# Killer Skies

- Homework 7 due Monday
- Solar Observing starts next week
- Last time: Gamma Ray Bursts
- Today: Gamma Ray Bursts Effects


Music: *Where Gravity is Dead* – Laura Veirs

# Solar Observing Next Week

## Happens next week:

**M-Th, 10:30am-1:30pm, weather permitting**

**At Campus Observatory**

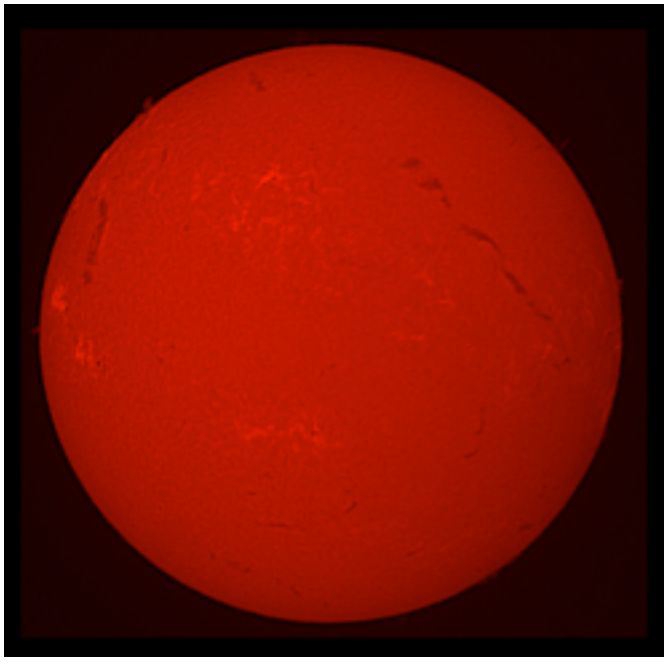
**(behind building)**

**Assignment details and report form on class website**

**Report due Nov 22nd**

**Subscribe to Solar Observing Status Blog for weather-related notices**

http://illinois.edu/blog/view/414



# Hour Exam 2

## Hour Exam 1 next Friday, Nov 8th, in class

- information on course website
- 40 questions (cover material from Oct 7th to today: Lect 14-24)

## May bring 1-page of notes

- both sides
- printed, handwritten, whatever

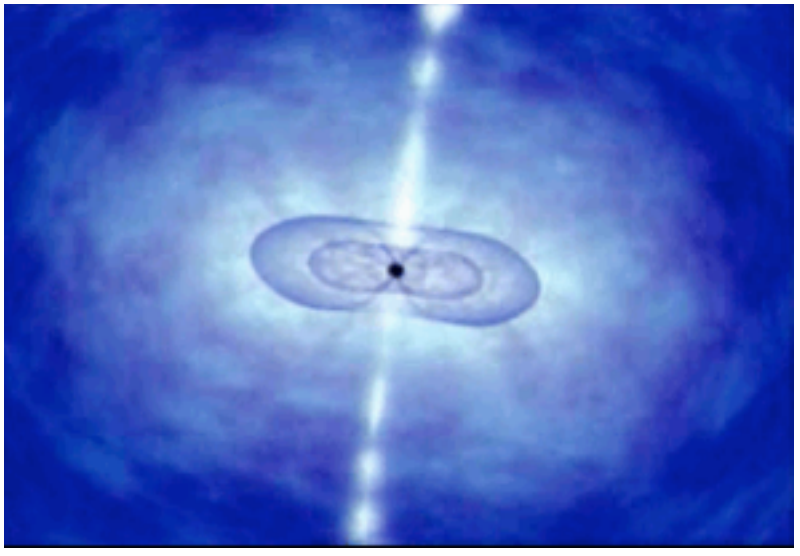
## Most useful study materials

- class notes
- iClicker questions
- study guide
- homework questions
- old exam

## Focus on concepts, main ideas

# 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.**



100 light years is 4 x the maximum distance that a supernova is likely harmful.

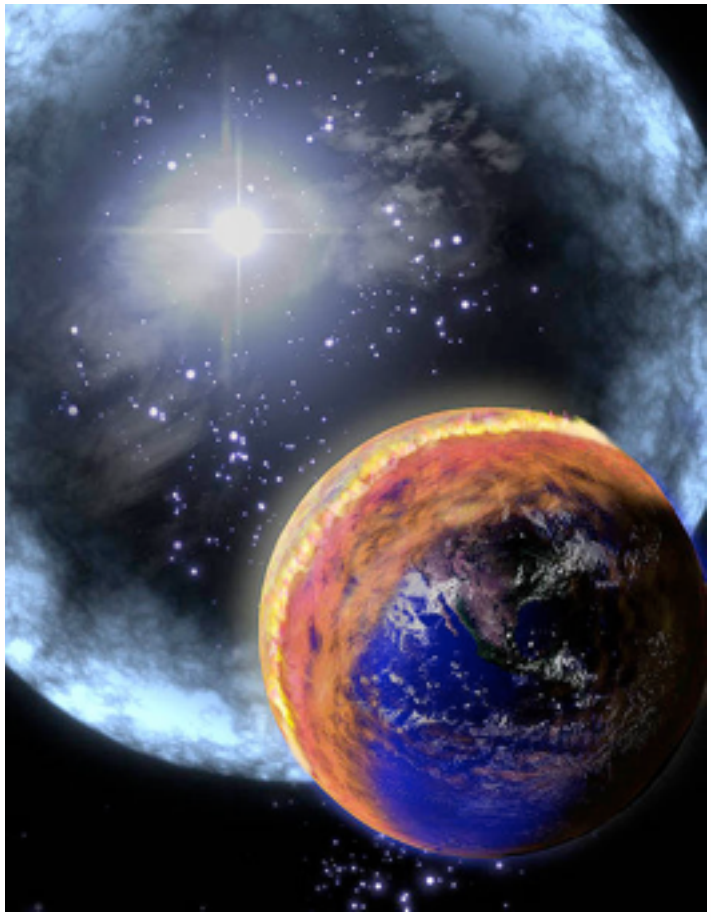
# GRB Damage

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!





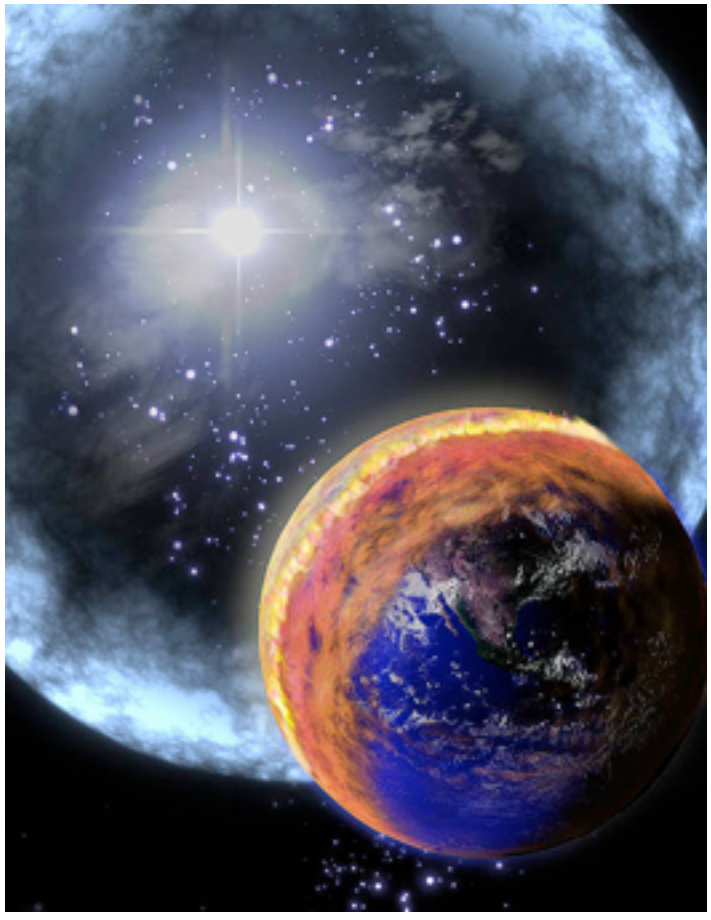
Probably not!

# 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

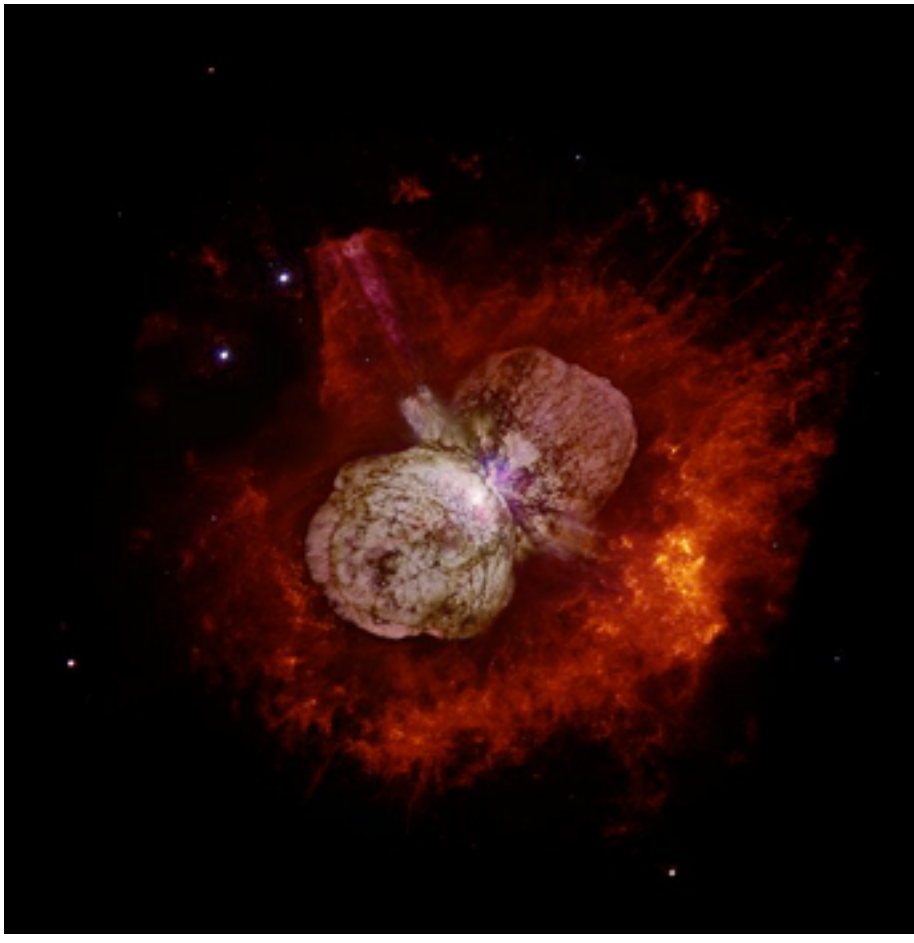
Okay, that was fun to speculate, but no likely candidates for GRB that close.

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,

Located 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!

Gives off more energy in one second as the Sun 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 two huge lobes of material, possibly the aftermath of this outburst.

# 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 would probably still give a sunburn.

# Eta Carinae Damage

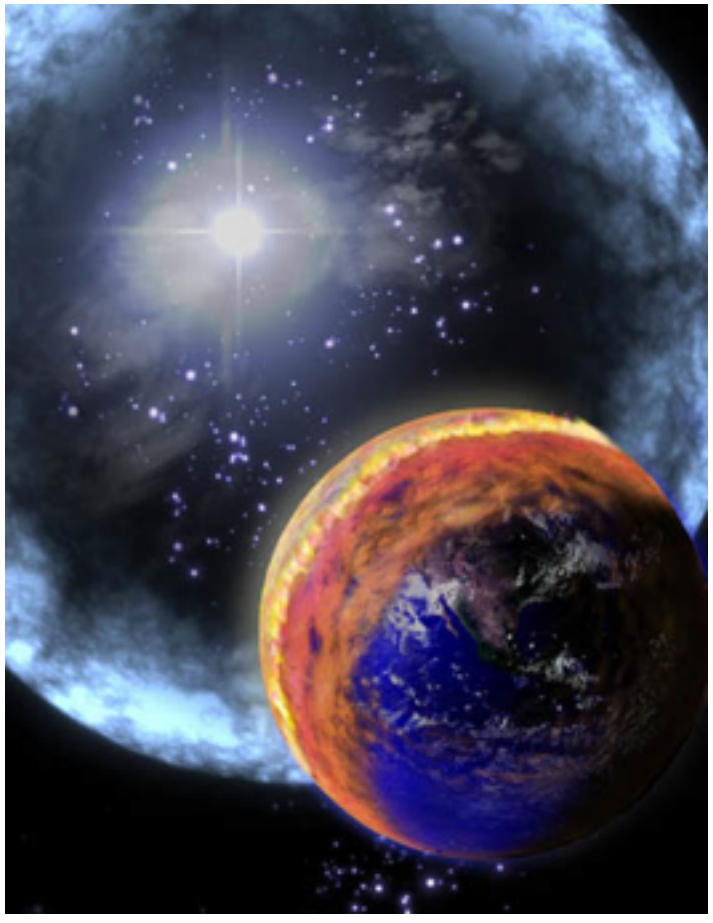
But the gamma-rays and X-rays?

Absorbed by the atmosphere, but worse effects than nearby supernova.

There would be a strong EMP (electromagnetic pulse) that would wipe out electronic devices for facing hemisphere

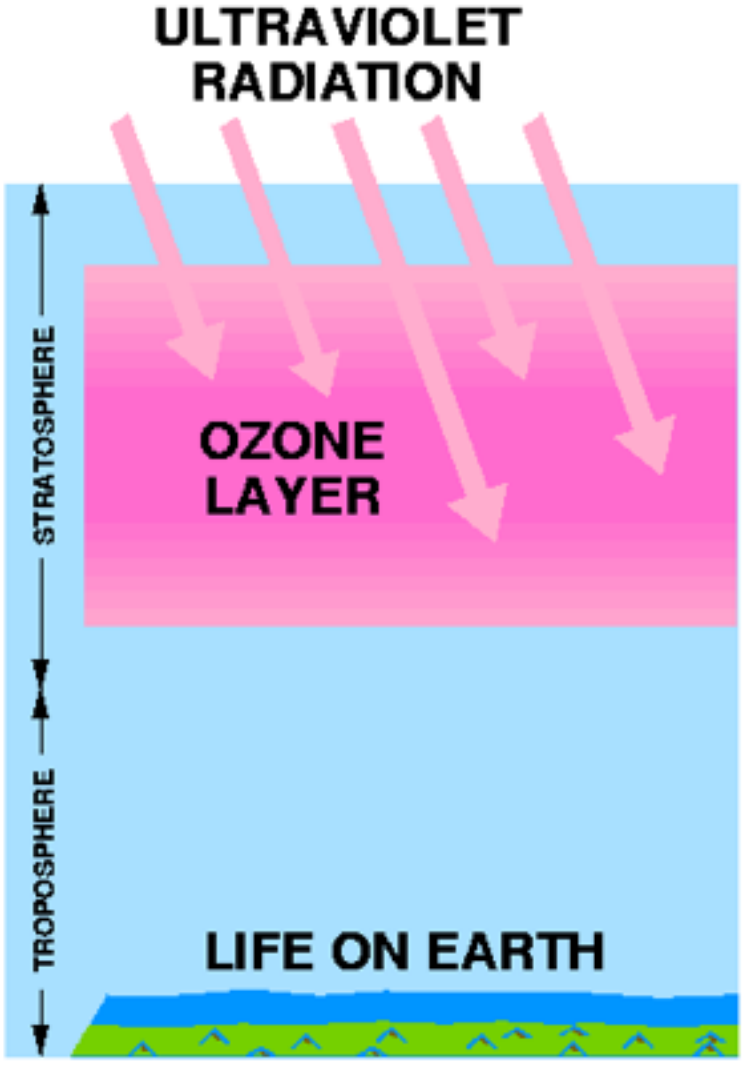
- Computers
- Power grids
- Airplanes
- Cars (emergency vehicles too)

All fried!



# Ozone Layer is Devastated

- Gamma-rays convert N2 and O2 into NOx (N, NO, $NO_2$)
- Catalysts to destroy ozone
- Up to half the ozone layer destroyed
- Takes years to recover
- Solar UV at the surface increases

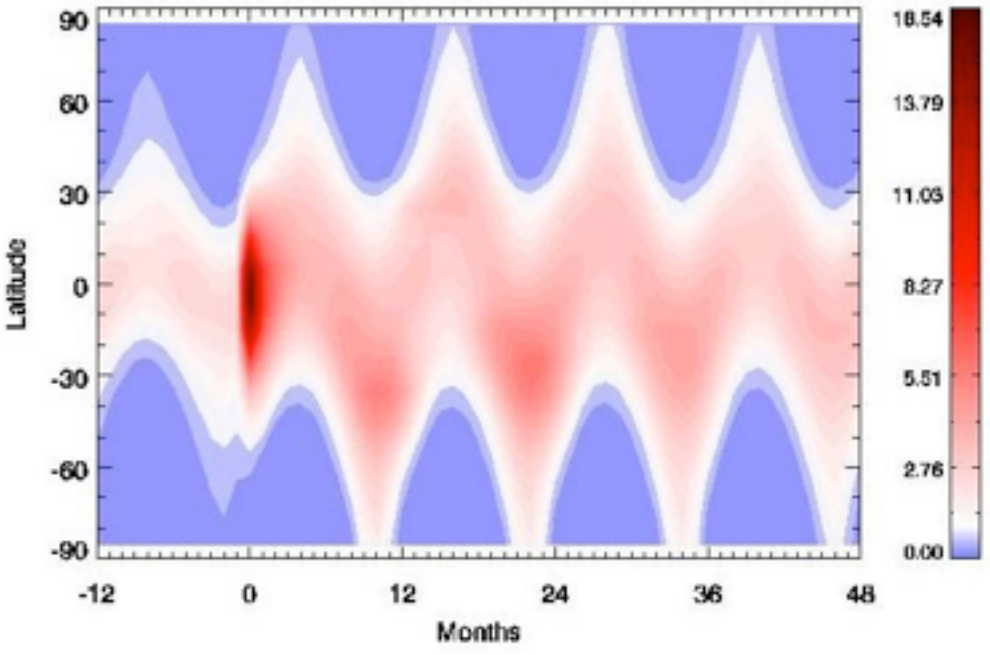





Even modest increases in the UV flux can be lethal to some organisms

# Increased solar UV a threat to life

- UV radiation can damage DNA
- Risk of cancer, death, infertility
- Surface-dwelling plankton and other life near the surface, would not survive
- Water blocks UV, so deeper ocean life would be protected

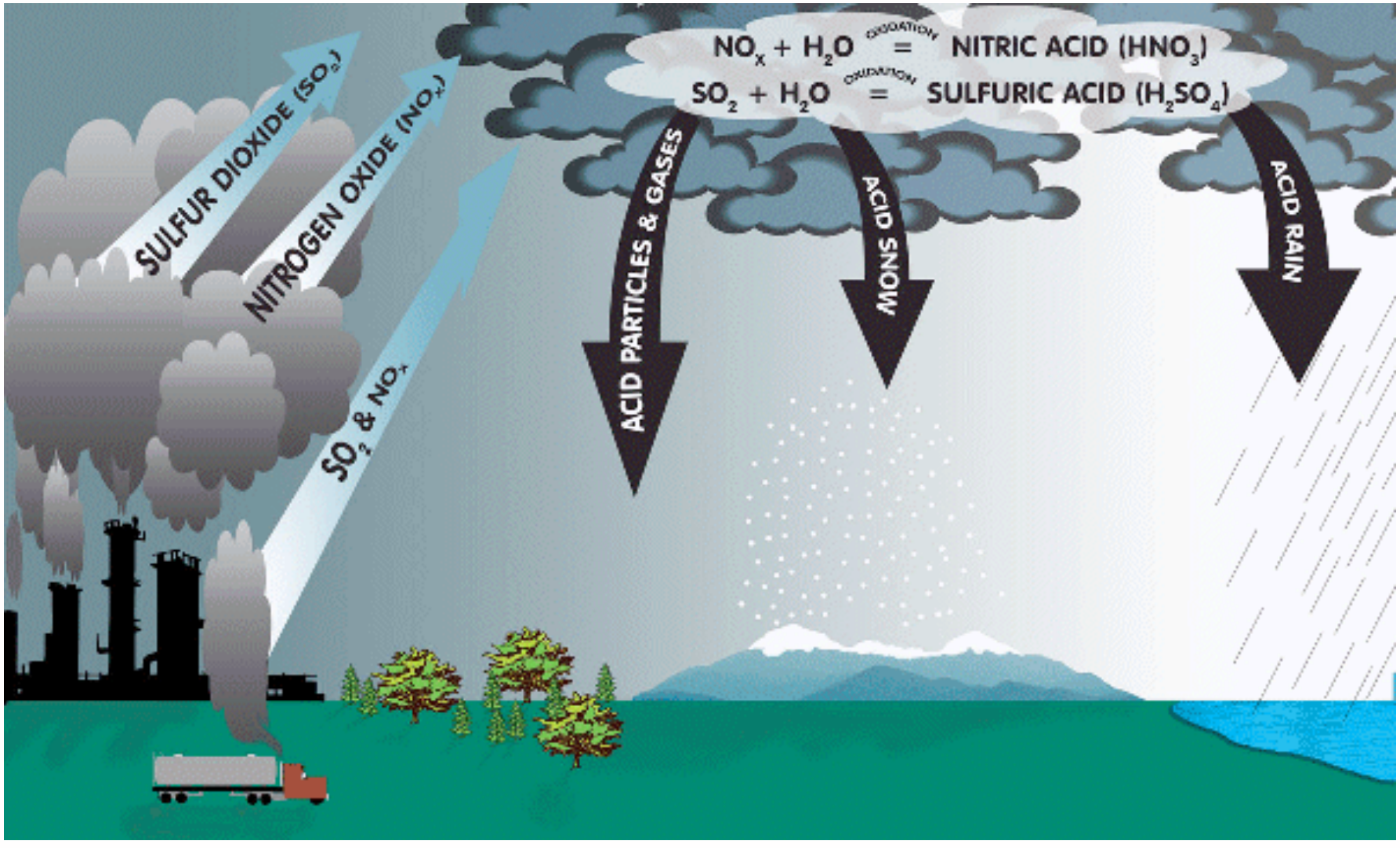



Anything darker than pink is lethal on the surface.

# Threat of Ice Age?

- $NO_2$ is a reddish-brown gas
- Its opacity also reduces the visible light from the Sun reaching the ground
- Less solar energy leads to reduction in global temperatures
- Trigger an ice age?

# Nitrogen oxides also cause acid rain!



# i>clicker question

**Why is it thought that Eta Carinae will probably not kill us all?**

A. It doesn't have a gun.

B. It will not go hypernova.

C. We don't think the lobes are pointed our direction.

D. It will likely turn into a planetary nebula.

E. Its too far away to be a danger.



Answer C

# GRB Rates?

Based on the observed Universal rate of 1/day, we can estimate the GRB rate in the Milky Way.

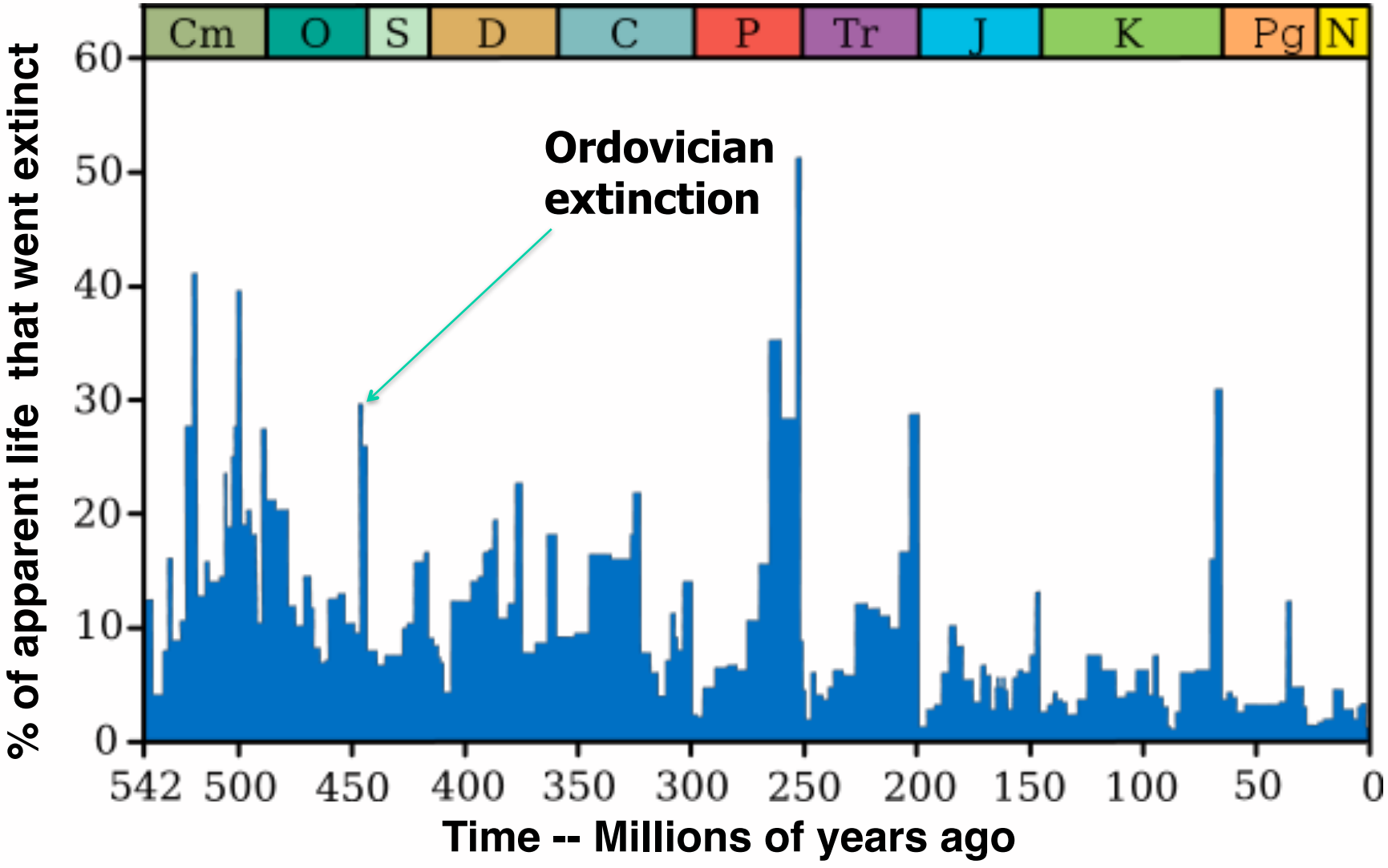
We expect about 1 burst per 100,000 or million years

Most not beamed at Earth

So about 1/billion years within 5000 light years

We have had ozone for two billion years, so any observable affect?

# Extinction Events -- Are any due to GRBs?




http://upload.wikimedia.org/wikipedia/commons/0/06/Extinction_intensity.svg



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. The late Ordovician event shows many characteristics that would be expected if it were initiated by a nearby GRB.

# Patterns of Ordovician Extinction

**Second-largest of the five major extinction events in Earth's history in terms of percentage of genera that went extinct**

**Second largest in the overall loss of life**

**More than 60% of marine invertebrates died**



Second-largest of the five major extinction events in Earth's history in terms of percentage of genera that went extinct
Second largest overall in the overall loss of life.  At the time, all known life was confined to the seas and oceans.[3]
More than 60% of marine invertebrates died

# Trilobite Extinction

In the Ordovician, trilobites were wide-spread and abundant

Yet, they went extinct while more restricted groups persisted

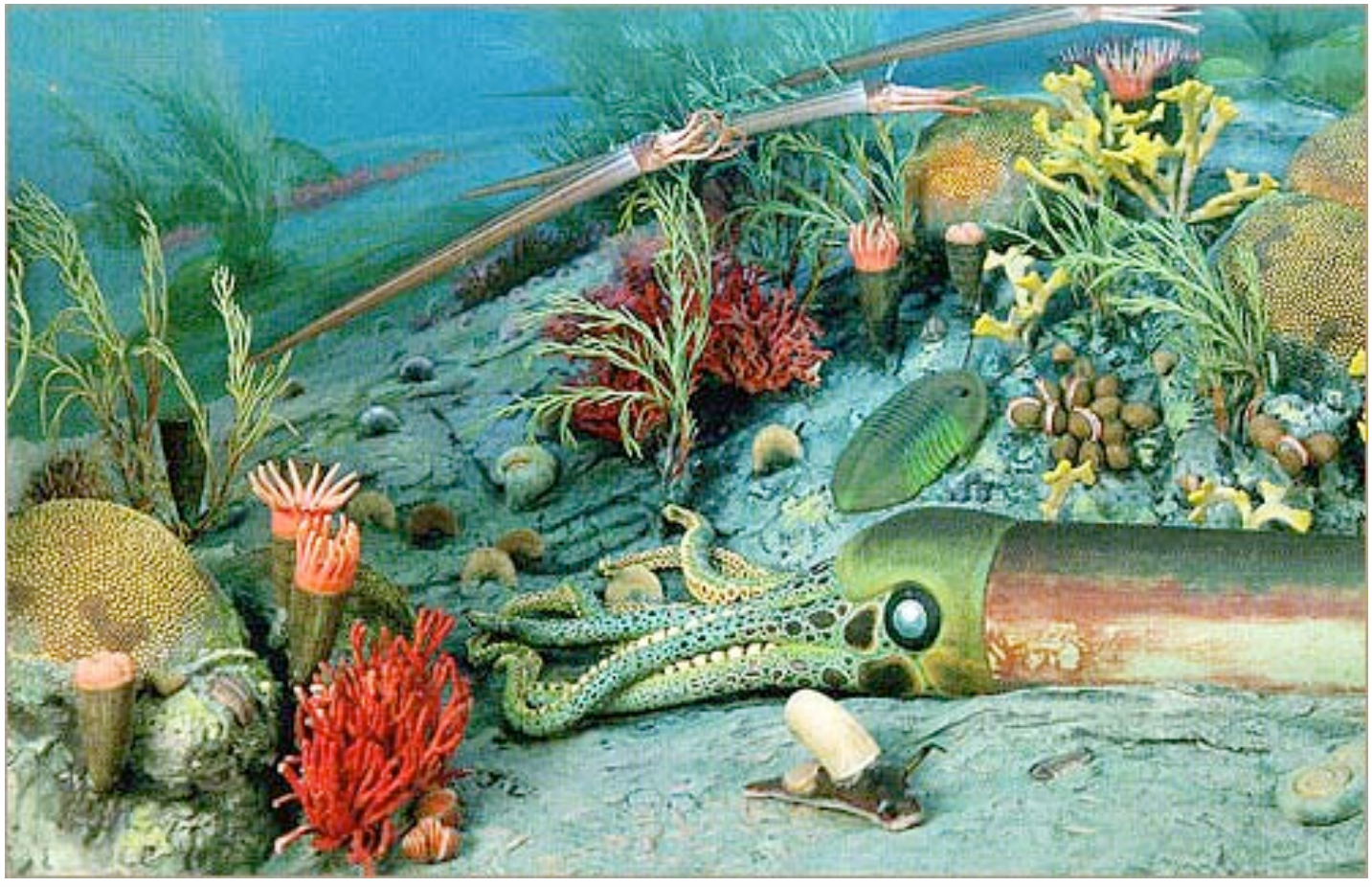
This is counter-intuitive

Abundant groups should be more extinction resistant



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.

# Extinction Patterns: Depth



**During the late Ordovician, species dwelling in shallow water were more likely to go extinct than species dwelling in deeper water**



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.

# Global Cooling and the Ordovician Extinction

Extinction has been linked to global cooling, glaciation, and sea-level fall

Climate models of the Ordovician show that it is difficult to initiate glaciation without a forcing impulse, such as a period of reduced sunlight



There may be a link between GRB and global cooling.

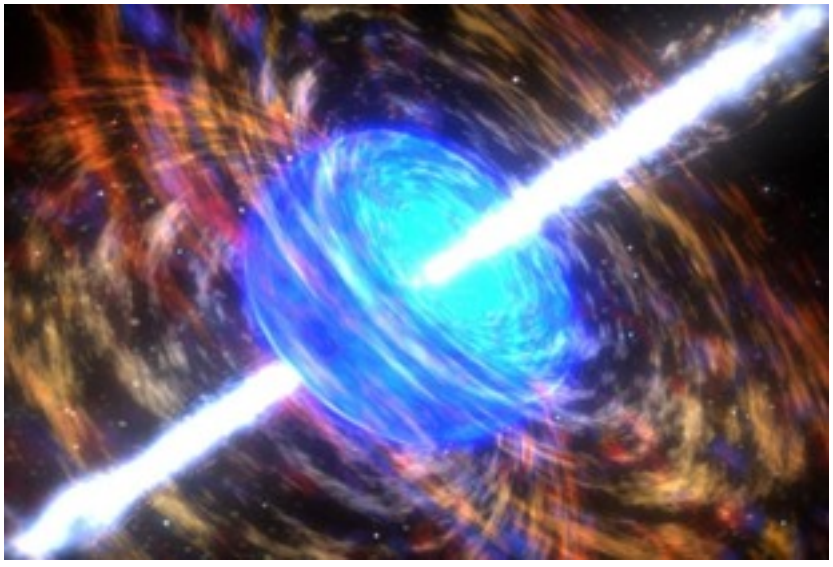
As mentioned before, GRBs produce atmospheric nitrogen dioxide, which initiates global cooling.

# Ordovician/GRB Connection?

**A GRB would have...**

- **Destroyed ozone layer, leading to increased solar UV**
- **produced $NO_2$, triggering global cooling**

**A one, two punch for life on the planet - initiates mass extinction**





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 surface floaters (plankton) and organisms with planktonic | Yes |
| Reduction of solar radiation – cooling | Yes – glaciation needed "kick" |

# But… the evidence is all circumstantial

## NO SMOKING GUN!
## (i.e. no direct evidence of a GRB)



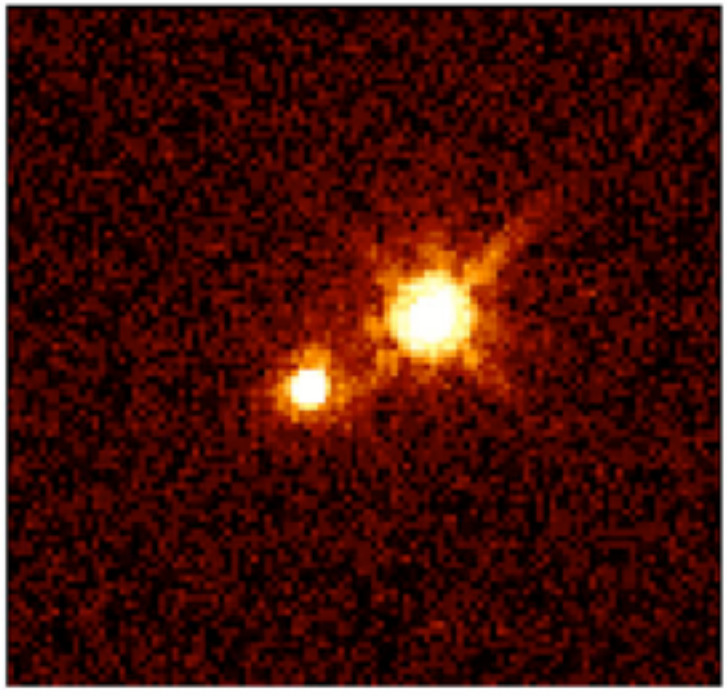
A strong GRB irradiation of the Earth is probable during the time interval since O2-enrichment of the atmosphere.
Such an event would destroy the ozone layer, exposing organisms to dangerous levels of solar UV.
At least one mass extinction shows characteristics compatible with GRB effects.

# May I have another Sir?

WR 104 is a massive star about 7000 light years away toward the Galactic center.

Again, a binary system.

With deep images, it looks more interesting.



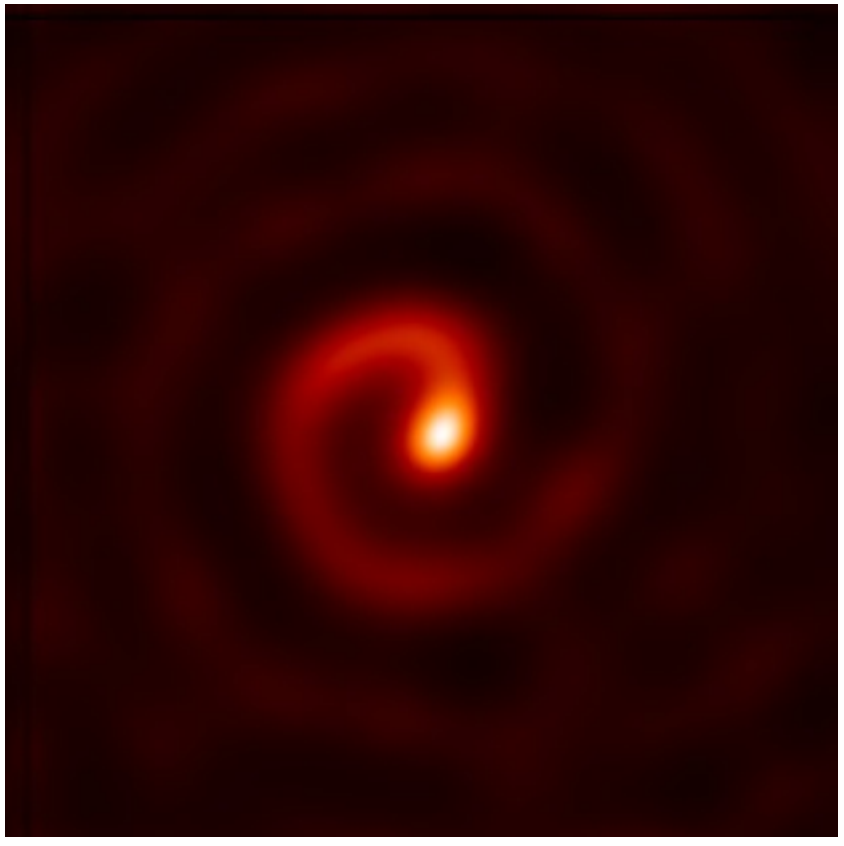
# May I have another Sir?

When you put together 8 months of images you see this.

The two stars are orbiting.

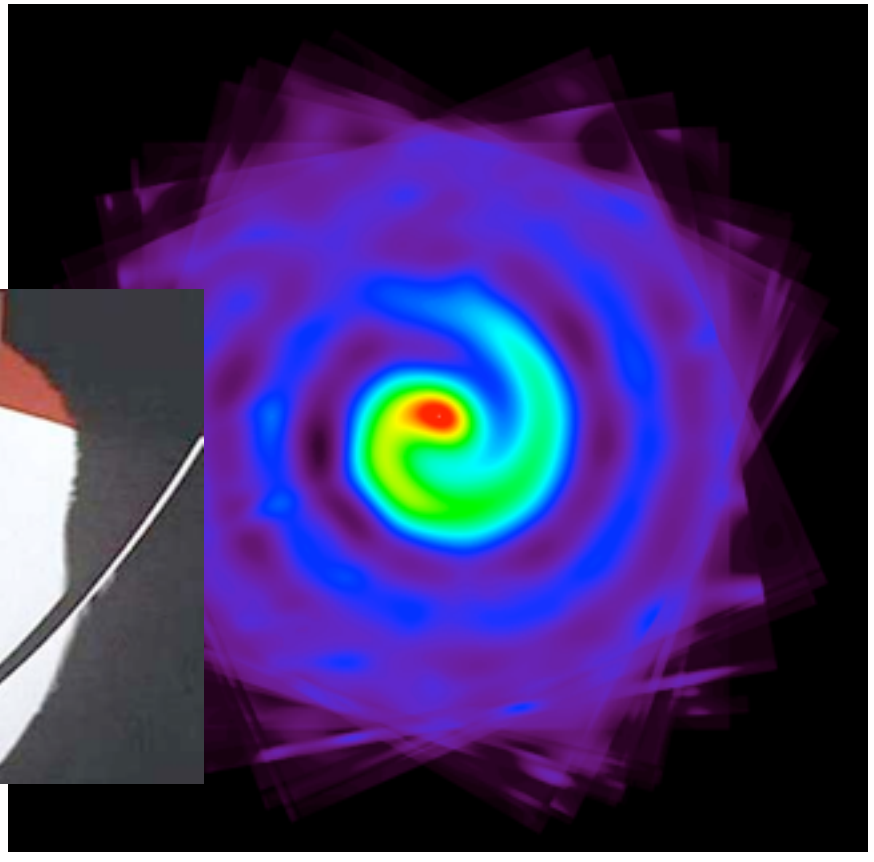
It looks like their rotation axis is pointing right at us!

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!**

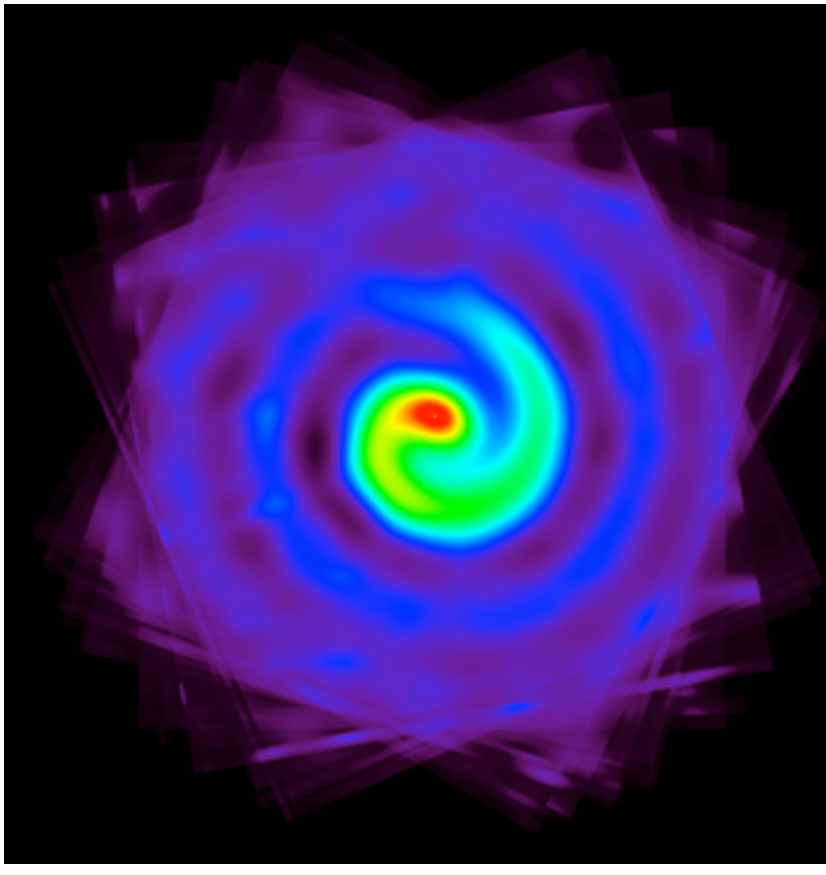


# May I have another Sir?

Would destroy 50% of our ozone layer

But, bottom line is we don't know if this star will be a GRB.

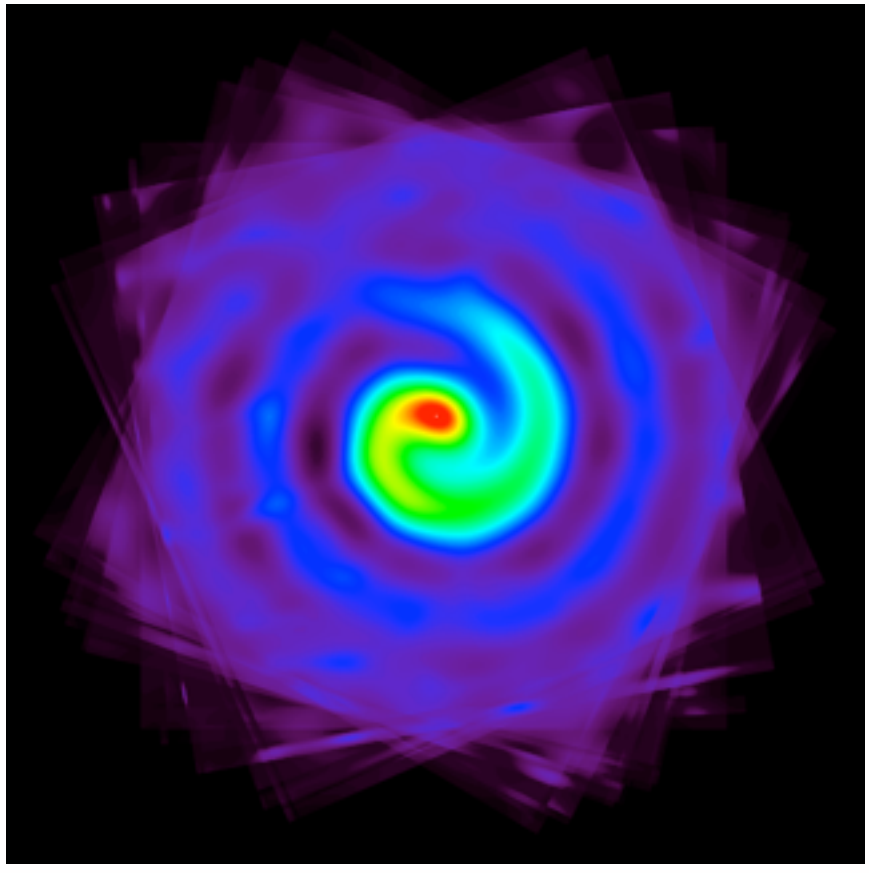
Most GRBs are happening in distance past, so the increased metallicity of stars today (from supernova) may make it impossible to make GRBs today.



# May I have another Sir?

**And new observations (different models) suggest that WR 104 is not pointed at us.**

**Need more observations!**

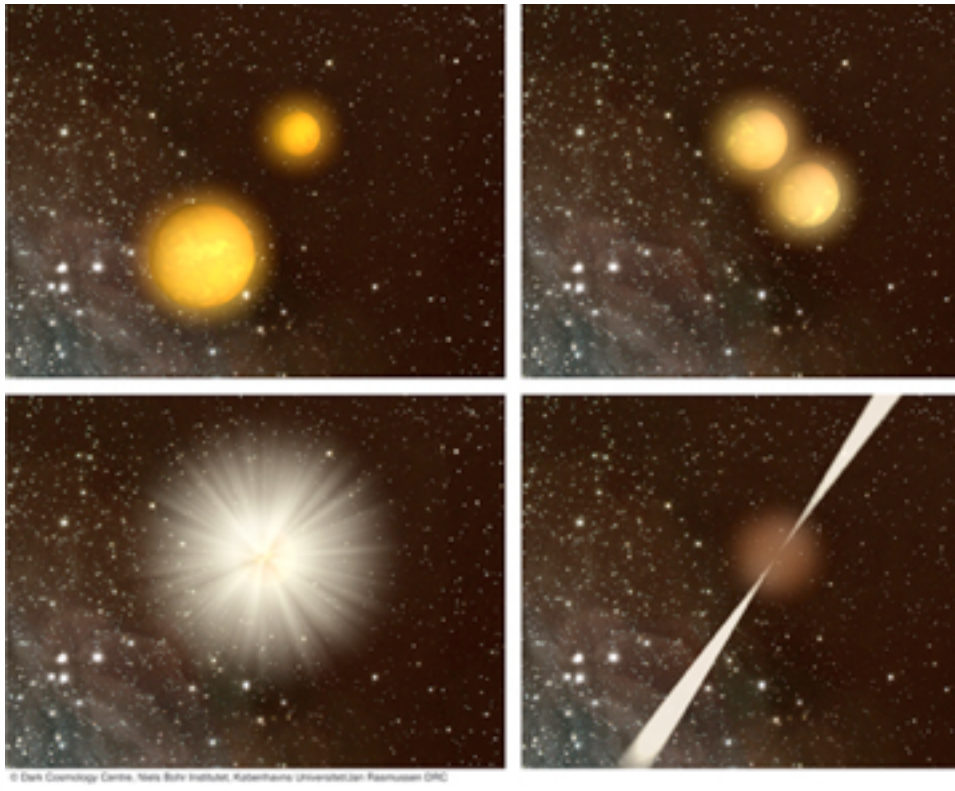


# And Shorts?

**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)

# Question

**Looking back through the mass extinctions of Earth, the Ordovician appears to be a possibility for a GRB. Which of the following facts was not observed in the Ordovician extinction?**

A. **Extinction of shallow (not deep) water organisms.**
B. **Extinction of surface floaters (plankton) and organisms with planktonic larval forms.**
C. **Mutations from gamma-rays, creating weird lifeforms.**
D. **Cooling of the Earth.**



Answer C

# 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.

# Death by GRB?


http://www.youtube.com/watch?v= 2agUY3mF4I

# 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, then it begins to dim.

Hours later, silent subatomic particles slam into the Earth's atmosphere.

No matter if people are 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!

# Imagine

A black hole coming right at us at 500 miles/ sec.

As it gets closer tidal effects– floods, earthquakes, and tsunamis.

As the 10 solar mass black hole reaches 7 million miles away, its gravitational pull equals that of Earth, everything on Earth is weightless.

Then, the pull of the black hole is more than Earth.

As the Earth gets shredded, you try to remember what Leslie said about black holes!

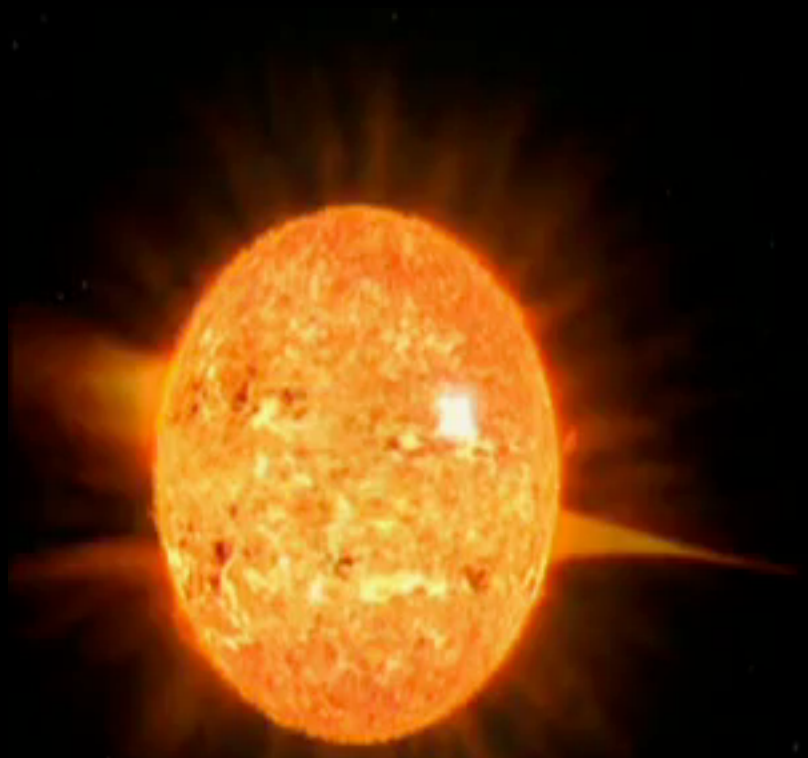
# Top 10 Ways Astronomy Can Kill you or your Descendents

## 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 ("black hole on a diet") 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.

# Killer Black Holes



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