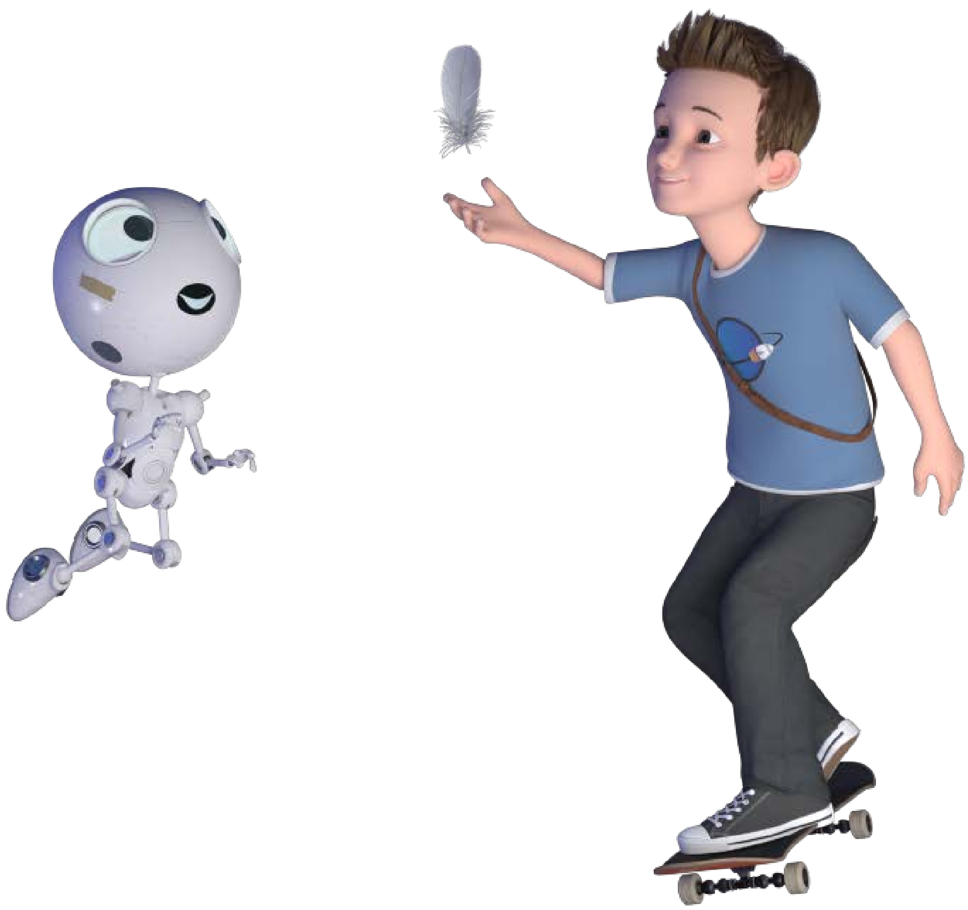
THE SECRETS OF GRAVITY

IN THE FOOTSTEPS OF ALBERT EINSTEIN

ACCOMPANYING MATERIAL ON THE FILM

INDEX



INFORMATION ON THE CONTENT

Learning should be fun!

“Limbradur - The magic of gravitation” is a film which seeks to inform children, young people and adults about the laws of nature and the discoveries of Albert Einstein as well as his own philosophy of always remaining inquisitive, asking questions and discovering the world for yourself.

Using the latest technological developments, we combine fascinating facts with an emotional story, thus generating an enduring learning effect. The audience are taken on an exciting voyage of discovery through space and time.

This accompanying material can be used before and after the film experience to provide background information going beyond the aspects dwelt upon in the film. On the following pages we have compiled further information and questions pertaining to Albert Einstein, the general theory of relativity and the effects of gravitation on our daily lives in a manner that is readily accessible for children and young people. To supplement the text, we want to arouse inquiring minds and encourage them to perform their own experiments by providing instructions and videos relating to gravitation. These videos can be viewed as a continuous whole or individually on the separate aspects.

OVERVIEW

Duration:	45 minutes
Genre:	Animation, family film, educational film
Written & directed by:	Dr. Peter Popp
Format:	360°- Fulldome
Distributed by:	REEF Distribution GmbH
Rating:	0 years - no age restrictions applicable
School classes:	Classes 5 - 10
Recommended age:	8 years or older

PLOT

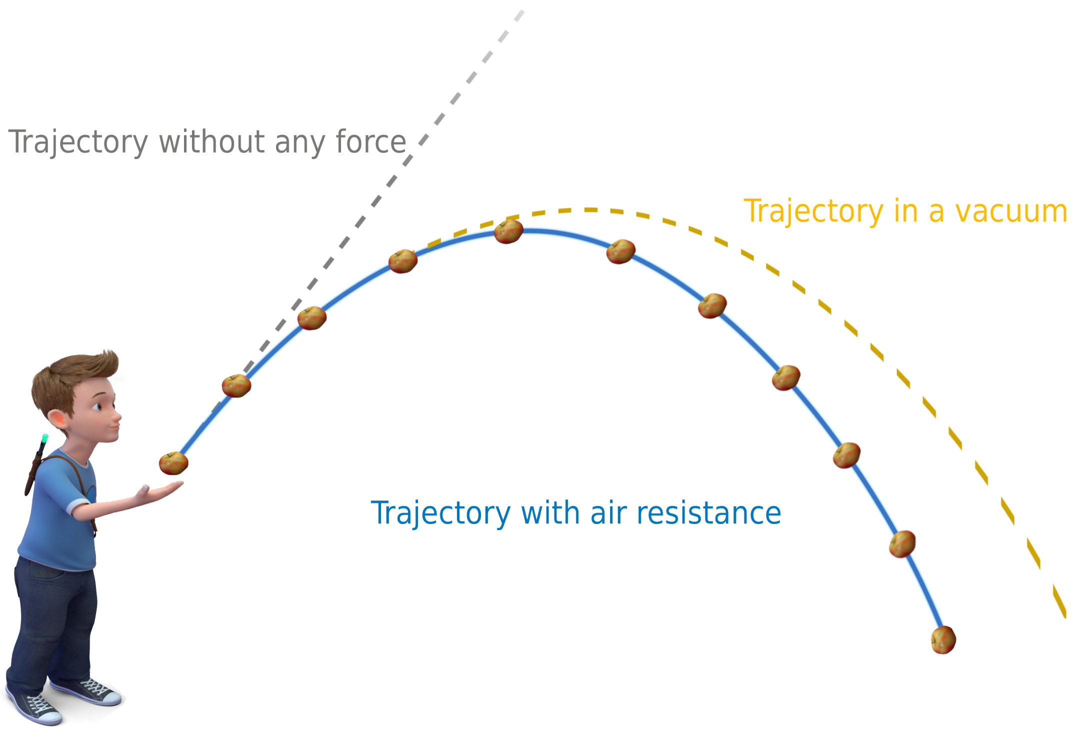
Why do things magically fall to the ground rather than floating in the air?

This is the very question that the young apprentice magician Limbradur asks. He wants to find out all he can about this law of nature and the mysteries of the universe. So, one night, he uses his magic powers to sneak into the Albert Einstein Museum. There, he encounters the small knowledge robot Alby and makes a deal with him - Limbradur's magic powers in return for Alby's knowledge. Alby takes Limbradur on an exciting journey through space and time, during which he explains the principles underlying gravitation and Albert Einstein's discoveries.

WHAT IS GRAVITATION?

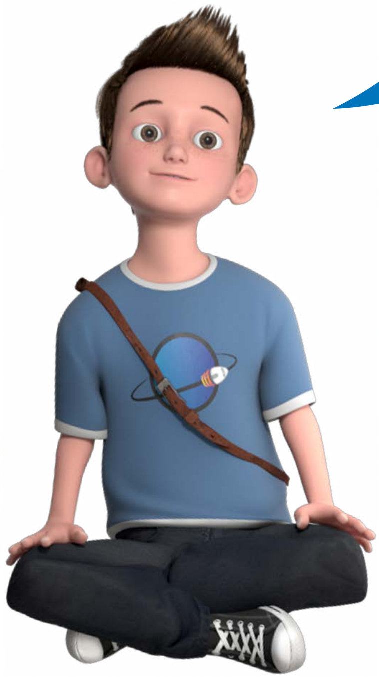
Gravitation comes from the Latin word “gravitas”, which roughly translates as “heaviness”. Gravitation means that two objects always attract each other wherever they may be. The extent of this mutual attraction depends on their mass and their distance from each other. The closer they are, the more they attract each other and the greater the mass, the greater the attraction will be. This means that larger objects attract smaller ones.

On the earth, gravitation causes all objects to fall to the ground because the earth has a greater mass than, say, a ball. If you throw a ball up into the air, it doesn’t fly in a straight line but invariably falls to the ground.



SIDE INFORMATION: THE DIFFERENCE BETWEEN MASS AND WEIGHT

Mass is a basic property of matter and a measure of the inertia of a given object. This means that it is the description of how much effort an object needs to change its speed - the greater the mass, the more effort is needed. It is a fixed factor that should not be confused with weight. Weight measures how much a body weighs under the effect of gravity. A body always has the same mass, but whereas it may weigh 50kg on the earth, it would weigh only 8kg on the moon and nothing at all in space due to the absence of any gravity.



Incidentally, all objects fall to the ground at the same speed, no matter how heavy they are. At least if they are not subject to any drag caused by the air.

DIFFERENT GRAVITATION MODELS

NEWTON AND THE FORCE MODEL

But where does gravitation come from and what is it precisely? There are two different models for explaining gravitation.

Legend has it that in 1665 the physics student Isaac Newton was sitting under a tree when an apple fell on his head. This prompted him to consider whether the earth possesses some force that attracts the apple. He started to perform calculations, developing Newton's law of universal gravitation of classical physics. This rule says that each mass has a gravitational force which attracts other masses.

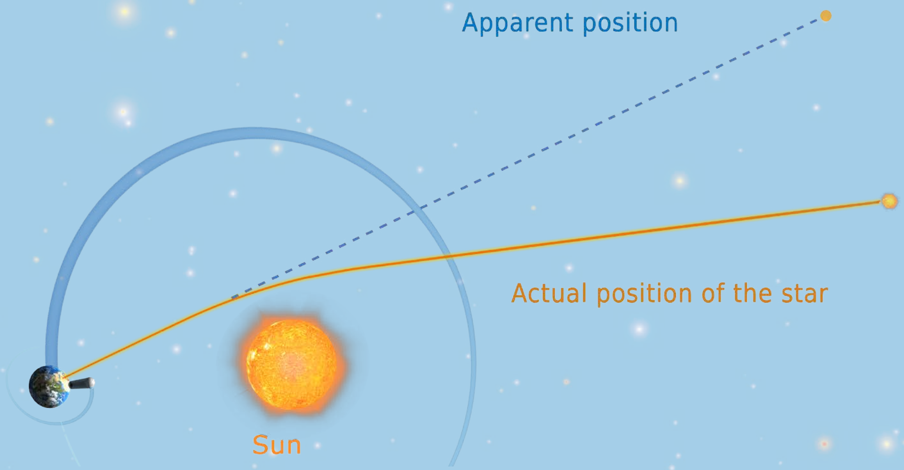
$$F_G = G \frac{m_1 m_2}{r^2}$$

F = force
G = gravitational constant $6{,}673 \cdot 10^{-11} \frac{m^3}{kg \cdot s^2}$
m = mass
r = distance

ALBERT EINSTEIN AND THE GENERAL THEORY OF RELATIVITY

Albert Einstein, on the other hand, explained the earth's attraction in a completely different way in his general theory of relativity, thus eliminating the inaccuracies that Newton was unable to explain. In contrast to Isaac Newton's classical model, gravitation does not act like a force in a fixed structure in Einstein's model. Einstein's theory says that mass and space are related in such a way that masses tell space how much it has to bend and this curvature of space, in turn, tells masses how they are to move in that they follow the curvature. This means that gravitation is actually due to the curvature of space arising around a mass. The greater the mass, the greater the curvature.

Sounds complicated, doesn't it? But it won't be after you've tried the following: Span a cloth, put different weight balls in, and see what happens.

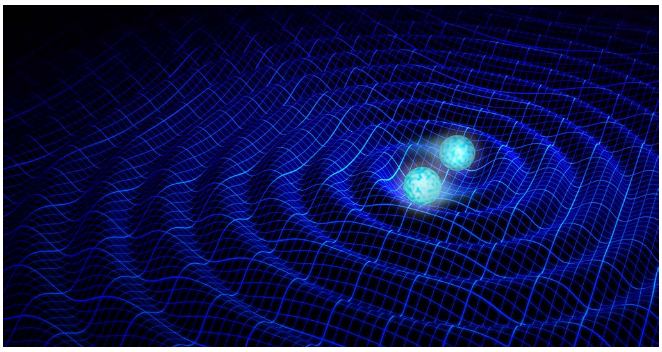


SIDE INFORMATION: ECLIPSE OF THE SUN

Einstein had postulated that the sun with its large mass would change space, causing the light from distant stars to be slightly deflected as it passed by the sun. Normally, the light from the sun is far brighter than that of other stars, meaning that this curvature cannot be detected. It is only during a solar eclipse that the light around the sun is dimmed sufficiently for other stars to be seen at the same time. In this way, the British astronomer Sir Arthur Eddington was able to photograph the deflection of light during the 1919 solar eclipse. He found that the apparent position of the stars around the sun had indeed changed in exactly the way that had been predicted in Einstein's general theory of relativity.

GRAVITATIONAL WAVES - THE SOUND OF THE UNIVERSE

When masses accelerate, they not only cause space to curve but also generate gravitational waves. Einstein described these waves back in 1916 on the basis of the general theory of relativity. Everything that accelerates in the universe emits gravitational waves that travel through space at the speed of light - much like a stone which causes ripples when it is thrown into the water. Similarly, the earth constantly produces gravitational waves by orbiting around the sun. Theoretically, the apple falling from the tree also creates ripples across space. However, as enormous quantities of energy are required to bend spacetime, the effects are barely noticeable. This is why it is so difficult to detect gravitational waves. It not only requires highly sensitive equipment but also very strong gravitational waves.

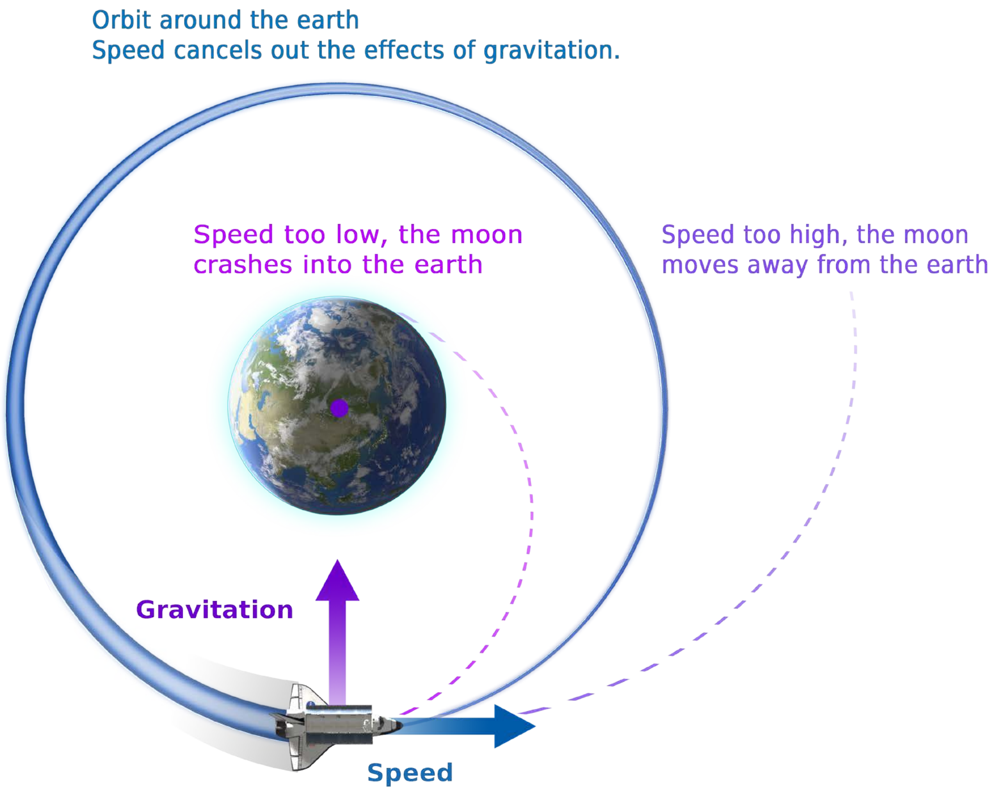


Physicists have been trying to detect gravitational waves for years. On 14 September 2015, they were measured for the first time when two black holes converged and the echo caused by this enormous eruption of energy was captured by researchers. This discovery is considered to be a milestone in the history of astronomy in the same league as events such as the lunar landing. This is because it not only provides further proof of the theory of relativity but now also allows invisible objects to be observed in the universe. In this way, scientists hope to be able to learn more about the hitherto elusive dark matter and explore further mysteries of the universe.

GRAVITY AND SPEED

In the solar system, gravitation determines the orbits of the planets, moons, comets and satellites. As the sun is the celestial body with the greatest mass in our solar system, it causes the strongest curvature of space, thus attracting the planets such as the earth and Mars to it. But what differentiates this from the experiment with the CLOTH? Why do the planets not fall into the sun like the balls?

This is because gravitational force is counteracted by another force which keeps the planets in their orbits, namely centrifugal force or speed. If an object travels at a sufficient speed, it is able to overcome the effects of gravitation. In this way, space shuttles with their powerful thrusters are able to fly at exactly the speed at which gravitation and centrifugal forces are in complete balance, allowing them to orbit the earth. This is like a set of scales which are completely balanced.



IN WHAT WAYS ARE WE AFFECTED BY GRAVITATION?

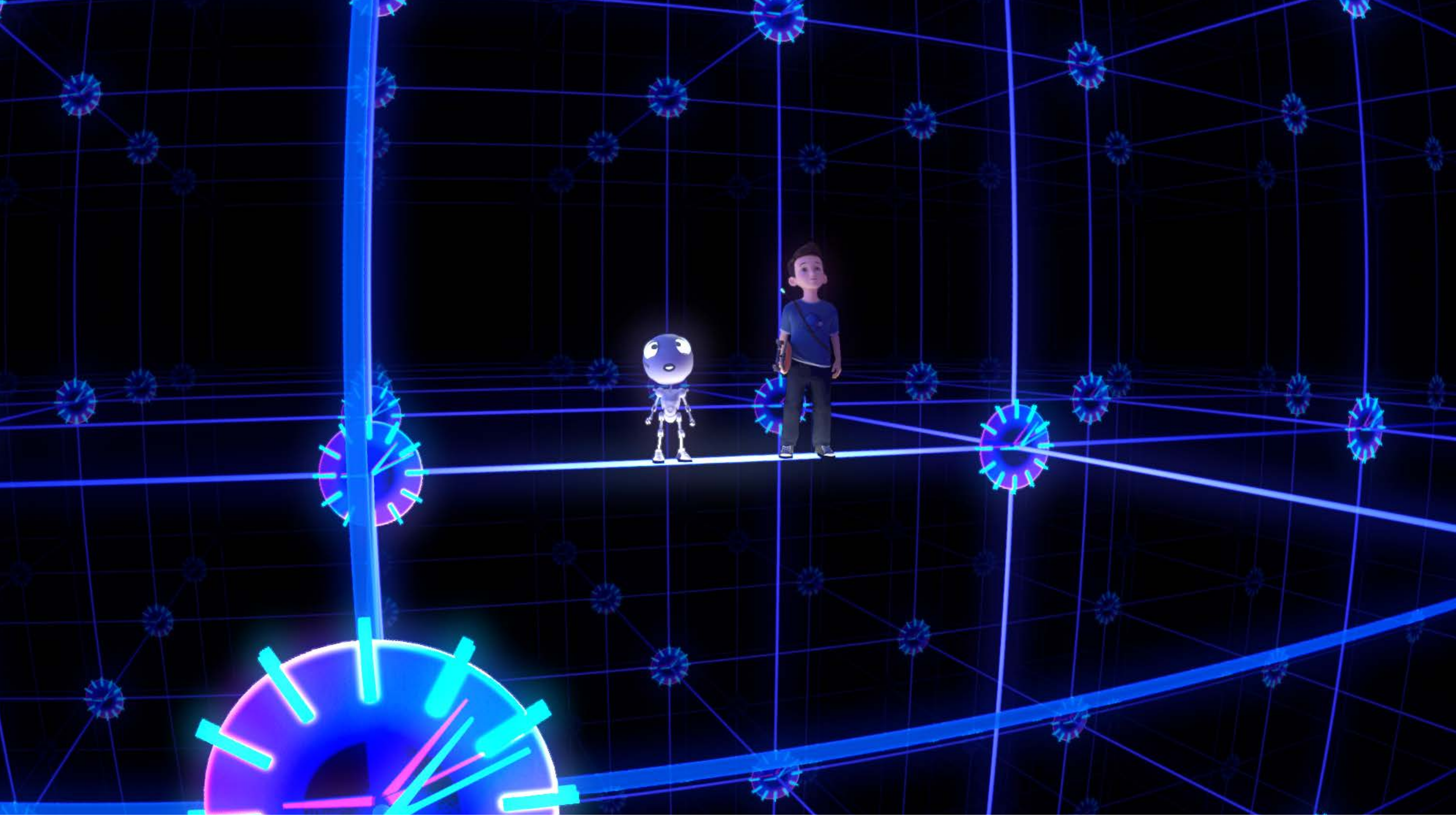
If it were not for gravitation, we would not even exist as there would be no stars, planets or moons. It was only through the effects of gravitation that it was possible for planets - and hence also our own earth - to form from the clouds of gas over billions of years. Without gravitation, our earth would have no atmosphere. The atmosphere supporting our earth which gives us the oxygen we need to breathe would simply fly away. However, the earth's gravity "captures" it, providing us with the basis for life. As well as this, gravitation makes the earth orbit around the sun, which is also crucial for life. What is more, the moon orbiting the earth causes the tides as the gravitational force which it generates attracts the water on the earth's surface. So, everything is connected with everything else. In addition, gravity pulls everything to the earth's centre, ensuring that it stays where it is supposed to. Otherwise, we would be floating around in space like an astronaut.

Talking of which, why is it possible for astronauts to take such giant leaps on the surface of the moon? Precisely because the moon has a smaller mass than the earth and, because of this, weaker gravitation. Different conditions would apply on the surface of Jupiter, which is far larger than the earth. What would that look like?

However, weight is not the only thing that astronauts must adjust to when they fly into space. Our bodies are perfectly attuned to the earth's gravity and are not accustomed to the effects of protracted travel through space. All our organs and muscles work to overcome the effects of gravity. The heart pumps blood into the brain against the pull of gravity. If there is no gravity, then our bodies and also our immune systems don't work as they should. That's why many astronauts fall ill when they first enter space, suffering from a loss of orientation, nausea and a severe decline in muscle mass if they don't move sufficiently and simply float around in space.

YOUR WEIGHT ON DIFFERENT PLANETS

	Your weight:
Mercury:	18.5 kg
Venus:	45 kg
Earth:	50 kg
Mars:	19 kg
Jupiter:	126.5 kg
Saturn:	53.5 kg
Uranus:	45.5 kg
Neptune:	57 kg



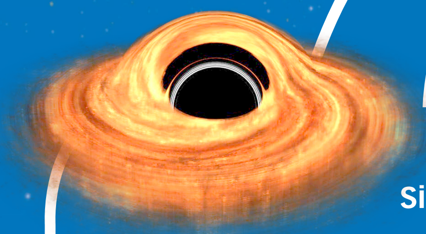
THE SECRET BEHIND TIME

As we have already seen, gravitation is caused by a change in space and influences us in many different ways. But what makes it even more mysterious is that it also influences time! According to Einstein, time is what we see on the clock. We have previously mentioned Albert Einstein's theory of relativity. Among other things, this says that space and time form a single unit known as spacetime.

But what has gravitation got to do with time? Every mass bends space. But if space and time are interconnected then this must surely mean that not only space but also time is stretched and bent. This changes time. The greater the mass, the stronger the gravitational effect, the greater the distortion and the slower time passes.

Side information: MUSIC

The atmosphere, i.e. the air that surrounds us, comprises tiny gas particles that are attracted by the earth due to its mass. This air can be caused to vibrate by different means and the result of this is what we hear as music.



Side information: BLACK HOLES

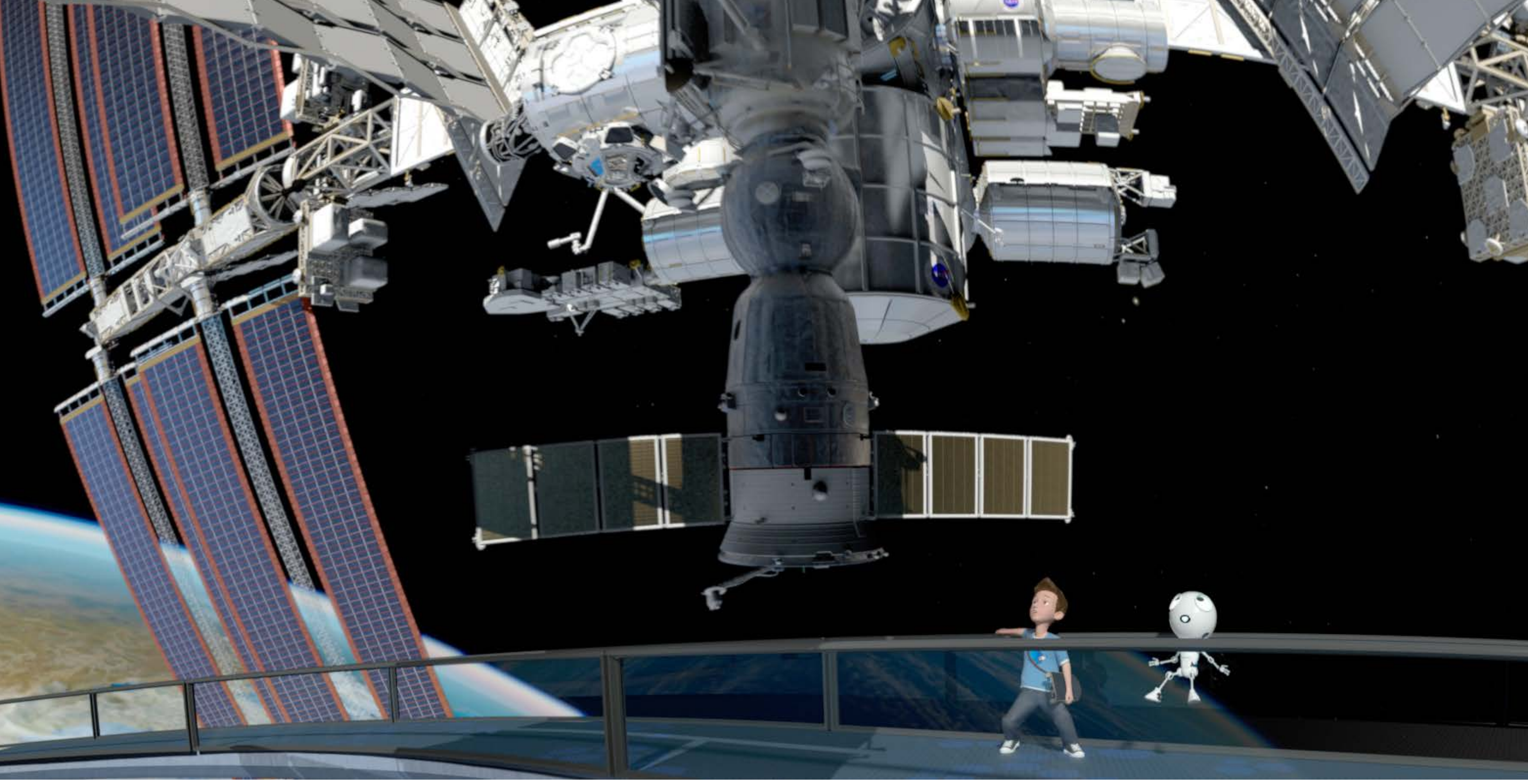
Black holes are amongst the most mysterious and extreme places in the entire universe. They are remnants of stars that have exploded and collapsed into themselves. They have an enormous mass which simultaneously expands at a very low rate. Spacetime is extremely curved as a result and the gravitational force becomes so powerful that the black hole attracts and swallows everything surrounding it. Even light. That's why they can never been seen directly, thus explaining why they are called "black holes". Time is also curved so heavily in their vicinity that it effectively stands still.

Side information: STARS

Some stars are in actual fact not where they appear to be because, despite its speed (300,000km per second!), light takes millions of years to reach us. So what we really see are galaxies which are billions of years old and may no longer even still exist. To all intents and purposes, we are looking into the past, at a time before any people even lived on the earth.

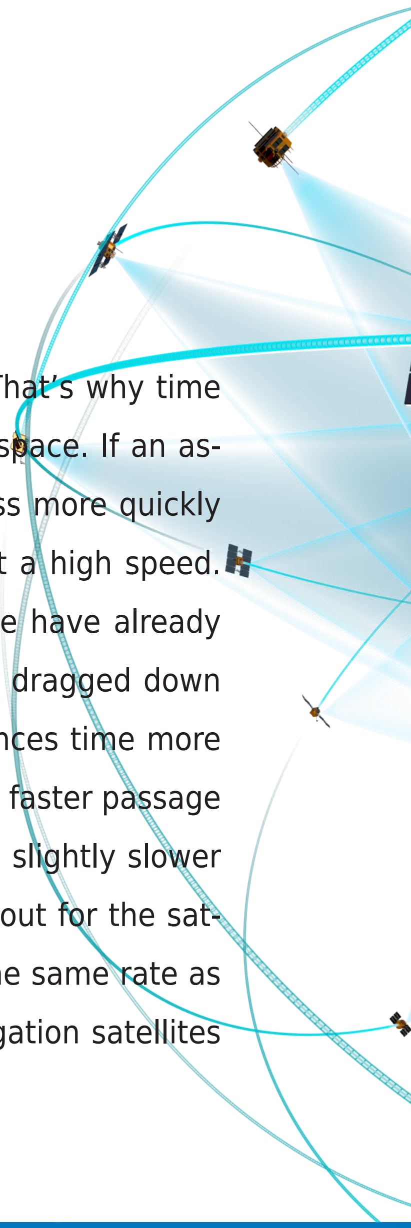
Side information: ROTATION

The planets in our solar system arose from a cloud of gas. Indeed, the planets still exhibit the original rotation of this cloud.



EVERYTHING IS RELATIVE

Every mass - such as our earth - causes the flow of time to slow. That's why time moves at a different speed here than it does in the voids of outer space. If an astronaut were to simply float over the earth, time would initially pass more quickly for him than on the earth. However, most things in space move at a high speed. This also applies to navigation satellites, for example, which, as we have already explained, mostly orbit the earth at a certain speed to avoid being dragged down by the earth's gravity. An object travelling at a high speed experiences time more slowly than someone on the earth. As these two effects - the slightly faster passage of time as a result of gravitational effects on the one hand and the slightly slower passage of time caused by speed - do not quite cancel each other out for the satellites. Consequently, the clocks fitted to them do not go at quite the same rate as clocks on the earth. This difference must be corrected for the navigation satellites to work correctly.

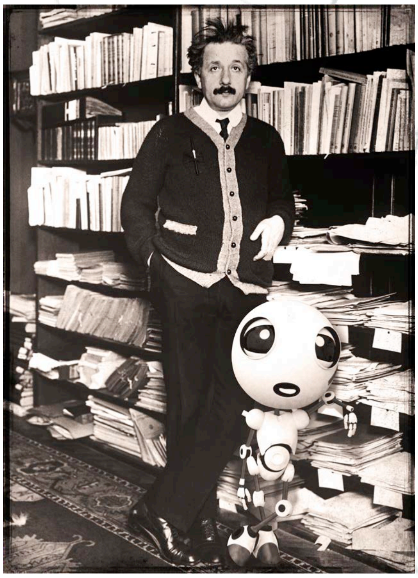


Side information: **NAVIGATION SATELLITES**

As gravitation weakens out in space, time passes a little more quickly there than it does down on the earth's surface. This minute time difference is sufficient to put the GPS system out by a kilometre after only a single day.
It is only with the assistance of the general theory of relativity that it is possible to correct this time difference by adjusting the clocks on board the navigation satellites.
If it were not for Albert Einstein, the GPS system would not work.

The fact that time passes more slowly for objects travelling at a high speed can be explained by Einstein's special theory of relativity. It assumes that the same laws of physics apply in every reference framework and that light travels at a constant speed of 300,000 km/s. However, if the speed of light is always the same, this means that time and space must change. This is a very complex notion, which we can only briefly touch on here. If you would like to find out more, ask your teacher to tell you about the special theory of relativity.

ALBERT WHO?

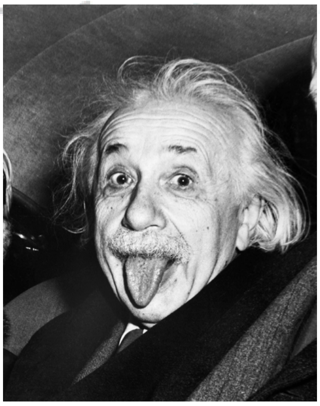


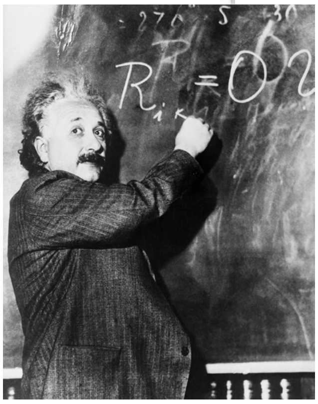
Albert Einstein is truly one of the most famous scientists ever. However, this is not only due to his fantastic discoveries but also to his personality. Einstein was not only super smart, but he was also a super cool guy. There are a large number of detailed biographies in book form as well as on the Internet. Here are a few interesting facts about Albert and his life:

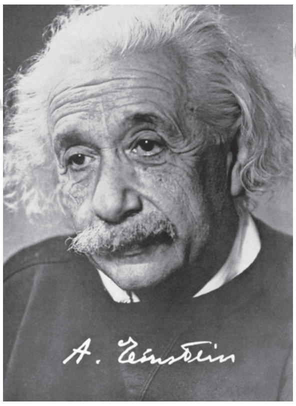
"Imagination is more important than knowledge because knowledge is limited!"

- Albert was born in Ulm, Germany, on 14 March 1879, the son of Jewish parents.
- Although he frequently demonstrated the powers of his mighty intellect later on, he didn't actually learn to speak until he was 3 years old. In other respects as well he was a late developer and had trouble remembering things.
- He found school incredibly boring but ever since his father had given him a compass at the age of 5 years, he developed a burning passion for science.

- In 1905, Einstein placed the world of physics on its head. At the tender age of only 26 years, he published the special theory of relativity and studies on quantum physics studies, namely the photoelectric effect, for which he ultimately received the Nobel Prize in 1921 - but not for the theory of relativity.
- Albert liked to go sailing although he had never learned to swim, and he also played the violin. He especially loved the music of Mozart.
- Einstein never wore socks as he was always annoyed by how quickly they got holes in them.







“Learning is experience.
Everything else is only information.”

“It is important never to stop asking questions.”

After the marriage with his first wife Mileva Marie, he married his cousin and had an illegitimate child.

In 1952, Einstein was asked whether he wanted to be president of Israel. He rejected the request, explaining that he had no experience in dealing with people. On his trip to America, he was named chieftain of an Indian tribe.

Einstein was never actively involved in the construction of the atomic bomb. However, his letter to the then US president Roosevelt and his E=mc2 played a material role in its development. Einstein regretted this and later became actively committed to world peace.

After his death in 1955, the US pathologist Thomas Harvey secretly removed Einstein’s brain from his body, sending small samples of it to neurological specialists to perform research into Einstein’s extraordinary intelligence. Parts of them are in medical museums to this very day.

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