

Background notes on astronomers

Manava (around 750 BC) Manava lived in India and was probably a Vedic priest, so he was interested in mathematics for religious rites. He is the author of one of the Sulbasutras. Manava was interested in squares and circles and found a value for π (pi) which was fairly accurate (3.125 compared to the modern value of 3.142).

Pythagoras (569 BC - 475 BC) Pythagoras of Samos (Greece) is often described as the first pure mathematician. He was influenced by philosophers who were interested in mathematics, and became very interested in Egyptian thought and religion when he lived in Egypt (535 BC to 525 BC). Pythagoras was taken to Babylon as a prisoner after Egypt was invaded, but he returned to Samos around 520 BC, and set up a school (more like a modern university) to discuss politics, philosophy, and mathematics. Pythagoras moved to Italy in 518 BC, and founded another school. Apart from his famous theorem, Pythagoras was interested in numbers, ratios. In astronomy, Pythagoras taught that the Earth was a sphere at the centre of the universe. He also realised that the Evening Star and the Morning Star were the same planet, Venus. He proved that the Earth was round using the shadow of the Earth on the Moon during a lunar eclipse, the fact that ships' masts appear over the horizon before the (bigger) hull, and that there are elephants in Africa (furthest west) and India (furthest east) so Africa and India must be very close to each other.

Eudoxus (408 BC - 355 BC) Eudoxus of Cnidus (in Turkey) started studying medicine in Athens, but then learnt astronomy from priests in Egypt. He made observations and built an observatory at Cnidus. His books concerned the rising and setting of constellations, which were helpful to those navigating around the Mediterranean Sea. He established a popular university. He developed a system to explain the motions of the planets around the Earth, called the spheres of Eudoxus, which involved around 27 spheres and was very complicated (and wrong!). Aristotle described Eudoxus' system in his book, but whereas Eudoxus thought of the system as a geometrical model, Aristotle thought it was a description of the real world.

Aristotle (384 BC - 322 BC) Aristotle was interested in physical subjects, but also had a good grasp of mathematics. He lived in Greece, and at the age of 17 (in 367 BC) he joined Plato's Academy in Athens. There, he laid the foundations of the biological sciences which were not superseded for more than 2000 years after his death. In 335 BC in Athens, Aristotle founded a school (like a modern university), the Lyceum, where all nature could be studied. Aristotle lectured on logic, physics, astronomy, meteorology, zoology, metaphysics, theology, psychology, politics, economics, ethics, rhetoric, and poetics. He was most interested in the orbits of planets and in comets. His books and lectures were published in 60 BC, after his death, by the final head of the Lyceum. Aristotle liked to follow fashion - he wore rings on his fingers and his hair was cut fashionably short.

Heng (78 AD - 139 AD) Zhang Heng lived in China, and was a mathematician, astronomer and geographer. He became chief astrologer and minister under the Emperor An'ti of China, which was not a safe job in those days. Zhang Heng described the positions of the stars and corrected the calendar in 123 AD to bring it into line with the seasons. He also invented a seismoscope for detecting earthquakes. This consisted of a cylinder with eight dragon heads around the top, each with a ball in its mouth. Underneath were eight frogs. When an earthquake occurred a ball noisily dropped from a dragon's mouth to a frog's mouth.

Hypatia (370 AD - 415 AD) Hypatia of Alexandria lived in Egypt, and was the first woman to make a substantial contribution to the development of mathematics. She was the daughter of the mathematician and philosopher, Theon of Alexandria, and studied mathematics under his guidance. She became head of the Platonist school (like a university) in Alexandria in about 400 AD where she was known as a charismatic lecturer in mathematics and philosophy. Hypatia helped her father to write an 11-part commentary on Ptolemy's great work, the 'Almagest', as well as writing her own commentaries on Ptolemy's other astronomical works. She also helped her father produce a new version of Euclid's 'Elements'. She was murdered by a mob of fanatical Christians who felt threatened by her scholarship, learning and depth of scientific knowledge. After her death many scholars left Alexandria, and it marked the end of the city as a centre of learning.

Tsu (430 AD - 501 AD) Tsu Ch'ung Chi was a Chinese mathematician and astronomer. He gave a value for π (pi) which was correct to six decimal places. He determined the precise time of the solstices by measuring the length of shadows at noon on several days near the solstice to reduce the errors.

Aryabhata (476AD - 550AD) Aryabhata the elder wrote some significant astronomical texts. He lived in Kusumapura (now called Patna), India, which was a major mathematical centre close to the capital of the Gupta empire. He wrote three books, including the masterpiece Arabhatiya. Aryabhata also wrote an astronomical treatise with 118 verses, including 25 verses on the reckoning of time and planetary models, and 50 verses on the sphere and eclipses. He believed the orbits of the planets were ellipses. Aryabhata also explained the causes of eclipses correctly, unlike others of his time who believed they were caused by the demon Rahu.

Abu'l-Wafa (940 AD - 998 AD) Mohammad Abu'l-Wafa Al-Buzjani was born in Iran and died in Iraq. He was a mathematician with an interest in astronomy, and worked at the court of the Caliph - Sharaf ad-Dawlah - in Baghdad. The Caliph required an observatory, which was set up in the garden of the palace in 988 AD, housing some very impressive instruments. Abu'l-Wafa was probably the first person to build a wall quadrant to observe the stars. However, the caliph died the next year and the observatory was closed. Abu'l Wafa continued his mathematical work by 'inventing' the tangent and compiling tables of sines and tangents. He used these functions to investigate the orbit of the moon, and recorded his work in 'Theories of the Moon'. His observational data on stars in 'Kitab al-Kamil' (Complete book) simplified Ptolemy's Almagest, and was used by many later astronomers.

Bacon (1214 - 1294) Roger Bacon lived in England, and studied geometry, arithmetic, music and astronomy. He received a degree from the University of Paris in 1241, but became interested in mathematics and science when he went to Oxford in 1247. He carried out systematic work on lenses and mirrors, and spent time planning his experiments (a remarkably modern approach - the scientific method). He gave a proposal for a telescope in his 'Opus maius' (Great Work). Bacon believed the Earth was a sphere, and that you could sail round it. Around 1276, Bacon was put into prison by his fellow Franciscan friars, charged with 'suspected novelties' in his teaching. However, Bacon continued to put forward his views.

Beg (1393 - 1449) Ulugh Beg lived in Iran and was the grandson of Timur, who invaded India shortly after Ulugh Beg was born. At the age of 16, Beg's father put him in control of Samarkand, and Beg invited several astronomers and mathematicians to the city. He built an observatory in Samarkand in 1428, and led scientific discussions on astronomy. Ulugh Beg's 'Catalogue of the stars' was the first comprehensive stellar catalogue since Ptolemy's. However his science was better than his politics and when his father died, Ulugh Beg could not hold onto power and was killed by his own son.

Peurbach (1423 - 1461) Georg Peurbach lived in Austria. He was appointed court astronomer by King Ladislaus of Hungary in 1454, and was professor of astronomy at the University of Vienna. He observed Halley's comet in June 1456, and wrote about astronomy and eclipses. He believed the planets were situated in solid crystalline spheres, but he also believed that the motions of the planets were controlled by the Sun.

Regiomontanus (1436 - 1476) Johann Müller Regiomontanus was born in Germany and died in Italy. He was a pupil of Peurbach, and became professor of astronomy at the University of Vienna when Peurbach retired. In 1468 Regiomontanus became astronomer to King Matthias Corvinus of Hungary. In 1472 he observed Halley's comet, and his observations were so accurate that his data were tied in with data taken 210 years later, proving the observers saw the same comet. He was interested in eclipses, and found the motion of the Moon could be used to predict longitude at sea. The pope summoned him to advise on calendar reform, but he died before he took up the post. Some say he died of the plague, others that his enemies poisoned him.

Copernicus (1473 - 1543) Nicolaus Copernicus was born in Poland. He went to university in Krakow and studied Latin, mathematics, astronomy, geography and philosophy, with a view to a career in the church like his father. He became a church official at Fraunburg cathedral, but lived in Bologna. He got hooked on astronomy when he went to Rome in 1500, studying mainly from a book written in 1220. He also built an observatory at Fraunburg, in one of the towers in the town's fortifications. In 1514 he distributed a hand-written book 'Little commentary' in which he described Copernicus' theory of the universe with the Sun (not the Earth) at the centre. In 1515 he began writing his major work, 'De revolutionibus orbium coelestium', which was finally published in 1543. Whilst writing this book, he advised the pope on calendar reform, was involved in frequent local wars, and reformed the currency. Copernicus died of a cerebral haemorrhage, and received a copy of his printed book on his deathbed.

Napier (1550 - 1617) John Napier lived in Scotland and was the son of Sir Archibald Napier, the Master of the Mint. Napier began studying theology at St Andrews University when he was 13, but completed his studies elsewhere. Mathematics was Napier's hobby, though, and he worked on spherical triangles and mathematical functions. He invented logarithms (published first in Latin in 1614 and then in English in 1616) which were invaluable for solving equations for planetary orbits. The book encouraged admirers to visit him - one came from London on a journey which lasted at least four days by coach and horses. He teased his servants, who thought he was a warlock, by walking round in his nightgown and cap with a cockerel covered in soot tucked under one arm. Laplace said that Napier's logarithms 'by shortening the labours, doubled the life of the astronomer'.

Galileo (1564 - 1642) Galileo Galilei lived in Italy. He was educated in a monastery, and decided he wanted to become a monk. His father wanted him to become a doctor and sent him to the university in Pisa where Galileo studied mathematics and natural philosophy (science) instead of medicine. Galileo taught mathematics and was given the chair of mathematics at the university of Pisa in 1589. He moved to the university of Padua and lectured on mathematics and astronomy. He lectured on the New Star - a supernova - discovered by Kepler in 1604, and determined that it was very far away, in the realm of the 'fixed stars' where nothing ever changes. Galileo heard about the invention of the telescope by a Dutchman, and built his own. By the end of 1609, Galileo had started observing the heavens and made some remarkable discoveries, such as mountains on the Moon and four small bodies orbiting Jupiter. He published these findings in 1610. Galileo observed the crescent shape of Venus, and deduced it must orbit the Sun and not the Earth. By 1616 his views were fixed, and he supported Copernicus's belief that the Sun - not the Earth - was the centre of the universe. An admirer of Galileo's was elected as Pope Urban VIII, and Galileo had six audiences with him to explain the Copernican theory. He published his famous work 'Dialogue concerning the two chief systems of the world' in 1632 having worked on it for six years. This led to him being condemned to house arrest. His next work 'Discourses and mathematical demonstrations concerning the two new sciences' was smuggled out and published in Leiden, Holland.

Kepler (1571 - 1630) Johannes Kepler lived in Germany, and is remembered for discovering the three laws of planetary motion, published in 1609 and 1619. He calculated the most exact astronomical tables hitherto known, which did much to establish the truth of the system which had the Sun at the centre. As a child, Kepler helped in his grandfather's inn, and bemused the customers with his arithmetical competence. Kepler went to a Protestant university in Tübingen, where he met Copernican theory, and later taught mathematics at Graz. In 1596 he published his first book, *Mystery of the cosmos*, in which he described the moons of Jupiter as satellites (from *satelles*, attendant). Kepler became a mathematical assistant to another famous astronomer, the observer Tycho Brahe, and used Brahe's observations to help develop his theories. The major breakthrough came when Kepler stopped using circles for the planets' orbits and used ellipses instead, with the Sun at one focus. *New Astronomy* was published in Heidelberg in 1609, describing the orbits of the planets. In 1604 Kepler wrote about a new star he had seen. Much later, this proved to be a supernova, and we can see the remains of the explosion today with big telescopes. Having corresponded with Galileo, Kepler built a very successful version of the telescope, now known as the astronomical telescope. In 1619, Kepler published 'Harmony of the world' which had a more advanced mathematical model of the universe. In 1616 he came across Napier's work on logarithms, and rejoiced at this new aid to his work, producing astronomical tables which (for the first time) were accurate over decades rather than a few years.

Newton (1643 - 1727) Sir Isaac Newton lived in England. Newton's father died before he was born, and the boy had an unhappy childhood. Despite being described as 'idle' and 'inattentive', Newton went to university, having had private coaching from the headmaster of his school, who instilled in Newton a passion for learning. Newton went to Cambridge to study law, but became interested in mathematics in 1663. In 1669, when he was only 27, Newton was appointed to the Lucasian Chair of Mathematics at Cambridge. Newton showed that white light was made of a spectrum of colours. He invented a reflecting telescope, and tried to prove the particle nature of light (now called photons), in addition to its wave-like nature. By 1666 Newton had described his three laws of motion and he imagined the Moon's motion was influenced by Earth's gravity. Halley persuaded Newton to write a full treatment of his new physics and its application to astronomy. In 1687 'Philosophiæ naturalis principia mathematica' or 'Principia' was published. Some say this is the greatest scientific book ever written. The work explains a wide variety of previously unrelated phenomena, from the tides to the orbits of comets. In 1701 he was elected president of the Royal Society, and remained so until he died. He was knighted by Queen Anne in 1705, the first scientist to be so honoured.

Halley (1656 - 1742)

W Herschel (1738 - 1822)

C Herschel (1750 -1848) Caroline Herschel lived in Germany and England. Caroline's father, Isaac Herschel, took her outside on frosty nights to see the constellations and comets, little realising the contributions his daughter would later make. When William Herschel became an organist in Bath, his sister joined him in 1772. William taught Caroline music, mathematics and astronomy. In 1785, when they lived in Windsor, William gave his sister a telescope. The next year, whilst in Slough, Caroline discovered her first comet. She discovered a total of eight comets between 1786 and 1797. In 1798 she submitted to the Royal Society an index to Flamsteed's star catalogue, with a list of 560 stars which had been omitted. She became involved with the education of John Herschel (William's son), and continued to work on mathematics. She completed her catalogue of 2500 nebulae, and in 1828 was awarded the gold medal of the Royal Astronomical Society. She was elected to honorary membership of the Royal Society in 1835.

Astronomers

J Herschel (1792 - 1871)

Adams (1819 - 1892)

Le Verrier (1811 - 1877)

Tombaugh (1906 - 1997)

Hubble (1889 - 1953)

Chandrasekhar (1910 - 1995)

Hoyle (1915 - 2001)

Bell Burnell (1943 -)