https://www.youtube.com/watch?v=yPVQtvbiS4Y&t=3668s

**What Actually Are Space And Time?**

**Co jsou vlastně prostor a čas?**

History of the Universe

469 tis. odběratelů

4,6 mil. zhlédnutí před 5 měsíci

**(01)-** A hundred trillion years from now, the last of a great civilisation hides in the darkness. Throughout their glory days, their engineers worked entire star systems. They dismantled planets and asteroids to construct an immense interstellar empire. But now, in the twilight of their time, all of this is long gone. All around them, the universe is dying as the last of the stars are going out. Over countless millennia, the sky has continued to fade into an eternal night. The aging universe gripped by desolation and decay, And so, in the darkness, they wait for the end. Long before they had realized it was coming They knew that the universe was on a path of inevitable decline. Methodically they hunted for a final place to wait out eternity. And embarked on their last great feat of engineering. Around a lost and lonely black hole, they built a new home. With demolished worlds as raw material, they constructed a shell to completely enclose the darkness. And within this thin shell, barely withstanding the gravitational grip of their savior, They eked out their meagre lives. The dwindling light of dying stars rained down upon their final home, Whilst the swirling black hole was harvested to power their existence. But more than that, the black hole at their heart gave them greatest gift of all, For the black hole gave them time. No one remembered the name of the great scientist who had discovered the nature of time. But the astro-engineers knew that time was not the same across the cosmos. And here, within the immense gravity of the black hole, time trickled more slowly. Whilst many years passed outside, mere moments flashed by within the immense sphere. And so the last of the civilisation watched the future play out in front of them. But they knew that they had only delayed, not averted, their ultimate demise. And the darkness would inevitably envelop them forever and ever. Of course, this story is little more than speculation. But it is built on a scientific idea that changed our universe. It’s been more than a century since Einstein’s relativity shook up our understanding of time and space. But how does it really work? And what does it actually mean? Both time and space seem so commonplace, so obvious, so everyday. But beneath their ubiquity they hide a multitude of unanswered questions - questions to which Einstein's theories only begin to answer. What is space made of? Does time exist? And will hunting for their ultimate nature lead to sudden clarity, or will space and time just become more elusive? “Einstein offered them lunch, and they accepted. So he moved a whole bunch of papers from the table, opened four cans of beans with a can opener, heated them, stuck a spoon in each and that was our lunch." Albert Einstein was a busy man, and often missed lunch. And that was back in 1915 - in the century since our lives have only become more chaotic. And that is why a meal kit service like HelloFresh is so great. Hellofresh delivers fresh, high quality produce straight from the farm to your door, with more than 55 weekly meal options. Great for everyone - especially if you want to get or stay fit and healthy. I am a big fan of fitness and eating the right food - but in honesty sometimes there just aren't enough hours in the day and a microwaveable meal seems like the only option. Hellofresh has saved me from this tasteless horror. The kits are fool

proof, genuinely really hard to get wrong, and that is coming from an absolute cooking disaster. And last but definitely not least, a recent survey has found their meals have been found up to 72% cheaper than dining out or grocery shopping. Go to HELLOFRESH.COM and use code HISTORY16 for up to 16 FREE MEALS and 3 surprise gifts. 16 free meals! This is a great company, and a smart way to eat healthily - and the cherry on top is that they are also carbon neutral. A big thanks to HelloFresh for supporting educational content on YouTube. As the lonely world lingered on, Its beating heart warped the very fabric of the universe around it. The civilisation had done everything they could to keep going, to put off the inevitable. But try as they might, they could only bend reality. They could not break it. "Behind it all is surely an idea so simple, so beautiful, that when we grasp it - in a decade, a century, or a millennium - we will all say to each other, how could it have been otherwise? How could we have been so stupid?" What is space? The question seems almost meaningless. As children we learn to describe our surroundings as up-down, left-right, back-and-front. We call it three dimensional and are free to explore each dimension. But just what is it, this universal platform on which we play out our lives?
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**(01)-** Za sto bilionů let se poslední z velké civilizace skrývá v temnotě. Během jejich slavných časů jejich inženýři pracovali na celých hvězdných soustavách. Rozebrali planety a asteroidy, aby vybudovali obrovskou mezihvězdnou říši. Ale teď, v šeru jejich doby, je tohle všechno dávno pryč. Všude kolem nich vesmír umírá, protože poslední hvězdy zhasínají. V průběhu bezpočtu tisíciletí se obloha nadále proměňuje ve věčnou noc. Stárnoucí vesmír sevřený zkázou a rozkladem, A tak v temnotě čekají na konec. Dlouho předtím, než si uvědomili, že se to blíží, věděli, že vesmír je na cestě nevyhnutelného úpadku. Metodicky hledali konečné místo, kde by čekali věčnost. A pustili se do svého posledního velkého inženýrského počinu. Kolem ztracené a osamělé černé díry postavili nový domov. Se zbořenými světy jako surovinou zkonstruovali skořápku, aby úplně uzavřeli temnotu. A v této tenké skořápce, stěží odolávající gravitačnímu sevření svého zachránce, prožili své skrovné životy. Ubývající světlo umírajících hvězd pršelo na jejich poslední domov, zatímco vířící černá díra byla sklizena, aby poháněla jejich existenci. Ale víc než to, černá díra v jejich srdci jim dala největší dar ze všech, protože černá díra jim dala čas. Nikdo si nepamatoval jméno velkého vědce, který objevil podstatu času. Ale astroinženýři věděli, že čas není v celém vesmíru stejný. A tady, v nesmírné gravitaci černé díry, čas ubíhal pomaleji. Zatímco venku uplynulo mnoho let, v obrovské sféře se mihly pouhé okamžiky. A tak poslední z civilizace sledovali, jak se před nimi budoucnost odehrává. Věděli však, že svůj konečný zánik pouze oddálili, nikoli odvrátili. A temnota je nevyhnutelně zahalí navždy a navždy. Tento příběh je samozřejmě o něco víc než jen spekulace. Ale je postaven na vědecké myšlence, která změnila náš vesmír. Je to více než století, co Einsteinova teorie relativity otřásla naším chápáním času a prostoru. Jak to ale doopravdy funguje? A co to vlastně znamená? Čas i prostor se zdají tak běžné, tak zřejmé, tak každodenní. Ale pod svou všudypřítomností skrývají množství nezodpovězených otázek – otázek, na které Einsteinovy teorie teprve začínají odpovídat. Z čeho se skládá prostor? Existuje čas? A povede honba za jejich konečnou přirozeností k náhlé jasnosti, nebo se prostor a čas prostě stanou nepolapitelnějšími? „Einstein jim nabídl oběd a oni přijali. A tak přesunul ze stolu celou hromadu papírů, otvírákem na konzervy otevřel čtyři plechovky fazolí, ohřál je, do každé strčil lžíci a to byl náš oběd." Albert Einstein byl zaneprázdněný muž a často vynechal oběd. A to bylo v roce 1915 – ve století, kdy se naše životy staly jen chaotičtějšími. A proto je

služba jídelních sad, jako je HelloFresh, tak skvělá. Hellofresh dodává čerstvé, vysoce kvalitní produkty přímo z farmy až k vašim dveřím, s více než 55 možností týdenního stravování. Skvělé pro každého – zvláště pokud se chcete dostat nebo zůstat fit a zdraví. Jsem velkým fanouškem fitness a správného jídla – ale upřímně řečeno, někdy prostě není dost hodin denně a Jídlo v mikrovlnné troubě se zdá být jedinou možností. Hellofresh mě zachránil před tímto nevkusným hororem. Soupravy jsou hloupé, opravdu je těžké se mýlit, a to pochází z absolutní kuchařské katastrofy. A v neposlední řadě nedávný průzkum zjistil, že jejich jídla byla nalezena až o 72 % levnější než stolování nebo nakupování potravin. Přejděte na HELLOFRESH.COM a použijte kód HISTORY16 pro až 16 JÍDEL ZDARMA a 3 překvapení. 16 jídel zdarma! Je to skvělá společnost a chytrý způsob, jak jíst zdravě – a třešničkou navrchu je, že jsou také uhlíkově neutrální. Velké díky HelloFresh za podporu vzdělávacího obsahu na YouTube. Jak se osamělý svět zdržoval, jeho tlukoucí srdce pokřivilo samotnou strukturu vesmíru kolem něj. Civilizace udělala vše, co mohla, aby pokračovala, aby oddálila nevyhnutelné. Ale ať se snažili sebevíc, mohli jen ohýbat realitu. Nemohli to zlomit. "Za tím vším je jistě myšlenka tak jednoduchá, tak krásná, že když ji pochopíme - za desetiletí, století nebo tisíciletí - budeme si všichni říkat, jak to mohlo být jinak? Jak jsme mohli byl tak hloupý?" co je prostor? Otázka se zdá téměř nesmyslná. Jako děti se učíme popisovat naše okolí jako nahoře-dolů, vlevo-vpravo, zezadu a zepředu. Říkáme tomu třírozměrné a můžeme volně prozkoumat každou dimenzi. Ale co to je, tato univerzální platforma, na které hrajeme své životy?
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**(02)-** It is a question that occupied the minds of the earliest philosophers. In the fourth century BC, Plato declared that space was the "The Nurse of Becoming", a medium in which everything existed, but with no qualities of its own - and his student Aristotle agreed that an empty void was impossible. But it would be more than two thousand years before our concept of space was born. By the coming of the seventeenth century, modern science was crystallizing. The processes of the universe were being codified into physical laws. And the understanding of these physical laws was evolving from myths and stories, to the language of mathematics. Of course, Isaac Newton was at the forefront of this revolution. But before he enters our stage, we must first start with a boat. In 1632, Galileo published his seminal work "Dialogue Concerning the Two Chief World Systems". He was in his mid 60s by this point, and had already had multiple run-ins with the Roman Inquisition for his assertions that the earth rotated around the sun. So he had decided to skirt controversy, and spend the intervening years quietly cementing his myriad ideas on space and the cosmos into a book. And at one point within this book, he muses on a boat. More specifically - the life of a sailor locked below deck in a windowless cabin. With plates and knives and a goldfish in a bowl on the table - a collection of birds, flies, and butterflies. Just what does the sailor experience? Tied up in port, the cabin is a picture of serenity, and all is calm as the goldfish swims happily in its bowl. On the table, plates and cutlery remain in their place, and the flying creatures happily flutter about. But finding itself in rough seas, the cabin heaves and falls with the ship. Plates and cutlery are wrenched off the table, water spills from the goldfish bowl. On calm seas with wind-filled sails, the ship would speed up. The sailor would feel this change, and see things sliding off the table. But when the wind finally drops, the ship sails smoothly on the glassy sea. Inside the cabin, all would be calm, serenity returning. For the sailor, it would be as if the ship was still in port and was not moving at all. A dropped plate would fall straight to the floor, and the sailor would sit comfortably in their chair. And it was here Galileo realised something. Without a window to reveal the truth, there are no experiments the sailor could do to reveal whether the ship was moving or not. He concluded that there must be no absolute concept of being at rest in space. Instead, everyone must experience any smooth, uniform motion in the same way. All uniform motion must feel like simply being still. Galileo declared, therefore, that any uniform motion is simply relative to any other uniform motion. And with this, the first theory of relativity had been born. Galileo´s sailor floats gently on their sailboat, on seas near the earth's equator - rotating at 1600 km an hour around the earth, which in turn orbits the sun at 67,000 km an hour, which in turn orbits the milky way at 720,000 km an hour, which in turn is travelling towards the Andromeda galaxy at 403,000 km an hour. And yet he feels nothing on his vast journey millions of kilometres from his starting point. Unfortunately upon publishing the book, Galileo once again fell foul of the Catholic Church - and was found guilty of heresy for his heliocentric view of the cosmos. The work was banned, and would not be removed from the church´s Index of Forbidden Books until 1835. Within a few decades of Galileo´s downfall, two of Europe's greatest minds were arguing about the nature of space. One of them, Isaac Newton, was born in England in 1642, within a year of Galileo's death. He needs little introduction, and is known now as one of the greatest thinkers of his age, perhaps one of the greatest of all time. Whilst not forgotten, his opponent, Gottfried Leibniz, is somewhat less well known today. Born in 1646 in what is present-day Germany, he was a leading thinker of his day, writing on mathematics and philosophy. He pondered deep metaphysical questions, including one that still haunts physicists and philosophers to this day - why there is something rather than nothing. It was in the development of calculus that the two men´s feud began. Whilst Leibniz published his work first, Newton claimed that he had stolen his ideas. As president of the Royal Society at the time, Newton set up a committee to investigate the dispute. Unsurprisingly the committee found in favour of Newton. And so this animosity carried over to their second disagreement. A simple question: What happens to a spinning bucket of water? Space, Newton declared, was a universal absolute, a rigid stage on which motion was played out.

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And both would exist in a universe devoid of matter to experience any motion.

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To argue his point, Newton asked us to think of a bucket of water. If the bucket sits at rest, the surface of the water would be flat and level.

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But if we spin the bucket, the water spins too and its surface becomes curved.

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Newton asked "Just what is the water spinning with respect to?" Newton claimed that the acceleration of the spin was relative to an absolute space - something

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separate to the object itself - spinning a bucket in an empty universe would also curve

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the surface of the water. But to Leibniz, space in an empty universe,

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devoid of any matter, simply made no sense. The properties of objects, Leibniz claimed,

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are essential in defining their meaning. Space only has meaning, in the relative locations

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of objects. And similarly, time only had meaning when discussing the relative motions of objects. Without matter Leibniz said, space and time
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simply have no role, and hence no existence. Sadly, Liebniz died in 1716, with the argument
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still in full swing - but it was Newton's ideas that stuck. “Absolute space, in its own nature, without relation to anything external, remains always
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similar and immovable, Absolute, true, and mathematical time, of itself, and from its
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own nature, flows equally without relation to anything external."
13:36
This so-called “absolute space and time” would be the accepted science for nearly two
13:41
centuries - but with the caveat of Galileo´s rejection of absolute rest. Absolute space may have won the debate - but absolute rest, a fixed point - was still an impossibility.
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Relativity was still part of the argument. But that only applied to space.
13:55
Time was a totally different matter. With its implicit direction, time appeared
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totally distinct. For Newton and Galileo, everyone’s clock across the universe ticked with absolute synchronicity. A universal beat that ran through every event
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in the cosmos. A second on Earth the same as a second everywhere else. But is this true?
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Is time malleable or an unswerving metronome that drags the cosmos forward? Does it itself
14:26
have properties or is it defined only by the events that run in its current?
14:32
To answer these questions we must begin not with physicists wondering about clocks, rulers and motion. But with heat.
14:49
In the distant future universe, around the aging black hole, our dying civilization sits
14:57
and waits. For sitting and waiting is all they can do. With the passing of the stars, raw energy had become the most precious thing.
15:06
To preserve what they had, they had slowed their very existence.
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Every aspect was focused upon survival, as their sleepy eyes watched the ever darkening
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skies. As total universal heat death crept across the cosmos, They realised that time was their ultimate enemy.
15:33
"You may see a cup of tea fall off a table and break into pieces on the floor… …but you will never see the cup gather itself

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back together and jump back on the table."
15:46
What is time? Like space, the nature of time occupied the minds of many ancient thinkers.
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In ancient Greece, Aristotle stated that time was simply the steps between before and after,
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whilst Hindu philosophers saw time as cyclical, from creation to destruction over four billion
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years. But it's true origin remained elusive.
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Like space, time seems to be something obvious, something that is just present.
16:19
But it is clearly a different beast - we cannot freely travel through time.
16:26
Unlike space, time has a direction - a distinct past and coming future.
16:32
As with space, scientists can be pragmatic and not worry about the nature of time. Coupled with a ruler, a clock completes the experimenter's toolbox.
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But it doesn't mean we can ignore the question. And to understand time fully, we first have
16:47
to think about horses and steam engines. The coming of the industrial revolution presented
16:58
humanity with a problem. The original engines of civilization, draught animals like horses and cattle, were relatively simple things.
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Understanding how much to feed them and how much to work them was easy. A certain number of bales of hay could guarantee a day's work from a well-fed animal.
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But what of new-fangled machines, such as a steam engine? How much work can you get out of a heap of coal?
17:22
This was an important question from an economic standpoint. Do you replace a horse with an engine if it is going to cost more to feed it?
17:31
And it was out of this conundrum that thermodynamics was born.
17:36
Many minds wrestled over the question of the ultimate efficiency of engines. Indeed - at the time of thermodynamics inception, a typical engine only worked at 3%.
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In a physical steam engine, the heat of the fire is used to boil water, But some of the fire's heat just radiates into the air.
17:55
Metal scrapes against metal, screeching loud and hot to the touch - both forms of energy
18:01

loss. In any physical steam engine, this loss of heat as waste is inevitable. Within the mathematics of thermodynamics,
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perfect efficiency was found to be an illusion. Energy is always lost as heat flows from one place to another. The concentrated energy released from burning
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coal must be degraded as it flows through the engine and some must be lost into the
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surroundings. And so a new measure was introduced to account for this increase of decay and disorder. Entropy.
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And it is probability that dictates how this happens.
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As the early 20th century physicist George Gamow put it: "For exactly the same reason the room in which you sit reading this book is filled uniformly
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by air from wall to wall and from floor to ceiling, and it never even occurs to you that the air in the room can unexpectedly collect itself in a far corner, leaving you to suffocate
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in your chair. However, this horrifying event is not at all physically impossible, but only
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highly improbable." Gamow goes on to give the waiting time of such an event - trillions upon trillions times longer than the entire age of the universe.
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Disorder is always statistically far more likely. Through the new laws of thermodynamics physicists revealed an inexorable growth in entropy as
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the universe marches on - a future universe destined to be more disordered and decayed
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than today’s. Not only steam engines, but whole planets,
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stars, galaxies, filaments - all marching from order to disorder.
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It was in 1862 that the grim logical endpoint of these ideas was proposed, by Lord Kelvin,
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for whom the measurement unit was named: "...although mechanical energy is indestructible, there is a universal tendency to its dissipation, which produces…exhaustion of potential energy
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through the material universe. The result would inevitably be a state of universal rest
20:04
and death, if the universe were finite and left to obey existing laws."
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And so, was this time? A constantly dying universe heading for inevitable heat death?
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Stars going out one by one in a steady march from potential energy to waste leaving the trillion year old universe dark and spent? One of the great minds to occupy themselves

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with entropy and the arrow of time was James Clerk Maxwell, the iconic Scottish nineteenth
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century scientist. His views on thermodynamics shaped our understanding of heat and gases - and he did all this with the assistance of a demon.
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Maxwell understood the implications of entropy. He knew that if he mixed two gases, one hot
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and one cold, the result would be warm gas. And he knew that the gas would stay warm and
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mixed rather than separating into two halves, with hot gas in one and cold in the other. But he wondered - what if we introduced a tiny demon who can sense each and every atom
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in the gas. This demon can turn around atoms, directing slow atoms to one side, and fast to the other. As the temperature of a gas is a reflection
21:24
of the average speed of its atoms, The demon has effectively separated the warm gas into two unequal halves, one hot, and one cold.
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The demon seems to have broken the laws of thermodynamics. It has taken the disordered state, the warm gas, and created a more ordered state, hot
21:46
and cold gas. And whilst only a thought experiment - arguments over the meaning of Maxwell's demon have raged for over 150 years.
21:56
Some have stated that the demon must be expending energy to sort the gas atoms, And so total entropy will continue to rise. However - some have proposed that it is not
22:07
energy that is important, But the fact that the demon uses information,
22:13
namely the speeds of the atoms, to do the sorting. Linking energy, entropy and information might seem a little strange,
22:21
But over the last three-quarters of a century, This link has become stronger and stronger.
22:26
And as any touch of a computer will tell you, processing information generates a lot of
22:32
waste heat. But the situation is more complex than that. It is not simply the processing of information that leads to waste heat, but the forgetting
22:43
of information. When we add three and two, the answer is, of course, five. But if I told you an answer was five and ask
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what two numbers are summed together, you cannot answer.
22:58
In a computer, logic gates combine electronic signals to do the addition -
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Whilst two numbers are fed in, they are forgotten as the single answer is spat out.
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The calculation is irreversible, the inputs lost to the universe.
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And, in the action of forgetting, the logic gates heat up a little.
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Thermodynamics therefore provides us with the ultimate limit for forgetting. Called the Landauer limit, it is the inevitable release of energy from erasing a single bit
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of information. And at room temperature it is just over 100th of an electron volt. Proven experimentally in 2012, scientists
23:43
believe that at present computer chips produce thousands of times more heat than this limit - but by 2035, they will most likely reach it.
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that tiny bit of waste heat inescapably increasing the entropy of the universe.
24:00
Ultimately, across the universe, it is this irreversibility of calculations that drives
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entropy to increase. forgetting information is therefore an essential
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ingredient for defining an arrow of time. Does this mean that for yesterday and tomorrow
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to have meaning, we must forget? Is the existence of the future implicitly
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tied to our inability to remember? And it is now we can return to our lonely
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civilization on the brink of universal heat death, in the far distant future…
24:39
When all useful energy is used up, and entropy is at maximum - would time even have any meaning?
24:47
Fundamental physics does not yet have a definitive answer, but it is an intriguing possibility.
24:52
But we have now reached a turning point. The foundations of time and space can only
24:58
get us so far - and though they are useful, there is a revolution coming.
25:04
A new order that will lead directly to the last days of our lonely black hole world.
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As we continue in our journey, we are going to have to explore new time, and new space.
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Within their black hole shell, many of the civilisation resigned themselves to their fate and dozed their way to the end. But a few curious minds, with their dwindling
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energy, still wondered about the universe. Great books that had existed for almost eternity
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told them how space could bend and ripple, Central to these books was the story of light.
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They knew that light’s speed was immense, and had used it to help measure their empire.
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They knew that light was a limit they could never break, no matter how hard they had tried.
26:04
And they knew that the speed of light had been the first step in the long journey to
26:10
understand how the universe really worked.
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"When you are next out of doors on a summer night, turn your head towards the zenith. Almost vertically above you will be shining
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the brightest star of the northern skies—Vega of the Lyre, twenty-six years away at the
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speed of light, near enough to the point of no return for us short-lived creatures…for
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no man will ever turn homewards beyond Vega, to greet again those he knew and loved on
26:42
Earth." The speed of light has always been mysterious.
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Early experiments in flashing lights back and forth had shown that it must be much faster than sound. So scientists wondered - was it infinite in
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speed? It was in 1676 that Danish astronomer Ole Romer finally found the answer. Romer was observing the moons of Jupiter as
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they circled the giant planet. And timing just when they entered the gas giant´s planetary shadow. He had assumed that the orbits ticked like
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clockwork, And so would be able to predict just when the eclipses of the moons would begin and end.
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But as he observed the moon Io throughout the year, his predictions got steadily worse,
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and then better again. It became clear that the accuracy of his predictions depended upon our distance to Jupiter, And he would need to include the extra time
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taken by light having to travel further. And so with Romer´s data fellow astronomer Christian Huygens calculated that light must move at more than 211,000 km every second,
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not far off our modern estimate of about 300,000 km per second. Romer’s observations confirmed that light was fast and finite - but precisely what light
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was would have to wait for two centuries - for as well as the confusing implications of James
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Clerk Maxwell's demon, he is also famous for intertwining electricity and magnetism into

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a single idea - electromagnetism. Light, he found, was nothing more than a self-propagating
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combination of the two - and written too into his equations was light’s blistering speed.
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But there was still a problem. Just what was this speed relative to?
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Maxwell’s equations gave no answers, so physicists began to search for a solution.
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Perhaps, they hypothesised, light travelled in an invisible medium? A mysterious ether
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permeating the entire cosmos? But that would also imply an ultimate state
28:48
of rest in the universe - a worrying thought, as that would break Galileo’s relativity.
28:55
The problem was severe - so whilst one group of physicists set out to measure the properties of this supposed ether, others took the evidence in front of them and made an even larger leap.
29:07
And chief among them was a young Albert Einstein. Einstein wondered why electricity and magnetism
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would not obey Galileo’s relativity. Why should experiments specifically using the flow of electricity or spin of a magnet reveal absolute motion?
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In a bold step he declared that they cannot. And with that, the special theory of relativity
29:35
was born. On Galileo’s ship, Einstein proposed, all experiments would yield the same results, whether the ship was secured in port, or smoothly
29:44
sailing on a glassy sea. Throwing a ball would of course not reveal whether the ship was moving But neither would measuring the speed of light!
29:53
The speed of light in a vacuum was constant - no matter the source. This final statement seemed to fly in the face of the universe as laid out by Newton.
30:02
In Newtonian mechanics you could simply add speeds together. And each observer would measure differing speeds dependent upon their own motion.
30:09
But according to Einstein, this was not the case for light. Everyone would measure the same speed. Whether the ship was stationary, going at 50 knots,
30:19
or 50,000. However if this was true, something else had to give - and the only freedom in the equations was the very nature of space and time themselves.
30:31
To work, each observer must have their own measurement of space. And each observer must have their own measurement of time.
30:42

With special relativity, it was the speed of light that was absolute - not space and
30:48
time. Space and time were no longer the universal stage on which physics played out. And just as Maxwell had combined electricity and magnetism, Spacetime too was about to unite. “Gentlemen! The views of space and time which I wish to lay before you … They are radical. Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality.” In 1908 Herman Minkowski, Einstein´s former professor, came up with an idea. In reaction to the revelations of special relativity in 1905, he had decided to explore the geometry of these new equations. In Einstein’s formulation, space was space and time was time, And to transform from one observer’s viewpoint to another, you needed to mix the two together. But Minkowski pointed out that it was simpler to mix space and time together - into spacetime. And to transform one observer’s spacetime to another through geometry. And so finally, combined spacetime was born. This new melding of the three dimensions of space and one dimension of time has come to be known as "Minkowski Space" - though Minkowski himself tragically died in 1909 before his idea had been fully embraced by the physics community. Newtonian space and time had been completely upended - but Einstein was still not happy. Though his ideas had revolutionized our ideas of space and time, they could not account for gravity. Newton’s gravitational equations needed the distance between masses And special relativity now told us that no one could even agree on what these distances were. So he went back to the drawing board and spent a decade thinking about gravity. What eventually emerged from these ruminations in 1915 was a solution that shocked physics to its core. Einstein took Minkowski’s geometric picture of spacetime, and made both space and time bendy and stretchy, the presence of mass and energy producing the curvature. Within his general theory, Einstein concluded that gravity, as a force, simply did not exist - the effects of gravity were encoded within the curvature of space and time. Newton’s picture of space and time was well and truly dead, for not only were space and time relative, they were flexible as well. The consequences of Einstein’s vision of relativity were quickly uncovered. In the special theory the relative tick of clocks depended on motion. And whilst everyone feels time passing at one second per second, Different clocks will tick off different amounts of time. With the coming of the general theory, time was shaken even more, As where you are also influences the tick of your clock. The presence of mass curves space and curves time, And so gravity can dictate the relative ticking of a clock. In 1916, Karl Schwarzschild solved the field equations of relativity for a spherical mass, and written inside his equations was a completely collapsed mass, squeezed into a point, Whilst it did not get its name for another fifty years, Schwarzschild had the mathematics for a black hole. Schwarzschild’s solution showed that black holes bend both space and time - and with this intense curvature comes intense gravitational pulls - not even light able to escape. In the vicinity of a black hole, where gravitational fields are immense, Time becomes more and more curved as you get closer to the centre. Compared to clocks in the distant universe, near the heart of darkness time ticks very slowly. And it wasn't just black holes that sprung from the new equations. In the century since Einstein’s gravitational insights, many more bizarre solutions have been found. Throughout the relativistic literature there are wormholes, warp drives and even entire curved universes. All built from the malleable nature of space and time.
35:15
In 1919, observations of the deflection of starlight proved his theory and made Einstein
35:20

a scientific superstar - and so scientists turned their attention to measuring the effects of general relativity exactly, to further cement the concept. One of the weirdest of these experiments was undertaken by Joseph Hafele and Richard Keating in 1971. Their equipment was a series of accurate caesium clocks, and a set of jet plane journeys that completely encircled the Earth. To begin the experiment, all the clocks were placed in the same location and synchronised. Some of the clocks then headed off on a plane, some heading to the East, and others to the West - some moving with the Earth's rotation, others against it. $7600 was spent on flights, with two seats on each plane going to “Mr Clock.” And because they were flying, they were in a different gravitational field to the clocks left behind on the ground. After the clocks had circled the world twice, they were all brought together. If the universe was governed by Newton's absolute time, they should all have remained in sync. But if Einstein was correct, relative motions and spacetime curvature would have desynced them. The experiment was run, and the clocks were reunited. They differed by a few hundred nanoseconds. Einstein was declared the winner. But there is one more test of relativity that has proven to be the most spectacular. In developing relativity, Einstein found that stretchy spacetime can wobble and ring. Just as Maxwell found that electricity and magnetism can ripple, so could gravity. But he could not decide if his mathematics were correct or if he was fooling himself And struggled to conclude whether these gravitational waves were part of reality. In 1974, Russell Hulse was a young astronomy student who made a spectacular discovery. With his supervisor, Joseph Taylor, he was peering at the universe with the 300m Arecibo Telescope, and he found a pulsar, a rapidly spinning dead heart of a star that flashed radio waves. This pulsar, PSR B1913+16, was spinning 17 times a second - and was not on its own, but orbited another dead star heart, a neutron star. And with the regular beeps of the pulsar, they were able to accurately chart out the cosmic dance. What they found, however, was quite unexpected. With Newtonian gravity, these dead stars would orbit each other for eternity, But Taylor and Hulse found that the orbits were shrinking, And the stars were slowly but steadily being drawn together. Somehow the energy of their orbits was leaking out into the universe. Taylor and Hulse realised Einstein's gravitational waves were an ideal culprit. They delved into the mathematics of general relativity, And calculated how the orbiting stars form ripples in spacetime - showing how they carry away precisely enough energy to explain the orbital demise. In 1993, Taylor and Hulse received the Nobel prize for their discovery - and 24 years later, the prize was awarded for the direct detection of gravitational waves.
38:48
The experiment was the Laser Interferometer Gravitational Wave Observatory, or simply LIGO for short, which with unimagined sensitivity, can feel the tiny ripples of spacetime.
39:01
LIGO has opened a new and exciting window on the universe They are uncovering merging black holes and the collisions between neutron stars.
39:10
And now astronomers even plan to hunt for the oldest gravitational waves, formed in
39:16
the birth of the universe. And so, in this new world ushered in by Einstein,
39:26
it is clear that the entire cosmos is written in the language of gravity, of curved and
39:32
warped space and time. But there was one more secret to uncover hidden
39:42

in the equations. First realised by Alexander Friedman in 1922 and later proved by Edwin Hubble, the expansion of the universe is the expansion of space
39:52
- expanding from an infinite point 13.8 billion years ago known today as the Big Bang.
39:59
Put simply: there was less space yesterday, and there will be more space tomorrow.
40:06
Every galaxy is moving further and further away from us, bar our local group, at an average
40:12
rate of 70 km/s/Mpc - which actually means that at the moment, for every 3.26 million
40:20
light-years distance from us a galaxy is, it is moving away from us at an extra 70 km/s/mpc.
40:25
So a galaxy 326 million light years from us is moving at 7000 km/s. And a galaxy 32.6
40:36
billion light years away? It recedes from us faster than the speed of light.
40:42
This may seem bizarre, after everything we have learnt up until this point - but the universe´s speed limit only applies to objects moving through space - and these galaxies
40:52
do not move through space. Space simply gets between them.
41:00
This expanding universe makes curving and bending spacetime even more complex to understand.
41:07
As equations show that space is infinite, what is happening is that the universe is
41:13
actually becoming less dense. And clearly, this decrease in density is not completely uniform across the universe. You, for example, are not slowly drifting
41:22
apart. Individual galaxies too hold themselves together due to their mutual gravity, But as this gravity is a manifestation of
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the curvature of space, What happens at the boundary between expanding
41:36
and non-expanding space? And that is not the only headache - as expanding
41:41
space makes the form of yesterday’s spacetime different to tomorrow’s spacetime - thus
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breaking what was thought to be one of the key properties of the universe - conservation
41:52
of energy. The importance of symmetry in physics was
41:59
laid out in detail by mathematician Emmy Noether - in this case a symmetry meaning that when you change your situation, the physics remains the same.
42:08

Changing location doesn't change physics, meaning momentum is conserved. And the fact that physics is the same today and tomorrow gives energy conservation.
42:17
But in an expanding universe, where spacetime is changing, this symmetry is shattered.
42:25
As space grows it doesn´t stretch - it doesn´t dilute. There is just more of it. But as they travel across an expanding universe,
42:35
photons are stretched, and they lose energy - and galaxies are robbed of their speed as
42:41
their motion grinds to a halt. Energy is simply not conserved as the cosmos
42:48
grows, and this is a conundrum that causes problems for physicists to this day.
42:58
And so, it may now seem that space has finally become physical, real - it can bend, expand,
43:06
curve and ripple. But there is a final twist, one final rug
43:12
to be pulled out from beneath us. It can be summed up in the words of the Nobel prize winner Steven Weinberg...
43:37
To the novice, this statement must seem almost bizarre. How can a leading scientist make such a claim?
43:44
Well, because he is absolutely correct – in Einstein's relativity, spacetime is truly
43:51
nothing. The mathematics look like bending and curving. But in reality, relativity tells us space is nothing and has no properties.
44:02
But what of time in this new picture? How were seconds, hours and minutes affected
44:10
by the dawn of relativity?
44:20
To the future civilization, time meant many things. They knew that their time was unique, unshared
44:28
by any others. They understood that clocks ticked differently, Dependent on where you are and what you are doing.
44:35
Their engineers had used this malleable nature of spacetime in shaping their civilization.
44:41
Great portals of distorted time and space allowed travel across the empire. Whilst the slow ticks near the gravitational pull of a black hole had been used to slow
44:50
time and allow them to watch the end of everything.
44:59

"People like us who believe in physics know that the distinction between past, present, and future is only a stubbornly persistent
45:08
illusion." WIth the coming of Einstein’s general relativity,
45:14
physicists were presented with a new headache. They knew that every particle in the universe had a past, present and future. And like a line drawn on a map, they could
45:24
chart the journey of a particle through the four dimensions of space and time, tracing out its worldline from the past to the future through a series of nows.
45:35
Each particle in your body, each electron and quark, journeys on its own worldline.
45:41
Before you were conceived, the worldlines were dispersed. But as you grew, many wordlines condensed into a bundle which is you.
45:49
And when you are gone, these worldlines will again scatter. For a fleeting moment in the life of the universe, You exist as little more than a collection
45:58
of wordlines, a brief knot in the fabric of eternity.
46:04
Whilst unsettling, this appears to make sense, so where is the headache?
46:09
Firstly, we have to remember what the relativity of time really means. With no absolute time, there is no uniform cosmic clock,
46:18
And this means that there is no such thing as a unique present, a true instant of now.
46:24
Without an absolute definition of a cosmic now, how do we define a unique notion of the
46:30
past? Without a now, just where does the future begin? Headache.
46:37
Within the equations of relativity, all pasts, presents, and futures are already written.
46:43
The entire history of all things is already out there - somewhere.
46:48
This notion, known as the ‘block universe’, has bothered many physicists and philosophers,
46:54
as without a now, the cosmos cannot simply unfold from moment to moment.
46:59
All we can do as we trace out our worldline is follow our predefined path.
47:04
And concepts dear to us, such as free will, are lost.
47:12
But this cannot be correct. We clearly remember the past, and the future
47:17
is a mysterious door that has yet to be opened. They are clearly different.

47:23
Or are they? Consider two electrons hurtling towards each
47:29
other. Both carry an identical negative charge, and, through electromagnetism, they repel. As they get closer, the repulsion grows and
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their motion gradually slows, stops, and reverses. Eventually, the electrons hurtle away from
47:43
each other, back the way they came. There seems nothing strange about this.
47:48
But imagine we filmed the interaction between the two electrons. And then showed the film to an audience of physicists - playing a mirrored version, the
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left switched to right and vice versa. Your audience of physicists would still notice nothing amiss with the movie on the screen. Switching left and right does not alter the
48:08
physics. On the screen, the electrons approach and repel - all appearing to be completely normal. But what if you went one step further - what if you were very clumsy and instead of switching left and right you switched past and future?
48:17
The film now runs backwards. Time has been reversed.
48:22
Your audience stares at the screen. What do they see? In this time-reversed movie, two electrons hurtle towards each other.
48:30
They get closer and closer, with their repulsion growing. Eventually, they halt in their motion and start to move away again.
48:37
With nothing out of the ordinary, the audience nods in approval at this simple display of
48:42
physics. But how is this possible? If you had run the slapstick of Laurel and Hardy backwards, the viewers would have noticed
48:51
- and would immediately know that something was wrong with the arrow of time. And herein lies the question: why is the electromagnetic interaction between electrons insensitive
49:01
to the direction of time? And not just electromagnetism, but gravity and the strong nuclear force are also unaffected. The weak nuclear force does misbehave slightly
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- but it is a very tiny effect. It seems that at their core, the universe’s
49:17
microscopic fundamental interactions do not possess an arrow of time.
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Time could flow one way or the other, and they simply would not care. But this leaves us with a disconnect. The macroscopic, large scale world we inhabit
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certainly does know about time. Cooling coffee, burning wood, exploding supernovae

49:41
- these are not processes that simply can be run backwards. You cannot unscramble an
49:47
egg. With a little thought, this seems a little
49:53
bit strange. Our large scale world is nothing more than the collective properties of an uncountable number of atoms.
49:58
And these atoms are interacting through a fundamental force, electromagnetism, each
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of the myriad of electromagnetic interactions unaffected by the direction of time.
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How can such an arrow emerge from the multitude of time ignorant interactions that take place
50:16
every second? How does time emerge? Some have claimed there is a definitive arrow, an imprint of a cosmological arrow of time.
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In the simple view of the block universe it stretches infinitely far into the past, and
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into the future. But this block universe clearly doesn’t appear to resemble our own. For we know that our universe didn’t stretch infinitely into the past – it had a beginning. From observations, we know that the universe was born almost fourteen billion years ago. We don’t know the process that brought it into being, but it was born with both space and time. Just where and how space and time came to be in the universe remains a mystery. But they have remained an integral part of the cosmos over all of its history. But there are other mysteries about the birth of the universe that we don’t understand. And in particular, it appeared to be extremely special, being both hot and dense, and strangely smooth. And this smoothness meant that the newborn universe had a very peculiar property. The universe was born with very low entropy. It might seem strange that smoothness implies low entropy. As a gas spread throughout a room has higher entropy than gas all squeezed in one corner. But for matter in the universe, this smoothness meant gravity could do its work, and fall together and eventually clump into stars and galaxies. And so as the universe expands, its entropy increases as the matter evolves. Gravitational potential energy is steadily converted into stars, planets, and people. Eventually, this energy is processed into waste heat that spreads throughout the universe. And it is this change from low to higher entropy that imprints onto the cosmos its arrow of time. Recent Nobel Prize winner, Sir Roger Penrose, has thought hard about our universe’s initial entropy. He concluded that the probability of this occurring by chance is one part in 10 to the 10 to the 123. Clearly, there must have been something special about our universe’s birth. But what this was, we still don’t know. And so would this mean that the block universe has no innate arrow of time? Without the big bang would it be impossible to distinguish the past from the future? Imagining how we would experience such a universe is very difficult to do. But indeed, maybe our ability to imagine anything at all is ultimately because of the special birth of the universe. On the tenth of June 1944, a British Halifax bomber was flying over France. With four hundred other bombers, it was supporting the D-Day landings in Normandy. But near the city of Laval, the aircraft was struck by German flak.

And crashed in flames into the French countryside. The entire crew perished in the crash. Seven lives were lost, seven lives in a war that eventually claimed millions. The pilot was a thirty-three-year-old Dutch volunteer, Willem Jacob van Stockum. And whilst his name is not familiar today, van Stockum was the man who discovered time travel. Of course, by the 1940s, time travel was a staple of science fiction. The Time Machine by H. G. Wells had been published half a century earlier. But this was all fantasy and whimsy - and a firm impossibility in Newtonian space and time. Yet within the new world of relativity - van Stockum had discovered a scientific basis. Mathematically, relativity is notoriously
54:07
challenging. Einstein himself had wondered if his field equations would yield any analytic solutions. But merely a year after presenting them to
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the world, the first such solution was found, as Schwarzhild derived his black holes.
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And so by the 1920s, the hunt was on for the mathematical form of the entire universe.
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Along with the giants of relativity - Einstein, Friedmann, de Sitter and others - laying down rules, finding expanding space which itself could
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be curved and even space where parallel lines could converge and diverge - some scientists
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explored the mathematics of hypothetical universes. And Hungarian mathematician Cornelius Lanczos
54:52
had found a rather peculiar solution. His equations described a universe of dust
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that was rigidly rotating. And whilst it didn't appear to describe our actual universe, it was an intriguing result.
55:05
van Stockum began to wonder about the journey of particles through such a rotating universe.
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As particles traveled from the past to the future, worldlines stretched around the universe.
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But as the universe rotated, time and space were stretched and distorted. And the nature of time itself became indistinct. Some worldlines stretched right around the
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universe and met themselves, forming closed loops. Along these, the future trod over the path of the past, over and over again.
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Physicists call these closed-loop worldlines time-like paths. But in everyday language, it was nothing less than time travel.
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That space and time can be so warped as to allow time travel was shocking. And whilst the rotating universe might not be physically realistic, it opened up the
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question of whether there were other routes to the past Or shortcuts to the future. van Stockum's goal was to head to Princeton

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to work directly with Einstein. But as the clouds of war were gathering, he looked back to Europe. Once his homeland was occupied, his desire
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was to get into the fight. And van Stockum's own worldline ended in a French field on a dark night in 1944. Whilst van Stockum's name is now lost to
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history, time travel and rotating universes are not - as they were rediscovered by the
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eccentric mathematician Kurt Godel, in 1949. Godel is remembered today as one of the greatest
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logicians of all time, and his famous incompleteness theorem still baffles today.
56:46
But his contribution to physics was equally shocking. Escaping the turmoil in Europe as the storm cloud of the second world war gathered, unlike
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van Stockum Godel did reach Princeton University. There he and Einstein became firm friends,
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with Einstein supporting his application for American citizenship, specifically by distracting
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him from pointing out flaws in the United States constitution to the judge seeing his case. It was at Princeton that Godel turned his
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remarkable mathematical mind to relativity, and the nature of spacetime - and in 1949,
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Godel's 70th birthday present to Einstein was a solution to the field equations of relativity.
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Like Van Stocken, he had found the mathematics of a rotating universe - and closed time-like
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curves that looped around his cosmos! On receiving his present, Einstein was, in
57:45
his own words, "disturbed" by the possibility. Godel´s wife had apparently knitted him a
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sweater too, but it was not part of the final gift. History does not recall why.
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Einstein died soon after, in 1955 and Godel followed him in 1978. As an old man, Godel asked astronomers if they had found if the universe was truly rotating.
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The answer was always "no it isn't" - and that Godel's universe is not our own.
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But the possibility that Einstein's relativity potentially allowed time-travel sent researchers
58:19
back to their equations. Could time and space really be bent back on
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themselves so far to allow temporal exploration? Physicists have continued to find mathematical
58:34
shortcuts through space and time, and there are now many solutions to Einstein’s
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equations in which space and time are extremely warped. It would seem that in Einstein's relativity, time travel remains a stubborn theoretical
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possibility. As an example, if you add spin to a black hole, space and time twirl also. And if you dive right through the centre,
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you might emerge somewhere and somewhen else. Another relativistic structure, a wormhole,
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builds a spacetime bridge between two locations, And potentially between two different times
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- but not necessarily a shortcut. So time travel appears to be written into the equations of relativity. The reality of these solutions, whether they
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can truly exist, remains unanswered. Perhaps we will never be able to focus enough
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energy into a single place For spacetime to bend right back on itself.
59:31
We now understand how Einstein's space time works - but we still don’t know what it
59:38
is. Where can we turn next? Well - it was not just Einstein who was charting a new path at the beginning of the 20th century.
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It was a dramatic period for theoretical physics - and quantum mechanics was at the forefront
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of the changing order. And so - perhaps, physicists thought - the
1:00:00
answer could lie at the smallest scales in the universe. In the far future, the civilization had become desperate. The stars had long died, and matter itself was starting to melt. Very few remained now, almost frozen in the darkness. The last of life grinding to a halt. But some eyes still stared into the skies, To witness the last bursts of light in the universe. The great books had told them this time would come, Warning them that not even black holes would last forever. Whilst the immense gravity of relativity held them together… On the smallest scale, the action of the quantum world resulted in their ultimate decay. For eons they had struggled to combine the two - the world of gravity had seemed so distant from the quantum. And so too their black hole home was dissolving. They could do nothing to stop it. Indeed, the last few were so very tired, They didn’t even try. "A university student attending lectures on general relativity in the morning and others on quantum mechanics in the afternoon might be forgiven for thinking that his professors are fools, or have neglected to communicate with each other for at least a century." There is a grave at Roselawn Cemetery in Tallahassee Florida. Written on it is the name of a man who died in 1984, aged 82. Unlike the others in the graveyard, the man also has a plaque at Westminster Abbey, Not far from the mortal remains of Isaac Newton. The plaque does not say much. It labels the man as a physicist and notes his birth

and death. But on the plaque is also an equation, a complex mix of Latin and Greek letters. And this equation was the first unification of Einstein’s relativity and quantum mechanics. The famous physicist Niels Bohr referred to Paul Adrien Maurice Dirac as the strangest man to visit his institute. Born in Bristol at the beginning of the twentieth century, he did not at first seem destined for scientific greatness. In 1923, Dirac began his studies at the University of Cambridge. famously focused on his science, He shunned many human interactions, and his conversations were mainly silent. His colleagues named the unit of one word per hour as a “dirac” in his honour. But whilst speech was slow, his mind raced around the problems of physics. It was a heady time to be a physicist, with both Einstein's new world of relativity and the bizarre implications of quantum mechanics opening up - were the fundamental secrets of the universe finally revealing themselves? When Dirac began his exploration of quantum mechanics it was written in the past. The mathematics of Schrodinger and Heisenberg played out on the stage of Newton. With the tick of an absolute clock, and Galileo’s vision of space. But Dirac knew that this picture of space and time was simply outdated. Surely the equations of quantum mechanics should reflect Einstein's new visions of space and time. This bothered Dirac, and he scrambled with the mathematics trying to make it work, spending his Sundays walking alone turning over the equations in his mind. And in December 1927, the fog began to clear. A relativistic quantum equation came into view. An equation that obeyed Einstein’s demand that there is no special rest in the universe. And Dirac used this equation to explain the simplest of particles, the electron. Suddenly, various peculiar properties of the electron made mathematical sense. Within Dirac’s equation, the electron spins and behaves like a small bar magnet, Both properties had been difficult to explain, but they were a natural consequence of relativity. But there was another property that was completely unexpected. If you take the square root of one, there are two solutions - plus one or minus one. In the same way, in explaining the electron the Dirac equation has two solutions. One solution is negatively charged and clearly represents the electron. But just what does the positive solution correspond to? Dirac wondered if it could be the proton, the positively charged particle within the nucleus. But being almost two thousand times more massive, that could not be correct. He eventually concluded his equation was predicting a new particle, the anti-electron. This particle should have the same mass as the electron but have the opposite, positive, charge. Antimatter. The Dirac equation was the birth of quantum field theory, the most successful physical theory. It is with these mathematics we describe all of the fundamental particles and forces, the basis of the modern standard model. And for each of the particles, there are anti-particles, electrons, positrons, quarks and anti-quarks. All a consequence of Einstein’s view of relative space and relative time. But quantum field theory is built on Einstein’s special theory of relativity. What of gravity and the general theory of relativity? What if we incorporate curved spacetime into the Dirac equation? Unfortunately, after such incredible early success - the last century has brought us no further in this quest. Within quantum field theory, the quantum wave function that underlies existence still plays out within the arena of space and time. Because of special relativity, this spacetime is more complex than Newton’s view, but space and time are still the universal stage. And this stage is broken when considering the curved spacetime of general relativity. Remember, in the general theory of relativity, space and time are dynamic and evolving. They are not simply the stage - they are players in the physics of the universe. Quantum mechanics was complicated enough, but after many years of work its various infinities had ultimately been tamed. With curving, bending, rippling spacetime - the infinities seemed uncontrollable. With the failure to simply merge gravity and quantum mechanics, some physicists have searched elsewhere. This has involved going back

to the drawing board, with new ideas for just what space and time are in the quest for the so-called "theory of everything" - the so-far fruitless search to tie the microscopic quantum world to the macroscopic world of general relativity and fully explain the universe. And of course these theories of everything have not necessarily made things simpler. In one of the leading contenders, string or m-theory, there might be 11 or even 26 dimensions. But what do these ideas have to say about the fundamental nature of space and time? Again it's not so simple. In m-theory, space and time are part of the fundamental structures of the universe. The strange, contorted shape of this structure in multiple dimensions explains everything. Not just space and time, but all matter, all radiation, and all of the forces. What are these fundamental structures made of? M-theory doesn't tell us. Another contender for the theory of everything is loop quantum gravity. On the face of it, this theory is even more bizarre, with space and time being quantum phenomena. At the tiny Planck scale, spacetime is chunky, fundamentally meshed together into a network. And to us, this subatomic mesh has the appearance of smooth space and time. Again, we can ask - what are these quantum grains made of? And again, we are left disappointed as they just are. But perhaps the solution is simpler than this. Perhaps - some have speculated - space and time do not exist at all. Remember at the start of this story we heard the disagreement between Newton and Leibniz. To Newton, space and time were part of reality and existed independent of the matter in the universe. Leibniz, however, said that it was the relationships between matter that defined space and time. Without them, space and time would have no meaning. And the relativistic vision of spacetime seemed to match this picture.
Einstein told us that matter defined the structure of spacetime, And spacetime told matter what to do. We know that in the quantum picture, spacetime appears to be lumpy. And that reality is possibly constructed of these bits of spacetime as the universe grows. But what if space and time are not really there? What if space and time are actually emergent phenomena, something we experience only as macroscopic beings? This might sound strange, but we know that we are sandwiched in the universe. This means that we don't feel the cosmological expansion that dominates the large-scale universe. And similarly, we don't feel the individual feel individual atoms as they collide with our skin. Instead, we have a collective term, temperature to describe what is happening. Perhaps space and time are the same? In 1997, Juan Maldacena found a key relationship in the mathematics of string theory and gravity. Known as the AdS/CFT correspondence, it could be accidental and of no consequence, but it could also be pointing to something deeper, The path to uniting quantum mechanics and gravity. But if this is the right path, something else emerges. Through this relationship, space and time become granular: pieces of fundamental length and fundamental time - Planck scale pixels that set the smallest resolution of the universe. This would mean that at the smallest scales, space and time would appear as nothing more than grains of sand on a beach. And so, perhaps there is no space between the grains of reality - no time between one grain and another. Perhaps to these grains, these are concepts that make no sense - there are only their relations, how they interact. For us, much larger than the scale of these grains, there is the concept of space. And somehow through the relationships of the grains, we experience the experience of experience. But underlying this, maybe ultimately, space and time simply don't exist, There are just fundamental bits and pieces, and their inter-relationships. This may feel uncomfortable. Just where is the "you" in this relational universe? Perhaps it is best to think of it like this: Most of us have come to terms with the fact that we are physically a collection of atoms. And somewhere in this collection, we, our consciousness, somehow emerges. We seem to be able to live with this illusion of our being. Maybe all we need to do is the same for

the stage on which we play out our existence. And so, we have come a long way and are approaching the end of our journey. Space and time, our focus along our path, both seemed so natural, seemed so normal. But we have seen that they are far more strange, more mysterious than they first appear. Though the space and time of Newton were simple and absolute, they became more complex with Einstein's curving spacetime. And the quantum nature of spacetime attempts to dice space and time into little pieces. But are we any closer to really understanding its true nature? A lot of hope is pinned on our next fundamental theories, That a theory of everything will eventually shine a light on the universal stage. And maybe written into the theory will be the true nature of space and time. Perhaps the block universe will be banished as the universe unfolds. Perhaps quantum processes are constructing a "now" one instant at a time. Or perhaps some process we have yet to imagine is defining reality. But, of course, nature is not bound to reveal its secrets. No matter how hard scientists work, they may never reveal the fundamental truth. We must face the fact that some mysteries might remain forever mysteries - indeed just what space and time actually are could forever be beyond our grasp. And so, finally we return to the twilight of the cosmos. WIthin their home, the last few watched their black hole slowly evaporate. All they wanted was to eke out one more day, one more moment. But eventually, the decay of the universe could no longer be shut out. They had manipulated space, they had mastered time, bent them to their will. But they could not defeat them. And then, there was darkness.
1:16:00
← Do této pozice, hodinu a šestnáct minut od začátku přednášky, bylo zbytečné, abych text překládal a komentoval. To, co se tam výše píše, všichni zájemci o fyziku ( mladí, staří, chytří, hloupí, vystudovaní, i nadšení laikové ) znají. Takže bych okomentoval jen poslední odstaveček, dva listy z celé 75ti minutové přednášky →

Einstein nám řekl, že hmota definuje strukturu (křivost 3+3 imenzí) časoprostoru, a časoprostor řekl hmotě, co má dělat. (..jak se „gravitačně" chovat v makroměřítku). Víme, že na kvantovém obrázku (s pohledem do kvantové úrovně) se časoprostor jeví jako hrudkovitý. (zrníčkovitý) A jak dlouho to (ne)víte ? → http://www.hypothesis-of-universe.com/docs/aa/aa_231.pdf ; http://www.hypothesis-of-universe.com/docs/c/c_461.jpg ; http://www.hypothesis-of-universe.com/docs/aa/aa_217.pdf A tato realita je možná konstruována …takže nevíte…z těchto kousků časoprostoru 3+3D, jak vesmír roste. Ale co když prostor a čas ve skutečnosti nejsou? Takže nevíte… Co když jsou prostor a čas ve skutečnosti emergentní jevy, něco, co zažíváme pouze jako makroskopické bytosti? Může to znít divně, ale víme, že jsme sevřeni ve vesmíru. To znamená, že **necítíme** kosmologickou expanzi, která dominuje **velkému – globálnímu** vesmíru. A **podobně necítíme**, že jednotlivec cítí jednotlivé atomy, když se srazí s naší kůží. Místo toho máme společný termín (společné tempo plynutí času), teplotu, která popisuje, co se děje. Možná je prostor a čas totéž? No, s touto odvážnou myšlenkou jsem přišel na net už před 18-20ti lety, ba před 40ti lety kdy nebyl internet, že…že Velveličina-vesmír „V" = sólo-stav (asymetrický) se štěpí na dva stavy (symetriecké), tj. veličinu DÉLKU a ČAS…a ty se pak štěpí zase na stav asymetrický: DÉLKU a ČAS a HMOTU, atd. ( Princip střídání symtrií s asymetriemi ; strom geneze je nastaven, připraven). Anebo vize : Velveličina „V" = sólo-stav (asymetrický) se štěpí na dva stavy zrcadlové, tj. **veličina „délka jakožto antičas", „čas jakožto antidélka", coby filozofický formalizmu** ""globálních stavů"".

A nyní můžeme položit na stůl formalizmus matematický o **přechodu linearity do neinearity**, přechodu „kvantové pěny“ na úrovni mikro-měřítka, jakožto linearita, jemná to pěna, hladké spojité postředí http://www.hypothesis-of-universe.com/docs/c/c_461.jpg ; http://www.hypothesis-of-universe.com/docs/c/c_486.jpg ; s přechodem do nelinearity, do globálních zakřivení makroměřítek, např. kuželoseček. (Gravitace jakožto parabola). http://www.hypothesis-of-universe.com/docs/c/c_037.jpg . Tohle bylo pro mě – matematického nevzdělance – důležité: pochopení „gravitace“ jakožto rovnice paraboly. **Matematický přechod linearity QM v nelinearitu OTR. (** to jak to matematika dělá, to nevím dodnes http://www.hypothesis-of-universe.com/index.php?nav=d **).**

V roce 1997 našel Juan Maldacena **klíčový vztah v matematice teorie strun a gravitace**. Známá jako korespondence AdS/CFT, **Maldacenův klíčový vztah je AdS/CFT (( k čemuž potřeboval dvě státnice na dvou universitách )) a…a můj klíčový ztah, *matematický*, je, že se najde v kuželosečkách, v přechodu elipsy do paraboly a z paraboly do hyperboly.** Nejsem dobrý matematik, rozhodně ne, i tak postrádám názor těch skvělých matematiků ! k mé víře klíčového vztahu mezi lineární pěnou – kvantová mechanika ve dvouveličinovém zápisovém provedení interakcí a nelineární OTR parabolou ( Těch plivačů názor nepostrádám, těch názory už znám: bludy a fantasmagorie) : **kde a proč se mýlím. NIKDY od r. 2000** se žádný odborník nenašel z ješitnosti , aby mi vsvětlil v čem jsou moje úvahy chybné.

*AdS/CFT korespondence je **teoretický princip spojení** mezi kvantovou teorií gravitace definovanou na anti de Sitterově prostoru a konformní teorií pole definovanou na hranici anti de Sitterova prostoru v nekonečnu. Ekvivalence platí přesto, že hranice má dimenzi o jednu nižší než celý prostor. Wikipedie*
mohla být náhodná a bez důsledků, ale mohla by také ukazovat na něco hlubšího, na cestu ke sjednocení kvantové mechaniky a gravitace. Od útlého mládí, fyzikálního mládí, „laické vzdělanosti“ presentuji názor, že „čistě hladký“ nekonečný stav časoprostoru je ten před Třeskem – monostav, a je to 3+3D mřížka-rastr-předivo….“bez měřítka“. Po Třesku nastala změna, symetrický duo-stav, presentace „tohoto“ časoprostoru ve dvou vývojvých směrech: do makrovesmíru se časoprostor **rozbaluje** a v mikrosvětě se časoprostorové dimenze **sbalují** do balíčků a vzájemných propojních v interakcích. Více o tom je na tisíci popsaných papírech. Pokud je to ale správná cesta, objeví se něco jiného. Prostřednictvím tohoto vztahu se prostor a čas stávají granulárními: **kousky** základní délky a základního času – **pixely** v Planckově měřítku, které nastavují nejmenší rozlišení vesmíru. Zrnitost je projevem ! „zvlněného-zmačkaného časoprostoru“ kiřivosi dimenzí ve stavu „pěny“ ( a záleží na volbě měřítka pro“zvoleného“ Pozorovatele.) To by znamenalo, že v nejmenším měřítku by prostor a čas vypadaly jako nic jiného než zrnka písku na pláži. O.K. A tak možná není žádný prostor mezi zrnky reality – žádný čas mezi jedním zrnkem a druhým. Ne, ne, chyba. I to „nic-něco“ i „mezery a nemezery“, i „jedničky a nuly“, i „bod-mezera-bod-mezera“, i plus-mínus-plus-mínus“, to vše je kontinuum. **I ta mezera patří do kontiua**, i to „nic“ je součástí jsoucna. Takže vše patří do Jsoucna, i to Nic, i mezery, atd. Možná pro tato zrna jsou to pojmy, které nedávají smysl - existují pouze jejich vztahy, jak se ovlivňují. Pro nás, mnohem větší než je měřítko těchto zrn, existuje pojem prostoru. A nějak prostřednictvím vztahů zrn prožíváme zkušenost zkušenosti. Ale za tím, možná nakonec, prostor a čas prostě neexistují, existují jen základní kousky a jejich vzájemné vztahy. Špatně, chyba…To může být nepříjemné. Kde je to „vy“ v tomto relačním vesmíru? Hlouposti…Možná je nejlepší si to představit takto: Většina

z nás se smířila s tím, že jsme fyzicky sbírka atomů. A někde v této sbírce se nějak vynořujeme my, naše vědomí. Vynořuje se na jevišti, „do dějiště proměn“ složitost kompexity na různých úrovních měřítek  Zdá se, že jsme schopni žít s touto iluzí našeho bytí. Možná vše, co potřebujeme udělat, je totéž pro jeviště, na kterém hrajeme svou existenci. A tak jsme ušli dlouhou cestu a blížíme se ke konci naší cesty. Prostor a čas, naše zaměření na naší cestě, obojí vypadalo tak přirozeně, vypadalo tak normálně. Ale viděli jsme, že jsou mnohem podivnější, tajemnější, než se na první pohled zdá. Ačkoli prostor a čas Newtona byly jednoduché a absolutní, staly se složitějšími s Einsteinovým zakřivením časoprostoru. A kvantová povaha časoprostoru se pokouší rozsekat prostor a čas na malé kousky. Ale jsme o něco blíž k tomu, abychom skutečně pochopili jeho pravou podstatu? Jsme, já věřím…; až pochopíte HDV budete o další kus k podstatě  blíš. Do našich dalších základních teorií se vkládá velká naděje, že teorie všeho HDV+ nakonec osvětlí vesmírnou scénu. A možná určitě ! bude do teorie zapsána skutečná povaha prostoru a času. Možná bude blokový vesmír vykázán, jak se vesmír rozvine. Možná kvantové procesy konstruují „teď“ jeden okamžik po druhém. Nebo možná nějaký proces, který si ještě neumíme představit, definuje realitu. Ale příroda samozřejmě není povinna odhalit svá tajemství. Bez ohledu na to, jak tvrdě vědci pracují, nemusí nikdy odhalit základní pravdu. Musíme čelit skutečnosti, že některá tajemství mohou zůstat navždy tajemstvími - skutečně to, co prostor a čas skutečně jsou, může být navždy mimo náš dosah. A tak se konečně vracíme do soumraku kosmu. Ve svém domě několik posledních sledovalo, jak se jejich černá díra pomalu vypařuje. Jediné, co chtěli, bylo prožít ještě jeden den, ještě chvíli. Ale nakonec se rozpad vesmíru už nedal zastavit. Manipulovali s prostorem, ovládli čas, ohýbali je podle své vůle. Porazit je ale nedokázali. A pak byla tma.

JN, 19.01.2023

Podoský říká

38:05 – trvá to už 50 let a pořád nevíme jak z této rovnice „matematiky“ http://www.hypothesis-of-universe.com/docs/c/c_098.jpg  vydolovat „fyziku“