ASTR 2030 Black Holes Fall 2011. In class group Project 2. Th Sep 29.

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River Model of Black Holes

According to the River Model of Black Holes, the behavior of objects near black holes is precisely as if space were falling like a river into the black hole. For spherical black holes, this model was discovered in 1921 by the German Nobel prizewinner Allvar Gullstrand and independently by the French mathematician and two-time French Prime Minister Paul Painlevé. In the model, space falls inward at the Newtonian escape velocity $v = \sqrt{2GM/r}$. The infall velocity is less than the speed of light c outside the horizon, equals the speed of light c at the horizon, and exceeds the speed of light c inside the horizon.

What does the river model predict for the answers to the following questions:

1. Suppose that you are a light beam (therefore moving at the speed of light) exactly at the horizon. What would happen to you if were pointed directly outward? [Do you fall in? Do you move out? Do you move sideways?] What would happen to you if you were pointed mostly but not exactly outward?

2. In what way, if any, does this behavior differ from the predictions of the Newtonian corpuscular theory of light, which in the hands of John Michell in 1784 gave the "correct" result for the radius of the horizon? [In the corpuscular theory of light, a corpuscle is emitted at the speed of light, and thereafter behaves much like a massive particle: it flies outward, and it either goes to infinity, or it turns around and comes back, depending on whether its initial velocity, the speed of light, is more or less than the escape velocity.]

3. Suppose that you are a light beam orbiting the black hole in a circular orbit. On this orbit, the so-called "photon sphere", are you at the horizon, inside the horizon, or outside the horizon? Justify your answer.

4. Make a connection between the appearance of the sky if you hover just above the horizon of a black hole, and special relativistic beaming. [How does a scene appear if you move through it at very close to the speed of light?]

5. Qualitatively, what would the river model predict for the tidal forces experienced by an infalling observer? [First, the tidal force in the radial direction. Think about the fact that the river is accelerating inward. Next, the tidal force in the perpendicular direction. Think about the fact that the river is converging (getting narrower) as it flows inward.]