

4/4/2008

Exam 3, Friday April 11. Chapters 8, 9, 10

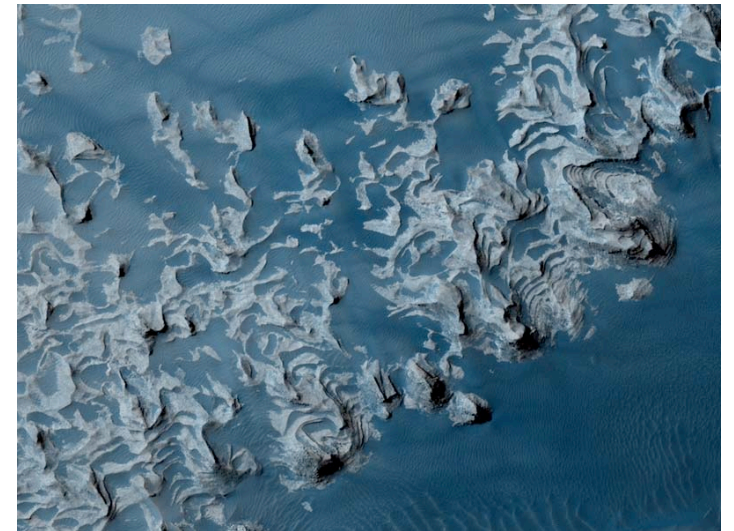
Chapter 8: Sections 8.1, 8.2, 8.5, 8.6, 8.7, 8.10

Chapter 9: (omit 9.6.3, 9.6.4)

Chapter 10: (omit 10.7)

Astronomy in the News - European Robotic *Jules Verne*
supply rocket docks with the Space Station

Pic of the day - layered rock
outcroppings on Mars

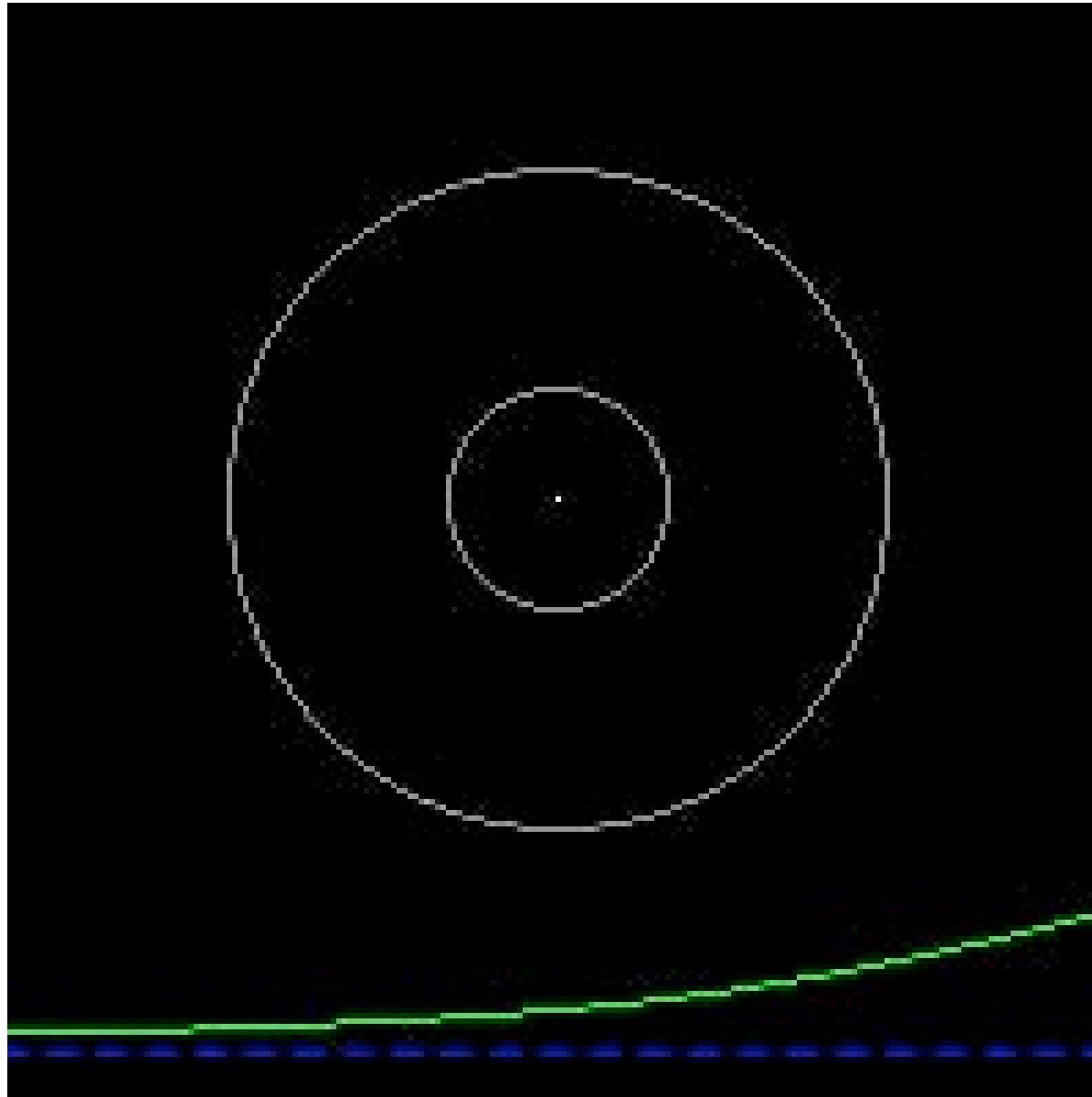




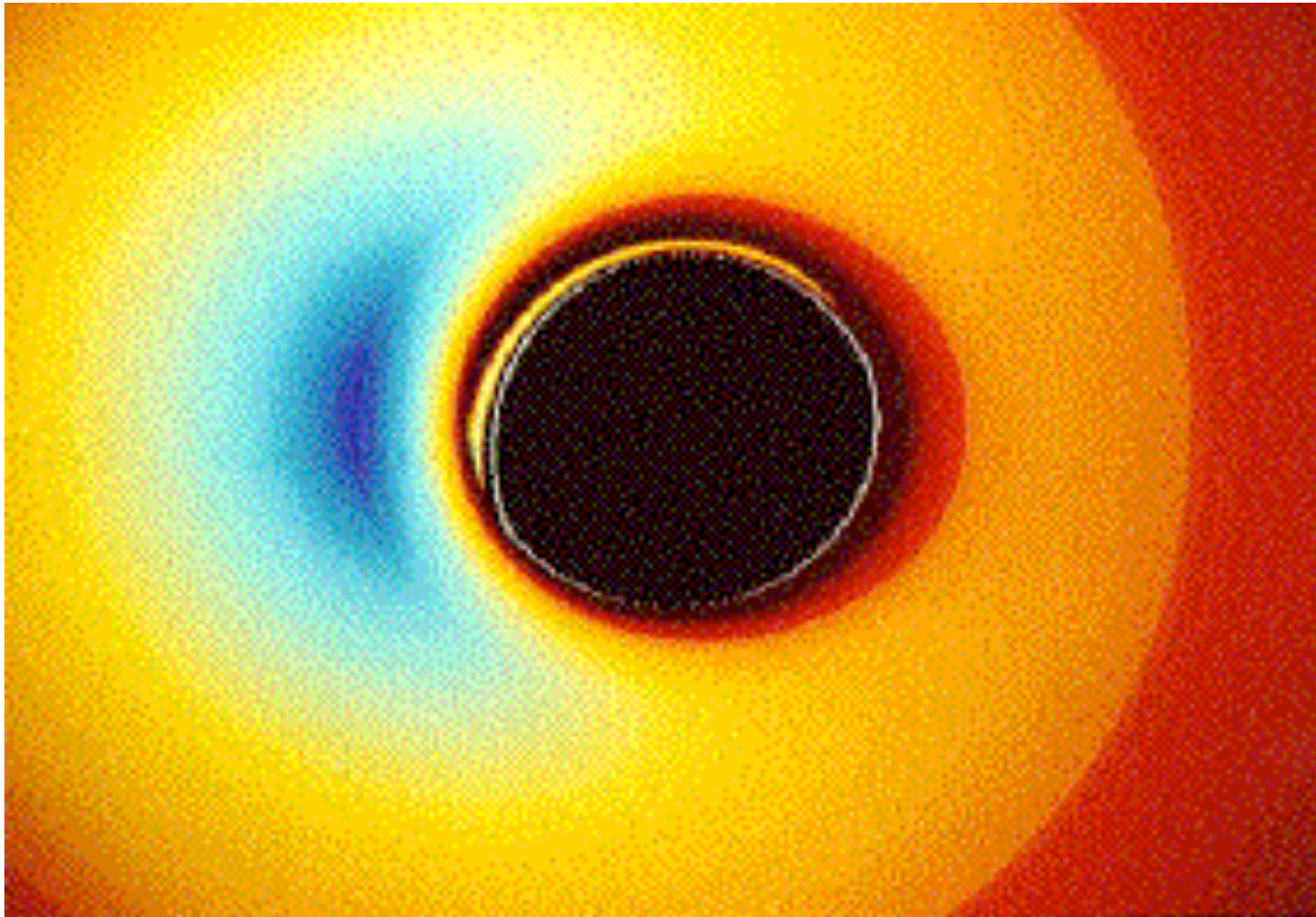
The path of light swallowed by a black hole

Last stable
orbit- outer
circle

Event
Horizon -
inner
circle



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 ($\sim 1000 - 10,000$ 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).

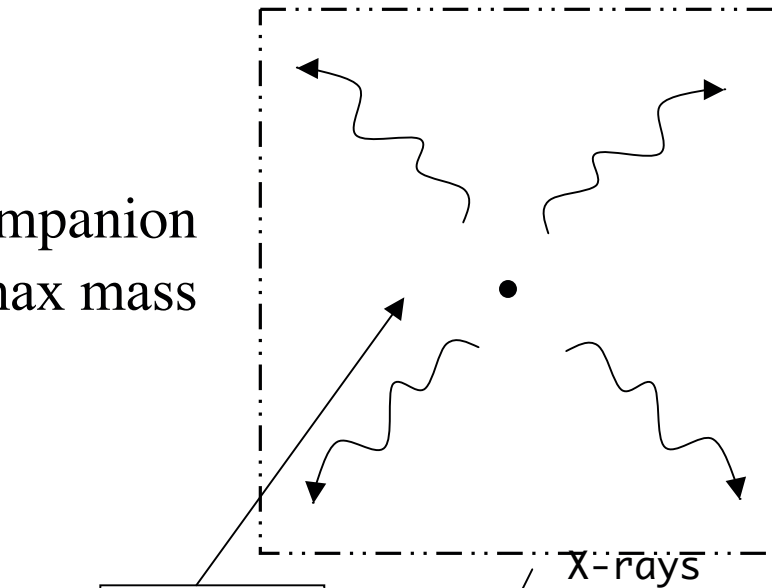
First and still most famous stellar-mass binary black hole candidate.

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

Cygnus X-1

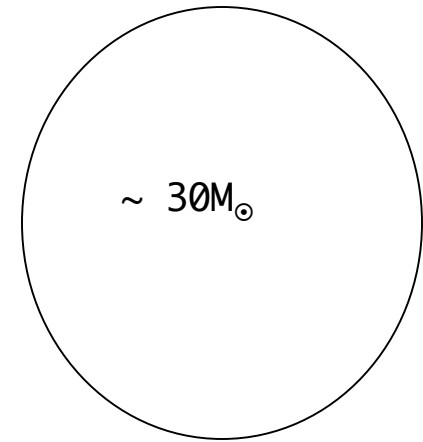
Optically dark
X-ray emitting companion
 $\geq 10M_{\odot} \gg \text{NS max mass}$
 $\Rightarrow \text{BH}$

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

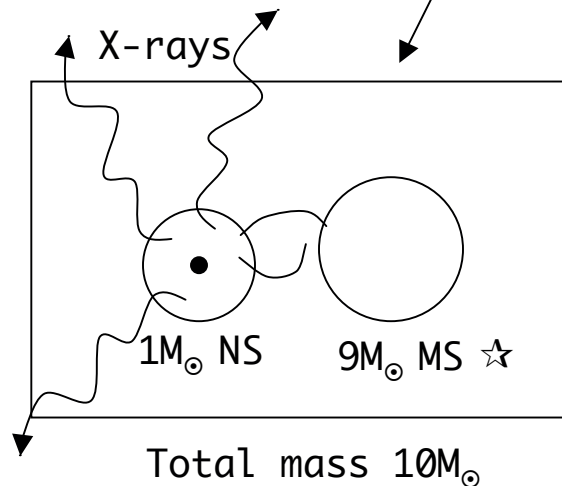


$M \sim 10M_{\odot}$
Not NS

?



Blue supergiant, mass
losing star



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.

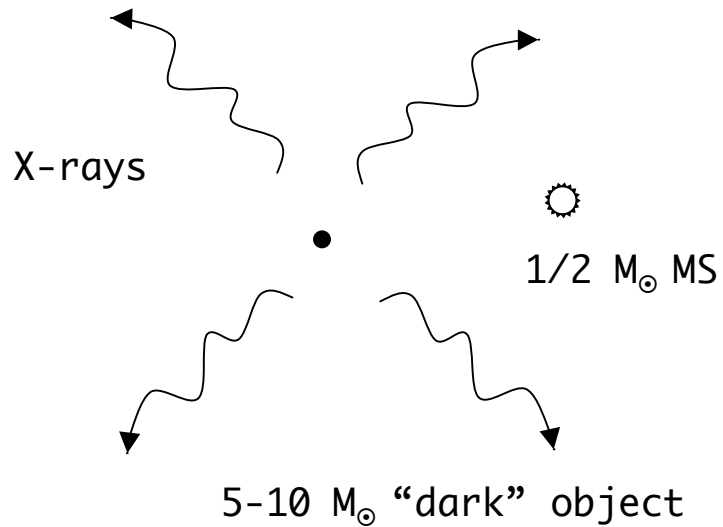
Expect only two or three systems like Cygnus X-1 in our Galaxy.

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 $\sim 1/2$ 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

⇒ 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!)