

Astronomy 150: Killer Skies



This Class (Lecture 10):
Impact Mitigation

Next Class:
The Aging Sun

HW3 due on Sunday

Exam 1 on the 25th!

Music: *Another One Bites the Dust*– Queen

What Do We Know About the Impact Hazard?



- WE KNOW THIS...**
- Very Well** • **How many asteroids and comets** there are of various sizes in Earth-approaching orbits (hence, impact frequencies are known).
 - Very Well** • **How much energy** is delivered by an impact (e.g. the TNT equivalence, size of resulting crater).
 - Somewhat** • How much dust is raised into the stratosphere and other **environmental consequences**.
 - Poorly** • **Biosphere response** (agriculture, forests, human beings, ocean life) to environmental shock.
 - Very Poorly** • Response of human **psychology, sociology, political systems, and economies** to such a catastrophe.

Outline



- What are the odds?
- Mitigation techniques

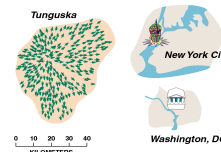
The Consequences in Perspective...



Meteorite punctured roof in
Canon City, CO



- Most effects are individually familiar (fire, wind, falling debris, seismic shaking...)
 - First-responders face nothing truly alien, no radiation
 - Synergy of many different effects in first 10 minutes
- Warning versus no warning (time and location)
 - Deaths and injuries dramatically reduced with warning
 - Property damage can be lessened somewhat
 - Even with no warning, individuals can reduce exposure by taking cover (within seconds to minutes) if they have been educated to recognize what's happening (Indian Ocean tsunami analogy)
- Impact disasters: local/regional versus global
 - Like Katrina, earthquakes, or wars...unaffected cities or nations can provide emergency response and recovery...
 - ...Unless the consequences are global



Mitigation by Civil Defense



- If a NEA strikes without warning, or if deflection seems uncertain or fails
- Warn, evacuate, store food supplies, plan for a large medical emergency, response and recovery operations...



Asteroid Histories Sampler



- Billions of yrs ago (Mars-sized): Creation of Moon
- 65 Million yrs ago (~10 km): Dino-killer
- 15 Million yrs ago (~10 km): fragmented before impact, but ~1km objects impacted Bavaria, destroyed much of Europe
- 50,000 yrs ago (~50 m): Arizona meteor crater
- 1908 AD (~50 m): Tunguska

Asteroid Histories Sampler (Recent)



- 1972 (~ 10m): The Great Daylight 1972 Fireball, went through the atmosphere, getting as low as 58 km over Montana
- 1989 (~300 m): missed by 700,000 km (where the Earth had been 6 hours earlier)
- 2002 (~100 m): 1/3 Earth-Moon distance, 120,700 km, only discovered three days after pass!
- 2004 (~500 m): 400,00 km, rediscovered 1 week before.
- 2009 (~30 m): 60,000 km, discovered 1 month before.

Asteroid Histories Sampler (Future)



- 2029 (~ 350 m): Apophis will come within 40,000 km. **In very dark sites, it will be visible with naked eyes** (Europe, Africa, and W Asia).
- 2036 (~350 m): Apophis is back. We don't know how close it will get, possible impact. We'll know better soon.
- 2880 (~1.1 km): 1950 DA, huge miss or impact?

Lifetime Chances?

Clark R. Chapman
Southwest Research
Institute

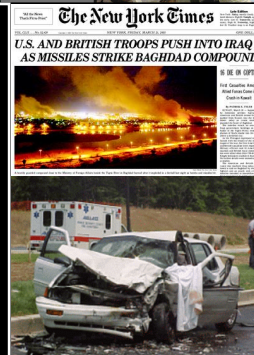
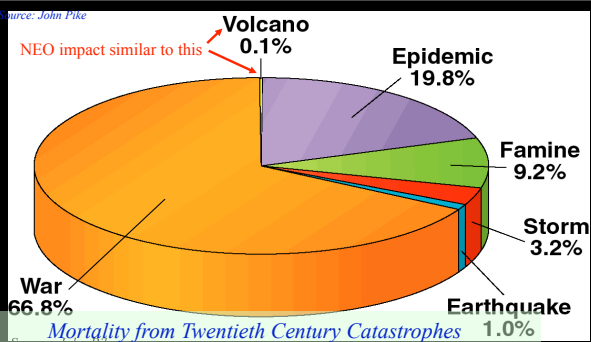
Cause of Death	Chance: 1 in
Motor vehicle accident	90
Suicide	120
Homicide	185
Falls	250
Terrorism (Middle East)	1,000
Fire or smoke	1,100
Electrocution	5,000
Drowning	9,000
Flood	27,000
Airplane crash	30,000
Lightning strike	43,000
Asteroid impact (global)	75,000
Terrorism (non Mid-East)	80,000
Insect bite or sting	100,000
Natural tsunami	100,000
Earthquake	130,000
Asteroid impact (regional)	1,600,000
Food poisoning (botulism)	3,000,000
Asteroid impact (local)	5,700,000
Shark attack	8,000,000



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This is hard to understand as there is very little chance that anyone in your lifetime will die from an impact. BUT, if a global impact occurs within the next 100 million years, billions of people will die, so the average per year is still relevant. Low chance, but high risk events!

How Important is NEO Threat? We've Many Other Things to Worry About!



Comparing NEO Impacts and Climate Change



NEO Impact

Similarities...

- They can potentially affect the globe
- Asteroids can be deflected to miss Earth

Dissimilarities...

- Global effects within 2 hours, global climate change within months
- Extremely unlikely to happen this century



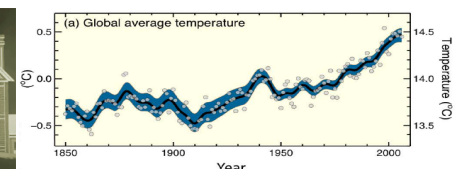
Climate Change

Similarities...

- Global warming is planetary in scale
- Society can reduce greenhouse gases

Dissimilarities...

- Timescale for major changes: about one century
- Actually underway right now



So can we ignore the risks?



- Well, an asteroid impact would be like a plane crash.... It doesn't happen very often at all -- air travel is very safe -- but when it does happen, a bunch of people die at once.
- It all depends on what risks humanity is willing to live with (e.g. cars kill lots more people, but no-one wants to ban them...).



What do you think?



Right now, the US Government is spending money on finding potentially hazardous asteroids -- asteroids that would not necessarily cause a mass-extinction but would probably wipe out millions to billions of people and decimate civilization.

As we saw, the chance of an asteroid doing this in the next few thousand years is remote.... But if it comes, it would be a big problem!

How much money should we be spending on this issue?

- A. \$0 per year -- we've got bigger problems to worry about.
- B. Few million \$ per year -- get some people working on it, and this cost is a drop in the bucket compared to e.g. DoD.
- C. Few billion \$ per year -- given the consequences, this requires lots of resources.
- D. Few trillion \$ per year -- Holy Crap, this should be our top priority!

What do you think?



A more immediate problem are the small asteroids that cause Tunguska like events. On a city they'd cause thousands to millions of deaths, but civilization would not be destroyed. Something like this could very well happen within the next hundred years.... Or it might not...

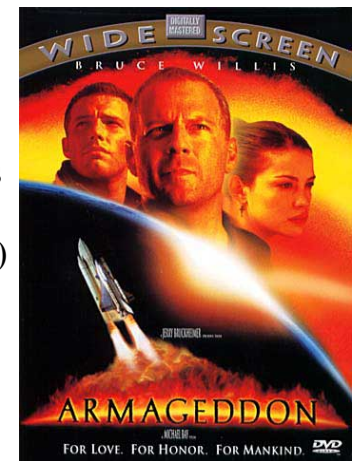
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Mitigation



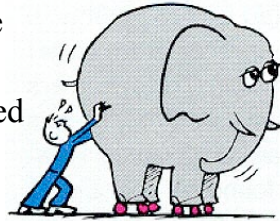
- The problem is the possibility of little or no warning
- There are proposals to use nuclear weapons and satellites to "shoot down" or destroy such killer objects (good idea?)
- For further edification, rent "Armageddon" (1998)
- <http://www.youtube.com/watch?v=iq6q2BrTino>



Early Detection is Key



- The earlier we can detect a threat, the easier it is to mitigate the danger.
- A very small change in velocity (speed or direction) can make a huge difference in months.
- Remember inertia (the resistance of mass to change motion), and these things are massive.
- So it is a difficult problem.
- And new comets would only have warnings of a few months!



<http://sol.sci.uop.edu/~jfalward/physics17/chapter2/chapter2.html>

So How to Mitigate?

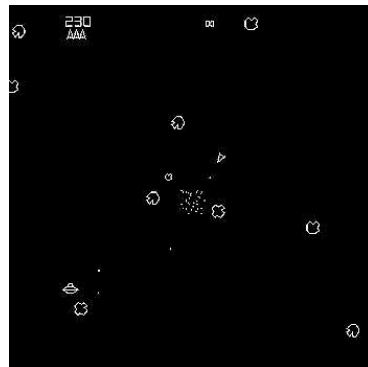


- Two main options:
 - Destroy
 - Can be problematic
 - Fragment into many pieces (all in the same orbit).. Have to track hundreds or thousands of objects now!
 - Delay
 - Earth is moving 30 km/s, or 1 Earth diameter every 7 minutes.

Blow the Mother Up!



- Typical option discussed is nuclear missiles.
- Might work, vaporizes or at least reduce mass.
- But, need to make sure not to fragment into many still dangerous pieces.
- Imagine twenty-five 50m pieces in the same orbit, would be hard to stop!



Blow-Up Job



- Other option is to blow up a nuclear weapon near the asteroid.
- But not too near to fragment it.
- Imparted energy could be enough to change orbit.
- Neutron bomb (nuclear blast where large fraction of energy is in neutrons) is thought to be most efficient, biggest transfer of energy maybe only chance for last minute threats.



<http://www.projectrho.com/rocket/rocket3x.html>

http://www.youtube.com/watch?v=XPS-m_sI7_k

Kinetic Energy Deflection



- Impact the asteroid or attach rockets.
- May still fragment, but most have impacts, so less likely
- Actually an ESA mission to test this is occurring in 2011!
- The aptly-named Don Quijote mission



http://www.esa.int/SPECIALS/NEO/SEMZRZNVGJE_1.html

Don Quijote



Two components:

- Sancho: orbits and accurately measures position
 - Plus the Autonomous Surface Package Deployment Engineering eXperiment, which checks out the impact site
- Hidalgo: impactor (10km/s)

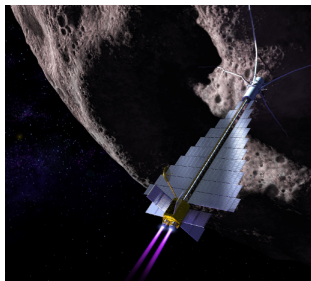


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The Ole' Space Tug



- Put a rocket on the asteroid!
- This can eventually move the rock, but
 - Rockets don't provide too much thrust
 - Will likely need many steerable rockets.
 - Remember that asteroids are rotating!
 - How to attach to a tumbling, rotating asteroid that may only be a big pile of rubble?



Gravity Tractor



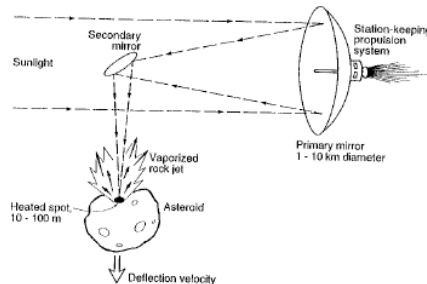
- Put an object near the asteroid!
- Using gravity, the asteroid is attracted to spacecraft.
- Spacecraft uses rockets to keep away, so slow pull.
- Would take ~10 years for moderate mass asteroid
- Works no matter the composition— rubble piles not fragmented.



Focus the Sun on it!



- Use the Sun to melt the asteroid surface.
- This removes material and creates a jet.
- <http://www.youtube.com/watch?v=dcqFylzjdys>

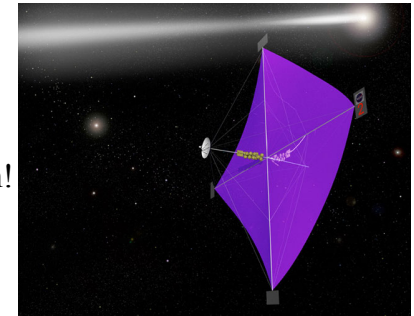


<http://www.lpl.arizona.edu/~jmelosh/HazardsDeflect.pdf>

Other Propulsion: Light Sails



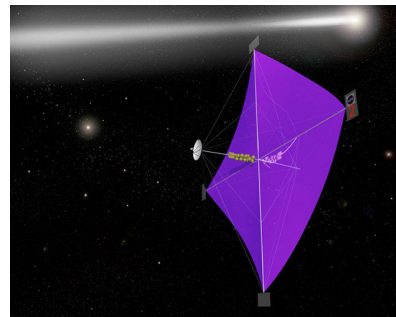
- Imagine a space sailboat but with photons of light hitting the sails and pushing it forward.
- Photons have energy but no rest mass.
- But, they do carry momentum!
 - It is related to the energy such that $p = E / c$
- So, such a craft is not propelled by solar winds!
- But by light bouncing off, like a mirror.



Other Propulsion: Light Sails



- Attach to an asteroid?
- It can work, but it would be slow.
- How to attach to a tumbling, rotating asteroid that may only be a big pile of rubble?



Other Ideas



- Paint it or wrap it in a reflective coating.
 - Hard to do, tumbling asteroid again, plus only pushes in direction opposite to Sun.
- Opposite idea is to sprinkle with soot to reduce Sun pressure (also Yarkovsky effect).
- Asteroid braking.
 - Perhaps a cloud of steam in front of the asteroid to slow it some.
 - Steam? Nuke a comet.



Say we find an asteroid that's going to hit us
30 years from now. What should we do?

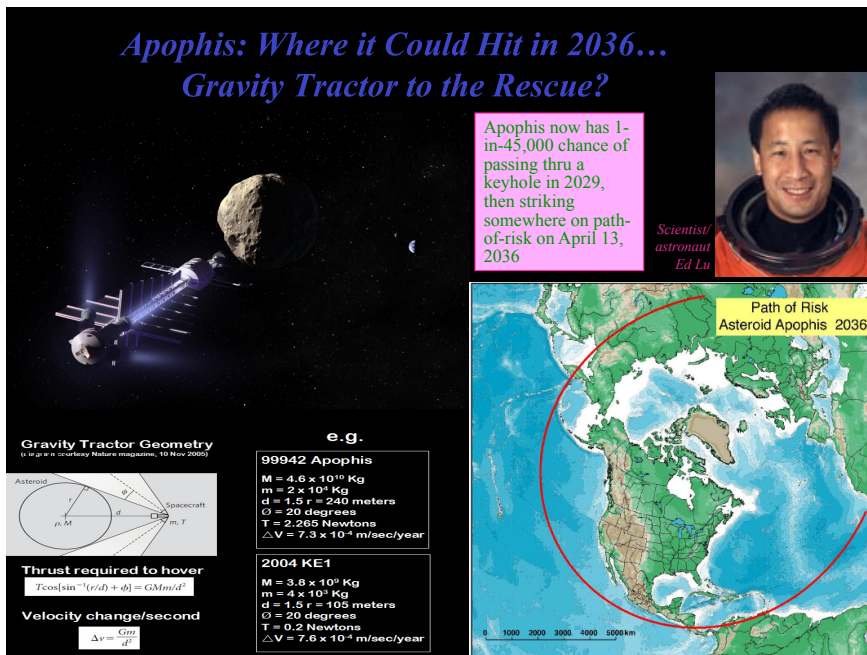


- A. Blow it up into smaller pieces.
- B. Deflect it with nukes as it enters Earth's atmosphere.
- C. Coat it in white paint.

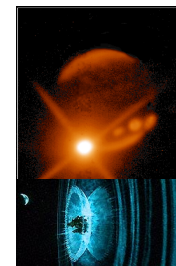
We do know of an asteroid that has a 1 in
300 chance of hitting us in 2880. What
should we do?



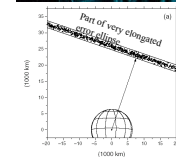
- A. Blow it up into smaller pieces that will dissipate and disintegrate over the next 800 years.
- B. Coat it in white paint as soon as possible.
- C. Nothing; by the 29th Century, technology will have advanced so much that it will probably be easy to mitigate the hazard.



Common Misperceptions



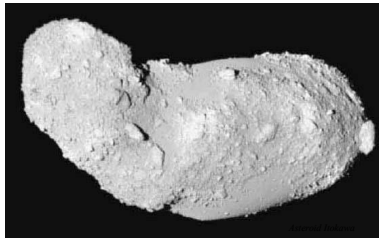
- Long waiting time until next impact
 - Instead, we should think of chances of disaster and our responsibilities “on our watch”
- Judging consequences quantitatively
 - Civilization-ending impact vs. K/T mass-extinction
 - “one death” vs. 100 deaths/yr vs. 3000 9/11 dead vs. we will all die in next 100 years (what are our values?)
 - Shoemaker-Levy 9 Jupiter impacts overshadowed the Rwanda genocide in the news (July 1994)
- “Blow it up” on the way in
 - Movies misrepresent reality of decades lead-time
- NEA is “on an impact course with Earth”
 - NEA discovery process, error ellipses, NEA orbits the Sun many times before impact: *not intuitive!*



Asteroids are Not Likely to Destroy our World...



- ...but we can contemplate the NEO hazard as the most extreme environmental disaster, and put the lesser, more likely ones into context...
- ...and distinguish between societal issues like global warming and true, sudden catastrophes.
- Many threats to society and our lives (flu, war, famine... global warming) are here today.
- Asteroids are in our future... as places to travel to, as fuel stations for a spacefaring civilization ...let's hope they don't come to us first!



Imagine

- Walking to class next week, you notice that you suddenly have two shadows.
- You turn quickly, and it looks like there are two Suns, but one of them is moving toward the horizon!
- Very Fast!
- As it meets the horizon, there is a incredible bright flash, and you can feel the heat!

Imagine

- An earthquake throws you to the ground, and you get a little worried as you notice that the trees in the distance have burst into flames.
- A sound wave bears down on you at 700 mph!
- Like a mighty thunderclap, it sweeps over you, pulverizing all the nearby buildings...
- As your body disintegrates, you wonder what Leslie was going to lecture on today.