TEACHER RESOURCE

SCIENCE CONTENT/ CURRICULUM LINK

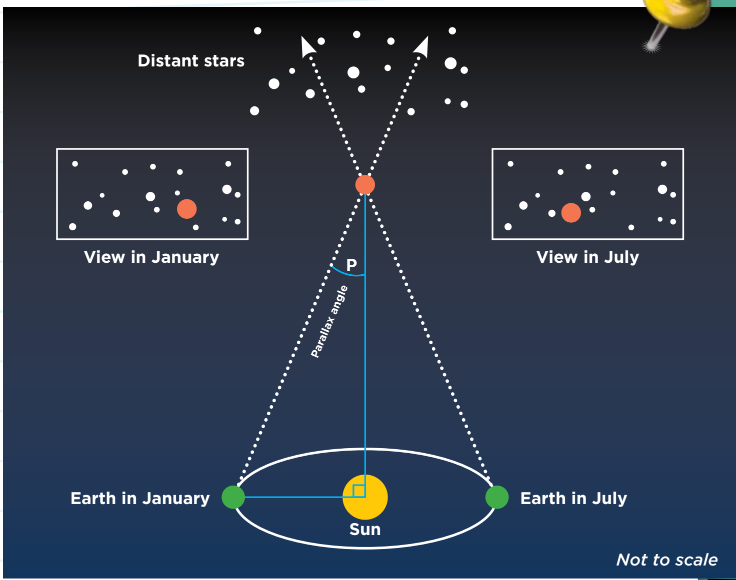
NATURE OF SCIENCE – UNDERSTANDING, INVESTIGATING, COMMUNICATING, PARTICIPATING & CONTRIBUTING

STARDOME OBSERVATORY & PLANETARIUM

FACTS, RESOURCES AND ACTIVITIES ON...

HOW FAR IS THAT STAR?

Measuring the Cosmos – PART ONE



Even the nearest stars are unimaginably remote. How can we hope to measure such distances when it is impossible to run tape measures out that far? In fact, it turns out that space is SO big, that no single method suffices. This resource investigates **parallax**, the first of three 'rungs' of the Cosmic Distance Ladder. Parallax is used to calculate distances to the nearer stars. Rungs two and three, covered in future resources, are used to determine much greater distances.

An object's distance is inversely proportional to its parallax angle.

The first celestial body to have its distance calculated by parallax was the Moon.

The parallax method depends on the fact that nearer objects appear to 'shift' when viewed from different angles. Imagine a line between two viewing positions, then a line from each point out to a target object, and you have a triangle. Triangles are awesome because if the length of one side (the baseline) and two interior angles (the parallax) are known, the lengths of the other sides can be easily calculated!

The baseline we use for stellar parallax is the distance between Earth and the Sun (1 AU or 'astronomical unit' – about 150 million km).

How do we make use of our AU baseline?

A nearby 'target' star's position is measured at a point in time. Six months later, when Earth is at the opposite side of its orbit (some 300 million km, or 2 AU away), the star's apparent 'shift' is measured. This angle will be tiny - only fractions of an **arcsecond**. One degree (small in itself) = 60 arcminutes = 3,600 arcseconds!

This angle is halved to create a very skinny right triangle (see figure). The angle in arcseconds can then be converted to a standard unit of distance called a 'parsec'.

One parsec (approx. 3.26 light-years) is defined as the distance to an astronomical object that has a parallax angle of 1 arcsecond. For example, the closest star to the Sun, Proxima Centauri, has a parallax of 0.769 arcseconds. A star's distance is inversely proportional to its parallax and conveniently we can use 'the small angle approximation' so: 1/0.769 = 1.3 parsecs (4.24 light-years).

We will quickly appreciate that stars with smaller parallaxes are further away.

While Earthbound observations are useful, space telescopes have greatly increased precision. ESA's Hipparcos, 1989-1993, was sensitive to the milliarcsecond and measured ~100,000 stars out to several hundred parsecs. NASA's Hubble Space Telescope followed, enabling distance calculations beyond 1,000 parsecs. ESA's Gaia satellite, with a mission to study more than 1 billion stars (1% of our galaxy), is pushing the limit to 10,000 parsecs.

Check out these other resources...

- en.wikipedia.org/wiki/Stellar_parallax
- lco.global/spacebook/parallax-and-distance-measurement/
- astronomy.swin.edu.au/cosmos/T/Trigonometric+Parallax

DISCUSSION POINTS

What are megaparsecs and what kinds of objects would we use these units of distance for?

How far away are the most distant stars visible without telescopes. How does this compare with the size of our Milky Way galaxy?

Define and discuss the difference(s) between parsecs and light-years

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ACTIVITY

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FOR YOUNGER STUDENTS

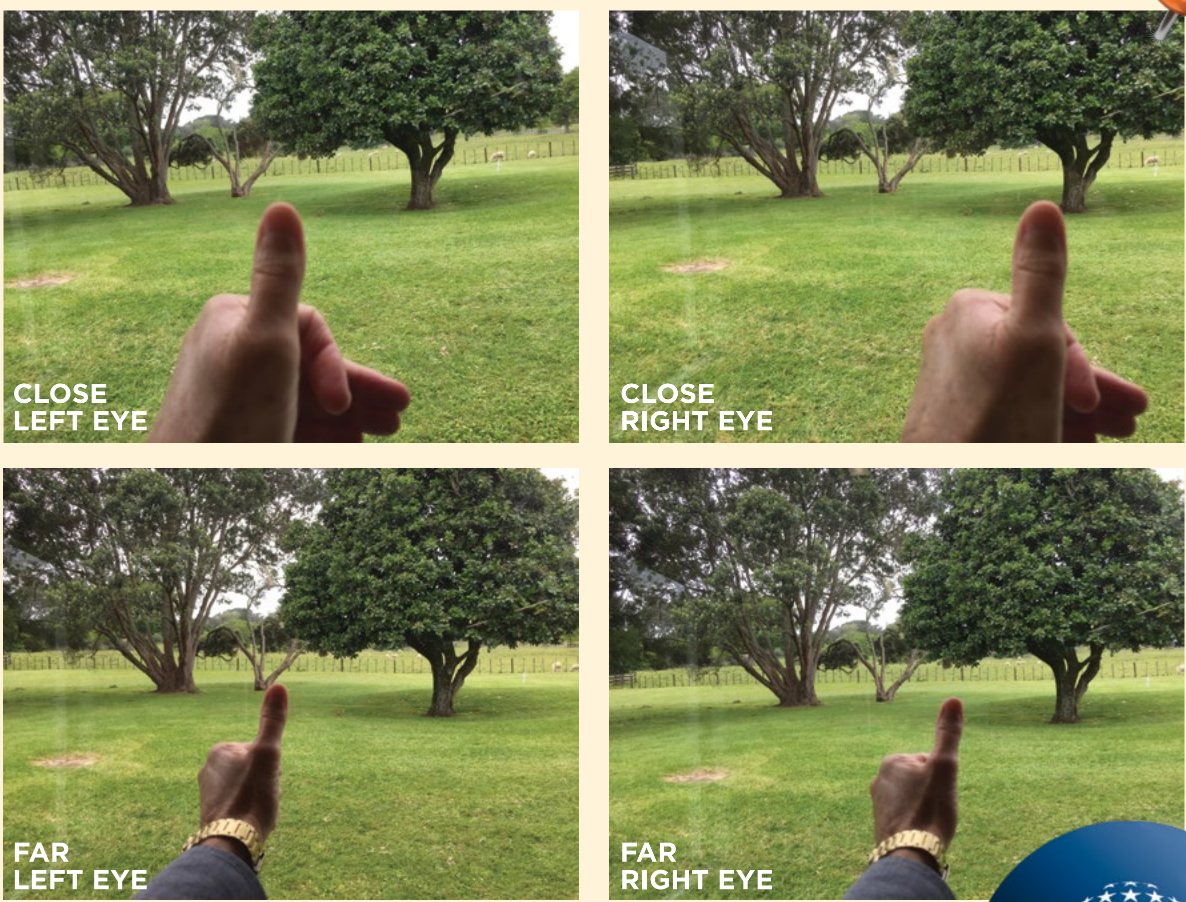
THUMBS

Everyone experiences parallax every day!
Here's an easy way to get students thinking about it.

- Stretch out your arm and extend your thumb upwards.
- Keeping your arm still, close your left eye and note where your thumb is in relation to fixed objects in the distance.
- Now close your right eye and open your left. You will notice that your thumb appears to have moved. Try this several times.
- Repeat the exercise with your thumb closer to your face. You should notice that your thumb now 'shifts' much further as you switch eyes.

Thus, the amount of shift (parallax), is related to the distance to the object. The closer the object is the greater the parallax.

From a human perspective, this is one of the reasons why having two eyes helps us to judge how far away objects are.



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ACTIVITY

FOR OLDER STUDENTS

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HOW FAR IS THAT OBJECT?

Students will calculate distances to two objects using parallax, before checking with a tape measure. Below is intended for indoors in a reasonably sized classroom but you can upscale it for outdoors.

YOU'LL NEED:

- Parallax Angle Measurer cut out (on A4 light card)
- Target object (needs to have a precise middle point – we suggest a creased paper or a toothpick standing upright)
- 2x Distance Measuring worksheet (1 per target object)
- Push pin
- Polystyrene sheets (1cm thick) OR enough corflute, or similar, glued together to provide for 1cm thickness
- 30+cm ruler
- Low residue sticky tape
- Tape measure

YOU'LL NEED TO MAKE:

- Cut along dashed lines, fold along dotted lines
- Cut polystyrene sheet to approximately fit the device ensuring at least one straight edge
- Attach the two components using the push pin, where indicated, and into the polystyrene sheet. Ensure the device is precisely aligned with the straight edge of the polystyrene. The pointer should be able to sweep across the angle scale

YOU'LL NEED TO CALCULATE:

It is essential that the alignments of equipment and eyeball sightings are performed as precisely as possible.

- Attach a length of sticky tape (about 60cm long) near the edge of a stable desk
- Mark two viewing points on the tape 30cm apart leaving at least 15cm of tape on the outsides of the points
- Set up a target object approximately at right angles to the tape between 1 and 5 metres away on the other end of the table or another same height table
- Place the angle measurer on the tape, aligning the push pin centre with one of the marked viewing points on the tape. Make sure the device is exactly aligned with the tape and held firmly in place
- Sight along the pointer piece of the device swivelling it so that the eye arrow (at the near end) and the target arrow (at the far end) line up exactly with the centre of the target. Ensure that the device does not shift while doing this
- Record 'target angle 1' in step one of the distance measuring sheet
- Repeat the process from the other viewing mark on the tape and record 'target angle 2' in step one
- Work out the parallax angle (the difference between target angles 1 & 2) and record
- In step two, read off the 'distance in baselines' corresponding to the calculated parallax angle. Record this in the appropriate box of step three
- If you're using the 30cm baseline (tape), then 0.3 goes in the second box in step three. Multiply number of baselines by baseline length to get 'distance to object'. Record
- Run out a tape measure and check the calculation
- Repeat the entire process for a second target at a distance slightly further. Parallax works for multiple distances!

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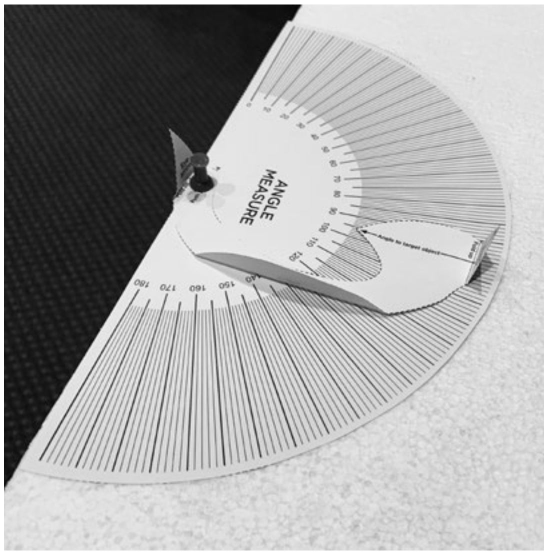
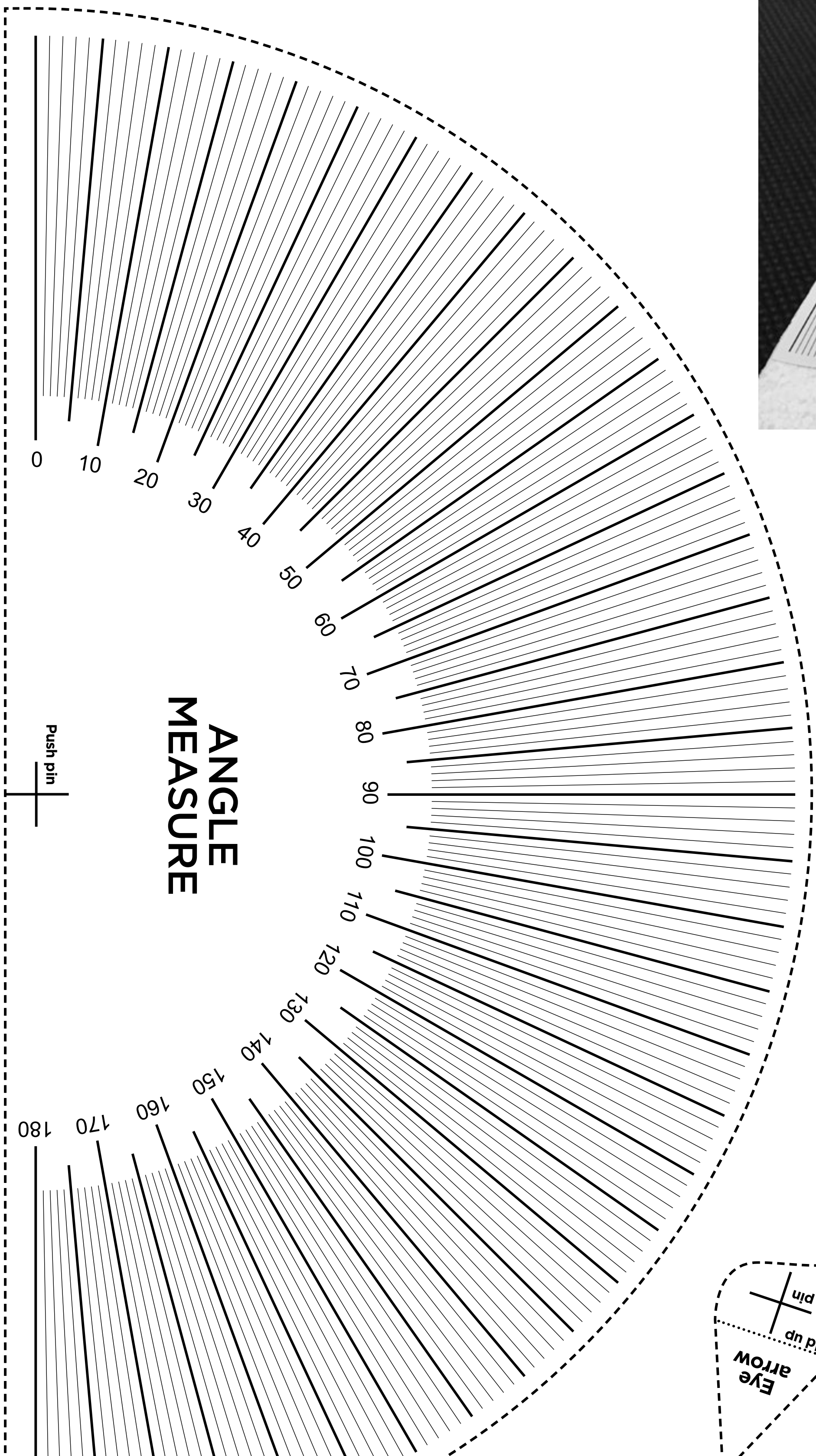
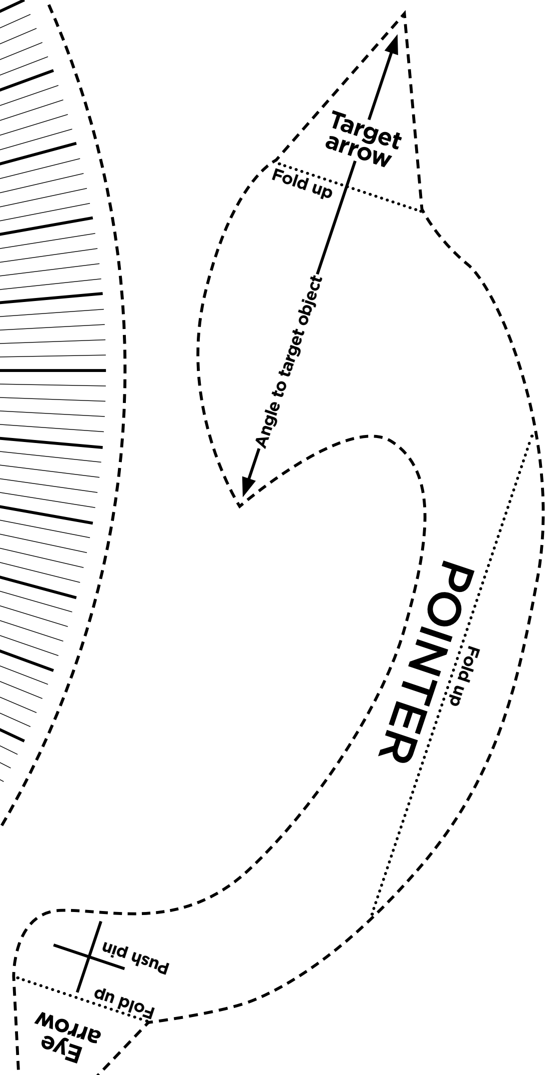
TEMPLATE

HOW FAR IS THAT OBJECT?







- Cut along the dashed lines
- Fold along the dotted lines

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TEMPLATE

HOW FAR IS THAT OBJECT?

DISTANCE MEASURING

STEP ONE

Target angle 1		
Target angle 2	–	
Parallax angle	=	

STEP TWO

Parallax angle	Distance in baselines
1°	57.3
2°	28.6
3°	19.1
4°	14.3
5°	11.4
6°	9.5
7°	8.1
8°	7.1
9°	6.3
10°	5.7
11°	5.1
12°	4.7

Accuracy decreases with larger angles

STEP THREE

Distance in baselines		
Length of baseline (metres)	x	0.3
Distance to object (metres)	=	

NOTE: If a calculated distance deviates significantly more than 10% from actual, calculations should be checked and the sighting repeated. Students should get to about 10% accuracy with care. If not, an average of several calculations should average out the errors.

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