Astronomy 150: Killer Skies

This Class (Lecture 18):
Boom, Supernova

Next Class:
Killer Supernova

HW6 due on Sunday!

Night Obs/Computer labs due in class on Oct 26th.

Music: ***We Are All Made of Stars*****– Moby**

Tonight

- FYI..
- I am giving a short lecture on star formation tonight at the Illinois Space Society meeting
- Wednesday at 7pm in 103 Talbot Lab
- No extra credit…

Night Obs

- Dates:
  - Monday, Sept. 21st ✔
  - Tuesday, Sept. 22nd ✗
  - Wednesday, Sept. 23rd ✗
  - Thursday, Sept. 24th ✗
  - Monday, Sept. 28th ✗
  - Tuesday, Sept. 29th ✔
  - Wednesday, Sept. 30th ✔
  - Thursday, Oct. 1st ✗
  - Monday, Oct 5th ✔
  - Tuesday, Oct 6th ✗
  - Wednesday, Oct 7th ✔
  - Thursday, Oct 8th ✗
  - Monday, Oct 12th ✗
  - Tuesday, Oct 13th ✗
  - Until 1 more clear night (M-Th) or up to the 22nd

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.

Turn in assignment in-class before Oct 26th or so.

Question

Did you go to the Observatory yet?

a) Yes, it was okay.
b) Yes, it was cool!
c) Yes, it was the highlight of my life so far!
d) Yes, but it was boring.
e) No, I admit that I put it off until the last minute. And I also agree that it might even be past the last minute. I realize that I may not get any credit for this. Gosh, I sure do hope that the sky clears up.

Question

Would people like the TA to have a few extra computer sessions sometime? Just for random help? Someone on the anonymous comments suggested this and if enough people are interested, I'll see what I can arrange.

a) Yes, I want them and will go.
b) Yes, I might go, but only if the times are convient.
c) Yes, I would like to go, but I doubt I will.
d) No, I don't need extra computer help.

1st Week of Nov?

I have to go to a conference/meeting in Munich the first week of Nov. Which of the following do you prefer?

a) Have a someone else lecture for those three days.
b) Do something else.

1st Week of Nov?

Which of the following "something else" do you prefer?

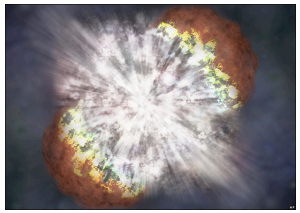
a) Do some more fields of asteroid finding.
b) Compass discussions of class topics, to be graded as participation.
c) Research papers
d) Changed my mind, more lectures with someone else.

Outline

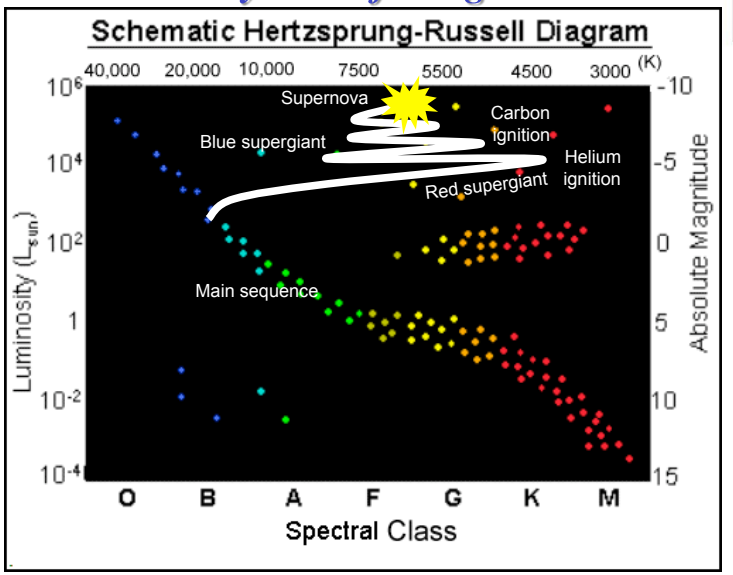
- Supernova explosion!
- Supernova Type I and Type II
- What happens to the Earth?

Core Collapse

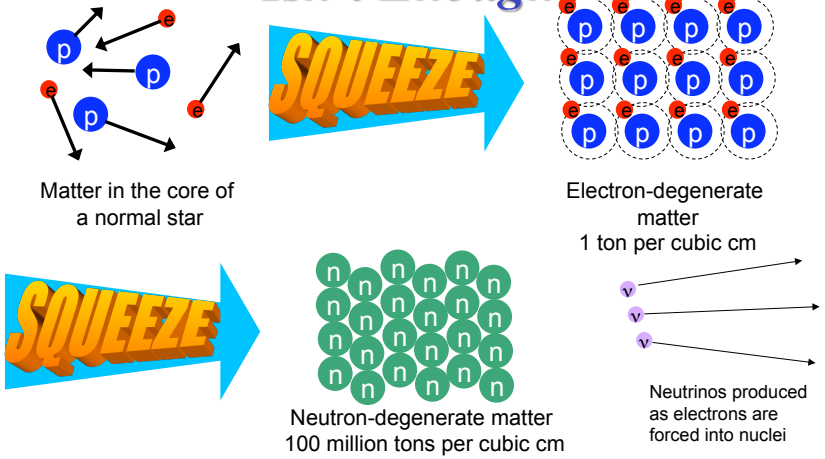
- Completely out of gas!
- Hydrostatic equilibrium is gone.
- The iron core of the star is supported by electron degeneracy pressure
  - Same pressure that supports a white dwarf
- Eventually, gravity wins…
  - This happens when the core is > 1.4 solar masses and no more outward pressure.
  - Remember the Chandrasekhar limit



Evolutionary Path of a High-Mass Star



When Electron Degeneracy Just Isn't Enough



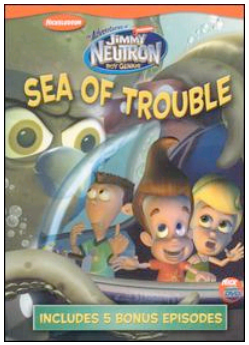
Question

What is the force that supports a white dwarf but can not support a massive stellar core.

a) Pressure from fusion
b) Pressure from CNO fusion
c) Electron degeneracy pressure
d) Gravity pressure
e) Neutron decency pressure

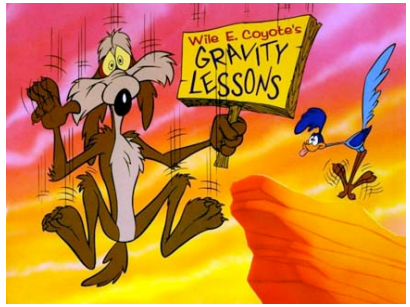
Core Collapse

- When core is greater than 1.4 M_{sun} – **core collapse!**
  - From 1,000 km across to 50 km in *1/10th of a second*
  - ***Nearly 10% speed of light!***
- The core is transformed into a sea of neutrons
  - Electrons are squeezed into protons, neutrinos released
  - High energy gamma rays produced
  - The core has nuclear density!
  - It Earth has same density, it would be 1000 feet in diameter



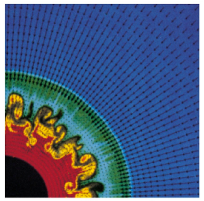
Core Collapse

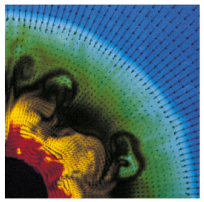
- Core suddenly collapsed
- Envelope has nothing left to stand on
- Envelope falls at significant fraction of the speed of light, slamming into compressed core



Supernova!

- Hitting the compressed core is like hitting a brick wall and the envelope gas reverses direction– blow-back.
  - But, by itself not enough to destroy star.
  - Material is so dense, that it is slightly opaque to the neutrinos produced
  - And 10^{58} neutrinos!
  - Neutrinos give the shock a "kick"
  - Rips the outer layers of the star apart
- Star explodes in a **supernova**


10 milliseconds


20 milliseconds

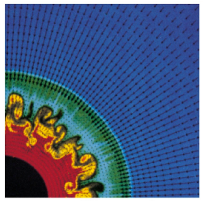
http://www.spacetelescope.org/images/screen/heic0609c.jpg

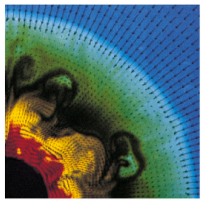
Supernova!

- The lifetime battle against gravity is lost.
- The core collapses under its own weight.
- Much of the mass of the outer region of the star, bounces back into space.

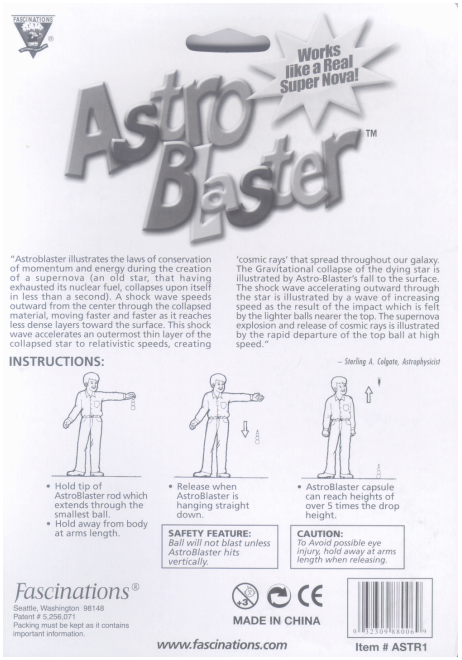
Supernova!

- The energy is enormous! The visible light is around only 1% of the energy output!
  - 99% of the energy in the form of neutrinos
- > 90% of the mass of star is ejected into space!
  - Fast, hot,





AstroBlaster!



Question

In the astroblaster demo, what did the little red ball represent?

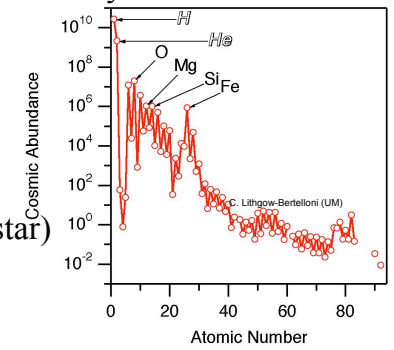
a) The inner core of the massive star
b) The envelope of the massive star
c) A low-mass stellar companion to the high mass star.
d) Iron.

Game Over!

http://www.youtube.com/watch?v=8MHb6_35XJM

Making Heavy Elements

- The star goes **supernova** and explodes. Some of C, O, P, S, Si, and Fe get carried away. At this point, even heavier elements can be made.
- During the explosion, energy-consuming fusion reactions are possible
- These by-products are *blasted* into space (>90% of star)
- Supernovae provide much of the building blocks for planets… and us!
- **We are recycled supernova debris!**
- **We are Star stuff.**

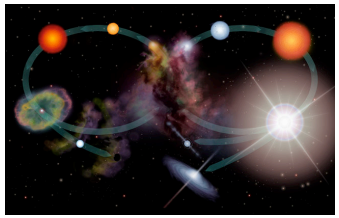


Delenn, B5

Stellar Evolution Re-Cycle

Circle of Life

- Massive stars form out of the interstellar medium
- They manufacture helium, carbon, nitrogen and more in their interiors by nuclear fusion
- Heavier elements (lead, uranium, etc..) are made during the supernovae
- Stars give these processed materials back to the interstellar medium when they die
- The processed materials are included in the gas and dust out of which the next generation of stars and planets will form



Question

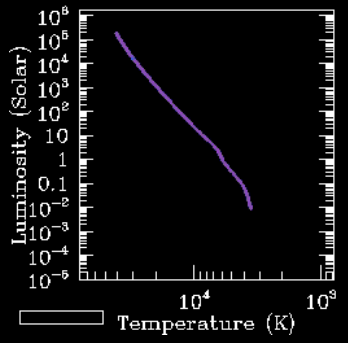
Why are we star stuff?

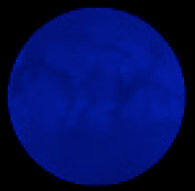
a) We are all going to Hollywood.
b) We are made up of small bits and pieces of stars.
c) We use fusion for power.
d) We are made up of the elements that were forged in the interior of stars.
e) We are just stuff, like stars.

Death throes

- What triggers a supernova?
  - Hydrostatic equilibrium is lost, gravity wins
  - Iron core with M > $M_{Chandra}$
- What happens?
  - Quick core collapse overcoming electron degeneracy pressure.
  - Outer layers rebound off the core, explosion of envelope

High Mass Stars (15 M_{sun})

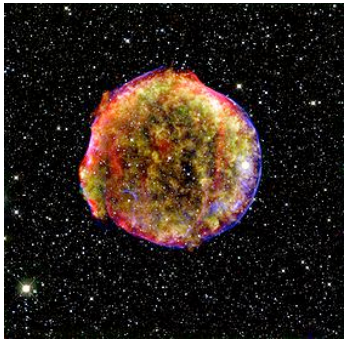




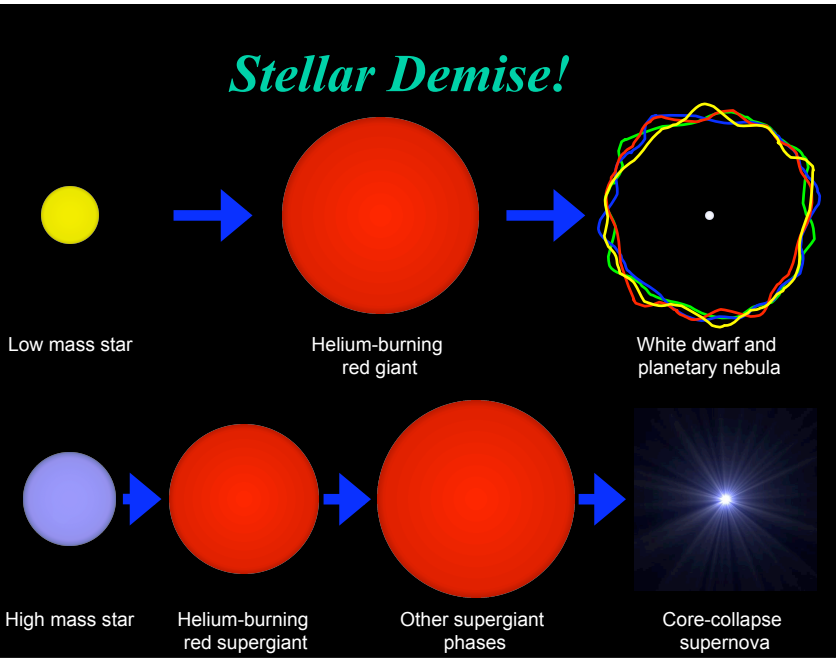
http://rainman.astro.uiuc.edu/ddr/stellar/index.html

Death throes: Type I

- So far, we've been talking about massive star core collapse supernova, which are called Type II.
- But there are also Type I supernova, from a white dwarf that exceeds the Chandrasekhar limit.
- Type I only occur in binary systems.

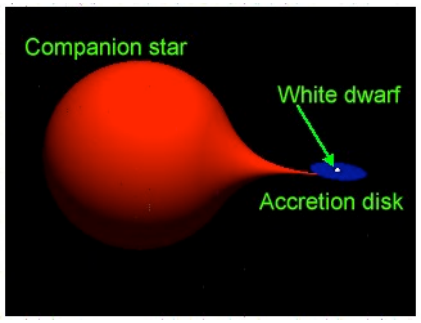


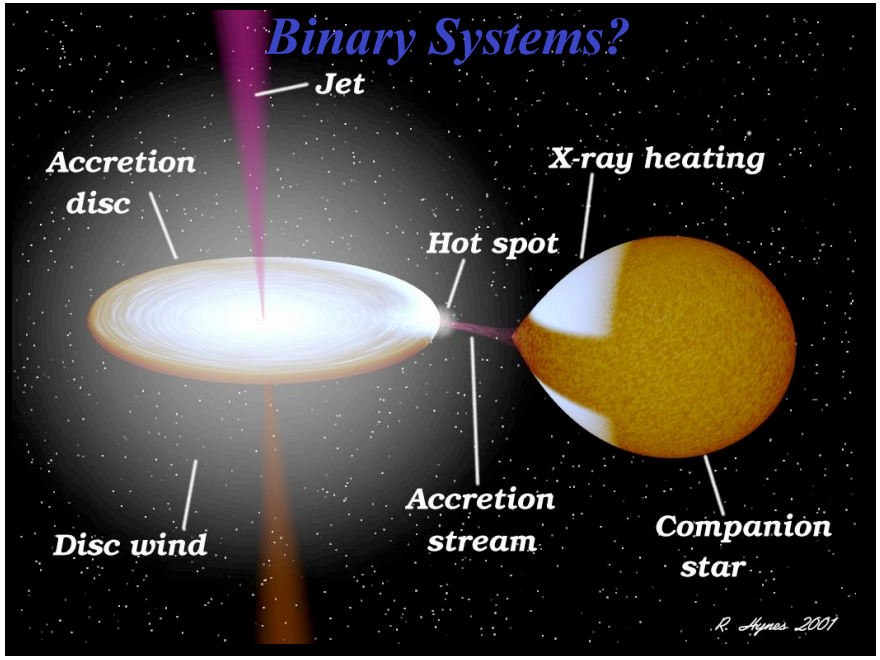
Stellar Demise!



Binary Systems?

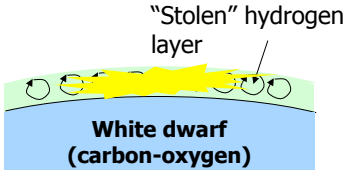
- In a close binary pair of stars with slightly different masses, the higher mass star evolves into a white dwarf first
- Later, the other star evolves into a red giant
- White dwarf then steals mass from its giant companion!

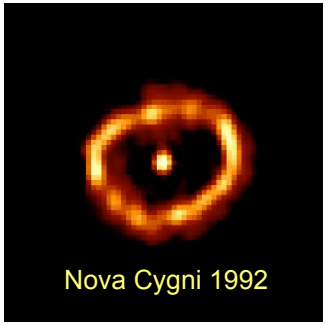




Novae

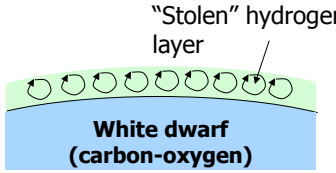
- If enough material piles up onto the surface of a white dwarf, can undergo explosive nuclear fusion
- White dwarf blows off this envelope and brightens by 100 – 1000 times
- Fades over a period of months
- This is called a **nova** (from Latin for "new")
- Common, about 20 per year in our galaxy





Supernovae: Type I

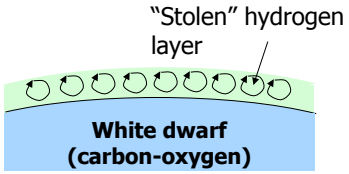
- If enough material piles up disaster is looming.
- The core suddenly reaches the Chandrasekhar limit– collapse!
- Causes a run away explosion that is hard to distinguish from a core collapse supernova.



http://www.youtube.com/watch?v=x0jh26fr8Xg

Supernovae: Type I

- Total energy is similar to a Type II
- However, Type I gives off more x-rays and gamma rays
  - This will even be more dangerous



http://www.youtube.com/watch?v=_0tn2sWyLFY