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making physics matter

Age 7-11 years

Research cards

Claudius Ptolemy

About

Claudius Ptolemy was born in Egypt in 100AD when it was part of the Roman Empire. He was a mathematician, geographer and astronomer and produced several important, ancient manuscripts. Ptolemy died in Alexandria in 186AD.

Working scientifically

Ptolemy carefully studied the work of all the astronomers who had lived before him – particularly the Babylonian and Greek astronomers. He learnt about all the methods that were used to observe and measure objects in the night sky using the naked eye. Ptolemy took all of the observations and measurements collected over the previous 800 years and used his excellent mathematical skills to develop his own model of the universe.

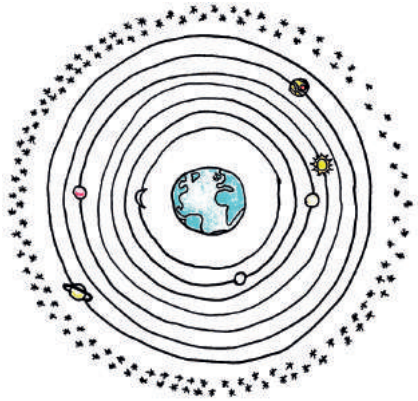
Ptolemy shared his model in an important manuscript called 'Almagest' which is the only surviving ancient text on astronomy. He created sets of tables which could accurately predict the position of any planet in the night sky at any time in the past or future. There were also tables that could predict the position of the Sun and Moon as well as the rising and setting of the stars. In addition, he included tables that predicted solar and lunar eclipses.

The most important feature of Ptolemy's model was that the Earth was at the centre – the geocentric model of the universe. Ptolemy's tables were so effective at predicting positions in the night sky that they were used to prepare astronomical and astrological charts for over 1,500 years.

Model of the universe

Ptolemy placed the Earth at the centre of his geocentric model. Using the data he had, Ptolemy thought that the universe was a set of nested spheres surrounding the Earth. He believed that the Moon was orbiting on a sphere closest to the Earth, followed by Mercury, then Venus and then the Sun. Beyond the Sun were a further three spheres on which Mars, then Jupiter and then Saturn orbited the Earth. Finally, the outmost sphere was where all the stars were located in the 48 constellations that Ptolemy described in his text.

It wasn't until 1543 that Polish astronomer Nicholas Copernicus (1473-1543) proposed a revised model putting the Sun at the centre – the heliocentric model of the universe.



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Research cards

Tycho Brahe

About

Tycho Brahe was born in Denmark in 1546. He was born to a wealthy family and was very well educated. In 1559 he began studying at the University of Copenhagen and became interested in astronomy. Brahe is well known for his accurate and detailed measurements of astronomical objects (the Sun, the Moon, stars and planets). He died in Prague in 1601.

Working scientifically

Tycho Brahe observed the night sky with his naked eye, using tools to make careful measurements of the objects he observed. He was obsessed with making the most accurate measurements he could. He developed more accurate versions of the sextant and quadrant (tools for measuring angles) than there had ever been by making them much larger.

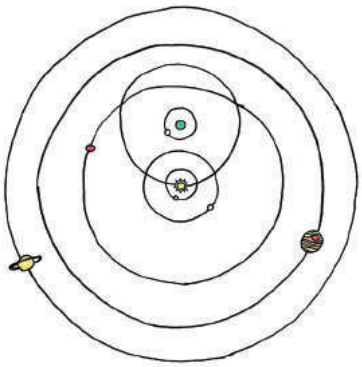
Tycho Brahe admired Copernicus greatly and he was the first person in Denmark to teach people about Copernicus' heliocentric model of the universe. Nevertheless, based on his religious and scientific beliefs, Brahe was certain that the Earth was at the centre of the universe. He combined the ideas of Ptolemy and Copernicus with his own accurate measurements to create a new geo-heliocentric model.

King Fredrick II gave Tycho an estate on the island of Hven so that he could build an observatory and laboratories to make increasingly accurate measurements. Unfortunately, after King Fredrick's death, Tycho Brahe fell out of favour with the Royal Court and went into exile. He became the official Imperial Astronomer in Prague where he was assisted by Johannes Kepler.

Model of the universe

Brahe's model of the universe put the Earth at the centre with both the Moon and Sun in circular orbits going around it. This feature of his model can be described as geocentric. Brahe's model then becomes heliocentric with the Sun (further from the Earth than the Moon) being orbited by the rest of the planets. Mercury was in a circular orbit closest to the Sun, Venus a little further out and then Mars. Beyond that, Jupiter and Saturn also moved in circular orbits around the Sun. Around all of this was a sphere of fixed stars arranged in the shapes of the constellations.

Tycho Brahe's assistant, Johannes Kepler, tried to convince him to use the Copernican model but Tycho could not be persuaded. After Tycho's sudden death from a bladder infection, Kepler used Tycho's data to develop his laws of planetary motion.



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Galileo Galilei

About

Galileo Galilei was born in Italy in 1564. He was a mathematician, astronomer, physicist, engineer and philosopher. His revolutionary ideas about the universe led him to being investigated by the Roman Catholic Church for heresy and declared guilty. Galileo spent the last years of his life under house arrest. He died in 1642 aged 77. In 1992, the Catholic Church expressed regret for how they had treated Galileo all those years earlier. Today, Galileo is considered to be the father of modern science.

Working scientifically

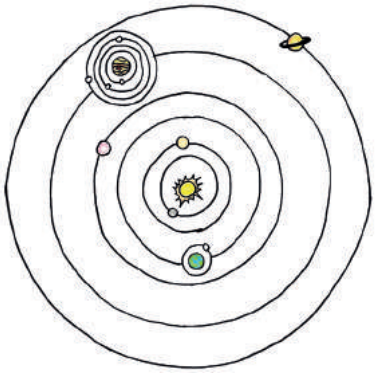
Galileo constructed the first astronomical telescope and used it to observe the night sky. His design included a convex lens at the opening where the starlight entered the telescope tube and a concave eye piece lens at the other end that magnified the image. It made astronomical objects look eight to nine times bigger than with the naked eye.

In 1610, Galileo observed the four largest moons of Jupiter – Io, Europa, Ganymede and Callisto – and concluded that they were orbiting Jupiter because their positions changed night after night. He also used his telescope to observe Venus having a cycle of phases just like the Moon. In 1612, Galileo was the first to spot the previously unseen planet Neptune, but didn't realise that it was another planet. He also observed the rings of Saturn, but he thought it was a moon on either side of the planet.

It was these discoveries that convinced Galileo that Copernicus' heliocentric model of the universe was correct.

Model of the universe

Galileo's model of the universe wasn't really a new model at all. He had found further evidence to support Copernicus' heliocentric model based on his observations and measurements of objects in the sky. He then looked for mathematical patterns in the data that he had collected. Copernicus wrote a book *On the Revolutions of the Celestial Spheres*, that was published just before his death in 1543. In this book Copernicus states that the Earth is not the centre of the universe, only the centre of the 'lunar sphere' (the sphere in which the Moon orbits the Earth). Instead, the Earth and the other planets orbit the Sun. Galileo added to this model having found out that Jupiter had moons orbiting it as well.



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Johannes Kepler

About

Johannes Kepler was born in 1571 in Germany. He was a mathematician, astronomer and astrologer. Starting his life as a mathematics teacher he later became an assistant to astronomer Tycho Brahe. Kepler is best known for his laws of planetary motion which formed the foundations of Isaac Newton's theory of gravitation in 1687. Kepler died in 1630.

Working scientifically

Kepler was an amazing mathematician and started his career teaching in Graz, Austria. In 1600 he moved to Prague to assist exiled Danish astronomer Tycho Brahe in analysing the amazingly accurate astronomical data he was collecting from his new observatory. Brahe was so impressed with Kepler's ideas that he soon shared all his data and the pair worked closely for over a year. However, they did not always agree: Kepler was certain that Copernicus' heliocentric model with the Sun at the centre was correct; Brahe was convinced that the geocentric model with objects all orbiting the Earth was the true model.

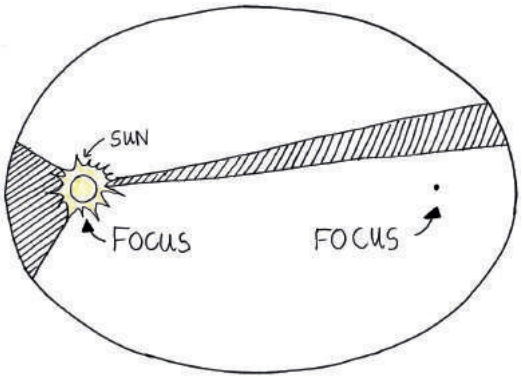
When Brahe suddenly died in 1601, all of his data was given to Johannes Kepler and it became his responsibility to finish Tycho Brahe's work. For the next 11 years Kepler investigated mathematical patterns in the data, making and testing hypotheses until he developed an even better understanding of the arrangement and movement of our solar system than anything that had gone before. His findings and conclusions were published in his book *Astronomia Nova* in 1609.

Model of the universe

Kepler's conclusions about the universe were aligned with Copernicus' model that had the six known planets orbiting the Sun (heliocentric). It was different in that Kepler proposed that the planets moved on elliptical (oval) paths rather than being objects fixed on nested spheres. Kepler summarised his learning with the laws of planetary motion that are still used today.

1. The planets all move in elliptical orbits with the Sun at one focus.

2. An imaginary line drawn from the centre of the Sun to the centre of the planet will sweep out equal areas in equal intervals of time meaning that the planet's speed changes during its orbit.



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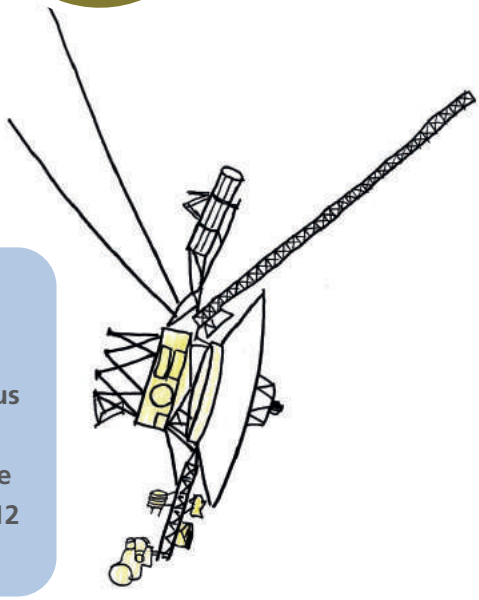
Research cards

Voyager 2



About

Voyager 2 was one of two robotic NASA space probes launched in 1977 to study the outer solar system. They were sent to explore Jupiter, Saturn, Uranus and Neptune and to send useful data back to Earth for analysis. Voyager 2 is the only space probe to have ever visited Uranus or Neptune. The probes have been travelling at 37,000mph for 40 years, and are now in interstellar space, 12 billion miles away.

Working scientifically

Hundreds of people worked on the Voyager mission, designing the spacecraft and launch system, designing and constructing the instruments, planning the trajectory and analysing the data once it was sent back to Earth.

The Voyager probes have many instruments to make a range of accurate measurements and observations, including:

Imaging Science System – two camera system to collect high resolution images

Radio Science System – to analyse planets' atmospheres, masses and gravitational fields

Infrared Spectrometer – to measure temperatures of planets and moons

Ultraviolet Spectrometer – to find out what gases are in the different atmospheres

Magnetometer – to measure magnetic fields.

The onboard computer was state of the art in 1977 but now the processor in an iPhone is 200,000 time faster with 250,000 times more memory.

Model of the universe

Voyager 2 developed our understanding of the outer planets as well as numerous new discoveries, including:

- observing changes to Jupiter's Great Red Spot, collecting high resolution images of the surfaces of many of Jupiter's moons as well as discovering new ones
- discovering that Saturn was orbited by many ringlets and collecting hundreds of high quality images of Saturn and its moons
- obtaining the only close up image of Uranus we have, and finding 10 new moons and a magnetic field that is at 55° to the planet's axis
- skimming about 3,000 miles from the top of Neptune's atmosphere, and spotting five new moons and four rings around the planet never seen before.

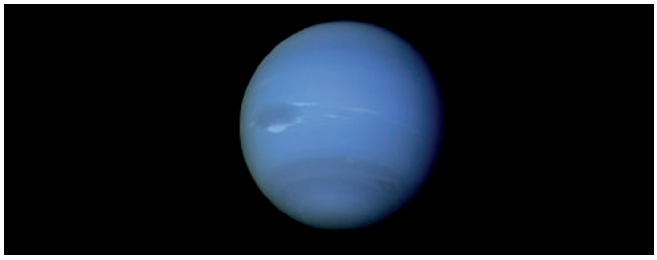


photo: NASA

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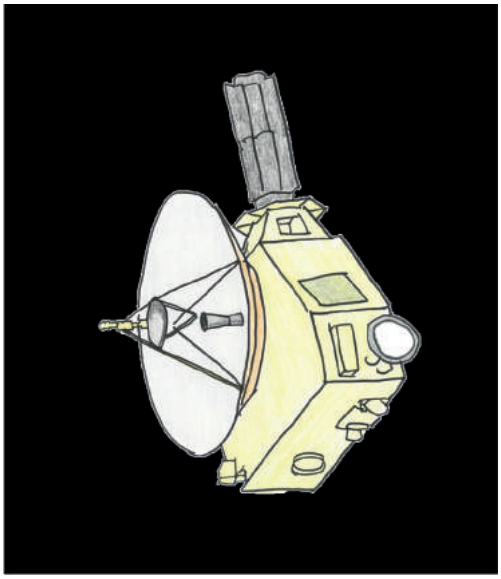
New Horizons



About

New Horizons was a NASA interplanetary space probe, launched in 2006 to study Pluto. Having launched from Cape Canaveral it reached Jupiter in 2007; it used Jupiter's gravitational field to catapult it out towards Pluto, increasing its speed to shorten the journey time. New Horizons flew 12,500km above the surface of Pluto in July 2015, making it the first spacecraft to explore the dwarf planet. The spacecraft was robotically controlled and set all of the accurate data it collected back to Earth for astronomers to analyse using computers.

Working scientifically

Hundreds of people worked on the New Horizons project, designing the spacecraft, planning the journey, developing the instruments and analysing the incoming data.

The spacecraft carried seven instruments to investigate the geology, surface composition, temperature and atmosphere of Pluto and its moon Charon, including:

- Long Range Reconnaissance Imager (LORRI) – to collect high quality images of Pluto and nearby objects
- Solar Wind Around Pluto (SWAP) – to find if the solar wind still exists at such a distance
- Alice – an ultraviolet spectrometer used to find out what gases were in the atmosphere of Pluto. There was also an Alice on Rosetta, an ESA spacecraft that travelled to study a comet.

Model of the universe

Before New Horizons we had found out very little about Pluto since Clyde Tombaugh discovered it from the Lowell Observatory in Flagstaff, USA. New Horizons has found out so much more to further develop our model of the solar system.

- There is geological activity on Pluto's surface with evidence of some young rocky surfaces.
- There appears to be frozen water inside Pluto's moon – Charon – and Pluto may well have an internal water-ice ocean today.
- Pluto has a vast 1,000km-wide nitrogen glacier in the shape of a heart that is the largest glacier in the solar system.

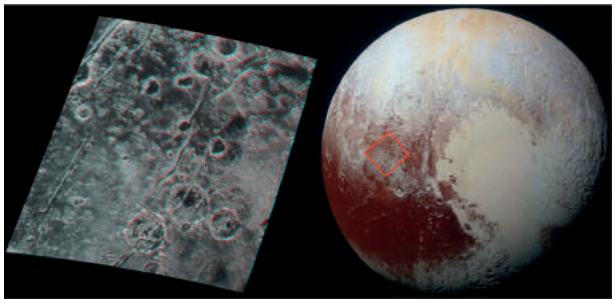


photo: NASA

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Writing framework

Name ..... Research team .....

Who or what are you researching?	
Where were they from/ where did this project take place?	
Between what years were they alive/when did this project take place?	
What was most significant about the discovery/project?	
What working scientifically skills did the scientist(s) show in making their discovery/ working on the project?	
Why was this discovery/ project important?	
What other interesting facts did you discover about this person or project?	
What else would you like to know about this person or project?	