Astronomy 330

This class (Lecture 21):
Lifetime

Next Class:
Putting it all together
Nicholas Cox

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

Paper Rough Draft

- Worth 1% of your grade, but really worth more.
- Due on or before April 15th! (Hard date!)
  - Beginning of class, else considered late.
- Should pretty much be the final paper.
- Will be looking for scope, ease-of-read, scientific reasoning, **proper citation**, and general style.
- 6 to 8 pages double-spaced 12-point font, not including references.

Paper Rough Draft

- ***Mars is a planet without an overzealous monkey population (Holt et al. 2000; James & Mann 2006; Walker 2007; Wikipedia: Mars).***
  - ***I expect to see a few refs per page!***

- Holt, W., Smith, E., Rowe, T., & Jones, A. B. 2000, The Astronomical Almanac for the Year 1994, Vol. 2 (2nd ed.; Washington, DC: GPO)
- Smith, A. B., Thomas, J. R., Major, W., & Peebles, P. J. E. 2006, Astrophysics Journal, 450, 12
- Wikipedia: Mars, http://en.wikipedia.org/wiki/Mars, Accessed: March 25, 2010, Updated: March 24, 2010

Presentations

- **Rebecca Reizner:** Telepathy

Outline

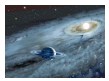
- What is the lifetime of a civilization that can communicate?

Drake Equation

Frank Drake

That's 1.9 Communicating life/century








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

# 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
	10 stars/ yr	0.75 systems/ star	1.5 x 0.11 = 0.165 planets/ system	0.47 life/ planet	0.42 intel./ life	0.78 comm./ intel.	yrs/ comm.

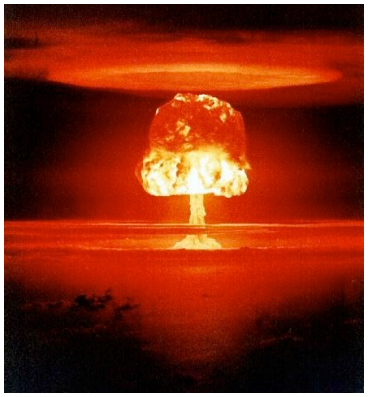
2. Population Growth

- Currently world population is around 6.7 billion (6.7×10^9).
- 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.

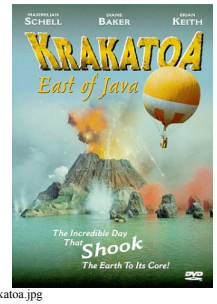
http://www.randomfate.net/MT/images/N_Korea_nuke.gif
http://cosmo.pasadena.ca.us/adventures/atomic/cold-war.html

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



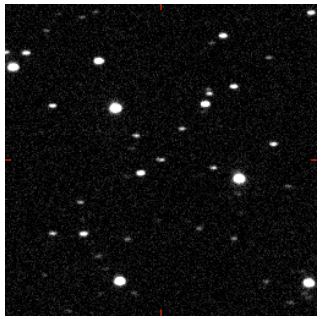
http://charm.hendrix.edu/astro/krakatoa.jpg

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?

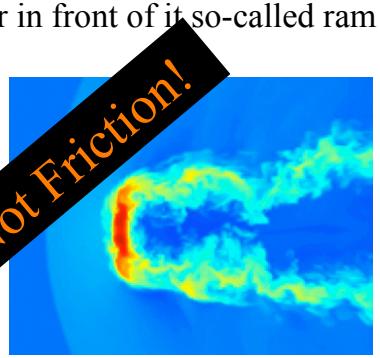


Asteroid 2004 FH. 30 meters in diameter. About 1 Megaton of TNT energy in an Earth impact! Passed within 7 Earth radii of Earth. Hiroshima was 15 kilotons.

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.

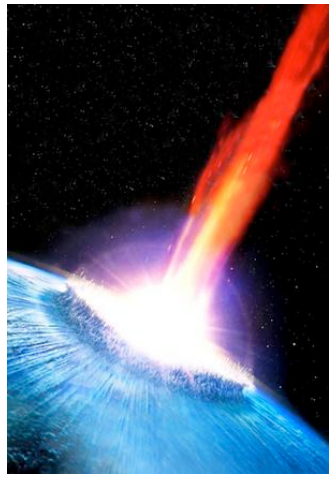


Ramming Speed!

- 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?

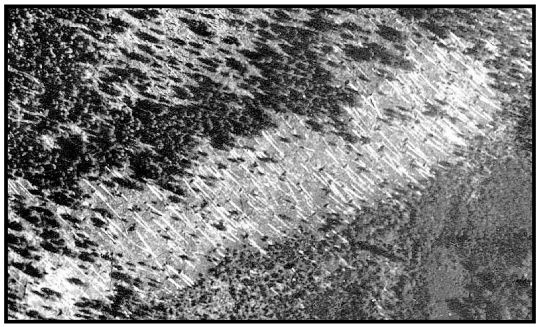
"Perhaps the earliest widely-held theory for the Tunguska explosion was that the world was about to end. As the minutes passed, this theory was dropped in favor of other, less final theories, until today one is hard-pressed to find anyone who truly believes the world ended on the morning of June 30,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

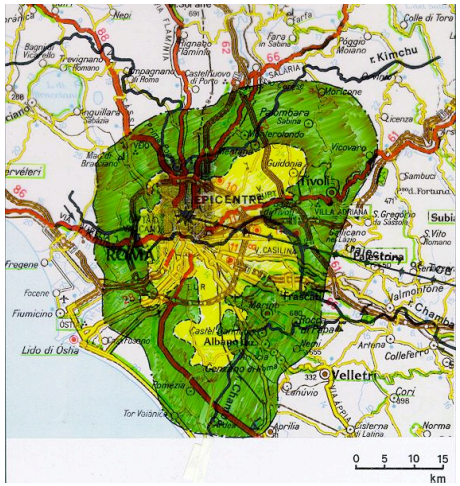
Tunguska, Siberia: June 30, 1908
A ~40 meter object disintegrated and exploded in the atmosphere

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?

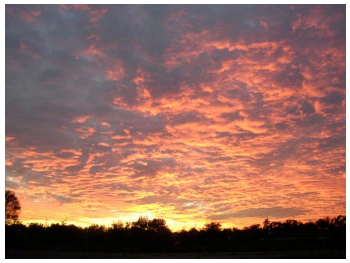
Area of devastation superimposed on a map of Rome. Yellow=charred trees; Green=felled trees

- 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!



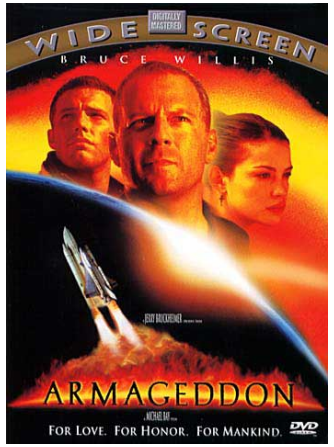
http://visionoftheworld.com/_wsn/page4.html

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?

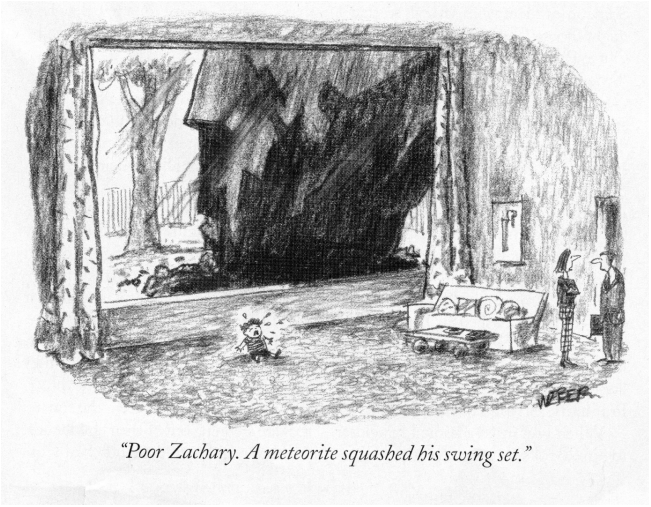
- Before the 20th Century, human population was much lower, so likelihood of someone being affected is lower.
- If someone did see a Tunguska, less likelihood of word getting around -- news didn't disperse as easily back then.

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, you have to wait only roughly tens to hundreds of years.



Effects upon children



"Poor Zachary. A meteorite squashed his swing set."

4. Natural Catastrophes

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

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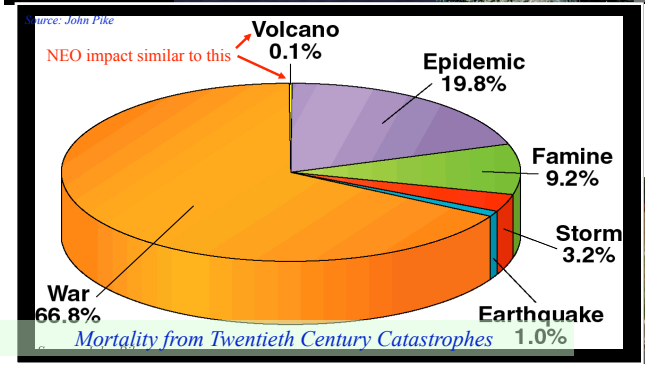
This is hard to understand as there is very little chance that anyone in your lifetime will die from an impact. BUT, if a global impact occurs within the next 100 million years, billions of people will die, so the average per year is still relevant. Low chance, but high risk events!

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

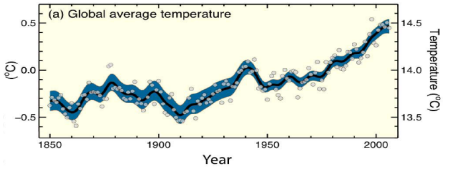
Climate Change

Similarities…

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

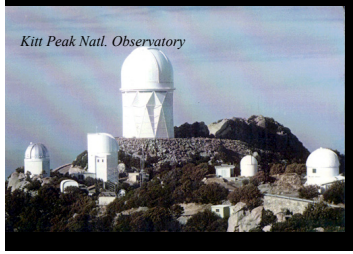
Dissimilarities…

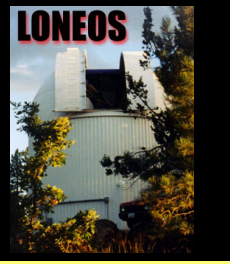
- Timescale for major changes: about one century
- Actually underway right now

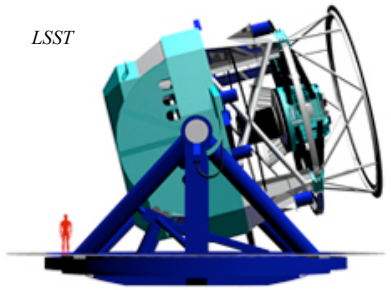


Near Earth Object Program

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



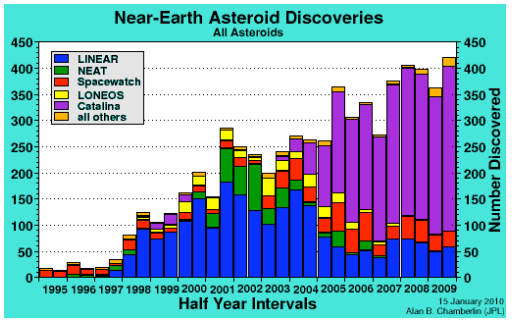




- Survey: 1998 to 2009, find >90% of NEOs >1 km diameter (Near Earth Objects)
- Congress ordered NASA to find 90% of NEOs >140 m by 2020
- http://www.youtube.com/watch?v=9_FZfxvTmNA

Killer Asteroids

- As of April 2010, 6,935 NEAs (>50 meters, so asteroids) are known.
- 804 of these are > 1km
- 1107 of these are classified as Potentially Hazardous Asteroids (PHAs)



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

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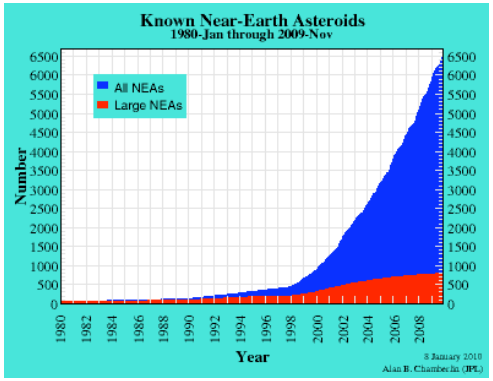
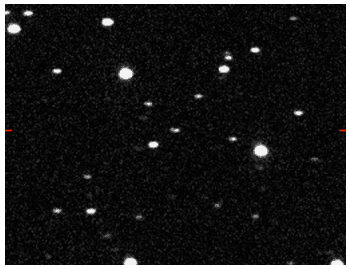


http://neo.jpl.nasa.gov/faq/

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.)

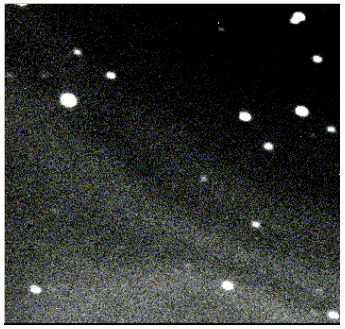


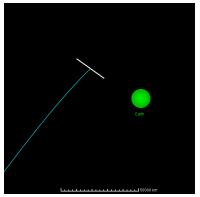
Asteroid 2004 FH. 30 meters in diameter. About 1 Megaton of TNT energy in an Earth impact! Passed within 7 Earth radii of Earth. Hiroshima was 15 kilotons.

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



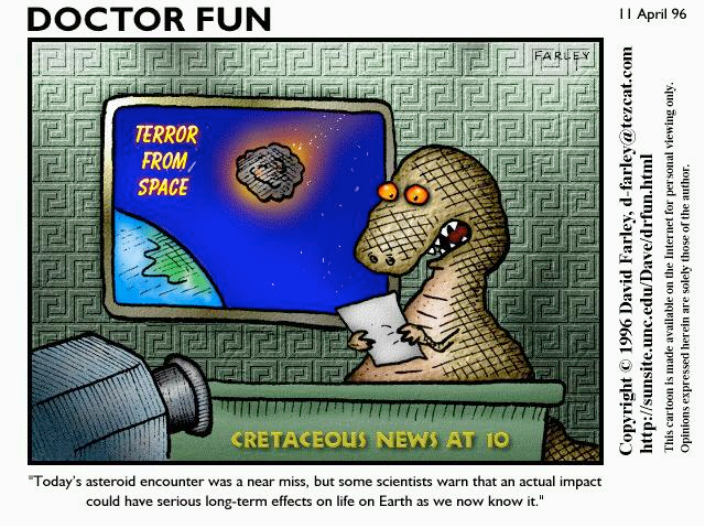


Killer Asteroids

- 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/

Be Aware



Killer Asteroids

- The Dino Killer was about 10 km in diameter.
- And, there are many asteroids out there that we still do not know about.
- On the long time-scale one of them will hit the Earth.
- What can we do if there is an immediate threat? There may be little time.

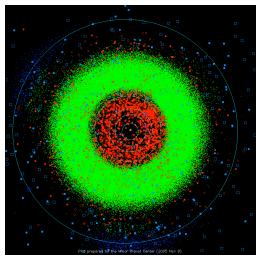
http://www2.ifa.hawaii.edu/newsletters/article.cfm?a=88&n=10

http://neat.jpl.nasa.gov/

http://www.ll.mit.edu/LINEAR/

Killer Asteroids

- Diversion or destruction of object.
- With sufficient warning it doesn't take too much to miss the Earth.
- One example is to change reflectivity of surface.
- Nuclear explosions may result in many small asteroids.
- Expensive and difficult, but advanced civilizations should be able to do it.



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Question

A larger asteroid will eventually hit the Earth again, what is the best way to avert it.

a) Bomb it.
b) Move to Mars
c) One word: lasers
d) Discover it years in advance.
e) There is already a secret project in place to avert any large asteroid– loose lips sink ships.

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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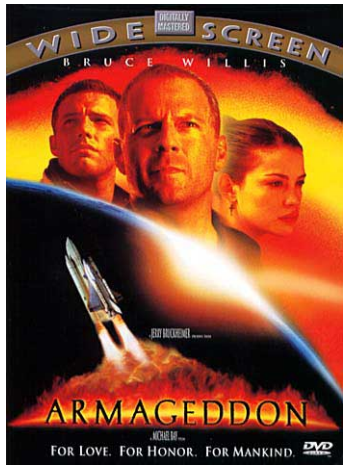
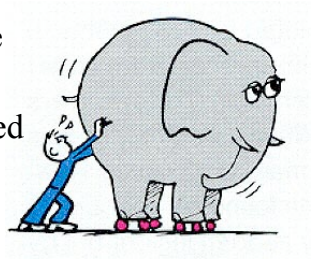
Mitigation

- 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

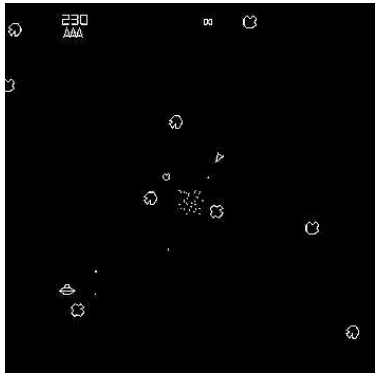
So How to Mitigate?

- 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

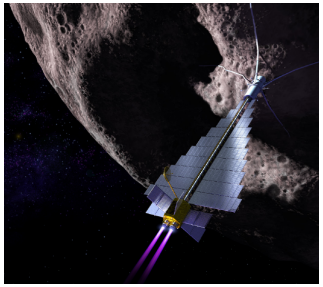
Two components:

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

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

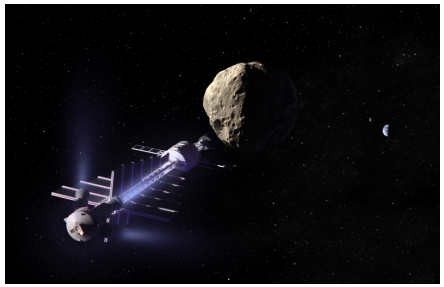
The Ole' Space Tug

- 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?



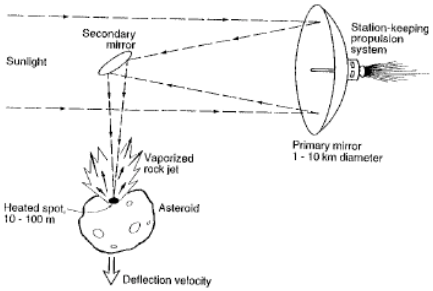
Gravity Tractor

- 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!

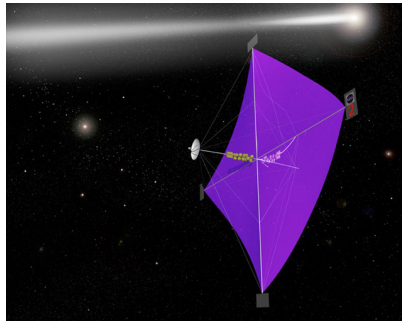
- Use the Sun to melt the asteroid surface.
- This removes material and creates a jet.
- http://www.youtube.com/watch?v=dcqFy1zjdys



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

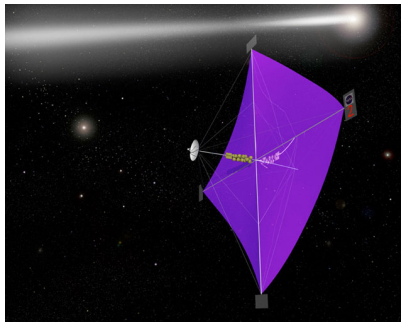
Other Propulsion: Light Sails

- 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.



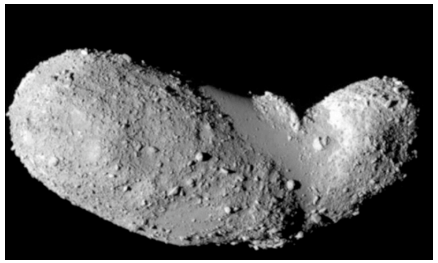
Other Propulsion: Light Sails

- 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

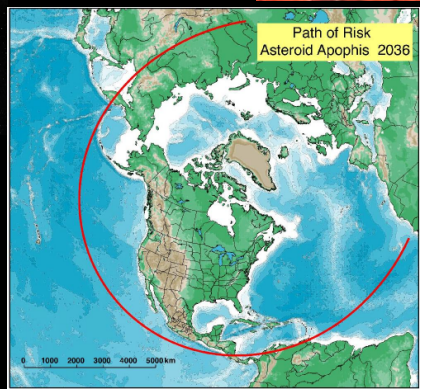
- Paint it or wrap it in a reflective coating.
  - Hard to do, tumbling asteroid again, plus only pushes in direction opposite to Sun.
- Opposite idea is to sprinkle with soot to reduce Sun pressure (also Yarkovsky effect).
- Asteroid braking. Perhaps a cloud of steam in front of the asteroid to slow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



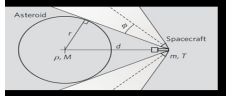
Apophis: Where it Could Hit in 2036… Gravity Tractor to the Rescue?

Apophis now has 1-in-45,000 chance of passing thru a keyhole in 2029, then striking somewhere on path-of-risk on April 13, 2036

Scientist/ astronaut Ed Lu



Gravity Tractor Geometry



Thrust required to hover

$$T\cos[\sin^{-1}(r/d)+\phi]=GMm/d^2$$

Velocity change/second

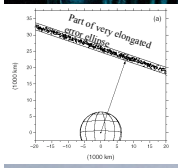
$$\Delta v=\frac{Gm}{d^2}$$

e.g.

99942 Apophis
M = 4.6 x 10^10 Kg
m = 2 x 10^5 Kg
d = 1.5 r = 240 meters
∅ = 20 degrees
T = 2.265 Newtons
△V = 7.3 x 10^-4 m/sec/year

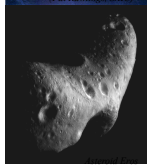
2004 KE1
M = 3.8 x 10^9 Kg
m = 4 x 10^5 Kg
d = 1.5 r = 105 meters
∅ = 20 degrees
T = 0.2 Newtons
△V = 7.6 x 10^-4 m/sec/year

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!