# Problem Set #3

Astro 2: Spring 2012

Due: April 24, 2012 (in class)

## Problem 1 *The Twin Paradox*

Suppose you travel to the Milky Way center at constant speed, very nearly the speed of light. In the meantime, your twin will remain on Earth. Since the distance to the center is about 25,000 light years, the round trip will take approximately 50,000 years to complete (from your twin's reference frame) .

Assume that you traveled so fast that time was 'dilated' by a factor of 1000. How old will you be when you get back? What about your twin? Explain why you and your twin are not of the same age, even though he was the one experiencing time dilation from your reference frame.

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## Problem 2 *Classical vs. Modern Theories of Gravity*

One thing that really bothered Newton about his theory of gravity is that it required 'action at a distance.' An example of such is the Sun influencing Earth despite a physical connection (such as a rod or rubber band) between the two. Does this problem occur in General Relativity? Explain.

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## Problem 3 *The Flatlander and You*

(a) In Fig. 22-4 in the book, we are given the impression that 2D curved spacetime is actually curved into some third spatial dimension out of the plane. Do you think that our 3D space must bulge out into a 4th spatial dimension? Don't focus on getting a correct answer here; just say what sounds reasonable to you. As always, describe your thinking process and reasoning.

(b) How can someone who lives in a 2D universe find out if his world is flat or curved? Could this work for us 3D people as well?

## Problem 4 *On the Search for Intelligent, Hopefully Nonviolent, Life*

Explain carefully why it seems unlikely that intelligent life on a planet orbiting another star would have a level of technology similar to ours.

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## Problem 5 *The Photon Sphere*

For a non-rotating black hole, there exists a specific radius $R_{PS} = \frac{3GM_{BH}}{c^2}$ where light will actually orbit the black hole in a circular path. Any further away and the light will escape; any closer and the light will fall into the black hole. This implies that there is a sphere of photons, called the 'Photon Sphere,' where photons orbit in all directions along great circles of the Photon Sphere.

(a) Remember that the event horizon is located at radius $R_{Sch} = \frac{2GM_{BH}}{c^2}$ (pg. 593). Why is it that the photon sphere is located farther away than the event horizon, instead of right on it?

(b) Now, when the black hole IS rotating, the situation changes in quite an interesting way. Since a rotating black hole will actually drag space along with it, photons orbiting in the same direction as the rotation will receive a sort of 'boost' since the photons will still move at $c$ in the dragged spacetime. Similarly, photons moving opposite to the direction of rotation will have a sense of lagging.

What happens to the photon sphere for a rotating black hole, in comparison to the nonrotating case? Hint: Faster objects have smaller orbits.

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## Problem 6

Write down three (3) things that puzzle you, this time about specific material from the course lectures, homeworks, or reading. Again, please be specific and clear.

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