

Friday, April 24, 2015

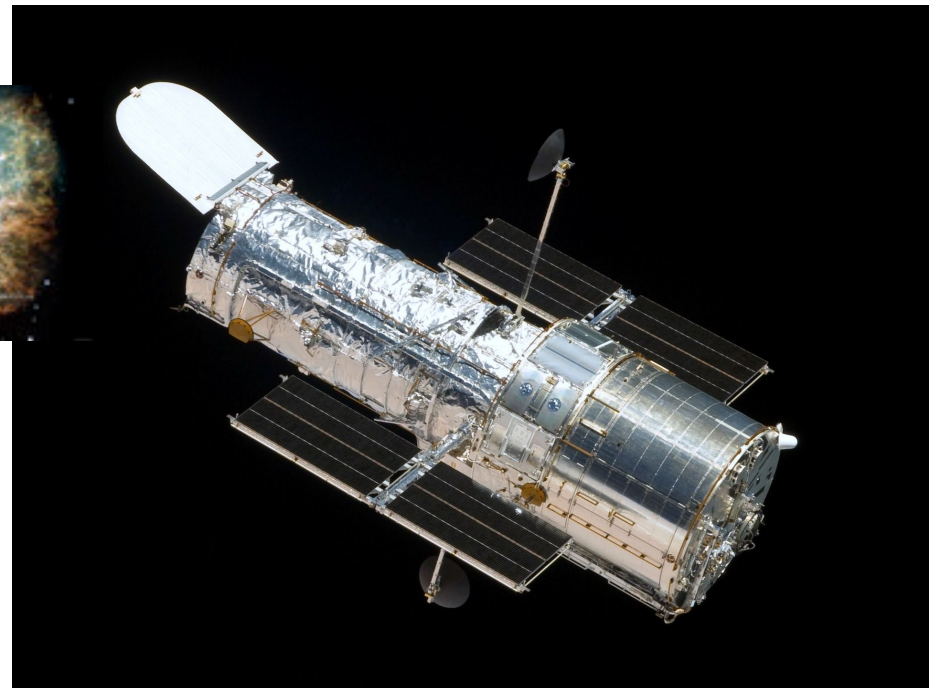
Fifth exam and sky watch, FRIDAY, May 8.

Reading for Exam 5:

Chapter 9 – Sections 9.6.1, 9.6.2, 9.7, 9.8; Chapter 10 - Sections 10.1-10.4, 10.9; Chapter 11 - all except Section 11.6 (abbreviated, focus on lectures); Chapter 12 - all; Chapter 13 (TBD); Chapter 14 - all

Astronomy in the news?

Happy 25th birthday,
Hubble Space Telescope!



Goal:

To understand how we search for real black holes and why binary systems with mass transfer and accretion disks are so important.

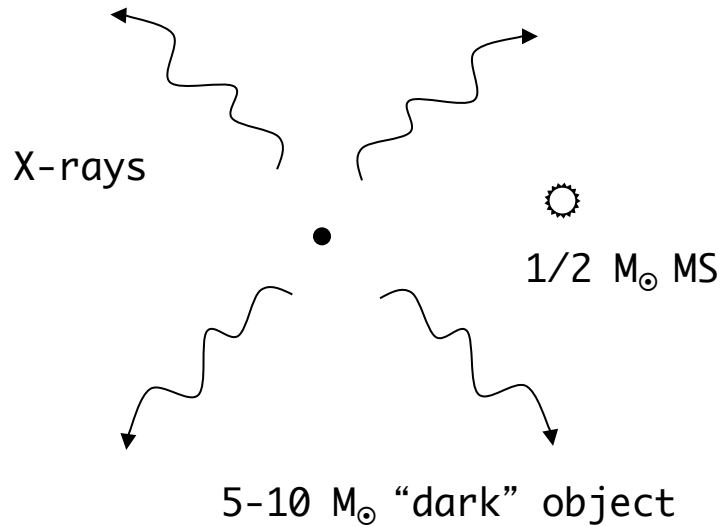
Expect only two or three systems like Cygnus X-1 in our Galaxy.

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 $\sim 1/2$ solar mass.

Observe ~ 45 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

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, current separation smaller than size of the star that made the black hole.

Possibilities:

Black hole progenitor swallows small mass companion while a red giant?

Companion forms from left-overs of collapse that formed the black hole?

Proving Black Holes

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

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

Evidence that in some circumstances 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**.

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

Black hole candidates in the directions of Sagittarius, Ursa Majoris, Perseus, Scorpius, Ophiuchus, Vulpecula, Monoceros, Lupus, Cygnus (2) (Find and observe the constellations for sky watch)

Cygnus X-1

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 45.

Goal:

To understand how we have discovered supermassive black holes and how they affect galaxy formation and evolution.

Gargantua: the giant black hole from the movie *Interstellar*



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! John Kormendy, Karl Gebhardt UT) 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]

Center of Milky Way Galaxy in direction of constellation Sagittarius – (find Sagittarius for sky watch)

Supermassive Black Holes

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!)



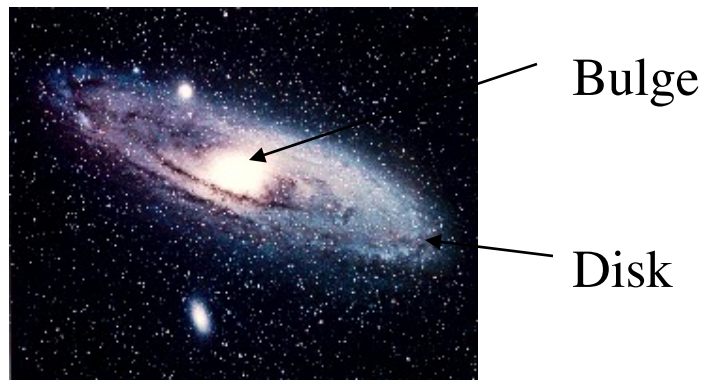
Surprising discovery:

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

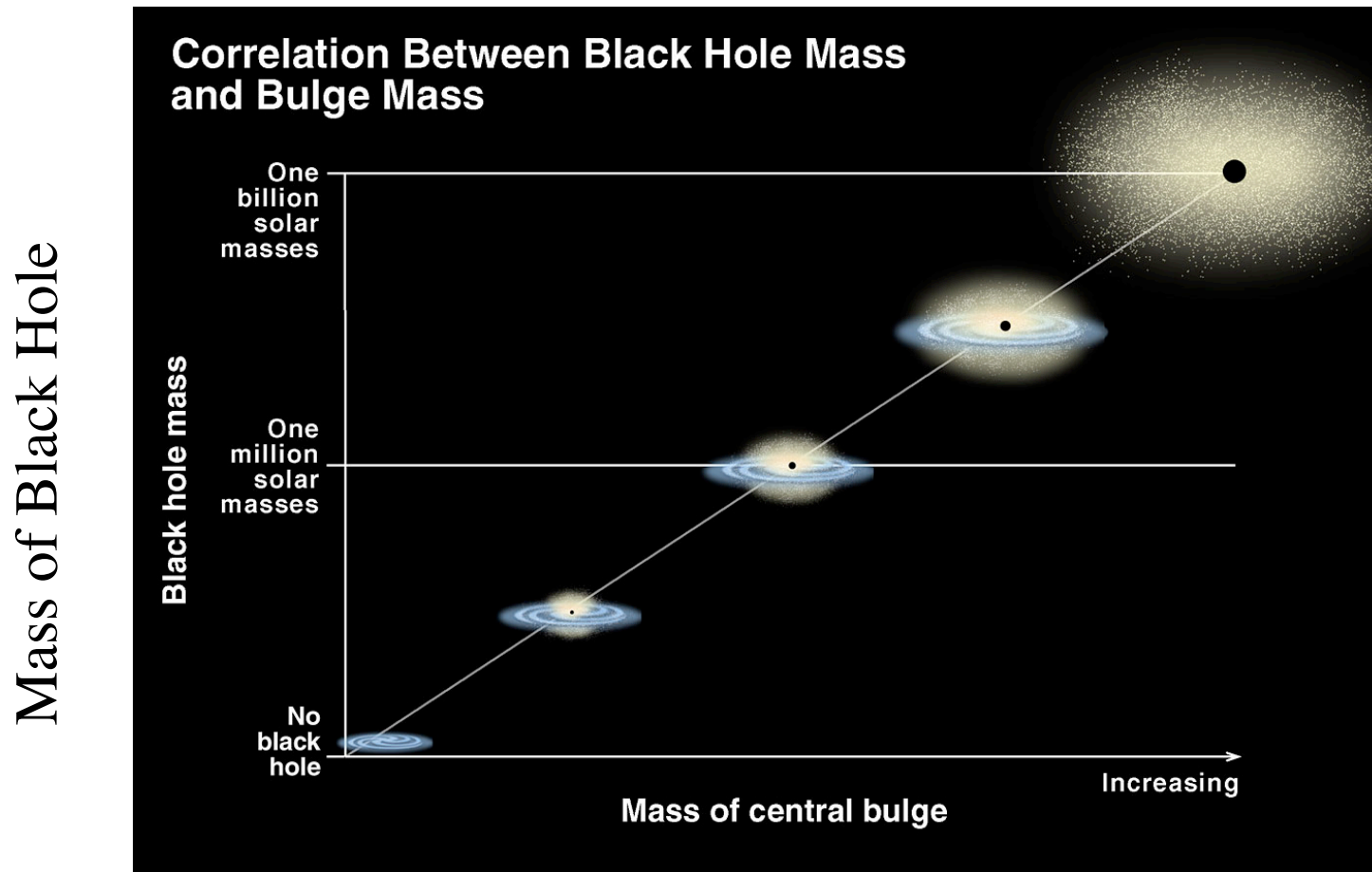
Formed of matter that somehow drained into the center of the galaxy, so galaxy could have large mass or small mass black hole depending on circumstances.

Recent work by John Kormandy and 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 Central Bulge of Galaxy

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.

