Group Index Card, 11/13

Next week (Nov. 20) we will begin talking about black holes. I want to get a picture of what you already know (or think you know) on this topic.

State 2 or 3 facts about black holes – items you believe are **true**.

Optional: If you can do so, state 1 or 2 things said about black holes that you believe are **false**.

Facts about Black Holes - 1

- "The event horizon is the surface in space from which nothing, not even light, can escape."
- "Every black hole has an event horizon." (Well, it actually gets more complicated for a rotating black hole; see pages 201 – 206 in Wheeler's book.)
- "If you replace the Sun with a black hole of the same mass, the orbits of the planets will remain the same." Yes. From distances far away from the black hole, its gravity behaves the same way as the gravity of an ordinary object /star of the same mass. It's only close-up that things start behaving strangely.

Facts about Black Holes - 2

- "Black holes are generated from the supernova of high-mass stars, if the mass of the collapsing core is more than 3 $M_\odot$." Yes, this is how we think so-called "stellar mass" black holes are created.
- "Most galaxies are believed to have supermassive black holes at their centers." These have millions or even billions of $M_\odot$. We're not sure how they form.
- "The accretion disks [around black holes] can produce high energy (short wavelength) electromagnetic radiation."
- "The Sun will not become a black hole." True.

Mass, Radius, and Density - 1

- With regard to mass, guesses run the gamut:
  - "Black holes don't have mass … have zero mass."
  - "Black holes are really massive."
  - "Black holes have infinite mass."
- All of these statements are incorrect. A given black hole has a specific mass, but it need *not* be a very large mass. It cannot have zero or infinite mass.
- I suspect that some students were confusing the concept of mass – the total amount of matter – with ***density***, the mass inside a volume corresponding to a given radius … see next slide.

Mass, Radius, & Density - 2

- Most were clearer on the idea of radius: "Black holes don't have a radius." A bit more precisely, they don't have a *physical surface*. There is, however, the event horizon, which is a hypothetical surface (like a Roche lobe), representing the boundary of a volume.
- "Black holes take up zero space… have zero radius." This is true in the sense that, theoretically, all the mass of a black hole is located at a single point in the center, the ***singularity***. The volume within the singularity is zero, although the volume within the event horizon is most definitely finite.

Mass, Density, & Radius - 3

- Density is defined as mass divided by radius. If you consider the supposed density at the singularity of a black hole of, say, 10 $M_\odot$, it would be:

  ρ = Mass/Volume = 10 $M_\odot$/ 0 = ∞, because any quantity over 0 is infinity. Mass need not be infinite!
- However, you can calculate a different quantity based on the volume within the event horizon. This is a kind of average density: $<\rho>$ = Mass/Event Horizon volume, and it is *not* necessarily very large. In fact, more massive BHs have lower average densities than smaller-mass ones, according to this definition.

Other Confusions

- "Black holes have a minimum mass of 25 $M_\odot$." Not true. You might be thinking of the minimum initial mass of a star that makes a black hole in a SN.
- "Black holes have tremendous gravitational pull … suck up things from everywhere." The gravity of a black hole is strong only when you are close to where the mass is. What's special about black holes (and other compact objects) is that their *surfaces* are shrunk down to tiny sizes, making it possible to get very close to the center of mass, while still being outside the object. Black holes will gobble up mass in this close-in realm, but not from very far away.