Brian Skinner Talks Physics, F...etball to Quantum Entanglement

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SPEAKERS

David Staley, Eva Dale, Brian Skinner, Janet Box-Steffensmeier

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B Brian Skinner 00:04

Yeah, it is weird. I mean, quantum mechanics so often violates the intuition that we gained by studying the human size objects around us.

J Janet Box-Steffensmeier 00:14

From the heart of the Ohio State University on the Oval, this is Voices of Excellence from the College of Arts and Sciences, with your host, David Staley. Voices focuses on the innovative work being done by faculty and staff in the College of Arts and Sciences at The Ohio State University. From departments as wide ranging as art, astronomy, chemistry and biochemistry, physics, emergent materials, mathematics and languages, among many others, the college always has something great happening. Join us to find out what's new now.

D David Staley 00:48

I'm joined today in the ASC Tech Studios by Brian Skinner, Assistant Professor of Physics, the Ohio State University College of the Arts and Sciences. His areas of expertise include condensed matter theory, quantum materials, and disordered networks, which I might be asking you about today. Dr. Skinner, welcome to Voices.

B Brian Skinner 00:48

Yeah, thank you for having me.

D David Staley 00:50

So, I would like to start off, first of all, by asking you about the work that you and your group have been doing in quantum entanglement, and you'll have to start first by defining what's meant by quantum entanglement.

B Brian Skinner 01:21

Sure. Quantum entanglement is a hard to define property. In one sense, what you can say is that quantum entanglement is when the collective state of some systems, some collection of objects, like electrons, for example, is impossible to specify by specifying the state of all the pieces in isolation. So, usually, you know, our intuition says if you have a system of objects and you tell me what each individual object is doing, then that completely specifies the state of the whole system. But, the laws of quantum mechanics show that you can have states that are not specifiable that way, that in some sense, there's information that's encoded in a mutual state, that there's information that's sort of shared non-locally between different parts, and we call that quantum entanglement. It's the idea that there's information about the system that is shared between these different parts.

D David Staley 02:13

And whenever I hear quantum, I think both really small but also, like, impossibly messy and just, sort of... well, this is a non-scientific term: weird.

B Brian Skinner 02:23

Yeah, it is weird. I mean, quantum mechanics so often violates the intuition that we gained by, you know, studying the human sized objects around us, and it is usually the domain of the small, although not exclusively, we're getting better and better at making larger things that can show quantum properties.

D David Staley 02:41

What are the kinds of systems that you're, that you're studying in your research group?

B Brian Skinner 02:45

Well, in a sense, we're trying to abstract away - at least in the line where we're studying quantum entangled specifically - we're trying to abstract away from specific systems, and instead just think about quantum entanglement as a general property. In a sense, we're trying to construct a theory that's like, you know, if you describe a theory of how epidemics spread, for example, you don't have to specify what kind of disease it is, we're generally talking about the spread of some kind of disease; we're trying to construct a similar kind of theory for quantum entanglement. We're trying to come up with a theory that describes how quantum entanglement grows, how it spreads, how it dies off, that works on a similar footing, a sort of mathematical theory that would be similar to the way we talked about the theory of how epidemics grow or the theories of how wildfires spread or something. We're trying to abstract away from specific systems toward general descriptions of how quantum... how quantum entanglement evolves in time. So, does this mean you're working purely with mathematics or is there any kind of, I don't know, observation involved? Yeah, so farwhat we're doing is a purely mathematical theory. We're theorists, we generally operate by pencil and paper. But, the goal is that, once we have a general theory, to now look at the world of specific systems and say, Oh, that's a good candidate for realizing the sorts of things we're talking about. Help the non-theorists sort of understand: how do, how do physicists do this? How do you, how do you just work with pencil and paper on these kinds of systems? Well, how do I say this... the hard part is not writing down the equations, the hard part is discarding many, many wrong ideas. So, you have a kind of a problem that you're interested in, and so you say, well, can I describe it this way, can I describe it that way, and you try something for a while and eventually realize this isn't going to work out, I started with bad assumptions, or I'm going down a direction that's not interesting. So, usually, the actual pencil and paper work where you're actually writing down equations and doing math and figuring stuff out is a pretty small fraction of the time you spend. Most of the time you spend, you know, pacing around and looking at the sky or arguing with your colleagues or reading books to try to figure out something you were supposed to have learned in graduate school. That's mostly how the research goes. Tell me about the arguments that you have. What's the nature of the arguments that you would have with colleagues? Not arguments like in anger but, but like an intellectual argument, right? Yeah, so, this is sort of how I was trained in graduate school. You know, I was hired as a PhD student at the University of Minnesota, and my research advisor would bring me a particular question and he'd say, "Here's the question and here's what I think the answer is, do you agree?" And he was some famous scientist, and I'm, you know, a 22 year-old kid or something, so I would say, "Yeah, I'm sure you're right." And then, he would always look disappointed. And eventually, I realized that what he wanted was for me to disagree with him, so that then we can have competing sides of an argument, and through that disagreement, something would be learned. And eventually, I realized how productive and useful that is for scientific thinking. And now I have my own graduate students and I tried to get them to argue with me, and I say the rule is, if you don't see why I'm right, you have to disagree with me. And then we'll have a disagreement, and maybe you'll win, maybe I'll win, but we'll learn something new.

D

David Staley 05:47

Well, I know that one of the recent results from your group is pointing to the existence of measurement-induced entanglement phase transition, which is a mouthful - you have to explain, explain what this is.

B

Brian Skinner 05:59

Sure. So like I said, we're trying to come up with a general theory for how entanglement grows and spreads in time. So, if you have a system of quantum mechanical objects, you can start in a state where you definitely know the state of all the individual pieces, and then if you allow them to interact with each other over time, it will become quantum entangled, which means it's no longer possible to specify all the pieces individually, some of the information about the system is encoded in a joint state. So, we're interested in the question of how that entanglement grows in time. And what we figured out is if you're leaving the system to its own, an entanglement that's growing with time, but at the same time, some individual, someone is coming along and sporadically measuring what's going on in the system, that measurement can block the entanglement from growing. And what we found is that there are two large classes of behavior: one where the entanglement keeps growing and growing and growing, and one where it quickly stops growing, is truncated or blunted from growing by the measurement process. And we found there's a very sharp, what we call phase transition in condensed matter physics, that separates these two classes. There's a specific critical measurement rate that turns the one kind of system where entanglement grows into the other one where it stops growing. And mathematically, it's very similar to the way we describe water turning into ice very abruptly as you lower the temperature -

D

David Staley 07:11

That's a phase transition, from water to ice.

B

Brian Skinner 07:13

That's a phase transition as well, yeah. So, this is a very different kind of phase transition. It's about the growth of quantum entanglement rather than the properties of some solid object, but it's similarly a sharp distinction between two different classes of behavior. And that is induced by measurement? Yeah.

D

David Staley 07:29

So, like, we're in the realm of Heisenberg, right, that the observer is influencing the system that they are observing?

B

Brian Skinner 07:35

That's right, yeah. If an observer measures the system frequently enough, it will change the way its entanglement behaves in some very dramatic way.

D

David Staley 07:42

So, you're not suggesting we shouldn't measure?

B

Brian Skinner 07:45

No, we should measure, and, I mean.... maybe the most... there are two interesting implications of this research: one is that if you have a quantum computer that's based on, say, growth of entanglement, creating some very entangled state, there's a certain critical rate at which you can make measurements if you want the entanglement to keep growing and to become large. Another implication is for how we describe physics on a classical computer. It turns out this transition also describes how hard it is to describe quantum mechanics on a classical computer.

D

David Staley 08:13

And when you say a quantum computer, give us a sense of... give us a sense what that is?

B

Brian Skinner 08:17

Oh, this is one of the big quests in physics right now, to build a computing quantum machine, by which I mean something that can make difficult calculations by using quantum entanglement, exploiting quantum entanglement, this idea that some information is encoded in a joint state between two different objects, using that to make difficult calculations. And that's a very big pursuit in physics right now, to make something that works and generically does hard calculations.

D

David Staley 08:42

So, not like ones and zeros, yes, and no, off and on - quantum is what, an inbetween state?

B

Brian Skinner 08:48

Yeah, quantum is something that... a quantum computer is something that allows superpositions between zero and one, so, something that can be in a state that's neither zero nor one, but that when you measure it becomes one of the two.

D

David Staley 08:59

How close are we to a quantum computer? Care to speculate?

B

Brian Skinner 09:04

I think the rule is that it's... no, I shouldn't speculate, let me just say that. I shouldn't speculate, there are people working very hard, and the time estimate they give you depends on how optimistic the person is. And as someone who's not close to it, I won't speculate.

D

David Staley 09:20

Are you optimistic?

B

Brian Skinner 09:21

Yeah, I think I'm optimistic that in the not too distant future, we will have quantum devices that do useful calculations for us consistently. I don't see a future, at least not a near future, where we have a quantum computer that replaces your laptop or your home personal computer, but it's easy to see them starting to be useful. It sounds like measurement is a really tricky thing to do at these, at these quantum levels, yes? No, measurement is almost too easy.

D

David Staley 09:48

Okay, in what way?

B

Brian Skinner 09:48

Like, measurement is whenever you allow the small delicate quantum thing to interact with a big thing; that's essentially a measurement. So, preventing measurements from happening is actually the heart heard of quantum computing, keeping it isolated away from something that would destroy its quantum state, because measurement in quantum mechanics is always destructive, it destroys whatever quantum information or at least removes the superposition part; it turns this magical thing that was both zero and one at the same time into something that's either a zero or a one. So, generally, what we try to do is prevent our quantum things from interacting with some environment or from some observer who's trying to measure it.

D

David Staley 10:26

I know your group is working in all sorts of other areas, and I wanted to explore some of these. So, for instance, you are working on a new method for generating electrical power from waste heat. I'm interested to hear more about this work.

B

Brian Skinner 10:38

Yeah, so very recently, there has been another revolution, so to speak, in condensed matter physics, which is to realize that this long running dichotomy we had about materials turns out to be incomplete. So, for about a hundred years, we thought that all materials could be divided either into conductors and insulators: conductors, things that conduct electricity, and insulators, things that don't, and there was a very specific definition of what that meant in terms of how the electrons behaved inside the material. And about a decade ago, it became clear there were materials that do not neatly fall into either the two classes, they have some properties of conductors, and some properties of insulators. And so now there's - and these are called the topological materials, topological semi-metals, you don't have to worry about topological means, it's kind of an abstract thing that looks knotted - so now, the race is sort of been on to find out, well, we have these new materials, what can they be good for? And something that my group has been interested in is what's called the thermoelectric effect; it's turning waste heat, say, that's coming off your car battery or your car engine or off a power plant or something, and turning that waste heat into useful electrical power, recovering some of that energy.

D

David Staley 11:45

How does... how do we do that? How do we recover that?

B

Brian Skinner 11:47

Well, the thermo electric effect is basically this idea that if you heat up one side of a solid material, then inside that material are electrons, and they tend to drift away from the hot side and accumulate on the cold side. You can think that on the hot side, they're jumping around really quickly, and they quickly jump to the cold side, and on the cold side, they slow down. So, they tend to accumulate on that side. And if you have charges accumulated on one side, that means you've generated a voltage, and you've turned some inert thing, essentially into a battery just by heating up one side - that's called the thermoelectric effect. It's been known for a very long time since, you know, 1800s or something, but it's very hard to make the magnitude of that effect large. Usually you put 100 Kelvin of temperature difference, 100 Celsius of temperature difference across some material, and you can maybe hope to get a millivolt of temperature out of it, and that's hard. So what we found is that these new topological materials, there's a way to get them to generate a much stronger signal than what is possible in either the conventional conductors or conventional insulators.

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David Staley 12:44

Consequences, implications of this research?

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Brian Skinner 12:47

Yeah, the dream ,of course, is to now have some very efficient energy converter, that now you can make all thermal processes more efficient by recovering some of the waste heat. And we're not at the level of making practical devices yet, but it does look pretty promising. And the hard part now is finding the right material and the right scenario, but we at least have a theory that shows it's possible, that something is possible here that wasn't possible in the traditional conductors and insulators. Well, I know another area that your group is working on is a general mathematical law for describing how people navigate through crowds. Tell me more about this.

D

David Staley 13:22

It's polite, right?

B

Brian Skinner 13:22

This was kind of a funny project that happened just because my high school best friend became a computer science professor, and then one day I was having lunch with him and he mentioned how he was trying to create some computer algorithm to simulate the behavior of crowds. And he said, there's a whole field of people trying to do this, but the field has become really messy, because there are many competing algorithms or competing models for how you should do it and everyone has their own favorite one that works in some cases and doesn't work in others. So, just over this lunch conversation, we came up with the idea that well, maybe instead of proposing our own different algorithm, let's just try to look at the crowds themselves and see what they do. And it turns out that recently, there's all this data available that basically just comes from people putting cameras over public spaces, like, put a camera in a shopping mall and look at the floor or in a college campus or something and just record the trajectories of people walking around. And what you see, of course, is that people tend not to collide with each other, which means there's some effective rule that they're following to prevent from colliding, and... Right. And the technical term for this is there's a social force, there's a social force that prevents people from running into each other or walking too close to each other or something. And how that social force behaves, like, what's the correct mathematical law for that social force has been a big question. And what we were able to do is to use some of the physics that I knew from studying electrons, which also tend to avoid running into each other, and use those tools from electrons, apply them to the crowd data, and infer from the crowd data, what's the correct form of the social force. I suppose that is determined in part by how big the crowd is, how many people were talking about? I'm imagining students crossing the Oval, for instance. Yeah, in some sense, it does, of course, depend on how dense the crowd is, how close people approach depends on how tightly they're packed. But, what we did find is that across a very wide range of settings, different densities, different countries, cultures, there's a very simple mathematical law that says that people base their decisions on a projected collision time. They look at their current position, their current heading, someone else's current position, current heading, they project to the future and they say, how far in the future in seconds will I collide with this other person? And they base their decisions on that time, and there's an effective force that goes, like, one over that time cubed. And so, we were very excited about this.

D

David Staley 15:46

You're not... no, you're not suggesting we behave like electrons?

B

Brian Skinner 15:49

No, electrons base their decisions on the distance in space, on how many centimeters they are away from another electron, but people base their decisions on how far apart they are in time, so, it's all about projecting to the future in your mind.

D

David Staley 16:03

I know that you're also working on a method for assessing super spreading of a disease - obviously very topical, given the pandemic we're living through.

B

Brian Skinner 16:12

Yeah, that was one of those situations where the pandemic was started and we're all hunkered down at home, and you can't help but think about the pandemic all the time. So, eventually, we decided, you know, what we might as well think about this seriously if we're already thinking about it all, we're gonna be thinking about it anyway. So, at the time, this was the early months of the pandemic, and the data that was publicly available were just case counts in different parts of the country, for example. And what you would really like to know from the case counts is, who's doing the spreading? Is it every infected person is uniformly infecting one or two others, or is it a few individuals who are, you know, infecting twenty others while most people are staying at home and infecting no one? And what we figured out is that you can infer that information just from the case counts themselves. I mean, if you just look at the rise of cases, that could be due to many people infecting a few or a few people infecting many. But what we figured out is, if you look at the statistical variation between different locations, different say, counties, then encoded in that statistics is information about who's doing the spreading. If it's a few people, then you see wide variation from one place to another. But if everyone is sort of uniformly infecting other people, then you see very little variation from one county to another in the exponential growth rate of the disease. So, what we did is we looked at that exponential growth rate from one place to the other, and we were able to infer quantitatively how much super spreading there is. And what we found at the time -and this is, this is no longer novel information, but it was at the time - we found that about 10% of people were producing 90% of infections, and you could see that just from, just from the cases.

D David Staley 17:49

Were epidemiologists happy to receive this, or was their attitude, hey, stay in your lane, stay out of where we work?

B Brian Skinner 17:57

Well, one answer to that question is that the epidemiologists were doing, you know, more direct ways of assessing super spreading, they were doing contact tracing, like, find an infected person and ask who they've been around, and then laboriously compiling all these statistics. So, they were arriving the same conclusion by a more laborious way. I didn't get any stay in your lane flack from people, but that's probably because at the time no one was staying in their lane, we were all obsessed with COVID, so I didn't get a lot of pushback.

D David Staley 18:25

Well, I have to ask about this line of research, because it just sounds so fascinating. You are working on a theory for optimizing play-calling in basketball: you have to explain this.

B Brian Skinner 18:35

This started when I was a graduate student and I went to the American Physical Society meeting one year, and I heard this lovely talk about network phenomenon, basically how traffic flows through a network that is susceptible to congestion, so, we have many cars trying to get from point A to point B. Rhe way that the traffic flows through the network is a game theoretical problem, that everyone wants to go the fastest way, but they know that everyone else wants to go the fastest way, and so roads get congested, and so forth. So, I heard this lovely talk about that phenomenon, and later, I was just sitting at my desk at work and wasting time on espn.com or something, and suddenly, the two ideas were in my head at the same time. And I thought, oh, there's a similar problem when you're play-calling in any sport, which is that you have some play that's your most effective play, and what you want to do is just run it all the time. But if you run it all the time, it kind of gets congested in the sense that the defense prepares for it and stops working as so well. So, what you want to do is spread out the play-calling a little bit, even though one play is working better than others, and that's a similar phenomena to how you would really like to spread out traffic a little bit, even when there's one road that's faster than the others. So, once I had made that analogy in my head, it was just, okay, write down the equations that you told me about traffic and just redefine what all the variables mean, and now you have this general rule for how plays should be used in a basketball offense. So, anyway, to me it was a lot of fun and it started a sort of small research direction of a lot of sort of mathematical problems about basketball strategy, and I had some fun - gave a talk at a weird conference that's co sponsored by MIT and ESPN.

D

David Staley 20:08

Oh, interesting.

B

Brian Skinner 20:10

Wrote a book chapter, had... had some fun with that, how I say, it was a hobby that I couldn't stop myself from doing.

D

David Staley 20:13

Has Chris Holtmann reached out to you at all, for advice?

B

Brian Skinner 20:16

Not yet, not yet.

D

David Staley 20:18

Well, and you've, you've gestured to this a little bit - I'm really interested in your sort of thought process. In other words, how do you come up with these ideas? How do you determine the problems that you want to solve?

B

Brian Skinner 20:31

I wish I had a good answer to that question. There are two answers, I suppose: one is that I am someone who has allowed myself to become very undisciplined, in a sense that there's not some problem that I feel like I have to push out and is my life's work, I allow myself to drift and have ideas come to me and be creative. And sometimes you just see that a good problem, you see an opportunity, something that you know how to do that people care about, and you run and you do it. Other times you see a problem, and you say, that's a dumb idea, I should not work on that. And then, over time, you find that it won't leave your head, and you say, Okay, I guess I have to do it, I guess I'm forced to work on this silly sounding problem, because it won't leave my head. And sometimes that goes somewhere very exciting that people care about, sometimes it goes immediately from obscurity to oblivion. And, you know, that's how I live, I guess.

D David Staley 21:18

Is that unusual among physicists, that sort of attitude toward ideas?

B Brian Skinner 21:24

Probably, if you average over all physicists, I'm a little more undisciplined than most. But, in a sense, I gravitated toward the field of physics that was most friendly toward this kind of behavior. I'm a theorist rather than experimentalist, which means I can change what I'm working on very rapidly without having to reconfigure my laboratory, because I don't have a laboratory. I gravitated toward condensed matter because it's sort of the field that's most poorly defined. It's a field that is defined by a set of techniques, a set of approaches, and its only defining trait is that we like to think about large groups of interacting things. But, that's all over the world, so.

D David Staley 22:03

You use the word creative to describe your process. You mean creative like an artist?

B Brian Skinner 22:10

No, I would say I'm much less creative than an artist. I've been around artists, and those are really creative people. What I do is something much less than that, which is just to allow myself to explore ideas that come to me. I don't feel like I'm a particularly creative person, I'm just more forgiving to my own whims, more tolerant of my own, you know, desire to do whatever occurs to me at the time.

D David Staley 22:34

Didn't Einstein call that play?

B Brian Skinner 22:36

Yes, I suppose so. When this job is fun, it feels like play.

D David Staley 22:39

You started to gesture to this, that you were drawn to condensed matter physics precisely because it's maybe the most undisciplined or poorly defined, I think, was the term you used:

why physics? How did you end up in physics at all, as opposed to, I don't know, studying basketball or being a botanist or something - why physics?

B

Brian Skinner 22:59

I think, like many physicists, the gateway drug was math, the gateway drug was... you know, doing algebra or something, and seeing that by manipulating symbols on a paper, you could predict something real about what was going to happen in the world. And that was just so exciting, that was so intoxicating to feel like by writing some symbols on a paper and scratching them around, you suddenly understand something new about the world and what's going to happen, and that naturally led to physics. Originally, I wanted to do robotics, and I found that I was a really poor designer. I was too scatterbrained and kept messing things up, so eventually physics it was. And that that feeling of just, you know, playing games of some kind that turn out to have real consequences for the world, that's... that was the draw of physics.

D

David Staley 23:43

You're not saying physicists are scatterbrained? Surely you're not making that claim?

B

Brian Skinner 23:48

I can only speak for myself, I suppose.

D

David Staley 23:52

Welll, you are working on some very interesting projects right now that I want to... that I'd like to dive into. You are working - you're trying - your group is trying to design an electron lens, you'll have to describe what this is for us.

B

Brian Skinner 24:05

Yeah, so I mean, the basic idea is that an electron lens would be something that focuses electrons to a point the same way that a lens focuses light to a point. And it turns out, there's a much more exact analogy that can be made in a particular kind of material. So, specifically in graphene, which you've maybe heard someone on here talk about before.

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David Staley 24:23

Carbon based, right?

B

Brian Skinner 24:24

Yeah, graphene is basically a single layer of carbon atoms. But what's interesting from my perspective is that an electron in graphene acts a lot like a photon, it acts a lot like light; it moves at a constant speed and its energy depends linearly on its momentum, it has no, no mass. And the difference is that the effective speed of light for electrons and graphene is much, much smaller, 300 times smaller. So when the way a lens works is by pushing light from empty space, where its speed is something, through a region where the speed is different, and just by making some region in space where light has to slow down, that alone produces focusing. The idea we became interested in is there's a way to modulate the speed of electrons in graphene, there's a way by putting it on top of something and twisting that something just right, you can make a region of space where the speed of electrons is different. Usually, that happens by accident, some unwanted thing that happens in the experiment and you wish it didn't happen. But, we started thinking, well, what if you could purposely make some region where the speed of electrons is lower, and if you made it in a lens shape, the electrons that pass through would get focused to a point.

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David Staley 25:33

I would have assumed that electrons move at a constant speed.

B

Brian Skinner 25:36

Yeah, they do mostly in graphene, but you can make them slow down by making some region that's twisted relative to the other parts.

D

David Staley 25:42

Tell us about your work with electron crystals.

B

Brian Skinner 25:47

Yeah, there's this old idea, due to Eugene Wigner in 1934, that there can be a transition between a solid and a liquid state of electrons that's created not by the temperature, but by the density of the electrons. So, you know, when you melt ice to form water, what you're really doing is turning up the temperature, which increases the electrons' kinetic energy, and when their kinetic energy becomes bigger than the energy of their interaction, they melt. For electrons, there's a certain kinetic energy that exists even at zero temperature, and that's the kinetic -

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David Staley 26:21

Zero centigrade, zero...? Oh, sorry, zero Kelvin, an absence of any kind of, any kind of temperature, absolute zero temperature. But, in quantum mechanics, you have what's called zero-point motion, which is to say that no quantum mechanical logic is ever allowed to be at rest, it's always jittering around, and the tighter you pack the electrons, the more of that energy they have. So, it was figured out that if you could lower the density of electrons, just past some critical value, they would suddenly freeze into a crystalline arrangement - that's called a Wigner crystal or an electron crystal. And that's an old idea, but we've been playing with it in new contexts, new materials, and having a lot of fun with that concept. There's that word play again. Finally, I know that your group is thinking about contexts in which many particle systems fail to follow the laws of thermodynamics - I want to make certain I read that right, fail to follow the laws of thermodynamics?

B

Brian Skinner 27:24

Well, first of all, I should say that we haven't invented a perpetual motion machine or, we're not, we're not... proposing one. But, the idea is that in addition to the famous laws like energy conservation, and you know, no free lunch that come with thermodynamics, there's an assumption that we tend to make in thermodynamics that whenever you have a system of objects, it will tend to explore all possible configurations that it can, like when you put air molecules in a room, they will tend to go to every corner of the room and fill it with uniform probability. So, we're interested in situations where that kind of thinking gets violated, where you put, you know, by analogy, you put your air molecules in a room, and you find that for some reason, they never fill the whole room, they stay in one side. And that would be a situation that you could not describe with thermodynamics. So, we're interested in particular kinds of quantum systems that are now kind of toy models, where for completely kinetic reasons, you never find them exploring all the possible configurations that they can, and therefore, the conventional laws of thermodynamics fail on you. That's called thermalization, and we're interested in failures of thermalization.

D

David Staley 28:28

Is this theoretical or is this observational work?

B

Brian Skinner 28:31

So far, mostly theoretical. The theory has kind of been leading in this direction, trying to suggest cases where it would happen, and then there are specific controlled experiments where you can try to make it happen. But, so far, these are mostly theoretical games.

D

David Staley 28:46

With any kind of applicability, you think?

B

Brian Skinner 28:51

Hard to say, jury's still out on that one. We mostly don't play these games because we want to do something useful, we play them because we couldn't stop ourselves from doing so. So, that's where we are.

D

David Staley 28:59

D

David Staley 28:59

And there's that word play again, in games. Is that a way to describe sort of your approach to doing physics?

B

Brian Skinner 29:06

Yeah, when I'm doing my job -

D

David Staley 29:07

Serious games, I should hasten to add.

B

Brian Skinner 29:09

When I'm doing my job well, I am playing games and they don't have to be serious. That's, that's how I would describe it.

D

David Staley 29:17

Brian Skinner, thank you.

B

Brian Skinner 29:19

Thank you.

E

Eva Dale 29:21

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