Names: ____________________
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AST 112: In-Class Activity #9

The purpose of this series of exercises is to learn about the expansion of the Universe and its implications. We will meet <u>outdoors</u>, weather permitting, at our usual class meeting time.

The instructor will place students into teams of 3 or 4. Students will need to cooperate in order to perform the activities & answer the questions. Each student team will turn in <u>one</u> paper.

<u>Introduction</u>

Edwin Hubble showed two specific characteristics about the motions of galaxies:

- Excepting the most nearby galaxies (those bound to us gravitationally), all galaxies are moving **away** from us
- The **more distant** a galaxy, the **faster** it is moving

We have two possible explanations to account for this behavior:

A. We are at the center of the Universe, with galaxies moving away from us, and some force making them move faster as they get further away

B. We are not at the center of the Universe, with our galaxy's motion behaving just as all the other galaxies behave, even if we can't directly see it

We will perform some activities that will help us understand which explanation is accepted by astronomers, and why.

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Answer the following questions about Explanation A:

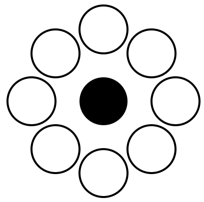
1. People once thought the Earth was at the center of the Universe, and then the Sun. Do people still think that way? Why or why not?

2. Do you know of any forces in nature that keep us (people) attached to the Earth? If so, which one(s)?

3. Do you know of any forces in nature that push *harder* the further away from the force's source? If so, which one(s)?

4. How likely, in your opinion, is Explanation A? Why do you think it would work – or, conversely, why do you think it won't work?

To address Explanation B, follow the instructions. Then answer the following questions:



All students: form a ring around the instructor, touching shoulder to shoulder. Keep your teams close together.

5. Estimate the arc distance between you & your nearest teammate. The arc distance is to be measured **along the arc of the ring**, not in a straight line. A ruler is not necessary, but you should decide on one common method of measurement. Record your result in the Table on the following page.

6. Estimate the arc distance between you & your other teammate (who must be further than the nearest teammate). Again, record the results in the Table.

7. Everybody reforms the ring, shoulder to shoulder. Facing the middle of the ring, everybody takes 2 steps *backwards*.

8. Repeat your measurements & for parts 5 & 6 above and record the results in the Table.

9. Recall that velocity (or speed) is simply distance traveled divided by time. We will assume that everyone took the same amount of time to step backward. Thus, if one person's arc distance is twice that of another person's, how much faster is the first person traveling compared to the second person?

10. Calculate the arc distance traveled by your two teammates. Record the results in the Table.

Arc-Distances Measured for an Expanding Ring

Teammate	First Arc Distance	Second Arc Distance	Distance Traveled
Nearest Teammate	_______	_______	_______
Farthest Teammate	_______	_______	_______

11. Are the distances traveled the same for both teammates? If not, which one's distance traveled is larger?

12. What do the distances traveled tell us about the velocities of each teammate?

13. How does everybody's velocity **relative to the center of the ring** compare to each other? Was your velocity (relative to the center) quicker, slower, or the same?

14. How do these results compare to Explanation B? Briefly describe your reasoning.

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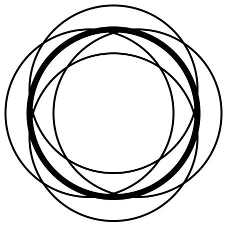
Finally, we can ask a few questions about the overall temperature *of the Universe. Again, follow the instructions, and then answer the following questions:*



First, reform the ring as it was when everyone was shoulder to shoulder.
One way of describing temperature for a gas is to look at the individual motions of its atoms & molecules. To simulate this, each student needs to "jitter" in place. We will assume that the more collisions with fellow students, the higher the overall temperature.

15. Begin jittering. Note how often you collide with your neighbors.

16. Everybody take two steps back. Again note how often you collide with your neighbors. Are collisions more frequent, less frequent, or the same?

17. Everybody take *four* steps *forward*. Again note how often you collide with your neighbors. Are collisions more frequent, less frequent, or the same?

18. What does this activity suggest about the temperature of the Universe when it was smaller (and therefore younger)?

19. What can we expect to happen to the temperature of the Universe in the (astronomical) future?

20. Here we have treated galaxies like they were gas particles. What does that tell you about the scale of the Universe?