

## Top Ten Signs Your Astronomy Professor May Be Nuts

(based on Lee Carkner List)



- 10) The title of every lecture is: "Man, Them Stars is Hot!"
- 9) His so-called "telescopes" are really just paper towel rolls covered in aluminum foil.
- 8) To illustrate the vastness of the universe, he makes everybody walk to Springfield.
- 7) Thinks he's married to the slide remote.
- 6) Your grade is based entirely on how many ping-pong balls you can fit in your mouth.
- 5) His so-called Drake Equation video is really just an old episode of Alf.
- 4) He makes everyone wear a soup pot on their head to protect the class from "Klingon mind control lasers".
- 3) About 90% of all classes involve dressing monkeys up to look like Frank Drake.
- 2) When you go to his office hours, he is always hiding under the desk so that the "space squirrels" can't get him.
- 1) The only observing advice he ever gives is, "Keep an eye out for the mothership."

## Paper Rough Draft



- Worth 1% of your grade, but really worth more.
- **Due on or before April 17<sup>th</sup>! (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.

## Astronomy 330



This class (Lecture 22):  
Lifetime

*Ryanne Ardisana*

Next Class:  
Communication

*Matthew Zettinger*

**HW 9 due tonight.**  
**Rough Drafts due next class!!**

*Music: It's the End of the World as We Know It – R.E.M.*

## Paper Rough Draft



Mars is a planet with 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, 2012, Updated: March 24, 2011

## Or?



- If you find a wikipedia article(s) (related to class) that has citation problems or missing content, you can edit for credit.
- First, in discussion section on Compass claim ownership of the article(s), first come/first serve.
- Must demonstrate 6-8 significant edits or improvements (print a before and after)– and email me the link to the history page so I can verify updates.

## Wiki-fixes



- Grade is determined on improvement quality and citations are important.
- Must show a draft of improvements by April 17<sup>th</sup>.

## Presentations



- Ryanne Ardisana  
[Life as We Know It: The Possibilities of Alternative Biochemistries](#)

## Outline



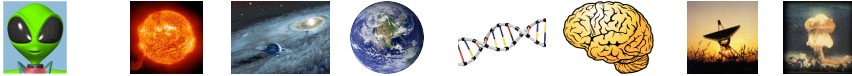
- Lifetime of alien civilizations.
  - Could be a whole class (oh it is..)
  - Pollution/population/war
  - Asteroids

# Drake Equation

Frank Drake



That's 0.96 Communicating life/year



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

# 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 communicate	Lifetime of advanced civilizations
20	stars/yr	0.8	2 x 0.11 = 0.22	0.775	0.505	0.7	yrs/comm.
		systems/star	planets/system	life/planet	intel./life	comm./intel.	

# Long-Lived Civilizations



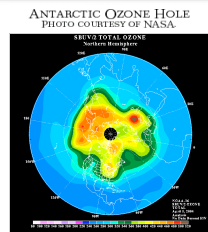
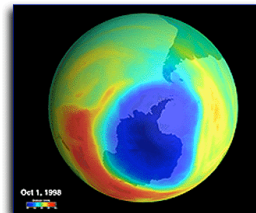
If you have “free-energy” might be more likely to have automated SETI transmission experiments for 1000s of years.



# Pollution from Civilization



- Ozone layer (O<sub>3</sub>) is formed from O<sub>2</sub> broken up by ultraviolet light
- Ozone protects life against harmful Sun rays.
- Chlorofluorocarbons (CFCs) destroy the ozone.

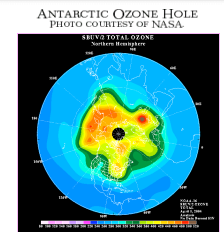
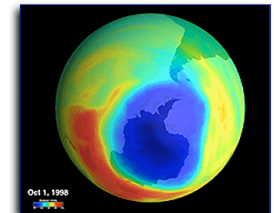


[http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/gif\\_files/sbuv16\\_nh\\_latest.gif](http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/gif_files/sbuv16_nh_latest.gif)  
<http://www.ngdc.noaa.gov/paleo/globalwarming/images/ozone.gif>

# Pollution from Civilization



- CFCs were used in A/C and refrigeration.
- Governments did not do much until a large hole appeared over Antarctica and N. America.
- Finally, being phased out, but the CFCs take about 20 yrs to reach stratosphere.
- The problem was predicted 25 years ago.

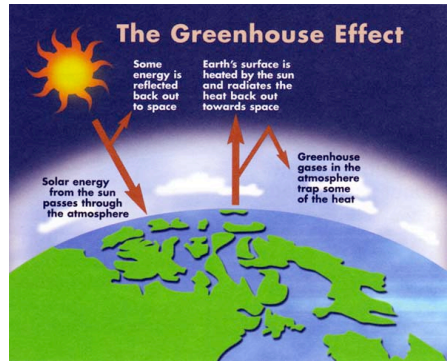


[http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/gif\\_files/sbuv16\\_nh\\_latest.gif](http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/gif_files/sbuv16_nh_latest.gif)  
<http://www.ngdc.noaa.gov/paleo/globalwarming/images/ozone.gif>

# Global Warming



- Burning of fossil fuels releases CO<sub>2</sub>.
- This is a greenhouse gas.
- Humans add more CO<sub>2</sub> to the atmosphere (50-100x) than natural sources— 25 billion tons each year!

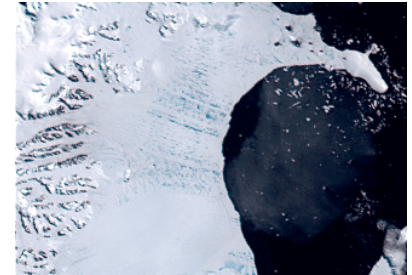


[http://www.climatechange.gc.ca/english/climate\\_change/images/ghg\\_effect\\_lg\\_e.jpg](http://www.climatechange.gc.ca/english/climate_change/images/ghg_effect_lg_e.jpg)

# Global Warming



- Why hasn't the temperature rise been more dramatic?
- The burning of coal releases sulfates-- form a haze that increases the albedo of Earth.
- So the effect is less than expected, but predictions suggest that CO<sub>2</sub> content will begin to dominate in this century.
- Already, large slabs of the Antarctica ice shelf have melted.



Destruction of Larsen ice shelf 2002. 3250 km<sup>2</sup> over 35 days. That's bigger than Rhode Island! Existed for at least 400yrs maybe 12,000yrs.

<http://www-nsidc.colorado.edu/iceshelves/larsenb2002/animation.html>

# 2. Population Growth



- Currently world population is around 6.9 billion (6.9 x 10<sup>9</sup>).
- 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<sup>15</sup>
- 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!

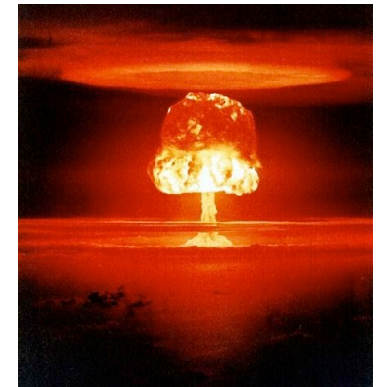


<http://w3.whosea.org/aboutsear/88-97-7.htm>

# 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-lives.
- Most destructive global nuclear war could cause a nuclear winter.



<http://www.daliistan.org/journal/rechist/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://www.randomfate.net/MT/images/N_Korea_nuke.gif)  
<http://cosmo.pasadena.ca.us/adventures/atomic/cold-war.html>

### Question



Although depletion of resources is a major issue for long term survivability of an advanced civilization, resource depletion really highlights a larger issue,

- energy.
- population growth.
- global warming.
- pollution.
- asteroids.

### 4. Natural Catastrophes



#### 1. Volcanoes

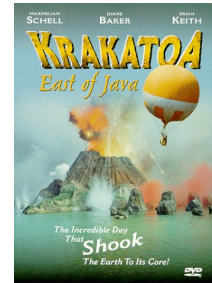
- Worldwide distribution of dust. Same idea as nuclear winter, but without radioactive fallout.
- Krakatoa eruption in 1883 near Java, blew away 75% of the island of Rakata. (Heard in Austria.)
- Prolonged low temperatures “Year with no summer”



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

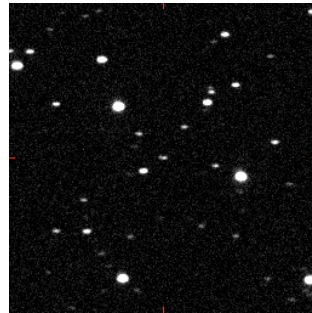
- Many in Earth-Crossing orbits– NEOs.
- Again, collision would create large amounts of dust in the atmosphere leading to global cooling.
- Small objects can cause significant damage because the Earth's orbital velocity is 30 km/s  $\Rightarrow KE = \frac{1}{2} M V^2$
- That means that a 0.25 km radius 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?



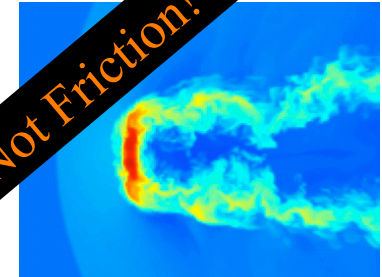
Asteroid 2004 FH. 30 meters in diameter. About 1 Megaton of TNT energy in an Earth impact! Passed within 7 Earth radii of Earth. Hiroshima was 15 kilotons.

<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 ( $9 \times 10^5$  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](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..”

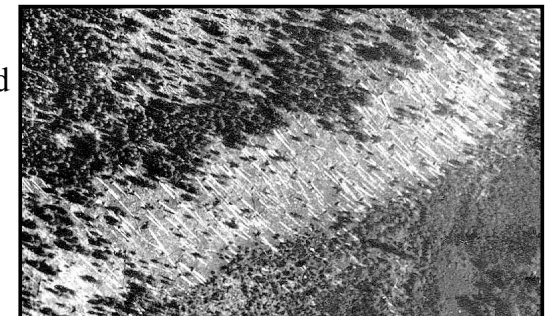
[http://en.wikipedia.org/wiki/Tunguska\\_event](http://en.wikipedia.org/wiki/Tunguska_event)

## 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

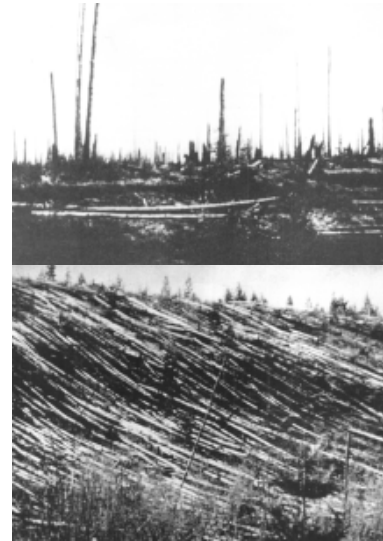


- In the central region, forests flashed to fires that burned for weeks
- A herd of 600-700 reindeer was incinerated



## 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<sup>2</sup> 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







**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**

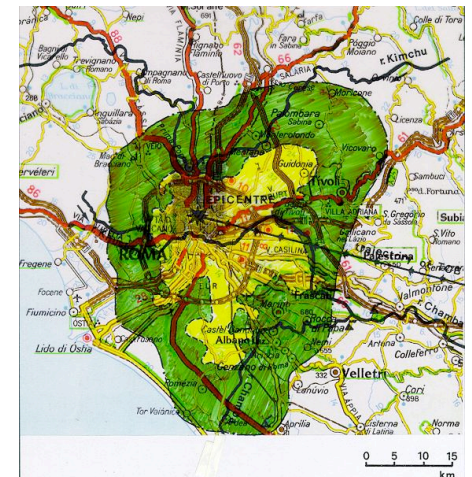


**Several hundred square miles of forest were destroyed.**  
**What if this had happened over a city?**

**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](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
<b>Asteroid impact (global)</b>	<b>75,000</b>
Terrorism (non Mid-East)	80,000
Insect bite or sting	100,000
Natural tsunami	100,000
Earthquake	130,000
<b>Asteroid impact (regional)</b>	<b>1,600,000</b>
Food poisoning (botulism)	3,000,000
<b>Asteroid impact (local)</b>	<b>5,700,000</b>
Shark attack	8,000,000



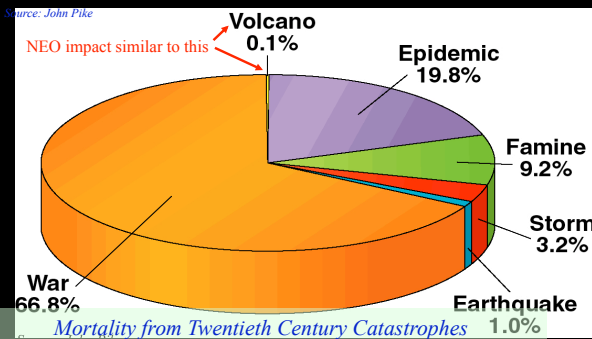
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This is hard to understand as there is very little chance that anyone in your lifetime will die from an impact. BUT, if a global impact occurs within the next 100 million years, billions of people will die, so the average per year is still relevant.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

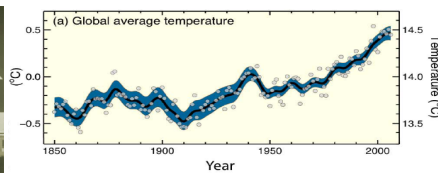
## Climate Change

### Similarities...

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

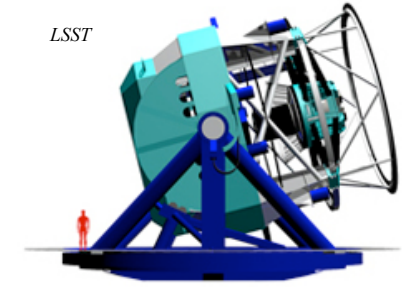
### Dissimilarities...

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



# Near Earth Object Program

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

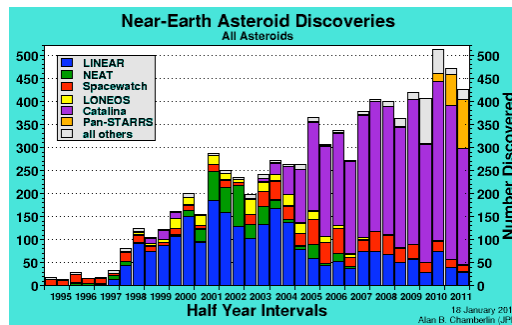


- Survey: 1998 to 2010, find >90% of NEOs >1 km diameter (Near Earth Objects)
- Congress ordered NASA to find 90% of NEOs >140 m by 2020 (Unfunded mandate!)
- [http://www.youtube.com/watch?v=9\\_EZ1xyTmNA](http://www.youtube.com/watch?v=9_EZ1xyTmNA)

# Killer Asteroids



- As of Jan 2012, 8,879 NEAs (>50 meters) are known.
- 841 of these are > 1km
- 1300 of these are classified as Potentially Hazardous Asteroids (PHAs)

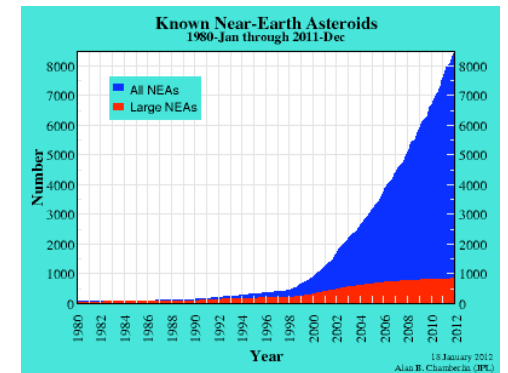


<http://neo.jpl.nasa.gov/faq/>

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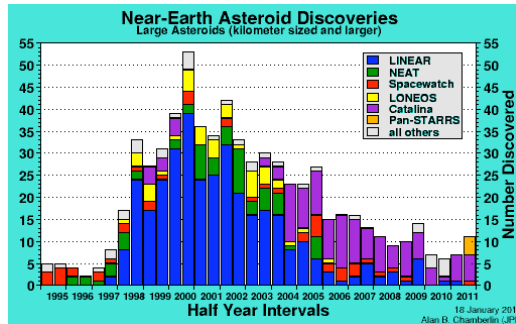
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## Killer Asteroids



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Note, these are all current NEOs, but new ones can come.

<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>

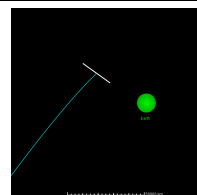
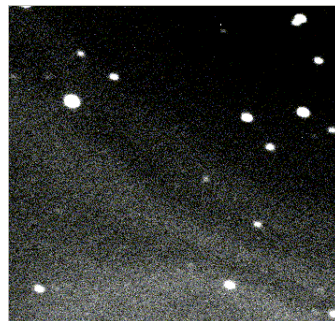
## The Asteroid with Our Name on It: The Deadly Impactor



## Killer Asteroids



- 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



- 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



### DOCTOR FUN

11 April 96



Copyright © 1996 David Farley, d.farley@tczcat.com  
http://sunsite.unc.edu/Dave/dr/fun.html  
This cartoon is made available on the Internet for personal viewing only.  
Opinions expressed herein are solely those of the author.

"Today's asteroid encounter was a near miss, but some scientists warn that an actual impact could have serious long-term effects on life on Earth as we now know it."

## 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/>

## 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...

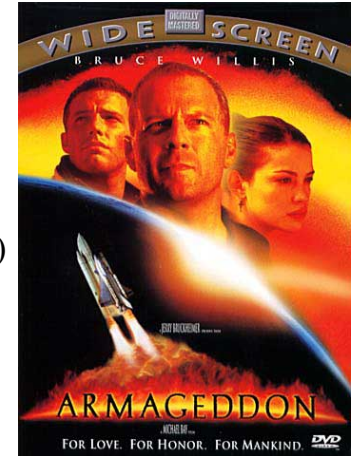
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## Mitigation: Advanced Civs



- 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!

