

Extraterrestrial Life: Lecture #26

Expected number of civilizations in the Galaxy is proportional to their mean lifetime

What hazards are there to civilizations?

Natural hazards: impacts from asteroids and comets:

- how frequent?
- how dangerous?

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Impacts by asteroids and comets are observed



Damage from the Tunguska impact in Siberia: 1908

Witnessed by a handful of people, but no-one known to have been injured

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Smaller events (atmospheric explosions with yield of a few kT) are quite commonly detected by satellites

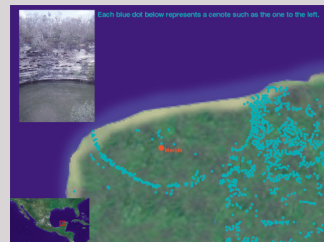


1972 event visible during daylight over Utah and Wyoming: appears to have been a ~10m diameter rock that grazed the Earth's atmosphere

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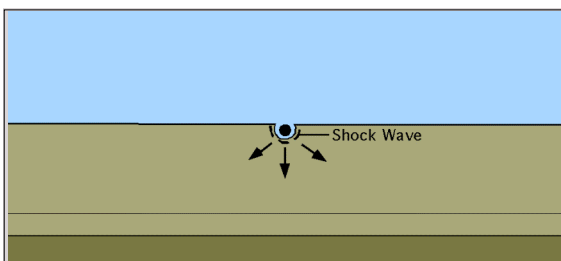
Large events are much rarer, but have enormously greater consequences:

~10km asteroid created a crater ~180km in diameter off the Yucatan peninsula



Parts of the crater can be traced out indirectly on the ground

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Impactors have speeds of 12-30 km/s, kinetic energy:

$$E = \frac{1}{2}mv^2$$

A 1 km diameter asteroid with a velocity of 20 km/s has an impact energy of 3×10^{20} Joules (~75,000 megatonnes TNT equivalent)

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Thin rock layer was deposited world wide as a result of this impact event



Identified as having an impact origin by Alvarez in the early 1980s - timing (65 Myr ago) coincides with the decline of the dinosaurs

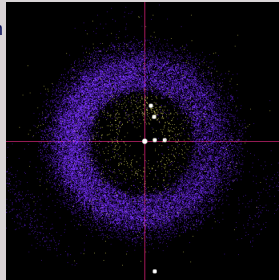
Distinguish between impactors potentially large enough to cause a global catastrophe ($d > 1$ km or so) and smaller events that would cause regional devastation.

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Numbers of near-Earth asteroids

Near Earth asteroid population is continually replenished by new bodies that leak out of the asteroid belt

Thought that all 3km+ size asteroids that could encounter the Earth are known, along with most of the 1km+ bodies (about 1000)



No known large body will impact the Earth in the foreseeable future - very small probability of a large comet arriving from the outer Solar System with little warning

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Smaller bodies are much more numerous:

Number dn with size between r and $(r+dr)$ increases steeply with decreasing r

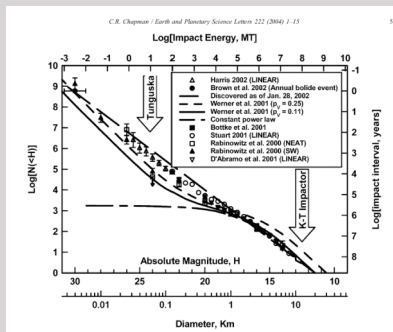
$$\frac{dn}{dr} \propto r^{-3.35}$$

Have determined the rough numbers of, but have not individually cataloged all the smaller bodies with sizes below 1km

PAN-Stars project is underway (first of four telescopes operational) and will complete census down to a size of about 300m

Probably another decade or more before all 100m objects (still quite dangerous) have been found

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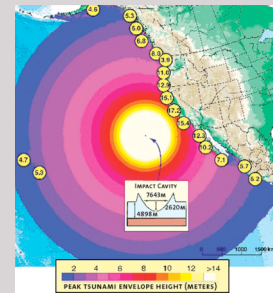


Estimated size distribution from Chapman (2004)

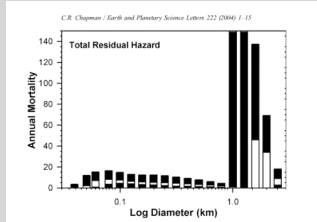
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Impact danger is roughly the same if the impact is on land or at sea: e.g. Apophis (350m across) would cause a devastating tsunami if it hit the ocean near a populated area

Unlike earthquakes, precise location of an impact could be predicted accurately in advance - would be possible to evacuate in advance



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In an insurance-type estimate, the risk from asteroids is dominated by rare but devastating events - e.g. a 1km asteroid impact occurs perhaps once per million years, but might cause 100 million deaths.

Per year, the average number of deaths is much smaller than from traffic accidents, earthquakes etc...

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If a near-Earth asteroid was found to be on a collision course, what options are there?



Trajectory of asteroids is dominated by gravity - predictable in most cases for at least 100 years. Structure of asteroids is not as well known - solid bodies or "rubble-piles"

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Small (100m) asteroid, impact with a spacecraft would knock it off course if applied early enough

Spacecraft mass m , velocity v , hitting an asteroid of mass M gives it a velocity kick:

$$\Delta v = \frac{m}{M} v$$

e.g. an asteroid of 100m diameter has a mass $M = 1.6 \times 10^9$ kg

Collision at 10 km/s with a 1000 kg spacecraft gives a velocity nudge of 6×10^{-3} m/s - very small!

But enough to deflect the trajectory 2000 km over 10 years...

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Similar strategy to the NASA mission *Deep Impact* would work best for a small asteroid or comet



Large body (1km across) is much harder to deflect

Explosions might work but there would be a danger of fragmenting the asteroid into many, equally dangerous pieces

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Summary

Large impacts have occurred on Earth in the past, and may well influence the course of evolution in unpredictable ways

Small impacts (asteroids < 1 km in size) can be locally devastating but do not threaten civilization

Census of the most dangerous asteroids is almost complete - none in dangerous orbits

Window of time a technological civilization is vulnerable appears to be small - not too hard to deflect asteroids

Frequency of impacts in other planetary systems is completely unknown...

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