4/22/05

Exam 4, Friday, April 29 (Chapters 9, 10, 11)

Extra Credit reports due last day of class, Friday, May 6

Final, Wednesday, May 11, 2 -5 PM

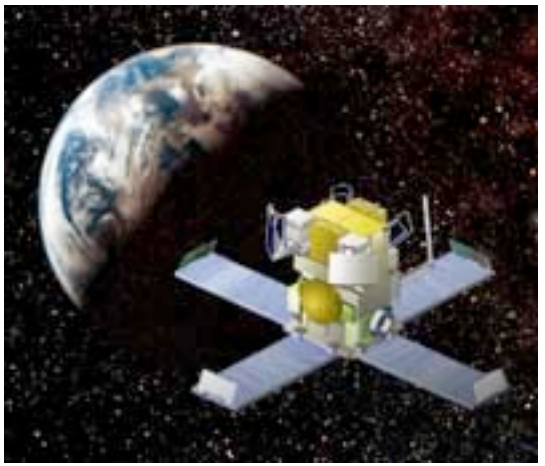
Supplementary reading - Draft of new, revised chapters for second edition, under “reading assignments” link

News: NASA relaxing Shuttle safety?

Pic of the day:

100th Anniversary of Einstein’s remarkable year.

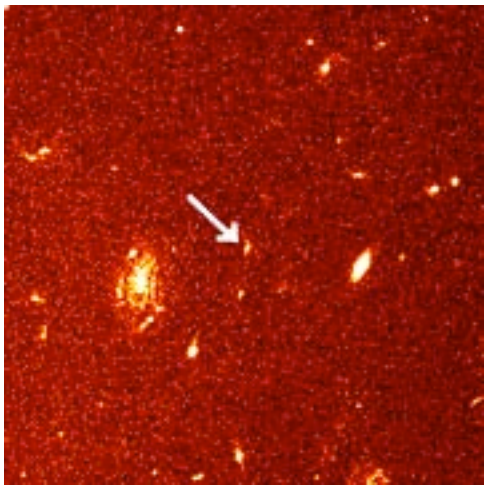
Gamma-Ray Bursts



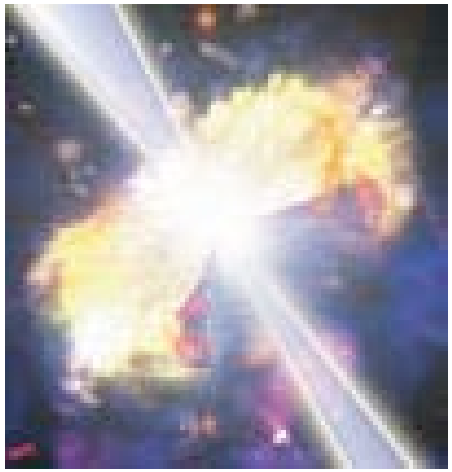
High Energy Transient Explorer

Cosmic explosions, flashes of gamma-rays lasting about 30 seconds, detected by satellites.

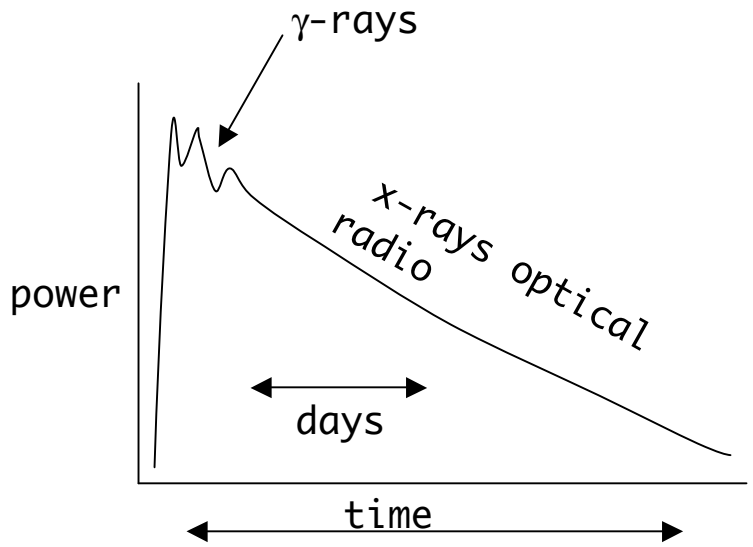
Seen across the Universe.



Energy is expelled in narrow jets.
Energy comparable to that of supernovae, but all in gamma-rays, with later ***afterglow*** in X-ray, radio and optical radiation.
Birth of a black hole?



Revolution in 1997: 1st detection of "after glow" - optical, radio, X-ray, fading light



Position localized - could bring full armament of modern astronomy to bear on the fading radiation.

⇒Found bursts were in distant galaxies - all at huge, cosmological distances

⇒ Very bright to shine that far

January 23, 1999 optical flash associated with the gamma-ray burst itself (need to discover, swivel telescope, look in 30 seconds!)

9th magnitude - human limit 6th magnitude, could almost see with naked eye, could have seen with good binoculars, but half way across the Universe! ***Brightest optical event ever recorded.***

If gamma-ray bursts shine equally in all directions, the energy released in gamma rays would be $3000 \times$ SN or $30 \times$ core collapse neutrinos.

Comparable to total annihilation into pure energy of entire star!

BUT

Light bulb versus laser pointer or flash light

Bursts do not radiate in all directions!

They are strongly focused into jets!

Bursts are focused into only 1/100 to 1/1000 of total sky

Typical gamma-ray burst energy ~ 1/3 supernova kinetic energy

But send matter at 99.997 speed of light

Supernova energy into a mass equivalent to Jupiter, not the mass of the Sun, as for supernovae

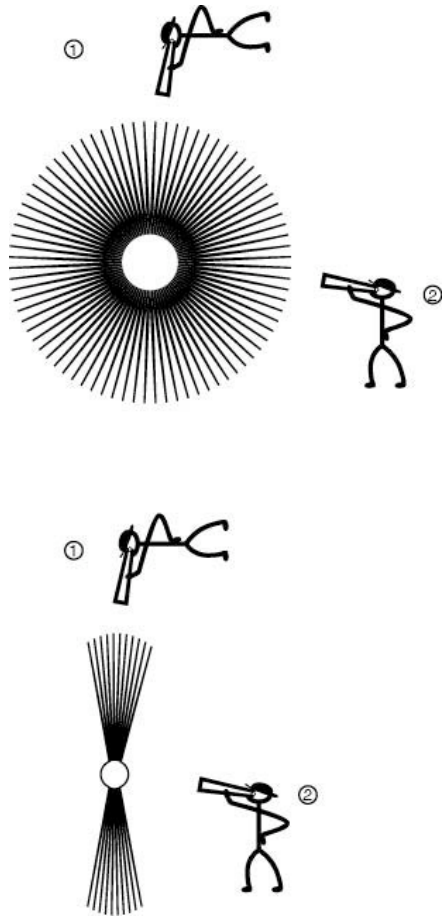


Figure 11.4

They explode ~100 times more often than observed (about 2 per day) because most have the jet aimed away from us.

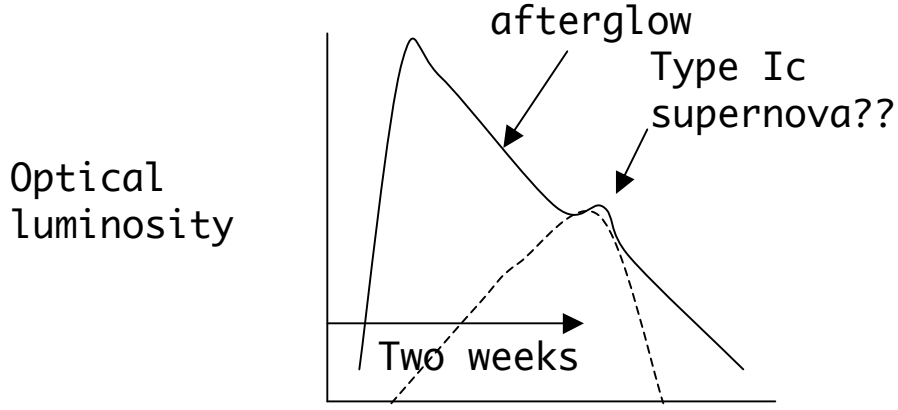
Find all gamma-ray bursts in regions of massive young stars

Something to do with death of massive stars

Explode once every 10^4-10^5 years in a given galaxy versus about once per 10^2 years for ordinary supernovae, so relatively rare.

Most popular guess is that gamma-ray bursts represent the birth of a black hole in the collapse of a massive star (might be a highly magnetized neutron star or *magnetar* - Chapter 8)

Circumstantial evidence for several bursts associated with supernovae.

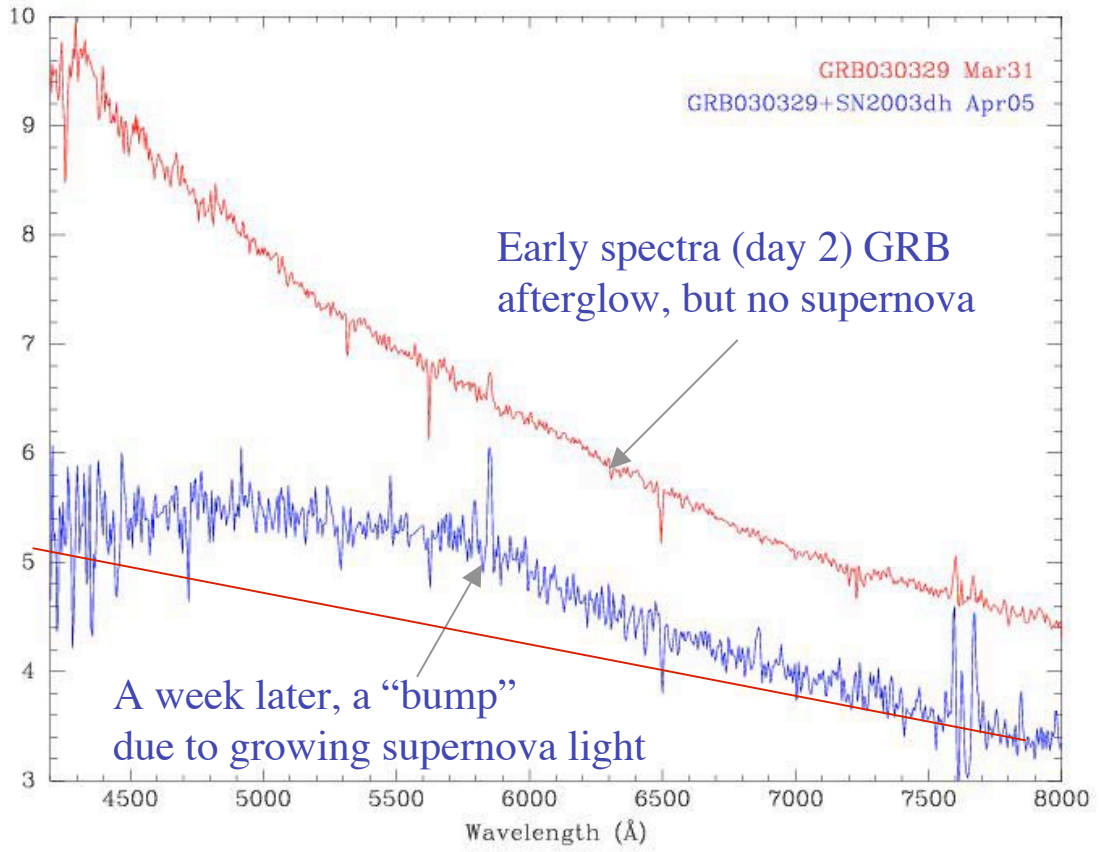


The raging issue: are gamma-ray bursts produced in some form of core collapse supernova? Circumstantial evidence...

THEN PROOF!

GRB 030329 was nearby, only 3 BILLION light years away! Relatively bright, an ideal target.

SN2003dh was discovered a week later! Spectrum of a Type Ic supernova



The current picture: Gamma-ray bursts result from the collapse of a massive star, probably to produce a black hole, that emits a tightly focused, highly relativistic jet.

Every burst, twice a day somewhere in the Universe - the birth of a black hole aiming its jet at us?

~100 aimed elsewhere for every one aimed at us.

NASA Animation: Black Hole Forming in Star, producing jet and Gamma-Ray Burst

Gamma-ray bursts are intensely bright lights

Can be seen at great distance

Probe cosmology, the early Universe

Dark Ages, after the Universe cooled off a million years after the Big Bang and before stars and Galaxies first formed half a billion years later

Gamma-ray bursts could be the first objects seen at the end of the Dark Ages as the first stars are born and die, over 13 billion years ago.

What's Next?

The Swift satellite launched
Wednesday, November 17, 2004

Swift discovering a gamma-ray burst
every few days!

Detailed follow up will tax all the
world's great observatories.

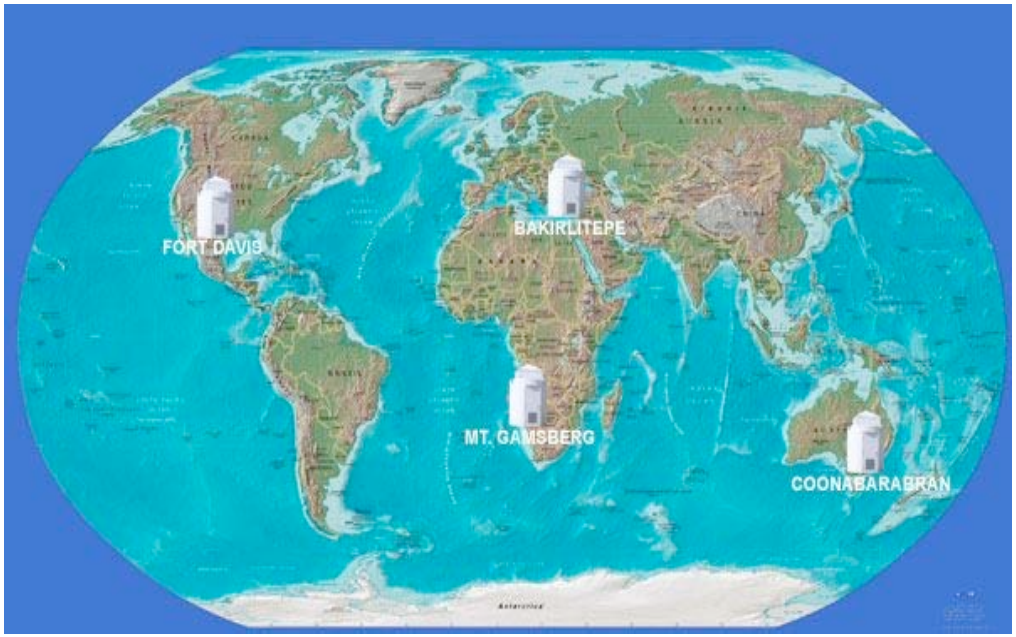
With on-going improvements, the rapid-response, queue-scheduled HET should be well-situated to compete.

Swift can do optical observations,
but needs a minute to swivel - too long!

We have joined the U. of Michigan RObotic Transient Source Experiment (ROTSE) collaboration.

Four ROTSE telescopes around the world. Texas, Australia, Namibia andTurkey.

18 inch mirrors, 1.85 degree squared field of view.



ROTSE can point and shoot within 6 secs of electronic satellite notification,take automatic snapshots every 1, 5, 20, 60 secs.

ROTSE will:
Discover the optical transient ***during*** the burst;
Follow the light in unprecedented detail;
Relay the discovery and coordinates to the HET for spectroscopic follow up.

Chapter 11 Our Expanding Universe

Expanding Universe - we observe all distant galaxies (so far away we cannot sense their individual gravity) moving away from us with speed proportional to distance: as if we were in the center of an explosion.

Our Universe is not a bomb in pre-existing empty 3-D space!

Lesson from Einstein - ***space itself can expand carrying the*** (almost motionless***) galaxies***

All distant galaxies move away from all other distant galaxies.
No galaxy, certainly not us, is in the center.

The result: speed proportional to distance