Astronomy 150:
Killer Skies

This Class (Lecture 11):
Mitigating Asteroids

Next Class:
Why does the Sun Shine?

HW5 due on Monday
EC due now!

Exam 1 on the 1st!

Music: *Sonne*– Rammstein

Exam 1

- Exam 1 in this classroom on Oct 1st
- 40 Multiple choice questions
- Will cover material up to and including Friday.
- May bring 1 sheet of paper with notes
  - Both sides
  - Printed/handwritten/whatever.. I don't really care
- Major resources are lecture notes and homeworks
- Try to understand major points more than anything.
- Have created and posted a study guide

Night Obs

- Dates:
  - Monday, Oct. 4th
  - Tuesday, Oct. 5th
  - Wednesday, Oct. 6th
  - Thursday, Oct. 7th
  - Monday, Oct. 11th
  - Tuesday, Oct. 12th
  - Wednesday, Oct. 13th
  - Thursday, Oct. 14th

Go to assignment page on class website for more info.

You **MUST** download worksheet before you go.

Can be cloudy, so check webpage before you go.

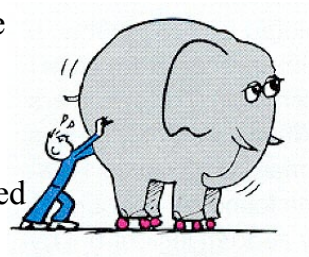
Outline

- Mitigations for asteroid threats

- The Sun is aging…
- It will run out of fuel…
- Even still it will get hot on Earth before that…

Early Detection is Key

- The earlier we can detect a threat, the easier it is to mitigate the danger. http://www.youtube.com/watch?v=XPS-m_sI7_k
- 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.
- And new comets would only have warnings of a few months!



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

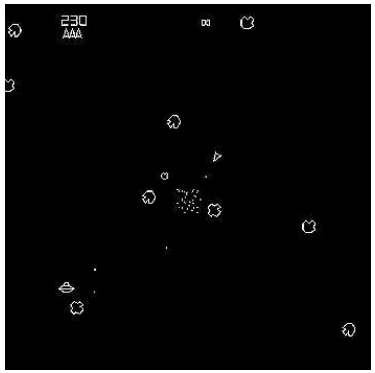
So How to Mitigate?

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

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 2013 or 2015!
- The aptly-named Don Quijote mission

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

Don Quijote

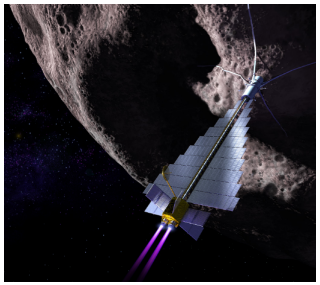
Two components:

- 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

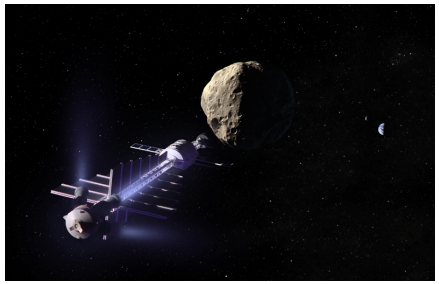
The Ole' Space Tug

- 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?



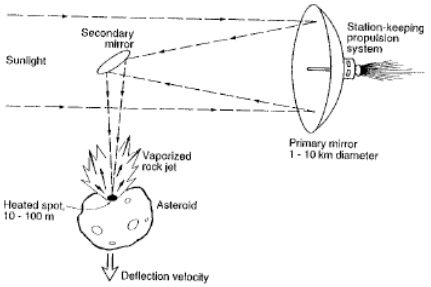
Gravity Tractor

- 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!

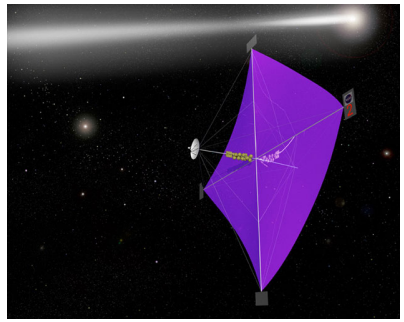
- Use the Sun to melt the asteroid surface.
- This removes material and creates a jet.
- http://www.youtube.com/watch?v=dcqFy1zjdys



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.



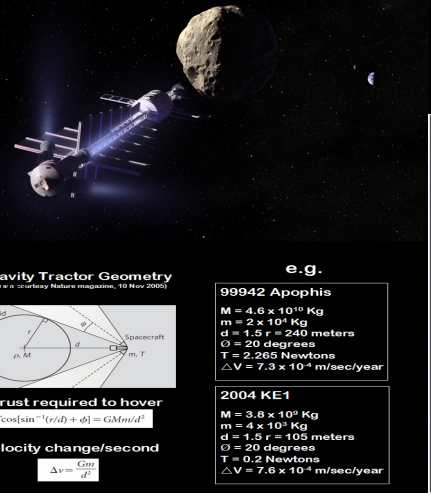
We do know of an asteroid that has a 1 in 300 chance of hitting us in 2880. What should we do?

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.

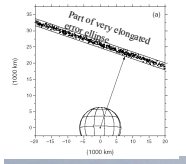
Apophis: Where it Could Hit in 2036… Gravity Tractor to the Rescue?

Apophis now has 1-in-250,000 chance of passing thru a keyhole in 2029, then striking somewhere on path-of-risk on April 13, 2036

Scientist/ astronaut Ed Lu

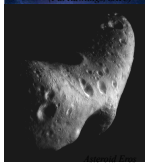


Common Misperceptions

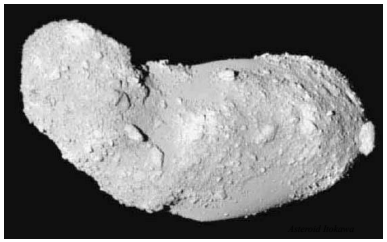


- Long waiting time until next impact
  - Instead, we should think of *chances* of disaster and our responsibilities "on our watch"
- Judging consequences quantitatively
  - Civilization-ending impact vs. K/T mass-extinction
  - "one death" vs. 100 deaths/yr vs. 3000 9/11 dead vs. we will *all* die in 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

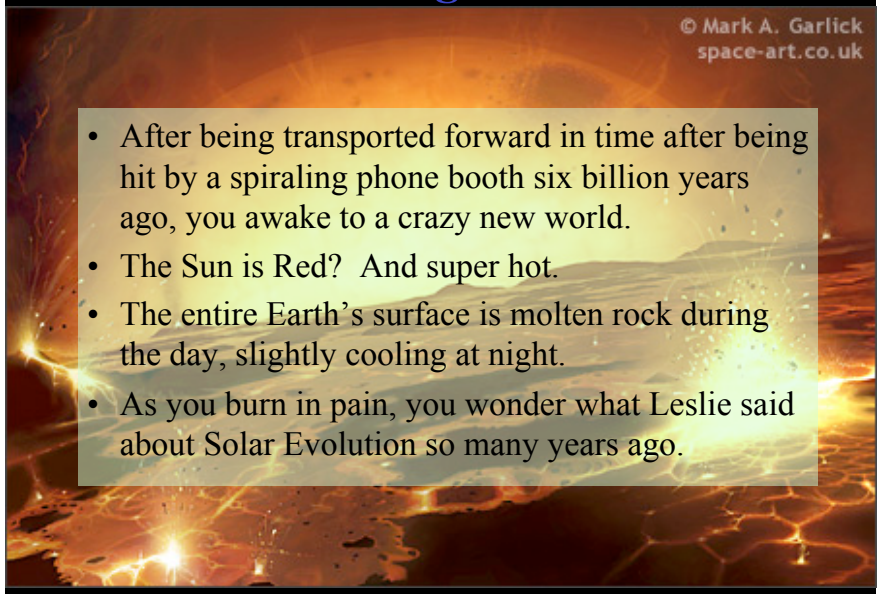
- An earthquake throws you to the ground, and you get a little worried as you notice that the trees in the distance have burst into flames.
- A sound wave bears down on you at 700 mph!
- Like a mighty thunderclap, it sweeps over you, pulverizing all the nearby buildings…
- As your body disintegrates,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

Asteroids are the number one astronomical threat, but not the only one!

Imagine

- After being dropped into suspended animation in a Pizza accident a billion years ago, you awake to a crazy new world.
- Disregarding the signs warning people to stay underground, you wander outside and see that the Sun is only about 10% more luminous, but it is crazy hot and the oceans are nearly gone.
- As you quickly succumb to heat stroke, you wonder what Leslie said about Solar Evolution so many years ago.

Imagine



- After being transported forward in time after being hit by a spiraling phone booth six billion years ago, you awake to a crazy new world.
- The Sun is Red? And super hot.
- The entire Earth's surface is molten rock during the day, slightly cooling at night.
- As you burn in pain, you wonder what Leslie said about Solar Evolution so many years ago.

Top 10 Ways Astronomy Can Kill you or your Descendents

2. Solar Evolution!

The Sun seems eternal, but it is changing. It has already changed quite a bit, and it will end!

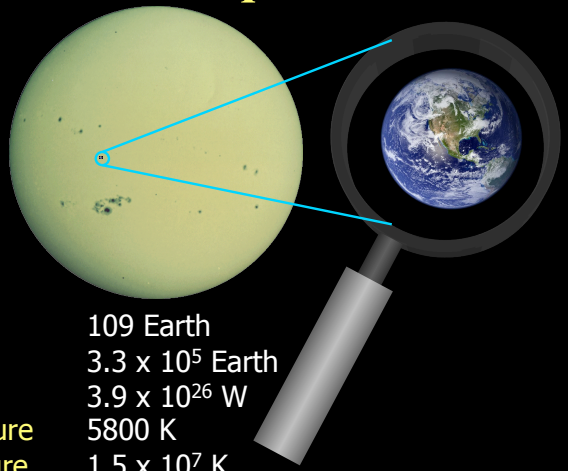
I mean rock impact may never happen, but this is going to happen.

The Sun will become a Red Giant, then a White Dwarf, and the party stops!

http://www.youtube.com/watch?v=Q-jsJF09AHA

Earth-Sun Comparison

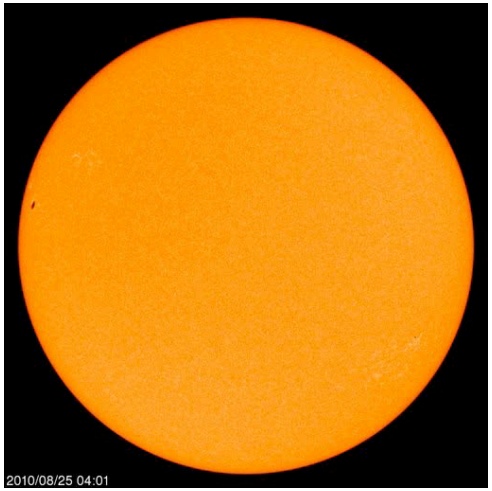
In general, a very typical star. Keep in mind that it is really a ball of gas/ plasma.



Visual radius	109 Earth
Mass	3.3×10^5 Earth
Luminosity	3.9×10^{26} W
Surface temperature	5800 K
Central temperature	1.5×10^7 K
Rotation period	25 days

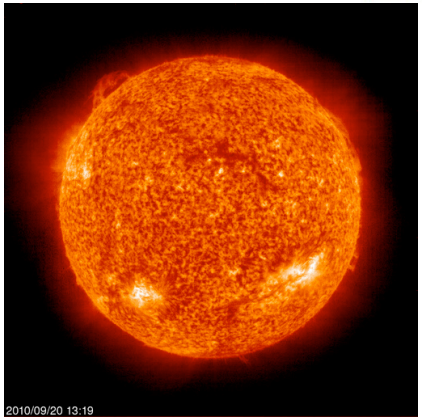
LIVE from the Sun

http://sohowww.nascom.nasa.gov/data/realtime/mpeg/



Question of Stability

- The Sun's size is constant.
- No weatherman says it will be especially hot tomorrow as the Sun's size will be increasing.
- Not expanding or collapsing.
- The Sun is stable! Why?



http://sohowww.nascom.nasa.gov/data/realtime/eit_304/512/

http://www.londonstimes.us/toons/index_medical.html

Question of Stability

- Not trivial, could have gone the other way
- Think: Sun is made of gas, yet not like a cloud, for example, which is made of gas but size, shape changes all of the time
- Not a coincidence: really good reason

"I just don't feel stable."

http://www.londonstimes.us/toons/index_medical.html

Why is the Sun Stable?

- What keeps gravity from collapsing the Sun?

- What keeps the Sun from exploding?