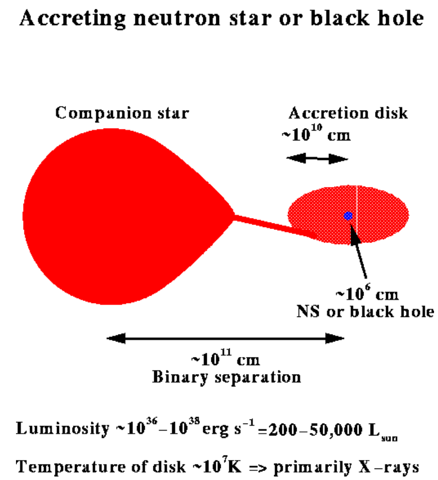
Group Participation Activity – Nov. 27

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?

X-ray binaries: with NS or BH's

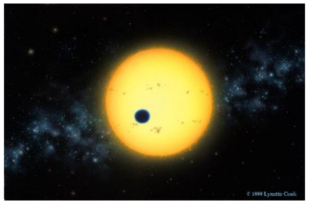


Mass flows from the companion star arrives near the NS or BH with high angular momentum (from the orbit); collects in a spinning "accretion disk," a holding tank for transferred mass. The disk is hot because of viscous forces (friction), so it emits optical, UV, and X-ray light.

Card Responses: NS or BH?

- "Neutron stars will have visible light (especially UV, X-rays because they're hot) that can be observed."
- Lack of luminosity corresponding to measured mass. Maybe, but the accretion disk is bright and usually overwhelms the faint light from the (tiny) N.S.
- "Large gravitational redshifts." This might work; it's been tried with X-ray emission lines.
- Differences in the properties of the accretion disk:
  - Accretion disk of a NS may reach further in, because there are no stable orbits close to a BH
  - "Flickering" instead of pulses suggests a BH

Photometric or "Transit" Method



A frequently missed question on Exam 2.5 asked how NASA's Kepler satellite can tell that an exoplanet is transiting its star. Many people imagined that it sees something like this (at left). That's ***wrong!***

When we look at a distant star, we cannot see the actual image of the planet silhouetted against its star, but the star's light is dimmed (slightly). By measuring the depth of the mini-eclipse, we can estimate the radius of the planet. To see this effect, we have to measure how the star's brightness varies with time – such a plot is called a ***light curve***.

Black Hole Accretion Disk

- Likewise, people seemed to think that we can actually see the shape of the star, the extent of the accretion disk, and a black spot in the middle. Again, that just "don't happen," as Kip Thorne said in the video on Tuesday.

Card Responses: NS or BH?

- "The mass transferred to the black hole appears to freeze or become frozen in time." This is like thinking you can see a "dot" crossing the star during the transit of an exoplanet. We can't see such detail!
- "There is a place where light should be, but isn't… missing light." Unclear. How do we know that light is "missing"? Using the orbit, we can get the mass.
- "Light from an accretion disk, for a NS, no light from a black hole." The accretion disk is outside the event horizon, so its bright emission *does* escape.

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

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})