

April 9, 2010

Reading: Chapter 11

Wheeler on travel Wednesday and Friday, No Wheeler office hours
Wed, Fri.

Exam 4, April 16.

Astronomy in the News?

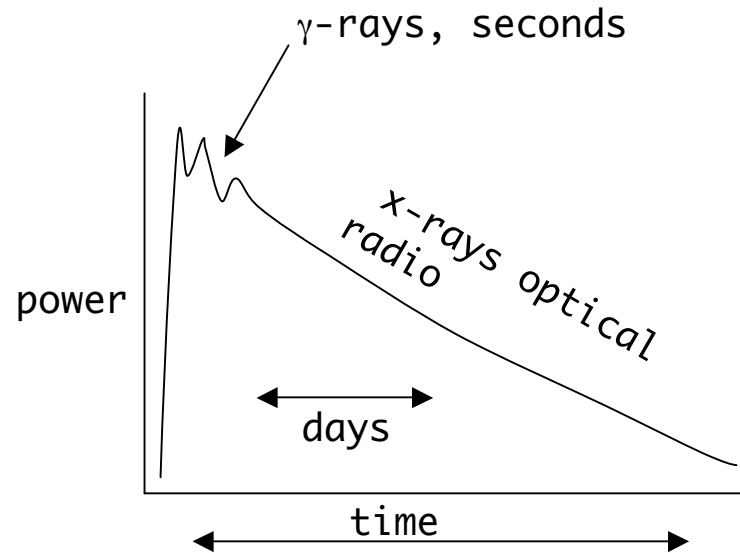
Pic of the Day -



Goal:

To understand what a gamma-ray burst “afterglow” is and why it is so important.

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, billions of light years away.

⇒ 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!

March 19, 2008, "naked-eye" GRB 080319B discovered by Swift satellite had a peak apparent magnitude of 5.8 and remained theoretically visible to human eyes for approximately 30 seconds.

September 16, 2008, GRB 080916C discovered by new Fermi Satellite, 12.2 billion light years away, was the intrinsically brightest optical event ever recorded, equivalent to brightness of 9000 supernovae.

April 23, 2009, GRB 090423 discovered by the Swift satellite, the most distant object ever observed in the Universe, about 13.1 billion years ago, when the Universe was only 630 million years old.

If gamma-ray bursts shine equally in all directions, the energy released in gamma rays would be 1000-10,000 \times SN or 10-100 \times core collapse neutrinos.

Comparable to total annihilation of entire star into pure energy!

Goal:

To understand the energy in gamma-ray bursts and why it is important that the energy is “beamed.”

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 about 1/100 of total sky

Typical gamma-ray burst energy $\sim 1/3$ supernova kinetic energy

But send matter at 99.997% of the speed of light

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

They explode ~ 100 times more often than observed (could observe about 2 per day if looked in all directions, all the time) because most have the jet aimed away from us.

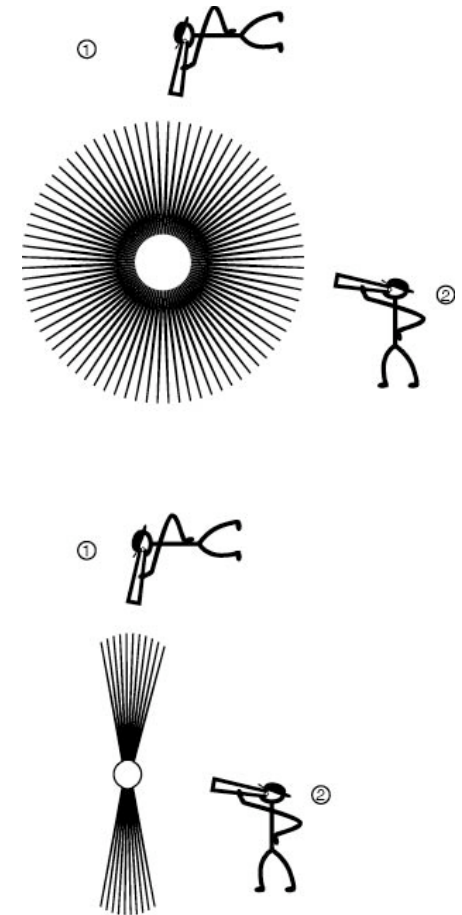


Figure 11.4

Goal:

To understand how gamma-ray bursts are connected to supernovae.

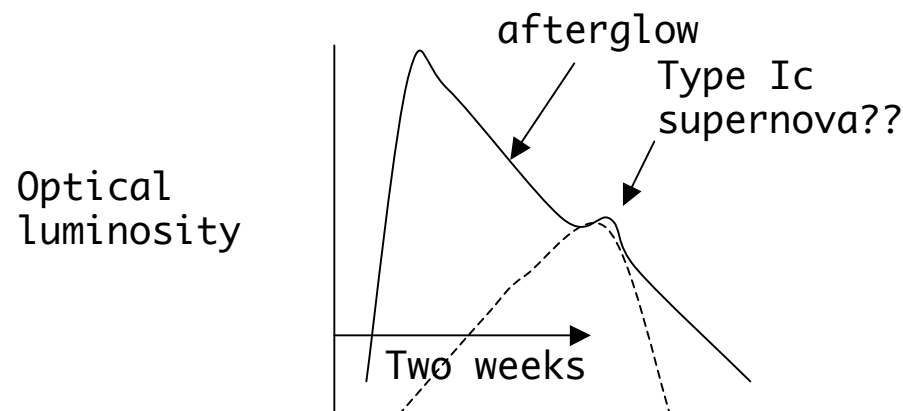
Find all gamma-ray bursts in regions of massive young stars

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)

Early 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 was followed by 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

By now many associated supernovae have been found: **all are Type Ic supernovae**

But all Type Ic supernovae are not gamma-ray bursts

The current picture: Gamma-ray bursts result from the collapse of a massive star from which the hydrogen and most of the helium have been stripped, 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.

Have not yet proven that black holes are involved. Tough problem!

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



One Minute Exam

It is important to understand that gamma-ray bursts emit their energy in tightly collimated beams because otherwise

- ➔ Estimates of the distance will be wrong
- ➔ Estimates of the mass of the black hole formed will be wrong
- ↑ Estimates of the energy emitted will be wrong
- ↓ Estimates of the type of supernova in which they explode will be wrong.

Goal:

To understand what the “Dark Ages” of the Universe were, why they came to an end, and what gamma-ray bursts have to do with that.

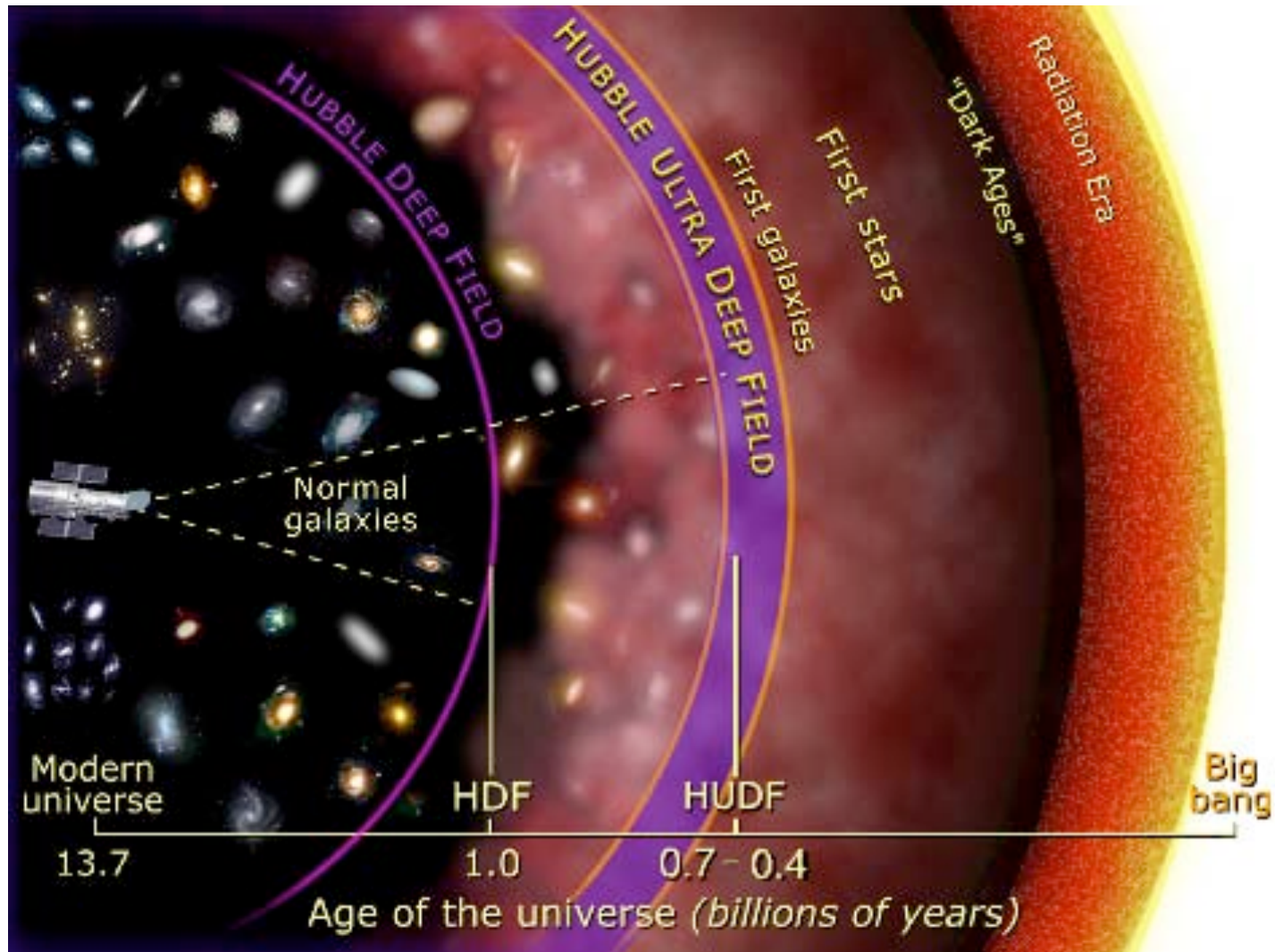
Gamma-ray bursts are intensely bright lights

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, before stars and Galaxies first formed half a billion years later

Point toward the Big Bang.



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. GRB 090423 is the first example.