

Topic 11 Astronomical Measurement Scales

(see also Topic 5 and Topic 7)

Edexcel GCSE Astronomy Course

Topic specification summary:

11.8 Be able to use information about the size of the Solar System

11.9 Be able to use the astronomical unit ($1 \text{ AU} = 1.5 \times 10^8 \text{ km}$), light year (l.y.) and parsec (pc)

11.12 Understand the use of transits of Venus (as proposed by Halley) to determine the size of the astronomical unit and thus the absolute size of the Solar System

NB These are also discussed in Topic 5 Observing the Solar System and Topic 7 Early Models of the Solar System

11.8 Be able to use information about the scale of the Solar System

Important sizes and distances to be familiar with include:

Mean diameter of Earth = 13000km

Mean Earth-Moon distance = 300 000km

Mean diameter of the Moon = 3500km

Mean distance between the centres of the Earth and the Sun = 150 000 000km

Mean diameter of the Sun = 1 400 000km

These dimensions are already getting very large in km so astronomers use more suitable units for larger distances.

11.9 Be able to use the astronomical unit ($1 \text{ AU} = 1.5 \times 10^8 \text{ km}$), light year (l.y.) and parsec (pc)

1 AU = mean distance between the centre of the Earth and the centre of the Sun.

In km it is approximately 150 000 000 km

The AU was used historically as distances in miles or km couldn't be measured so distances were simply compared with the Earth-Sun distance using the AU scale.

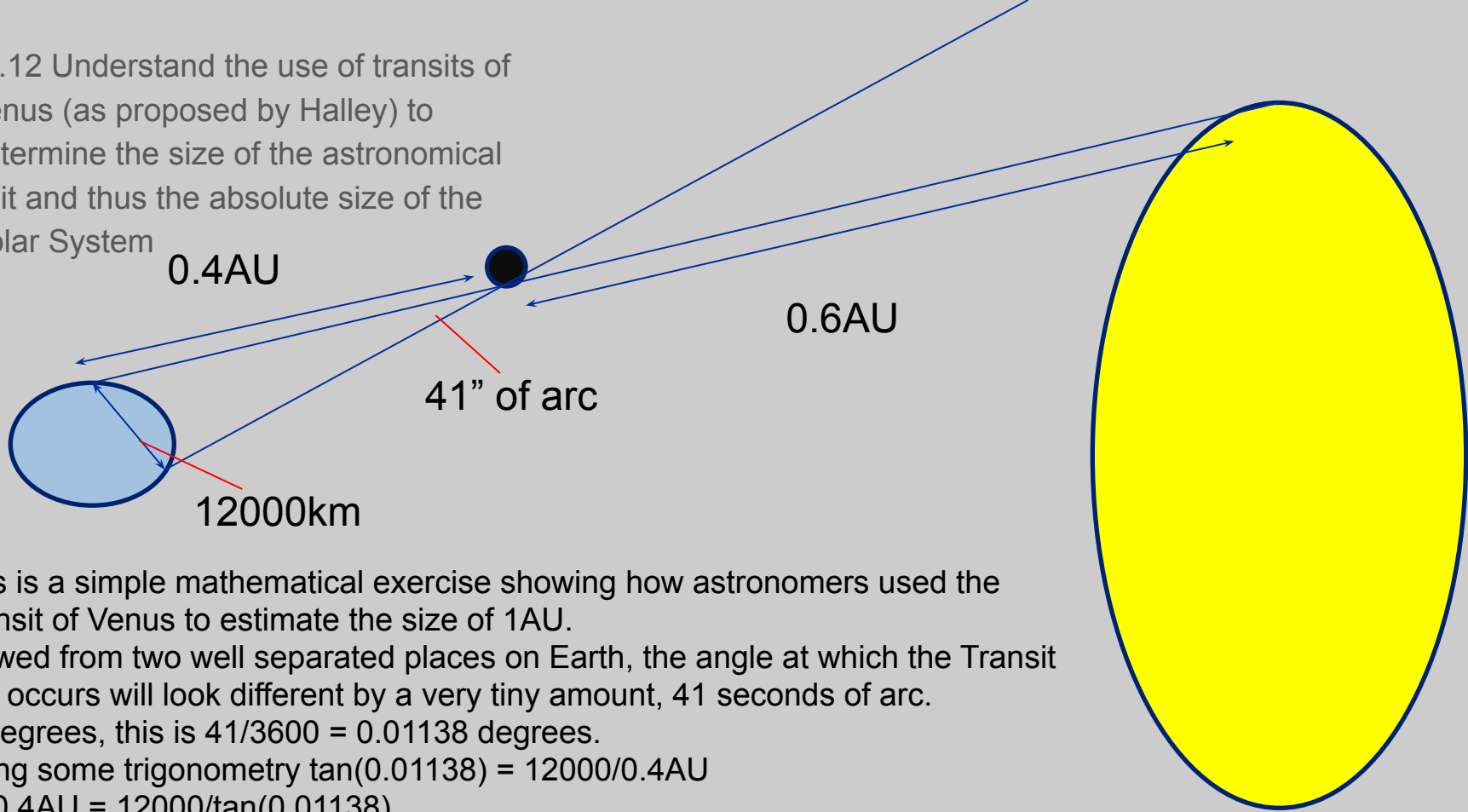
Find the scale of the solar system in AU and km here:

https://www.exploratorium.edu/ronh/solar_system/scale.pdf

This is fun - choose your own scale to overlay the solar system on a map of where you live:

<https://thinkzone.wlonk.com/SS/SolarSystemModel.php?obj=Sun&dia=100m&lat=51.750000&lon=-1.250000&table=y&map=y>

11.12 Understand the use of transits of Venus (as proposed by Halley) to determine the size of the astronomical unit and thus the absolute size of the Solar System



This is a simple mathematical exercise showing how astronomers used the Transit of Venus to estimate the size of 1AU.

Viewed from two well separated places on Earth, the angle at which the Transit first occurs will look different by a very tiny amount, 41 seconds of arc.

In degrees, this is $41/3600 = 0.01138$ degrees.

Using some trigonometry $\tan(0.01138) = 12000/0.4\text{AU}$

Or $0.4\text{AU} = 12000/\tan(0.01138)$

Using a calculator, find the value of 0.4AU then divide your answer by 0.4 to estimate the size of 1AU in km.

The Light Year (ly)

- The light year is the distance travelled at the speed of light in a vacuum in a period of one year
- **Speed of light = 299,792,458 ms⁻¹**
- How far is a light year in m?
 - Distance in m = Speed of light in ms⁻¹ x 365.25 x 24 x 3600
- This is a huge distance by Earth standards, but not once we look outside our solar system (see examples on next slide)
- We can also use smaller intervals of time to describe astronomical distances such as:
 - Distance from Sun to Earth = 8 light minutes
 - Distance from Moon to Earth = 1 light second

The 'size' of the universe in light years

Circumference of Earth 0.133 light seconds

Distance to Moon 1.28 light seconds

Circumference of Sun 15 light seconds

Sun-Earth distance 8 light minutes

Sun-Pluto distance 5.5 light hours

Diameter of the Ring Nebula 20 light months

Sun - Alpha Centauri 4.3 light years

Sun-Centre of Milky Way 27,000 light years

Sun-Andromeda galaxy 2 million light years

To the Virgo cluster 50 million light years

To the nearest other galaxies more than 80 million light years

To Distant quasars about 8 billion light years

To the Cosmic horizon 12-13 billion light years

The parsec (pc)

The 'parsec' (pc) is the distance to an object that makes a parallax angle of 1' (one second) of arc when the Earth moves between the extremities of its orbit.

This is best explained using the diagram on the following slide:

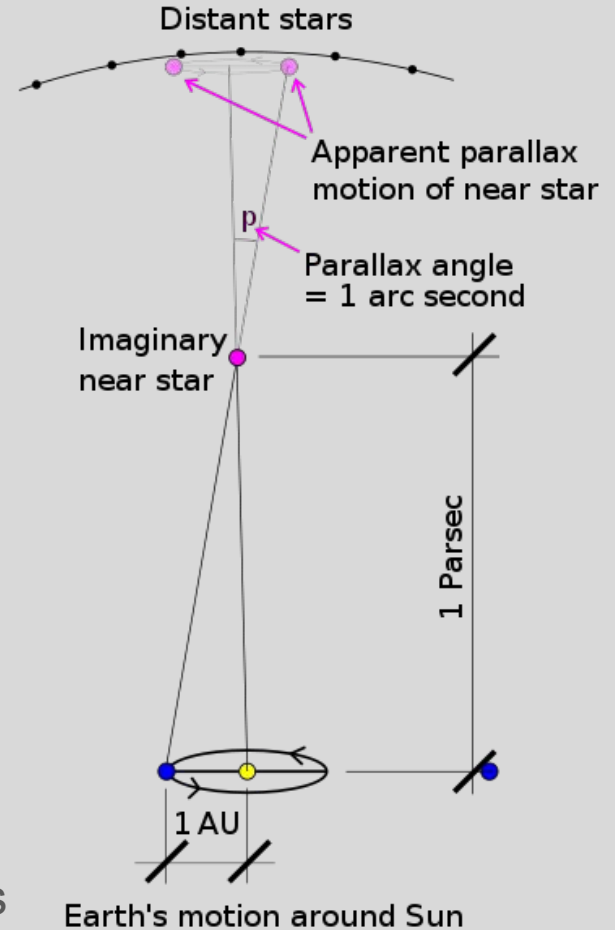
The geometry of the parsec

Look at a fixed object in front of you, cover your left eye with your left hand and then quickly cover the right eye with your right hand instead you will see the chosen object appear to move from side to side.

This is called parallax where the apparent position of an object depends on the angle you view it from.

The Earth is a moving observatory and this changes the viewing angle of stars in the sky as shown in the diagram.

The further away an object is though, the less of a change you will see - very distant stars appear fixed as their parallax angle is too small to detect.



Measuring in parsecs

The diagram on the previous slide shows that **the parsec (pc) is a distance from the Sun to a nearby star which has a parallax angle of 1 arc second when viewed from points in the Earth's orbit 1AU apart.**

(This will be a time difference of 3 months or one quarter of an orbit; after half an orbit the Earth will have moved 2AU from its original position.)

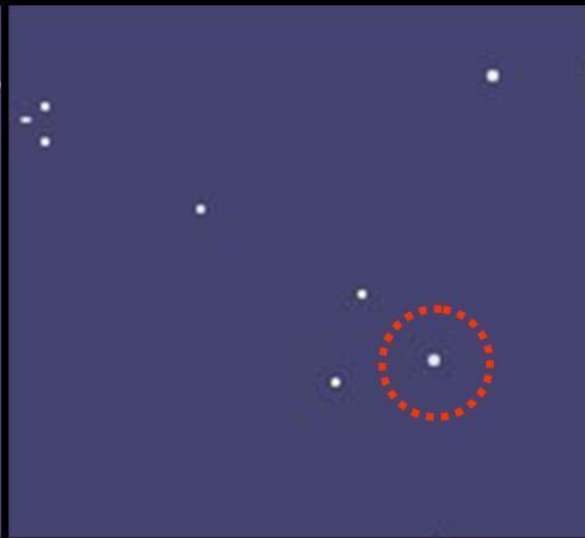
The next slide shows a simulated example of what this parallax shift would actually look like when observed through a telescope.

The first diagram shows the target star, HT Cas(12/96) in the red circle, viewed at a certain time, the second six months later and the third shows both images on top of each other. Distant star patterns appear fixed, whereas the target star appears to have moved.

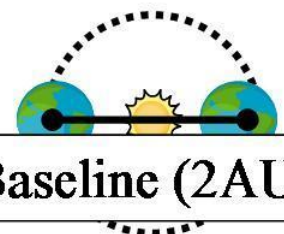
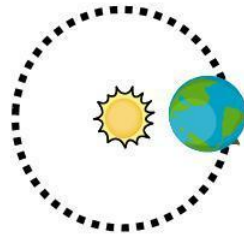
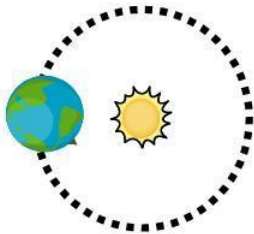
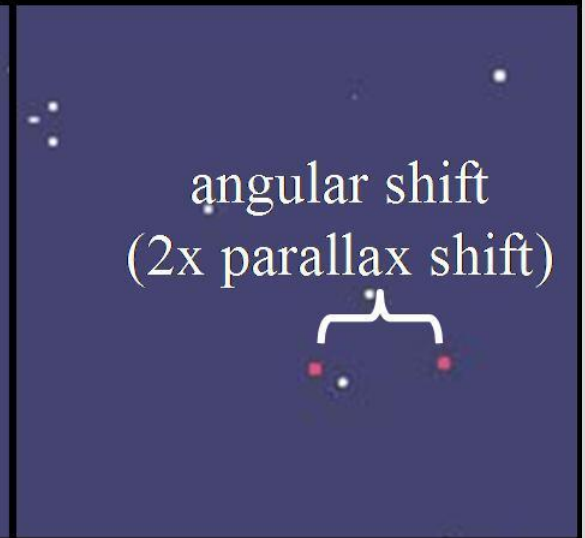
Image of HT Cas (06/96)



Image of HT Cas (12/96)



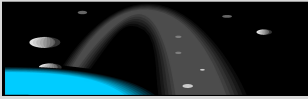
Composite image



Baseline (2AU)

Distance conversion exercise - fill in the blank spaces in this table (check your answers on the final slide)

	Metres	AU	Parsecs	Light years
Metres	1		3.2×10^{-17}	1.1×10^{-16}
AU	1.5×10^{11}	1		1.6×10^{-5}
Parsecs	3.1×10^{16}		1	3.26
Light years	9.5×10^{15}			1



	Metres	AU	Parsecs	Light years
Metres	1	6.7×10^{-12}	3.2×10^{-17}	1.1×10^{-16}
AU	1.5×10^{11}	1	4.8×10^{-6}	1.6×10^{-5}
Parsecs	3.1×10^{16}	2.1×10^5	1	3.26
Light years	9.5×10^{15}	6.3×10^4	0.31	1