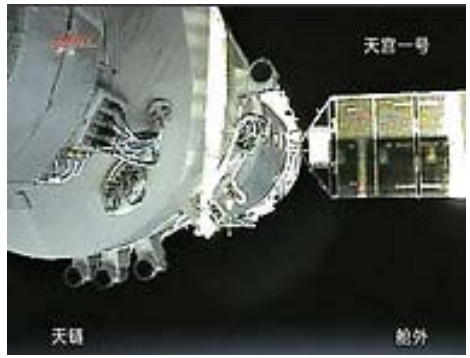
Friday, November 4, 2011

Exam 4, Friday, November 11

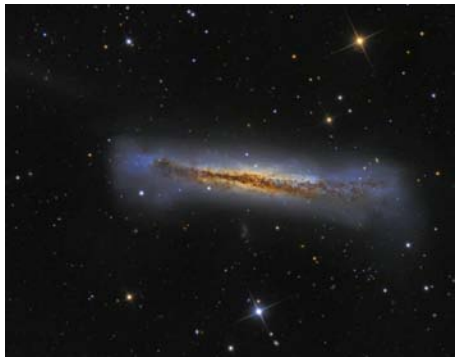
Reading: Chapter 9, Sections 9.5.1, 9.5.2, 9.6.1, 9.6.2. 9.7, 9.8; Chapter 10, Sections 10.1-10.6, 10.9

Astronomy in the news? The docking of the Shenzhou 8 capsule with the Tiangong 1 module was broadcast live on Chinese national television.



The Fabric of the Cosmos, second installment November 9, PBS (KLRU) 8 PM (re-runs http://www.klru.org/schedule/viewProgram.php?id=246736). Subsequent installments, next two Wednesdays, Nov 16, 23.

Pic of the day: edge-on spiral galaxy



First Episode of The Fabric of the Cosmos

"What is Space?

Mixed 2D embedding diagram with 3D hyperspace by showing bowling ball curving elastic space, another ball rolling in that space. Did not illustrate the "flowing inward" of space, crucial part of gravity.

Introduced acceleration of the Universe, Dark Energy, couple of weeks from now in class.

Introduced Black Hole Information, notion that information is encoded on the surface of the black hole, that we are holograms. Last week of class.

Goal:

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

Black Holes for Real

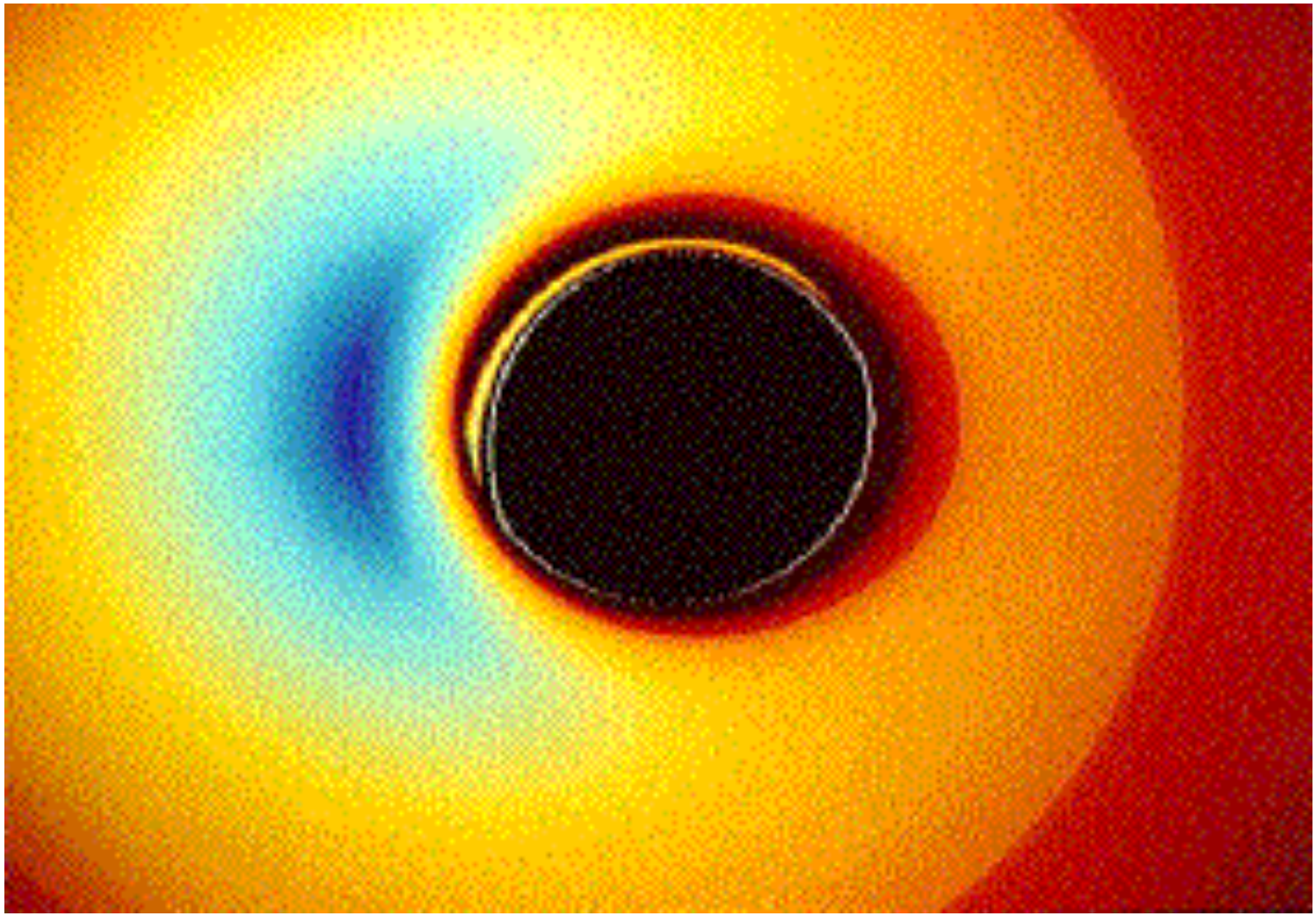
Look for binary systems, where mass accretion occurs.

Will not see the black hole, do not yet have the technology to “see” a black spot.

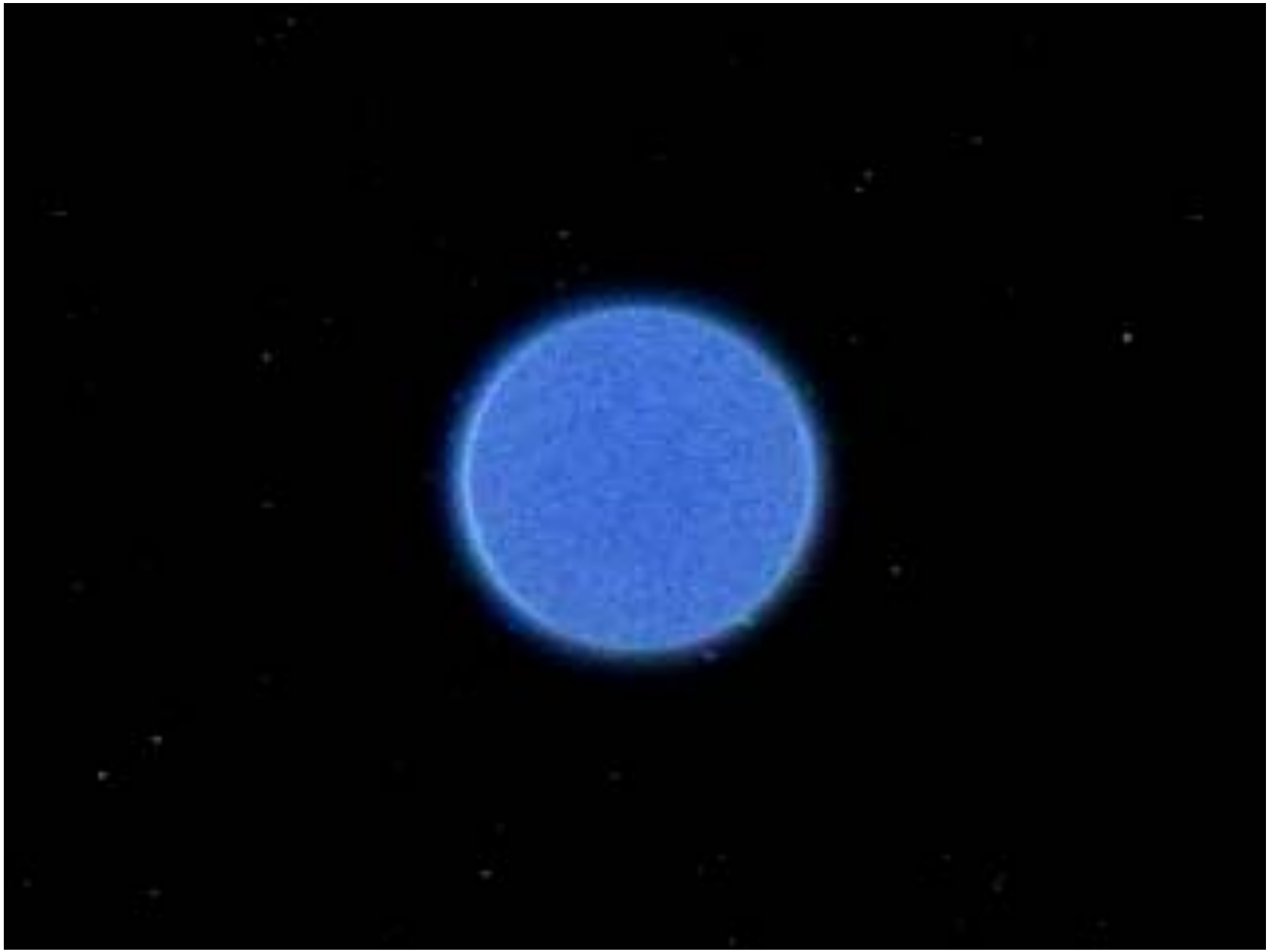
Can detect the ***halo of X-rays*** from orbiting matter, the accretion disk, near the event horizon that will reveal the presence and nature of the black hole.

Look in accreting binary systems!

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



Black holes are so weird and so important that the standards of evidence have to be high!

Current evidence is still primarily circumstantial, but very strong:

Stellar mass black holes (several to ~ 10 solar masses), in 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.

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There are about 20 binary star black hole candidates in our Galaxy and in the Large Magellanic Cloud (near enough to detect the X-rays) that have masses measured to be greater than 3 solar masses, and hence too massive to be a neutron star.

There are another 25 binary star black hole candidates with simlar X-ray properties, but no measured mass.

Cygnus X-1

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

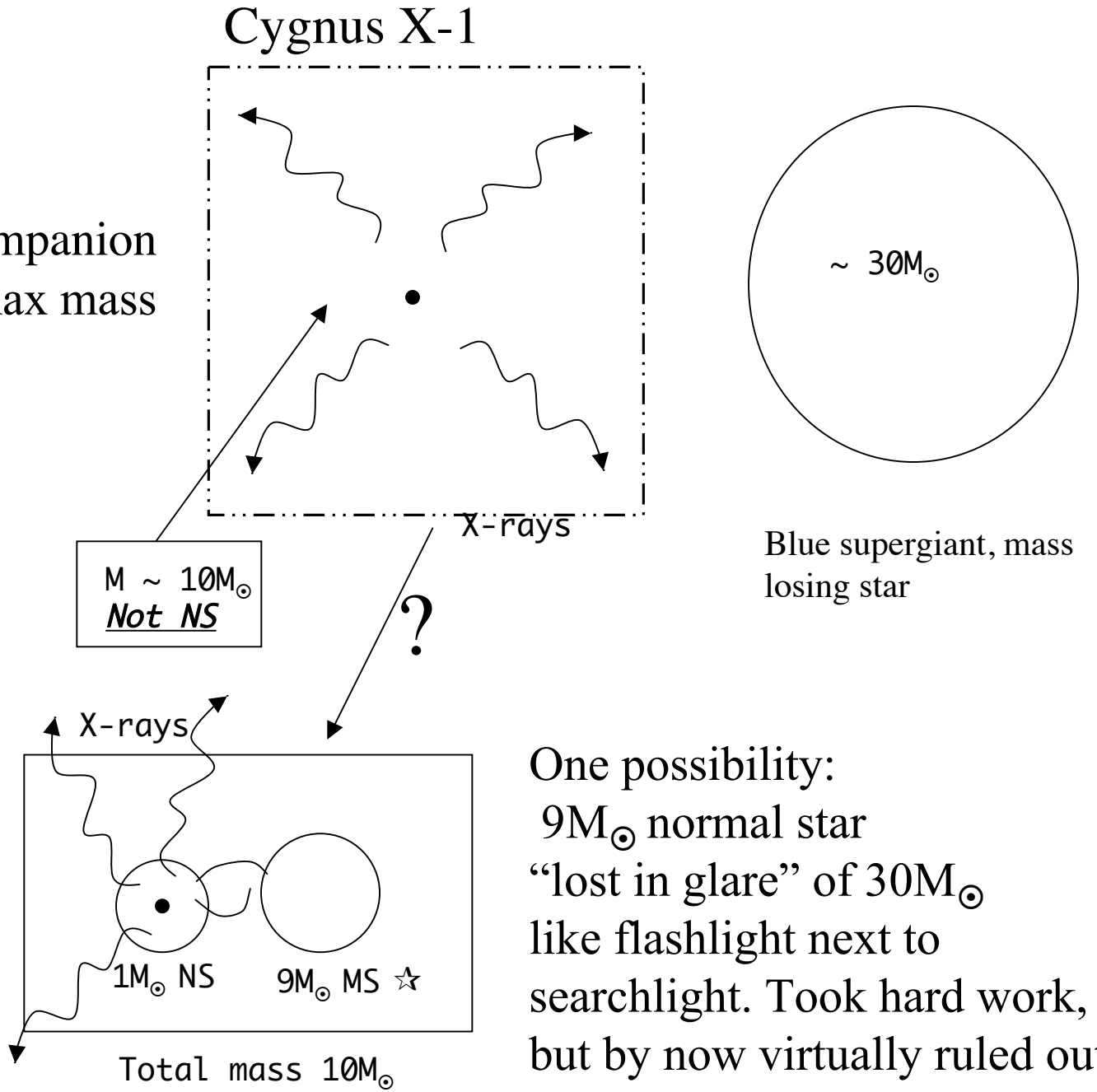
Discovered in 1970's by Uhuru Satellite (Swahili for Freedom).

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 for sky watch!

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. Took hard work, but by now virtually ruled out.

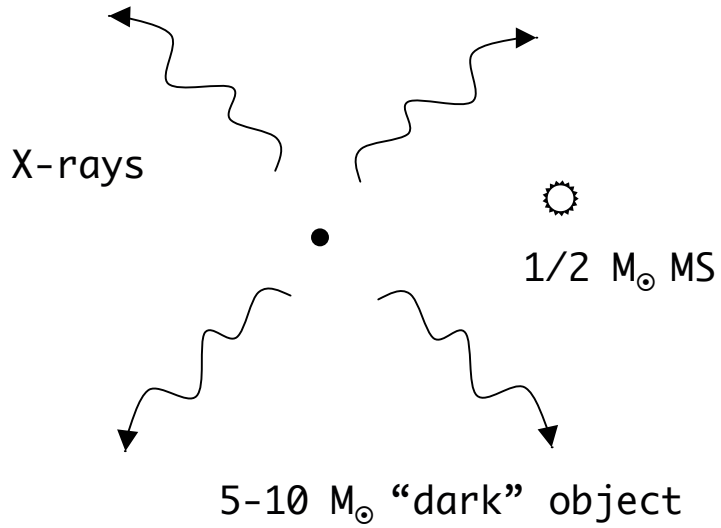
Expect only two or three systems like Cygnus X-1 in our Galaxy.

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 ~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

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 45.

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

Goal:

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

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, 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 ⇒ 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)

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!)