Inquiry Investigation 9-A

Skill Check

Initiating and Planning

✓ Performing and Recording

✓ Analyzing and Interpreting

✓ Communicating

Materials

- ruler
- calculator

Math Skills

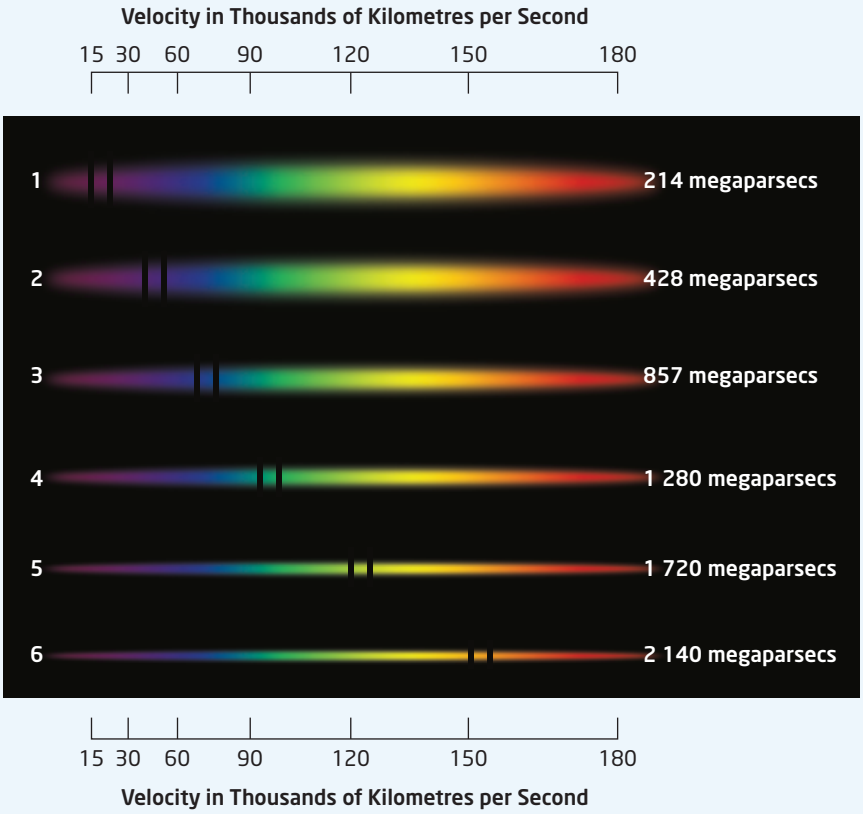
Go to **Math Skills Toolkit 3** for information on graphing.

Estimating the Age of the Universe

There is a relationship between a galaxy's redshift and its distance from Earth. When this relationship is plotted, the slope of the line gives the Hubble constant, H. Once you have a value for H, you can estimate the age of the universe, in years, using the equation $\frac{10^{12}}{H}$. The units of the Hubble constant are kilometres per second per megaparsec (km/s/Mpc). See below for information about parsecs.

The spectra of six galaxies are shown below. Each spectrum contains a pair of spectral lines. The spectral lines are normally seen in the far ultraviolet part of the spectrum. Due to the motion of each galaxy, however, these lines have been redshifted. The amount they are redshifted depends on the velocity of the galaxy. The velocity of each galaxy can therefore be determined from the redshifted position of the absorption lines.

Note that the terms *velocity* and *speed* are not exactly the same. *Velocity* is speed associated with a direction. Astronomers use *velocity* because galaxy motion is associated with a direction: either toward Earth (blueshift) or away from Earth (redshift). Also note that the distances given for the spectra are in megaparsecs. A parsec is 3.26 light-years, so a megaparsec is 3.26×10^6 light-years. Astronomers use megaparsecs for graphs of this type.



The spectra from six galaxies are shown here.

Question

How can you estimate the age of the universe?

Hypothesis

If galaxy velocity and galaxy distance data are known, then the age of the universe can be estimated by plotting these data and using data from the graph in an equation.

Procedure

1. Make a table like the one shown. Give your table a title.

Galaxy	Distance from Earth (megaparsecs)	Velocity (thousands of km/s)
1	214	15
2		
3		
4		
5		
6		

2. Refer to the spectra in the figure. Use the redshifted position of the spectral lines to determine the velocity of each galaxy. To do this, use a ruler to line up the centre of the left spectral line with the velocity scales at the top and bottom of the chart. The velocity scales give the galaxy's velocity in thousands of kilometres per second. Record the velocity and distance of each galaxy in your table. The first entry has been done for you.
3. Use the data in your table to plot a line graph of galaxy velocity (in thousands of km/s) against galaxy distance (in megaparsecs). Put galaxy distance on the x-axis and galaxy velocity on the y-axis. See the Math Skills Toolkit on page 557 for more information about graphing.
4. Draw a line of best fit through the points.
5. The slope is the Hubble constant, H. Calculate the slope of the line, which is the rise over the run. For help calculating slopes, see the graph below.

Analyze and Interpret

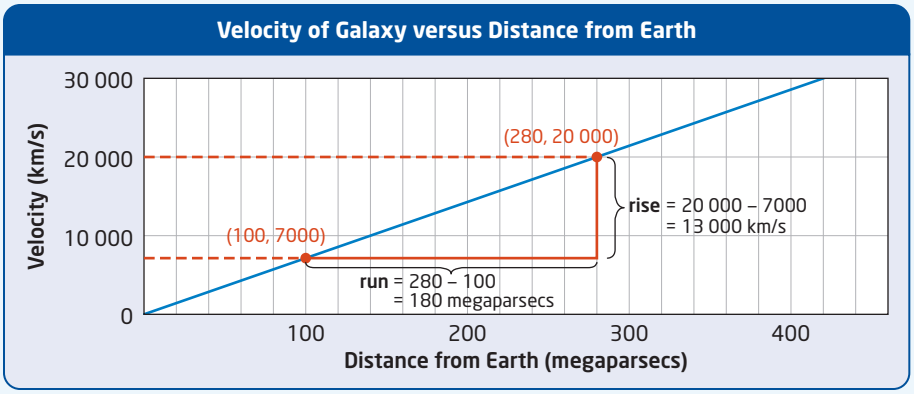
1. The age of the universe is given by the equation $\frac{10^{12}}{H}$. Use your value of the Hubble constant from step 5 to estimate the age of the universe in years.

Conclude and Communicate

2. How does the age of the universe that you calculated compare with the currently accepted age of slightly less than 14 billion years?

Extend Your Inquiry and Research Skills

3. **Inquiry** Predict the age you would calculate if you used the spectral line on the right. Repeat this investigation to check your prediction.
4. **Research** Research the Hubble constant, including the controversy surrounding it and how its value has changed over time.



This graph can help you calculate the slope of a line.

Inquiry Investigation 9-B

Modelling the Expanding Universe

In this investigation, you will model the concept of universe expansion.

Skill Check

- ✓ Initiating and Planning
- ✓ Performing and Recording
- ✓ Analyzing and Interpreting
- ✓ Communicating

Materials

- marker, black or blue
- balloon (light colours only and with no marks on it)
- clothespin
- string
- ruler

Distance	M1	M2	M3
From A to B			
From A to C			
From A to D			
From A to E			
From A to F			

Question

If all the galaxies around Earth are moving away from Earth, does this mean that the Milky Way galaxy is at the centre of the universe?

Prediction

Write your own prediction based on what you learned in this chapter.

Procedure

1. Make a table like the one shown. Give your table a title.
2. Use a marker to draw six dots on an uninflated balloon. Draw three dots on each side of the balloon, and make each dot about the size of the eraser at the end of a pencil. Label the dots A to F. The dots represent individual clusters of galaxies.
3. Partially inflate the balloon, and twist and clip the opening shut with a clothespin. (Do not tie the balloon.) Using a piece of string and a ruler, measure the distance between dot A and each of the other five dots. Record these distances in your table under "M1."
4. Unclip the balloon, inflate it some more, and then tightly reclip it. Measure the new distances between dot A and the other dots. Record your results in the table under "M2."
5. Inflate the balloon one last time, until it is almost completely full. Measure the distances, and record them in the table under "M3."

Analyze and Interpret

1. What pattern do you see in the three sets of measurements you took as you inflated the balloon?
2. Does this model help answer the question and verify the prediction? Why or why not?

Conclude and Communicate

3. From your observations, what can you conclude about the motion of galaxy clusters relative to one another, as the universe expands?

Extend Your Inquiry and Research Skills

4. **Research** Dark energy is causing the universe to expand. Research dark energy to learn how scientists initially reacted to this discovery.