Astronomy 330

<u>This class (Lecture 23):</u>
Lifetime 2
Matthew Zettinger

<u>Next Class:</u>
Future of Civilization
Adam Flanders
Stefanie Pansch

Papers due today
HW10 is due Thursday.

Music: *Supermassive Black Hole*– Muse

Presentations

- Matthew Zettinger
  Alien Abduction

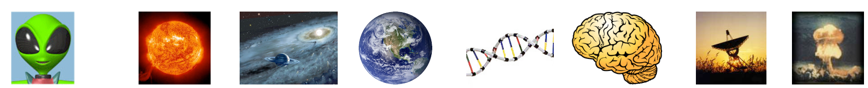
Outline

- Lifetime of alien civilizations.
  - End of the Sun (Solar System)
  - End of the Universe
- What is L?

Drake Equation

Frank Drake

That's 0.96 Communicating life/year



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

N	R_*	f_p	n_e	f_l	f_i	f_c	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
	20 stars/ yr	0.8 systems/ star	2 x 0.11 = 0.22 planets/ system	0.775 life/ planet	0.505 intel./ life	0.7 comm./ intel.	yrs/ comm.

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

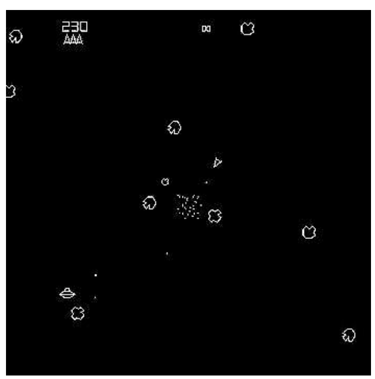
So How to Mitigate?

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

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

Don Quijote

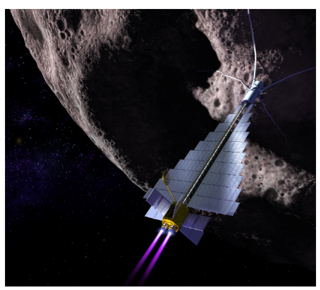
Two components:

- 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

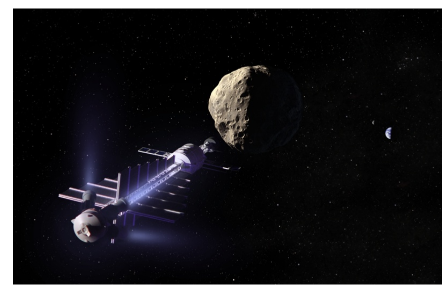
The Ole' Space Tug

- 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?



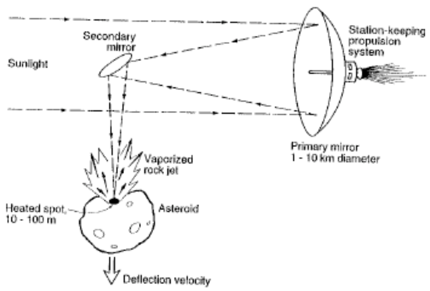
Gravity Tractor

- 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!

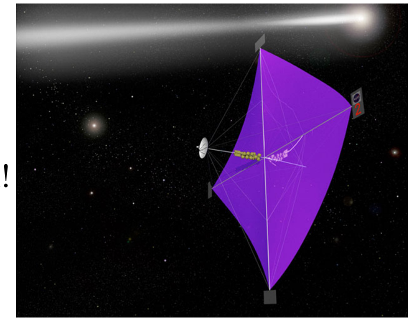
- Use the Sun to melt the asteroid surface.
- This removes material and creates a jet.
- http://www.youtube.com/watch?v=dcqFy1zjdys



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

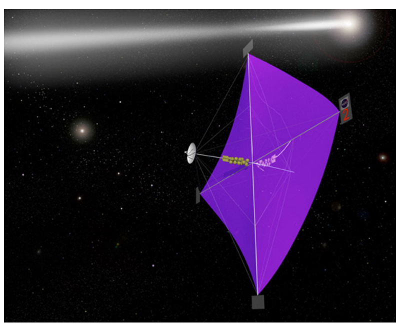
Other Propulsion: Light Sails

- 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.



Other Propulsion: Light Sails

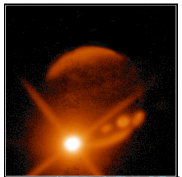
- Attach to an asteroid?
- It can work, but it would be slow.
- How to attach to a tumbling, rotating asteroid that may only be a big pile of rubble?

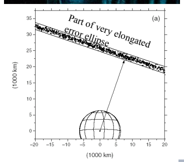


Other Ideas

- 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.

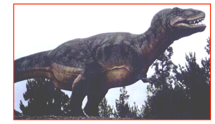
Common Misperceptions

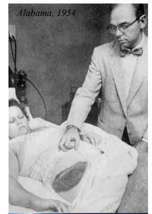


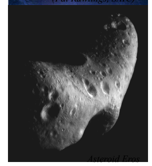


- Long waiting time until next impact
  - Instead, we should think of *chances* of disaster and our responsibilities "on our watch"
- Judging consequences quantitatively
  - Civilization-ending impact vs. K/T mass-extinction
  - "one death" vs. 100 deaths/yr vs. 3000 9/11 dead vs. we will *all* die in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

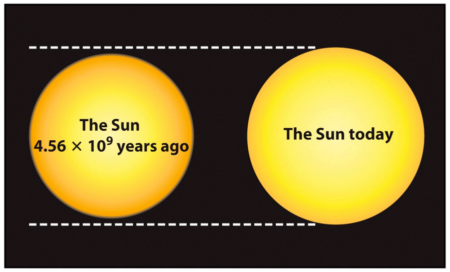
4. Natural Catastrophes

3. Stellar Evolution
   - The Sun is halfway through its lifetime on the main sequence.

http://www.astroimages.net/Media/SolarSys/AR03.html

Life of a Low Mass (Sun-like) Star

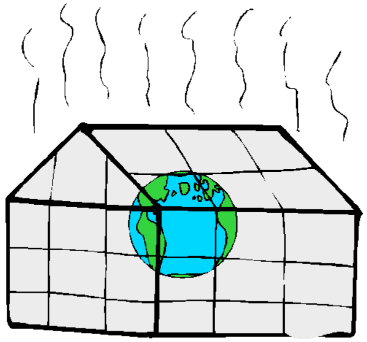
- Most of its life is spent in the happy pursuit of burning H ⇒ He
- With time, luminosity and temperature evolve gradually in response
  - Stays on the Main Sequence, but still evolves..
- The Sun is now 40% brighter and 6% bigger than zero age MS.



http://wings.avkids.com/Book/Myth/Images/ocean_sun.gif

Life of Our Sun

- Over the next billions of years, our Sun will continue to increase in luminosity.
- So in 1+ billion years, our Sun will be 10% more luminous.
- This will cause a "moist" greenhouse effect adding 10 degrees F to the average temp.



http://www.solcomhouse.com/Greenhouse_Effect.gif

Life of Our Sun

- This increase in total energy will have a major impact on the Earth!
  - Ice caps melt
  - Costal regions flood
  - Equator becomes uninhabitable
  - Antarctica becomes warm

http://changeyourways.wordpress.com/2009/06/12/what-on-earth/

Life of Our Sun

- Increased temperature means that the lighter elements, like water molecules in the air, will have enough speed to escape Earth completely.
- The water of Earth begins to pack up and leave!
- In 1.1 billion years, the continents will be deserts and the oceans are beginning to evaporate.

http://www.esquire.com/cm/esquire/images/Gd/desert-1108-lg.jpg

Life of Our Sun

- As the Sun, uses up the hydrogen in the core, the Sun increases by 40% in brightness in 3.5 billion years.
- By that time, all of the oceans are gone!
- The baking sediments at the bottom of the oceans, release CO_2
- Earth will become Venus-like!
- Then the heat makes even those heavier molecules leave the Earth.
- The Earth will be a barren rock in about 4 billion years!

http://wings.avkids.com/Book/Myth/Images/ocean_sun.gif

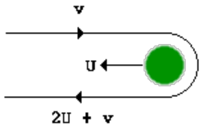
Mitigation

1. Move the population
   – I hear that Mars could be a nice place to live.
   – Need to terraform Mars, which could take a while.

http://www-cache.daz3d.com/sections/contests/upload_files/3195.jpg

Mitigation

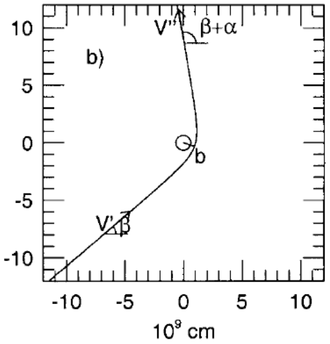
2. Move the Earth
   – There is no place like home, so move it to a nicer place, farther away from the Sun.
   – Use gravity assist or the sling shot technique.



http://upload.wikimedia.org/wikipedia/commons/8/8e/Grav_slingshot_simple_2.gif

Mitigation

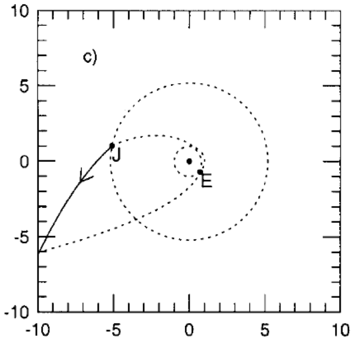
2. Move the Earth
   – Asteroids to the rescue?
   – Move many large asteroids in front of the Earth, sends them toward the Sun and the Earth outwards.
   – Need to do this every 6000 years to make Earth survive until the Sun hits the Red Giant phase.



Korycansky et al. 2001

Mitigation

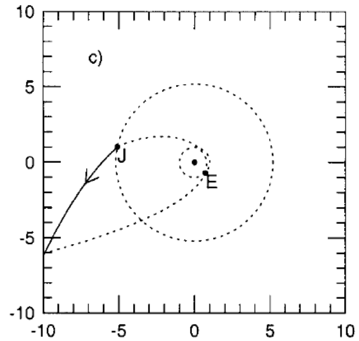
2. Move the Earth
   – For billions of years!
   – We don't have enough large asteroids.
   – We'll have to recycle.
   – The idea is to transfer energy from Jupiter's orbit to Earth's orbit.



Korycansky et al. 2001

Mitigation

2. Move the Earth
   – Could keep us safe for a good 6 billion years!



Korycansky et al. 2001

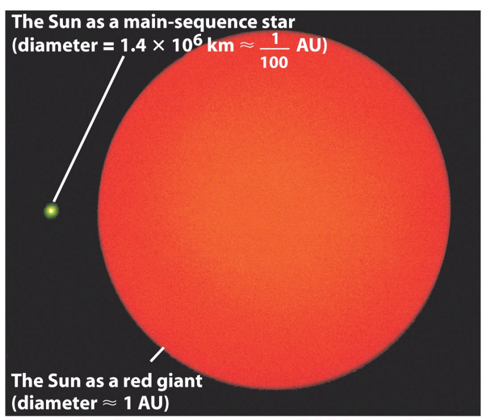
How much Gas do we have left?

- Even if we could save the Earth during this time of increased brightness, eventually the Sun runs out of fuel.
- Total energy available is easily calculated by mass of hydrogen in Sun and energy released by each hydrogen conversion.
- We only have about 6 billion years left!

http://skeptically.org/sitebuildercontent/sitebuilderpictures/.pond/suv-econ-gas-pump.jpg.w300h294.jpg

In 6-7 Billion years

- The Sun will expand to 100-250 times bigger than it is now!
- The same mass but now it's bigger.



The Sun today and as a red giant

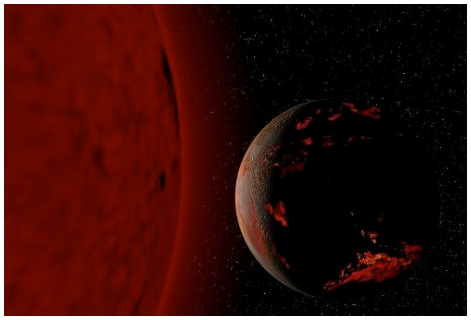
In 6-7 Billion years

- The surface gravity decreases and the Sun has more luminosity.
- The solar wind turns into a stellar wind, and it looses material as it expands, about 10^7 times more than now.
- It's blowing it all away!

http://www.astropix.com/wp/wp-content/uploads/2006/12/2006_02.JPG

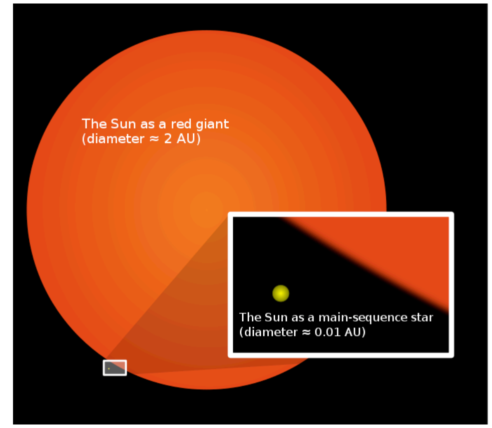
In 6-7 Billion years

- During the time it expands the Sun loses a significant fraction of mass.
- So, the planets move outward.
- Planets race away as the Sun expands.
- Who wins?
- We aren't yet sure.



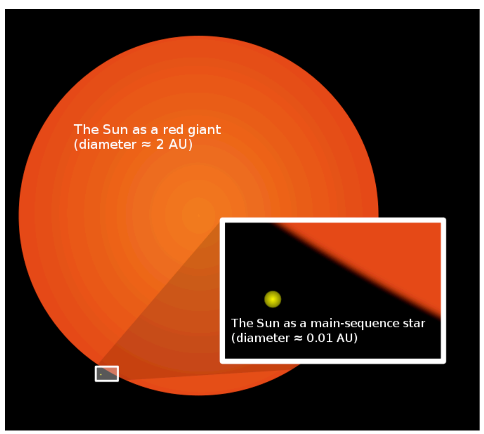
In 6-7 Billion years

- We use to think that the Sun would gobble the Earth.
  - Mercury gone
  - Venus probably gone
  - Earth?
- BUT even if not, with the Earth's oceans and atmosphere gone, crust still melts.
- Not good…



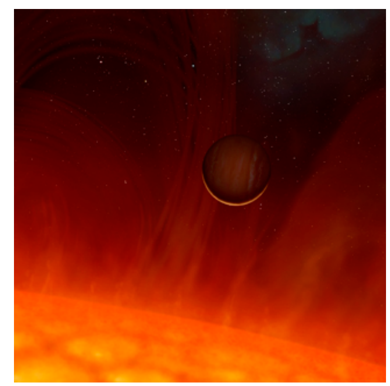
In 6-7 Billion years

- Mars?
  - For sure too hot.
- Jupiter's Moons?
  - Still too hot
  - Europa's water vaporizes
- Even the moons of Uranus and Neptune may be too hot.



Mitigation

- We would have to move the Earth out to Pluto or further!
- Probably not possible.
  - Interactions with Jupiter may eject us from Solar System
- Even then, Sun no longer in equilibrium, may oscillate in size or brightness.
- BUT, we got billions of years to figure it out!



http://www.sciam.com/media/inline/FA992809-E7F2-99DF-30B7058698177187_1.jpg

Natural Catastrophes

3. Stellar Evolution
   - Advanced civilization can likely find solutions.
   - Eventually, we would have to leave the Earth, move the Earth, or move to Mars.

http://www.boulder.swri.edu/~terrell/dtart_old.htm

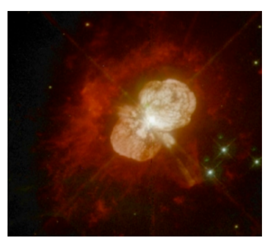
Question

In 5 billion years, our Sun will begin to turn into a red giant, on its way to a white dwarf. But never fear,

a) An advanced civ can stop the Sun from evolving.
b) We can always move to Venus.
c) An asteroid will probably hit and destroy the Sun first.
d) The Moon will be fine.
e) The Earth's oceans will evaporate before then.

4. Natural Catastrophes

4. Killer Supernovae!
   - Death of a nearby massive star would be bad news.
   - Explosion within 30 ly would destroy ozone layer.
   - Right now, no candidates.
   - Unlikely to happen in time scales of less than 2 billion years.
   - A supernova event ~2 Myrs ago may account for an extinction event.



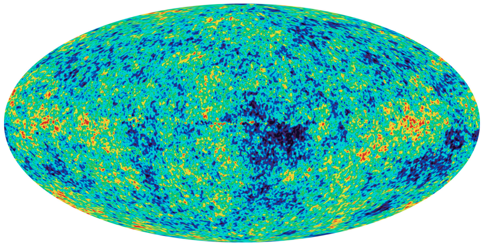
Question

A nearby killer supernova

a) is the most scary, as we won't know about it.
b) would have to be very close, but it could destroy the ozone layer .
c) is a supernova in our Galaxy.
d) would not cause any real damage, no matter how close it was.
e) will evaporate the oceans.

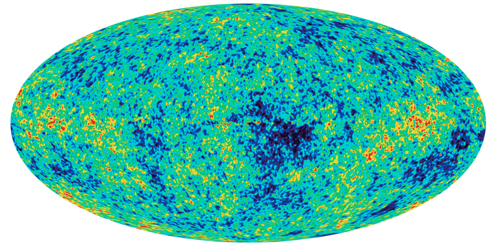
4. Natural Catastrophes

5. Ultimate limit to L!
   - Fate of the Universe.



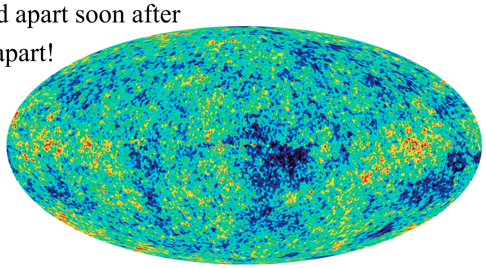
4. Natural Catastrophes

5. Ultimate limit to L!
   - A Big Crunch: 10^{12} years (a trillion years)
     - But, WMAP results from the cosmic microwave background suggest that we are in a flat universe.
     - Which does include dark energy



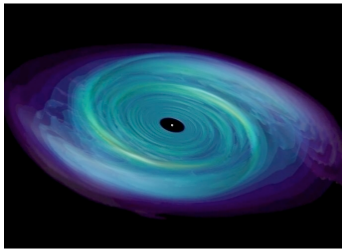
4. Natural Catastrophes

5. Ultimate limit to L!
   - The Big Rip?
     - If repulsive force increases– Brooklyn may expand too.
     - Gravity/E&M forces can not hold Galaxies rip apart
     - Could rip the MilkyWay apart in ~1 billion years
     - Earth gets ripped apart soon after
     - You get ripped apart!



4. Natural Catastrophes

5. Ultimate limit to L!
   - Big Rip seems unlikely
   - We'll know soon.
   - If we are just in a flat Universe, then it is a matter of energy.

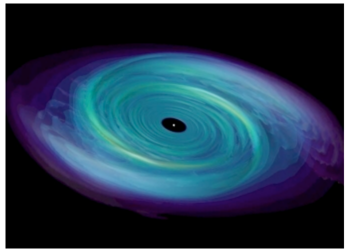


http://www.youtubeom/watch?v=oGVYG0ce1Ps

http://homepages.wmich.edu/~korista/web-images/accretion_ncstate.jpg

4. Natural Catastrophes

5. Ultimate limit to L!
   - The end of the Universe… the death of the dark.



http://homepages.wmich.edu/~korista/web-images/accretion_ncstate.jpg

Stelliferous Age: 10^8 to 10^{15} years

- Last stars to form will happen in a few hundred billion years.
- Stars age and die
- In about trillion years all Sun-like stars are gone from the Universe forever.
- Only stars left are low-mass red dwarfs (~0.1 solar masses), which can live for trillions of years
  – Lots of these stars and they get brighter with age, so Galaxy brightness doesn't change too much

Stelliferous Age: 10^8 to 10^{15} years

- In 7-8 trillion years, in our Galaxy (Milkomeda), the last red dwarf stops fusing, becoming a white dwarf.
- These tiny white dwarfs will stay hot for quite some time.
- Wait another few trillion years and they fade.
- So when the Universe is 100 trillion years old, the Universe goes dark.

Really Dark

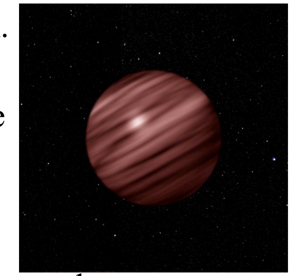
- If the Universe keeps expanding, it get worse for astronomers.
- The Galaxies we can see now, far away galaxies move out of our view.. Too far to see given the age of the Universe… out of our horizon.
  – The observable Universe is less and less
- The one giant elliptical galaxy (all that is left from our local group) is all that can be seen.
- The Universe appears empty!

Humans?

- We have 100 trillion years!
- Maybe longer, by smashing stars together to make fusion last longer.
- Won't last too long.
- When the Universe is slightly older than 100 trillion years old, the human race is out of fuel, out of stars, and out of luck.
- But the Universe isn't done!

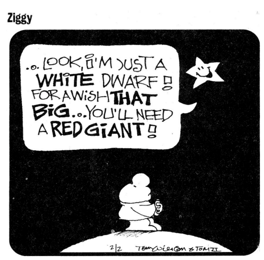
The Degenerate Era: 10^{15} to 10^{40} years

- Stellar corpses are all around the Galaxy.
- Every once in a while, a black hole will accrete a compact object, creating light again.
- Corpses may collide (remember we are talking 100 trillion years of time not the measly 13.7 billion of the Universe so far), and create new stars.
- Brown dwarfs, which did not have enough mass to fuse, can collide, making new stars.
- New life? Different Universe..



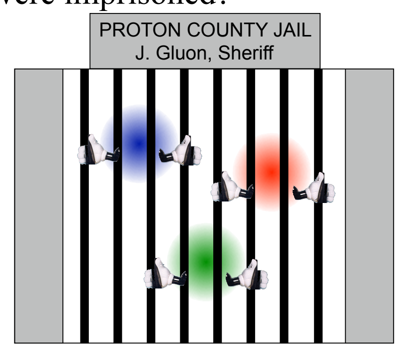
The Degenerate Era: 10^{15} to 10^{40} years

- But after a trillions, then quadrillions, and then quintillions of years, everything that can ever burn has happened.
- The Galaxy starts to lose weight.
  - Interactions with the stellar corpses, cause all the low-mass objects to be ejected from Galaxy.
  - High-mass objects fall to the center.
  - Supermassive Black Hole feeds!
- If the Earth still orbited the dead Sun (white dwarf) it is likely kicked out of the Sun and the Galaxy– a frozen dead planet in intergalactic space.



Proton Decay

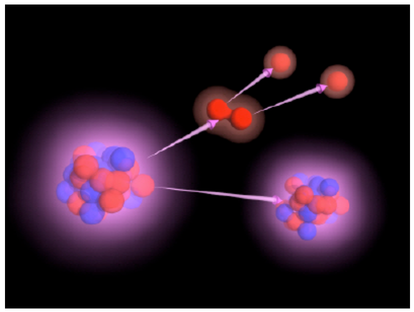
- Remember when quarks were imprisoned?
- We think that protons are radioactive.
- Except that they decay with a half-life of about 10^{31} years.
- Time is all that is left.



10^{31} years to life
Little chance of parole

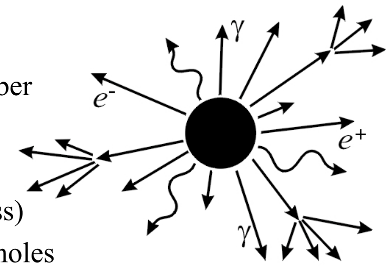
Proton Decay

- This proton decay creates heat again, feeble heat.
- What does non-proton life do?
- White dwarfs will evaporate
  - At -454 F, they are the hottest thing around!



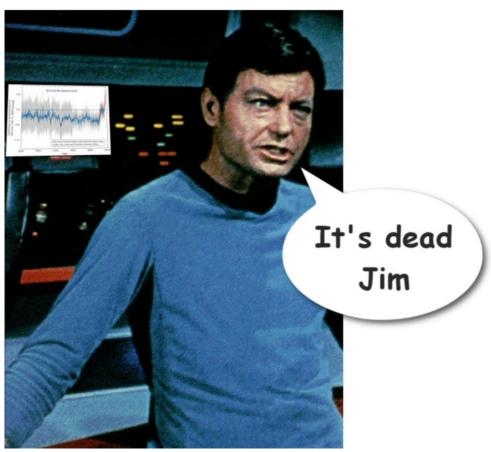
The Black Hole Era: 10^{40}-10^{92} years

- Black Holes survive.
  - Not made from matter, remember
- Galaxy is
  - The Supermassive Black Hole (1-10% of original Galaxy mass)
  - Trillions of stellar mass black holes
  - Lower mass stuff that was thrown out, so very far away.
- Hawking radiation is slow, but it will begin to evaporate the black holes
  - Slow, but lots and lots of time



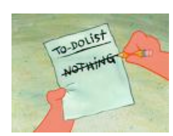
The Dark Era: 10^{92}- Infinity

- 10^{92} is crazy!
- I mean really, really crazy!
- The weight of a single proton to the rest of the Universe is only 10^{79}!
- Still, at this point, the Universe is dead!
- Dead Jim!



The Dark Era: 10^{92}- Infinity

- Beyond this, two particles will once in a great while interact, but nothing will really happen.
- Universe is dead, randomized, and silent.
- Nothing really will ever happen again..
- Or will it?

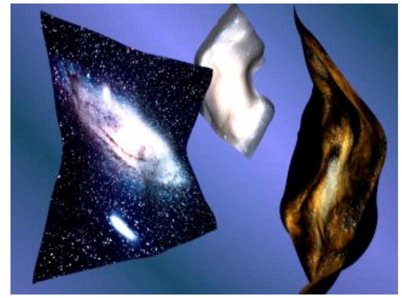


The Dark Era: 10^{92}- Infinity

- Rebirth?
- We don't know what caused the Big Bang.
- Maybe it happens again?
- Maybe it already has?

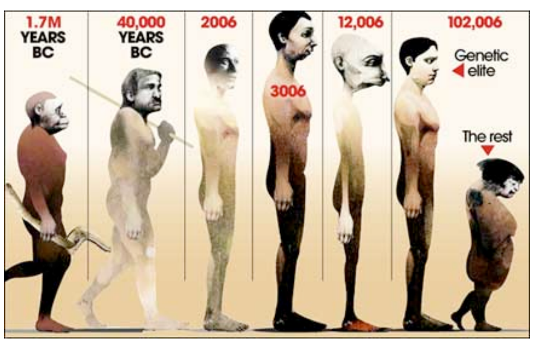
Branes, Branes!

- One idea is that the Universe has 11 dimensions
  - Our 4 dimensional Universe floats around in this space
  - Other universes float there too (called branes, short for membranes)
  - Sometimes they collide
  - Violently disturbed, energy/matter heat up, expanding space
  - Sounds familiar..



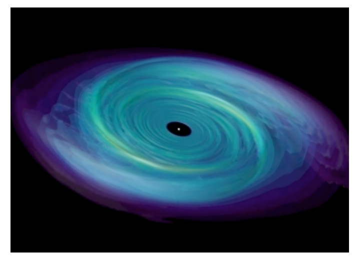
Mitigation

- Are you kidding me?
- If humans live this long, they won't be anything we'd recognize as human.



4. Natural Catastrophes

5. Ultimate limit to L!
   - Bottom line is that the maximum age is speculative.



http://homepages.wmich.edu/~korista/web-images/accretion_ncstate.jpg

Top 10 Ways Astronomy Can Kill Humans

1. Impacts
2. Sun Evolution/Coronal Mass Ejections
3. Supernovae
4. Gamma-Ray Bursts
5. Rogue Black holes
6. Rogue White Dwarfs
7. Galaxy Collisions
8. Cosmology
9. Quasars
10. Aliens

L-ing it

- We are talking about the amount of time that an advanced civilization (averaged over time) can communicate.
  - They may not want to for long periods of time
  - They may give up
  - They may be killed off
  - They may run out of resources
- Solving our energy problem (cheap energy) will give the largest lifetimes.

What is L?

- How long on **average** can an advanced civilization exist?
- Again, we only have a sample of 1 from which to discuss. What is our civilization's lifetime?
  - Short Term (100-1000 yrs)
    - Give up on communication due to budgets.
    - Depletion of resources.
    - Population.
    - War.
  - Long Term (10^5 to 5×10^9 yrs– age of galaxy is 10^{10} yrs and we took half of that to evolve)
    - Stellar Evolution.
  - Don't forget the random volcano, asteroid, or supernova.
  - Still in many cases an advanced civilization may be prepared for many of the issues!