

10
EXTRAORDINARY
Ideas
that SHAPED our
UNIVERSE

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Dedicated to teachers everywhere.

*I hope this can be the physics
textbook you've always wanted
for your students!*

*Kids: always try to be a little kinder
than is necessary. That's how you
become extraordinary people who
shape our universe!*

Welcome to the **10 EXTRAORDINARY IDEAS THAT SHAPED OUR UNIVERSE**

This book will take you from the beginning of time as we know it, right up to the present day – and even slightly into the future. On this journey, you'll learn about forces, electricity, stars, magnetism and relativity, as well as black holes, atoms, sound, light and the mystery that is dark matter!

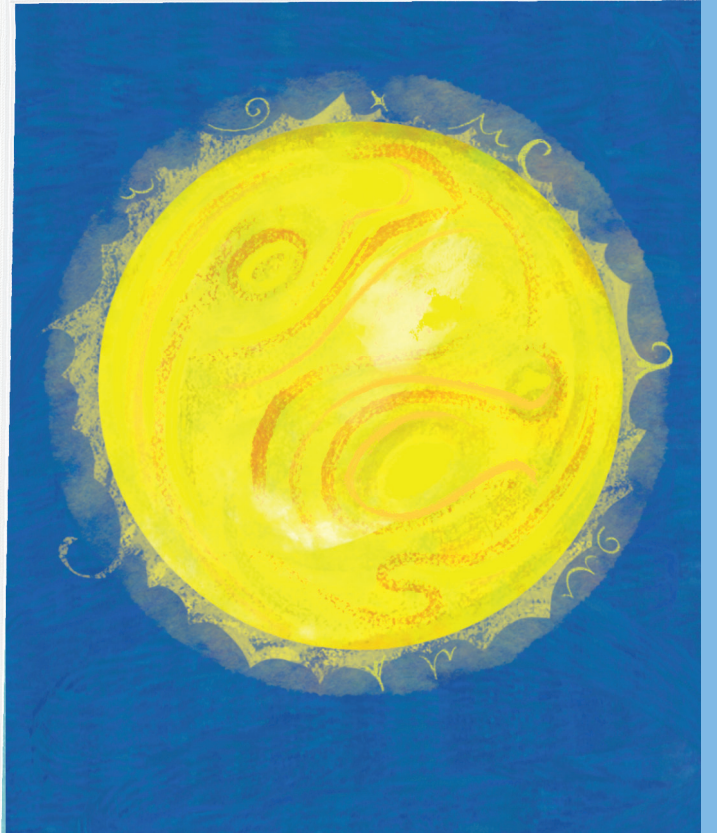
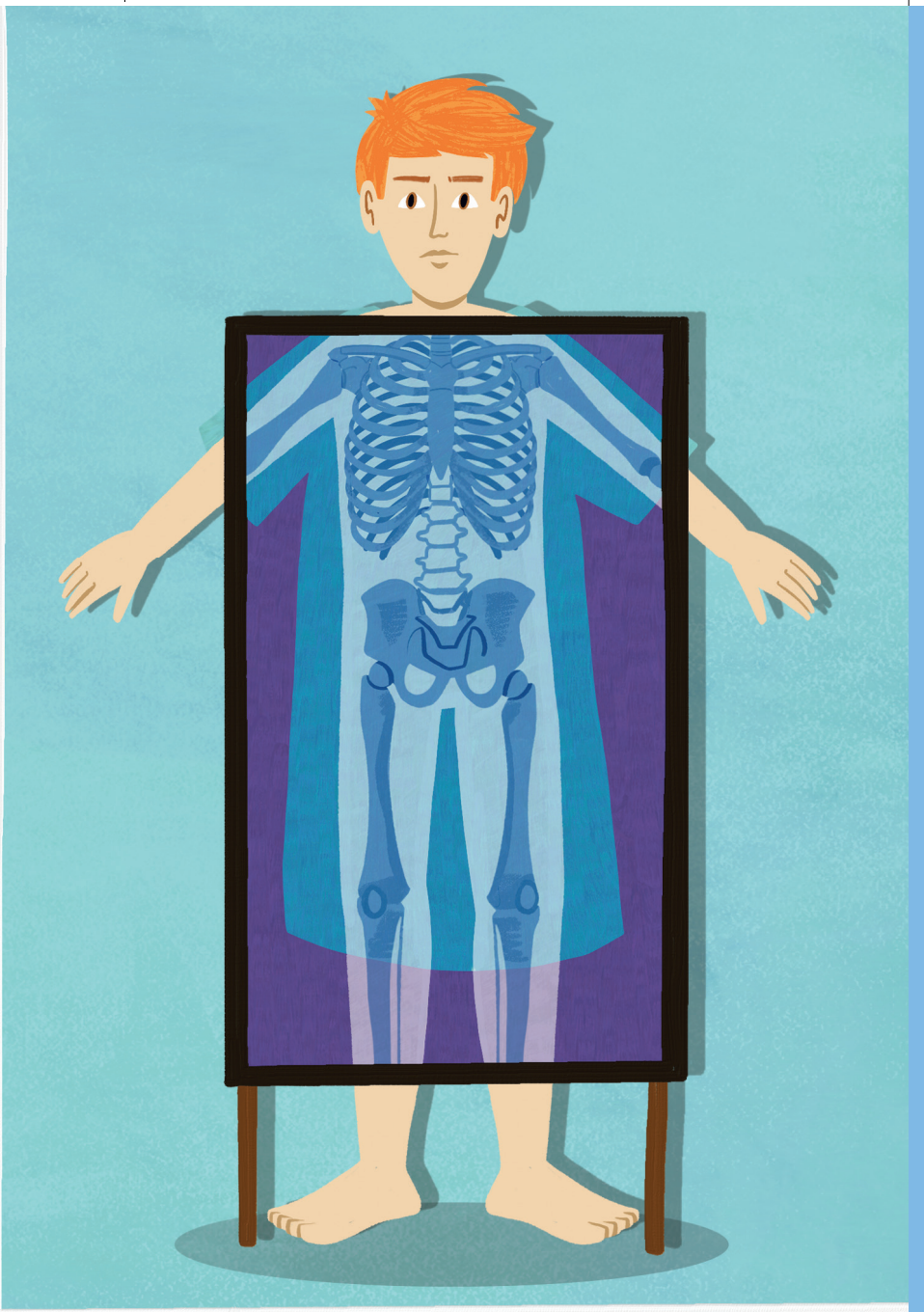
These ten ideas have shaped our history, but within them are lots of smaller discoveries that are just as important to humankind. Along the way, we'll meet some amazing hidden figures who discovered (sometimes by accident!) things that changed our understanding of the world as we know it.

We'll also collect some BIG facts about these topics, which you can use to wow your friends! For example, did you know that there is a sea creature called a chiton, which looks a bit like an underwater woodlouse, that has magnetic material in its teeth? Read on to find out more . . .





INTRODUCTION



The SPEED OF LIGHT

We're kicking off with one of the most mind-blowing ideas – something that might make your head hurt, but in a good way: the speed of light, and how we measure it!

Think about walking into a dark room and flicking on the light switch. What happens? The lights turn on and the room lights up almost instantaneously. But how does light travel? And how fast is it *really*? Let's find out . . .

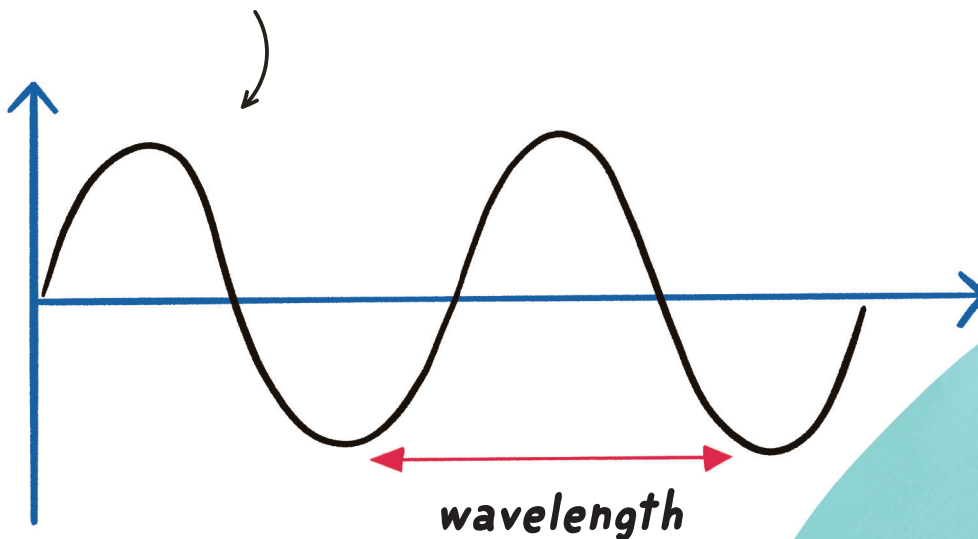
HOW DOES LIGHT TRAVEL?

First things first, light always travels in straight lines. This is why you get a shadow when you put your hand in front of a torch or lamp. The light can't travel through your hand, and it can't curve around it either. So the area where the light can't reach is in darkness, creating a shadow.

Light is really, REALLY fast. I'm talking faster than any world-record-breaking sprinter, faster than a cheetah, faster than when you eat a melting ice cream! Nothing that we know of in the whole UNIVERSE can travel faster than the speed of light.

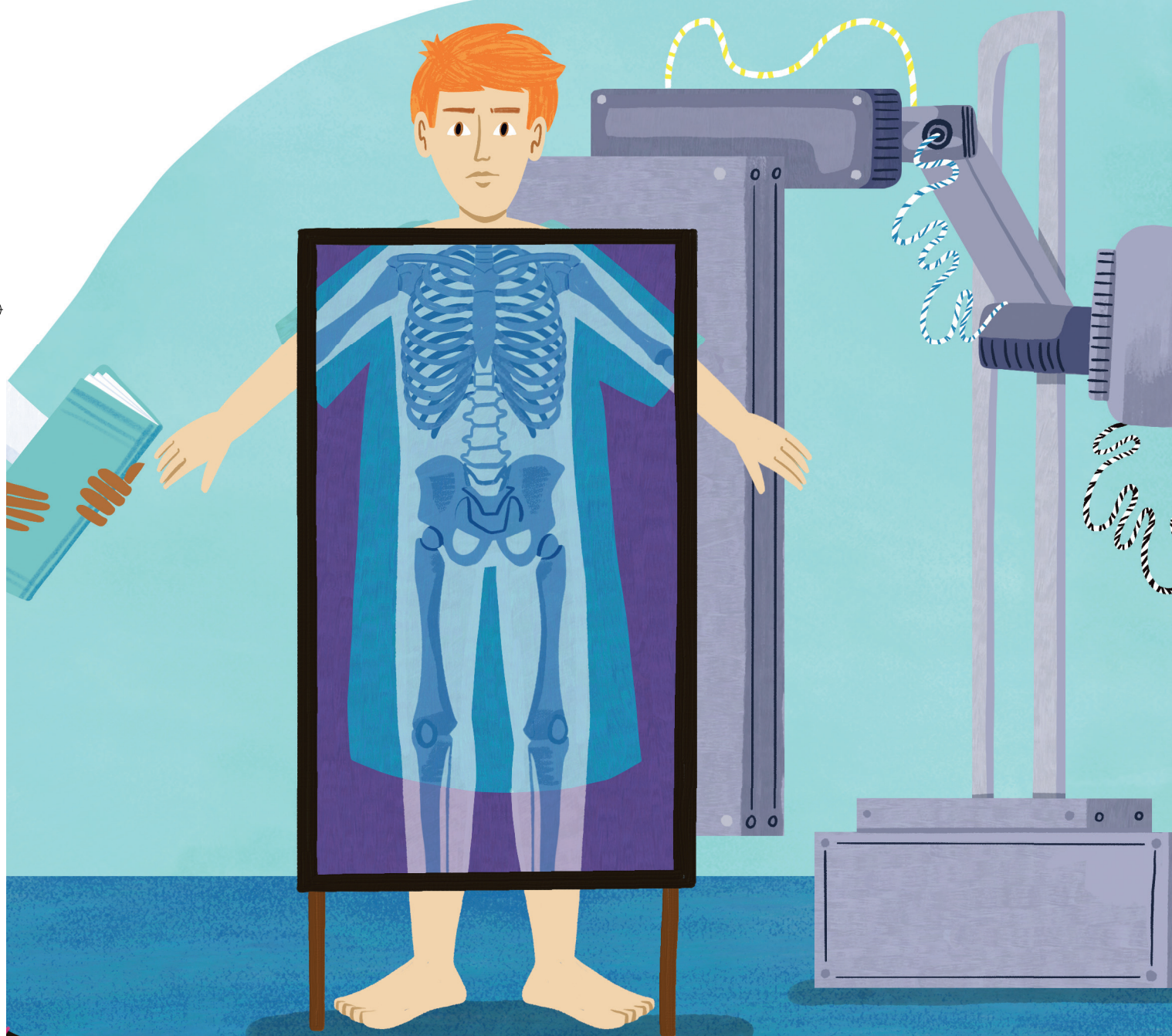
But light doesn't just suddenly appear when you flick a switch – it does actually have to travel. It just travels *really* fast. Think about a thunderstorm. Did you know that thunder is the noise that lightning makes? Light travels much faster than sound, so the lightning gets to our eyes faster than the thunder gets to our ears!

Hundreds of years ago, people believed that light could be made up of lots of tiny particles. But we now know that this isn't true. Light is energy that travels in waves, and it is part of what we call the electromagnetic spectrum. A light wave travels up and down as it moves forward, a bit like ripples on the surface of a lake. We call this a **transverse wave**.



THE ELECTROMAGNETIC SPECTRUM

Energy that travels in waves, such as light, is called radiation – and there are other kinds of radiation too. This is where the electromagnetic spectrum (or EM spectrum for short) comes in. The EM spectrum is all around us, and we use different parts of it every single day. Different waves in the EM spectrum have different amounts of energy. EM waves with much higher energy than visible light include X-rays, which doctors use to take pictures of people's bones. Waves that have less energy than visible light include microwaves, which we use to heat our food, and radio waves, which are used in mobile phones and (you guessed it) – radios!



HOW DO WE SEE LIGHT?



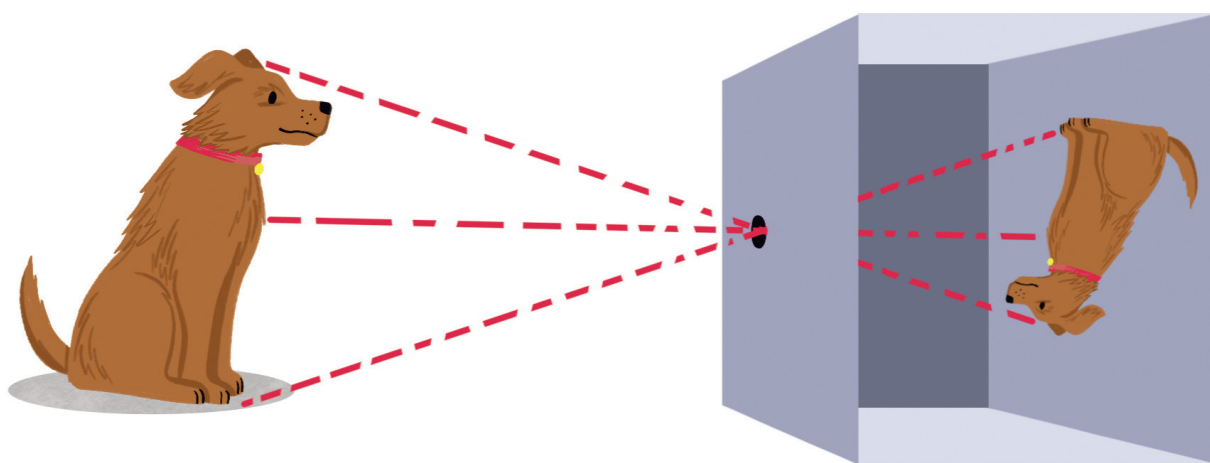
IBN AL-HAYTHAM

A long time ago, humans didn't really understand what light was or how it travelled. Some ancient Greeks even thought that our eyes gave off light, like laser beams! Then along came a mathematician and astronomer called Ibn al-Haytham, who would change how people understood light and vision.

He was probably born in Basra, in what is now Iraq, in 965 CE, Ibn al-Haytham was an incredible thinker in science, mathematics and philosophy. He is probably most famous for his book on optics – the study of eyes. Ibn al-Haytham was also one of the first scientists to use experiments to prove his theories. In one of his experiments, Ibn al-Haytham hung two lanterns at different heights and observed how the light shone through a tiny hole in the wall of a dark room. He realized that the light from the lanterns created two different spots on the wall opposite, and that he could draw a direct line between each spot and the lantern it came from. He had just proven that light travels in straight lines!

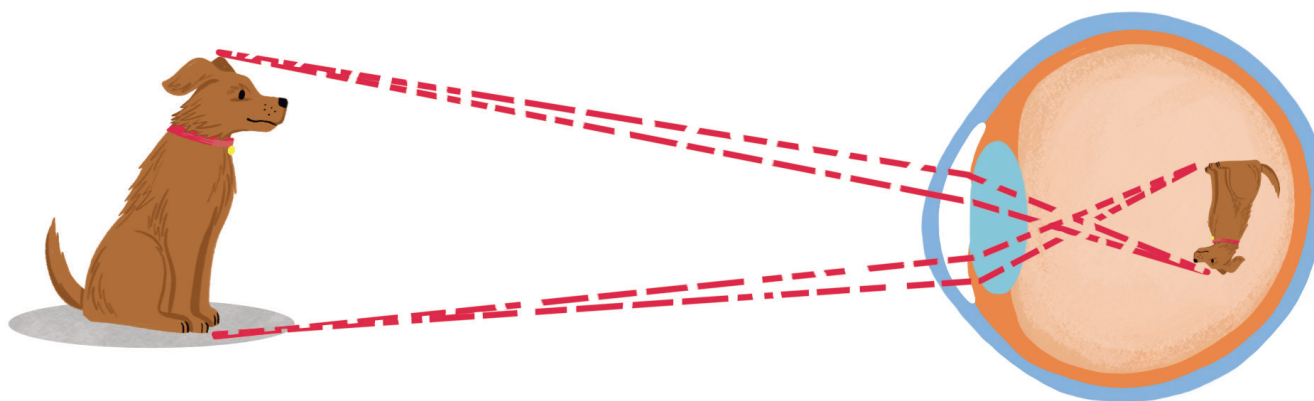
THE CAMERA OBSCURA

Ibn al-Haytham also invented something called the camera obscura, or *albeit almuzlim*. He used another dark room with a tiny hole in the wall, this time projecting an image through the hole. The picture that appeared on the opposite wall was upside down! This is because the light rays crossed over as they travelled through the hole, flipping the image.



The way the camera obscura works is quite similar to our eyes. When light enters your eye, it is focused by the lens, a clear disc (which is a bit like a camera lens!), and on to the retina, the lining at the back of your eye. The image that is projected on to your retina is actually upside down, but your brain is able to decode the image, so that you see things the right way up!

Ibn al-Haytham's camera obscura changed how people understood light and vision, and it also helped to inspire modern photography. That's one big eye-dea!



WHAT IS THE SPEED OF LIGHT?

The speed of light is . . . drumroll please . . .



However, to make it easier, scientists often use the rounded-up version of 300,000 km/s, or 300,000,000 metres per second. By comparison, sound travels at just 340 m/s!

But the speed of light is only 300,000 km/s when travelling in a vacuum. A vacuum is a space with nothing in it – not even air! Space is a vacuum, and on Earth, we can create a vacuum in a laboratory by sucking all the air out.

If light travels through other materials, such as air, water or glass, it is a bit slower. This is because when light is travelling through a gas, liquid or solid, the density of the material means there are particles in the way and the light gets slowed down.

Density is a measure of how closely packed a substance's particles are. Solids are more dense than liquids, and liquids are more dense than gases.

The 'c' for the speed of light comes from the Latin word for swiftness – celeritas!

The speed of light in a vacuum is always the same, no matter what. This means that it is a constant – a value that does not change – and scientists use a symbol to represent it. The speed of light is represented by the lower-case letter 'c' – you might see it sometimes in books.

If we were able to travel at the speed of light, we could get to the Moon in just over 1.28 seconds. But if we were travelling in a normal car, travelling at the maximum speed allowed on a UK motorway, it would take over 100 days to get to the Moon – and that's only if we didn't stop!

**SPEED = DISTANCE
OVER TIME**

Speed is measured as the distance travelled divided by the time taken to get there. So, if you know the distance between two points, and the time an object takes to get from one point to the other, you can work out the speed by dividing distance by time.

MEASURING THE SPEED OF LIGHT

OK, so we know that light travels around 300,000 km/s – but exactly *how* do we know this?

For centuries, astronomers and mathematicians puzzled over how to measure the speed of light. And several scientists tried – and failed! – to come up with an experiment to work it out. Let's find out about a couple of them . . .

EXPLOSIVE EXPERIMENTS

In 1629, a scientist called Isaac Beeckman had an *explosive* idea for measuring light. He set up mirrors at different distances from a barrel of gunpowder and asked people to look in the mirrors as he blew the barrel up! Beeckman wanted to know if these helpers could see any differences in the explosion flash reflected from each mirror. This method might have been fun, but it didn't provide any useful results.



OPEN THE SHUTTERS

In 1638, the famous astronomer and mathematician Galileo had a try. He and his assistant stood a set distance apart, each holding a lamp with a shutter. The plan was that Galileo would open his shutter to shine the light to his assistant, and as soon as his assistant saw it, he was to open his shutter in reply. Galileo would count his pulse as a way of measuring the time in between the two shutter lights. Then, to work out the speed of light, he would divide the distance between them by the time it took for the second light to turn on.

The idea was simple, but unfortunately it didn't work. No matter how close Galileo and his assistant were, he couldn't easily measure the time it took for light to travel between them. The light was simply travelling too fast to measure!



THE SPEED OF LIGHT AND JUPITER'S MOON

Later that century, in 1676, another astronomer stumbled across a way to measure the speed of light. Ole Rømer was studying one of Jupiter's four largest moons, Io, and trying to work out when eclipses of this moon might happen.

MANY MOONS

You probably know that Earth has just one moon, but other planets in our solar system have lots of moons. For example, Mars has two moons, Neptune has 16, Jupiter has 95 and Saturn has 274! A lunar eclipse happens when a planet moves in between its moon and the Sun, blocking out the Sun's light so that the moon is left in shadow. On Earth, lunar eclipses happen between two and five times a year. But Jupiter's moon Io is eclipsed about once every two days!

Rømer noticed that when Earth was at its closest point to Jupiter, called conjunction, the lunar eclipse would happen earlier than he predicted. But when Earth was at its furthest point from Jupiter, called opposition, the lunar eclipse would happen later.

Rømer realized that the lunar eclipses weren't actually happening at different times; they just *appeared* to happen later when Earth was furthest away from Jupiter, because the light had to travel further to reach Earth. He worked out that the time it took for the light to travel between the two points was about 22 minutes. We now know that the correct time is about 16.7 minutes, but Rømer wasn't far off!



ACCIDENTAL DISCOVERY!

Rømer wasn't trying to measure the speed of light – but his work on the lunar eclipses of Jupiter led him to the important discovery that light takes longer to reach Earth the further away we are from other space objects.

