
LAB 13. EXPANDING UNIVERSE

Introduction

You will relate the velocities of galaxies to their distance from us. This is what Edwin Hubble did around a hundred years ago, but we have more data now. Hubble found that the farther a galaxy is from us, the faster it recedes from us. Is that also what the current data show? Is the relationship a simple direct proportion, as Hubble's data suggested? Is the constant of proportionality, the "Hubble constant," authentically constant?

This is an online lab developed by the Vera C. Rubin Observatory.

Supplies

Computers to access the Rubin Observatory website

Procedure

Getting started

Ideally, I'd like you to work in pairs for this activity. If there are an odd number of students, one group may have three people. Or, one independent student can go solo.

1. Open a web browser, and type "rubinobservatory.org/education" in the address field. This brings you to a page with several activities.
2. Click on the one titled "Expanding Universe." This brings up a new tab.
3. Click on the "Start Investigation" button. This brings up the first page of the activity, or perhaps a log-in page. Log in if necessary, and then start in earnest. The progress bar at the top of the page shows how far you have gotten in the activity, with thumbtacks to indicate "checkpoints" along the way. This divides the activity into four parts. The arrow buttons at the bottom of the page take you forward or backward to the next or previous page.

Running the activity

First part: Introduction

This part gives the background of Edwin Hubble's discovery that the Universe is expanding, giving credit to astronomers he worked with, astronomers who developed the measuring techniques he used, and theoretical physicists who modeled the cosmos. If you have time, look at some of their biographies whose links are provided in the activity. Or do that on your own time later. The human stories are interesting.

The tools to estimate distances presented in this activity are two "standard candles" of known absolute luminosity: Cepheid variable stars, and type 1a supernovae. To estimate recessional velocities, the Rubin Observatory will use the technique of photometric redshift. These tools rely on numerous assumptions, which future understanding may modify. But if the data are recorded faithfully, the numbers will still be useful.

4. In this exercise, you find the distances and recessional velocities for four galaxies. Click on the photographs of supernovas and the nuclei of their host galaxies to obtain the

numbers. The time display may partly obscure the video that you click on; this may be a factor of the size of your monitor screen.

5. Next, plot the points for the four galaxies in a Hubble plots. You may need to scale the plot to fit the galaxy data; you can do this by clicking and dragging in the plot itself, and by moving the slider bar.
6. To finish this activity, answer a few questions about the Hubble plot and what it implies about the universe.

Second part: Determining the rate of expansion

Now that you made a Hubble plot from the perspective of our Galaxy, the website will use the same data to build plots from the perspectives of the other galaxies in the exercise. The galaxies are displayed on the right side of the window; you can rotate and zoom the galaxies to see how they are arranged in three-dimensional space. You don't need to build a frame or string beads onto thread!

7. Click on the icons for the individual galaxies to graph Hubble plots from their perspectives.
8. Answer the questions about the velocities of the galaxies and what it means for the universe.

Third part: Using evidence to support your ideas

Here we look at a Hubble plot to a much greater distance. Is it still in the form of a straight line?

9. Answer the questions about what the newer data (from galaxies at greater distances) tell us about how the universe behaved long ago.

Fourth part: Reflect and Discuss

10. Answer the questions. Everything has been guiding you to these answers. Notice that the data tell you what has happened, but it doesn't tell us *why* it is happening.

Finishing Up

First: **Don't leave without checking in with your instructor!**

11. When you get to the end, click the "REVIEW YOUR ANSWERS" button. This brings you to a record of the questions and your answers.
12. With the review window open, consult your instructor to **discuss your findings** and your answers. Be patient at this step, because your instructor needs to discuss their answers with every lab group.
13. When your instructor checks you off, you may leave. You do not need to download your answers or submit anything to Canvas unless you have made arrangements to complete the activity outside of the lab.
14. Leave **after** your instructor checks you off, or after you make arrangements for alternative completion of the activity.