SNC1D The Study of the Universe

Student Activity: Using Parallax: How Far is that Star?

Topics	**Timing**
distance/astronomical units	preparation: 5 min
light year	activity: 25 min
parsec	
parallax	

Specific Expectations

SNC1D

A1.8 analyse and interpret qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis, identifying possible sources of error, bias, or uncertainty;

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions;

D2.3 plan and conduct a simulation that illustrates the interrelationships between various properties of celestial objects visible in the night sky (e.g., set up flashlights of various intensities at different distances from an observation point to help illustrate why the brightness of a star viewed from Earth is a function of both its actual brightness and its distance from Earth) [IP, PR, AI];

D3.3 describe the major components of the solar system and the universe (e.g., planets, stars, galaxies), using appropriate scientific terminology and units (e.g., astronomical units, scientific notation, light years).

Introduction

Since the distances to the stars cannot be measured directly, astronomers use a variety of techniques including triangulation and parallax, comparison of absolute and apparent magnitude, and Cepheid variables. Triangulation is an indirect method of measuring the distance to an object by imagining a triangle between the observer at two positions and the object (see Fig.1). Parallax, as used in this activity, is the apparent motion of a relatively close object when viewed by the observer from two different positions. In this activity, students learn how parallax and triangulation can be used to indirectly measure the distance to stars. Students will also consider the limitations of using parallax to measure the distance to objects that are further away.

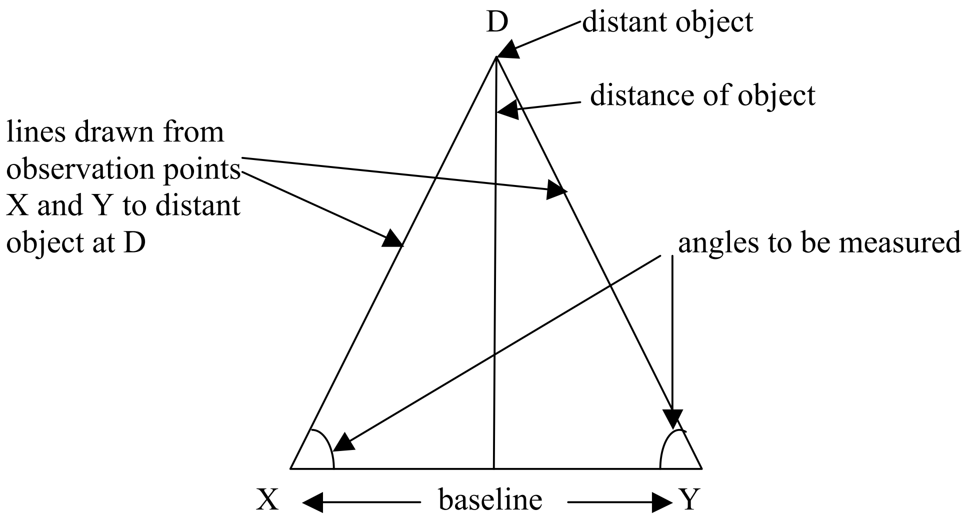

Fig.1 Using triangulation to determine the distance of an object

To determine the distance of an object using triangulation, one needs know the length of the baseline (XY) and the magnitude of the two angles for the lines drawn from the observation points X and Y to the same point on the object at D. A scale diagram will then give the shortest distance of the object at D from the baseline (i.e., the length of a line meeting the baseline at 90°).

Materials

1 piece of blank paper (5.5 cm × 18 cm)
desk/table
meter stick
tape
push pin
marker or pencil

Safety Considerations

None

Procedure

1. Discuss how triangulation and parallax are used to determine the distance to a star.

Part 1

2. Ask all the students to hold one of their thumbs close to their faces with one eye shut. Students should observe that the thumb "covers something" in the background, such as a picture on the wall. Now instruct the students to, without moving their thumb, look with the other eye. They should notice that their thumb now covers something else in the background, at a considerable distance from the first object covered. Wink back and forth. There is an apparent change in the position of the thumb.
3. Now ask students to extend the arm fully and look through the first eye, with the thumb covering the same object as when they started, and then change eyes. Wink back and forth. Students should see that the apparent change in position is significantly less than before.
4. **Predict**

Have the students predict what would happen if they could hyper-extend their arms until the thumb actually touched the first point on the wall.

5. Introduce and explain the term “angular shift”: the apparent motion of a relatively close object when viewed by the observer from two different positions.

Part 2

Organize students into groups of 2 or 3. Briefly describe the apparatus set-up, explaining that the pin represents a star and that they will observe its apparent movement when viewed from two slightly different points.

6. **Predict**
   What happens to the angular shift of a pin (star) as the distance to the pin increases?
7. **Observe**
   Tape the piece of paper on the wall. Place the desk about 2 m from the wall.
8. Tape the meter stick to the desk, perpendicular to the wall and pointing to the middle of the paper. The 100 cm mark should be closest to the wall.
9. Place a push pin in the meter stick at the 50 cm mark.
10. One student stands behind the desk and looks directly along the meter stick. The student’s nose must be in line with the meter stick, with one eye on each side of the meter stick. This student then closes his or her left eye and directs another student to make a mark on the paper where the pin appears (point A in Fig.2).

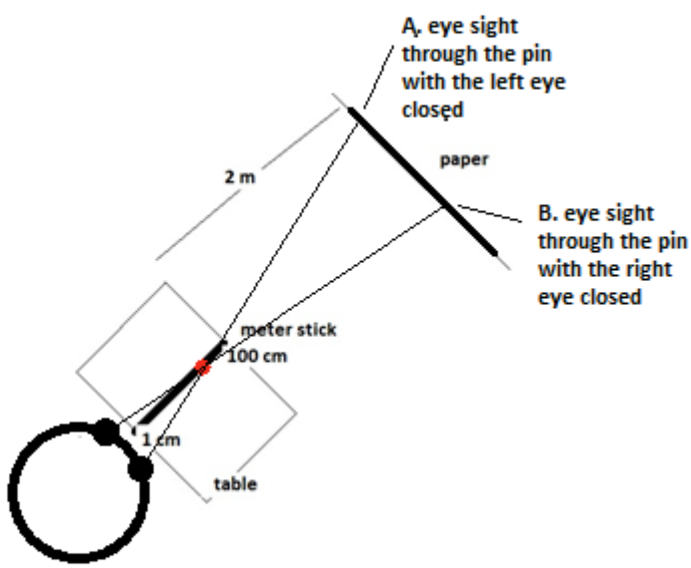

Fig.2 Using parallax to determine the distance of an object

11. Without changing viewing distance or eye height, the first student then closes his or her right eye and directs the other student to make a second mark on the paper where the pin now appears (point B in Fig.2).
12. The students then measure the distance between the two points A and B and record their observations.
13. Students repeat Steps 9 to 12 with the pin at 75 cm and 100 cm on the meter stick. The points on the paper could be labelled A_1, B_1, etc. It is important that the student’s head be in exactly the same position for all the measurements.
14. **Explain**

Ask students to describe and explain their observations, and predict what will happen if the pin (star) were even further away. They should consider how the distance between A and B changes as the distance to the star increases.

Disposal

Dispose of the paper in the recycling bin. Store the rest of the materials for reuse.

What happens?

Part 1

If the thumb was touching the background (e.g., picture on the wall) and was viewed by first one eye and then the other, there would be no apparent change in the position of the thumb. This illustrates that parallax has limitations in determining distances in space, since the apparent change in position is smaller for more distant objects.

Part 2

The angular shift of the pin (shown by the distance between the two points A and B on the paper) decreases as the pin's distance from the viewing point increases. Eventually students should observe that the apparent change in position is too small to measure. Ground-based measurements therefore limit this technique to stars within a distance of 160 ly.

How does it work?

The angular shift of the pin occurs because you are viewing it from two different angles: from your left eye and from your right eye. As the distance to the pin increases the triangle is stretched (the height of the triangle increases) and the apparent shift in position of the pin (and the parallax angle, p) decreases.

Next Steps

- Students could research other techniques (and their limitations) that astronomers use to determine distances to the stars.
- **Enrichment**: Students may research and use the formula $d = \frac{1}{p}$ (where d is distance to a nearby star in parsecs and p is the parallax angle in arcsec).
- **Extension**: Research the parallax angles for various stars and have students calculate their distances. Then to further reinforce the math skills, have them convert their answers into ly, AU, or km, and express as scientific notation.

Additional Resources

1. ESA – using parallax to determine the distance to a star: http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=35616&fbodylongid=1661
2. Australia Telescope Outreach and Education – definitions of terms related to triangulation and parallax: http://outreach.atnf.csiro.au/education/senior/astrophysics/astrometrytop.html