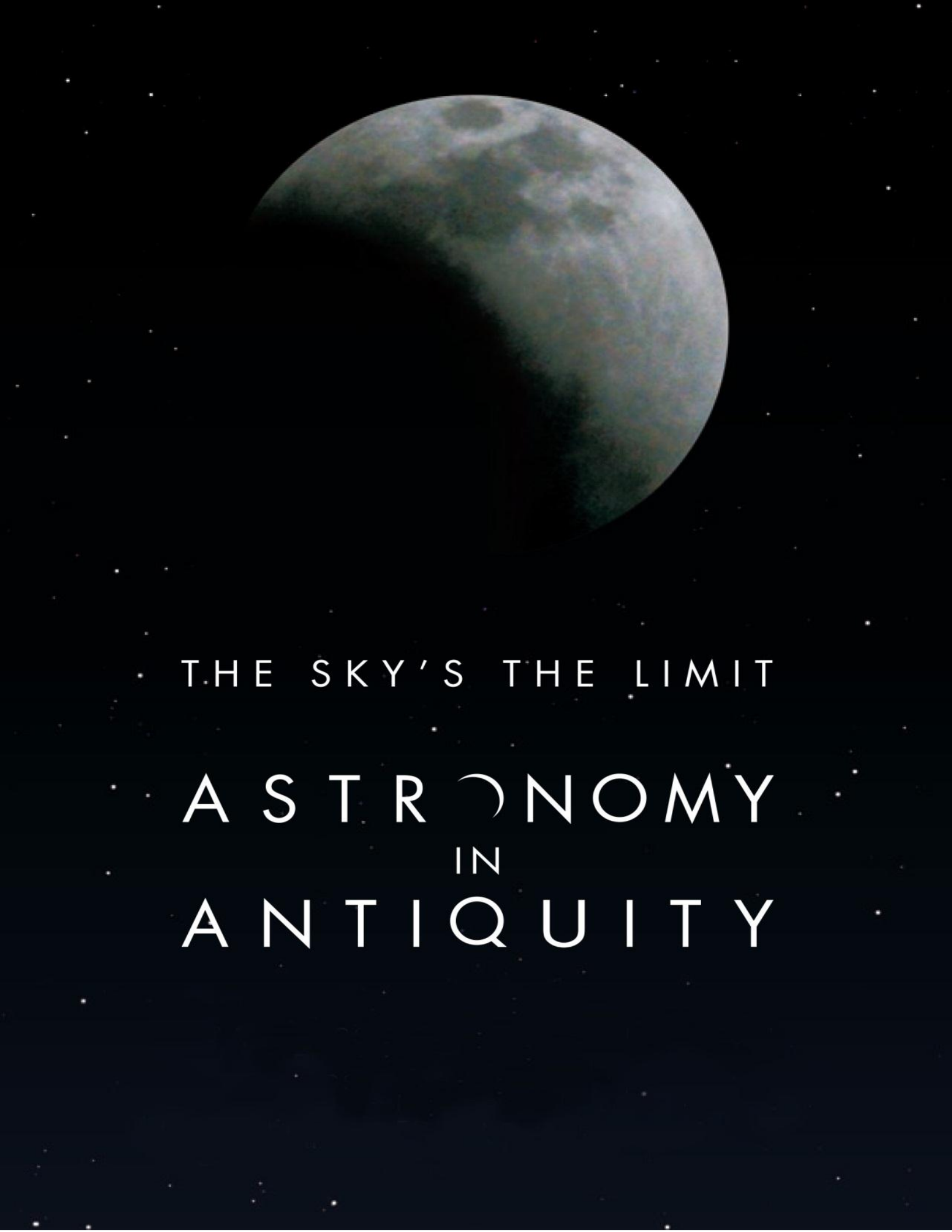
THE SKY'S THE LIMIT
ASTRONOMY
IN
ANTIQUITY

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THE UNIVERSITY OF SYDNEY

INTRODUCTION

THE SKY'S THE LIMIT: ASTRONOMY IN ANTIQUITY

Ancient people looked to the skies to make sense of the world. Following the stars allowed people to predict the change of seasons, track time and create calendars. Sailors, as they struck out across the seas, used the night sky to guide their path. Architects designed tombs and temples to align with celestial beings for superstitious and practical reasons. Astronomy and astrology systematised these observation.

The exhibition included information and objects from Ancient Britain, Australian Aboriginal, Egyptian, Greek, Roman and Persian cultures. It also considered the re-awakening of astronomical research in the Renaissance.

The exhibition collated objects from the collections of the Nicholson Museum, the Macleay Museum and from Rare Books and Special Collections Library at the University of Sydney. Objects were borrowed from the Museum of Ancient Cultures at Macquarie University, from the Lady Denman Museum, Huskisson and from private lenders.

The breadth of time and the variety of objects and cultures represented in the exhibition provided a rare opportunity to explore the topic of astronomy and contrast the lived experiences of past peoples.

The exhibition posed such questions as: How was the ancient experience of the heavens different to our own? What did they believe? What impact did the heavens have on their daily lives? How did they mark time? What did they discover about the way the universe worked?

The exhibition highlighted how our interaction with the heavens has changed markedly since ancient times. How, for many of us, the changes of the seasons, the tides, the phases of the moon, the position of the planets have minimal day to day effect. However, the ancient influences can still be felt. The calendar we use is Roman (with a medieval adjustment), the date of Christmas - a pagan festival of the sun. The zodiac and practice of astrology is inherited from ancient Greece and Rome.

The philosophers and scientists of the ancient world showed remarkable aptitude when understanding the heavens and utilising their observations, captured not least in the Antikythera Mechanism, a model of which was included in the exhibition. Constant, regular observation and recording allowed the construction of Stonehenge. Greek philosophers and astronomers such as Thales, Aristotle, Aristarchus of Samos, Eratosthenes and Ptolemey advanced the understanding of the heavens. This tradition was advanced by the likes of Abd al-Rahman ibn Yunus and Muhannad al-Battani. These foundations were built upon by the Renaissance astronomers, Copernicus, Kepler, Galileo and later Newton.

As Newtown himself said "If I have seen farther, it is because I have stood on the shoulders of giants". We owe a debt to those who went before.

Dr Elizabeth Bollen, Assistant Curator, Nicholson Museum

A DARK SKY

Just remember that you're standing on a planet that's evolving
And revolving at nine hundred miles an hour
That's orbiting at nineteen miles a second, so it's reckoned
A sun that is the source of all our power
The sun and you and me and all the stars that we can see
Are moving at a million miles a day
In an outer spiral arm, at forty thousand miles an hour
Of the galaxy we call the 'milky way'
GALAXY SONG, MONTY PYTHON

Today we have largely lost our connection with the skies. With images from space of our own planet, spherical and beautiful, our view of ourselves is completely removed from that of previous civilisations. We are amazed by scientific discoveries, the vastness of the universe and the beauty of images beamed back from Space.

Not only have we written ourselves out of the creation of the world with the Big Bang theory, we rarely look to the skies for the clues of how to live our daily life.

Shut inside at night with the lights on and the television flickering, or walking through the city doused in street lights, we look up and see only a few of the brightest, forlorn, stars shining through.

Not so very long ago our ancestors had a very different experience of the earth and therefore gazed at a very different sky.

So imagine, if you will, a world where the only light is provided by the sun, the moon, the stars and the camp fire you gather around in the evening. You wait through the long dark nights of winter and pray for the warmth of the sun to return. You hunt by the light of the moon, with the stars in the sky to guide you home. You are in awe of the expanse of the night sky and the burning of the sun, the realm of your gods. You look to the skies to make sense of your place on earth.

LESSONS IN THE SKY

Those who sat under the stars every night looked into them and saw patterns. The naming of these patterns, the constellations, was not so much a matter of discovery as the deliberate finding of significant figures from the myths and legends of the people. The stars were examined, not to understand how the universe worked, but to find out the will of the gods, to preserve the traditions of a culture and to establish an order to the activities and events on earth.

The zodiac, derived from the Ancient Greek 'living creatures', is a band of stars. As the earth makes its journey around the sun, these stars rise, are visible, then set and are hidden at different and regular times of the year. The creatures and characters that cultures saw in the stars regularly reflected the seasonal activities that would took place on earth at the time when the stars were visible. The stories were woven around the stars and yet were anchored to events on earth.

Egyptians prepared for the annual flood of the Nile by watching the stars. In myth, Osiris is viciously killed by Set and deeply mourned by his wife Isis. In the sky Osiris was represented by the constellation we know as Orion, Isis by the bright star Sirius. Each year in June, the star of Isis reappeared on the horizon, saw her husband and was reminded of her grief. She began to cry and her copious tears caused the Nile to flood, inundating the land and beginning the prosperous agricultural cycle.

In *Works and Days* Hesiod, writing in Greece in the 8th century BC, used the stars to provide the farmer with a precise schedule of events.

The Pleiades, a bright star cluster, and Orion were used to time events on the farm.

when the Pleiades … and Orion set, it is time to start ploughing [614–17]

when the Pleiades rise, begin the harvest. [383–4]

when Orion first appears, make the servants thresh the sacred grain of Demeter. [597–8]

A stone or wooden tablet, called a parapegma, was set in public places and marked with the seasonal astronomical events, such as the rising of certain stars. As each event was observed, a peg was moved beside the event allowing Greek farmers to track their year.

At Kurringai, Sydney, the figure of an emu is carved into the rock. It is a representation of the emu that the local people saw in the sky amid a mass of celestial dust in the Milky Way. Once a year the emu constellation mirrored the orientation of the carved emu and when this happened the people knew that the real emus were about to lay eggs and that they could begin to collect and enjoy this nutritious food.

MARKING TIME

The Universe offers us four different methods of telling time. The day: the 24 hours it takes for the earth to rotate on its axis. The lunar month: the 29.53 days it takes for the moon to orbit the earth. The solar year: the 365.24 days it takes for the earth to orbit around the sun. And the sidereal year: the 365.26 days it takes for the earth to complete its orbit in relation to the stars.

These periods of time can be seen in the sky and felt on earth. The sun rises and sets. The new moon grows to a full moon and then wanes to a crescent. The stars in the sky rise and set. The seasons change and the length of days and nights varies.

After the day, the easiest time marker to observe is the lunar month. But the seasons are of such significance for practical purposes that tracking the solar year is desirable. Unfortunately the lunar month and the solar year do not work together easily.

The Babylonian calendar consisted of 12 lunar months of 29 or 30 days. Each month began with the first sighting of the crescent moon. With only 354 days to the year, the calendar was quickly out of whack with the seasons. By 499 BC the months were regulated by the 19 year or 235 month lunisolar cycle, known as the Metonic cycle. A 13th month was added to 7 of the 19 years which helped synchronize the lunar and solar cycles.

Julius Caesar (100–44 BC) inherited a Babylonian calendar that had fallen well behind the seasonal year. He took advice from Sosigenes of Alexandria who suggested a new calendar based on the solar year, or 365.25 days. Caesar introduced five intercalary days spread throughout the year. The month would no longer coincide with the moon, but the calendar year would align with the seasons. The months would alternate between 30 and 31 days in length. Julius Caesar ensured that his month, July, was a 31 day month. 12 months with alternating 30 and 31 days added up to 366 days, three quarters of a day too long for the solar year. February was stripped of a day, making 29, except for every 4th year when a 30 day month would make up the quarter day. When Augustus came to power in 27 BC, he wanted his month of August to be as long as Caesar's and so took another day from February leaving us with the month lengths we still use.

The solar year is 11 minutes shorter than 365.25 days so, despite these measures, the Roman calendar still slipped through the seasons and by the 16th century there was a 14 day discrepancy between the calendar and the spring equinox. Pope Gregory readjusted the calendar and 4 October 1582 was followed by 15 October while Easter was moved from 25 to 21 March. The winter equinox was forced back 4 calendar days and, along with the 5 intercalary days of the Julian calendar, accounts for our year beginning an arbitrary 9 days after the winter (or summer) solstice. To prevent such a slippage reoccurring, century years not divisible by 400 would no longer be leap years.

The Russians didn't adopt the Gregorian calendar until after the October Revolution of 1917 – which actually dates to 7 November in our calendar.

THE SUN GOD

The sun God Ra was the supreme god of the Egyptians. He sailed in his boat through the day, passing into the Underworld at night, and was reborn each morning in the form of a scarab beetle. On his head Ra wore a sun disc with a cobra rising out of it. This symbol, the uraeus, was adopted by the Pharaoh, Ra's representative on earth. In the Middle Kingdom (2055–1759 BC) the northern Egyptian god Ra was combined with the southern god Amun, the breath of life. The cult of Amun-Re became so strong that its priests threatened the power of the Pharaoh.

Cat. 17

Amenhotep IV craved a new deity to define his rule (1353–1336 BC). He chose Aten, the sun disc as the supreme god. The Pharaoh changed his name to Akhenaten 'he who is beneficial to the Aten'. The worship of other gods was suppressed. Temples were closed and images of Amun-Re were systematically removed. Akhenaten founded a new capital city el-Amarna. He built an enormous temple at Karnak and others at Memphis and Sesebi in Nubia. Rather than the traditional dark shrine, these temples were centred round pillared courts and open to the sun. They were decorated with a new style of art, best described as expressionistic. The god Aten was depicted as an orb with a uraeus and rays ending in hands, either open or holding an ankh, giving life to the Pharaoh and his wife Nefertiti.

Despite his alignment with Aten, Akhenaten could not escape his mortality. When he died the people of Egypt reclaimed their gods. Ra was reinstated as the sun god and Amun as the giver of life. The temples of Aten were pulled down, the artworks destroyed and all trace of Akhenaten and his wife were erased. Fragments of the temples have survived, reused in later buildings. A rare example from the temple at Memphis is on display, it retains the names of Akhenaten and Nefertiti (cat. 1).

When the Roman Emperor Aurelian won a military victory near Emesa in AD 272 he turned to the nearest local god to give thanks for the victory. This was the sun god, Deus Sol Invictus, who was subsequently proclaimed the supreme god of the Roman state in AD 274. The emperors that followed used this sun god as a potent symbol of military power. Even after he had converted to Christianity, Constantine continued to use the symbol of Sol on his coins.

The Church took over the festival of the Unconquered Sun on 25 December and converted it to their own festival of birth and new beginnings: Christmas.

MAKING THE SUN RISE

In the bleak and cold of midwinter, the inhabitants waited in the ever shortening days and ever lengthening nights for the sun to reappear. As the last rays of the midwinter's sun sank behind the Trilithon archway of Stonehenge, the full moon rose directly above the Gateway. The moon sat high and bright in the sky, illuminating the stone circle. The people gathered within, waited through the longest night of all. Ceremonial activities overflowed to celebration when the weak beams of the winter sun entered the stone ring at dawn. The inhabitants were reassured that the days would again begin to lengthen. The gods had been appeased and the abundance of summer was promised.

At dawn on midsummer's day the sun rose bright over the Gateway. The worshippers gave thanks to the sun. They knew now that they would begin to see less of it but the ceremonies they undertook would ensure that the sun would return.

The cremated remains of the ancestors were buried in and around the stone circle. Rituals involved these rulers of the past and gave strength to those of the present. Just as the sun and moon, so human rulers would rise and decline.

Constructions like Stonehenge functioned as a calendar or a clock. The people marked the spots the sun and moon rose and set, and year after year they perfected their markings and monumentalised the ritual observatory in stone. Such structures assisted people to predict the changing seasons and to time their activities accordingly.

The first circular ditch and bank enclosure was constructed at Stonehenge in 3100 BC when timber markers were erected to track the movements of the sun and moon. By 2600 BC the huge stones were erected. These were carted from Marlborough Downs some 30 kilometres away, an expensive venture that required a coordinated effort by the local community. The layout of the stones was perfected from 2600–1800 BC, and made the tracking of the sun and moon more accurate.

IT'S IN YOUR STARS

The greatest and smallest of happenings are shaped to accord with the progress of a beneficent or maleficent star
SENECA, CONSOLATION TO MARCIA 18. 3

The first modern newspaper horoscope appeared in a British newspaper in 1930 to mark the birth of Princess Margaret. Astrology has since enjoyed a new popularity. Just by turning to the back of a magazine you can learn the best time to look for love, to ask for a promotion or to exercise caution.

Today, astrology sits a long way from modern astronomy, but in antiquity astronomy and astrology were part of the same practice. Philosophy, religion, medicine, cosmology and astrology all prompted star gazing and many of the observations and techniques led to the development of astronomy.

If the rising of Sirius foretold the flooding of the Nile, what else could be predicted through star observation?

The word horoscope is from the ancient Greek and literally means the observations of an hour. The aim is to predict general patterns and pre-programmed circumstances of a future life based on the inspection of the celestial bodies on the eastern horizon at a particular time, most often at the hour of birth.

Geometry is central to horoscopy. The Greeks divided the sky into 12 zones, each ascribed to one of the 12 zodiac constellations. In Greece and Rome the calculation of the angles between the zodiac constellations, the planets, the sun and moon caused either positive or negative tensions in the person born under them. Planets at 180° or 90° were a negative force, while those at 120° or 60° to the zodiacal sign were positive. Special power was given to the celestial bodies on the eastern horizon, the ascendant sign. Arabic astrologers paid special attention to the sign through which the sun was moving.

Are you really the sign that you think you are?

The earth's axis is not fixed. Rather, as it rotates it wobbles slightly, similar to a spinning top; the earth precesses. The earth maintains a tilt of 23.5° but rotates slowly around the tilt taking 25,800 years to complete a revolution.

The earth's precession causes the constellations to move westwards and slip slowly through our solar calendar at a rate of one zodiac sign every 2,150 years.

When the Greeks devised the system of the zodiac they started in Aries and gave the first 30º to Aries, 30–60° to Taurus, Gemini 60–90° and so on.

As the wobble of precession has caused the intersection between the celestial equator and the ecliptic to move westward along the ecliptic some 36°, your assigned star sign may not be the zodiac you were born under.

Cat. 3

Medicine by Starlight

In the Ancient and Medieval periods different star signs were assigned to different parts of the body.

'the Ram, as chieftain of them all is allotted the head, and the Bull receives as of his estate the handsome neck; evenly bestowed, the arms and shoulders joined are accounted to the Twins; the breast is put down to the Crab, the realm of the sides and the shoulder-blades are the Lion's, the belly comes down to the Maid as her rightful lot; the Balance governs the loins, and Scorpion takes pleasure in the groin; the thighs hie to the Centaur, Capricorn is tyrant to both knees, while the pouring Waterman has the lordship of the shanks, and over the feet the Fishes claim jurisdiction'
MANILIUS, 1ST CENTURY AD

RULING BY STARS

Why did the emperor Augustus use the symbol of Capricorn on his coins and official art, including the Gemma Augustea. Born on 23 September 64 BC he was not a Capricorn, but his intention was clear. Capricorn heralds the end of the long days of winter, it is the sign of the new sun, of a new year, a new beginning, so the rule of Augustus ushered in a Golden Age.

On the cuirass worn by Augustus in the Prima Porta statue, Caelus the god of the sky, and the deities of the sun, moon and dawn hover above the victorious peace Augustus has brought to Rome.

Tiberius, Augustus' successor, relied on astrology for darker means. Juvenal reports that in his last days on the island of Capri, Tiberius surrounded himself with astrologers whose job it was to determine the horoscope of any up and coming politician. Should their readings indicate they were born to be great leaders, Tiberius would see that they were quickly assassinated – the astrological secret police.

Nero was apparently unconcerned by prophesies that he would lose the throne, being sure that he would be able to earn a healthy living as a lyre player!

One had to be careful when making enemies of astrologers. In AD 69 Vitellius banned astrologers and they retaliated by predicting his imminent death. He killed all the astrologers he could find but died himself only 3 months later!

Domitian's death on 18 September AD 96, was also foreseen by the astrologers he tried to eradicate:

Astrological predictions had long since warned him in what year and day he would die; they even specified the hour ... On the day before Domitian's assassination … he remarked: There will be blood on the moon as she enters Aquarius, and a deed will be done for everyone to talk about throughout the entire world… The next morning he condemned to death an astrologer who had said that the lightning predicted a change of rulers. Domitian scratched a festering wart on his forehead and made it bleed, muttering: I hope this is all the blood required. Presently he asked for the time. As had been prearranged, his freedmen answered untruthfully: The 6th hour, because they knew it was the 5th he feared. Convinced that the danger had passed, Domitian went off quickly and happily to take a bath; whereupon his head valet, Parthenius, delivered the news that a man had called on very urgent business, and would not be put off. So instead Domitian dismissed his attendants and hurried to his bedroom – where he was killed.
SUETONIUS, LIFE OF DOMITIAN

People in power have continued to look to the stars. In 1588, Queen Elizabeth I consulted her astrologer John Dee and the battle against the Spanish Armada was delayed until the sun moved into a beneficial alignment with Elizabeth's moon. American president Ronald Reagan was influenced by the advice of astrologer Joan Quigley, a confident of his wife Nancy. The couple were convinced when Quigley showed them retrospective star charts that warned of danger to the President in March 1981, the month he survived an assassination attempt. Former Chief of Staff, Donald. T. Regan, reported that the most powerful man in the world was regularly a prisoner of the White House as the couple's faith in astrology prevented him from going out.

PHILOSOPHICAL ASTRONOMERS

The great thinkers of Greece who turned their eyes to the sky did not carry out experiments but rather used their minds to seek rational answers for the observations they made.

Thales (625–547 BC), a Greek philosopher, travelled to Babylon and Egypt to learn what the ancient civilisations had long observed in the skies. According to Plato, Thales was so busy staring at the stars, he fell down a well. It is likely that Thales did indeed spend time working down a well. The well's narrow opening allowed Thales to focus on a small section of the sky and watch the stars move across it.

Aristotle (384–322BC) believed, as did his predecessor Empedocles, that all matter consisted of 4 elements: Earth and Water, which moved downwards, and Fire and Air which moved upwards.

Aristotle reasoned that the earth was at the centre of the universe, and considered it too heavy to move. The earth was surrounded by an ocean of water, a sphere of air and an outer sphere of fire. Seven spheres carried the sun, the moon and the five visible planets (Mercury, Venus, Mars, Jupiter, Saturn) and an 8th sphere beyond carried the fixed stars.

Aristotle observed that the sky did not appear the same from different places, proof that the earth was not flat. He observed a lunar eclipse, saw the shape of the shadow cast across the moon and confirmed Plato's theory that the earth was the perfect shape, a sphere.

Aristarchus of Samos (310–230BC) calculated the distance and size of the sun and moon. Being certain that the sun was bigger, he proposed that the sun, rather than the earth was at the centre of the universe.

Respect for Aristotle, who had dismissed similar theories by stating that if the earth was moving we'd all be blown off, prevented this accurate view from being accepted and astronomers continued to place the earth at the centre of things.

Eratosthenes (273–195BC) busied himself with mathematics. He calculated the circumference of the earth by observing the shadow cast at two different locations at noon. The difference of this angle was 1/50 a full circle so the distance between the two cities, 5,000 stadia, was 1/50 of the earth's circumference making a circumference of 252,000 stadia or 39,690km not far off the 39,940km of the modern measurement.

The great astronomer Ptolemy (2nd century AD) summarised astrological understanding in his treatise *The Almagest*, a body of work that was consulted for almost 14 centuries. He followed Aristotle, placing the earth at the centre of the universe. To solve the mystery of the planets, which do not follow the simple and regular path of the stars but travel at irregular speeds and change direction, Ptolemy placed them on turning circles on a turning sphere.

ASTRONOMY IN THE HOUSE OF WISDOM

Arabic observatories, sponsored by the wealthy, were setup where observations could be made, instruments perfected and research written. Taqial-din finished his observatory in time to observe the comet of 1577, which he said was a positive omen for the sultan. War, plague and civil unrest suggested otherwise and the religious men forced the observatory closed, believing it best not to probe into Allah's secrets.

The teachings of the Greek philosophers were kept alive in the Islamic world. In 762 the new capital, Baghdad, was founded. Here the court came in contact with Greek works studied at the Alexandrian school at Jundishapur. The caliph Harun al-Rashid sent agents into the Byzantine world to bring back Greek manuscripts to Baghdad's House of Wisdom.

The people of Baghdad had inherited a lunar calendar that had been readjusted to follow the seasons by adding intercalary days. Muhammed preached against the addition of intercalary days that realigned a lunar calendar with the seasons. So the Islamic year was, and still is, 11 days shorter than the solar year. The months and festivals such as Ramadan move through the seasons.

Each month in the Islamic year began with the new crescent moon. A cloudy night could prevent the correct identification of a new month and lead to variation in the date from one city to another. By reading the Greek texts the astronomers were able to employ Ptolemy's theory of lunar motion, and refine it, to calculate the beginning of a new month.

Islam required the call to prayer to summon the faithful at the right times. While sunset, nightfall and daybreak could be observed, mid-morning, midday and afternoon were more difficult to calculate. Early in the 9th century, al-Khwarizmi developed an algorithm (the word is actually a corruption of his name) to calculate prayer times.

The calculations required the user to know their latitude and the sun's position on the ecliptic for that time of the year. The points between the observer, the sun and the pole formed a triangle and by employing the rules of trigonometry al-Khwarimi's calculated his tables. By observing the altitude of the sun and consulting the tables, a person could tell the time.

The time-keeper, muwaqqit, became an official at the mosque, providing a secure and respected position from which further astronomical observations could be made. Ibn al-Shatir, circa 1350, muwaqqit at Damascus, made modifications to the Ptolemaic model of the world. The mathematical solutions he found to calculate the movement of the moon and the planets, bare close comparison with those employed by Copernicus, though there is no evidence that Ibn al-Shatir's work reached Europe.

Abd al-Rahman ibn Yunus, circa 980, recorded hundreds of observations of planetary conjunctions and eclipses which remained in use in Cairo in the 19th century. Muhammad al-Battani (850–929) wrote a treatise on the orbit of the sun. This work reached Spain and became a reference book for Copernicus. The interaction between Islamic and European culture in Spain reawakened Western astronomy.

THE WESTERN REAWAKENING

In the 13th century, Thomas Aquinas christianised Ptolemy's view of the world. He placed the earth at the centre of God's creation. Angelic beings governed the stars, the sun, the planets and the moon which in turn had an impact on the animals, plants and stones of the earth. Man, created in the image of God, was the focus of God's universe.

COPERNICUS 1473–1543 preferred Aristarchus' theory of the earth orbiting the sun rather than the Ptolemaic, now Christian, view of the earth at the centre. Copernicus placed each of the planets, including the earth on a circular path that took it around the sun. The further away from the sun, the longer it took for the planet to orbit. The earth was one of these planets, rotating all the time to create the day as it faced the sun and the night as it turned from the sun, and the cycle of the seasons as it completed its orbit of the sun. Copernicus' theory provided a partial explanation for the irregular movement of the planets, caused by the earth and the other planets passing each other on their orbit around the sun.

In 1543, Copernicus published *On the Revolution of the Orbs*. Expecting trouble from the church the publisher included a preface stating that the book was simply to be used for making calculations and was in no way a reflection of reality. Nonetheless, in 1616 it was banned by the Catholic Church.

KEPLER 1571–1630 respected the observations of Copernicus but believed that his calculations were wrong and was on the look out for data to modify his findings. Tycho Brahe, a Danish nobleman who had built an observatory to measure the stars and planets, welcomed Kepler in 1594. After considerable frustrations and miscalculations, Kepler stumbled upon the problem with Copernicus' system: the planets did not travel in circles around the sun but in ellipses.

GALILEO 1564–1642 heard of an instrument that combined two pieces of glass, one concave the other convex, and had the miraculous result of bringing far things closer. Galileo turned the telescopes he fashioned to the sky. He saw the moon and the stars in a way they had never before been seen. He discovered that Jupiter had moons and tracked their orbit around the larger planet. His observations proved that the earth was moving around the sun and not sitting at the centre of things as the Church continued to preach. He published *The Celestial Messenger* a treatise that found him no favour with the Pope.

In 1624 Galileo began a second book that presented a conversation between three characters. Salviati was a believer in the findings of Copernicus, Sagredo believed in the Ptolemaic view but was happy to listen and learn and, the derogatorily named Simplicio, who was a firm believer in the Ptolemaic system and who blatantly presented the beliefs of the Church. The Pope reacted in fury and Galileo stood trial for heresy. Perhaps hoping that he would be able to convince his accusers of the truth of his views, he defended himself at trial, to no avail. He was forced to retract his beliefs and was placed under house arrest for the rest of his life.

ISAAC NEWTON 1643–1727, a dreamy student, brought the endeavours of his forebears to fruition. The observation in 1666–67, of an apple falling from a tree, revealed to him the force of gravity. As his mind worked on, he theorised that the greater the mass, the greater its gravitational pull, and through this theory he was able to explain why the planets orbit the larger sun and why the moon makes its journey around the earth. Newton shared his success with his forebears:

If I have seen farther, it is because I have stood on the shoulders of giants

THE ASTROLABE

Hipparchus (194–120 BC) is credited with the invention of the astrolabe. This instrument measured the altitudes of celestial bodies and assisted Hipparchus in mapping the stars.

The Greek astrolabe consisted of a disc of brass that was suspended from a ring. An alidade (a rod) was pinned at the centre of the back of the astrolabe. The user swivelled the alidade and pointed it at a star or planet. They then read the altitude of this celestial body from the scale that was engraved on the outer circumference of the disc.

The days of the year, and the position of the sun on the ecliptic (i.e. in relation to the zodiac) could be marked on the outer circumference of the astrolabe. The astrolabe, in its simplest form, tracked the sun in relation to the calendar: it told time.

A planispheric astrolabe was more elaborate. After reading the altitude of a single star, the front of the astrolabe was rotated and that star was positioned on the astrolabe as it had been sighted. As a result all the stars, both those that were visible and those that were yet to rise, were plotted correctly by the astrolabe. This had many useful applications for astronomers and assisted astrologers in formulating horoscopes. Astrolabes were perfected by 11th and 12th century Arabic astronomers.

The Mariner's Astrolabe, such as the one on display (cat. 17), was a simpler tool used to determine the latitude of a ship at sea. It was most popular in the late 17th and 18th centuries. To calculate latitude, the altitude of the sun was measured at noon by looking along the alidade to the sun and consulted the scale inscribed around the edge. The sailor then referred to a table which told him the position of the sun above or below the celestial equator for that particular time of year. By combining the measured latitude with the information from the table, he could calculate the altitude of the celestial equator and thus the ship's latitude.

THE ANTIKYTHERA MECHANISM

In 1900, Captain Dimitrios Kontos and his crew were sailing home after a season of sponge diving off the North African coast. A wild storm blew them off course and forced them to shelter in a bay of the rocky island of Antikythera. As they waited for the seas to settle, the divers decided to explore. The first who dived down returned spluttering to the surface saying that naked female bodies were on the sea floor. After closer inspection it was revealed that in fact these were sculptures. The crew had stumbled on the wreck of a 1st century AD ship.

They reported their discovery to the Greek government who commissioned the divers to salvage all they could. Beautiful sculptures, furniture and jewellery were the items that captured the headlines. But a small wooden box measuring about 32 x 16 x 10 cm was the real treasure. Inside this box, the calcified remnants of the Antikythera Mechanism were revealed.

The Antikythera Mechanism, now housed in the National Museum, Athens, is an elaborate device that consists of some 32 bronze gears. These gears were fitted together to create a machine that accurately reproduced, on any given date, the movement of the sun, the moon, the five planets and the stars. The dials on the back of the device plotted the solar and lunar cycles that formed the basis of the ancient calendar. This mechanism showed how the universe worked.

The Antikythera Mechanism is a unique find. However, Cicero (106–43 BC) writes about such devices. Certainly the complexity of the Antikythera Mechanism suggests that it is the result of many experiments; earlier models and later refinements have simply not survived.

1. Fragment from a temple of Aten at Memphis
14th century BC
Rays of the sun are highlighted with red paint. A falcon-headed ewer is being offered to the sun. On the ewer, the names Akhenaten (row 2, column 2) and Nefertiti (row 2, column 3) are preserved.
NMR.1143

2. Bronze figurine of the goddess Isis with her son Horus
Late Period 747–332 BC
The Egyptians associated the star Sirius with Isis, as the star forewarned the flooding of the Nile.

3. Apulian red figure bell krater fragment
c. 425–400 BC
One of the Dioskouroi, the twins of Gemini, with star above.
NM52.65

4. Apulian red figure bell krater
Dijon Painter, 380–365 BC
A celestial festival with a satyr and maenad.
NM46.3

5. Roman silver coin
Denarius, uncertain mint, After 27 BC
Capricorn on the reverse of a silver coin of Augustus.
ON LOAN FROM MACQUARIE UNIVERSITY MUSEUM OF ANCIENT CULTURES, C.21

6. Greek bronze coin
Antioch on the Orontes, 4 BC–AD 16
Aries the ram under a crescent moon.
NM2003.22

7. Greek bronze coin
Ephiphanes and Callinicus, Kings of Commagene, AD 72
Capricorn with star and anchor below.
NM2004.635

8. Red figure lekythos
Athens, 430–425 BC
The moon goddess Selene.
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Cat. 9

9. Bronze coin of Constantine I
Ticinum mint, AD 313–317
On the reverse is the god of the sun, Sol Deus Invictus.
NM 2004.1441

10. Bronze figurine of the god Amun, the breath of life
Late Period
NM94.29

11-14. Scarab beetles from a tomb at Jericho.
The Egyptians believed a scarab beetle deity, Khepri, rolled the sun across the sky just as the beetles pushed balls of dung across the land. As these beetles were thought to be born from dead matter, they became a symbol of new life. Khepri was the sun renewed at dawn, an aspect of the sun god Ra.
NM53.264, NM53.270, NM53.272, NM53.276


Cat. 13

15. Model of the Antikythera Mechanism
Designed by Dr Allan Bromley, Made by Frank A Percival, 1989
Demonstrates the complexity of the gears and dials of the Mechanism that maneuvered the upper cycle of the 19 year calendar and the lower cycle used to predict solar and lunar eclipses. The recent research of Allan's collaborator, Michael Wright, has advanced the understanding of the Mechanism beyond that shown in this model.
ON LOAN FROM THE ESTATE OF DR ALLAN G. BROMLEY

16. The Felix Astrolabe
Early 18th century
Brass mariner's astrolabe.
ON LOAN FROM THE HALLORAN COLLECTION, LADY DENMAN HERITAGE COMPLEX, HUSKISSON

17. Texts from the *Book of the Dead*
Third Intermediate Period, 11th–8th century BC
Papyrus depicting Amun-Re with the owner of the text, the female religious singer of Amun-Re and noble Mut-em-heb.
NMR.402

18. Peter Apain, *Cosmographia*
1524 (this edition 1550)
Apian was a student of Cosmography, a broad science of the Universe. The publication Cosmographia presented an introduction to astronomy, cartography, surveying, geography, navigation, weather, mathematical instruments and so on. The astronomical theories are based predominantly on those of Ptolemy. Elaborate cardboard models, called volvelles, were included in Apian's books to compute the positions of planets.
ON LOAN FROM UNIVERSITY OF SYDNEY, RARE BOOKS

19. Gallileo Galilei, *Systema Cosmicum (Dialogi dei Massimi Sistemi)*
1624 (this edition 1699)
This book was declared heretical as in it Galileo proved that the earth moved around the sun. He further enraged the Pope by naming the character who presented the theories of the Church, Simplicio. In the frontispiece, opposite Galileo's portrait, Aristotle, Ptolemy and Copernicus are depicted.
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20. Johannes Kepler, *Tabulae Rudolphinae*
1627
In this book Kepler presented tables that helped compute the positions of the planets. Kepler's Temple of Astronomy, depicted in the frontispiece, pays homage to his predecessors. At the left are Hipparchus and Ptolemy; in the centre Copernicus and to the right Tycho Brahe. On the top left Physica holds a globe casting a shadow and Optica carries a telescope. Along the bottom Kepler works at a desk alongside a map of the Danish island of Hven, where Tycho Brahe made his observations.
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21. Johannes Kepler, *Astronomia Nova*

1609

In this book, Kepler presented his observations of the planet Mars. Most importantly in this work, Kepler abandons the theory that the planets moved in a circular path, a notion central to the theories of Aristotle, Ptolemy and Copernicus. Kepler proved that Mars and the other planets have elliptical orbits.

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22. Untitled [Waterholes at Liluldja]

Gulunggul, 1946

Collected by R M Berndt, North East Arnham Land, Trial Bay

plywood, ochre

In North East Arnhem Land, the people of the Dhuwa moiety believe that the sun was the mother of their ancestral beings, the Djankawa. When the ancestral beings first travelled to the mainland, the sun rose and its rays fell on all the places in Arnhem Land to which the Djangkawa would travel.

The artist Gulunggul told Roland Berndt that this painting depicts what the Djangkawa saw. The hatching shows the rays of the sun, or the reflection of the sun on the water. The sun rays change during the day: the sun is weak at dawn, and then heats up in the morning, it is hot at midday and through the afternoon, and cools off at sunset. At the bottom of the painting water goannas dive in the water.

This is the reading of the image that can be told to the public. Members of the Dhuwa moiety, however, have deeper and varied understandings of this image, depending on their position in the ritual hierarchy. A child would read one story, a woman another, an initiated man would know the secret-sacred readings of the image, whilst an elder would hold the 'inside' knowledge.

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Cat. 1

Further Reading

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The Antikythera Research Project: www.antikythera-mechanism.gr