# LAB 12
# Doppler Shift and the Changing Universe

## Purpose

The purpose of this lab is to have you use the spectral analysis of different galaxies in the universe to calculate their relative movement, velocity, and distance from the Earth as determined by Doppler shift. This information can then be used to infer about the present state of the universe. Doppler shift is a change in the wavelength of light emitted from a celestial object that is moving relative to an observer (see Figure 12–1). If the object's motion is toward the observer, the wavelength is reduced, also known as a blue shift. If the object is moving away from the observer, the wavelength is increased, also called a red shift. Astronomers analyze the light emitted from stars and galaxies by using a spectroscope, which reveals the

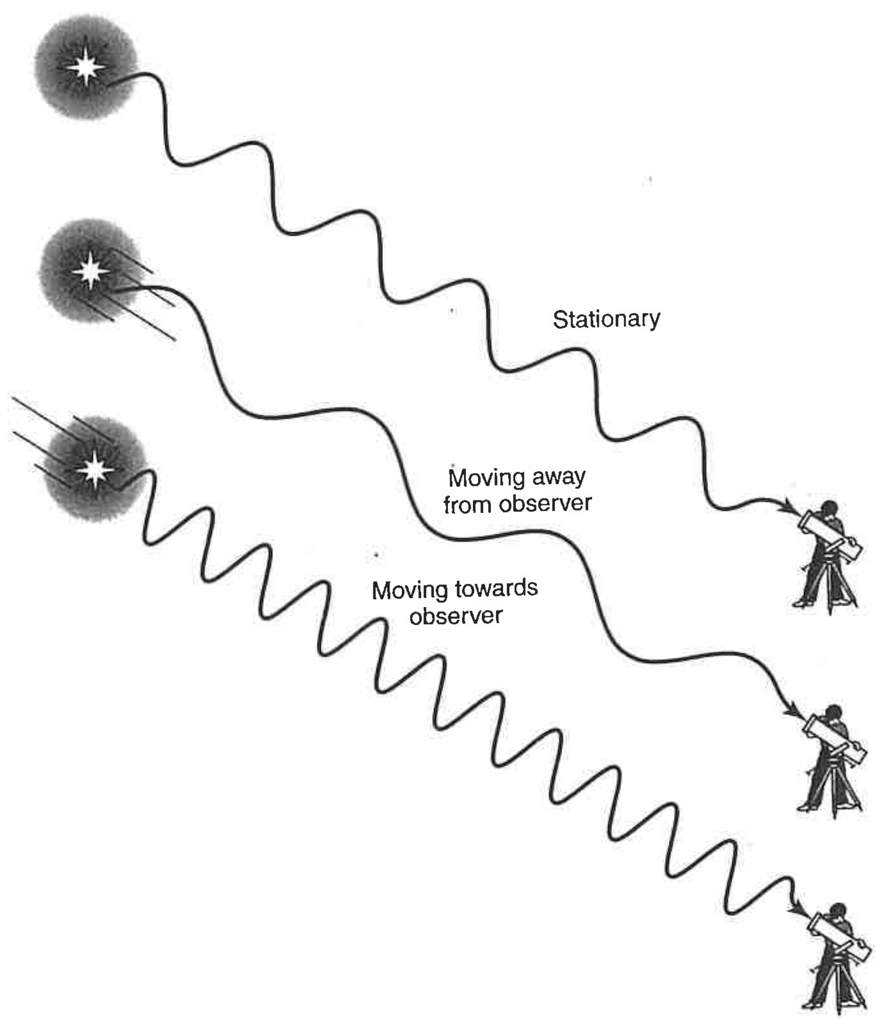


FIGURE 12–1 Doppler Shift

object's spectrum. Lines in the spectrum reveal the different types of elements that are present in the object, which occupy a specific location within the spectrum. Astronomers then compare the spectral lines of a star or galaxy with a laboratory standard. This often reveals a shift in the location of the spectral lines caused by Doppler shift. The specific change in location, or shift in the spectral lines, can then be used to determine the relative motion of the object, its velocity, and how far away the object is.

## Materials

ruler
colored pencils

## Procedure A

1. Use a red colored pencil to draw a line on each galaxy spectrum shown in Figure 12–2, which represents the location of the hydrogen spectral line as listed in Table 12–1. For example, the Virgo A galaxy's hydrogen spectral line should be drawn at the 658.8 nanometer position.

2. Now that you have drawn in all of the galaxies spectral lines for hydrogen as observed through spectral analysis, add the location of the laboratory hydrogen spectral line to act

**TABLE 12–1**

| Galaxy | Hydrogen Spectral Line Location (nm) | Wavelength Shift | Velocity Calculation | Velocity km/s | Distance Calculation | Distance from Earth (MLy) |
|---|---|---|---|---|---|---|
| Virgo A | 658.8 | | | | | |
| M65 Spiral Galaxy in Leo | 657.8 | | | | | |
| The Coma Pinwheel Galaxy | 661.3 | | | | | |
| Cetus A | 658.5 | | | | | |
| M58 Spiral Galaxy in Virgo | 659.3 | | | | | |
| M109 Spiral Galaxy in Ursa Major | 658.3 | | | | | |
| Andromeda | 655.3 | | | | — | 2.9 |

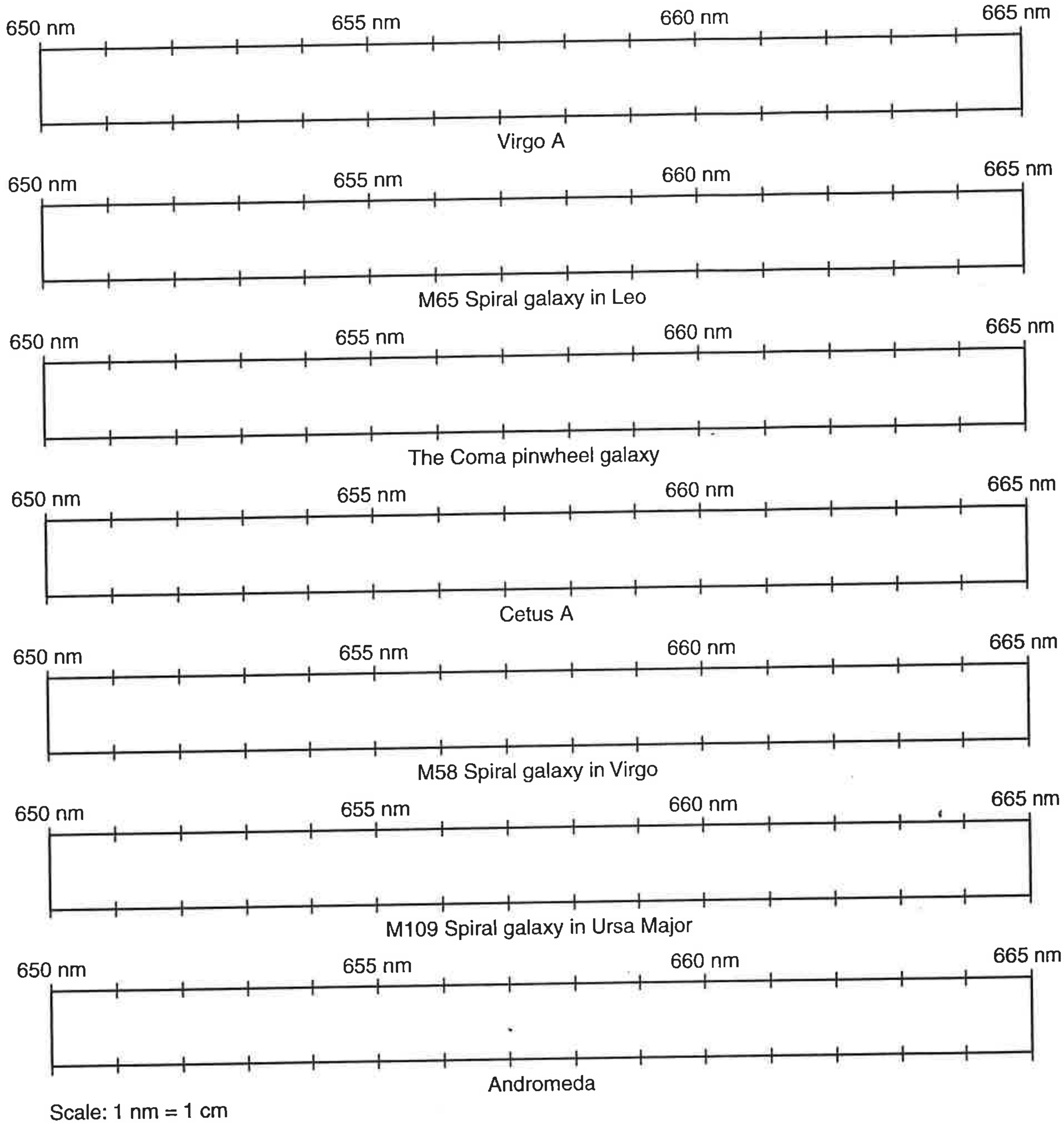


**FIGURE 12–2 Absorption Spectrums of Various Galaxies (650–665 nm range)**

as a reference point. The spectral line for laboratory hydrogen represents how the spectrum should appear for an object that is not in motion; therefore, any change in the location of the hydrogen line observed in a galaxy or star spectrum represents a Doppler shift. The laboratory standard spectral line for hydrogen is 656 nanometers. Using a green colored pencil, draw in the laboratory hydrogen spectral line in the correct location on each galaxy's spectrum in Figure 12–2.

3. Next, the specific wavelength difference between the laboratory hydrogen and galaxy's hydrogen spectral lines can be used to determine a galaxy's radial velocity. The radial velocity is the speed at which the galaxy is moving either directly toward or away from an observer. Using a metric ruler, determine the difference in wavelength to the nearest tenth, between the laboratory hydrogen and each galaxy's hydrogen spectral line using the equivalent of 1 centimeter = 1 nanometer. If the wavelength of the galaxy's hydrogen is greater than the laboratory hydrogen, record the wavelength difference as a positive number to the nearest tenth of a nanometer in red pencil in the Wavelength Shift column of Table 12–1. If the wavelength of the galaxy's hydrogen is less than the laboratory hydrogen line, record the wavelength difference as a negative number in blue pencil in Table 12–1.

4. The shift in wavelength between the laboratory hydrogen and galaxy's hydrogen spectral lines can now be used to calculate the radial velocity of each galaxy using the following formula:

$$\frac{\text{radial velocity (km/s)}}{\text{300,000 km/sec}} = \frac{\text{wavelength shift}}{\text{656 nm}}$$

Enter the wavelength shift value into the formula, and then solve for the radial velocity for each galaxy. Show your calculations and record your answers in Table 12–1.

5. Now that you have determined the velocity for each galaxy, use it to calculate the relative distance from the Earth using Hubble's law. Hubble's law, also known as The Law of Red Shifts, was developed by astronomers Edwin Hubble and Milton Humason in 1931. It states that the distances to galaxies are proportional to their velocities. Use the following Hubble's law formula and the galactic velocities you determined from step 4 to determine the relative distance of each galaxy from the Earth. The *25 km/s/million light years* value in the formula represents the Hubble constant.

$$\text{Distance (millions of light years)} = \frac{\text{radial velocity (km/s)}}{\text{25 km/s/million light years}}$$

Record the distance for each galaxy to the nearest tenth in the Distance from Earth column in Table 12–1. The distance for the Andromeda galaxy has already been calculated because Hubble's law applies only to receding galaxies.

## Procedure B

1. Use your data from Table 12–1 on the velocity and distance for the seven galaxies you analyzed in Procedure A to create a line of best fit graph. The *x*-axis should be labeled "Distance (millions of light years)," and the *y*-axis should be labeled "Velocity (kilometers/second)."

## Conclusions

1. Describe how an increase or a decrease in the wavelength of spectral lines from a galaxy or star can be used to infer its motion.

2. When the wavelength of a spectral line emitted from an object increases, which end of the visible light spectrum does it move toward, and what is the object's motion relative to Earth?

3. When the wavelength of a spectral line emitted from an object decreases, which end of the visible light spectrum does it move toward, and what is the object's motion relative to Earth?

4. What did the results of your analysis of the spectral lines of the seven galaxies reveal about their motion relative to Earth?

5. Describe two ways that the Andromeda galaxy differs from the other six galaxies you examined.

6. Do the results of your study of galactic motion suggest that the universe is currently in motion, and if so, is it expanding or contracting, and why?

7. Explain how the results of your study of galactic motion either support or refute the big bang theory.

8. What is the relationship between the distance of a galaxy from the Earth and its velocity?