teachers guide

Measuring the Universe 3: Distances in the Universe

Components

	NAME	DESCRIPTION	AUDIENCE
	Distances in the Universe teachers guide	The guide provides information on how to use the presentation and worksheet in this resource.	teachers
	Measuring distance presentation	The interactive presentation explains two processes astronomers use to measure distance.	students
	Measuring distance worksheet	The student worksheet accompanies the presentation, *Measuring distance*.	students

Purpose

Students understand that astronomers use different methods and techniques to measure distance across the Universe.

Outcomes

Students:

- describe how astronomers use parallax to directly measure distances to nearby stars in the Milky Way galaxy;
- describe Cepheid variables and supernovae as examples of standard candles, and explain how these are used to measure distances to other galaxies; and
- describe how these methods are used to develop 'rungs' on the cosmic distance ladder.

Activity summary

ACTIVITY	POSSIBLE STRATEGY
Students view the presentation, *Measuring distance*, and complete the associated worksheet.	teacher-led whole class activity, or in pairs or individually
Discussion either about the worksheet questions or in summary of the concepts dealt with in the presentation.	teacher-led, whole group

Technical requirements

The presentation is provided in two formats: Microsoft PowerPoint and Adobe PDF.

The guide and worksheet require Adobe Reader which is a free download from www.adobe.com. The worksheet is also provided in Microsoft Word format.

Using the presentation, *Measuring distance*

This presentation provides an interactive explanation of some techniques used by astronomers to measure distances to remote astronomical objects, including planets, stars and galaxies.
The presentation includes interactive slides that aim to develop concepts of parallax, apparent and absolute brightness, and their relationship in explaining what is meant by a 'standard candle' and the 'cosmic distance ladder'.

Part I

The presentation starts with an opportunity for students to expose pre-conceived notions about astronomical distances.

Suitable discussion questions are provided in the presentation and an accompanying worksheet. Questions on the presentation that have a matched activity in the worksheet are coloured yellow.

Students may investigate the phenomenon of parallax through a practical exercise that provides a concrete experience to relate to as the concepts are developed further.

The presentation develops the concept of parallax experienced in this activity, first through a familiar context, then in relation to objects close to the Earth, and then more distant objects. Factors that effect parallax are established and applied to distance measurement. An image of the Milky Way galaxy that shows the limits of stellar parallax as a tool for measuring distance marks the end of part I.

Students view an outstretched thumb against a background object through alternate left and right eyes to experience the phenomenon of parallax.

Optional activity

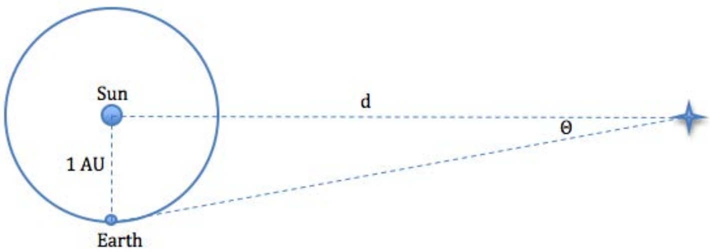
More able students may participate in extended parallax discussions to include the geometric relationship that defines a standard unit of measurement in astronomy – the parsec.

One parsec is the distance to an object that has a parallax angle of 1 arc second (an arc second is 1/60th of an arc minute, or 1/3600th of a degree).

One parsec is approximately equal to 3.26 light-years, or 3.086×10^{13} km.

Parallax angle is measured using a baseline of one astronomical unit (1 AU), which is the mean distance from the Earth to the Sun.

The mathematical relationship is shown in the following diagram:



The baseline of 1 AU is shown as the distance between the Sun and the Earth. For a hypothetical star that is 1 parsec from the Sun (which means that d = 1 parsec), the angle θ is one arcsecond (or 1/3600 of a degree).

The distance to the nearest star to Earth, Proxima Centauri, is 1.29 parsecs. It has a parallax angle of 1/1.29 = 0.78 arcseconds.

So how big is a parsec?

1 AU = 149 597 871 km

θ = 1 arcsecond
= (1/3600) x (π/180) radians
= 4.848×10^{-6} radians

So, using simple trigonometry:

$\tan(\theta)$ = 149 597 871 / d

This can be rearranged to:

d = 149 597 871 / $\tan(\theta)$

For very small angles, $\tan(\theta) \approx \theta$, so

d = 149 597 871 / 4.848×10^{-6} km
= 3.08×10^{13} km
(about 30 trillion km)

Part 2

In the second phase of the presentation, students explore methods used by astronomers to determine distances that cannot be measured using parallax. Students are introduced to the distance-luminosity relationship and concepts of absolute and apparent brightness. Detailed information about these concepts is included in a background sheet included in the SPICE resource, *Measuring the Universe 4: Explanation of the cosmic distance ladder*.

Students may use the data in slide 23 to construct a graph to help reveal the limitations of the distance-luminosity relationship in determining distances to stars. This leads to the need for 'standard candles' — objects of known brightness that can be used to determine brightness and distance of other stellar objects.

As stars do not all have the same intrinsic luminosity, astronomers need to use techniques that rely on other physical characteristics of stars. Students are introduced to one of these, the period of Cepheid variable stars, followed by an explanation of how it can be used to measure distance.

The standard candle is linked to properties of Cepheid variables and then to some classes of supernovae. Using type 1a supernovae, astronomers can measure distances to very faint and distant galaxies.

The presentation concludes with a summary of these first two steps of the cosmic distance ladder which is followed up in the elaborate resource.

Acknowledgements

Designed and developed by the Centre for Learning Technology, The University of Western Australia. Production team: Leanne Bartoll, Alwyn Evans, Bob Fitzpatrick, Dan Hutton, Trevor Hutchison, Paul Luckas, Jodie Ween and Michael Wheatley, with thanks to Roger Dickinson, Jenny Gull and Wendy Sanderson.

Web: spice.wa.edu.au
Email: spice@uwa.edu.au
Phone: (08) 6488 3917

Centre for Learning Technology (M016)
The University of Western Australia
35 Stirling Highway
Crawley WA 6009

Questions on light-years and parsecs

1. Convert 3.5 parsecs to light-years.

   3.5 x 3.26 = 11.41 light-years

2. Convert 7.8 light-years into parsecs.

   7.8 / 3.26 = 2.39 parsecs

3. The star Sirius has a parallax angle of 0.38 arcseconds. How far away is Sirius from the Earth, in parsecs and light-years?

   1 / 0.38 = 2.63 parsecs,
   or 2.63 x 3.26 = 8.58 light-years

4. What is the parallax angle of the star 'Wolf 359', at a distance of 7.8 light-years?

   Distance to Wolf 359 is
   7.8 / 3.26 = 2.39 parsecs,
   so parallax angle is:
   1 / 2.39 = 0.42 arcseconds.

Centre for Learning Technology (M016)
The University of Western Australia
35 Stirling Highway
Crawley WA 6009

Associated SPICE resources

Measuring the Universe 3: Distances in the Universe may be used in conjunction with related SPICE resources to address the broader topic of tools used by astronomers to measure distances in the Universe.

DESCRIPTION	LEARNING PURPOSE
Measuring the Universe This learning pathway shows how a number of SPICE resources can be combined to teach aspects of how astronomers measure distances in the Universe.	
Measuring the Universe 1: Transient astronomy A video describes mysterious gamma ray bursts, which were first observed in the sixties.	**Engage**
Measuring the Universe 2: Virtual observatory Students use a learning object to simulate processes used by astronomers to discover supernovae.	**Explore**
Measuring the Universe 3: Distances in the Universe A presentation and worksheet introduce different methods used by astronomers to measure distances in the Universe.	**Explain**
Measuring the Universe 4: The cosmic distance ladder The cosmic distance ladder is the term used to describe the collection of techniques used by astronomers to measure distances in the Universe. Measurements established by one technique are used to calibrate techniques that measure greater distances.	**Elaborate**