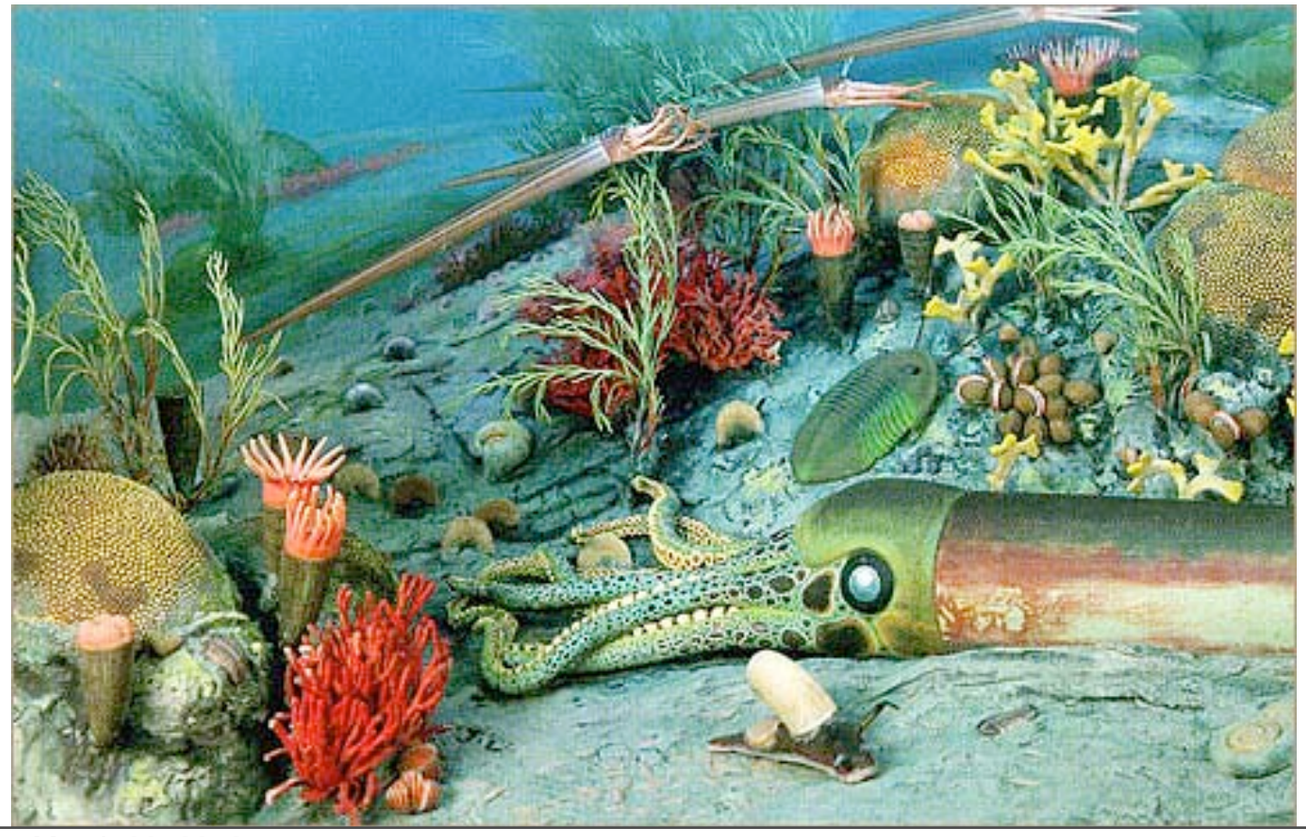
Astronomy 150: Killer Skies
Lecture 27, March 30

Assignments:

- HW8 due at start of class
- Good news: no homework next week
- Bad news: Hour Exam 2 next week
  information on Course Website
- Also next week: Solar Observing next week

Last time: Killer Gamma-Ray Bursts

Today: A Gamma-Ray Burst Extinction? And: Black Holes



iClicker Poll:
Hour Exam 1 Question Count

The exam will be multiple choice.

You will have the usual 50min of classtime:

no more, no less.

How many questions would you like?

few Qs = each counts more, but more time per question

many Qs = each counts less, but less time per question

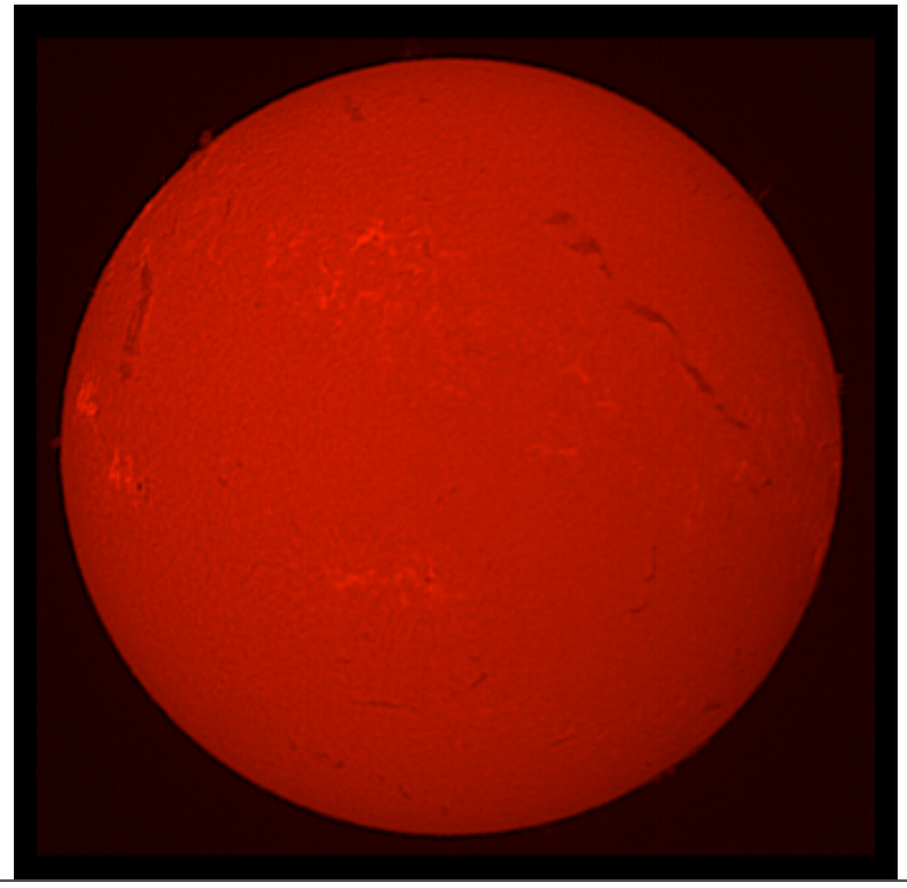
A. 20 each question: 5% of total score, avg time 2min 30sec
B. 25
C. 30 class choice for # questions on Exam 1
D. 35
E. 40 each question: 2.5% of total score, avg time 1min 15sec

Solar Observing Next Week

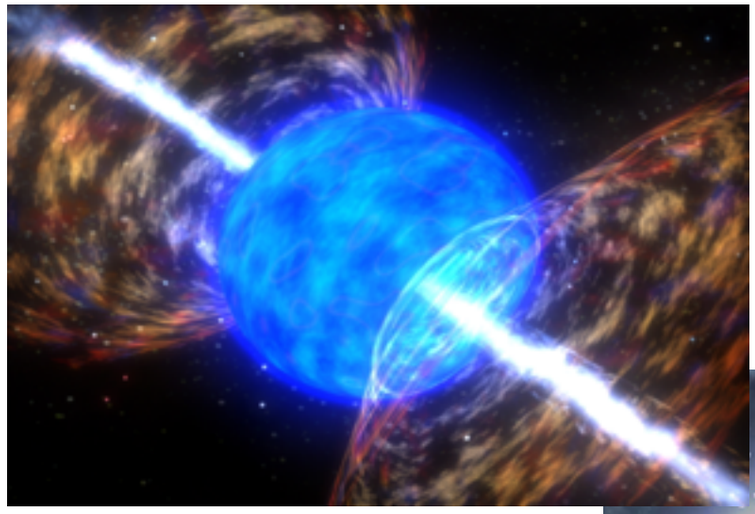
Happens next week:

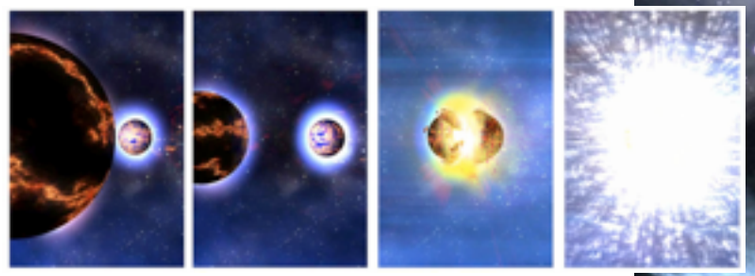
- M-Th, 10:30am-3:30pm, weather permitting
- At Campus Observatory (upstairs in dome)
- Assignment details and report form on class website
- Report due April 13th
- Subscribe to Solar Observing Status Blog for weather-related notices

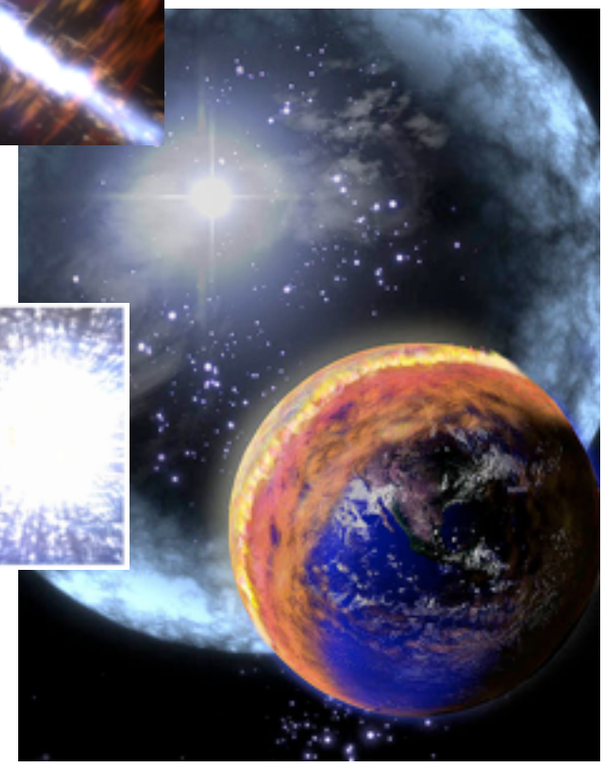
http://illinois.edu/blog/view/414



GRB Threat: Recap







Gamma-Ray Burst: Cosmic Blowtorches

Longer-duration GRBs connected to massive stars

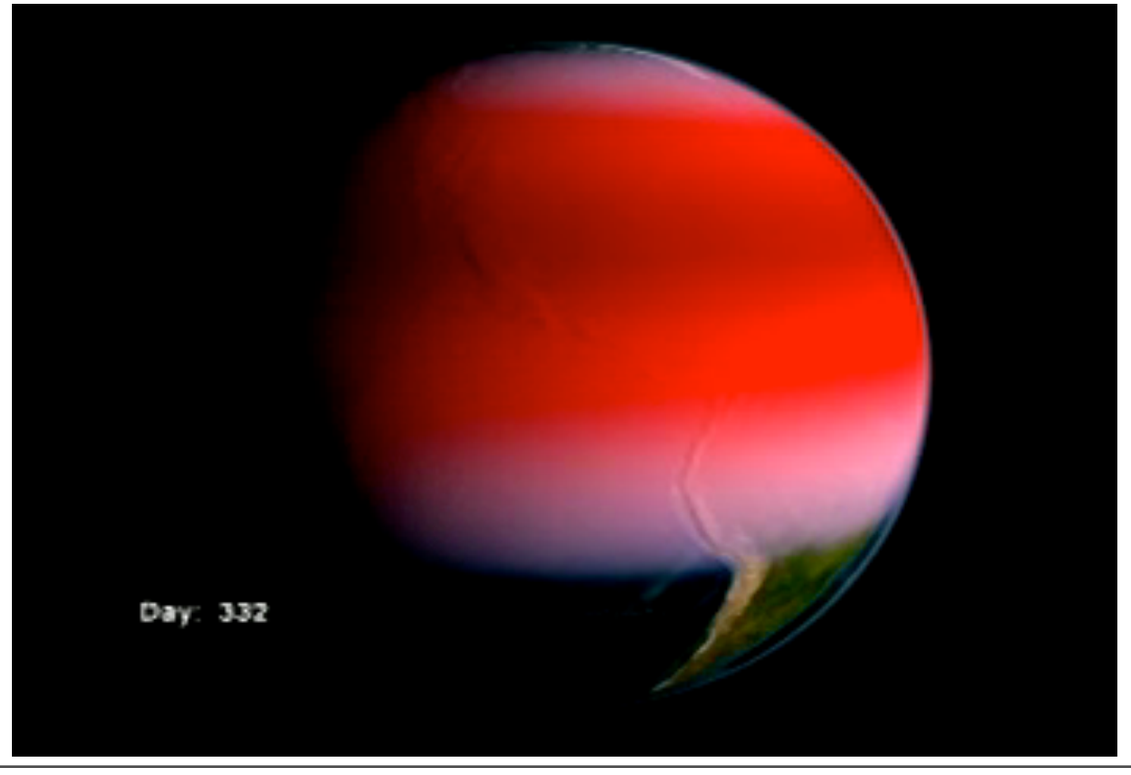
- proposed origins: rapidly rotating, very massive star
- gravity too strong for neutron star--collapses to form black hole
- black hole pulls in and swallows most of surrounding hot, magnetized material (accretion disk)
- friction and magnetic felds generate beamed “jets” moving nearly at speed of light
- perhaps no supernova explosion at all: “collapsar”
- or perhaps powerful explosion: “hypernova”

Shorter-duration GRBs: mergers

- proposed origins: merging of pairs of neutron stars
- or merging of NS and black hole
- no supernova, not in regions of star formaion

GRB Threat: Supernova on Steroids

- danger similar to SN: ionizing radiation damages atmosphere
- ozone layer destroyed
- acid rain created
- dimming of sunlight



GRB Rates?

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

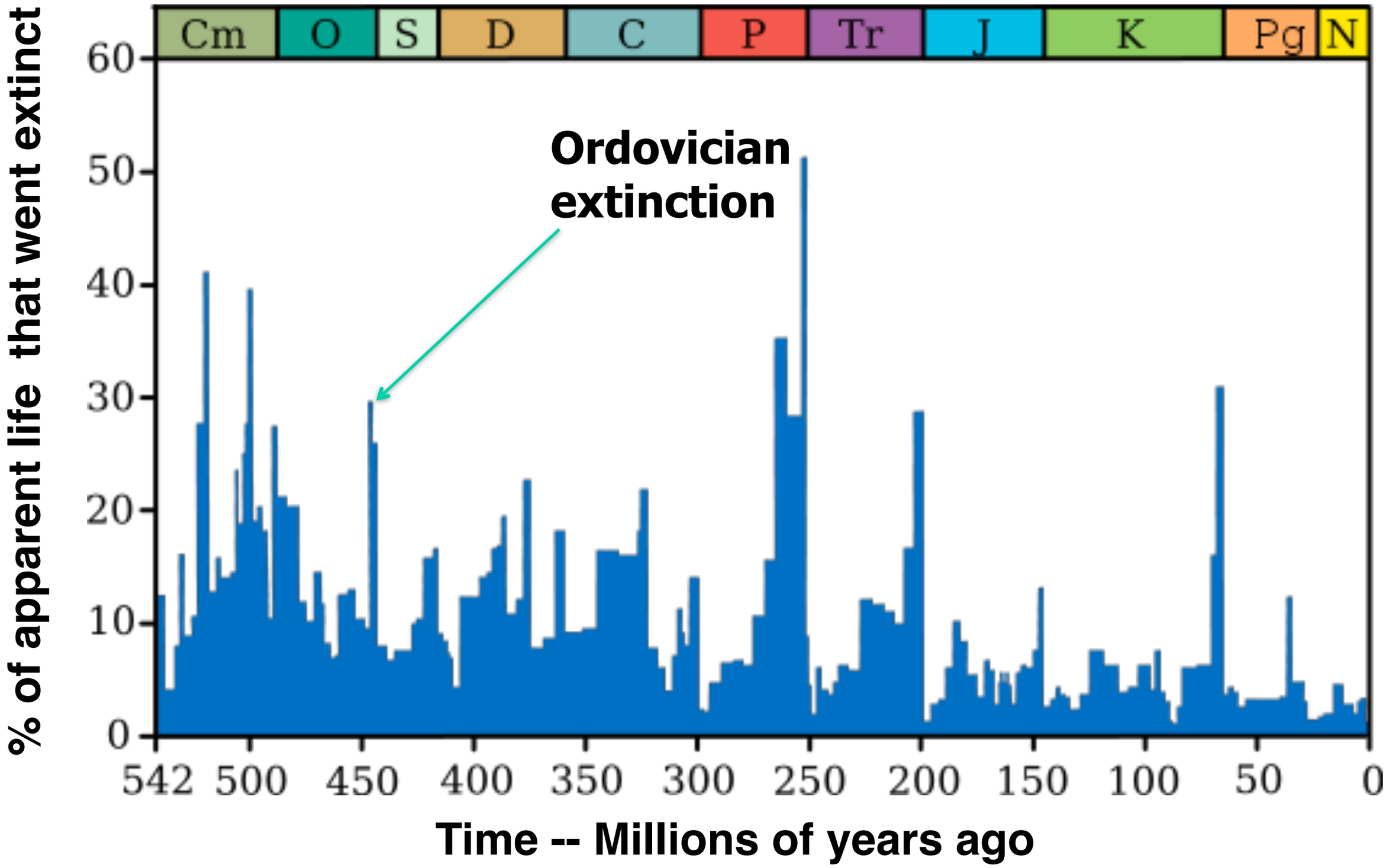
We expect about 1 burst per 100,000 or million years

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

Patterns of Ordovician Extinction

Third-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

Trilobite Extinction

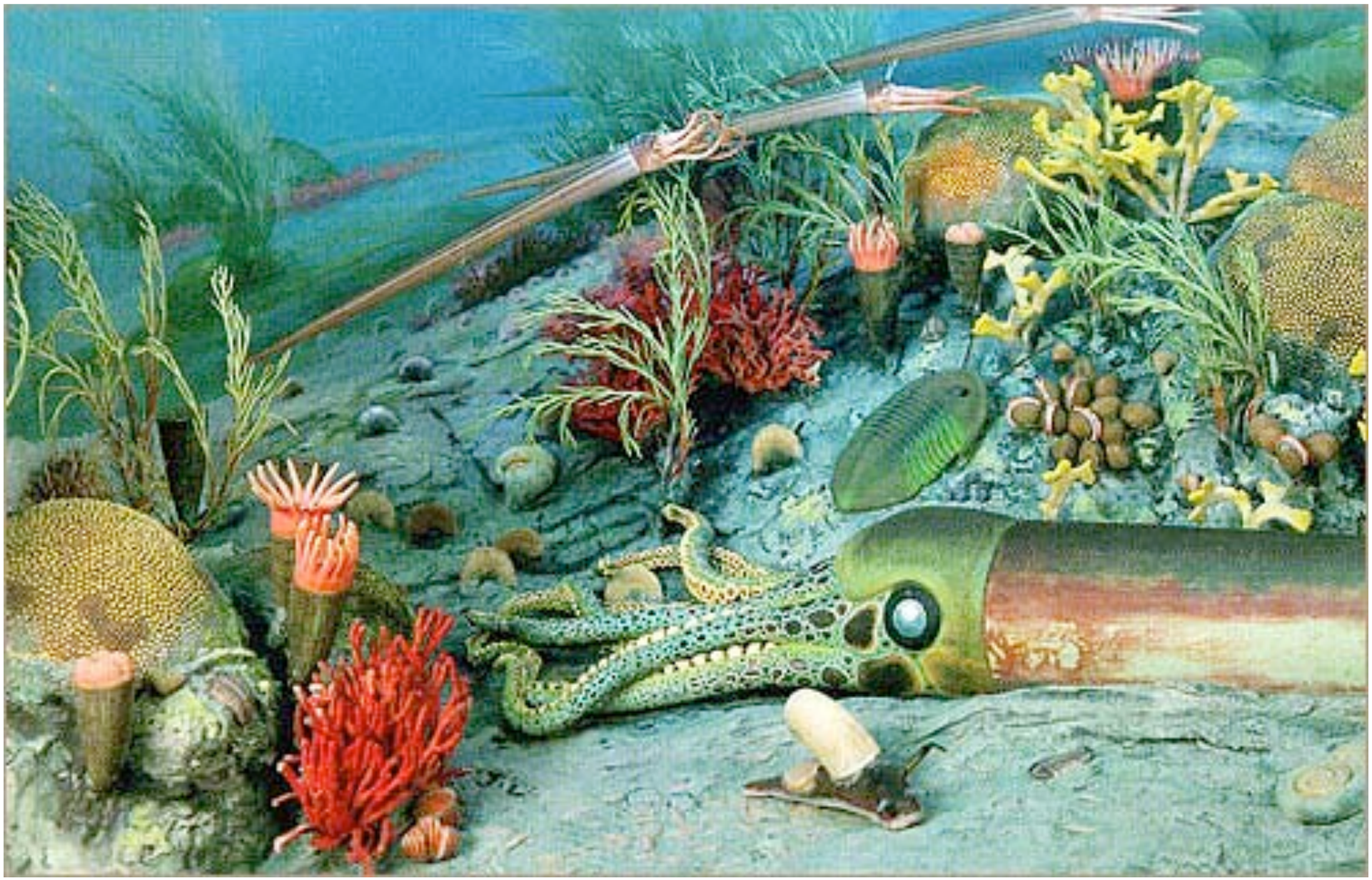
In the Ordovician, trilobites were wide-spread and abundant

Yet, they went extinct while more restricted groups persisted

This is counter-intuitive

- Abundant groups should be more extinction resistant

Extinction Patterns: Depth



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

Global Cooling and the Ordovician Extinction

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

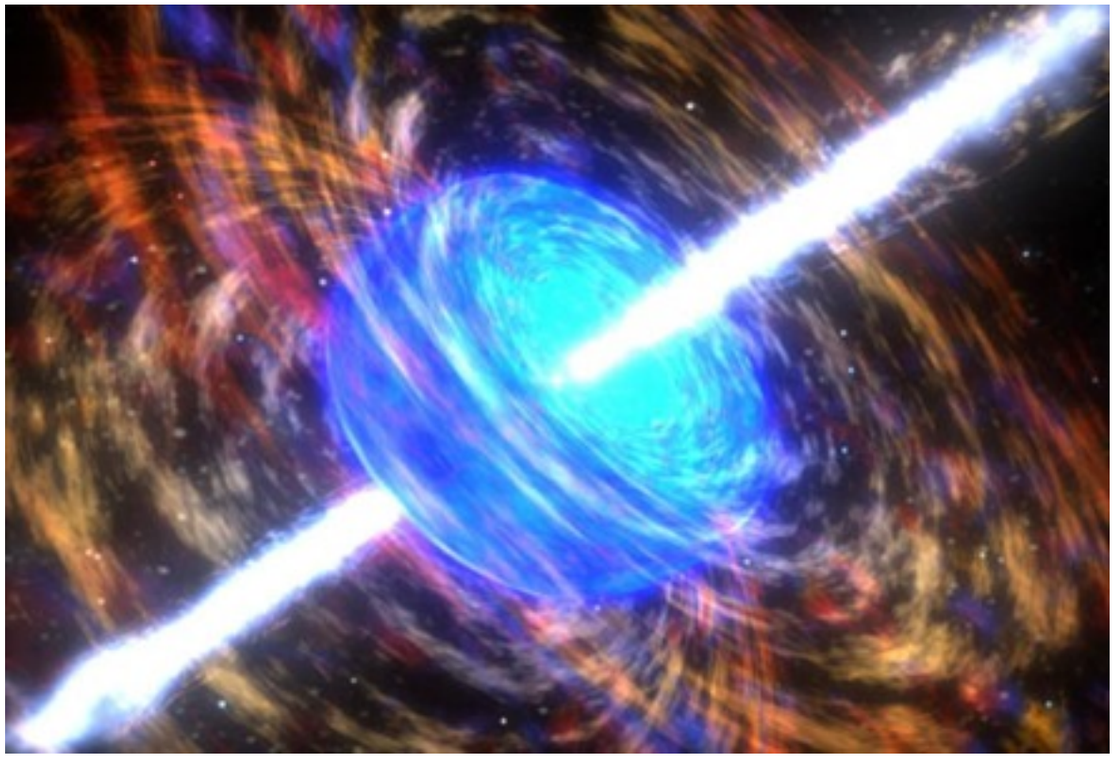
Climate models of the Ordovician show that it is difficult to initiate glaciation without a forcing impulse, such as a period of reduced sunlight

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



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 larval forms	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)

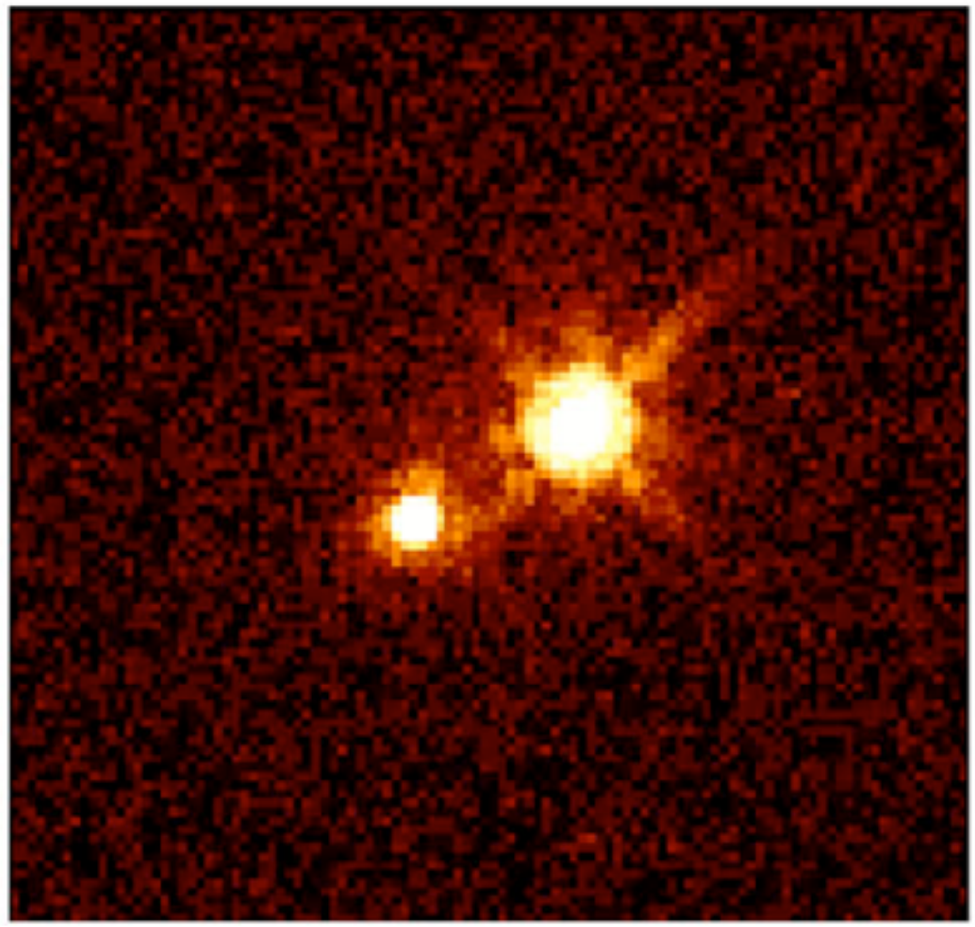
May I have another Sir?

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 images, it looks more interesting.



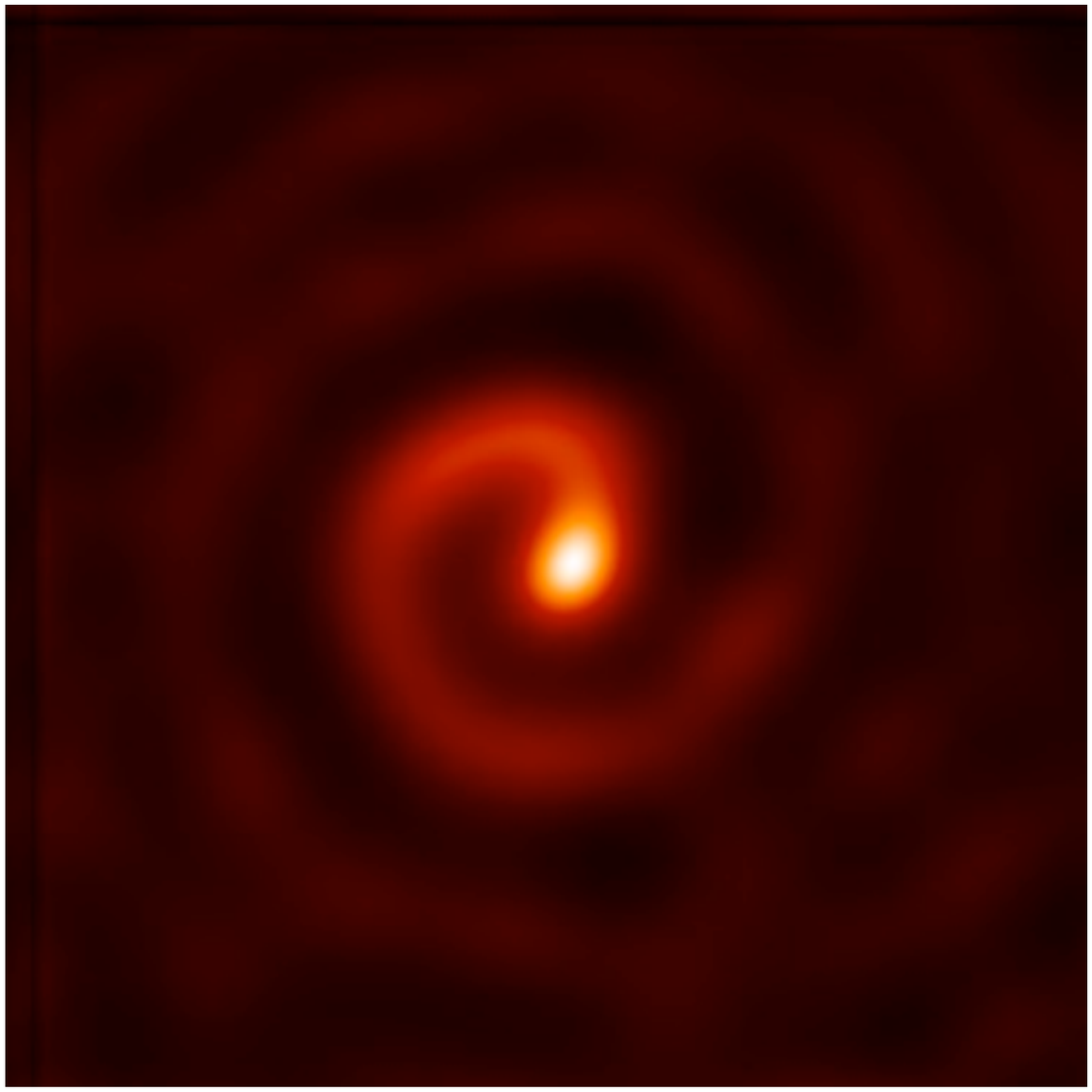
May I have another Sir?

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

The two stars are orbiting.

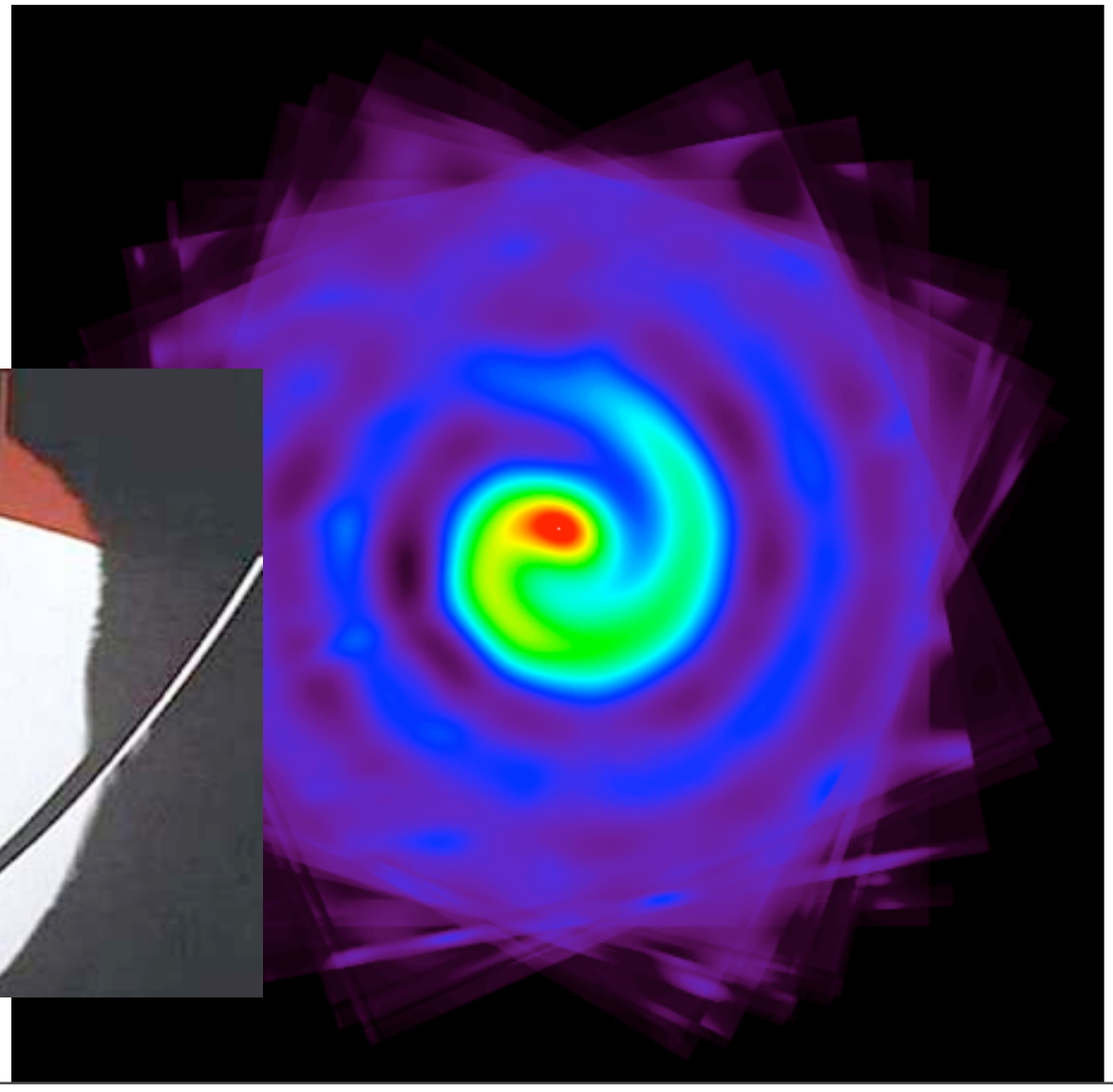
It looks like their rotation axis is pointing right at us!

Down the barrel of a GRB gun?



May I have another Sir?

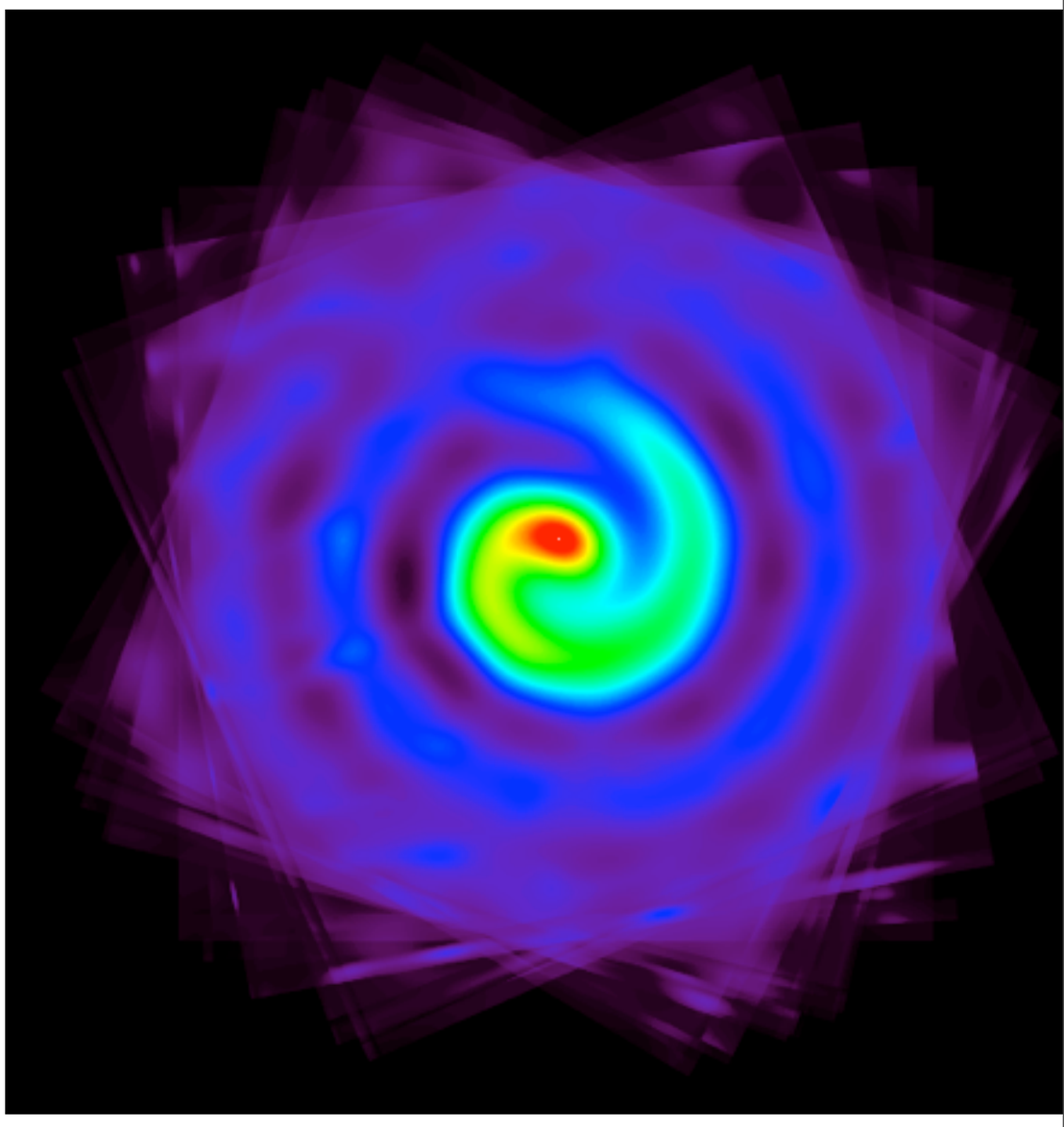
The most massive of the pair is in the last stage before a supernova, so it could blow at any time up to probably hundred thousand years!



May I have another Sir?

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

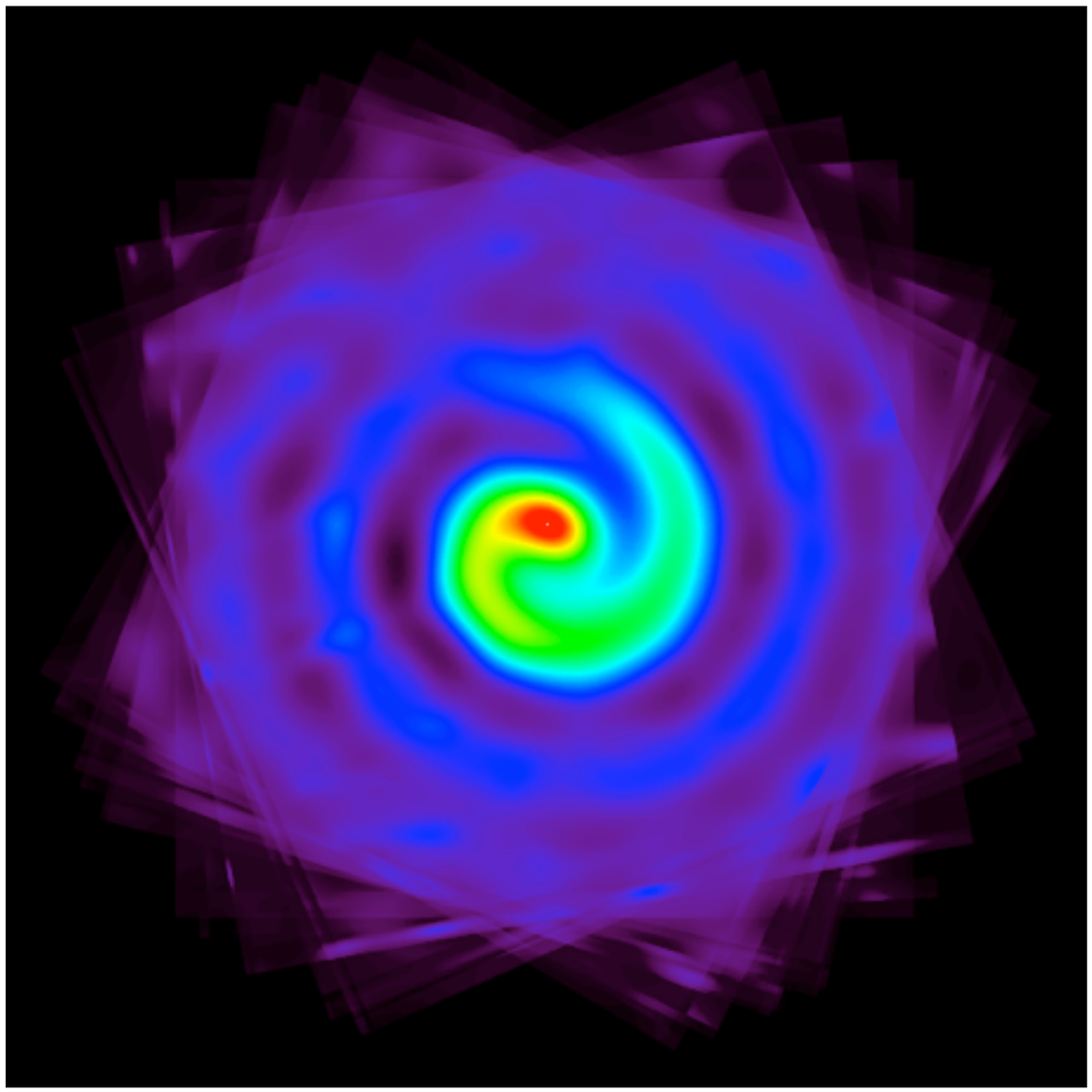
Most GRBs are happening in distance past, so the increased metallicity of stars today (from supernova) may make it impossible to make GRBs today.



May I have another Sir?

New observations (different models) suggest that WR 104 is not pointed at us.

Need more observations!

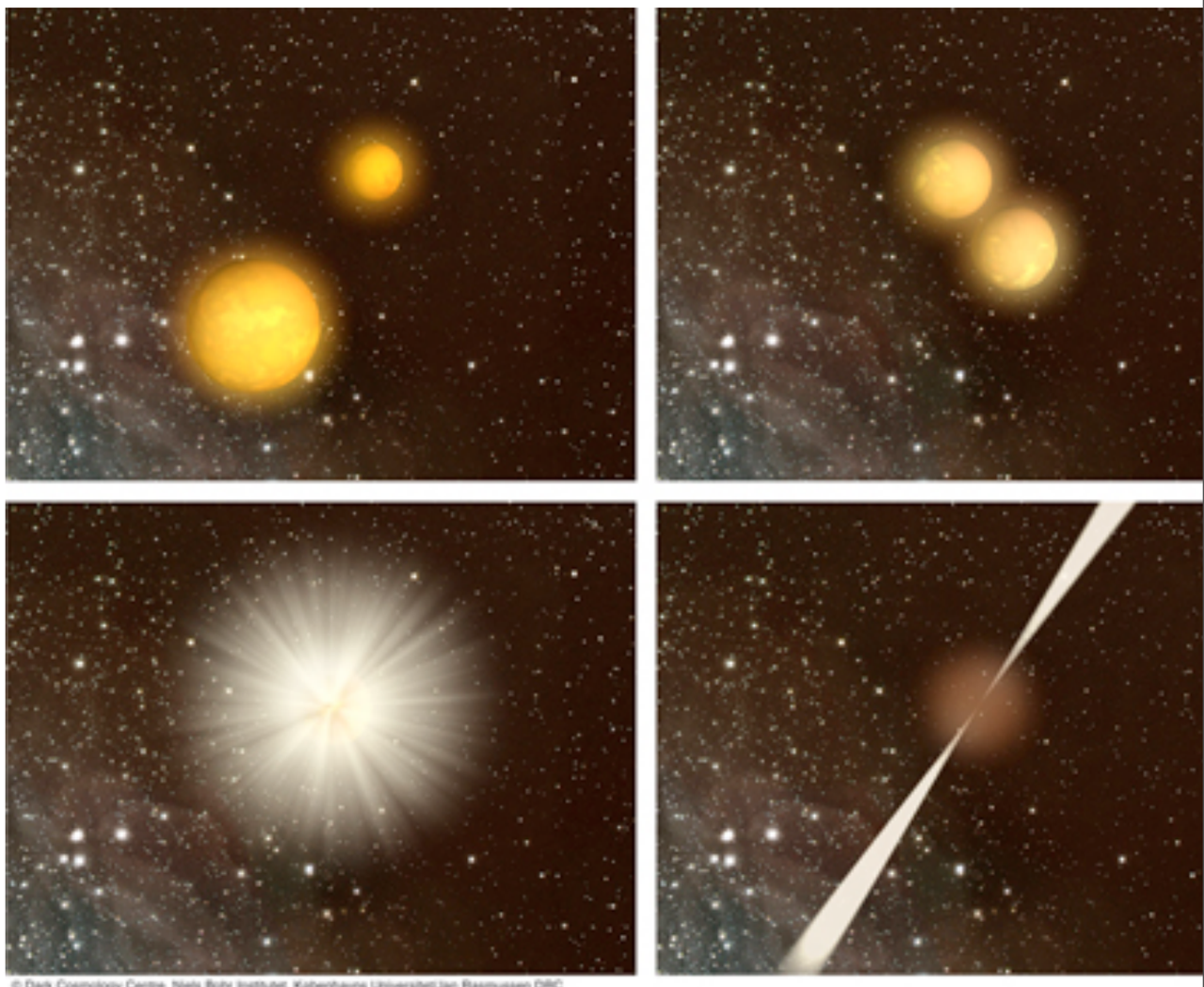


And Shorts?

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

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 Brian 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 Brian said about black holes!

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 ("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.

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

Black Hole Formation

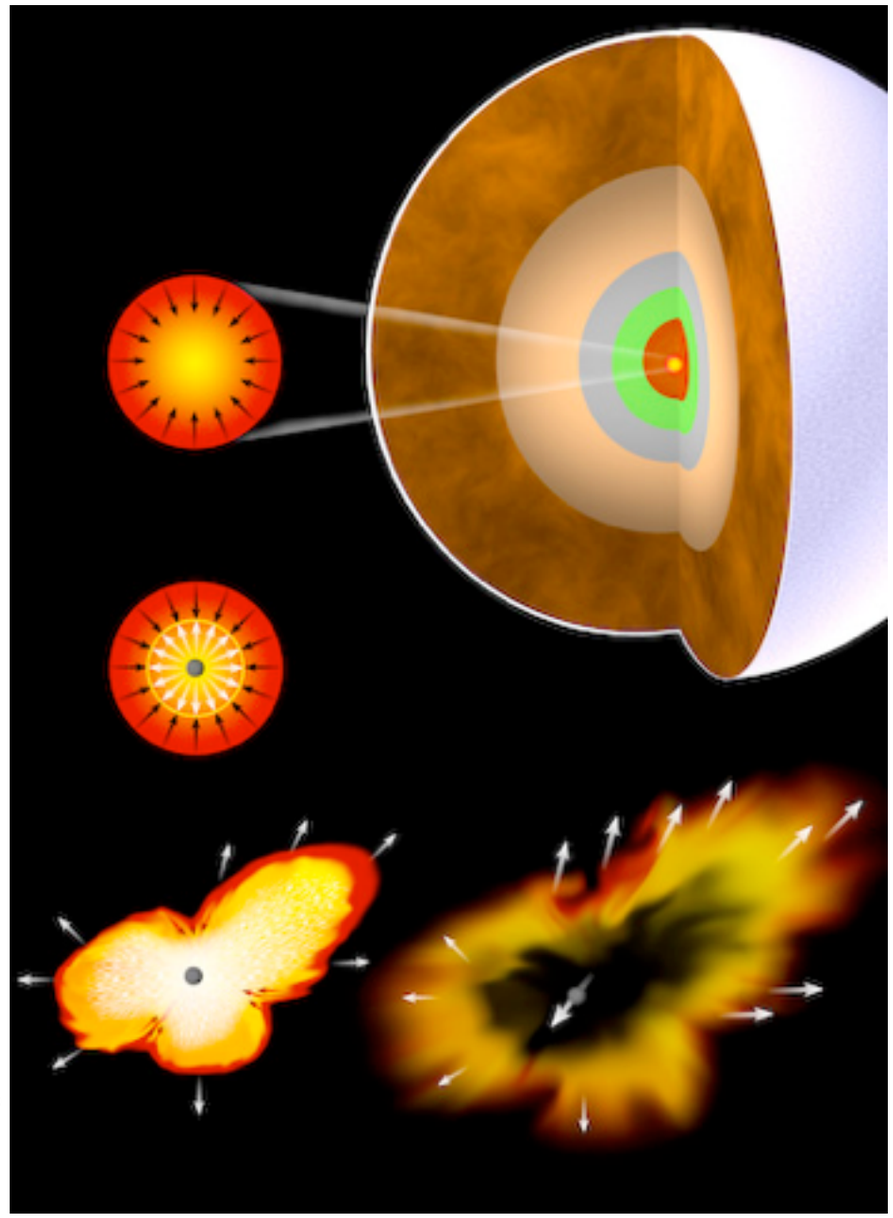
Recall: a star's life is a struggle against it's own gravity

In the death of a massive star

- i.e., end of life for stars 8 M_{sun} < M < 30(?) M_{sun}
- core collapses under its own gravity
- crushed until forms neutron star

but if very massive star > 30(?) M_{sun}:

- keep adding mass until neutron star gravity is too strong for neutral repulsion
- core collapses and cannot be stopped
- matter falls into a single point (?) at center
- struggle against gravity lost forever
- a black hole is born!



Black Holes in Context

- most stars do not form black holes
- most stars not massive enough even to make supernova
  recall: the Sun will not die this way!
- and even massive stars mostly not massive enough to make BH, instead make neutron stars
- but: some stars are massive enough
- black hole formation is an inevitable part of star birth and death
  a fact of life in the universe!

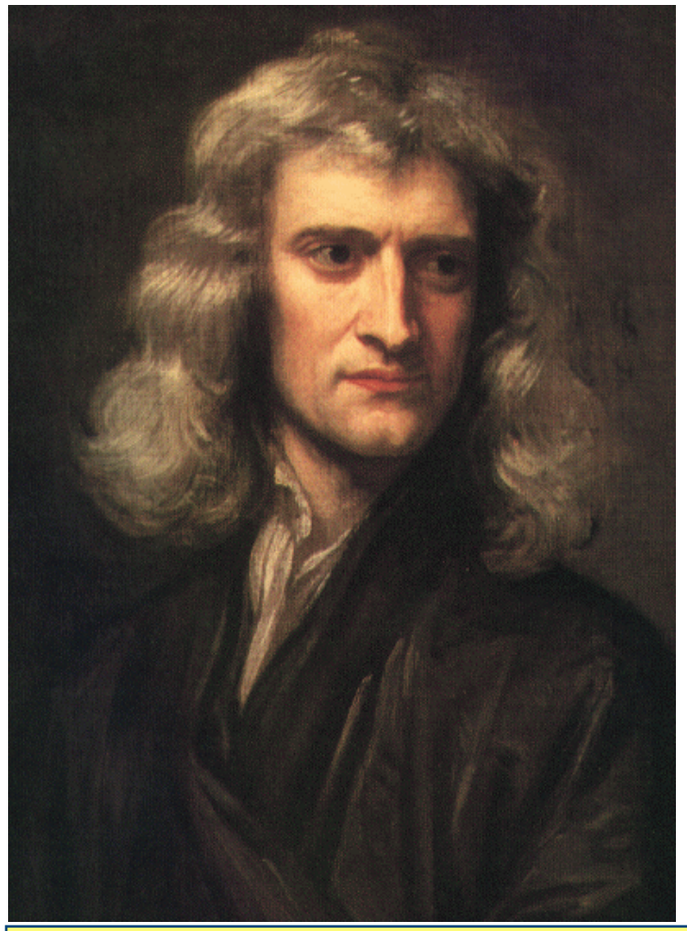
Extreme Gravity

the heart of a black hole is a region of ultrastrong gravity

to understand: need gravity theory that works even when applied to extreme situations

thus far: we have used Newton's theory of gravity

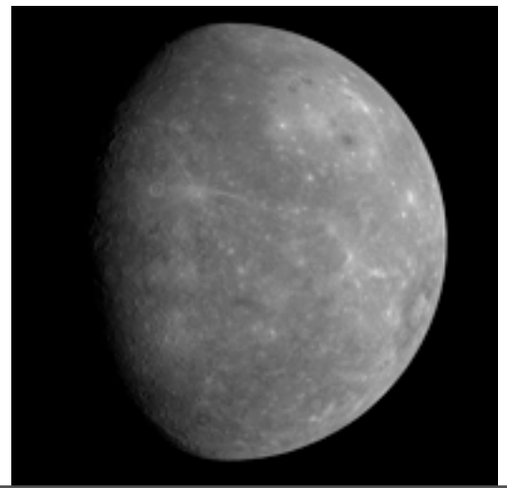
- one of hugest achievements in science!
- excellent (but not perfect!) description of motions in the Solar System and beyond
  - explained Kepler's laws
  - predicted existence of Neptune based on funny motions of Uranus
  - routinely use to measure masses of other stars and planets



Sir Isaac Newton (1642-1727)

But: around 1900, motions of Mercury found to disobey predictions from Newton's gravity law

- observed orbit differed from predictions by 23 arc seconds per century
  - a challenge to even measure orbit this well
  - but discrepancy confirmed to be real
- this must be explained: theory has to explain all reliable data



iClicker Poll: Mercury Behaving Badly

It's 1910. You graduate Illinois to become a world-leading Astronomer. You are aware of the problem with Mercury's orbit. Explaining this will lead to fame and fortune (Nobel Prizes recently invented!).

Vote your conscience:

What's the answer, and what do you do to prove it?

A. **Newton's gotta be right. So must be unseen source of gravity. Look for new planet (or some other mass source) near Sun**

B. **Newton must be wrong. Develop new theory that explains Mercury and makes new predictions that can be tested**

C. **I'll hedge my bets: look for new planet, but also work on new gravity theory**

Mercury Solution

If Newton right, need more "dark matter" -- a planet near Sun whose gravity can influence Mercury

- Hypothesized new planet: "Vulcan"
- can predict where it must be
  but nothing is there

So: Newton's theory fails!

- And notice: fails for planet closest to Sun
- where gravity is strongest

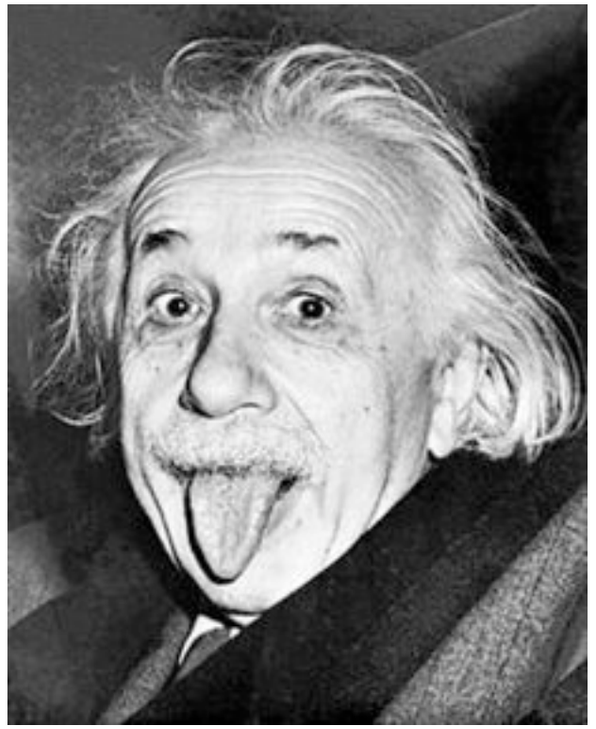
Must develop new gravity theory

- that gives similar predictions to Newton when gravity is weak
- but different predictions when gravity is strong

such a theory was developed in 1915 by Albert Einstein

- the General Theory of Relativity
  aka "General Relativity"
- explains solar system motions including Mercury's
- makes profound new statements about space and time and the fate of the Universe
- a critical part of the rest of this course and of 20th and 21st century science
- and just what the doctor ordered for describing the black holes

Give it up for Big Al!

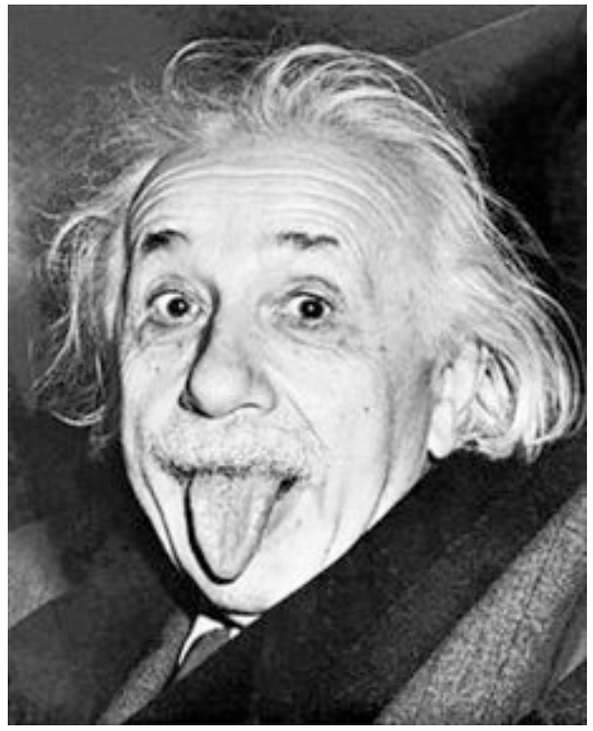


Space, Time and Motion

Recall Galileo/Newton special cases of motion

Free Body

- object with no net forces acting
- motion is a straight line, constant speed



Important to note that all free bodies move this way. straight line, constant speed, independent of size, mass

- Q: Why?
- Newton: That's the way it is!
- Q: Be more specific: that's the way what is?
- Einstein: that's the way space and time are

  if nothing else going on (no forces) space and time constructed so that free bodies move in straight lines at constant speed independent of nature of the object

Motion really reflects nature of space and time

Motion and Gravity: Free Fall

Special Case of Motion #2: Free Fall

- motion only due to gravity

Recall Galileo's "Tower of Pisa" experiment

- objects fall at same rate if dropped together
- same regardless of size, shape, composition

Newton says:

- it's a coincidence
- it just so happens that gravitational mass
  - the way objects "feel" or "couple to" gravity
    - $F_{grav} = m_{grav}g$
  - is always exactly the same as inertial mass
  - which is the way objects resist acceleration
    - $a = F/m_{inert}$

Einstein says:

- too amazing to be a coincidence
- must be telling us someting deeper...

Einstein's Equivalence Principle

Einstein notes:

- Gravity causes acceleration, but in "democratic" way:
- all objects accelerate the same

Einstein's Equivalence Principle: i

- in a closed room, no experiment can distinguish (non-gravitational) acceleration vs gravity

But note:

- acceleration is aspect of motion
- relates to objects' travel through space and time
- so equivalence of gravity=acceleration will have impact on nature of space and time