Tuesday, April 14, 2009

Third Exam, ***This Thursday***. Neutron Stars and Black Holes

Chapter 8:Sections 8.1, 8.2, 8.5, 8.6, 8.7, 8.10
Chapter 9: all except 9.6.3, 9.6.4
Chapter 10: Sections 10.1 - 10.6, 10.8

Review Sheet posted

Review Session, Wednesday, 5:00 PM RLM 15.216B

Astronomy in the News: Hubble repair mission scheduled for May 12.

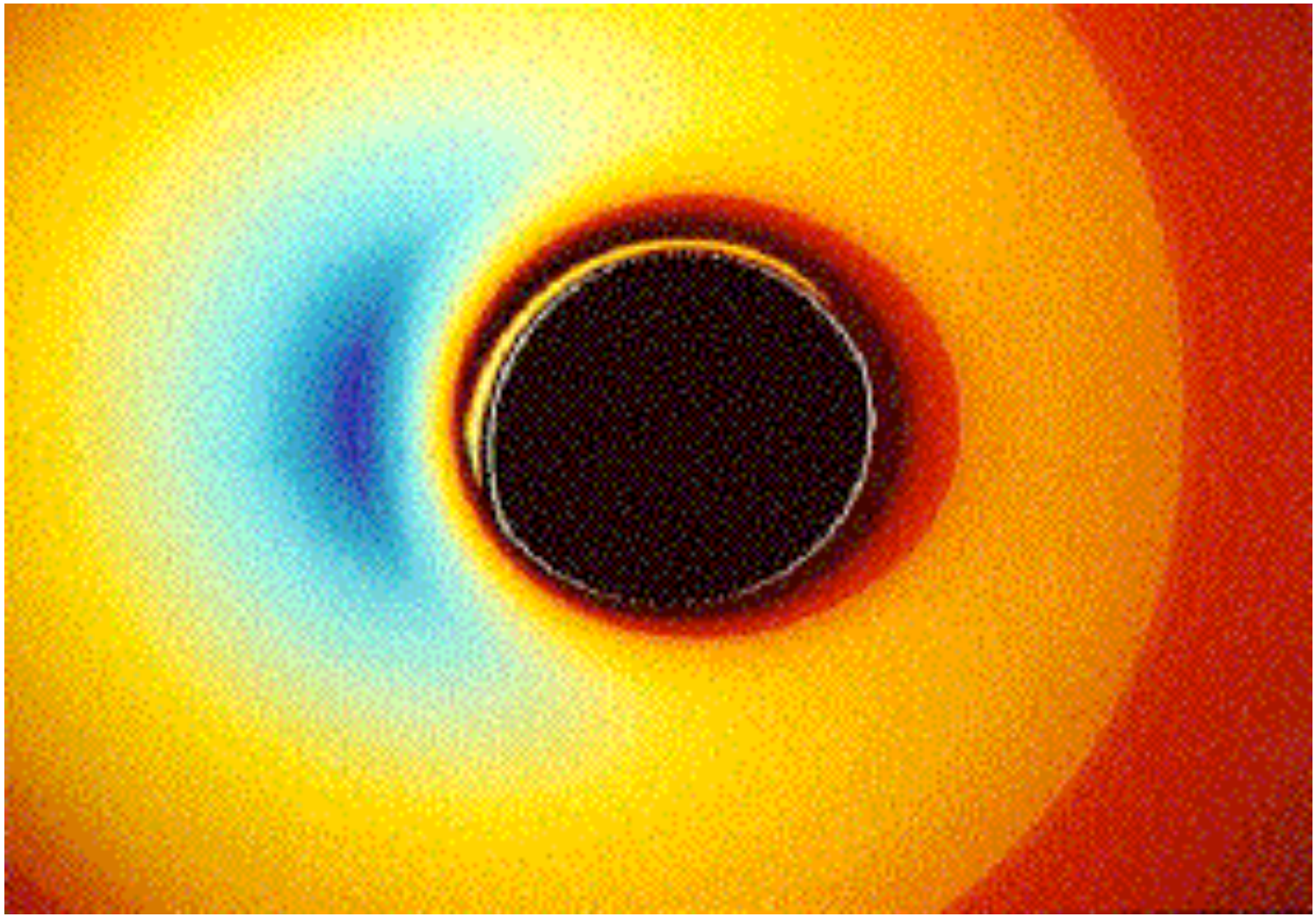
Pic of the Day - Spiral galaxy M101, probable recent collision created "waves"

International Year of Astronomy extra credit

Do some research on the IYA.

Write up a brief report. 1/2 to 1 page.

Goal is to get close-up study of strongly warped space



Perez and Wagoner, Stanford: computer simulation of radiation from inner black hole accretion disk

Current evidence is still primarily circumstantial, but very strong:

Stellar mass black holes (several to ~ 10 solar masses), binary systems in our Galaxy or nearby galaxies

Intermediate mass black holes (~ 1000 - 10,000 solar masses)??, in binary systems or stellar clusters in our Galaxy or nearby galaxies

Supermassive black holes (million to a billion solar masses) in the middle of our Galaxy and in the middle of many, many others.

Circumstantial arguments for presence of black hole in a binary system:

Only neutron stars and black holes have the high gravity necessary for intense X-rays.

Use Kepler's laws to measure the total mass of the system, astronomy to determine the mass of the mass-losing star, subtract to get mass of "unseen" companion emitting X-rays.

Maximum mass of neutron star is ~ 2 solar masses

Intense X-ray source with mass exceeding 2 solar masses is, by a process of elimination, a candidate black hole.

Cygnus X-1

First X-ray source discovered in the direction of the constellation Cygnus.

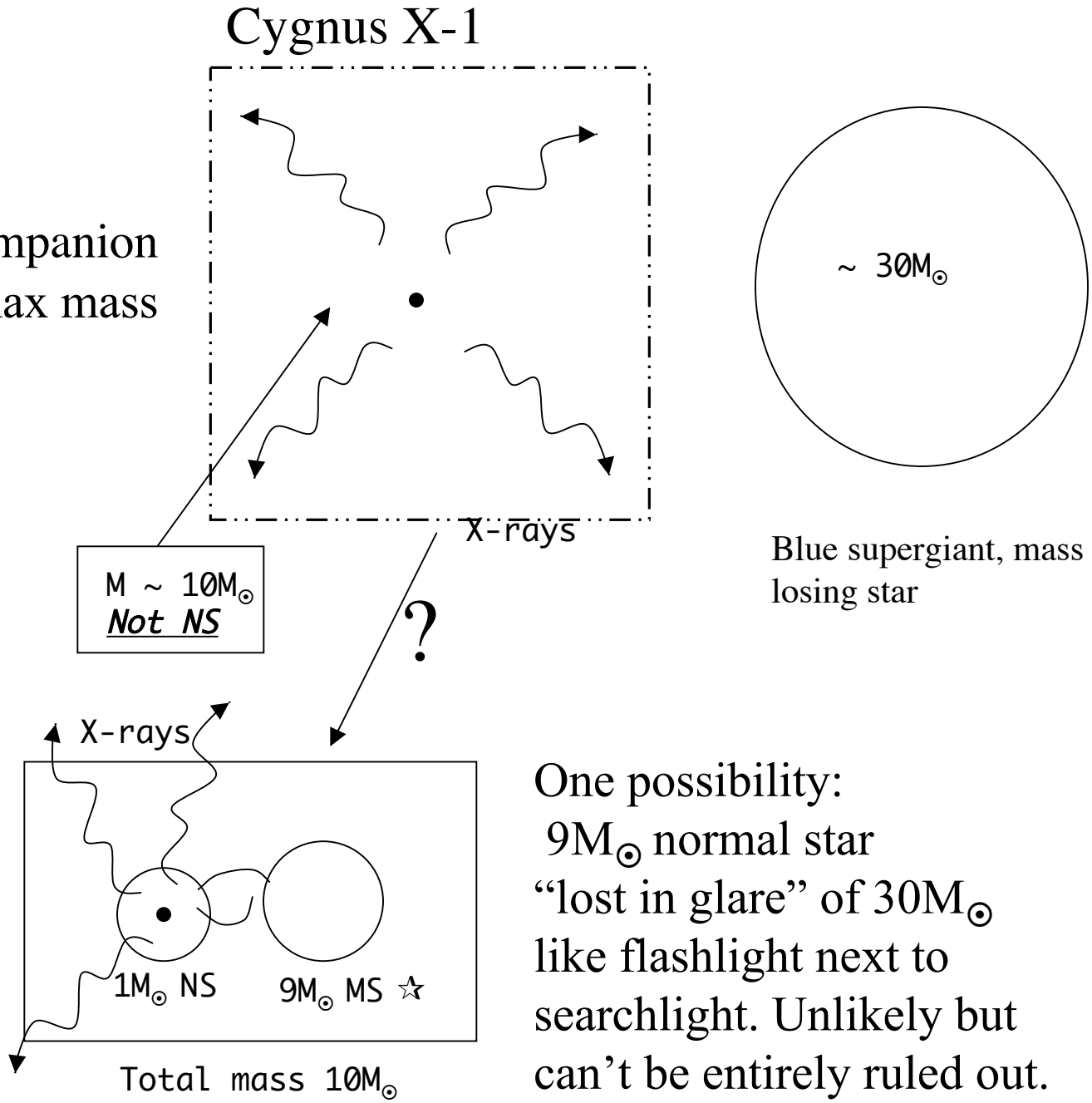
Discovered in 1970's by Uhuru Satellite (Swahili for Freedom).

First and still most famous stellar-mass binary black hole candidate.

Can't see this system with the naked eye, but can find constellation Cygnus - look for it!

Optically dark
X-ray emitting companion
$\geq 10M_\odot$ >> NS max mass
$\Rightarrow$ BH

Could nature be tricking us? All we really know is that there is a $10M_\odot$ "thing" emitting X-rays



One possibility:
$9M_\odot$ normal star
"lost in glare" of $30M_\odot$
like flashlight next to searchlight. Unlikely but can't be entirely ruled out.

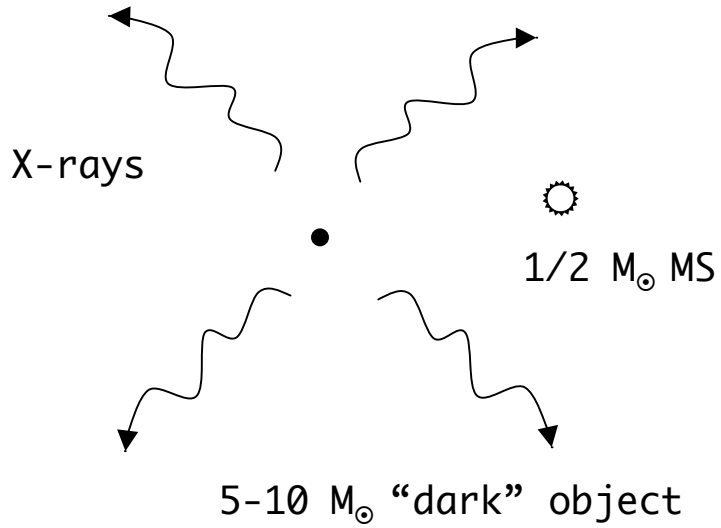
Expect only two or three systems like Cygnus X-1 in our Galaxy.

Bright, massive, short-lived companion

Maybe only one, and we found it!

Surprisingly, most binary black hole candidates have small mass main sequence companions, typically ~ 1/2 solar mass.

Observe ~20 such systems and guess there may be ~1000 in the Galaxy



For systems with small mass companions cannot hide a 3rd star in the system

$\Rightarrow$ best black hole candidates.

Evidence still circumstantial but virtual proof of black hole

Candidates in the directions of Sagittarius, Ursa Majoris, Perseus, Scorpius, Ophiuchus, Vulpecula, Monoceros, Lupus, Cygnus (2) (Find and observe the constellations for extra credit)

AO620-00 = Nova Mon 1975 = V616 Monocerotis - one of the first and best studied with a small mass companion, black hole about 5 solar masses.

V404 Cygni - somewhat evolved companion, but one of the best cases for a black hole with “dark’ mass of about 12 solar masses.

Two candidates in the Large Magellanic Cloud:
LMC X-1, LMC X-3

Total number of such systems known, about 20.

Not sure how these binary systems form.

Would have expected massive stars that can make black holes in core collapse to have massive companions, like Cygnus X-1.

Need to have black hole very close to small mass companion, separation smaller than size of the star that made the black hole.

Possibilities:

Common envelope swallows small mass companion?

Companion forms from left-overs of collapse?

All low companion mass systems are ***X-ray Novae***

Flare every few years to decades for months, like neutron star X-ray transients

Dwarf Nova-like accretion disk flushing instability

No black hole analog of nova or X-ray burster. Why not?

The black hole is black and the disk does not produce X-rays in the "off" state. There are billions of small mass stars in the Galaxy.

Do not notice these systems until they erupt!

There are probably 100 "sleeping" black hole systems that we have not discovered for every one we have. Perhaps 1000 such systems in the Galaxy (but 100 million more 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, not neutron stars can produce very hot, rarified inner accretion regions, making gamma-rays, but few X-rays.

Evidence that the object has **no surface**.

Evidence that black holes, not neutron stars, produce jets

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

End of Material for Exam 3

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:

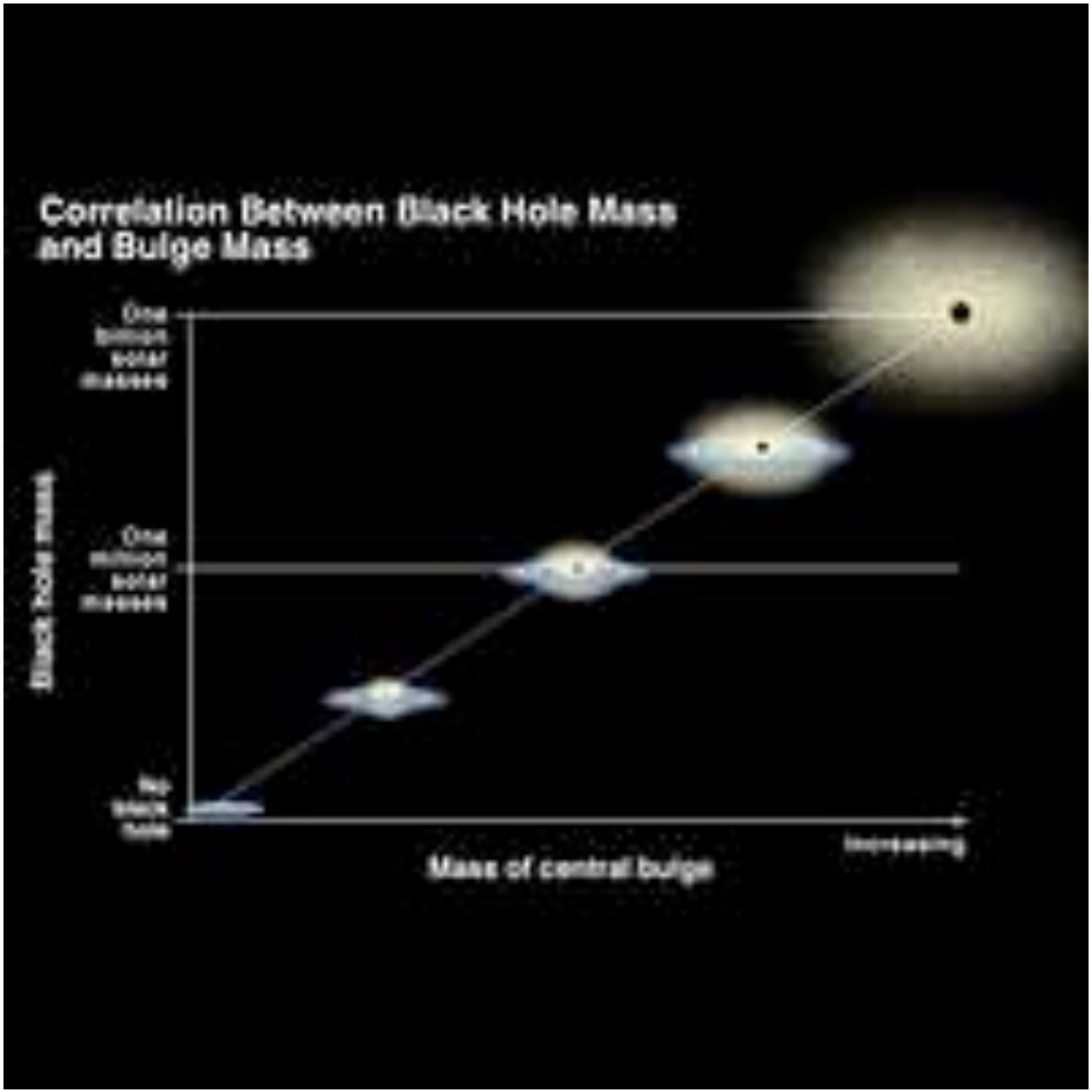
It was long thought that supermassive black holes were somewhat incidental to galaxies,

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

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.