

Monday, April 17, 2017

Exam 4, Skywatch 4, Friday, April 21.

Review Session Thursday, 5 – 6 PM, Welch 2.308.

Lectures 21 to 30

Reading for Exam 4:

Chapter 8 Neutron Stars - Sections 8.1, 8.2, 8.5, 8.6, 8.10;

Chapter 9 Theory of Black Holes: 9.1 to 9.5, 9.8

Astronomy in the news?

Some “compact dwarf galaxies” may contain black holes nearly as massive as the galaxy.

Or not.



Goal:

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



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 in binary star system with mass exceeding 2 solar masses is, by a process of elimination, a candidate black hole.

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 similar 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).

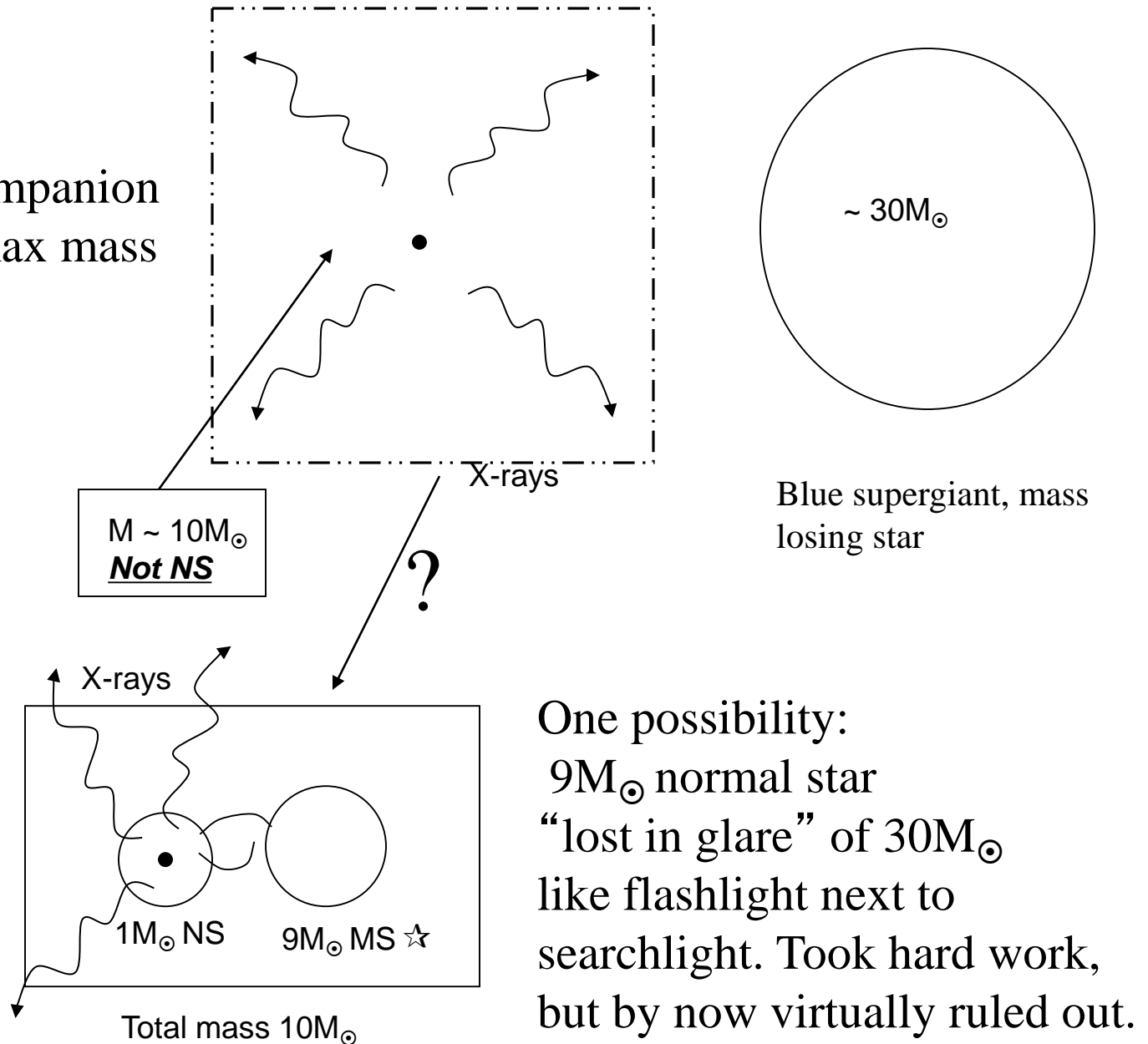
First and still most famous stellar-mass binary black hole candidate.

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

Cygnus X-1

Optically dark
X-ray emitting companion
 $\geq 10M_{\odot} \gg$ 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.

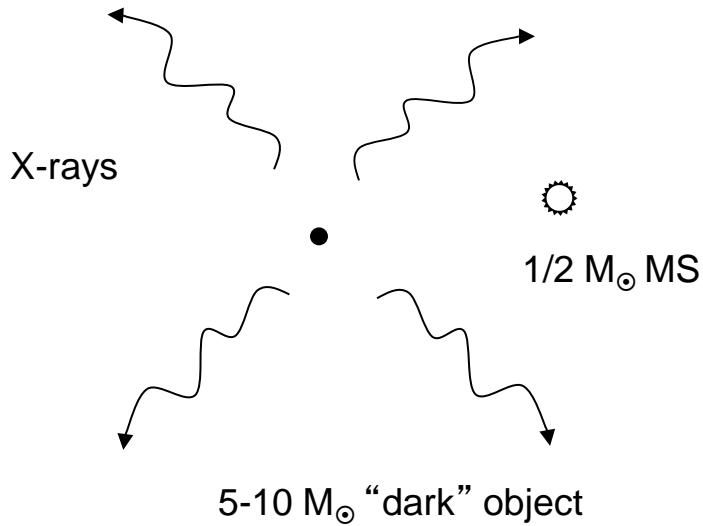
Expect only two or three systems like Cygnus X-1 in our Galaxy.

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 $\sim 1/2$ 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

⇒ 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

One Minute Exam

How can we discover a stellar mass black hole that has no accretion disk around it?

 Look for X-rays

 Look for gamma-rays

 Look for jets

 We can't

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*

