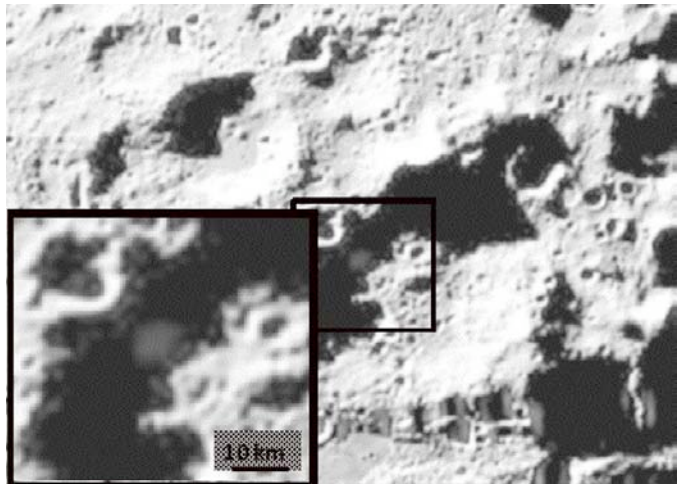
Thursday, November 19, 2009
reading: Chapters 10 - 14: see Reading link, next page, for details
Fourth Exam, Thursday, December 3
Final Sky Watch, IYA reports due on Sunday, December 6

Course Evaluation Online - please do that. The TA's and I pay close attention to comments.

Astronomy in the News:

Pic of Yesterday - water-containing plume on the Moon.



Reading for Fourth Exam: REVISED

Chapter 10, Sections 10.1-10.6, **10.9**-10.10
Chapter 11, Sections 11.1-11.5, **11.8**
Chapter 12, all
Chapter 13, all
Chapter 14, Sections 14.1-14.5

Proving Black Holes

Astronomers search for ways to directly determine that the dark X-ray producing object is a black hole, not a neutron star.

How would you identify a black hole of 1 solar mass?

Evidence that in some circumstances (the accretion disk “storage” phase) black holes, but not neutron stars, can produce very hot, rarified inner accretion regions, making gamma-rays, but few X-rays.

This is evidence that the object has **no surface**.

There is evidence that black holes, not neutron stars, produce jets

One Minute Exam

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

One with a 30 solar mass ordinary star

One with a 1/2 solar mass ordinary star

One with two black holes in orbit

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:

 Dwarf Novae

 Classical Novae

 X-ray Bursters

 X-ray pulsars

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!)

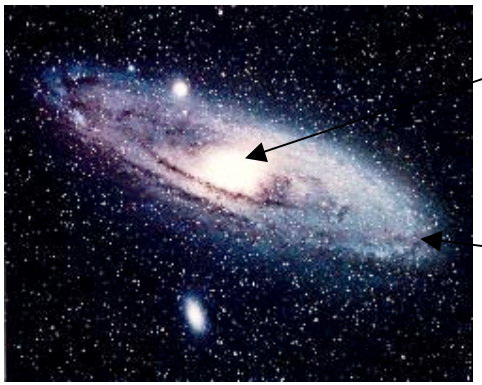
Surprising discovery:

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

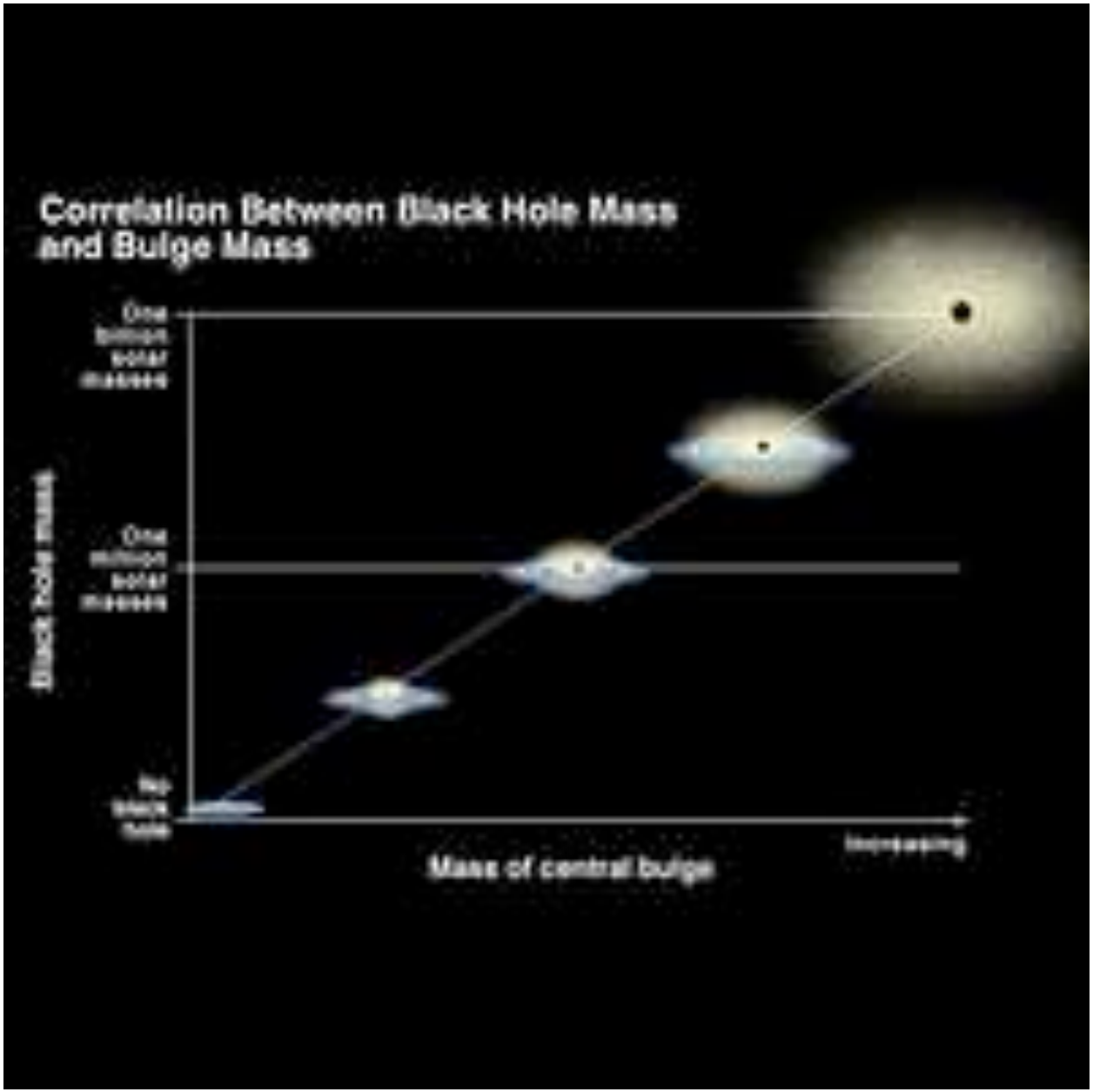
Formed of matter that somehow drained into the center of the galaxy, so galaxy could have large mass or small mass black hole depending on circumstances.

Recent work by Karl Gebhardt (UT) and others 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.

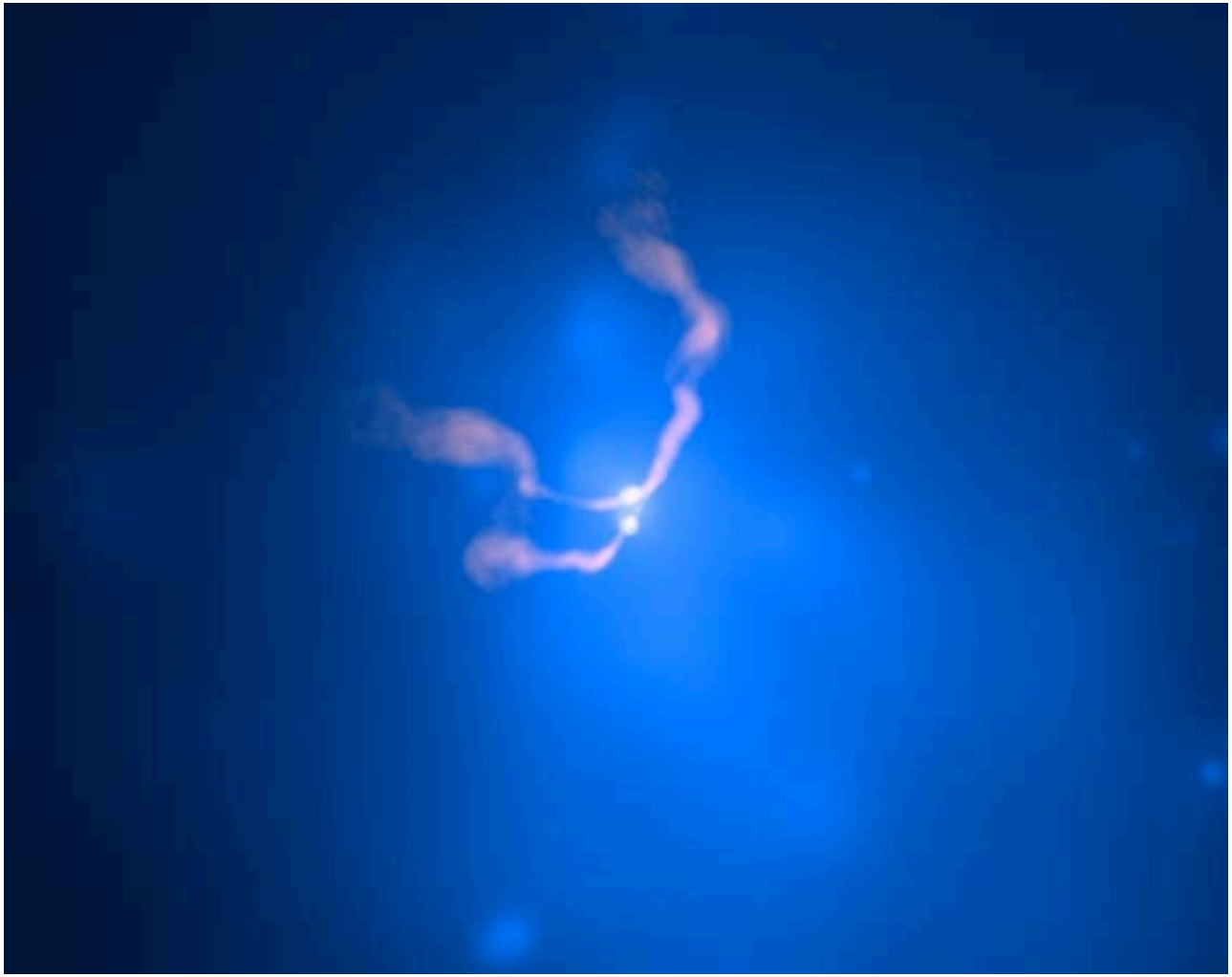
This means that ***the formation of the black hole is somehow intimately connected with the formation and structure of the whole galaxy.***

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.



One Minute Exam

How can we discover a stellar mass black hole that has no accretion disk around it?

 Look for X-rays

 Look for gamma-rays

 Look for jets

 We can't

One Minute Exam

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


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


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


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

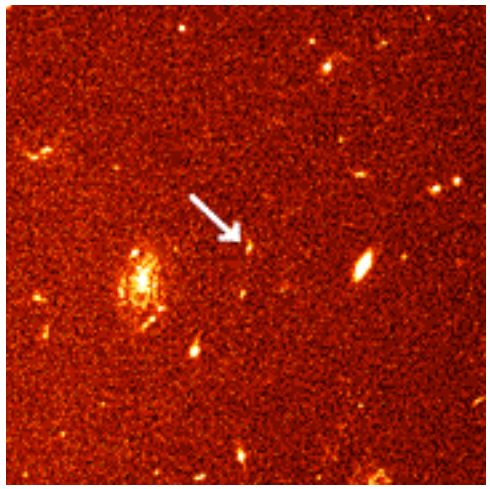

The larger the radius of the galaxy, the larger the mass of the black hole

Gamma-Ray Bursts (Chapter 11)

Swift satellite

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

Seen across the Universe.



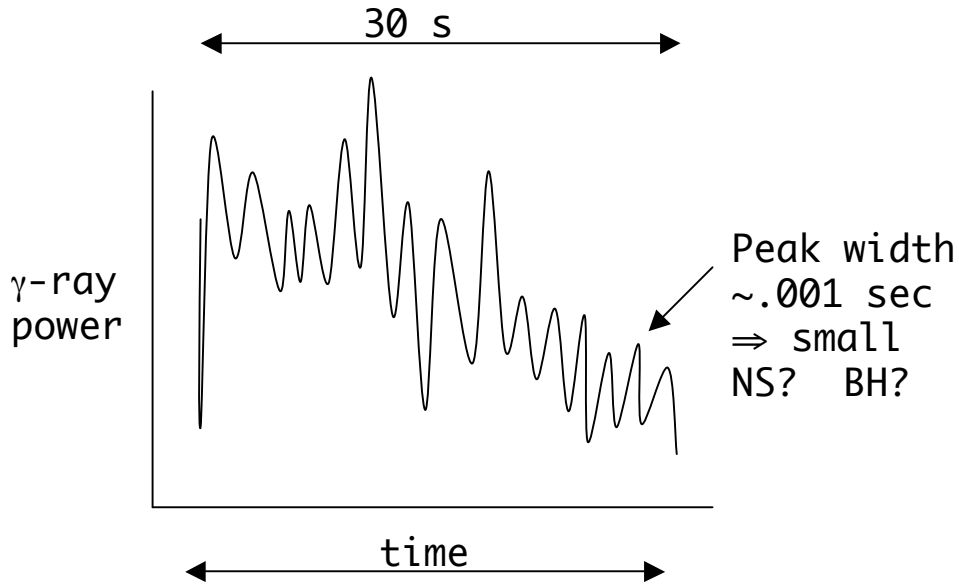
Energy is expelled in narrow jets.
Energy comparable to that of supernovae,
but all in gamma-rays, with later ***afterglow***
in X-ray, radio and optical radiation.
Birth of a black hole?

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

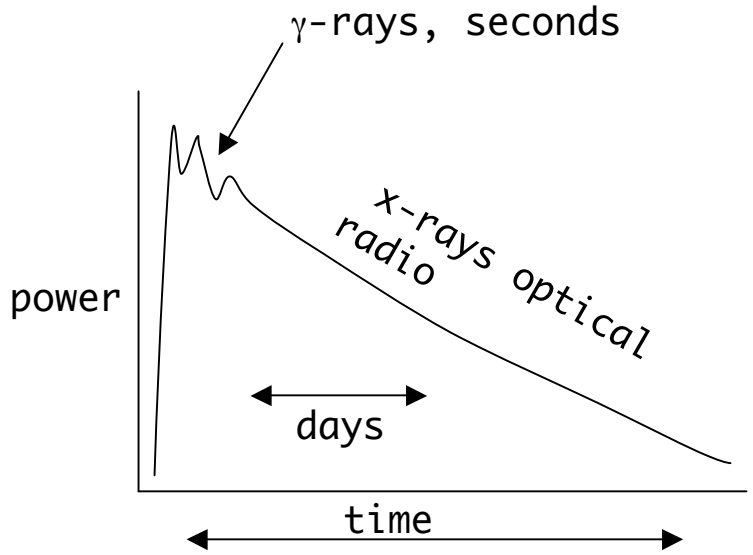
Flare of γ -rays lasts ~ 30 sec

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!

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 way, 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 × SN or 10-100 × core collapse neutrinos.

Comparable to total annihilation of entire star into pure energy!

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 ~ 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

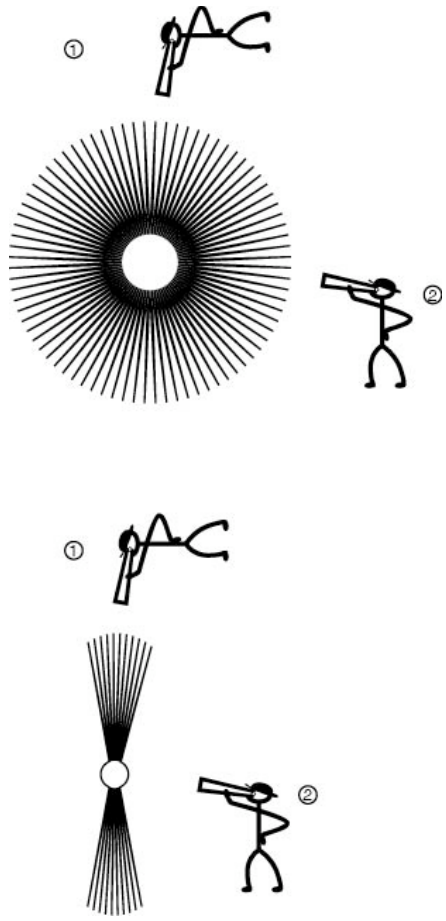


Figure 11.4

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.

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.