HW 7 A2020 Out 4/13/2010 Due 04/20/2010

1 (6 pts) In the following exercise, fill out the answers on paper, but also illustrate and annotate your balloon using a marker. Please put your name on the balloon.

a. Take the balloon handed out in class and inflate balloon. Draw a great circle on the balloon. The center of a great circle must go through the center of the balloon. Label this great circle 1.

b. Draw another circle approximately 1 inch above the first circle that is parallel to the great circle. Label this as parallel circle. Is this 2^{nd} circle a great circle? Why or why not?

c. If the surface of the balloon is considered to be curved spacetime, could a free floating object travel along the 2^{nd} parallel circle? Why or why not?

d. Draw a second great circle, starting 1" below the first great circle. Start the 2^{nd} great circle so that it is *initially* parallel to the first great circle. Label this as circle as great circle 2. Do the two circles intersect or not?

e. Imagine there are two spaceships floating through curved space following the great circles on the great spacetime balloon. Would they always be the same distance away, or would they move closer or further from each other?

Returned the marked balloon with your homework set (preferably inflated)!

2. (4 pts) The average density of the Milky Way (averaging over the entire disk, halo and bulge) is equivalent to 100 Hydrogen atoms per cubic meter. Is this higher or lower than the critical density of the Universe? (the critical density is given in lecture 19).

How does this explain why the stars in the Milky Way do not expand away from the Milky Way as the Universe expands?

3. (5 pts) Imagine you are an 18th century scientist, trying to judge which one of the following is a scientific theory for explaining the motions of falling objects. For each choice, write a sentence why that choice is or is not a good scientific theory. The choices are:

    a. Everything falls at 9.8 meters per second^2
    b. Falling bodies are pulled down by invisible creatures
    c. Everything will instead rise up (instead of fall down) in 2012
    d. Falling bodies are pulled down by the force of gravity, as given by $F = G\, m_1\, m_2 /\text{dist}^2$

Possible reasons why a given choice is not a theory include: does not make testable predictions, invokes supernatural entities, is a hypothesis unsupported by strong evidence, is in contradiction with the evidence, or is a simple observation - not a more general theory.

4. (4 pts extra credit) Determine which of the following is an inertial reference frame. Your friend gets into his spaceship:

   a. If the spaceship is accelerating, is it an inertial reference frame?

   b. If the spaceship is going straight with a constant velocity of 0.9 c, is it an inertial reference frame?

   c. If the spaceship is going in a circle, is it an inertial reference frame?

   d. If it is orbiting the Earth, is it an inertial reference frame?

5. (3 pts extra credit) Your friend gets in his spaceship. He goes 0.9 c and travels 4.3 light years to Alpha Centauri in 4.8 years of travel time –in the reference frame of Earth.

   a. On a separate piece of paper, calculate how much your friend will age given the equation of time dilation.

   b. Calculate the distance between Alpha Centauri and Earth in your friend's reference frame (remember in his reference frame, the Earth and Alpha Centauri are flying past at 0.9 c – so you can apply the equation of length contraction).

   c. Note you find that your friend ages more slowly because time is going more slowly in his spaceship. Your friend thinks the trip is shorter because the distance between Alpha Centauri and Earth is shorter in his reference frame. Are these points of view consistent?

$$\text{Time Dilation}: \quad t' = t\sqrt{1-\left(\frac{v^2}{c^2}\right)}$$

$$\text{Length Contraction}: \quad l' = l\sqrt{1-\left(\frac{v^2}{c^2}\right)}$$

$$\text{Mass Increase}: \quad m' = \frac{m}{\sqrt{1-\left(\frac{v^2}{c^2}\right)}}$$

6. (3 pts extra credit) Imagine that the universe was no longer expanding, but was contracting towards a big crunch. What would Hubble's law look like? Make a graph of what the Hubble law is for an expanding universe (distance vs velocity) and then make the same graph for the contracting universe.