SDSS Introduction to Redshift and Distance in Space

All-class activities that accommodate blind and visually impaired students using Sloan Digital Sky Survey Images

Introduction

Central to the study of astronomy is our never-ending quest for better measurements of distance in space. The concept of visual perspective that sighted people take for granted is very difficult for blind students to comprehend. It is essential for all students studying astronomy to have a firm conceptual understanding of *the manner in which the knowledge of the behavior of light is used to measure distance*.

The only information we receive from objects in space is the light or electromagnetic radiation they emit. We can use electromagnetic radiation to create images that show how the size and shape of the object appear in the sky, or we can create a graph of the amount of radiation across the different wavelengths using a spectrometer.

In this series of activities, students develop an understanding of distance in space through the concept of redshift. They begin by reviewing how the angular or apparent size of galaxies decreases with increased distance. Next, they are given images of galaxies they are told are the same actual size at different distances. Students are asked to sort the images in order of their distance from Earth. After some discussion, students order their galaxies according to size.

Students build on the concept of visual perspective with the addition of the spectrum graph that corresponds to each of the images. Through a series of tasks and discussions, students are introduced to redshift and uncover the relationship between redshift and distance. These activities can be used as an effective introduction to the SkyServer projects related to galaxies and the Hubble Diagram and under the assumption that students have a foundation in the nature of light.

Timeframe

Part I - Paper Plate Perspective — 20 min
Part II - Size and Distance Relationship Using Galaxy Images — 15 min
Part III - Examining Spectra, Discovering Redshift — 30 min

What You Need (for all the activities)

- ☐ Ten 6-inch Wikki Stix per group of four students (see *Getting Ready* for ordering information)
- ☐ One set of galaxy images and spectra per group
- ☐ One set of tactile galaxy images and spectra for each blind or visually impaired student. See below for more details.
- ☐ One 6-7-inch paper plate per student
- ☐ Two 3-4-meter lengths of string per group
- ☐ One protractor per group (see *Getting Ready* for resources for measuring tools for the blind)
- ☐ One piece of cardstock per group
- ☐ One pair of scissors per group

Getting Ready – Before you begin these activities

1. Well in advance of beginning these activities, you will need to order a sufficient quantity of wax-covered string – Wikki Stix. Because they are very versatile for creating tactile images and graphs, we recommend you **buy them in bulk**. You can find them in craft stores, or they can be ordered on-line. For ordering and more ideas on how Wikki Stix can be used in education, go to Wikki Stix.

2. The galaxy images and spectra for these activities can be downloaded and printed from Galaxy Images. You will need one set of copies for your class; you will need to produce one copy of thermal expansion images and graphs for each blind student. Using a thermal paper expansion machine is a relatively inexpensive and easy way to produce tactile graphics. An image is transferred onto thermal expansion paper with a photocopier or a computer printer. When it is passed through the machine, dark lines and areas are raised up which allow blind students to explore the image by touch. If your school or district does not own a thermal paper expansion machine, check with your director of special education or pupil services to explore other options.

3. Because it is very important that blind students DO the activity, we recommend ordering a specially adapted protractor if you do not have one already available. Several different kinds are on the market. A good place to browse your options is at The American Printing House for the Blind.

Part I: Paper Plate Perspective

1. Divide the class into groups of four students. Distribute one paper plate to each student and two lengths of string and a protractor to each group.
2. Tell the students that, in the form of the paper plate, each person is holding a galaxy of the same size. Ask students: "Does the actual size of this galaxy change if I take it down the hall?" Continue asking similar questions at greater distances until you have firmly established that the location of the object has nothing to do with the size. Then ask, "What *does* change about the galaxy as we move it further away?" Sighted students will readily identify that the apparent size of the object changes with distance. The remaining steps of this activity will clarify this concept for blind students and refine it for sighted students.
3. Explain that you are going to model what happens to light waves as they travel from an object to a camera or your eye. Each group is going to place their galaxies at three different distances from the observer.
    a. One student represents the observer and holds the ends of the two strings in one hand so that the ends touch. The string represents light waves in your model that are coming from different parts of the galaxy. Remind students that although light travels as a wave, the wave moves in a straight line. Light from the galaxy moves outward in all directions in a straight line. The two strings in this model represent just two waves that travel from each side of the galaxy to our detector.
    b. Two students take the galaxy to some distance at least 40 cm from the observer. They hold the galaxy between them with one end of each string touching each side of the paper plate galaxy.
    c. A fourth student uses a protractor to measure the angle created by the strings running from each side of the paper plate to the observer. This student is representing the observer's eye or any other recording device.
    d. Record each measurement and repeat so that each student has the opportunity to do each job. It is not necessary for groups to record the distance to the object as long as they have recorded them in some order, either increasing or decreasing the distance from the observer. *Note: Because blind students are not able to see the overall set-up of the model, it is important that they participate in each of the roles. Encourage them to feel the change of each angle for themselves as well as to record the measurement.*
4. Direct each group to re-read their measurements aloud and agree on a statement that describes what they demonstrated. Each group should share their conclusions.
5. Introduce the use of the words "angular size" to describe students' observations that the angle measured between each edge of the galaxy decreases with increased distance. Explain to the class that in order for the eye or a camera to detect the shape of the galaxy, the angular distance between edges must be big enough for the light waves coming from them to be detected as separate. You may want to introduce the word "resolve" as the correct term that refers to a camera or the eye's ability to distinguish two points as separate.

6. If the light waves get too close together, they cannot be distinguished from one another. Check for understanding by asking, “What would the image appear to be if a galaxy had an angular size smaller than the camera was able to resolve?” If any student has trouble identifying that the galaxy would appear to be a point, use letters of the Braille alphabet as an example. (“If the dots that form the letters were moved together so they were almost touching, what would happen to your ability to tell one letter from another? Why?”)
7. Have groups re-word their conclusions using the concept of angular size (and resolution if you chose to introduce it). Make this conclusion available to blind students in whatever media is most accessible for them.

Part II: Size and Distance Relationship Using Galaxy Images

1. Divide students into groups of eight. Provide each group with a set of the galaxy images. Provide one complete set of images in a tactile format to each blind student.
2. Explain that each of these images was selected from the Sloan Digital Sky Survey because, relatively, they are the same actual size but are different distances from Earth. (Yes, you know this is cheating, but you are trying to teach something very specific.)
3. Give the students a minute to examine their galaxy. Remind groups with blind participants of the need to state which galaxy they are describing before they start. Ask the students to think about things like the location of the galaxy on the page, other objects in the field of view, the size of the galaxy, and the amount of detail visible. Everyone should take a turn. The group can even name their galaxy.
4. Take some time to share observations, and then direct the students to line their galaxies up in order of their distance from Earth. Allow them to pursue any idea they agree upon, but it is expected that they will quickly organize themselves by size. Use the tactile galaxies in the groups where that set is available so the blind students are able to fully participate and review the results.
5. When finished, compare results either by sharing the order out loud or by having groups circulate to view the ordering produced by other groups. Were there any differences? Why?
6. Guide students to formulate a statement that reflects what they have just demonstrated, such as: *Galaxies of equal size will appear smaller with increased distance from Earth.* Ask students to give an example of how two galaxies could appear to be the same size but be at different distances. *One small galaxy is close to Earth, and a second, larger galaxy is at a greater distance.*
7. Ask students, “If galaxies come in a range of sizes, is there a way to tell which galaxy is really closer?” Students may have some thoughts about relating the distance to the amount of detail that they observe. In this case, point out that larger galaxies will allow the camera to capture more detail. In the end we need another tool to help us measure distance: the spectrometer.
8. Explain to students that astronomers can capture and record the light or electromagnetic radiation coming from a galaxy in an image, or they can send that

light through an instrument that will spread the light out according to wavelength. This instrument is called a spectrometer.

Part III: Examining Spectra, Discovering Redshift

1. For each galaxy image used in Part I, hand out the matching SDSS spectrum graph. As with the previous activity, blind students should receive a complete set of tactile images and matched spectra. Instruct students to follow along as you explain the features of the graph.
    a. As you move from left to right on the X-axis, the wavelength of the light increases. The scale on each of the graphs is the same.
    b. The Y-axis is the amount of light captured by the spectrograph. The scale on each of the graphs is NOT the same, so you are NOT able to make valid comparisons between the graphs without considering the scale of the Y-axis. Explain that each of the graph's Y-axes begins with zero at the bottom, and the maximum measurement is located at the top of the axis. The zero point and the maximum value on each Y-axis are labeled in Braille as well.
    c. The line on the graph is a record of the amount of light (Y-axis) that was recorded at each wavelength (X-axis).
2. Instruct students to examine their graphs and share their observations with the group. Begin with the galaxy that is closest to Earth. Remind them to report the maximum intensity recorded on the Y-axis. They should notice a pattern: *The amount of electromagnetic radiation decreases with increased distance.* This should make sense since the galaxies chosen in this activity are all approximately the same actual size. Just as the sound from a bell grows fainter with increased distance, so does light become fainter with increased distance. (This activity will not address the inverse square law of light, so be careful about allowing students to draw the connection from the previous activity that the smaller the angular size, the fainter the galaxy appears. This makes intuitive sense but is not the most scientifically accurate explanation. See *The Inverse Square Law of Light – Adaptations for Blind and Visually Impaired Students* for more information on teaching this concept.)
3. All students should notice that they have one particularly large peak on their graph. Ask the group to come to an agreement about what this might mean in general: *There is one particular wavelength of light common to all the galaxies that is very abundant.*
4. Explain to the class that hydrogen gas is the most common element in the entire universe. In fact, three quarters of the visible universe is composed of hydrogen. When hydrogen is heated, it emits a number of different wavelengths of electromagnetic radiation. The most common is called Hydrogen-alpha. Because it is so common, the H-alpha peak (or emission line) is observed on every galaxy spectrum.
5. Explain that in the 1920's when astronomers discovered that there were other galaxies at great distances from our own, the search began for a way to measure this distance. As astronomers started using the new spectrometer technology, they discovered something surprising that was to help them in that quest.

6. Construct a graph to compare the distance and position of the H-alpha line on the spectrum graph.
    a. Each group will lay out the axis for a graph using waxed string (Wikki Stix) onto a piece of cardstock (landscape position).
    b. Lay small pieces of Wikki Stix across the X-axis, one for each galaxy. This will mark the position on which students will record their measurements for each galaxy in increasing distance from Earth as determined during the previous activity.
    c. For each graph cut a length of Wikki Stix equal to the distance between the H-alpha line to the right edge of the graph. Make the measurements from near the top of the line since the base of the line is broader than the top.
    d. Each student will contribute to the graph by laying their length of Wikki Stix on the graph above the mark for their galaxy.
7. Observe the graph and draw conclusions. The graph should reveal that the position of the H-alpha line is not the same for each galaxy. In fact, the graph shows that the position of the line moved to the right (got smaller) with increased distance to the galaxy.
8. Explain to the students that they have just observed the same phenomena that astronomers uncovered almost 100 years ago: that the spectral lines of galaxies shift to longer wavelengths than expected. The further the galaxy is from Earth, the greater the shift. Because the color we see as red is a longer wavelength of electromagnetic radiation, we refer to this shift as redshift. For a more detailed explanation and examples, see Preflight readings, Redshift and Spectra at the new SDSS Voyages website.

If you have other ideas about how to adapt Sloan Digital Sky Survey images, activities, and data for special needs learners, please contact us at voyages@sdss.org.