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Columnist and Physics

How physics is helping us to explain why time always moves forwards

While time is relative, it still flows in one direction for every observer. We don't yet understand why, but some physicists are looking for answers that invoke the evolution of entropy, says **Chanda Prescod-Weinstein**

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Time is a huge problem. Of course, there is our social and biological sentiment about it: we all want more of it and/or are worried about its passage. As I come up against the deadline for turning in my next book, I'm feeling that strongly. But there is also a deeper physical issue, which is that we don't know why it always moves forwards. This is true even in the context of relativity, where space and time are unified.

You would think that might give the phenomenon some flexibility. In fact, a few columns ago, I pointed out that soap operas 🔗 /article/mg25934561-000-how-soap-operas-can-help-us-understand-special-relativity/ are a great way to think about how time works in special and general relativity, since time dilation seems to be central to that style of storytelling. By this, I mean that time 🔗 /article/mg25433910-500-what-is-time-the-mysterious-essence-of-the-fourth-dimension/ flows faster for some plot lines than others in the shows I watch (*Emmerdale* and *Coronation Street*). This is akin to the way time passes differently in special relativity for observers who are moving relative to one another.

It is also similar to the way that the presence of a gravitational field affects the flow of time. Time passes slower close to a massive object and faster when there is less gravity. So, for example, someone 🔗 /article/2160951-super-accurate-atomic-clock-used-in-real-world-for-first-time/ at sea level will measure a different time flow rate than a Sherpa at the top of Mount Everest.

But while time is relative, it still flows in one direction for every observer. Sure, people might disagree about how much time has passed during an event, but they will still agree that as time passed, it always moved forwards.

It isn't clear why this should be so – why space-time emerged with an arrow of time. It is also the case that my *Emmerdale* model ignores the existence of quantum mechanics 🔗 /definition/quantum-mechanics/, which has various ways to throw a wrench into our understanding of how time works.

One of the features of quantum mechanics is that it is less predictive than Newtonian physics. While this doesn't affect the flow of time per se, it does complicate how we might think about our expectations that we can predict what will happen next. Quantum predictions are less certain.

Another prediction of quantum mechanics is the phenomenon of entanglement. Imagine two particles that are close enough to each other that they are capable of interacting with each other. Then the particles part ways – perhaps they are two relativistic particles, moving almost at the speed of light. In a classical physics picture, we expect that the particles are no longer connected when they have a sufficiently large spatial distance between them. Not so in quantum mechanics. There they remain entangled, meaning that if we change one correlated property in one of the particles, the other will also change accordingly.

People might disagree about how much time has passed, but they will agree that it always moved forwards

This should trouble you. If you remember relativity, you know that the speed of light is finite. That means information isn't supposed to travel between distant locations instantaneously. It should take time for it to get from point A to point B, with the speed of light being the fastest that it can move.

Yet in the quantum entanglement scenario, information seems to flow instantaneously between particles. In other words, the particles have a concept of simultaneity, but only with each other and only after they have been set up together to start in a specific way.

It does seem that quantum mechanics can give us a hint about the arrow of time. One of the laws that can be shown to emerge from quantum calculations is the second law of thermodynamics. This says that the amount of entropy – which is roughly a measure of disorder – in a system tends to grow.

This idea was first found in experiments that pre-date the advent of quantum mechanics, but it was later shown that it could be proven from quantum theoretical principles. Given the correlation between the tendency of entropy to increase and the tendency of time to increase, physicists who think about the arrow of time have tried to explain it by looking for answers that invoke the evolution of entropy.

There are scientists who see it otherwise. In his book *The Janus Point: A new theory of time*, Julian Barbour points out that if we look at cosmological scales, the universe doesn't tend towards disorder, but rather towards complexity. He argues that to understand the arrow of time, we have to think about what drives the evolution of complexity. He even claims it might explain how entanglement works, but he doesn't explain how to make this consistent with relativity.

Of course, none of this thinking changes the challenges we face with time in our everyday lives – at least not yet. But next time you are feeling stressed or frustrated about time, just remember that no one understands it and that this mystery can inspire some of our most creative thinking.

Chanda's week

What I'm reading

I'm working my way through Night Flyer: Harriet Tubman and the faith dreams of a free people *by Tiya Miles.*

What I'm watching

I quite enjoyed the 1960s French classic film La Piscine*.*

What I'm working on

I'm writing the final 20,000 words of the first draft of my next book, The Edge of Space-Time*.*

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