Tuesday, November 17, 2009
reading: Chapters 10 - 14: see Reading link, next page, for details
Fourth Exam, Thursday, December 3
Final Sky Watch, IYA reports due on Sunday, December 6

Astronomy in the News:

Water on the Moon! 26 gallons blasted from Crater.
Resource? Lunar history.

Leonids last night

Shuttle launch Monday - last Shuttle to take crew members to/from International Space Station. Russian Soyuz rockets for next 5 - 7 years until next launch capability ready (unless extended, stay tuned!).

Pic of the Day - artist's view of dwarf
nova from orbiting planet

Reading for Fourth Exam:

Chapter 10, Sections 10.1-10.6, 10.9-10.10
Chapter 11, Sections 11.1-11.5
Chapter 12, all
Chapter 13, all
Chapter 14, Sections 14.1-14.5

Chapter 10 - Finding Black Holes for Real

There may be 1 - 100 million black holes in the Galaxy made by collapsing stars over the history of the Galaxy. How do we find them?

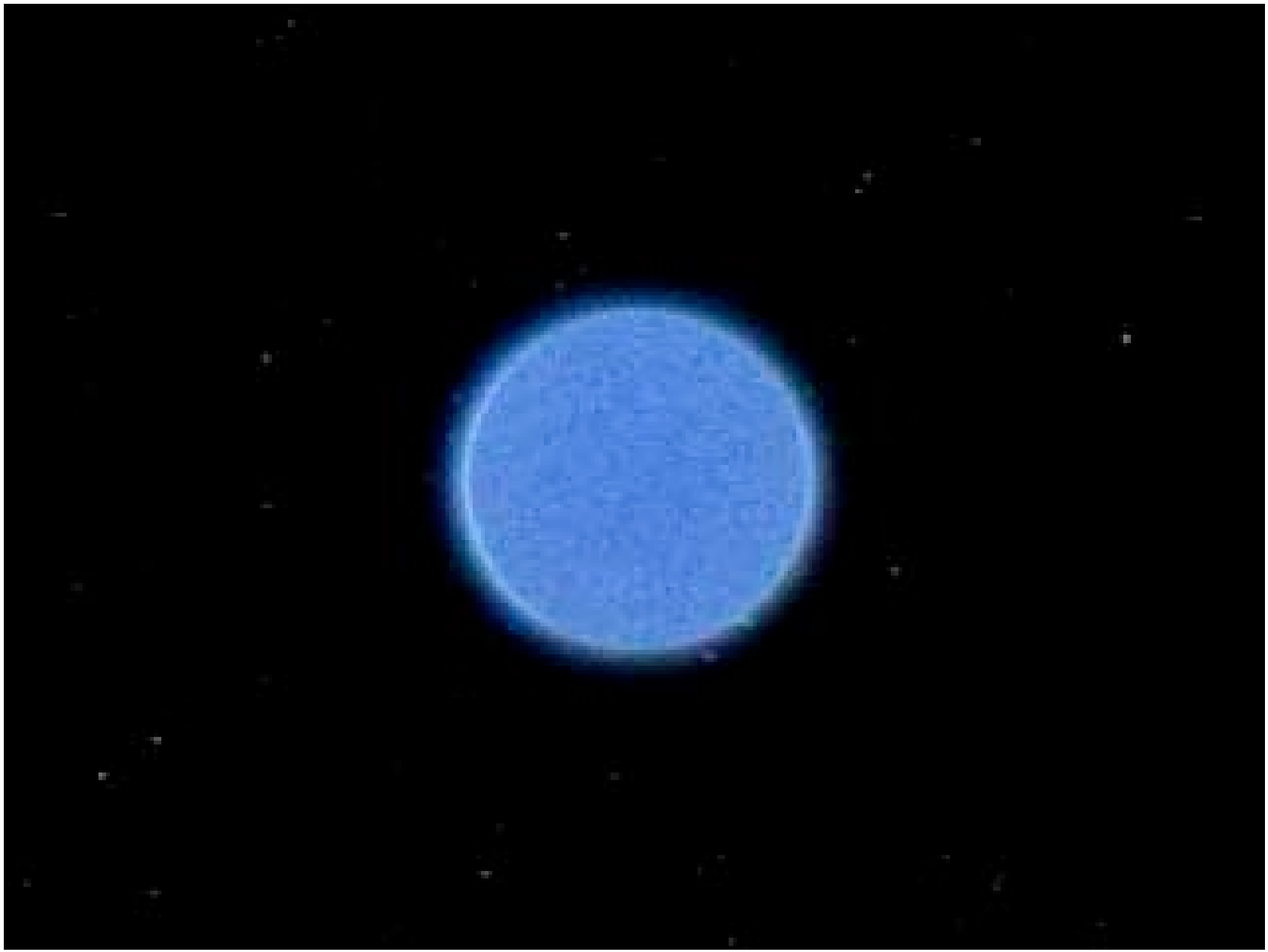
Black holes made from stars are really black! (Negligible Hawking radiation).

Those alone in space not impossible to find, but very tough. None yet identified.

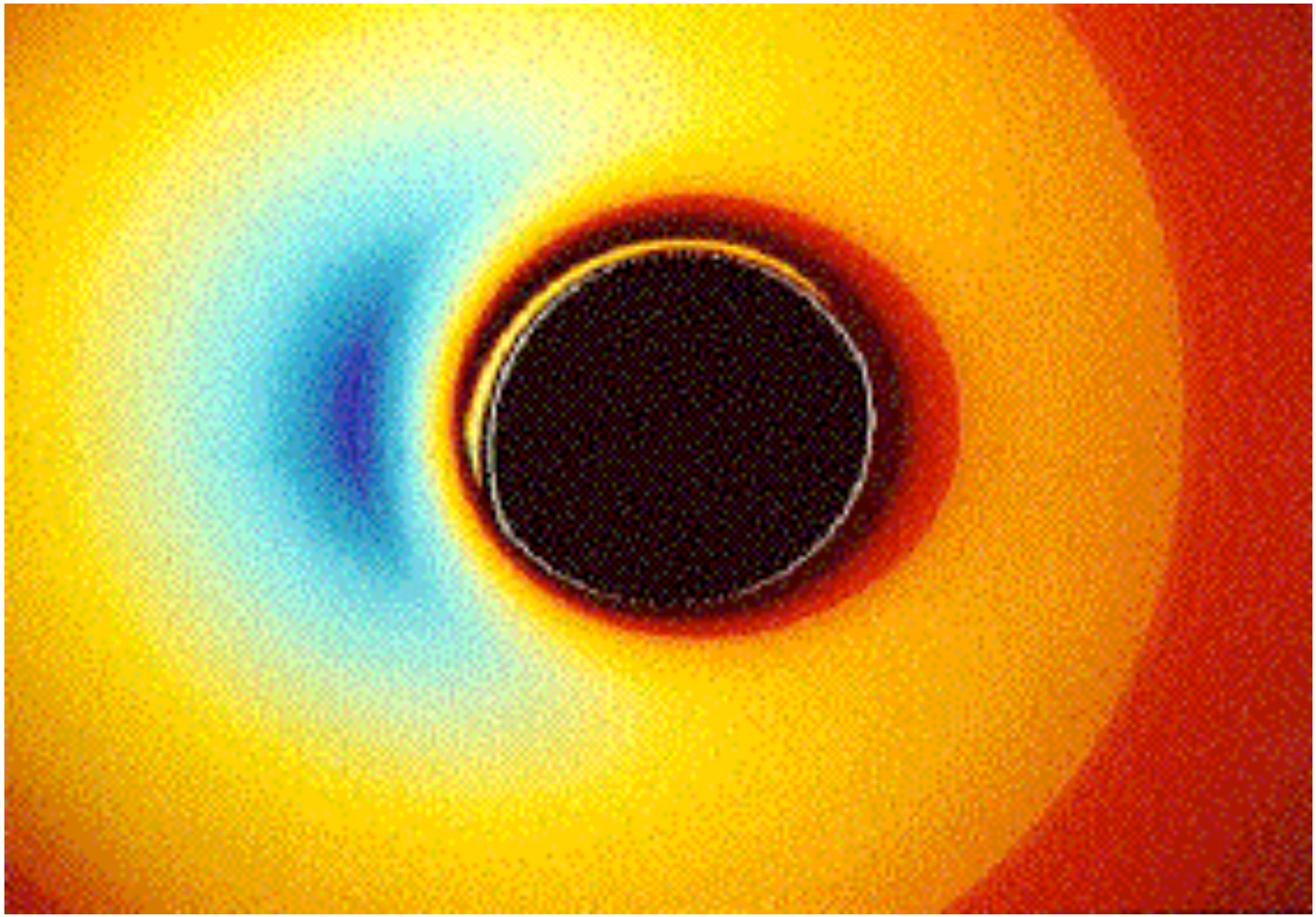
Look for binary systems, where mass accretion occurs.

Will not see the black hole, cannot yet "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

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.

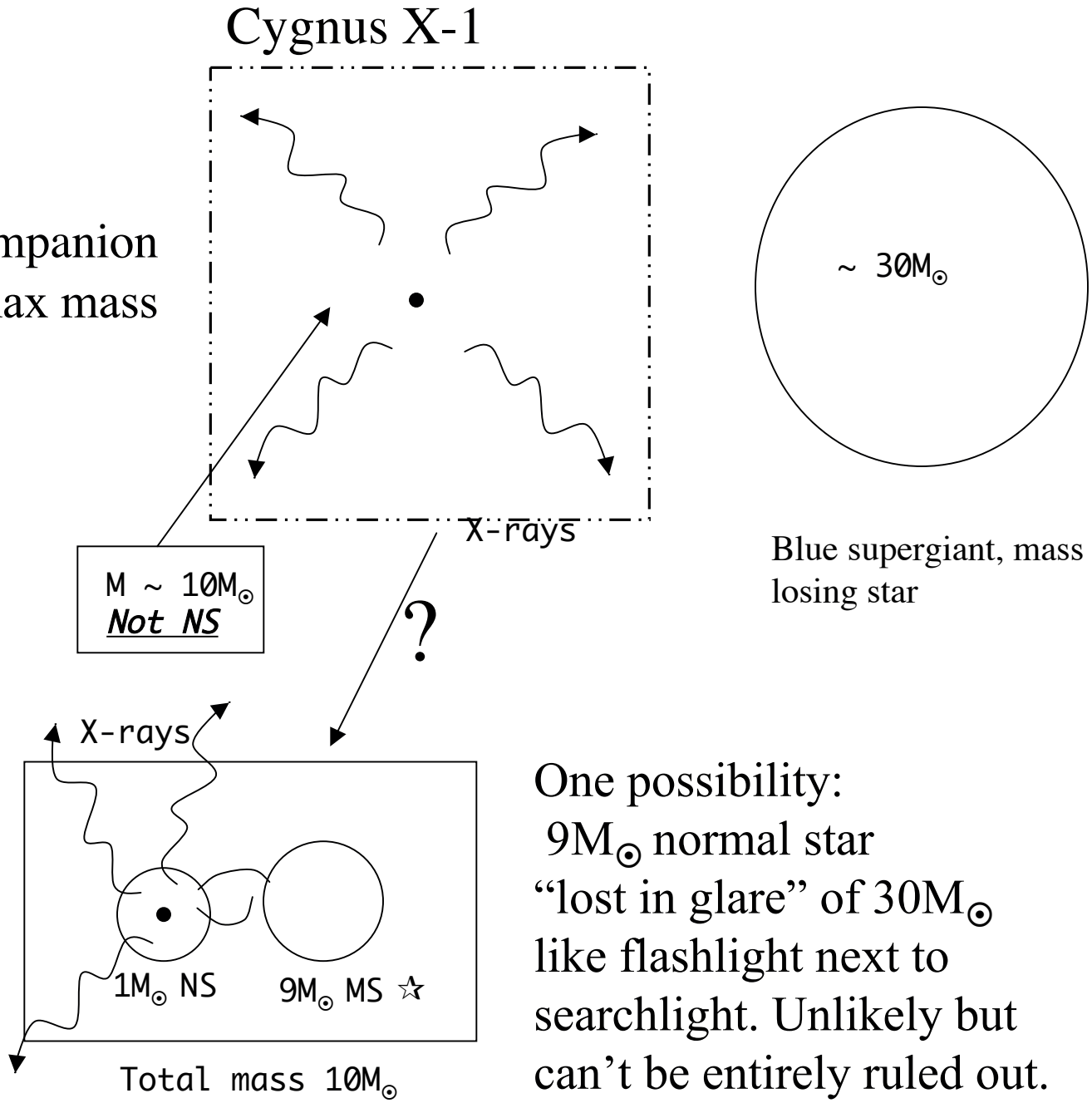
Discovered in 1970's by Uhuru Satellite (Swahili for Freedom).

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.

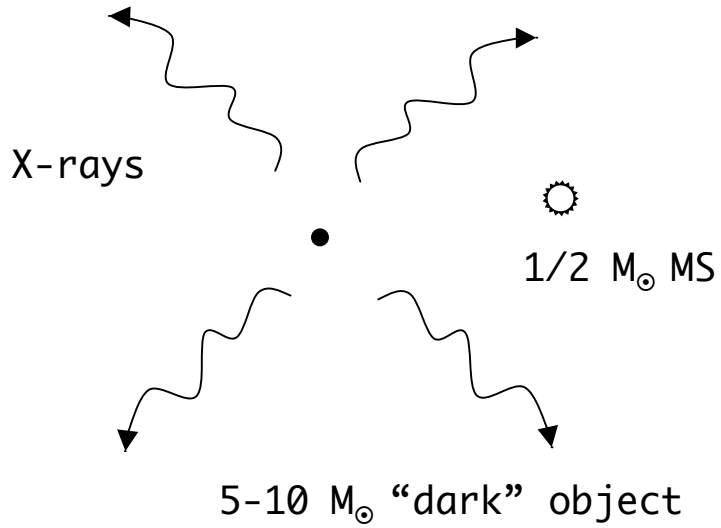
Expect only two or three systems like Cygnus X-1 in our Galaxy.

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!)