Exam 2

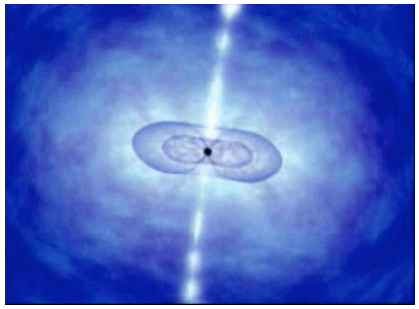
- Exam 2 in this classroom on Nov 5th
- 40 Multiple choice questions
- Will cover material from Lecture 12 to 25.
- May bring 1 sheet of paper with notes
  - Both sides
  - Printed/handwritten/whatever.. I don't really care
- Major resources are lecture notes, in-class questions, and homeworks
- Created and posted a study guide

Outline

- Short term GRBs, the threat
- Past Effects of GRBs on Earth

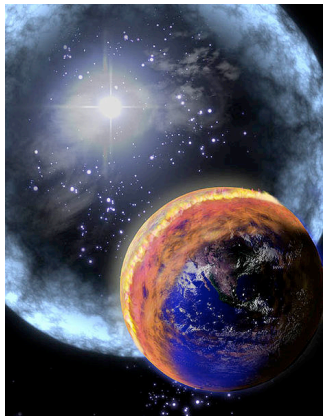
GRB Damage

- GRBs are similar to supernova, BUT they can be dangerous from further away, much further away.
- Let's play with a GRB beamed at the Earth from only 100 light years away.
- The beam will encompass the entire Solar System, but it will only last about 10 seconds.
- On the Earth, only one hemisphere will be in danger a first.



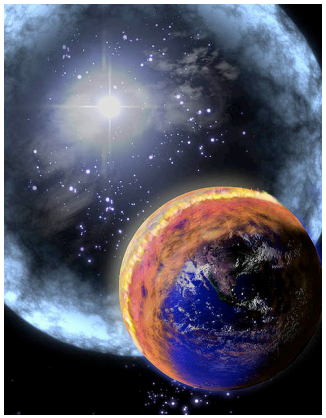
GRB Damage

- The energy dumped on the Earth's surface is staggering.
- It's like blowing up a 1 megaton nuclear bomb on every square mile of the surface.
- Probably not enough energy to boil away the ocean or strip away the Earth's atmosphere.
- But, this is still something that is 600 trillion miles away!



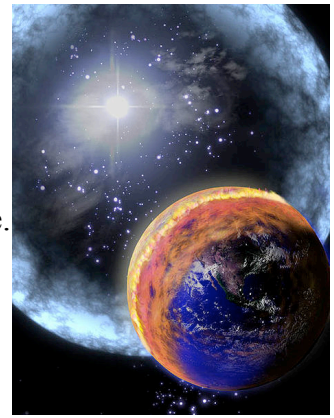
GRB Damage

- For a GRB that close, if you looked at the burst, you would be blinded.
- Outside, the heat would roast you.
- Then influx of UV would give you lethal sunburn



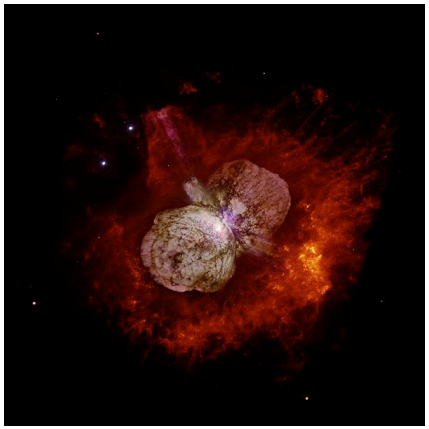
GRB Damage

- The ozone layer instantly destroyed.
- The Earth's surface would be sterilized, even underwater to a few meters.
- Perhaps best not to mention x-rays and gamma-ray exposure.



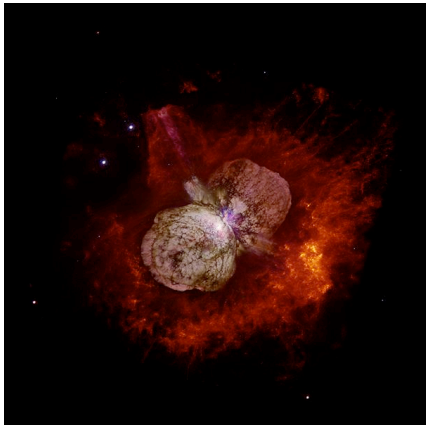
What's Nearby

- Okay, that was fun to speculate, but no likely candidates for GRB that close.
- They are more rare than supernova.
- So what is the possible nearest GRB candidate?
- One of the most massive stars in our Galaxy Eta Carinae, about 7500 light years away, in Southern Sky so can't see it from Urbana.



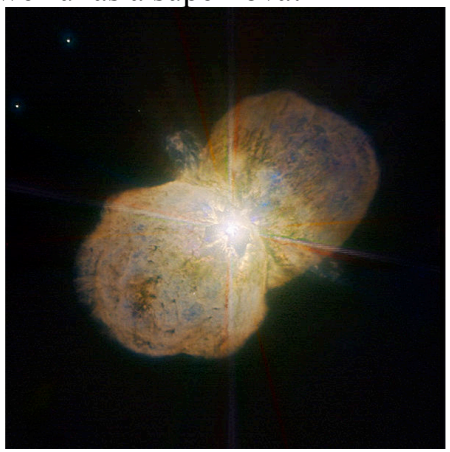
Eta Carinae

- Binary system, the most massive component of which is 4 million times brighter than the Sun!
- It give off more energy in one second as the Sun does in 2 months!
- About 100 solar masses!
- In 1843, Eta Carinae did something weird.



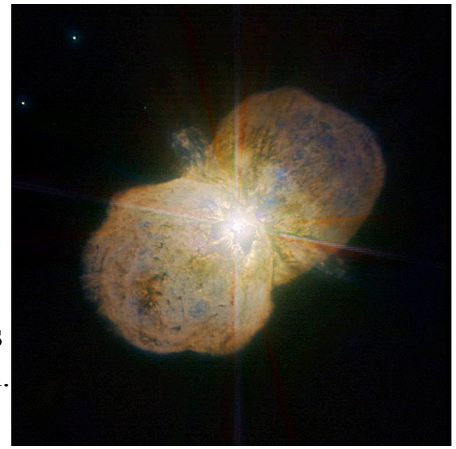
Eta Carinae

- It had a violent spasm, blowing off huge amounts of material, almost as powerful as a supernova!
- It was the second brightest star in the sky!
- It lost about 10 times the mass of the Sun, moving at a million miles per hour.
- Today, we see the aftermath as two huge lobes of material.



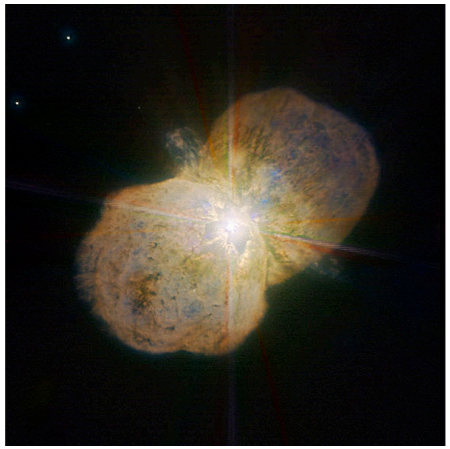
Eta Carinae

- These supernova impostors are seen in other galaxies too.
- We don't know when it will blow– today or in a million years.
- It might be a hypernova, or GRB, but maybe not.
- Regardless, the current orientation of the star (note, the lobes) suggests that it will miss the Earth.
- Can change though.



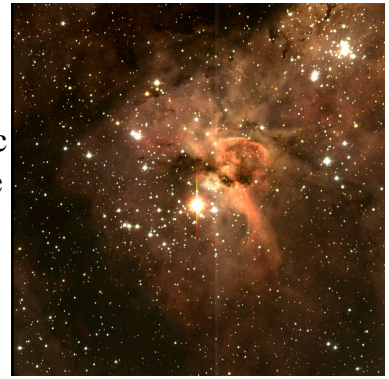
Eta Carinae Damage

- Let's play with what would happen if Eta Carinae did hypernova with the Earth in the beam.
- Even at 7,500 light years bad things will happen.
- Would be about 10 times brighter than the full Moon.
- The UV light from it would probably give a sunburn.



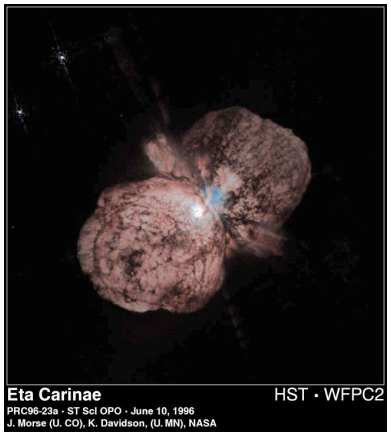
Eta Carinae Damage

- But the gamma-rays and X-rays?
- Absorbed by the atmosphere, but worse affects than nearby supernova.
- There would be a strong EMP (electromagnetic pulse) that would wipe out electronic devices for facing hemisphere
  - Computers
  - Power grids
  - Airplanes
  - Cars (emergency vehicles too)
- All fried!



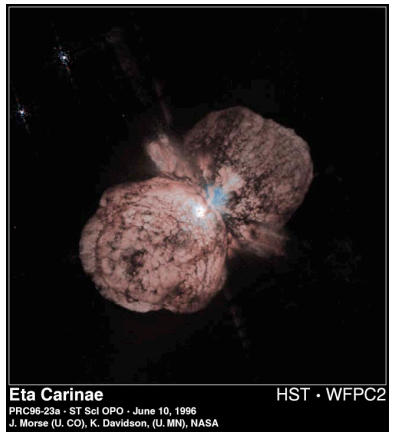
Eta Carinae Damage

- But, perhaps all that doesn't matter as the atmosphere is already feeling the affects.
- Ozone layer devastated
- Would take a decade to recover.
- Base of the food chain hurt badly.
- Create reddish-brown nitrogen dioxide, which will reduce the light, ice age anyone?



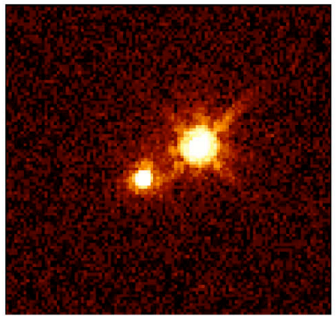
Eta Carinae Damage

- Nitrogen dioxide will also cause acid rain.
- In addition to light, the GRB will send out subatomic particles, creating a shower of muons (heavy electrons)
- That may imply something like 10 times a lethal dose!
- And muons can penetrate about ½ mile into rock, so everyone on that hemisphere is toast.
- 7500 light years is 50 quadtrillon miles away!



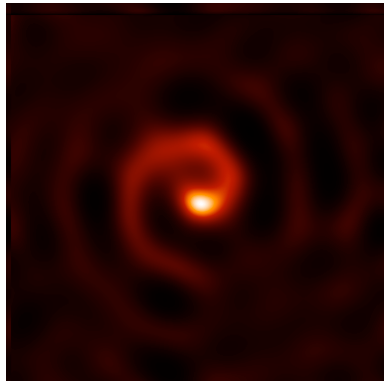
May I have another Sir?

- WR 104 has gotten considerable interesting as of late.
- It is a massive star about 7000 light years away toward the Galactic center.
- Again, a binary system.
- With deep Keck images, it looks more interesting.



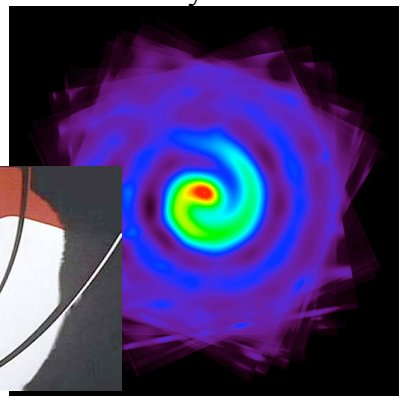
May I have another Sir?

- When you put together 8 months of images you see this.
- The two stars are orbiting.
- It looks like their rotation axis is pointing right at us!
- Down the barrel of a GRB gun?



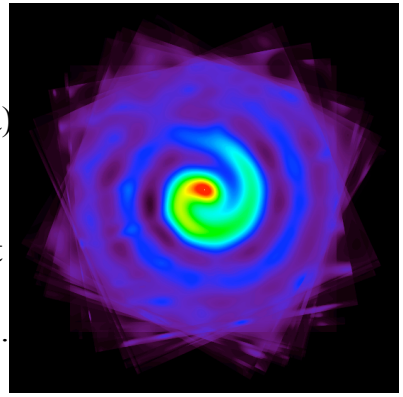
May I have another Sir?

- The most massive of the pair is in the last stage before a supernova, so it could blow at any time up to probably hundred thousand years!



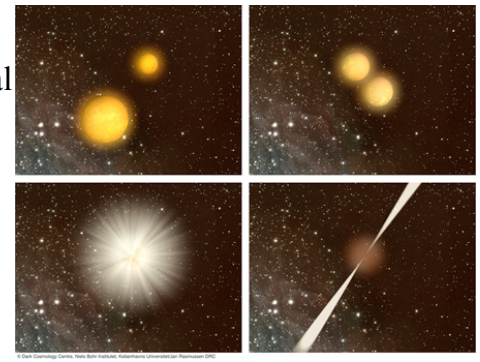
May I have another Sir?

- But, bottom line is we don't know if this star will be a GRB.
- Most GRBs are happening in distance past, so the increased metallicity of stars today (from supernova) may make it impossible to make GRBs today.
- New observations (different models) suggest that WR 104 is not pointed at us.
- Need more observations!



And Shorts?

- But what about neutron star-neutron star or neutron star-black hole mergers?
- Although not as rare as hypernova, since they don't have as much total energy in the burst, they are much less likely to cause death.
- So, keep them in mind but don't worry too much.

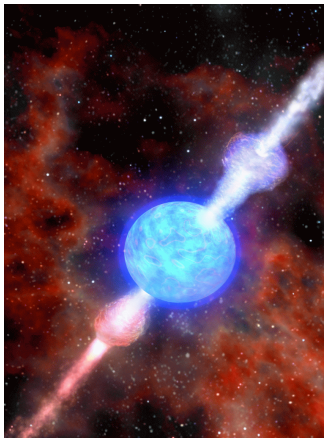


The Neutron Stars Merging Scenario

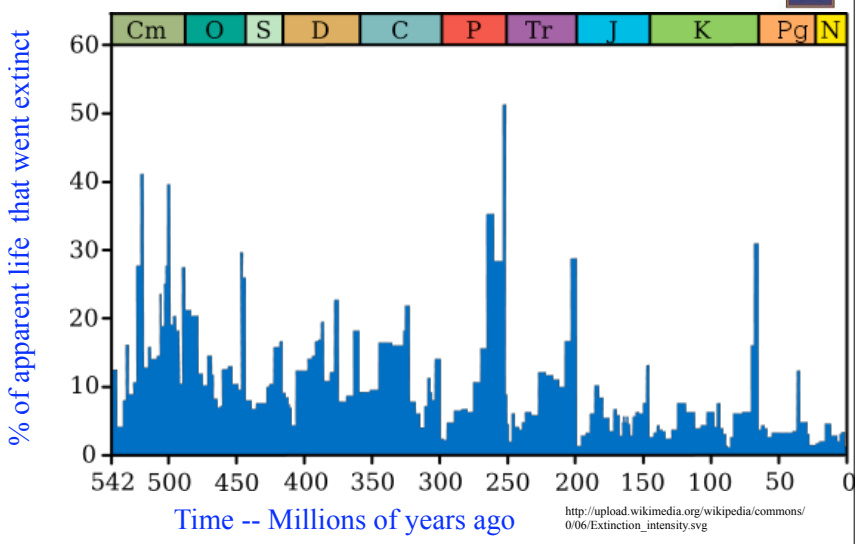
ESO PR Photo 32c/05 (October 6, 2005) © ESO

Rates?

- Based on the observed Universal rate of 1/day, we can estimate the GRB rate in the Milky Way.
- We expect about 1 burst per 100,000 or million years.
- But most are not beamed toward Earth.
- So about 1/billion years within 5000 light years.
- We have had ozone for two billion years, so any observable affect?



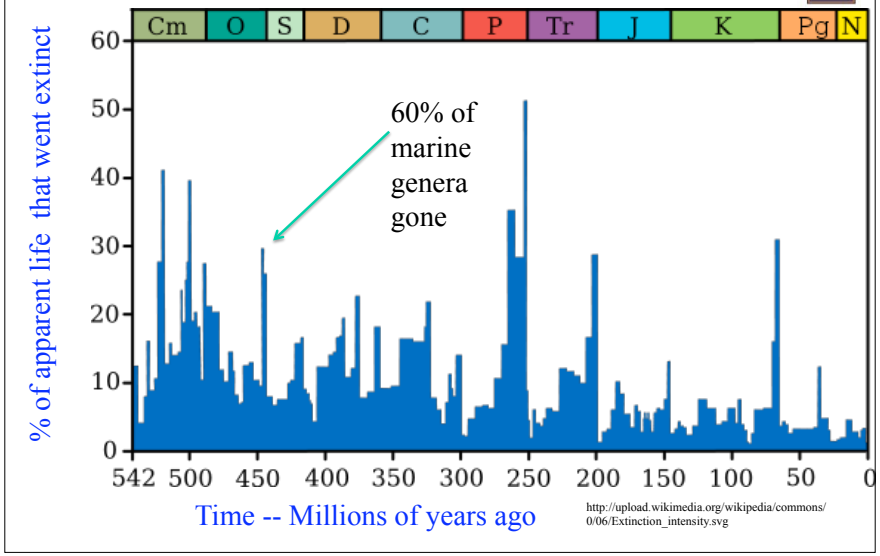
Extinction Events -- how many are due to GRBs?



GRBs and Mass Extinctions

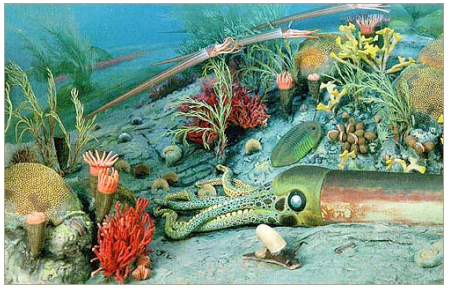
- Many possible causes for mass extinctions (remember impacts), but gamma-ray bursts (GRB) may also have contributed.
- A beamed GRB within our own galaxy could do considerable damage to the Earth's biosphere.
- And, a number of nearby GRB have irradiated the Earth since life originated.
- The late Ordovician event shows many characteristics that would be expected if it were initiated by a nearby GRB.

Extinction Events -- how many are due to GRBs?



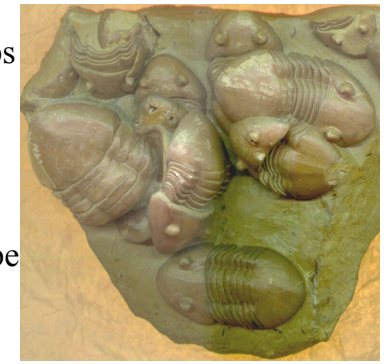
Patterns of Ordovician Extinction

- The late Ordovician is one of the largest mass extinctions in terms of its scale and scope.
- Two large, abrupt extinction events, separated by 0.5-2 million years.
- All major marine invertebrate groups show high rates of extinction during this interval.



Patterns of Ordovician Extinction

- The late Ordovician is unusual in that many groups like the trilobites, important Ordovician animal groups in terms of their relative abundance, diversity, and geographic range, go extinct while the more restricted groups persist.
- This is counterintuitive; one might predict that (due to stochastic factors) widespread, more abundant groups should be more extinction resistant.



Depth Dependence of Late Ordovician Extinctions

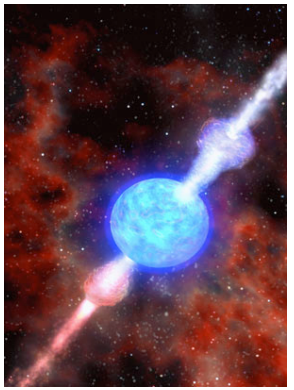
- Extinction of trilobites correlates with the amount of time spent in the water column.
- Young trilobites are plankton-like larva.
- Such animals were more likely to cover a broad geography, but they were more likely to go extinct during this time.
- During the late Ordovician, species dwelling in shallow water were also more likely to go extinct than species dwelling in deeper water.

Global Cooling and the Ordovician Extinction

- Extinction has been related to alternating global cooling and warming correlated with the two pulses of the late Ordovician mass extinction.
- There may be a link between GRB and global cooling.
- As mentioned before, GRBs produce atmospheric nitrogen dioxide, which initiates global cooling.
- Climate models of the Ordovician show that it is difficult to initiate glaciation without a forcing impulse, such as a period of reduced sunlight.

Ordovician/GRB Connection?

- Extinction could have been initiated by a nearby GRB.
- Ozone layer destruction followed by greatly increased solar UV would be catastrophic.
- And GRB could have triggered the global cooling: a one, two punch for life on the planet.
- Notably, the kind of water depth dependence found in the late Ordovician extinction pattern would emerge naturally from the attenuation of the UV radiation.



Predicted as GRB Effects	Observed in late Ordovician
Extinction of shallow (not deep) water organisms	Yes
Extinction of free-swimming organisms	Yes
Extinction of surface floaters (plankton) and organisms with planktonic larval forms	Yes
Nitric acid rain	Productivity oscillation in biosphere possibly related to nitrate boost
Reduction of solar radiation – cooling	Yes – glaciation needed "kick"

Extinction Conclusion

- A strong GRB irradiation of the Earth is probable during the time interval since O_2-enrichment of the atmosphere.
- Such an event would destroy the ozone layer, exposing organisms to dangerous levels of solar UV.
- At least one mass extinction shows characteristics compatible with GRB effects.

We have no smoking gun.

http://www.youtube.com/watch?v=0YQof5_E7sk 1:50

Mitigation

- Not much… there would be no warning.
- Only chance is to know about them.
- Although dangerous GRBs can be far away, we could examine them as necessary with best telescopes to determine danger levels…

Mitigation

- With time our civilization should travel to the stars to provide better chance of sudden death.
- But, remember GRBs are rare and unusual, so unlikely to happen.
- Don't worry, be happy.

Imagine

- The beam comes without warning.
- You're walking downtown, hanging out, suddenly, an incredibly bright light in the sky!
- It hurts to look at it at first, then it begins to dim.
- Hours later, silent subatomic particles slam into the Earth's atmosphere.
- No matter if people were inside or not, a large fraction of the Earth is exposed to lethal radiation.
- 60% of the population of the world starts dying from the high dose.

Imagine

- The ozone layer has been dramatically damaged, and solar UV radiation will kill off the food chain.
- A thick layer of smog forms and the sky turns a dark reddish-brown. Plants begin to die, then the acid rain starts.
- A new ice age begins.
- Survivors realize that the supermassive star Eta Carinae exploded.
- As you die, you wonder how a star trillions of miles away killed you, and why didn't Leslie talk about it in class?

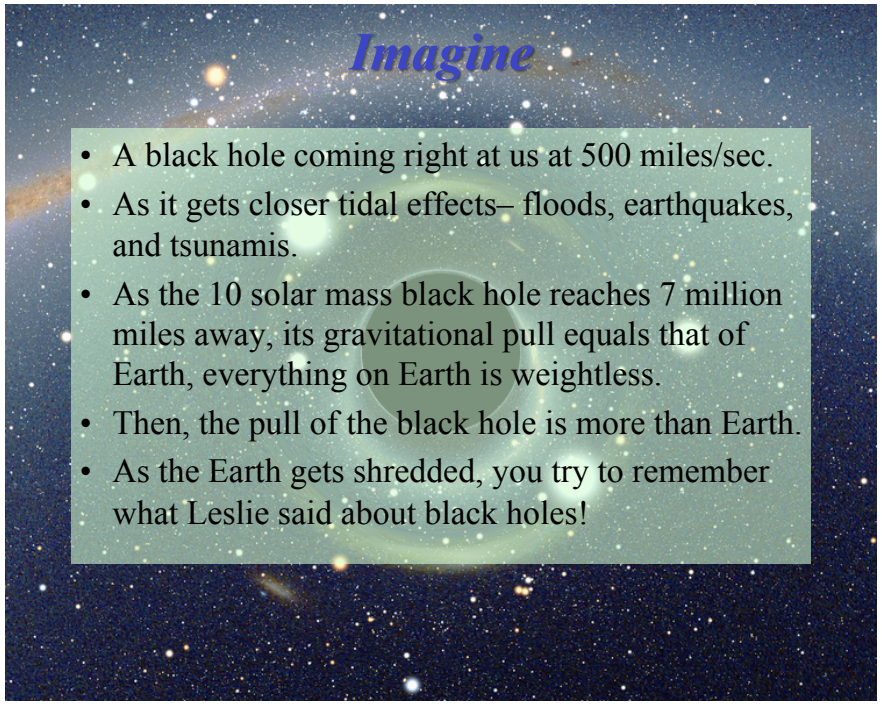
What about All those White Dwarfs, Neutron Stars, and Black Holes?

Could the large number of compact objects left over from stellar evolution cause any problems?

Would I be asking that question in this class if they couldn't?

Imagine

- An amateur astronomer trying to see Uranus is the first to notice. It's in the wrong place!
- Later, Jupiter is in the wrong place, then Mars!
- Even the Sun has moved!
- What is happening?! Oh, the Earth has moved.
- Panic spreads as scientist realize that a compact object has entered the Solar System and its mass is throwing off the orbits!
- Once the orbit was fixed for the object, telescopes looked for the object, but nothing– a black hole!



Top 10 Ways Astronomy Can Kill you or your Descendents

6. Rogue compact objects–White Dwarfs/Neutron Stars/Black Holes.

   Black Holes don't suck, but if they hit you it sucks.

A non-accreting black hole is nearly impossible to detect. Since the beginning of time all massive star's dead bodies litter the Galaxy. But still massive stars are not very common. Neutron stars and especially white dwarfs are more common, and if old enough, these will be hard to detect.

http://www.youtube.com/watch?v=ou3TukauccM&NR=1