A Ballooning Universe

It is difficult for many students to understand the idea that the universe can extend infinitely in all directions and still be expanding. The students grapple with this concept by making a "curved two-dimensional" balloon model of the universe.

Before Class

If you don't have ready-made tape measures, photocopy a "Do-It-Yourself Tape Measure" (master on page 48) for each pair of students. This can be made into a double master so that you can chop the photocopies in half lengthwise to get twice the number of tape measures.

In Class

1. Imagine a universe of many galaxies distributed throughout space. We can make a two-dimensional model of that universe by drawing galaxies on the surface of a balloon.
2. Hand out a balloon and pen to each pair of students. Have them take turns drawing several galaxies on the balloon. Have them mark a unique name (or number or letter) by each galaxy that they draw.
3. Hand out a tape measure for each team. Alternatively, hand out the "Do-It-Yourself" sheet with scissors and tape for each team. They can cut and tape the ruler strips from sheet into one long strip to be used as a "paper tape measure" for measuring the distance around the balloon.
4. Have each student draw a "Distance Table" on a blank sheet of paper and label the rows:

   "Distance 1: Between Galaxy ___ and Galaxy ___,"
   "Distance 2: Between Galaxy ___ and Galaxy ___,"
   "Distance 3: Between Galaxy ___ and Galaxy ___,"and "Circumference of Universe_____."

   There should be three blank columns.
5. Have one student in each team blow up the balloon so that it just barely starts to inflate, then hold the neck of the balloon pinched between two fingers so that it does not lose air. Have the second student of the team measure the separations between three pairs of galaxies on the balloon and record the galaxy names and distances in the Distance Table. The second student also measures the distance around the balloon with the tape measure and records that distance in the last row of the table. The first student of the team can then release the balloon and copy the measurements onto his or her own Distance Table.
6. Ask the students to predict what the distances between the galaxies will be if they expand their balloon universe to twice the size that it was for their first measurement. Have them write their predictions by the distance entries that they recorded in their Distance Tables.
7. To see if their prediction is correct, one student holds the paper tape measure in a loop twice as big as the circumference of the balloon in their first measurement. The other student blows up the balloon to fit. It may take a few tries to get it just right. Once the balloon fits the right circumference, the balloon blower pinches the neck of the balloon to keep air from escaping, while the other team member measures the distances between the same three

	Measurement 1	Prediction	Measurement 2
Distance 1: Between Galaxy ___ and Galaxy ___			
Distance 2: Between Galaxy ___ and Galaxy ___			
Distance 3: Between Galaxy ___ and Galaxy ___			
Circumference of Universe			

Materials

- Balloon (1/pair of students)
- Marking Pen (1/pair of students)
- Tape Measure (1/pair of students) or a "Do-It-Yourself Tape Measure" (master on p. 48), scissors, and tape for each pair of students
- Blank sheet of paper, 8.5" x 11" (1/pair of students)

pairs of galaxies as were measured before, and records the measurements in the table.

8. Have teams report their results.
9. Ask for conclusions with the following questions:

Are all the galaxies moving away from one another? [Yes.]

Is there any "center" on the surface of the balloon? [No. The center inside the balloon doesn't count because two-dimensional people living on the two-dimensional surface would not be able to go to that center.]

What are the weaknesses in our model of the universe?

In what ways might our balloon universe model be different from the real universe?

In the real universe, evidence shows that all galaxies are moving away from each other.

Will our universe expand forever or will it stop expanding and start collapsing someday? [No one knows. Scientists today are carefully measuring the rate of expansion, and may soon be able to determine what the fate of the universe will be.]

Going Further

Have your students select a galaxy on the balloon to represent our Milky Way galaxy. Point out that the Milky Way is not at the center of the universe, since there is no center on the balloon's surface. Have the students measure and record the distances from the Milky Way to all the other galaxies when the balloon is small, and again when the balloon is large. The **changes** in distances can be used to help in understanding Hubble's Law (Part D of the next activity, The Expanding Universe).

Background for the Teacher

The real universe is not like the surface of a balloon; the universe has 3 dimensions of space, not just two; the universe is expanding in Einsteinian "space-time," a FOUR-dimensional space that is not at all reasonable to common sense; the galaxies themselves are not expanding (the way they do on the balloon; it is the time and space between them that is expanding. One similarity: the real universe does not have a center, any more than the 2-dimensional surface of the balloon has a center. See Abbott's *Flatland* and any of the excellent popularizations of cosmology for more information.

A Ballooning Universe — Do-It-Yourself Tape Measure