edexcel

Topic Guide:

Archaeoastronomy

GCSE (9-1) Astronomy

Pearson Edexcel Level 1/Level 2 GCSE (9-1) in Astronomy (1AS0)

Pearson

Archaeoastronomy

Contents

Specification Points

3.6 Understand how the gradual precession of the Earth's axis affects the appearance of the Sun, Moon and stars, when observed from Earth, and its use in archaeoastronomy.

3.7 Be able to use data relating to the rate of precession of the Earth's axis.

6.4 Understand why there is a range of constellation, asterism and star names among different cultures

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.

Introduction

The study of patterns in the stars, the shape and orientation of the Milky Way and the cycles in the movements of the Sun, Moon and naked-eye planets is one of the oldest areas of human study and for millennia has helped humans to manage many aspects of their lives.

This area of the Specification looks at the patterns which ancient peoples would have used and how they represented them, both in their minds and in the structures which they have left behind.

Archaeoastronomy

Some of the oldest images which are known to have been created by humans record notable astronomical events such as eclipses and novae and representations of the Milky Way. Many of them predate even the earliest recorded examples of writing or number. It is quite possible that the need to record patterns and cycles in the movements of astronomical bodies was the driving force for humans to create systems of writing and number.

Our earliest ancestors wandered the planet, hunting and gathering available food as and when they found it. However, about 12 000 years ago, groups of humans around the world began to settle in particular areas, cultivating food and keeping animals so as to ensure a reliable food supply all year round.

The motions of astronomical bodies provided the means for these early farmers to keep track of the time of the year and thus to organise sowing and harvesting. For these early people, watching and recording the positions of the Sun, Moon and stars would have been an important part of everyday survival. In addition, the ability to use these astronomical cycles to predict events would have brought great power to those early astronomers.

Nowadays we record positions in the sky in terms of concepts such as Right Ascension and Declination whereas ancient cultures clearly used animals and mythological figures, many of which survive in the constellation and star names which we still use today. The changes in the motions of astronomical bodies were also recorded, often as stories and legends, many of which also survive to this day. It is clear from the accuracy and detail of these accounts that ancient astronomers watched the sky with great care and for generation after generation, many thousands of years before the invention of writing or even the first telescopes.

Almost all religious systems also drew heavily upon this rich imagery in the sky. The origins of the dates of many religious festivals are thought to lie in astronomical phenomena such as the New Moon, solstices, equinoxes or even the positions of some constellations.

The Naked-Eye Sky Cycles

As might be expected of naked-eye astronomers, the two astronomical cycles which were identified and used by all ancient cultures were those of the Sun and the Moon, as ways of managing their agricultural and religious calendars.

Many cultures used the background of the stars as a way of recording the apparent annual movement of the Sun across the Celestial Sphere.

Example 1: Hathor and the Flooding of the Nile

The Ancient Egyptians used the legend of the goddess Hathor as a way of recording the annual first appearance or 'heliacal' rising of the star Sirius in the dawn sky. This was a vitally important astronomical event as it was a clear signal for the forthcoming flooding of the River Nile.

In this legend, the ageing god Ra sent the goddess Hathor to Earth to kill those people who had spoken ill of Ra. Unfortunately, Hathor began killing too many people so Ra poured thousands of pots of beer into the Nile, making its waters rise and turn brown. As Hathor drank from the Nile she became so drunk that she was unable to kill any further.

In Egyptian mythology the god Ra represented the Sun – in this legend grown old as the strength of the Sun wanes towards the end of the summer. Hathor represented the bright star Sirius and the legend reminded Egyptian farmers that when Sirius became visible in the darkening dawn skies of late summer, the River Nile would soon flood.

The flooding of the Nile was of huge importance for Egyptian farmers as it spread fertile mud across the land on either side of the river.

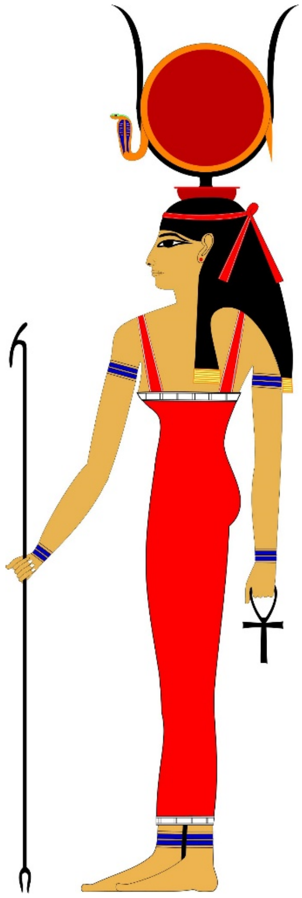

Figure 1: Hathor. In ancient Egyptian mythology the goddess Hathor was associated with the bright star Sirius, whose heliacal rising was of great importance.

Although the Sun appears to rise and set each day due to the rotation of the Earth, its changing position on the Celestial Sphere means that in some parts of the year it rises some way north of East and sets north of West, taking a high arc around to the South and spending much more than twelve hours in the sky. These times of the year are called Summer.

Conversely, at other times of the year the Sun rises some way south of due East and sets south of due West. It takes a short low arc towards the south and spends much less than twelve hours in the sky. These times of year are called Winter.

The day of the most northerly sunrise and sunset is called the Summer Solstice (June 21st in the northern hemisphere) and the day of its most southerly sunrise and set is called the Winter Solstice (December 21st in the northern hemisphere).

The directions of sunrise and sunset on these two days therefore marked the extremes of the Sun's motion on the horizon throughout the year. Consequently, we can see these 'solsticial' directions clearly marked in the buildings and monuments of almost every ancient civilisation. They effectively allowed ancient civilisations to use the Sun as a calendar.

Example 2: Stonehenge

One of the most impressive surviving examples of astronomically related construction is the world-renowned Neolithic stone circle in southern England known as Stonehenge. Although some of the giant stones' astronomical alignments are still being debated today, the stone circle would have allowed ancient astronomers to identify the solsticial extremes of the Sun's motion as well as the extremes of the Moon's rising and setting positions:

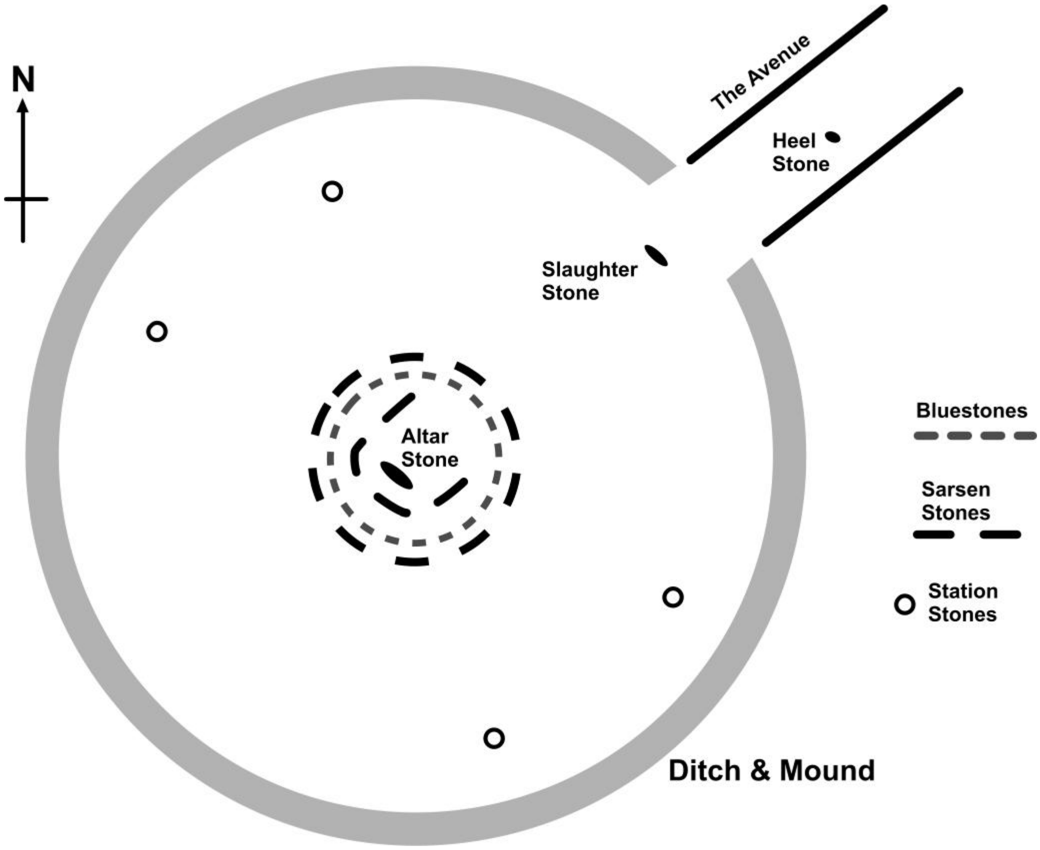

Figure 2: Stonehenge. A simplified plan of how the Stonehenge monument may have looked in the past. The long, raised mound known as 'The Avenue' and the Heel Stone, to the north-east of the stone circles strongly suggest that the monument was designed to mark astronomical events which occur along the North-east / South-west axis such as the midsummer sunrise and the midwinter sunset.

Solsticial directions – Stonehenge also provides a way of using the Sun's rising and setting positions between their midsummer and midwinter extremes to keep track of the passage of time through the year – an essential requirement for ancient civilisations.

Standing at the Altar Stone at the centre of the monument and facing towards the Heel Stone, an observer will see the Sun rise over the Heel Stone on the midsummer solstice, June 21st. This alignment within the monument thus marks the northern limit of the sunrise.

Although many people visit Stonehenge to watch the sunrise on the midsummer solstice, many astronomers think that the ancient builders may have entered the monument along The Avenue, facing in the opposite direction from the Altar Stone, in order to witness the sunset on the midwinter solstice, December 21st. This would have been a very important date for those involved in farming around the monument as it marks the first night of the winter which is not longer than the previous one, i.e. the darkest point of the year. There is also archaeological evidence that people came from great distances to a midwinter festival at Stonehenge.

The other key solsticial points are also marked by particular stones which can be seen to align with these key points on the horizon for an observer standing at the Altar Stone.

This would have allowed Stonehenge's ancient builders to keep track of the progress of the year and thus organise many of their social, religious and agricultural activities.

Lunar alignments - The northern and southern limits of moonrise and moonset directions can also be identified using the stones of Stonehenge. Standing at one of the Station Stones to the side of the main circles of stones and looking eastwards or westwards across the monument to another of the Station Stones will indicate the most northerly and southerly positions of moonrise and moonset during the year.

Since the rising and setting of the Moon is not of any direct use in determining the time of year, this suggests that the ancient builders of Stonehenge may have attached some other significance to the Moon and its changing position and shape each month. They would certainly not have been alone in this as a wide range of cultures still have religious festivals whose dates relate to the lunar cycle such as Easter and Eid. Extreme changes in the altitude of the Moon would also have allowed multi-year cycles to be marked.

These lunar alignments at Stonehenge show us that its builders were aware of the Saros cycle – the 18.6 year period for the Sun, Moon and Earth to return to exactly the same position relative to each other. This is a remarkable achievement given that a typical human life span in the Neolithic period may have been little more than forty years.

Other alignments – over the years a wide range of possible astronomical alignments have been identified between the stones of the Stonehenge monument. The difficulty is that of knowing whether these alignments were intended by the monuments' builders or simply chance alignments given the large number of stones it contains. It is also hard to be certain of the stones' exact original positions and all possible alignments depend heavily on the choice of viewing position.

In particular, the circle of 56 holes in the ground which surround the stones, known as the Aubrey Holes, has often been suggested as a further astronomical feature of Stonehenge. Some astronomers have noted that 56 is almost exactly the number of years in three Saros Cycles (3 x 18.61 years) and that wooden or stone markers placed in the Aubrey Holes and moved on at intervals could therefore be used to keep track of progress through the Saros Cycle, presumably to help predict the dates and directions of eclipses.

Others have noted that 56 is twice 28, which is approximately the number of days in a lunar month – a fact which could also be utilised in a system of moveable marker posts or stones to predict eclipses.

Although these and many other astronomical explanations for the Aubrey Holes are feasible, the small amount of evidence which remains after several thousand years means that this is likely to remain an area of active debate amongst archaeologists and astronomers for many years to come.

The structures which people all over the world set up in ancient times to mark the motions of the Sun, Moon and stars in the sky obviously took on tremendous practical and religious significance for them. As a result, these structures were often very large and represented multigenerational effort. It is likely too that great attention was paid to their intended astronomical use.

Example 3: The Great Pyramid

The construction of a building as huge as the Great Pyramid of Giza was an incredible achievement but the accuracy with which it is aligned with both the Earth's cardinal points and with some of the brightest stars is even more amazing.

The sides of the Great Pyramid are aligned North, South, East and West to an accuracy of one twentieth of a degree. This is almost the limit of resolution of the human eye, making it clear that the Ancient Egyptians made its alignment as close to perfect as they could measure with the naked eye. It is also clear that such accuracy could only have been achieved by using astronomical objects such as the Sun and stars.

Once again, many alignments between structures within the Great Pyramid and certain bright stars have been suggested but the difficulty remains that of determining which alignments were intended by the Pyramid's builders and which were coincidental.

Precession

The complex gravitational field in which the Earth orbits the Sun makes its path much more complex than the simple ellipse predicted by Kepler's Laws of Planetary Motion. In addition to orbiting the Sun once a year and spinning on its axis once each day, the Earth's motion contains many other periodic motions. The most noticeable of these is the precession of the equinoxes.

As the Earth spins on its axis, it also wobbles like a spinning top. This means that the direction in which the Earth's rotation axis is pointing complete a small circle amongst the stars, once every 26 000 years. The North Celestial Pole, which is simply the projection of the northern end of the Earth's rotation axis out into space and onto the Celestial Sphere, will gradually change the place on the background of the stars at which it is pointing. Over the period of one complete precession, the Earth's rotation axis completes a circle with a radius of about 2.5º, as shown in Figure 3.

In simple terms, this means that the constellations and patterns which provide the backdrop for the Celestial Sphere change very gradually over the years. Although the North Celestial Pole currently points in a direction very close to the bright star Polaris, in the time of the builders of Stonehenge and the Pyramids, the star Thuban in the constellation of Draco would have been closest to the North Celestial pole. Over the coming millennia, precession will mean that stars such as Gamma Cephei or Vega will be used as our 'pole star'.

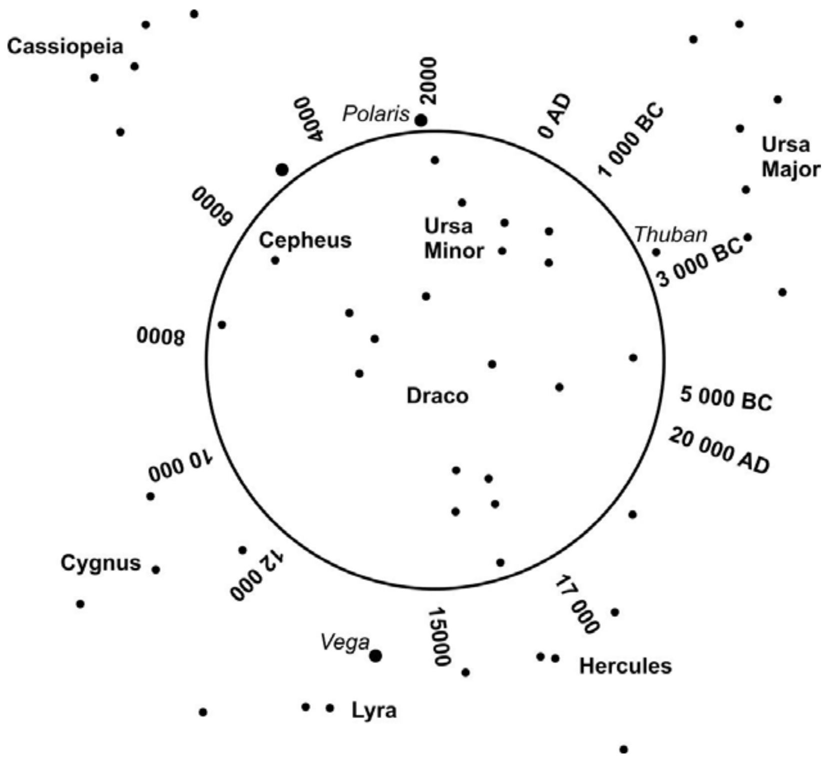

Figure 3: Precession of the North Celestial Pole. The circle shows the position of the North Celestial Pole amongst the background of the stars, from 5000 BC to 20 000AD.

Although precession only produces extremely slow changes in the alignments between the Celestial Sphere and the stars, it was written about by the Greek astronomer Hipparchus in the second century BCE[1] and careful records have been kept of it ever since.

As a result it is possible to re-create the possible alignments between many ancient monuments and the stars in the times when they were originally built.

Example 4: The Riddle of the Sphinx

The statue of the Sphinx, next to the three great pyramids on the Giza Plateau near Cairo in Egypt faces due east and has therefore greeted the sunrise every day for many thousands of years. Since it faces precisely due east it only aligns exactly with the rising Sun on two days each year – the Vernal and Autumnal Equinoxes on the 21st March and the 21st September.

Figure 4: The Sphinx. Sited next to the three great pyramids on the Giza Plateau near Cairo in Egypt, the date of the Sphinx's original building has always been something of a mystery since the Ancient Egyptians left no record of its building. The precession of the Earth's axis may help to shed some light on this mystery...

In the present era, the Sun appears to be in front of the constellation of Pisces, the fishes, on 21st March. Many millennia ago, as a result of precession, the Sphinx would have faced constellations which we now call Taurus, Scorpio or Leo at sunrise on the Vernal Equinox. The similarity between the shape of the Sphinx's body and the group of stars which we now call Leo the Lion has even led to some quite extreme suggestions for the date of its construction.

This particular archaeoastronomical debate may well last for another several thousand years!

[1] Some of the cycles within the calendar systems of a number of ancient civilisations have suggested to some that a knowledge of precession may date from even earlier times.

Further Support

The following websites contain further information about the topics covered by this Support Sheet:

1. Almost all the people and places described in this sheet have individual entries in Wikipedia.

   www.wikipedia.org

2. The Royal Astronomical Society's Leaflets for Schools contain material to support the teaching of several of the topics covered by this sheet. In particular, there is an RAS leaflet on 'Stonehenge and Ancient Astronomy' produced in association with Professor Clive Ruggles. It provides an excellent and authoritative introduction to archaeoastronomy in general and an excellent overview of the astronomical alignments of the Stonehenge monument.

   www.ras.org.uk/publications/other-publications

3. The Royal Greenwich Observatory website contains resources relevant to many of the topics covered in this sheet and was itself the site of the work of some of the astronomers mentioned. It is therefore a unique location for students of GCSE Astronomy to visit.

   www.rmg.co.uk/royal-observatory

4. The Educators section of the NASA website contains a wide range of resources to support students and teachers learning about many of the astronomical topics covered in this sheet.

   www.nasa.gov/audience/foreducators/index.html

5. The British Museum in central London contains a vast range of exhibits of all kinds related to ancient astronomy. Their website has resources specifically designed for schools and learners.

   www.britishmuseum.org

6. The Society for the History of Astronomy provides its members with a regular newsletter which covers aspects of the historical development of astronomy across the millennia.

   www.societyfortheehistoryofastronomy.com

7. The Science Museum in central London has a large collection or artefacts related to the study of astronomy through the ages. Its website provides resources for schools and those studying this aspect of astronomy.

   www.sciencemuseum.org.uk

Checkpoint questions

1. Write a definition of each of the following terms:
    a. Day
    b. Month
    c. Year
    d. Cardinal points
    e. Solstice
    f. Equinox
    g. Constellation
    h. Asterism
    i. Precession
    j. Eclipse
    k. Celestial Pole
    l. First Point of Aries
    m. First Point of Libra

2. Find details of the stone circle or similar monument closest to your location. Identify the way in which it may have allowed its users to find:
    a. The cardinal points (north, south, east and west)
    b. The directions of sunrise and sunset at the equinoxes and solstices
    c. The directions of the most northerly and southerly moonrise and moonset

3. Precession means that the direction of the North Celestial Pole completes a circle against the background of the stars once every 26 000 years.
    a. Calculate the amount by which it moves each year. Give your answer in arc minutes (‘) and arc seconds (“).
    b. Use your answer to (a) to estimate a possible age for an ancient monument whose structures appears to be 24º out of alignment with a particular bright star.
    c. Estimate the year when precession will bring the monument back into alignment with the bright star in question.