4/7/2008

Exam 3, This Friday, review sheet today, review Thursday, 5 PM RLM 15.216B

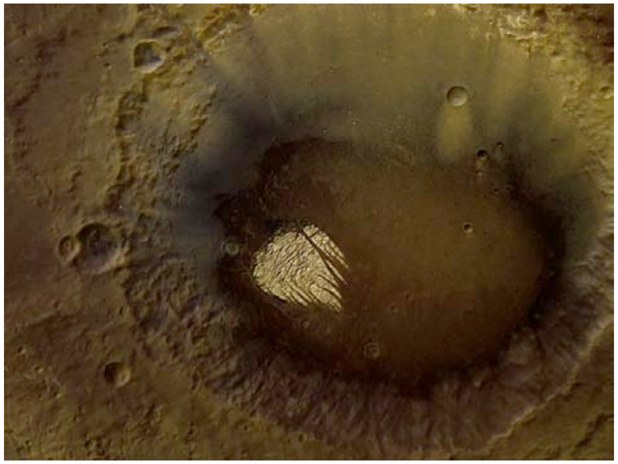
Chapter 8: Sections 8.1, 8.2, 8.5, 8.6, 8.7, 8.10

Chapter 9: (omit 9.6.3, 9.6.4)

Chapter 10: (omit 10.7)

Astronomy in the News -

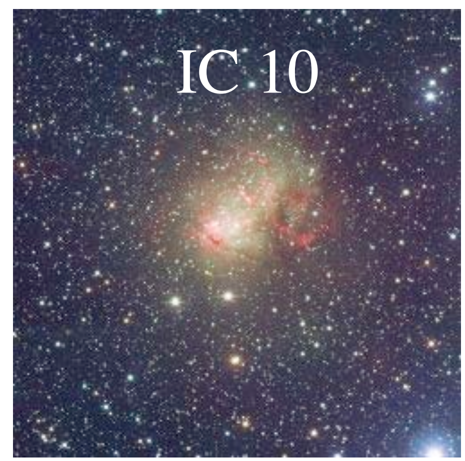
Pic of the day - more Mars rock outcroppings from orbit



Two recent reports of especially massive black hole candidates orbiting stars.

One in relatively nearby spiral galaxy M33, 3 million light years away, 15.7 solar masses, companion 70 solar masses (announced October 17, 2007).

Another in a relatively nearby dwarf irregular galaxy, IC 10, 1.8 million light years away, 24 - 33 solar masses (announced October30, 2007).



Both challenge the theory that massive stars should blow off most of their mass in stellar winds.

Late result - April 1, 2008

System toward constellation Ara in southern hemisphere,

Smallest mass black hole yet discovered - X-ray nova flared in 2001, mass just now accurately measured

3.8 solar masses

Still well above neutron star mass limit of 2 solar masses

Not clear why nature does not produce black holes of 2+ solar masses, neutron stars that have just been tipped over the edge by excess accretion.

One Minute Exam:

The best candidate for a binary star system with black hole is:

A) One with a 30 solar mass ordinary star
B) One with a 1/2 solar mass ordinary star
C) One with a 70 solar mass ordinary star
D) Cygnus X-1

One Minute Exam

The X-ray flares from binary black hole systems are thought to be from the same basic physics as:

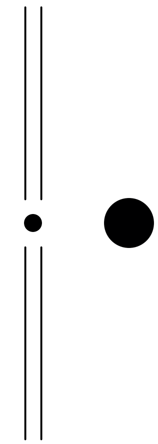
A) Dwarf Novae

B) Classical Novae

C) X-ray Bursters

D) X-ray pulsars

Often see jets during X-ray flare from black hole X-ray novae.



These systems are called “microquasars” since some quasars with supermassive black holes have jets.

Accreting neutron stars don’t seem to make jets.

Another hint that these binary X-ray nova systems contain black holes.

Argument is independent of weighing the black hole with Kepler’s law.

In quiescent “off” state of X-ray novae, a hot, low-density ~ spherical region may form, ***Despite heat, little radiation is emitted because of low density.*** Heat is carried (advected) inward with the flow of gas toward the event horizon, rather than radiated away as for an accretion disk.

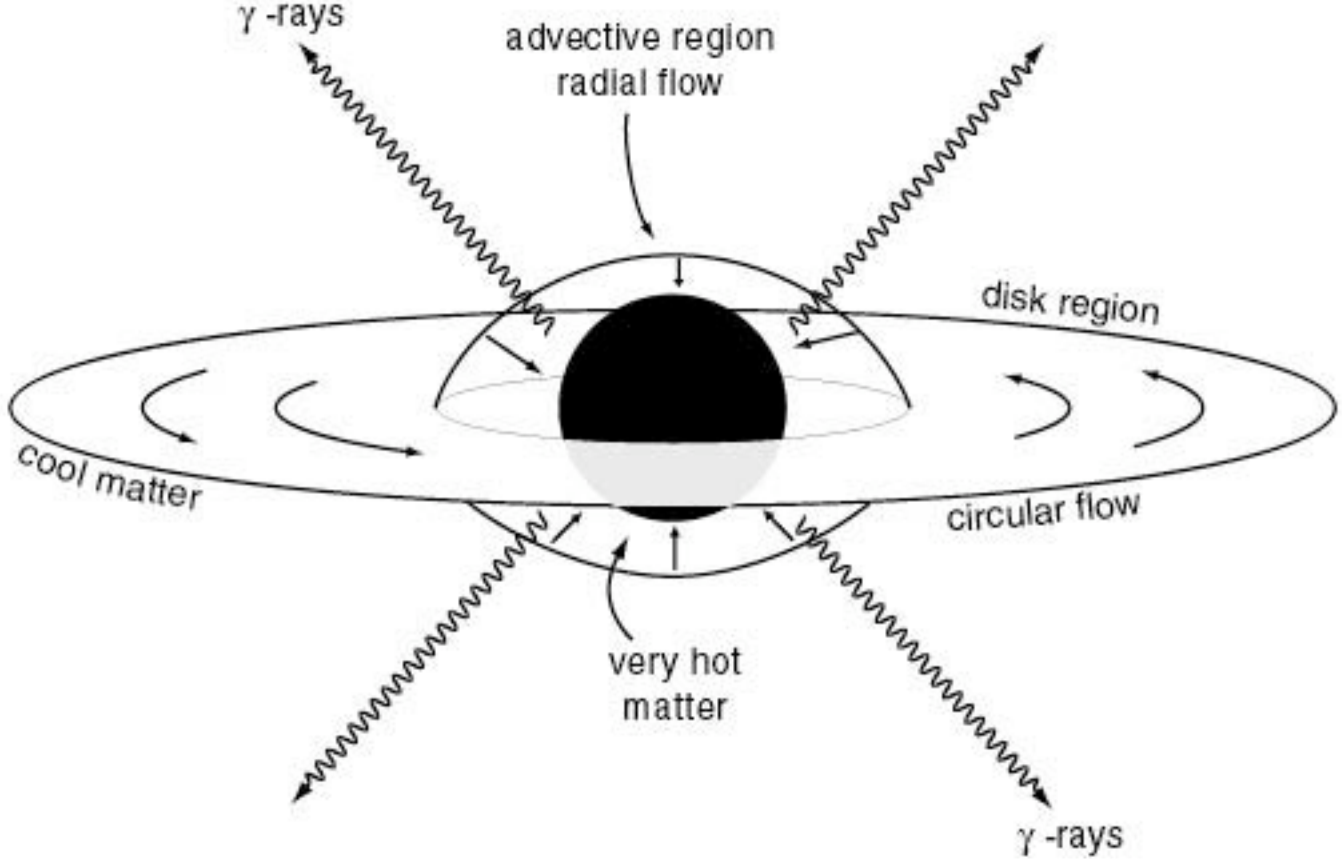
Very hot, $e^{\pm}$ electron/positron matter/anti-matter pairs may form (energy to mass, $E = mc^2$), annihilate to produce ***gamma-rays.***

Low density => low efficiency to produce radiation
=> ***low X-ray luminosity***

Only works for black hole, not for neutron star, lower energy X-ray radiation from ***surface*** of a neutron star would cool and spoil the hot region.

Low X-ray luminosity, gamma-rays, ***clues that there is no surface***
=> ***possible proof of black hole! Again, independent of mass***

Fig. 10.1


γ -rays
advective region
radial flow
disk region
cool matter
circular flow
very hot
matter
γ -rays

Supermassive Black Holes

Long suspected in quasars, active galactic nuclei: huge power from small volume, billion solar mass black hole could do it.

More recently, proof that many (even most!) ordinary galaxies also have a supermassive black hole in their centers (dead quasar).

Again, do not yet see a “dark spot” but use Kepler’s Laws, motion of many stars, gas ⇒ orbital period, separation

3.7 million $M_{\odot}$ black hole in our Galaxy UCLA [link - movie]

Up to billion $M_{\odot}$ black holes in quasars.

Jet from billion $M_{\odot}$ black hole in center of M87, large elliptical galaxy in the Virgo cluster (find Virgo!)

Surprising discovery:

It was long thought that supermassive black holes were somewhat incidental to galaxies,

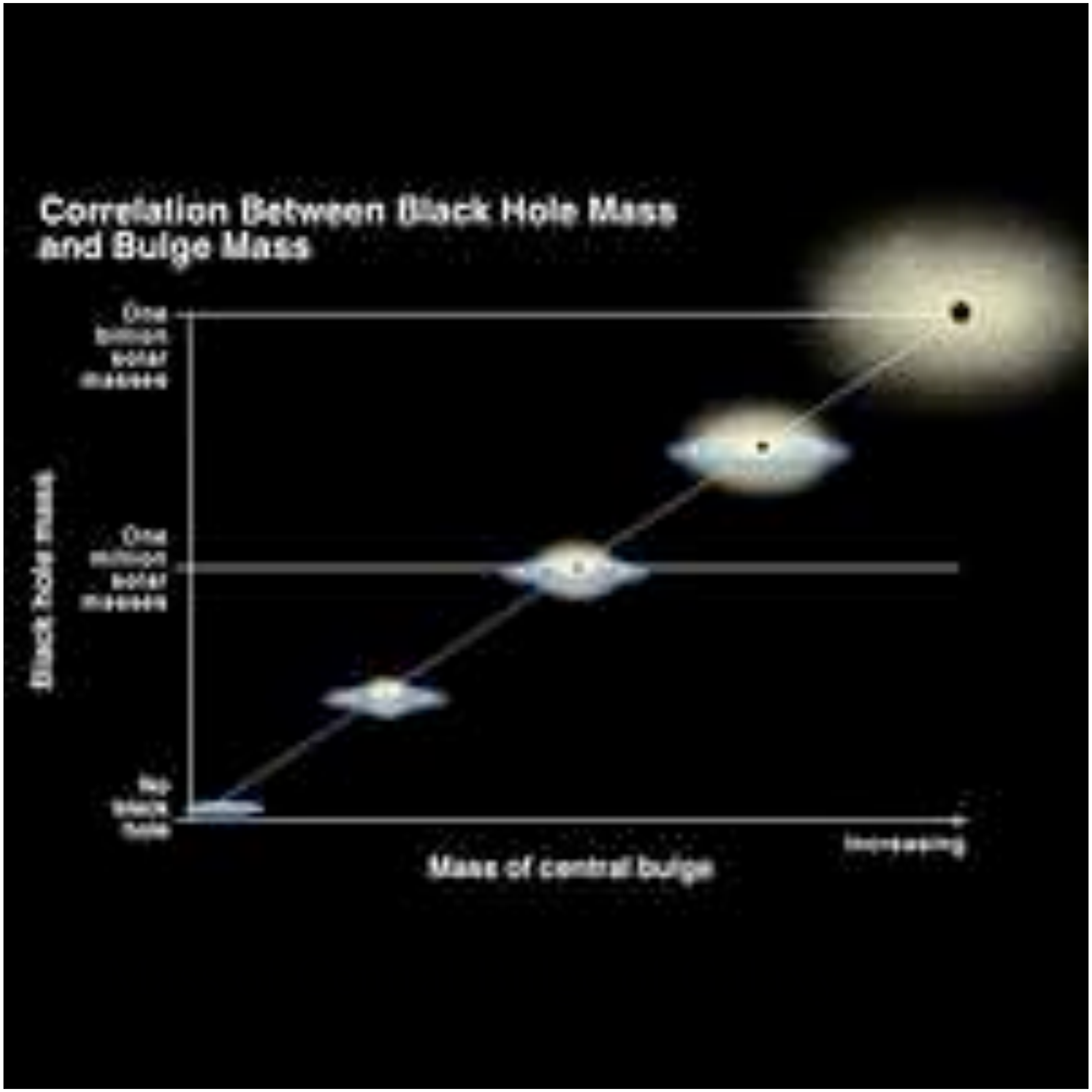
Formed of matter that somehow drained into the center of the galaxy, so galaxy could have large mass or small mass black hole depending on circumstances.

Recent work by Karl Gebhardt (UT) has shown that even stars so far from the center that they cannot possibly feel the gravity of the black hole *now* are moving in such a way that ***the larger the mass black hole, the higher the speed of the stars!***

Andromeda
M31

Correlation Between Black Hole Mass and Galaxy Bulge Mass

Mass of Black Hole



The implication is that the mass of the galaxy (at least the inner portions, the Bulge) is always close to 800 times the mass of the black hole.

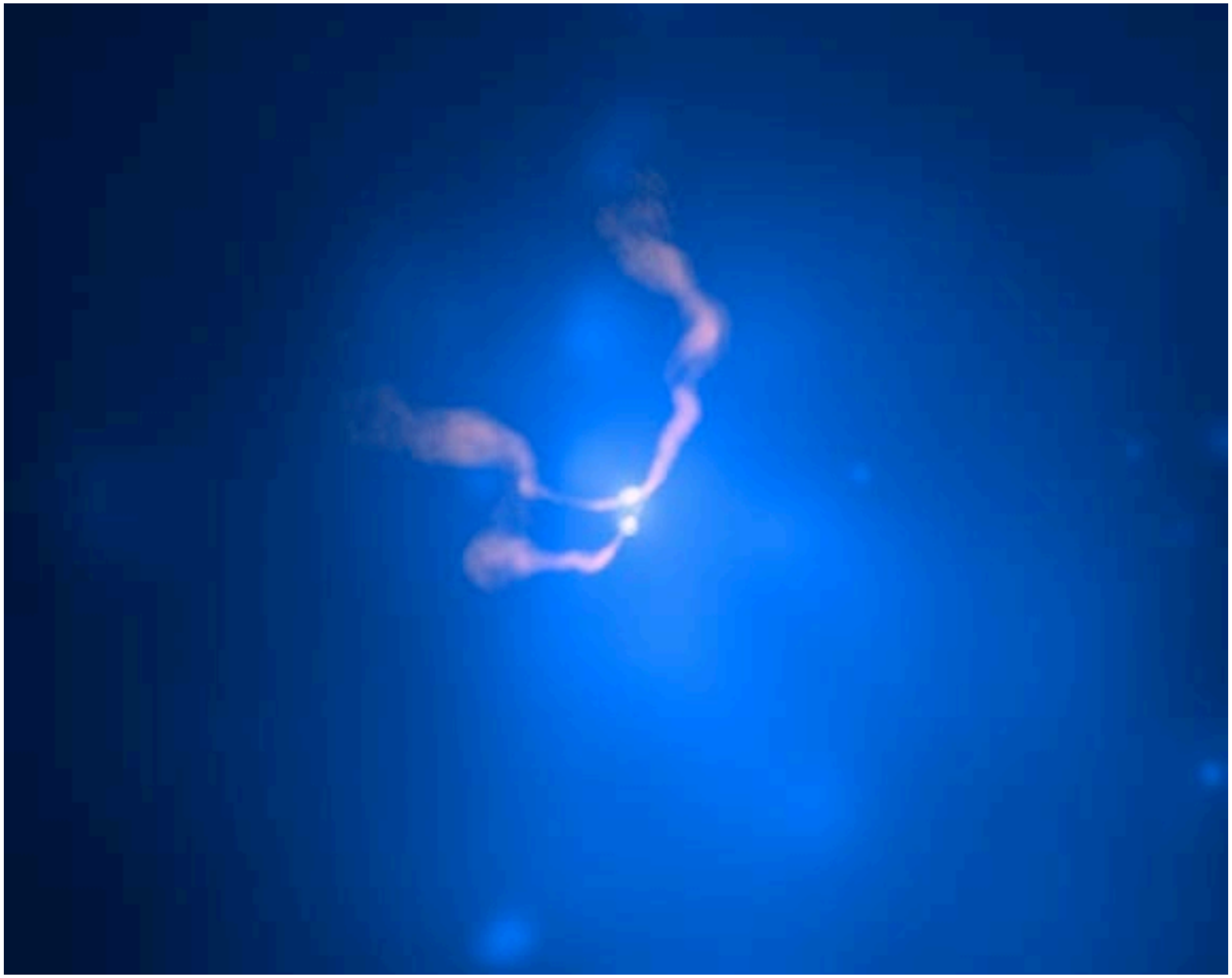
This means that ***the formation of the black hole is somehow intimately connected with the formation and structure of the whole galaxy.***

Galaxies "know" how big a black hole to make.

Mechanism uncertain: Does the galaxy control the black hole or the black hole somehow control the galaxy?

Most popular current idea: energy from accretion of matter into disk around black hole feeds back to the surrounding galaxy, blowing excess galaxy gas away when galaxies are young and growing.

Colliding black holes in 3C75, feed energy back into the stars and gas of the colliding galaxies.



The latest chapter in the story:

Intermediate mass black holes, of order 1000 - 10,000 $M_{\odot}$

First suspected from very bright X-ray sources,

Even the gravity of a neutron star would not be enough to bind the mass (see Eddington limit luminosity, Chapter 2, Section 2).

This remains controversial.

Gebhardt and co-workers have apparently found intermediate mass black holes in ***globular clusters*** using stellar velocities.

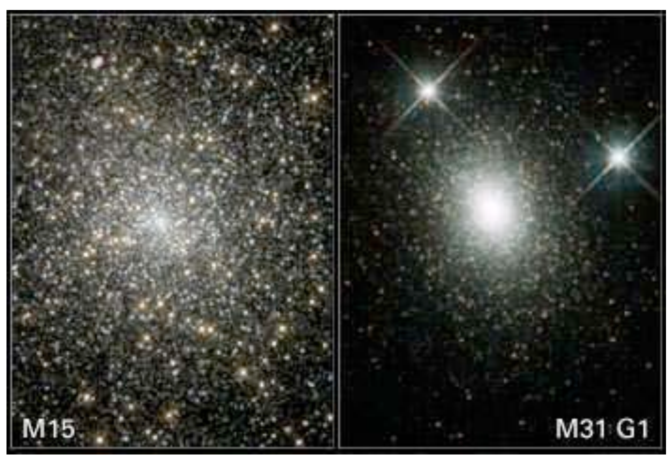
Globular clusters are old, nearly spherical clusters containing about 100,000 stars.

Remarkably, these black holes may follow exactly the same bulge mass, black hole mass relation as galaxies, the black hole is about one thousandth of the mass of the globular cluster!

These star clusters also "know" how big a black hole to form!

Maybe a clue to how the process works in whole galaxies.

M 15 in our Galaxy, 4000 $M_\odot$ black hole



G1 in Andromeda galaxy, 20,000 $M_\odot$ black hole

Latest development:

Gebhardt and recent Texas PhD Eva Noyola will announce in the April 10 Astrophysical Journal the identification of a black hole of 40,000 solar massses in the center of the globular cluster Omega Centauri

Find Centarus for sky watch

One Minute Exam

What is the relation between the mass of a supermassive black hole and the galaxy in which it resides?

A) There is none, the black hole can be big or small, depending on how it grew and for how long

B) The larger the mass of the galaxy, the smaller the mass of the black hole

C) The larger the mass of the galaxy, the larger the mass of the black hole

D) The larger the radius of the galaxy, the larger the mass of the black hole

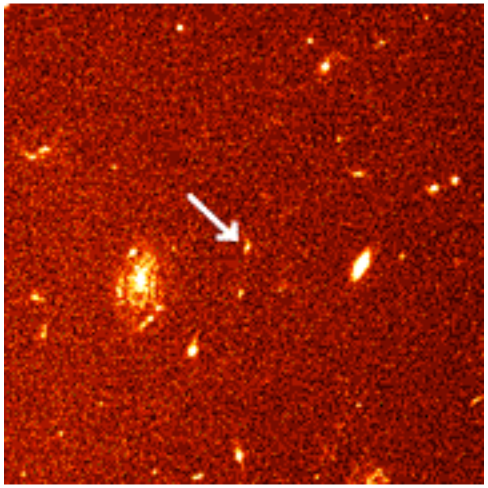
End of Material for Exam 3

Gamma-Ray Bursts (Chapter 11)

Swift satellite

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

Seen across the Universe.



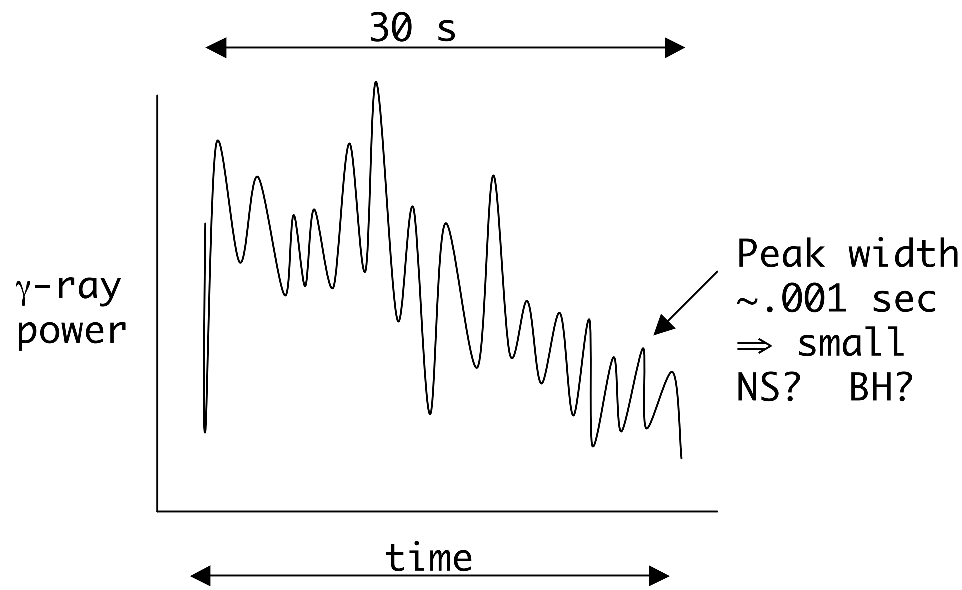
Energy is expelled in narrow jets.
Energy comparable to that of supernovae, but all in gamma-rays, with later ***afterglow*** in X-ray, radio and optical radiation.
Birth of a black hole?

Gamma-Ray Bursts unite ***stars*** and ***cosmology***

Mystery since late 60's - satellites to monitor space nuclear test ban treaty, avoid confusion between astronomical effects, and bombs

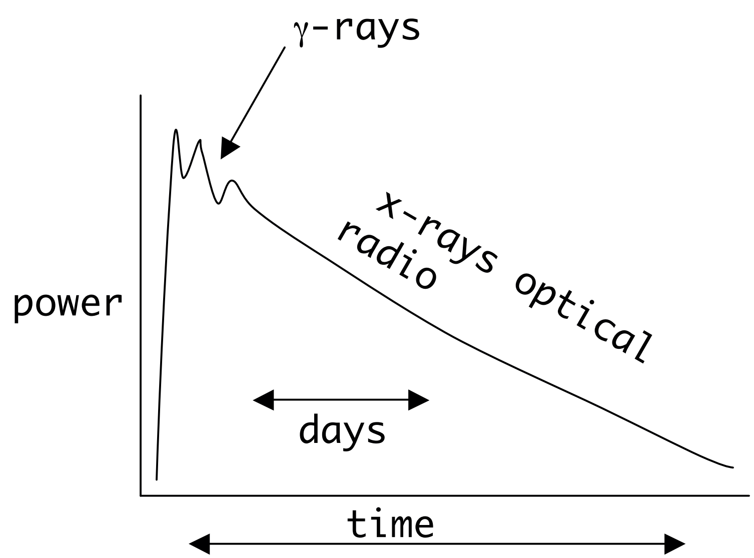
Flare of γ -rays lasts ~ 30 sec

Never Repeat - for 30 years, no optical counterpart,
C*an't focus gamma-rays*.
Did not know which of millions of stars to look at.



Did not know the distance: guesses ranged from within the Solar system to cosmologically distant

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! ***Brightest optical event ever recorded.***

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

Comparable to total annihilation into pure energy of entire star!