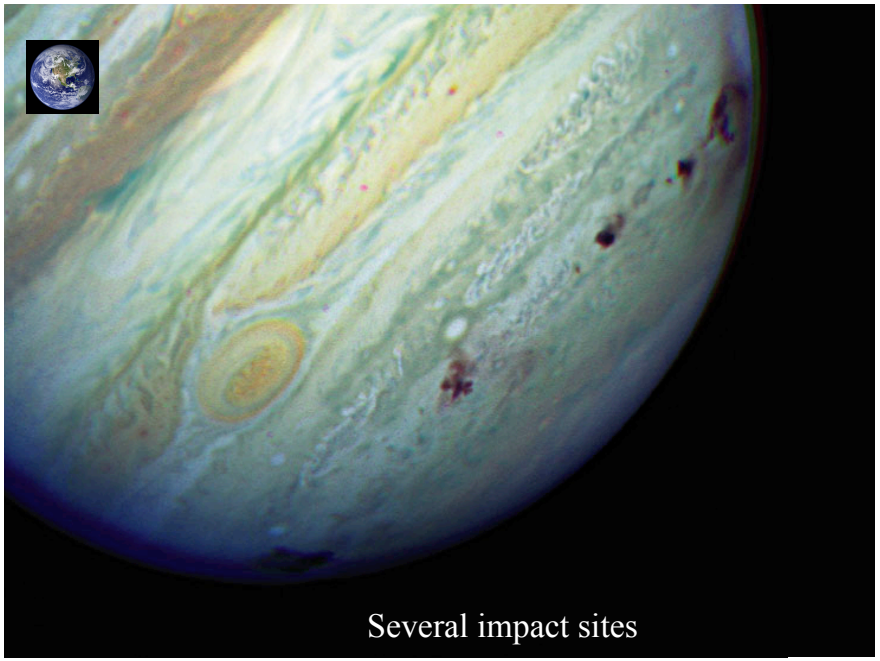




Dusty debris at an impact site -- it's as big as Earth! (Though note that this is debris on the top of Jupiter's atmosphere. The comet exploded in the atmosphere & didn't hit ground.)



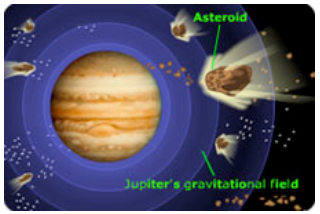




Several impact sites

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

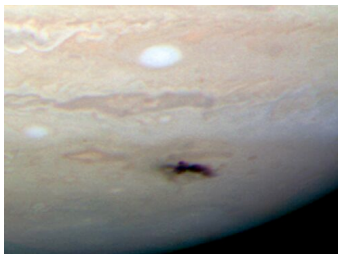
Interesting Questions

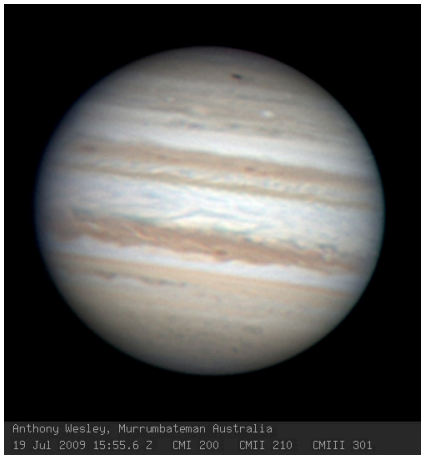
What is the important lesson learned from Shoemaker-Levy 9?

a) A comet is more likely to hit the Earth than an asteroid.
b) That large impacts can happen today.
c) We are protected from all asteroids by the atmosphere.
d) 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/

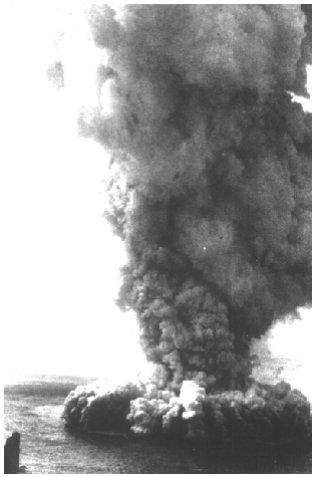
Consequences of a large impact event

For an object of about 1 km or larger

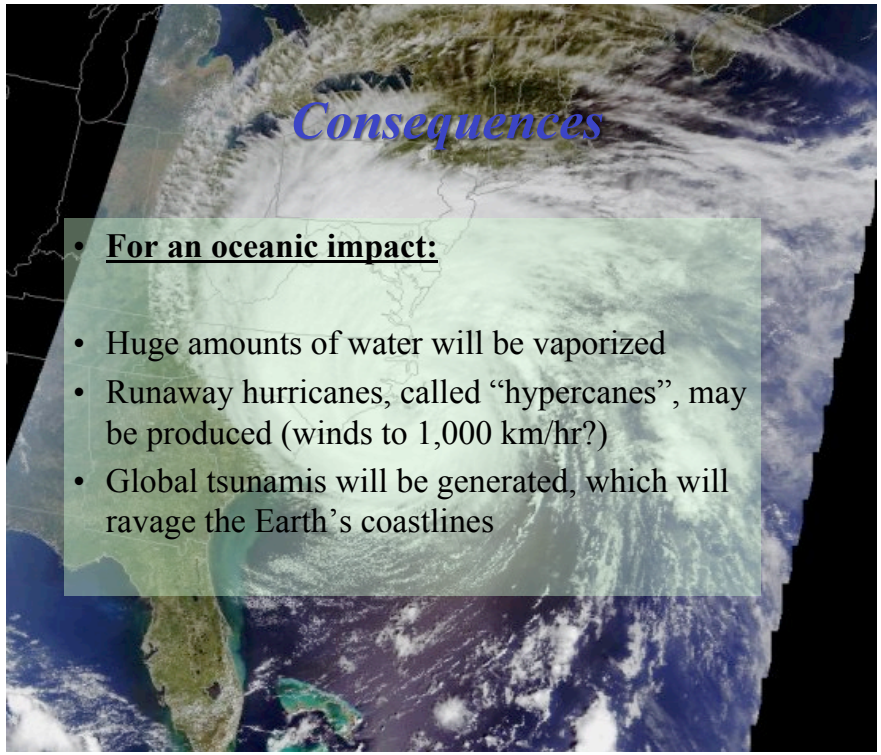
http://www.spaceflightnow.com/news/n0602/22plutoimpact/

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

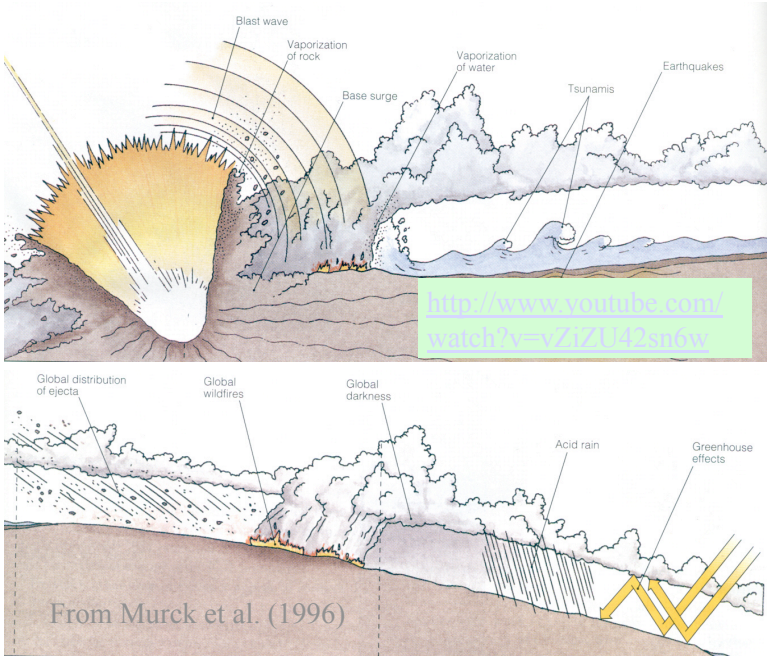
Consequences

- 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



http://www.youtube.com/watch?v=vZiZU42sn6w

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

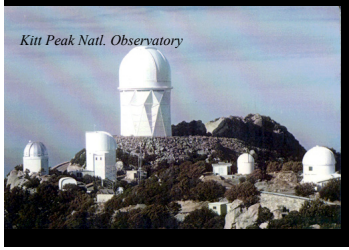
Interesting Questions

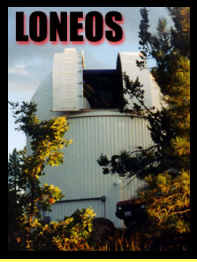
Which of the following is not a consequence of a large impact?

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 .

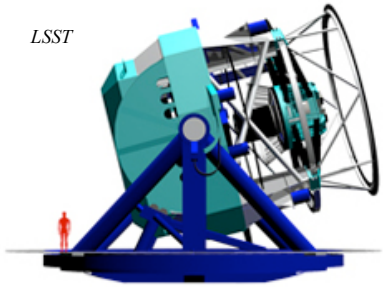
Near Earth Object Program

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

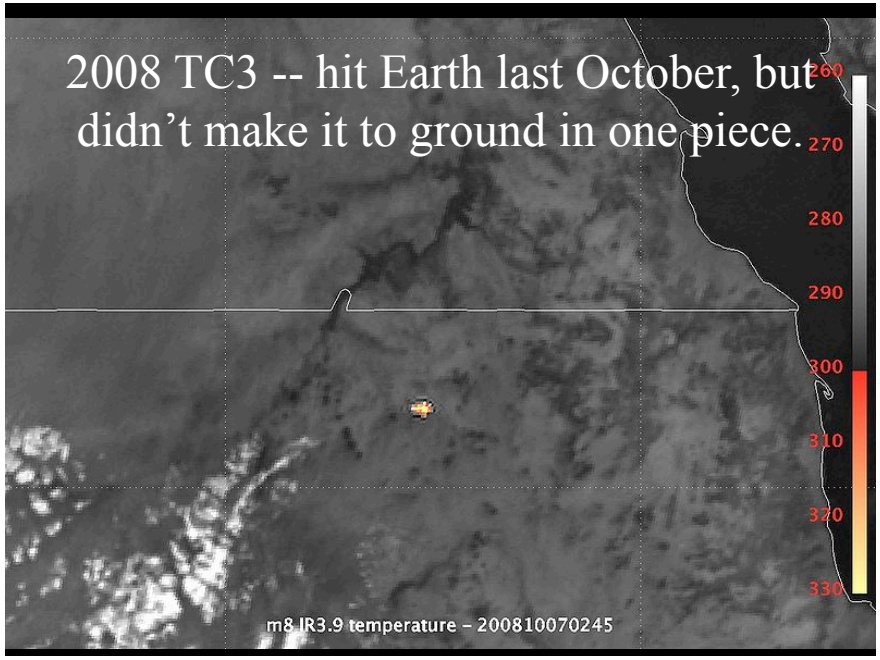




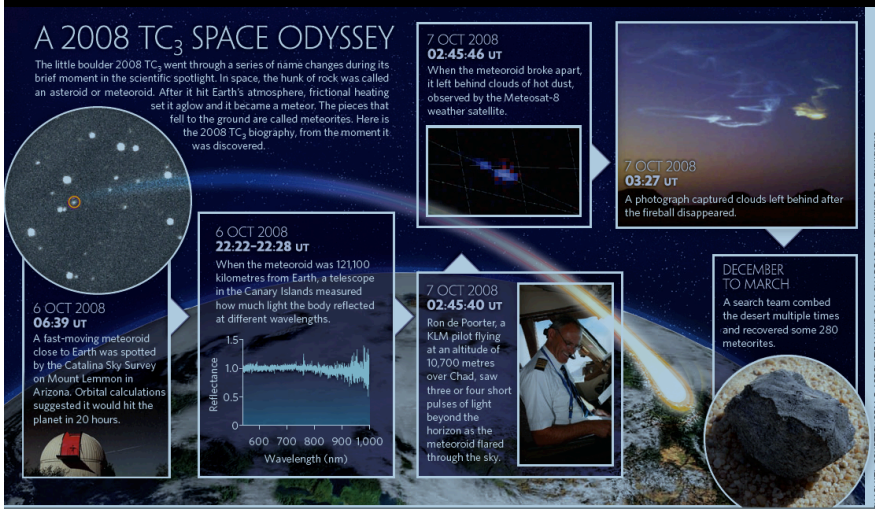
LSST



- 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_FZfxvTmNA



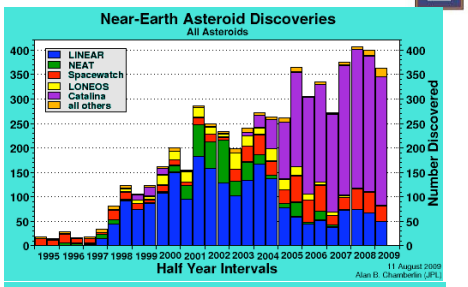
Significance: First asteroid detected before it was going to hit Earth. First meteorite recovered from such an asteroid.

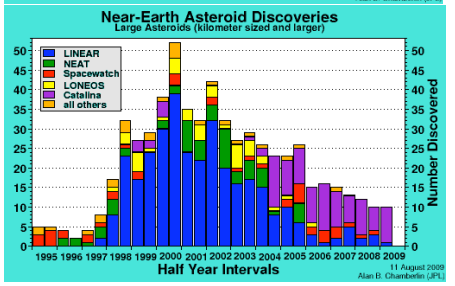


Killer Asteroids

- As of August 2009, 6,246 NEAs (>50 meters, so asteroids) are known.
- 1060 of these are > 1km
- 145 of these are classified as Potentially Hazardous Asteroids (PHAs)

http://neo.jpl.nasa.gov/faq/





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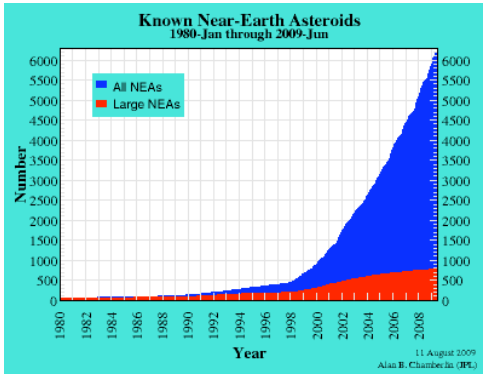
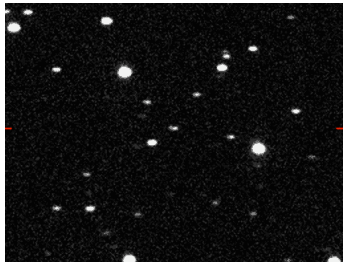


http://neo.jpl.nasa.gov/faq/

The Asteroid with Our Name on It: The Deadly Impactor

- We haven't seen it yet.
- But we want to find all the "potentially hazardous" asteroids, to be sure nothing's coming soon…. (Though statistics are on our side.)

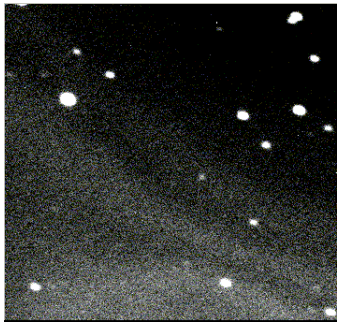


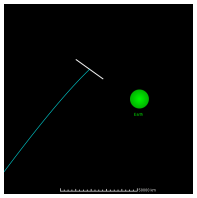
Asteroid 2004 FH. 30 meters in diameter. About 1 Megaton of TNT energy in an Earth impact! Passed within 7 Earth radii of Earth. Hiroshima was 15 kilotons.

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

The Asteroid with Our Name on It: The Deadly Impactor

- The most famous "close call" is asteroid Apophis (which might have hit us in 2036).
  - 250 meters in diameter, approx.
  - There was a scare for a while because the chance of a hit was 1 in 300.
  - Currently the chance is only 1 in 45,000.
  - Highest Ranked on the Torino Scale





Scale It! Torino Scale

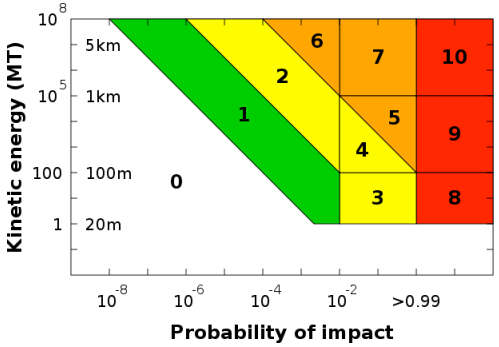
Apophis was ranked a 4!

As a better description of its orbit was found, it dropped to a 1.

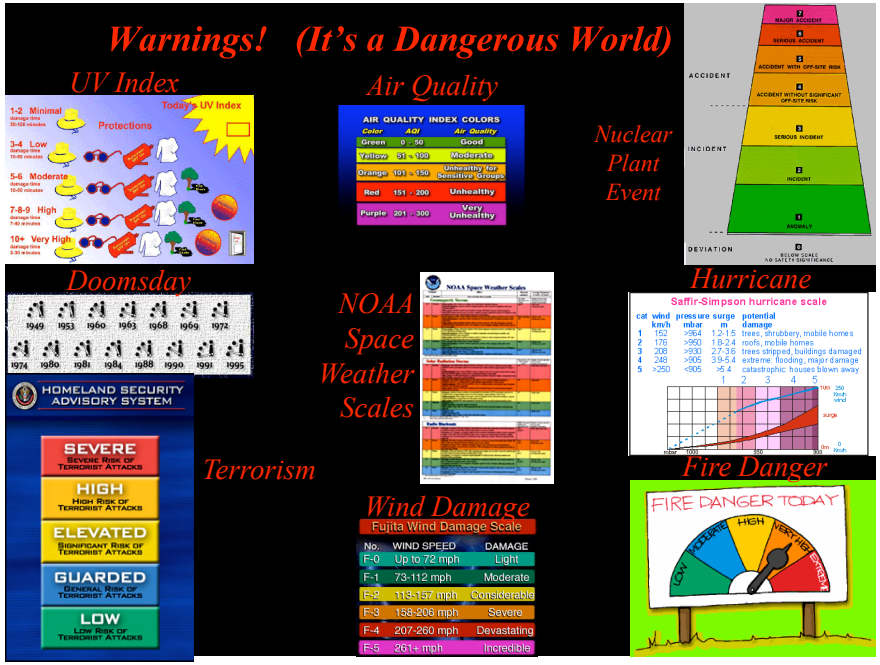
0	The likelihood of a collision is zero, or well below the chance that a random object of the same size will strike the earth within the next few decades. This designation also applies to any small object that, in the event of a collision, is unlikely to reach the Earth's surface intact.
1	The chance of collision is extremely unlikely, about the same as a random object of the same size striking the earth within the next few decades.
2	A somewhat close, but not unusual encounter. Collision is very unlikely.
3	A close encounter, with 1% or greater chance of a collision capable of causing localized destruction.
4	A close encounter, with 1% or greater chance of a collision capable of causing regional devastation.
5	A close encounter, with a significant threat of a collision capable of causing regional devastation.
6	A close encounter, with a significant threat of a collision capable of causing a global catastrophe.
7	A close encounter, with an extremely significant threat of a collision capable of causing a global catastrophe.
8	A collision capable of causing localized destruction. Such events occur somewhere on Earth between once per 50 years and once per 1000 years.
9	A collision capable of causing regional devastation. Such events occur between once per 1000 years and once per 100,000 years.
10	A collision capable of causing global climatic catastrophe. Such events occur once per 100,000 years, or less often.

Scale It!
Torino Scale

4 other objects have been rated a 1, three are still listed as 1's.



http://neo.jpl.nasa.gov/images/torino_scale.jpg



"Apophis" Story

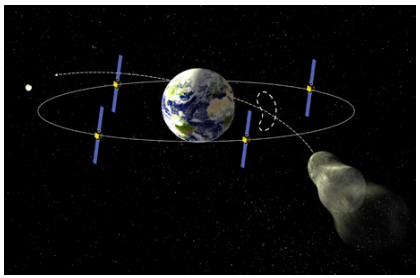
- On Dec. 23rd, JPL and Univ. of Pisa announce that this NEA has 1-in-200 chance of hitting Earth on 13 April 2029 with force of thousands of megatons: first ever TS = 2!
- As of 27 Dec., new observations over holidays *raise* impact chances to 1-in-37: TS = 4!!!
- Uncertainty in object's size could mean TS = 5, or 7.
- Earlier images found (unlikely!) and analyzed on 28 Dec.: it will miss by 5 Earth <u>diameters</u>.

"Apophis" Story

- Month later, Arecibo radar shows that positions are wrong: Apophis will miss by just 5 Earth <u>radii</u>, *under* geosynch. communications satellites.
- If Apophis passes through a small "keyhole" (1-in-several-thousand chance), it would return to impact 13 April 2036. (This chance now reduced to 1-in-45,000.)
- Media frenzy averted by holidays, Indian Ocean tsunami. But many "what if's" and other issues…

"Keyholes"

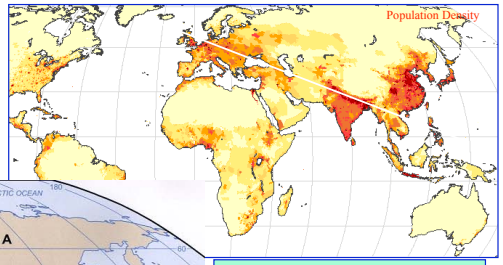
- Calculation of orbits for the future is difficult, small variations or interactions can change future wildly.
- A "keyhole" is an orbit interaction region such that the asteroid will collide with Earth on its next orbital pass.
- For Apophis the keyhole on the next pass is only 600 meters in diameter.



- Error bars on orbit right now are around 3000 km, so we have to wait and see.

To Tell or Not to Tell…

- In the 1-chance-in-37 that it would hit, extreme destruction would occur within the zone between the dashed lines, somewhere along the solid red line.
- You can hardly imagine a line crossing more densely populated areas.



There was hot debate about whether to release the possible impact points after they were calculated on Dec. 24th. NASA officials, scientists argued we should wait for perhaps a year. ***But withholding information from the public violates risk-communication principles!***

Interesting Questions

Should possible impacts like Apophis be announced as soon as they are found, or should we wait until it is confirmed?

a) Wait until better than 90% sure.
b) Give us info immediately, then update.

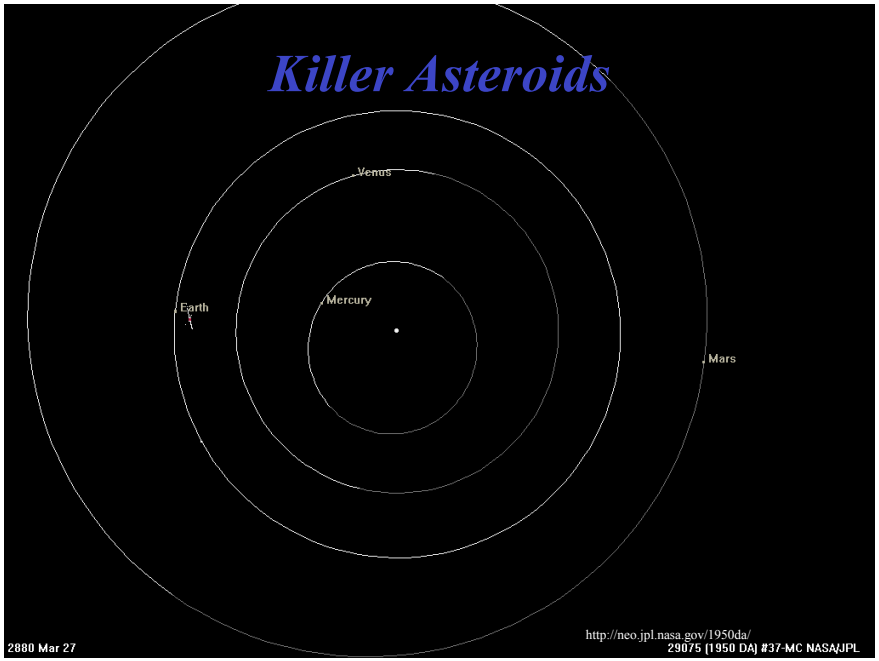
What Today's Dangerous Rock?

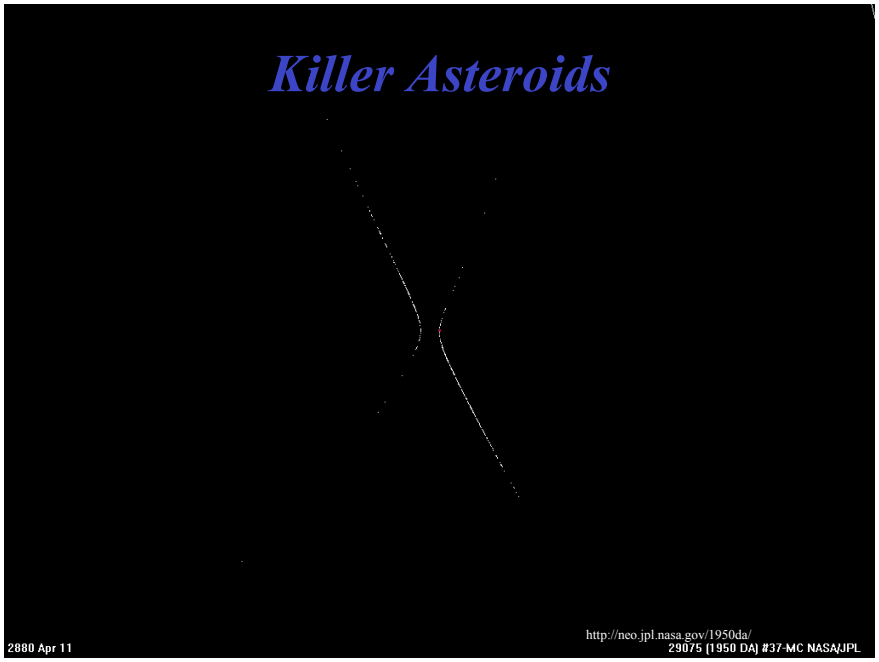
- http://neo.jpl.nasa.gov/risk/index.html

Killer Asteroids

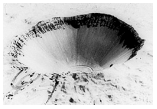
- The most dangerous known is 1950 DA (~1km), will get close in March 2880 (0.33% chance of collision).
- We can not accurately predict orbits more than 20 years in advance, but 1950 DA would have 100,000 Megatons of energy.

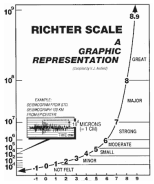
http://neo.jpl.nasa.gov/1950da/



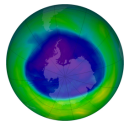


Environmental Consequences of Civilization-Threatening Impact

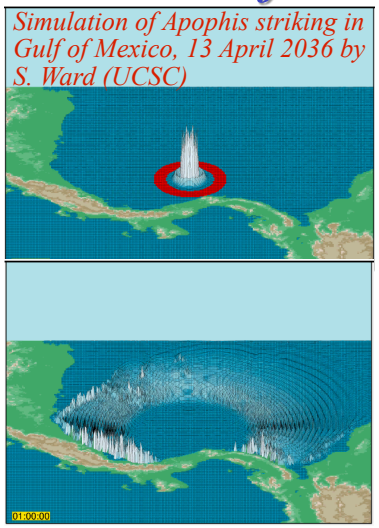




- Total destruction in near-crater zone
  - Destruction zone 30 times the size of the asteroid
- Tsunami ("tidal waves")
  - Inundation of shores of impacted ocean
- Stratospheric dust obscures sun
  - Sudden global climate change threatens agriculture
- Widespread fires
  - Re-entering ejected material broils Earth's surface
- Poisoning of the biosphere
  - Sulfates, nitric acid, ozone layer destroyed
- Earthquakes
  - Modest effects compared with everything else



Consequences of Ocean Impact of 300-meter NEA



- Crater (and central "peak") in water collapses, generating a high but short-wavelength tsunami
- Run-up on proximal coasts depends on dissipation, off-shore topography, etc.
- Within minutes to hours, major destruction is possible within kilometers of coastline
- Consequences approximately like those of Dec. 2004 Indian Ocean tsunami

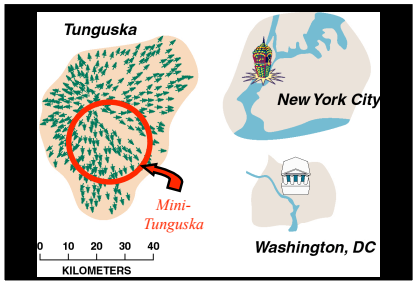
Consequences of Land Impact by 200 meter to 2 km NEA

- ***Consequences are well understood from nuclear bomb tests and studies of terrestrial and lunar impact craters.***
- Crater rim ~15 times diameter of NEA; total destruction zone twice as big (4 – 40 km from ground-zero)
- Explosion fireball: 3rd deg. burns 10 – 100 km from ground-zero; firestorm 30 – 300 km from ground-zero
- Air-blast, overpressure destroys all structures 10 – 100 km away; poorly-built structures destroyed (within minutes) by winds, earthquake, falling debris up to 70 – 700 km from ground-zero
- Ozone layer destroyed globally by NEAs >500 m diameter
- Atmospheric pollution (sulfate aerosols, nitric acid rains, injection of dust and water into atmosphere); "year without summer" for NEAs ~1 km diameter, global agricultural disaster ("impact winter") possible for NEAs >2 km diameter (land or ocean impact).
- Electromagnetic Pulse? Could bring down power-grid and communications just when they are most desperately needed.

Help!

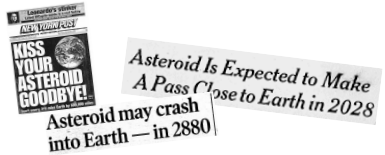
"Mini-Tunguska": Once-in-a-Century Atmospheric Explosion

- Nature of Devastation. *30-40 m "office building" rock hits at 100 times speed of jetliner, explodes ~15 km up with energy of 100 Hiroshima A-bombs. Weak structures damaged/destroyed by hurricane-force winds out to 15 km. If over land, dozens or hundreds may die, especially in poor, densely populated areas (minimal damage in desolate places).*
- Probability of Happening. *but most likely over an ocean or sparsely-populated area.*
- Warning Time. *Very unlikely to beforehand; no warning at all.*
- Mitigation Issues. *Little can be done in advance (an adequate search system would be very costly). Rescue and recovery would resemble responses to a "normal" civil disaster. No on-the-ground advance preparation makes sense, except public education about this possibility.*



Secondary Consequences from Small, Likely Events

OVER KASHMIR? OVER ISRAEL? HOW WOULD THE GENERALS RESPOND?



- Public and government over-reaction to 9/11 (e.g. stock market volatility, homeland security hysteria) could be replicated by a modest, unexpected impact disaster.
- An otherwise harmless but brilliant bolide (fireball) could be mistaken for an atomic attack, causing a dangerous response.
- Even sensational journalism or a mistaken prediction about a possible future impact could be disruptive.