Astronomy 150:
Killer Skies

This Class (Lecture 19):
Killer Supernova

Next Class:
Gamma Ray Bursts

HW6 due on Sunday!

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

Music: *We Got the Neutron Bomb*– The Weirdos

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-Thursday, Oct 12th –15th ✗
  - Next week, only 1 more clear night (M-Th).

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.

Computer Lab Help

- We are going to try to have to computer help sessions next week at the Oregon Lab.
- Monday and Tuesday 11:30am-12:45pm.
- Will you go to one of these?
  a) Yes, Monday
  b) Yes, Tuesday
  c) I want to go, but the times don't work for me.
  d) No, I don't want to go anyway.

Outline

- Supernova are good news for life.
- Supernova are bad news for life.
- What happens to the Earth?
  – Ozone layer gets fried

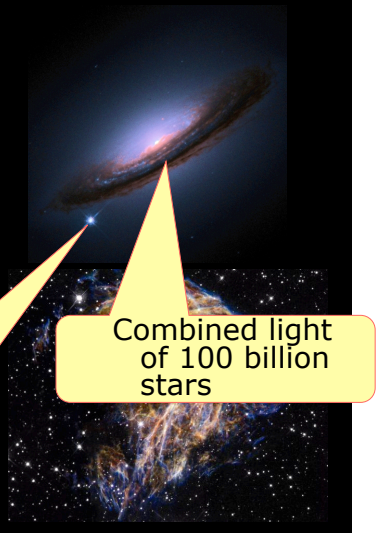
Supernova Explosions

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



Combined light of 100 billion stars

Light from a single supernova

How Close is Too Close?

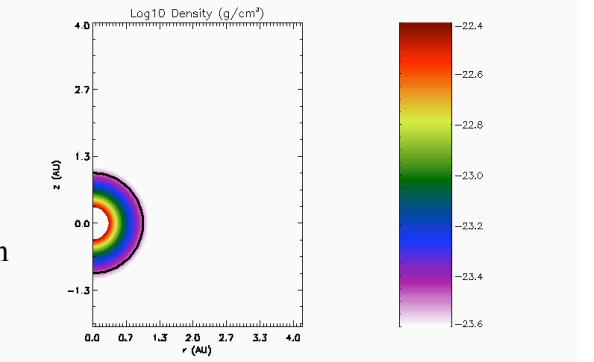
Minimum safe distance:
About 30 light years
Note: nearest star is 4 light years

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

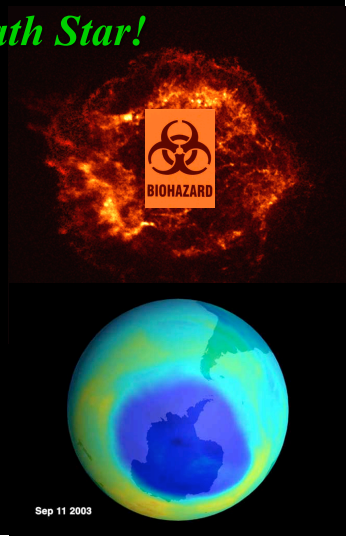
or

Attack of the Death Star!

Indirect:

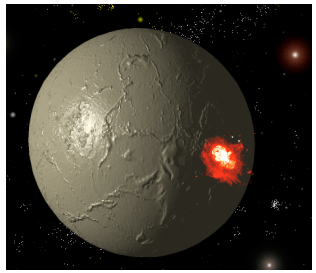
Radiation damage to atmosphere

- 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 or no 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

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.
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.

O_2

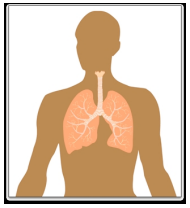
Breathe this

O_3 (ozone)

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.

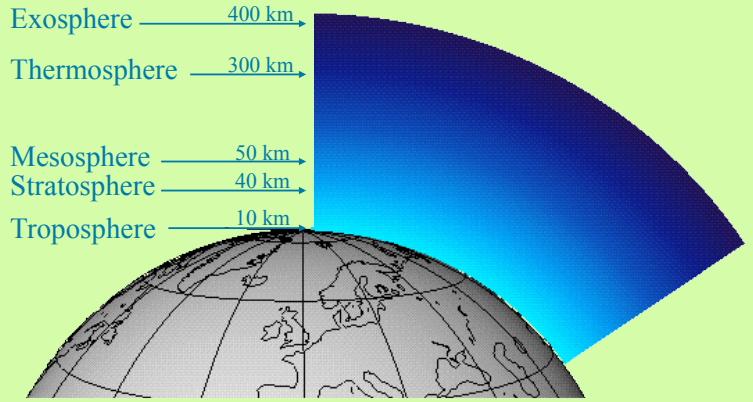


What is the Ozone layer?

- **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

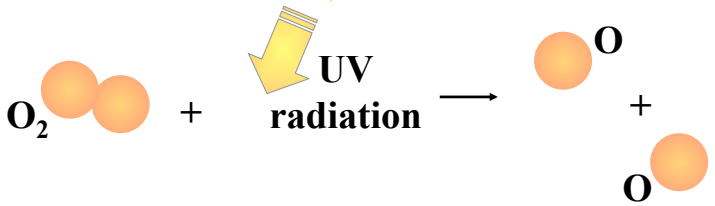
- **In the stratosphere**, the ozone layer is an essential protector of life on earth as it absorbs 99% of the harmful UV radiationbefore it reaches the earth.
- Note that because ozone is very reactive, it has to be created in the stratosphere– smog will not save us.

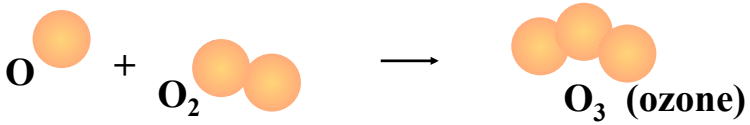
Location of Stratosphere



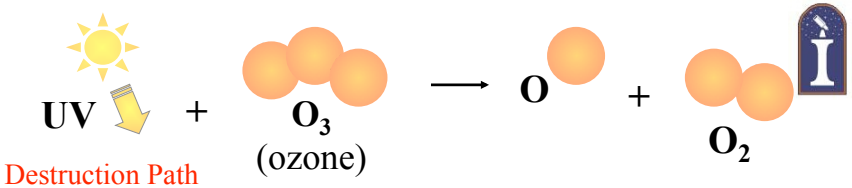
Ozone is thinnest around the equator and denser at the poles.

Oxygen in the Atmosphere

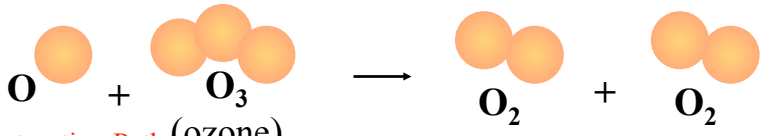




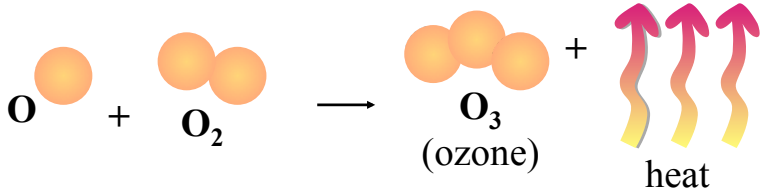
Once oxygen was abundant in the atmosphere, over hundreds of million of years, ozone built up 10-30 miles up.



Destruction Path

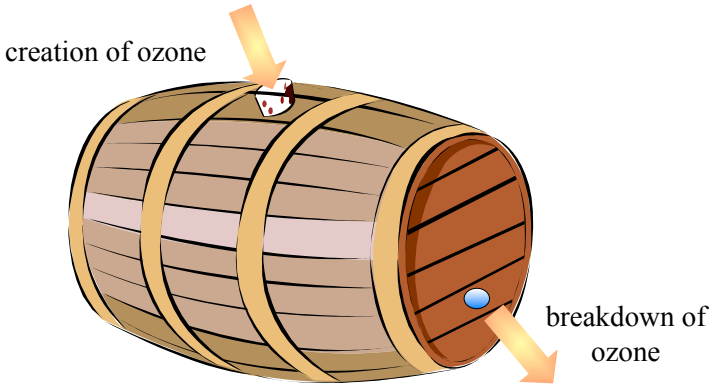


Destruction Path

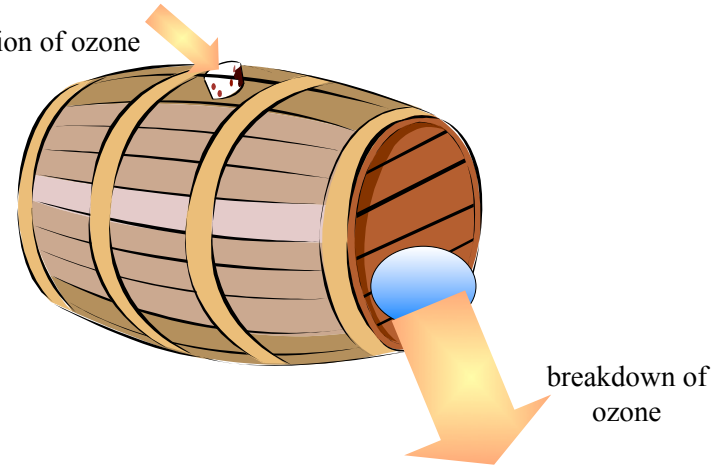


Creation Path

Dynamic Equilibrium

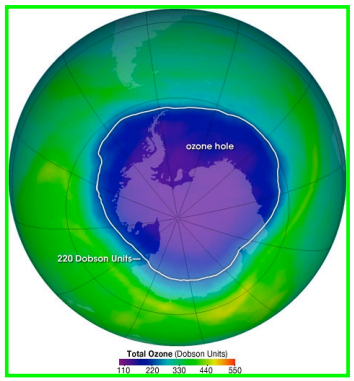


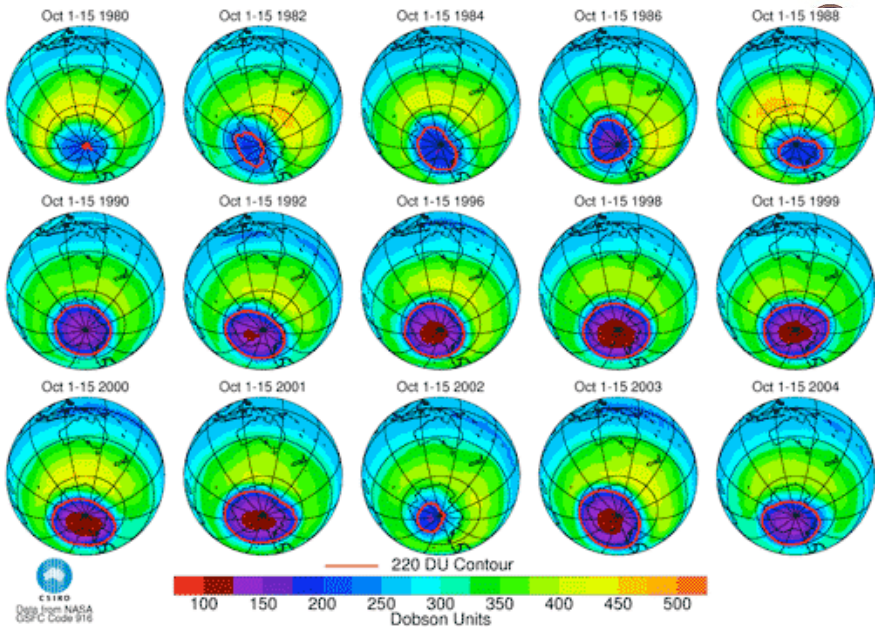
Anthropogenic Ozone Depletion



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

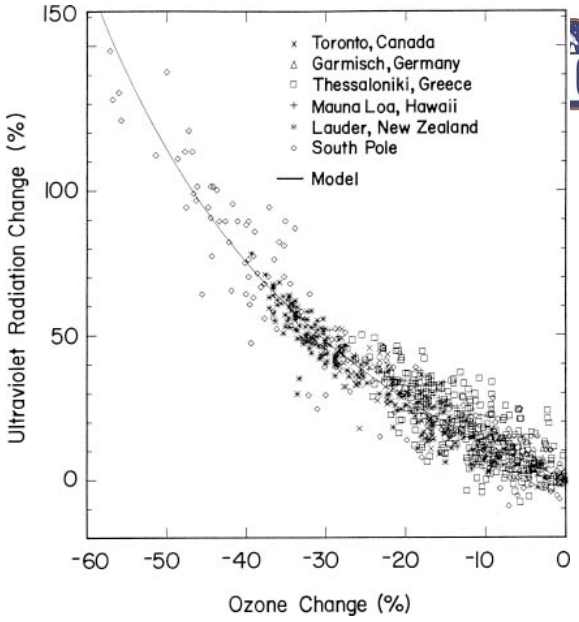
You want to patent an ozone maker and place it on the top of tallest building in Chicago to replenish the ozone layer. But,

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.

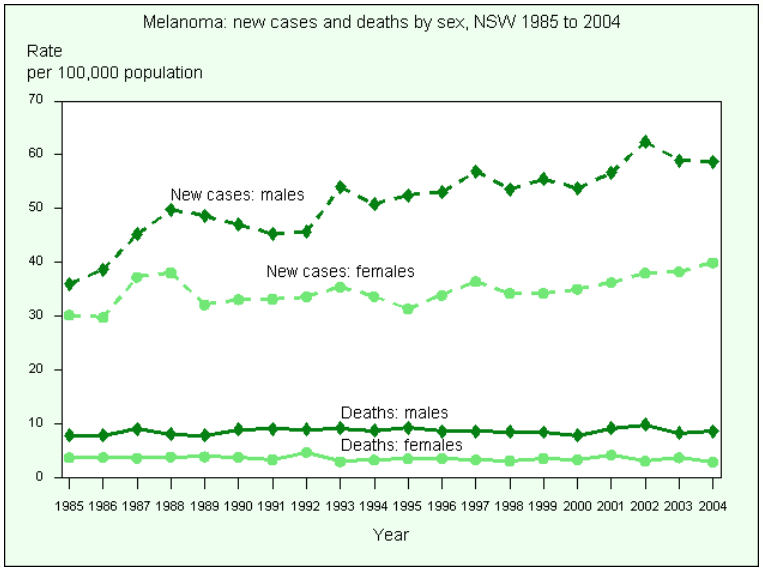
As Ozone levels have decreased, UV radiation has increased

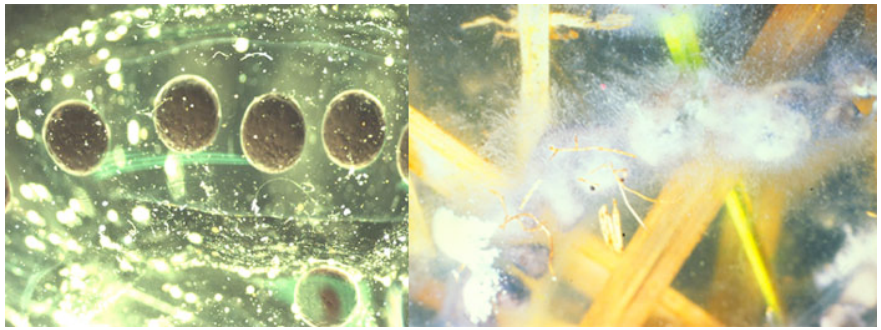


Ultraviolet Radiation

- 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.

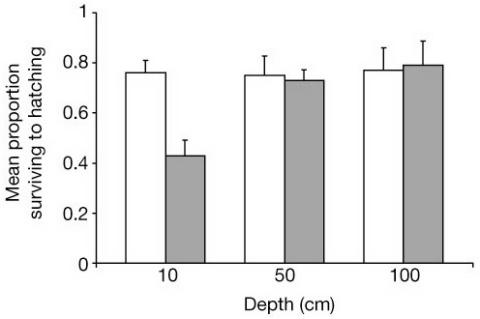
Skin cancer rates are increasing





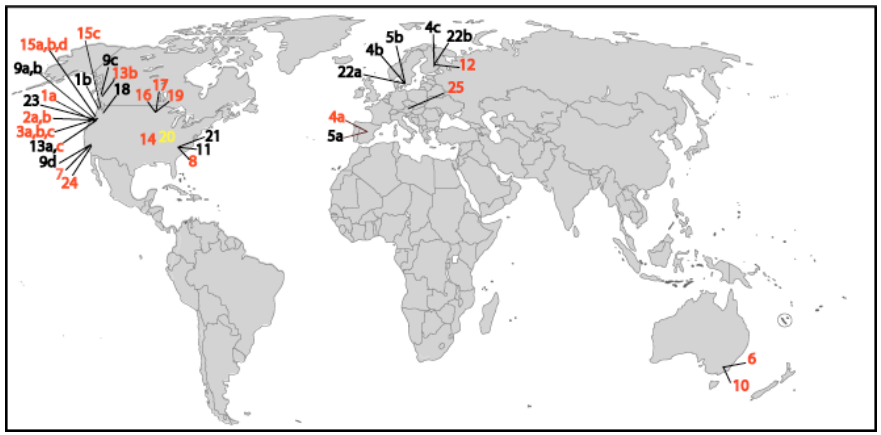
Organisms in Shallow water aquatic habitats are most vulnerable

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

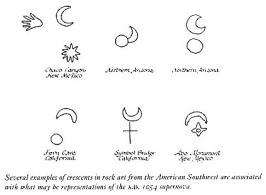


Red numbers show declines, black - no decline

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

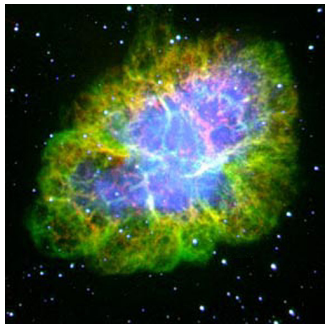


The crescent moon was visible in western North America near the Crab supernova in the predawn eastern sky on July 5, A.D. 1054.

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

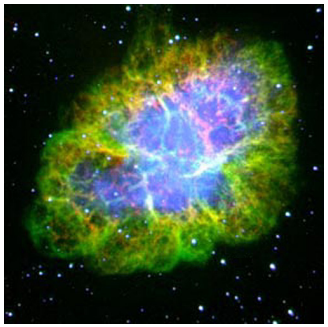
- 1054 AD
- Europe: no record
- China: "guest star"
  - So bright, could see it during the day for most of July.
- Anasazi people
  - Chaco Canyon, NM
  - Rock Paintings
- Also seen by Korean, Arabic, and Japanese astronomers

The 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

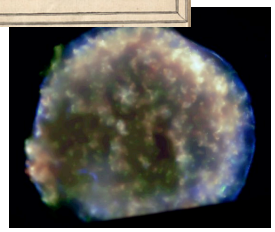


- Even after 10 centuries, it is one of the brightest visible nebulae in the sky!
- In just a few weeks, it released as much energy as the Sun will over 12 billion years!
- In X-rays and radio, the crab is **still** one of the brightest objects in the sky!
- In gamma-rays, the **brightest** object in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



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.

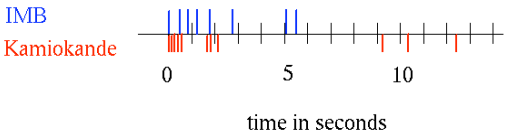
Supernova 1987A

Original star was a B3 blue supergiant

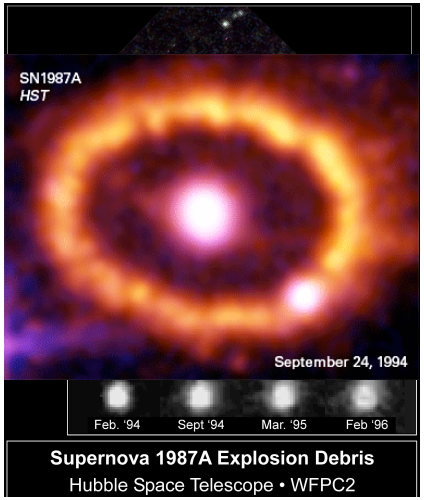
Before Feb. 23, 1987

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 that occurred in our Galaxy was how long ago?

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

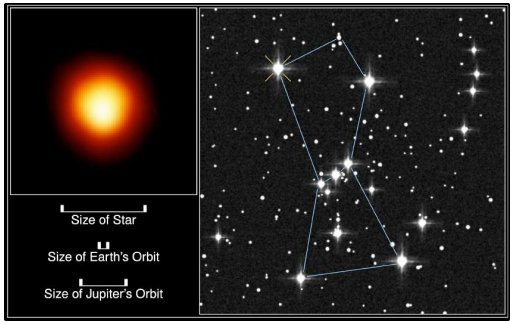
What's Nearby?

- To do real damage to the ozone layer, a type II supernova would perhaps need to be within ~30 light years and maybe ~40 light years for a Type I.
- What is around us now?
- Massive stars:
  - Spica, ~10 solar mass, MS, 260 lyrs
  - Shaula, ~10 solar mass, MS, 365 lyrs
  - Dschubba, ~12 solar mass, MS, 400 lyrs
  - Al Niyat, ~12 solar mass, MS, 400 lyrs

Millions of years to go. Don't forget we and they are orbiting the Galactic center, so a lot can change.

Betelgeuse

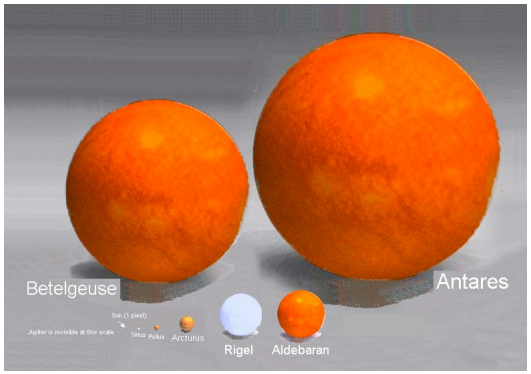
- 85,000 times brighter than the Sun, but 436 lyrs away.
- Red Supergiant
- ~15 solar masses
- Clearly an evolved star
- Over the last 15 years it has shrank 15%!



- When might it blow? We don't know.

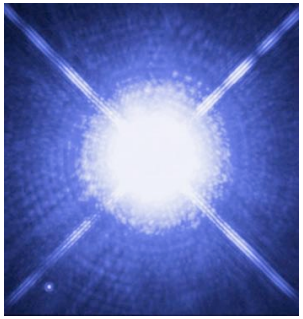
Betelgeuse

- When it does go supernova, even at 426 lyrs, it will be as bright as a Gibbous Moon, leaving shadows on the ground!
- Probably only about 10 million years old



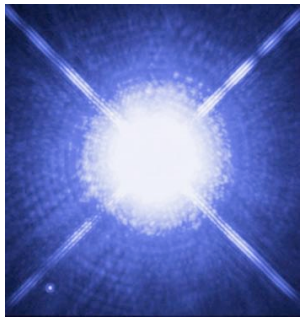
Type I Candidates?

- Nothing really close by.
- White dwarfs are an old population and they tend to disperse in the Galactic disk more, making them more unlikely to affect us.
- That said, one of our very, very close stars is Sirius (9 lyrs!), which is a white dwarf and main sequence A star companion.



Are you Sirius?

- Main sequence star is about 2 solar masses.
- Sirius B, the white dwarf, is about 1 solar mass.
- Someday, Sirius A will become a red giant.
- But most likely, it will not become a supernova Type I.
- Anyway, it is 10-100 million years away from becoming a red giant.



Supernova Explosions Near Earth

In our Milky Way galaxy:

- About 1-2 SN/century
- Most far away: spectacular but harmless

Now: no nearby candidates

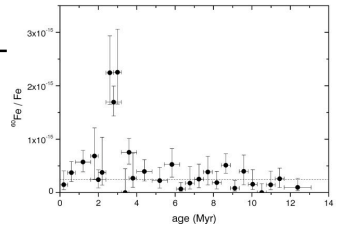
Sleep well tonight!

But over the 4.5 billion year history of Earth:

Many nearby events!

Proof of Concept?

- Recent experiments uncovered evidence of a nearby supernova about 3 million years ago.
- Radioactive iron atoms have been found in ancient samples of deep-ocean material-- debris from this explosion.
- Explosion was close, probably a "near-miss," which emitted intense and possibly harmful radiation.
- The resulting environmental damage may have led to some extinctions.



Mitigation

- Not much
- Try not to live too close to a massive star near the end of its life.
- Try not to live too close to a binary system with a white dwarf.
- With time, our species should one day travel to the stars.
- We could monitor nearby candidates.