**Name**__________________________ **Section**_______________

**Partner(s)**_______________________ **Date**_______________

# DECIPHERING STELLAR MOTION

In this activity you will explore how an astronomer can determine the motion of a star based on the light received from it and then predict its future position. You will be using sound waves to simulate visible radiation.

How can you tell that an object is moving toward or away from you?

Suppose you were not able to see the object but could hear it. How would you know if it was approaching you or moving away from you?

Try a quick experiment. Have one person (astronomer) stand in a hallway with his or her eyes closed. Have a second person walk toward or away from the "astronomer" while conversing at a normal volume. Repeat the motion in the opposite direction. Have the astronomer record his or her observations here.

What data was the "astronomer" collecting in this experiment? What was the tool used to collect the data?

As a person gets closer to the "astronomer" the volume, or amplitude, of the sound increases and as she walks away the volume (amplitude) decreases. We equate the change in amplitude with a change in distance. If a sound-emitting object is moving toward you rapidly, the sound waves also become compressed. As a result their frequency increases and the resulting sound increases in pitch. The opposite occurs as the sound-emitting object moves away. We can measure the change in pitch to determine if an object is approaching or receding.

In astronomy, to determine the distance to a star we generally use visible radiation rather than sound waves, but the idea is the same. For a star moving toward you the light waves are "compressed", the wavelength decreases, and the frequency increases. The light appears to shift from its normal wavelength toward the blue end of the visible spectrum. We say it is "blue-shifted". As an object moves away, the wavelength increases and we say the incoming light is "red-shifted". The amount of shift is related to the velocity of the star.

To explore how an astronomer might determine stellar motion we will use a motion detector or sensor that sends out and receives sonic signals. Although this is not the procedure an astronomer would employ, the principle is the same. When you activate the sensor it sends a sound wave that is reflected off nearby objects. Based on the time delay from emission to receipt of the signal, the sensor and/or a program in the calculator can compute the distance to an object and the velocity if the object is moving toward or away from the detector.

**Procedure** (This assumes the RANGER program is already loaded in the TI-83.)

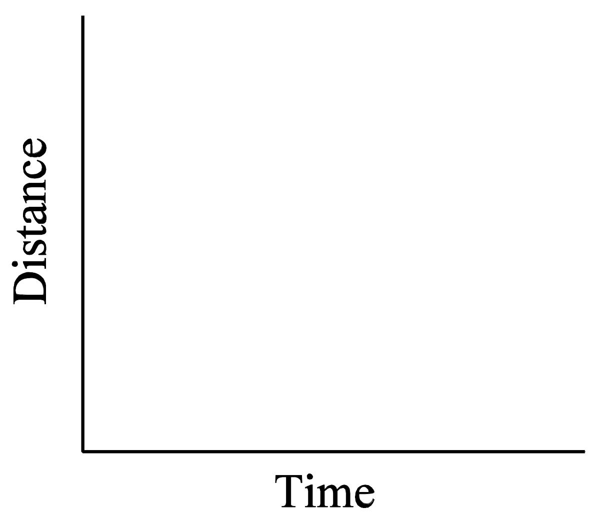
1. Locate a relatively flat wall that you can walk toward and position yourself about 3 meters from the wall.

2. Connect the CBR to the calculator with the link cable to the TI-83. Start the RANGER program by pressing **[PRGM]** and selecting RANGER, then press **[ENTER]**. Choose SETUP/SAMPLE. Make sure the settings are as shown here:

| | |
|---|---|
| REALTIME: | YES |
| TIME(S) | 15 |
| DISPLAY | DIST |
| BEGIN ON: | [ENTER] |
| SMOOTHING: | LIGHT |
| UNITS: | METERS |

3. Select START NOW. Walk slowly toward the wall at a constant speed holding the motion detector as steady as possible. Right after you begin walking hit **[ENTER]** on the calculator. When you finish collecting data the graph will be displayed. If you don't like the resulting plot hit **[ENTER]** and REPEAT SAMPLE and do the procedure again.

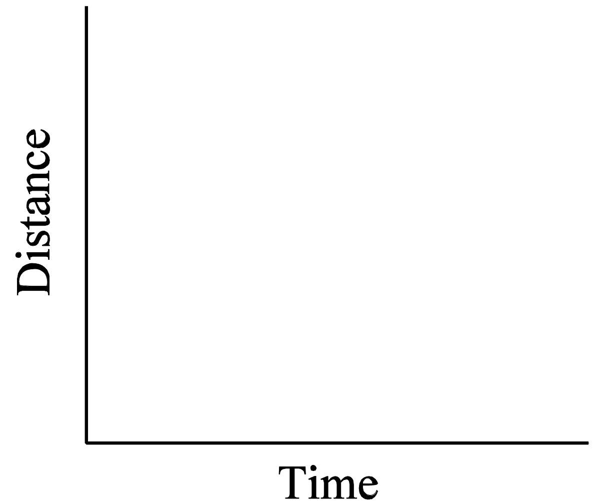
   What does the resulting graph of distance versus time look like? Sketch the graph below. Explain.



4. Hit **[ENTER]** and select REPEAT SAMPLE. Repeat the procedure starting about 1 meter from the wall and walking slowly backwards at a constant speed.

Sketch the resulting graph here.

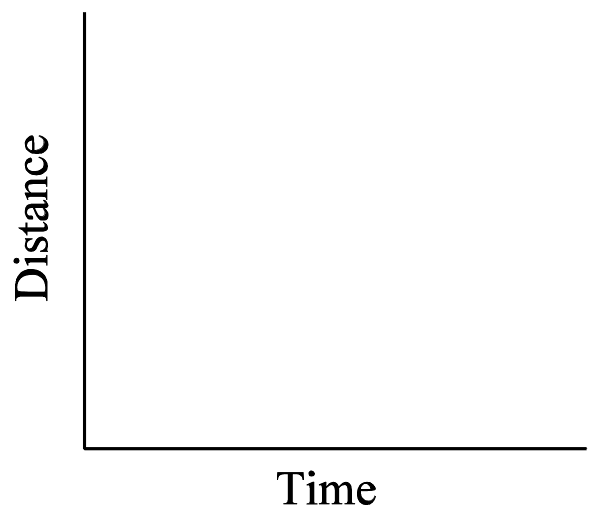
Does the resulting graph of distance versus time look the same? Explain




From a graph of distance versus time, how would an astronomer be able to tell if a star was moving toward or away from the Earth?

Suppose a star was in orbit around another object (such as another star) and an astronomer was measuring the distance of that star from the Earth. Sketch what the resulting data might look like when graphed.

Explain why you sketched the graph the way you did.




Let’s try out your prediction.

5. Find an area where you have a flat wall and can walk in a circle with a diameter of about 1.5 meters always staying at least 1 meter away from the wall. Using the string and masking tape, mark various points on the circumference of the circle.

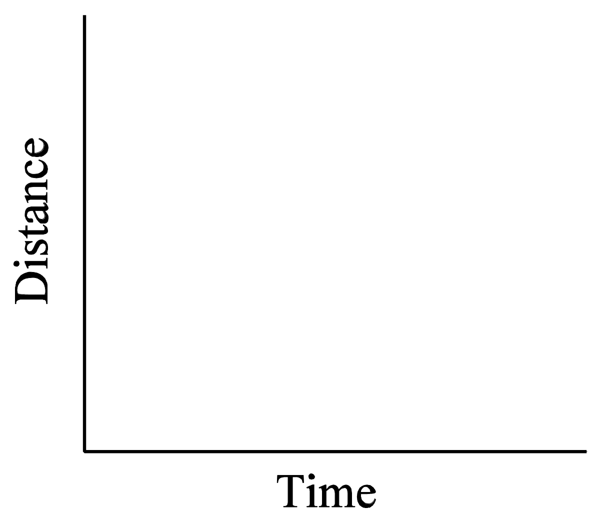
6. In the RANGER MAIN MENU select SETUP/SAMPLE. Change settings as necessary until you have the set below.

| | |
|---|---|
| REALTIME: | YES |
| TIME (S): | 15 |
| DISPLAY: | DIST |
| BEGIN ON: | [ENTER] |
| SMOOTHING: | LIGHT |
| UNITS: | METERS |

7. Select START NOW. Point the motion sensor at the wall and begin to walk around the circle. Always keep the motion sensor pointed steadily at the wall. After you are in motion press **[ENTER]** on the calculator. Continue walking until the motion sensor stops flashing. You should make it around the circle at least three times while the data is being collected.

8. The calculator will display the graph of distance versus time. If you want to repeat the data collection hit **[ENTER]** and REPEAT SAMPLE.

   Sketch the graph here.




Press [ENTER] and select SHOW PLOT. You will need this plot to address some of the following questions.

**Analysis**

Consider the last graph you generated.

1. What is the physical meaning of X?

   What is the physical meaning of Y?

2. Is the graph what you predicted? Why or why not?

3. The amplitude of the wave pattern you produced is $(Y_{max} - Y_{min})/2$. Use the **[TRACE]** function to find $Y_{min}$ and $Y_{max}$. You can move on the curve from point to point by using the cursor keys: **[<]** and **[=]**. Calculate the amplitude of the wave for three of the wave cycles and the average amplitude.

   Cycle 1 A = ________________
   Cycle 2 A = ________________ Average A = __________________
   Cycle 3 A = ________________

   Thinking about what you did to get this data, what does the amplitude represent?

   Why might the amplitude values vary?

4. The period of the motion we collected data for is the time it takes for one complete cycle. The easiest way to determine this is to measure the time between two consecutive maxima or two consecutive minima. Use the **[TRACE]** feature on your calculator to find the appropriate points. Determine the period for three cycles and calculate the average period.

   Cycle 1 P = __________________
   Cycle 2 P = __________________ Average P = __________________
   Cycle 3 P = __________________

   Are the periods for all three cycles the same?

   What might cause the variation in the periods?

5. It would be valuable to see if there is an equation that models the orbiting star system that we simulated. If we can uncover an equation, we can use it to predict the position of our orbiting star at any given time.

From your experience, do you recognize the type of function that would generate this pattern of data? Explain.

When you are done with the data hit **[ENTER]** and select QUIT.

**Discussion**

Press **[2nd][STAT PLOT]** select Plotsoff and press **[ENTER]** twice. Use the function editor, **[Y=]** to enter $Y_1$ = sin (x), get the x by using the **[X,T,È,n]** key. Press **[ZOOM] [0]** to see the function plot.

The sine function should look like the data for circular or orbital motion. In this case the amplitude of the sine wave was equal to the radius of the circle and the period is the time to make one complete revolution. If you move faster what happens to the period? Try it!