TEACHER RESOURCE

SCIENCE CONTENT/ CURRICULUM LINK
NATURE OF SCIENCE – UNDERSTANDING, INVESTIGATING, COMMUNICATING, INVESTIGATING & CONTRIBUTING

STARDOME OBSERVATORY & PLANETARIUM

FACTS, RESOURCES AND ACTIVITIES ON...

HOW FAR IS THAT STAR?

Measuring the Cosmos – PART TWO

In our resource How far is that Star – PART ONE we learned how distances to nearer stars are measured using the parallax method. That technique constitutes the first of three 'rungs' of the Cosmic Distance Ladder. 'Standard Candles', a second rung method, builds on the first. It enables astronomers to measure distances to objects much more remote, even to distant galaxies.

Inverse-square law of light

We know that a light source looks dimmer the further away it is. This relationship between distance and apparent brightness is described by the 'inverse-square law of light'. Since light spreads out in all directions from its source, its intensity as seen by an observer varies inversely in proportion to the square of the distance from the light source.

Nice – but how can we know a star's intrinsic luminosity if we don't know its distance?

Standard Candles and very faint starlight

Fortunately, there are certain types of stars, like Cepheid variables, whose intrinsic luminosities can be known. We call such stars 'standard candles'.

In 1912 Henrietta Leavitt discovered that Cepheid pulsation periods are closely related to their luminosities and that by timing their periods we can know their intrinsic luminosities!

Now the light from these distant stars can be incredibly faint (e.g.: 1000's of times dimmer than the unaided eye can see), but by using powerful telescopes and 'CCD photometry', astronomers can literally count the photons of light being received!

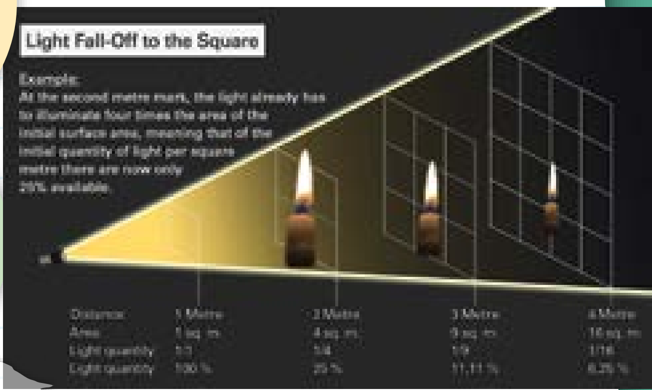
The space between stars is not completely empty, and since the already weak starlight is affected by inter-stellar dust and gas, astronomers must take this into account.

Type 1-a Supernova explosions, observable to enormous distances, are also 'standard candles'.

Cepheid & RR Lyrae Stars are useful for 'nearby' galactic distances ~29 million parsecs or nearly 100 million light-years.

Recent findings suggest that Cepheids might not be exactly standard. They may lose mass as they age which might affect measurements.

Andromeda Galaxy – our neighbour in space. Credit: NASA/Robert Gendler.



Inverse-square law of light.

Cosmic Distance Ladder 'rung two builds on rung one'

The distances to nearer cepheids have been accurately determined using parallax. Knowing their distances and intrinsic luminosities, we're able to calculate distances to more distant 'same period' cepheids and the clusters and galaxies containing them!

In 1923 Edwin Hubble found Cepheids in what was then known as the Andromeda nebula (see image). The distance he calculated was short of its modern value, but it was clear that it was outside the borders of the Milky Way. This led to the understanding that our galaxy is just one of many in a vast cosmic ocean.

Check out these other resources...

- en.wikipedia.org/wiki/Cosmic_distance_ladder
- britannica.com/science/astronomy
- openculture.com/2012/05/measuring_the_universe_how_astronomers_learned_to_measure_celestial_distances_explained_with_animation.html

DISCUSSION POINTS

Discuss the size of galaxies, their distances, and the types of objects we're now able to measure distances to.

Today's distance estimate to the Andromeda Galaxy is 2.48 million light-years. Hubble's calculation was 900,000 l-y. Why might this be?

How would inter-stellar dust and gas affect 'standard candle' distance calculations?

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ACTIVITY

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HOW FAR IS THAT LIGHT?

Students will observe the inverse-square law of light at work, graph their results, and calculate the distance of a randomly placed object using this principle.

WHAT YOU WILL NEED

- Phone or other small, bright light source
- Ruler
- A4 Graph paper: 2 sheets. One with 1cm squares, the other with 0.5cm squares (2 lines/cm)
- Construction paper with 1-cm squares
- Craft knife and scissors/guillotine
- 2 medium-size bull-dog clips (straight sides)
- Cardboard box in good square condition
- Tape or blu-tak

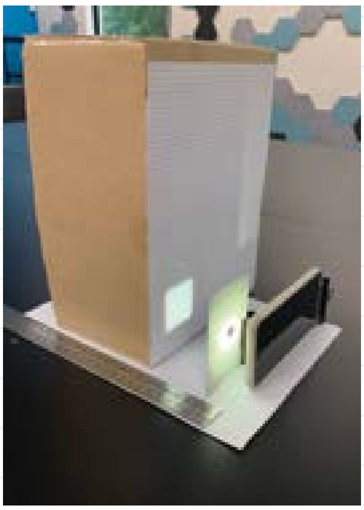
ASSEMBLY (AS PER IMAGES)

1. Cut a 1cm square near the centre of the construction graph paper ('the card').
2. Cut down 'the card' so the hole will be at the same elevation from the table as your phone light once the activity is set up. Slice enough from the other sides of 'the card' so it won't flop around when stood up.
3. Mount the 2 lines/cm paper to the side of the box.
4. Fix the other A4 graph paper to a flat table surface and stick the ruler to the close edge.
5. Attach bull-dog clips to the edges of: a) 'the card' and b) your phone, so they stand.
6. Place the phone atop the right-hand end of the ruler and graph paper on the table.
7. Place 'the card' 2cm to the left of the phone. Ensure both are upright and that the phone light and 1cm hole are aligned and 2cm apart.
8. Position the graph paper box 2cm to the left of 'the card' (4cm from the phone light). If correct, you should count 16 squares illuminated on the box. Keep the distance between the phone light and 'the card' constant at 2cm throughout the experiment.

EXPERIMENT

1. Put the 'graph box' at different distances from the 'the card' and phone. Count the lit squares on the box at each distance, recording the 'number of squares lit' versus 'distance' on the DATA TABLE.
2. Complete the DATA TABLE by calculating and recording the 'area lit' and 'relative brightness'.
3. Plot the 'relative brightness' values on the GRAPH. Join the dots and draw a curve through the plots.
4. Remove the ruler and place the 'box' at a random distance somewhere within the range of all your measurements. MARK its position on the graph paper on the table.
5. Count the number of squares lit, then calculate and record your data all the way across the bottom row of the DATA TABLE.
6. Plot it on the curve of your GRAPH, drop to the x-axis to find out its distance. Also calculate the distance using the simple formula: distance = (sq.rt. of area lit) x2. We are multiplying by two since in our experiment $1cm^2$ area is lit at a distance of 2cm.
7. Physically measure the actual distance the box was from the light. Compare.

Set up



Mid experiment

WRAP UP

Discuss their graphs and calculations as a class. This could take a mathematical slant and/or further investigation into its astronomical application.

TAKE A PHOTO OF YOUR ACTIVITY AND SEND IT TO US. WE'D LOVE TO SEE IT! EDUCATION@STARDOME.ORG.NZ

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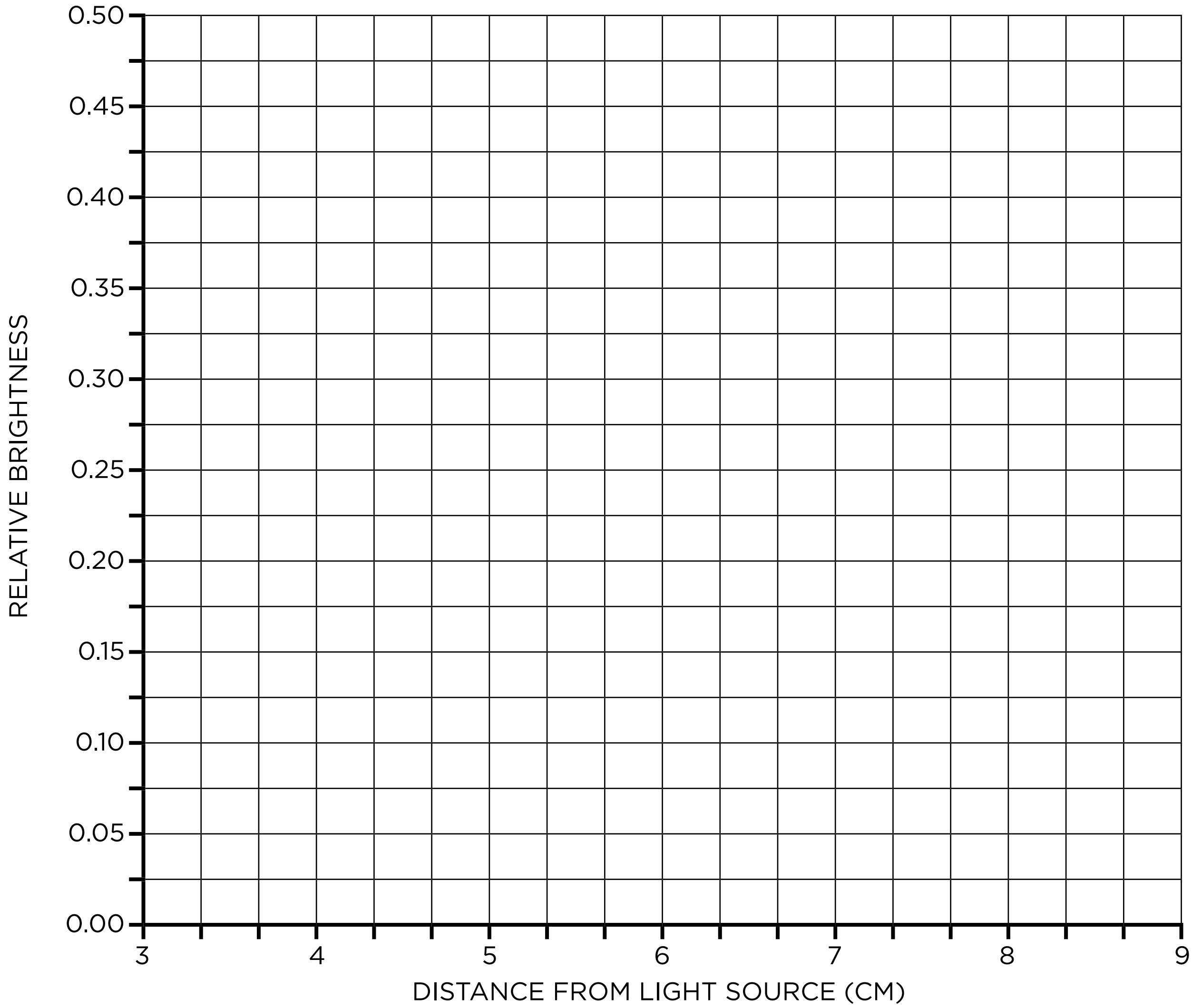
TEMPLATE

HOW FAR IS THAT LIGHT?

DATA TABLE

Distance from light source (cm)	Number of squares lit	Area lit $\left(\frac{\text{No. of squares}}{4}\right)$	Relative brightness $\left(\frac{1}{\text{Area lit}}\right)$
2	4	1	1.00
3	9	2.25	0.44
4			
5			
6			
7			
8			
9			
?			



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