

4/20/05

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

Revised Chapter 10 - Black Holes in Fact

Draft Chapter on Gamma-Ray Bursts (expanded part of Ch 11)

News:

Pic of the day:

Barnard's Loop in Orion's Belt

Winds? Old supernovae?



In quiescent “off” state of X-ray novae, a hot, low-density \sim 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.

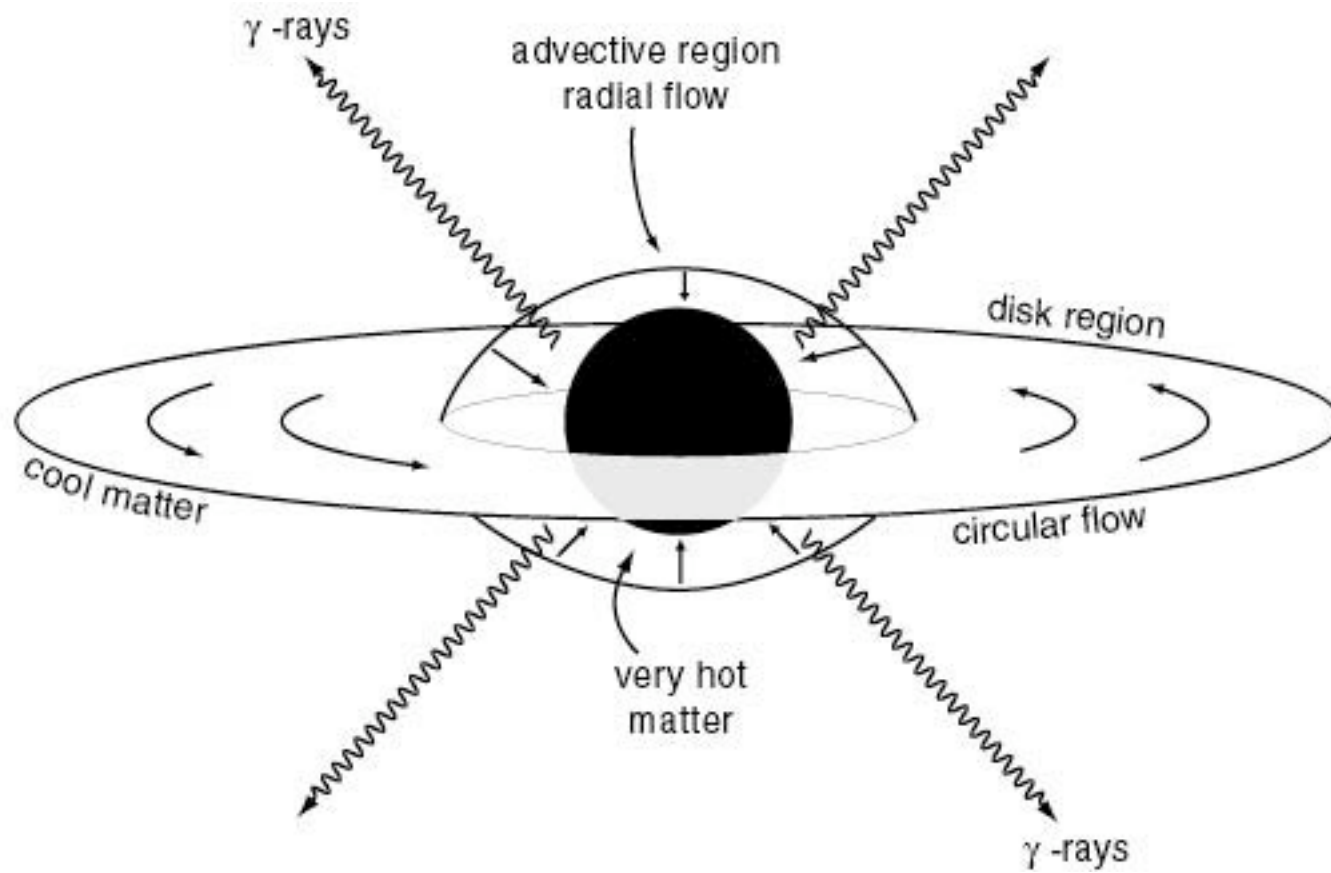
Very hot, e^\pm pairs may form (energy to mass, $E = mc^2$), annihilate to produce ***gamma-rays.***

Low density \Rightarrow low efficiency to produce radiation
 \Rightarrow ***low X-ray luminosity***

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

Low X-ray luminosity, gamma-rays, ***clues that there is no surface***
 \Rightarrow ***possible proof of black hole!***

Fig. 10.1



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 \Rightarrow 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!)



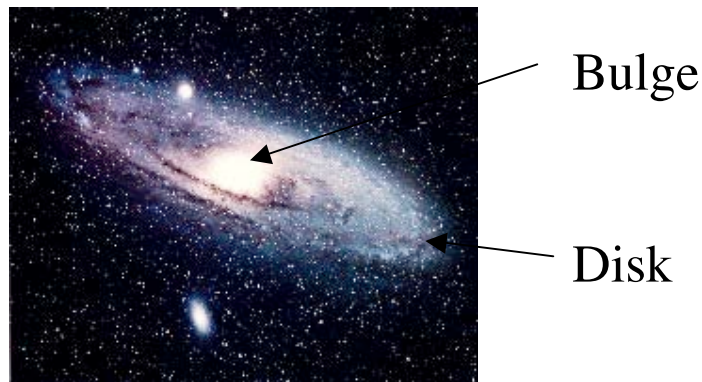
Surprising discovery:

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



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?

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 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

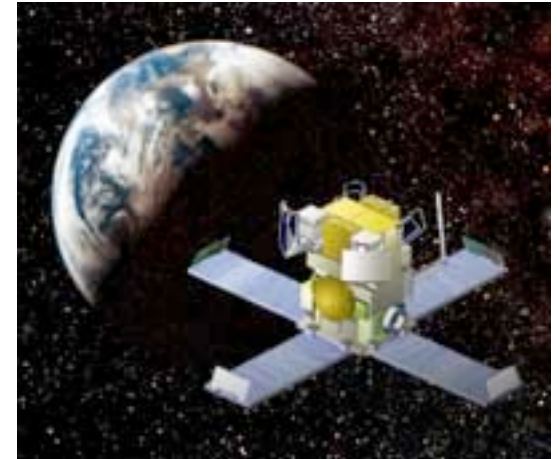
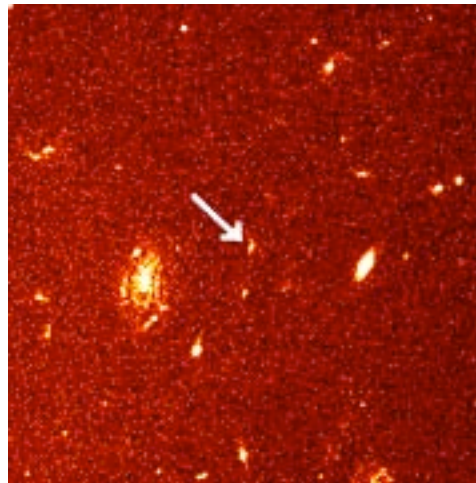


G1 in Andromeda
galaxy, 20,000 M_{\odot}
black hole

Gamma-Ray Bursts

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

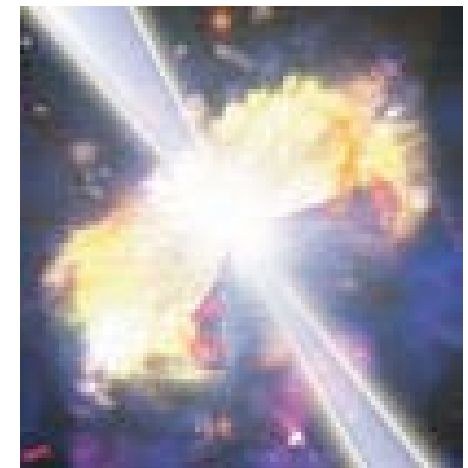
Seen across the Universe.



High Energy Transient
Explorer

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*

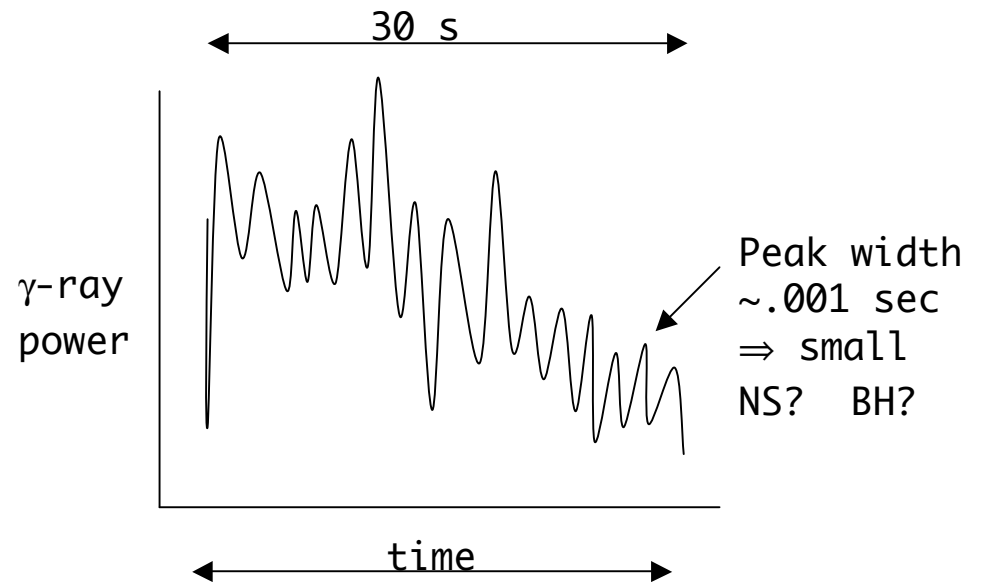
Mystery since late 60's - satellites to monitor space nuclear test ban treaty, avoid confusion between astronomical effects, and bombs

Flare of γ -rays lasts ~ 30 sec

Never Repeat - for 30 years, no optical counterpart,

Can'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