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Does Time Exist? Chad Orzel (406)

Existuje čas? Chad Orzel (406)

Dr Brian Keating

249 tis. odběratelů

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Join my mailing list https://briankeating.com/list to win a real 4 billion year old meteorite! All .edu emails in the USA us will WIN! Today on Into the Impossible, we're exploring the fascinating realm of time with none other than the timekeeper himself – Chad Orzel. Chad is a professor of physics and science communicator renowned for his popular science books, How to Teach Quantum Physics to Your Dog, Breakfast with Einstein, and How to Teach Relativity to Your Dog. He is also a regular contributor to Forbes.com. In his most recent book, A Brief History of Timekeeping, Chad revisits the delicate negotiations involved in Gregorian calendar reform, the intricate and entirely unique system employed by the Maya, and how the problem of synchronizing clocks at different locations ultimately required us to abandon the idea of time as an absolute and universal quantity. From sundials to sandglasses and mechanical clocks, this sharp and engaging story isn't just about the science of timekeeping—it's a riveting tale encompassing politics, philosophy, and the very essence of space and time. Tune in!

Time in a Nutshell → Join my mailing list https://briankeating.com/list and win a real 4 billion year old meteorite! All .edu emails in the US us WIN! Today on Into the Impossible we explore the fascinating realm of time with none other than the timekeeper himself – Chad Orzel. Chad is a physics professor and science communicator known for his popular science books How to Teach Your Dog Quantum Physics, Breakfast with Einstein and How to Teach Your Dog Relativity. He is also a regular contributor to Forbes.com. In his latest book, A Brief History of Timekeeping, Chad revisits the delicate negotiations surrounding the reform of the Gregorian calendar, the complex and completely unique system used by the Maya, and how the problem of synchronizing clocks in different places ultimately required us to abandon the idea of time as an absolute and universal quantity. That is a fallacy, a misguided vision and a misunderstanding of time. Time is a quantity, existential, fundamental, which does not run. Only when an object (material object and immaterial cursor) moves in the time dimension can we speak of flow – the pace of time passing, which is the cutting of time dimensions into dimensions. Intervals of time will be reflected in the Observer, who watches the unfolding of dimensions + space-time. Time is a universal quantity, but the flow-passage of time may not be universal. *From sundials to hourglasses and mechanical clocks, this sharp and engaging story is not just about the science of time measurement – it is a gripping story involving politics, philosophy and the very essence of space and time. Tune in!*

0:00

(01)- Today on in the possible we're exploring the fascinating realm of time but none other than the master timekeeper himself Chad orzel renowned for captivating books such as how to teach quantum physics to your dog and breakfast with Einstein Chad is here to unveil the mesmerizing narrative woven into his latest Masterpiece a brief history of timee keeping you find that time passes at different rates when people are moving relative to one another in the book he revisits delicate negotiations involved in the Gregorian calendar reform the intricate and entirely unique system employed by the Mayans and how the problem of synchronizing clocks at different locations ultimately required us to abandon the idea of time as an absolute and Universal quantity from Su dials to sand glasses and mechanical clocks this sharp and engaging story isn't just about the science of timekeeping it's a riveting tale encompassing politics philosophy and the very essence of space and time itself how do those two things coexist how does that linear March into the future and the cyclical rep I how do those play with each other so right now it's about that time let's get started so Chad you've written this wonderful uh book it's not new it's two years old now A Judging a book by its cover Brief History of timekeeping I bought the you were kind enough to send me the the hard cover the soft cover rather with a beautiful illustration and we're going to go through it I listened to it on audiobook as well I really enjoyed it as we do on this podcast one thing is uh mandatory for authors such as yourself who grace us and that's to judge the book by its cover you're never supposed to do it but you got to do it and that's to do the following chat so please take us through the title The subtitle and the delightful intricate modern times looking gears and the artwork so those three features of the book help us judge this book by its cover so yeah the the title is is a brief history of timekeeping and it's very much what what it sounds like it's it's a a book about the Science and Technology of of tracking time over the last several thousand years I don't remember the exact wording of the subtitle but something like the science of keeping time from Stonehenge to atomic clocks and that sort of gets you the sense sense of the scale uh so it's from kind of Bronze Age Neolithic kind of of monuments all the way up to the current state of-the-art and atomic clocks and even a little bit about sort of speculative atomic clocks that uh will go to even higher level of precision than than we can manage now the gears on the on the cover that was the work of the the art department at uh Ben Bella books who's the publisher for this and the minute we saw that that those popped uh I don't know what that gear train is actually from uh but it it looks really great and you know jumps off the off the blue cover and like yes that's the the one tweak I think they they I think they may have rotated the the the picture slightly just to get the the words the the very first pass at it it it ended up looking like a history brief of timekeeping and uh so they they turned it a little so it was a little clearer what order the words go in it's impossible not toh note the direct correlation with uh the most famous book the third book that I've written according to chat GPT if you ask it what books is Brian Keon written he's written uh losing the Nobel Prize into the impossible in A Brief History of Time I heard the great Steven Hawking at the Royal Society in 1994 or five and he couldn't talk but he could use a speech synthesizer yeah and at the end he graciously accepted questions and there was a member of the audience who asked him Stephen uh you've written this book almost nobody has read it anyone who has read it doesn't understand it you even claim in the book that every equation reduces The Audience by half tell me Stephen the questioner asked Hawking why did you write this book and after five minutes of you know kind of uh just just painstaking silence we're all just waiting for him to move his eyes across the computer generating his voice and he said because I needed to pay for my daughter's College Chad you've got two kids you're obviously devoted to your kids and your pets you write this book for the money to pay for them to go to college it's nice to

have a little extra money but uh you know I work at a college so uh so getting them uh getting them through is is going to be not as as difficult as it might be in in some other circumstances yeah if you were at UC San Diego you know what we get here we don't we don't get free tuition we get instate tuition that's all um so I really enjoyed this book and and part of the

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(01)- Today we explore the fascinating realm of time, but none other than master timekeeper Chad Orzel, famous for his riveting books such as How to Teach Your Dog Quantum Physics and Breakfast with Einstein Chad, is here to reveal the fascinating narrative woven into his latest masterpiece A Brief History of Timekeeping and you'll discover that time passes at different rates, Note. The different rates are **"observed"** by a basic observer held at rest, but that "different" rate may not be ||on|| the observed object!!, as people move relative to each other, the book revisits the delicate negotiations surrounding the reform of the Gregorian calendar, the complex and completely unique system employed by the Mayans, and how the problem of synchronizing clocks in different locations ultimately required us to abandon the idea of time as an absolute and universal quantity. what does clock synchronization (the chosen pace of time, for choosing interval units) have to do with abandoning the quantity of time as an absolute existential entity???, …and thus abandoning space-time with 3+3 dimensions (?) from Su dials to sand glasses and mechanical clocks, this sharp and engaging story is not just about the science of time measurement it is a gripping story involving political philosophy and the very nature of space and time itself, I wonder how the author will portray the "nature" of time here… how these two things coexist, how the linear march into the future and the cyclical repetition, how these play out, so right now it's about time, let's get started, so Chad, you wrote this amazing book, it's not new, it's been two years. I judge a book by its cover **A Brief History Measurement of Time**, Measurement of time says nothing about the nature of time…

I bought it, you were kind enough to send me a hardcover, a softcover rather with beautiful illustrations and we'll go through it. I listened to it on audiobook too, I really enjoyed it, just like on this podcast one thing is mandatory for authors like you who grace us and that is to judge a book by its cover you should never do that but you have to do that and that is to do the following chat so please guide us with the title the subtitle and the beautifully intricate modern gears and the artwork so those three features of the book help us judge this book by its cover so yes the title is a brief history measurement of time and it's very similar to what it sounds like it's a book about the science and technology of timekeeping over the last few thousand years. I don't remember the exact wording of the subtitle but something like the science of timekeeping from Stonehenge to atomic clocks and that will give you a sense of scale so it's from the Bronze Age, Neolithic, kinds of monuments. The path to the current state of technology and atomic clocks and even a little bit about some kind of speculative atomic clock that will go to an even higher level of accuracy, what is the good of that =super accuracy of intervals measured= to compare to the interval chosen = unit of time?? than what we can currently manage, the gears on the cover that were the work of the art department of uh Ben Bella books, who is the publisher of this and at that moment when we saw those that jumped out, I don't know what the gears are actually from, but it looks really cool and you know it jumps out of the blue cover and like yeah, that's the only edit. Blah-blah I think they I think they could have rotated the picture a little bit just to get the words, the very first pass at it ended up being a history short timer and uh, so they rotated it a little bit so it was a little

clearer what order the words go in, it's impossible not to notice the direct correlation with the most famous book, the third book I wrote according to the GPT chat, if you're asking what books **Brian Keon** wrote, he wrote uh losing the Nobel Prize to the impossible in *A Brief History of Time*. I heard the great **Steven Hawking** at the Royal Society in 1994 or five and he couldn't speak but he could use a speech synthesizer yeah and at the end he kindly took questions and there was one audience member who asked him Stephen eh you wrote this book almost nobody has read it, those who have read it don't understand it, you even claim in the book that each equation reduces the audience by half, and…this agrees with my experience, because I have read hundreds of articles on cosmology (in 24 years) and watched hundreds of videos and almost nowhere was there mathematics in them …and yet the universe was explained here, the basic new physics was explained, everyone understood… questions at public lectures were never about physical mathematics, but about physical reality…; I say this to my archenemies (Hnědkovský, Bílý, Sedliský, etc.), who claimed that without mathematics my hypothesis is worthless, empty gibberish…, I objected that: then the whole cosmology is gibberish, because the equation is not demonstrated in it… tell me Stephen, the interviewer asked Hawking why you wrote this book, and after five minutes you already know, somehow uh, just tedious silence, we are all just waiting for him to move his eyes through the computer generated voice and say, because I needed to pay for my daughter's college. Chad, you have two kids, you obviously care about your kids and your pets, you're writing this book with the money you're going to pay for them to go to college, it's nice to have a little extra money, but you know, I work at a college, so getting them, uh, pushing them through won't be as hard as it might be under other circumstances, yeah, if you were there UC San Diego you know what we get here, we don't, we don't get free tuition, ||we get in-state tuition, that's all|| um, so I really liked this book and part of the book
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(02)- reason we're talking today although I wanted to talk to you for a while we met in person about five years ago now at an APS meeting in Denver Colorado it was great to meet you at a an event for authors and and popularizers as as we're sometimes called but you're also a hardcore scientist and uh contribute a lot to um cold Adams and we'll get into some of those techniques had Bill Phillips on who you must know from your time in Maryland oh yeah bill bill was my thesis adviser yes I was gonna say I suspected it given the uh I tried to look up some papers that you written uh with him but Galileo's telescope helmet it was uh I only had so much time but Bill was on about a year and a half ago just a delight love talking to him he's fabulous and we'll get into some uh some topics in the future of timekeeping and and where do we go from here and why do we go from here why why do we need clocks that can do you know fto at seconds and whatnot but the one of the reasons that talking today is because of a uh somewhat uh brushed comment that I made or maybe you made on Twitter which is that I was on The Joe Rogan Experience last summer and uh I was talking about my hero Galileo who's around here somewhere in puppet form and I I claimed that he had you know tried to solve this time Problem by inventing this you know Apple Vision Pro like device with instead of you know one camera had two telescopes attached to it and uh the court rejected it or the the you know the the people in charge rejected it uh because you know you could only see Jupiter nine months of the year and you could only see it at night where was I wrong you know how should I be shamed publicly what did I say wrong to to Dr Rogan that uh that raised your ey if anything I don't remember exactly the the details the the telescope helmet

thing that he he drew up is is uh is is wonderfully steampunk looking it's it's really uh quite a quite a device you the idea there is that if you could observe the eclipses of the moons of Jupiter you can get very accurate uh measurement of what time it is and those are are very reliably predictable and you can use that to set a clock uh and in fact people did that a lot in the 1600s you know the technology for doing that on shipboard just wasn't wasn't there it's it's not it's not stable enough even with the even with the helmet to be able to to Really zoom in and and see those eclipses and get the timing that you need to to do a good measurement of longitude people were doing that on land and and you could do uh you know travel across the ocean then set up your telescope on land and figure out the longitude very accurately that way that that worked pretty well but on shipboard it was pretty hopeless Galileo is also usually credited with inventing the pendulum clock uh and he did have the idea to do the the pendulum clock but by the time he had the idea he was he was uh rather elderly and and basically blind so um they never got it to work one of his son his son and uh one of his his students worked at it for a little while but never never made a a working prototype so it was uh chrisan hins uh almost you know 30 40 years later who who got it to work designed the first working pendulum clock and had it made by a clock maker uh named Solomon Coster um who's one of those these these people who no actual picture of him exists uh which is sort of interesting is from that per that that time period you know hyans you can find lots of Engravings of hyans but Coster is a is a complete loss yeah looking at that um Al although there is some lore there's so much lore with timekeeping I mean it's so important so integral to everything we do in life and and so forth but and you gave it a definition which is in congruence with what Frank wilch told me when we talked as well about time and that's you know time is what a clock measures uh but that's sort of you know tautological you know if I said you know length is what a ruler measures or or it wouldn't be as satisfying right so we somehow will accept that uh for time but nothing else why why is that why is time why does time get a free pass the phrasing I like to use I think I lifted from Bill Phillips actually is that a clock is a thing that ticks and it it does some regular repeated action that you can count so you know the the pendulum on a pendulum clock swinging back and forth that happens in a very regular way and you count how many times that happens and that's the thing you use as the clock I think the reason that that time kind of gets uh a little bit of a a pass there is it's unlike length uh you know unlike space it we only experience it in One Direction right we we move from the past to the Future and we do that in a in a rather inexurable way you can't you can't go back in time um and so it it has this quality that well it only goes in One Direction uh and

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(02)- the reason we're talking today, even though i wanted to talk to you for a while, we met in person five years ago at the aps meeting in denver colorado, it was great to meet you at an event for authors and popularizers as we're sometimes called, but you're also a hardcore scientist and you contribute a lot to um cool adams and we're going to get into some of those techniques that **bill phillips**, who you must know from your time at maryland oh yeah bill bill was my thesis advisor yeah i was going to say i suspected that given that, uh, i was trying to look up some papers that you wrote with him, but galileo's telescopic helmet it was uh, i only had so much time, but bill was about a year and a half ago just a delight, i love talking to him, he's wonderful and we're going to get into some of the topics in the future time measurement and and where do we go from here and why do we go from here, why do we need clocks, no comment that you can know fto in seconds and what else, but one of the reasons you're talking today is because of a uh, somewhat maudlin comment that I made or maybe you made

on Twitter, which is that I was on **The Joe Rogan Experience** last summer and uh I was talking about my hero Galileo, who's here somewhere in puppet form, and I was claiming that this time he tried to solve the problem by inventing this, you know, a device similar to the **Apple Vision Pro**, instead of, you know, one camera had two telescopes attached and the court rejected it or you, you know, the people in charge rejected it because, you know, you only saw Jupiter nine months out of the year and you could only see it at night, where I was wrong, you know how embarrassed I should be publicly, what I said wrong to **Dr. Rogan**, že to zvedlo vaše oko, pokud něco, nepamatuji si přesně ty detaily, ta věc s helmou dalekohledu, kterou nakreslil, je, vypadá úžasně steampunkově, je to opravdu Uh, docela docela zařízení, máte představu, že pokud byste mohli pozorovat zatmění měsíců Jupiteru, můžete získat velmi přesné měření kolik je hodin a ty jsou velmi spolehlivě předvídatelné a můžete to použít k nastavení hodin a ve skutečnosti to lidé dělali hodně v 17. století, znáte technologii, jak to dělat na lodi, prostě to nebylo, nebylo tam není to není, není to dostatečně stabilní ani s helmou, abyste mohli opravdu přibližte se a podívejte se na zatmění a získejte načasování, které potřebujete, abyste mohli udělat dobré měření zeměpisné délky, lidé to dělali na souši a vy byste mohli cestovat přes oceán, pak nastavit svůj dalekohled na souši a přijít na to zeměpisná délka velmi přesně tak, že to fungovalo docela dobře, ale na lodi to bylo docela beznadějné Galileo je také obvykle připisován vynálezci kyvadlových hodin a měl nápad udělat kyvadlové hodiny, ale v době, kdy dostal nápad, byl docela starší a v podstatě slepý, takže se jim to nikdy nepodařilo, jeden z jeho synů, jeho syn a jeden z jeho studentů na tom chvíli pracovali, ale nikdy nevytvořil funkční prototyp, takže to bylo uh **chrisan hins asi Heigens** ehm, skoro víte, o 30 40 let později, kdo, kdo to dal do práce, navrhl první funkční kyvadlové hodiny a nechal je vyrobit výrobcem hodin jménem Solomon Coster um, který je jedním z těch lidí, kteří nemají jeho skutečný obrázek, ehm. Je docela zajímavé, z toho, že z toho časového období víte, hyans, můžete najít spoustu rytin hyanů, ale Coster je úplná ztráta, jo, když se na to díváte, um Al, i když tam je nějaká tradice, je tu tolik lore s měřením času, myslím je to tak důležité, tak integrální ke všemu, co v životě děláme a tak dále, ale dal jsi tomu definici, která je v souladu s tím,
what **Frank Wilch** told me when we were also talking about time, and that is you know that time is what clocks measure well, it's better to say (in the scientific community) the rate of passage of time is what clocks measure and measure "the number of chosen unit intervals", then clocks show "total interval" = time, time commonly used in civil (use) is a "phrase for time"... (e.g. I was 3 hours and 3 minutes in the supermarket) uh but that's something you know tautologically, you know, if I said you know that length is what a ruler measures, no, length is a quantity, but distance is an interval measured by a ruler, or it wouldn't be so satisfactory right, so we'll somehow accept it uh for time, but nothing else,why, why is it that there is time, why does time have free passage a phrase I like to use. I think what I picked up from **Bill Phillips** is that a clock is a thing, yes, a mechanism that ticks intervals, "selected intervals", that ticks and does some regular repeating action, yes that you can count so you know what the pendulum on the clock swings back and forth, which happens very regularly and >you count how many times that happens, and that's the thing, mechanism that you use as a clock. I think the reason why time is running a bit is because of the unlike length uh you know, unlike the universe we only experience it in One Direction >we move from the past to the future we move "through time, through the time dimension" and thus cut intervals on it..., in other words: ***"time doesn't run for us, but we run for it, after it, on it, on the time dimension"*** *and we do it in a rather inexorable way, you can't, you can't go back in time*

because the curvature of the time dimensions (we have 3+3D) has been unrolling since the big bang um and so it has such a quality that it only works in One Direction and
……..

(03)- so there's sort of a more of a Simplicity to the to the experience of time that that lets you get away with a very operational definition like you know time is what you measure with a clock and a clock is the thing that ticks hey there guess what time it is yes it's time for you to finally subscribe to the show that you've been listening to and enjoying all this time I found that only about 50% of You Are subscribed or following the podcast video or audio so wherever you're here just take a quick second to subscribe hit the follow button or the plus button or subscribe on YouTube wherever you are watching or enjoying this content it really makes a huge difference and allows me to continue getting great guests like Chad on the podcast so go ahead hit that button and thank you so much for your support let's get back to the episode the kind of other notion is that uh you know the origin of time in conjunction and the The connection between time and astronomy measurement of time in aure ason omy is incredibly intermingled and I think it be it would be useful to kind of go over these and what you know at first glance you might not think well I'm going to talk to some an expert about time and then talk to an astronomer but of course they're intimately related and I I kind of want to uh get you know the historical sweep I hate it when I go on as an author and the podcast house say you know explain your book and great details so we don't even need to buy the short form you know brilliant summary of it we just need to listen to the podcast so um why is astronomy so you know
11:02
irrevocably associated with the measurement of time well I mean the most obvious uh things in the natural world that tick in a in a really continued way are the the Motions of objects in the sky right so the Sun every day uh if you're you're in California so I'm assuming it's sunny uh it's it's pretty dreary here too cloudy I think it's warmer where you are today in SK the uh the the sun you know R es in the the East and moves across the sky and sets in the west and that happens every day with with amazing regularity and that's a thing you can count you can you know say okay well the sun rose and then it moved across the sky and it's set and and now it's risen again and that's a tick that's one day you can make it a little more fine grained by doing something like you know Hammer stick in the ground and then you look at where the shadow points and you can say well that gives you a little more resolution you know finer
12:00
resolution to subdivide the day um and that that works very well there's also you know at night there's the the second
12:07
most obvious moving thing in the sky is the moon and that has the the really nice property that it also changes shape on a very human kind of time scale right over over the course of several days you see it go from you know a tiny little crescent to uh you know the the the quarter moon and then the and then the full moon and you see that evolution that follows a very regular pattern small Crescent gets bigger shrinks down disappears small Crescent gets bigger shrinks down disappeared right that that happens over and over and that gives you another kind of clock and so it's the what is the origin of timekeeping is trying to use those patterns to Mark the passage of time and to sort of predict when is uh when is this going to happen again right how many days will it be before the moon is full again or more importantly like how many days will it be before its planting season again

13:01
right before we need to to do agrarian things to ensure that we have enough food to carry on as a as a civilization the other thing that kind of resonates throughout here is the application of the measurement of time uh to navigation
Why is longitude so hard to measure? which again you know is not immediately obvious to a lay person perhaps so why don't you speak a little bit about that it's easy to measure latitude with a telescope and uh an ability to see at least close to Polaris or other stars even you can you can measure it with any Star but but in particular uh but why is longitude such a difficult proposition to measure yeah longitude is tricky because the you know the Earth is a sphere and it's rotating and there isn't the same uh fixed Point latitude is easy because you know you can look at the height of the Sun at noon or you can look at the the elevation of the the North Star uh at night and uh pretty directly do a little tiny bit of trigonometry and get what the you
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(03)- takže je tu trochu větší jednoduchost prožitku času, který vám umožní dostat se pryč s velmi operativní definicí, jako že víte, čas je to, co měříte hodinami, a hodiny jsou věc, která tiká hej, hádejte, kolik je hodin ano, je čas, abyste se konečně přihlásili k odběru pořadu, který jste po celou dobu poslouchali a užíváte si sledování po celou dobu. Zjistil jsem, že sledujete pouze 50 % videa nebo zvuku ať už jste kdekoli, věnujte krátkou vteřinu odběru, klikněte na tlačítko Sledovat nebo na tlačítko plus nebo se přihlaste k odběru na YouTube, ať už sledujete nebo si užíváte tento obsah, je to opravdu obrovský rozdíl a umožňuje mi i nadále získávat skvělé hosty, jako je Chad, na podcast, takže pokračujte stisknutím tohoto tlačítka a mockrát vám děkuji za vaši podporu vraťme se k epizodě, druh jiné představy je, že víte, že je neuvěřitelně spojení mezi měřením času a času a astronomie promíchané a myslím, že by bylo užitečné je trochu projít a to, co víte na první pohled, vám možná nebude dobře myslet, promluvím si s nějakým odborníkem o čase a pak s astronomem, ale samozřejmě spolu úzce souvisí a já bych vás chtěl seznámit s historickými přelety. Nenávidím to, když pokračuji jako autor, a podcastové shrnutí říkají, že v krátké formě to víte, dokonce ani nevíte, že potřebujete vysvětlit vaši knihu, stačí si poslechnout podcast, takže hm, proč je astronomie, abyste věděli
11:02
neodvolatelně spojené s měřením času dobře, myslím tím nejzřejmějším uh věci v přírodním světě, které tikají opravdu nepřetržitým způsobem, jsou pohyby objektů na obloze správně, takže slunce každý den uh, pokud jste, jste v Kalifornii, takže předpokládám, že je slunečno uh je to docela ponuré tady příliš zataženo, kde je dnes na východě tepleji, myslím, že je dnes Rh the East a pohybuje se po obloze a zapadá na západ a to se děje každý den s úžasnou pravidelností a to je věc, kterou můžete spočítat, můžete vědět, říkat dobře, slunce vyšlo a pak se pohybovalo po obloze a zapadlo a teď znovu vyšlo a to je klíště, že jednoho dne to můžete udělat trochu jemnější tím, že uděláte něco jako umíte, že umíte dobře zabodnout se do stínu, a pak se podívejte, kam dobře zabodnete. Trochu více rozlišení znáte jemnější
12:00 předsevzetí rozdělit den, um a že to funguje velmi dobře, také víte, že v noci je druhý nejviditelnější pohybující se věc na nebi je měsíc a ten má tu opravdu pěknou vlastnost, že také mění tvar na velmi lidském časovém měřítku přímo v průběhu několika dní, vidíte, jak to odchází, znáte malý malý srpek až po uh znáte čtvrtměsíc a pak a pak úplněk a vidíte, že se děje evoluce, která sleduje velmi pravidelný vzor, malý srpek se zvětšuje, malý srpek se zmenšuje a mizí dolů který vám dává jiný druh hodin, a tak to je to, co je původem měření času, snaží se použít tyto vzorce k označení plynutí času a k předpovědi, kdy se to stane

znovu, kolik dní to bude, než bude měsíc znovu v úplňku, nebo co je důležitější, kolik dní bude před opětovnou sezónou výsadby
13:01
těsně předtím, než budeme muset udělat agrární věci, abychom zajistili, že budeme mít dostatek jídla, abychom mohli pokračovat jako civilizace, druhá věc, která tu tak nějak rezonuje, je použití měření času uh na navigaci Proč je tak těžké měřit zeměpisnou délku?, což opět víte, není pro laika hned zřejmé, tak proč se trochu nezmíníte o tom, že je snadné změřit zeměpisnou šířku dalekohledem a uh schopnost vidět alespoň blízko Polárky nebo jiných hvězd, i když to můžete změřit s jakoukoli hvězdou, ale zejména uh, ale proč je zeměpisná délka tak obtížný návrh změřit ano, zeměpisná délka je ošidná, protože víte, že totéž u Země je koule zeměpisná šířka je snadná, protože víte, že se můžete podívat na výšku Slunce v poledne nebo se můžete podívat na nadmořskou výšku Polárky v noci a docela přímo udělat trochu trigonometrie a získat to, co chcete.
…….

(04)- what your latitude is uh very very easily
14:03
there isn't that kind of fixed point with longitude because that's the direction in which the Earth is rotating so everything is constantly moving in in the longitudinal Direction and that makes it a lot more complicated the only way to to figure out you can figure out a difference in longitude if you know a difference in time right and time is measured by say the position of the sun if the sun is directly overhead for me here on the East Coast then it's going to be you know 3 hours Short of directly overhead for you on the west coast and that difference tells us the longitude right the how that the difference in where we see the sun at the same instant in time tells us our difference in longitude so you need to be able to to know the time at two widely separated locations to be able to determine longitude if your fastest mode of travel is foot or horseback it doesn't really matter very much cuz you're never going to go far enough that that you you have to worry about that but if you're going
15:05
you know many thousands of miles on on relatively fast moving ships trying to make a glob spanning Empire or later on when you get to things like like railroad trains uh and then eventually airplanes right you can experience these changes in time in a very real way and then it becomes really important to know when you are as well as in order to determine where you are and of course the you know the Notions of so many of these things are both familiar and
The relativity of simultaneity terrifyingly you know abstract to many people and throughout the book you do an excellent job kind of explaining the mindset of the time and what was thought to be the prevailing you know best measurements of time and then all of a sudden comes this guy in 1905 with his paper on relativistic Dynam electrodynamics which we don't normally associate with relativity and all hell
16:00
breaks loose talk about the challenge of what we just described in a in on a a moving framework on a planet that's moving around a star that's moving and a Galaxy that's moving talk about the relative relativity of simultaneity and how that was a philosophical uh you know upheaval as well as a scientific upheaval there's a really good uh paper I mentioned it in the book it's available online uh you know in a trans ated free form by HRI panker called the measure of time uh and he he makes a really good point that that like sort of essentially

everything we do when we're talking about measuring time is a matter of convention and and sort of uh choice for convenience right we we can determine what time it is by looking at the eclipses of the moons of Jupiter but when we do that we say well we can predict the eclipses because we assume Newton's Laws of of gravity and that describes the orbit of those moons and so we know where that's going to be and we assume that the speed of light
17:04
between here and there is is finite and very large and we we know what it is and you put all that stuff together and then you get something that works as a clock but you could make very different assumptions about the world we're just choosing to use those ones because they're convenient to us right and so that gets you sort of time has this sort of necessarily has this kind of Relativity to it that that everybody's experienc is a little different and and we obtain some kind of commonality by making a choice of convention what Einstein pointed out is that you know you if you look at the behavior of of things you would say the laws of electrodynamics predict that there's one and only one speed of light and if you um you know look into that you can arrange it so that there is in fact one and only one speed of light at the cost of changing uh our Notions of time and that the time has to pass at a different
18:00
rate if you're moving uh in order to ensure that there's one and only one speed of light and this this is a thing that is an idea that a number of people sort of encountered this issue with the speed of light and electrodynamics and how do we explain this and that sort of thing and Einstein's uh big point was to to point out sort of going back to what we said at the very beginning that you know you can't talk about time unless you talk about how you're measuring the passage of time you can't talk about time in two widely separated places unless you talk about how you synchronize those clocks at those widely separated places and when you go through the details of how would you do that how would you synchronize clocks how would you you get that you find that time passes at different rates when people are moving relative to one another and then the whole theory of special relativity unfolds from that can you talk about gravity and it's not immediately obvious to probably most people that gravity
……

(04)- jaká je vaše zeměpisná šířka, velmi snadno 14:03 není tam takový pevný bod se zeměpisnou délkou, protože to je směr, kterým se Země otáčí, takže se vše neustále pohybuje v podélném směru a to je mnohem složitější, jediný způsob, jak zjistit, že můžete zjistit rozdíl v zeměpisné délce, pokud znáte rozdíl v čase správně a čas se měří řekněme polohou slunce, pokud je slunce přímo nad hlavou pro mě tady na východním pobřeží, abyste byli 3 hodiny, abyste byli na krátké pobřeží a tento rozdíl nám říká zeměpisnou délku správně, jak nám rozdíl v tom, kde vidíme slunce ve stejný okamžik v čase, říká náš rozdíl v zeměpisné délce, takže musíte být schopni znát čas na dvou široce oddělených místech, abyste mohli určit zeměpisnou délku, jestli je váš nejrychlejší způsob cestování pěšky nebo na koni, na tom opravdu moc nezáleží, protože nikdy nezajdete dost daleko, ale pokud se o to musíte starat
15:05
znáte mnoho tisíc mil na relativně rychle se pohybujících lodích, které se snaží vytvořit globus zahrnující Impérium, nebo později, když se dostanete k věcem, jako jsou železniční vlaky a nakonec letadla, správně, můžete tyto změny v čase zažít velmi reálným způsobem a pak je opravdu důležité vědět, kdy jste, stejně jako pro určení, kde jste, a samozřejmě víte, že pojmy tolika z těchto věcí jsou známé i známé. Relativitu simultánnosti děsivě znáš jako abstraktní pro mnoho lidí a v celé knize odvádíš skvělou práci tím, že vysvětluješ tehdejší

myšlení a to, co bylo považováno za převládající, znáš nejlepší měření času a pak najednou přijde tento chlapík v roce 1905 se svou prací o relativistické elektrodynamice Dynam, kterou si normálně nespojujeme s relativitou a celým peklem.
16:00
uvolňuje řeč o výzvě toho, co jsme právě popsali v pohyblivém rámci na planetě, která se pohybuje kolem hvězdy, která se pohybuje, a galaxie, která se pohybuje, mluví o relativní relativitě simultánnosti a jak to bylo filozofické uh, znáte otřesy stejně jako vědecké otřesy, existuje opravdu dobrý článek. Zmínil jsem se o tom zdarma v online knize uh panker nazval mírou času a řekl opravdu dobře, že podobně jako v podstatě všechno, co děláme, když mluvíme o měření času, je věcí konvence a jaksi pro pohodlí můžeme určit, kolik je hodin, když se podíváme na zatmění měsíců Měsíce, ?? ale když to uděláme, říkáme dobře, že můžeme předpovědět zatmění, protože předpokládáme, že Newtonovy zákony a gravitace Měsíce a gravitace popisují bude a předpokládáme, že rychlost světla
17:04
mezi tady a tam je konečný a velmi velký a my víme, co to je, a dáte všechny ty věci dohromady a pak dostanete něco, co funguje jako hodiny, ale můžete si vytvořit velmi odlišné domněnky o světě, které se právě rozhodly použít, protože jsou pro nás vhodné, a tak vás dostaneme, má tento druh nutně takový druh relativity, který je společný, že každý si vybírá trochu jinou zkušenost a konvenci. Einstein poukázal na to, že víte, že když se podíváte na chování věcí, řekli byste, že zákony elektrodynamiky předpovídají, že existuje jedna a pouze jedna rychlost světla, a pokud víte, podívejte se na to, že to můžete zařídit tak, že ve skutečnosti existuje jedna a pouze jedna rychlost světla za cenu změny našich představ o čase a že čas musí plynout jinak.
18:00
ohodnoťte, pokud se pohybujete, uh, abyste zajistili, že existuje jedna a pouze jedna rychlost světla, a to je věc, která je myšlenkou, že řada lidí se s tímto problémem setkala s rychlostí světla a elektrodynamikou a jak to vysvětlíme a Einsteinův velký smysl byl upozornit na to, že se musíme vrátit k tomu, co jsme řekli na samém začátku o měření času, že víte, že dokážete, nemůžete mluvit o čase na dvou široce oddělených místech, pokud nemluvíte o tom, jak synchronizujete ty hodiny na těch široce oddělených místech, a když si projdete detaily toho, jak byste to udělali, jak byste synchronizovali hodiny, jak byste dospěli k tomu, že zjistíte, že čas plyne různými rychlostmi, když se lidé pohybují vůči sobě navzájem, a pak se odvíjí celá teorie speciální relativity z toho, že můžete mluvit o gravitaci a to pravděpodobně není pro většinu lidí zřejmé
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(05)- should affect a clock and yet it does and can you EXP explain the notion separate from the
19:01
effects of special relativity on which gravitational fields can affect the passage of time for for different observers you know one of my favorite Einstein stories is he he described you know the happiest thought of his life is a day he was in the patent office and he was thinking about somebody falling from a high place and you know the the thing that separates a genius like Einstein from normal people is he was not imagining a specific annoying coworker being pushed out a window he was thinking you know very generally about the physics of somebody falling and realized that when you're falling you feel weightless like as you're falling you don't feel a sensation of weight and that led him to realize that there's this

connection between gravity and acceleration and at the time he had been trying to extend special relativity the the theory that that governs uh people in motion relative to one another to include motion that was changing uh changing direction changing speed uh accelerate in physics terms and he
20:00
realized that that there's this connection between gravity and acceleration so in the same way that thinking about how do you synchronize clocks in separated locations uh leads you to the notion that people moving at constant speed relative to one another experience time passing at different rates when you start to factor in the effect of acceleration and say okay it can't be possible to tell the difference between accelerating in One Direction and having gravity pull in the opposite direction then uh that leads inexorably to the conclusion that gravity affects the passage of time and and this is a thing that we can directly measure you can uh there's a famous experiment done at uh MIT in the in the 50s or 60s where they they shot uh light up a uh they call it a tower but it's really a stairwell in the in the physics building at at Harvard and and showed that the frequency of the light reaching a detector at the top was very slightly different than the frequency when it left the source at the bottom and that difference is exactly accounted for by the effect of gravity on time that that
21:05
Einstein predicted general relativity yeah that happiest thought of Einstein actually as a segue gives me opportunity to move into education because when I think about what artificial intelligence may or may not do to us uh as a species I think of that quote often because in what sense could a computer you know uh visualize the visceral sensation of free and furthermore in what sense could it have a happiest thought I mean what is its happiest thought when it's fully charged I mean how how is it how is it going to relate to these Notions of of the great gonan experiments that einon and others practicing and so you're Master educator you're known for um special attention to the craft of being
+a professor you and I can talk shop now uh now that we passed the 20 minute Mark which is the average view duration for my videos shame on you out there you should watch the whole thing actually if you're if you heard me shame you you're actually listening so I love you're doing you're doing great keep it up keep listening stay till the end um by either that or you're you're playing it on double speed that's right so uh when we
The future of education after COVID think about being a professor I thought you know part of the the book that was written during covid as I understand your book and um I thought covid would be the death nail for our profession in some sense I thought zoom and paying full tuition which I assume is you know similar here there at Harvard I just talked to uh Eric mouri yesterday $57,200 at Harvard look these are kind of you know cartel level price tags and yet nothing really happened differently we emerged from covid uh basically doing the same thing uh you and I scrape on a big piece of Rock with a little piece of rock and uh and that's the same as was done in the University of bolognia in the year 1080 when the first Western uh University started so um are we you know basically safe from AI overlords what do
23:01
you think do the profession look like uh for master Educators such as yourself one of the things that that Co revealed and that that that having to make that really rapid transition into online education revealed is that there there's really a a crucial in-person sort of live element to it that's that's hard to do without that you you really need the ability to to sort of have give and take and conversations and adjust on the Fly that's that's hard to do online you know I did uh the book came out during a covid surge so like I did a bunch of speaking events but they

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(05)- should affect the clock and yet it does and you can EXP explain the concept separately from
19:01
effects of special relativity on which gravitational fields can affect the passage of time for different observers you know one of my favorite Einstein stories is him describing you know the happiest thought of his life is the day he was in the patent office and he thought about someone falling from a high place and you know the thing that separates geniuses like Einstein from normal people is that he was not very well known for thinking that he would be a particular physicist someone falling and he realized that when you fall you feel weightless like when you fall you don't feel the sensation of weight and that led him to realizing that there is a connection between gravity and acceleration and at the time he was trying to extend the special theory of relativity which governs people in motion relative to each other to include motion that was changing uh changing direction changing speed and accelerating in physical terms
20:00
they realized that there's this connection between gravity and acceleration, so thinking about how you synchronize clocks in separate places leads you to the idea that people moving at a constant speed relative to each other experience time passing at different speeds, that's a stupid sentence… (Einsten wouldn't say that) when you start to factor in the effect of acceleration and you say well, it's impossible to tell the difference between acceleration in the opposite direction and a pull in the opposite direction, that gravity affects the passage of time and that's something we can directly measure, you can uh, there's a famous experiment done at uh MIT in the 50s or 60s where they shot, uh lit it up and uh they call it a tower, but it's actually a staircase in the physics building at Harvard and it turns out that the frequency of light at the top and bottom was very different than the frequency at the bottom. The difference is explained precisely by the effect of gravity on time. Yes, the curvature of space-time changes from the ground upwards, so in each level the pace of time passing is different, longer intervals, while the pace of the ticking of a watch does not change with the change in distance from the Earth.
21:05
Einstein predicted general relativity, yeah, the happiest thought about Einstein actually gives me an opportunity to cross over into education because when I think about what artificial intelligence may or may not do for us, uh as a species, I think about that quote often because in what sense could a computer you know visualize a visceral sense of freedom and furthermore in what sense could it have the happiest idea of how charged the happiest idea as I think it will be related to these ideas of the great gonan experiments that einon and others practice and so you are a master educator are you known to pay special attention to the craft of being? + professor you and I can talk now that we've crossed the 20 minute mark which is the average length of my videos to watch shame on you out there you should watch the whole thing if you did if you heard me shame on you actually listening so i love that you're doing this you're doing great keep listening stay until the end um either that or you are we're playing it right so uh The future of education after COVID think about being a professor i thought you knew the part of the book that was written during covid because i understand your book and i thought covid was going to be the death knell for our profession in a sense i thought zoom and paying full tuition which i assume you know similar here at harvard i just talked to eric mouri

yesterday you know these prices are $57,200 and yet nothing happened at harvard we emerged from covid uh basically we're doing this same, you and I are scraping at a big piece of rock with a little piece of rock and uh and that's the same thing that was done at the university of bologna in 1080 when the first western university started so we know we're basically safe from the AI overlords what they're doing no comment
23:01
Do you think the profession looks like for master educators like you one of the things that Co has revealed and that what this really rapid transition to online education has had to do is that there's a really essential in-person live element that's hard to do without you really need the ability to give and take and conversation and adapt has come out hard when you're doing it online. The increase in like I've done a lot of speaking events but they
…….

(06)- were all remote because it was it was the I think the Omron or Delta one of one of those variants and you know every all the inperson stuff was canceled and it's really hard to do like uh talks for an audience when you can't see them directly and you can't interact live in
24:00
the the way you know you see the little tiny faces on the side of the zoom window but you can't really get much from that and so you know we did uh we did a a term of fully remote we did um a term you know I taught a course on Quantum Computing in a hybrid format and that you know sort of worked but it's really hard to have people in in the the different places you know and have that that kind of interactivity and that that read the RO room and and and adjust things as needed you know if I'm going too slow I can sort of tell and I can speed up or if I'm if I'm losing the audience and like okay clearly this isn't Landing I can you know do this on the Fly and it's it's a lot harder to do that in the kind of asynchronous video way that you you tend to on on the internet you know when we opened back up in person in the the fall of of 2020 um you know we we had started bringing students back on on campus in September it was really something to see how
25:03
grateful people were to be back in person in school and uh the length that students were willing to go to like the the restrictions on masking and socialization and and all sorts of of activities that they that they were willing to put up with for the sake of being in in person because people really value that that content and that that in-person interaction the tech is almost there but it's not it's not yet maybe some you know VR kind of thing uh eventually gets you there but you know as it is it's still not there's still something about being in the same room with people that's kind of that feels really essential to to making progress in education you know friend Galileo and Einstein and Carl Sean and
The standard definition of time many others you know practiced this this um you know craft for for so long but
26:02
yeah I do think that there could be some potential opportunities also because why talk to you know uh me you know Brian keing and learn you know cosmology when you could talk to some Avatar of Edwin Hubble uh and so I I do worry about it and actually speaking to Eric yesterday was quite terrifying because you know his whole um shtick is that we should flip the classroom and have basically the the students read the book the night before and uh catch up and do some problem solving and then come to class and then debate with their other students and that actually has a two-fold purpose it it actually you know um rewards the the

uh the students that are highest performing because they get to teach and when you teach you learn as you and I know better than just reading and consumption and it benefits the lower performing students at Harvard they have a lot of low performing student they're they're known for that at least half of them are below average I mean I I know that for sure so you
27:01
know they they get the benefit from the students that are highly engaged and and have a future in it whereas you know you and I you know we we we may have our days numbered I guess but getting back to timekeeping you know and I thought about this book I interviewed Um Zack weiners Smith last week about his book a city on Mars I actually spoke to Elon Musk on Twitter spaces X bases rather a couple of weeks ago and I asked him look man you can't be serious about going to Mars it's it's basic Al a one-way death trip if you make it the best case is that you die on the way you know and and and you may like it uh you know but the people traveling with you you know when they're as rich as you on the spaceship it doesn't matter that you had $250 billion US Dollars you know who cares when you're you know in the middle of uh you know the halfway point to get to Mars he still have six months left with this guy so I said are you really serious about this I mean which you know he has 10 11 12 kids we don't know for sure uh but you know what what are you what are you doing here buddy and he really couldn't answer and as mom broke in and said well we don't have to worry about that for a while and uh but uh made me think about interplanetary
28:05
timekeeping let's say we do get there Mars could be as close as I think four light minutes from Earth it could be as far as 20 imagine civilizations set up there it's impossible for any real-time you know guidance activities but um what would be sort of a standard let's make the standard now instead of the peace meal network of you know that was set by railroad Architects that you depict in the book and uh and the other ways of keeping time what would be you know if you were musk or you were on his board how would you partition the uh the
……..

(06)- they were all remote because it was, I think, Omikron or Delta one of those variants and you know all the personal stuff was canceled and it's really hard to do those kinds of talks to an audience when you can't see them directly and you can't interact with them live
24:00
as you know, you see those little little faces on the side of the zoom window but you can't really get much out of it and so you know we did uh, we did a semester fully remote, we did a term which you know I taught a quantum computing course in a hybrid format and which you know worked but it's really hard to have people in different rooms that you know and you adapt and adjust things that you need. I know if I'm going too slow, I can kind of say it and I can speed it up, or if I am, if I'm losing the audience and like okay, sure, this is not a landing I can, you know you do it on the fly and it's much harder to do it in the asynchronous video way that you have on the internet, students, you know when we opened, we started bringing you in person in the fall of 2020 we had a camp in September it was really something to watch
25:03
the grateful people were to be back in school in person, and the lengths that the students were willing to go, they liked the limitations of masking and socializing and all the kinds of activities that they were willing to endure in order to be in person because people really appreciate that the content and that the personal interaction is almost there, but it's not yet,

maybe it's not yet something that you know, that's a stutter... but ultimately you know, there's still something about being in the same room with people that is really essential to the advancement of education, you know friend Galileo and Einstein and **Carl Sean** and Standard Definition of Time many others you know practiced this craft you know for so long but
26:02
yeah i think there could be some potential opportunities too because why talk to you do you know **Brian Keing** ? and you're learning that you know cosmology when you could be talking to some Avatar Edwin Hubble and so i'm worried about that and actually yesterday's conversation with Eric was pretty scary because you know his whole stupidity is that we should flip the class and basically finish some problem and then basically finish the students, talk about nothing… the class and then debate with your other students and that actually serves a dual purpose you know actually it rewards those students who are the highest performers because they can teach and when you teach you learn in a way that you and i know is better than just reading and consuming and that benefits the lower performing students at harvard who have a lot of low performing students who are known to be at least half below average i mean you thunder, this is supposed to be a lecture on ***The Existence of Time*** and not about student problems…!
27:01
they know they benefit from students who are very engaged and have a future in it, whereas you know you and I know, we we, maybe our days are numbered, I think, but let's get back to measuring time let's get back to the existence of time and not measuring you know and I was thinking about this book. Last week I was talking to Um Zack weiners Smith ?? about his book City on Mars. I actually talked to Elon Musk on Twitter Spaces X base looks like it's serious a few weeks ago man you can ask it goes One way death trip O.K. if you do that best case scenario is you die like you know and and you might like it you know but the people that are traveling with you you know when they're as rich as you are on the spaceship it doesn't matter that you had $250 billion you know who cares when you're, you know in the middle of the months you know there's really only half way left to get to Mars with this guy who you know has 10, 11, 12 kids we don't know for sure uh but you know what you are what you're doing here buddy and he really couldn't answer and as mom broke in and said okay we don't have to worry about that for a while **and again** this is not an exposition about time and his existence… and uh, but uh, it got me thinking about interplanetary
28:05
timekeeping, let's say we get there Mars could be as close as I think four light minutes from Earth, it could be as far as 20, imagine civilizations being set up there, it's impossible to do any real-time guidance activities, but what would be some kind of standard, let's make a standard now instead of the peace meal network that you know was set up by the railroad. The architects that you portrayed, you would know the ways you behave and how you keep time on its board, how you would divide uh the
……..

(07)- timing and coordination of time so I we have in uh you know a very deep Way Gone to uh a sort of universal standard for time right we currently don't Define time anymore in terms of the rotation of the earth I mean colloquially we do but you know the official SI definition of time is that the second is it's uh 9,192,631,770 oscillations of the light emitted as uh cesium atoms move between two particular uh hyperfine States and that is a a fixed definition that we use for you know to Define what is 1 second and then you can just use seconds as the basis

for whatever completely decoupled from from the U the rotation of the earth there's a really good um series of science fiction novels uh by verer Veni uh the um the the one that I'm thinking of in is a deepness in the sky which has uh civilization as they they Interstellar Travelers and then uh they talk about everything in terms of uh kiloseconds and megas seconds and you know so multiples of so many, seconds and that that works uh actually you know surprisingly well so if you going to start organizing things on an
30:00
interplanetary scale probably you would go for for completely decoupling from any of the planets and just say look we a second is a second is a second you got a cesium atom you measure a hyper fine splitting you know what a second is now just count those right and um and that's that's the way to go probably uh you know make it not tied to to to hours as we currently know them but some multiple of seconds as we currently know hey back one last time to ask you for something special which will give you something special you'd like a real piece of space schuts real life medor right or if you just like to find out about the insights that we can glean from Nobel laurates billionaires astronauts and in claimed authors in space science and technology you can with my free Monday magic newsletter please go to briank king.com list and sign up now as a token of my gratitude I give away a real live piece of space dust a 4 billion year old meteorite to one lucky subscriber each month I also provide them guaranteed if
31:03
you have a edu email address and you live in the United States go to brian.com edu for that special offer now back to the remaining moments of this wonderful episode about time yeah you mentioned verer vingi I can't resist Attosecond clocks mentioning he's a Alum a proud Alum of UCSD and math department we have a surprising number of of great illustrious uh science fiction authors from David brck and past guest on the podcast Greg Benford also a guest on the podcast Kim Stanley Robinson past guest and uh non-graduate but he um he went on to some success a guy by the name of Andy Weir they all did time here at UC San Diego he did he's done well for himself yeah I mean can you imagine what kind of career he had if he actually had a ba from UCSD can you imagine what he could have got on to yeah God we could use that that Weir wing of the Astron yeah exactly let's talk about uh your your training your research before we get back to some timekeeping which is
32:01
intimately related as I mentioned uh we had uh Bill Phillips on last year the sense that I got is this is great and and and it's wonderful technology Atomic fountains and uh and and going Way Beyond the cesium but I mean as you say in the book light travels one foot per nanc you know so you're talking about billions of nanc billions of feet I mean we can't even conceive of using such a there are other system atic effects that come into play that you know the Earth's magnetic field and and others that will have bigger effects if you try to use it as a clock so what's the point of it other than Gathering and garnering Nobel Prize is there is there a technological implic not that all science must have technology Downstream from it but what you know taking your thesis work on forward what types of of Technology could result from you know having atosc clocks for example there are these uh experiments that have been done in a couple of places in uh at nist and Boulder and then there's also there's a group in in Tokyo uh more recently they're doing these experimental clocks
33:06
uh and you can start to do Exotic physics things with them so one of my favorite demonstration experiments ever is this uh experiment with aluminum ion clocks at uh nist and

Boulder where they they made two identical clocks using a a transition in aluminum ions as the basis of their their measurement of frequency and then they they raised one of them about one foot above the other they just used hydraulic jacks to lift the whole laser table up a foot higher and they could see that these tick at distinctly different rates right and this is the effect of gravity on time um and you can start to exploit that to to do very sensitive tests of general
…….

(07)- timing and time coordination so i have in uh you know very deep way gone to uh kind of universal standard for time right we currently no longer define time in terms of the rotation of the earth i mean colloquially yes but you know the official SI definition of time is that the second is uh 9,192,631, transmitted light as oscillac that's imperfect speech, it's Maruška's slapping in fifth grade uh uh uh specific uh hyperfine states and that's the fixed definition that we use so that you know what 1 second is and then you can just use seconds as a basis for anything that's completely separate from the rotation of the earth there's a really good series of sci fi novels uh by verer Veni uh the one i'm thinking about, i don't… i'm interested in time and other cosmological questions…, verne interested me when i was 8 then that celestial civilization has uh and travel talks about everything in terms of uh kiloseconds and megaseconds and you know so many multiples of so many seconds and that it works, uh actually you know surprisingly well so if you start organizing things on the
30:00
interplanetary scale you would probably choose to completely separate from any of the planets and say look a second is a second is a second you have a cesium atom you measure the hyper fine divisions you know what a second is now count the right ones and uh and that's the way to go probably uh you know not to tie it to a clock because we currently know what time we know it that's horrible..., I wouldn't even stand that kind of talk from a barber... but some of the special times that we currently know you want something special you want a real piece of the universe schuts real life medor right or if you just want to learn about the insights we can get from billionaire Nobel laureates astronauts and patented authors in space science and technology you can with my free Monday Magic newsletter, go to briank king.com list and subscribe now as proof of my true gratitude for space dust for every year I will give away 4 billion happiness for every year of life I will give away one billion happiness a month I also provide them guaranteed if
31:03
you have an e-mail address for educators and live in the United States, go to brian.com edu definitely not, today is the last time I read and heard from you !! - **I'm ending..**

pro tuto speciální nabídku nyní zpět ke zbývajícím okamžikům této nádherné epizody o čase ano, zmínil jste verer vingi Nemohu odolat Attosekundové hodiny zmiňují, že je Alum hrdý Kamenec z UCSD a matematického oddělení máme překvapivý počet hostů z minulosti na skvělé podcastové autory z Bena a Grebrcka, také z podcastu, science fiction a Grebrg uhford host na podcastu Kim Stanley Robinson minulý host a uh neabsolvent, ale on ehm pokračoval k nějakému úspěchu chlápek jménem Andy Weir, všichni dělali čas tady na UC San Diego udělal to dobře pro sebe ano, myslím, dovedete si představit, jakou kariéru měl, kdyby měl bakalář z UCSD, dovedete si představit, co by mohl mít na tom, že by se dostal k vašemu výcviku, jo, o vašem výcviku, o tom, o vašem výcviku, uh váš výzkum, než se vrátíme k nějakému měření času, což je
32:01

důvěrně související, jak jsem zmínil, minulý rok jsme měli Billa Phillipse, mám pocit, že je to skvělé a je to úžasná technologie Atomové fontány a uh a jdoucí cesta za cesiem, ale myslím, jak říkáte v knize, světlo cestuje jednu stopu za nanc, víte, takže mluvíte o miliardách nanců, miliardy dalších systémů pomocí takových efektů, dokonce myslím, že můžeme dospět k miliardám nanců, dokonce i k takovým efektům hrajte, že znáte magnetické pole Země a další, které budou mít větší účinky, pokud se je pokusíte použít jako hodiny, takže jaký to má smysl jiného než shromažďování a sbírání Nobelovy ceny je, že existuje technologický implikát, ne že celá věda musí mít technologii od ní, ale to, co víte, když posouváte svou diplomovou práci kupředu, jaké typy technologií by mohly vzniknout z toho, že víte, že byly provedeny tyto experimenty, například existuje několik experimentů uh v nist a Boulder a pak je tu také skupina v Tokiu, nedávno dělají tyto experimentální hodiny
33:06
a můžete s nimi začít dělat věci z exotické fyziky, takže jeden z mých nejoblíbenějších demonstračních experimentů je tento experiment s hliníkovými iontovými hodinami v uh nist a Boulder, kde vyrobili dvě identické hodiny pomocí přechodu v hliníkových iontech jako základ jejich měření frekvence a pak zvedli jednu z nich asi jednu stopu nad druhou, jen použili hydraulické zvedáky, aby mohli zvedat celé tyto pravé o stopu výš a mohli vidět všechny tyto pravé zvedáky o metr výš a toto je vliv gravitace na čas a můžete to začít využívat k provádění velmi citlivých obecných testů
……

relativity or you can use it for uh geodyssey for uh looking at at the gravitational profile of the earth basically move to different places and compare uh these these Ultra precise atomic clocks if you want to get
34:03
really pardon the expression Pi in the sky you can put these things on satellites and and make a detector for gravitational waves so if you had a network of satellites with ultraprecise atomic clocks in them we know from ligo
34:16
as you know a gravitational wave comes in the the uh space expands and
34:22
contracts a little bit and you see the mirrors in your inner therometer move you could also with a network of atomic
34:28
clocks you know space and time are different aspects of the same thing in relativity time would speed up and slow
34:33
down slightly and you could see that as sort of a Rippling through your network of ultra precise clocks and that would
34:40
give you an ability to to measure uh gravitational waves in a in a regime of
34:46
you know sort of wavelengths and frequency of those those waves that you can't access uh readily other ways um
34:54
which would be really interesting and then there's even more like wild stuff stuff that we aren't sure exists like U

35:02
possibility that the constants of nature change over time so all of these atomic
35:07
clocks are based on the energy splitting between two uh two levels in an atom and
35:13
those are set by things like the ratio of the electric uh charge on an electron
35:18
to Plank's constant and the speed of light and uh the different transitions in different atoms uh depend differently
35:26
on that that ratio so some will get bigger if the this collection of
35:31
constants called the fine structure constant if that gets bigger uh some of these transitions will uh move to higher
35:38
frequencies and others will move to lower frequencies so if you compare to uh atomic clocks using different kinds
35:45
of atoms and you look over time if your clocks are precise enough you can tell
35:51
is the fine structure constant getting bigger or smaller uh over time and there are some really exotic theories in the
35:58
sort of string theory uh and other extensions beyond the standard model that that predict that that is a thing
36:04
that could happen that the the you know ratio of the electric charge and the speed of light and planks constant would
36:11
be getting bigger or smaller over uh over time uh and you could test that
36:16
directly with sufficiently precise atomic clocks just comparing their frequencies over the course of you know
36:22
a year five years 10 years uh you can do that at at a level where you really test some of these theories so when we look
Why time is so much more perplexing than space
36:29
going backwards in time starting with Einstein and the you know relativity of
36:34
simultaneity and the Newtonian Clockwork universe and then going back even
36:40
further back to you know these ancient sorts of calendars that you talk about U
36:45
along with their concomitant predictions of Doom what is it about time especially
36:51
that uh that kind of hearkens terrifies um you know maybe maybe in ins Stills

36:58
fear in mankind that so much so that when we have these paradigmatic you know
37:03
shifts like Newtonian or uh uh and even changing calendars that you have these
37:08
kind of almost existential effects on humanities can you speculate you're a physicist not a psychologist but
37:15
nevertheless what what is it about time and not space I mean you know space is is equally you mysterious and and may
37:22
have aspects of quantization and and philosophical ramifications but why is it time time in particular since the
37:29
time of the Mayans and even before I'm sure that has so uh imprinted on the
37:35
psychology of man uh that we can't seem to escape it yeah I think it's you know
37:40
uh ultimately it comes down to you know thing I said at the beginning that that we experience time in One Direction only
37:46
right we we move inexorably from the past to the present to the future or you know we're sort of eternally in the
37:52
present but we only see time moving in One Direction Right space you know I can
37:58
I can go outside I can walk East I can walk west I can I can you know walk North and South I can I can jump uh not
38:05
all that high anymore but you know I can I can get up in the air a little bit or climb upstairs go downstairs right I can
38:12
move all sorts of different directions in space time you you really only it's a one-way trip right none of us are
38:19
getting any younger we're we're moving forward into the future at 1 second per second at the same time there's sort of
38:25
this this tension that that time necessarily involves these Cycles right we measure Time by counting the repeated
38:32
ticks of something that's doing the same thing over and over we Mark the passage of of days and years through these these
38:40
cycles and so there's this this tension between sort of the cyclical nature of things right everything comes around
38:47

again it's it's winter now soon it'll be spring then it'll be summer and you know
38:52
eventually it'll be winter again and we repeat that cycle of seasons over and over uh not so much in California but uh
38:59
you know we we we have the the these this cyclical thing that's going on but at the same time we we move forward into
39:06
the future in a in an irreversible kind of way and that tension I think really
39:12
you know brings in a certain amount of Fascination so you you have these you know sort of competing and there there's
39:18
threads in in all different cultures a sort of competition between you know the
39:25
the very Christians sort of of worldview where you know the the world has a beginning and it moves forward to you
39:32
know the Book of Revelations and then it comes to an end uh and it's a linear progression from point A to you know
39:39
from point Alpha to point Omega and then we're done versus sort of a more cyclical kind of thing like you see in
39:45
some of the the Eastern uh cultures where you have ideas of rebirth and repetition the Mayan calendar was really
39:53
all about these uh these cycles that repeat over and over and over and and
39:58
and uh go you know come back around many times again and there's that tension
40:04
between those two things that that drives a lot of of Science and philosophy and culture and just thinking
40:10
about how do how do those two things coexist how does that linear March into the future and this cyclical repetition
40:17
how do those play with each other looking at uh you know back towards the
How to teach students new things
40:22
uh the career that you've had and working with someone like Bill Phillips um read a quote that you paraphrase from
40:29
him on Twitter everyone should follow Chad on Twitter well as well uh you said in his name most people are very happy
40:35

to be reminded of things that they already know you rarely lose by including too much background
40:40
information how do you apply that kind of advice that's for seminars but when you're teaching something fundamentally
40:46
new of course it's something they don't know so how do you remind them of something when it's abono you know it's
40:51
a it's completely new for them as in your wonderful book yeah it's it's a tricky balance right I teaching this
40:58
term I'm teaching Newtonian Mechanics for uh for you know first year college
41:03
students that's really a mix of of that sort of thing because we we rely a lot on you know look you're you know we're
41:10
talking about the physics of the motion of everyday objects you know you know how these things work right if I take a
41:17
ball and I throw it to you know in your general direction you can make a pretty good prediction of where that ball is
41:23
going to be and you know most students can at least make a good effort catching
41:28
the the ball right we know how things tend to move but at the same time we don't know the the physics we don't know
41:36
how to how to quantitatively predict some of these things and and so there's a a you know going back and forth
41:42
between okay you have an intuition for how this this works uh and also now I'm
41:48
going to do something that that is unexpected that follows from the principles of physics that that lead to
41:54
the the thing that you you did understand and then sure to trying to show people that that no these are these
41:59
are consistent right you know one of my my favorite demo demos that's you know Dum you can do it at your your own house
42:06
is you know you get like a a basketball or a soccer ball a heavy ball that'll bounce and and a light one like a racket
42:13
ball or a tennis ball and you you know hold the light ball right on top of the of the heavy one and drop it uh you know

42:20
if you drop either one from sort of you know chest height it'll bounce back maybe to your waist uh but if you drop
42:26
one on top of the the light one on top of the heavy one when it hits the ground it'll kick way up into the into the air
42:33
and you know bounce off the ceiling um and you can explain that really easily using the the physics of of momentum uh
42:41
and just understanding the the principles that are involved in collisions very unexpected uh you know
42:46
always gets a gets a good reaction from a a class or you know do it with elementary school kids uh they they love
42:52
that and then they're always you know do do the do the heavy one see if you can put it through the ceiling but but um
42:58
you know but understanding that that um that idea you know gets you some some
43:04
new understanding of of principles of physics that you can go on and apply to unfamiliar things and I should point out
On education
43:10
you know speaking of time and uh and branding I think that you know pek phelip should Rebrand at least one watch
43:17
should be a PCH Philips and they should partner with Bill uh maybe they can get him a free watch you know he he needs it
43:24
I'm sure he's he's doing okay so let's uh finish up by talking talking about education you're Ren now not only for
43:29
your books you're uh you know one of the few people U that I know um who hasn't I
43:35
don't think you've been on Jeopardy but you've been a Jeopardy question or Jeopardy answer I have a a a short video
43:41
clip in which Alex TC says my name uh which is is that's that's bucket list
43:47
stuff what in terms of um you how you divide your time between teaching you
43:52
know keeping research in mind writing popular books um and also you know
43:58
technical mentorship how do you divide your time and and what is your uh what is kind of your philosophy overall and

44:04
how you keep uh balance between these different aspects of of your life it changes uh year to year and term to term
44:12
in the course of the Academic Year you know it depends a lot on what I'm teaching at any given time This this
44:17
term you know January through now has been really heavy teaching just because
44:22
of the nature of the particular course I'm doing but you know I try to make a point to block out a few hours a day in
44:30
the morning I've to my chagrin I've turned into a morning person in my middle age and so I'm I get up really
44:39
early because you know I get up at like 5: and I walk the dog and feed the dog
44:44
and and then you know get the kids up and and you know off to school and then
44:50
I'm in the office at like 7:30 so I block out some time in the morning for working on my own stuff for working on
44:57
on on books and and blog posts and and you know articles and and that kind of
45:03
thing and that's that's really important to sort of separate out that that particular time you know and then the
45:10
the teaching is you know that that's on a relatively rigid schedule and you know
45:16
in the summer it's more focused on Research frequently have students
45:21
working in my in my lab on on various projects and you know that's more of a
45:26
you know meet with them daily and okay what are you doing okay you know try this thing next and you know do this and
45:33
and talk about what you know what the future of the project is and so that's a that's a its own process so you know
45:39
these things go in Cycles uh you know the academic years September to to June
45:45
and you know we're in in session at a session and things things move around a
45:50
little bit but yeah that's the most important calendar that you don't mention in the book you mention Gregorian Mayan but you don't mentioned
45:57
the academic the academic calendar yeah the you know the the you know starts in

46:02
September everybody freaks out at you know uh at the end of the the term and
46:07
you know and then there's a sort of a period in May where everybody's mad because it's coming to the end of the
46:13
year and everybody's nerves are shot and then uh you know we got we got two weeks to graduation and everybody's SN snippy
46:20
at each other and then you know and then there's a big you know sigh of relief and then we're into the summer so when
46:25
you were writing I don't think you're still as active writing for Forbes as you were once uh several years ago but
46:33
um you published a wonderful little article uh which basically becomes part of the uh the book but talk about the
46:39
five biggest surprises so maybe you can end with of all the biggest surprises in the history of timee keeping the
46:45
characters the tools the uh the kind of existential dread that came about in
46:52
many ways tell me Chad what was sort of the greatest you know surprise to you right wrting this book it's always kind
46:58
of a form of me search when you do this type of research right so what was your favorite surprise as we wrap up the
47:04
thing that that I was most surprised to learn and and the the book started as a course that I offered a couple of times
47:11
at at Union uh with the same title brief history of timekeeping which I was stunned that nobody had used the most
47:17
surprising thing was learning that uh mechanical clocks and sand glasses are
47:23
of comparable vintage right that you know you think of s you know an hourglass you know with the like you
47:30
know Sands in an hourglass or the Days of Our Lives kind of thing you you think
47:35
that would be like a technology that's just 10,000 years old people have been doing this forever but it's actually
47:41
they don't the first verified reference to that is in the early 1300s there's a
47:47

mural on a on on a wall in a church in Sienna Italy that um that shows an
47:54
hourglass in in recognizable form and that's the first time that one of one of
47:59
those is unambiguously depicted and at around the same time you have mechanical
48:04
clocks uh people had invented those two things those two technologies at about the same time and the other interesting
48:10
thing about them is that uh nobody knows who invented either uh they just sort of show up right there are just um
48:18
hourglasses are a thing in Europe people have them they're using them to to measure time and it and it's just kind
48:25
of everywhere and mechan IAL clocks just start showing up in churches at at you
48:30
know in that like you know 12300 kind of range they just start appearing and
48:36
there's no like one inventor that we can point at and say this guy did you know
48:42
is the one who came up with the idea of the mechanical clock it's just suddenly they everywhere um so it's a really
48:48
interesting uh Testament to sort of the power of of anonymous tinkerers right somebody somebody figured out how to
48:55
make this work and it succeeded so well that nobody remembers who they are anymore Chad orzel Professor Union
Outro
49:02
College and good old SKC New York my former homeland of New York at least
49:08
although I was more in the deep south of uh of New York I want to thank you for your time in this wonderful book and
49:14
sending me a copy and I've uh I've got my own audio copy which I devoured as
49:19
well Chad thank you so much for spending so much of your time your valuable time
49:24
oh I just want to say one last thing if uh if it's true that you believe that it's true that uh a man who has one
49:30
clock knows what time it is but a man with two clocks never is sure that always confused one must make you one of
49:37

the most you know confused people in the world but this book is incredibly easy to read clear and just a delight to read
49:43
and listen to Chad thank you so much for sending your time today yeah thank you for having me on this was fun if you
49:48
watch all the way to the end I know you'll love this interview with Nobel Prize winner Bill Phillips who's Chad
49:54
orel's the PHD adviser and click here for a playlist of the best episodes from the past few weeks see you next time on
50:01
into the impossible goodbye next time…forever
JN, 07.03.2025 shame on the effort