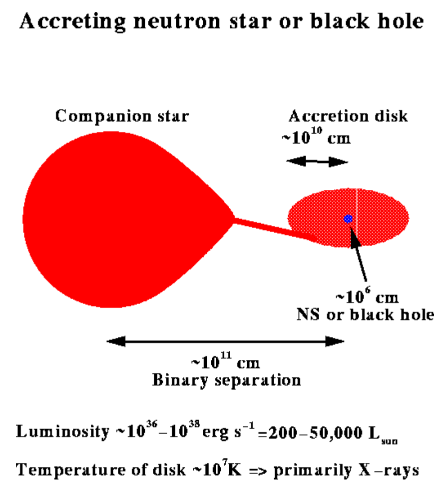
Agenda for Ast 309N, Nov. 29

- Quiz 8 – now!
- Next Tues: repeat first-day survey (partic. Credit)
- Next Thurs: Exam 3 (no make-up possible). Office hours and help session on Tues., Wed. afternoons
- X-ray binaries: neutron stars or black holes?
- Gamma-ray bursts (GRBs)
- Card: ask questions for Exam 3 review on Tues.
- Course-Instructor Survey

X-ray binaries: with NS or BH's



Mass flows from the companion star arrives near the NS or BH with high angular momentum (from the orbit); collects in a spinning "accretion disk," a holding tank for transferred mass. The disk is hot because of viscous forces (friction), so it emits optical, UV, and X-ray light.

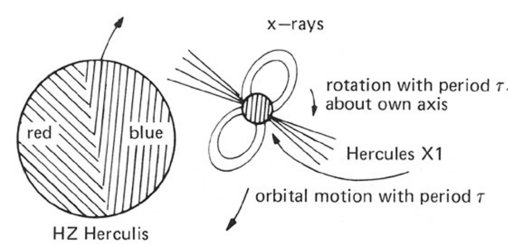
Group Participation Activity – Nov. 27

Suppose you have an interacting binary system containing a compact object that might be either a neutron star or a black hole. Discuss how you might be able to tell which of these is present.

(a) What observable things (kinds of electromagnetic radiation, light variations, other things) might lead you to guess that a neutron star is ***probably*** present? That a black hole is ***probably*** present?
(b) What observation could definitively ***prove*** that a black hole is present?

An X-ray Binary with a NS: Hercules X-1

HZ Hercules = Her X-1, the 1st X-ray source found in Hercules. It exhibits an X-ray pulse every 1.2 seconds, and the X-rays are eclipsed every 1.7 days. The orbital radius is 5 $R_\odot$!



→ The neutron star has 0.9 $M_\odot$ and a strong magnetic field that funnels infalling material to its poles. The X-rays heating the "facing" side of the companion.

X-Ray Binary Containing a Neutron Star

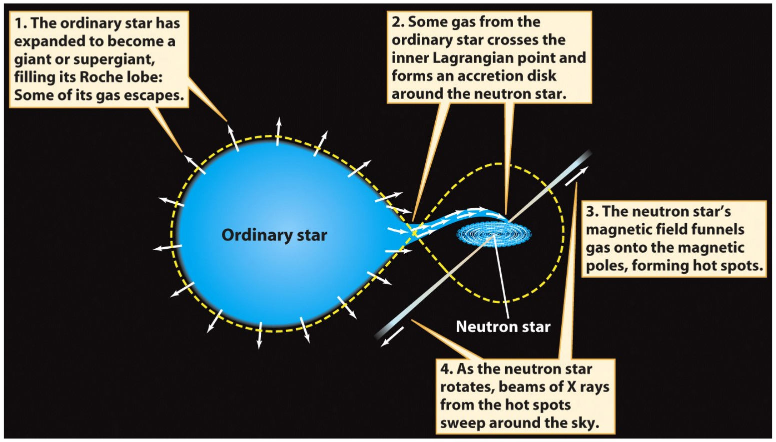
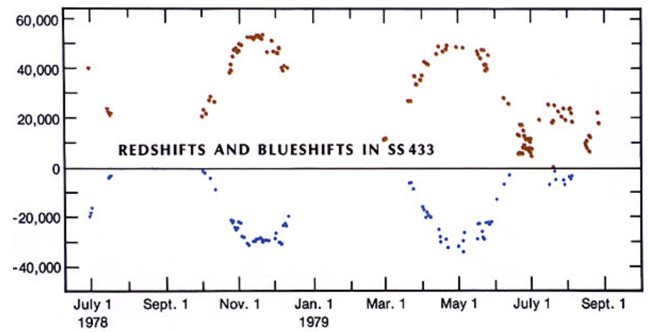


Figure 21-13
Universe, Eighth Edition

The Bizarre Object SS 433

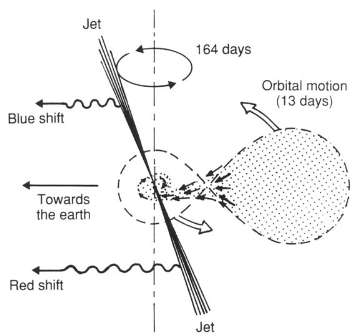
First noticed in 1978, this object features an optically visible star inside a SNR; X-ray emission indicating a binary with P_{orbit} = 13 days; and extraordinarily high Doppler shifts, with velocities of up to ¼ c!



X-ray Binary SS 433

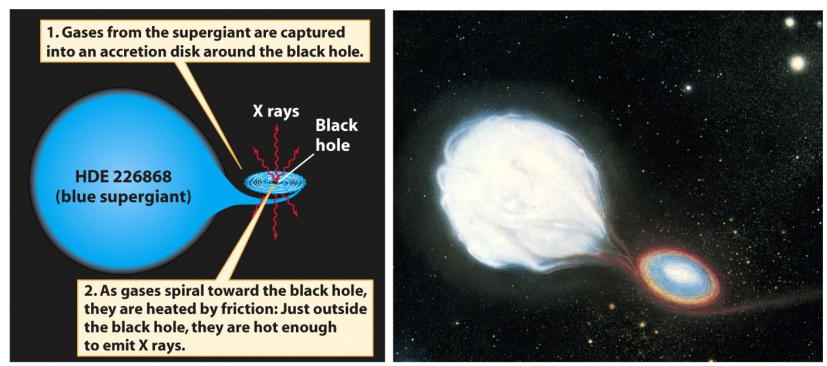
A neutron star with an accretion disk that "shoots" jets of relativistic particles

The NS wobbles on its axis, "turning" the jets around to describe a circle, as it precesses



Each jet is alternately red-shifted, blue-shifted, then red-shifted again; period of this wobble is 164 days.

X-ray Binary with a Black Hole



(a) A schematic diagram of Cygnus X-1 **(b) An artist's impression of Cygnus X-1**

Figure 22-11
Universe, Eighth Edition

Definitive Proof: NS or BH?

- Need to measure the unseen object's mass
  - Use orbital properties of companion
  - Solve for the mass, using familiar methods!
  - Remember the issue of tilt; if you don't know the orbit's inclination, your answer is a *lower limit* to the companion's mass…

$$\frac{(M_{star} + M_{BH})}{M_{Sun}} = \frac{(a/A.U.)^3}{(P/yr)^2}$$

- It's a black hole if it's not an ordinary star *and its mass exceeds the neutron star limit* (~3 M_{Sun})

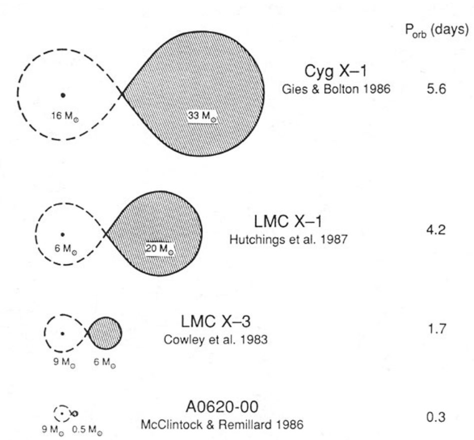
Possible Evidence: NS or BH?

- Look for evidence of *regular* blips of emission with a short period, from a beam or "hot spot" on the surface of a spinning neutron star (black holes don't have a physical surface!)
- Differences in the properties of the accretion disk
  - the inner accretion disk around a NS may reach higher temperature than one for a BH because material can still be seen close to a NS surface
  - The width of emission lines from the accretion disk can tell you the orbital speed of the disk, and from that, the mass of the central object

Some Binaries with Black Holes

Four X-ray binary systems which probably contain black holes.

A0620-00 was the first system found where the companion star is a low-mass object instead of a massive star. (These are now called LMXBs.)



Introduction to Gamma-Ray Bursts (GRBs)

We watched two video clips of Alex Fillipenko describing the initial discovery of GRBs and the finding that the sources of these bursts are in distant galaxies, extremely far away. Read ch. 11 in Wheeler, and we'll continue discussing GRBs next Tuesday.