Astronomy 150:
Killer Skies

This Class (Lecture 20):
Killer Supernova

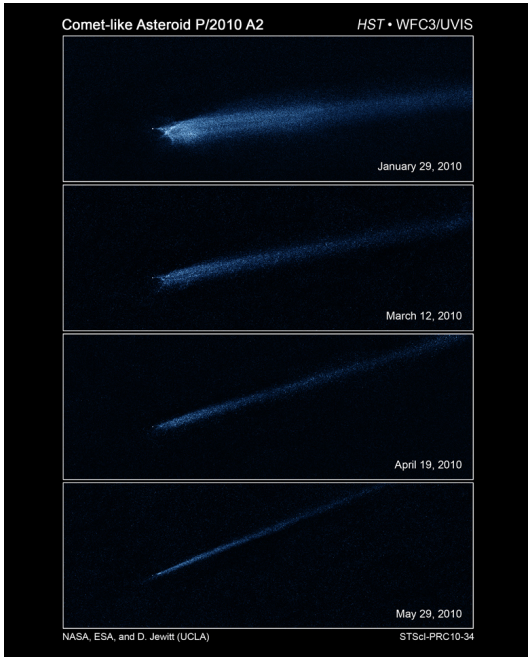
Next Class:
Gamma Ray Bursts

HW7 due Monday!
No lecture on Monday–
Computer lab opportunity

Music: *Supernova*– Liz Phair

Collision

- Two asteroids collided in 2009.
- Expected dramatic shrapnel
- Instead saw this "X" shaped
- Likely meter sized impact on 150 meter comet-like asteroid



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 ✔
- Monday, Oct. 18th
- Tuesday, Oct. 19th

Starts at 8pm until 10pm
(expect to spend ~40 mins)

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.

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 am waiting until the last possible minute. It is worth 5% of my total grade, so I guess I'll try to get over to the Observatory either Monday or Tuesday.

Questionnaire

It was anonymous, but you still get extra credit.

Many positive statements.

Other Comments:

- Too much math and too little math.
- Too fast and too slow.
- “Sometimes you talk too fast when you explain concepts”
- More demonstrations.
- Teach longer
- The computer lab is too hard. [It is worth 10% of your grade!]
- “I never really walk away from class with any new knowledge, but this could be because I took ASTR 100”

Questionnaire

Other Comments:

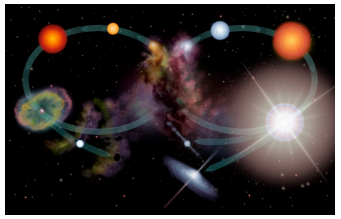
- Better worded exam/homework questions
- “Maybe it would be nice to have half (or less) of class for general review”
- “The review questions for the first exam didn't really help at all for the actual exam”
- I think too many of the test questions involve "which of the following is the BEST answer?"

Outline

- Supernova and their affects on Earth
- And if more massive?

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– we are star stuff!

Question

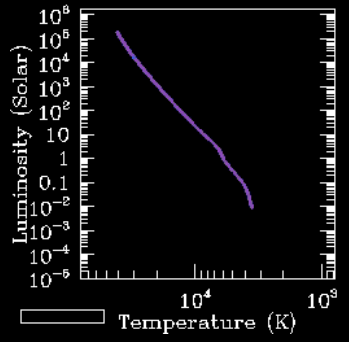
Why are we star stuff?

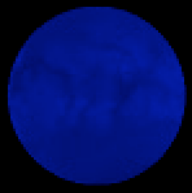
a) We are all going to Hollywood.
b) We are made up of small bits and pieces of stars.
c) We use fusion for power.
d) We are made up of the elements that were forged in the interior of stars.
e) We are just stuff, like stars.

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

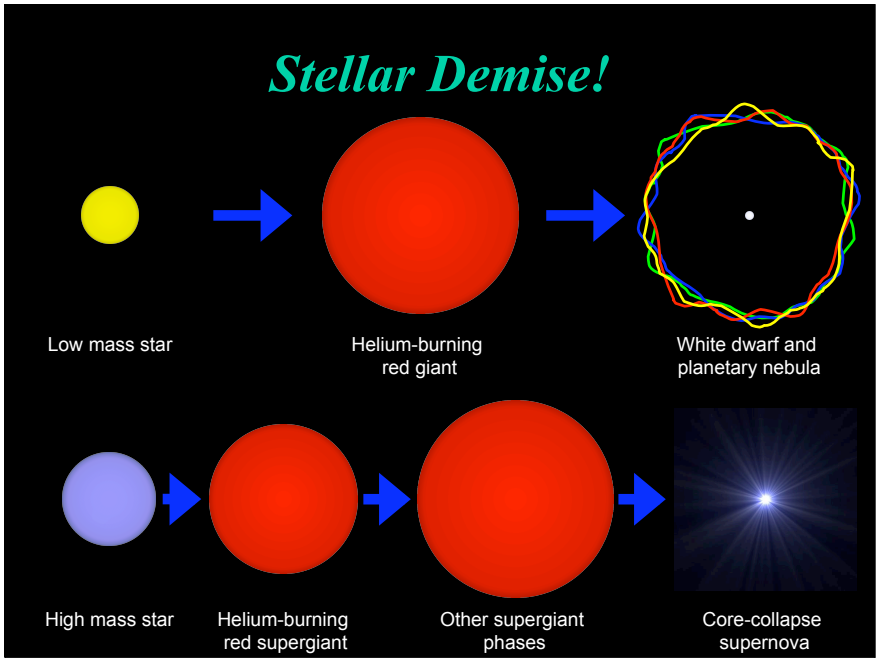
High Mass Stars (15 M_{sun})





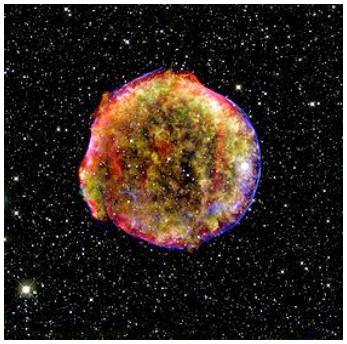
http://rainman.astro.uiuc.edu/ddr/stellar/index.html

Stellar Demise!



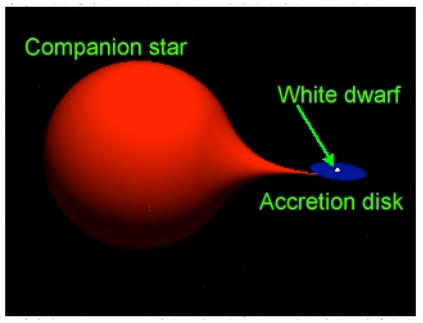
Death throes: White Dwarf

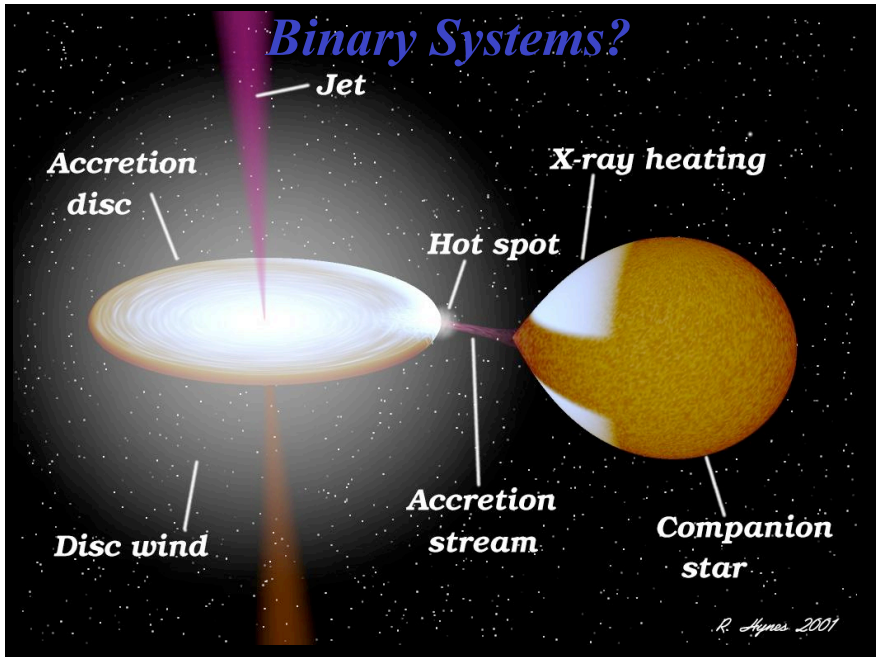
- So far, we've been talking about massive star core collapse supernova.
- But there are also special cases of supernova: a white dwarf exceeding the Chandrasekhar limit.
- White Dwarf supernova occur after the white dwarf was formed– typically in binary systems.



Binary Systems?

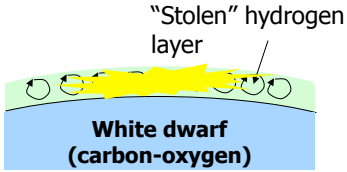
- In a close binary pair of stars with slightly different masses, the higher mass star evolves into a white dwarf first
- Later, the other star evolves into a red giant
- White dwarf then steals mass from its giant companion!
- Or two white dwarfs orbiting each other, with decaying orbits

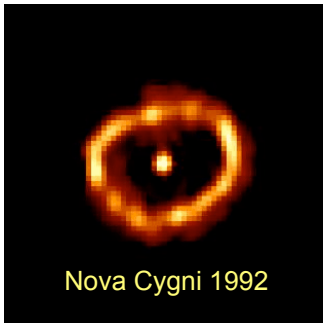




Novae

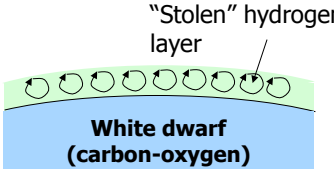
- If enough material piles up onto the surface of a white dwarf, can undergo explosive nuclear fusion
- White dwarf blows off this envelope and brightens by 100 – 1000 times
- Fades over a period of months
- This is called a **nova** (from Latin for "new")
- Common, about 20 per year in our galaxy





Supernovae: White Dwarf

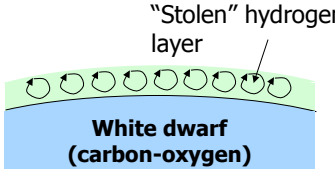
- If enough material piles up disaster is looming.
- The core suddenly reaches the Chandrasekhar limit– collapse!
- Causes a run away explosion that is hard to distinguish from a core collapse supernova.



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

Supernovae: White Dwarf

- Total energy is similar to a massive star core collapse
- However, White Dwarf supernovae give off more x-rays and gamma rays
  - This will even be more dangerous



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

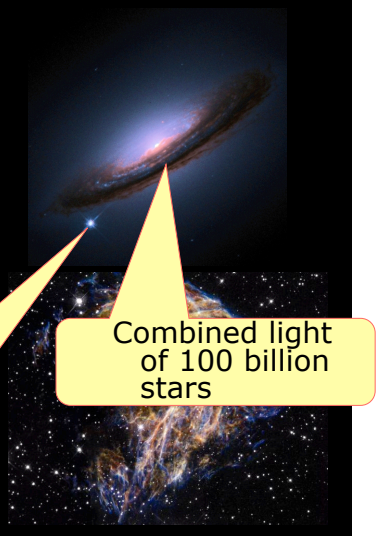
Supernova Explosions

The Death of Massive Stars
>10 M_{sun}

- Spectacular
- Rare
- Crucial for life
  …but don't get too close…

What do we see?

- Bright: can outshine galaxy
- Rapid changes in time:
  max in days
  dims over weeks
- Shock wave launched
  Fast, ultra-hot gas



How Close is Too Close?

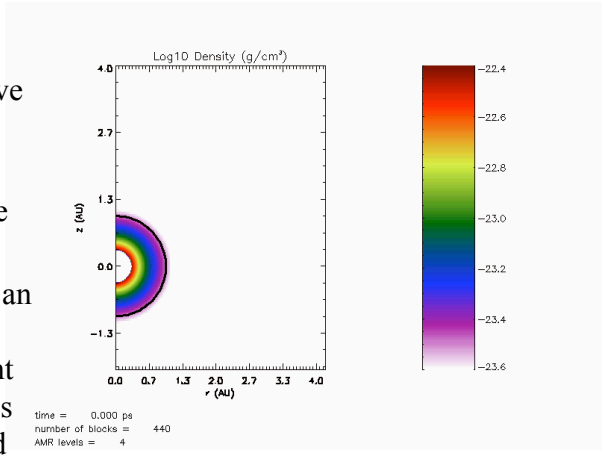
Minimum safe distance:
About 30 light years
Note: nearest star is 4 light years

30 light years

Q: ill effects of cosmic WMD?

Cosmic WMDs

- Death of a nearby massive star would be bad news.
- Will influence Solar System
- For example, an explosion within 30 light years modifies the solar wind



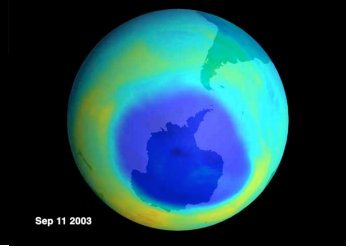
Surgeon General's Warning:
Supernovae are Dangerous to Your Health!

Biological damage if too close
- Mass extinction due to SN

Direct:
- DNA damage due to high-energy particles (neutrinos)

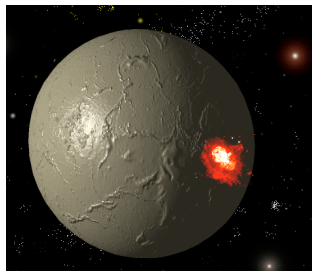
Nachbarsternsupernovaexplosionsgefahr
or
Attack of the Death Star!

Indirect:
Radiation damage to atmosphere
- Destruction of ozone layer
  …which is bad because?…
- No protection from ultraviolet (UV) light
- Then Sun's UV unfiltered
- Kills small plants/bacteria at bottom of food chain
- Damage all the way up



The Earth's 1st Atmosphere

- The inner circumstellar disk had most gases blown away and the proto-Earth was not massive enough to capture these gases.
- Any impacts (e.g. the moon), would have blown any residual atmosphere away.
- The first atmosphere was probably H and He, which was lost quickly.



http://www.udel.edu/Biology/Wags/wagart/worldspage/impact.gif

The Earth's 1st Atmosphere

- The interior heat of the Earth helped with the Earth's early atmosphere.
- Volcanoes released gases (water vapor and CO_2)
- Another scenario is that impacted comets released – water, carbon dioxide, and nitrogen
  - The first true atmosphere.
  - No oxygen! You would die on the early Earth!

http://www.fli-cam.com/images/comet-liner.jpg

The Ozone Layer

Early Earth:

- No ozone present
- UV light directly hit the planet surface
- Oceans provided only refuge from UV radiation– ocean life only.
- Evolution worked its magic

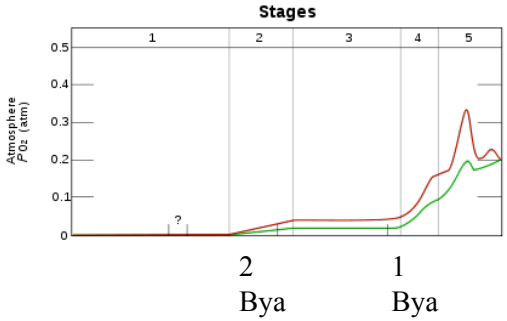
http://www.uweb.ucsb.edu/~rixfury/conclusion.htm

Our Atmosphere

- Rocks with ages greater than **2 billion** years show that there was little oxygen in the Earth's atmosphere.
- The current composition: 78% nitrogen, 21% oxygen, and trace amounts of water, carbon dioxide, etc.
- Where did the oxygen come from?
- Cyanobacteria made it.
  - Life on Earth modifies the Earth's atmosphere.
  - Mass extinction, but new life could emerge.
  - The land became habitable for life! (We had an ozone layer!)

http://www.uweb.ucsb.edu/~rixfury/conclusion.htm

Our Atmosphere



http://en.wikipedia.org/wiki/Great_Oxygenation_Event

Question

You are transported back in time to 3 billion years ago. What do you notice?

a) The Sun is red.
b) Jupiter and Mars are switched in their orbit due to tidal interactions.
c) The Earth's oceans are devoid of life.
d) That you can't breathe.

What is Ozone?

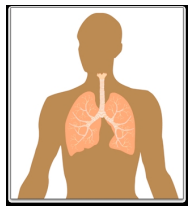
- **Ozone (O_3)** is a highly-reactive form of oxygen.
- Unlike oxygen (O_2), ozone has a strong scent and is blue in color.
- Ozone is highly corrosive and toxic and is used as a disinfectant.

Breathe this

Don't breathe this

Ozone…

- Ozone is very highly reactive and will combine with other substances easily.
- Near the earth's surface, these reactions cause rubber to crack and damage people's lung tissues.
- Inhaling ozone can damage the respiratory tract, which enables us to breathe.

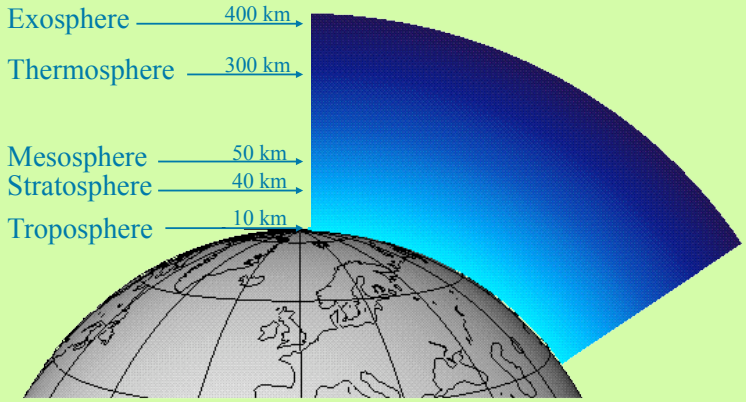


What is the Ozone layer?

- **Ozone** exists within both the tropospheric and stratospheric zones of the Earth's atmosphere
- **In the troposphere**, ground level ozone is a major air pollutant and primary constituent of smog

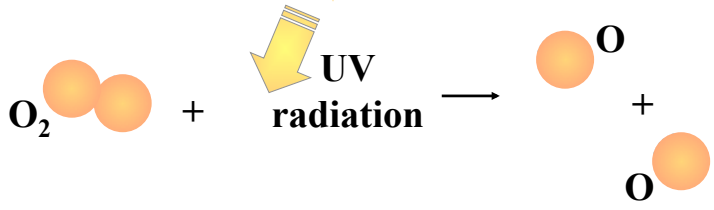
- **In the stratosphere**, the ozone layer is an essential protector of life on earth as it absorbs 99% of the harmful UV radiation before it reaches the earth.
- Note that because ozone is very reactive, it has to be created in the stratosphere– smog will not save us.

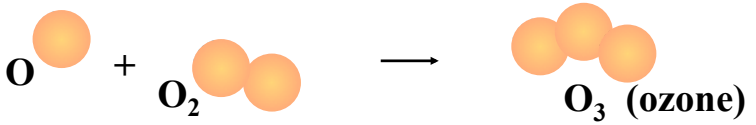
Location of Stratosphere



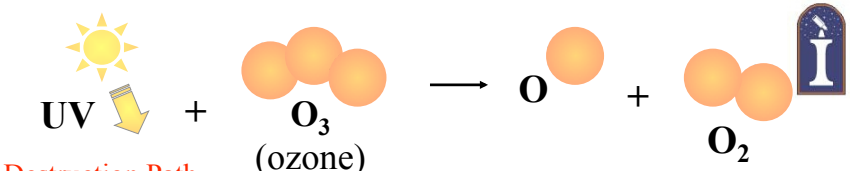
Ozone is thinnest around the equator and denser at the poles.

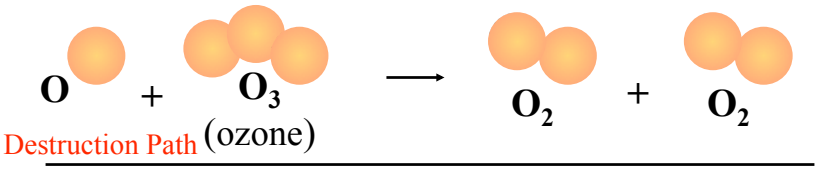
Oxygen in the Atmosphere

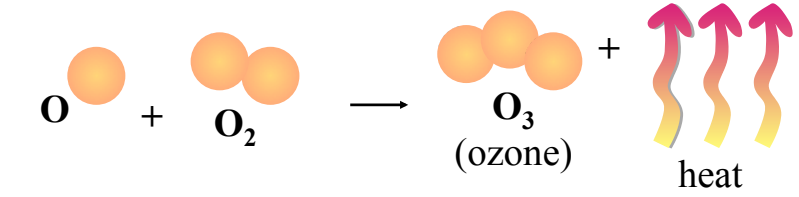




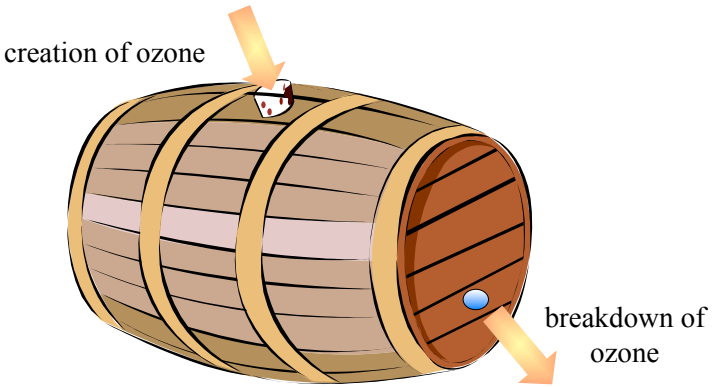
Once oxygen was abundant in the atmosphere, over hundreds of million of years, ozone built up 10-30 miles up.



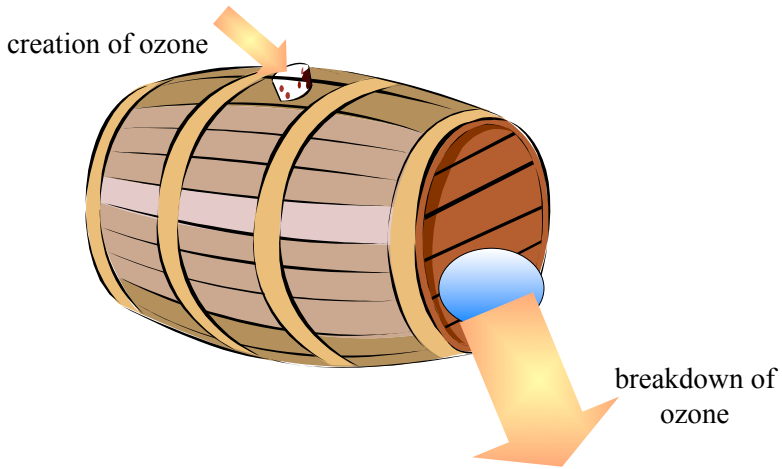




Dynamic Equilibrium

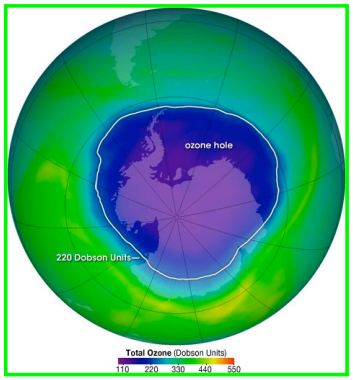


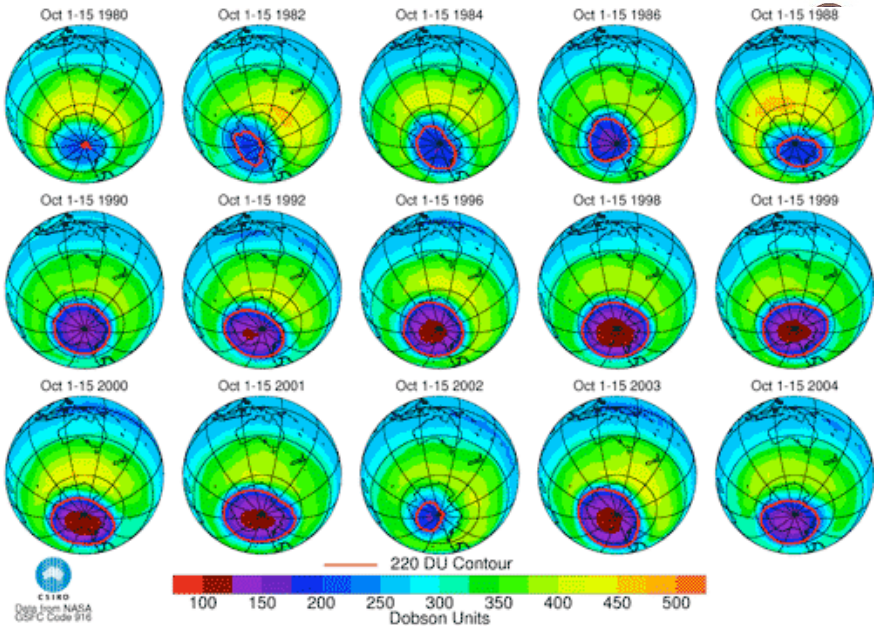
Anthropogenic Ozone Depletion



What is the Ozone Hole?

The **ozone hole** is not technically a "hole" where no ozone is present, but is actually a region of **depleted ozone** in the stratosphere over the Antarctic that happens at the beginning of Southern Hemisphere spring (August-October).





Question

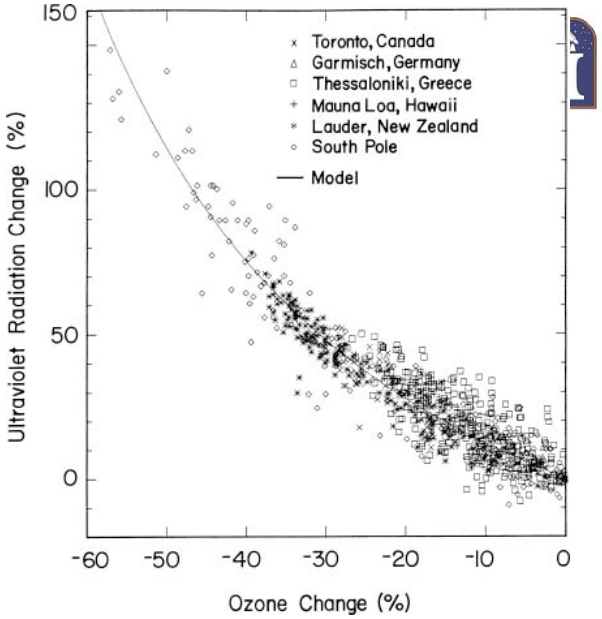
You want to patent an ozone maker and place it on the top of tallest building in Chicago to replenish the ozone layer. But,

a) The patent is probably already held by Google.
b) Supervillians will try to stop you.
c) Ozone is highly reactive and won't make it up to the stratosphere where it is needed.
d) You can never make enough to save the planet.
e) You need to use UV light to make the ozone and that will be dangerous in a city.

What causes Ozone Depletion?

- Ozone Hole caused by chemicals called CFCs, short for chlorofluorocarbons.
  - CFCs escape into the atmosphere from refrigeration and propellant devices and processes
  - They are stable, last for decades.
  - This long life allows some CFCs to eventually reach the stratosphere, float around the stratosphere, breaking up ozone molecules.
- One molecule of CFC can destroy more than 100,000 molecules of stratospheric ozone.
- Today, no spray cans contain CFCs. Other chemicals are gradually replacing the CFCs in air conditioners.

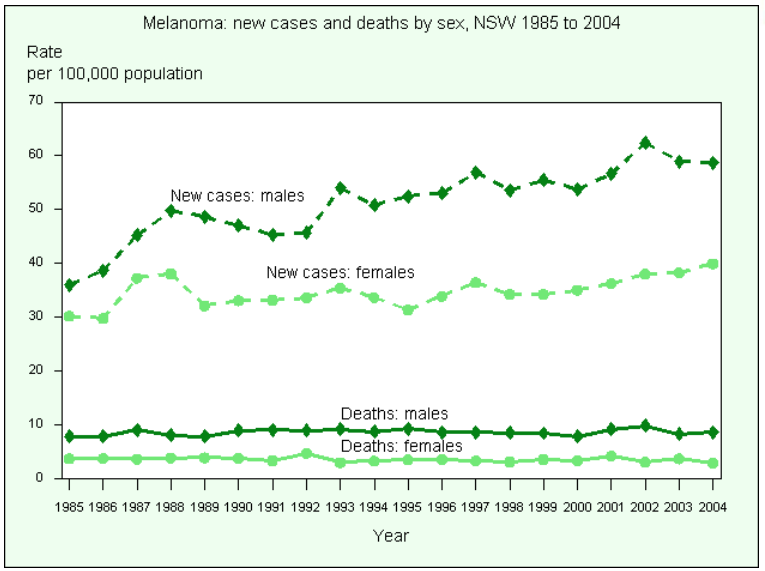
As Ozone levels have decreased, UV radiation has increased

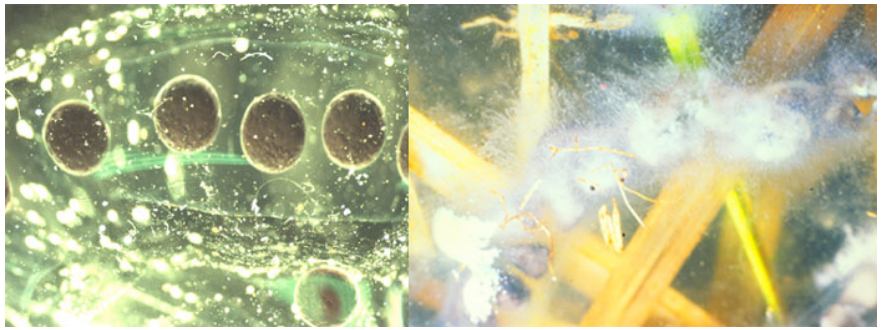


Ultraviolet Radiation

- The depletion of the ozone layer leads to higher levels of ultraviolet radiation reaching Earth's surface.
- This in turn can lead to a greater incidence of skin cancer, cataracts, and impaired immune systems, and is expected also to reduce crop yields, diminish the productivity of the oceans, and possibly to contribute to the decline of amphibians that is occurring around the world.

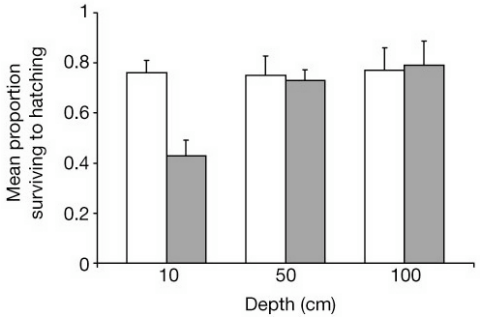
Skin cancer rates are increasing





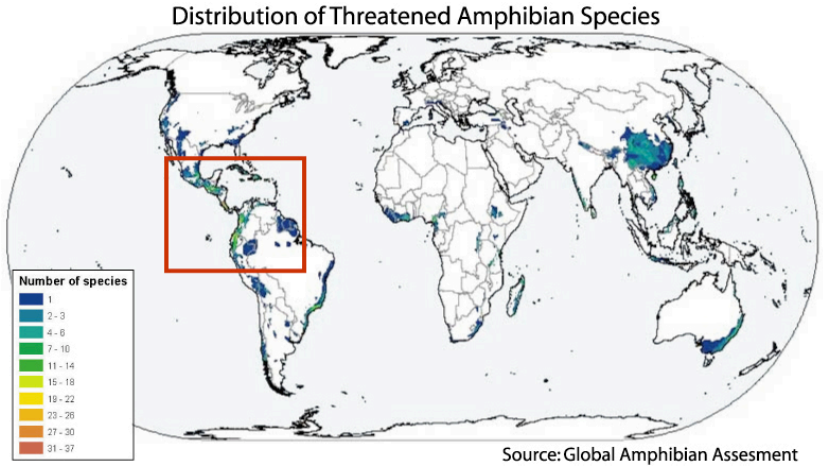
Organisms in Shallow water aquatic habitats are most vulnerable

If you screen UV (white bars) survival is better



Increases in radiation seem to increase suseptibility to diseases

World wide decline in amphibians is due in part to increases in UV radiation

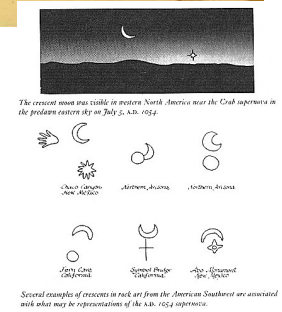


Supernova Explosions in Recorded History

- Clearly, destroying the ozone layer is serious business.
- We don't want to be too close to a supernova!
- But, how close have we been in the past?

Supernova Explosions in Recorded History

- 1054 AD
- Europe: no record
- China: "guest star"
  - So bright, could see it during the day for most of July.
- Anasazi people
  - Chaco Canyon, NM
  - Rock Paintings
- Also seen by Korean, Arabic, and Japanese astronomers

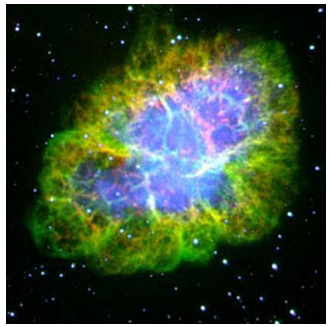


The crescent moon was visible in western North America near the Crab supernova in the predawn eastern sky on July 5, A.D. 1054.

Several examples of crescents in rock art from the American Southwest are associated with what may be representations of the A.D. 1054 supernova.

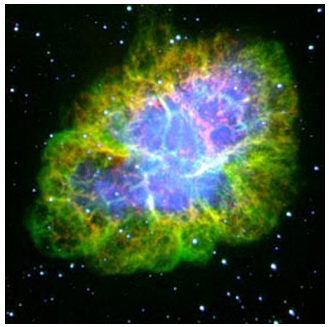
The Crab Nebula

- First discovered in 1731.
- Photographs showed it to be expanding.
- Tracing it backwards, it should have been visible in 1054.
- **The Crab Nebula** — a supernova remnant, a massive star supernova
- Distance to the Crab is 6,500 lyrs (40 quadrillion miles!)



The Crab Nebula

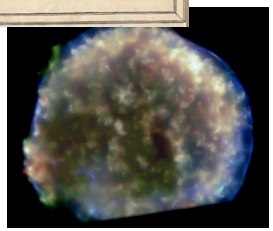
- Even after 10 centuries, it is one of the brightest visible nebulae in the sky!
- In just a few weeks, it released as much energy as the Sun will over 12 billion years!
- In X-rays and radio, the crab is **still** one of the brightest objects in the sky!
- In gamma-rays, the **brightest** object in the sky!



Creatures from the Crab Nebula?
http://www.youtube.com/watch?v=OacAgQO9vvo

Supernova Explosions in Recorded History

- November 11, 1572
- Recorded by Tycho Brahe
  - Called it a **"nova stella"** (new star)
- For about two weeks the supernova could be seen in the daytime!
- Modern view (X-rays):
  - Tycho's Supernova Remnant
- Probably a white dwarf supernova



November 11, 1572
Tycho Brahe

On the 11th day of November in the evening after sunset ... I noticed that a new and unusual star, surpassing the other stars in brilliancy, was shining ... and since I had, from boyhood, known all the stars of the heavens perfectly, it was quite evident to me that there had never been any star in that place of the sky ...

I was so astonished of this sight ... A miracle indeed, one that has never been previously seen before our time, in any age since the beginning of the world.

Supernova 1987A

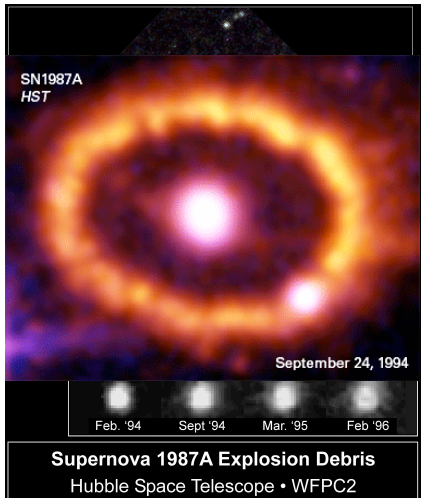
Original star was a B3 blue supergiant

Before Feb. 23, 1987

Supernova 1987A

- 1987A happened in the satellite galaxy LMC (150,000 lyrs away)
- Star was about 20 $M_{\odot}$
- Detected neutrinos from the core (most of explosion energy) for 13 secs about 20 detected.

Supernova 1987A - Today



http://www.youtube.com/watch?v=tYLwGmUO6zU

Question

The most recent supernova seen by humans in our Galaxy was how long ago?

a) Today
b) Yesterday
c) Last year
d) Last century
e) Over 400 years.