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BY BENJAMIN WINTERHALTER(HTTP://DAILY.JSTOR.ORG/AUTHOR/BENJAMIN_WINTERHALTER/) /

DECEMBER 26, 2015

I ❤️ PHYSICS: A LOVE STORY

Abstract design made of colorful clouds and space elements.
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This began inauspiciously. My foray into the world of physics, that is. One evening, some of my —having consumed a not-insignificant number of drinks—decided to watch a NOVA special on called *Fabric of the Cosmos*, hosted by *Elegant Universe* author Brian Greene. Much to the astonishment of the other viewers, I could not bring myself to accept string theory's claim, prese the video as a scientific fact, that there are exactly 11 dimensions, 10 of space and 1 of time. Th seemed to me a conjecture that, whatever its theoretical elegance, simply wasn't logically neces as far as we knew, there could be an infinity of dimensions, imperceptible, say, by any means w found the arrogance of claiming to know *for certain* that the universe has exactly *X* dimensions- unshakeable confidence that our mathematical models had hacked into God's computer—baffli Shouldn't our observations of the incredible vastness of the cosmos—awe-inspiring photograph deep space(http://hubblesite.org/gallery/album/)—teach us some humility about our place withir Thus began the journey.

I feel it's better to confess upfront that I am no physicist. I do not mean to present myself as any authority on the subject. I got a B+ in high-school physics and took two astronomy courses as a undergrad, one a survey of cosmological theories from the ancients to the present (coupled with reading of Thomas Kuhn's *The Structure of Scientific Revolutions*), the other simply called "The Planets," a favored topic of mine since childhood. That is the full extent of my background.

* * *

I drove a rented sedan to New York City to interview Peter Woit, a theoretical physicist at Colun has taken refuge in his university's mathematics department. He's a refugee because his criticis string theory have made him the subject of some derision among other physicists, who have su him to such trollish epithets(http://nautil.us/issue/24/error/the-admiral-of-the-string-theory-wars) "incompetent, power-thirsty moron" and "stuttering crackpot-in-chief."

According to Professor Woit's 2002 article in *American Scientist(http://www.jstor.org/stable/278 mag=i-heart-physics-love-story)*, string theory "is built on the idea that elementary particles are pointlike objects but are the vibration modes of one-dimensional 'string-like' entities," which exis dimensional spacetime. But, Woit points out, there's an obvious problem with that: String theory requirement of 10 spatial dimensions is "in serious disagreement with all the evidence of one's s He continues: "Matching string theory with reality requires that one postulate six unobserved sp dimensions of very small size wrapped up in one way or another. All the predictions of the theor depend on how you do this, but there are an infinite number of possible choices, and no one ha idea how to determine which is correct." Crazy like a fox: apparently my half-drunk skepticism w misplaced.

Professor Woit's Not Even Wrong(https://www.math.columbia.edu/~woit/wordpress/), a blog tha a name with his 2006 book, argues—in an inimitably even-handed tone—that string theory has problem. Simply put, it makes no testable predictions, not even wrong ones. So, Professor Woit why are we spending so much time on ideas that, although they *could* be right, are systematica defined so as to avoid friction, experimental contact with the real world? What can be gained fro scientific theory that can never be tested? How is that different from theological speculation?

I didn't so much interview Professor Woit as assault him with enthusiasm for his ideas. Over co his office at Columbia, I told—in mostly-honest detail—the story of how I'd come to be speaking about string theory at that very moment. I asked whether there wasn't something about the insti culture of physics preventing people from hearing his criticisms. "When two mathematicians dis he replied, "you could lock them in a room with blackboards and chalk and one of them would eventually admit defeat. With string theory, it's very much the opposite." Was this political, not li Democrat and Republican, but political in the sense of being about the allocation of funds for re "Absolutely."

* * *

In Professor David Kaiser(http://www.jstor.org/stable/27858550?mag=i-heart-physics-love-story stately office at MIT, which I visited on a hot August day, he keeps a plush toy made to look like cosmic background radiation(https://en.wikipedia.org/wiki/Cosmic_background_radiation), a gift wife. He took a level approach to my naïve questions, excitedly getting up to his office's blackbo help me understand how, despite "all the evidence of one's senses," higher-dimensional spaces least theoretically possible, a point Professor Woit had also made. I understood, at least, that o very simply write "X = A × B × C × D × E," call all of A through E "dimensions," and then claim t shown that X was five-dimensional, but I could not get outside my own head enough to actually a higher-dimensional space. What would it *look* like? Professor Kaiser said that, although some physicists claim to be able—with a kind of mathematical clairvoyance, which arouses in me a m wonderment and mistrust—to picture higher-dimensional objects directly, most people find it ea reason about them by analogy to lower-dimensional spaces. You're an ant trapped in a flat worl here, this picture(https://en.wikipedia.org/wiki/Four-dimensional_space) helped me unkink the k tubes of my monkey mind.)

In our world, nature is the ultimate arbiter of what's true and what's not.
—ANDREW FRIEDMAN (2015)

But still Professor Woit's points were troubling, I thought. Pro Kaiser responded with equanimity: "I don't think many string —as they may have been when Peter was writing—are claim have 'read the mind of God' anymore." There had been, acc Professor Kaiser, a recognition among many theoretical rese working in string theory that the initial enthusiasm for it—a th whose ambition was no less than being the Theory of Everything, a bridge between quantum mechanics and Einsteinian relativity—was out of proportion with the amount of evidence for it (t zero).

Professor Kaiser and I also discussed some then-recent observations of the cosmic backgroun radiation, data that would support—or not—the theory of cosmic inflation(http://www.ctc.cam.ac.uk/outreach/origins/inflation_zero.php), the idea that, in the very microseconds after the big bang, the universe expanded very rapidly for the tiniest eye-blink of

That might sound unremarkable, but consider: The cosmic background radiation is (more or les same temperature in all directions. However, *without* assuming inflation, photons launched from opposite ends of the universe could not have "talked to" each other, could not be causally conn any way, they would have to travel faster than the speed of light, which—sorry, J. J. Abrams fa cannot. One way out of this apparent maze is (*ta-da!*) rapid inflation in the early universe—muc rapid than the more mundane "metric expansion(https://en.wikipedia.org/wiki/Metric_expansion_of_space)" of space we're used to— allows us to account for the uniform temperature.

The observations I mentioned, deep-space measurements from a Harvard telescope at the Sou called BICEP2(https://www.cfa.harvard.edu/CMB/bicep2/), however, proved to be duds, researc getting over-excited about their results before bothering to cross-check them for sources of erro Announcements of the big discovery hit the pages of *The New York Times(http://www.nytimes.com/2014/03/18/science/space/detection-of-waves-in-space-buttres landmark-theory-of-big-bang.html?_r=0)*: we had recorded gravitational waves from the ancient consistent with cosmic inflation. However, it was later revealed, when the BICEP measurement compared against those from the Planck satellite(http://www.esa.int/Our_Activities/Space_Science/Planck), that the researchers' data ca *Scientific American(http://www.scientificamerican.com/article/gravitational-waves-discovery-now officially-dead1/)* wrote, "be entirely attributed to dust in the Milky Way rather than having a mor ancient, cosmic origin." I could have predicted that, I thought. Hadn't someone told me about th overenthusiastic—nay, arrogant(http://www.jstor.org/stable/3824529?mag=i-heart-physics-love- culture of physics?

* * *

So much for string theory—fascinating though it was to speculate, I felt satisfied that, at the ver didn't have to accept an 11-dimensional world as my own. And so much for Brian Greene's high version of the universe, his slickly computer-animated, catchy-metaphor-laden science vids. Ho one more-or-less tangential point from my conversation with Professor Kaiser stuck with me like so I ventured back into the world of physics, not to be confused with the physical world.

One thing that had always bugged me, I confessed, was Schrödinger's cat(https://en.wikipedia.org/wiki/Schr%C3%B6dinger%27s_cat). According to one interpretation quantum mechanics, before a subatomic particle is observed, it exists in a state of superpositio between possible worlds, literally neither here nor there. But what, Schrödinger asked, if the sta that subatomic particle were somehow linked to the fate of an unfortunate cat trapped inside a presentation of the paradox varies in its description of the mechanism of the cat's death, but the idea is that, if the particle is in State A, Ms. Mittens lives on; if it's in State B, then little schnooku it. Is one forced to say that, until one opens the box, the cat exists in a state of superposition, ha and half dead? Nonsense.

A simple solution occurred to me: Why not say that quantum mechanics is just a description of w —as humans—*know* about the state of the cat—excuse me, universe—at a given moment in tir rather than a set of claims about what literally exists? Professor Kaiser chuckled knowingly at th saying that there is already [a whole debate in the literature(http://www.jstor.org/stable/2392394: mag=i-heart-physics-love-story)] about it, with the "it's about what we know" people being called epistemics—after the Greek letter Ψ (psi), used to represent wave functions in quantum mecha and the "it's literally true" people being called, somewhat pointedly, "psi-ontologists." I felt intuiti attracted to the psi-epistemic interpretation—found it pleased my aesthetic sensibilities—but co say for a fact that there weren't, at any given moment, an infinity of possible universes filled—w betide my allergies—with possible cats.

* * *

So it was that I found myself sitting at my desk—a not-too-hot summer day in Cambridge—talki Andrew Friedman, a post-doc at MIT, who is one of the leading researchers on psi-ontology. W give my journey a fitting end, I decided, in the anxious thirty or so minutes before I actually calle to pour myself a Canadian Club.

According to Friedman's 2015 article for [PBS(http://www.pbs.org/wgbh/nova/blogs/physics/2015/05/quantum-word-real-world-thing/)]: "If think of the universe as a video game, the so-called 'Ψ-ontic' view holds that the wave function source code." The Ψ-epistemic view, by contrast, maintains that "the wave function is just a cor computational tool that doesn't capture all of the underlying reality."

But, I couldn't help but wonder, was this even something a normal person would worry about? " people are willing to just trust scientific authority," Friedman said. "They find that there's no poin trying to talk about the reality of quantum mechanics. They might say that we have to just radica revise our notions of what reality is. That's an understandable, but ultimately uncritical, accepta

According to Friedman, both the psi-epistemic and psi-ontological camps are faced with the tas trying to reconcile experimental observations that agree with the predictions of quantum mecha such as the phenomenon known as [quantum entanglement(https://en.wikipedia.org/wiki/Quantum_entanglement)], in which the states of two | *even particles on opposite sides of the universe*, are fundamentally enmeshed—with Bell's theo philosophical formulation that says, essentially, "if that's happening, there must be some physic mechanism for it, and quantum mechanics doesn't provide one." (Physicists refer to it as a "no-g theorem.") Bell's formulation of the idea, Friedman explained, makes three fairly plausible-soun assumptions:

1. Information can't travel faster than the speed of light ("locality").
2. There is an underlying reality ("realism").
3. There is causal independence between an experimenter's choices about how to measu universe and his or her observations ("freedom of the experimenter").

But, Friedman said, experimental observations like entanglement—spooky action at a distance(http://www.technologyreview.com/view/427174/einsteins-spooky-action-at-a-distance-older-than-thought/), as Einstein called it—suggest that one or more of these assumptions must false. If the results agree with quantum mechanics, in other words, then one of Bell's postulates hold. Brian Greene comes back here, maintaining, in an article for NOVA(http://www.pbs.org/wgbh/nova/physics/spooky-action-distance.html), that it's locality. He that entanglement "strongly supports the conclusion that the universe admits interconnections t not local. Something that happens over here can be entwined with something that happens ove even if nothing travels from here to there—and even if there isn't enough time for anything, eve travel between the events." I see. So certain, are we?

Friedman feels that it's the third assumption that's most open to question, and he is part of a tea will conduct an NSF-funded experiment designed to put pressure on it, with the pilot test to beg sometime in 2016. In other words, Friedman is suggesting that, perhaps, since observer and ins are part of the same world, their pasts can't be assumed to be independent. How will he do it? ' want to let the universe itself make the decision about the settings of the detectors," he said. "W to use light from distant galaxies at opposite points in the universe to 'choose' the settings of th detectors, objects whose causal pasts could not be interrelated because they're so far apart." S great! Feels like friction.

But there's a caveat: cosmic inflation. If it is true that cosmic inflation occurred, even these dista quasars could, in the very early universe, have known each other, been part of the same beatin of the universe.
