Fairy Dust in Physics: How Non-Physical Views of Information Impede Theory Progress

(Edited Transcript)

Terry Bollinger

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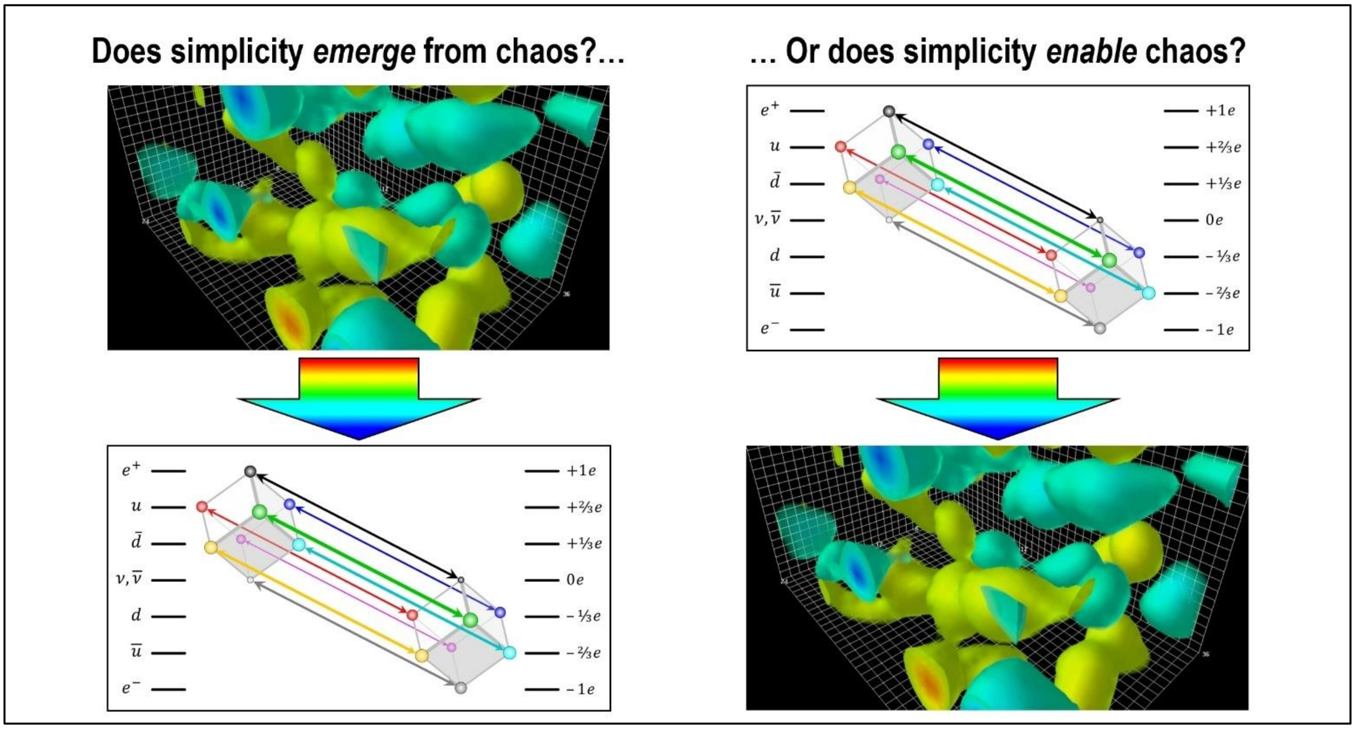


Is the microstructure of the universe made of sparse, persistent information, or dense, chaotic information?

This is the edited YouTube transcript with references. You can view the full video at https://youtu.be/JjCiI3_7pdg

Topic-related live comments before presentation:

[0:25] If you look in the deep literature, there's always something there somewhere. Everybody — no matter what the topic is — somebody has a paper somewhere, which is something that surprised me about looking in the deep literature. I remember that for the fermionic cube I came up, I started saying, "*Eh*… somebody's probably already done that." Then I found out that Glashow himself was the first one to do it, which really surprised me. I had no idea that it had that long of a history, or that it goes back to somebody that important in the Standard Model. But it's always interesting what you can find if you dig really deep into the literature.

And original papers! I just love original papers. They're never what you think they are. They become kind of like a sacred literature, and everybody then assumes everything in the paper is perfect. Of course, that's never true — it's *never* true! Because every paper is a human undertaking, and we all have our little things. It's just that when you have that as a critical starting point, you tend to forget that some of the thinking went into it is actually more interesting than the result they come out. They had to look at the problem from all sorts of different angles, and you lose those angles — you lose that *insight* — that the original authors had.

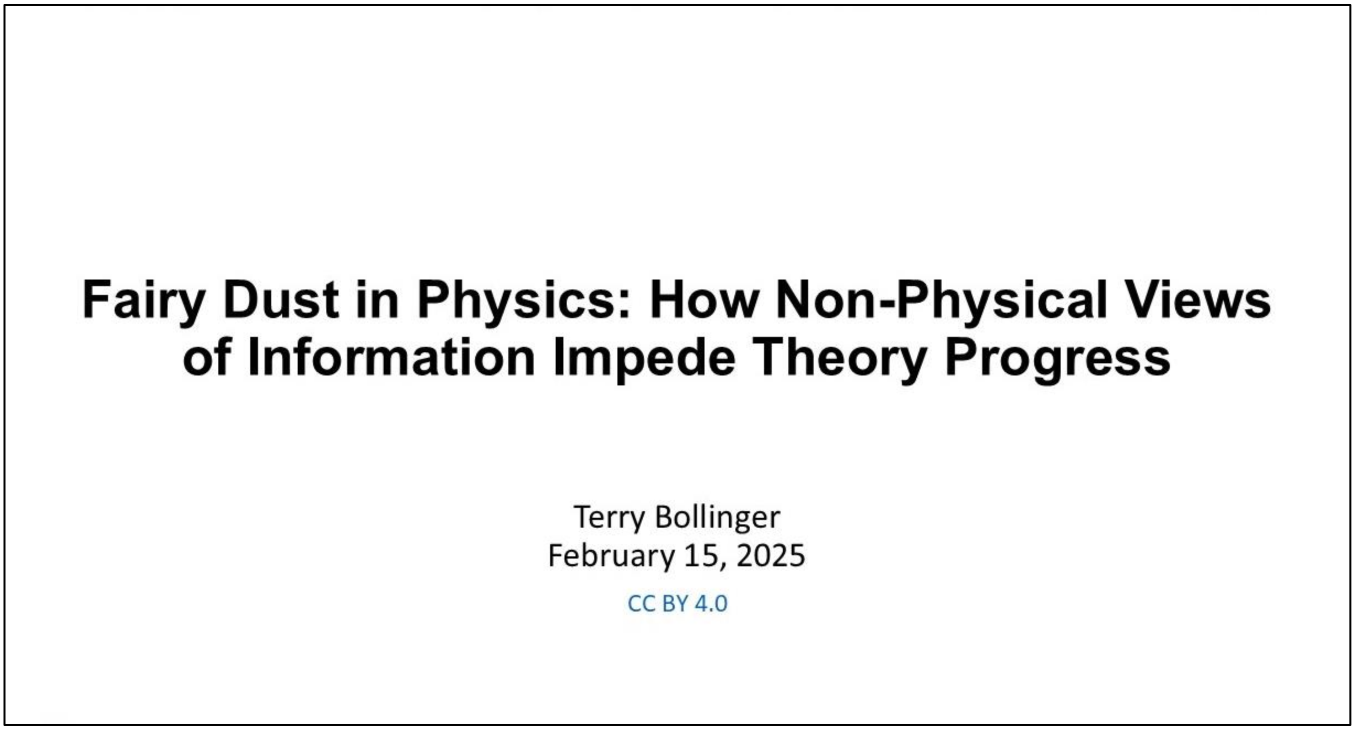
Einstein — my *gosh*, the way he would *look* at things! You couldn't stop his mind from examining all these different angles, and the angles were so different from what other people were looking at. Just an amazing mind! So you get into his papers, and it's just *so* impressive, and such a different way of analyzing some the problems. It's fun to kind of get into his mind a little bit.

[5:04] One of the reasons the slides are so detailed is just to give people some reference that I'm not just throwing things out *randomly*, but actually, this is a result of looking at a lot of papers, and looking at them very closely, and asking what are they really saying. Sometimes what they're really saying is surprising — *quite* surprising. An example I'll get into that most people realize is that modern physics for the last 30 or 40 years has abandoned special relativity. They don't believe it anymore! I'll get into it in the talk, but… *that's remarkable!*

And the way it the way it happened… I even remember when it happened, because I remember they first started doing lattice theory for quantum chromodynamics. I remember the event. I remember the first few papers, and said, "Wow this is a really good calculation technique!" But then it took over, and people started believing the model more than what was actually showing up in the evidence. It's just such an unusual sequence! But things drift in a curious fashion. You get this powerful tool, and everybody uses it, so you think, "Wow, I guess that *because the tool so powerful*, it must be the reality!" And that's always a little tricky because, you [must also] say, "Yes, but what's the full set of experimental evidence?" And the experimental evidence for good-old Einstein's special relativity is the most rock-solid evidence anywhere in science. So, now, you want to be a little careful about abandoning that too casually. So… interesting how some of these things proceed.

Curt Jaimungal has a really nice little snippet at the end of one of his reviews [1] where he just talked about how since 1980 — it's a very specific date — not a single Nobel Prize has been awarded for anything that is truly innovative in the sense that the Standard Model was. The Standard Model was *amazing*! Those were such marvelous times. I just *loved* reading science articles at the time because everybody would come out with a new data-based insight into the nature of particle physics. And it was just such a *wonderful* time to watch physics! But after that, it changed so dramatically because [physics insight] just kind of wraps up, and everything just *paused*. So, Curt Jaimungal's point was that since 1980, all Nobel prizes in physics have been for elaboration. Not a single one has been for something truly new. He did a quite a bit of analysis on it, and I think he was surprised by the result.

[1] C. Jaimungal, *The Great Stagnation in the Crisis in Physics*, Theories of Everything (YouTube), Aug. 11, 2024. https://youtu.be/6tFKTTwZZ9o



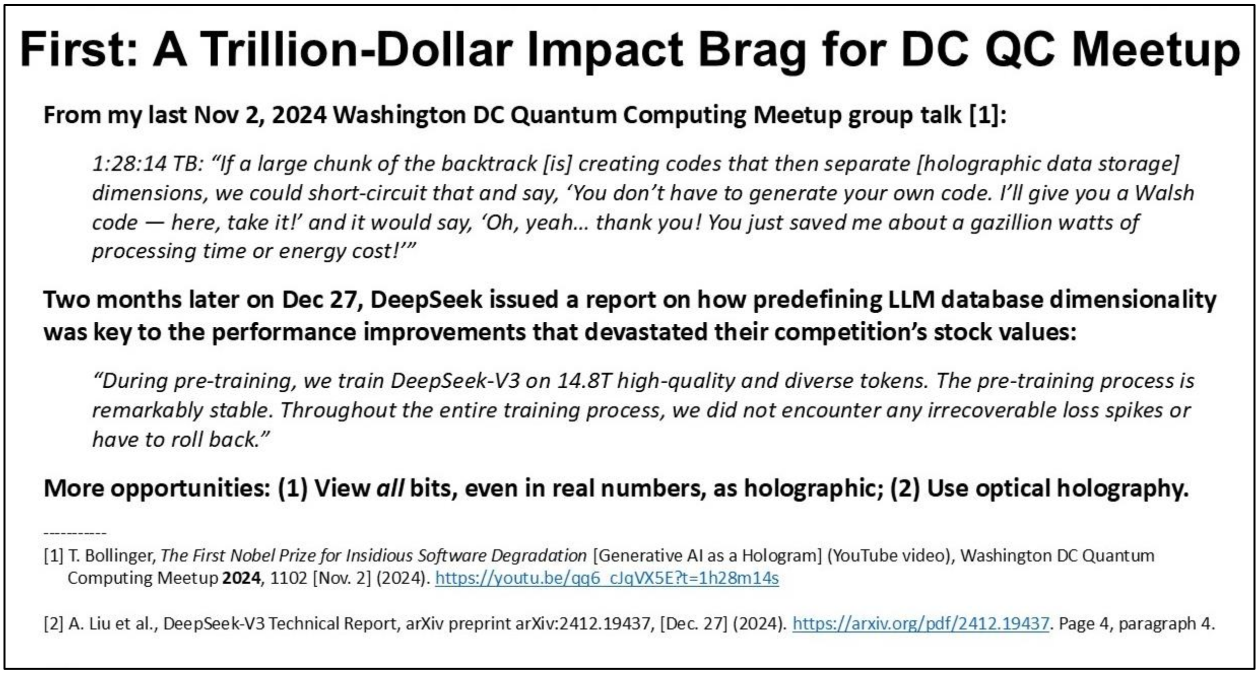
1

[8:00] Okay, the topic today is one that I find deeply interesting, which is the role of information in physics. And of course, that's a topic people have been fascinated by for a long time. But the particular focus that I've had — and this is coming partly from my computer science background — is, "What is a bit?" What is the nature of information? You have to be a little careful about that because the definition of information is a little more nebulous than it should be, and we do have to be a little careful about those implications.

So, the title of my talk is "fairy dust," and by that I'm referring to what I call chaos bits. Chaos bits are ones that are generated and not actually part of the physics when the physics is stable and at rest. They only come into being when you poke it — when you do some kind of damage to the system. A classic example which I didn't cover in the presentation is when you look at an electron orbital and you say, "There's an electron moving around in there somewhere." In terms of physical evidence, the only way you can ever say the electron moves around in that orbital is if you put an incredible amount of energy into the orbital and destroy it.

You have to be careful in the difference between *generating* chaos and actually *having* chaos. They turn out to be two different things in different contexts. They also have direct relevance to things like the vacuum density problem: Why is the vacuum [in quantum field theory] so dense? If [your approach] is generative, you don't have that problem. If you make it into something where chaos controls everything, and chaos cancels chaos — then *yes*, you have all sorts of problems with vacuum density.

So: *Fairy Dust in Physics*: Possible paths for trying to get a better handle on new physics theories that do not contradict what we have. It's extremely important that we preserve the content of theories we have, but we need to do *something*, because it's been a long time now that we've had stasis in physics theory.



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[10:17] I will [start by putting] in a brag. Someone else pointed this out to me — I didn't even realize it at first — that when this whole thing of DeepSeek first came out, someone looked at it and said, "Terry, isn't this the holographic interpretation of large language models that you mentioned?" And I had no idea. Was it? Okay, it turns out that what DeepSeek did, as they reported the issue two months after the last time I talked to the DC Quantum Computing Meetup [2], [was] follow one of several pieces of advice [I had given] [3]

[It's] probably completely unrelated — although, at the same time, it's two months later. I don't know [if they saw it or not] — I have no idea.

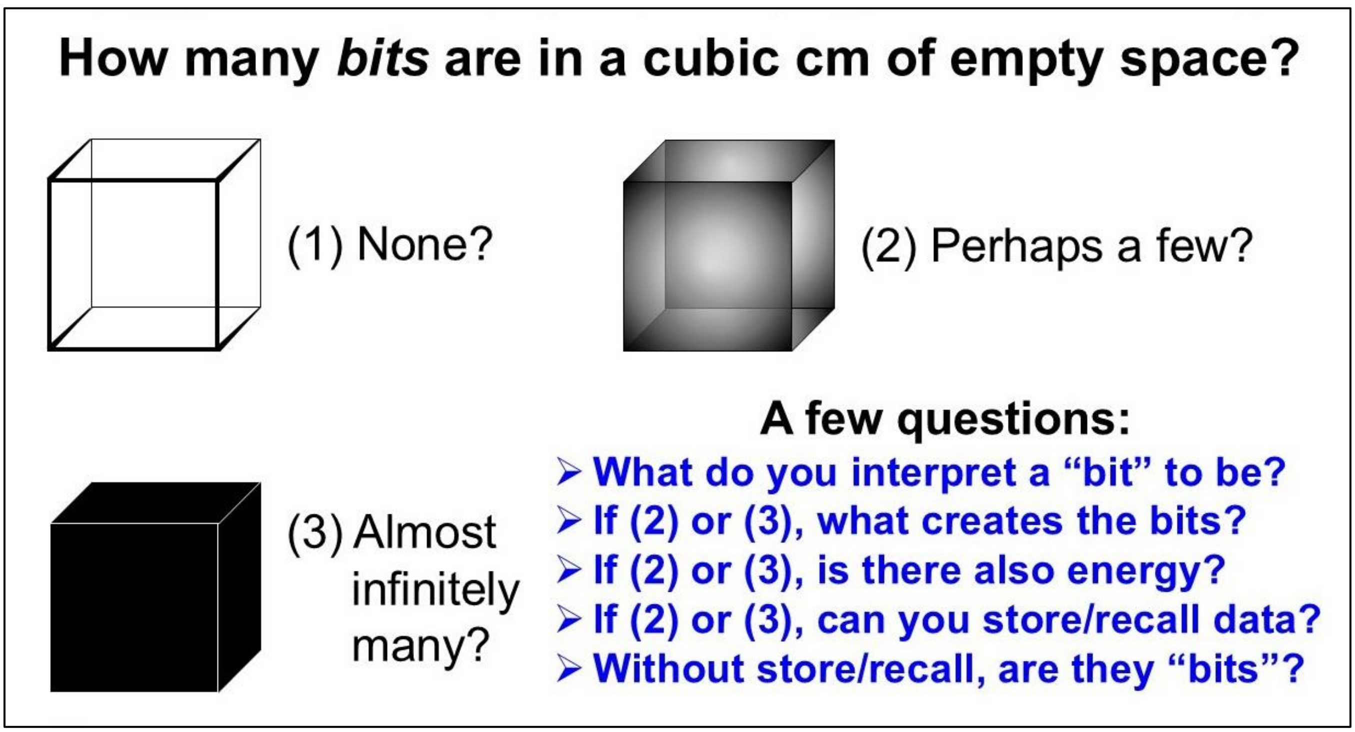
[In any case,] one of the recommendations I gave pretty explicitly [2] is, "You can save a lot of money if you break it up and realize it's holographic. You [need to recognize] that you have pseudo-dimensionality and a separate issue of data processing." So, if you put those two into two separate categories, you have the potential to save an enormous amount of processing time and processing energy. That was one of my suggestions in the partial quote up here [on the slide].

The innovation they did was pretty much just that. They did it in a very smart way. They pre-trained it with some stable diverse [data samples that] created the pseudo-dimensionality that they needed. And then… lo and behold! All of a sudden, the data and everything just kind of collapsed and you had a huge reduction in the energy with which they then, at least for a few days, caused a trillion-dollar drop in stocks for some of their competitors. So, I bring this out in as a preface to this talk. Obviously, it is a brag, but I honestly think DC Quantum Computing Meetup had a real impact with this one — that it made a difference by presenting a different way of modeling the same issue that people were looking at. I also use it as a brag, saying that sometimes we need to look at different ways — different mathematical models, different ways — of approaching the same problem. In this case I think the holographic interpretation of large language models is a very good model for it.

Also, it's not done yet. The one that they grabbed was the least radical of at least three suggestions that I made for this. So, the idea that, first of all, treating the bits as holographic medium produces profound differences in how you would organize these chips right down to the to the silicon level. The other impact which also has not been explored as far as I know is that Optical holography holographic storage is a real thing I mean that's an existing technology and I think there an intriguing possibility that used Optical OA transforms which are so much cheaper than accidental matrix multiplication version of it, which is I think is what we're doing that you have a real impact for this so this was kind of fun it just like oh wow yeah that may have had an impact and even if it didn't it was a prediction before the fact of saying that yeah you can get a really good reduction on this and that turned out to be true so little brag and say so when I talk about different ways of looking at physics I'm trying to suggest the same idea maybe we could look at the underlying mathematics in a different way and wind up getting some at least some different math.

[2] T. Bollinger, *The First Nobel Prize for Insidious Software Degradation* [Generative AI as a Hologram], Washington DC Quantum Computing Meetup **2024**, 11021300 [Nov. 2] (2024). Video: https://youtu.be/qq6_cJqVX5E. Slides: https://sarxiv.org/apa.2024-11-02.1300.pdf. Paper: https://sarxiv.org/apa.2024-10-23.1000.pdf. Relevant quote: [1:28:14] TB: *"If a large chunk of the backtrack or the backpropagation on many of our LLMs is actually for the purpose of creating codes that then separate the dimensions, we could short-circuit that and say, 'You don't have to generate your own code. I'll give you a Walsh code — here, take it!' and it would say, 'Oh, yeah… thank you! You just saved me about a gazillion watts of processing time or energy cost!'"*

[3] A. Liu et al., *DeepSeek-V3 Technical Report*, arXiv preprint arXiv:2412.19437 [Dec. 27] (2024). https://arxiv.org/pdf/2412.19437. Page 4, paragraph 4: *"During pre-training, we train DeepSeek-V3 on 14.8T high-quality and diverse tokens. The pre-training process is remarkably stable. Throughout the entire training process, we did not encounter any irrecoverable loss spikes or have to roll back."*



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[13:44] Now, a simple question: How many bits are in a cubic centimeter of empty space? This was a topic that Richard Feynman once famously addressed in a talk to a huge group of mathematicians at Princeton [4]. It's also interesting because he essentially *mocked* his own theory when he was talking about that. He said that, according to his entire quantum electrodynamics theory, a cubic centimeter of empty space is absolutely *boiling* with *energy*, and *computation*, and *bits*, and *all sorts* of things going on — just a *tremendous* amount of activity. After he points this out, he then proceeds to say, "Yeah, but it's probably all wrong. It's probably something more like checkers."

And he got a laugh for it — a laugh at the expense of his *own theory*, the one that he got a Nobel Prize for!

Why did he do that? Because he knew something wasn't *right*. I won't say he *knew* it [for certain], but he strongly suspected something wasn't right. But he couldn't figure out *what*. He was one of the most honest physicists I've ever seen in things like that. When he couldn't do something, he would always admit it and say, "I don't *like* this!" In his last few papers before his passing, he felt like he had failed on understanding what an electron *is*. He just couldn't get it to work out right.

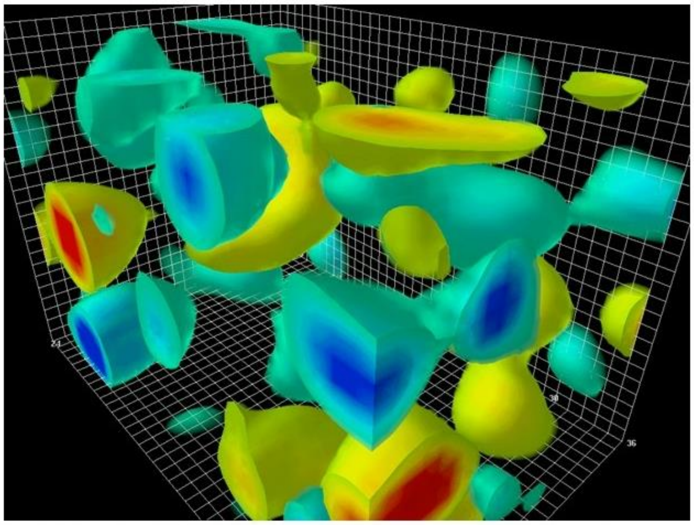
So, following up on Feynman's question: How many bits are in a cubic centimeter of empty space?

That's really the center of what I'm talking about today. Are there none? Maybe there's a few, a scattering, a couple here, a couple there. Or could you have — as Feynman talked about from quantum electrodynamics, quantum field theory in general — almost *infinitely* many transient bits just *running around* down there, just doing *all sorts* of stuff. And it makes an interesting question: If you have bits there — and this is something I'll get back to — if *do* you have bits in space, can you *store data* in space, and can you *retrieve* data from space?

Most of our intuitions are that you cannot do that, and that's an important intuition. So, we might say, "There's a lot of activity going on down there." But in terms of *persistent* bits, that gets a little trickier, because how would I actually do that? It's not easy to define how to do that [storing and retrieving of persistent bits in empty space].

[4] R. Feynman, *The Relation of Mathematics and Physics* (Lecture 2 of 6 in The Character of Physical Law)," Cornell Messenger Lectures, Nov. 1964. https://www.feynmanlectures.caltech.edu/fml.html#2. [50:44]: *"I must say, that it is possible — and I've often made the hypothesis — that physics ultimately will* not *require a mathematical statement, that the* machinery *ultimately will be revealed: It's just a prejudice, like one of these other prejudices. It always bothers me that, in spite of all this 'local' business, what goes on — in no-matter-how-tiny a region of space, and no-matter-how-tiny a region of time, according to the laws as we understand them today — takes a computing machine an* infinite *number of logical operations to figure out. Now, how could* all that *be going on in that* tiny *space? Why should it take an* infinite *amount of logic to figure out what one* stinky, tiny *bit of space-time is going to do? So I made the hypothesis, often, that the laws are going to turn out to be, in the end, simple like the checkerboard — and that all the complexity is from size."*

"Almost infinitely many" ➔ Quantum field theory



Derek Leinweber CC BY 4.0: Visualizations of Quantum Chromodynamics
In 2004, Nobel Laureate Frank Wilczek used this animation in his Prize Lecture.
https://upload.wikimedia.org/wikipedia/commons/2/2a/Quantum_Fluctuations.gif

DM = Derek Muller, Veritasium (YouTube)
DL = Derek Leinweber, University of Adelaide, Australia
https://youtu.be/J3xLuZNKhlY?t=1m2s, Apr 30, 2013

DL: "What you're looking at here is the energy density of the gluon field fluctuations. Where the little red spots come out, the energy density is very high, and it fades down through the colors so, at the lowest energy, the field fluctuations are not rendering in this animation, so we can actually see into it."

DM: And what we see is a bubbling soup of quantum field fluctuations that come and go incredibly quickly. The frame rate of this simulation is one million billion billion frames per second. Now that is truly high speed! The dimensions of this box are absolutely tiny: They are a millionth of a billionth of a meter, roughly enough space to stick two protons. But there are no protons here. **This is a simulation of the vacuum 'on its own,' what we normally think of as 'empty space.'**

DL: "Empty space is actually full of this quark-and-gluon field fluctuations. And, on average, it is possible to annihilate a quark from ***empty space*** *because it* ***is not empty!****"*

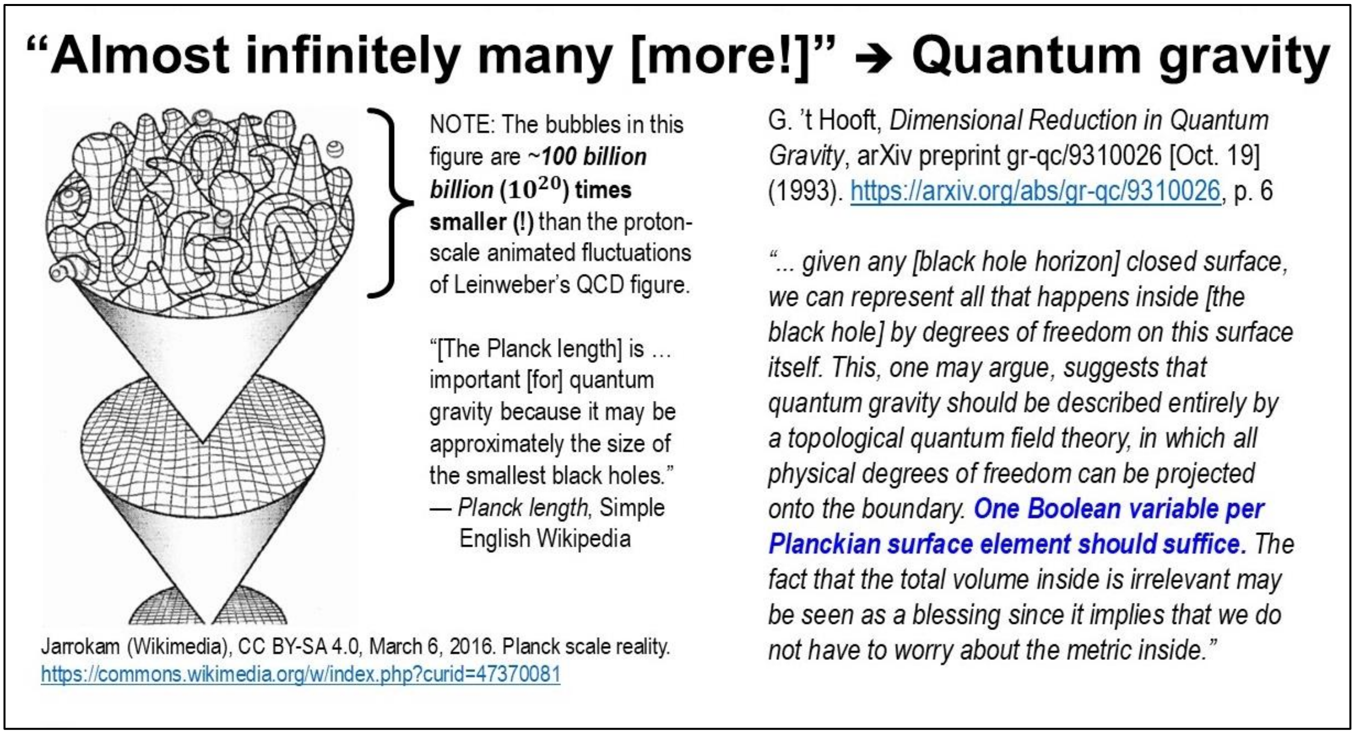
4

[16:25] Quantum field theory produces some fascinating results when it's applied to, say, the structure of proton. Most people have seen this figure at one time or another. If you follow physics at all, you've likely seen this marvelous little animation done by Derek Leinweber [5]. It was used in 2004 by Frank Wilczek in his Nobel Prize speech. It shows what happens when you push the calculations down to incredibly short levels inside of a proton or a couple protons. What happens is these fields — the color force, they call it, as well as the electric force — become just very chaotic. You have this mass of fluctuations that are going on that are tremendously complicated. So, this is not some I this not some casual representation Derek Leinweber did. This is an excellent piece of work in which he did the calculations — he worked this out. I think people — I remember I did — thought this was just somebody's casual animation showing quantum fluctuations. *Not at all!* This is this is solid, *solid* work — such good work that they used it in a Nobel Prize talk.

So, there's a scale here that's roughly that of protons. One of the conclusions that people come to from this — which Derek Leinweber states — is that empty space is *not* empty. It's full of incredible intensity and density of this kind of material. So, [this animation is] very standard and often used in that same sense [of demonstrating the intensity and density of activity in empty space].

Now there's a funny little twist on this. People often talk about [Leinweber's animation] as if this was the same thing as space itself. It is not! This is a simulation of the forces inside of a proton.

[5] D. Muller and D. Leinweber, *Empty Space is NOT Empty*, Veritasium (YouTube), **2013**, 430 [Apr. 30] (2013). https://sarxiv.org/ref.2013-04-30.pdf



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[18:28] If you want to go to space you have to go 100 billion *billion* times smaller! So, to say there's a bit of a shrinkage there is an understatement! You have to go *way*, way smaller than what I just showed before you [can] start talking about *spacetime* having frothing oscillations and all those sorts of things.

Now, notice [in Slide 5 that] someone — it's actually Jarrokam, whoever Jarrokam is, from Wikipedia — did a nice little figure on it. He shows pretty much exactly what the great Archibald Wheeler came up, which is saying that if you look at spacetime very closely, you should see a frothy effect very similar to what we saw in the previous diagram, but at a tremendously smaller scale. At this [scale you have] energy densities that are so intense that they actually form tiny little black holes that appear and disappear. So, this was work [Wheeler] did back in 1955. He actually called them *geons* [6] — he had a name for them. If you look it up, it's a different terminology, but Wheeler is the one who came up with it. He gave the analogy about how you can look at [spacetime] from different size [scales].

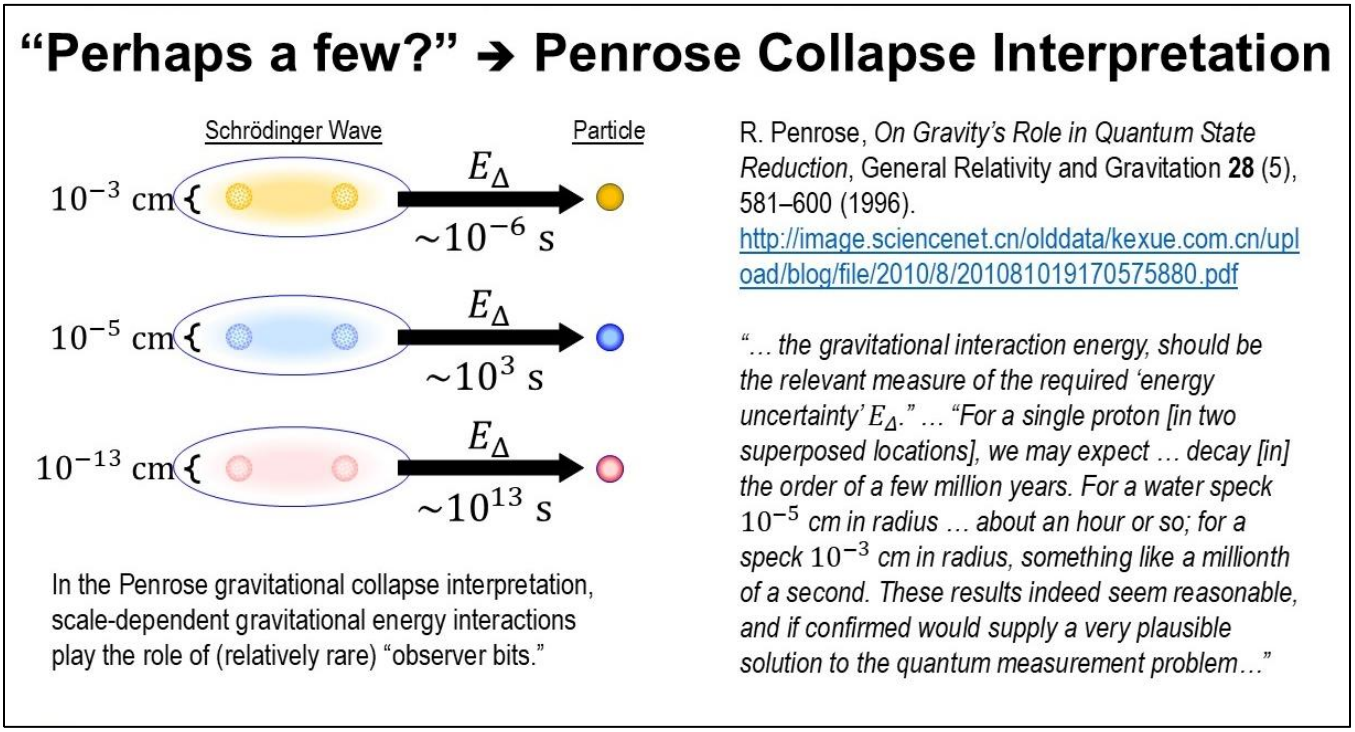
So, that's the Wheeler background. Now, to me, though, the more interesting result, in more recent times by the great Dr. Gerard 't Hooft — a really great man, a magnificent thinker, and a very nice person, too, by the way — he took this same idea and looked at it in terms of saying, "What would happen at the surface of a black hole?" Using a certain argument in which he used a lattice theory — and I'm going to come back to that, he explicitly used a lattice theory — he came up with an estimate of what the number of black-hole-like entities would be on this surface [7].

That seems kind of weird, if you think about it: Black holes on black holes! It's a quirky way of looking at it, but it still captures this idea of the frothy surface of the black hole [where] you have these additional quantum effects going on at a very small scale. At one point in his paper, he just makes the flat-out statement — a postulate — that [there is] "one Boolean bit per Planckian surface element." That is kind of an indirect way of saying "these little micro black holes" because the Planck energy is where you form these little black holes, of which you can see … a little example in that one [tiny bubble] there [on the slide 5 figure].

This led to the entire field that is now called the holographic universe. From this, other people extrapolated the idea that, well, if you have all these bits on the surface, and they have this, you know, [form that is] essentially not that different from a holographic film, the internal projection of those bits would be a hologram with a finite density — a finite [resolution] limit, because you have a finite — a very large, but finite — number of bits. So this led to the whole idea [of the holographic universe]. If you've ever heard of the holographic universe, this is exactly where it came from. First, it came from Wheeler's geons, and then Gerard 't Hooft came up with this elaboration of the idea that these [geons] would turn into bits on the surface of black hole. So, a fascinating bit of work.

[6] J. A. Wheeler, *Geons*, Physical Review **97** (2), 511 (1955). https://blackholes.tecnico.ulisboa.pt/gritting/pdf/gravity_and_general_relativity/Wheeler_Geons.pdf

[7] G. 't Hooft, *Dimensional Reduction in Quantum Gravity*, arXiv preprint gr-qc/9310026 [Oct. 19] (1993). https://arxiv.org/abs/gr-qc/9310026, p. 6.



6

[22:01] Here's another one. This one intrigues me because it's quite different. Never take anything Roger Penrose says too casually! He really can put twists on things, and [come up with] ways of looking at them that are quite unique. [So you] should never take what he says casually, even if it sounds pretty wild. It took decades for me to come around on some issues, [such as his idea of brain] quantum effects at room temperature. Then somebody comes out with experimental results that say, "Oh yeah, *yeah* — quantum effects at room temperature!" [8] So, you want to take what [Penrose] says seriously.

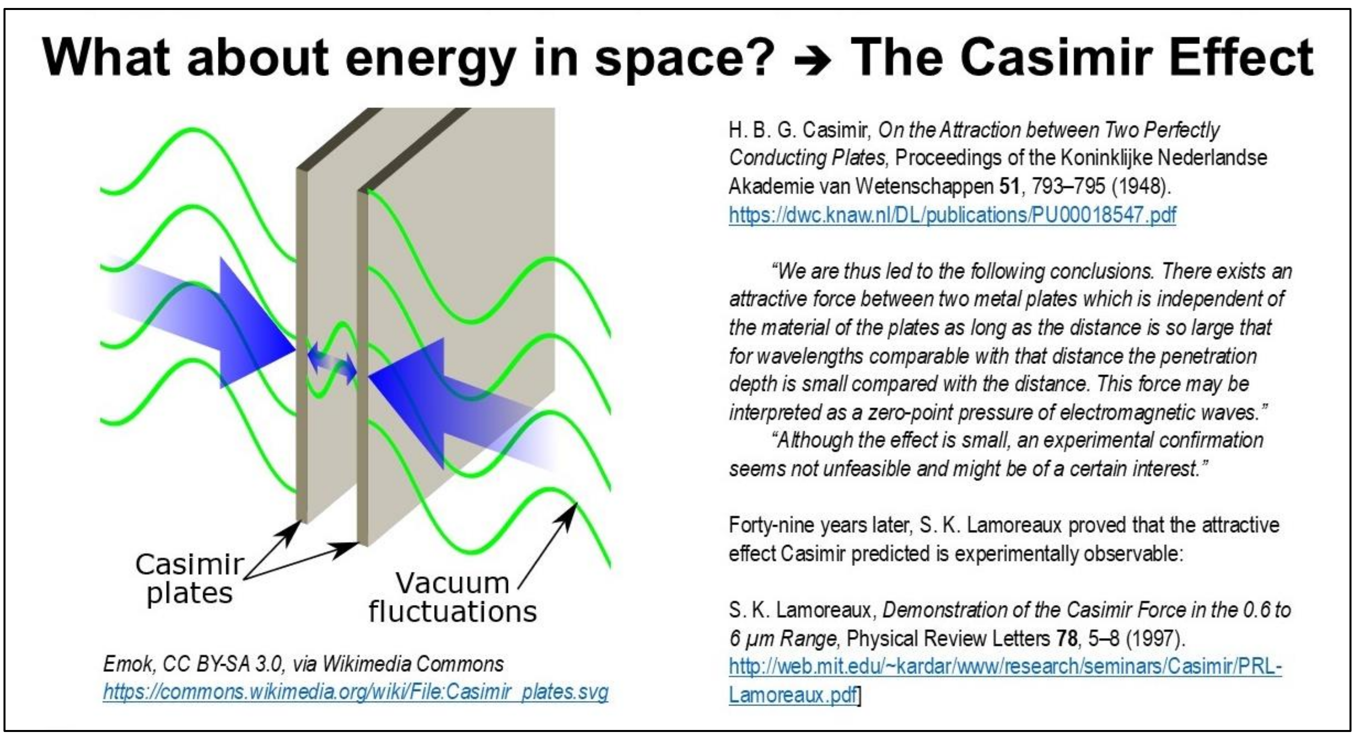
[Penrose] came up with this really interesting idea that the resolution to this contradiction that we see between the quantum universe and the regular universe is *gravity* [9]. He says that *gravity* — because it adds a little delta of energy, which he has labeled there as E_Δ — on very small scales, the gravity is so weak that it's not going to have much effect. But as you get bigger, [the effect of gravity] becomes drastic. So, the idea of a quantum superposition of positions, for example — which, in some ways, I would argue is the *real* quantum superposition, [since] you've got to be very careful when you start superposing more complex states.

But position? Absolutely. That has been proven experimentally so well it's just incredible. Gigantic molecules have been shown to go into location superposition — there's no ambiguity about that… Well, there's no ambiguity under the usual interpretation, but there are different interpretations that go off in a different way of [interpreting such experiments]. But just by experimental results in two slit experiments, this is considered an extremely solid result — and I would concur with that very much, because these are very odd effects. They [work] on all sorts of neutral molecules. It doesn't matter — you don't have to be using metals. All you need is two slits and some kind of thing going through them, and all of a sudden, you can't define the path that the molecule took. So: quantum superposition.

Penrose uses gravity — which is essentially a little minor curvature in space — to add a little bit of energy to that space, because curved space has energy. He collapses the wave function with that. And it fits proportionally with a lot of things. One could point out that there are also some issues with this, but it's an interesting theory — and it does add *real* bits to space. It says that for every bit of space, if you have a little bit of curvature there, there are a few bits. And the bits are permanent bits. They're not just these transient things that were showing up in those previous two diagrams where everything's just frothing around. These are bits that actually persist, because you have matter that's sitting there stabilizing that curvature. So, if you have a little speck of dust that's 10^{-3} cm, it's very small, but in terms of gravitational effects [on quantum superpositions], it's big enough to make a difference.

[8] N. S. Babcock, G. Montes-Cabrera, K. E. Oberhofer, M. Chergui, G. L. Celardo, and P. Kurian, *Ultraviolet Superradiance from Mega-Networks of Tryptophan in Biological Architectures*, The Journal of Physical Chemistry B 128 (17), 4035–4046 [May 2] (2024). https://pubs.acs.org/doi/epdf/10.1021/acs.jpcb.3c07936

[9] R. Penrose, *On Gravity's Role in Quantum State Reduction*, General Relativity and Gravitation **28** (5), 581–600 (1996). http://image.sciencenet.cn/olddata/kexue.com.cn/upload/blog/file/2010/8/201081019170575880.pdf



7

[25:04] And… We cannot skip Casimir effect! Oh my gosh! The Casimir effect is the electromagnetic version of these drastic fluctuations at small scales. What Casimir did…

[With the help of Bohr! Bohr is very much a character involved with this. People don't realize that. Bohr was the one who suggested the idea to Casimir. Casimir, at first, forgot to give him credit and later apologized and said, "Yes, Bohr absolutely gave me the idea, and I kind of went with it." So, Bohr and Casimir… [If you are Casimir], what are you gonna do? Casimir was a [mere] solid-state physicist, [and] one of the most famous theoretical physicists in the world says [to you], "Hey, here's an idea!" So Casimir, *not too unreasonably*, took it as a serious idea!]

What Casimir did was propose this intriguing idea that because the [plates] block outside electromagnetic waves, you essentially have an incomplete pressure between the plates [10]. Certain modes of vibration just can't be there. This happens if you have ever been boating and you notice that when you pull your boat next to a dock, the boat tends to pull towards the dock. In fact, you have got to be careful — you can get your hand mashed if you're not careful.

That is the same thing. What is happening there is your boat and the dock are forming a restricted area in which only a certain limited number of modes of vibration are possible, whereas the ocean has any vibrations it wants. So, the result is [that] you get a net push inwards to push the two plates together. This is often called the zero-point energy. Casimir predicted it, and a fellow named Steve Lamoreaux, almost 50 years later, finally was able to demonstrate that this is real — this happens, this is not just an imaginary effect [11]. You know, you can say, "Well, this probably isn't real" — but no, they've done good work and shown — it's not easy work, but they have shown that this is a real effect. This, too, would be an example of the chaotic aspect [of space]. In this case, the chaos really is on the outside of the plates. People think in terms of negative pressure inside, [but] you need to kind of flip it the other way around because what's happening is saying that the outside world has chaotic electromagnetic fields that are just going crazy all the time, and then you have this safe area here where they disappear, just like the boat next to the dock.

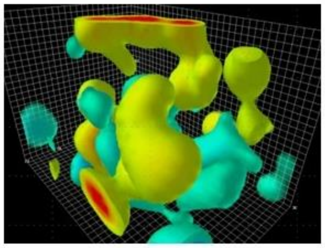
So, people talk about zero-point energy, but a better way to think of it is like enormous energy out *here*, and then a safe space where the energy cannot get into it. That gives you more accurate view. It shows up in the figure here. If you actually look at the figure, that's what it is trying to show with this [larger set of outside waves].

So, Casimir effect: Again, [a case of] chaotic bit-like energy and bits, [and] a close connection [with the earlier chaos cases]. Certainly a related concept!

[10] H. B. G. Casimir, *On the Attraction between Two Perfectly Conducting Plates*, Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen **51**, 793–795 (1948). https://dwc.knaw.nl/DL/publications/PU00018547.pdf

[11] S. K. Lamoreaux, *Demonstration of the Casimir Force in the 0.6 to 6 μm Range*, Physical Review Letters **78**, 5–8 (1997). http://web.mit.edu/~kardar/www/research/seminars/Casimir/PRL-Lamoreaux.pdf

A Closer Look: Quantum Field Theory



Derek Leinweber: *"**What you're looking at here is the energy density of the gluon field fluctuations**. **...** on average, it is possible to annihilate a quark from empty space because it is not empty. … The empty vacuum actually costs an enormous amount of energy to create, and if you were able to create it, you'd discover that that is actually unstable — that any sort of perturbation would push that empty vacuum into something where **the vacuum is actually full of quantum field fluctuations**."*

- If you count *fields* as real, how "empty" is the space inside a proton?
- Question: If you could uniformly fill a room with flux fields as intense as the ones inside a proton, what would happen if you stepped in?
- Answer: Instantaneous obliteration down to your sub-particle level, followed obliteration of earth and possibly the entire solar system.
- Is it accurate to label regions containing such fields "empty" space?
- Nitpick: "*gluon* field fluctuations" versus "*quantum* field fluctuations."

8

[28:00] Let's take a closer look at this [issue of small-scale chaos], though. There are some issues!

First, let's look at that figure about the excellent calculations done about gluon field fluctuations [5]. These are the calculations that help to describe the behavior inside of a proton. This is work that has experimental consequences, so that is always a powerful argument in favor of it. And the author of the work made the comment, "Well, this shows that empty space is *not* empty."

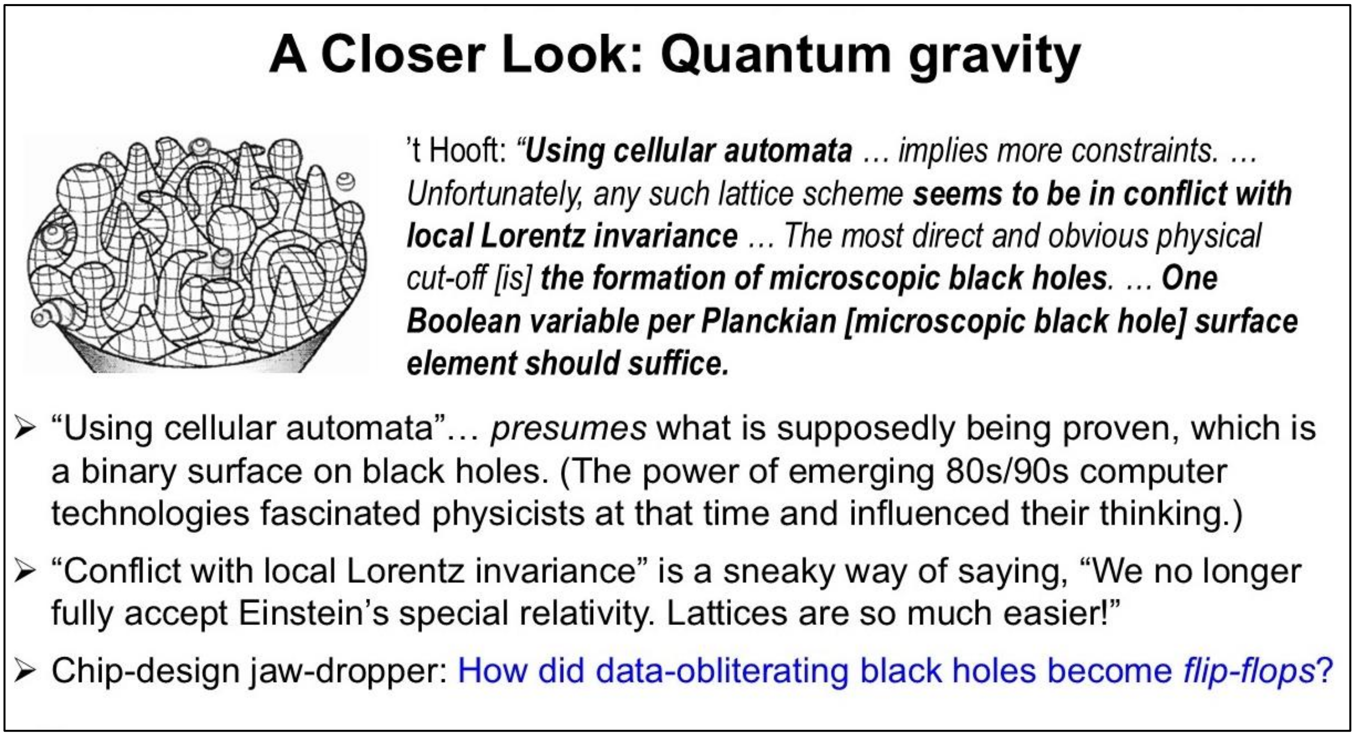
Now, let's look at that a little more carefully. The question is really simple, you see it right there: If you could fill — now you can't really do this for, obviously, for all sorts of reasons I could get into — but if you *could* uniformly fill a room with flux fields — that's a combination of electric and color forces — as you can the ones inside a proton, what would happen if you stepped inside that room? The answer is, of course, [you would be] instantly obliterated.

[Actually,] it would be much worse than that. It would be like taking a *room-sized chunk* of a neutron star and putting it in the middle of your house. And *nothing good* would come from that, I guarantee you! At least the Earth would be obliterated — I'm not going to do some calculation, somebody can do a calculation of what would happen [if they want] — but you'd at least do in the Earth, and probably do in the Sun, too. So, consider the whole solar system pretty much obliterated.

Now, the question comes down to this: Is that *really* empty space you're talking about, or is that space filled with one of most intense energetic fields proven to exist anywhere inside the universe? And I would simply say the latter. *Of course* it's the latter, because you have these fluctuations, but these are fluctuations [that come] *after* [assuming] the existence of *unbelievably* intense fields. We think of the electric force is powerful at our [everyday charge-separation] scale. Think what it's like inside of a *proton*, where you have oppositely-charged [quarks] a [mere] *proton*-distance away from each other? And that's not even including the color force! So, you want to be a little careful on that.

So, I would have the nitpick on that it's *gluon* field fluctuations, which is what *is* going on because you have these actual force fields and force particles, versus *quantum* [fluctuations], which imply empty space. I think we have a terminology issue on that, and I want to be a little bit careful on that.

So, a great result, impressive work. Leinweber did fantastic work on this, and it is predictive work, as far as I know, since it showed some of the actual consequences in terms of proton behavior. But you have to be careful about some of the casual statements. Are these *really* quantum field fluctuations, or are they fluctuations generated by an *existing* field?



9

[30:52] Now, quantum gravity. Incidentally, there's a good reason why this is not as detailed, and I think I mentioned this before. But there is no self-coherent mathematical theory for predicting this. That's a "little" detail that gets skipped over sometimes — that when you try to quantize spacetime at this level, there's lots of ways you can *kind of* do it, *sort of* — but not to the level you can with the gluons. It's not as predictive as that. So, this is not a result of a real simulation. This is an extrapolation of what Wheeler said about this.

Now [let's] focus more on the idea that space is full of *holographic bits*.

One of the things that's interesting about 't Hooft's paper [7] is that he starts off very early using cellular automata. Why did he use cellular automata? The 1990s were an amazing time for computer technology. Computer technology was doing *everything* — you know, bits and computation were getting smaller and smaller, and it just seemed like there was no limit to how far [down in size] you can get those. And the physics community started paying attention to this. So, the idea of, "Can we use these ideas?" became very much a consideration. You see it in quantum computing. You see it in Yuri Manin [12][13], who actually preceded Feynman by a couple years in talking about the possibility of quantum-level computing with these devices.

So, it's not too surprising that cellular automata [— interconnected networks or lattices of small computers —] became a point of fascination. Physicists looked and say, "Can we model [physics] better [using these computer models]? And they had successes! They had successes when quantum field theory and quantum chromodynamics

— the same one that we saw the earlier active animation — benefited greatly by using a lattice approach. So, [that lattices] really caught on, and people start using [them broadly].

There's just one problem. It's almost too obvious to say, but I'll say it anyway: If you're using a lattice, you're using a *single* inertial frame, and you have abandoned special relativity. [Why?] Because in special relativity the vacuum is not attached to a single frame. Never! It just isn't. Einstein's whole point was you can have a thousand different observers going a thousand different speeds, some near the speed of light, some going slowly, and when they all look at the same region of empty space, they all see exactly the same thing. There's nothing different [about that space] to any of them. The empty space always looks the same. That's the very heart of special relativity: This amazing *inability* to see anything different about empty space. Everybody sees the same empty space. Even if they're all looking at the *same* empty space, they see the same emptiness.

If you use cellular automata, you lose that. You have to! You've created a computing *web!* You know, the fact that it's smaller doesn't make any difference. It's just like a computing web here on Earth. It's attached to Earth. It's attached to Earth's initial frame. It's no different here. This is not a complicated issue in terms of why that happens.

So — and they use this wording, you'll see this in a lot of papers — "seems to conflict with local Lorentz invariance." So, that is *kind of* a sneaky way of saying, "Eh… this is so useful [that] we're just going to assume that special relativity doesn't work." So, it's a hypothesis, but it's not stated explicitly. In one of Penrose's books, I remember the first time I read all the way to the back of the book, I said, "Oh! He doesn't believe in special relativity!"

You don't *get* that in the front! *Nobody* says that up front because it's too it's too controversial! People would object if you just say point blank, "*Yeah*, we think special relative is going to fail." But the truth is that most of physics since 1980 has assumed that special relativity *will* fail. They talk about "cutoffs," they talk about "conflicts with local invariance" — there's a whole terminology that goes along with this. But it always says the same thing. You *have* to assume that if you get *too energetic*, special relativity is going to fail. Because it's on a lattice! You can't push your computing lattice beyond a certain point. Again, this is not complicated; this is a very "computer" argument. It's not very complicated. If you push your lattice beyond a certain point, it can't do it anymore. It's going to fail no matter how powerful it is. So, that's what's going on with these things.

Now, the other point I want to make about Gerard 't Hooft's paper is this same fascination led to what I would consider *way* too *non-factually based* assumptions about technologies that the physicists were *not* very familiar with, such as, "What is a storage bit?"

The idea that a storage bit is a same thing as a *data obliterating microscopic black hole*… I'm *sorry*, but just from a computing viewpoint, *that doesn't follow*. I'm not saying that 't Hooft doesn't go through an argument — he does, he goes through a lattice-based argument in which he uses the lattice to constrain the dimensions, and winds up with bits. But if you start with a lattice, *you've already started with bits!* If you start with the assumption — if you say, "I assume that everything is a lattice, and therefore… Oh, look! I've proved it's a lattice!" *Of course* you've proved it's a lattice, because that was your initial assumption. That is very much what this paper does. By assuming a lattice in the initial assumption, *of course* you're going to wind up with bits. There is essentially no other outcome.

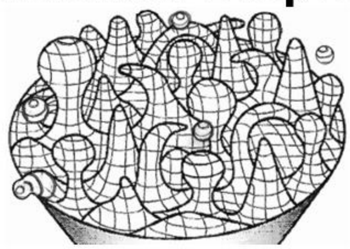
But calling microscopic black holes bits, just kind of arbitrarily? *It doesn't follow.* Black holes don't behave like bits. Storage bits require structure; they require a lot of engineering, frankly. They require a certain finite amount of mass. That's why you have trouble making bit arrays too small. Back in the 90s, it seemed like bits were just going to get shrink until they were nothing — until they were black holes, I guess! — but that's not really what happens with those bits. So, [there's a] problem with the [arguing] that bits are so common [based on] using this approach.

[12] Y. Manin, *Computable and Uncomputable* [Introduction, pages 14-15 only, in English], Apabistia References (1980). https://sarxiv.org/ref.1980-10-09.p14-15.engl.pdf

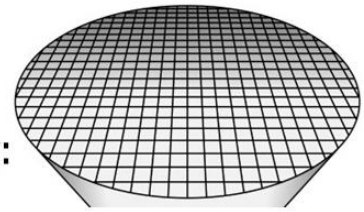
[13] T. Bollinger, *Biomolecular Quantum Computation*, TAO Physics **2020** (10), 1007 [Oct. 7] (2020). DOI: https://doi.org/10.48034/20201007.

2020 Experimental Disproof of Planck Scale Foam

Wheeler's 1955 "Planck foam" speculation:



HAWC 2020 gamma-ray tested reality:



J. A. Wheeler, *Geons*, Physical Review **97** (2), 511 (1955). https://blackholes.tecnico.ulisboa.pt/gritting/pdf/gravity_and_general_relativity/Wheeler_Geons.pdf

S. Carlip, *Spacetime foam: a review*, Reports on Progress in Physics **86** (6), 066001 (2023). https://iopscience.iop.org/article/10.1088/1361-6633/acceb4/ampdf

Carlip: *"In the mid-1950s, Wheeler … argued that quantum fluctuations … at the Planck scale [lead] to wild and rapidly varying fluctuations in spacetime geometry and topology, which he called 'spacetime foam.'"*

Wheeler: *"To the transatlantic passenger flying above it, the ocean appears smooth… [but] in a lifeboat he sees the foam forming and breaking."*

A. Albert et al., *Constraints on Lorentz invariance violation from HAWC observations of gamma rays above 100 TeV*, Physical Review Letters **124** (13), 131101 (2020). https://arxiv.org/abs/1911.08070

"… a hard photon decay cutoff due to LIV [Lorentz invariance violation] would be at the same energy for any source … HAWC [evidence of 100 TeV photon emissions from at least four astrophysical sources] thus can exclude [the possibility of new, non-Lorentz-invariant physics emerging at any energy level less than] the LIV energy scale …, $E^{(1)}_{LIV}$, [which we have now set] to greater than 10^{31} eV. [This new upper bound for continuation of standard Lorentzian physics is] over 1800 times the Planck energy scale [of] $E_{Pl} \approx 1.22 \times 10^{28}$ eV."

10

[37:19] Even worse — and I *cannot* understand why this happens, I *really truly cannot* — there was a time when theoretical physicists paid every bit of attention they possibly could to every experimental result that they saw. That is not what happens anymore! In 2020, a team — about a hundred scientists are on the paper, it's an excellent paper, extremely data-based [14] — they looked at the extreme tera-electron-volt (TeV) gamma rays that are known to exist in the galaxy, from four different sources. These are a good test for the whole lattice theory because, like I said earlier, just like if you have a lattice here on Earth, if you push it too hard — if you try to push too much data through it — it falls apart. In the terminology of physics, they call that a "cutoff." They say, "We expect a cutoff in which standard physics will fail." That is the terminology.

Wheeler's Planck foam [15] was just such a cutoff. He said that, after a certain point, special relativity is going to fail. It's going to produce something like [the foam in this left figure]. There are experimental results that say, *"That… is… wrong!"* [The results say] that despite the incredibly tiny scale of this Planck foam, the HAWC 2020 [study] was able to say that in order for tera-electron-volt gammas to cross the cosmos over this supposed lattice of spacetime, *they're going to fall apart!* They have to because, after a certain point, they lose resolution, and these things are just too intense. So, they would fall apart.

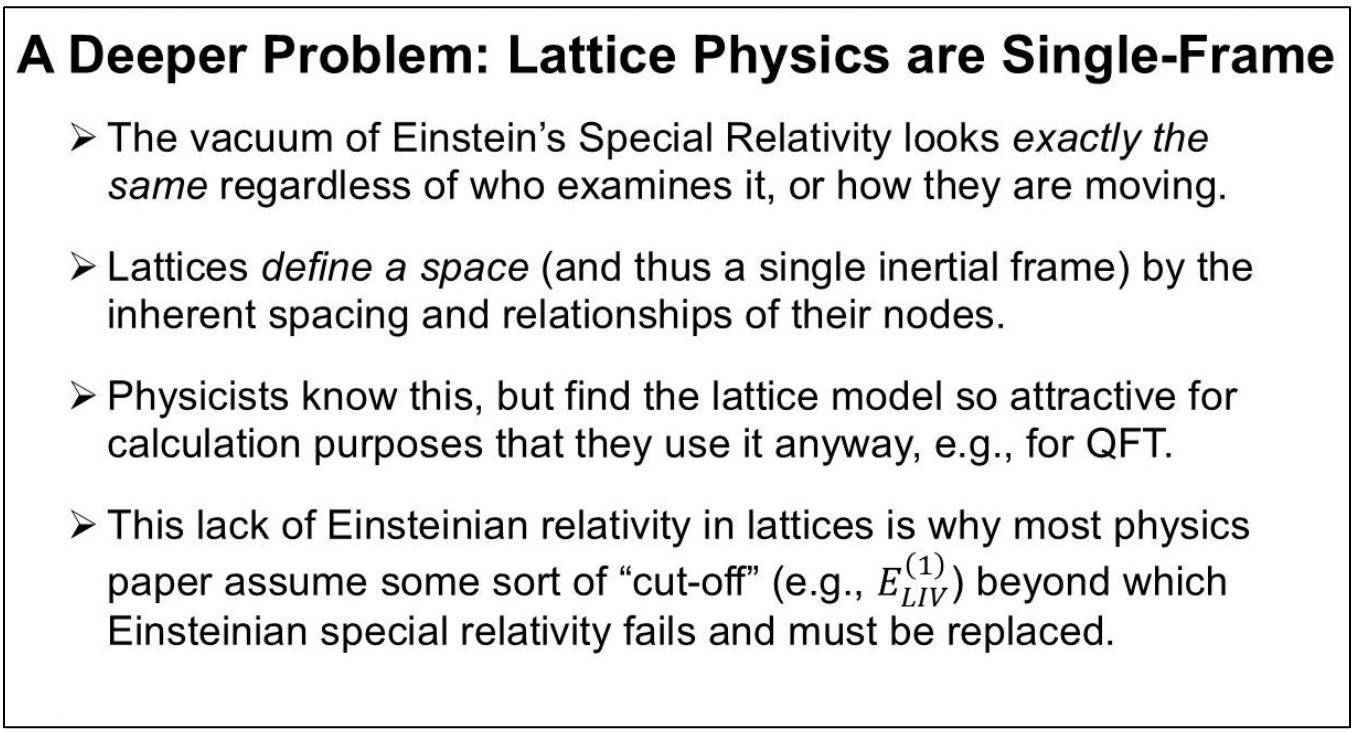
And what did [HAWC] see when they looked for that? They saw *absolutely nothing*. Special relativity — Einstein — was right. It doesn't *matter* how energetic the photon is, it still sees space the same way. So, the actual figure — the *experimental* figure on the right; that one is my figure, I kind of made it from the other one — that's the *correct* one on the right. It doesn't exist — there is no Planck foam!

But people ignore that! They just say, “Oh well, it’s just another experimental result.” No, it’s *not* “another experimental result,” it’s a hundred physicists using some of the best experimental equipment in the world, getting a very solid result — and you’re just going to say, “Yeah, it doesn’t matter.” *No*, you can’t *do* that! You have to you have to take that into account.

The simple truth of it is that this postulate by Wheeler failed by a factor about 1800 — about 2,000 times — and that’s just from the data available. I mean, it’s hard not to extrapolate and say that if you go even higher it’s just going to get worse. So, that’s another reason to be careful about the Planck scale foam, because it’s been experimentally disprove.

[14] A. Albert et al., *Constraints on Lorentz invariance violation from HAWC observations of gamma rays above 100 TeV*, Physical Review Letters **124** (13), 131101 (2020). https://arxiv.org/abs/1911.08070.

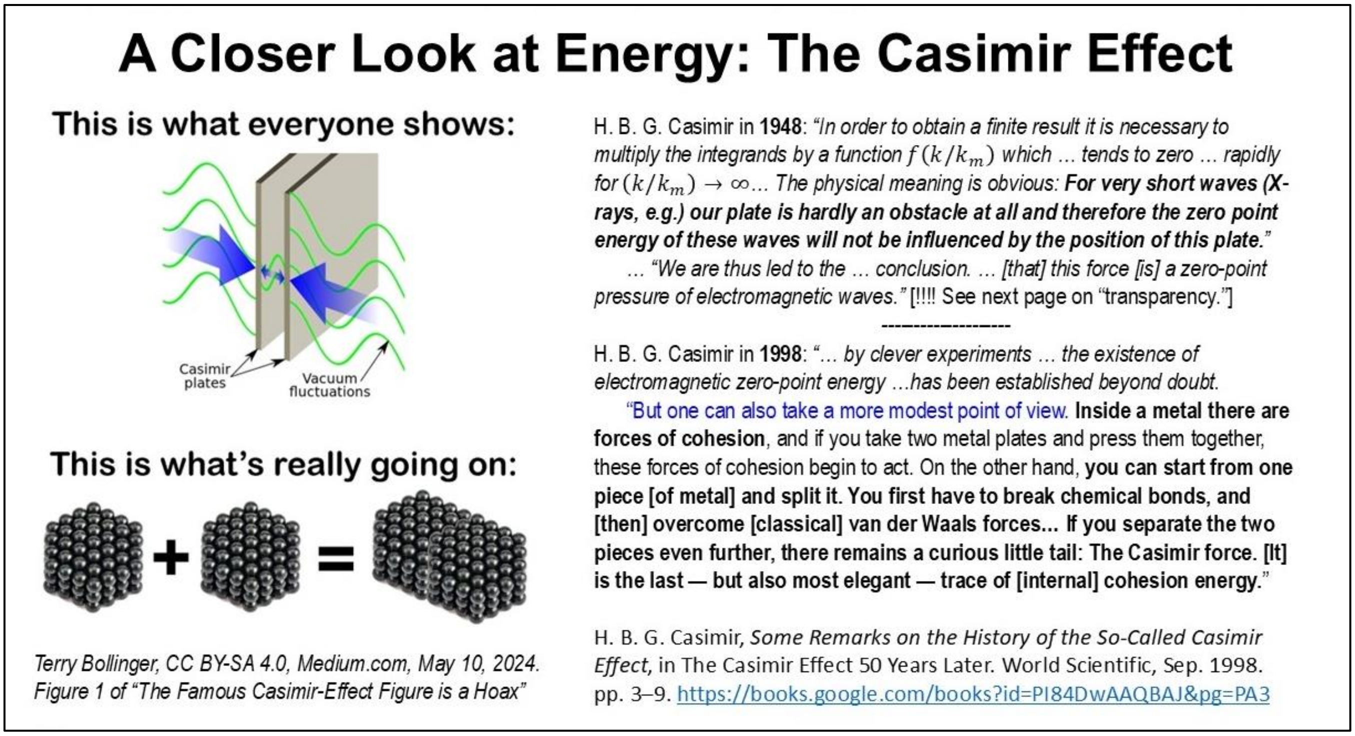
[15] S. Carlip, *Spacetime foam: a review*, Reports on Progress in Physics **86** (6), 066001 (2023). https://iopscience.iop.org/article/10.1088/1361-6633/acceb4/ampdf



11

[40:15] As I talked about [earlier] — I got ahead of myself a little bit this — lattices define a space. They define a network. Physics models [have been] using lattices since, I think it was about in the early 1980s. I remember reading the articles back in the 1980s, somewhere in that range. People started doing this and said, “Hey, this works pretty well!”, and it did — it absolutely does.

But this gets into this whole cutoff issue. [You can see the cutoff term in the lower-right paragraph of Slide 10, $E_{LIV}^{(1)}$] [14]. (Where they get the notation I have no idea: E to the *parentheses*… not just 1, but *parentheses* [around] 1.) And that’s the Lorentz invariance [LIV] limit down there [in the subscript]. [This is the cutoff where] they expected where special relativity would fail — and most physicists believed it would, even if they didn’t say it out loud. [But] it didn’t work. Einstein… *won*.



12

[41:06] The Casimir effect! Oh, I *love* the Casimir effect!

[The Casimir effect is the one where electromagnetic vacuum fluctuations push two metal plates together if they get very close, due to geometric suppression of lower-frequency electromagnetic resonances in the gap between the plates.]

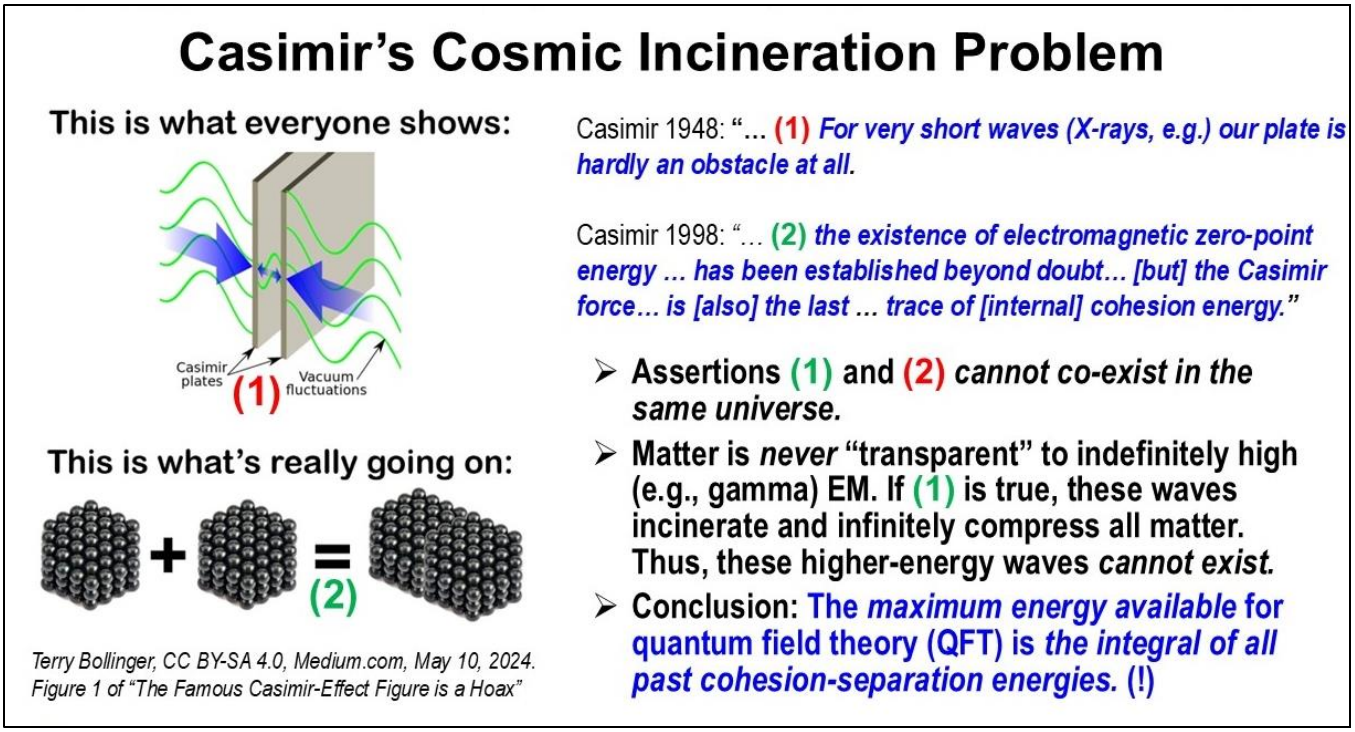
There's a *problem* with the Casimir effect. In 1948 [10], Casimir made a statement [in a paper] — I remember my reaction when I read this paper — I just like threw my hands up and said, "*You've got to be kidding!* You *can't* seriously *say* that!" He said that, "The reason why only certain frequencies seem to affect the plates is because… eh, the plates are *transparent* to X-rays. The X-rays just go *right through them."*

[Laugh.] *You can't do that* if you're going to take this seriously!

[First, some background:] What he did is put in a fudge factor function where the function just says, "Oh, for reasons we don't quite understand, it just *drops off* on those higher level [frequencies]. Now, there's *nothing wrong* with putting in a fudge factor when you're trying to agree with experimental data — don't get me wrong on that! His "fudge factor function" — that's hard to say several times fast! — was a genuine function … expressing something he was observing … from the data, which was that these [electromagnetic pressure effects seemed to] fall off [at higher frequencies]. And yet, within that fall off, you've got this behavior … [that] seems to be a [geometrically determined] absence of [certain electromagnetic] oscillation [modes between the plates].

So, this takes you up to 1998, when Casimir essentially says *both*, at the same time, in the same paragraph [16]. He says [paraphrasing], "Clearly, we have proven that there is a wave-suppression effect [between the plates] that causes the plates to be pushed [towards each other]. But… *but!...* We've also proven, indisputably, that [this attraction is] nothing more than a gradual fall-off of the cohesion forces of the plates [after] you first broke them apart." Incidentally, on some work I did [earlier], I came up with a model of breaking two plates apart, [but] I had no idea [then] that Casimir had used the same argument. So, I was [laugh] *very pleased* when I saw that, "Oh, he does the same argument!" But my argument there was, "You can break them apart, but you don't have to put them together. And if you break them apart, your [total energy] is never going to exceed the bonding force." Which is exactly what Casimir said.

[16] H. B. G. Casimir, *Some Remarks on the History of the So-Called Casimir Effect*, in 'The Casimir Effect 50 Years Later.' World Scientific, Sep. 1998. See pages 3–9. https://books.google.com/books?id=PI84DwAAQBAJ&pg=PA3



13

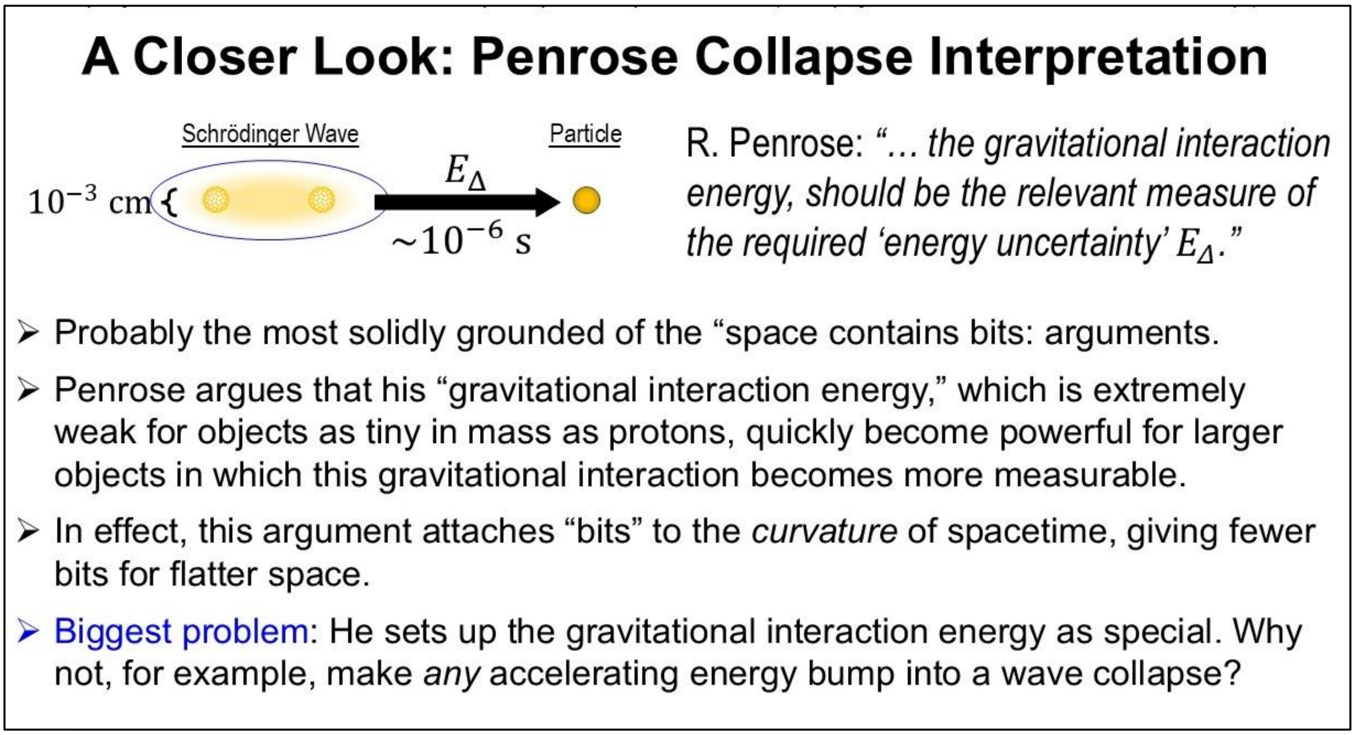
[43:26] So how do you *reconcile* those two? Because the first [explanation Casimir] gave is *absurd* — you can't really do that. If you *do that*, what happens is you incinerate the cosmos! If you seriously believe that every point in space has an almost infinite amount of electric and other force resonances going on all the time, the wave intensity pushing those plates becomes not quite infinite — because you have that little blackhole [Planck energy] limit that Gerard 't Hooft talked about — but it becomes almost infinite. What *really happens* is everything in the universe is crushed and incinerated by the vacuum… *period*. There's no "transparency" issue. You can't reconcile that statement that he made 1948 with what we've seen in universe, or with the statement from 1998 that Casimir made.

This to me is one of those interesting things because if you think about what Casimir said in 1998 and you assume that he did good work — and he *did* — he established two things at once, but they're paradoxical. What he's *really* saying is that every time in quantum field theory that you assume infinite energies exist at the lower level [of spacetime scale], you're wrong. Now, *Casimir* didn't say it that way, but if you look at his statements, you can't get around it. What he really says is, "No. The maximum energy that feeds quantum field theory — down to the QED loops and everything — has to fade, and the fading is determined by the maximum cohesion energy of when the masses were first separated." In other words, if you imagine all of the universe starting as just one ball and you break it apart, there's an energy that is required to do that breakup. Rather than being infinite, it's quite finite, and actually rather small. And *that* is the energy that drives quantum field theory.

Now, this could be a whole different talk. But I think this is just an intriguing area. Always in quantum field theory, we're trying to cancel the smaller components — you know, so you can get away from the infinite energies. So you start getting into these really convoluted renormalization schemes that Feynman came up with — a brilliant idea.

But at the same time, you're always trying to cancel these infinite energies. Maybe the problem is that you shouldn't be invoking those [infinite energies] at all. The energies are those of the matter that you've separated, and you have to put a finite limit on that.

So, I think Casimir inadvertently gave a *very* good piece of advice that you have to reconcile these two paradoxical conclusions in order to get a quantum field theory that does not go to infinity. Our maths don't do a good job of that, but he pointed a way — that there's a possibility — that somehow, these two have to be reconciled. Not just a possibility; I would say it's a *necessity*. If you don't want to incinerate the universe — which is *what happens* with *quantum field theory* if you take Casimir's plate results *seriously* — and you get rid of the silly X-ray idea because, what… *gamma rays* don't have any effect when the gamma rays go through you? No, no… you just can't *do* that. So, fascinating. That one paragraph by Casimir in 1998 has some really good insights.



14

[46:52] A quick look at Penrose's collapse interpretation [9]: I said that he shows "real bits" in space. *But*… if you look carefully, you know curvature attracts matter, but matter *creates* curvature. So the problem in this one is that, yes, you have bits — but the bits *really* reside in the particles that are curving the space. Take away those particles and once again, space goes back to *zero* persistent bits: You can't store anything in it, you can't put anything in it, you can't take anything out of it, you can't store your address in a piece of cubic centimeter of empty space. There's no storage mechanism. Penrose gave an actual storage mechanism, but once again, it relies on matter.

The other thing I would comment on in Penrose's work is he sets up this idea of this E_Δ as being the cause of the collapse. This is something I've said before in little essays and miniature papers: Why not take that all the way? *Every* acceleration — not so much the energy, but the acceleration: momentum changing in the inertial frame. If you're going to say that, why not just say *any* acceleration collapses the wave function? Because that's essentially what the gravitational energy is: An acceleration. So, I would take that idea that Penrose had, but I would go *way*, *way* beyond that and say, "Let's just flip it all upside down." Say that acceleration — every time an acceleration happens — it collapses a wave.

Now, the reason it's not easy to do that it has impacts on your math, to say the least. There's a lot of sunk-cost investment in mathematics. For instance, a hydrogen atom would become a continual collapse effect where the electron is constantly collapsing. We think of [the electron orbital] as *quantum*, but it actually would be the electron [wave] constantly collapsing because of the attraction of the proton, and vice versa. *That's why you have hydrogen atoms*: [the electron and proton are] *observing* each other while sticking together. So, I like Penrose's idea, but I would take it *much* farther. And in terms of space storing data? *No*. It's the matter that stores data, even in the Penrose interpretation.

Chaos vs. Persistence: What Counts as a Bit?

- The Penrose concept of space containing bits due to very slight curvatures captures an important point: Persistence.
- Fluctuating fields and foamy spacetime are fully chaotic and *do not* store information in a persistent fashion.
- For quantum chromodynamics, the *persistent* information is strikingly small and simple: three quarks of two types.
- The Penrose concept has persistence because it relies not just on space, but on *matter* — fermionic matter — to shape space.
- Hypothesis: Persistent information *requires* fermionic matter.

15

[49:02] Chaos versus persistence: What *counts* as a bit? When people talk about infinite energy and bits and computational processes going on inside a cubic centimeter of empty space, as Feynman talked about, do any of those bits endure? The answer is *no,* because you cannot find a mechanism by which you can store data in that spot and remove data from that spot. Penrose's idea comes closest, but again, [even that's] really just an extrapolation of matter.

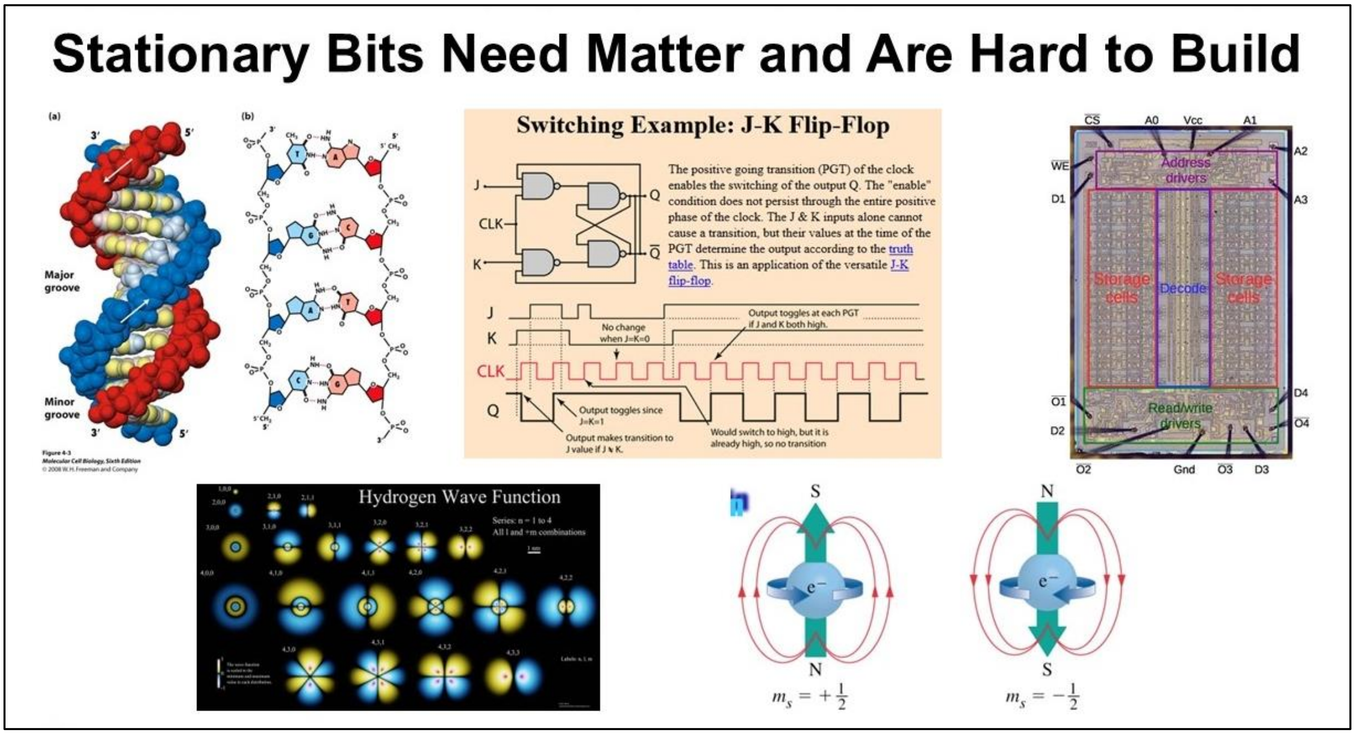
So, if they don't persist, do you really want to call them under the same name? I would say no. So, you would have different kinds of bits:

(1) You have *persistent* bits — persistent information. What is the persistent information, for instance, in a proton? Is it all of that cloud and all of that chaos [we saw earlier in the Leinweber's chromodynamics animation in Slide 4]? No, it's *not*. The persistent information goes back to the original simple model of the proton, which is three quarks of two types. Once you nail those pieces of *persistent* information down — the ones attached to actual matter — then everything else arises *from* that persistent information. The calculations are real, but you want to make a distinction.

(2) *Chaos bits* arise as a result of *processes*, and should not confused with persistent bits that actually *hang in there* and stick around.

Now, I would take that hypothesis a little bit further and say, in particular, [only] fermionic matter — that is, the half-spin [particle] matter, the matter and particles we're made of, [creates persistent bits] …

[Oops, I'm a slide ahead,] let me get to this first:



16

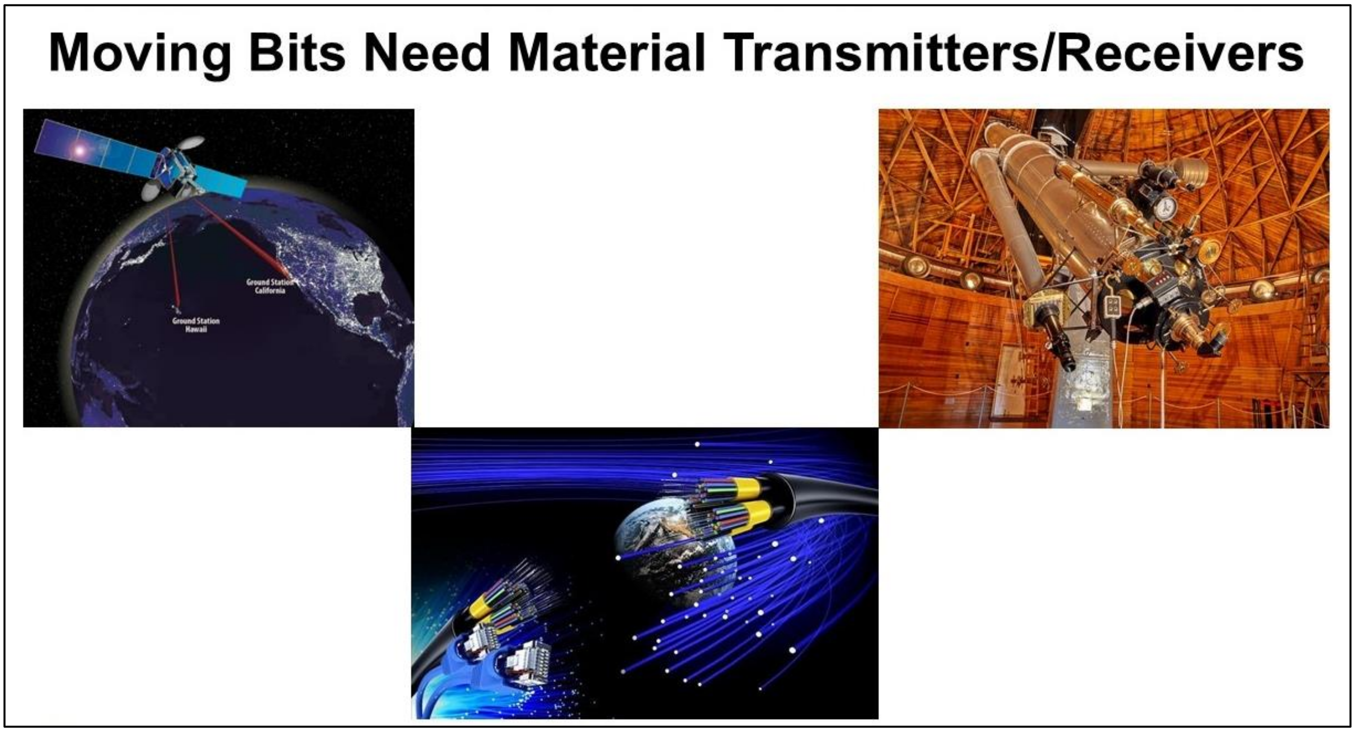
[50:40] The stationary bits are *hard to build*. They're not trivial, and we need to get away from that idea that, as in the case of the 't Hooft paper, that they just kind of "appear." *No, they don't!*

The first invention of something that *really* could be a bit was done a few billion years ago, and it's called DNA and RNA. Those are arguably the first bits [with well-defined, quantized write-read behaviors]. They're quad bits, but they're still bits, and they have *exactly* that property of [quantized] persistence of information over time that leads to a much better definition of history and time.

But technologically, these are complicated devices. As you get [larger and more recent], you get flip-flops. Those are very stable. They use a lot of matter. The more you shrink the matter, the more difficult it becomes to make *stable* information. You can get *transitory* information, but you can't get stable information. The hydrogen wave function, I would argue — as I mentioned before — the capture of the electron by the proton, and vice versa, in which they're constant accelerating each other, arguably is one of the reasons why a hydrogen atom can store information. The existence of a hydrogen atom in a volume of space absolutely stores information, but it has this peculiar relationship where these [two particles, the proton and electron] are essentially probing each other.

I want to mention one at the bottom there, the one about electrons. People think of electrons as qubits — they think of it as the perfect qubit or the perfect bit, [whichever] way you want to think of it. It's classical in a spin glass memory: You flip it this way, or you flip it that way, and you get a *bit*. The point that people forget in the mathematical models is, "Where did the magnetic field come from?" Because until you accommodate the magnetic field, you don't really have a bit. So you say, "Well, I'll just put a small magnet around it." Oh, *really?* How big is your magnet going to be?

I would argue that the smallest case you have would, again, be the hydrogen atom, because you can have the para and the ortho versions of the [electron] orbital because of just this effect. But until you get that magnet, you don't really have a bit. So, instead of saying the *electron* is a bit, the more correct statement is, maybe, the smallest bit possible is a hydrogen atom with the two different orientations of the spins of the two particles inside. So, we have to be careful [when] defining a bit that we don't get sloppy and make it too small for to really be a bit.



17

[53:15] The other form of information is when you have electromagnetic radiation, in particular, but other forms of radiation — neutrinos would also count, [for example]. But the trouble is you need receivers to give *scale*, *meaning*, context, [and] *structure* to these. So, the idea of *transient*, *moving* bits is a really interesting one, and deals with the boson side of the world. But [you need] bits that are *stable* and *stationary*. I think that's very important. Until you have *stationary* bits, it's hard to construct a universe. I'm not saying it's impossible — maybe you can construct a universe with nothing but bosons just going around, I don't know… gravitationally orbiting each other, or something? But it's going to be *really* tricky.

Fermions just are *so* important for this idea of information that stays in place. When you have information that stays in place, you can see something like *me* sitting here in one piece, *persisting*, because I'm made out of fermions. If I didn't have fermions, this wouldn't be happening. Same thing for you folks: You wouldn't be out there sitting if you didn't have fermions giving you the ability to go straight through time without moving laterally through space. So, the idea of stable, persistent bits is an important concept, and it seems deeply tied to the fundamental particles [called fermions].

How Do Bits Work in Mathematics?

- All mathematical equations are written using static bits.
- Much of math is devoted to transforming such bits reliably.
- All *applications* of equations require computed interpretations.
- In the case of physics, those interpretations must have testable experimental consequences.
- Problem:
  - Need for non-data-storing **chaos bits** *explodes* at small physics scales (e.g., color force fluctuations [real], quantum foam [false], Casimir [false]).
  - Are such physics chaos bits real, or are they a feature of mathematics?

18

[54:36] Now, I made comments [complaining] about using fairy dust — chaotic bits — disguised as persistent bits.

I'm suggesting that some of our mathematics are part of … why we have *so much* of this chaotic type of bit structure going on [in our physics models]. One example I did not give in the slides, but I'll give it [here], is the idea that there's a [point-like] electron *running around* inside of a hydrogen orbital.

That only makes sense experimentally if you [inject] *enormous* energy, like a gamma ray, to knock that electron out of that orbital. [The reason you need higher energies to see the electron as an entity smaller than an orbital is because the volume of space in which you can say with certainty that a particle exists within an otherwise wave-like representation of depends on the wavelength of the energy probe used to find the smaller particle location. [17] Furthermore, identifying an exactly point-like location for the electron is impossible because it would require a gamma ray with infinitesimal wavelength and thus infinite energy — an obvious impossibility in the universe as we observer it experimentally.] In all other [situations] — in all the other conditions — [the electron orbital is the] lowest-energy state. Simply, [the fact that the orbital is the lowest energy state possible for a bound electron] says that the electron orbital *is* the [electron].

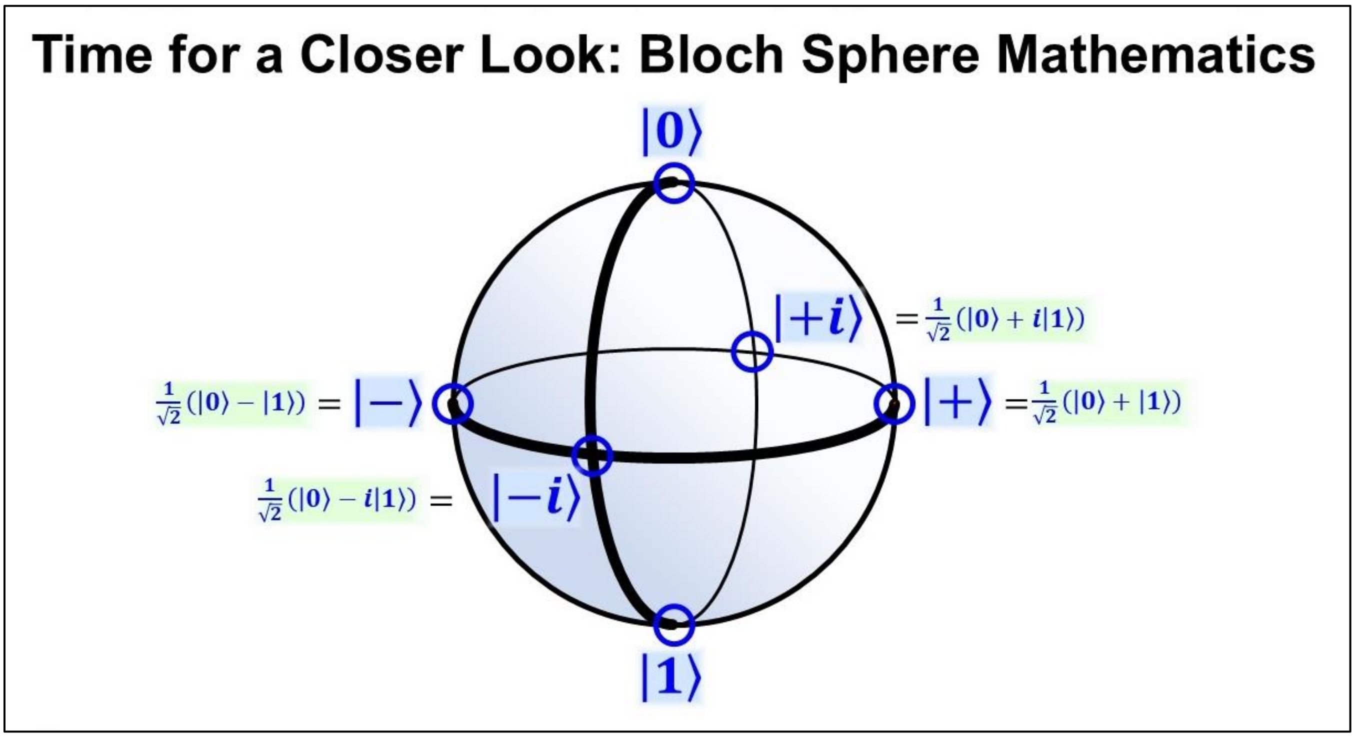
Now, what we say instead is [that the orbital] is a superposition of an *infinite* number of *infinitely* energetic, *infinitely* diverse wave functions.

Can you see how there might be a little bit of a problem here? Are we taking a generative approach [that explicitly recognizes the need to add indefinitely more energy just to approximate point-like electron states within the orbital], or are we just launching into the *most* elaborate, *most* energetic, *most* impossible physically, because we *can't* get a point electron — and *declaring* that to be the reality?

So, much of our math has certain interesting habits built into it. [We need to] get … a [lot] more careful about whether we're *creating* chaos bits, or if the chaos bits are really part of the activity — which they can be, but those are usually a much smaller part. A lot of these chaos bits [are not real]. In the examples I gave, color-force fluctuations are real fluctuations. Quantum foam *is not*. It's experimentally *disproven*. Casimir is an interesting case because it has *some* reality to it, but clearly, we're not getting the whole picture.

So, are these chaos bits that we're we coming up — things like the infinite computation in a cubic centimeter space that Feynman talked about — are that real, or are they a feature of our mathematics?

> [17] R. Feynman, *Why the location of an electron depends on the wavelength of the detection probe* [Lectures III 1-6 para 10]," The Feynman Lectures on Physics **III** (1965). https://www.feynmanlectures.caltech.edu/III_01.html#Ch1-S6-p10.
> *"Let us try the experiment [of looking for which of two slits the electron passes through] with longer [light] waves [as probes]. … A terrible thing happens. … Due to the* wave nature *of the light, there is a limitation on how close two spots can be … seen as … separate. … So now, when we make the wavelength longer than the distance between our holes, we see a* big *fuzzy flash when the light is scattered by the electrons. We can no longer tell which hole the electron went through! We just know it went somewhere! And … we begin to get some [electron self-] interference effect [again]."*



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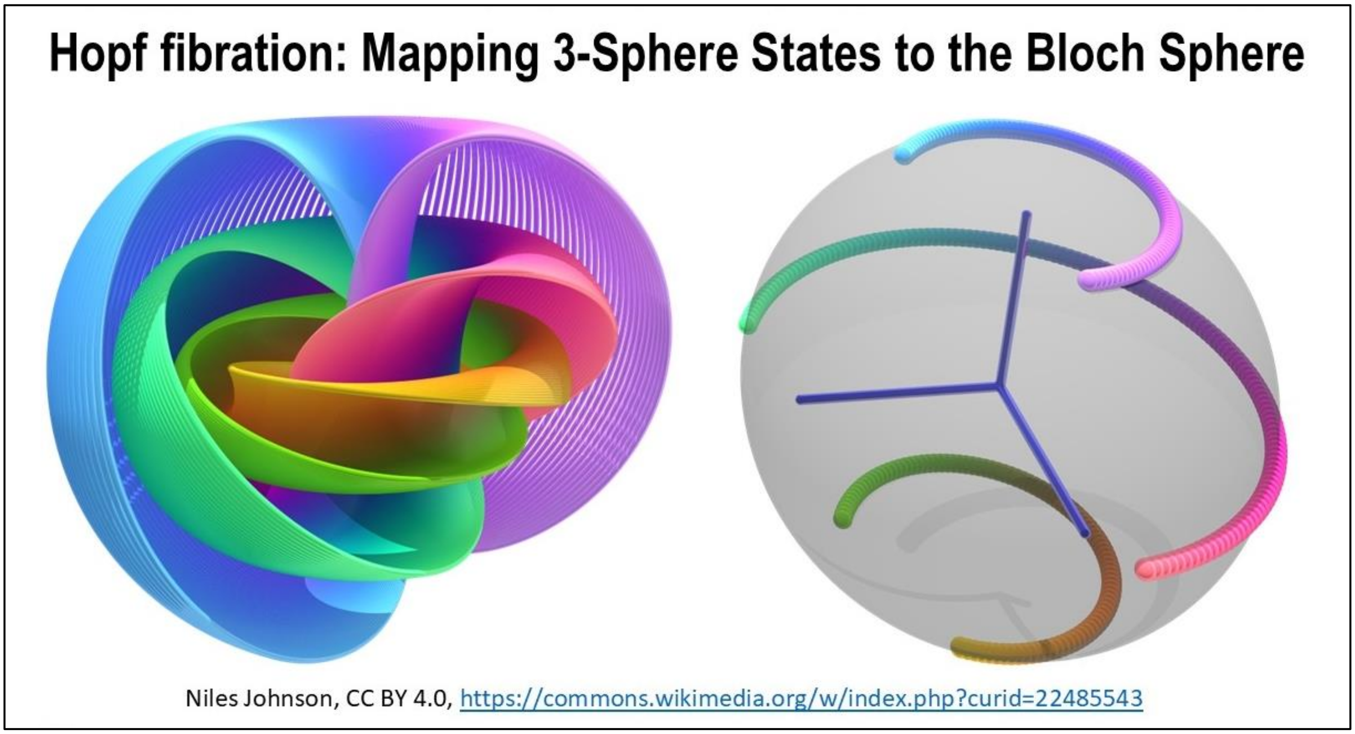
[56:42] Now, I'll go on a little tangent. Let's find a specific case, examine it a little bit, and see if that gives some insight. This is the *Quantum Computing* group, so you guys should all know Bloch spheres!

This is a standard way to represent a qubit in mathematics. [It has] wonderful properties. I love the way these things work in terms adding things together and you essentially move around little pathways on the sphere. So it gives a good idea [of how qubit operations work].

You have your stable states at the bottom and the top. I never figured out why the one state $|1\rangle$ is at the bottom. To me, it seems like the zero [state $|0\rangle$] [should be] at the bottom. I don't know why — that's the way it's been done. You'll see in a second why I think zero would make more sense at the bottom, but nonetheless, they put the zero state at the top.

[The $|0\rangle$ and $|1\rangle$ are] arbitrary state [labels]. I think everybody would agree that a qubit is completely symmetric between two states. There's no difference between [the $|0\rangle$ and $|1\rangle$] states; it's just an arbitrary bit of labeling.



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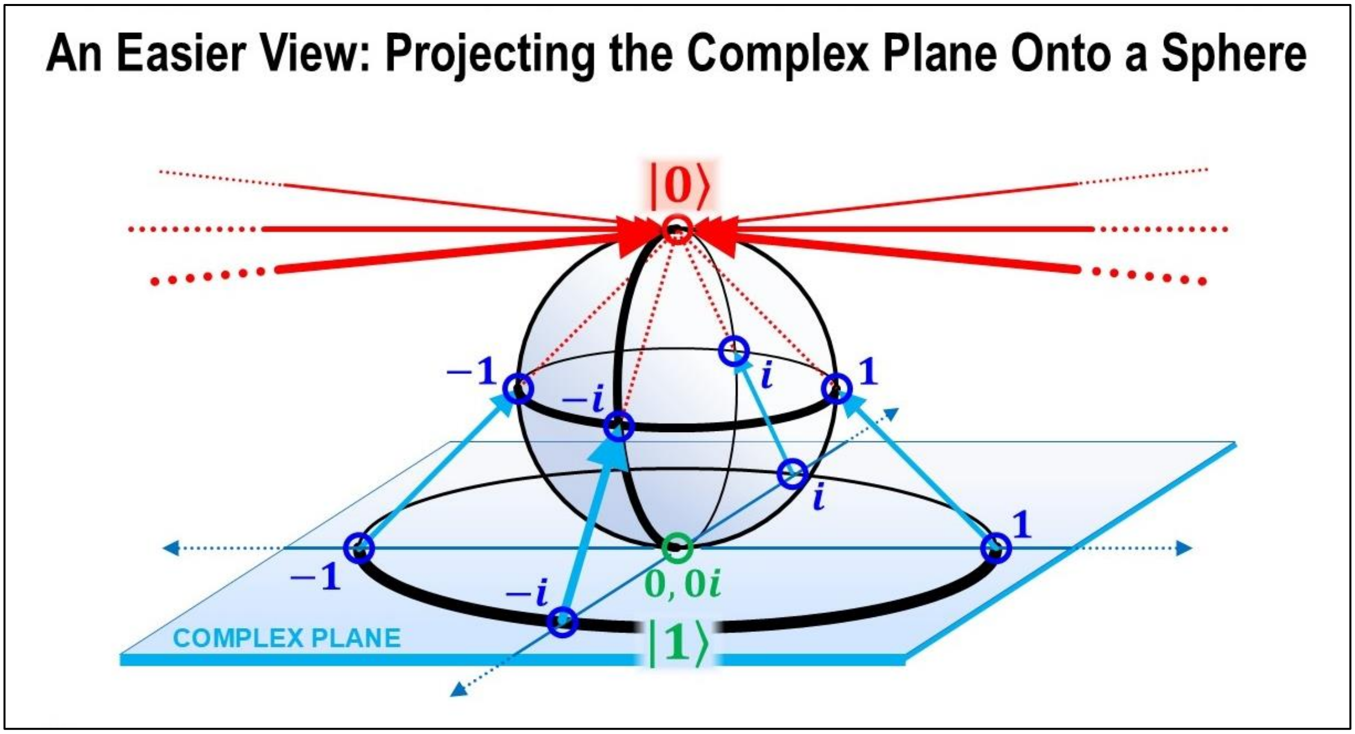
[57:34] Now, if you look at the deeper structure of that little simple Bloch sphere, this is what you get into [18]. So, if this looks a little confusing, that's because you're mapping four-dimensional spheres — which are actually called 3-spheres; how's that for confusing? — [into three-dimensional spheres, which are called 2-spheres].

(Four-dimensional spheres are called 3-spheres, three-dimensional spheres are called 2-spheres; you work with it. It can be a cause of considerable confusion. They [are named this way because they] focus on the surface as opposed to the to the embedding space.)

In any case, you have these mappings of a four-dimensional sphere that gives a full complex phase information into a three-dimensional sphere. That's where the Bloch sphere comes from. It's called a Hopf fibration… Hopf fibrations are marvelous work that was done back I think in [I think the] 1930s — a long time ago [19]. It was an interesting bit of topology.

[18] D. W. Lyons, "*An Elementary Introduction to the Hopf Fibration*," Mathematics magazine **76** (2), 87–98 (2003). https://arxiv.org/abs/2212.01642

[19] H. Hopf, *Über die Abbildungen der dreidimensionalen Sphäre auf die Kugelfläche*, Math. Ann. **104**, 637–665 (1931). First 2 pages (sample): https://link.springer.com/chapter/10.1007/978-3-662-25046-4_4



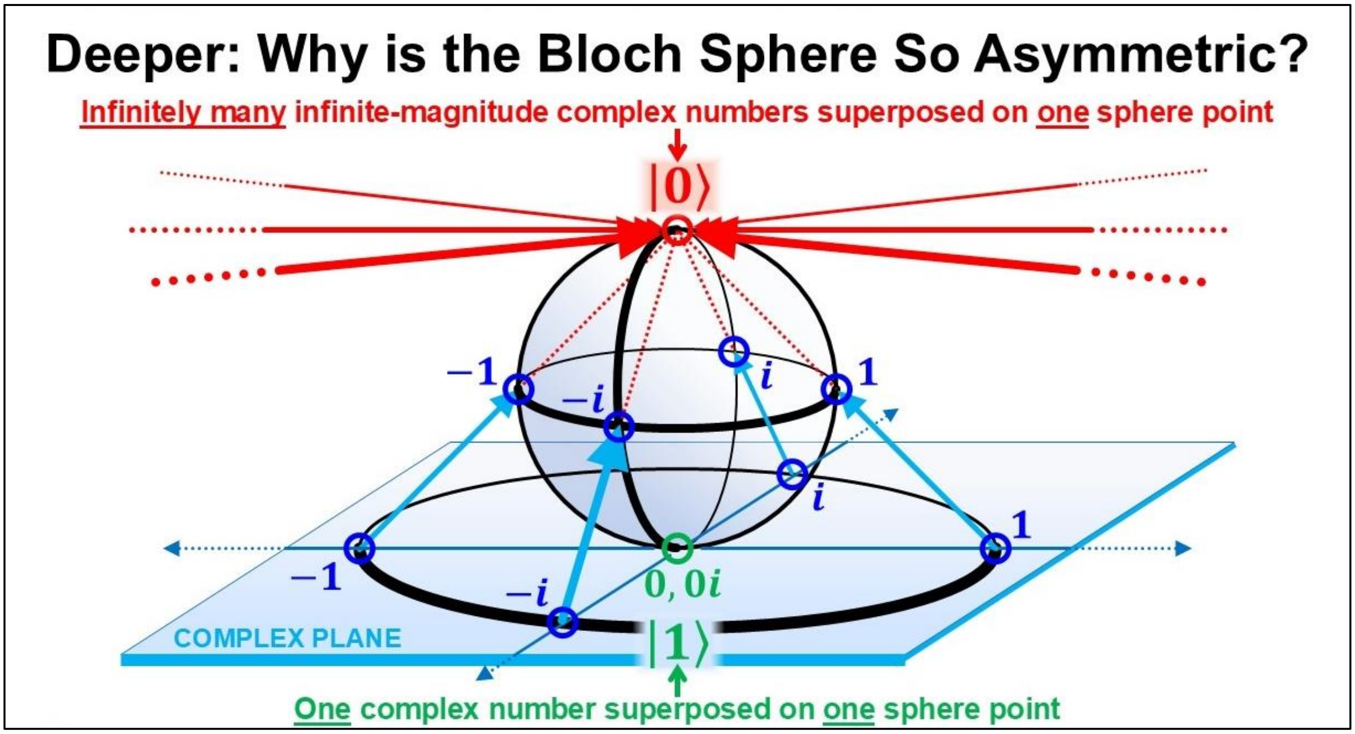
21

[58:30] Now, a simpler way of doing that same thing — [and] a figure you're more likely to have seen — is what's called a Reimann sphere [See Wikipedia]. This is a projective space, and I'm going to skip over this quickly. But you can see what's going on here. … You have a complex plane, just an ordinary complex plane, real and imaginary … [and] you take [every point on that complex plane] and project it towards that top point.

(Maybe that's why they call [the top point] zero, because that's where everybody's projecting to.)

So, as you project it, you capture where the number on the complex plane falls onto the sphere. When you stretch that out to infinity, … [the complex numbers] that are infinitely far away all wind up on the very top point [of the sphere], [while] the bottom [of the sphere] has only one point.

So, this gives you another way of understanding that whole messy thing about the Hopf fibration. [It's] a little bit easier way, I think at least conceptually. You can see what's going on: "Yeah, it's projecting into it."



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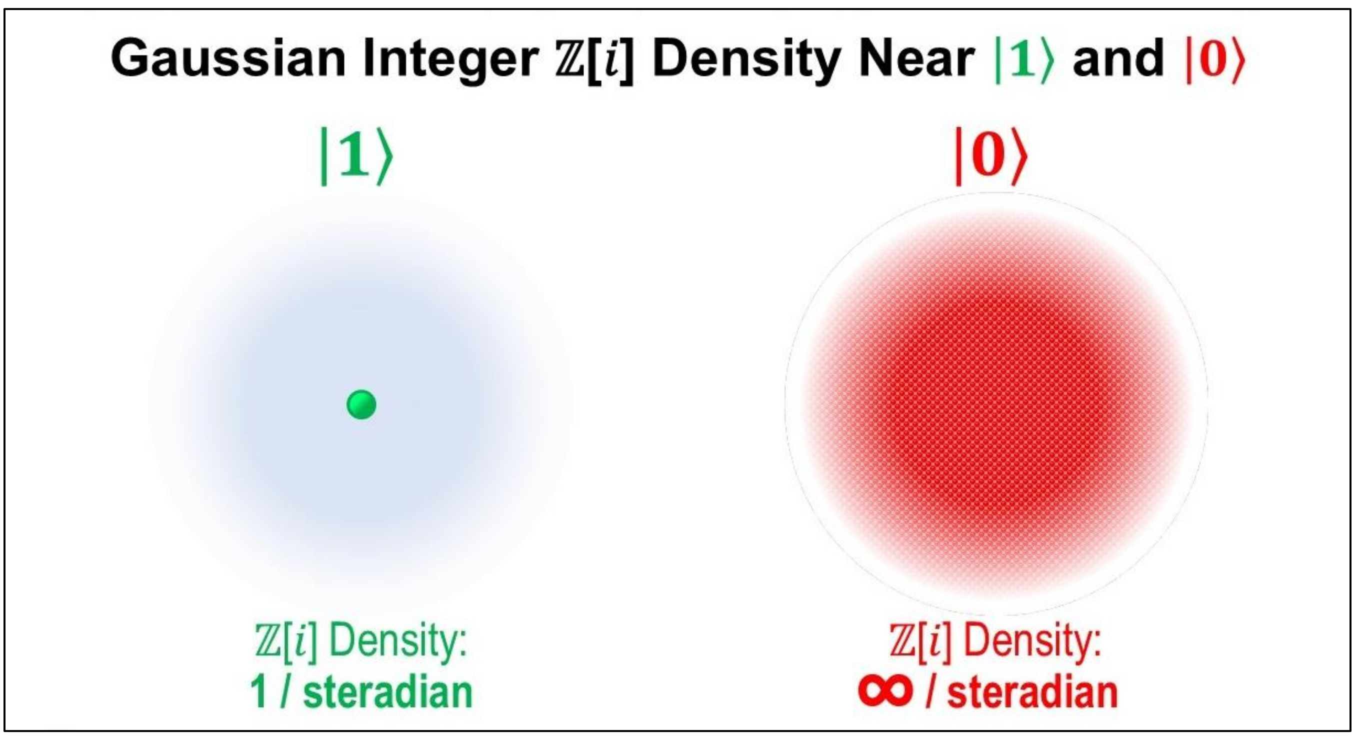
[59:43] But *why is it so asymmetric*?? Anytime you have a mathematical structure that is *highly* — in this case *infinitely*, literally, asymmetric — to represent a concept that you know is simple and small, you want to wonder, "Is that *really* the best way to represent that, or am I creating math noise? Am I creating chaotic bits in my mathematics that are representing something that doesn't really make any difference?

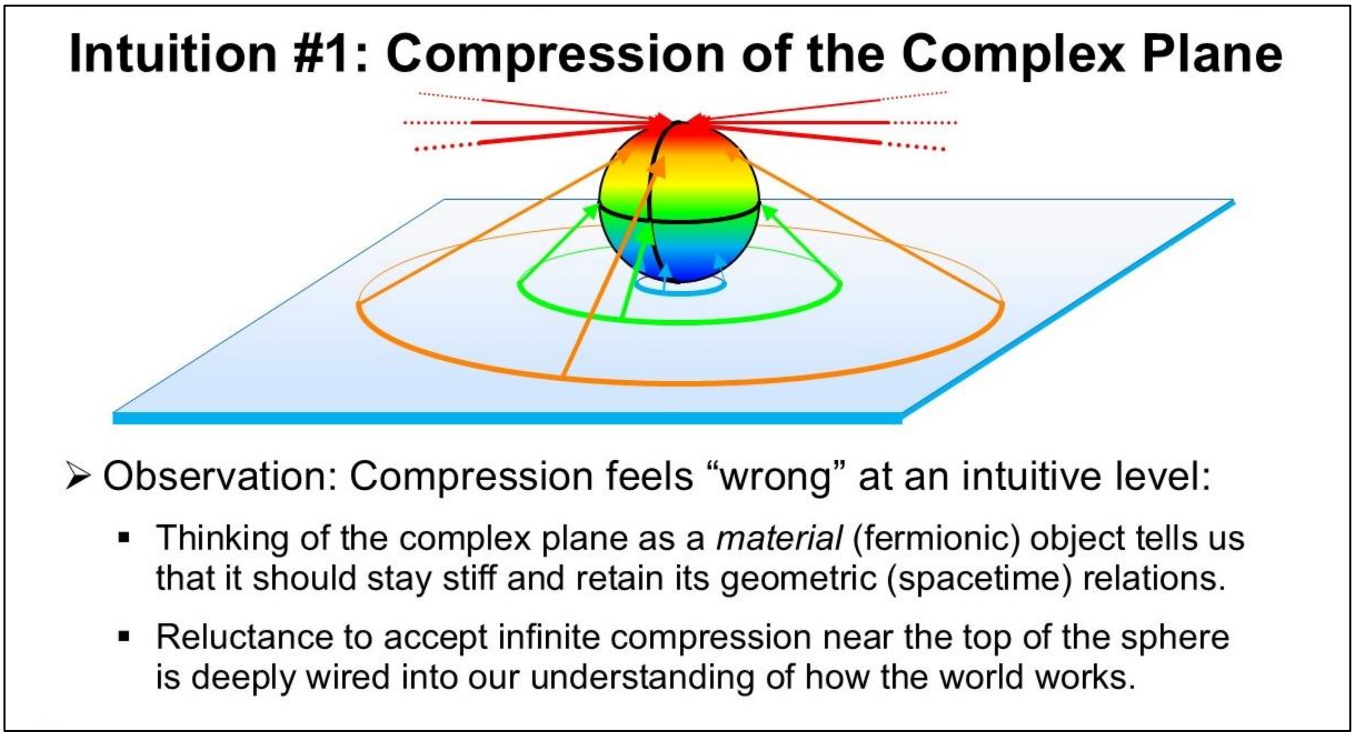


23

[1:00:12] And there *are* chaos bits — there is fairy dust — in this representation. One of the clearest ways to look at is to look at the [local] density of integers.

[Some background on complex number integers:] If you have an integer in complex numbers, they have a fancy name for it: It's called a "*Gaussian integer*," $\mathbb{Z}[i]$ — Z, square brackets, i. It just means that, you know, both the real imaginary components are integers. So, you just end up with this nice little checkerboard grid of the complex plane. That's all that means.

So, if you take the checkerboard grid of all the integers in the complex plane, and you project them onto the sides [of a sphere], you get exactly *one* [integer] per steradian — which is a three-dimensional version of an angle — you just get *one* at the bottom, *aaand*… you literally get an *infinity* of them at the *top!* You can't get much more asymmetric than that — that's really pushing the limit!



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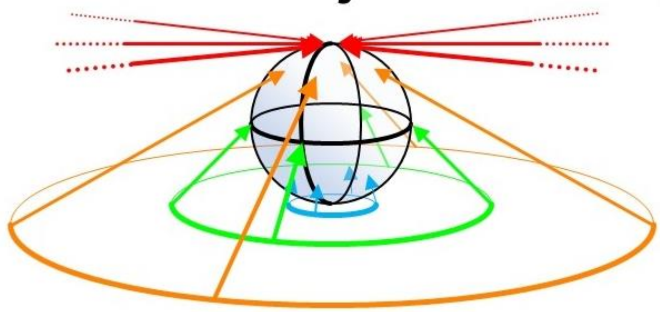
[1:01:09] So, let's look at this from two different ways. The first, Intuition #1, is compression of the complex plane. What if you just took the complex plane and *folded* it into a Bloch sphere? *It feels wrong*. You say, "Oh no… you can't *do* that! You're pulling things from infinity, you're stretching them, it's going to get red-hot at the top very quickly as you start *squeezing* everything together [there].

So, the idea of thinking of the complex plane as an actual physical entity just feels *wrong*. And that's interesting, because we like to think of planes as being *kind of* like physical objects? They're "kind of" solid, like a sheet, and they're kind of *there*. But in *this* case [of severe compression at the top], our minds rebel a little bit.

Intuition #2: Projection of Rays



- Observation: Ray projection "feels" like the right approach:
  - The name gives away the source of the intuition: Classical light.
  - It is easy to picture beams of light projecting states onto the sphere.
  - Question: Is this "boson" intuition truly better than the fermionic one?

25

[1:01:51] So, Intuition #2: This is why the terminology calls these *rays*, because this makes more sense. You say, "No, no, no — I'm not going to do that, I'm not going to *compress* the complex plane, I'm going to *map* it. I'm going to map the plane using the same procedure as before. So, I just create a copy of the number, and then I project it, and wherever it hits the sphere, I just write down that same number.

Now, here's the point I want to make: Both of the behaviors — both of these intuitions — are based on particle physics, because the sheet concept and the compression concept are based on fermions and how fermions behave, and the projective concept is based on how bosons behave — specifically, photons.

Now, when you're doing this kind of mathematics, and it is this abstract, it's good to recognize that you are *also* taking a *lot* of physics [ideas], and inserting them into the concept. When you try to do *either* of these [intuitions], you have problems.

Let's go back to [Intuition #2], for instance. Even though you're projecting, you're projecting using *classical* photons, *classical* [— that is, purely geometric —] light. Does that exist? No, it does not. Can you do infinite density at the top and record the information? No, you cannot. It assumes infinitely small atomicity and recording devices at the top. The mathematical abstraction may *seem* like it's a pure form of math, but, in fact, you're using and borrowing some *very* classical physics in order to get it.

One of the most classical features [that] you've assumed, for instance, is infinite light speed: How long does it take you to project from infinity? *Zero* time, because it's *math*. *Really?* Okay, what happens when you apply that in the physical world, where that *never* is true? You're going to get *noise*. Why? Because the physical world doesn't *work* that way. We *know* it doesn't work that way! If you project infinite [numbers of] photons onto one point, does the physical world work that way? No, it does not! Photons are quantum. They only [mark] real paths under certain precise conditions. Otherwise, they behave more like waves. So, there are some interesting issues that go on with using these ideas.

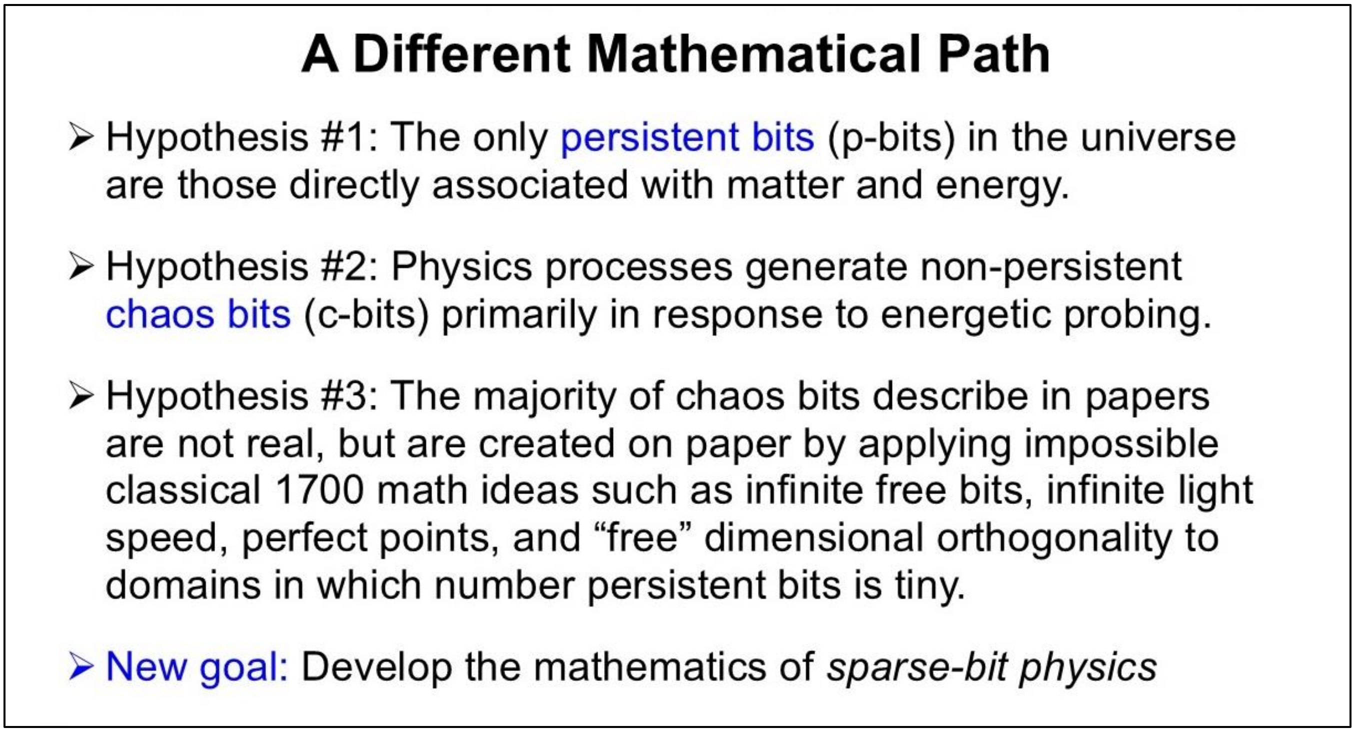
Are the Givens of Math Just Classical Physics?

- Any concept of geometric stiffness and angles requires familiarity with fermionic condensed matter physics.
- This idea is so critical to survival that it is wired into our brains.
- Real fermionic matter has *finite* (atomic or particle) bit density.
- From quantum physics, we now know classical (geometric) optics is an illusion that assumes point-like, bullet-like photons.
- Light projection also assumes *infinite many data receptors* at the $|0\rangle$ top of the Bloch sphere.
- Light projection also assumes *infinite light speed* for $|0\rangle$ rays.

26

[1:04:17] This idea of infinite light speed… that one, in particular, gets me. Mathematics is *full* of infinite light speeds, yet people never realize that. It's just a standard thing [to think], "It's *pure math*, so I don't have to [worry about mundane physics ideas like lightspeed].

Well, maybe you *do*! If you want to use your pure math on the *physical world* that *never, ever does that*, you have a potential for causing some disastrous dissonances that don't have *anything* to do with physics, but have *everything* to do with the set of assumptions that you put *into* [your mathematical model, such as the idea]. [Examples include the assumption] that you can project *all* this information into one spot, [or] that it doesn't matter if there's an *infinite* amount of information in an *infinitesimal* bit of space. You can *say* [things like] that, but can you actually *do* [things like] that, in terms of any real system that you're trying to model?



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[1:05:00] So, the path I’m suggesting on this, in terms of saying, “Where we could maybe make some progress?” on some areas that have been *really* stubborn for a long time now, is that we make a distinction between *persistent* bits like the ones I mentioned for a proton, [and *chaos* bits that arise only by adding energy to the system].

[Here’s a simple example:] What is a proton made of? Three quarks of two types. And once you know those numbers, *that’s* the persistent information that continually defines a proton.

So, you flip [the chromodynamic model] upside down and say, “*Really*… anything beyond [the three quarks of two types] is *generative*. It’s what happens when I put a lot of energy *into* the proton — [when] I *poke* it, and I *knead* it, and I *stick it with a gamma ray* — *then* I get these more complex behaviors. But to say that the persistent information there is more complex doesn’t really match what we see. The chaos bits are the generated part.

Here’s the bluntest part: Most of these [chaos-generating] ideas come from 1700s math that was *pre-quantum*, *pre-relativistic* and, frankly, *incredibly* naïve, because 1700s math just *assumed* that infinite information storage at any point in these hypothetical spaces is *just fine*. And yet, all the information bits that we see — that give persistent information — are [physically] complex [material] structures that require at least a couple fermions — and we don’t *know* any other way to do it, [that is, to store information].

So, if you [base] your [physics] mathematics on ideas that *cannot* map into the physical universe, you have to be careful.

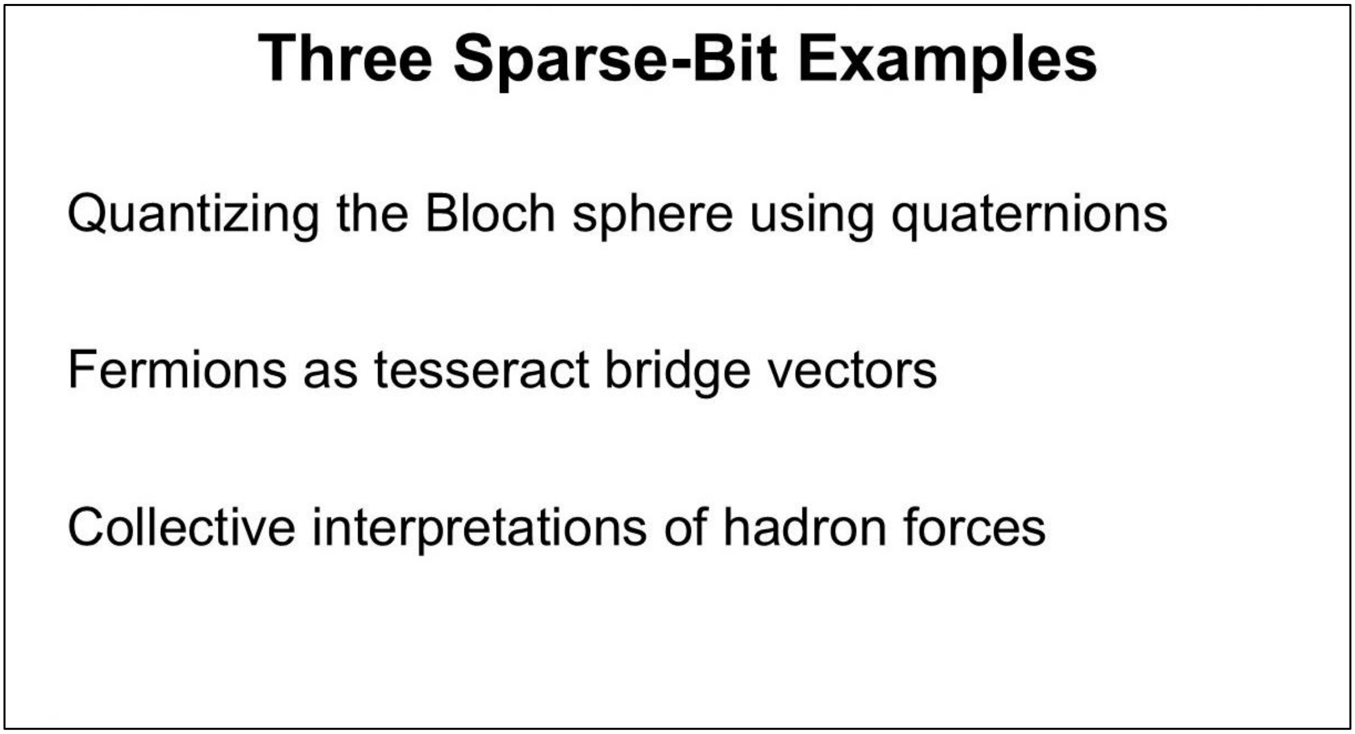
Another one I’ll point out is orthogonality. It is *extremely* common to talk about infinite numbers of dimensions — Hilbert spaces — and never consider the idea that there might be a *cost* for each dimension. [But] what if you flip that around and say that very dimension has a cost?

We actually have good physics information for saying that: It’s the orthogonality of sine waves. If you want to construct an orthogonal system, you need to get sine waves that are *long* enough, and *energetic* enough, and *persistent* enough that their frequencies can be distinguished, just like we do on radios.

That is actually the definition of orthogonality in physics, and it seems to apply even to our dimensional concepts. You can't just say that dimensionality orthogonality is *free* any more than you can say that information is free. You have to make some judgments if you want to model physical universe. If you're just doing an exercise and doing what do you want to do, that's a different thing.

But for mathematics that fits for physics we need to be a little sparser — and this is really the core of my suggestion: sparse bit physics, ones in which we say there's some limited number of bits those are the ones that count. Other things generate *from* those bits. So you wind up with this very thin lattice model of reality in which you have a very small number of persistent bits that can generate — collectively, especially — incredibly complex behaviors [and] very smooth-looking structures. But they are never really that [perfect]. It's always just an approximation.

The classical world wasn't really good on … how small atoms were and whether there was a limit there. But [if] we keep replicating [the implicit classical idea of infinitely small atoms and infinitely dense information], we have to be careful. Sparse-bit physics is a way of saying, *eh*, maybe we've got to look a little *closer* at what you can do.



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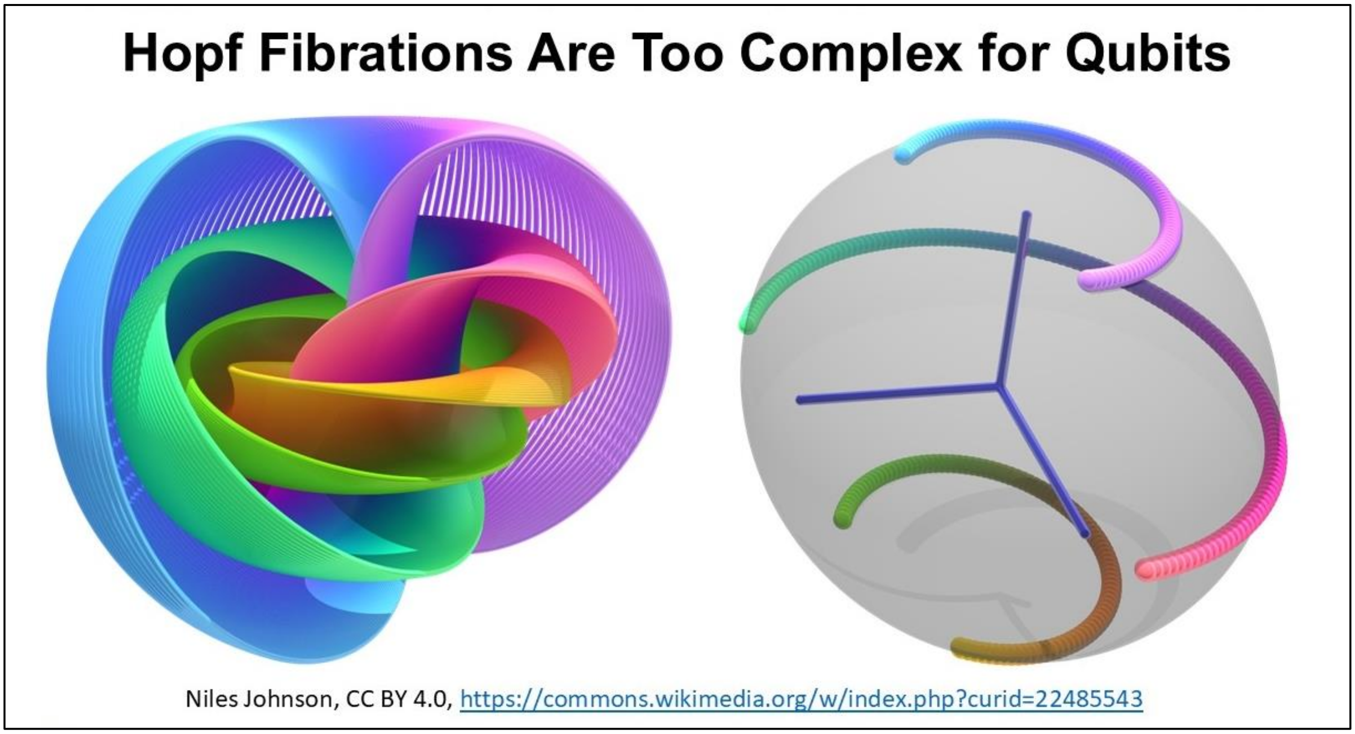
[1:08:17] Now, I'm going to give three examples, and then I'll wrap it up.



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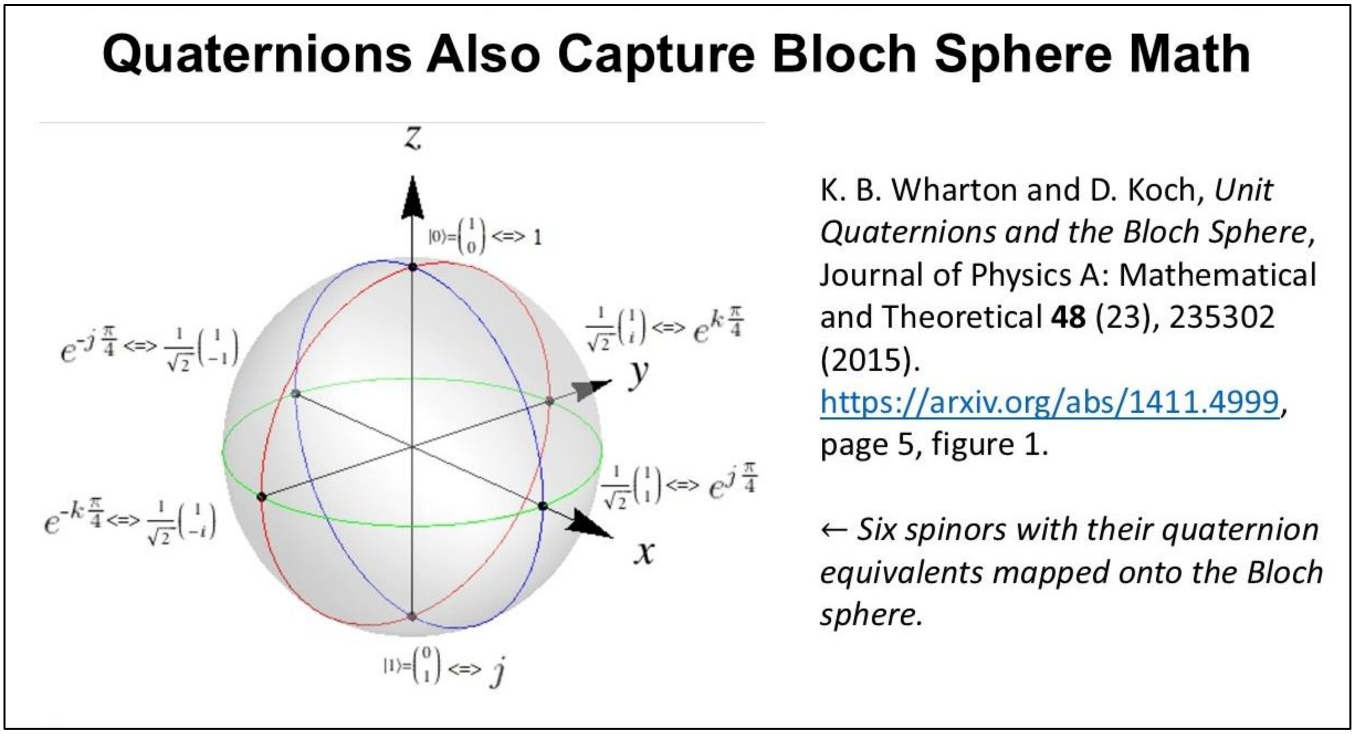
[1:08:22] [My first example is] quantizing the Bloch sphere. Again, this [Hopf fibration model] is *ridiculously too complex* for [representing something as simple and fundamental as] a *qubit!* I'm sorry [laughs], but I've have seen people… I had a conversation with someone [who] wanted to apply *relativistic curvature physics* on some of these structures, because they were so complex they could *do* that!

Now, *stop and think* about it! Are you applying those ideas to what a qubit really *is*, or just to the *model* of it? And if your model gets this complex, *yes*, you can start doing thing like *applying general relativity* to it because you've got this *enormous* fabric representing *one stupid qubit!* And that, maybe, is not the best way to *do* that, because *one little qubit* is still just *one little qubit*.

Maybe we should be focusing more on saying, "How do I get that one little qubit working?" and then on, "How do I get some models to do it?"



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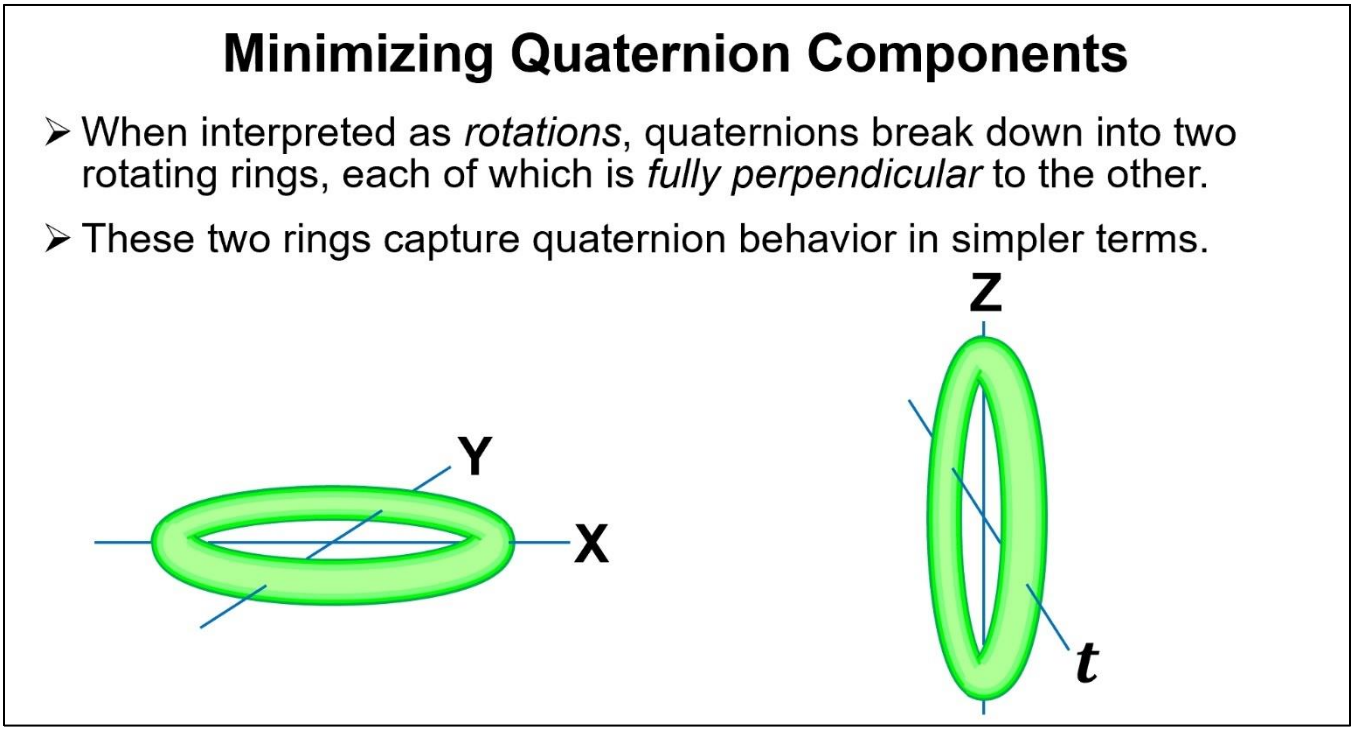
[1:09:15] And the nice thing is, there *are* alternatives to Bloch spheres. The approach I like most is to use quaternions. Slide 30 shows one example of how one might map quaternions onto a Bloch sphere and vice-versa.

Quaternions are the next level of something called the hypercomplex number series. The first member of this series are the complex numbers, which are two-dimensional and have one imaginary axis. Next in this series is the quaternions, which are four-dimensional numbers with three imaginary axes.

(There is a delightful story about how the great mathematician William Rowan Hamilton, who had been trying unsuccessfully for months to extend the concept of complex numbers into three-dimensional space, was walking with his wife over the Brougham (Broom) Bridge in Dublin. As he crossed the bridge, he suddenly saw the resolution to the difficulties that had been plaguing his attempt: Adding one more dimension. This was his creation of the fully self-consistent four-dimensional complex numbers called quaternions. He was so delighted with his insight that he wrote it down immediately engraved the equations defining quaternions on the bridge to make absolutely sure he did not lose the idea before getting home.)

Quaternions are a great technique for representing rotations in both three and four dimensions, and they only have need numbers. As it turns out, this means they also contain just enough data to serve the same purpose as Bloch spheres, except in a far more compact and local representation than is possible with Hopf fibrations that extend to infinity.



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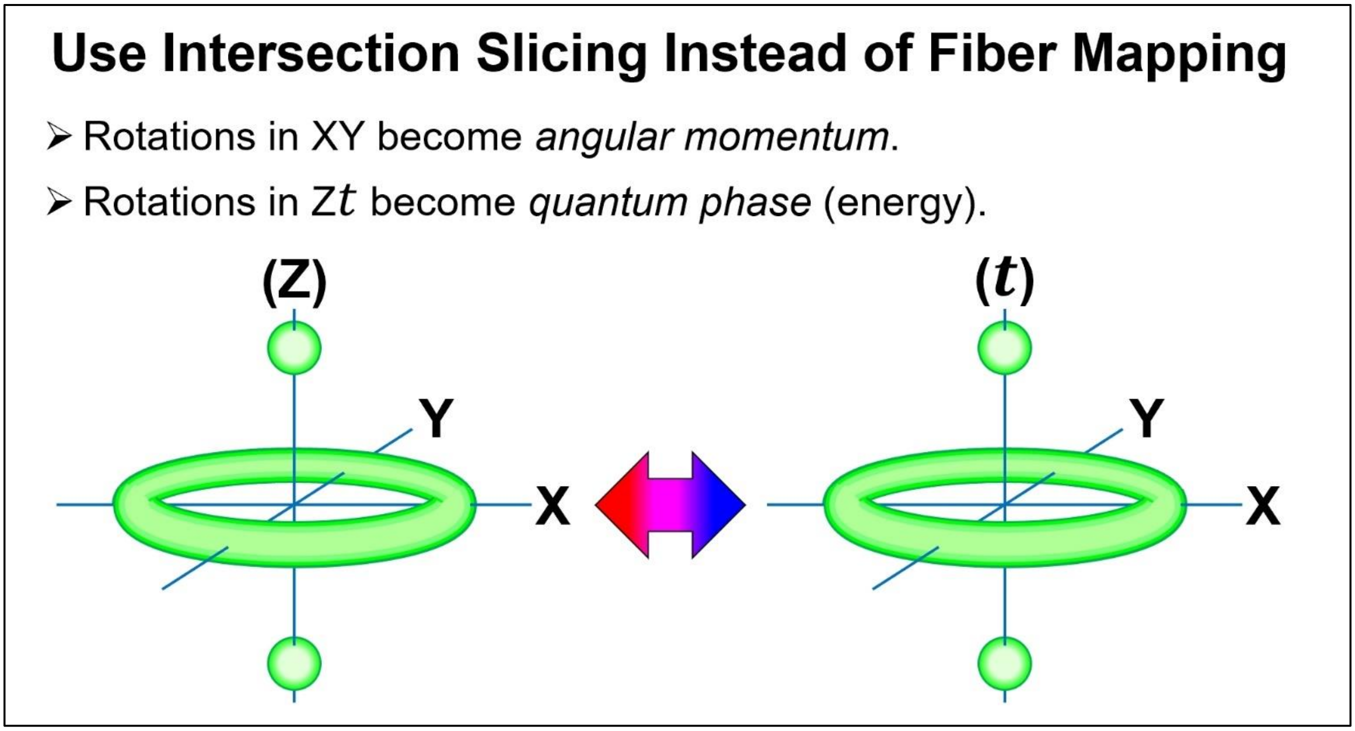
[1:10:01] I would suggest that you can simplify even more than that. Because you have a fourth dimension, quaternions allow you to do something not possible in three-dimensional space: Create *two* rotations that are fully orthogonal to each other and *do not intersect* as they rotate. Each of these two rotations can be clockwise or counterclockwise, giving a total of four unique paired rotation states per quaternion.

I've labeled these axes $X, Y, Z,$ and t, though in quaternion literature they are more commonly called $i, j, k,$ and the real axis. Taking the existence of two *orthogonal* rotations in quaternion space as a hint for where to find the persistent information, I can then interpret quaternion behavior as captured most compactly by two unit-radius rings XY and Zt, each of which can rotate clockwise or counterclockwise. I should mention that it's pretty common in physics to interpret time as an imaginary axis — an idea Minkowski first proposed — but in this case I'm flipping that convention and saying, "No, *time* is the real axis, and the three imaginary axes are the ones that correspond to three-dimensional space."



32

[1:10:41] Now here's the funny thing about higher-dimensional spaces: You can have two rings, both with rotations that are completely orthogonal to each other — without interfering with each other. You can't *do that* in three-dimensional space, so our brains have a little trouble wrapping around [the idea] [20]. But as you go into higher dimensions, you start rotating around larger-dimensional objects, [not just one-dimensional rotation axes]. So, if you take a *slice* of that — what I call an *intersection slice* [of the two quaternion rings rotating independently in four-dimensional space] — and put this four-dimensional object … into three-dimensional space in a certain orientation [that maximizes the visibility of the both loops,] what would [the result] look like [to us in three-dimensional space?]

The answer is you get you get two of these [rings-with-dots structures whose exact state depends on *when* you look at them]. [In both cases,] one of [the rings] shows [up as a complete ring], while … the other [ring] turns into two dots. [These dots are the only locations where you have] … intersections [of the second ring] with regular space…

[That is, if you tilt the four-dimensional pair of mutually rotating quaternion rings for maximum visibility in observer xyz space coordinates, you get one fully exposed ring and one mostly-hidden ring. The mostly-hidden ring — which still shares one dimension, Z, with the xyz space of the observer — shows up as two dots located above and below the center of the visible ring. The two dots represent the points in observer space where the unobservable fourth dimension of the hidden ring, labeled here as time t, shrinks to zero and thus allows the Z part of the mostly hidden ring to become visible.]

[Furthermore, applying the hypothesis that these rotating rings represent *persistent* information, including phase, then the visible state of the hidden ring cannot be fully stable. The visible dots of the hidden ring must instead alternate between Z-like persistent information and t-like persistent information, as shown in the labels. If the persistent information is "space-like," the mostly-hidden loop will exhibit a cycling disappearance or jitter of that quantity. Conversely, if the persistent information is "time-like" in character, the mostly-hidden ring should exhibit a limited and exceptionally short-range version of time (e.g., think of quark containment in protons and neutrons). This interpretation suggests that the deeper reason for confinement of quarks is that they use a definition of time that cannot exist at large scales, leaving them confined within the 10^{-15} m diameter (1 femtometer) of protons.]

[For another] example of where you can go with extremely simplified [sparse bit] physics assumptions [based on perpendicular quaternion rotations], if you take XY for angular momentum and take Zt to be energy — quantum phase — you can produce some very interesting models.

One consequence of using this model that I found interesting was [when] I used this model to come up with what's called a dual-universe model. It was actually a very simple exercise of just playing around with this small number of bits [21]. [Years later], I found out that [Latham] Boyle and [Neil] Turok had [later] done their own version of [a dual universe model] [22], and I got into a conversation with Latham Boyle.

I think were both a little confused. He [probably] thought I had gone through some extremely complicated mathematical analysis similar to what they [had done] to come up with [their dual universe model] — [an analysis] with continuity functions — and all I had done was play with quaternions. And yet, I was seeing some extremely similar things to what they were seeing. So, without [necessarily] saying that [my dual-universe theory] is a *good* theory, it's [definitely] an *interesting* way to look at things — [one] where you [use] very sparse bits [to make predictions similar to those of a far more complicated real-continuity analysis effort.]

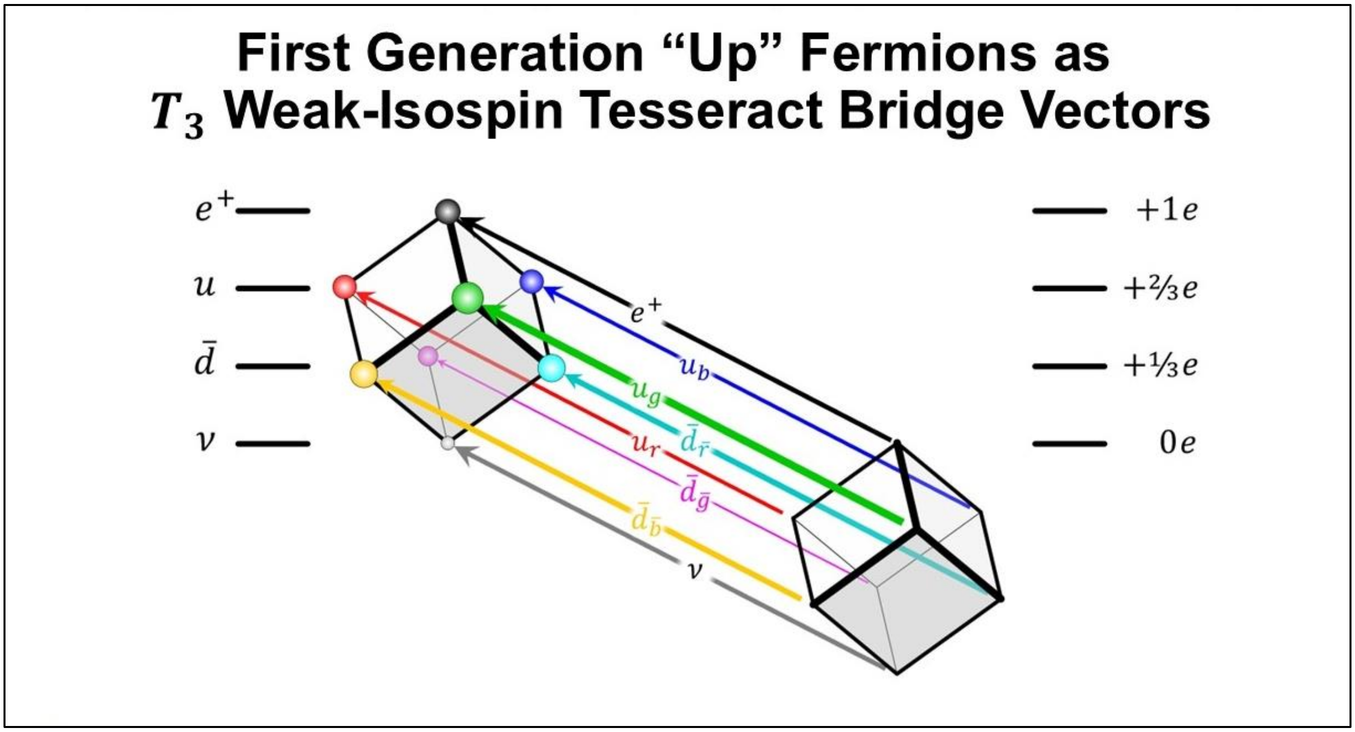
[Also,] if you look at the structure here — the fact that you have a [mostly hidden] loop that is jittering between the Z-axis and the t-axis, [with parts of the hidden loop showing up cyclically at two locations along what] we usually think of the axis of spin — [that potentially] is an interesting statement about quantum uncertainty.
[Why? Because] you're saying that you've got something hidden that you can't quite see, and it's jittering back and forth between our usual definitions of time [and space].

So, these [sparse bit analysis] paths give some interesting [new] ways to think of problems.

[20] R. Feynman, *Why is torque a vector*, Feynman Lectures on Physics, Vol. I, Sec. 20-1, Para. 12 [Jan. 12] (1962). https://www.feynmanlectures.caltech.edu/I_20.html#Ch20-S1-p12. "Why is torque a vector? It is a miracle of good luck that we can associate a single axis with a plane, and therefore that we can associate a vector with the torque; it is a special property of three-dimensional space. In two dimensions, the torque is an ordinary scalar, and there need be no direction associated with it. In three dimensions, it is a vector. If we had four dimensions, we would be in great difficulty, because (if we had time, for example, as the fourth dimension) we would not only have planes like xy, yz, and zx, we would also have tx-, ty-, and tz-planes. There would be six of them, and one cannot represent six quantities as one vector in four dimensions."

[21] T. Bollinger, *4D Quantum Dynamics* [Origin of the negative-mass dual-universe concept]," Apabistia SFL, **03**, 200709141857 [Sep. 14] (2007). https://sarxiv.org/sfl.03.2007-09-14.1857.pdf

[22] L. Boyle, K. Finn, and N. Turok, *CPT-Symmetric Universe*, Physical Review Letters **121** (25), 251301 (2018). https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.121.251301



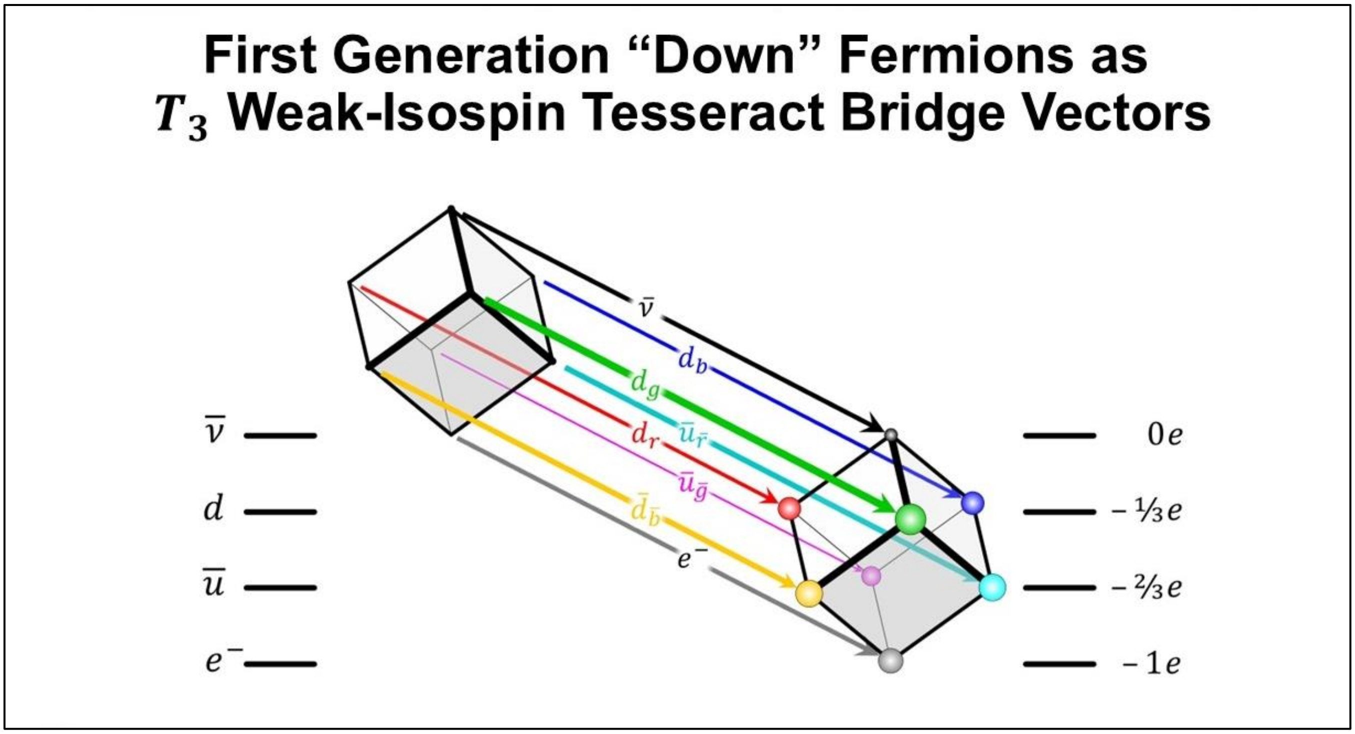
33

[1:12:57] Here's another one. This is one I did a full paper on a little while back [23].

You can model all the particles of the first generation of fermions as a *tesseract* [— that is, as the four-dimensional equivalent of three-dimensional cube]. Not only does it work, it works *really well*. You end up with two sets. You have the *up* fermions, which go *up*, literally, in terms of charge, but also in terms of some of the properties they have, like weak isospin.

And yes, I'm getting deep into some terminology: These are T3 weak isospin tesseract bridge vectors. So, you actually represent them as the two *opposite sides* of a tesseract, because this *is* a tesseract. I know it looks like two cubes with lines between them, but that's a full tesseract I've drawn there, and the vectors that bridge them are the weak force. So, you wind up with the weak force not just being important, but actually more fundamental. It's part of what defines what these [fermions] are.

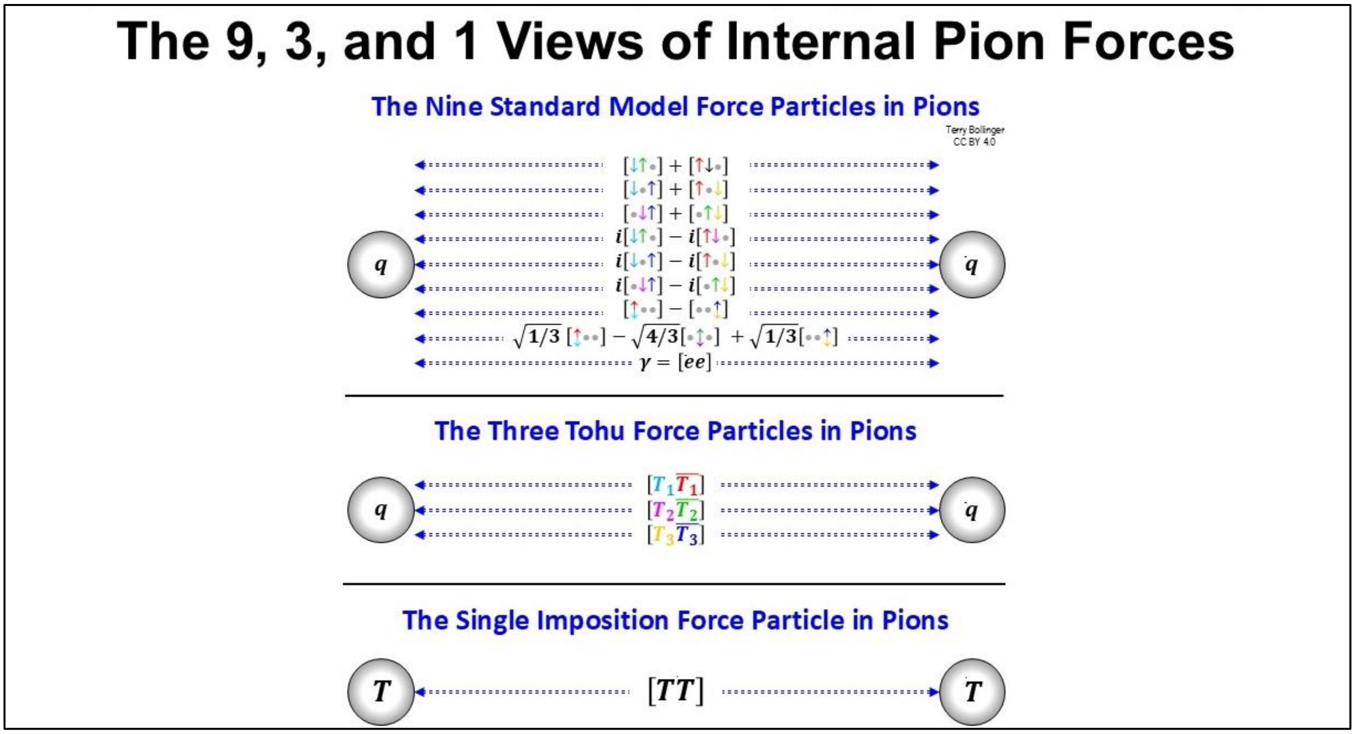
[23] T. Bollinger, *How to Make Cubes and Fundamental Particles*, Apabistia Notes **2025**, 01301130 [Jan. 30] (2025). https://sarxiv.org/apa.2025-01-30.1130.pdf



34

[1:13:55] Going in the opposite direction, you get the *down* fermions. You get a *different* set of these things. This includes both fermions and anti-fermions, but again: A simple structure that is surprisingly robust. I did not come up this cube originally — *Glashow* was the one who came up that cube — which, again, surprised me greatly. I *thought* I had come up with it. But then I did a literature search, and I found out nope, nope… this had been represented back in 1979 [24]!

[24] S. L. Glashow, *The Future of Elementary Particle Physics* [HUTP-79/A059]," Harvard University Preprints, Jul. 1979. https://inspirehep.net/literature/144466. See page 29 (PDF page 15).



35

[1:14:22] Now, [here is] another example of [chaos] collapsing, the idea that [if you remove generated noise bits, you get a simpler and more physically accurate model of how the system behaves in its unexcited rest state.] The top [particle in the figure] is called a pion, [and it] has a very complicated set of [internal] interactions with gluons [that bind a quark to an anti-quark].

So, the collapse idea — the idea that you need to focus on what are the *persistent* bits — collapses [the internal gluon interactions] down [in] two levels. … Using the rishon terminology [of Haim Harari and by Michael Shupe, who [independently] came up with some ideas for organizing quarks,] [25][26] first you collapse [the complicated gluon interactions] down to three different particle [interactions].

But then you [collapse it further, all the way down to] one [interaction]: You say, no, [there's basically just *one* interaction going on, and all the higher, more complex [interactions] are the ones you get when you *poke* [that single interaction] — when you add external [energy and] noise to that [much simpler single interaction].

So, again, it's a generative approach as opposed to a superposition approach. It's not saying superposition is the *wrong* way to do it, [because superposition works]. The trouble the superposition [is] that you're going get less noise if you focus a little more on where it's coming from.

[25] H. Harari, *A schematic model of quarks and leptons*, Physics Letters B **86** (1), 83–86 (1979). https://inspirehep.net/files/ba8aff83b7524d346172cc5801dd9046

[26] M. A. Shupe, *A composite model of leptons and quarks*, Physics Letters B **86** (1), 87–92 (1979). Abstract and figures only: https://www.semanticscholar.org/paper/A-composite-model-of-leptons-and-quarks-Shupe/784d5ac818cdb8f40464c3be4cf477178b3ec86b

Summary

- Physics is simpler than it seems, but also a lot stranger because space and time become properties of matter.
- Much of the complexity in current theory is c-bit noise created by using 1700s continuum math idealizations of classical physics in domains where only create non-physical noise.
- The goal of physics should be to create elegant, extremely sparce models in which persistent bits are rare and precious.
- Understanding space and time better are critical.
- March 15: The missing parameter that makes space fractal.

36

[1:15:32] So, summary:

I would say physics is actually [simpler, but also stranger, than we think]. People sometimes say physics is so complex that we will never understand it for a thousand years. I've heard good physicists say that. I just *don't buy that*! If that was true, how could Einstein have ever done what he did? How could Maxwell have ever done what he did? They didn't have all this enormous detail that, and yet they were able to come out with *very* good theories!

So, I don't buy that.

[Louis] de Broglie: He came up with his famous wave particle duality *literally* by poking around on an algebraic equation with three variables, and just *looking* at it… *staring* at it… for a *long time!* And eventually, he said, "Oh well, you know… this kind of seems to mean *this*."

Dirac! When he did his work, same thing: He just kept *looking at* a simple equation, saying, "There's got to be some way to do this." And it worked out.

So, I don't *buy* the idea that the universe is *infinitely complex*. I think that's the chaos bits talking to us.

Complexity of current theory? I think we *really* need to examine our understanding that mathematics is fundamental when the math is based *heavily* on physics — which it *is*. Planes! Right angles! Distances! All these things are taken from physics. Ray projections! These are mixes of bosonic and fermionic physics that we have not *acknowledged* in our mathematics. Our mathematics need to get more "quantum aware" — and by that, I *don't* mean just keep modeling quantum mechanics using the same exact models that have these problems. We need to think a little bit about whether we need a mathematics that is, *itself*, more uncertain.

So, I would say that the goal to make progress in physics is to create *elegant* but *extremely sparse* models. I gave some partial examples of just what I mean by that, with those three early [examples I covered in these slides]. I'm saying: Focus on this idea of *persistent* bits. Which are the ones that keep *hanging around*, stubbornly, and don't want to give up? Why do these [persistent bits] create these other more complex structures?

Mixed in with this is the idea that we *really* need to understand space and time better. Abandoning special relativity [only] because lattices are good [for performing calculations], but they are [also] *single inertial frame* — that *doesn't cut it*. You can't just *abandon* special relativity! You have to acknowledge [there is] something very weird about how space works, and we're not quite getting there.

At talk I'm giving next month — a month from now, on [March] 15th — I'll examine that a little bit closer. As you can see, I'm very much a fan of Einstein. But he also *missed* a parameter, and I can show you *extremely specifically* which parameter he missed, why he missed it, and why the consequences are fascinating, because what looks like smooth spacetime turns *fractal*. So, you get spacetime that's broken up by the material objects inside of it. I don't know what the full implications of that will be, but I think there's a missing parameter, and we need to look at that.

And, with that, I am done.

Questions and Answers from after the presentation:

[1:18:58] Helen Ma (HM): Thank you for the great talk and if you any questions please feel free to ask.

[1:19:09] Questioner 1 (Q1): Thanks very much, Terry. It's quite interesting and a bit complicated for some of us. I just want that, at the beginning of your presentation, you talk about bits and information, and you didn't quite come out with a definition, actually, of what information is. So, I wonder if by information, you mean bits — and then, if you mean bits, [do] you mean spins, effectively? Isn't it? Can you comment on that, please?

[1:19:47] Terry Bollinger (TB): When I gave the definition of information, I [was] specifically talking about bits, and actual physical constructs of bits. In the examples I gave earlier, the simplest bit I can think of would be an electron in a magnetic field … presumably created by another particle, such as a proton. I would say that's an example of a two-state device that gives bits that persist over time.

[Thus] I am using a specific definition of bits in which I'm attaching them to material objects, and saying that *only* these versions of bits this property of persistence. Persistence just means they're historical — that you can actually create a history. Of course, without a history, you can't create a timeline, so there's an intimate relationship with how we define time.

Those are a remarkable and *strange* set of properties. I think because we're swimming in the fishbowl all the time — we *have* persistence, we *exist*, we *stay* here, we're *stable* — we don't realize just how remarkable, how absolutely *remarkable*, that is. Those [properties] are the definition of bits.

So, yes, I'm trying to make bits into actual material objects. That's why I went through the whole space argument saying, "Can you have bits in space that allow you to actually store data?" I think most people say the answer is *no* — that even if you assume space is very complex, you can't use it as a storage device. You can send a wave through it, but then you're cheating because you just added energy. As soon as you add energy, the energy carries information, not the space.

So empty space is *empty*, and one of the reasons why special relativity works is because the fact that it's empty means everybody sees the same thing: *nothing*. That's very heretical in terms of quantum field theory interpretation, yet Casimir was the one who said it. You can't really have quantum field theory and those other properties at the same time.

Addendum: After some thought, here is a more direct to your question about my definition of bits and information.

I am distinguishing between two concepts: *Persistence*, which does not necessarily take the sharp binary form of a bit, and *information*, which *approximates* absolute binary certainty through clever combinations of at least two persistent entities.

Persistence seems to require spin, with massive spin ½ fermions being absolutely essential for building a universe capable of meaningful definition of space and time. This is because massive fermions (not neutrinos) can move *only* in time while also permitting space-like separations.

A *bit* is not the same because persistence alone is analog. An electron spinning in space has persistence, but does not become a *bit* until it sets up a "second level spin" — an *orbital* spin — with another persistent particle, the proton. The simplest bit then becomes the ortho and para spin states of ground-state hydrogen atoms.

All bits are approximate because of decay instabilities. The fact that our universe permits extraordinarily stable bits is why we exist, since living organism require at least some persistent "either-or" information to exist (e.g., in DNA) to build up additional complexity over time.

[1:22:09] Q1: How do you reconcile with the string theories as you go to small and smaller particles or almost non-existent particles?

[1:22:22] TB: Good question. I avoided string therapy because I didn't want to get into that whole thing. The figure [on Slide 10] where I showed you the experimental consequences of the 2020 gamma ray observations experimentally [14] eliminated not only geons and Wheeler's quantum froth, but they also completely eliminated all versions of string theory. So, if you want to go by the experimental results, you can't have string theory because it doesn't match observed reality. The scale of the strings is *far* too large. They're like elephants trying to thread a needle. … They're the same scale as the Planck constants that 't Hooft talked about.

That's not a popular statement because everybody just *loves* string theory and the vibrations. There's a *fascinating* history about where string theory came from, and it's just an *incredible* sequence. But the *real* string theory is the *hadronic* string theory. That was the name of it … *string theory* [27]. It was how the quarks are bound together by the color force. The color forces are the strings — they are the universe's *smallest* strings.

But then it got *borrowed* and scaled down *20 orders of magnitude* to create "super" string theory [28][29], which has *never* been proven. [In sharp contrast,] hadronic string is *incredibly* well-proven. It's just quark orbitals!

So, they scaled it down, made a hypothesis, and *abandoned* all particles. So, not surprisingly, ["super" string theory] doesn't match [any of this]. So, none of this [sparse bits idea] is compatible with string theory in *any* fashion, because … again, string theory has been experimentally disproven, even if it is not widely acknowledged. If you've got *an entire department* based on string theory, what are you going to *do*? Do you say, "Oh yeah, there's an experiment that just told us our *whole department* doesn't make any sense." That's a tough one. I acknowledge it's a tough one, but you can't do it.

[27] L. Susskind, *Harmonic-Oscillator Analogy for the Veneziano Model*, Physical Review Letters **23** (10), 545 (1969). https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.23.545. Last two words: "rubber band."

[28] R. C. Slansky, *Regge trajectories and the origin of the superstring hypothesis* [in 'Toward a Unified Theory: an essay on the role of supergravity in the search for unification'], Particle Physics: A Los Alamos Primer, p. 92, 1988. Superstring hypothesis summary begins on bottom left paragraph on page 92. https://www.google.com/books/edition/Particle_Physics/55M4AAAAIAAJ?gbpv=1&pg=PA92

[29] J. Scherk and J. H. Schwarz, *Dual Models for Non-Hadrons*, Nuclear Physics B **81** (1), 118–144 (1974). https://books.google.com/books?id=CF4GCwAAQBAJ&pg=PA191

[1:24:19] Q1: Yes, but mathematically — well, I don't want to dwell on this, but string theory, to some extent, has shown some resilience mathematically. Experimentally, you might be right that they haven't proven … the theory. But going back to this question of information: Suppose that [string theory] is correct. Then as you go [down] to the string level, [do] you mean that there is *no* information? That [strings] cannot preserve information?

[1:24:53] TB: Could you please say the question again?

[1:24:55] Q1: I was saying, let's imagine that the string theory is correct. As you go down to this string level — to the lowest levels of vibrations of this energy, when it you reach that level — it means would that you would *not* be able to have information, based on your definition that requires fermions.

[1:25:26] TB: Well, actually, if you assume string theory is correct, you have *infinite* information because each string *is* a storage device. That's where that's there's a contrast in what I'm saying about sparse bits. … Think about what a string *is*. First of all, it has [an] infinitesimally small diameter. It has finite length, which often they'll say, "Well, that's why it's *not* infinitely energetic!" But *no*, [that's not correct because] the infinitesimal *diameter* [of the string] gives it infinite energy, infinite precision, infinite energy, and infinite information content.

So, every string captures *any* amount of information you might want. So, if you assume string theory is right, the [string] is absolutely *saturated* with real, causal information. But this is also what causes a lot of the problems with that. And again, I can't help but go back to it: The idea of these strings, in every version I've seen, is *incompatible* with experimental results. Everything — quantum loop gravity, the [Wheeler spacetime] froth, the strings — all of those contradict Lorentz invariance seen at that scale, because we don't *see* any structure down there. By a factor of [about] 2000 — that's not a small margin!

So, strings have all the properties of classical matter. They have inertia, they have ability to revolve, they have … what we would call chemical cohesion. Creating a string is very *difficult* in the physical world. So [what happens] is all these properties are just… *given* to particle physics strings. Just *attributed* to them! They have cohesion, they have length, they have inertia, [and so forth]. Once you have all those things [built in as *givens*], you *have* to get regular physics popping out of them at different levels. There's no other [possibility, since] you already have most of classical physics *in* them. So, I would leave it at that.

[1:27:28] Q1: That's fine. Thank you, thank you for your answers. Bye.

[1:27:32] Q2: Terry, I really like the way you talk and the way you have analogies. It fits my thinking very well, and I appreciate that and my question is based on this information energy paradigm that you have. What do you see as the possible options for a quantum random access memory — a QRAM — system? Is it possible to have [such a device]? Or is it something you see to possibly being developed in a certain medium? What are your views on that?

[1:28:07] TB: For quantum *information* [— storage and retrieval of data —] one thing that I'm suggesting is that the actual storage information is, again, very limited. It literally goes back to the standard estimates that you get from mass energy that [only] allow you to have only so much information.

In terms of quantum *computing*, I think there are some *really* interesting issues [and potentials] here, because when you take the sparse bit approach, many of the most interesting behaviors coming out of, for instance, molecular quantum computing — which is a real thing; chemical biochemical molecules seem able to compute results in ways that we don't quite get [30][31][12][13] — they do it extremely efficiency, very often, and at extremely low cost — and they're not accidental. They're part of the design features [of, for example, Hopfield's biomolecules].

Understanding how that works will depend in part, I think, on getting rid of some of the [chaos bit] noise parts.

So, I don't think we can have real big increase in storage, but I think quantum computation could get very interesting if we take a sparse approach. … We [may] find out quantum computation [at room temperature] is not as hard as we thought it was for certain situations, because the universe does it *all the time!* … [After all], none of us would be alive and sitting here if [biomolecules in each of our cells] weren't doing trillions [or] quadrillions of quantum-ish calculations [on] how to configure themselves *all the time*. We don't have a good grasp on that. Manin talked about that, [but] immediately switched to computers — which is hilarious, because he *nailed* it [when he] said all these molecules were so efficient — [but in the next paragraph he said,] "Let's use computers instead!" It's a hilarious juxtaposition of paragraphs.

[In any case,] we're missing something [big] there, and I think it's a good opportunity.

[1:29:57] Q2: Thank you.

[30] J. J. Hopfield, *Electron Transfer Between Biological Molecules by Thermally Activated Tunneling*, Proceedings of the National Academy of Sciences **71** (9), 3640–3644, [Sep.] (1974). https://www.pnas.org/doi/abs/10.1073/pnas.71.9.3640

[31] J. J. Hopfield, *Kinetic Proofreading: A New Mechanism for Reducing Errors in Biosynthetic Processes Requiring High Specificity*, Proceedings of the National Academy of Sciences **71** (10), 4135–4139 [Oct.] (1974). https://www.pnas.org/doi/abs/10.1073/pnas.71.10.4135

[1:30:07] HM: There's a comment [and question] from a participant. The comment is, "Casmir in the [water waves] analogy requires an energy source. The big question is, 'What is this source?' In [the Bohmian interpretation of quantum] physics, [the mass-proportional quantum phase frequency of an] electron [behaves like a clock, and its oscillations should] create a [ripple in the] pilot wave [of the electron]. [Could such mass-frequency-related pilot wave ripples] be sufficient [to act as the source of the wave pressures in the Casimir effect?]"

[1:30:26] TB: Oh [By which I meant: "That's a really interesting question since your idea is to attach the waves that cause the Casimir effect to material particles with finite energies. However, I'm not sure how well I understood the question, or how to answer it, because I'm not accustomed to thinking in terms of pilot waves, let alone in terms of this new idea of pilot wave *dynamics* that I think you are proposing. So, my brain is trying to translate your question into something more like the long-range bonding by residual forces I think of for the Casimir effect."]

[My first response is to go back to my] slide about the Casmir incineration problem [and why it argues for some attachment to the Casimir wave energy to the finite energies of physical particles, as I believe the questioner is suggesting]. That's actually what I was saying: That if you take the same [unconstrained-by-matter] quantum forces that Feynman talked about, saying, "This doesn't seem right [to have] so much energy in one cubic centimeter of space." [4] … If you take that [view], that is your energy source: Empty space has almost infinite energy. [That's]where you get all these conversations about zero-point energy, which is coming this issue that [all this infinity of space-created waves] compresses these [plates together with infinite force]. [Such an interpretation] assumes that there's infinite frothing of waves in all the empty space around [the plates].

But it's *paradoxical*, because that level of intensity has impacts — and Casmir kind of skipped over that casually.

What Casmir [was] getting at with his statement about cohesion is more interesting, [and more in keeping with the pilot wave idea I think you are proposing, as best understand it]: that there *is* a source of oscillations, there *is* a source of energy, there *is* a source of [both] of these — but it comes from the *matter itself*. It's a long-range relationship. Casmir essentially says that exactly: That it's a long-range relationship between the clumps of matter.

Feynman talks about this he gives a precise calculation about the intensity of these things. So, I think we have to recognize the reality of these fluctuations, but [moderate them by] realizing they're attached to matter.

So… not sure how good of an answer that is, but that's the best I can do.

[Addendum: I found this question intriguing because it attaches Casimir oscillations in a remarkably direct fashion to the total mass and energy of (presumably) local particles. My difficulty in answering, again, is that I don't use pilot waves and thus have difficulty understanding this (I think) new idea of a "dynamic" pilot wave — one with oscillations encoded on it, which is probably not really a pilot wave but something new — means in terms of long-distance cohesion energies. But such views are often interconvertible, so there likely is such an equivalence. That makes this an interesting approach to addressing the finite energy limits of the Casimir force.]

[1:32:05] Jarek Duda (JD): Yes. So, personally, I agree. I'm organizing a conference about time, and some people are saying that the clock [of time] is propelled by some [form of] noise in the vacuum. But I don't think that makes sense. So, I've searched for a clock [that is associated with] the particle. We need the clock itself [to have] oscillations. Also, a resting neutrino has oscillations. So we need these proportions for these kinds of oscillations. So the question is, "What is it?" So, if you have something interesting, I have a conference on March 27 that I'm organizing. I put information here [in the comments] if anyone is interested.

[1:32:59] TB: Jarek, could you repeat your main question or observation?

[1:33:07] JD: I have a clock mechanism for electrons oscillations. I can put up my recent [arXiv]preprint for this… preprint arXiv:2501.04036 [32]

TB: Maybe put a reference or a link [in the chat]?

JD: Okay, so here is my clock mechanism. This is my recent preprint; [it's now] in the chat [32].

The question is how to make that the resting clock. A resting particle already has a clock. So, there is a mechanism which comes from my complete model. This mechanic says so this is simp article for the to form the king that this one plus one-dimensional soliton. So, we need to add to make it make it time crystal that that in the lowest energy state, it already has a tendency for the oscillations. So, this mechanism using [subtle negative squared curvature Hamiltonian contribution] terms — which for non-negative temporal derivatives of the space brings a tendency for a non-negative space derivative. So, I have some mechanisms, and if anyone is interested, there will be a mini-conference in one and a half months.

TB: Of course, I would agree that every particle has a clock because of the oscillation issue: energy (mass) is a clock; you can't you can't separate those.

JD: Sure, but what are the properties of this clock? That is the question. What is the mechanism for the proportion of the clock?

TB: Ah… I think that's a really interesting question.

JD: Yes, so if somebody's interested, we have a conference. I put … the link for the conference we have [coming up]. So, there are few persons [attending]. Personally, I have the mechanism in the preprint above and to discuss it. So, I'm not certain if all the particles have [this clock property], but [it's] definitely [there]. For the electron, it's confirmed experimentally, and [also] for neutrinos. But besides [those two], we don't know what's happening with other particles. So, [the mass-based clock] should 2000 times faster for the proton [relative to the electron, since a proton is about 2000 times more massive], but we don't know; [a clock that fast] is too difficult to measure. So, if somebody's interested, I think there are one or two slots for this mini-conference. …

[1:35:59] TB: I can't see the conversation right now, but I'll take a look.

[32] J. Duda, *Time crystal ϕ⁴ kinks by curvature coupling as toy model for mechanism of oscillations propelled by mass, like observed for electron and neutrinos*, arXiv preprint arXiv:2501.04036 [Jan. 2] (2025). https://arxiv.org/pdf/2501.04036

[1:36:13] TB: Any other questions? I am fine with wrapping it up.

[1:36:19] Q1: Yes, there is a question. You were talking about very high-level concepts and I'm not trying to level up with the with the level of sophistication here, but I have several naïve questions. First of all, when you mention sparse, what does it do to the density matrix? The other thing is, when Einstein was talking about warped space, can I understand it in terms of sparsity or quaternions?

[1:36:59] TB: Good, good questions. As I mentioned before, with the sparse approach, if if some of the math would have to be how put it one way I expressed it a couple times is that if you flip the aums upside down and say your first and most critical principle is conservation — period. Conservation any kind of probability flow: the idea is the first principle is conservation, then you get the symmetries coming from that — which is literally the inverse of Noether. … You would start with finite conservation of mass energy, and then properties come out from that.

[1:38:20] TB: Your second question was… I'm sorry, again, your second question?

[1:38:27] Q1: About warped space: associating it with singularities, sparsity, quaternions…

[1:38:34] TB: The best argument for space having existence — I think one of the reasons why people think there *is* a space fabric — is general relativity. It has shown us that curved spacetime is a very good way to model what happens — an incredibly predictive way to do it.

So, to use a sparse-bit model, what you have to do — and this not just on general relativity, it's on a whole bunch of things — you have to go to a model how particles interact directly with each other in ways that are not standard [according to our usual ideas of how space and time work]. [These interactions are] more like quantum entanglements [than classical physics], so you get into some of the "quantum entanglement" theories of spacetime.

[That] would be one way to express [what is happening], but I think entanglement is … a clumsy way to get at those issues. Clearly, particles can interact in ways that *don't* follow the usual definitions of space and time.

Curved space would then be a product of those relationships. I'll get into this next month, but this idea that that spacetime has a *fractal* structure because you have a serious conflict between two definitions of time: Time that has progressed, that you've actually seen and *observed*, versus time as defined by *physics*. Those two don't match after you accelerate a system — they actually come into conflict with each other.

That [has] relevance to the overall understanding of spacetime structure, and would have some kind of impact in general relativity. [After all,] if you can't reconcile two different fundamental definitions of time, you're going to have some issues! [These time disparity issues] seem to have some correlations [to how space ends up looking curved], but we don't understand well [enough] how particles fully interact with each other [to explain these correlations to curved space]. We see the specific interpretations of them as waves or as particles, but something much more entangled — and much less localized — seems to be going on underneath that. I think that it's just a fascinating area, but I don't think it's easily resolvable.

[Addendum: Here is a more answer your questions about how (1) singularities, (2) sparsity, and (3) quaternions relate to curved space in a sparse-bits model:

Regarding singularities, (1), black hole singularities do not appear to exist, both theoretically and experimentally. They result from folks getting a bit sloppy with their first-person interpretations of how the equations work at the mathematical singularities at event horizons. Singularities don't exist theoretically because even though a ship falling smoothly and without angular momentum (which, incidentally, is impossible) into a black hole moves smoothly from its own perspective, proportional time dilation requires the black hole to evaporate by Hawking radiation before the ship reaches its center [33][34]. In practice, angular momentum, down to and including the particle level, tears the ship apart and forces its particles to enter into stable momentum-state orbits at the event horizon [34]. These are more akin to stellar-scale particle orbitals and Fermi bands than classical orbits, just with a wider variety of particles than electrons. This "dark mirror" interpretation of event horizons is an expansion of work by Sánchez [35] and 't Hooft [36] on "antipodal" interpretations of black hole event horizons that keep infalling particles in this universe and, eventually, make them visible again on the opposite (antipodal) side of the black hole.

Experimentally, it's becoming increasingly apparent that objects that fall into black holes enter into very slow (by our time) orbits in which they periodically reappear (send out characteristic signals) at periods of years or decades [37][38]. That is more consistent with gradual conversion into momentum states at the event horizon than the existence of singularities. My own view is that should abandon the idea of a singular scale for space and view the interior of a black hole as an instance of space so "magnified" that not even a single particle can reside there [38].

As for (2), sparsity, all spacetime becomes interactions between the units we think of as conserved particles. You get very smooth, detailed spacetime when you have lots of particles, such as in black holes, and very sparse, grainy spacetime at the low-mass limit of quantum mechanics. GR and QM are a scale continuum, not separate physics.

Regarding (3), quaternions, there's an excellent chance that the two-perpendicular-orbits feature of quaternions is capturing two of the most essential features for creating persistent particles: Mass (quantum phase orbit including time) and angular momentum (an orbit in ordinary xyz space). This would be true for both half-spin fermions and whole-integer-spin bosons, but only the fermions would have the ability to define space and time by enabling object to move *only* through time. Space then becomes orthogonal to that time-only motion.]

[33] T. Bollinger, "*Why Black Holes Evaporate Before You Cross Their Event Horizons*, Backreaction (Sabine Hossenfelder) **2020**, 1212 [Dec. 12] (2020). https://backreaction.blogspot.com/2020/12/are-singularities-real.html?showComment=1607805558828#c2682181072735415087

[34] T. Bollinger, *Falling Into a Black Hole: Five Even Odder Effects*, Apabistia Notes **2022**, 10032230, [Oct. 10] (2022). https://sarxiv.org/apa.2022-10-03.2230.pdf. For black hole evaporation as you fall inward, see Effects #5 and #4. For conversion of matter into momentum-space quantum orbitals on the event horizon — the no-singularities, "dark mirror" interpretation of the event horizon — see Effect #3.

[35] Norma Sánchez, *Semiclassical Quantum gravity in Two and Four Dimensions*. Gravitation in Astrophysics, Springer, 371–381 (1987). Preview pages: https://link.springer.com/chapter/10.1007/978-1-4613-1897-2_14. Dr. Sánchez appears to have been the first to propose the concept of "antipodal" mapping of how matter responds to falling into a black hole. This simply means that the matter eventually (but very slowly, via Hawking radiation as best I can tell) comes out the other side — the *antipode* — of *the same black hole* in which the matter falls in, rather than, say, in some other universe (the "white hole" concept). Gerard 't Hooft later (see [36]) expanded her idea into a momentum state interpretation.

[36] Gerard 't Hooft, *Black hole unitarity and antipodal entanglement*. Foundations of Physics **46**, 1185–1198 (2016). https://arxiv.org/abs/1601.03447

[37] Y. Cendes et al., *Ubiquitous Late Radio Emission from Tidal Disruption Events*, arXiv preprint arXiv:2308.13595 [Aug. 25] (2023). https://arxiv.org/abs/2308.13595

[38] T. Bollinger, *Black Hole Burps and the Asymmetric Orbital Scale Hypothesis*, TAO Physics **2023**, 0922 [Sep. 22] (2023). DOI: https://doi.org/10.48034/20230922.

[1:40:42] Q1: Yes. Well, time is known [to be] problematic. But, if I can [derive] some tools [or insights] from the surprising bending of light [around a corner] — and light is very basic and very essential in all this discussion — if light can go around a corner, which was a surprise to me, or can exceed the speed of light — you know, the famous [constant] *c* — … maybe we can [also] do some paradigm shift in our understanding of time. … [For example,] there is a trick in differential equations [where] you do stretch coordinates — slow time, fast time. Maybe we can allow different *intervals* of time to behave *differently* than [how] we think of time in a [strictly] linear way.

[1:41:44] TB: Yes. Were you aware that Einstein in, I think it was 1911, gave a [lecture] in which he specifically added an additional condition that said, "Since we cannot tell that light goes at different speeds in opposite directions…" — this was a big issue back in Lorentzian times; it seems strange to us now, but in the Lorentzian formulation, light could go at different speeds in opposite directions — Einstein said, "… Well, [since] I've proven that you *cannot* [detect] that … I will *add* an additional constraint, [which is that the speed of light] is universal in *both* directions."

This is kind of funny, because … in that same lecture, he spent a lot of time *dismissing* arbitrary constraints — and then he *literally* [adds an entirely new] arbitrary constraint, [and even calls it that]. The reason that's important is because once you eliminate the … constraint that Einstein [added], you have a better resolution of frame-to-frame time relationships [such as the Twins Paradox], which gets back into this issue about disparities in time definition.

So, you [get] the best [and most self-consistent] definitions of time if you assume that everything [in every inertial frame] has accelerated from some [shared original] state of rest. [Every object not still in that shared original state of rest] essentially experiences time asymmetrically — that their speed of light behaves asymmetrically — that their speed of light goes *faster* in one direction and *slower* in the other — for *them!* But they can't see it! So, it's just this lovely combination of invisibilities that you see. And yet, you can't just ignore them. As I tell friends sometimes, if you have the speed of light going a billion times faster forward and a billionth of the speed [of light] backwards, there is *no experiment* you can do in the universe to disprove that.

Derek Muller in [the YouTube channel] Veritasium once gave a nice video on this issue [39]. … People have tried [to prove lightspeed is always the same in opposite directions], but it turns out you *can't do it*. But the *reason* you can't do it is because it's fundamental to special relativity. [It turns out that] you can't have special relativity *without* that property.

So I would agree there's there there's more into this issue of the speed of light.

[Also,] you mentioned the speed of light [on a] geodesic. Yes, but a photon is not a *particle* [as it crosses space]. A photon [crossing space] is a *wave*, so when we see a photon coming from a gravitational lens 10 million light years across, it didn't cross it as a *particle* — it crossed as a *wave*. So, we have to be a little careful about [using an] overly classical [geometric definition of light when describing curvatures in spacetime]. [Thus] there's a quantum aspect even to the [general relativity] definition of spacetime curvature.

[39] D. Muller, *Why No One Has Measured The Speed Of Light*, Veritasium (YouTube), Oct. 31, 2020. https://youtu.be/pTn6Ewhb27k. Quotes:
[4:46] DM: *"It's possible that the speed of light is half of c in one direction and then instantaneous on the return journey*."
[TB Note: DM's slowdown-speedup example is not possible. Special relativity imposes the constraint that when two or more inertial frames interact, speedup in one direction and slowdown in the opposite direction must be reciprocals of a single real number called the Relativistic Doppler factor, $R = (c + v) / (c - v)$.
[16:40] DM: *"… maybe this is an odd quirk of the universe and there's no good reason for it. Or maybe, when physics takes the next paradigmatic leap, our inability to measure the one-way speed of light will be the obvious clue to the way general relativity, quantum mechanics, space, and time are all connected… and we'll wonder why we didn't see it before."*

[1:44:26] Q1: And the wave has to cater to or observe the curvature, namely changing its own properties?

[1:44:40] TB: Yes… I think I heard what you said [for the word 'cater'].

[1:44:42] Q1: Can I entertain you with something which is quite imaginary, and this is, why don't we think about Doppler effect of sound waves for lights?

[1:44:58] TB: Oh, sure, relativistic Doppler. If you look at my website, I have a whole little thing in which I have someone pretending to be Einstein and talking about looking at the results that they were actually traveling in a speed of light [40]. The only way you can actually reconcile some of the time dilation this is use a relativistic Doppler effect. That is actually a better and more fundamental description than Lorentz contraction, and it's well studied for like for different kind of cosmic jets. That's where it first came up. But you really do need to do that, and if you don't use relativistic Doppler, you [are going to have inconsistent results].

I was not aware of [the math for the relativistic Doppler] area. I had derived an equation [for a quite different issue of quantifying time dilations geometrically] [41][42], and I was looking around [one day] on relativistic Doppler, and… there was the same equation! So, the same one pops up. It *has* to.

[Intriguingly,] Lorentz contraction turns out to be an *average* of the [relativistic] Doppler [and its] inverse [42]. So, you can make a strong argument — I think actually a simple argument — that the Lorentz factor is a *composite* factor. It's not the final word.

[40] T. Bollinger, *Einstein and the Mystery of My-Train-Only Time Dilation*, Apabistia Notes **2023**, 07201330 [Jul. 20] (2023). https://sarxiv.org/apa.2023-07-20.1330.pdf

[41] T. Bollinger, *The four observable time ratios for A launched to B at velocity v*, Apabistia Notes **2023**, 01212102 [Jan. 21] (2023). https://sarxiv.org/apa.2023-01-21.2102.pdf

[42] T. Bollinger, *Special Relativity Conversions with Relativistic Doppler, Binary Rapidity, and Age Gradients*, Apabistia Notes **2023**, 02082230 [Feb. 8] (2023). https://sarxiv.org/apa.2023-02-08.2230.pdf.

[1:46:05] Q1: Wonderful! You inspire! It's a first for me, but it's well known for you.

[1:46:15] TB: Great question; I love the relativistic aspect.

[1:46:19] Q1: Yes, thank you so much, thank you.

[1:46:22] Q3: Terry, is it okay for me to ask another question? At the beginning of your presentation, you talk about this AI — the new [DeepSeek] AI from China — and then you spoke about the holographic [interpretation of such AIs]. So I wonder: I'm not familiar with this with the ideas of holographics … storage. Is this holographic [view] you mentioned just a mathematical tool, or physical storage?

[1:46:56] TB: There are two answers to that. [I meant *both* a mathematical tool *and* a physical data storage method.]

[First,] the [mathematical re-interpretation of LLM databases as] holographic storage [is an idea] I [first] proposed [in] my [Washington DC Quantum Computing Meetup] talk [on Nov. 2, 2024]. You can find [links] to the paper [43], to these slides [44], and to the video [45] back on November 2 if you Google "Apabistia Notes"…

[Also,] holographic [data] storage absolutely is … a real technology that people are using, but only experimentally because it's never gone out into [commercial use]. You use light, and essentially you make a dynamic hologram that you can change and alter. So it's real technology.

The other part, [the mathematical re-interpretation of LLMs as holographic databases, comes from] the analysis I did looking at the details of how the whole Transformer model works. My conclusion was that they accidentally used holographic storage — that they came up with these quasi-dimensions, which they do talk about — and quasi-dimensions are actually data-defined. There are terms for these when you do it explicitly. They developed these almost accidentally, incidentally? Which is very *costly* way to do it — essentially, by slow evolution … [by] trying it, and trying it, and trying again, till you finally converge onto a set of quasi-orthogonal dimensions.

[These quasi-dimensions] are like codes. They use this [method] in radio cellular transmission, [in something called code-division multiplexing.] It's not a new technology. But the way Hopfield did it, [was] kind of *accidentally?* I don't think he had any idea what he had really done. He attributed [the fault tolerance he was seeing in his networks] to being like [the quantum order-from-chaos emergence he had studied a decade before in] biomolecules. [That misattribution] was a *huge* mistake, because it's *not*. [Holographic fault tolerance] is a very different phenomenon.

But [Hopfield did] come up with an incredibly clever *holographic* algorithm. [That] is my assertion — in fact that's something I want to work on and give an actual proof of: That even Hopfield's original network is holographic. I think that would be a fairly straightforward proof.

So, the assertion I made about the LLMs is just that they're all holographic storage devices. One of the reasons why they're so powerful for answering questions is that the holographic interpretation allows you change "perspectives" very easily, which is literally what you do with the LLM. So it's kind of like a conversational version of a hologram — you know, you look at it from a slightly different angle and you see a slightly different conversation. I think that's a really good model for understanding some of this.

In the case of DeepSeek, they seem to have confirmed at least one aspect of that when they went out and preconstructed the quasi-dimensional structure. They said, "Oh, it *is* quasi-dimensional… so let's go out and define the quasi-dimensions!" [They did it in a] … straightforward, clever way, which was [to use] good data sampling. So, they didn't do anything really convoluted — that's almost a pun in that context — they didn't do anything very complicated. But it worked! It worked *really well*, [well] enough that it embarrassed a whole lot of people.

It goes farther than that. Using [the bits stored in the computer representations of] real numbers as *bits in a hologram* is *not* a good way to do [a hologram]. You're complicating the access to [those real-number bits] by making them into matrix multiplications. What you *really* need is a more direct, bit-level holographic access memory. I suspect [you could shrink] some of these systems … down to incredibly smaller size [with vastly] less power requirements, especially if you use optics.

Optics are [incredibly fast and energy-efficient at doing] Fourier transform, and matrix multipliers are *not*. That is that is the most expensive way to do a Fourier transform… well, [maybe] not the *most* expensive, but it's surely not the best way [either], especially if you don't *realize* that what you're really doing is a Fourier transform. So I think there's still a lot of potential in [taking entirely different hardware approaches to LLMs, including first switching to all-bits-are-equal data storage with instructions optimized for Fourier transforms, and, eventually, going to optical holographic data storage and processing to access the mind-bogglingly faster and more energy-efficient Fourier transform efficiencies of light.]

[Finally,] I want to put in the qualifier that I am *not* an LLM Advocate. I'm actually very unhappy with how they've been presented as being intelligent. They are just databases! I would also add them on that viewing them as some kind of holographic databases, or as just some kind of database.

You can also say they're just probability word-pair databases because every [piece] of data gets converted into a probability word-pair. And then [folks] wonder why you get random results! Well, if your basic storage mechanism is not a bit but instead it's a … probabilistic — as in, "it can change each time you query it" — word-pair… well, *yeah*, you're going to have trouble no matter *what* you do [to get] completely solid answers, because you essentially corrupted your data at the most basic unit of storage! So, I have a lot of problems [with that]. [There are] a lot of strange things going on with the whole LLM [approach]. They sound very good, but because of that fundamental decision to use probability word-pairs.

[If you] look below the [level of the LLM] Transformers, every [piece] of data is a probability word-pair. I sometimes like to call them Marco-Polo pairs. You know, … if I say "Marco," what are the odds you're going to say "Polo"? So, that's essentially how [data is] stored in all of these databases. These [databases] should *not* be presented with being sentient. They cannot do analysis. If you ask them give me a summary, they'll give you a summary with some inaccuracies. If you ask them give a detailed analysis of why [something] is wrong, they can't do that unless they can grab [an analysis] that's already *there*. Even [then], they'll get a little bit off.

So, I think … real AI technologies are coming someday, but [the LLM] path is *not* the right one.

[43] T. Bollinger, PAPER: *The First Nobel Prize for Insidious Software Degradation* [Generative AI as a Hologram], Apabistia Notes **2024**, 10231000 [Oct. 23] (2024). https://sarxiv.org/apa.2024-10-23.1000.pdf

[44] T. Bollinger, SLIDES: *The First Nobel Prize for Insidious Software Degradation* [Generative AI as a Hologram], Apabistia Notes **2024**, 11021300 [Nov. 2] (2024). https://sarxiv.org/apa.2024-11-02.1300.pdf

[45] T. Bollinger, VIDEO: *The First Nobel Prize for Insidious Software Degradation* [Generative AI as a Hologram], Washington DC Quantum Computing Meetup **2024**, 11021300 [Nov. 2] (2024). https://youtu.be/qq6_cJqVX5E

[1:52:56] Q3: Thank you.

[1:53:01] TB: Any other questions?

[1:53:03] HM: Yes, I noticed a chat question from [Doug]. "Do you think there's a superluminal, instantaneous transfer of signal, since [in entanglement experiments] there is experimental violation of the Bell Inequality, even under the constraints of special relativity?"

[1:53:23] TB: This is one that if you poke around on my website, [you will find that] I don't even believe there's such a thing as non-locality [46]. The reason is you *never* get non-locality until [*after*] you get a speed-of-light signal to the other location.

The first one to point this out was … [Asher Peres,] a really good physicist who mentioned this in one of his final papers [47]: When you collapse a bit that's entangled with [some bit at] some other site, *nothing changes at that other site*. There is *absolutely no change*. The *only* time you get the correlation is *after*, at the speed of light, you reach that distant site… and *then* you get a correlation.

I just thought was the … most marvelous statement of how non-locality *really* works, which is that it's not *really* non-local. You have this *finite [speed] spread* of this wave, … and until [that wave] arrives, *nothing happens*… *nothing changes*… *nothing's impacted* — whatsoever!

Now, if you want my deeper and even more speculative… (well, [to me] it's *not* speculative [since, as far as I can tell, it's just a more accurate, less interpretive description of what happens experimentally]) … my interpretation of what's really going on there is [that] we have too rigid of a concept of what space and time *are*.

That is, [I would say that] what's actually happening is we are constructing [*non-fundamental*] spacetime definitions [— spacetime "stories," so to speak —] of what we *think* happened, [but always and only] *after* the fact [of their occurrence]. The actual physics is something a little bit weirder, and we don't have a good handle on that yet.

That's why, … in certain cases, we *cannot* create a coherent space-time construction of what happened. [That is] because [such an interpretation is] *just not there*. We're accessing physics that that don't work quite that way [— that is, that can *never* be described under the rules of a rigid four-dimensional spacetime metrical framework.]

But in terms of sending a signal faster speed of light? Entanglement doesn't do that. It changes your *interpretation* after the [arrival of the wave describing what happened at the other location], but it never *does* [anything] faster than speed of light.

I have a little article somewhere [46] about how nonlocality is a bogus concept — that we need to stop thinking that way, because we're assuming an overly rigid definition of spacetime.

[46] T. Bollinger, *Non-Locality is a Word Without Physical Meaning*, Apabistia Notes **2024**, 05020858 [May 8] (2024). https://sarxiv.org/apa.2024-05-02.0858.pdf

[47] A. Peres, *Quantum Information and General Relativity*, Fortschritte der Physik: Progress of Physics **52** (11-12), 1052–1055 (2004). https://arxiv.org/abs/quant-ph/0405127. Page 2: *"When Alice measures her spin, the information she gets is localized at her position, and will remain so until she decides to broadcast it. Absolutely nothing happens at Bob's location. From Bob's point of view, all spin directions are equally probable, as can be verified experimentally by repeating the experiment many times with a large number of singlets without taking in consideration Alice's results. ... For Bob, the state of his particle suddenly changes, not because anything happens to that particle, but because Bob receives information about a distant event. Quantum states are not physical objects: they exist only in our imagination."*

[1:55:43] TB: Anyone else?

[1:55:44] Q1: Yes, I was wondering: At some point, you mentioned DNA and RNA. I apologize [if I did not hear all you said, since I was] outside (we have a lot of snow here today). I was wondering [whether, with all these new] concepts, paradoxes, and paradigm shifts, … you can see [applications in] biology and medicine [for] bit storage at the DNA and RNA level, since biological cell-to-cell interaction and signaling are exchanges of info?

[1:56:36] TB: Yes. I think cells have this worked out to a level that we are still just poking at. The reason I say that is they figured out that the *best* systems have a *combination* of digital, highly historical, extremely classical information, which is DNA — it appears they may have started with RNA, but [eventually] they got this DNA thing down just right — and yet they *also* use the Hopfield mechanisms [30][31]. [Those are the papers for which Hopfield] *should* have gotten his Nobel Prize rather the [later egregiously erroneous] one [from 1982] [48]. His [much more insightful] 1974 papers … [are] on how molecules are doing some kind of *quantum* computation. …

Cells use *both* [digital and quantum]. They don't have this rigid line that we keep trying to [use to] force everything [into] all-digital, [as in] "It's got to be a giant computer!" No, [computation in a cell] does *not* [have to be like a giant computer]. [Instead,] cells use the [digital and quantum] tools that seem to fit [each situation].

I think we have a lot to learn from cells. I think there's a huge benefit from understanding that aspect of biology better from a more physics level. How are they combining digital and quantum to optimize the properties of both? I think cells are very good at that. That is why they survive so well.

[48] J. J. Hopfield, *Neural networks and physical systems with emergent collective computational abilities*, Proceedings of the National Academy of Sciences **79** (8), 2554–2558 (1982). https://www.pnas.org/doi/abs/10.1073/pnas.79.8.2554

[1:57:47] Q1: Yes. I've been causing some noise and surprise amongst biologists by telling them that, "Watch the bacteria, and maybe we can build the computer based on bacteria."

[1:58:01] TB: I would not be surprised. I think that's an intriguing assertion, I really do. I that is because you're getting at that idea that molecular room temperature quantum computing goes on all the time in bacterium. *So why not?* This is where I wish Manin [12][13] had gone a different route. Manin was so immediately fascinated by computers that he flipped instantly, just after talking about quantum computation in molecules and how energy efficient they were. He switched to a model that essentially encumbered the concept of a qubit with giant computers that are hyper-classical. So, I can understand why it happened. I just wish he had gone another route. But I think [what you are proposing, computers based on bacteria,] is an intriguing idea.

[1:58:45] Q1: You mentioned the name Manin?

[1:58:47] TB: Manin, M A N I N, Yuri Manin. Again, on my [main publishing] website, https://sarxiv.org/apa, I've got some quotes from him [12]. If you look at my website, I think down near the bottom — it's just a list, I haven't tried to order anything — but I've got some nice quotes from Manin.

[1:59:09] Q1: The mathematician?

[1:59:11] TB: Manin the mathematician, Yuri Manin, yes.

[1:59:13] Q1: Okay, I came across the name.

[1:59:15] TB: That's the same one. But he did some marvelous writing about quantum computation early on. I think it was actually some lectures from Radio Moscow.

[1:59:24] Q1: Wow, fantastic, thank you again.

[1:59:27] TB: Thank you.

[1:59:34] TB: Anyone else? Helen, are we a wrap?

[1:59:59] HM: So, if there are no more questions, please check out our next event on March 15 with Terry again. I just posted a link on the chat. Or, you can search for Washington DC Quantum Computing Meetup and you'll find the link to sign up for the event. Thank you for all Coming. See you next month.

[2:00:25] Q1: Thank you, everyone.