https://www.youtube.com/watch?v=BcvUoah66m8

What Creates Time? A Challenge to Scientific Orthodoxy

Co vytváří čas? Výzva pro vědecké pravoslaví

World Science Festival

1,33 mil. odběratelů

28 787 zhlédnutí Premiéra před 19 hodin #briangreene #worldsciencefestival #entropy

Scientist and author Julian Barbour joins Brian Greene to explain his heterodox views on the nature of time, entropy, and cosmic origins. This program is part of the Big Ideas series, supported by the John Templeton Foundation. Participant: Moderator: Brian Greene.

Vědec a autor **Julian Barbour** se připojuje k Brianu Greenovi, aby vysvětlil své heterodoxní názory na povahu času, entropie a vesmírný původ. Tento program je součástí série Big Ideas, kterou podporuje John Templeton Foundation. Účastník: Moderátor: **Brian Greene**.

0:01
(01)- [Music] in today's conversation I'm pleased to be speaking with Julian Barber who has spent decades thinking about the Deep Mysteries surrounding the nature of time you may know of him through his books that he's written among which we have the book The End of Time the Janice Point these are wonderful treaties on the nature of time that are accessible to a general person in the audience who's interested in these deep issues as well as informative to the acting professional because in these books Julian really described some of his forfront thinking on the nature of these issues so I'm so pleased to bring Julian into the conversation welcome Julian how are you doing today I'm doing very well
Welcome to Julian Barbour
thank you Bri great pleasure to be talking to you thank you and and where are you at the moment where are you
1:01
joining us from I'm sitting in the in the middle of England about 20 mil north of Oxford in a beautiful old house built in 1659 to bring time in exactly and and so this is where you have done most of your research if I understand correctly is that right that's right yes uh I I've been working away on this now in this house for over 50 years uh and and it's been a bit of a little bit of a conference center I've had some very distinguished people here and some very fruitful discussions some of the well-known people working in quantum gravity have been here um Roger Penrose even has been a couple of times um no not Steven Hawking but uh it's been wonderful and we have a little W I have a whiteboard up to my right and and we've had little seminars here yeah it's beautiful you know I you know I went to to graduate school at Oxford so I I know that in environment well and before we get into our deep conversation about
2:05
your work and the nature of time your own trajectory within the course of of

Barbour's backgroundphysics and thinking about these ideas where did you go to school and how what was the trajectory that took you to this beautiful Farmhouse oh that's a fabulous bit of luck all told so about the age of 10 I I I was uh Blown Away by discovering astronomy and from the age of 10 I wanted to be an astrophysicist that took me to study mathematics at Cambridge then I started an astrophysics uh doctorate in in Munich in Germany um but I'd gone there for a year first of all to to to learn Russian and German because I wanted to read Russian Pushkin in in in Russian extraordinary uh and there I um and I started on this
3:00
astrophysics PhD but then quite by chance I read about the one popular science article at the great Quantum physicist Paul durak had written in the Scientific American in May 1963 in which he had questioned whether four-dimensional symmetry is a fundamental feature of the physical world he'd come to that conclusion from studying the dynamical structure of general relativity as a dcal Theory not as a space-time Theory and that had led him to this amazing conclusion and I read this and then I suddenly said to myself well what is time and I've never stopped since then and uh I at about the same time I uh started reading and learning about an Mark's ideas about the relativity of motion and also Mark's statement where he said it's utterly impossible to measure the changes of
4:00
things by time quite the contrary time is an abstraction at which we arrive by means of the changes of things uh and in fact my first scientific paper was giving mathematical expression to that idea uh and then I had thought I would get a position at a university in this country after in Britain after I'd got my doctorate uh but I talked to um a well-known relativist Felix pirani and said what's it like like being an academic he said well if you're confident you can do three things go for it and the three things are the administration giving the lectures and producing one or two good uh Theory uh papers a year and when he said that I knew I couldn't possibly do that because I was wanting to think about these really deep problems what is time what is motion what is space and there was no way I was going to produce one or two papers a year so uh by that purely by chance i' read an
5:04
advertisement in nature for people who knew Russian science and English could produce English to translate Russian scientific journals so they sent me a couple of trial things and they said you can have as much work as you'd like so for 28 years I I earned my living by translating Russian scientific journals uh but meanwhile that gave me about a third to a quarter of my time to do what I wanted uh complete Freedom so then it was actually five or six years before my first paper got published but then it was in nature and it attracted quite a lot of interest and eventually led to a wonderfully fruitful collaboration with a very good Italian theorist Bruno berotti well that's an extraordinary Story I mean it's interesting the three
………………………………………………………………………………………………..

(01)- [Music] in today's interview I'm delighted to be able to speak with **Julian Barber** who has spent decades pondering the Deep Mysteries around the nature of time, the nature of time, what is it? Can you give me some examples?... which you may know of him through his books, among which we have The End of Time the Janice Point these are wonderful treatises on the nature of time that are accessible to a general audience who are interested in these deep issues, and informative for actors because in these books Julian has actually described some of his direct reflections on the nature of these >issues,?? so I'm very pleased to bring Julian into the interview welcome Julian how are you today I'm very well. Welcome to Julian

Barbour thank you. Bri it's a pleasure to speak to you thank you and where are you at the moment where are you
1:01
joining us from I'm sitting in the middle of England about 20 miles north of Oxford in a beautiful old house built in 1659 to keep time accurately and that's why you did most of your research here, if I understand correctly that's right, yes, uh I've been working on this in this house now **for over 50 years**, that's amazing, I know what I'm saying, I've been working on something very similar myself for 44 years. I know and it was a bit of a conference centre, I had some very important people here and some very fruitful discussions. Some of the famous people working in quantum gravity were here um **Roger Penrose** even a few times um no no **Steven Hawking** was here but it was amazing and we have a little W. ?? I have a whiteboard on my right and and we had little seminars here yeah it's beautiful you know I you know I I went to graduate school at Oxford so I know that in the environment well and before we get into our deep conversation at
2:05
your work and nature of time your own trajectory throughout Barbour's fundamental physics and thinking about these ideas where did you go to school and what was the trajectory that led you to this beautiful estate oh that's a wonderful piece of luck all of that was said about the age of 10 I I I was fascinated by the discovery of astronomy and from the age of 10 I wanted to be an astrophysicist which led me to study mathematics at Cambridge then I went on to do a PhD in astrophysics in Munich in Germany er, but I went there for a year to learn Russian and German because I wanted to read Russian Pushkin in Russian and extraordinary Russian and that's where I started
3:00
PhD in astrophysics, but then I happened to read about a popular science article by the great quantum physicist Paul Dirac that he wrote in Scientific American in May 1963 in which he asked **whether four-dimensional symmetry**, of dimensions, that is, of quantities, is a fundamental feature of the physical world. I came to this conclusion by studying the dynamical structure of general relativity as a theory of dcal, not as a theory of spacetime, and that led him to this amazing conclusion and I read this and then suddenly, I said, okay, **what is time** and since then I have never stopped and around the same time I started reading and learning about Mark's ideas about the relativity of motion and also Mark's statement where he said that = **it is absolutely impossible to measure changes**
4:00
of things over time, = on the contrary time is an abstraction that we get to by changes in things . That's interesting; I've been sitting at my computer for 10 minutes now thinking about what is right…; I'm thinking and it seems to me that both are true…, changes in things happen continuously and changes in the rate of time also… and actually my first scientific paper gave a mathematical expression to that idea (?) and then I thought I would get a place at a university in this country after I was in Britain after I got my PhD, uh, but I was talking to a well-known relativist **Felix Pirani** and I said what is it like to be an academic, he said well if you are sure you can do three things. for that and three things are the administration that lectures and produces one or two good uh theory uh papers a year and when he said that I knew I couldn't do it because I wanted to think about these really deep issues. There is time, what is motion, what is space and I didn't want to produce one or two articles a year anyway, so purely by chance I read

5:04
an advertisement in Nature for people who knew Russian science and English could produce English to translate Russian scientific journals, so they sent me some trial stuff and said you can have as much work as you want, so for 28 years I made a living translating Russian scientific journals, but in the meantime it gave me about a third to a quarter of the time to do what I wanted, complete freedom, so it actually took five or six years to get my first paper published, but then it was in Nature and it attracted quite a lot of interest and it eventually led to a wonderfully fruitful collaboration with a very good Italian theorist **Bruno Berotti** well, that's an extraordinary story. I mean it's interesting the three
…………………………………………………………………………………………………

(02)- criteria that you laid out you know the administrative you know giving the lectures and producing the papers thought you were going to say I couldn't
6:01
bear do the doing the administrative or giving the lectures which for many of us is something that uh we try to steer away from but that's an extraordinarily wonderful story that has given you the freedom to not have to worry about I guess writing grants and trying to you know feed the academic Beast which of course is part of what we as you know in the Traditional Academy have to do so that's quite wonderful you mentioned a number of things in your inspiration you know dur and and M you know MCH certainly is a thinker who's had a profound impact on on many of us thinking about physics Einstein himself of course was influenced by mock thinking we're going to get into the details but from 30,000 ft where do you stand on the nature of time I mean was
Barbour's thinking on the Nature of Time
7:00
minkowski correct in say reformulating Einstein's special relativity in this space time Arena which was not the original context that Einstein used to to frame his ideas was that the right move or was that a misleading move I would say it's right and wrong I think uh I mean the interesting thing is if you read that wonderful paper of MOSI 1908 where he introduces the notion of space time he actually said it's such a wonderful thing he says it should be it should be called absolute uh but there is no trace of any marchan awareness of what is time and what is motion uh he he it's completely well Einstein said of it it's it's uh Newton had the concepts of absolute space and absolute time and minkovsky had the notion of absolute space time but there's a very revealing moment in in uh
8:02
in that paper where minkovski says of his construction that he's proposing so as not to leave a yawning void anywhere let us suppose that everywhere there is something let us call it substance so he's as it were sprinkling Gold Dust all over this complete uniformity so that you can see where things are and with respect to it's a it's a monstrous lie that's not the way the world Works uh and to bring in my other great hero has who's influenced me hugely which is libnet and libnet says if there were no Variety in the world we could do nothing so liet builds up everything from variety and this is what's lacking now my feeling is and in fact I would say the work that I've done with some very good collaborator Botti Carol Kash lots
9:02
of the big figures in in quantum gravity um what you can show is that there's a different way of arriving at general relativity where the end product is in local bits of SpaceTime you have minkovski structure that's what Einstein took he has that there now I my feeling is that we

should rethink general relativity and I was able to do that with some of my very good collaborators and say that uh the minkovski thing is the final bit it's the end product not the starting thing and then general relativity looks very different so I would I mean it's it's clear general relativity is incredibly good about describing the universe as it now is I however I have a fairly strong suspicion it's on somewhat shaky foundations that go back to to that
10:00
starting point of minkovski I mean that's a presumably a fairly minority view right I think most of us were schooled in the standard way of thinking about general relativity which is if you go into Free Fall then you're able to at least locally eliminate gravity if you're in free fall and you let something go it'll fall with you you don't see you see tidal gravitational forces which can be as as minimal as you want if the masses are small and in that Free Fall frame of reference it's as if you're in a gravity free environment it's as if you're in the context of Einstein's special relativity it's as if you are in a little piece of manowski space is that an approach that you want us to move away from I I want to say say how does it get there now what Mark said was uh the the key thing is that's what you call local inertial frame of reference in fact it was Mark's Work That stimulated somebody called Ludwick
11:04
Langer to coin the expression inertial system so the question is where does the inertial frame of reference come from and Mark's conjecture was that it's an effect of all the bodies of the in the universe moving relative to each other that is somehow manifested locally and this is what the work in the first place that I did with berotti showed how that can be done and then later with a very top relativist nilo muru uh who did very important work on the initial value problem with Jimmy York uh in general relativity we showed how that that comes to be so really the whole universe is like a swarm of bees all moving relative to each other but their
……………………………………………………………………………………………..

(02)- the criteria that you set, you know the administration you know the lecturing and producing papers thought you would say I can't 6:01 bear doing the administration or lecturing which is something for many of us that we try to avoid but it's an extraordinarily wonderful story that gave you the freedom to not have to worry about writing grants and essays you know feeding the academic beast which is of course part of what we as you know in Traditional academia have to do so that's pretty amazing that you mentioned in your inspiration a number of things that you know dur and and M you know MCH is certainly a thinker who has had a profound impact on many of us when we were thinking about physics einstein himself was of course influenced by the false thinking that we're going to get into the details but from 30,000 feet where you're standing about the nature of time i mean barbour's thinking about the nature of time 7:00 minkowski was right, that reformulating Einstein's special theory of relativity in this arena of spacetime, which was not the original context that Einstein used to frame his ideas, was that the right move or was that the wrong move I would say that's right and wrong, I think uh I think the interesting thing is if you read that wonderful MOSI 1908 paper where he introduces the concept of spacetime, he actually said it's such a wonderful thing, he says it should be, it should be called absolute uh, but there's no trace of any marching awareness of what time is and what motion is, uh he he, that's perfectly fine, Einstein said about that, it's uh Newton had the concepts of absolute space and absolute time and Minkowski had the concept of absolute spacetime but there's a very revealing moment in uh 8:02 in that paper where Minkowski talks about his construct that he proposes that there's no gaping void left anywhere, let's assume that there's something everywhere, let's call it

matter, so it's like it sprinkles all this complete uniformity with Gold Dust, so I see where things are, and as far as that goes, it's a monstrous lie, that's not how the world works uh and bring in your other great hero who influenced me enormously, which is libnet and libnet says that if there was no Variety in the world, we couldn't do anything, so liet builds everything out of variety and that's what's missing now, my feeling is and in fact I would say the work I've done with some very good collaborator **Botti Carol Kash**. That's an interesting observation, that you learn about another physicist for the first time in 40 years (Botti) and he's said to be a **remarkable physicist**. I read an awful lot of articles on physics, where there are awful lot of physicists, and in 40 years, in those piles of physics, one appears who hasn't appeared for 40 years, hasn't shown himself anywhere with anything. And he's said to be a wonderful physicist. (?!) Why won't we meet amazing physicists in 40 years, never, anywhere??, a lot
9:02
of big numbers in quantum gravity um, what you can show is that there's another way to get to general relativity, where the final product is in local pieces of spacetime, you have the Minkowski structure, that's what Einstein took, he has it there now, my feeling is that we should rethink general relativity, why? It hasn't been said to anyone for 100 years "that it's flawed and should be reconsidered", why? and I managed to do that with some of my very good collaborators and say that the Minkowski thing is the last piece, it's the final product not the starting thing and then general relativity looks very different, so I would like to say that it's clear, general relativity is incredibly good at describing the universe as it is now. But I have a pretty strong suspicion that it's on a somewhat shaky foundation that goes back to that
10:00
Minkowski starting point. ? oh, I can spout nonsense too... I mean, it's probably a fairly minority view, that yes, I think most of us have been trained in the standard way of thinking about general relativity, which is that when you go into free fall, you're going to be able to at least locally eliminate gravity, if you're in free fall and you let something go, it falls with you, you don't see, you see tidal gravitational forces, which can be as minimal as you want them to be, if the masses are small, and in this free fall frame of reference, it's like you're in a gravity-free environment, like you're in the context of Einstein's special theory of relativity, like you're in a little bit of Minkowski space, that's the approach you want us to move away from. To say how it got there now, what Mark said was uh, the key thing is that you call it a local inertial frame of reference, actually it was Mark's work that stimulated someone named Ludwick
11:04
Langer coined the term inertial frame, so the question is where does the inertial frame of reference come from and Mark's assumption was that it's an effect of the motion of all the bodies in the universe relative to each other that somehow manifests itself locally, and that's what the work I did in the first place with **Berotti** showed how it could be done, and later with the very top relativist **Neil Muru** uh, this is the first time I've heard of these scientists (how is it possible that I've been around them for 40 not found anywhere in the scientific literature) (?) who did very important work on the initial value problem with **Jimmy York** in general relativity, we showed how it happened that the whole universe is like a swarm of bees moving towards each other, yes, the boiling vacuum is like a swarm of bees…the curvatures of all 3+3 dimensions of space-time change chaotically in it, not only in free space-time, **but also inside matter** !!!... but their
………………………………………………………………………………………………

(03)- effect is to create what looks like a rigid framework locally and that's your your your thing
12:01
that you have uh when you're free falling so it's how that framework of the free fall comes into existence that is the important thing and I think we could I think we can show that that that's in these papers and very important in this people don't I think properly appreciate it is the work on the initial value problem of general relativity you you you can't just start calculating in general relativity you have have what's called solutions to the initial value problem and that's the work that Jimmy yor and his first PhD student neilo muru did in in 19771 um and that I think is is a very different way of looking at at general relativity and if I'm relying on Paul der I'm not ashamed of that and and so just going back to to Mark's perspective for a moment I think many in our audience would be familiar with the thought experiment say of of Newton's bucket right Newton himself described
13:04
how you know if you have a bucket of water and you spin it the water begins to climb up the sides of the bucket it's very familiar another version of it which is perhaps simpler to think about if you have two masses connected by a string and as they start to spin around their Common Center the string will pull taut and a question that MCH asked was why does it pull tot and his answer as you made reference to in a slightly different context is it's the fact that there's all this Mass out there in the universe and the spinning motion is relative to that mass that's out there but that suggests that if you were to have a completely empty universe and something were to spin around the bucket or the masses the water wouldn't climb up the side the masses wouldn't pull taut because there'd be nothing with respect to which they would would be spinning and so where do you come down on that question Einstein at least in my
14:06
reading of the general theory of relativity and I think it's a fairly commonplace one would say that SpaceTime is enough of a thing to set that reference and so the water would climb up the bucket spinning around in an otherwise empty Universe the masses would pull taught in an otherwise empty universe that's kind of an anti-an idea that comes out of general relativity does your reformulation give a different Intuition or a different answer for that I I think it might let let me say one thing about about Einstein I always say
Barbour talks about Einstein
he deserves six or seven Nobel prizes but when it comes to actually what he said about M I think he made a complete and utter mess he kept on changing I mean all through his life he was changing his his views on that and at the end of his life now first of he' spent six or seven years of the best years of his life trying to create Implement Mark's ideas at the end of his
15:05
life he just said it was completely wrong a moment's thought would show that it was irrelevant once field thei had coming I think that was all completely wrong but it that in no way takes from Einstein's greatness but to come back to how you should think about it when there's nothing there I explain things as best I can using the idea of Point particles in space because there you can see the issues clear most clearly so let me the way I like to illustrate it is is with so the simplest Universe you could
Barbour illustrates the idea of point particles in space
possibly imagine would be of three particles so they would be at the vertices of this triangle and then they would move relative to each other and and that would be everything that there is

so the the at at a different instant of time the triangle would have a different shape it would be would be like that and they would move there now what you can do you can develop a mchan
16:05
theory which shows how those separations between the particles are really only the ratios how the shape changes so uh when I showed you that triangle it appears to have a size but that's relative to my head and so forth like that if the triangle itself if the triangle is aware of itself all it can be aware Ware of is is is is is uh it's relative thing so the the particle here can sort of see it see what the angle is looking to the other things it's only the angles that are visible to the triangle with itself so you should think in terms of shapes so uh I've been it's now about 25 years ago I call the expression shape Dynamics and it's about how shapes change and then you can say that the shapes change in such a way that Newton's absolute space and time
17:06
and absolute scale Play No role at all and then in that context you can show how first of all the universe overall has no net rotation that's no angular momentum at all uh and and has its energy exactly zero but then you can show how locally uh things behave so you can exactly
……………………………………………………………………………………………….

(03)- the effect is to create what looks like a rigid frame locally and it's your thing
12:01
that you have uh when you're free falling so how that free falling frame is created is an important thing in free fall the object moves = it slides along curved geodesics with the same curvature of its motion and I think we could, I think we can show that that's in this paper and very important in this people don't. I think I appreciate correctly that it's work on the initial value problem of general relativity, you can't just start calculating in general relativity, you have what's called solving the initial value problem and that's the work that **Jimmy Yor** and his first PhD student **Neilo Muru** did in 19771 ? and I think it's a very different way of looking on general relativity, and if I rely on **Paul Dirac**, I'm not ashamed of it, so I'll just go back to Mark's ? Who is this Mark, it's nowhere in this article... perspective for a moment. I think many of our audience would be familiar with the Newton's Bucket thought experiment that Newton himself described
13:04
how do you know you have a bucket of water and you spin it the water starts to climb the sides of the bucket it's very well known another version that's maybe easier to think about if you have two masses connected by a string and as they start to spin around their common center the string gets taut and MCH who is MCH? asked why it pulls and his answer as you mentioned in a slightly different context is the fact that there's all this mass out there and the universe and the rotating motion is relative to the mass that's out there but that suggests that if you were to have a completely empty universe and something was spinning around the bucket or the masses the water wouldn't climb the side the masses wouldn't stretch because there would be nothing for them to spin relative to and so where did you come up with this question Einstein at least in my
14:06
reading general relativity and I think it's quite common, one would say that spacetime is sufficient to set this reference, and so water would climb up a bucket spinning in an otherwise empty universe, which would be pulled by the masses, teaching in an otherwise empty universe, which is kind of an anti-idea that comes out of general relativity, gives your

restatement a different intuition or a different answer to that. I think that might allow me to say one thing about Einstein. Barbour talks about Einstein, he deserves six or seven Nobel Prizes, but when it comes to what he said about M, about Marek I think he made a complete and utter mess, he kept changing, I mean his whole life, changing his views on it and at the end of his life now in the first place he spent six or seven years of the best years of his life trying to create Marek's ideas at the end of his life. ??
15:05
life just said that was completely wrong, a moment's thought would show that it was irrelevant once the field comes in, I think it was completely wrong, but that in no way diminishes Einstein's greatness, but to go back to how you should think about it when there's nothing there, matter isn't there, but there's this spacetime, the curved dimensions I'll explain things as best I can, I'll use the idea of point particles in space because that's where you see the problems most clearly, so let me, the way I like to illustrate it, is with the simplest universe you can. Barbour illustrates the idea of point particles in space maybe imagine they were three particles, so they would be at the vertices of this triangle and then they would move relative to each other and that would be all there is, so at another point in time the triangle would have a different shape it would be like this and they would move there. What can you do, you can create **mchan**, ??
16:05
a theory that shows how these separations between particles are actually just ratios, how the shape changes, note, the curvatures of the dimensions change not the "shape of the object", the object here is spacetime, not the three points, so uh, when I showed you that triangle, it seems to have a size, but that's relative to my head and so on, like if the triangle itself, if the triangle is aware of itself, everything it can be aware of Ware of is is is is is is is it's uh, it's a relative thing, so the particle here can kind of see what angle it's looking at other things, they're just angles, two points are "standing" and the third point is flying around in a circle back and forth... that's the Pythagorean theorem..., and it's important to look at it with a "different style of thinking": when (in STR) the object is in motion, the "in" will change, the "using" "a", ($a = x/t_2$; $a = x/t_1.t_2$), so the object will rotate, or rather its own system will rotate. And that's the "new thinking", it's the movement of the "third point" in the triangle "along the arc of the circle" Thales' circle (connect the thinking with that bucket of water) which are visible to the triangle with itself so you should think in terms of shapes, so uh, I was, it's now about 25 years ago

years ago, I call the term shape Dynamics and it's about how shapes change, shapes? Of what? No. The curvatures of dimensions change and then you can say that shapes change in such a way that Newton's absolute space and time
17:06
and absolute scale Play no role at all and then in this context you can show how first of all the universe as a whole has no net rotation, to the net rotation is added also motion=displacement along "another dimension. Is that a parabola from the circle..., it has no angular momentum at all and has exactly zero energy, and what is zero? Mass, or length? Or time? And why? but then you can show how things locally uh. behave as exactly as you can
……………………………………………………………………………………………

(04)- recover this was in my paper in 1982 with with Bruno Botti um which Roger penro communicated to the proceedings of the Royal Society showing how uh you could uh you

could have all of the particles in the universe uh moving relative to each other but then that would create local frames of reference in which the bucket would Spin and the water would go up the sides of the wall of the bucket uh so all of that I would say is is is pretty clear so I I think one should I think one should
18:02
think about reformulating general relativity uh but it's it's still a wonderful Theory I mean nobody can doubt it my guess is that that it's definitely very good now in the present Epoch of the University Universe it may be either wrong or misunderstood near Big Bang and I think we'll probably able to come on to that how we might think about it in a different way near the Big Bang yes well I you know I think many of us who've worked on on quantum gravity whether it's string theoretic approach or Loop quantum gravity I think many of us have come to a similar conclusion that in extreme environments like near the Big Bang or near the singularity of a black hole it's likely that general relativity needs to be modified in in in some way and I'd love to come back to that but I want to stay simple first so in your example of the three particles as a toy
19:06
universe in which you can begin to develop from first principle some notion of what is the right language what are the right considerations to talk about space and time how do you think of time in that setting I mean you use the language at one moment the particles are in this configuration at another moment they're in another configuration so it seems to be relying on the Fairly traditional idea that you can't talk about time without change but are you imagining that this time is existing outside of those three particles or those three particles in this toy universe in some sense generating a notion of time by their relative positions uh my position is that instants of time exist and in the simplest case an instant of time would be just the shape formed by the three particles my model Universe three
20:05
particles their shape defines an instant of time at a different instant of time that shape would be different and then I would say that it's important to distinguish between those instants of time and what I would call duration is something that we imagine characterizes the difference between them so I would say dur is the diff is the difference between instance uh but the instance are the fundamental things so I think we our first ideas are of I mean imagine looking at the stars in the sky and in in Arizona at night I mean fabulous experience we see angles between between the stars that that's my most basic way of thinking but then if if we look long enough we can see that the stars have moved if we if we stand
21:02
there for a thousand years we will begin to see slight changes in the stars and I think that's the way we should think about it now what I think Newton did was really introduce a way of thinking about that change which makes that change seem to unfold in a particularly smooth way and that's what I think duration is it's something that we introduce the fundamental thing are the the triangles or the the the the overall the the the the relative shape of the universe how that changes but Newton taught us to describe that in a very wonderful way which makes it appear uh particularly uniform and it's expressed in the conservation of energy that that energy is conserved but I would say that energy conservation is not really the fundamental thing that's half of it is put in energy has two parts it has the
22:00
kinetic energy and it has the potential energy the potential energy is the reflection of how the particles are relative to body that for me is fundamental that is that is the rock on which I

stand but then the change of that thing and the the it's our choice of saying that that must happen in a particular way that then creates kinetic energy so I would say kinetic energy is a human creation to make sense of the universe and we all all agree on the same convention so we all manag to agree particularly here on the surface of the Earth that that energy is conserved because it's all governed by the total law of the whole universe that's how I see it sure now now Newton just to sort of get his program off the ground needed

Could Newton have done a better job describing Space and Time?

to articulate the starting point and certainly in the pipia he talks about a definition so to speak of space and a definition so to speak of time but when

23:03

you parse out the language roughly speaking all Newton really said was there is this Arena

……………………………………………………………………………………………

(04)- to restore it was in my paper in 1982 with **Bruno Botti** that Roger Penrose gave to the Royal Society and showed how you could have all the particles in the universe moving relative to each other, but then it would create local frames of reference in which the bucket would spin and the water would rise up the sides of the bucket wall, so the local curvatures of spacetime are sometimes with the same denominator (that locality), and sometimes with the same denominator in another locality…And in that locality then >operate< “packets” of curved dimensions, where if = if a pack has the same curvature as another pack, they are identical particles…and the interactions behave “according to the rules” etc. interpretation elsewhere… so all I would say is, it is quite clear, so I think one should think that one should

18:02

think about reformulating general relativity, I have been having a lot of fun with that for a long, long time…; briefly: step one: in OTR take the “G-constant” and remove the dimensions from this constant. This will create a dimensional imbalance in the equation, so it must be solved with step two: in the equation substitute the “letter” “m” for the dimensions of the two quantities Length and Time…; a linear equation with n+m dimensions will be created, where…where it is possible – step three: create, realize, build “packages of dimensions”, which will already be elementary particles …and we have a linear equation, the QM equation!!! So we have modified OTR = corrected it to QM, that's the point, that: OTR must be allowed to “rule” in the gravitational macroworld. And QM must be allowed to rule in the microworld and not connect them. If you want to connect them, you must remove the dimensions from the G-constant. - That was brief. The complex thing is then the "head = reader's brain", there must occur the thinking that leads to understanding the curvature of dimensions = sometimes it is "parabolic" curvatures = OTR and sometimes linear curvatures = QM where packages merge into other packages at a constant linear balance of dimensions, and with curvature changes … - - Was it brief?? but it is OTR still an amazing theory. I mean no one can doubt it, my guess is that it is definitely very good, now in the current era of the university two-quantity universe, it can be either wrong or misunderstood. near the big bang, and I think we will probably be able to figure out how we could think about it in a different way, I've already done it…, near the big bang yes, well, I know, I think many of us who have worked on quantum gravity, whether it is string theoretical approach or loop quantum gravity. I think many of us have come to a similar conclusion that in extreme environments like a) near the big bang or b) near a black hole singularity, it is likely that general relativity must be **somehow** modified and that means what?? find many to infinitely many ways to modify it??

No. After the big bang, matter is not yet "finished", there is a state of extremely curved dimensions, spacetime in the foam of dimensions starts to unwrap and in parallel with this (in that foam, in the plasma) "packages, cocoons of curved from curved dimensions = mass elementary particles, and fields of "open curvature" start to be produced and I would like to come back to this, but I want to keep it simple first, so in your example of three particles as toys
19:06
a universe in which you can start to develop from first principles some idea of what is the right language, what are the right considerations when talking about space and time, how do you think about time in this environment. I mean you use language, at one moment the particles are a) in this configuration at another moment, they are b) in another configuration, O.K. watch out, we are in a "linear" environment here (where //packages and interactions are transformed) so it seems that they rely on a fairly traditional idea that **you cannot talk about time without change**, about the passage of time without changing the curvatures "in packages" and in the "linear equation of interactions", when changing the configurations of matter, or both..., but you imagine that this time exists outside these three particles no, no, on the contrary. Time here is not stoic, it is the passage of time and the passage of time means "cutting intervals into a time dimension", → which makes the object both complex and simple (e.g. a cursor on a dimension), or those three particles in this toy universe in a sense generating the idea of time by their relative positions uh my position is that moments of time exist and in the simplest case a moment of time would be just the shape formed by three particles, my model. Universe Three
20:05
particles their shape defines a moment in time ?? at another moment in time, this shape would be different. And then I would say that it is important to distinguish what? between these moments in time

moments and what I would call duration is something that we imagine characterizes the difference between them so I would say that major is the difference is the difference between instance uh but instances are basic things so I think our first ideas are I think imagine you're looking at the stars in the sky and in Arizona at night I mean wonderful experience we see the angles between the stars that's my most basic way of thinking but if we look long enough we can see that the stars have moved if we stand
21:02
there for a thousand years we start to see tiny changes in the stars and I think that's the way we should think about it now. Sure, trivial, all astronomers have been doing that for 3000 years. I think Newton really introduced a way of thinking about this change that made this change seem to unfold. A particularly smooth path and that's what I think duration is something we're introducing. The basic thing is triangles or the the the the the the the relative shape of the universe as it changes, but Newton taught us to describe it in a very wonderful way that makes it look particularly uniform and it's expressed in the conservation of energy, or in the conservation of "a certain package of the number of dimensions and the curvatures of those dimensions" so that as a package it is the same as another package... under different parameters, that that energy is conserved, but I would say that the conservation of energy is not really the basic thing because half of it is put into energy it has two parts that it has
22:00

kinetic energy and it has potential energy, potential energy is a reflection of how the particles are relative to the body, which is fundamental to me, that's the rock that I stand on, but then the change of that thing and that's our choice to say that it has to happen in a certain way which then creates kinetic energy, so I would say that kinetic energy is a human creation that makes sense of the universe, and we all agree on the same convention, so we all we can agree especially here on the surface of the Earth that this energy is conserved because it all follows the complete law of the entire universe, so I see it now for sure, a "certain" package of the number of dimensions and the curvatures of those dimensions. Newton, just to get his program going. Could Newton have done a better job of describing space and time? articulate the starting point and certainly in the pipi he talks about the definition of space so to speak and the definition of time so to speak, but when
23:03
roughly speaking all Newton really said was that there is this Arena
………………………………………………………………………………………………..

(05)- called space I'm just going to assume that it's there and there is this thing called time which seems to flow I think his language was equably in equal increments from moment to moment but when you try to purse out what that really means it's hard to feel that it's any more than just a dictate you know by Fiat there is this thing called space there is this thing called time can we do better than that could Newton have done better than that yes and interestingly he was very close to it because um let me just briefly say how how I would say time and clocks developed so um I mean there were in in the time of the ancient Greeks there were water clocks and things like that and S clocks and and all that like that but the key thing is the laws of planetary motion
24:04
could never have been discovered if it weren't for the existence of what we now recogn what was then eventually recognized to be a fabulous clock which is the rotation of the Earth or the rotation of the Stars so that defines what's called siderial time the the time that the Stars tell and uh the great Greek ancient astronomers hipparchus and toy they made their observations and then they were dated by by the time and then uh that eventually led to the capern revolution to Fabulous observations by Tio brah and then for me the one of my huge Heroes is Kepler who by the way whose in intuition was very like Ernest Marx and in fact I I've I've go on record and say that in fact in many ways Kepler discovery of the laws of planetary motion was the first great
25:01
Triumph of M's principle long before M but uh what Kepler discovered was Kepler's second law what Kepler of the planets that the planets in their motion around the Sun sweep out equal areas in equal times now the key thing about that is the expression I use is that those clocks that each of the planets Define by the area they sweep out marches in step with the rotation of the earth which is an independent clock so I say that you can't say that one clock is a good clock you say that a collection of clocks are good if they all keep the same time their rates may be different but the ratios of the rates must stay the same and then so so the next big advance in in in really fundamental scientific time keeping is comes with Kepler Second Law then the next thing is the astronomer Royal
26:04
flamsteed UH 60 or so years later at greenage who showed that the pendula pendulum clocks keep time with uh with the rotation of the earth with siderial time and not with solar time not

with mean solar time so and now that's exactly what happens with modern atomic clocks cuz it is not one single clock I mean the it's a fabulous situation now with the way timekeeping is done there are sort of six Master clocks in Boulder Colorado uh they're the best ones and there's some very good ones in Brun Brunswick in Germany then there's about a hundred all around the world and they're all matched up and they can't use just any one of them because they have glitches uncontrollable glitches and then on top of that they have to take into account things like continental drift uh the Chandler wobble of of where and now they even have to
27:01
take into account how the tides are moving on the earth uh to to to determine time it's a it's a colossal Enterprise but the key thing is ultimately always to get as my expression is Marching In step it is a wonderful story and I mean the most modern time pieces you know these atomic clocks I think some of them are based on cesium 133 you know the vibrational modes gives you this cyclical process The pendula Swinging is a cyclical process the motion of the planets is a cyclical process so we have found that by finding ever more stable cyclical motion we can have ever better clocks but if you were to be pressed and say what is it that they are measuring would you make it a self-referential statement that they're all measuring the same kind of thing because the ratios stay the same as you
28:00
made reference to or is there some independent notion that we can really use as the definition of time or should time be simply defined in this very straightforward operational sense as that which clocks measure I I think for practical purposes and the mere fact that we're able to talk to each other because a huge part of us talking to each other is messages is being about coordinating the clocks between you and me uh that that a vast amount of the information is devoted to that I I would my guess my feeling is that the whole universe is just evolving it's getting it's getting more richly structured I think we're going to come on to this a bit later and I think just that overall thing just all of these things that clocks are picking up is just part of
……………………………………………………………………………………………..

(05)- called space I'm just going to assume that it's there and there's a thing called time that seems to flow I think his language was from moment to moment evenly in equal increments but when you try to dig into what it really means it's hard to feel that it's anything more than just a dictate that you know from Fiat there's something called space there's something called time we can do better than Newton could do better yes and the interesting thing is he was very close to it because um let me just briefly say how I would say time and clocks evolved so um I mean in the time of the ancient Greeks there were water clocks and things like that and S clocks and all that but the key thing is the laws of planetary motion
24:04
would never have been possible to discover if there wasn't the existence of what we now know what was eventually recognized as the wonderful clocks which are the rotation of the earth or the rotation of the stars so they define what is called sidereal time. The time that the stars tell, and the great ancient Greek astronomers hipparchus and toy who made their observations, and then it was dated by time and then, which eventually led to the Capernaum revolution to the amazing observations by **Ticho Brahe** and then for me one of my huge heroes is **Kepler** who by the way, whose intuition was very similar to Ernest Marx and I actually went on record and said that actually in many ways Kepler's discovery of the laws of planetary motion was the first great

25:01
triumph of M's principle long before M, but what Kepler discovered was Kepler's second law of that Kepler about the planets that the planets sweep out of the same areas in the same times as they move around the Sun, now the key thing about that is the expression that I use is that those clocks that each of the planets defines by the area that they sweep out march in step with the rotation of the earth, which are independent clocks, so I'm saying you can't say that one clock are good clocks you say a collection of clocks is good if they all keep the same time their rates can vary but the ratios of the rates have to stay the same and so the next big advance in really fundamental scientific timekeeping comes with Kepler's second law then the next thing is the astronomer Royal
26:04
flamsteed UH 60 or so years later in Greenage who showed that pendulum pendulum clocks keep time with uh with the rotation of the earth with sidereal time and not with solar time not with mean solar time so and now that's exactly what's happening with modern atomic clocks because it's not one clock i think it's a wonderful situation now with the way timekeeping is done there are about six main clocks in Boulder Colorado uh they are the best and a few very good ones are in Brun Brunswick Germany then there are about a hundred around the world and they are all aligned and they can't just use one of them because they have faults. Uncontrollable faults and then on top of that they have to take into account things like continental drift, Chandlerian wobbles of where and now they even have to
27:01
consider how the tides move on the earth, uh to the point of determining time, it's a colossal Enterprise, but the key is to always get it in the end because my expression is Marching In Step it's an amazing story and I mean the most modern timepieces that you know, these atomic clocks I think some of them are based on the number of ticks, or the frequency of ticks cesium 133 you know the vibrational modes give you this cyclical process. The pendulum Swinging is a cyclical process the movement of the planet is a cyclical process so we found that by finding an increasingly stable cyclical movement we can have an increasingly better clock, O.K. a mechanism that produces the same "number of ticks" per unit of time...; author Barbour admires the "local, local pace of time" here, but did he also investigate why we have the pace we have here on Earth. Is this pace the same everywhere in the universe, or just in our galaxy. Is this pace changing throughout history, just in galaxies or even outside them...etc. but if you were pressed to say what it is that it measures, would you make it a self-referential statement that You all measure the same kind of things because the ratios remain the same as you??
28:00
was he referring to or is there some independent concept that we can actually use as a definition of time, do you have a definition for the "quantity Time" ? and also for the "rate of time"? or should time simply be defined in this very straightforward operational sense as what a clock measures. Clocks do not measure anything, we measure, the clock only "ticks" intervals and we compare them with the intervals in the time dimension performed by the object, the object moves along the time dimension and we then perceive this as the "pace of time passing", we perceive changes in the size of the intervals that the object "produces by its displacement" "over time" (over the time dimension), but the clock still ticks at its own pace. I think that for practical purposes and the mere fact that we are able to talk to each other, because a large part of us who talk to each other are messages about the coordination of the clocks between you and me, that there's a huge amount of information devoted to that. The

universe is fair, it's evolving, it's getting richer, I think we'll get to that a little later, and I think overall all these things that the clocks are picking up are just part of

……………………………………………………………………………………………………

(06)- that one single on onward evolution of the universe which I will argue is to Greater structure uh greater
29:05
complexity uh that that's what's going on that that's what I would say and so why don't we turn to that now and before we get to some of the ideas that you've
How to characterize Entropy and the unfolding of the Universe
been developing recently and in fact over the course of many decades I thought it would be worthwhile to spend a little time on on the more conventional story that has emerged through the work of of many thinkers and you made reference before to Roger Penrose Penrose of course has played a a vital role in this idea and trying to have some understanding of how to characterize the unfolding of the universe and of course entropy is an idea that has played a vital role in that story so maybe we can take a a step back and just imagine where say in the 1800s and there are steam engines that
30:01
people are trying to understand and in trying to get a grasp on why steam engines always were releasing a certain amount of heat to the environment there was always waste coming from you burn this Fuel and you want the fuel to make that piston push against that air in a canister driving whatever mechanical device it is to undergo its mination there's always waste and that led people like you know even further back carau it led people like bolman to this notion of entropy which is a very slippery idea especially for those who are not well versed in the language of mathematics how in a general context do you think about intuitively and how would you describe to a general audience this notion of entropy well first of all let let me say that I think the discovery of the laws of thermodynamics by William Thompson later Lord Kelvin and Rudolph clausius in Germany it's one of the most beautiful stories in in in physics but um I think the key thing well let me first of all say uh I think a thing which has been amazingly ignored is that all of the law the the laws of thermodynamics and then their explanation through the atomistictheory of statistical mechanics the the atomistic explanation of it all of that developed out of the study of steam engines now steam engines stop working if the steam escapes from the cylinder and uh so if you look at all the great initial papers that uh we that the ones that I've mentioned and you've mentioned uh including also the Great American um
32:00
Gibbs and and Maxwell they all assume particles molecules in a box so the typical situation describing entropy you can think of it as as if you got uh uh a box with air and you start off with a little cube of ice in the bottom corner of one bottom corner of the box and that ice in a crystal latish is very highly structured there are water molecules in the air all floating around a bit by bit the uh the ice melts becomes water and then the water evaporates and then all of its water molecules are spread around the thing and that's an irreversible process now technically if you could stop uh all the particles and exactly reverse their motions they would go back to that uh block of ey that little cube of ice but that never happens and that process is is uh from a highly ordered State you've gone to a highly disordered state so
33:03

this is basically what people say is the growth of entropy uh and there's no doubt that that's correct and I mean the the things that have come out of the study of entropy and thermodynamics and statistical mechanics are just wonderful it goes on and on and still going on marvelous discoveries perhaps the most incredible of all was the discovery of of of the first Quantum Effects by Max plank based on uh trying to make sense of of these these processes with radiation I think there's only one person before me if I may boast about it who said what happens if the box is not there and if say these particles are interacting through gravity now the one person who did question that was was ludc boltzman in 1896 when he was involved in a very famous debate with the German zero who later became a great
34:00
logician about explaining the second law of Thermodynamics and uh so Meo was relying very heavily on the a famous theorem that panker had proved just a few years earlier the recurrence theorem which if you have a dynamical system like that in a box if you wait long enough it will come back arbitrary close to any position it was in in previous so both uh Meo said I want the second law of Thermodynamics to say entropy must always increase but uh in this situation it's clear it will go back again and there's actually it's more or less just a footnote from bman who says are we so sure that the universe is in a box and satisfies the recurrence
…………………………………………………………………………………………………...

(07)- principle and I don't I'm not sure that anybody else has taken it up if you read uh um gibbs's book published just at the end of his life very great book where he he develops all his theory with his probability and lille's Theorem and he says but I must point out that this
35:06
Theory will fail if the system can expand into Infinite Space or the momenta can become unboundedly large because then my probabilistic arguments will fail but he doesn't say uh what what could go then now Einstein said that the only physical Theory which he was convinced would never be overthrown within the domain of applicability of its basic concepts is thermodynamics but Einstein didn't spell out what those basic concepts are and the basic concept is essentially the system must be in a box or mathematically speaking technically it's that the Solutions of the dynamical system can only explore a phase space of bounded leil
36:06
measure and if it's unbounded I would say the diff it's a difference between night and day before we get there because that that that is a key point but I just want to make sure that we cover the more conventional system a little bit more fully just to tie it into our theme on on the nature of time so if we are in a bounded system like a body as you have described things if you start in an ordered State it's quite clear that over time the system overwhelmingly is likely to go to a more disordered state so you had the ordered ice in a nice crystal lattice and over time those molecules they melt they fill up the box and it's a more disordered environment now you're also saying that that transformation from from order to disorder from low entropy to higher entropy it's a tendency even in that
37:05
setup it's not an ironclad law because as you made reference there are those who showed that if you wait long enough the system through its random motion will find its way back arbitrarily close to the ordered state that it began with so it's a statistical statement the second law of Thermodynamics even in this constrained setup is a statistical statement it's overwhelmingly likely to go from order to disorder but you wait long enough and highly unlikely intuitively unlikely things will happen the system can find its way back arbitrarily

close to beginning so in in that bounded setup we seem to have at least some semblance of a notion of time

The Arrow of Time

having a direction it tends to go from order to disorder now again we're going to then move in a moment to the more General situation where we're not in a box but even in that more constrained

38:01

setup this seems to be progress it seems to give us some sense of an understanding of why there is an orientation to time order toward disorder but as people like Roger Penrose pointed out and maybe you did too there's a presupposition in there that there is some initial state of order from which we can then degrade toward Disorder so it does raise the question of where did the original order come from and this led people to suggest a new principle of physics called the past hypothesis that for some reason that we don't understand things began in an ordered State near the big bang and we have been living through the degradation of that ordered State ever since is that a compelling set of words words to you for how we can have an arrow of time come in in a cosmological setting or are you

39:04

going to ask us to slide that to the side in favor of ideas that you have developed uh yes I am uh in fact I would say it's it's it's perfectly all right for me living in this lovely house where I am I'm I'm slowly degrading I I will move next door into the churchard it's very beautiful uh but I would say it's completely the wrong way to think about the Universe I think uh um I I think uh well nothing is ever certain in science so this is this is just my conviction but I think it's quite persuasive and and I I just go to the oldest dynamical Theory which exists which is Isaac Newton's theory of universal gravitation and there um if the energy this has been known since 1772 if the energy is non

40:00

negative uh the uh so the energy is either zero which is the one that Mark would like and I do like uh uh and and then the system uh well there's two possibilities the most common one if the energy is zero or it's positive is that in the infinite Newtonian past the size of the system will be infinite great infinitely great it will come down to a finite size and then go up again to an infinitely great size and uh that's that size is measured by a ruler outside the universe but that already defines two uh bidirectional arrows of time going either way from that point of minimum size so if I were God looking at this happening from outside and I had my ruler to

…………………………………………………………………………………………………..

(07)- principle and I don't. I'm not sure anyone else has picked up on it, if you read uh um Gibbs' book published just at the end of his life, a very great book where he develops all his theory with probability ||and Lille's Theorem|| and he says, but I have to point out that this

35:06

theory fails if the system can expand into infinite space or the momentum can become infinitely large because then my probabilistic arguments fail, but he doesn't say what could happen, then Einstein said that the only physical theory that he was convinced would never be overthrown within the scope of its basic concepts is thermodynamics, but Einstein didn't explain what those basic concepts are, and the basic concept is basically the system has to be in a box or mathematically speaking technically it's that the solutions of a dynamical system can only explore the phase space of a bounded leil,

36:06
measure, and if it's unbounded, I would say the difference is the difference between night and day before we get there because that's a key point, but I just want to make sure we cover the more conventional system a little more completely, just to tie it into our topic about the nature time, so if we are in a bounded system, like a body, as you described things, if you start in an ordered state, it is quite clear that over time the system is most likely to go to a more disordered state,

INSERT:
The past is completely classical according to Smolin. Try to think like this: Before the big bang, the universe was just a smooth infinite space-time without matter, without the flow of time and without expansion (because it was infinite in 3+3 dimensions). Then there was that jump change from the "previous state" to the "subsequent state = our warped universe" with matter and fields, and with the unrolling of time and the unrolling of lengths and that to…??, to what? Either it is that it is unfolding "into Nothingness..., or "our warped space-time with matter" floats in the original flat Euclidean grid-network-web 3+3D...and then the "present" is flowing-unfolding into the "future not "into Nothingness", and the past is already a deterministic state, the future is not known how "transformations of curvatures of dimensions are reshaped". The past is "preserved" as the changes developed and happened, they are definitive, yes; the future is changes that will occur...sure, but we have known that for 2000 years. This is not new knowledge for understanding "time" completely, nor for understanding the opinion that: ***"time does not flow for us, but we flow for it"***. Furthermore, talking about entropy or "becoming" (Heidegger) will not help us to know other "behavior" of time: whether it has the same pace of passage throughout the history of the Universe, whether the pace of passage of time does not change in different stages of history…, whether the pace of passage of time is the same "throughout the Universe" or is it different locally, in many space-time locations of the Universe. It will not help us to find out "why" the pace of passage of time is exactly the way it is on Earth. It will not help us to further investigate why the pace of passage of time on Earth is the fastest and everywhere else it is supposedly slower and slower (see the statement of the Czech professor Kulhánek). It will not help us to find out whether time also has dimensions. It will not help us to further investigate "how time curves" and where and what follows from that. It will not help us to find out what kind of behavior time has in the "antiworld", i.e. in the second quadrant of the Universe "behind the gate". Etc. These are no longer probabilities. They are definitive. They have already happened. They cannot happen. That is the question of "what" can and cannot happen of the same thing from the past. That is also not stated exhaustively 100%. However, the future is quantum.???? To produce the future, the Universe needs probabilities, and QM, but that does not mean that for future reality it does not need, for example, gravity, or elementary matter, which has been unchanged since the Big Bang. (the electron has been the same for 13.8 billion years and will be so in the future). So the future is not just quantum. END OF THE NIPPLE from https://www.hypothesis-of-universe.com/docs/aa/aa_227.pdf ;

SECOND INSERT: …and if this knowledge leads to the constant creation of more information, then entropy also increases. http://www.hypothesis-of-universe.com/docs/h/h_030.pdf And since the classical definitive past becomes known and cannot return to the unknown, time cannot be reversed The flow of time in one direction cannot be reversed into the opposite arrow only on the macroscale. On the microscale on

Planck scales "the world of quantum mechanics", this can be done, e.g. by "packing 3+3D, which leads to the production of matter http://www.hypothesis-of-universe.com/index.php?nav=e and entropy cannot be reduced either (…) We really don't know what time is, we know it; we just don't know everything about it, but we are quite sure that this entropy in the universe is increasing, and therefore it is increasingly disordered. No, it is also, ordered http://www.hypothesis-of-universe.com/docs/eng/eng_009.pdf ; http://www.hypothesis-of-universe.com/docs/g/g_041.pdf ; http://www.hypothesis-of-universe.com/docs/aa/aa_078.pdf This means that entropy must have been much lower earlier, especially near the big bang. Disorder and complexity of ordered states are two different views of the matter. How did the universe get to this superordered, low-entropy state in the beginning? http://www.hypothesis-of-universe.com/docs/aa/aa_078.pdf That is a mystery. It is not a mystery, the understanding is obvious here http://www.hypothesis-of-universe.com/docs/eng/eng_009.pdf But it brings our discussion of time to the scale of the universe and cosmic time. I wish my endless monologue (20 years) was also a discussion-dialogue for once.
END OF SECOND NIPPLE.

…so you had ordered ice in a nice crystal lattice and over time those molecules that melt fill the box and it's a more disordered environment, now you're also saying that the transformation from order to disorder from low entropy to higher entropy is a tendency in that too
37:05
Setting, it's not an iron law because as you mentioned, there are those who have shown that if you wait long enough, the system through its random motion will find its way back arbitrarily close to the ordered state it started in, so it's a statistical statement the second law of thermodynamics even in this limited setting is a statistical statement, it's very likely to go from order to disorder, but you wait long enough and highly improbable intuitively improbable things happen the system can find its way back arbitrarily close. So to begin with, in this limited arrangement, it seems that we have at least some semblance of a concept of time. The arrow of time has a direction that tends to go from order to disorder, now again, then in a moment we'll move to a more general situation where we're not in a box, but even in this more limited one.
38:01
This setup seems to be progress, it seems to give us some sense of understanding why there is an orientation towards order in time towards disorder, ordered states go to disordered ones "smoothly" (in accordance with the flow of time), AND disorder goes to order by a "jump", an instantaneous jump … The Big Bang was an "instantaneous jump" = a change from a state of spacetime with **k = 0** to a state with **k = infinity**, a jump, but as people like Roger Penrose have pointed out and perhaps you have done as well, there is an assumption that there is some initial state of order, k = 0 from which we can then degrade towards disorder, k = infinity ; t = 0. Or repetition: **Before** BB is the curvature of all dimensions k = 0 ; t = infinity. A jump occurs = change of state **After** BB is k = infinite; t = 0. Now the genesis of "our" universe occurs, which ends with t = infinity; k = 0 and…and the cycle repeats itself as Mr. Penrose wishes … so it raises the question, where did the original order come from, where from? The order of spacetime with 3+3 dimensions of spacetime **is an order** because it is here with all 3+3 flat dimensions, k = 0, space is infinite, time >zero< stoic, without flow, the state of this

universe – spacetime is without matter, (and therefore without energy), without physical fields, without laws, without rules, without principles and this led people to propose a new principle physics called the past hypothesis, ? which for some reason that we don't understand things started in an ordered state near the big bang and since then we've been experiencing the degradation of this ordered state, which is a compelling set of words that tells you how we can let the arrow of time enter the cosmological environment or you are this speech doesn't explain anything
39:04
we're going to ask us to move it aside in favor of the ideas that you've developed uh yes I am uh in fact I would say that it is it is it is it is perfectly fine for me to live in this beautiful house where I am, I am slowly degrading. ?? You should understand that entropy is there at every step, but also next to entropy there is >something< that gets more complex with each jump, the complexity increases and…and that gets included in the "entropy avalanche". I'll move next door to the church, it's very beautiful, but I would say that's a completely wrong way to think about the universe. O.K. God belongs to the human realm, the Universe is a different realm where you "work with physics"... I think there's nothing certain in science, so this is just my belief, but I think it's pretty convincing and I go to ||the oldest dynamic theory|| that exists, which is *Isaac Newton's theory of universal gravitation* and there, if energy has been known since 1772, if energy is not
40:00
negative uh, uh, so energy is either zero, which is what **Mark** would like, ?? who is that and I like uh uh and and then the system uh well, there are two possibilities, the most common, if the energy is zero or positive, is that in the infinite Newtonian past, the size of the system will be infinitely large infinitely large, it will drop to a finite size the expansion of dimensions "overcomes" the actions of "collapsing" dimensions...the result will be again 3+3D spacetime with k=0 and then it will increase again to an infinitely large size that entropy = 3+3D spacetime with k=0 and that is the size that the ruler measures outside the universe, but that already defines two uh, two-way arrows of time going in both directions from this point of minimum size, I am convinced that in the developed Universe (from BB to big-cruich) the **one-way arrow** (of time) in the macroworld into the nonlinear OTR equation (due to the expansion of the curvatures of all dimensions i.e., three time dimensions) has been applied, outweighed **the two-way arrow** was applied **in the microworld** to QM in the linear equation of interactions (for reasons of production of elementary particles of matter and their mutual transformations-transformations, the explanation of that is elsewhere) so if I were God, I would look at it from the outside and I would have my ruler to
………………………………………………………………………………………………

(08)- measure it I would see those arrows of time and they are there by
41:00
Newton's Laws there's no special past hypothesis has to go in that point of minimum size which is what I call the Janis point is there an immediate consequence of Newton it's a twool line proof out of Newton's Laws it's Newton's second law and the fact that the gravitational potential it has a property called homogeneity of degree minus one and it's negative definite so it's a two-line proof and it was already known in 17 19 72 uh but now what is much more interesting is if you were inside that universe and you could look at its shape what its shape is and the shape is most uniform at that Janis point and as it goes away from it in both directions the shape gets more structured clusters form and those clusters particularly you get Kepler

pairs forming that's two particles going around each other in capan orbits and as they do all of these
42:00
ones they start marching in Step each Kepler pair becomes a rod clock and Compass all in one and they all are Marching In Step becoming synchronized with each other in the most fantastic uh growth of order so at the where J just so you're saying these klarian pairs which are just two particles orbiting around each other in essence become a clock because it's cyclic Motion in essence become a rod because there's some specific separation between them that's the the major the length of the Li and that gives you a compass as well because you've got a Direction that's comp as well yeah so you're saying that there it's a general property of just classical we're talking classical Newtonian physics here and the usual classical neonian gravitational pole between Mutual massive objects if you start with some random configuration of particles in the
43:00
I hate to use this language but infinite path just to give us a language to speak about it you're saying that the general solution ultimately has the shape that you are describing that it will collapse down to some minimum size and from there it will then evolve into these cut capillarian pairs as it evolves toward the the future from that point yes every every solution well it's not quite every solution because there are even more interesting ones which we'll come to but basically uh there is so you can imagine this a Newtonian timeline and the direction in the timeline is completely nominal so you can say that's going forward or that's going forward but in the middle there's always in the middle there's a situation where the particles are like a swarm of bees and in both directions away from it all of this fantastic structure emerges and that is just come straight out of Newton's Laws it's nothing whatever to do with anybody putting in a special past hypothesis or anything like that but is that different I mean bolts boltzman of course had this
44:05
this idea that you start with you know gas in a box and it's got random motion and if you wait long enough through sort of the recurrence ideas as well but any configuration will be sampled if you wait long enough you wait long enough those particles can have an entropically decreasing evolution get to a low entropy State and from there you can then unfold to a higher entropy State toward the future where there can be structur and root to that high entropy future is this an an example of that or is this somehow distinct from that Bol Manan idea no no no it's completely different that that effect there Bri when you have the uh this this entropy normally it's tiny fluctuations that that happen you you have to wait immense time but except for
45:00
those very brief moments when you would get a big fluctuations uh the situation is always like a swarm of bees the swarm of bees in Newtonian theory is just at that one point there there's only one swarm of bees in the thing like that and in both directions away from it so it's a completely different picture it's completely and utterly different and this was first pointed out uh in in this paper by myself and my two collaborators Tim klovski and Flavia McCarty published in 2014 in physical review letters and they were so worried about it they sent it to five referees and what was the worry what was the what was the worry then I mean it's an unfamiliar way of framing things I mean because we were overturning a a a dogma of 170 years saying there's no exp basically for 170 years people had
46:01

thought there was no explanation for the arrow of time and we were showing it least in Newtonian theory that that is an arrow of time comes out of the the oldest known theory of dynamical theory so it's a Time symmetric configuration in the sense that from this minimum size the evolution that way or that way looks very similar so you sort of have time symmetry ……………………………………………………………………………………………..

(08)- measure it I would see those arrows of time no, I didn't, because they are in the microworld on Planck scales and there are
41:00
Newton's laws, there is no special past hypothesis, why doesn't it exist? it has to go to a point of minimum size, which I call the Janis point, there is an immediate consequence of Newton, it is a two-line proof from Newton's laws, it is Newton's second law and the fact that the gravitational potential has a property called homogeneity of degree minus one and is negatively definite, so it is a two-line proof and it was known already in 17. 19 72 uh, but now it is much more interesting if you were inside that universe and you could look at its shape, what shape it has and the shape is most uniform at that Janis point hm, the design is nice, but where is the description of that design, i.e. "what can the Janis point do"? and as it moves away from it in both directions, the shape creates more structured clusters, from what? If from the dimensions of quantities, then it could be my packages of elementary particles, from them complex matter and especially these clusters create Kepler pairs, which are two particles, from what?, which move around each other on Capan orbits that's what? and like all these
42:00
they start marching in step every pair of Keplerians becomes, i.e. as if after waving a magic wand "becomes"? by a bar clock ?? and compass in one and all marching step by step they synchronize together with the most fantastic growth of order, ?? so where J just so you say these Clarian pairs which are just two particles orbiting each other essentially become clocks, particles become clocks?? because it is cyclical The motion essentially becomes a rod, and the motion becomes a rod?? because between them there where it came from, there it came from … a certain specific separation which is the greatest of the length Li **lithium** and which gives you a compass also because you have a Direction which is also a compass, yes, so you say it is a general property of only classical, what? I almost don't feel like reading any further. There is nothing ***sensible*** here… we are talking about classical Newtonian physics here and the usual classical neon ? gravitational pole between Mutually material objects if you start with some random configuration of particles at
43:00
I hate to use this language but the infinite path just to give us the language to that's cackling cackling talk about it you say the general solution eventually has the shape you describe that it collapses to some minimum size and from there it then evolves into these cut capillary pairs how does what "it"? evolve towards the future from that point yes every solution well it's not exactly every solution because there are even more interesting ones that we will get to but basically there is, so you can imagine it's a newtonian timeline and the direction on the timeline is completely nominal so you can say it's going forward or it's going forward but in the middle there's always a situation where the particles are like a swarm of bees and in both directions away from this whole fantastic structure emerges and that's what comes straight out of newton's laws it's nothing to do with someone introducing a special past hypothesis or something but it's different i mean bolts boltzman of course had that

44:05
this idea that you start with you know gas in a box and it has random motion and if you wait long enough through the ideas of repetition but every configuration will be sampled if you wait long enough you wait long enough which particles can have an entropically decreasing evolution it gets to a low entropy state and from there you can then evolve to a higher entropy state towards the future where the structure and the root of this high entropy future can be, ?? it's example of that or is this somehow different from the idea Bol Manan no no no it's completely different that the effect there Bri when you have uh this this entropy I don't know if this is the compiler doing this or the author doing this... normally it's small fluctuations that it happens, you have to wait an enormous amount of time, but except for 45:00
those very short moments when you would have big fluctuations uh the situation is always like a swarm of bees, the swarm of bees in Newton's theory is right at that one point, in such a thing there's only one swarm of bees and in both directions away from it, so it's a completely different picture, it's completely and completely different and I first pointed this out in this paper me and my two collaborators **Tim Klovski** and **Flavia McCarty** published in 2014 in Physics Review Letters and they were so worried about it that they sent it to five referees and what a concern it was, what a concern it was,

then i think it's an unknown way of framing things, i think because we've been flipping ?? and and the 170 year dogma says there's no exp basically in the 170 years that humans have had ?? i don't even know what they're talking about
46:01
we thought there was no explanation for the arrow of time, this is the first UNDERSTANDABLE sentence after 20 minutes of reading… and we showed it at least in the newtonian theory that this arrow of time comes from the oldest known theory of dynamical theory, so it's a time symmetric configuration ?? without explanation i don't know what it is in the sense that from this minimum the size of evolution looks very similar anyway, so you have some time symmetry slap on slap
…………………………………………………………………………………………..

(09)- in aggregate but if you I gather are an observer on one side of the growth or the other your world appears to have an arrow of time because you're not really aware of the overall picture is that a way of describing it that's at that stage and that's the stage we got to 10 years ago now um as I was writing the Janice point I became much more interested in the very special there are very special Solutions which are much more remarkable now these have
47:02
been known about for about30 years they're called total Collision Solutions now there are Newtonian Solutions where you have the shape that the the particles form is changing but then they're very special and it can happen that all the particles come together in a very special way and they all Collide at once at the center C of mass and that's called a total collision and there's a very special shape there and then if you time reverse that that's a Newtonian big bang and then instead of having this Janice Point situation you have a very special situation at uh at the start of that and then then it's like half of those Janis Point things so you start with a very special State and then the the the again all these cap Pairs and form and that is I'm I'm really only getting clear on
48:03

this I would say so Newton when he created Dynamics he introduced the concept of absolute space and absolute time and with absolute space comes a notion of absolute scale so then what I'm now arguing is I'm now going to say that Newton got one thing absolutely two things absolutely right his second law of motion and the gravitational force law but he introduced extra structure which was like putting well let me say it was like putting angels in a prison absolute space and time and scale so they couldn't do so that the Universe couldn't do what it wants to do and so I say let's look at all the solutions that Newton Theory but only but throw away all of those

49:00

which are contaminated or have been put in prison by his absolute space time and scale and then what is left is just these very special Solutions no other Solutions than these ones that start they are actually maximally Orting they are remarkably like a past hypothesis because they're very very uniform they're not perfectly uniform there are always some non-uniformities in them and then they go off in a very special way and basically they will start more or less in thermal equilibrium but nevertheless following a very particular course and then they will will go on and I think this is potentially very very interesting and it's I would say there's miraculous things in Newtonian Theory which are only now coming to light and so would it be a way of

Past Hypothesis and Newtonian Physics

50:00

summarizing it whereas the conventional story that many of us have been telling requires that we make this Assumption of the so-called past hypothesis and again just that the audience is completely aware of what the terminology means that is the assumption that in the distant past we were in a state of high order very low entropy allowing us to then degrade to higher entropy as we head toward the future you would want to say that you don't really need to make that assumption per se because it's a natural dynamical consequence at least in Newtonian theory that you would find yourself in that state and then from there things would degrade to higher disorder from that point is that a reasonable summary no no no no they the the there would be no degration it would just be getting ever better ordered all the way it would be the the Universe would start with uh I would make the distinction between uniformity and

51:03

structure or variety so the so the picture that I have now is the universe starts at its most uniform shape that it can possibly have it's not perfectly uniform there'll always be certain uh differences and then it will go and get more and more structured uh more and more varied and and I would say there are sort of nuggets of variety which form these are my Kepler pairs um and so this so we're now showing what it would look like now this is in two Dimensions uh and uh this is what the if it was a two-dimensional Newtonian Big Bang this would would look what the big bang would look like now the you will see that the density of the particles this is a thousand particles the density of the particles is increasing from the center to the rim now if that were done in three dimensions that would be an

52:04

incredibly perfect sphere uh it wouldn't be completely uniform but it would be a very uniform density with a perfect spherical rim and that's a very wonderful property of Newtonian Theory solely in Newtonian gravity it's Newton's potential theorem it's what explains why the Sun and the moon the celestial bodies are spherical and it's a it's a very interesting property so basically uh what you're seeing there is is uh Newtonian gravitational forces pulling it towards

………………………………………………………………………………………

(09)- in summary but if I think you are an observer on one side of the growth of what? or the other, your world seems to be the arrow of time because you are not really aware of the big picture, that is the way to describe it it is at that stage and that is the stage that we got to 10 years ago, now that I wrote the point Janice, I have become much more interested in very special, existing very special solutions that are much more remarkable now. Is there anyone who understands this and understands it?...

47:02

which have been known for about 30 years, they are called total collision solutions, so the "total collision solution" has been known for 30 years, so what?... now there are Newtonian solutions, where you have a shape, that the shape of the particles changes, well, I have a shape, and that is a Newtonian solution…what? but then they are very strange and it can happen, it can also happen that at Komorní Hůrka (that is near Aš in western Bohemia) the ground opens up, smoke comes out and the devil comes out and makes brm, brm, brm …**, that **all the particles come together in a very strange way** and they all collide at once in the center of mass C and this is called total collision and there is a very strange shape (it has two corners) and then, when you turn it over time, it's a Newtonian big bang, wow amazing. So that's what it has to be called "new science" !! and then instead of having the situation with Janice Point= at that Chamberlain Hůrka… you have a very strange situation at the beginning of it and then it's like half of those things Janis Point, so you **start** with a very strange state and then again all these pairs of caps and form **and that's me** I'm really just clear

48:03

I would say it like Newton when he created Dynamics, introduced the concept of absolute space and absolute time and with absolute space comes the concept of absolute scale, so now I'm arguing that now I'm going to say, that Newton one got absolutely two things and they're absolutely fine, his second law of motion and the law of gravitational force, but introduced a strange structure that was like putting well let me say it was like putting angels in prison= absolute space, time and scale so they couldn't do it, that the Universe couldn't do what it wanted, that's a unique piece of work …, and so I say let's look at all the solutions that Newton's theory, but let's throw all those away that's Czech like a hoof…

49:00

that are contaminated or have been trapped by his absolute spacetime and scale, and then there are only these very =special Solutions=, no other Solutions than the ones that start, are actually Orting's at most, they are remarkably like the past hypothesis because they're very =very uniform, they're not perfectly uniform=, there's always some non-uniformities in them and then they start off in a very special way and basically =start more or less= in thermal equilibrium, =but still= they follow a very specific course and then they'll continue and I think it's potentially very interesting and I would say that there are =miraculous things= in Newtonian theory that are only now coming to light, and so that would be the way Past Hypothesis and Newtonian Physics

50:00

to summarize that, Yes, let's sum it up: it's about shit and it's worth shit… (**I didn't learn what time creates**). I've lost my appetite for reading whereas the conventional story that many of us have been telling requires us to make this assumption of the so-called past hypothesis and again just so the audience is fully aware of what this terminology means which

is the assumption that in the distant past they were in a high order state of very low entropy which allowed us to degrade to higher entropy as we move towards the future is to say that you don't really need this assumption per se because it's at least a natural dynamical consequence in Newtonian theory that you would find yourself in this state and from there things would deteriorate to higher disorder from that point on is that the reasonable summary no no no no there would be no degradation it would just get more and more ordered as it were the universe would start uh I would make a distinction between uniformity and
51:03
structure or diversity so the picture I have now is the universe starts in its the most uniform shape it can have is not perfectly uniform there will always be some differences and then it will go and it will become more and more structured uh more and more diverse and I would say there are kind of nuggets of diversity that make up these are my Kepler pairs um and so this so now we show what it would look like now this is in two dimensions uh and uh this is what if this was a two dimensional Newtonian big bang it would look like what the big bang would look like now you will see the particle density this is a thousand particles the particle density now increases from the center to the edge if this was done in three dimensions it would be an 52:04 an incredibly perfect sphere it would not be completely uniform but it would be a very uniform density with a perfect spherical edge and that is a very amazing property of Newton's theory only in Newtonian gravity it is Newton's potential theorem this explains why the Sun and the Moon celestial bodies are spherical and it is very interesting property, so basically what you see there is uh Newtonian gravitational forces pulling it in the direction
…………………………………………………………………………………………………….

(10)- the uh the center but at the same time there are repulsive forces so-called hook forces pushing it apart so it's holding it in Balance um but then uh uh in those hook forces aren't really there uh so so the Newtonian Theory they would collapse uh
53:01
but um then you you just run time the other way and you you get a situation where you start looking like that and then you just get ever more structured uh and and ordered into the future to it was Fineman who first said about the past hypothesis he said to explain the second law of Thermodynamics you have to assume that something is added to the known laws of nature which is not part of the known laws of nature to have that special condition in the past and that's what David Albert uh I you probably know him in he's in New York like you uh has called the past hypothesis so what we saying is that if you actually just look at the essential core of Newtonian Theory you don't need a past hypothy it's sitting there in Newton's Theory and it was disguised by Newton introducing his ideas of absolute space time and absolute came in with absolute scale but I'm confused on on one point
54:02
so I obviously it's very appealing to have the conditions that we impose by Fiat calling it the past hypothesis is just a fancy way of saying we don't really understand how it came to be but we're going to demand that there was a time in the distant past that was highly ordered your approach is saying that's a natural consequence of of Newtonian physics but from there wouldn't you then in aggregate talk about a drive toward greater disorder from that point if you're including both the matter degrees of freedom and the gravitational degrees of freedom or would you want to deviate from that part of the conventional story as well that that part I didn't understand what is what is really happening is as these uh what I call these nuggets of

variety so the the great thing about uh Newtonian gravity and also general relativity which is very in many ways is very close to Newtonian gravity uh um you you get
55:04
clusters form and when clusters are formed that is essentially creating the conditions of a steam engine so uh a very good example of this is globular clusters so globular clusters these things with a million stars uh beautiful things um they would they are eff effectively thermodynamic systems and some and you can more or less Define an entropy for them so we don't quite know how they form but they have some sort of entropy and then they sort of heat up in the center and things like that uh and there is a a beautiful theory of them but in fact actually bit by bit they evaporate and as they evaporate uh this quantity which we call the complexity so there's a key quantity which is not the Newtonian gravitational potential but it's the gravitational potential multiplied by the quantity which defines the size of the system so it's a scale
56:03
invariant quantity and that gets ever more structured and and so that's what's really going on so but when these clusters form they have a for a short for a period a certain period of time they behave to a very good approximation thermodynamically so I would say that thermodynamics is an emergent law of nature which is has exists in a localized uh sort of what you can you get an approximation to a thermodynamic system in a fin in a bounded region of space for a bounded length of time but it comes into existence and it it it uh falls apart and and so that's that I would say is is a is a very satisfactory State of Affairs so my view is that there is there is an overall law of the
57:02
universe and then there are emergent local laws of nature one of which is thermodynamics or the laws of thermodynamics and that the second law of Thermodynamics applies only transiently to for these systems that come into existence and then go out of existence and in the simplest case of the Newtonian uh nbody problem those Kepler pairs those are the ones that exist forever they are a little bit like black holes they form they never well uh unless quantum mechanics comes in which is a natural next question so the

Newton's Theory and General Relativity

results that you made reference to I gather have their most solid foundation as you described it in Newtonian classical mechanics when you try to push the ideas to say general relativity to go beyond Newton's version of classical
58:01
Theory or to Quantum Mechanics how far can you push them to date I well this this is very much a conjecture but my conjecture is that um so first of all these very special Solutions you would never see that they could they would that this total Collision or the time reverse Big Bang you you can't if you just set up ordinary initial conditions and on a computer and evolve them you will never find them because it's it's you would have to be aiming with infinite accuracy so you can't get them and the conjecture and I emphasize it is a conjecture that I have at the moment is that really general relativity at the Big Bang starts off just like I've described and that it might just be that inflation is I mean inflation is a wonderful thing but they have an awful lot of difficulty
59:01
understanding how it starts so my my intuition my my hunch is that really if if you could do the same to general relativity there's there's an absolute scale in general relativity now let me come in with Einstein here because this is very interesting so the key Concepts which Einstein

took over straight from minkovski are proper distance and proper time so these are absolute quantities these rely on a clock and a ruler outside the universe and already in 1921 Einstein was pointing out that he committed he did there's something not quite right with general relativity because he says there's two quite distinct things in general relativity there's the metric which gives you your special time your proper time and your proper distance and then brought in from
1:00:00
outside completely independently rods and clocks which rods
1:00:06
and clocks which measure them and then he comes back to that in his autobiographical notes at the end of his
1:00:13
life in 1949 where he says this is this is wrong he said I committed a
1:00:20
sin those rods and clocks should emerge out of the equations of was a theory not
1:00:27
brought in by hand like that but it was never done people
1:00:34
philosophers of science are aware of this this issue I mean that that that passage is often taken up now what is
1:00:40
interesting is we have shown exactly how this happens in in Newton's Theory the rods and clocks emerge within Newton's
1:00:47
Theory Newton's theory is such a good approximation to general relativity I think it's well I
1:00:53
mean it is happening in general if General relativity is the theory describing the universe that it is now
1:00:59
rods and clocks are forming all over the place naturally whenever a planetary
1:01:04
system is forming the these are rods and clocks or or even presumably one can also just talk about you know the
1:01:10
wavelength of radiation emitted in an atomic transition at one location versus
1:01:18
its measured value at another location those ratios that's a pure number and
1:01:24
that pure number is descri describing a scale factor by which say in our universe universe has expanded so isn't
Quantum Mechanics
1:01:32
that an internal measure of size and how size can change
1:01:38
dynamically uh yes now but I'm not I hope I'm picking you up but let me come
1:01:43

in because I think what you said is something very important we we spoke earlier about cesium atoms and these
1:01:49
marvelous atomic clocks now they did not and they could not have existed in the
1:01:54
universe before the first Supernova exploded because that's what created the cesium
1:02:01
atoms so those rods and clocks did not exist until what is it at least 300,000 no
1:02:09
it's it's it's a I don't know quite how far it is into the universe but it's quite a long time by the way Heisenberg
1:02:17
was very skeptical about this idea of going all the way back to know exactly when the Big Bang was because he said
1:02:24
rods and clocks didn't exist then so that's pretty I think one really should think
1:02:30
about that so I I I come back to say and you can see this happening in the
1:02:36
Newtonian Theory those rods and clocks do not exist until the kep pairs are
1:02:42
formed B I'm just want Julian just want to push it a little bit further I I mean once you have quantum mechanics as part
1:02:49
of your fundamental description as well as say the general theory of relativity
1:02:55
you can build this length called the plank length out of the fundamental
1:03:00
constants and that seems to be a fundamental Rod that comes intrinsically
1:03:06
out of the theory against which all other lengths can be compared so isn't
1:03:12
that a fundamental Rod or length that comes directly from the theory itself
1:03:19
it's there's no doubt that it's meaning it it has meaning in the present epoch
1:03:25
I'm not so sure again I think it's questionable whether it had any meaning
1:03:32
before let me say though now the now you'll probably say Julian we better
1:03:37
stop this discussion because I'm now going to say well even my collabor my
1:03:43
main collaborator and I are now really even beginning to wonder about quantum
1:03:48
mechanics whether whether it whether it whether there are wave punction and planks con
1:03:56
let me just say one thing about um well we've got there this's already a paper

1:04:02
by me out out on the archive um the thing that already puts a question mark
1:04:09
over quantum mechanics is the role of the planks constant Plank's constant is
1:04:15
a dimensionful number that's again presupposing rods and clocks outside the
1:04:20
universe so that's a first question and
1:04:27
perhaps we could let let me let me say what now so I've obviously been thinking about these things now you will know
1:04:34
about this the famous problem of time in general in in quantum gravity so back in

The Wheeler-DeWitt Equation

1:04:40
197 like wheeler dwit equation the wheeler dwit equation Bryce Bryce dwit wrote down what is now called the
1:04:47
wheeler dwit equation which is still used and discussed a great deal and the
1:04:53
extraordinary thing about that was that he had a wave function of the universe but it was just static it didn't change
1:04:59
uh and Bryce already suggested that the way
1:05:04
to resolve this apparent disappearance of time was to recognize that time is
1:05:09
always told by some something that's moving the hands of the clock must move to tell the time so he said we we take
1:05:17
one degree of Freedom one Motion in the universe and we say that is telling time
1:05:22
and then we see how uh the other degrees of freedom are changing relative to the
1:05:28
one we've chosen to be the clock and that's called an internal time and that
1:05:33
is still being explored now I mean every now and then papers come up on that now
1:05:40
when I was writing the Janice point I thought I was thinking a lot about I I
1:05:45
my my first book The End of Time was about it trying to make sense of it I suddenly thought what about this
1:05:52
quantity that that we call the complexity which is which is is really the quantity which is governing
1:05:57
Newtonian gravity what about saying that is time because that that grows secularly it it

1:06:06
fluctuates a bit but it grows almost linearly with Newtonian time it it
1:06:11
emerges and grows like that I said suppose that is an internal time so this
1:06:20
was an extremely conventional uh uh suggestion it's at
1:06:26
the end of chapter 18 in the Janice point if viewers like to look it up and
1:06:32
then uh so I have my concept of shape space so shape space is uh uh for a
1:06:39
certain number of particles it's all the shapes that they can have and then uh
1:06:46
these shapes will have certain values of the complexity there will be a minimum there will be just one shape which has
1:06:52
the absolute minimum that that's the shape of the big bang and then there are what I call isoc complexity surfaces
1:07:00
these are all the infinitely many shapes that have the same value of the
1:07:05
complexity so then I said let us call that time or shall we say the difference
1:07:12
of that complex take away the absolute minimum and that's the age of the shape
1:07:18
and then on on uh so taking that as time I then wrote down a completely conven
1:07:26
time dependent shinger equation where I used that time as the as the time but
1:07:33
there couldn't be a Plank's constant in it because it's not scaling variant so but it was completely
1:07:39
conventional I very soon realized that it would have a unique solution because
1:07:46
of this very special structure of of shape space that there's always this very special most uniform shape which I
1:07:53
called Alpha uh but then I got into discussion with
1:07:58
my collaborators uh Tim klovski and Flavia mccar so let me guess you're going to
1:08:05
say this gives you a measure a measure on shape space is that where this is this is going well it is yes so what
1:08:11
what it the the first step was we realized that this not only is the
1:08:17
solution unique but it it has the same value at all values at at on the iso

1:08:23
complex all the that have the same complexity so uh then
1:08:30
immediately Tim Koslowski said yes that's not a trivial Theory because there's a probability measure on shape
1:08:37
space so uh so there's in
1:08:42
fact once you take out scale the key thing that I'm now saying
1:08:48
threedimensional scale invariance is the symmetry which has been ignored for
1:08:54
centuries and it if I'm right it has it has the potential I believe to
1:08:59
completely and utterly change physics and cosmology because it says that
1:09:05
there's probabilities for shapes so you say you still say that the complexity is
1:09:10
your internal time but then that will immediately give you probabilities for
1:09:16
shapes now what was the wit trying to do he was trying to find probabilities not
1:09:22
for shapes in Newtonian Theory but the anal would be for configurations where there a scale as well but the key thing
1:09:30
is now we're getting probabilities for shapes and it's nothing we do it without
1:09:35
a wave function and we do it without Plank's constant and it's sitting there like
1:09:41
like a like a born density it's it's marvelous it all that would be a very
1:09:47
different way of of of doing physics and so it's certainly exciting to see that there are directions that are quite
1:09:54
different from the mainstream that are being developed and have a chance of perhaps succeeding it' be great to see
1:10:00
have this all unfolds in time but as our time is running short there are two things that I wanted to get to related
1:10:07
to the conversation that we've had so far which is when one talks about

Barbour's view of how complexity arises in the Universe

1:10:14
complexity people have struggled over the course of a long period of time to find a rigorous definition of
1:10:22
complexity we kind of know it when we see see it there are systems that look

1:10:28
very simple there are systems that look very complicated and therefore we kind
1:10:33
of know that there is some notion of complexity your notion of complexity
1:10:39
that you have defined I know there's a rigorous mathematical articulation of it
1:10:45
in terms of you know the small scale separations of particles versus the large scale separation of particles in
1:10:52
in your shape space we don't have to go into the mathematics of it but it's a combination of those two considerations
1:10:58
that you use to define mathematically some notion of complexity your
1:11:04
definition of complexity as you've described it though qualitatively speaking as you noted it it
1:11:10
monotonically increases and in that way can be used as a clock my
1:11:17
intuition about complexity doesn't do that I'm wondering if you can help me
1:11:22
Square the two if I take a you know the the canonical very simple system if I
1:11:28
just you know have milk that I pour into coffee right initially it's it's pretty
1:11:34
simple I've got you know uniform coffee I've got uniform milk if I then pour the
1:11:40
milk in if I wait long enough it also gets pretty simple it's just this you know brownish liquid which is pretty
1:11:48
uniform not much structure in there not much complexity but it's in the
1:11:53
transition between the two that I find complexity where I've got tendrils of milk that are winding their way through
1:12:01
the coffee and it's that intermediate step where there's structure so the
1:12:06
intuition that I have from that simple example and in many other examples is you know we start with low complexity we
1:12:13
go to High complexity and then we come back down to low complexity you presumably want to
1:12:20
disabuse me of that intuition with this other notion of complex that it always
1:12:26
increases can you help me Jive match those two in some way that will make my
1:12:32

brain embrace them both well it's it's it's again exactly the same with the
1:12:38
steam engine because the uh when you're talking it's quite correct what you're saying about uh stirring the cream in
1:12:45
the coffee and and uh very nice it is too but of course you've always got the coffee in the mug so that's actually the
1:12:52
the the cylinder of the steam engine so that may be the way to think about how complexity arises in in the universe so
1:12:59
the way I think about it is to say given just points in ukian space
1:13:07
what scale invariant number characterizes the extent to which
1:13:13
they're either uniformly distributed or clustered and that number if it's to be
1:13:19
scal invariant it must be a ratio of two lengths and it must take them into account all on an equal footing and
1:13:27
there's really only the two simplest sensible candidates are what are called
1:13:32
the root mean Square length that's the quantity which measures the size of the Newtonian system and the other one is
1:13:38
the mean harmonic length which very interestingly is the inverse of the Newton gravitational potential so you
1:13:45
take the ratio of those and so the mean harmonic length the mean root mean
1:13:51
Square length is the average of the long sizes and the mean harmonic length is the average of the short sizes so you've
1:13:58
got the long divided by the short and that is what we what I call our
1:14:05
complexity and it's extraordinarily interesting quantity now amazingly that
1:14:10
is the essential irreducible core of Newton's theory of universal gravitation
1:14:16
if that isn't striking I don't know what is uh and liet I already said liet says
1:14:22
that if there's no Variety in the world you can't say nothing so just Define
1:14:28
Variety in terms of points in space and you've got the absolute essence of
1:14:35
Newtonian Universal gravity and so what does the farf far future of the universe
1:14:40

look like to you I mean most of us you know especially taking into account modern cosmology let's assume that there
1:14:47
is some dark energy as the observations at least seem to suggest we imagine the
1:14:53
far future of the universe black holes have evaporated through the Hawking process stars have long since either
1:15:00
been swallowed up by black holes or they've disintegrated we just have a bath of particles wafting through this
1:15:06
ever expanding universe is that the vision of the
1:15:11
future that you have as well uh no well first of all let me
1:15:18
really say this is well everything I've said is conjectural of course everything in science is conjecture it can always
1:15:24
be over thr the key thing is I mean what sounds so horrendous with this accelerated
1:15:31
expansion of the universe going on forever is that everything gets diluted because it's it it's it's spread out but
1:15:39
then you're forgetting scale invariance so it's really the shape that count so the the dilution has no meaning at all
1:15:46
in this context so it's really the the structure that forms so the cosmic web
1:15:51
now uh is is a better way to think about it but the you just imagine that you
1:15:57
could either blow up the cosmic web but leave all the structure the key thing is the structure so my conjecture is is
1:16:07
that there isn't a heat death in the future but that there that the Universe gets ever more structured and
1:16:14
potentially ever more interesting uh that's a very
1:16:20
big guess very big hope but I would say if it's right this is going to get rid
1:16:28
of I mean the discovery of thermodynamics cast a PA over the whole
1:16:34
of this thinking with with the notion of heat death the heat death was coined within two or three years of of the
1:16:41
discovery of the laws of thermodynamics I would say we we may we
1:16:47

may be able to change that I think at the very I what at the very least I hope people will start questioning these
1:16:52
things because I say it is staggering that people just didn't ask these questions before so there this are we in
1:16:59
a box is that the right way to think about it uh what are the implications of
1:17:06
three-dimensional symmetry three-dimensional scale invariance they're very very far reaching and they
1:17:12
they do play a very important it does a generalization of it to three-dimensional conformal invariance
1:17:18
is very important in general relative not four-dimensional but three-dimensional that's in that work of
1:17:24
your ameru on the initial value problem in general relativity right and again Ju Just for the audience I mean the idea of
1:17:31
scale invariance is an idea that many people have thought about there are reasons to suspect that it's not a
1:17:38
fundamental symmetry of the universe at all times there are scales in the universe I mean Roger Penrose recently
1:17:46
has argued that you know near the big bang and say near the heat death we
1:17:52
might we just might have scal in variance emerging a new which has allowed him to come up with his
1:17:59
conformal cyclic cosmology I don't know if you have any thoughts about that but it's not at all clear that scale and
1:18:05
variance should be a fundamental symmetry at all times throughout our three-dimensional Universe right I mean
1:18:12
that too is is part of the conjectural Assumption from which your work emerges
1:18:17
yeah well all I would say I mean I have discussed these things with with Roger
1:18:23
several times and we're not going to agree uh but
1:18:28
uh all all I I mean as I say it's conjecture what I'm putting
1:18:34
forward but I I I'm certainly very confident that certain really key issues
1:18:39

have been monumentally ignored through the history of of physics and I just
1:18:47
hope people will take them seriously and and let's see what comes out of it at the end uh critical in this is also
1:18:55
uh how Infinity comes into it I mean there's a paper on complexity that I and
1:19:00
a couple of collaborators uh will be submitting to the archive and a journal fairly soon uh where I start developing
1:19:09
ideas about infinitely many particles the Newtonian nbody problem always has a
1:19:14
finite number of particles but I am beginning to see ways to make infinitely many particles and that rather nicely
1:19:21
does begin to match up with modern cosmology with the idea of an infinite
1:19:27
flat universe three-dimensionally flat universe so um there's hope there it
1:19:32
sounds quite exciting but it's before we wrap up I did want to spend just a couple minutes on on one final topic
Barbour's view of human perception of time
1:19:39
perhaps a little bit less Technical and more sort of human in its question which
1:19:46
is we started out with your notion of shape space that particles at a given
1:19:52
instant have one or another relative configuration to each other of course
1:19:58
you gave the simple example of a three particle Universe just as a toy model so that we could all wrap our heads around
1:20:03
it we can extrapolate that of course to the world around us I mean every moment we are aware of a configuration of
1:20:10
particles in the world around us and you consider those to be little I guess the
1:20:16
language that you have used in some of your books is time capsules you know a moment in time a moment in time and yet
1:20:23
somehow our Human Experience is not discrete moments our Human Experience
1:20:30
ties those all together into some continuous Evolution and people have
1:20:36
worried for a long time where does that experience of this flow of time come
1:20:42

from now many of us have come to the conclusion I'm interested in your perspective that that's a very human
1:20:50
phenomenon it's a very psychological phenomenon perhaps there is some reason for it in evolutionary history that our
1:20:57
brains have been able to wend these all together into this film from the snap
1:21:03
shops I is there anything more to it than that I mean does your work suggest that that is the right way of thinking
1:21:09
about it that the mind just somehow builds the film out of the snap shops or is there something deeper to
1:21:16
it uh that that's very much and and I think there's something in support of it so when I wrote the end of time I I
1:21:24
could suggested that when we see a king fisher in Flight what is really in our brain is
1:21:32
really sort of say six or seven snapshots of the King Fisher and the Brain plays the movie for us now uh uh
1:21:41
the end of time was read by a very interesting lady uh Kathleen gray who
1:21:47
got in touch with me uh and she was uh one of these people who uh at that stage
1:21:54
did not experience life continuously but as a series of snapshots and in fact so
1:22:00
extreme in her case that she would get the snapshots in the wrong order so she couldn't even cross a road safely
1:22:08
because uh the snapshots were coming she would see a car going away from her when it was coming towards her and she was
1:22:14
then introduced to Oliver Sachs who got her medication which cured her and at
1:22:20
about the same time I got an email from an American Veteran who had the same problem he'd had an injury a brain
1:22:27
injury and he too was seeing uh uh the things of snapshots and the Army said
1:22:35
they would do surgery on him but his mate had said don't let him cut you so he said he was living with it uh and the
1:22:43
I think I keep meaning to check it again I think Oliver Sax's last book was stream of Consciousness he refers to
1:22:51

research which is supporting that so there is a name for that phenomenon um
1:22:58
and I you might I somewhere in the house I can't find it is I've got Oliver sax
1:23:04
yeah know I do too um yes but have a look at that one it's say the stream of
1:23:09
Consciousness but also somebody I got an email from uh someone saying oh by the
1:23:15
way your idea's been confirmed by some research in Paris so I looked at it and
1:23:21
it seemed to suggest it so my my son in Paris is a brain physiologist so I said
1:23:26
does this look okay to you he said well the experiments a bit bit not totally
1:23:31
clean but it looks okay and by the way these guys are in my Institute they e call noal uh but Brian can I just come
1:23:39
back one thing about that that plank length these were discovered by um uh so
1:23:46
after my collaborators and I had discovered had realized that there would be this probabilities of shap Apes uh I
1:23:56
had already worked out that there would be a high probability that all the smallest separations in in these uh
1:24:04
configurations would be of the same size um that I won't go into the argument
1:24:11
it's it's it's quite nice it's it's an addition to boltzman and this is this is
1:24:16
confirmed they they are they do turn out so basically and it's well it's a
1:24:22
statistical argument How would you get from that most uniform shape to one uh
1:24:29
this one well you you you've got to uh you've got to increase the
1:24:34
complexity you can do that by putting just two or three particles closer to
1:24:39
each other but then you will find uh but then you realize there are infinitely
1:24:45
more ways to increase the complexity by putting a whole lot at about the same
1:24:51
separation to each other so that led me to predict before this discovery was
1:24:56
made by the student Manuel ISO in Paris in it's three years ago he made
1:25:04
this discovery these extraordinary filaments this was a significant Discovery in in Newton's theory of

1:25:09
gravity um and if you look at them you see that all the smallest separations
1:25:15
are the same so in some senses something very like a plank length is coming
1:25:20
straight out of of this notion so I think it is it is pretty interesting that is fascinating but just so I fully
1:25:27
understand so this is a start a simulation that starts with some number of Newtonian mutually gravitating
1:25:34
particles and when evolved in the right way yields this kind of filamentary
1:25:39
structure as one of the dynamical outcomes of that starting point it would
1:25:45
it would be this is a very special one this could be this could be a possible start of a big bang but something very
1:25:52
like it would would come out the one which was very uniform would be the big
1:25:57
bang itself and then relatively soon after this you would get uh something like this uh and if we go to the one
1:26:05
where there's 12 uh of these slides you you see so so top left you will see
1:26:11
there there's a one that's completely uniform and then you see the structure growing the complexity is just
1:26:17
increasing by the way you see this is the complete opposite of entropy increasing uh or you go from uniformity
1:26:25
to interesting structure the the universe just gets ever more interesting
1:26:31
but but jul I know we're we're we're running low on time but I do want to just make one point so the more
1:26:37
conventional physicist description would be sure in a non-
1:26:44
gravitating system that would be a strange set of pictures to go from you
1:26:50
know uniformity to less uniformity to go from high entropy to lower entry but in
1:26:56
a gravitating system we normally say gravity does of course cause clustering
1:27:02
and indeed if you take your advice and don't only think within the Box in a
1:27:08
real gravitating system as particles cluster energy and radiation are

1:27:13
released and if you take into account the entropy that that released radiation gives to the wider environment compared
1:27:21
to the entropy that goes down for the filament or clustered structures and overall the entropy does go up you just
1:27:28
have a sort of two-step process where the entropy goes down in the structured part it goes up in the external world
1:27:35
and on overall balance when you do the calculation the overall entropy does go up so it doesn't feel to me so counter
1:27:43
to my entropic intuition to see gravity yielding structure well yes and no if I
1:27:49
may uh I I will go back to uh if I may say so it begs the question of how you
1:27:57
define entropy for the universe and uh I think I can rely on
1:28:04
Gibbs who says it you can't if the system can can expand into Infinite
1:28:09
Space the notion of entropy loses its meaning yeah but I guess in many of
1:28:14
these systems I can sort of still put it in a bigger box so long as I'm assured
1:28:20
that the system I'm studying the radiation will be captured within that box that's that's perhaps all that I
1:28:27
need to make it rigorous mathematically but of course the point you're making is is it deep one and a subtle one trying
1:28:33
to apply these ideas to a completely open expanding system is difficult mathematically to do this is enforcing
1:28:40
the validity of the law of thermodynamics by Brute Force by putting in something which cannot be there I
1:28:46
mean step Hawking did this he he wanted to see about the equilibrium between a
1:28:52
black hole and the radiation that gives off say puts a big box around it this is
1:28:57
I mean it it's just come off it tell that to the Marines it's just unbelievable idea who's going to find
1:29:05
that out in the universe out there that's been put there by a theoretician who wants to maintain the second law of
1:29:11

Thermodynamics and and it works remarkably well of course as an idealized context within which to do the
1:29:18
calculations but but your your point is well taken we certainly would like to go beyond those kinds of non-physical
1:29:26
approximations but they do a a wonderfully good job at getting answers that that seem to work incredibly well
1:29:34
but in any eventually it's been a fascinating conversation covering you know issues of the hour of time the

Conclusion

1:29:40
growth of complexity the growth of entropy and as well the psychological phenomenon of the flow of time and I
1:29:48
just wish you well in your continuing studies of this most mysterious concept
1:29:54
the concept of time thank you for joining us was great Brian yes I look.
1:29:59
forward to further discussions absolutely thank you so much [Music]
……………………………………………………………………………………………….

JN, 03.02.2025 Barbour mě strašně zklamal…