7.Early Models of the Solar System

Edexcel GCSE Astronomy Course

ABINGDON SCIENCE PARTNERSHIP

Topic specification summary:

7.1 Understand the use of detailed observations of solar and lunar cycles by ancient civilisations around the world for:

a agricultural systems b religious systems c time and calendar systems d alignments of ancient monuments

7.2 Understand that the current celestial alignment of ancient monuments differs from their original celestial alignment due to the precession of the Earth's axis

7.3 Understand early geocentric models of the Solar System

7.4 Understand the advantage of the addition of epicycles, as described by Ptolemy

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

7.6 Be able to use the astronomical unit (1 AU = 1.5 × 108 km), light year (l.y.) and parsec (pc)

7.1 Understand the use of detailed observations of solar and lunar cycles by ancient civilisations around the world for: **a** agricultural systems **b** religious systems **c** time and calendar systems **d** alignments of ancient monuments

How would astronomy help with each of the items, a,b,c,d, in the list above? Think about these questions and discuss them with other if you can. No answers are given here - they are ideas you must think about.

- Why do farmers need to know the time of year to grow food and raise animals?
- Why did knowing when an event would happen, such as an eclipse, make religious leaders more powerful?
- Why would astronomy have been a good way to tell the time and date in ancient times before mechanical timing devices were invented?
- Why did ancient people build large, stone monuments aligned with significant events?

Find out more - follow the links and write down the answers:

- What is **heliacal rising**? Who was Sopdet? Why was the heliacal rising of Sirius important to the Ancient Egyptians?
- https://www.encyclopedia.com/science/encyclopedias-almanacs-transcripts-and-maps/astrology-and-astronomy-ancient-world
- Which astronomical object did the Maoris in New Zealand rely on to set their calendar?
- https://en.wikipedia.org/wiki/Heliacal_rising

Fill in some information in this table using the link below:

Examples of civilisations and religions that used astronomy to develop calendars:	**Examples of astronomical events that led to myths, superstitions or festivals:**	**Examples of ancient monuments aligned with astronomical events (click on the photos):**
B_______________	C_______	S__________
M_______	S______ __________	C______ I____
G_______	B______ M____ (or L_____ E______	N_________
I_________	S______ E_________	J______ M______
P_______	W_____ S_________	
E__________		

https://www.space.fm/astronomy/earthmoonsun/ancientobservations.html

7.2 Understand that the current celestial alignment of ancient monuments differs from their original celestial alignment due to the precession of the Earth’s axis

What does precession mean and why does it affect alignments?

Find the information to answer these questions from this site https://www.space.fm/astronomy/planetarysystems/precession.html

1. Write a definition of precession.
2. What causes the Earth’s precession?
3. Who first realised that precession was happening?
4. Why are star catalogues re-published every 50 years?
5. What is the connection between the stars Thuba, Polaris and Vega?
6. What is the consequence for the alignment of ancient monuments?
7. What is the time period of the Earth’s precession?
8. Try the two questions in the link check your answers.

Useful links and resources for further study on archaeoastronomy

https://www.space.fm/astronomy/planetarysystems/archeoastronomy.html

https://www.space.fm/astronomy/planetarysystems/geocentricheliocentric.html

https://www.space.fm/astronomy/earthmoonsun/measuring.html

7.3 Understand early geocentric models of the Solar System
7.4 Understand the advantage of the addition of epicycles, as described by Ptolemy

What do the words geocentric, heliocentric and epicycle mean?

If you don’t know find out and write down the definitions:

https://www.dictionary.com/browse/geocentric

https://www.dictionary.com/browse/heliocentric

https://www.dictionary.com/browse/epicycle

Retrograde motion and epicycles were covered in Topic 5 - you can revise the idea by looking back to the Topic 5 presentation here
https://www.abingdonsciencepartnership.org/wp-content/uploads/2020/04/Solar-System-Observation.pdf

Now, find out more about each of these ideas and the reasons why models of the solar system changed over time...

Geocentric vs heliocentric models

Find the answers to the questions from here:https://phys.org/news/2016-01-heliocentric-universe.html

1. Who is usually credited with creation of the heliocentric model?
2. Which 2nd century CE Greek philosopher's geocentric model was accepted by most astronomers up until the 16th century CE?
3. What two, common observations led to the geocentric model?
4. What was the reason for the deferant sphere in Ptolemy's model?
5. What was the reason for the epicycle in Ptolemy's model?
6. What were Copernicus's seven principles for a heliocentric model?
7. What could the heliocentric model explain about observations of Venus and Mercury and the motions of Mars and Jupiter?
8. Read to the end of the article and list the nationalities or cultures of other astronomers who had suggested a heliocentric model.

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

7.6 Be able to use the astronomical unit (1 AU = 1.5 × 108 km), light year (l.y.) and parsec (pc)

Ideas about the scale of the solar system have been discussed in other presentations, such as Topics 1,3 and 5.

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.

The Astronomical Unit (AU)

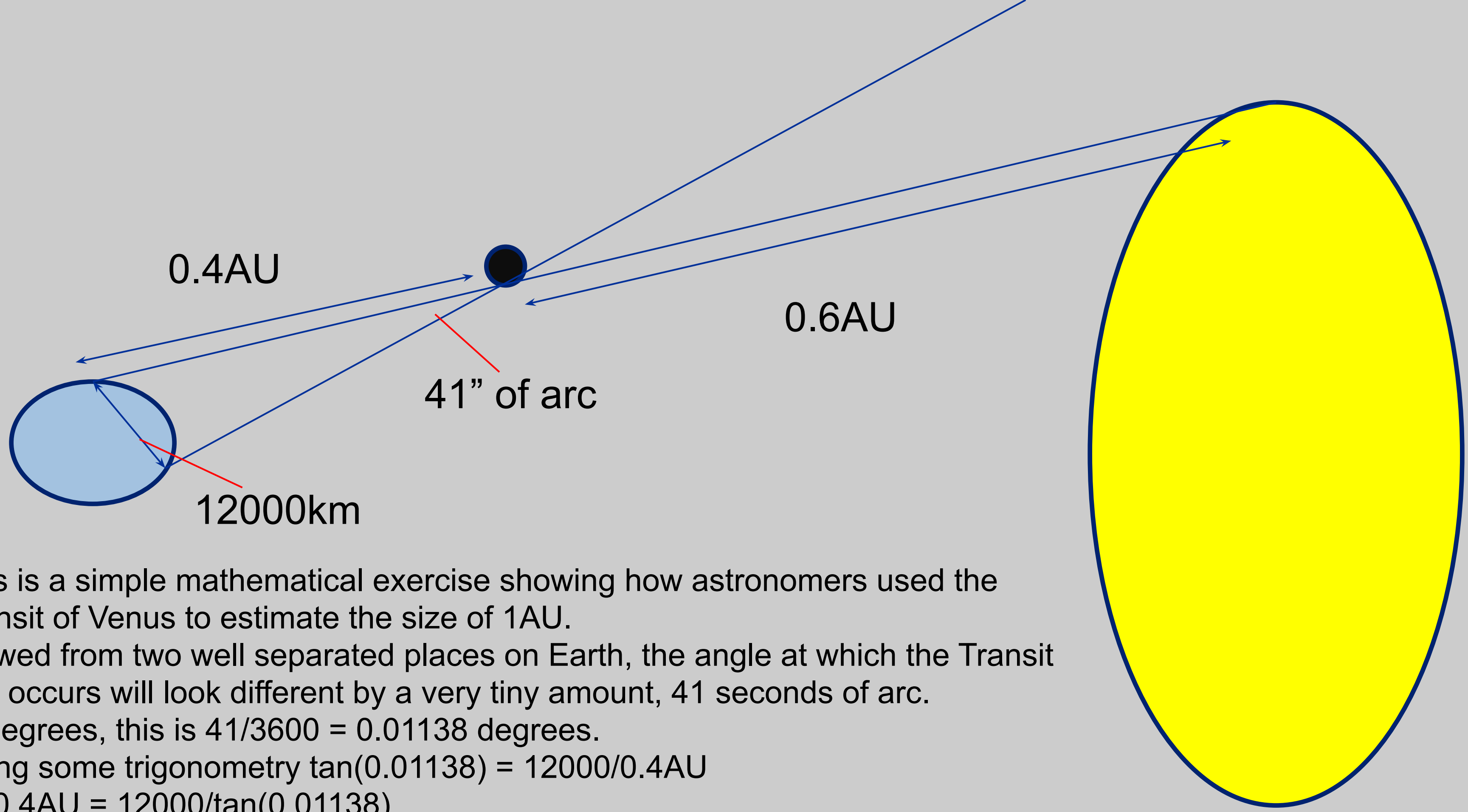
1 AU = mean distance between the centre of the Earth and the centre of the Sun.

In km it is approximately 150 000 000km

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



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) = 12000/0.4AU

Or 0.4AU = 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:

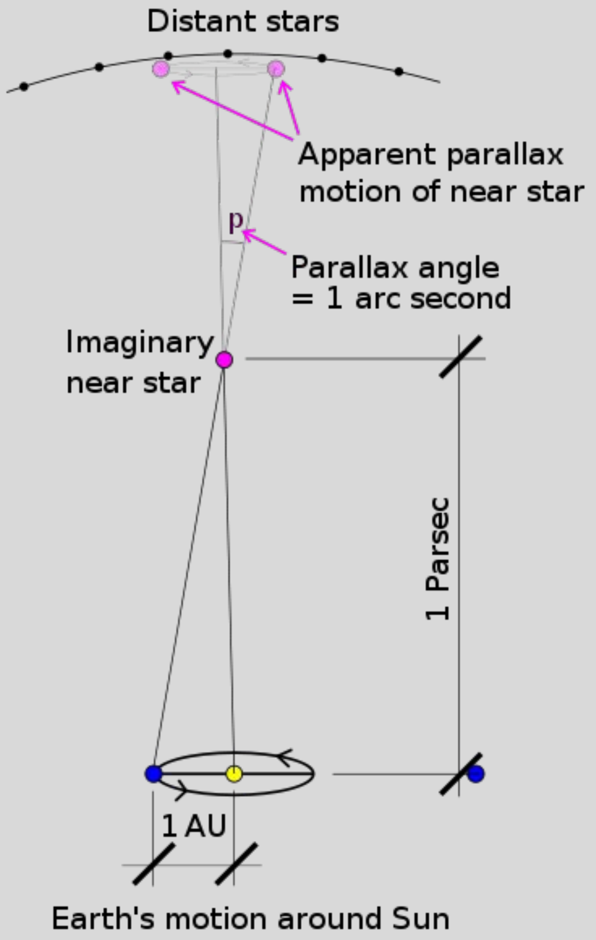
The geometry of the parsec

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 t**he 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.

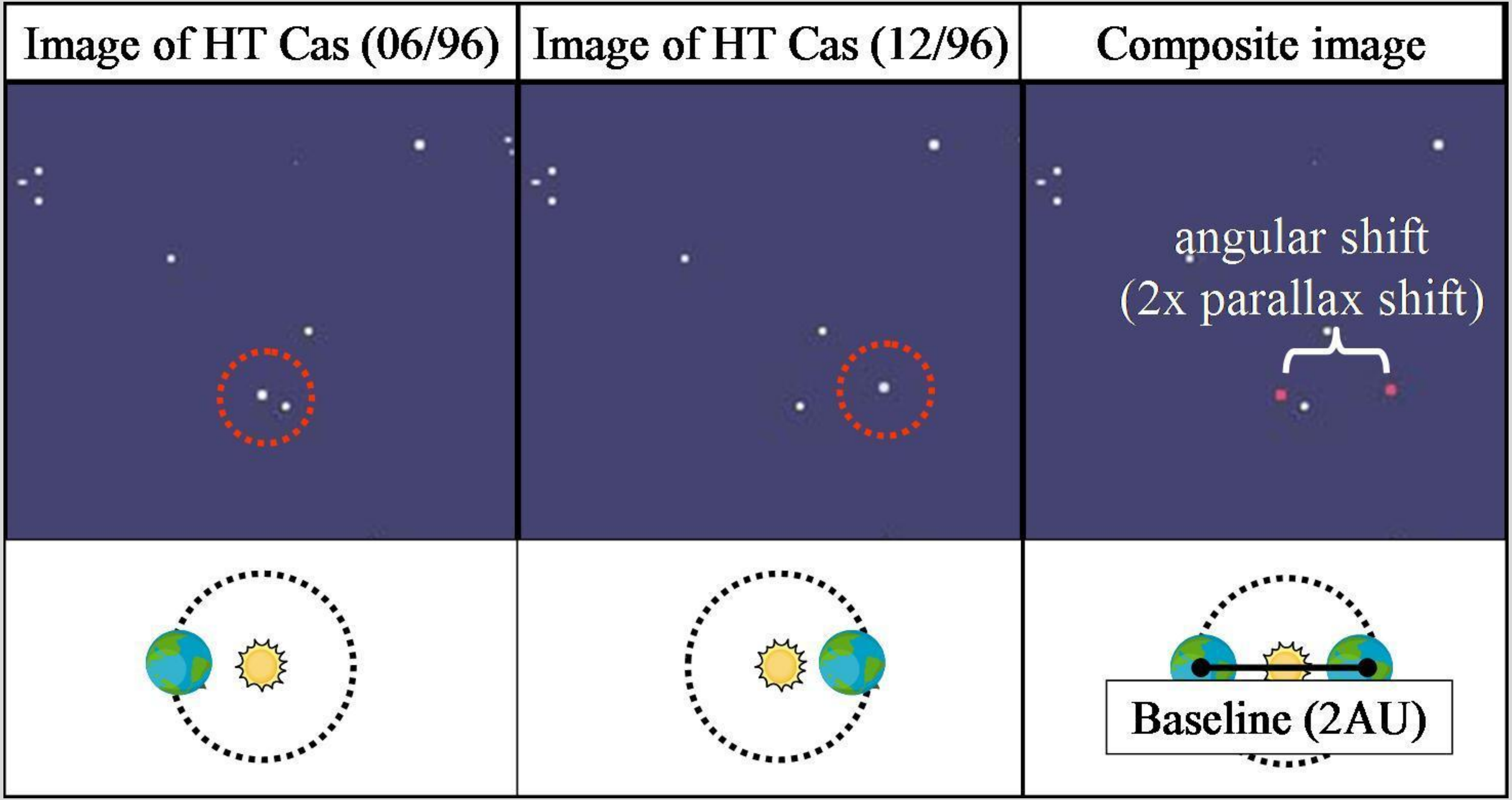
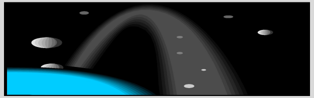
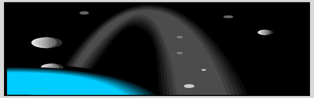


Image of HT Cas (06/96)
Image of HT Cas (12/96)
Composite image
angular shift
(2x parallax shift)
Baseline (2AU)

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}	$3.2\times10-^{17}$	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