11/13/06

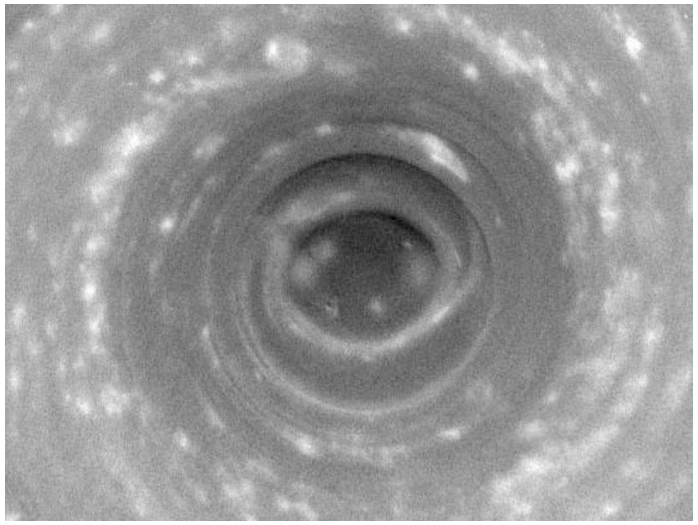
Exam 3, Chapters, 8, 9, 10, This Friday, November 17

Review sheet this afternoon or tomorrow

Review session RLM 4.102 Thursday 5 PM or see me or Sean.

News?

Pic of the day - Storm on Saturn's south pole



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) Cygnus X-1

D) The Crab Nebula

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.

Some show “superluminal” motion

An optical illusion that occurs when the source of light moves near the speed of light, so chases its own emission.

These systems are called “microquasars” since some quasars with supermassive black holes have show the same effect.

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

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.

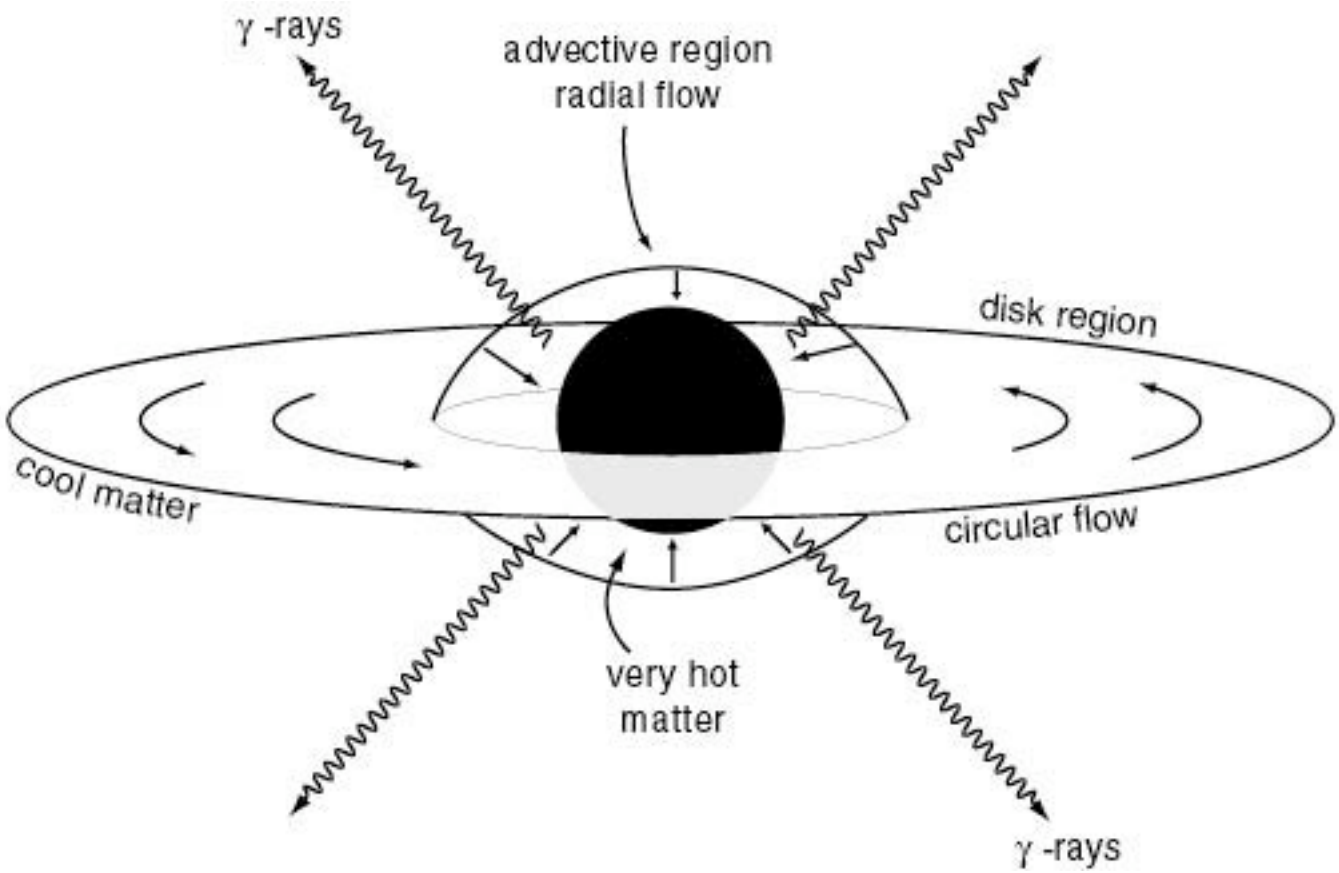
Very hot, $e^{\pm}$ electron/positron matter/anti-matter pairs may form (energy to mass, $E = mc^2$), annihilate to produce ***gamma-rays.***

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

Only works for black hole, not for neutron star, 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***
=> ***possible proof of black hole!***

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!)

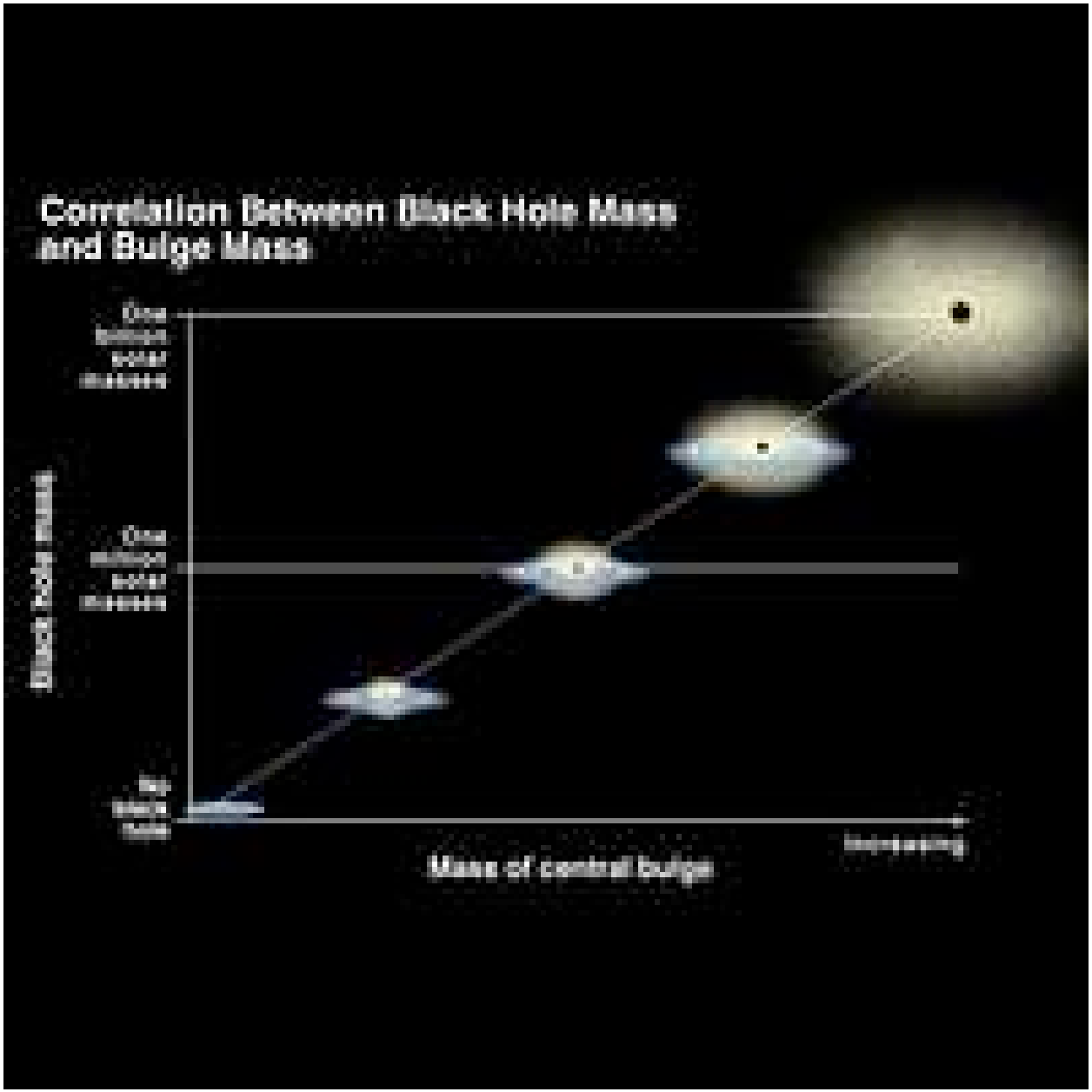
Surprising discovery:

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 Bulge Mass
Mass of central bulge

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.

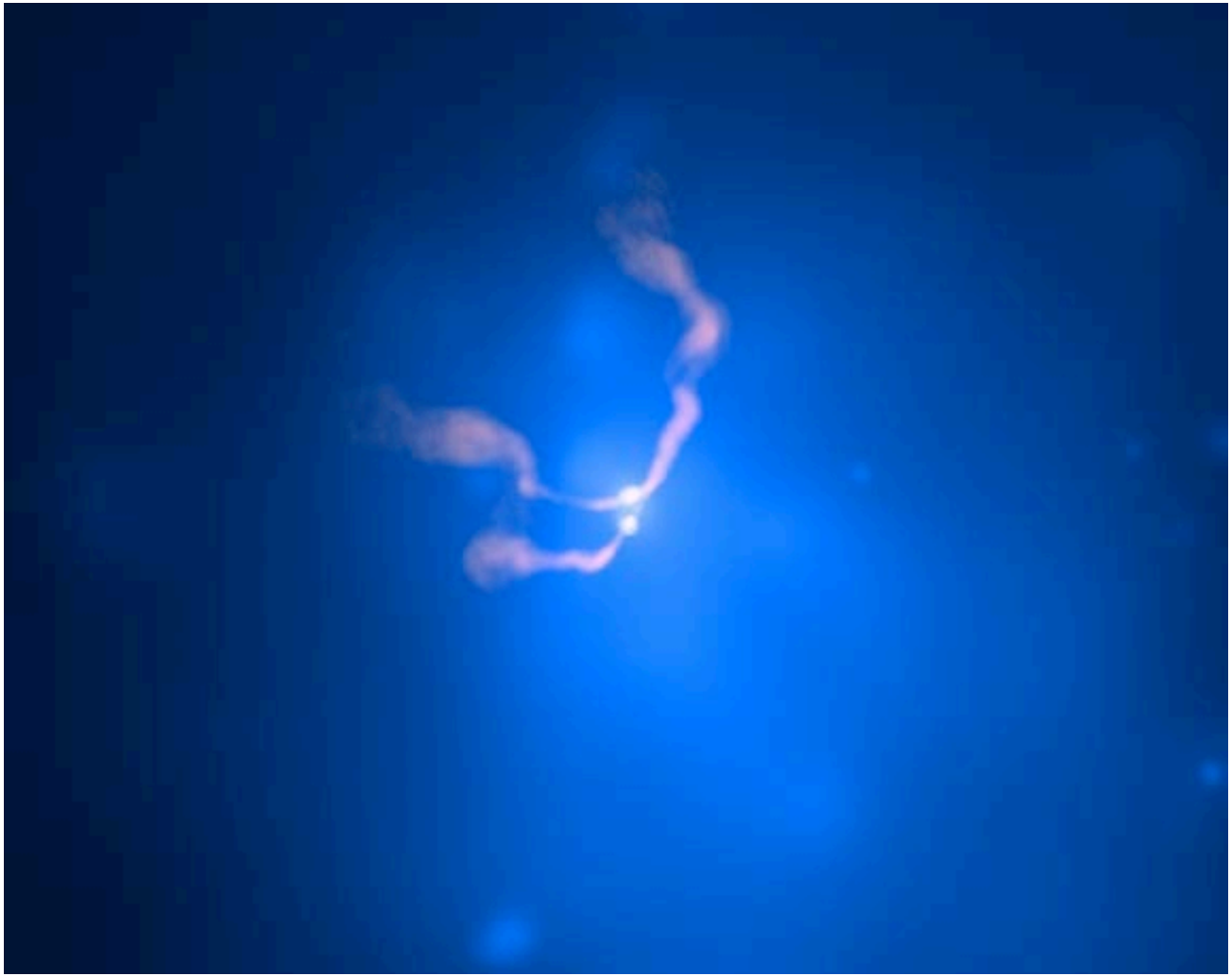
This means that ***the formation of the black hole is somehow intimately connected with the formation and structure of the whole galaxy.***

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.

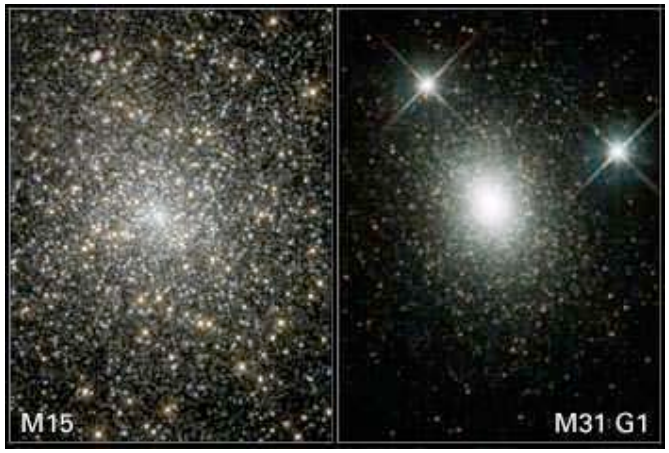
Globular clusters are old, nearly spherical clusters containing about 100,000 stars.

Remarkably, these black holes may follow exactly the same bulge mass, black hole mass 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

End of Material for Test 3